U.S. Department of the Interior
National Park Service

Satellite-Derived Measures of Landscape Processes
DRAFT Monitoring Protocol for the Southwest Alaska Network

Protocol Narrative

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I. Background and objectives

Background and history

A primary goal of vital signs monitoring is to describe long-term trends in ecosystem properties to better understand their dynamic nature (Bennett et al., 2005). The Southwest Alaska Network (SWAN) has identified several physical and biological processes to monitor across all parks in the Network. These processes have been combined into the vital sign Landscape Processes and include the following:

1) Onset and freeze-up of ice on large freshwater bodies
2) Pattern and timing of snow cover
3) Timing of green-up and senescence in vegetation

The large size and wilderness character of the five park units that comprise the SWAN (Alagnak Wild River, Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Kenai Fjords National Park, Lake Clark National Park and Preserve) limit the feasibility of broad-scale, ground-based measurements. Common themes associated with the monitoring of Landscape Processes are the need for a temporal window of days to weeks, the ability to track processes at a large spatial scale across the region, and the potential to use remotely sensed data to interpret and integrate these processes.

The primary tool to monitor these landscape processes will be multispectral satellite data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS). Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, continuously acquiring data in 36 spectral bands at a spatial resolution of 250, 500, and 1000 m. High resolution (15-90m) ancillary data provided by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) will be available as acquired. ASTER images received to date have already been processed and provided by the USGS Center for Earth Resources Observation and Science (EROS). As such, this protocol does not address processing or analysis of ASTER data.

Images derived from MODIS data can be analyzed manually or with algorithms to provide information about the landscape processes discussed above. Initial protocol development has been accomplished through an Interagency Agreement (IA) with USGS EROS. This protocol documents applications for MODIS data that have been developed for the SWAN.

Rationale for monitoring landscape processes

The SWAN Region occupies an area between 57° and 61° N where coastal-temperate and boreal systems merge. Low annual temperature flux, mean annual temperatures ≥ 0 °C, and high precipitation characterize the region (Redmond et al. 2005). Tree-ring chronologies and local weather records suggest a temperature increase of roughly 2 °C since the 1980s in the Lake Clark region (Driscoll et al. 2005), in agreement with the increase in average surface temperatures reported for the northern latitudes during the past century (approximately 0.09 °C/decade; ACIA, 2005). Additional temperature increases of approximately 4-7 °C are projected over the next century in the Arctic (ACIA, 2005). Along with decreases in sea ice and land glacier extent, warming over terrestrial areas has increased the frequency of mild winter days, resulting in changes in the timing of river-ice break-ups, and the frequency and severity of ice dams, floods, and low flows (ACIA, 2005). Observations from remotely sensed data and ground measurements in arctic, subarctic and boreal systems have documented such variation in the timing of freeze-thaw events (e.g., Kimball et al. 2004a, 2004b) and lake ice formation (e.g., Duguay et al. 2003, Wynne and Lillesand 1993), and have indicated shifts in plant phenology as a result of lengthened growing seasons (e.g., Delbart et al. 2005, Beaubien and Hall-Beyer 2003).

Anticipated climate-driven changes in the SWAN include sea-level rise, greater storm intensity and frequency, altered seasonal hydrology, accelerated glacial retreat, and shorter duration of lake ice cover. Storage and release of snowpack is pivotal in regulating linkages between terrestrial and aquatic systems in the region, and appears to play an important role in determining lake ice thickness and the timing of break-up (Duguay et al. 2003). It is unlikely that discrete dates can be identified for ice formation and freeze-up, or for snowpack development and loss, as these processes appear to occur over a period of days or even weeks. A more realistic approach may include monitoring the timing and duration of these transition periods in the SWAN (e.g., for lake ice formation or snowpack development), in addition to the length of the ice- and snow-free season. As with changes in ice formation, changes in snow depth and duration may lead to significant shifts in the timing and amount of runoff, and may also strongly influence growing season dynamics and net primary productivity.

Widespread increases in indices of vegetation greenness (e.g., normalized difference vegetation index (NDVI)) and biomass in northern high latitudes (Myneni et al. 1997, 2001), as well as an earlier onset of the growing season in northern regions of North

America, Asia, and Europe have been observed using satellite-derived measurements (Piao et al. 2005, Stockli and Vidale 2004, Hicke et al. 2002). Early work with Advanced Very High Resolution Radiometry (AVHRR) data included the derivation of metrics for onset of greenness, time of peak NDVI, rate of senescence, and integrated NDVI (Reed et al. 1994). More recently, MODIS vegetation index data have been used to identify transition dates within annual time series, enabling investigators to monitor vegetation dynamics at large scales without user-defined thresholds (Zhang et al. 2003). Using data collected from 1982-1998, Hicke et al. (2002) showed peak net primary productivity (NDVI) in Alaska and western Canada occurring in late spring and early summer, apparently associated with warmer early season temperatures. Likewise, earlier start-of-season and/or later end-of-season dates recorded from 1989-2003 appear to have contributed to increased growing season length in the Bristol Bay Lowlands and Kuskowim Delta, Alaska (Reed, 2006).

Understanding the interactive effects of landscape, climate and disturbance on ecological condition is integral to the preservation and protection of public lands, and to determining the appropriate management strategies to employ. Park ecosystems develop and are maintained by landscape processes related to climate, geology and hydrology that operate over a range of scales and influence the abundance and productivity of plants and animals. While natural processes are largely outside the control of natural resource managers, understanding these processes provides important ecological context for interpreting changes in park resources. For example, documenting broad-based events such as the duration of snow and ice cover is particularly important because extreme events can have immediate and long-lasting effects on ecosystems and species. Furthermore, monitoring landscape processes may support ecological forecasts that alert park managers to future issues of management concern such as the potential for floods or wildland fires.

Measurable objectives

Monitoring of landscape processes in the SWAN parks is designed to document changes in snow and ice cover and vegetation productivity (NDVI). Monitoring questions identified by the SWAN include the following (Bennett et al. 2005):

- How are onset, duration, and extent of ice cover changing on large lakes in the SWAN region?
- How are timing, location, and duration of snow cover changing in SWAN parks?
- How are onset, duration and relative biomass of vegetation changing in SWAN parks?

The primary objectives for monitoring are outlined in this protocol:

1) Estimate variability and long-term trends in the timing and duration of lake ice formation (freeze-up) and thaw (break-up) in large lakes in the SWAN region.
2) Estimate variability and long-term trends in the timing and duration of snow cover in the SWAN region (establishment of snowpack; snowmelt).

3) Estimate variability and long-term trends in growing season NDVI in the SWAN region (start- and end-of-season dates; duration of growing season; maximum NDVI).

A fourth objective, the estimation of long-term trends in the timing and extent of sediment plumes in large freshwater lakes, will not be addressed at this time. The SWAN staff has examined available MODIS surface reflectance images for lake sediment plumes and has been unable to interpret ecologically meaningful information.

II. Sampling Design

The best technology currently available to address the SWAN's landscape processes monitoring objectives is MODIS. The calibration, spatial detail, and geolocation quality of MODIS data are significant improvements over its predecessor, AVHRR, which provided 4- to 6-band multispectral data at a resolution of 1.1 km. The combination of moderate spatial resolution, high temporal observations, and 100% coverage of the SWAN provides a framework of continuous and complete monitoring of the Network using the suite of MODIS products.

The MODIS satellite sensor processing system produces data at three spatial resolutions: 250m, 500m, and 1000m. The sensor collects 250m resolution data in the visible red and near infrared wavelengths, 500m data in the visible, near-infrared, and mid-infrared wavelengths and 1000m data from the visible through the thermal infrared wavelengths (Table 1). Because of its wide swath width (2330 km), the MODIS sensor collects near-global coverage every day, with multiple swaths (usually 2 or 3) over the SWAN.

Primary Use	**Band**	**Bandwidth (μm)**	**Spatial Resolution (meters)**
Land/Cloud/Aerosols Boundaries	1	620 - 670	250
	2	841 - 876	250
Land/Cloud/Aerosols Properties	3	459 - 479	500
	4	545 - 565	500
	5	1230 - 1250	500
	6	1628 - 1652	500
	7	2105 - 2155	500
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	1000
	9	438 - 448	1000
	10	483 - 493	1000
	11	526 - 536	1000
	12	546 - 556	1000
	13	662 - 672	1000
	14	673 - 683	1000
	15	743 - 753	1000
	16	862 - 877	1000
Atmospheric	17	890 - 920	1000

Water Vapor	18	931 - 941	1000
	19	915 - 965	1000
Surface/Cloud Temperature	20	3.660 - 3.840	1000
	21	3.929 - 3.989	1000
	22	3.929 - 3.989	1000
	23	4.020 - 4.080	1000
Atmospheric Temperature	24	4.433 - 4.498	1000
	25	4.482 - 4.549	1000
Cirrus Clouds Water Vapor	26	1.360 - 1.390	1000
	27	6.535 - 6.895	1000
	28	7.175 - 7.475	1000
Cloud Properties	29	8.400 - 8.700	1000
Ozone	30	9.580 - 9.880	1000
Surface/Cloud Temperature	31	10.780 - 11.280	1000
	32	11.770 - 12.270	1000
Cloud Top Altitude	33	13.185 - 13.485	1000
	34	13.485 - 13.785	1000
	35	13.785 - 14.085	1000
	36	14.085 - 14.385	1000

Table 1. Spatial and spectral characteristics of MODIS bands and their primary use.

The level of change that can be detected by the sampling being instituted for this protocol is a direct result of the temporal and spatial resolution of the various datasets. The spatial extent of any change must be resolved by the satellite. The spatial accuracy of MODIS data is generally said to be approximately 50m, therefore the minimum mapping unit of MODIS data is approximately 100m (accounting for possible 50m mis-registration in all four directions) plus the base resolution of the MODIS product. For example, the vegetation index data (250m resolution) has a minimum mapping unit of approximately 350m. This means that any change that takes place on the landscape must be resolvable at 350m spatial resolution. The change does not have to be 350m in extent to be measurable – a significant change (e.g., clearcuts) of less than 350m may impact the reflectance characteristics of the pixel sufficiently to influence the satellite measurements. Therefore, we may state that the level of change detectable by this sampling method must be resolvable at the spatial resolution of the various products. Similarly, we may state that the level of change in the temporal domain is resolvable according to the temporal resolution of the various products (Table 2).

Data Set	**Spatial Resolution**	**Temporal Resolution**
Calibrated Radiance	250m	daily
Snow Cover	500m	8-day and daily
Vegetation index (NDVI)	250m	16-day
Phenology measures		
Start of Growing Season	250m	Annual
End of Growing Season	250m	Annual
Duration of Growing Season	250m	Annual

Peak Growing Season	250m	Annual
Seasonally Integrated NDVI	250m	Annual

Table 2. Spatial and Temporal characteristics of SWAN MODIS data products.

MODIS data and data products are distributed by the EROS Land Processes Distributed Active Archive Center (LP DAAC), the Level 1 and Atmosphere Archive and Distribution System (LAADS), and by the National Snow and Ice Data Center (NSIDC) DAAC. The land processes MODIS data set includes 9 primary products (e.g., vegetation index (VI), surface reflectance, etc.) that are produced at a variety of spatial resolutions and temporal frequencies to yield over 40 land-related products.

The calibrated spectral radiance data are available through the LAADS, and require associated Geolocation files (also available from LAADS) for georeferencing the data sets (see SOP 4). Surface reflectance products were carefully evaluated for lake ice metrics and found to be unsuitable due to problems with patches of missing data, the aerosol corrections and between-path mosaicking anomalies.

The daily stitched products are further processed into temporal composites of 8 days or 16 days in order to reduce the effects of cloud cover and to reduce the data volume that would quickly become overwhelming with daily products. The data are processed into higher level products using a variety of algorithms that have been vetted and extensively reviewed by the scientific community. The MODIS products that are being supplied as baseline datasets to the SWAN and their spatial and temporal resolutions are given in Table 2. The snow data set is provided as both 8-day composites (corresponding to maximum snow extent during the 8-day period) and daily snow extents at 500m resolution; the vegetation index product is provided as 16-day composites and 250m spatial resolution.

The phenology products are derived from the 250m VI data. Any use of the general "VI" term is in reference to the MODIS product which contains both a NDVI and an Enhanced Vegetation Index (EVI) product. In reference to the standard "VI" product for this protocol, NDVI will be used. These phenology data are supplied as annual summaries (i.e., one summary value for each of the phenology metrics for each year). The products are produced in units appropriate for each metric they represent: i.e., the start and end of season metrics are expressed as Julian date, duration of growing season is expressed as number of days, and seasonally integrated NDVI is expressed in daily accumulated NDVI units (Table 2).

III. Data Acquisition, Processing and Analysis

In this portion of the narrative, the procedures for data acquisition, processing, and analysis will be discussed. Figure 1 provides a graphical representation of these procedures. The primary goal is to streamline the procedures for acquiring MODIS data from the LP DAAC, NSIDC and LAADS in addition to providing scripted methods for processing data into a usable format.

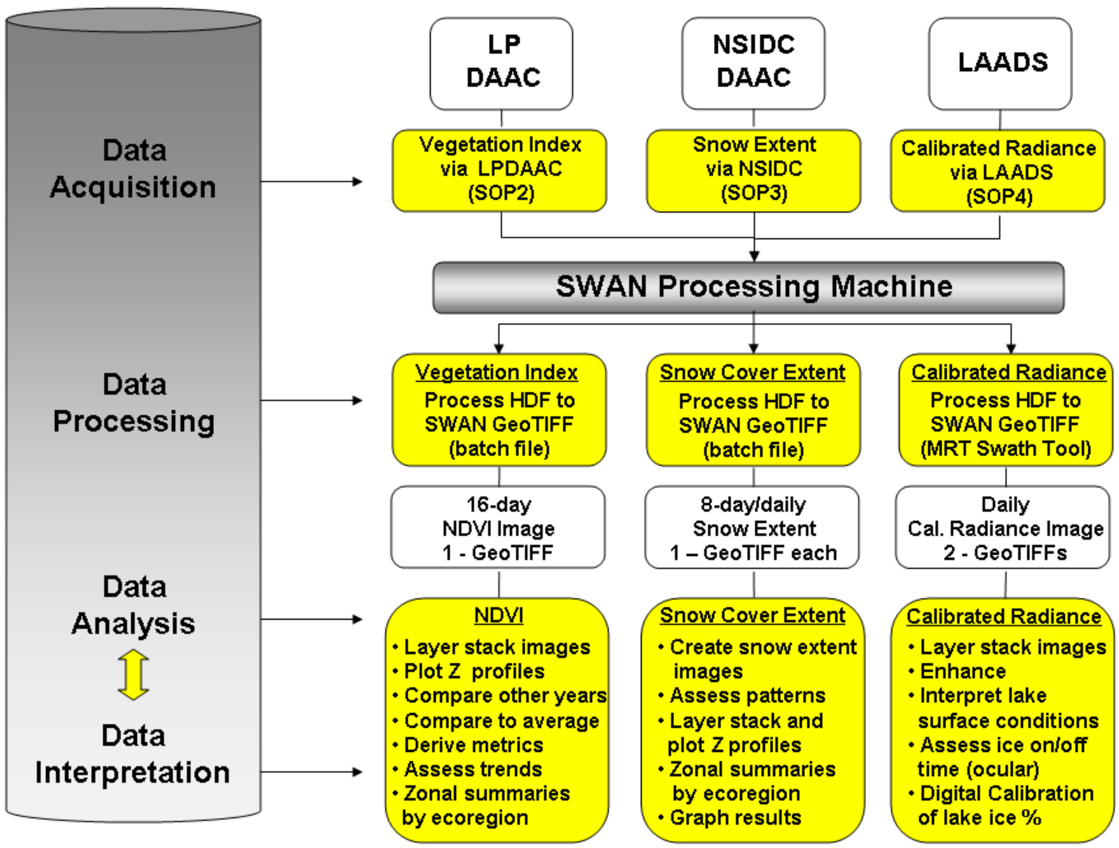


Figure 1. Flowchart of data acquisition, processing, analysis and interpretation for standard MODIS products. Yellow boxes represent procedures that are further described in the SOPs. The arrow between data analysis and data interpretation represents the analytical nature of these procedures.

The set of software that is required for the data processing and analysis consists of image processing, geographic information system, special-purpose free software provided by USGS, graphics software, and a spreadsheet or database (Table 3). In addition, a set of scripts are also required to run certain routines in the processing stages of the protocol. Table 3 lists the required software, the general application of the software and the SOP for which it is used.

Software	Application	SOP
ENVI	Image processing	2,3,4
IDL	Image analysis	2
ArcMap	Multiple data layer analysis	3

MODIS reprojection tool (MRT)	Image reprojection	2,3
MRT-Swath	Image reprojection	4
Excel	Data summary and reporting	2,3,4
ftp	Data transfer	2,3,4
Photoshop	Image enhancement	4
VI-processing script	Image processing	2
Snow (daily) processing script	Image processing	3
Snow (8-day) processing script	Image processing	3

Table 3. Software requirements for the Landscape Processes Protocol.

Data Acquisition

In addition to the baseline historical data sets that have been provided to the SWAN, three primary MODIS data sets are to be operationally acquired for monitoring of SWAN vital signs. These include the following:

- MODIS calibrated radiance from LAADS
- MODIS Normalized Difference Vegetation Index (NDVI) from LP DAAC
- MODIS snow cover extent from NSIDC DAAC

Both the LP DAAC and NSIDC DAAC have ‘data pools,’ or repositories of gridded MODIS data that are accessible via standard File Transfer Protocol (FTP). Calibrated radiance data for SWAN are selected and downloaded via FTP from the LAADS website at NASA Goddard.

The individual SOPs (SOP 2-4) provide further detail for each product type.

Data Processing

The files downloaded from each of the archive centers will appear as discrete tiles of data. The tile reference system is simply the row (vertical) and column (horizontal) number of the tile within the scheme. Coverage of the SWAN requires six tiles; h09v02, h09v03, h10v02, h10v03, h11v02, h11v03. The tile locations are shown in Figure 2.

Each data tile is provided in HDF-EOS format and is in the Sinusoidal projection. Since HDF-EOS is uncommon in many off-the-shelf image processing/geographic information system (GIS) packages and the Sinusoidal map projection severely distorts the SWAN, we have incorporated processing protocols that convert these tiled data to a single GeoTIFF image file in the Alaska Albers Equal Area Projection (Appendix 1).

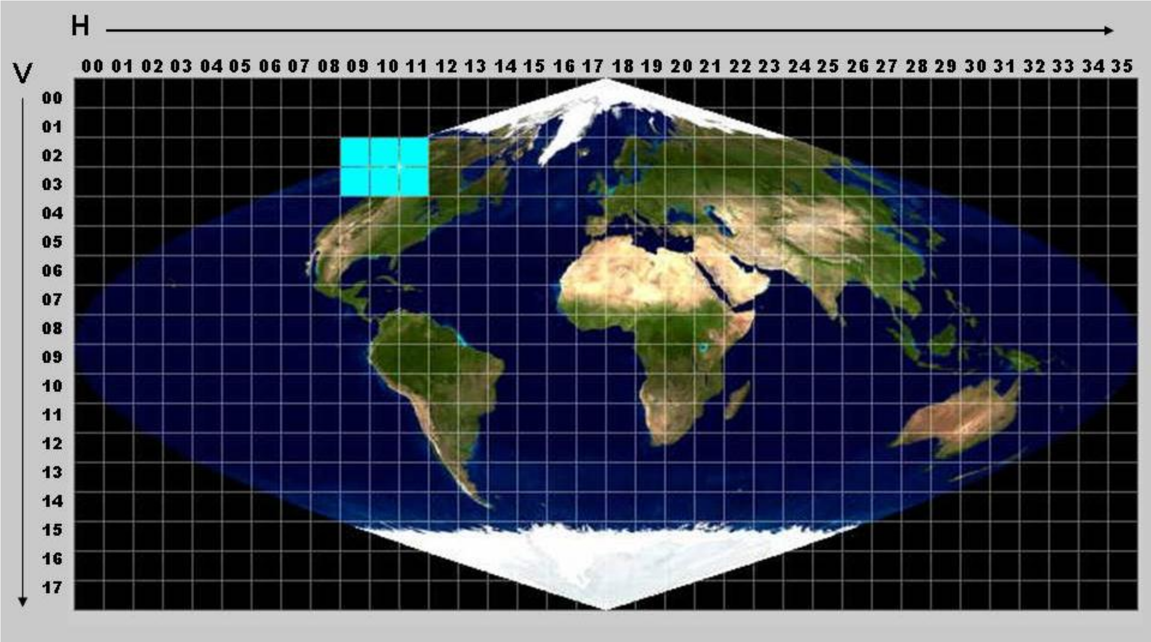


Figure 2. Horizontal/Vertical tile locations for coverage of the SWAN.

In the case of the NDVI and snow cover data, once the data tiles have been downloaded from the appropriate DAAC location, NPS personnel run a simple executable (List_HDF.exe) to create a text file containing the full set of HDF tile names for each composite period. The output text files are named using the four-digit year and three-digit Julian date corresponding to the first day of the composite period (i.e. 2006001.txt, 2006009.txt, etc.). This HDF-EOS file list is used as an input to the data processing scripts.

The processing scripts utilize the MODIS Reprojection Tool (MRT), which was developed by the LP DAAC to address issues related to data format and projection. The MRT can mosaic, subset, reproject, and reformat the raw HDF-EOS tiles in a single process. It can be executed using either a graphical user interface (GUI) or directly from the command line.

For the SWAN, batch file scripts have been developed that will execute the mosaic and resample commands within the MRT command line structure. These commands require that two input files exist; a list of raw MODIS tiles for processing and a parameter file that describes the spatial subset, projection, and output format. Parameter files for each composite period through 2008 have been provided for each of the MODIS products.

When data have been downloaded from the respective data pools, NPS personnel need only run the list executable described above to create the input text file and then execute the product batch file to create consistently processed time-series collections of MODIS NDVI and snow cover data sets.

The daily calibrated radiance data will utilize the MRT Swath tool for processing the MOD02 calibrated radiance HDFs and their corresponding MOD03 geolocation files into two single band files. The methods for processing these data using the MRT Swath GUI are further described in SOP 4 of this protocol.

Data Analysis

While there are proven methods for monitoring landscape processes using vegetation index data, the analysis of other data sets for SWAN vital sign monitoring will be largely exploratory in the initial phase of protocol implementation. Hence, we provide detail of the methods used for time-series analysis of the vegetation index data (SOP2) and present suggested analysis techniques using the calibrated radiance and snow cover data sets.

Calibrated Radiance. Analysis of calibrated radiance data will largely be through manual interpretation of natural color and/or color infrared composited imagery for the assessment of metrics such as lake ice formation and break-up and duration of freeze-up and break-up seasons, (SOP 4). Periodic digital calibration will standardize the interpreters to the images and each other.

Normalized Difference Vegetation Index. The MODIS vegetation index data that have been collected for the SWAN provide a unique opportunity to study changes in vegetation phenology over time. A variety of methods for using time-series NDVI data have been developed to extract critical phenology metrics such as the start of the growing season (SOS), time of peak greenness, end of growing season (EOS), and duration of growing season (DOS). The derivation of such parameters through time allows for the comparison of trends in the timing and magnitude of such events. The SWAN will use methods identified by Reed et al. (2003) to calculate annual summaries of phenology metrics. Analysis techniques for phenology metrics and annual reporting of vegetation trends are further described in SOP 2.

Snow Cover. The MODIS snow cover product will be used primarily as a measure of the on/off period throughout the Network. This product does not provide a measure of snow depth, but rather a maximum extent of snow covered area within an 8-day composite period or on a daily basis. These data have been used successfully to monitor snow cover accumulation and depletion across large areas. For the SWAN, it is useful to quantify the presence of snow in terms of a zone (ecoregion) which can be compared from year to year. We will use a simple ecoregion analysis, conducted within a GIS framework, to provide percent cover for every 8-day period (SOP 3). Where more temporal detail is needed, daily snow cover data can be used.

IV. Data Management

Data management will be a critical component of this protocol as both data volume and data diversity will be significant issues. Data management will be required at two levels; operational and archival. Operational data management includes the routine acquisition and processing of MODIS data and handling the subsequent data analysis. Archival data management includes handling the databases that will serve as baselines for vital sign monitoring and the long-term data sets that are created during analysis procedures.

Operational Data Management.

The priority operational data management is to organize the pertinent data products for transfer to the archival data management. Secondary concerns will include handling the raw data products from the LP DAAC, NSIDC DAAC, and LAADS, efficient, yet conservative management of temporary files, production and storage of analysis files, and deletion of temporary files. The operational data management will be the responsibility of the research ecologists and will include ongoing communication and revision to the process with the data management specialist.

The operational data management will include the following steps:
1) downloading of data from LP DAAC, NSIDC DAAC, and LAADS
2) implementing the standard data processing scripts
3) implementing non-standard data processing (as needed)
4) conducting data analysis
5) transferring the archival data to data manager

As the operational data management will be conducted in a PC environment, a suggested organizational structure for operational data management follows. It is assumed that the primary disk drive will be D:\ in this example:

D:\SWAN\MODIS_CalRad\yyyy
D:\SWAN\MODIS_VI_16day\yyyy
D:\SWAN\MODIS_Phenology\yyyy
D:\SWAN\MODIS_SNOW_8day\yyyy
D:\SWAN\MODIS_SNOW_daily\yyyy

where yyyy is the year the data are collected. Each of these file folders is where the primary data processing will take place. The standard processing will take place approximately every month. Under normal conditions, the set of processes should be completed in two to three days.

Because a number of ancillary files are necessary for the routine processing of the snow and vegetation index products, files with the following file extensions will be present within each of the file folders listed above:

*.txt	text documents containing file names for input to data processing scripts
*.prm	parameter files that are necessary for reprojecting files
*.tif	output image files that are to be placed into the data management archive

These files should be maintained in the operational system, but only the *.tif files should be delivered to archival data management.

As mentioned earlier, in addition to the routine data processing, the research ecologists will be conducting exploratory analysis on a regular basis that should not involve data that are housed in the file folders listed above. A conservative data management structure that does not endanger any of the routinely processed files is recommended. Therefore for the exploratory data analysis, the following parallel file structure is suggested:

D:\SWAN\Analysis\ MODIS_CalRad\yyyy
D:\SWAN\Analysis\MODIS_VI_16day\yyyy
D:\SWAN\Analysis\MODIS_Phenology\yyyy
D:\SWAN\AnalysisMODIS_SNOW_8day\yyyy
D:\SWAN\Analysis\MODIS_SNOW_daily\yyyy

Archival Data Management.

Archival data management will be required on all the baseline (standard) data sets and those data sets resulting from analysis procedures that merit promotion from operational to archival status. A data set consisting of processed MODIS products has been provided to serve as the original baseline data dating from February, 2000. The existing data set and projected data volumes are approximately as shown below in Table 4:

Existing Data Set (2000-present)	**Size (Gb)**
Calibrated Radiance	88.0
Vegetation Index (NDVI)	7.8
Phenology metrics	0.6
Snow Cover 8-day & Daily	7.5
Total	97.0
Projected Annual Increase	**Size (Gb)**
Calibrated Radiance	13.0
Vegetation Index (NDVI)	0.9
Phenology metrics	0.1
Snow Cover 8-day & Daily	1.1
Supplemental satellite data, inc ASTER	5.0
Total	≥20.0

Table 4. Existing and projected data volumes for SWAN MODIS and ASTER products.

There will be an estimated increase in data volume of 15-20 gigabytes per year. In addition to the basic data sets, there will be supplemental satellite data collected for augmenting this information. The supplemental data could include high resolution imagery (e.g., ASTER) that could be helpful in interpreting details that may not be discernible on the MODIS imagery. Additional data sets will also result from data analysis applications. These supplementary data sets may result in an additional 5 gigabytes per year.

The completed data products will be stored long-term as read-only files on the Alaska Regional central data file server. These data will be jointly managed by the SWAN data manager and the Alaska Regional Office (AKRO) GIS staff and will adhere to the AKRO GIS requirements. These data will be available to Alaska NPS staff by using the ArcGIS Theme Manager or by direct access to the data file server. The National Park Service does not have the capability to post data sets of this size on the Internet at this time. Public access to these files will be by special request. Metadata for available products will be posted on the NR-GIS Clearinghouse.

Draft or interim data will be stored short-term on the SWAN Team data file server and will be read-write accessible to SWAN staff. These data include files that are originally downloaded or temporary files used to generate the final data products. These should be removed when the final data products are completed.

Backup procedures for these data sets should follow the National Park Service's normal procedures. Backups are managed by the Alaska Regional Information Technology staff as described in the SWAN Data Management Plan, Section 11.5.

Documentation

One metadata record per image type will be produced and will meet the Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata (CSDGM). The metadata records should cite this protocol in the 'Larger Work Citation' field. An example metadata file is shown in Appendix 2.

Quality Assurance/Quality Control and Validation

Quality assurance and control is a major element of the original MODIS product development (before the Landscape Processes Protocol is implemented). For a summary of the types of processing QA/QC that have been implemented, see an overview of the Land Data Operational Product Evaluation (http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/newPage.cgi). Similarly, many of the standard MODIS products have undergone validation experiments. The MODIS Land Processes Validation web site summarizes many of these efforts (http://landval.gsfc.nasa.gov/index.php).

V. Analysis and Reporting

This portion of the narrative includes descriptions of analysis techniques and products for the lake ice, snow cover and for the NDVI derived phenology metrics. It also provides examples of products that may be useful in annual reporting of vital signs monitoring.

Lake Ice

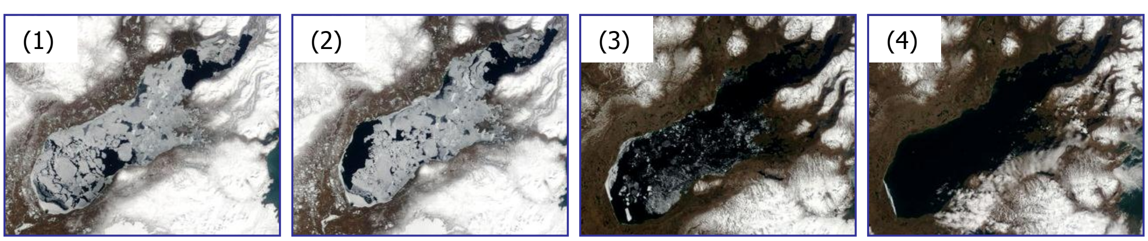
SWAN is located in an extremely dynamic region of Alaska, where maritime and continental climate regimes meet. Climatic patterns are exacerbated by topographic relief and peninsulas that extend into the North Pacific Ocean and Bering Sea. Ice metrics on large lakes and lake complexes are indicators of the cumulative thermal regime across SWAN (Jeffries et al, 2005). A warming climatic trend should lead to shorter ice-bound seasons on lakes, while overall colder climate will lead to longer ice seasons. These trends will likely vary spatially across SWAN and be reflected in different lakes. The objective of this protocol is to determine the natural variability in ice season in SWAN and detect long term trends in ice season duration and freeze-up/break-up dates.

Lake ice metrics are interpreted from daily MODIS Calibrated Radiance (MOD02) images. Lake ice metrics are break-up date, freeze-up date and duration of ice season, break-up season and freeze-up season. Seventeen lakes and lake systems are selected for interpretation of ice cover. Each daily image is examined and the ice cover estimated and recorded. Calibrated radiance data are available early in the processing stream, so have no atmospheric corrections. As such, they can not be automatically compared between dates. Manual interpretation of calibrated images is used to derive the ice season metrics. Digital calibration is used to standardize ocular estimates through time and between interpreters.

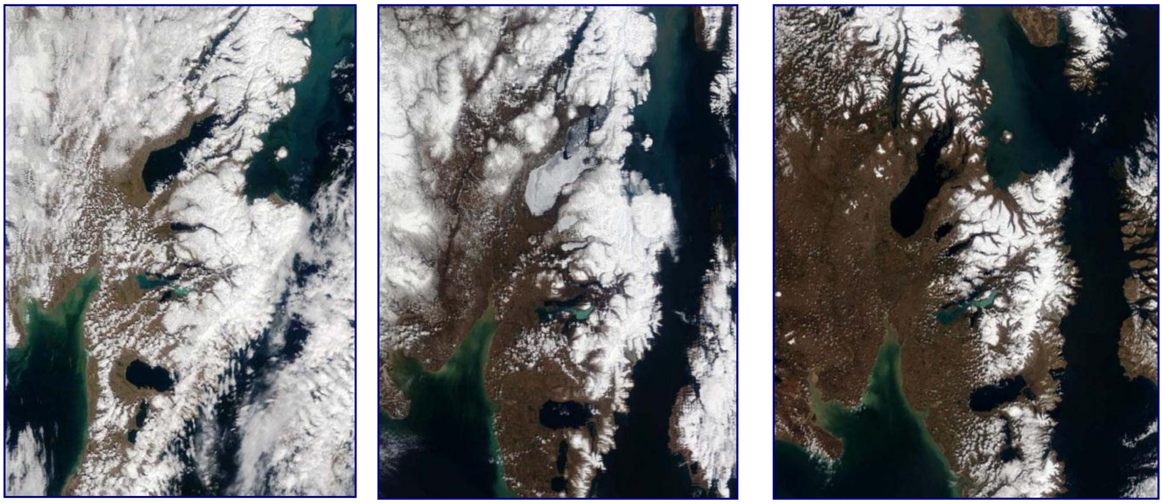
Freeze-up date is when ice cover is >90%. Break-up date is when ice cover is <10%. Ice season is the number of days between freeze-up and break-up (Jeffries et al, in press). Number of days for break-up season and freeze-up seasons are also recorded. Annual reporting will consist of a chronology of lake ice events and processes (dates of onset, freeze-up and duration).

The long term record will be analyzed to determine if there are trends in dates and duration of ice events. Preliminary interpretations of the MODIS data suggest that landscape-scale phenomena across the SWAN are complex. For example, large lakes vary in their timing and rate of freezing and often do not have single freeze-up or break-up events. Some lakes freeze early in the season and remain frozen until late in the spring, when they break-up very rapidly (Fig. 3). For these lakes, break-up dates have been surprisingly consistent across years (2001-2006). Other lakes are much more variable, and in some years do not freeze at all.

Below (L-R): MODIS time series of breakup of lake ice on Lake Iliamna, April 15 - May 10, 2005. (1) April 15; (2) April 17; (3) May 8; (4) May 10. Rapidfire images.



Below (L – R): MODIS time series of mid May 2001-2003 for the Alaska Peninsula from Lake Clark south to Becharof. Rapidfire images.



May 17, May 12, May 16,

Figure 3. Timing of lake ice breakup for Lake Iliamna and interannual variation of ice cover for Lake Clark.

Vegetation Index

A major utility of the vegetation index time series is the ability to measure seasonal vegetation dynamics (Fig. 4). Phenology metrics of start of season (SOS), end of season (EOS), duration of the season, time of maximum NDVI, value at maximum NDVI, and total growing season NDVI were provided to the SWAN for the years 2000-2005. As part of the operational processing stream, the SWAN will acquire 16-day composites of vegetation index data throughout the year. Once a full year has been acquired, the new data will be added to the vegetation time series and phenology metrics will be derived for the additional year.

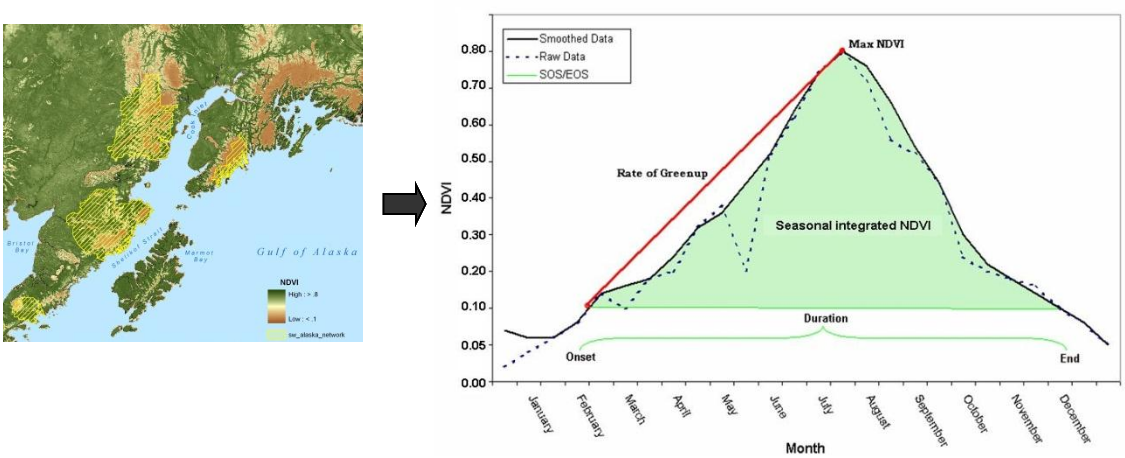


Figure 4. NDVI image (left) and the profile for a single year (right), illustrating derived phenology metrics.

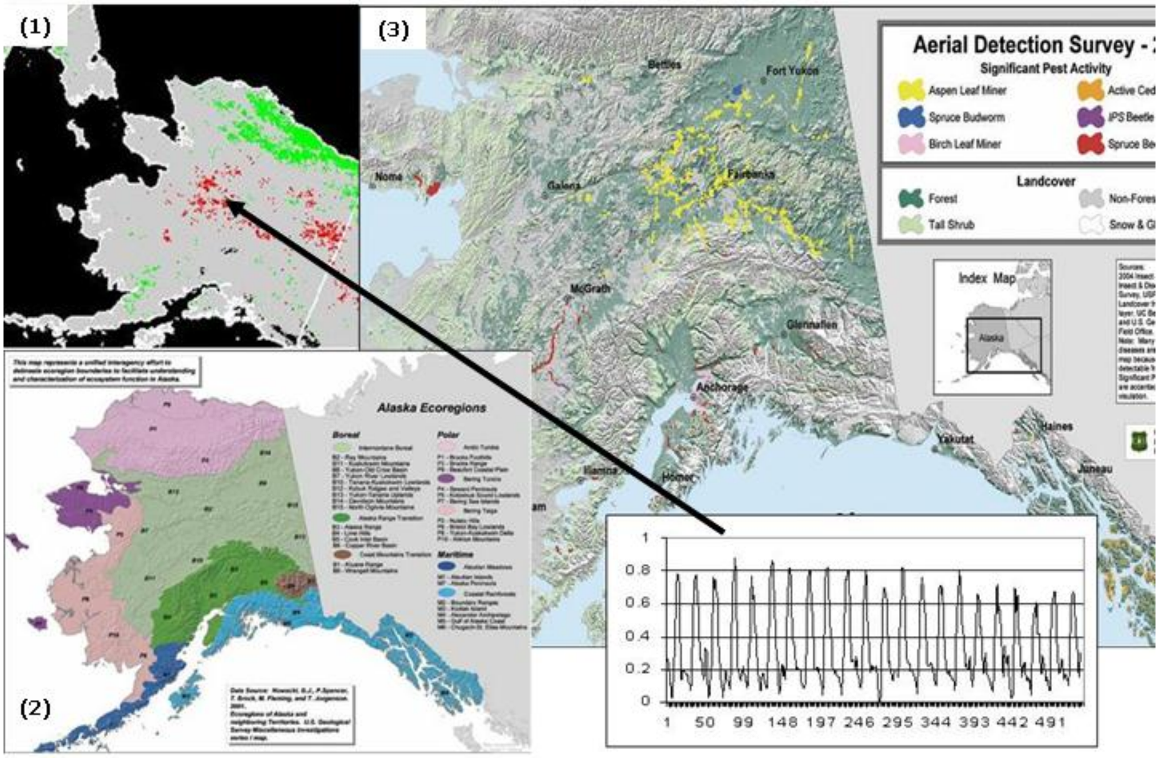


Figure 5. Trend analysis of the AVHRR time series of North America shows both increasing (green) and decreasing (red) trends in growing season NDVI in Alaska during the years 1982 – 2003 (1). Decreasing productivity was localized to a single boreal ecoregion (2) and the areas of decrease coincide with defoliation or forest mortality (3).

The results of the phenology analysis will be evaluated for each of the primary vegetation communities in cooperation with network ecologists. As the length of the temporal profiles of vegetation dynamics increase, they provide the opportunity to analyze trends in vegetation phenology patterns over time. Figure 5 shows an example of trends in growing season greenness for Alaska using coarse spatial resolution high temporal resolution data acquired from AVHRR. The areas in red indicate a trend toward reduced growing season greenness, while the areas in green are indicative of increasing greenness trends during the same period (1982- 2003).

The trend analysis technique applies a best-fit line to the phenology metric data and performs a simple t-test to determine if the slope of the line is significantly different from 0. Slopes that are significantly greater than 0 indicate an increasing trend, while slopes significantly less than 0 represent a decreasing trend. While this type of analysis is typically used for looking at medium- to long-term trends in vegetation dynamics (> 10 years), annual reporting will be limited to the mapping of annual phenology metrics (Fig. 6), and/or the plotting of time series for SOS, EOS, etc., for visual comparison with previous years (SOP 2).

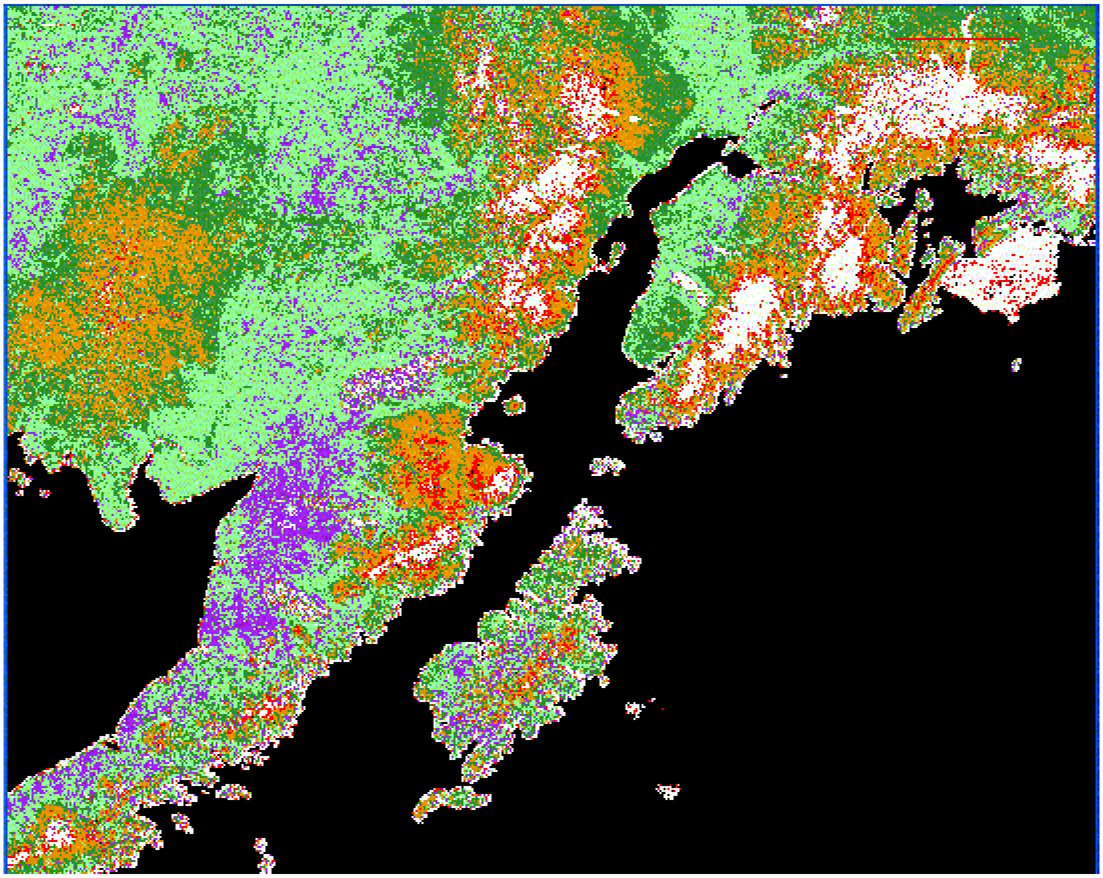


Figure 6. Time of start of season image, 2004; White = no growing season, purple = SOS in March, light green = SOS from April 1-15, dark green = SOS from April 16-30, orange = SOS in May, and red = SOS in June.

Snow Cover

MODIS provides a standard measure for monitoring the extent of snow covered area within the SWAN via both daily and 8-day composite snow products. The snow cover products are created by applying a normalized difference snow index (NDSI) algorithm to the surface reflectance. The result is a classified image that allows the analyst to identify incremental changes in snow cover throughout the region as well as quantify the snow covered area within a given zone.

The snow cover data is available approximately 3 – 4 days after the close of the composite period, allowing timely measures of snow cover over large areas. Visual analysis of snow patterns, such as those seen in Figure 7, can be compared with previous years to identify anomalous snow conditions. As with the NDVI product, ancillary data (e.g., from SWAN weather stations) has the potential to greatly inform monitoring efforts with MODIS.

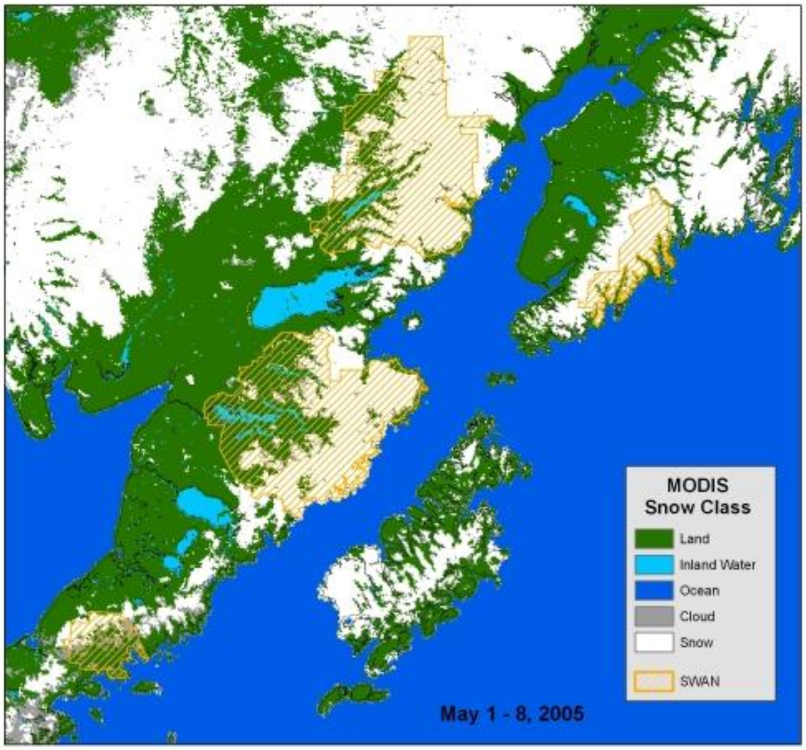


Figure 7. Eight-day MODIS snow cover extent image for 1-8 May 2005. The major classification categories and the SWAN park boundaries are mapped.

A more quantitative measure of the snow cover extent can be derived using a zonal coverage for time series analysis of snow covered area. The defined zone could represent an ecoregion, drainage basin, park or some other delineation for which snow covered area would be a meaningful metric. Here, we will summarize snow duration and extent by ecoregion (Nowacki et al, 2002) using the 8-day snow cover composites. Standard snow cover accumulation/depletion curves relate the percent of a basin or zone that is covered by snow to elapsed time during both the snow accumulation and snow melt seasons. Such curves help provide an indication of the temporal and spatial extent of seasonal snow pack and its potential impact on water resources. A steep decrease in snow-covered area can be indicative of either shallow snow pack or high melt rates. On the other hand, a slow decrease results from either a deep snow cover or slow melt rates most likely due to low temperatures. Plotting snow cover versus growing degree days can help reduce this ambiguity, however this would require additional climate data inputs, such as those from the new SWAN weather stations. Curves measuring the maximum extent of snow cover as a function of time without regard to air temperature can still be very useful in the assessment of snow covered area.

The time series plot shown in Figure 8 illustrates the comparison of 2004-05 snow cover with the previous year as well as a short term average condition calculated using 4 years of MODIS snow data. The plot illustrates that while the onset of the snow season in this area was later than the comparison periods, the duration of cover was longer, the spatial extent of cover was greater, and the time of depletion was later, indicating an abundant supply of melt water in the spring.

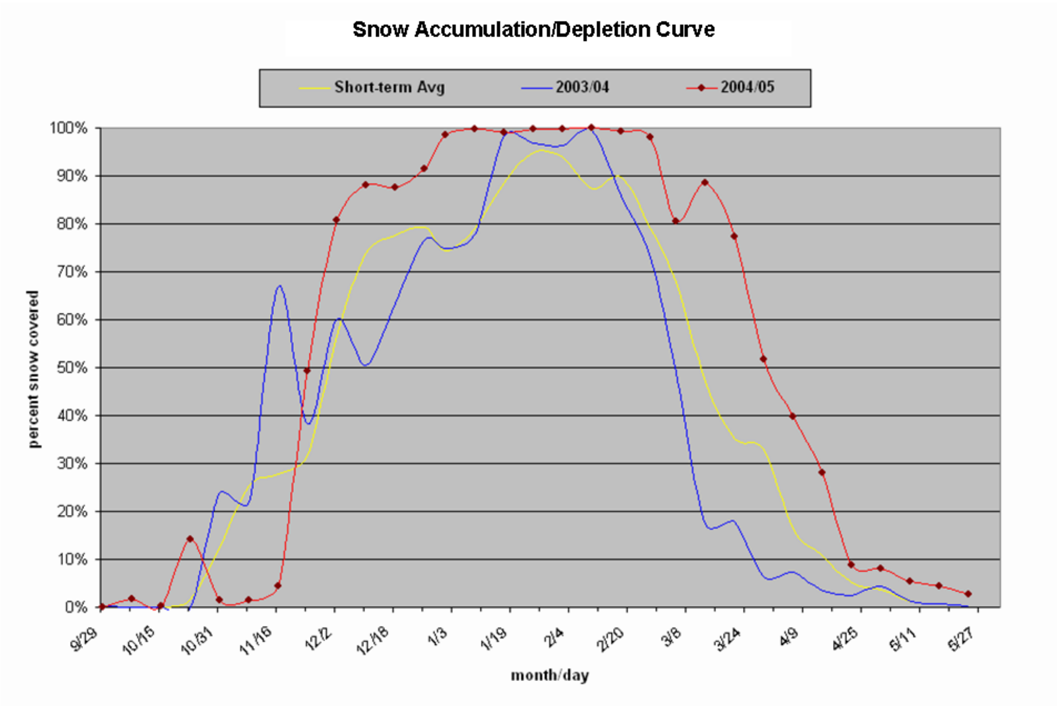


Figure 8. Example of a snow accumulation/depletion summary.

As a supplement to the 8-day composite data, daily snow cover imagery can be used to more precisely measure the timing of snow cover events given cloud free acquisitions. Another use of the daily images for analysis of annual snow cover conditions will be to create daily time series of snow cover for each year and assess temporal patterns using the z-profile plotting functions in ENVI. The procedures and applications of this type of analysis are further described in SOP 3.

Reporting

Communication of monitoring results will occur through annual summary reports and informal meetings with park managers, and through multi-year synthesis reports. Annual reporting will consist of a chronology of lake ice (dates of onset, break-up, and duration), snow cover (dates of first measurable snowfall, establishment of permanent snowpack, beginning of melt, end of melt) and productivity metrics (dates for start and end of season, maximum NDVI, integrated NDVI) for selected study areas. In addition, spatial variation in these metrics will be recorded (e.g., extent of snow cover) and a range of values provided for each metric across the Network (e.g., variation in date of lake ice onset across the Network). Any observed anomalies, or any conditions that may confound interpretation of the data, will be recorded. Changes to the protocol will likewise be documented. Synthesis reports could include results of time-series analyses, graphical representation of selected metrics (e.g., Fig. 6), and/or mapped regions of change (e.g., areas experiencing a shorter or longer growing season (Fig. 5), or earlier or later onset of lake ice). Table 5 outlines metrics that will be included in annual and multi-year reports.

Ancillary data used during data analysis and interpretation and verification may include SWAN climate/temperature records (e.g, Harding Icefield Weather Station), lake ice records (e.g., X:\Libraries\Database_Water\SWAN\AK_Lake_Ice_Monitor_History), historic accounts and journals, and informal reports from park pilots and backcountry rangers. Guidelines for formatting annual summary and 10-year synthesis reports are as follows:

http://www.nature.nps.gov/im/units/swan/Libraries/Data_Management/DataManageGuidelines/SWAN_ReportAnnualFinalSpec_0412.pdf

Vital sign	**Metrics**
Lake ice	For a given lake: • date of initial freeze-up • date of final freeze-up - continuous ice • date of initial break-up • end of break-up – ice-free • duration of break-up season • duration of ice season • duration of freeze-up season • duration of ice-free season • range of break-up and freeze-up dates, seasonal durations across SWAN region
Snow cover	For a given study area or ecoregion: • date of first measurable snow cover • date of snowpack establishment – onset • date of first measurable snow melt • end of snow melt – snow-free Across SWAN: • maximum extent of snow cover (mapped) • range of snow onset and melt dates across study areas
Productivity	For a given study area or ecoregion: • date of first measurable NDVI - onset • date of decline in NDVI – senescence • maximum NDVI • integrated NDVI • duration of growing season Across SWAN: • range of onset and senescence dates across study areas

Table 5. Reporting summary for landscape processes vital signs.

VI. Personnel Requirements and Training

The implementation of this protocol (Table 6) requires a diverse skill set including expertise in remote sensing, geographic information systems, data management, and landscape ecology (Table 7). Although the levels of expertise required for the continuity of the protocol vary, a high level of competence is necessary to build the protocol and standard operating procedures and maintain them through the initial stages of the project. After the procedures have been successfully operating, the level of expertise required in remote sensing, geographic information systems, and data management will be reduced. However, an ongoing high level of expertise by ecologists will be required throughout the duration of this protocol, as data interpretation cannot be completely automated.

Task	**Personnel**
Data acquisition: -Routine downloads -Automated preprocessing	Data Technician
Data processing: -Custom processing, enhancements	Ecologist or Remote Sensing Specialist
Data analysis and interpretation: -Manual interpretation of metrics -Manual or automated determination of metrics -Spatial analyses -Trend analyses -Data summaries	Ecologist, with assistance from GIS Specialists, Remote Sensing Specialist, and Statistician
Reporting	Ecologist
Data management: -Copy new files to Central Data Server -Manage data formats, directory structure, archiving -Maintain consistent data characteristics and software compatibility with other SWAN data sets	Data Manager, GIS Specialist, and Ecologist
Backups	All Users (local) and AKRO IT staff (archives)
Minor protocol revisions and documentation	Remote Sensing Specialist and/or Ecologist
Development of alternative processing scenarios: major protocol revisions	USGS-EROS staff or similar expertise

Table 6. Work flow and responsibilities for monitoring of landscape processes.

Data downloads and processing will need to be accomplished at least monthly before the data are deleted from the LP DAAC and LAADS data pools. These tasks will require a minimum of 3-4 days/month. Interpretation of the images will be conducted annually.

The analysis, interpretation and reporting phases of these SOPs will require approximately 0.5 FTE by the ecologists and remote sensing/GIS specialists combined.

Personnel	**Qualifications/Experience**
Data Manager	• Experience with data stewardship and developing applications for data analysis
Remote Sensing Analyst	• Extensive experience with MODIS products and specialized software (MODExtract, MODIS Reprojection Tool (MRT), MODIS quality assurance tool - Land Data Operational Product Evaluation (LDOPE)) • Experience with image processing, including ENVI software • Experience in regional-scale remote sensing applications • Experience in deriving phenological metrics • Experience with time-series analysis
GIS Specialist/Analyst	• Experience in assembling data sets with disparate characteristics (e.g., raster/vector, map projections, data formats) and harmonizing them
Ecologist/Analyst	• Familiarity with SWAN landscapes and landscape processes, including field experience • Experience in manual interpretation of satellite imagery and derived products • Ability to synthesize information from multiple data sets to develop summary reports of short- and long-term variation in phenological metrics
Data Technician	• Experience with GIS and data management

Table 7. Personnel qualifications for monitoring of landscape processes.

Training procedures.

All personnel involved in this protocol should receive training in ArcGIS and ENVI software on a one to two year schedule.

VII. Operational Requirements

Workload /Acquisition Schedule

Because these data are ingested and stored at their respective archive centers, the timing of data collection is not as crucial as in field based protocols. Nevertheless, maintenance of an up-to-date archive of SWAN data sets will require adherence to a regular download and processing schedule.

Calibrated Radiance data are continuously maintained and available from the LAADS web site. Vegetation index data remain staged on the LP DAAC data pool for up to one year. On occasion, these data are removed from the data pool prematurely, but always remain available via the EOS Data Gateway (EDG). In the case of the snow cover data, the NSIDC DAAC maintains a complete archive of 8-day and daily data in their data pool. As with data via the LP DAAC, if these would be removed from the data pool, they are always accessible through the EDG.

Table 8 shows the composite period length and the number of days, after the close of the composite period, when products are typically available for download. Downloading will take place at least monthly - well before the data are deleted from the data pools. If analysts miss several periods and the data are no longer available in the data pool, they can be retrieved from the EDC Archive or LAADS using the procedures outlined in Appendix 3 and SOP 4.

Product	Composite Length	Availability (# of days)	Source
Calibrated Radiance	daily	1	LAADS
Vegetation Index	16-day	5-7	LP DAAC
Snow Cover Extent	8-day	3-4	NSIDC DAAC
Snow Cover Extent	daily	2-3	NSIDC DAAC

Table 8. Approximate data availability schedule for each MODIS product.

Hardware Capability

The hardware requirements for processing, storage, and analysis of MODIS satellite imagery include a personal computer with a minimum of 2.0 GHZ processor and 1.0 GB or greater of memory. These are minimum requirements; to achieve maximum performance in processing and manipulation of imagery, more powerful processors and memory are necessary. A minimum hard drive capacity of 200 GB is recommended for MODIS processing and storage.

Software

The software requirements for utilizing MODIS data sets can be categorized into two groups. Software tools necessary for the acquisition and processing of raw MODIS tiles and swaths, and software packages that allow the processed imagery to be viewed and analyzed with other spatial data.

The software tools for acquisition and processing of MODIS tiles and swaths include the following:

- MODIS Reprojection Tool (MRT)
- MODIS SWATH Reprojection Tool (MRT-Swath)
- Land Data Operational Product Evaluation (LDOPE)

All of these are freeware tools that can be downloaded from the LPDAAC website (http://edcdaac.usgs.gov/datatools.asp).

The image processing and GIS software that is used for display and analysis of processed imagery will be left to the discretion of the NPS. However, we recommend RSI's ENVI image processing software and ESRI's ArcGIS. Adobe Photoshop is also an invaluable tool for rapid image viewing and feature enhancement.

Software installation instructions (MRT, MRT-Swath, and LDOPE) are found in SOP 1.

VIII. Procedures for Revising Protocol

The steps for changing the protocol (either the protocol narrative or the SOPs) are outlined in SOP 6. Each SOP contains a revision history log that should be filled out when a SOP is revised. The new version of the SOP and/or protocol narrative should then be archived in the SWAN protocol library under the appropriate folder.

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SOP 1: Software Installation

Satellite-Derived Measures of Landscape Processes
Southwest Alaska Network

Standard Operating Procedure (SOP) # 1

Software Installation

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

This Standard Operating Procedure outlines the installation instructions for software necessary to acquire, process, and reformat the standard MODIS image products set forth in this protocol. The software tools for processing raw MODIS tiles include:

- **MODIS Reprojection Tool (MRT)**
- **MODIS Swath Reprojection Tool (MRT-Swath)**
- **MODIS Land Data Operational Product Evaluation (LDOPE) Tools**

This SOP also includes instructions for **IDL Metrics** setup in order to utilize the tools for deriving seasonal metrics from the NDVI time series. Separate procedures for installing each of these tools are outlined below.

The MODIS tools are freeware downloadable from the Land Processes Distributed Active Archive Center (LP DAAC) website: (http://edcdaac.usgs.gov/datatools.asp). The IDL Metrics tools have been provided to the SWAN for use in this protocol.

1.1. MODIS Reprojection Tool (MRT)

The MRT software tool enables users to read data files in HDF-EOS format (MODIS Level-2G, Level-3, and Level-4 land data products), specify a geographic subset or specific science data sets as input to processing, perform geographic transformation to a different coordinate system/cartographic projection, write the output to file formats other than HDF-EOS, and are executable on Unix (Sun, SGI), Windows (9x, 2000, NT, XP), and Linux operating systems.

This SOP is intended for use on the Windows operating system.

MRT Installation Procedures:

1. Register for access to the MODIS download page at the LP DAAC. From the MRT distribution page (http://edcdaac.usgs.gov/landdaac/tools/modis/index.asp), select registration and receive a username and password that allows for downloading of binaries, source code, and documentation (Fig. 1.1). A username and password will be emailed to the address that you provide.

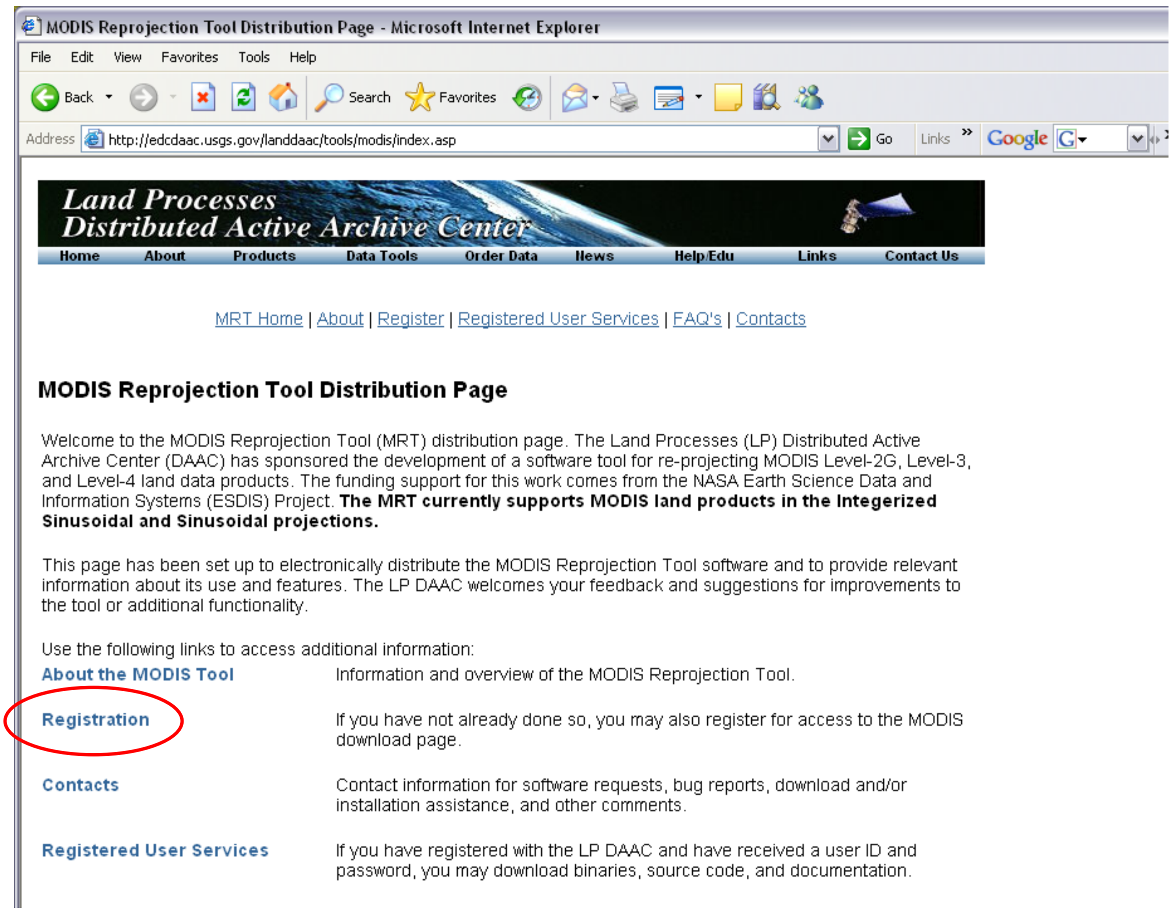


Figure 1.1. Registration procedure for MODIS Reprojection Tool.

2. Log on to "Registered User Services" using your login information for access to Downloads (Fig. 1.2).

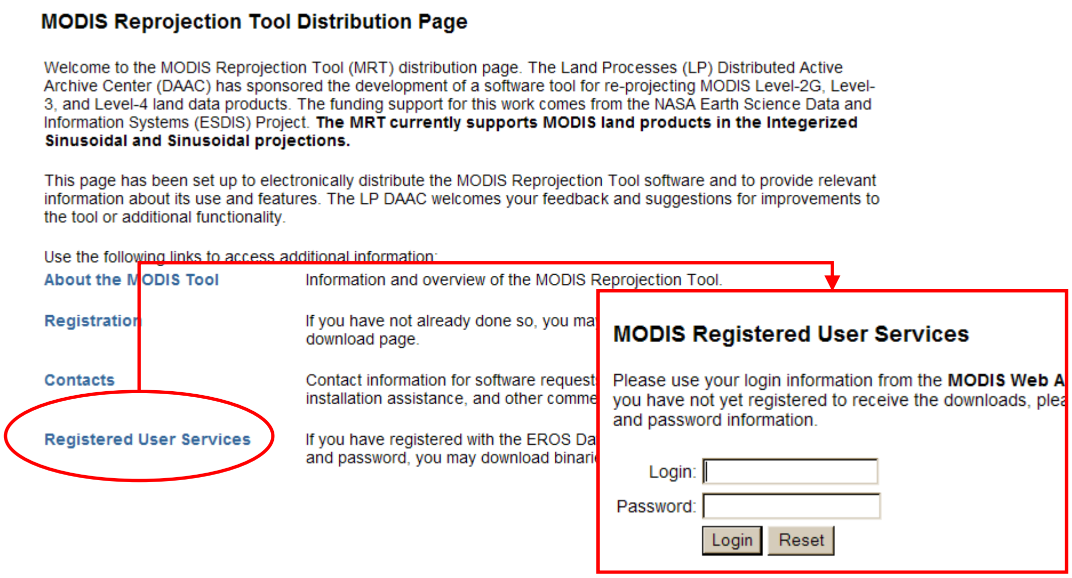


Figure 1.2. Login procedure for downloading MRT.

3. From the Registered User Services page, select Download to access release notes and code for the appropriate platform (Fig. 1.3). The standardized procedures for this protocol are intended for use on the Windows platform.

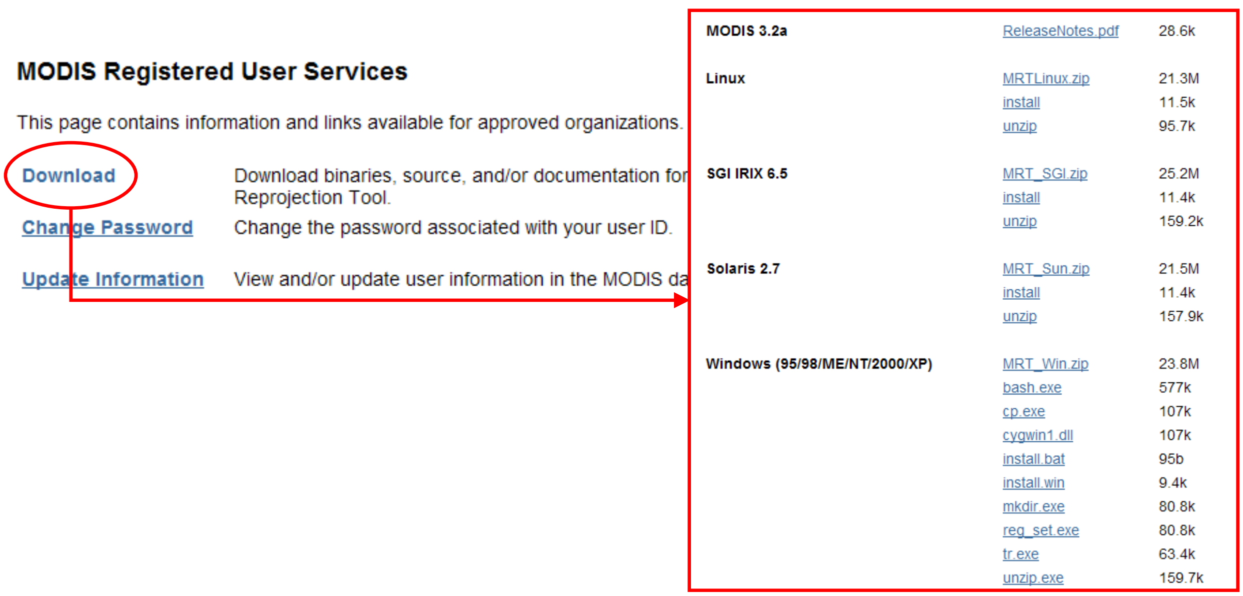


Figure 1.3. Initiating download procedure for MRT files.

4. Create a MRT directory on the C drive (i.e. C:\MRT) of your local computer. Use 'right click', 'save target as' to individually copy each Windows platform file from the download page to the C:\MRT directory (Fig. 1.4).

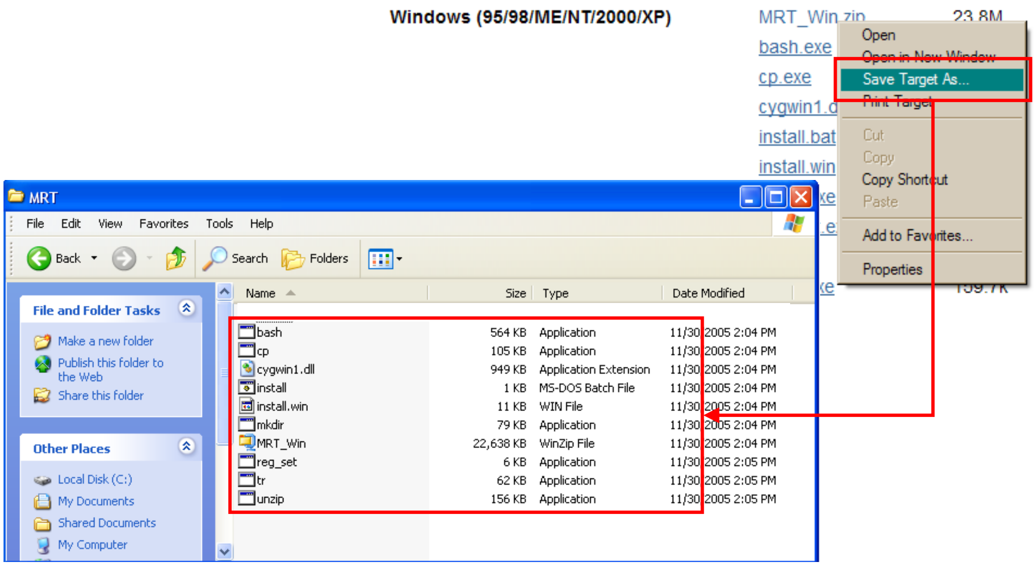


Figure 1.4. Download procedure for MRT.

5. Open a command prompt window and navigate to the C:\MRT directory where the Windows files were saved. Type **install**. You will be given information necessary for continuing installation of the MRT and for obtaining necessary Java software if it is not already installed on your system. Java is used for the graphical user interface (GUI) version of the MRT. Issues related to Java software are discussed in procedure # 8. At this prompt, type **y** to continue with the installation .

6. You will then be prompted to enter an MRT directory path. Since you've already created the C:\MRT directory, press **enter** to install to a MODIS sub-directory at this location. A second prompt will state that the MODIS sub-directory doesn't exist and ask if you want to create it. Type **y** to continue.

7. The installation will proceed to create a MODIS directory in the current location and extract a number of files/folders to the new directory. You will then be prompted to identify what version of Windows you are running. Simply type the **number** associated with your operating system and press **enter**.

8. You will be prompted to enter the path to the Java *bin* directory on your machine. Most PCs already have Java installed in C:\Program Files\Java\…, since the MRT does not process pathnames with spaces in them it will error if this path is given. You will need to make a copy of the Java directory and place directly under the C drive (i.e. C:\Java\...etc.). The next step in installation is to **type the full path to the Java bin directory** and press **enter**. The install program will test the Java path and verify that it is an adequate version. If the version of Java does not meet the minimum requirements, a web location for downloading a newer version is

provided (Fig. 1.5). In the event that your system does not contain a Java *bin* directory, you can access the latest version of Java at the following location: http://java.sun.com/downloads/. Select the most recent version from the Java Platform Standard Edition dropdown list.

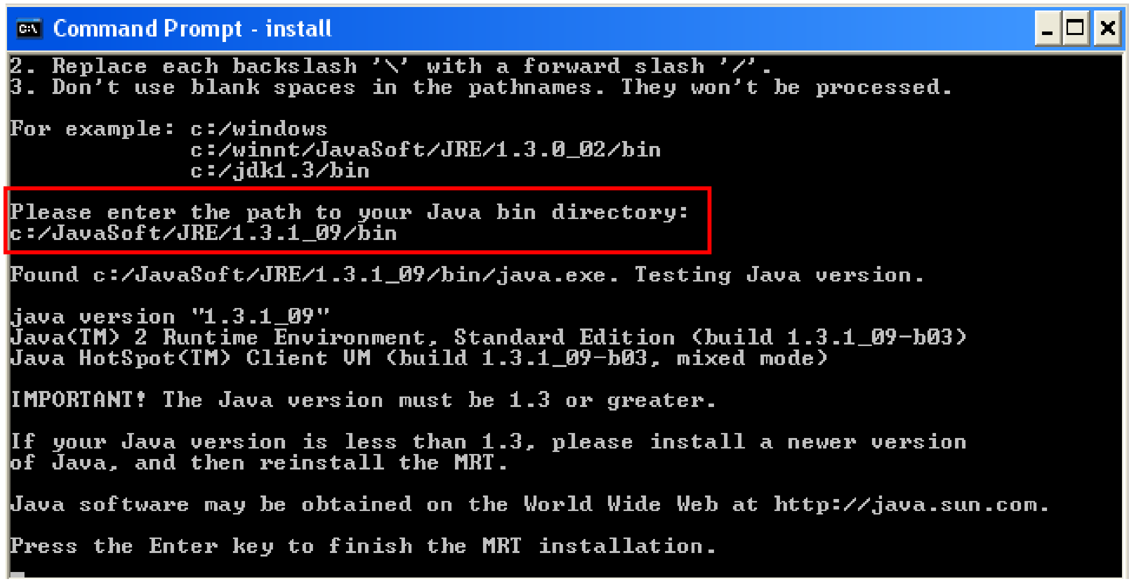


Figure 1.5. Enter the pathname of the Java bin directory.

9. Once the installation is complete, you should see the successful installation Screen (Fig. 1.6). You can test the installation by navigating to C:\MRT\Modis\bin and double click on the ModisTool.bat file. If installed properly, this should launch the GUI interface for the MRT.

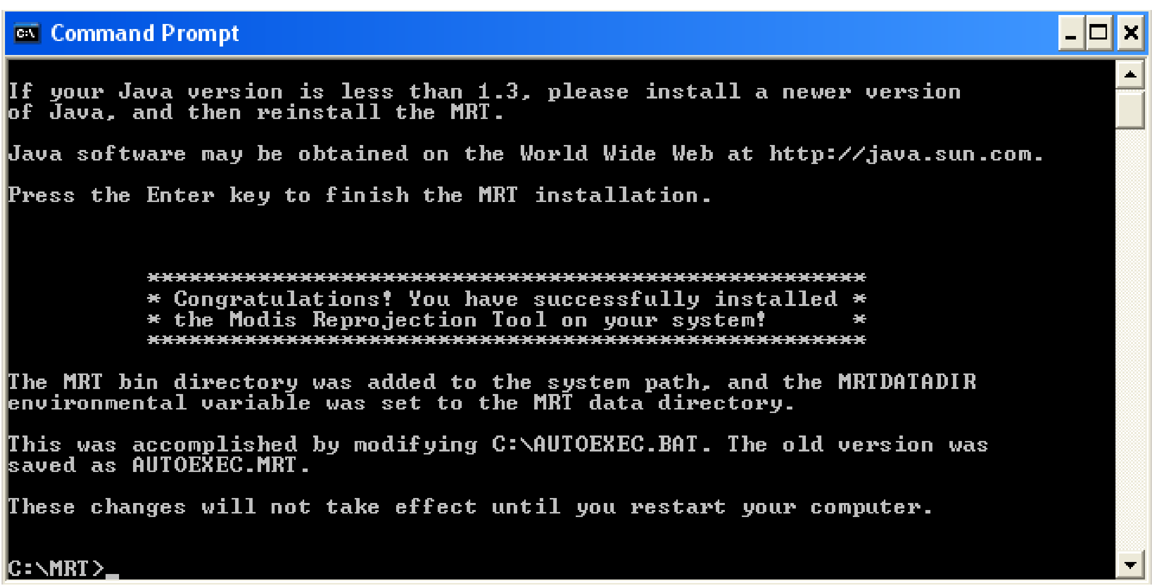
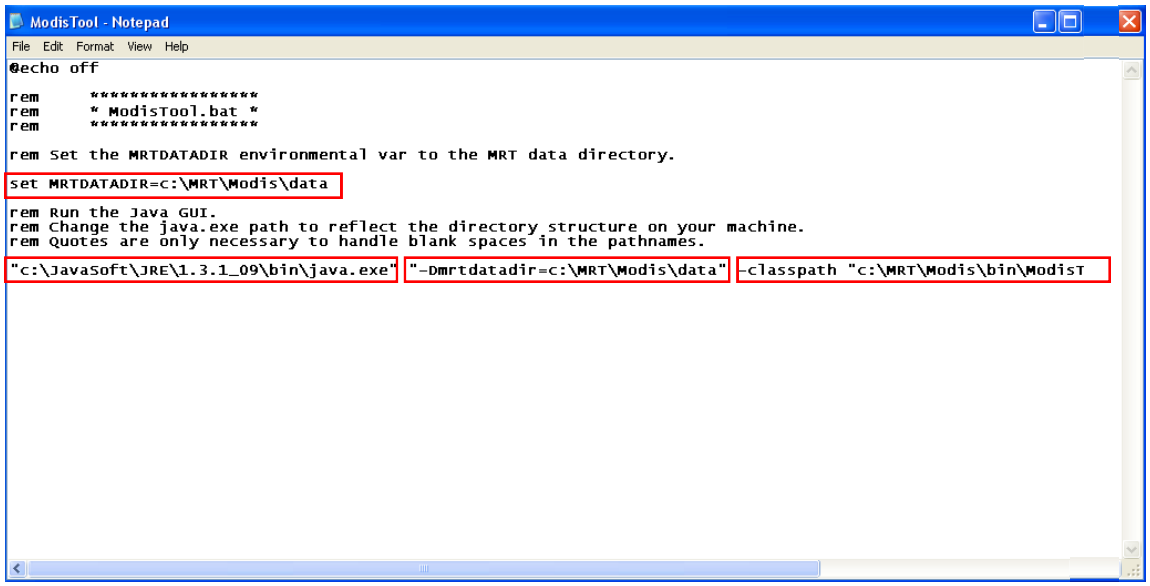


Figure 1.6. Message confirming successful installation of MRT.

10. Installation problems with the MRT are almost exclusively related to directory paths. If you experience problems with the installation, the first place to troubleshoot would be the ModisTool batch file referred to in procedure 9. Using a text editor such as Notepad, open the batch file and confirm that the directory paths are accurate with regard to where files are located on your local computer (Fig. 1.7). Correct paths as necessary, select File > Save, and test. **Note: The MRT will not work with any spaces in the path or file names.**




```
@echo off

rem      ******************
rem      * ModisTool.bat  *
rem      ******************

rem Set the MRTDATADIR environmental var to the MRT data directory.

set MRTDATADIR=c:\MRT\Modis\data

rem Run the Java GUI.
rem Change the java.exe path to reflect the directory structure on your machine.
rem Quotes are only necessary to handle blank spaces in the pathnames.

"c:\JavaSoft\JRE\1.3.1_09\bin\java.exe" "-Dmrtdatadir=c:\MRT\Modis\data" -classpath "c:\MRT\Modis\bin\ModisT
```

Figure 1.7. Text editor description of filenames to confirm proper naming conventions.

11. If you are unable to troubleshoot the problem, please contact the LP DAAC User Services at the following address:

LP DAAC User Services
U.S. Geological Survey (USGS)
Center for Earth Resources Observation and Science (EROS)
47194 252nd Street
Sioux Falls, SD 57198-0001
Phone : 605-594-6116
Toll Free: 866-573-3222
866-LPE-DAAC
Fax: 605-594-6963
Email: LPDAAC@eos.nasa.gov
Web: http://LPDAAC.usgs.gov
Hours: 8:00 a.m. – 4:00 p.m. (Central Time Zone)

1.2. MODIS Swath Reprojection Tool (MRT-Swath)

The MRT-Swath were developed by the Land Processes Distributed Active Archive Center (LP DAAC) for re-projecting MODIS Level 1-B and Level 2 swath data to gridded products. This tool will be used for processing of the MODIS Calibrated Radiance data (MOD02) and associated MOD03 geolocation files.

The installation procedures for the MRT-Swath tool are identical to those for the standard MRT outlined in section 1.1 of this SOP.

1. Use the same username/password that was emailed to you on registration for the MRT to access the "registered user services" link on the MRT Swath distribution web page, http://edcdaac.usgs.gov/landdaac/tools/mrtswath/index.asp (Fig. 1.8).

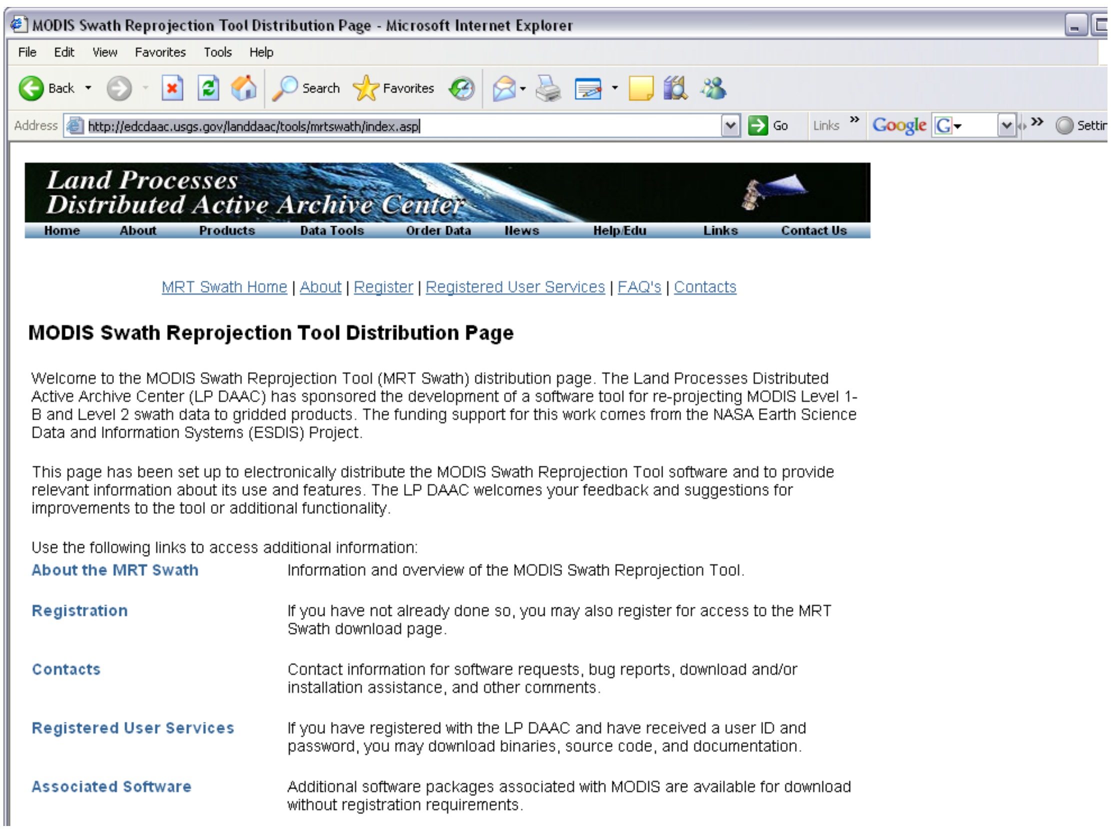


Figure 1.8. MRT-Swath distribution page.

2. From the "registered user services" page select "download" to access the Windows platform files as outlined in step 3 of the MRT installation.

3. Create a MRTswath directory on the C drive (i.e. C:\MRTswath) of your local computer. As with the MRT installation, use'right click', 'save target as' to individually copy each Windows platform file from the download page to the C:\MRTswath directory.

4. Follow steps 5 – 10 of the MRT installation substituting the "C:\MRTswath" directory path in place of "C:\MRT" in that procedure. The MRT-Swath also uses Java for its graphical user interface, so the same considerations with regard to the Java *bin* directory apply here. If you've already installed the MRT, the directory structure of access to the Java *bin* directory has already been established.

1.3. MODIS Land Data Operational Product Evaluation (LDOPE)

The LDOPE software tools were developed to assist with the analysis and quality assessment of the MODIS Land (MODLAND) products. The tools have been developed with feedback from the MODLAND science team and incorporate the scientific knowledge, experience and insights gained during the substantial MODLAND product development period. These software tools are invoked as stand-alone executables from a command-line interface. The software is supported on Irix, Solaris, Linux, and Windows operating systems.

LDOPE Installation Procedures:

1. Since the LDOPE tools are also distributed through the LP DAAC, the same username/password established to download the MRT and MRT-Swath tools can be used for the LDOPE downloads (see MRT procedures 1 & 2 in SOP 1.1).

2. Log on to the MODIS LDOPE "registered user services"webpage, http://edcdaac.usgs.gov/landdaac/tools/ldope/dist/index.asp, using your login.

3. From the Registered User Services page, select **download** to access installation guide and runtime executables (Fig. 1.9). For the Windows operating system, download **Win_bin.zip** from the runtime list and save it directly to the C drive.

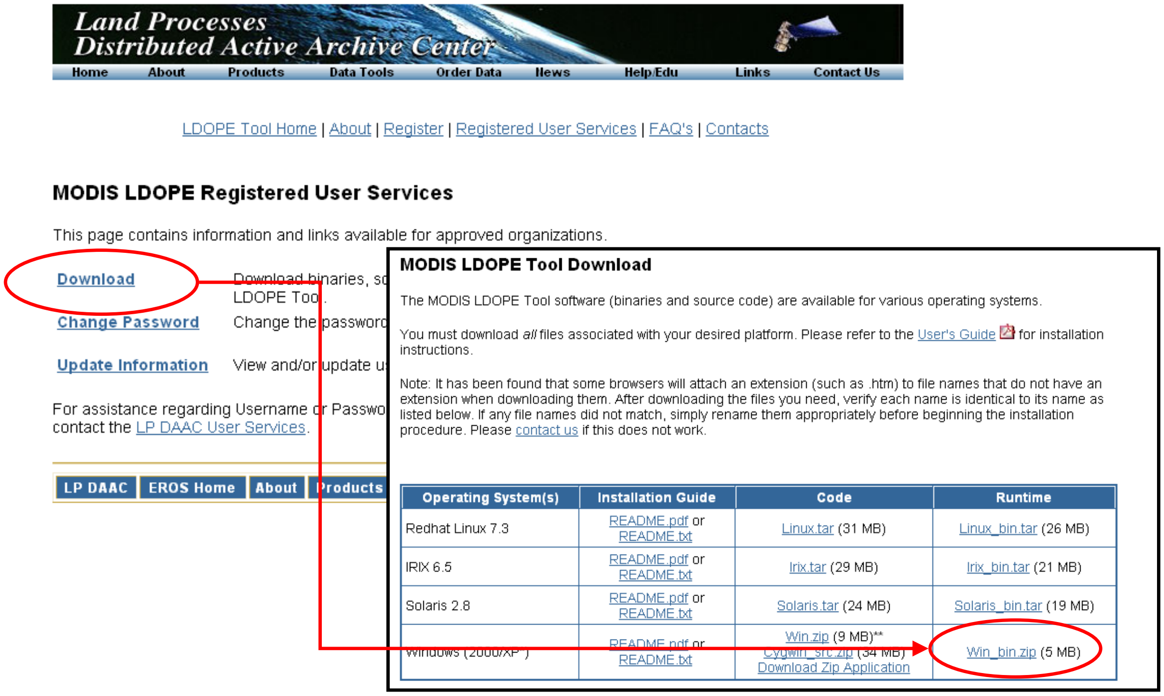


Figure 1.9. Initiating download for LDOPE software.

4. On the C drive, **right click > LDOPE_Win_bin.zip file**, and choose **extract to folder** (Fig. 1.10).

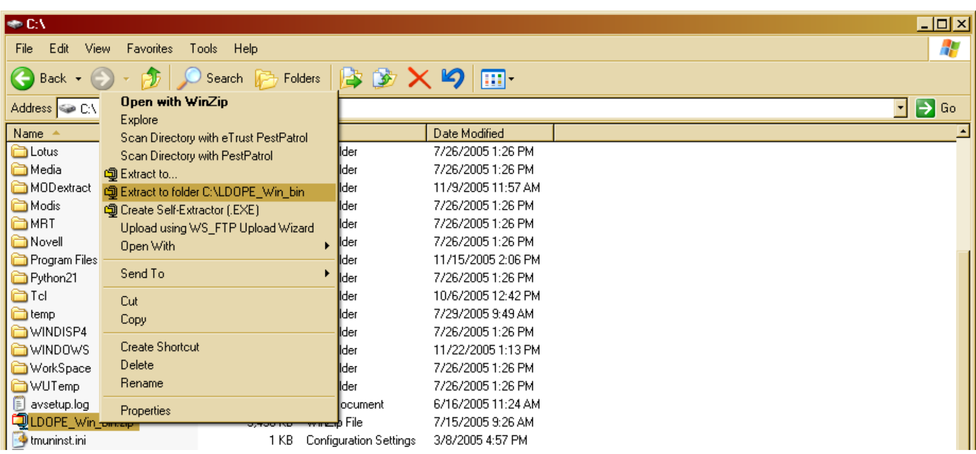


Figure 1.10. Download procedure for LDOPE software.

5. The directory LDOPE_Win_bin includes two subdirectories: **bin** and **ANCILLARY**. The 'bin' directory contains the LDOPE executable files and the 'ANCILLARY' directory contains the projection parameter files containing the projection parameters for all land tiles in Sinusoidal and Integerized Sinusoidal projections .

6. The next step is to set an environment variable (ANCPATH) that points to the ANCILLARY directory. Begin by clicking the Windows **"start"** > **"settings"** > **"control panel"**. Double click on the **"system"** icon. (Fig. 1.11)

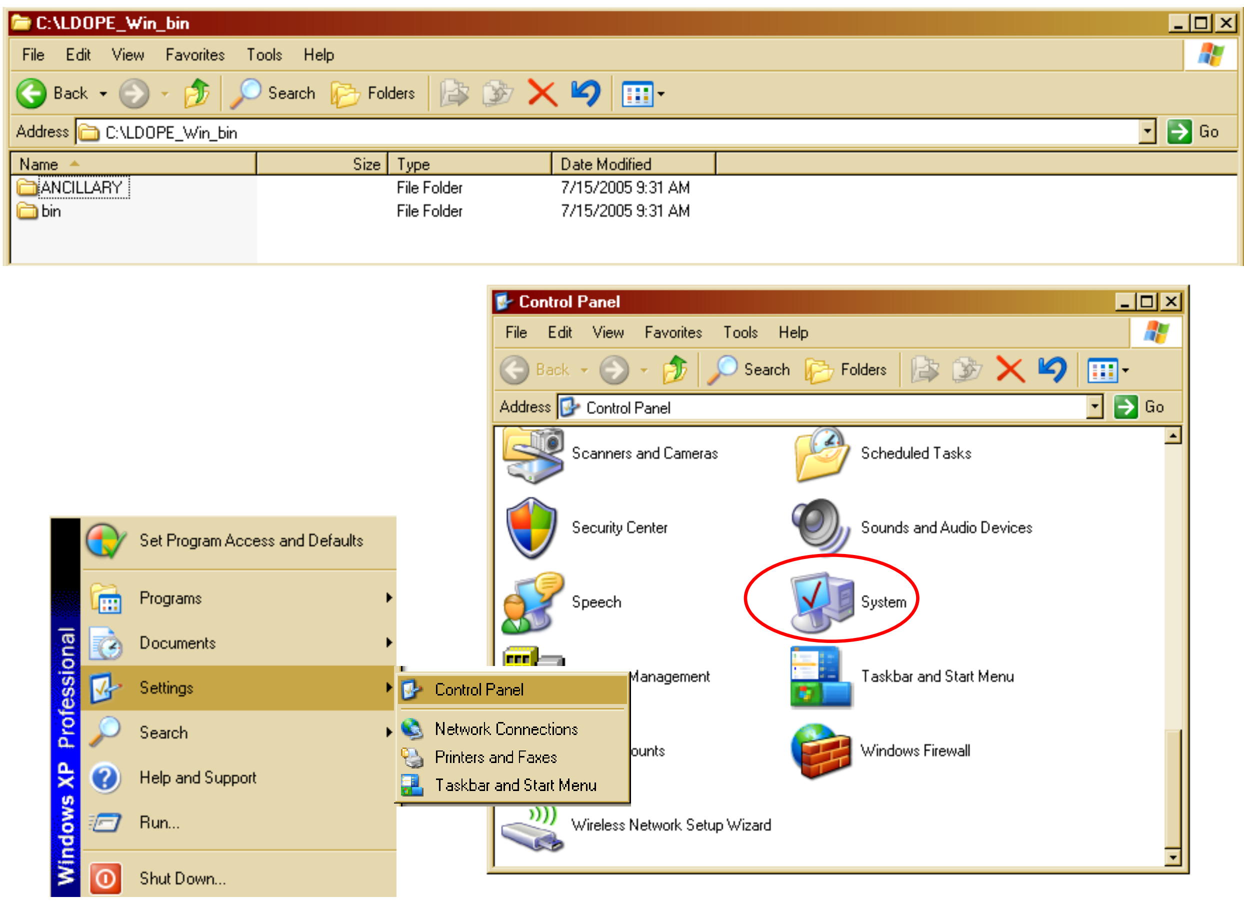


Figure 1.11. Accessing the system properties dialog box.

7. From the system properties menu select the **"advanced"** tab and click on **"environmental variables"** to open the environment variables listing (Fig. 1.12).

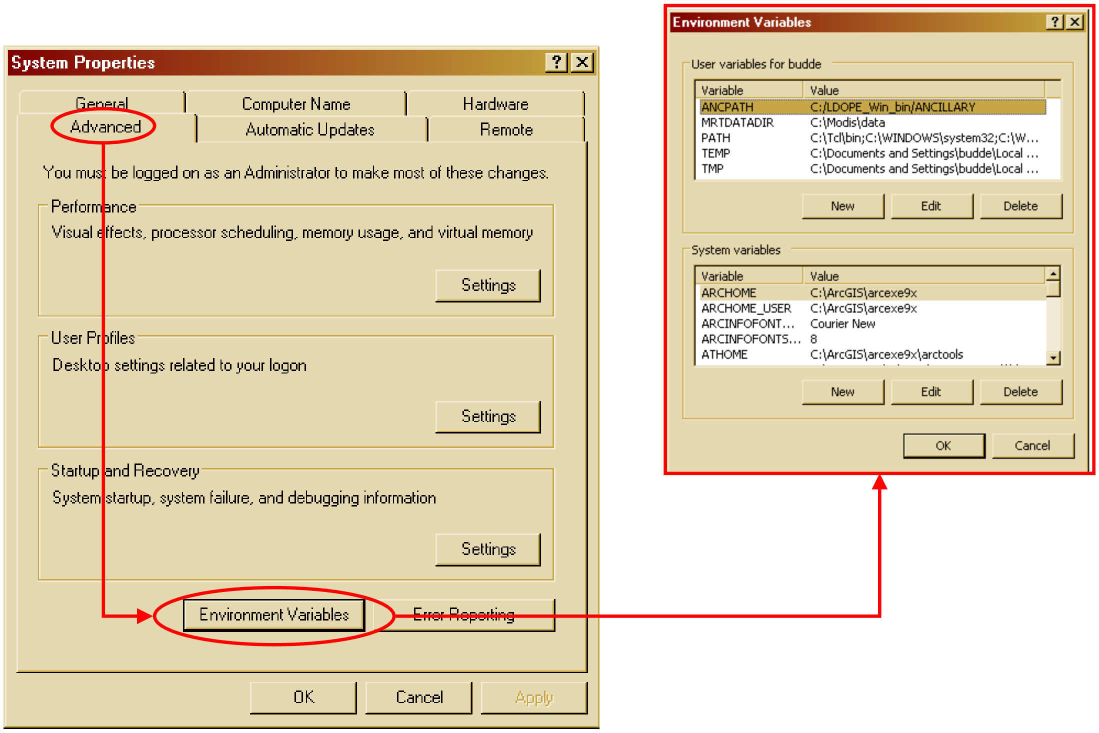


Figure 1.12. Accessing the Environmental Variables listing.

8. In the top panel labeled **"user variables …"**, select new and put the following in the "new user variable" window: **Variable Name = ANCPATH** and **Variable Value = C:/LDOPE_Win_bin/ANCILLARY**. Click **Ok** (Fig. 1.13).

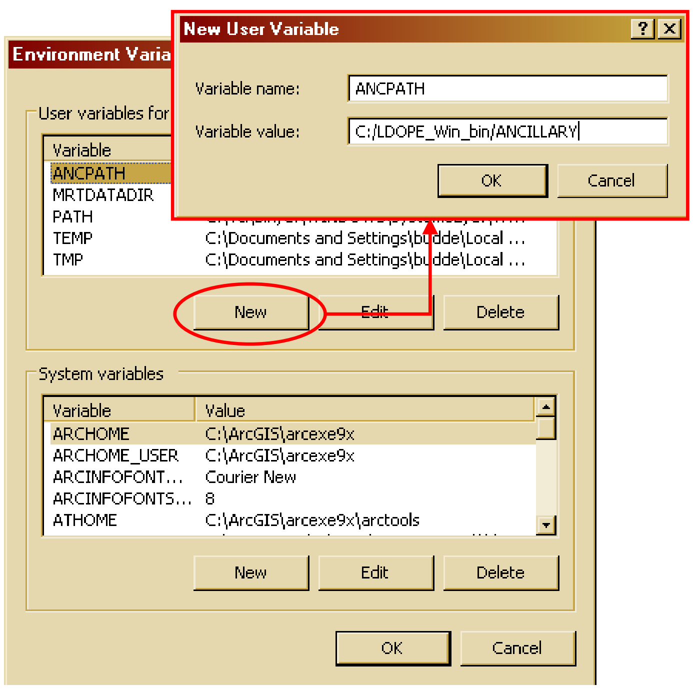


Figure 1.13. Assigning the ANCILLARY path to the ANCPATH variable.

9. An optional step, is to add the binary ('bin') directory path to the $PATH variable to allow the LDOPE executables to be run from any directory on the local machine. Access the environmental variables window (procedure 7). Select the **PATH** variable from the list and click the **edit** button. Add the binary directory path (**c:\LDOPE_Win_bin\bin**) preceeded by a semicolon (;) to the list of variable values. Click **ok** to apply changes (Fig. 1.14).

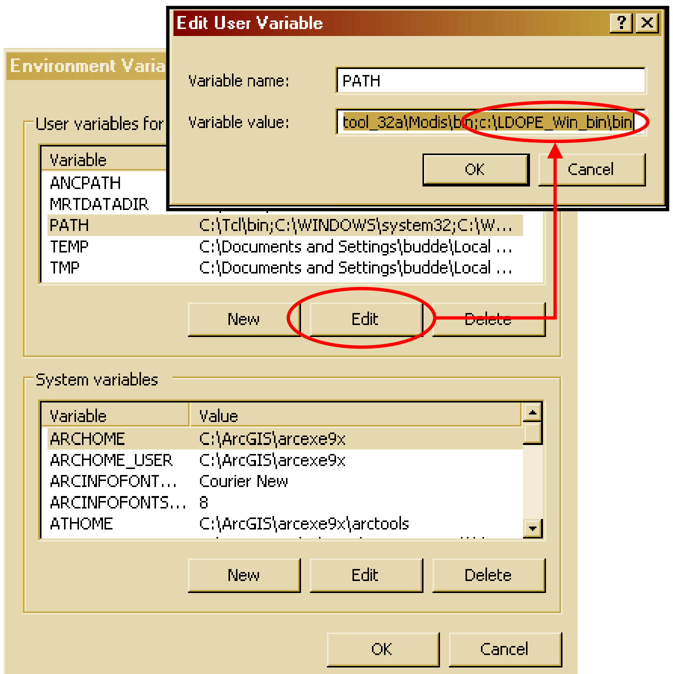


Figure 1.14. Assigning $PATH directory to allow the LDOPE executables to be run from any directory.

You have completed installation of software tools for processing raw MODIS HDF-EOS files.

1.4. IDL Metrics Setup

The IDL tools are used for deriving seasonal metrics (i.e. start of season, end of season, etc.) from the NDVI time series data. The program files for executing the tools must reside in a specific directory structure that must be referenced within the IDL preferences.

IDL Metrics Setup Procedures:

1. The first consideration is that the METRICS/idl/bin directory must reside somewhere on the local machine (Fig. 1.15). This directory and sub-directories have been provided to the SWAN.

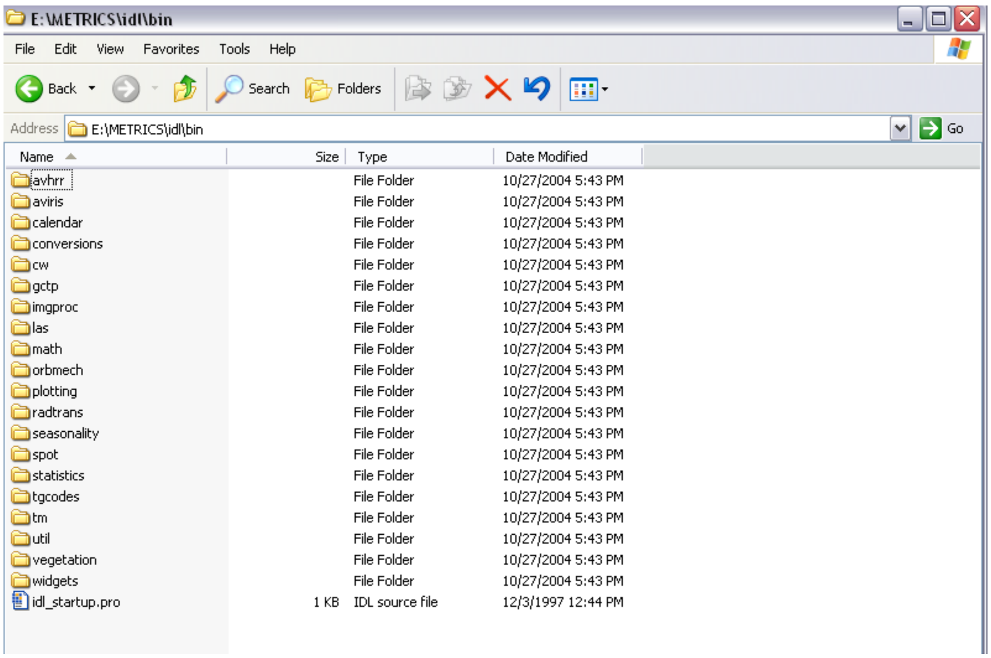


Figure 1.15. Example of the location of the METRICS/idl/bin directory.

2. Access IDL to add the directory path to the IDL preferences. Click ***Start > Programs > RSI ENVI > IDL.***

3. From the IDL window, select ***File > Preferences***. Within the preferences dialog box select the ***path*** tab and use the ***insert*** button to navigate to the METRICS/idl/bin directory and select ***ok***. This will add the directory path to the IDL preferences (Fig. 1.16).

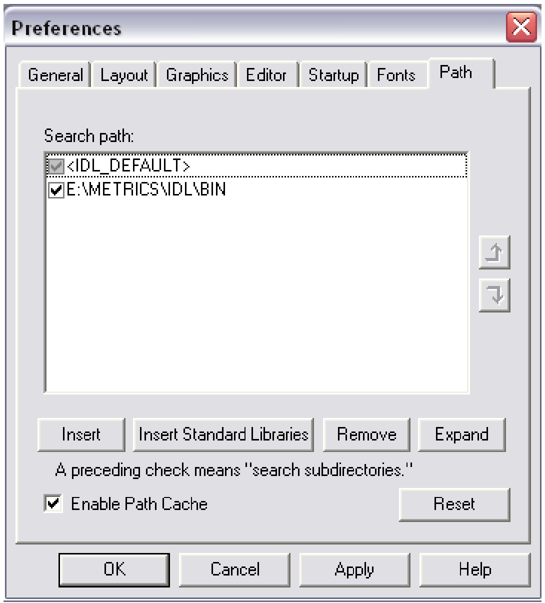


Figure 1.16. Setting the METRICS/idl/bin directory path in the IDL preferences.

4. The next step is to set the working directory where your data reside and where the output of the "imetricsoncube" program will be written. To do this select the ***startup*** tab from the IDL preferences. If you've closed the preferences dialog, use ***File*** > ***Preferences*** to reopen. From the ***startup*** tab, use the ***browse*** button to navigate to the working directory and select ***ok*** (Fig. 1.17).

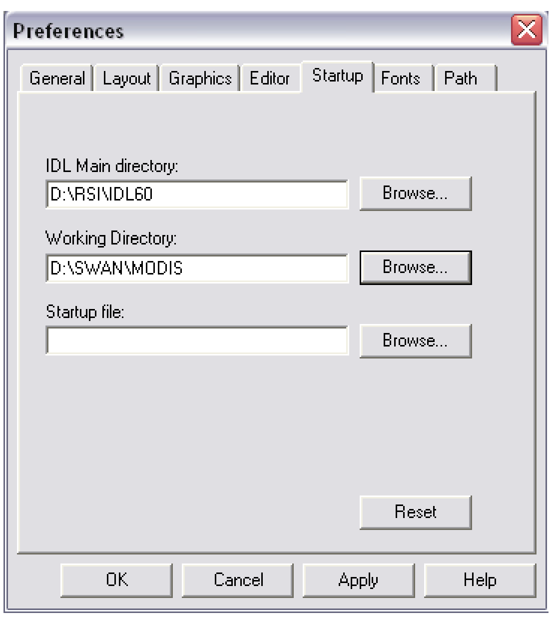


Figure 1.17. Setting the Working Directory.

This completes the process for the IDL Metrics setup. Procedures for executing these program commands are included in SOP 2.

SOP 2: Vegetation Index and Phenology Metrics

Satellite-Derived Measures of Landscape Processes
Southwest Alaska Network

Standard Operating Procedure (SOP) # 2

Vegetation Index and Phenology Metrics

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

This Standard Operating Procedure outlines the procedures for acquisition and processing of the standard MODIS Vegetation Index (MOD13Q1) product. This product is available from the Land Processes Distributed Active Archive Center (LP DAAC) Data Pool.

One of the intents of this protocol is to make the processing and analysis of these data more automated and therefore more standardized and user-friendly. The procedures outlined below represent those steps necessary to execute a set of scripts that have been provided to the SWAN in an effort to meet this intent.

The processing of MODIS NDVI products should be performed according to the processing schedule outlined in Table 2.1.

Action	SOP	Frequency
Data acquisition	2.1	Monthly
NDVI processing	2.2	Yearly
NDVI data exploration	2.3	Yearly
NDVI data smoothing	2.4	Yearly
Phenology Metrics	2.5	Yearly
Reporting	2.6	Yearly

Table 2.1 MODIS NDVI processing schedule.

The output from this set of SOPs will be georeferenced NDVI data at a 16-day compositing schedule for the SWAN region. From the NDVI data, phenological metrics (e.g., time of start of growing season, duration of season, etc) are computed and then statistically summarized for ecoregions within SWAN.

The software and scripts that are required to run this set of SOPs are listed below in Table 2.2.

Software	Process
File transfer protocol (ftp)	File transfer
ListHDF_v2	List HDF file names
MRT	Process hdf files
ENVI	Image processing
Smooth	Smooth NDVI data
IDL	Calculate phenology metrics
IDLmetrics scripts	Calculate phenology metrics
VI Processing scripts	Process VI files
Excel (or other spreadsheet)	Reporting

Table 2.2. Required software for processing NDVI data.

MODIS 250m 16-day Vegetation Index (MOD13Q1)

Any use of the general "VI" term is in reference to the standard NASA-EOS MODIS Vegetation Index product which contains both a normalized difference vegetation index (NDVI) and an enhanced vegetation index (EVI) product. In this protocol, only the NDVI product is utilized.

2.1 Data Acquisition Procedures

Required software: none

The MOD13Q1 products are routinely placed into the LP DAAC Data Pool as soon as they are produced. The data policy at the time of this writing is to keep one year (the most recent year) of the VI product online at the Data Pool at any one time.

Each month, the data technician should navigate via a web browser to the Data Pool and download all new MOD13Q1 data to the local, operational computer. To access the data:

- Open an Internet browser of your choice.

- Navigate to the website for the Data Pool:

  http://lpdaac/datapool/datapool.asp

- After reaching the Data Pool, click FTP MODIS (Fig. 2.1)

Figure 2.1 Navigating the LP DAAC Data Pool

- Double-click the file folder labeled MOD13Q1.004 (or current version of the MODIS collection; see SOP 6 regarding revisions to the Protocol for new MODIS collections).

  You will see a set of file folders that are labeled with a date corresponding to the first date of a composite period. For example, a file folder labeled “2006.09.14” will contain MOD13Q1 16-day composite data beginning on 14 September, 2006.

- Double click the file folder name that corresponds to the data you wish to download. You will see a listing of many file names.

- For easier navigation, change the view of your Internet browser by **clicking on the View tab** at the top of the browser and selecting **Details**.

  The MOD13Q1 files are listed in tile order. The tiles are sorted first by the horizontal tile number and next by vertical tile number. The first listed tile (using the 2006.09.14 folder) is:

MOD13Q1.A2006257.**h00v08**.2006280030442.hdf

The above file name is parsed according to the following:

MOD13Q1 – product name
A2006257 – Acquisition date; year 2006, day 257 (beginning of composite period)
h00v08 – horizontal and vertical tile numbers
2006280030442 – processing time; year 2006, day 280, hour 03, minute 04, second 42

Note: Many MODIS files are named according to their Julian Date. Julian day is simply the sequential day number, starting from Jan 1 and running through Dec 31. In the example above, day 2006257 is Sept 14, 2006. Julian dates will change during leap years.

- Scroll downward until identifying the 6 tiles that comprise the SWAN and **highlight each of the files by left mouse-clicking** on the first file, then depressing the control key and clicking the left mouse button on the subsequent file names (Fig. 2.4). It is only necessary to select the *.hdf files, not the *.hdf.xml. The files that should be selected are:

h09v02, h09v03, h10v02, h10v03, h11v02, h11v03

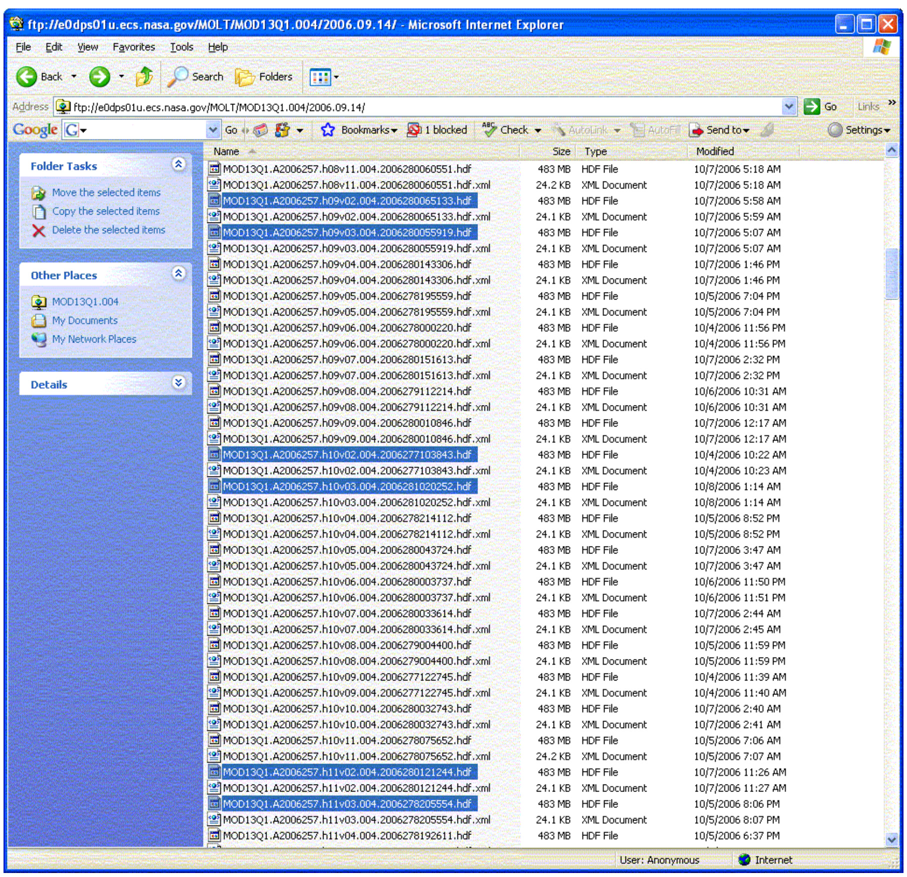


Figure 2.2. Selection of files in data pool.

- Open the destination file folder (e.g. D:\SWAN\MODIS_VI_16day\2006).

- Drag and drop the selected files from the Data Pool into the file folder.

  Notes:
  Depending on the connection speed of the local network, the download may take some time. If a large number of 16-day periods are being acquired at one time, it is recommended that this acquisition step be run overnight.

  Another caveat is that the LP DAAC has standard maintenance periods every Wednesday from 7a.m. to 11a.m. Central time and other unforeseen downtimes. SWAN personnel should avoid trying to acquire data during the scheduled downtime and should be aware that problems with the MODextract process may be due to server issues at the LP DAAC. These are listed on the Earth Observing System (EOS) Data Gateway welcome page (http://edcimswww.cr.usgs.gov/pub/imswelcome/). The user may need to scroll down the page to access the LPDAAC.

Earth Observing System Data Gateway (EDG) for Data Acquisition

In the event that any of these data are no longer available via the respective data pools, an alternative method for data acquisition does exist. The EOS Data Gateway provides a method for searching and ordering any of the MODIS data sets from all DAAC locations.
Detailed procedures on how to use the EDG are provided in Appendix 3 "**Grid data for Surface Reflectance processing"**

SOP 2.2 NDVI Processing
Required Software: MRT, VI processing scripts LDOPE?

After a year's collection of MOD13Q1 HDF files (23 files that correspond to 23 time periods – the number of 16- day periods in a year) have been transferred to the local SWAN machine, the next step is to execute a program called **List_HDF_v2.exe**. This script is provided to SWAN on the "Big Disk" remote hard drive of images and software, and can be found in the D:\SWAN\MODIS_Software directory. List_HDF_v2 creates a text file of the file names that is used in the next SOP, where all the HDF files are processed.

- Double click on the **List_HDF_v2** executable to open a small dialog box. Using the dropdown file structure, point to the directory where the HDF files reside and will be processed and click ok.

- Navigate to the directory (e.g. D:\SWAN\MODIS_VI_16day\2005) and assure that a set of new files named ***yyyyddd.txt*** have been written. Each of these files contains the list of hdf file names that correspond to each of the 16-day composite periods

Execute the batch file **SWAN_vi_script.bat** found in the annual directory where data are being processed (D:\SWAN\MODIS_NDVI_250m\2005 in this example). The batch file will process only those files for which text files (created above) and original HDF files exist. Note that the ASCII text files from which that *.bat files were created are also included in the directory for any unexpected editing that may be required (in case of MODIS version changes, path name changes, etc.).

- Execute the script by **double-clicking** on the filename.

The execution of this batch file will launch an MS-DOS window that shows the progress of the processing. The batch file uses command line MRT processes and LDOPE quality evaluation tools to process the vegetation index data.

1) The first step of this process creates a mosaic of the NVDI band (band 1).

2) The second step of the process creates a mask of poor quality data by accessing quality assurance information in the NDVI_Quality band (band 3). Poor quality data include pixels with high aerosol content, cloud contamination, or snow and ice cover.

3) The third step applies the quality mask to the NDVI mosaic

4) The fourth step executes the resample, subset, reproject, and reformat parameters to produce a single band NDVI image for analysis.

5) The final step of the process deletes temporary files that were created during the processing.

The output from this procedure is a set of 23 NDVI files (one for each 16-day composite period) in Geotiff format (with *.tif file extension) covering the SWAN region, in an Alaska Albers map projection.

- Navigate from the My Computer icon to the file folder where the data reside (in this example, it is D:\SWAN\MODIS_NDVI_250m\2005). Assure that the output files are present. Their filenames will be, for example:

  NDVI_2005_001.250m_16_days_NDVI.tif (for composite period beginning with day 1 of the year)

SOP 2-3. Interpretation of Normalized Difference Vegetation Index (NDVI) data

This section describes one of several possible approaches for exploratory analysis and interpretation. The NDVI data interpretations require layer stacking of multiple NDVI images and comparing the images from one year (or multiple years) to another (e.g., an index year of historical extreme) or to the recent historical average. The following procedures assist the user to interpret the NDVI data sets:

1) Layer stacking
2) Link windows and create corresponding Z-profiles
3) Data smoothing
4) Plot NDVI time-series in Excel
5) Compare data to "average" conditions
   -Calculate statistics
   -Create difference image

SOP 2.3.1 Layer stacking
Required Software: ENVI

- Initiate ENVI by double-clicking on the ENVI icon on your desktop. In the main ENVI window, open the NDVI data files using the following procedure.

- **File** > *Open Image File*

  Assure that you navigate to the proper file folder where the data that were processed in SOP 2.2 reside. The files have the filename structure:

  NDVI_2005_001.250m_16_days_NDVI.tif

- Select (and open) all of the NDVI *.tif files that were output from the MODIS scripts for one year of observations. This will result in a total of 23 selected images for a single year. Scroll through the "Available Bands List" to assure that all of the images are present.

- View one (or more) of the images by highlighting the image name (for example, NDVI_2005_321.250m_16_days_NDVI.tif, by clicking the Band 1 listing under the filename, then clicking the Load Band button at the bottom of the window (Fig. 2.3).

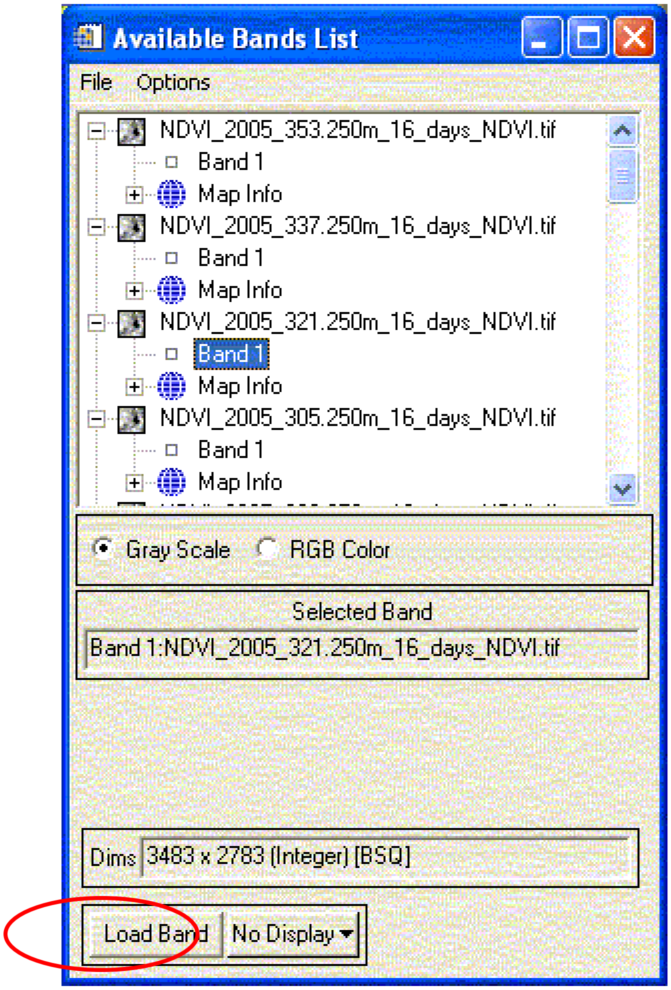


Figure 2.3 Selection of image for file display

Three display windows will pop up, displaying the image at three different levels of detail; the "scroll" window displaying the entire image at reduced resolution, the "image" window (largest of the display windows) displaying the image at 1/1 pixel resolution, and the "zoom" window at a default (but adjustable) zoom of 4x. To adjust the zoom power, you may click on the -/+ buttons at the bottom of the popup window.

In the next procedure, you will stack all of the images (layers) into one multi-band image in order to begin analysis of the data as a one-year data set.

- From the Main ENVI window, select **Basic Tools** > *Layer Stacking*
- Click the *Import File* button.
  - select all of the *.tif files as Input Files from the Available Files list. You may select all of the files at the same time, by using the control or shift key on your computer while mouse-clicking. After all the files have been highlighted, Click OK.

In order to analyze the data in the proper temporal sequence, assure that the files are in the correct chronological order (image one corresponds to the Jan 1 observation, etc.). For example, Fig. 2.4 lists the data in reverse chronological order.

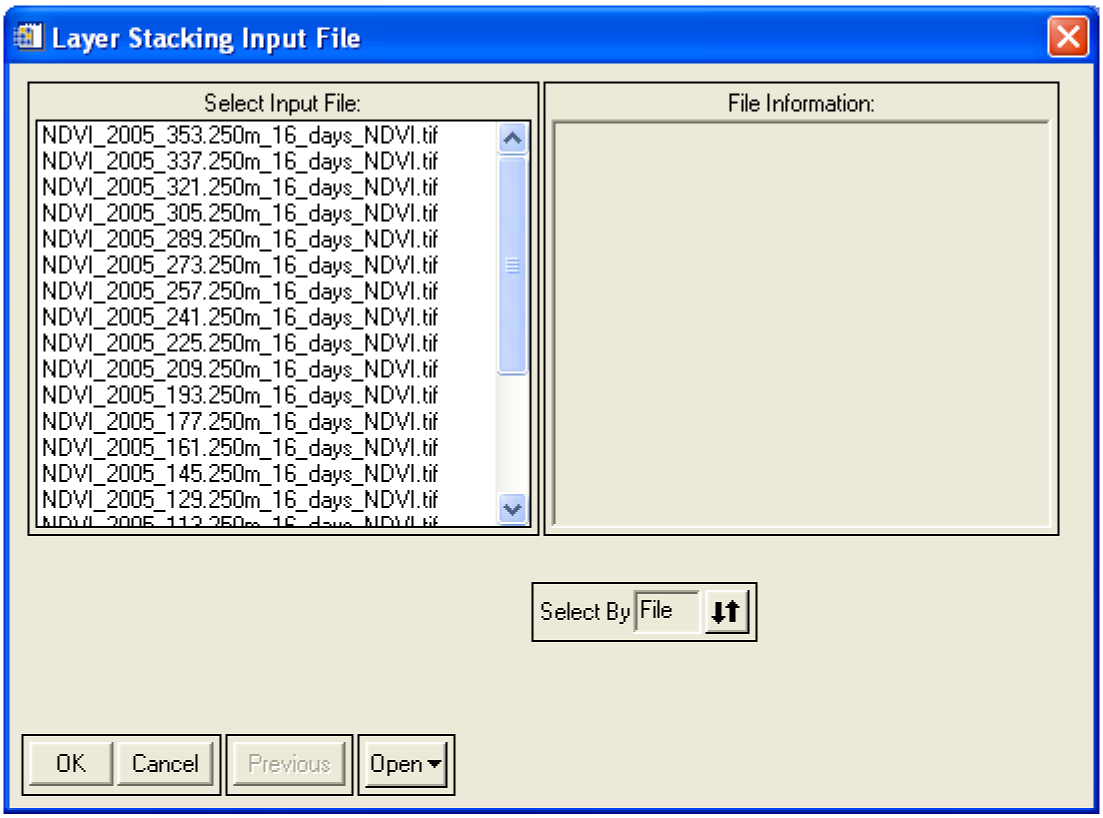


Figure 2.4. Listing of Input files for Layer Stacking procedure.

- Click the *Reorder Files* button – Note that the center mouse button reorders from bottom to top. Assure that the filenames are in the proper order:
    NDVI_2005_001.250m_16_days_NDVI.tif
    NDVI_2005_017.250m_16_days_NDVI.tif
    NDVI_2005_033.250m_16_days_NDVI.tif
    NDVI_2005_049.250m_16_days_NDVI.tif
    .
    .
    .

- *Enter Output Filename* > SWAN-NDVI-2005.

Note: Assure that you have navigated to the proper destination file folder before clicking OK to initiate the process.

The newly created Layer Stack will now appear in the Available Bands List.

- Display the new file by highlighting one of the Layers in the SWAN-NDVI-2005 file and clicking the Load Band button in the Available Bands List

- To display the temporal sequence (profile) of the NDVI data, **right click** in one of the Display windows and select **Z profile (spectrum).**

This displays a scaled NDVI value on the y-axis and band number (corresponding to time of year) on the x-axis (Fig. 2.5).

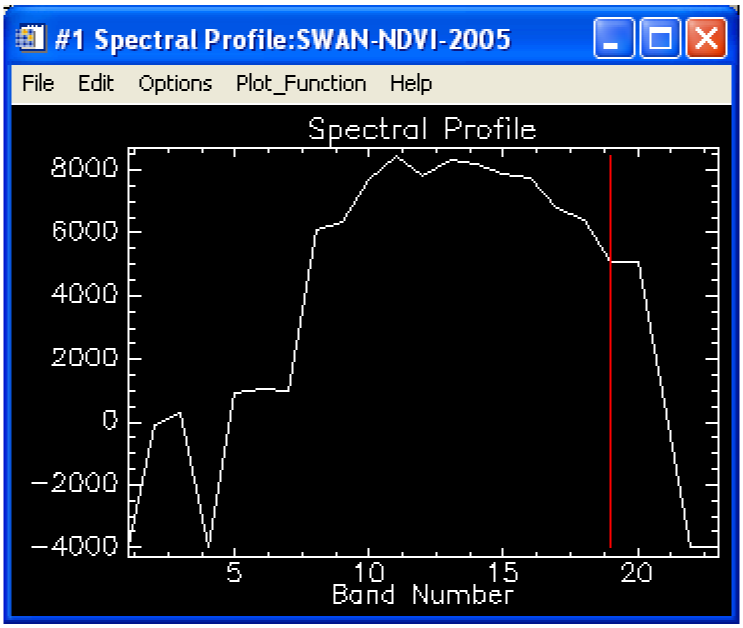


Figure 2.5. Temporal profile of a pixel.

You can observe instances of snow and cloud contamination (-4000 values) that need to be addressed before phenology metrics may be calculated.

SOP 2.3.2 Link Windows and create corresponding Z-profiles
Required Software: ENVI

The following methodology may be used to compare any set of time-series NDVI images. It is assumed that the layer stacking for individual years of VI has already been performed and are available for processing.

- Clear all images from the *Available Bands List* by clicking **File** in the Available Bands List window and selecting **Close All Files**. You will receive a warning that this will close all files. This is, indeed, what you wish to do, so select **OK**.

To compare two (or more) years of data, first open the image data and make sure they appear in the Available Bands List.

- In the Available Bands List window, click **File** and select **Open Image** File. Navigate first to the file folder containing a stacked data set, as prepared in the previous SOP. Select the stacked year (e.g., SWAN-NDVI-2005).

- Repeat the previous step and select a different year of stacked NDVI data (e.g., 2004).

Display the same band (say, Band 3) for each year in its own display window.

- First **highlight** one of the bands from 2004 (e.g. the 3rd listed layer), then click **Load Band** at the bottom of the *Available Bands List* window as in Fig. 2.3.

- Scroll down in the *Available Bands List* until you reach the 2005 data, and **highlight** the same band as you did for the 2004 data (e.g. the 3rd layer). At the bottom of the Available Bands List window, click the **Display # 1** button – select **New Display**. A blank display window will appear. Now click **Load Band** and the highlighted image band will be displayed.

In the next sequence, link the two display windows and display the temporal sequence for the same area (pixel) for the two separate years.

- Right click in one of the display windows and click **Link Displays**. A popup window will appear prompting for which displays should be linked. Leave the default values as are and click **OK.**

- To display the Z-profile (temporal sequence in this example), right click on the display window and select **Z-profile (Spectrum)**. Repeat for other display window(s). This creates a popup window with a temporal profile of the NDVI for each specified year.

You may now navigate through either of the images and left-click any place on the image and the Z-profiles for each year of data will update. To compare the individual years, it is important that the graphic scales be the same. The ENVI Z-profile function scales the y-axis depending on the data ranges.

- The y-axis scaling may be fixed by using the *Z-profile window* menu **Edit** > **Plot parameters**. Select Y-Axis and use a range of 0 to 9000 and click OK. Repeat the scaling for both Z-profile windows.

The resulting graphs may be compared side-by-side to identify differences in vegetation activity between years. For example, Fig. 2.6 illustrates NDVI differences between 2001 (left) and 2004 (right) for a single pixel. While the early season characteristics between the two years are similar, the profile for 2004 shows an extended autumn (lasting one or two observations longer than 2001).

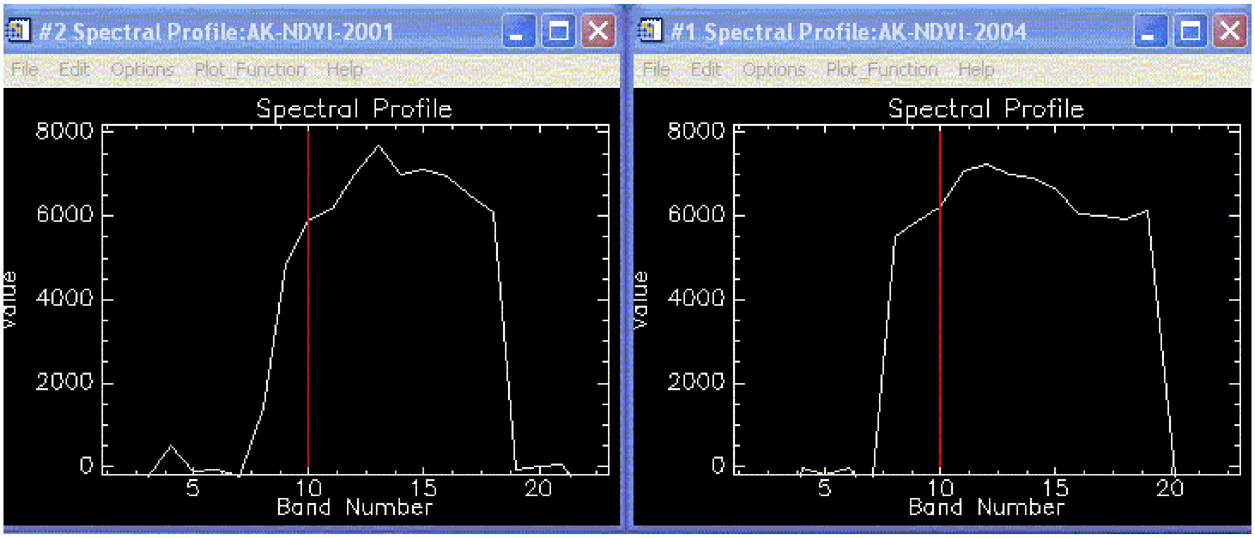


Figure 2.6. NDVI profiles for 2001 (left) and 2004 (right) for a pixel in SWAN

SOP 2.3.3 Data Smoothing

Many NDVI images exhibit areas with unsatisfactory values (masked out during the QA procedures) that were identified during SOP 2.2. A smoothing procedure can be performed on the NDVI imagery that eliminates the masked values by substituting temporally interpolated values. This results in a clean image that is appropriate for interannual analysis (Fig. 2.7).

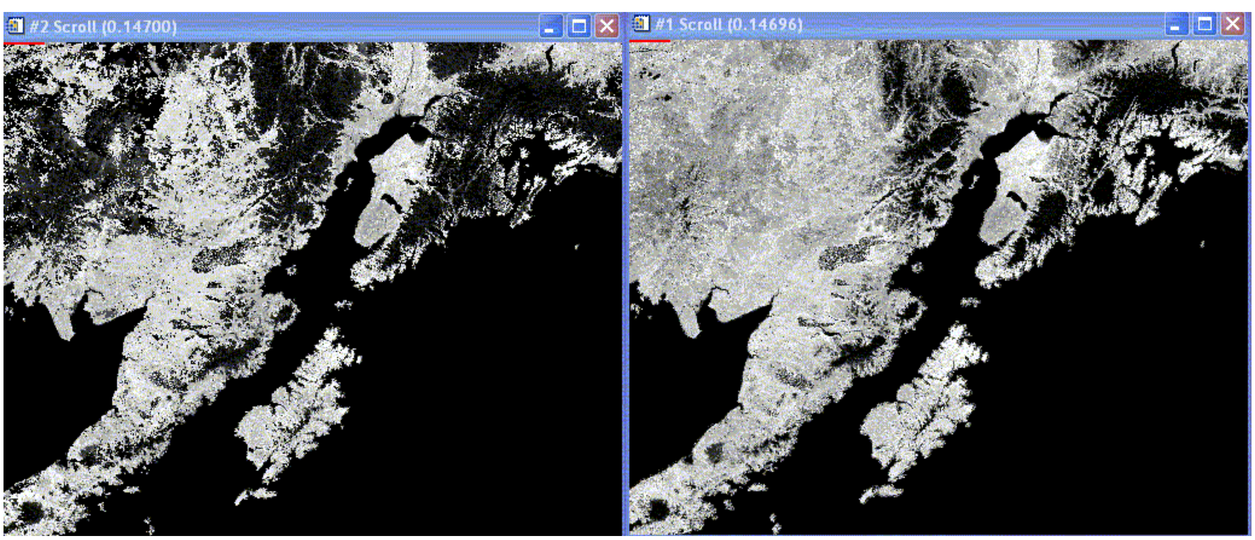


Figure 2.7. Before (left) and after (right) smoothing images of NDVI.

The smoothing operation permits a more realistic depiction of the vegetation conditions throughout the year (Fig. 2.8).

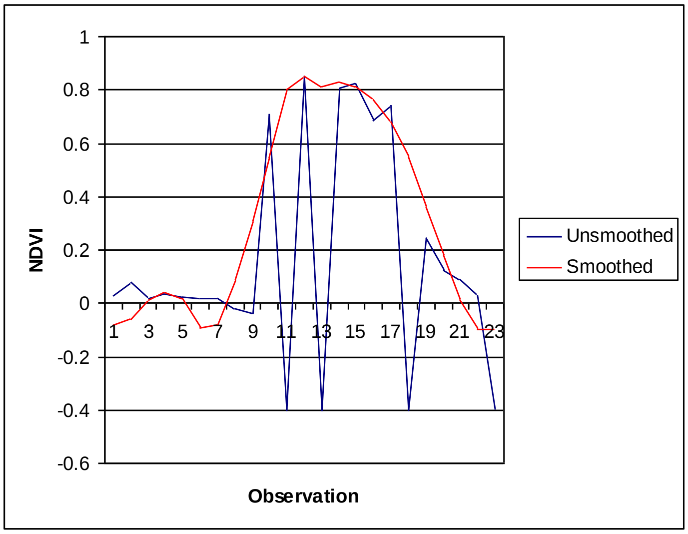


Figure 2.8. Results of smoothing operation on annual time-series.

To perform the smoothing operation, you first convert the data to byte range, then combine multiple years for assuring that the temporal smoother has data both before and after the dates of analysis for its operation (it operates using a temporally moving window), then execute the smoothing operation.

SOP 2.3.3.1 Convert the data to byte data range
Required Software: ENVI

The smoothing procedure operates on a stacked data set. The first step in this process is to convert the previously stacked data to byte range - this reduces the data volume, while retaining the temporal characteristics of the data that are required for the time-series phenology analysis.

To convert to byte:

- **ENVI > Basic Tools** > *Band Math*
  - Within the Band Math window, ***Enter an expression***:

    byte((b1/100)+100)

    This expression has been supplied to the SWAN in a restorable file. You may restore this expression by clicking the *Restore* button and navigating to where the file is stored: (D:\SWAN\ENVI_Expressions\BandMath-byte). Assure that the expression is highlighted and click **OK**.

- A new window will open **Variables to Bands Pairings** > *Map Variable to Input File* >
    - Select the stacked image created earlier: SWAN-NDVI-2005
    - *Enter Output Filename*: Navigate to proper file folder and enter SWAN-NDVI-2005-byte (Fig. 2.9)

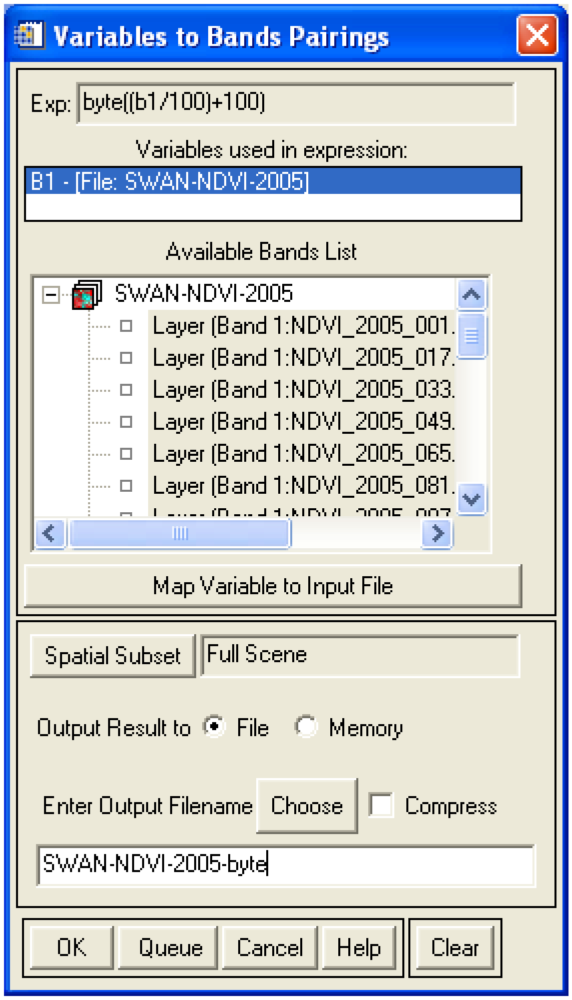


Figure 2.9. Band Math expression to convert to byte

This step converts the VI data from a scaling of 1/10,000 to the 0-200 data range.
In this new scaling, the data may range from 0-200, where a NDVI value of -1 corresponds to 0, an NDVI of 0 = 100, and an NDVI of 1 = 200.

The data are now ready to be prepared for temporal smoothing to eliminate the snow, cloud, and aerosol contamination.

Note: If there is ever a need to convert to "true" NDVI values (such as reporting values for a publication), use the equation: NDVI = (Scaled NDVI -100) / 100

SOP 2.3.3.2 Prepare multiple-year data stack for smoothing
Required Software: ENVI

Since the smoothing process utilizes a temporal moving window (Swets et al, 1999) it requires that data be present both before and after the data that are to be smoothed. Therefore, the next step is to "pad" the data that are to be smoothed (2005) with one year of data before (2004) and one year of data after. In many cases, such as this example, we repeat the final year of the series (in this example, 2005, again) when the collection for the following year (2006) has not yet been completed. Assuming that no data sets are open and in the ***Available Bands List,*** begin ENVI and:

- **Open Image File** > Open the 2004 stacked, byte data.

- **Open Image File** > Open the 2005 stacked, byte data.

- **Basic Tools** > *Layer Stack*
  Import File…import stacked 2004 data
  Import File…import stacked 2005 data
  Import File…import stacked 2005 data again

- Assure that the files are in the proper order: 2004, then 2005, then 2005 again. If not, initiate the ***Reorder Files*** function. Choose an output filename (SWAN-NDVI-040505-byte), press **OK**. This will result in a 69-band file that is ready to be smoothed.

SOP 2.3.3.3 Run Smoother
Required Software: Smooth, ENVI

The data are now ready to be temporally smoothed using techniques described by Swets and colleagues (1999).

- Begin a command prompt window (**Start** > **Programs** > **Accessories** > ***Command Prompt***) and change directories to the location of the smoother program, first by switching to the appropriate drive **(e.g. > d:)**, then changing directories to the appropriate path (**d:\> cd SWAN\Smoother**).

This file folder contains the correct parameter file for executing the smoother for each year (e.g., smoothparams2005.txt).

- Initiate the smoothing algorithm from the command prompt:
  d:\swan\smoother> smooth smoothparams2005.txt

Note: the input and output paths in the smoothparams200.txt file may need to be changed (using a text editor) to correspond to the source and destination file folder locations.*

The smoother will then begin operation and will update the operator by displaying each line that is being processed. The estimated operating time for this operation is 20-30 minutes, depending on computer speed, other processes that are running, etc.

The results may then be displayed in ENVI from either the main ENVI window or the ***Available Bands List*** by the following procedure.

- **Open Image File** > navigate to where the new smoothed image resides and select it > SWAN-NDVI-040505_sm

Since the image was created outside of ENVI, it does not yet have valid header information (file description, projection information, etc.) so a popup window will appear and request information about the file.

- *Select Input Header Info From* > *Other File* and select the previous byte image (SWAN-NDVI-040505-byte).

Note: this file (SWAN-NDVI-040505-byte) must be in the Available Bands List – if not, open the image using procedures described earlier.

This will assign the proper header information to the file.

- Display the file using procedures described earlier

- Right click within one of the image windows and select **Z-profile (Spectrum)** to view the new, smoothed temporal profile of the NDVI imagery. Note that the new graph displays 3 years of data, due to the stacking of multiple years (Fig. 2.10).

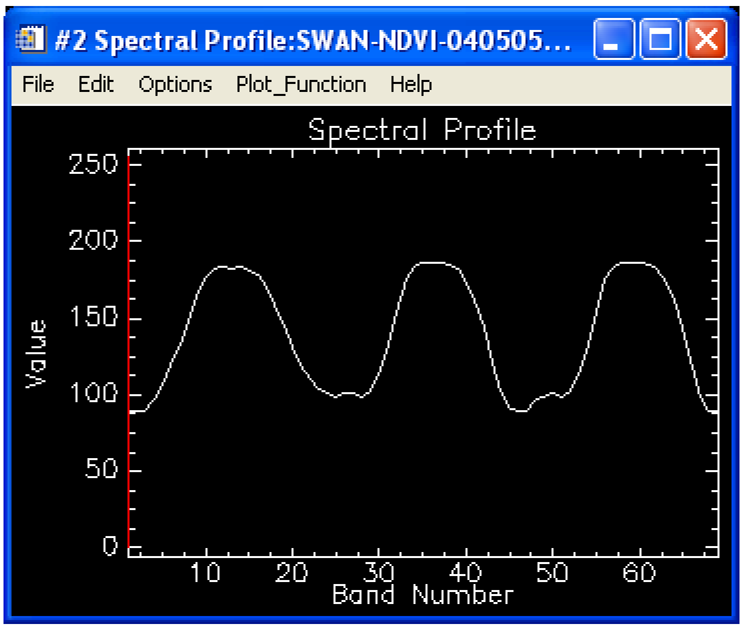


Figure 2.10. Three years of smoothed data.

SOP 2.3.3.4 Subset image into one, smoothed year of data
Required Software: ENVI

Now that the year of concern (2005 in the example) has been smoothed, it needs to be taken from the 3 year stack, so it can stand alone and be used for other applications. From the ENVI Main Menu, select:

- **Basic Tools** > *Resize Data* (Spatial/Spectral). This will popup a window prompting the user to *Select Input File*. Select the file that has been smoothed and with the header information added (SWAN-NDVI-040505_sm, in this example).

The window will then activate fields for *Spatial Subset* and for *Spectral Subset*.

- Click *Spectral Subset*. This will popup a new window called File Spectral Subset that lists all the individual date images (bands) that comprise the stacked image in chronological order. Scroll down the window until you reach the first band of the year that you are trying to isolate (Fig. 2.11). Highlight this band and all other bands (using the shift or control key) for the year of data that you are subsetting. Click **OK**.

This will return you to the Resize Data Parameters window. Do not change any other file parameters.

- *Enter Output Filename* (e.g., SWAN_NDVI_2005_sm). Click **OK**.

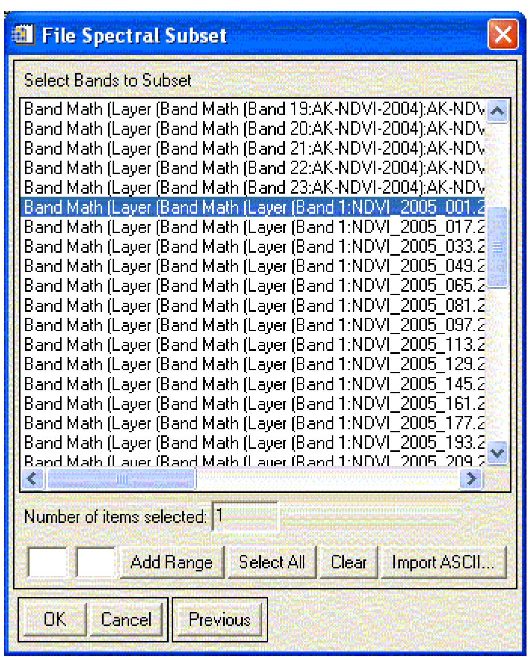


Figure 2.11. Listing of bands in spectral subsetting process.

SOP 2.3.4 Plot NDVI time-series in Excel or other spreadsheet
Required Software: ENVI and Excel (or other spreadsheet)

By comparing the annual time series between two different years, patterns of vegetation activity may be analyzed. Besides examining the data using the ENVI Z-profile function, it is also possible to transfer the data points to Excel to perform spreadsheet functions on the data (for data manipulation, display, etc.).

To transfer the data to Excel, first display the one-year image created in the previous SOP.

- Right click in the image window and select **Z-profile (Spectrum).**

- use the Z-profile window menu and select File → Save Plot As → ASCII. A popup window will appear. Highlight the *Select Plots to Output* (Fig. 2.12) and enter an *Output Filename*. Click **OK**

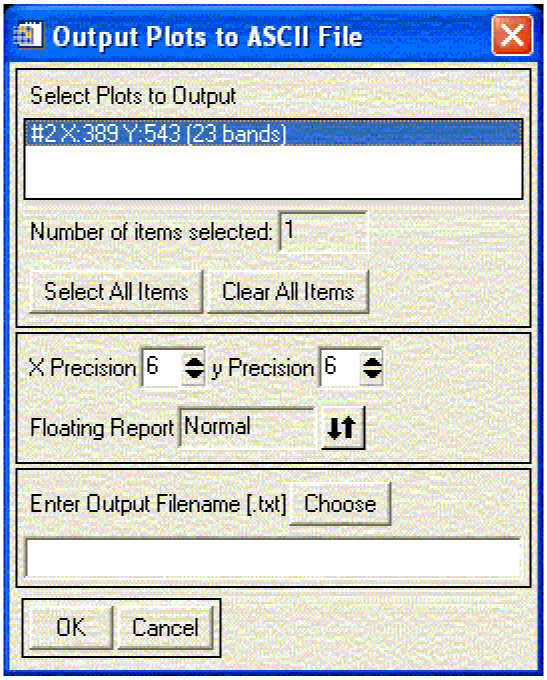


Figure 2.12. Output Plot to ASCII window.

This will save the plot values to an ASCII text file, which can then be easily imported into Excel or another spreadsheet or database. In this manner, several annual plots may be saved and plotted on the same graph so that interannual differences in vegetation activity may be viewed simultaneously for any pixel (Fig. 2.13). This kind of chart may be used to interpret the vegetation dynamics of a pixel for each year. In this example, it is clear that 2001 had the shortest growing season, while 2003 and 2004 had earlier springs.

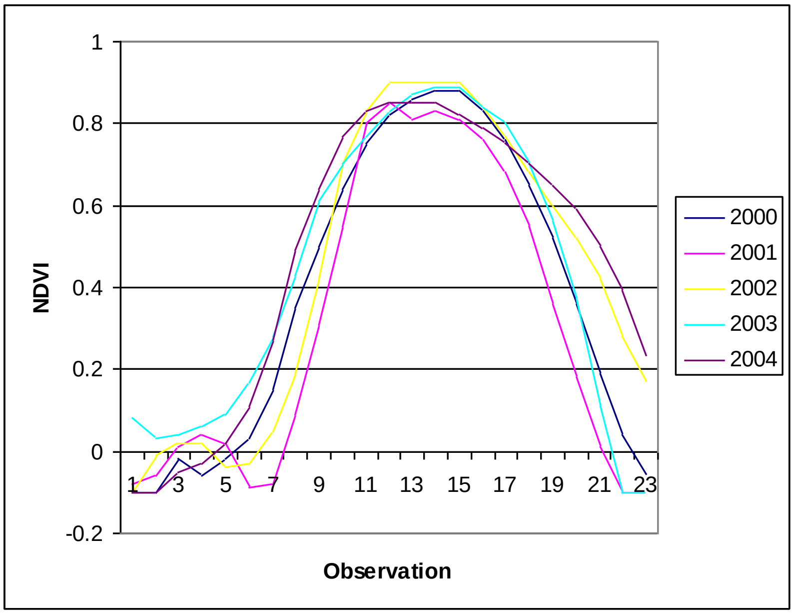


Figure 2.13. Annual vegetation index temporal curves from 2000-2004.

SOP 2.3.5 Compare data to "average" conditions
Required Software: ENVI

It is often useful to compare a current observation with the average conditions. This SOP describes calculating average conditions as defined by the conditions during the period of data collection (since 2000 in the case of MODIS) and then a technique for visualizing a comparison of current conditions (or conditions from any single year of observation) to the average.

SOP 2.3.5.1 Calculate Statistics
Required Software: ENVI

ENVI permits the ready calculation of mean values by the following procedure. In this example, a mean NDVI multi-band image will be created.

- First, open all six of the smoothed NDVI images, one for each year 2000 – 2005, using procedures described earlier. These are found in the file folders, D:\SWAN\MODIS_VI_16day\yyyy, where yyyy is the year of observation.
- From the ENVI main menu click **Basic Tools** → *Band Math*. A *Band Math* popup window will appear.
- Within the *Band Math* popup window, *Enter an expression*. For calculating the mean for six layer-stacked images, the expression may be: byte ((B1 + B2 + B3 + B4 + B5 + B6) / 6), where B1 through B6 are the stacked images for Year 1

through Year 6. When the expression is satisfactory, click **OK**. A ***Variables to Bands Pairings*** popup window will appear.

Within the ***Variables to Bands Pairings*** window, the user is required to assign the variables to data that are in the Available Bands list.

- Highlight the first Variable (*B1 – [undefined]*), click the **Map Variable to Input File** button. Select the appropriate layer-stacked NDVI input for the variable (in this example, B1 is assigned to SWAN_NDVI_2000_sm).

- Proceed through each of the remaining variables (B2 through B6).

- *Enter Output Filename* (be sure to navigate to the proper destination file folder) and click **OK**.

The result is a stacked image containing the mean NDVI value for each of 23 bands. Other statistics may be calculated as well – see the ENVI main menu → Help for Band Math for calculating other statistics. The limits are set only by your creativity with Band Math.

SOP 2.3.5.2 Create Difference Image
Required Software: ENVI

You may create an image depicting the difference between any observation and average conditions. This can be performed either for the entire year (procedure below) or for a single composite period. This procedure is performed using Band Math.

- From the ENVI main menu click **Basic Tools** → *Band Math*. A *Band Math* popup window will appear.

- Within the *Band Math* popup window, *Enter an expression*. For calculating the difference between two images, the expression is **(B1 – B2)**. Assign B1 to the year under analysis and B2 to the mean value image. The result may then be displayed using the usual ENVI display SOP.

- *Enter Output Filename* (be sure to navigate to the proper destination file folder) and click **OK**.

The result is a stacked image containing the difference in NDVI between the year under analysis and the mean value for each band.

SOP 2.4 Phenology Metrics

Phenology - the study of the timing of biological events (such as spring greenup and fall senescence) is an indicator of an ecosystem's response to a suite of environmental variables, most notably climate. The role of remote sensing in phenological studies, while still under development, is increasingly regarded as a key to understanding large area seasonal phenomena. Repeated observations from satellite-borne multispectral sensors provide a mechanism to study regional scale phenology and monitor the potential impact of changing phenology on ecosystems. For instance, a trend toward earlier spring greenup may result in earlier animal movement.

Remote sensing has been used to study phenology in a research mode from the 1970's through the 1990's (e.g., Badhwar, 1984; Lloyd, 1990; White and others, 1997; Reed and others, 2003). Recent research in remote sensing phenology has primarily been focused on the AVHRR and MODIS satellite sensors because of their daily repeat cycles (at high latitudes) and sensor configurations that are suitable for vegetation studies. Because of these characteristics, they have the ability for use in deriving remote sensing phenology estimates for operational ecosystem monitoring.

Phenological variables that may be estimated from satellite remote sensing are the time of the start of the growing season (SOS), end of growing season (EOS) and the growing season length (GSL). When deriving phenological characteristics from remote sensors, the object is not species, population, or even community specific phenology, but rather the characteristics of individual pixels. If the pixel size is on the order of hundreds of meters, the objective usually becomes characterizing the phenology of a mosaic of several vegetation types. Because of the more general target, the specificity of phenology that can be determined is reduced. The contribution of the individual phenology of the various components of a pixel are mixed and the integrated phenology of the pixel is usually addressed in terms of a more general statement such as the start or the end of the growing season, rather than more specific measures such as first-leaf or bud-burst.

The various approaches that have been used for satellite phenology can be grouped into three types; threshold-based, inflection points, and trend derivatives. Threshold-based measures use either a pre-defined or a relative reference value for defining the start of season. For example, in one of the earlier efforts at using AVHRR for setting a definitive date for SOS, Lloyd (1990) used a NDVI = 0.099 as the threshold value in a study using AVHRR NDVI data. When the NDVI reached this threshold value, SOS was reached. Such a reference value can be very effective at defining local SOS values, but there is difficulty in using such values over environments with different soil background characteristics or with land cover types. The inflection point approach usually involves creating a model to describe elements of the time-series curve. One example is Zhang and others (2002), whose algorithm is based on finding when the curvature of the NDVI time-series changes from one linear stage to another, i.e. from decreasing to increasing or increasing to decreasing sections. The points with maximal curvatures are where the phenology changes phase. Similar to the previously discussed approaches, phenology estimates derived from curve characteristics seek to identify where the VI data exhibit a rapid, sustained change. For example, Reed and colleagues (1994) determine SOS by employing a backward-looking moving average. NDVI values are compared to the average of the previous *n* observations to identify departures from the established trend. A trend change is defined as when the NDVI values become larger than those predicted by the moving average. This is the approach used for the SWAN region.

While comparing the remote sensing derived start of season values to informally observed dates, the remote sensing derived values sometimes seem to be early. But in some instances, this first flush of greenness may not be discernable to the naked eye. During an early May, 2006 overflight of the Kenai Peninsula, we were not able to distinguish any greenness (leafed out trees or shrubs) with our eyes, however, we noted that moose and bears were actively grazing - indicating that green shoots may have been present beneath dead grasses. These shoots affect the surface reflectance measured by the satellite sensor. Regardless, the technique utilized for this study does identify the identical location on the temporal curve for each year of observation, thereby supplying a consistent, objective metric for time-series analysis.

SOP 2.4.1 Prepare Data for Calculating Phenological Metrics
Required Software: ENVI

To derive Phenology Metrics for one year, three years of smoothed NDVI data are required. This is because the algorithm operates by examining data both before and after the time of analysis to identify trend shifts. When examining the most recent year of observation (a typical analysis scenario), there is not yet any data after the time of observation. In this instance, we repeat the current (most recent) year of observation. Therefore, the first step in this procedure is to create a layer stack of smoothed data.

- Assure that the *Available Bands List* is empty. On the *Available Bands List* window, click **File** > ***Close All Files***.

- Open the required files. On the *Available Bands List* window, click **File** > ***Open Image File***, open the smoothed files for 2004 and 2005.

- Stack these data using the same procedures as used in SOP 2.3.1. Stack them in the order, 2004, 2005, then 2005 again. Note that if a complete year of smoothed 2006 data were available, those data would be used instead of repeating 2005. Assure that the data are in chronological order before clicking OK. **Enter Output Name**: *SWAN-NDVI-040505_sm*. The result is a 69-band file.

Before the phenological metrics can be calculated, two data preparation steps must be performed. Some of the calculations in the metrics algorithm require the slope of the NDVI value through time as an input variable. When there is an extended period of time where the NDVI value is identical (such as masked values over snow, cloud, aerosol or water), the slope becomes zero. This slope value is later used as a divisor in part of the metrics algorithm and crashes the program as it currently operates. Therefore, a workaround is to search for and alter these values. We have constructed an ENVI image that can be used as part of an ENVI Math Expression to identify and eliminate these constant values.

SOP 2.4.2 Eliminate the extended snow, cloud, or aerosol pixels
Required Software: ENVI

During the original MODIS processing of NDVI (SOP 2.2) snow, clouds, and high aerosols were flagged and written as a value of -4000, which during the transfer to byte data range and the smoothing process becomes a value of 90. Water values in the image also need to be masked in order to avoid nonsensical phenology metrics. Water values can vary, but generally have an NDVI value of 0 (DN of 100) or less. This procedure involves identifying values of less than or equal to 100 in the data set and recoding them to values that are near a value of 100 (ranging from 100-102) – values that are in the realistic range of NDVI values.

A 69-band image (D:\SWAN\ENVI Expressions\69band-fill), corresponding to 3 years of MODIS 16-day data has been prepared containing these values in alternating bands to eliminate the constant value issue discussed above. Before starting the next procedure, assure that the **69band-fill** image has been opened and is in the Available Bands List.

- On the *Available Bands List* window, click **File** > ***Open Image File***, open D:\SWAN\ENVI Expressions\69band-fill

- Under **Basic Tools** > *Band Math* when the Band Math popup window opens, select,
    - *Restore* (this function will restore an existing Band Math expression). A popup window for a filename will open. Navigate to D:\SWAN\ENVI Expressions and select the file BandMath-fill. This will insert the following expression into the Band Math window:
        - byte((B1 le 100) * B2) + byte((B1 gt 100) * B1)

This expression states that if B1 (input smoothed image) is less than or equal to 100 (previously masked data values), assign the value of B2 (the fill image containing the 100-102 values). If greater than 100, B1 retains the original values of B1. The byte portion of the expression assures that the data remain in byte range, rather than the default floating point data type.

After clicking **OK**, a new window will popup that prompts the user to assign variables to the expression (Fig. 2.14).

- Make sure that B1 – [undefined] is highlighted, and then press the button *Map Variable to Input File*. This spawns a new window containing the possible input files – select the newly stacked, smoothed image (SWAN-NDVI-040505_sm).

- Next, highlight the next variable B2 – [undefined] and map that variable to the fill file (69-band-fill).

- Choose an output name (SWAN-NDVI-040505-fix). Press **OK**.

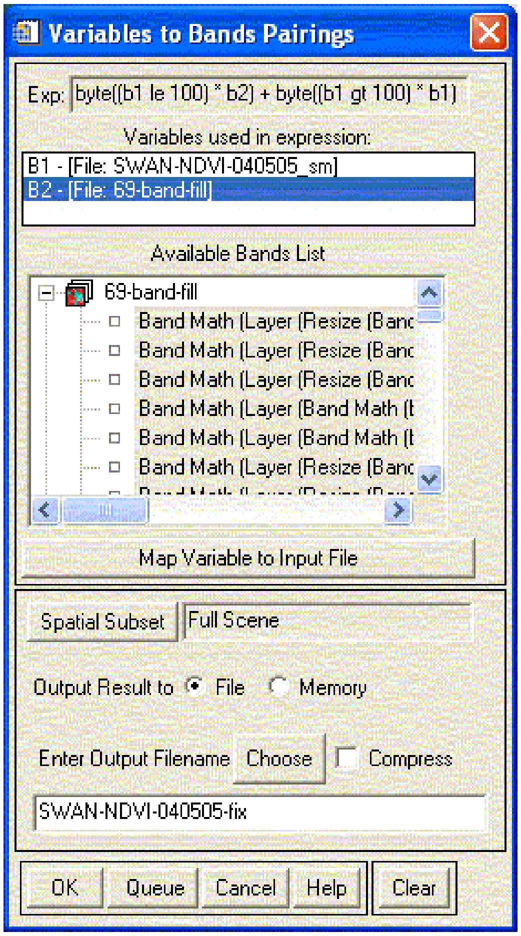


Figure 2.14. Band Math procedure to "fix" smoothed data prior to calculating phenological metrics.

SOP 2.4.2 Calculate and Process Phenological Metrics

Required Software: IDL, ENVI

- Initiate IDL by clicking on the IDL icon on your desktop
- Assure that the IDL data directory points to the proper path. From the toolbar at the top of the IDL window: **Files** > **Preferences** > **Startup** > **Working Directory** – navigate to the location of the smoothed, fixed data created in SOP *.*). Click **OK**.
- Navigate to the MODIS_software directory. Double-click the metrics.txt file for the appropriate year (2005 in this example – metrics2005.txt). The text file will contain the following expression:

imetricsoncube,'SWAN-NDVI-040505-fix',3483,2783,69,3,22,20,23,1

- Cut and past the command into the IDL command line (Fig. 2.15). Press the Enter key on your keyboard.

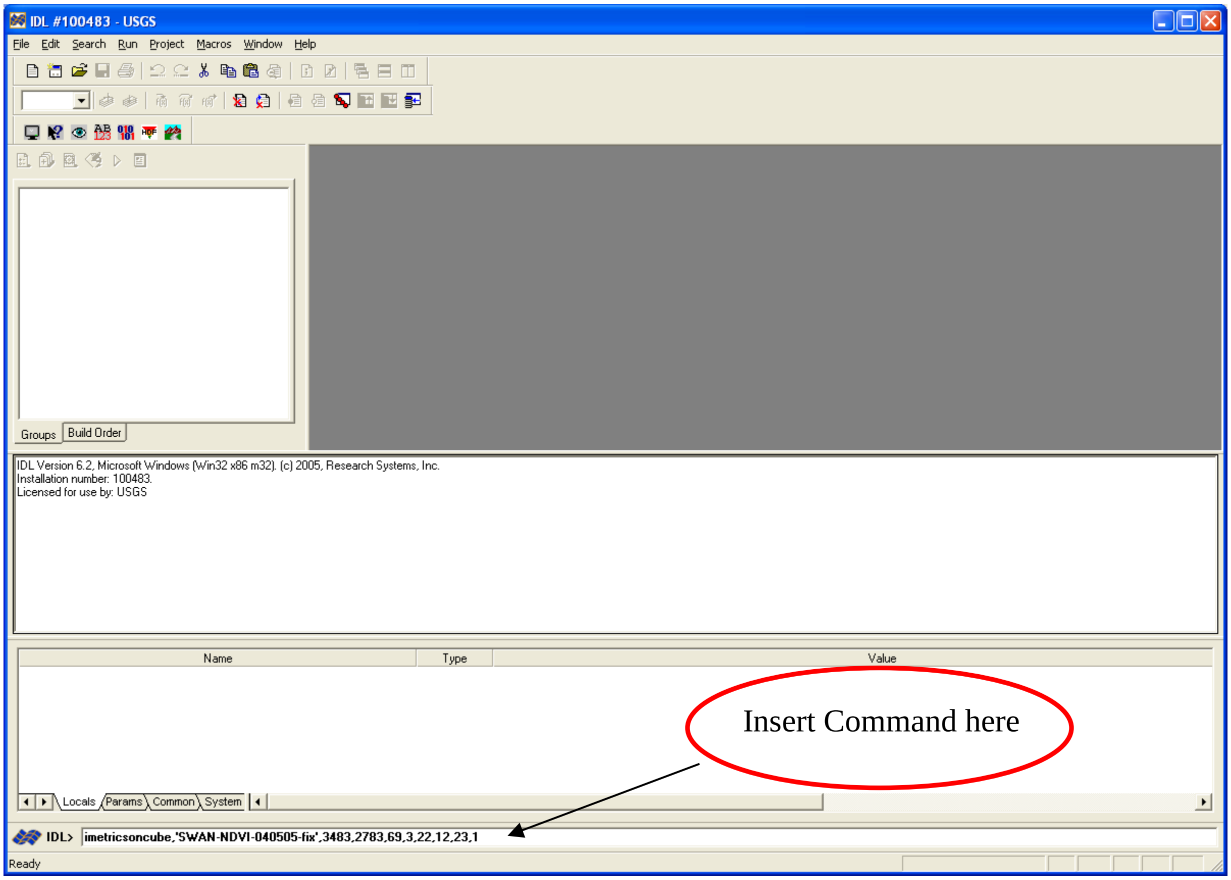


Figure 2.15. Placement of the IDL command line.

The process takes approximately 3 hours, depending on computer speed and other processes that may be running on the computer.

This program outputs 12 files, only a few of which will be used for analysis of the SWAN (Table 2.3).

Metrics Filename	Phenological metric
SWAN-NDVI-040505-fix.eosn	End of season NDVI value
SWAN-NDVI-040505-fix.eost **(EOST)**	End of season time
SWAN-NDVI-040505-fix.maxn **(MAXN)**	Maximum NDVI value
SWAN-NDVI-040505-fix.maxt **(MAXT)**	Time of maximum NDVI
SWAN-NDVI-040505-fix.ndvitodate	Accumulated NDVI at last observation
SWAN-NDVI-040505-fix.rangen	Range of NDVI values
SWAN-NDVI-040505-fix.ranget **(RANGET)**	Duration of growing season
SWAN-NDVI-040505-fix.slopedn	Rate of NDVI decrease to EOS
SWAN-NDVI-040505-fix.slopeup	Rate of NDVI increase from SOS
SWAN-NDVI-040505-fix.sosn	Start of season NDVI value

SWAN-NDVI-040505-fix.sost **(SOST)**	Start of season time
SWAN-NDVI-040505-fix.totalndvi **(TOTALNDVI)**	Seasonally integrated NDVI

Table 2.3. Listing of phenological metrics and their default filenames.

The following phenological metrics are being used for SWAN monitoring: EOST, MAXN, MAXT, RANGET, SOST, and TOTALNDVI.

- Navigate to the file folder containing the phenology metrics and **delete** the files with the following suffix: **eosn, ndvitodate, rangen, slopedn, slopeup, sosn**.

SOP 2.4.2.1 Delete padded years of data from the Metrics files.
Required software: ENVI

- Initiate ENVI by clicking on the ENVI icon on your desktop

- Open the file that was used to derive the metrics (e.g., SWAN_NDVI_040505-fix), **File**> **Open Image File**

- From the main ENVI window, **File**> **Open Image File**> Select one of the phenology files (e.g. SWAN-NDVI-040505-fix.eost). Because these files were created outside of ENVI, header information is required. A popup window will appear with blank spaces for Samples, Lines, Band, etc.

- Click the button "*Input Header Info From*", click "*Other File*…", select "SWAN_NDVI_040505-fix". Click **OK**.

- Edit some of the entries in this window. The Samples (3483) and Lines (2783) are correct. However, you must change Band from **69** to **3**. Also, the Data Type should be changed from **Byte** to **Integer**. Click **OK**. You may now use this file (SWAN_NDVI_040505-fix.eost) as an "Input Header Info From" for the other phenology metrics files.

- From the main ENVI menu, **Basic Tools** > **Resize Data** *(Spatial/Spectral)* From the popup window, *Select Input File* > Highlight 3-band metrics file (e.g. SWAN-NDVI-040505-fix-eost) and click *Spectral Subset* button. Highlight only Band 2. Click OK. For the Output Filename, Choose:

D:\SWAN\MODIS_VI_16day\2005\Phenology\EOST-2005

Repeat the process for the other phenology metrics.

SOP 2.4.2.2 Mask bad data values

Required software: ENVI

In this step, we remove bad data values (due to a poorly defined NDVI "season") where phenology metrics were not satisfactorily identified, so these values do not affect subsequent statistical analysis. The bad values are assigned a value of 0, which will not be considered in subsequent steps. An ENVI Band Math Expression has been created for each of the phenology metrics for cleanup.

- Open image file of phenology metric, whose bad data values will be fixed

- Band Math > Restore >
  - Navigate to ENVI Expressions file folder and select EOST-fix (or the appropriate metric "fix" expression).

- Highlight expression in Band Math window, click OK

- Assign B1 variable to the Phenology metric file

- Enter Output Filename (be sure to navigate to proper output file folder):

D:\SWAN\MODIS_VI_16day\2005\Phenology\EOST-2005-fix

SOP 2.4.2.3 Mask water
Required software: ENVI

In this step, we mask water values – again, so they are not included in statistical analysis.

- Open image file of fixed phenology metric

- Open the water mask image: (D:\SWAN\Ancillary_Data\watermask)

- From the ENVI main menu, select **Basic Tools** > **Masking** > **Apply Mask**. An ***Apply Mask Input File*** popup window will appear.
  - From the Apply Mask Input File popup, Select the "fixed" phenology metric file (e.g., EOST-2005-fix). Click the ***Select Mask Band*** button and select watermask file. Click OK
  - An ***Apply Mask Parameters*** window will pop up. Keep a Mask Value of 0.
  - Enter Output Filename: EOST-2005-fixmask.

SOP 2.4.3 Interpretation of Phenological Metrics
Required Software: ENVI

The phenological metrics data may be displayed and analyzed in ENVI similar to the other data sets described earlier. First the multiple years of a single metric should be layer stacked using procedures described earlier (SOP 2.3.1). After a stack of a single metric (e.g. SOS) is displayed, a Z-profile may be created using SOP 2.3.2 (Fig. 2.16).

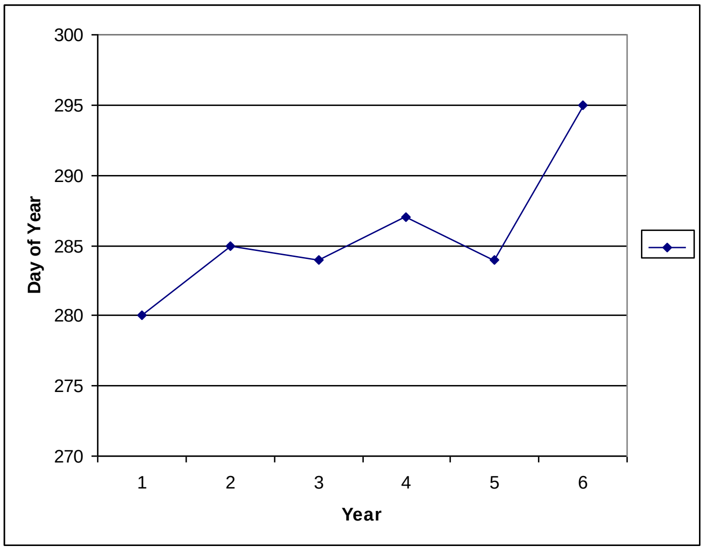


Figure 2.16. End of season day for a pixel in SWAN for years 1 (2000) through 6 (2005).

Such profiles provide information on any trends toward later or earlier ends of season on a pixel-by-pixel basis. Although the sample size is currently too small to achieve statistical significance, there will soon be a sufficient number of years of observation to perform trend analyses for these metrics.

An alternative data set that may be used for such trend analysis is the AVHRR vegetation index collection. An example of such an analysis follows using the Global Inventory Modeling and Mapping Studies (GIMMS) AVHRR data provided by NASA at 8-km resolution and dating from 1982-2003 (Tucker et al., 2004) (Fig. 2.17). This database has 15-day NDVI composites covering the entire Earth's surface. This permits medium-term monitoring of vegetation conditions and provides an example of what can be performed for the 250m phenology metrics when the data collection grows.

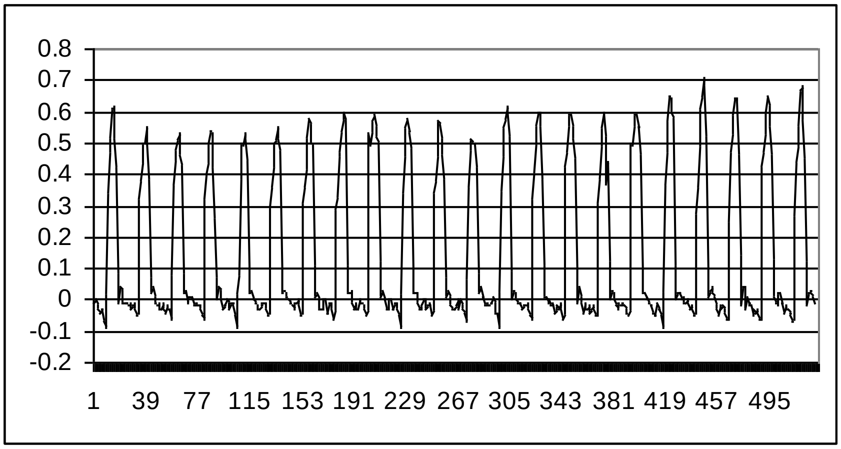


Figure 2.17. NDVI time series (1982-2003) for a pixel in SWAN region.

Phenology metrics may be derived from these data in the same manner as for the MODIS 250m collection (Section V). This results in a much more temporally dense time-series for which statistical analyses are appropriate. Figure 2.18 is an example of the start of season plotted for a pixel in the SWAN region for each year from 1982-2003. A best-fit trend line is plotted through the data values and shows a trend toward earlier starts of season for this time period.

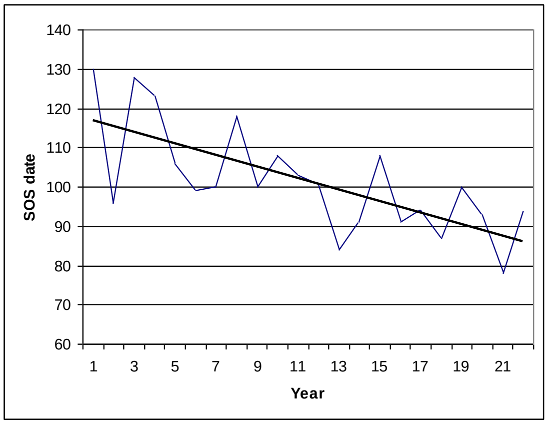


Figure 2.18. Time of start of season for 1982-2003 for a pixel in SWAN region

A t-test may be performed on the data to determine if the slope of the line is statistically different from zero and define a significant linear trend. The test statistic is defined as:

$$t = b/s$$

where b = slope of the best fit line, and s = standard error of the points.

This test may be performed pixel-by-pixel and an image can be created illustrating regions with, for example, significantly earlier or later starts of season (Fig. 2.19).

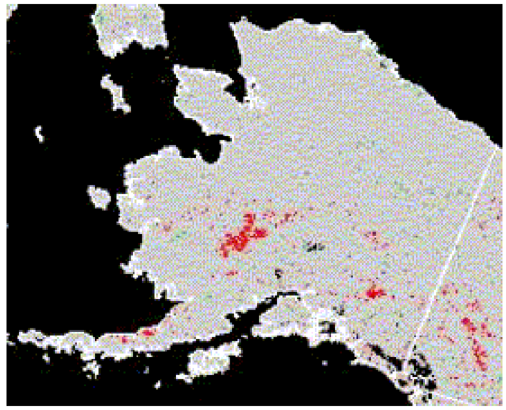


Figure 2.19. Regions in Alaska with significantly earlier (red) or later (green) starts of season.

This kind of analysis may be performed and summarized by different summary units (e.g., National Park, ecoregion, watershed, etc.) and updated as new data are collected. The summary units may also be combined (e.g., by land cover type within a watershed) and annual reports generated. This kind of analysis will be possible when a sufficient number of years of data are available to achieve statistical significance.

SOP 2.5 Generating an Annual Summary Report

Required software: ENVI, Excel (or other spreadsheet, database, or statistical package)

To generate annual summary statistics of the phenology metrics, a stratified random sampling approach is recommended that will stratify by ecoregions. ENVI software is used to conduct the sampling, and then Excel (or another spreadsheet or database manager) can be used to analyze the results. The steps are to first create the stratified random sample, then to sample the data of concern, and finally to analyze the resulting data.

SOP 2.5.1 Create a stratified random sample.

Required Software: ENVI

Note that the sample has already been established for the SWAN and the file (Ecoregion-sample.roi) is placed in the data directory. However, if the SWAN analysts wish to take a different density of samples or use a different sampling scheme, the following procedure will permit them to do so.

- Open the image that will be used for stratification – the ecoregions file (D:\SWAN\Ancillary_Data\SWAN_summary_eco)

- Under the ENVI main menu, select **Basic Tools** > **Statistics** > **Generate Random Sample** > **Using Ground Truth Classification Image**
    - Select the stratification image (ecoregion file; SWAN_summary_eco)

- Select/deselect any classes that you want (*deselect Unclassified*)

- You have the option to control the sampling type as Random/Stratified

Random/Equalized or Random (*Select Stratified Random*)

- Select the stratification as proportionate or disproportionate (*select proportionate*)

- Select the Minimum Sample Size as a percent or as number of pixels (*select Percent*)

- Change the percent to 0.5. This number was selected to meet the requirement to be at the 95% confidence level that the results are within an error of 2 days. This can be adjusted according to the analysts needs.

- You may view the sample size for each class by clicking on the ***view class sample*** sizes button

- Output to a Single ROI (region of interest) or Multiple ROIs (*select Multiple*) – this will isolate the results by ecoregion

- Enter Output ROI Filename (e.g., Ecoregion-Sample.roi)

- Click OK

SOP 2.5.2 Sample the data set of interest;
Required Software: ENVI

- Open the image you wish to be sampled

- Under Basic Tools, Select **Region of Interest** > ROI Tool

- Assure that there are no ROIs currently listed in the window
  - Select All > Delete

- Restore the ROI file that you created in the previous step (Ecoregion-Sample.roi) File > Restore ROIs…
  - Navigate to D:\SWAN\Ancillary_Data directory and select Ecoregion-sample.roi

- File > Output ROIs to ASCII…
  - Select the image that you wish to be sampled (EOST-2005-fix).

  In the Output ROIs to ASCII Parameters window, *Select all items*

- Output filename: EOST-2005-stats.txt

SOP 2.5.3 Summarizing the resulting data;
Required Software: Excel (or other spreadsheet, database, or statistical package)

Analyzing the resulting data requires working with off-the-shelf software, such as Microsoft Excel or some other spreadsheet, database, or statistical software package. The scenario given here is for using Microsoft Excel.

- Initiate Excel

- Open the text file created in the previous step using Excel, File > Open, navigate to proper file folder and select proper file for analysis (e.g. EOST-2005-stats.txt).

- When the Text Import Wizard initiates, Choose the file type that describes your data > *select Delimited,* click Finish

The spreadsheet will then open with a description of the file, followed by the data. It is best to create new worksheets for each ecoregion to ease the analysis. The first step is to examine the top of the file and gain an understanding of the file structure. The top of the file will look something like in Fig. 2.20.

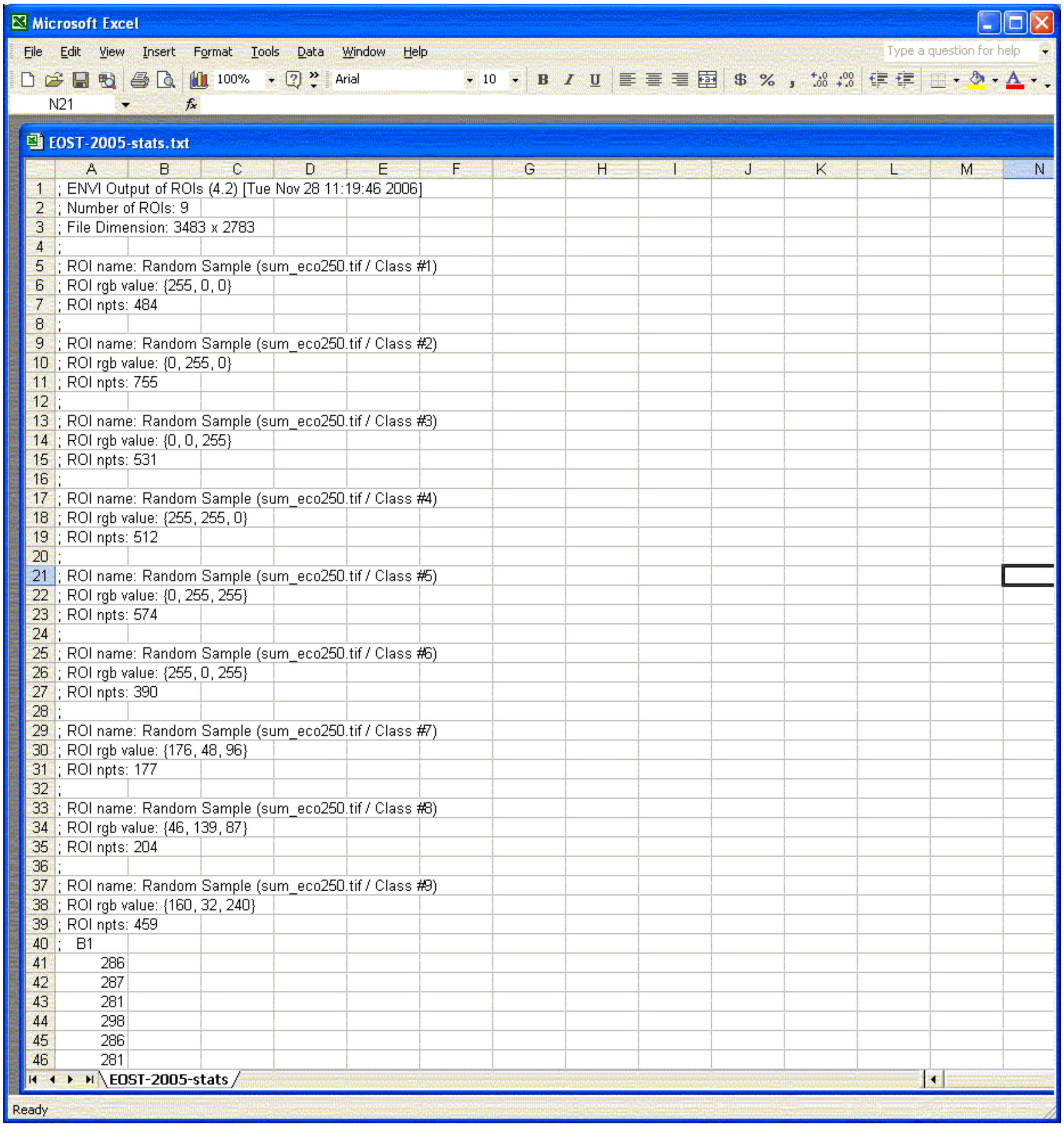


Figure 2.20. Excel file contents after importing statistical output text file.

The top of the file describes class-by-class (ecoregion-by-ecoregion) the number of points that were sampled. For example, Class 1 contains 484 points. The next step of the process involves cutting and pasting class-by-class the data points into a new worksheet.

- Highlight with your cursor the data for Class 1 (484 points in this example). Note that there is a blank row in the spreadsheet between each class' data (Fig. 2.21).

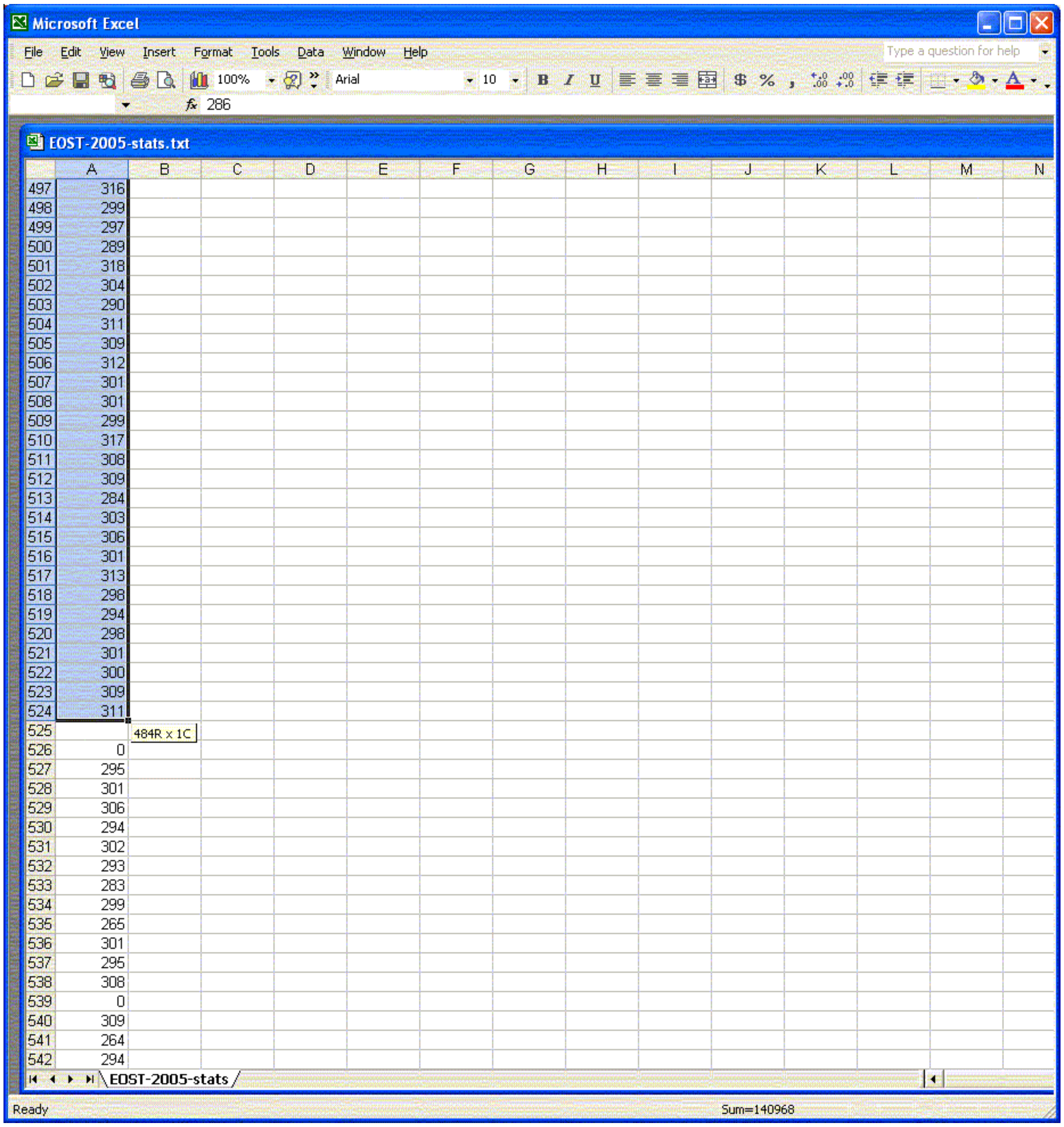


Figure 2.21. Cutting and pasting data, class-by-class.

- Right-click on the highlighted data and select Cut.
- Open a new worksheet and paste the data you have just cut. On the Excel window, select **Insert > Worksheet**. A new worksheet will appear.
- Right-click on the first row/column (1A) and click Paste. The data will appear in the first column. In this example, these are the end-of-season dates that were sampled from the EOST-2005-fix image. It is a good idea to rename the worksheet (by highlighting and replacing the worksheet name) with the ecoregion name and/or number
- Since we earlier masked out the bad data with 0's, some of the data will need to be eliminated before statistics can be run. Sort the data from low to high

- Highlight the data column
- Select Data > Sort… (select the column that contains the data)
- The data will be sorted from low to high. Now highlight the rows that contain 0's and right-click and select **Delete**.

To calculate statistics, use standard Excel functions to calculate the appropriate statistics (e.g., Average, STDEV).

These summary statistics can then be placed into Table form and compared between ecoregions and between years for each of the phenology metrics.

Quality Assurance/Quality Control and Validation

Quality assurance and control is a major element of the original MODIS product development (before the Landscape Processes Protocol is implemented). For a summary of the types of processing QA/QC that have been implemented, see an overview of the Land Data Operational Product Evaluation (http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/newPage.cgi). Similarly, many of the standard MODIS products have undergone validation experiments. The MODIS Land Processes Validation web site summarizes many of these efforts (http://landval.gsfc.nasa.gov/index.php).

While the quality of the MODIS data is evaluated using the QA information outlined above, validation of data analysis and interpretation, in terms of actual SWAN landscape processes, requires a much more intensive effort. The issue of validating satellite derived measures of these various processes is beyond the scope of this protocol and will need to be addressed by SWAN I & M staff as further investigations are undertaken. There are low-cost options for documenting landscape processes such as start of season (e.g., documenting plant development in the Anchorage area), but a full-scale (network-wide) validation effort would be very difficult and labor intensive. It may be possible to identify a small localized area that could be evaluated as a test validation site for each of the standard MODIS products. The feasibility of such a validation site will be evaluated by SWAN personnel during the initial protocol implementation. Therefore, no formalized procedures for validation of data analysis and interpretation are included in this protocol.

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SOP 3: Snow Cover Extent

Satellite-Derived Measures of Landscape Processes
Southwest Alaska Network

Standard Operating Procedure (SOP) # 3

Snow Cover Extent

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

Update on Oct 13, 2006: During protocol testing, the authors found that the 8-day MODIS Snow Cover Extent product (MOD10A2) was, in some cases, overestimating the extent of snow pack. Daily snow cover products were assessed and compared to the 8-day composite to confirm that more area was being flagged as snow than was present in the daily images. Therefore, the authors have addressed this issue by acquiring daily snow cover data (MOD10A1) throughout the history of the Terra satellite to supplement the 8-day composites. Both daily and 8-day composite data will be acquired. The authors recommend processing both the daily and 8-day products, using the dailies as a supplement to the 8-day data to resolve conflicts and to identify more specific days of snow occurrence. The current data set of MODIS Terra daily snow cover extent begins on Julian day 055 of 2000 to present.

The processing of MODIS Snow products should be performed according to the processing schedule outlined in Table 3.1.

Action	SOP	Frequency
Data Acquisition	3.1	Twice Monthly
Daily Snow processing	3.2	Twice Monthly
8-day Snow processing	3.3	Twice Monthly
Data Visualization /Analysis	3.4	Monthly/Yearly as needed
Summarizing / Reporting	3.5	Monthly/Yearly as needed

Table 3.1 MODIS Snow processing schedule.

Software and scripts that are required to run this set of SOPs are listed in Table 3.2

Software	Process

File transfer protocol (ftp)	File transfer
List_HDF	List of HDF file names (.txt)
MRT	Process HDF files
Snow Processing Scripts	Process Snow Files
ENVI	Image Visualization/Analysis
Excel (or other spreadsheet)	Reporting

Table 3.2. Software required for processing MODIS Snow data.

3.1. Data Acquisition Procedures

Required Software: FTP client

Acquisition of MODIS 8-day and daily snow cover data from the National Snow and Ice Data Center (NSIDC) DAAC (http://nsidc.org/daac/) will utilize the NSIDC "data pool" which allows users to download files via FTP. At the time of writing the NSIDC policy was to stage all current and historical data on the data pool indefinitely.

3.1.1. MODIS 500m Daily Snow Cover Extent Data (MOD10A1)

- Using either a command line prompt or an FTP client, access the NSIDC data pool at the following location:

  ftphost: n0dps01u.ecs.nasa.gov
  username: anonymous
  password: your email address
  ftp directory: SAN/MOST/MOD10A1.004 (daily collection 4)

- Navigate to the daily directory from which you want to download data. The daily directories are named using the following format: yyyy.mm.dd, where yyyy equals a four digit year, mm equals a two digit month, and dd equals the two digit calendar day.

- Download only the HDF files necessary for coverage of the SWAN parks (i.e. h09v02, h09v03, h10v02, h10v03, h11v02, h11v03) to the daily MODIS Snow directory. The filenames begin with MOD10A1.A2006293 (four digit year and 3 digit Julian day), followed by the horizontal and vertical tile locations. An example of a complete filename is shown below.

  MOD10A1.A2006293.h09v02.004.2006298153221.hdf

3.1.2. MODIS 500m 8-Day Snow Cover Extent Data (MOD10A2)

- Using either a command line prompt or an FTP client, access the NSIDC data pool at the following location:

ftphost: n0dps01u.ecs.nasa.gov
username: anonymous
password: your email address
ftp directory: SAN/MOST/MOD10A2.004 (8-day collection 4)

- Navigate to the 8-day directory from which you want to download data. The 8-day directories are named using the following format: yyyy.mm.dd, where yyyy equals a four digit year, mm equals a two digit month, and dd equals the two digit calendar day.

- Download only the HDF files necessary for coverage of the SWAN parks (i.e. h09v02, h09v03, h10v02, h10v03, h11v02, h11v03) to the 8-day MODIS Snow directory. The filenames begin with MOD10A2.A2006293 (four digit year and 3 digit Julian day), followed by the horizontal and vertical tile locations. An example of a complete filename is shown below.

MOD10A2.A2006293.h09v02.004.2006298153221.hdf

If the desired data are not staged on the NSIDC data pool, see Appendix 3 for information on ordering via the EOS Data Gateway (EDG).

3.2. Daily Snow Cover Processing

Required Software: List_HDF, MRT, Daily Snow Processing Scripts

- Once the MOD10A1 HDF files have been retrieved from the NSIDC FTP site and reside on the local SWAN machine, run the **List_HDF.exe** script provided in the MODIS software directory (e.g. D:\SWAN\MODIS_software). **Double click** on the executable file to open a small dialog box.

  Using the dropdown file structure, **point to the directory where the HDF files are located and click ok** (Fig. 3.1). This will create a text file named with the four digit year and three digit Julian day of the HDF files (i.e. 2006293.txt).

  Note: Many MODIS files are named according to their Julian Date. Julian day is simply the sequential day number, starting from Jan 1 and running through Dec 31. Julian dates will change during leap years.

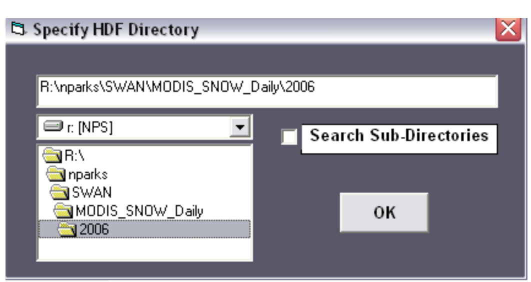


Figure 3.1. An example of the List_HDF dialog box.

- Execute the batch file SWAN_daily_maxsnow_script.bat found in the annual directory where data is being processed (D:\SWAN\MODIS_SNOW_daily\2006 in this example). The batch file will process only those files for which text files (created using List_HDF) and raw HDF files exist.

The execution of this batch file will launch an MS-DOS window that shows the progress of the processing. Since the batch file is written to process a complete year, it will flash a number of error screens for dates that have already been processed or are not yet available. It uses command line MRT processes to extract the maximum snow extent data set (data set [or band] 1) from the daily MODIS snow product, mosaic the individual tiles, and apply the predefined projection parameters for the SWAN region to the output image (see Appendix 1 for these parameters).

- The result is a GeoTIFF image with the following pixel classification values (Table 3.3):

Value	Classification
0	Missing
1	No Decision
3	Scan Angle Limit Exceeded
4	Erroneous Data
11	Night
25	Snow-Free Land
37	Lake or Inland Water
39	Open Water (ocean)
50	Cloud Obscured
100	Snow-Covered Lake Ice
200	Snow

Table 3.3. Classified pixel values for maximum snow extent products.

3.3. 8-Day Snow Cover Processing

Required Software: List_HDF, MRT, 8-Day Snow Processing Scripts

Processing the 8-day MODIS Snow Cover data is identical to the steps used in section 3.2 for the daily data. Use the same procedures, substituting MOD10A2 and 8-day for MOD10A1 and daily.

3.4. Data Visualization / Analysis
Required Software: ENVI

The visualization and analysis of the MODIS snow cover products is largely exploratory. In addition to viewing the classified snow cover images and assessing the spatial extent of snow cover on either a daily or an 8-day time step, we have also established some basic methods for analysis. These include exploiting the high temporal frequency of the daily data using profiles of the daily time series and quantitatively summarizing the extent of snow cover within a defined zone using the 8-day composite data. The following procedures will be used:

1) Visualization of the Daily and 8-day composite data.
2) Layer stacking and Z-profiles of Daily data.
3) Quantification of 8-day extent by ecoregion.

3.4.1. Snow cover Data Visualization

- Start ENVI by double clicking the desktop icon

- Select ***File*** > ***Open Image File*** and navigate to either the daily or 8-day snow directories where the GeoTIFF outputs were written for a given year (SOP 3.2 or 3.3) and select a .tif file. The selected file will be displayed in the available bands list.

- Select ***Band 1*** > ***Load Band*** with the grayscale button selected. A black and white classified image (Fig. 3.2) will be displayed.

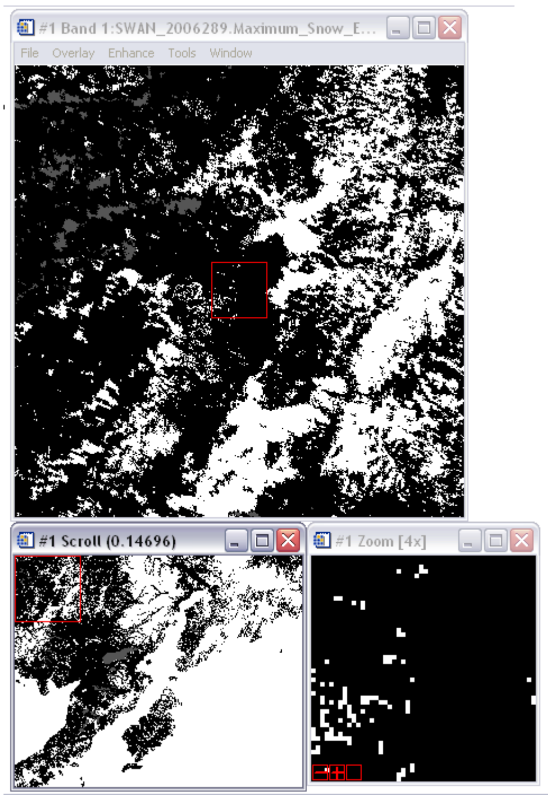


Figure 3.2. Display of an 8-day snow cover image in 3 ENVI windows.

- Since the black and white classified image isn't very meaningful, apply a color map to the image so individual classes can be distinguished. From the large display window select ***Tools*** > ***Color Mapping*** > ***Density Slice***, select ***Band 1***.

- From the density slice dialog box select ***File*** > ***Restore Ranges*** and navigate to the 8-day or daily snow cover directories and select the ***SWAN_maxsnow.dsr*** file and click ***Apply***.

- The .dsr file contains color assignments for each of the classification values in the image (Table 3.3). The values will generally be in the range from 25 – 200 as seen in Fig. 3.3, where green is snow free land (25), light blue is inland water (37), dark blue is ocean (39), gray is cloud (50), aquamarine is snow-covered lake ice (100), and white is snow (200). Not all classes are represented in each image.

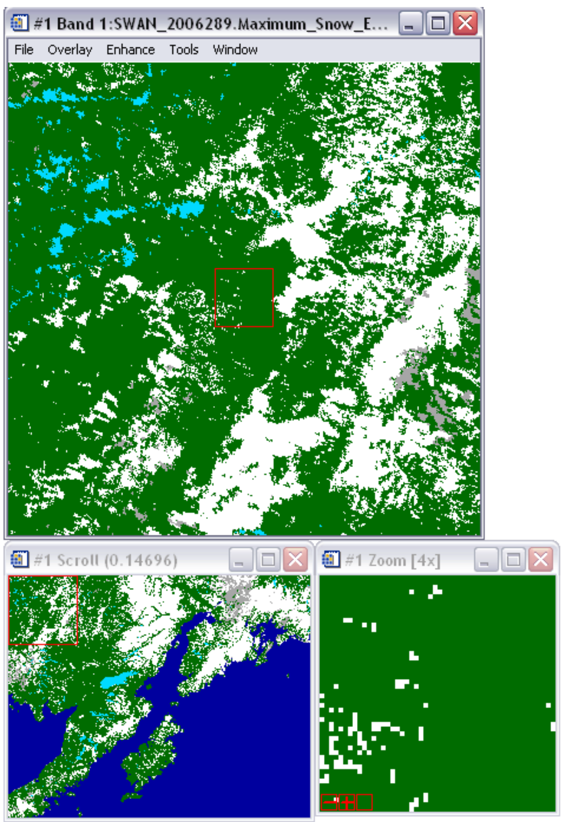


Figure 3.3. Display of an 8-day snow cover image with the color map (.dsr) file applied.

- If you are uncertain of a pixel value or want to explore the image in more detail, you can use the ***Cursor Location/Value*** option under the ***Tools*** menu of the large display window and navigate with your cursor to view the latitude/longitude and classification values of individual pixels.

3.4.2. Layer Stacking and Z-Profiles of Daily Data

As a means of utilizing the high temporal frequency of the daily snow cover data it may be useful to stack an entire year of daily data into an annual stacked image. These can then be assessed using the Z-profile tools on a per pixel basis to identify specific dates of snow on / off times, snow persistence, cloud persistence, etc.

The procedures for layer stacking and producing Z-profiles are outlined below.

- Start ENVI if necessary

- Select ***File*** > ***Open Image File*** and navigate to the annual directory where daily imagery is located. Select all images that you want to stack using the shift key to select multiple images. The available bands list will include all the images selected (this could take a little while to populate if you're doing a complete year of 365 images).

- From the ***Basic Tools*** menu select ***Layer Stacking*** to launch the layer stacking parameters window. Select the ***Import File*** button and select the list of files that you loaded into the available bands list (Fig. 3.4), again using the shift key to select multiple images and click ***ok***.

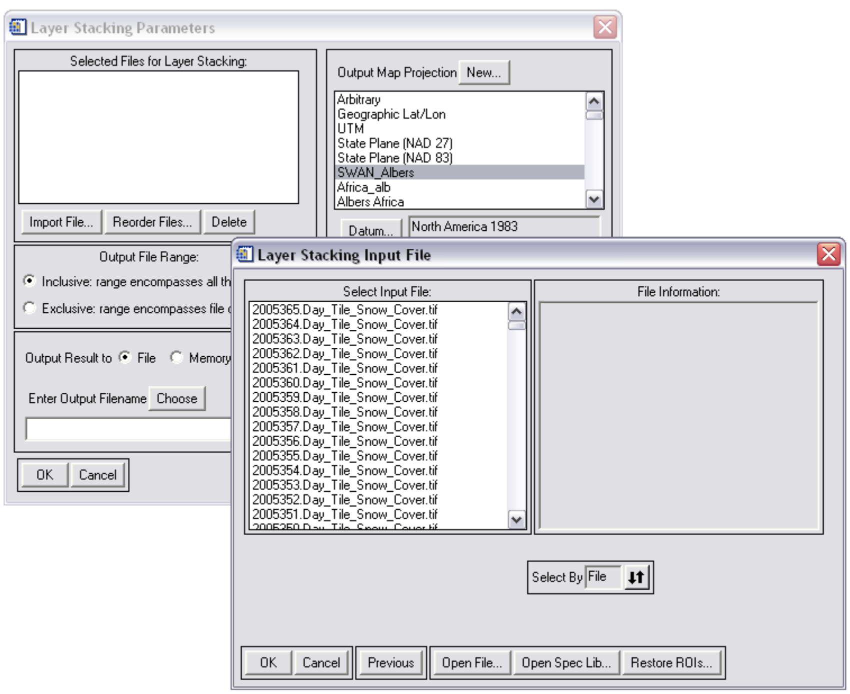


Figure 3.4. Layer stacking parameters box and list of input files for stacking.

- After the files have been loaded into the selected files listing, select the ***Reorder Files*** button to show the temporal (chronological) order in which the images will be stacked. The default will list the files in descending order with day 365 as the first file, day 364 as the second and so on. Reverse the order of the images to be chronological by ***holding the cursor over the file names*** and ***clicking the center mouse button***. The files will now be in order from 1 – 365 (Fig. 3.5). Click ***ok***.

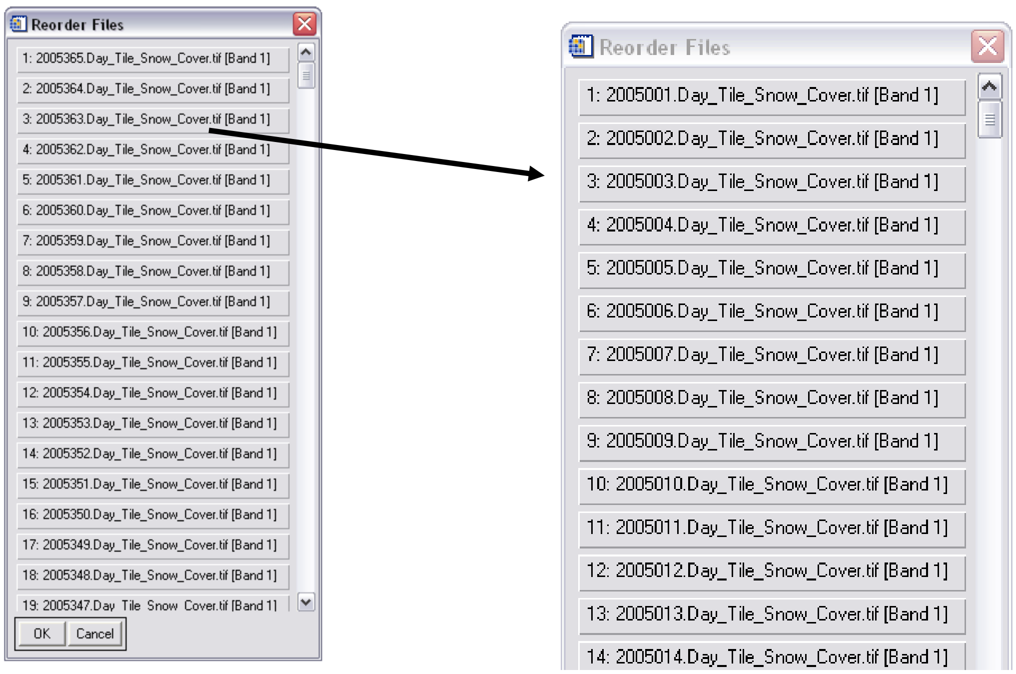


Figure 3.5. Reverse file order by clicking the middle mouse button over the file listing.

- ***Enter an output filename*** > ***2005_snowstack > click ok.***
- The layer stack image will display in the available bands listing when completed. Display one band of the image by ***selecting a band*** and clicking ***load band***. Apply the colormap (.dsr) file to assign color to the image if desired.
- You are now displaying one band of a 365-band image. To view the Z-profile of the daily snow cover time series select ***Tools*** > ***Profiles*** > ***Z- profile (spectrum)***.

The spectral profile displays for the single pixel where the cursor is located (Fig. 3.6). As you move the mouse over the image, the profile changes for each pixel selected. It should be noted that the Z-profile for the classified snow cover image is quite different from a more continuous measure such as NDVI. The profile of the classified image varies greatly from day to day as a single pixel may be classified cloud then snow then cloud all in the span of a 3 day period.

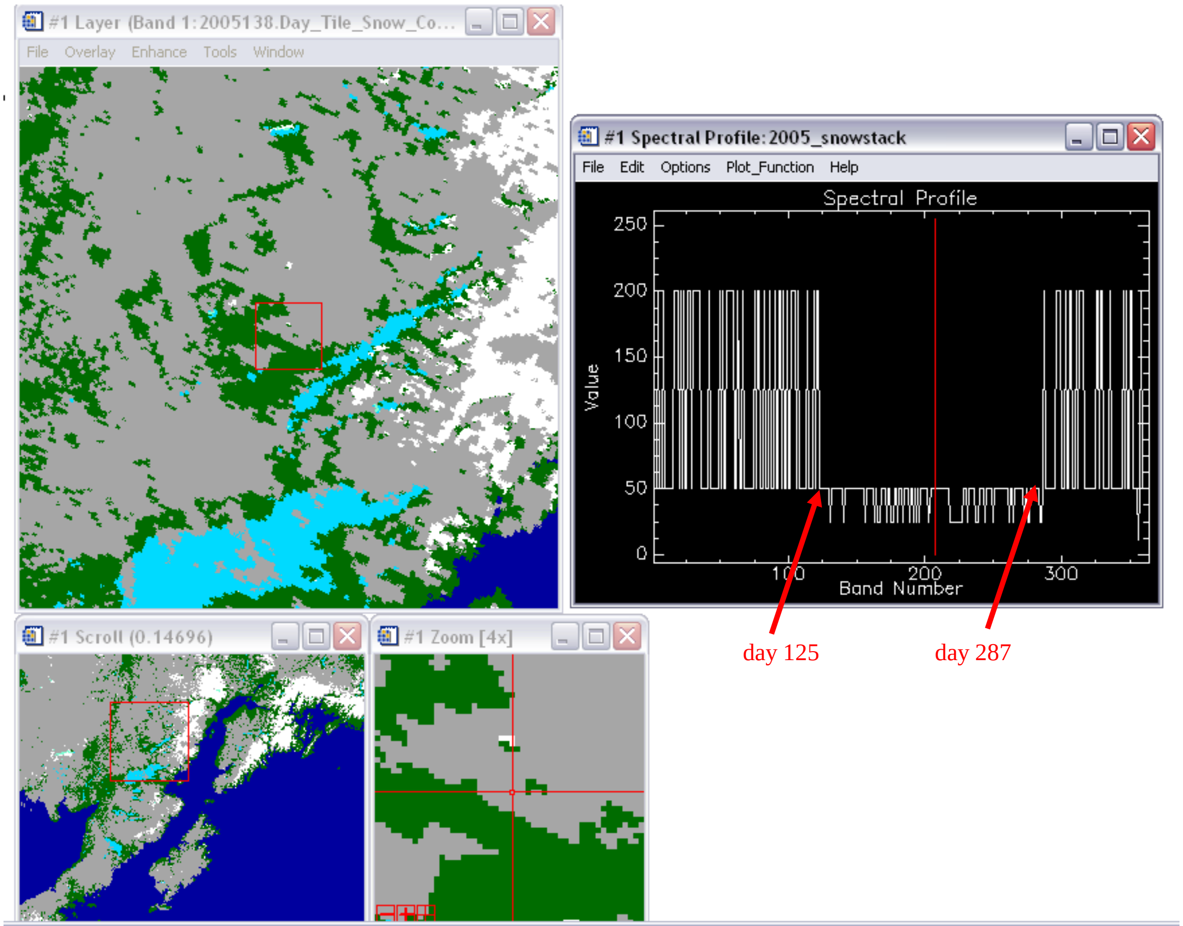


Figure 3.6. Spectral profile of a single pixel from one year of stacked snow cover data.

The example in Fig. 3.6 for 2005 shows that this pixel was largely snow covered (values of 200) or cloud (values of 50) until approximately day 125 (5 May). The pixel was cloud or snow-free land (values of 25) through day 287 (14 October).

Layer stacking and the Z-profile tools allow a quick per pixel assessment of the snow cover time series. This may be a useful tool for pinpointing more specific snow on/off dates than can be obtained from the 8-day maximum snow extent data.

- The values that make up the profile can be easily saved to a text format for importation to a spreadsheet by selecting ***File*** > ***Save Plot As*** > ***ASCII*** from the profile window.

The example above illustrates the pervasive influence of cloud on the daily image acquisitions. The very nature of a temporal composite, such as the 8-day snow cover, assists in minimizing cloud effects and may represent a more suitable product for quantifying snow cover extent within a specified zone.

3.4.3. Quantification of 8-day Snow Cover Extent by Ecoregion

This portion of the SOP will outline the procedures for quantifying the spatial extent of snow cover every 8 days using the composite snow cover product and selected ecoregions throughout the SWAN parks and surrounding areas. Stratification by ecoregion was determined to be the most suitable for summarizing snow cover measurements. Detailed procedures for summarizing an 8-day period are outlined below.

The procedure uses the ***Confusion Matrix*** function in ENVI. This function compares a classification result with ground truth information. In this case, we will use the ecoregions as a classification and the MODIS 8-day snow cover image as the ground truth information.

- Start ENVI if necessary

- ***File*** > ***Open Image File*** and navigate to D:\SWAN\MODIS\Snow_summary. Load the ***SWAN_summary_eco.tif*** file to the available bands list.

- The confusion matrix requires that the inputs be ENVI classification files, therefore you need to edit the ecoregion header from ***TIFF*** to ***ENVI Classification***. To do this select ***File*** > ***Edit ENVI Header*** and select the ecoregion file from the input file list. In the header info dialog box, select ***File Type*** > ***ENVI*** > ***Classification***. In the number of classes box that opens, change the number to ***10*** classes and click ***ok*** (Fig. 3.7). The ecoregion file used in this example contains 9 classified ecoregions and 1 'no data' class. Click ***ok*** in the "class colormap editor" box and the "header info box".

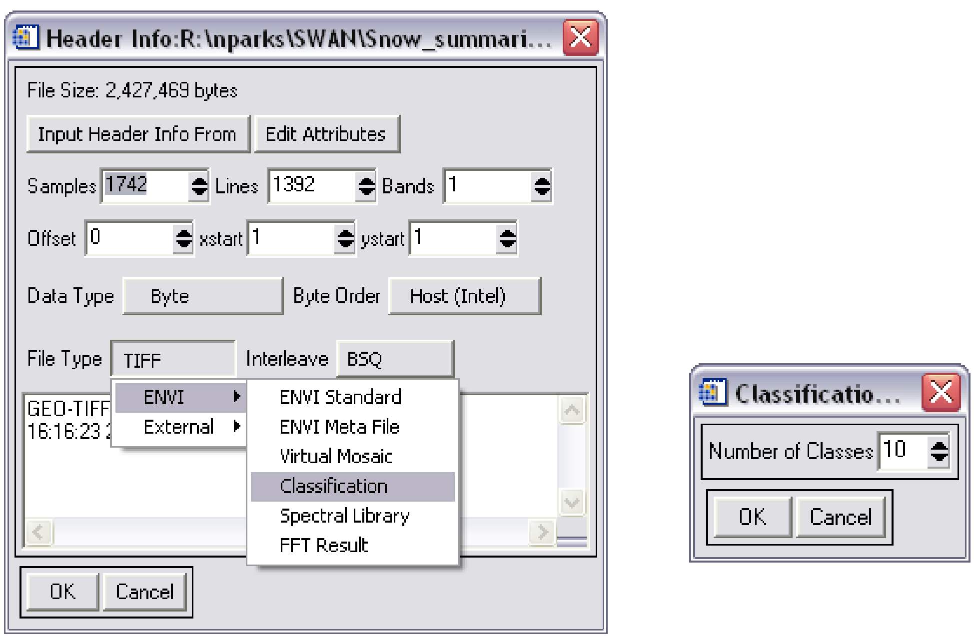


Figure 3.7. Conversion of TIFF image to ENVI Classification image.

- Display the ecoregion classification image by selecting ***Band 1*** > ***Load Band*** and you will see each ecoregion is assigned a different color (Fig. 3.8).

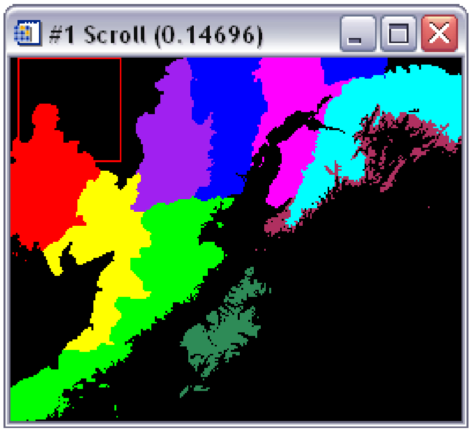


Figure 3.8. Example of an ecoregion classification image.

- Open the 8-day snow cover image that you want to summarize from the MODIS_Snow_8day directory (***File*** > ***Open Image File***).

The 8-day image file also needs to be converted to an ENVI classification image. Rather than summarizing all possible classes in the snow cover product, we will only summarize Land (class 25), Cloud (class 50), and Snow (class 200). We will reassign values of 1, 2, and 3, respectively, to each of these classes.

The following outlines this procedure.

- From the ***Basic Tools*** menu, select ***Band Math***. We have provided a band math expression that will convert the land class to values of 1, the cloud to values of 2, the snow to values of 3 and all other classes to unclassified.
- In the band math box select ***restore*** and navigate to the D:\SWAN\MODIS\Snow_summary directory.
- Select the ***snow_bandmath.exp*** and click ***open***. The expression will be loaded to the top of the band math dialog box.
- ***Highlight*** the expression and click ***ok***.
- In the next box that opens, select the ***map variable to input file*** button, ***select the 8-day snow image that you loaded*** (SWAN_2004297.Maximum_Snow_Extent.tif in this example) and click ***ok*** (Fig. 3.9).

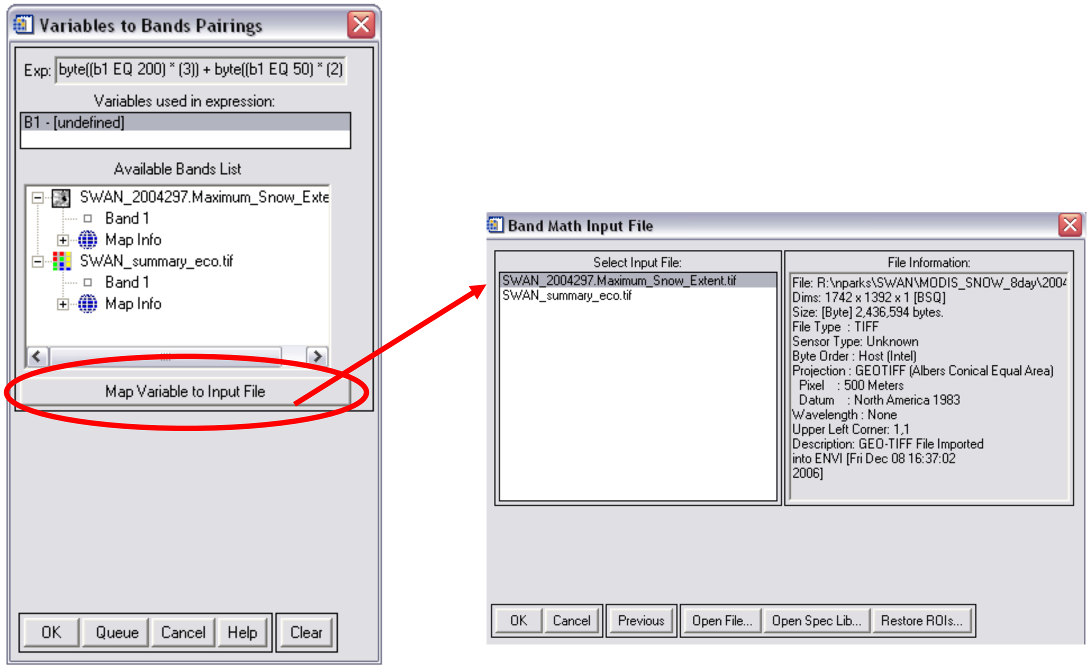


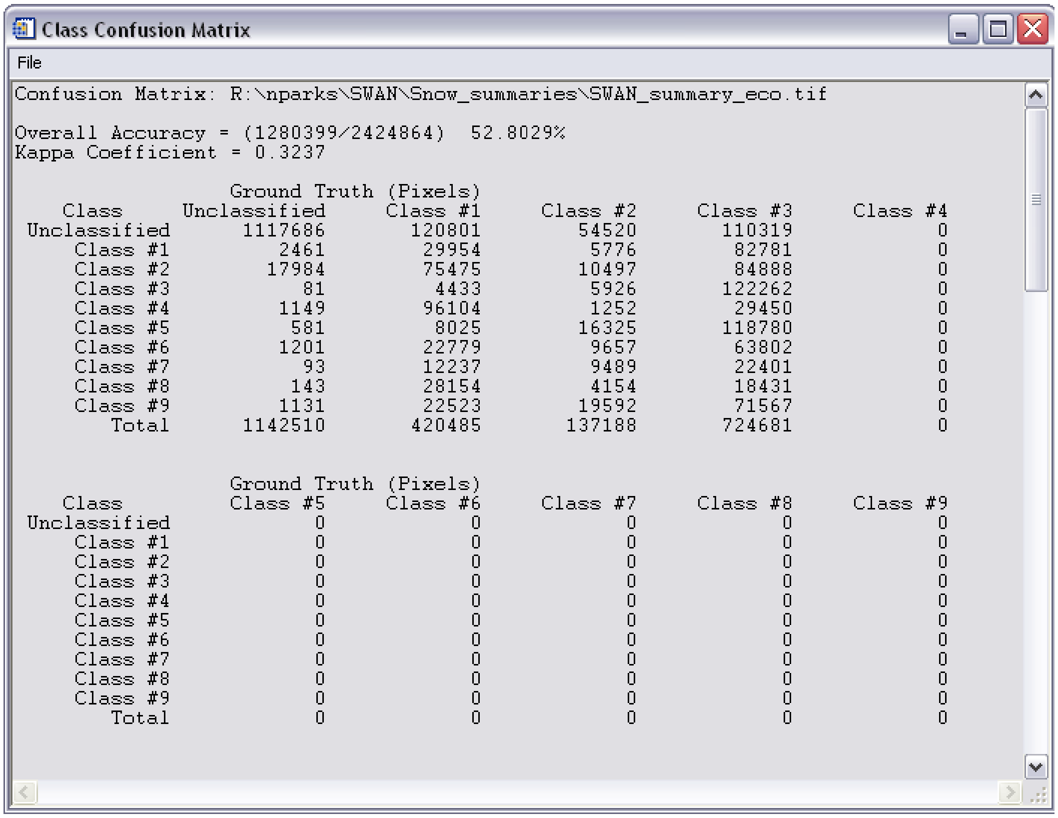
Figure 3.9. Mapping the band math equation to a specific snow cover image file.

- At the bottom of the ***variables to bands pairings*** dialog box that opens, select the ***choose*** button to assign an output filename and location. Click ***ok*** and the new image is added to the available bands list.

- Edit the ENVI header of the new image from ***ENVI standard*** to an ***ENVI Classification*** file type. Use the same procedure outlined above for converting the ecoregions file from TIFF to ENVI Classification. Although we only have 3 valid classes and 1 'no data' class, select ***10*** as the number of classes (the confusion matrix requires that both the classification and the ground truth image have the same number of classes – a symmetrical matrix).

- ***Run the Confusion Matrix Function*** on the two classification images by selecting ***Classification*** > ***Post Classification*** > ***Confusion Matrix*** > ***Using Ground Truth Image***.
- In the Classification Input File box, select the ***ecoregion*** file as the ***classification input*** and click ***ok***.
- In the Ground Truth Input File box, select the ***four-class snow image*** created in the previous step as the ***ground truth*** and click ***ok***.
- Click ***ok*** in both the ***match class parameters*** box and the ***confusion matrix parameters*** box.

The output is a matrix that includes the 9 ecoregion classes along the left margin and the number of pixels for each of the four classes (unclassified, land, cloud, and snow) that are present in each ecoregion (Fig. 3.10). Note that the non-existent classes in the snow image (classes 4 – 9) show values of 0 for each summary ecoregion. The sum of the 4 classes identifies the total number of pixels within that ecoregion.



Class Confusion Matrix

File

Confusion Matrix: R:\nparks\SWAN\Snow_summaries\SWAN_summary_eco.tif

Overall Accuracy = (1280399/2424864) 52.8029%
Kappa Coefficient = 0.3237

	Ground Truth (Pixels)				
Class	Unclassified	Class #1	Class #2	Class #3	Class #4
Unclassified	1117686	120801	54520	110319	0
Class #1	2461	29954	5776	82781	0
Class #2	17984	75475	10497	84888	0
Class #3	81	4433	5926	122262	0
Class #4	1149	96104	1252	29450	0
Class #5	581	8025	16325	118780	0
Class #6	1201	22779	9657	63802	0
Class #7	93	12237	9489	22401	0
Class #8	143	28154	4154	18431	0
Class #9	1131	22523	19592	71567	0
Total	1142510	420485	137188	724681	0

	Ground Truth (Pixels)				
Class	Class #5	Class #6	Class #7	Class #8	Class #9
Unclassified	0	0	0	0	0
Class #1	0	0	0	0	0
Class #2	0	0	0	0	0
Class #3	0	0	0	0	0
Class #4	0	0	0	0	0
Class #5	0	0	0	0	0
Class #6	0	0	0	0	0
Class #7	0	0	0	0	0
Class #8	0	0	0	0	0
Class #9	0	0	0	0	0
Total	0	0	0	0	0

Figure 3.10. Confusion matrix output summarizing 3 classes of the MODIS 8-day Snow Cover product by ecoregion.

- From the confusion matrix output, select ***File*** > ***Save text to ASCII*** for importation to a spreadsheet program.

3.5. Summarizing / Reporting

Required Software: Excel (or other spreadsheet, database, or statistical package)

Summarizing and reporting of MODIS snow cover extent data could be performed in several possible ways. Once the data are in ASCII form, they may be input into a number of spreadsheets, databases, or statistical packages for a variety of reporting scenarios. Following is one method of summarizing the output from the confusion matrix.

Figure 3.11 illustrates a spreadsheet that could be created for each ecoregion that would facilitate the incremental tracking of snow cover. As each 8-day period of snow cover is assessed by ecoregion, the results from the confusion matrix could simply be input to a spreadsheet that would convert the pixel counts to a percent cover and plot those on a time series graph.

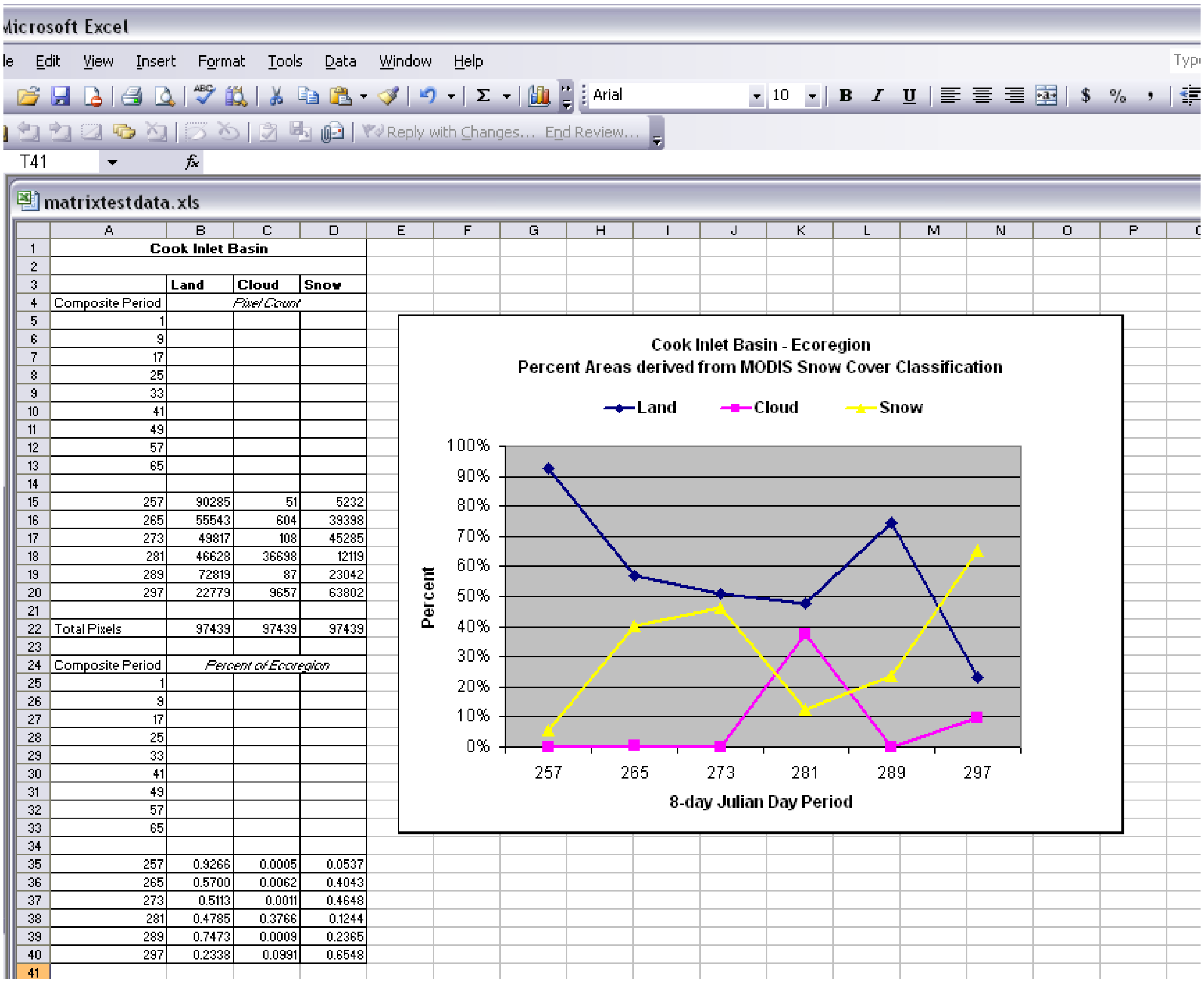


Figure 3.11. Example of a possible reporting mechanism for the quantification of snow cover within an ecoregion.

The example of the Cook Inlet Basin in Fig. 3.11 illustrates the onset of the snow season showing nearly 100 percent snow-free land during period 257, followed by corresponding decreases in land and increases in snow during the next 8-day period (265). Early season variability in all three classes is evident for the latter periods beginning at period 281.

During the initial phase of the protocol implementation, SWAN I & M staff will evaluate these analysis techniques and develop more detailed methods of reporting that coincide with ecological monitoring objectives.

SOP 4: Lake Ice

Satellite-Derived Measures of Landscape Processes
Southwest Alaska Network

Standard Operating Procedure (SOP) # 4

Lake Ice

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

This SOP explains the procedures for browsing, acquiring and processing daily MODIS calibrated radiance images and interpreting them for lake ice metrics. Many other features and processes will be evident as the images are examined for lake ice. This SOP requires downloading, processing and archiving daily calibrated radiance images of 250m data for bands 1 and 2 (red and near infrared). These images will be archived as single band geotiff images in the SWAN image archives.

The processing of MODIS Calibrated Radiance products for lake ice metrics should be performed according to the processing schedule outlined in Table 4.1.

Action	SOP	Frequency
Data Browse	4.1	Daily-weekly
Data Acquisition	4.2, 4.3, 4.4	Weekly-monthly
Data Processing	4.5, 4.6	Monthly
Interpretation of ice cover	4.7	Monthly
Ice season metrics	4.8	Yearly
Annual comparision/trends	4.9	Yearly

Table 4.1 MODIS calibrated radiance processing and ice metrics interpretation schedule.

The software packages that are required to run this set of SOPs are listed in Table 4.2.

Software	Process
Internet Browser	Data search and order
File transfer protocol (ftp)	File transfer
MRTSwath	Georectification
ENVI	Display, mosaic and enhance

Photoshop	Additional enhancement, image viewing and interpretation
Photo manager such as ACDSee	Rapid image viewing, image labeling and management
Excel (or other spreadsheet)	Data recordation and reporting
ArcMap	Digital calibration of ocular estimates

Table 4.2. Required software for processing calibrated radiance data and interpreting ice metrics.

SWAN is located in an extremely dynamic region of Alaska. Maritime and continental climate regimes meet over the SWAN. Climatic patterns are exacerbated by topographic relief and peninsulas that extend into the North Pacific Ocean and Bering Sea. Ice metrics on large lakes and lake complexes are indicators of the cumulative thermal regime across SWAN (Jeffries et al 2005, Latifovic and Pouliot 2006). A warming climatic trend should lead to shorter ice-bound seasons on lakes, while overall colder climate will lead to longer ice seasons. These trends will likely vary spatially across SWAN and be reflected in different lakes. The objective of this protocol is to determine the natural variability in ice season in SWAN and detect long term trends in ice season duration and freeze-up/break-up dates.

Lake ice metrics are interpreted from daily MODIS calibrated radiance images. Lake ice metrics are freeze-up date, break-up date and duration of ice season, freeze-up season and break-up season. These metrics are derived from ocular estimates of ice cover on selected lakes across the SWAN region. Calibrated radiance images are the MOD02 data and corresponding MOD03 georectification files.

The complete list and general descriptions of MODIS products are found at multiple websites. A simple overview is at: http://modis.gsfc.nasa.gov/data/dataprod/index.php

Download, process and archive a MODIS MOD02QKM image for **EVERY DAY**. Sometimes multiple images (ie an Aqua and a Terra image) may be processed for a single day. Feel free to collect images that range outside the SWAN region if they show events or features which affect SWAN.

4.1. Data Browse

There are several browse facilities for MODIS data. The easiest one to use is the Rapidfire site maintained by NASA Goddard: http://rapidfire.sci.gsfc.nasa.gov/production/**.**

Thumbnails of every MODIS image are displayed by Julian day and Zulu time. Terra images are at the top of the web page, and Aqua images at the bottom. Using the Julian calendar at the top of the webpage, select the date of interest. The website then displays all images available for that day. There are roughly three passes per day for Alaska by each satellite: an eastern overpass centered over SE Alaska, a central overpass often centered over SWAN, and a western overpass over the Bering Sea and Aleutians. These images are acquired late in the Zulu-time day: usually between 20:00 and 23:50 hours. This roughly corresponds to late morning local time. The swaths are chopped up into five second pieces called granules. Review the thumbnails on the right of the page for Terra, and the left for Aqua. You can usually recognize SWAN by the arc of the Gulf of Alaska or the line of the Alaska Peninsula and the Aleutians.

Double clicking a thumbnail will display a natural color version of the image in a separate window with the default resolution of 1 km. If desired, you can download larger images (up to 250m resolution), or other band combinations or products (e.g., NDVI or color infrared). Although these images are not geometrically corrected, quite a bit of information can be interpreted from these raw images when the area of interest is in the center. The edges of these images are distorted due to the bow-tie effect of the sensors. They can be downloaded as uncorrected jpegs.

1. Use these thumbnails to select dates and times for further downloading and analysis or to interpret large scale features and phenomena across the SWAN region. Record the Zulu time of the granule. It may be necessary to select two granules if the images are split directly over SWAN.

2. Other browse sites include:
    - University of Alaska Fairbanks Geophysical Institute (swath-based images, mostly summer. Primary application is for wildfire.) http://www.gina.alaska.edu/page.xml?group=data&page=alaska_images
    - http://landweb.nascom.nasa.gov/cgi-bin/browse/browse.cgi
    - Snow and Ice products http://modis-snow-ice.gsfc.nasa.gov/intro.html
    - (hint: check out the Gallery at http://rapidfire.sci.gsfc.nasa.gov/ for the pick of the day's amazing images from around the world. It will give you ideas of what you can see with MODIS data.)

4.2. Data Search

Use the LAADS web page to select and order the exact granules (files of SWATH data) for the SWAN every day.

- http://ladsweb.nascom.nasa.gov
    - Data
    - Search (see Fig 4.1 for the entry screen). Note that you have limited time to fill out and submit this screen. (5 minutes)
        - Product Selection
            - Select Aqua or Terra
            - Group = Level 1 products
            - Products: select desired products, usually MOD (MYD)02QKM and MOD(MYD)03

            Note: File naming conventions assign MOD to Terra and MYD to Aqua.
        - Temporal Selection
            - Type = individual dates

        - yyyy-ddd (julian day) *or* mm/dd/yyyy (calendar day)
    - Collection Selection = 5
    - Spatial Selection
        - Coordinate system = latitude/longitude
        - A new screen appears, enter bounding coordinates for SWAN

          North = 62
          West = -160 East = -146
          South = 56
    - Coverage Selection
        - Day
        - Both (necessary for low sun angle days where part of the granule is white on the thumbnail. NASA assigns "night" to portions of the granule with low sun angles.)
        - (uncheck night)

    - Metadata Selection
        - Filtering = off for both PGE and QAPercent
        - Uncheck box that says "Require that the filtered metadata fields be defined to be included in the search results"
- Click SEARCH

Note—as of 12/06, the Save and Load functions are not working on Windows OS.

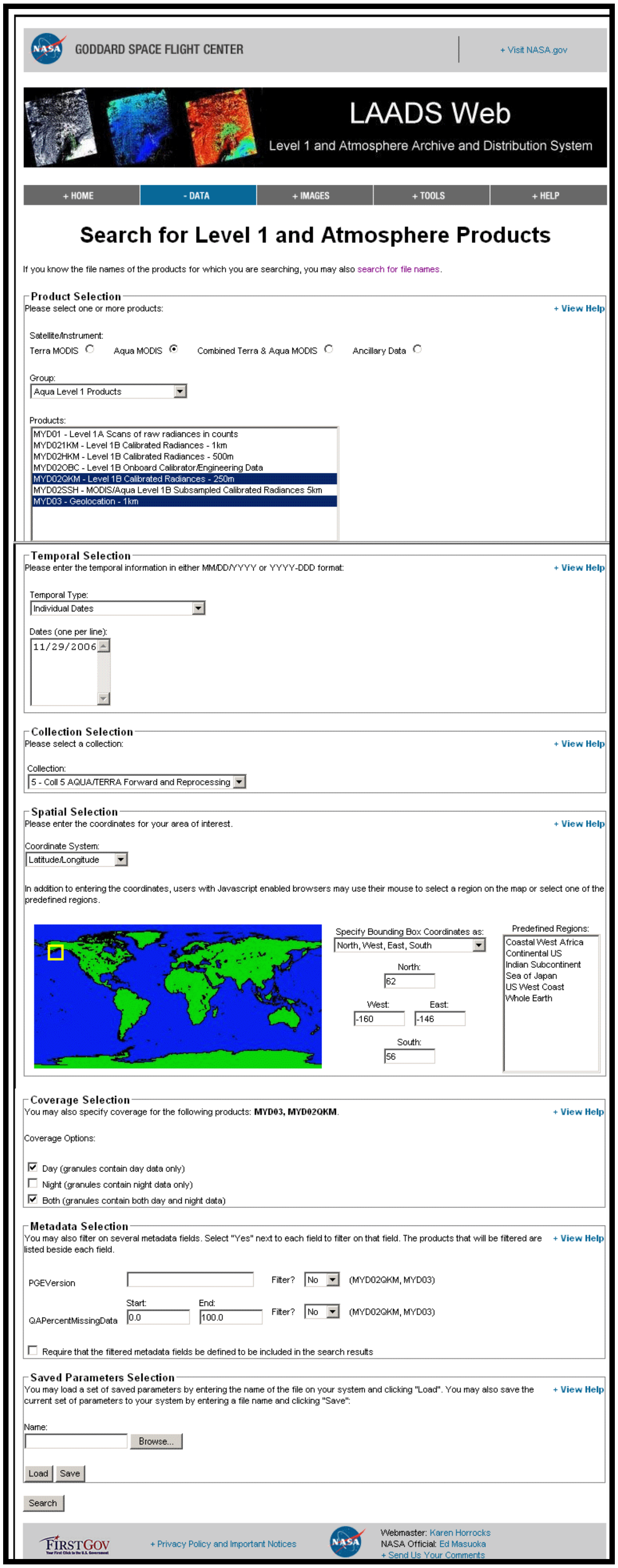
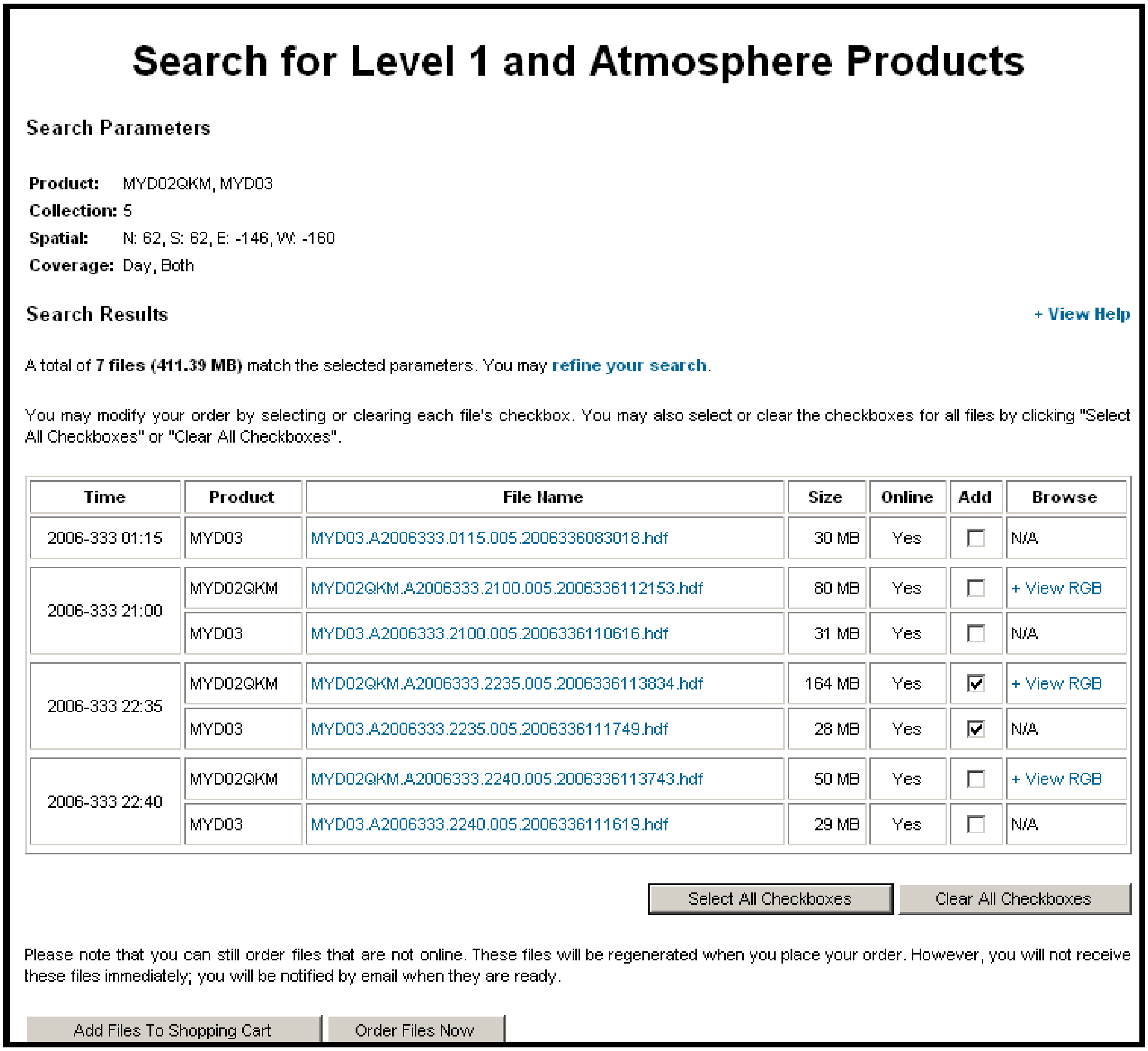

GODDARD SPACE FLIGHT CENTER
+ Visit NASA.gov
LAADS Web
Level 1 and Atmosphere Archive and Distribution System
+ HOME
- DATA
+ IMAGES
+ TOOLS
+ HELP
Search for Level 1 and Atmosphere Products
If you know the file names of the products for which you are searching, you may also search for file names.
Product Selection
Please select one or more products:
+ View Help
Satellite/Instrument:
Terra MODIS
Aqua MODIS
Combined Terra & Aqua MODIS
Ancillary Data
Group:
Aqua Level 1 Products
Products:
MYD01 - Level 1A Scans of raw radiances in counts
MYD021KM - Level 1B Calibrated Radiances - 1km
MYD02HKM - Level 1B Calibrated Radiances - 500m
MYD02OBC - Level 1B Onboard Calibrator/Engineering Data
MYD02QKM - Level 1B Calibrated Radiances - 250m
MYD02SSH - MODIS/Aqua Level 1B Subsampled Calibrated Radiances 5km
MYD03 - Geolocation - 1km
Temporal Selection
Please enter the temporal information in either MM/DD/YYYY or YYYY-DDD format:
+ View Help
Temporal Type:
Individual Dates
Dates (one per line):
11/29/2006
Collection Selection
Please select a collection:
+ View Help
Collection:
5 - Coll 5 AQUA/TERRA Forward and Reprocessing
Spatial Selection
Please enter the coordinates for your area of interest.
+ View Help
Coordinate System:
Latitude/Longitude
In addition to entering the coordinates, users with Javascript enabled browsers may use their mouse to select a region on the map or select one of the predefined regions.
Specify Bounding Box Coordinates as:
North, West, East, South
North:
62
West:
-160
East:
-146
South:
56
Predefined Regions:
Coastal West Africa
Continental US
Indian Subcontinent
Sea of Japan
US West Coast
Whole Earth
Coverage Selection
You may also specify coverage for the following products: MYD03, MYD02QKM.
+ View Help
Coverage Options:
Day (granules contain day data only)
Night (granules contain night data only)
Both (granules contain both day and night data)
Metadata Selection
You may also filter on several metadata fields. Select "Yes" next to each field to filter on that field. The products that will be filtered are listed beside each field.
+ View Help
PGEVersion
Filter?
No
(MYD02QKM, MYD03)
Start:
End:
QAPercentMissingData
0.0
100.0
Filter?
No
(MYD02QKM, MYD03)
Require that the filtered metadata fields be defined to be included in the search results
Saved Parameters Selection
You may load a set of saved parameters by entering the name of the file on your system and clicking "Load". You may also save the current set of parameters to your system by entering a file name and clicking "Save":
+ View Help
Name:
Browse...
Load
Save
Search
FIRSTGOV
+ Privacy Policy and Important Notices
Webmaster: Karen Horrocks
NASA Official: Ed Masuoka
+ Send Us Your Comments

Figure 4. 1. Search for SWAN calibrated radiance granules using LAADS website.

4.3. Data Order

The search function returns all granules (SWATH chunks) for the day and area specified. For each granule, a thumbnail should be available by clicking the appropriate "view RGB" on the right side of the screen. Uncheck the granules (images) you DONT want,leaving checked the images you do want. This is where it is useful to have the zulu time of the pass that best covers SWAN. It helps narrow down the granules of interest. When you have finished your searching and selection, press "**order data now**" at bottom of screen (Fig 4.2).



Search for Level 1 and Atmosphere Products

Search Parameters

Product: MYD02QKM, MYD03
Collection: 5
Spatial: N: 62, S: 62, E: -146, W: -160
Coverage: Day, Both

Search Results + View Help

A total of **7 files (411.39 MB)** match the selected parameters. You may refine your search.

You may modify your order by selecting or clearing each file's checkbox. You may also select or clear the checkboxes for all files by clicking "Select All Checkboxes" or "Clear All Checkboxes".

Time	Product	File Name	Size	Online	Add	Browse
2006-333 01:15	MYD03	MYD03.A2006333.0115.005.2006336083018.hdf	30 MB	Yes	☐	N/A
2006-333 21:00	MYD02QKM	MYD02QKM.A2006333.2100.005.2006336112153.hdf	80 MB	Yes	☐	+ View RGB
	MYD03	MYD03.A2006333.2100.005.2006336110616.hdf	31 MB	Yes	☐	N/A
2006-333 22:35	MYD02QKM	MYD02QKM.A2006333.2235.005.2006336113834.hdf	164 MB	Yes	☑	+ View RGB
	MYD03	MYD03.A2006333.2235.005.2006336111749.hdf	28 MB	Yes	☑	N/A
2006-333 22:40	MYD02QKM	MYD02QKM.A2006333.2240.005.2006336113743.hdf	50 MB	Yes	☐	+ View RGB
	MYD03	MYD03.A2006333.2240.005.2006336111619.hdf	29 MB	Yes	☐	N/A

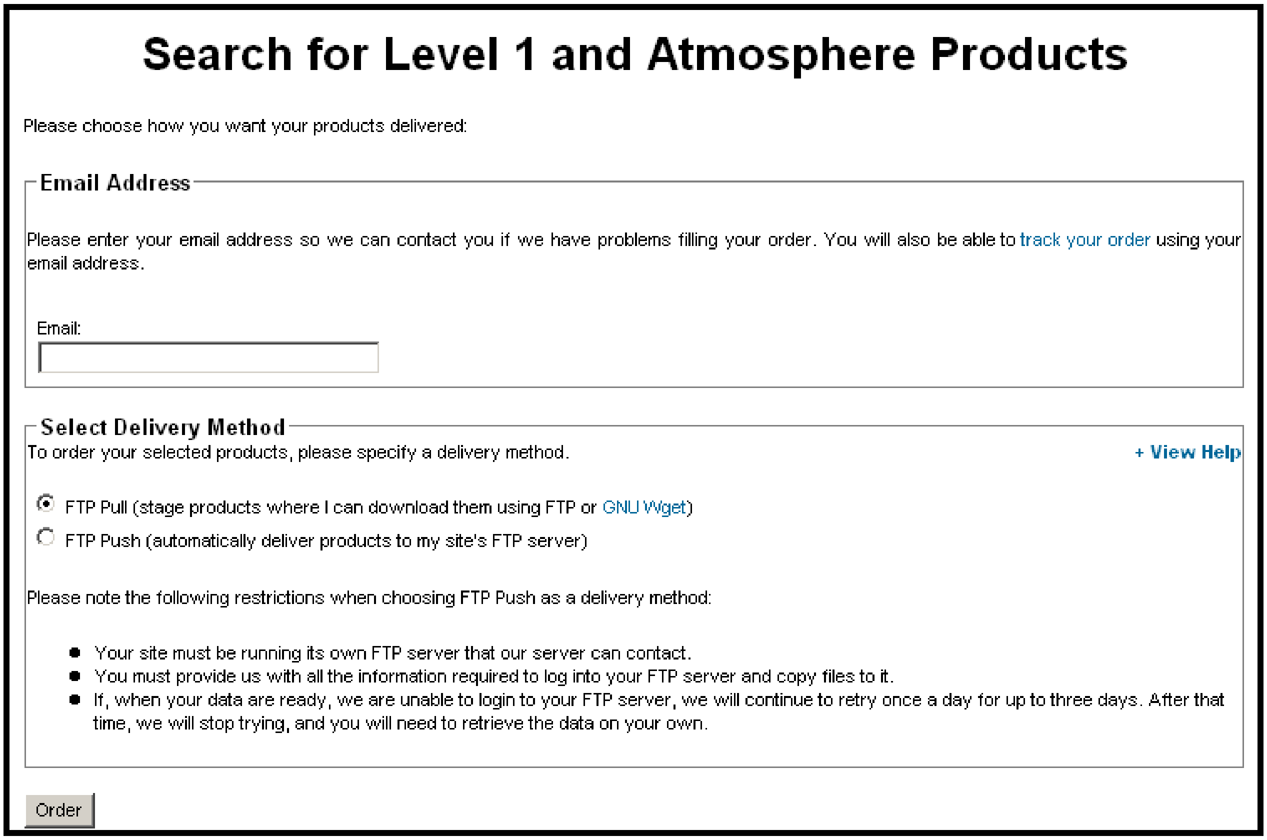
Select All Checkboxes | Clear All Checkboxes

Please note that you can still order files that are not online. These files will be regenerated when you place your order. However, you will not receive these files immediately; you will be notified by email when they are ready.

Add Files To Shopping Cart | Order Files Now

Figure 4. 2. Search results for calibrated radiance granules. Retain checks for desired granules and associated geolocation files.

Another screen appears (Fig 4.3): fill out your email address
Select delivery method: check FTP Pull
Press Order



Search for Level 1 and Atmosphere Products

Please choose how you want your products delivered:

Email Address

Please enter your email address so we can contact you if we have problems filling your order. You will also be able to track your order using your email address.

Email:

Select Delivery Method

To order your selected products, please specify a delivery method. + View Help

FTP Pull (stage products where I can download them using FTP or GNU Wget)

FTP Push (automatically deliver products to my site's FTP server)

Please note the following restrictions when choosing FTP Push as a delivery method:

- Your site must be running its own FTP server that our server can contact.
- You must provide us with all the information required to log into your FTP server and copy files to it.
- If, when your data are ready, we are unable to login to your FTP server, we will continue to retry once a day for up to three days. After that time, we will stop trying, and you will need to retrieve the data on your own.

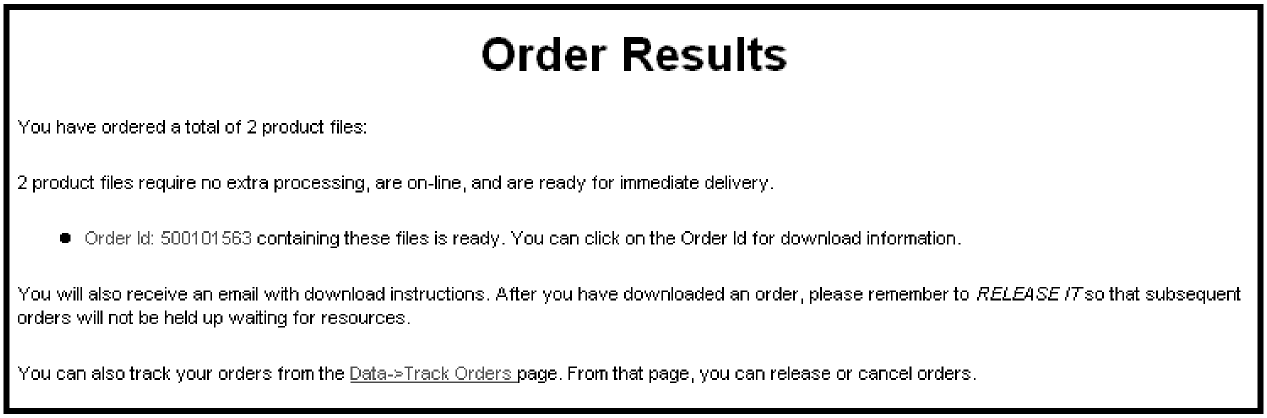
Order

Figure 4. 3. Screen to specify email and delivery method.

4.4. Data Download

Required Software: ftp

a. If your selected granules are available online, you will get a message with an order number (Fig 4.4). Click on the Order id: ############## to get details of your order (Fig 4.5)>



Order Results

You have ordered a total of 2 product files:

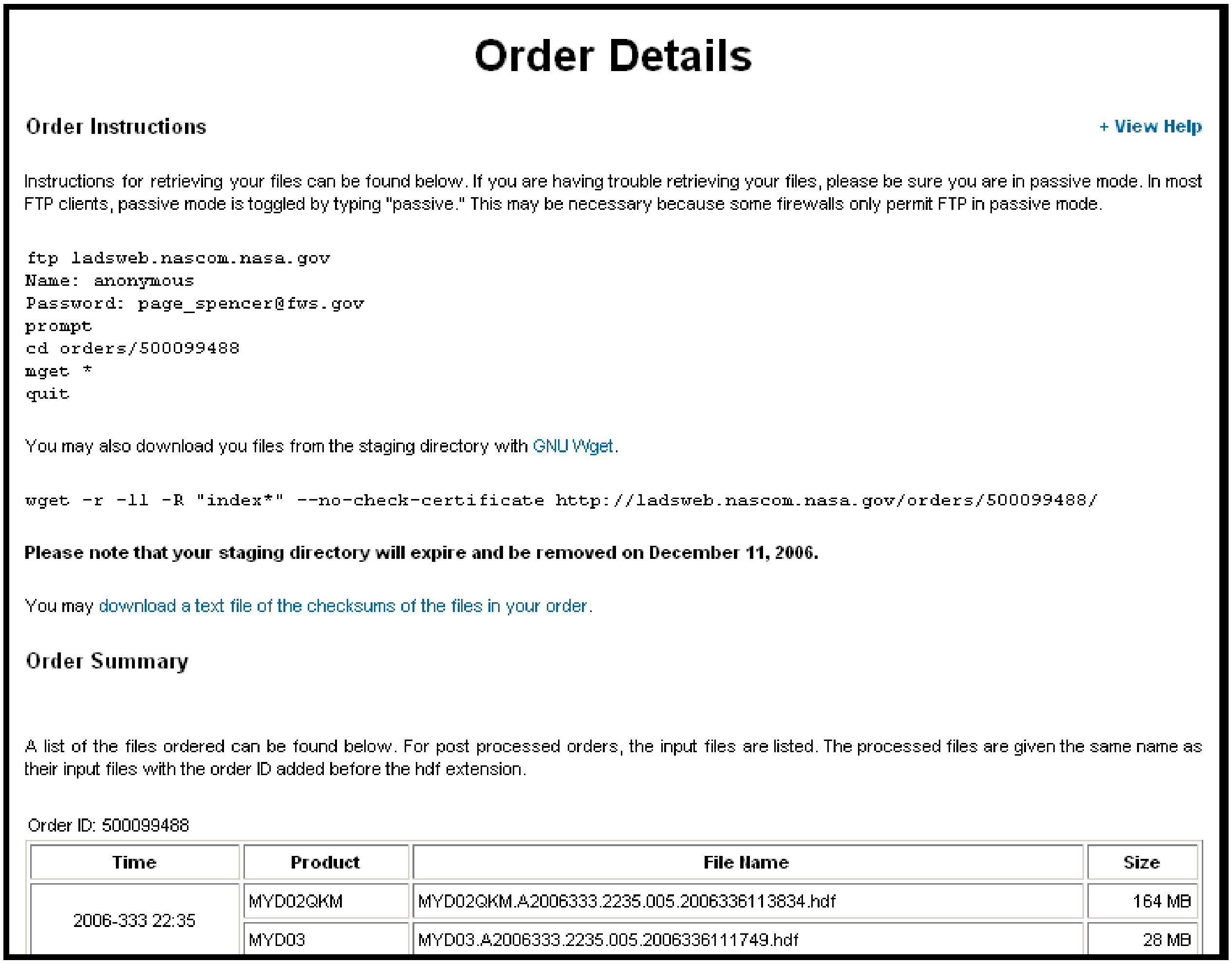
2 product files require no extra processing, are on-line, and are ready for immediate delivery.

- Order Id: 500101563 containing these files is ready. You can click on the Order Id for download information.

You will also receive an email with download instructions. After you have downloaded an order, please remember to *RELEASE IT* so that subsequent orders will not be held up waiting for resources.

You can also track your orders from the Data->Track Orders page. From that page, you can release or cancel orders.

Figure 4. 4. Order number for online granules.



Order Details

Order Instructions **+ View Help**

Instructions for retrieving your files can be found below. If you are having trouble retrieving your files, please be sure you are in passive mode. In most FTP clients, passive mode is toggled by typing "passive." This may be necessary because some firewalls only permit FTP in passive mode.

```
ftp ladsweb.nascom.nasa.gov
Name: anonymous
Password: page_spencer@fws.gov
prompt
cd orders/500099488
mget *
quit
```

You may also download you files from the staging directory with GNU Wget.

```
wget -r -l1 -R "index*" --no-check-certificate http://ladsweb.nascom.nasa.gov/orders/500099488/
```

Please note that your staging directory will expire and be removed on December 11, 2006.

You may download a text file of the checksums of the files in your order.

Order Summary

A list of the files ordered can be found below. For post processed orders, the input files are listed. The processed files are given the same name as their input files with the order ID added before the hdf extension.

Order ID: 500099488

Time	Product	File Name	Size
2006-333 22:35	MYD02QKM	MYD02QKM.A2006333.2235.005.2006336113834.hdf	164 MB
	MYD03	MYD03.A2006333.2235.005.2006336111749.hdf	28 MB

Figure 4. 5. . Details of granule order on LAADS website. Use this information to download data.

b. You will receive two emails from the ladsweb. The first one is an order confirmation and gives your order ID (duplicates screen for online data). The second email tells you where your data are posted. Older data have to be reprocessed before posting. This will be referred to as POD (processing on demand), and may take a day or two (or sometimes a week). The geolocation files (MOD03 or MYD03) will usually be available immediately. It is recommended to keep a log of order numbers and file names as it is easy to lose track of the data and associated geolocation files if they are available several days apart.

Order Notification email:

```
Your Order ID is: 500016314
```
Make a note of this number, you need it for downloading

```
The data you ordered has been staged, and you can retrieve the data
through anonymous FTP using:
            ftp ladsftp.nascom.nasa.gov
            username: anonymous
            password: Page_spencer@fws.gov

            cd /orders/500016314
            binary
```

```
prompt
mget *
```

Note: The files will be deleted after 7 days, please download the files before they get deleted.

c. You will need FTP software to get your data from the LAADS web. Either use the regular FTP command that comes with Windows, or download one you prefer. A very useful one has been NcFtp, available for free downloading from www.ncftp.com. NcFtp displays the download progress for each file, which is very useful as you download these large files. Regular FTP doesn't give progress reports, and sometimes you are not sure the connection is still working. Another good one is WS_FTP (http://www.ipswitch.com/Products/WS_FTP/). It cost $90, but has a nice GUI and is not as prone to timing out as regular FTP or even NcFtp.

Note: DO NOT USE WINDOWS COPY and PASTE commands—it takes a long time and the connection will often time out.

For Nctp:

- Open a DOS Command window:
  Start→All Programs→Accessories→Command Prompt
- Change to the drive on your computer where you want to save your files (drive letter and a colon)
  Example: >j:
- Change (cd) to the directory on your computer where you want to save your files
  Example: > cd {*name of directory}*

Note: For help using DOS, type "help" at the > prompt, and a list of commands will appear. The command cd .. will take you up up a level in the directory tree structure, and that cd pathname will take you down or across the directory tree structure.

- ncftp to the FTPHOST site:
  Example: ncftp ladsftp.nascom.nasa.gov
- cd to the FTPDIR
  Example: cd /orders/500016314

Note: the order number comes in your email from LAADS or the order details screen.

- ls to list files
- get all the files:
  Example: mget *.*

The files will start downloading. The ETA: counter shows approximate time remaining for that file. This process can take a long time. If a connection is fast, you may get them at the rate of one .hdf file every 20-30 minutes. This is a good thing to do at the end of the day. DO NOT CLOSE the DOS WINDOW! If all goes well and the connection doesn't break, you should have your files by the next day (Fig 4.6). When the files are finished downloading, type quit to exit the ftp program. You will then have a data file (MOD02QKM) and a geolocation file (MOD03) for every granule you selected.

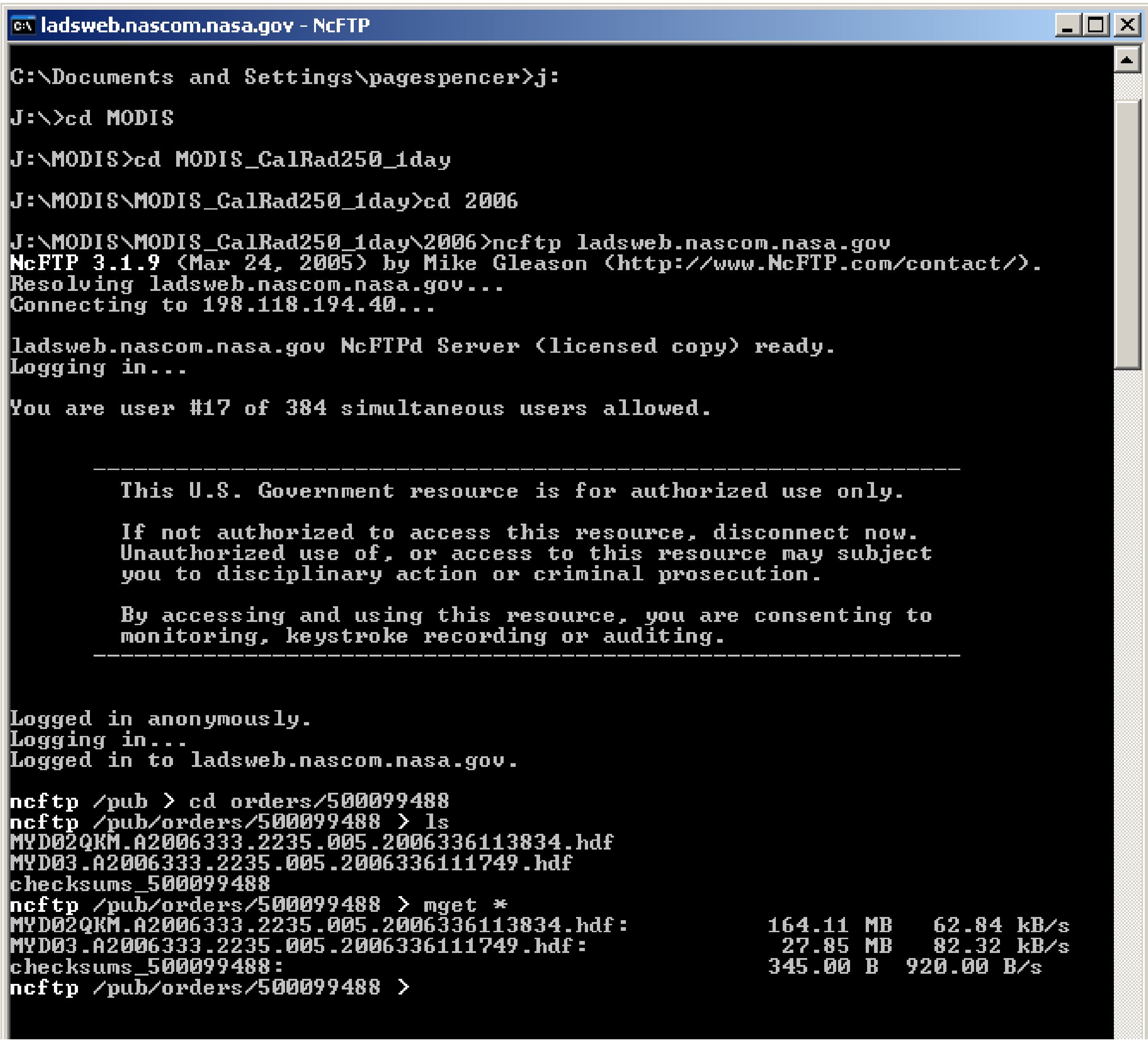


Figure 4. 6. DOS Command Prompt window for data downloads. Example with ncFTP software.

4.5. Data Processing

Required Software: MRT Swath

1. Geometric Correction (Reprojection)

The MRT Swath Reprojection Tool can be found at the home page for the Land Products DAAC (http://LPDAAC.usgs.gov/main.asp) under Data Tools. Download the software and install it per the instructions on the web site and SOP 1. You must process the unrectified MOD02 files using the MOD03 geolocation files. Proceed with displaying, stretching and enhancing. Note that the effects of the atmosphere have not been removed from this product;

smoke, water vapor and various spectral scatterings will affect the data values. However, the spatial patterns are valid, and should not show the well-intentioned artifacts of automatic aerosol correction and path selection.

Run the MRTSwath using the shortcut you created during installation. A black window labeled MODISTool.bat comes up, quickly followed by the MODISTool GUI. Fill out the GUI screen as follows (Fig 4.7):

- Open Input File -- navigate to the directory where you saved the downloaded SWATH files (hdf files). Select the desired MOD02 .hdf files. The Input File Info box is automatically populated by the MRTSwath.
- All the bands in your hdf tile files are displayed in the "Selected Bands" box on the right. Put the files you DON'T want over in the "Available Bands" box on the left by selecting them and pressing the << button. You should keep the bands labeled xxx_b0 and xxx_b1. These bands are the spectral data, and the b# corresponds to the band number of the MODIS sensor. See http://LPDAAC.usgs.gov/modis/table2.asp or Table 2.1 in the Protocol Narrative for a listing of band numbers and their corresponding wavelength ranges.
- Spatial Subset: Input lat/long

  1. UL corner is 62 latitude, -160 longitude
  2. LR corner is 56 latitude, -146 longitude

  These are the boundaries of the SWAN region.

- Specify corresponding MOD03 geolocation file. Match up Ayear/julianday/zulutime of data collection, which is the first date number in the hdf file name, not the second. The second set of numbers that starts with the year is the processing time.

- Specify Output File: browse to directory where you are putting projected files and specify file name (SWAN_yyyyddd.tif). Be sure to add the .tif to the filename. The MRT will add the band number and product type to whatever you specify as a root file name. (see sidebar and SOP 5 for directory structure and file naming conventions.
- Output file type is GEOTIFF
- Resampling Type is Nearest Neighbor
- Output Projection Type is Albers Equal Area

- Edit Projection Parameters:

SMajor : 0.0
SMinor : 0.0
STDPR1 : 55.0
STDPR2: 65.0
CentMer: -154.0
OriginLat: 50.0
FE : 0.0
FN : 0 .0
Ellipsoid: GRS 1980

- Output datatype is same as input datatype
- Output pixel size is whatever you ordered (250m, 500m or 1000m)
- Press Run button. A Status window appears and tracks the processing for each band. The MRTSwath writes the final files to the directory and name specified in the Output File window. You will have a geotif image for each spectral band you specified in the Selected bands window.

The images and interpreted derivatives will be stored under the following directory structure:
Drive name:\AREA\SENSOR_ProductType(or metric)_TimePeriod

i. Year
   a. Files

Drive name will be the drive letter (e.g, D:\, J:\) plus any higher level directories (e.g., J:\SWAN\Remote_Sensing)

AREA will be the geographic area of interest, usually "SWAN", but may also be "AllAlaska", or other networks or areas of interest.

SENSOR will be "MODIS" or "ASTER"

ProductType will include
SNOW
SurfRef500
SurfRef250
VI
CalRad500
CalRad250
Phenology
SnowCover
LakeIce

TimePeriod will be the time period represented. Currently these include
1day
8day
16day

Year subdirectories will be the calendar year

File names will use the following convention:

a. Image file names :

AREA_YearJulianDay.ProductType_IdentifyingInformation.FileType

b. Input files and output files such as .txt or .prm files for automated processing are named by their scripts, or provided by USGS EROS. These will reside in the appropriate year directory.

- **AREA** will usually be "SWAN", but may also be "AllAlaska" or other networks or areas of interest.
- **YearJulianDay** will be four digit year followed by the three digit Julian day. Remember that for multiple day composites, the Julian day is the first day of the composite.
- **ProductType** will be sur_refl, cal_rad, VI, etc. Many of these files will be named during the mosaicking and reprojecting by the MRTs, as discussed in SOPs 2 and 5.
- **IdentifyingInformation** will vary depending on the stage of processing the file represents. The MRT will append the band number in this position. Other likely information may include enhancements, band stacks, stretches, density slices, smoothing, or a host of interpretation processing. There will often be multiple fields in the filename for this information.
- **FileType** will be the three letter suffix which identifies the file type. These often identify the program that generated the file, such as .doc for Word files, or .xls for excel spreadsheets. Many of the data files will be GeoTiff or Tiff (.tif) files generated by the MRT, ENVI and/or Photoshop during processing. Files downloaded from the LP DAAC will

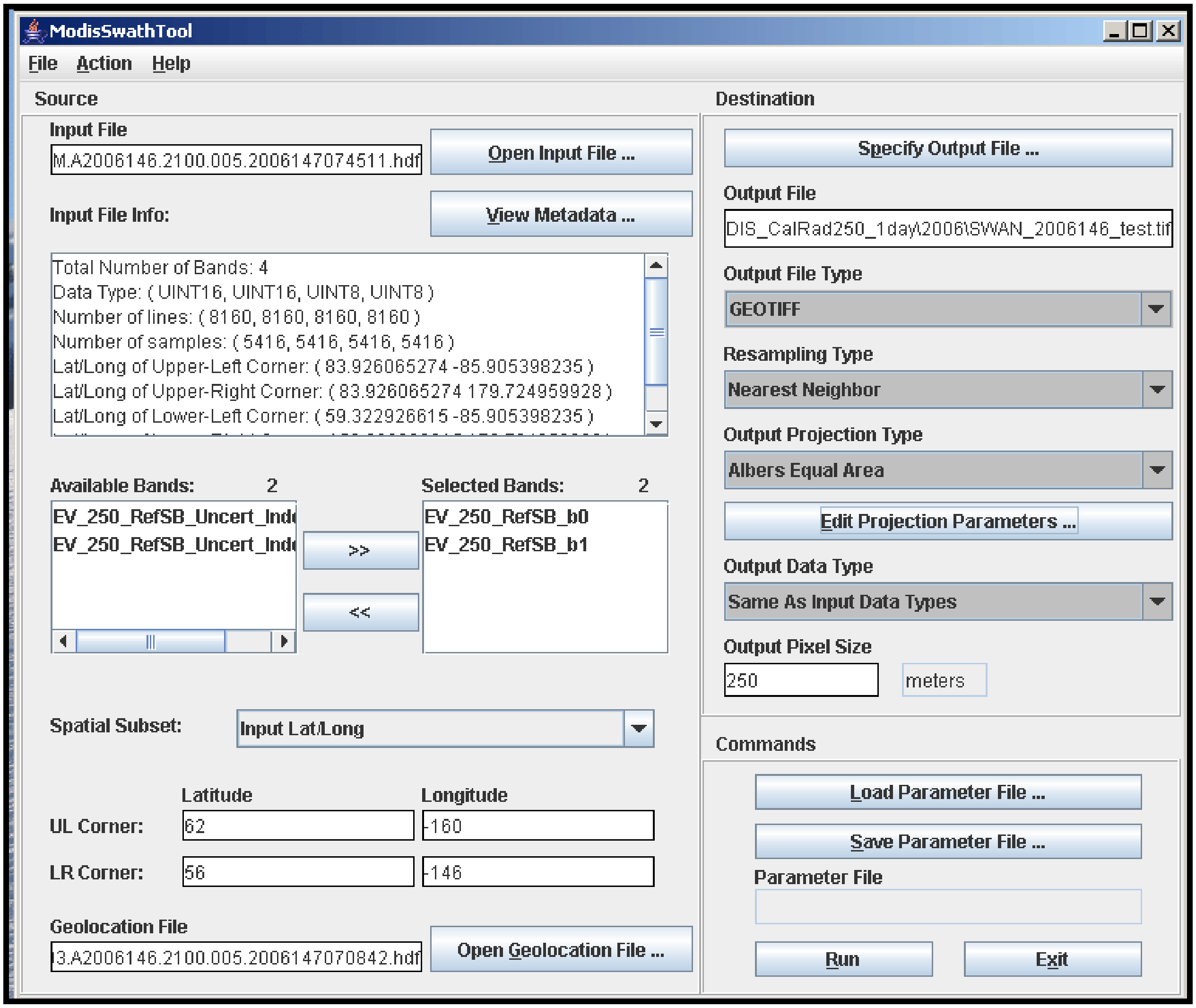


Figure 4. 7. MRTSwath Graphical User Interface for data processing.

2. Image building and Enhancement

Required Software: ENVI

This step uses ENVI software to stack the bands into a single file. ENVI may be used for further enhancing, or you may export a .tif file for enhancing with a package such as Photoshop. Using ENVI retains the georeferencing and individual spectral bands, so the image can be used in various GIS software or for further image analysis functions. Using Photoshop creates a color image where the red/green/blue channels are no longer spectral data, but simply color values of a picture. Photoshop may be used to create graphics for interpretation, posters or publications where the actual spectral data values are no longer needed.

The steps required are as follows:

1. Open calibrated radiance (MOD02 swath – output from SOP 4.5) data in ENVI software
2. Display as natural color or color infrared false color composite
3. Stack data into multi-band image
4. Mosaic sub-images into one SWAN image
5. Enhance for manual interpretation

Open the files in ENVI

In the Main ENVI menu, select File → Open Image File. Select desired bands (*.tif files) from the geometrically corrected list for standard SWAN calibrated radiance products. The file names should be displayed in a pop-up window entitled Available Bands List.

Display as natural color or infrared false color composite.

Natural color or color infrared displays can be made using the 500m calibrated radiance data. Specify the appropriate bands from the available bands list and load RGB. Color infrared displays can also be created using the 250m calibrated radiance data.

For example, the file names (individual bands) for one date may be:

SWAN_2004001.cal_rad_b01

SWAN_2004001.cal_rad_b02

where SWAN_2004001.sur_refl_b01 is calibrated radiance from year 2004, day 001, and bxx represents band number. To display the various band combinations, select the RGB option on the Available Bands List and assign the color (R,G,B) guns as follows:

Natural color

- Red gun band 1
- Green gun band 4
- Blue gun band 3

False color infrared

- Red gun band 2
- Green gun band 1
- Blue gun band 4 (or repeat band 1 with 250m data)

Stack data into multiband image

There are several methods to stack the individual bands into a single image (which then becomes easier to handle). One method is as follows: from the ENVI main menu, select File→ Save file as→ ENVI standard. The ENVI standard file will be a flat binary file with an associated header file (*.hdr). Stack as many bands in the file as you will want to work with. The suggestion here is to stack 500m bands 1,2,3, and 4 for one date into a single image or 250 m bands 1 and 2 into a single image. The resulting file will be a multi-band image of the SWAN region. You can use this to proceed with ENVI processing, including various stretches and other enhancements. This is the image for archiving in the SWAN data set. If one granule doesn't cover the entire SWAN region, mosaic additional granules and save the final two-banded image that covers SWAN.

Image Mosaicking

It may take more than one SWATH granule to cover the entire SWAN region. Download and process as many granules as necessary to cover SWAN (usually 2). Then mosaic the images to form one image of SWAN for each day.

- In ENVI—at main menu
- Basic Tools→Mosaicking→Georeferenced→Import→Import files and edit properties
- Select or browse to one of the SWAN images. After it displays in the little image window, select the other file. They should each display in the mosaicking window. Be sure to keep the same spectral stretch for all files. Use the appropriate value for background pixels to set to transparent so you don't have black patches in your mosaic.
- Then go to File→apply in the mosaicking window. Specify an output image name.

4.6.Enhance image for manual interpretation

The calibrated radiance data that are produced using SOPs 4-1 through 4-5 may be used for interpretations regarding vegetation development, land use/land cover change, ice development and break-up, and other applications. The basic approach toward interpreting the data is to import the data into ENVI, create time-series imagery, and compare the data to previous years' observations for periodic reporting (e.g., annual, decadal).

Enhance display image (this does not change actual data values, only the display). Using the Display Image Menu, select Enhance. Using the scroll window as the target, the preprogrammed stretches for Linear 2% and the Square Root make a quick and often useful enhancement. Another useful enhancement is in the Main ENVI Menu: Transform → Photographic Stretch. This stretch has cleaned up images with several "foggy" bands and results in a clean appearing image.

For finer tuning of specific features, use the interactive stretching at the bottom of the menu. In the histogram window menu:

a. Stretch_Type→Piecewise Linear
b. Add nodes to the white stretch line in the histogram with the middle mouse button
c. Options→Edit Piecewise Linear
d. Enter new (output) values for each node in the right column (LUT Val). Different LUT values may be used for experimentation until a suitable enhancement is achieved.

For real color enhancement: (this does change the actual data values of the images). In the Display Image Menu, select Enhance → Interactive Stretching. The default stretch is Linear Stretch. To make each of the bands consistent choose the radio buttons (R, G, and B) individually and change the stretch values to 0 : 2500. After changing the stretch value for a single radio button (e.g., R), click the Apply button (Fig 4.8)

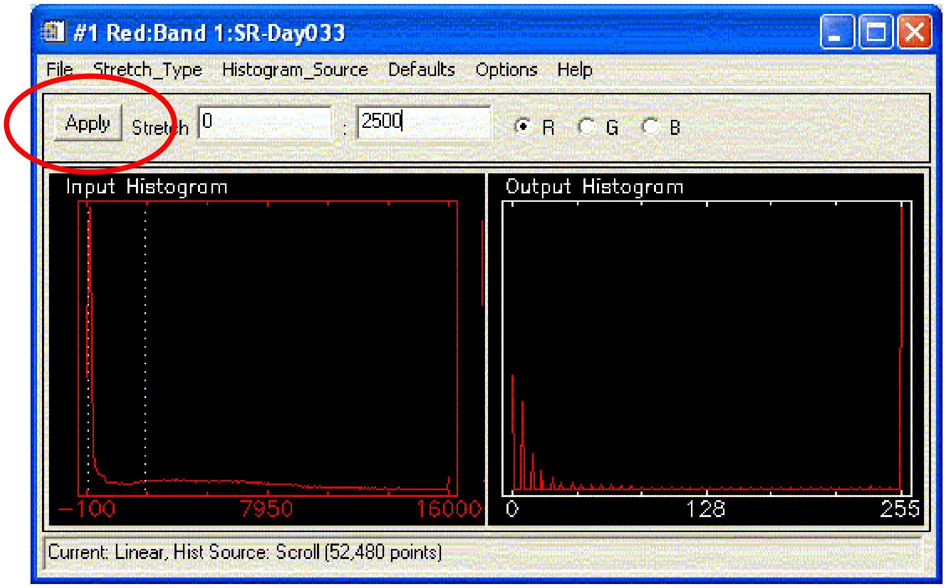


Figure 4. 8. Recommended linear stretch values for calibrated radiance images.

Repeat the same stretch for the green (G) and blue (B) bands.

For the false color infrared images, use a stretch of 1: 10000 and follow the same steps.

Export the files in tif, .bmp, or .jpg formats if you want to work with them in graphics or text packages. These formats can be read by Photoshop, Powerpoint, or other graphics packages and word processing packages. To export an ENVI display to one of these formats, do the following:

- Right mouse click in the display window.
- In the pop-up window, select "Save image as".
- Under "Output File Type, select desired format (tif, bmp, jpg).

You may open the resulting file in Photoshop and use the Image Adjustments functions to enhance the color balance, brightness and contrast.

4.7. Interpret freeze-up and break-up on selected lakes in the SWAN Region.

Required Software: Photoshop (or equivalent), ArcMap

The current method for analyzing ice on and off of lake systems is by manual interpretation. The analyst examines the images in the region of the lakes and makes a determination about the stage (% cover) of ice on the lake.

Ice appears as white on both natural color and CIR images, so solid snow covered ice is easily interpreted. Likewise, open water is predominately black or dark blue on both image composites, with lighter blue or bluegreen signifying a sediment load in the water. Open water is easily interpreted from natural color and CIR images. Wet ice, such as may occur during break-up or by overflow on solid ice, appears pale blue (blue ice). Wet ice is often mottled with white and black, reflecting the ice and water mosaic. Another form of blue ice is when the frozen over lake is wind swept during winter storms. Cracks often show in the ice, indicating that you are looking at ice rather than open silty water.

During freeze-up, ice may form during cold weather, break apart and refreeze, often several times before the lake is frozen over for the winter. During break-up, parts of large lakes will often melt out earlier than others. Sometimes, large pans of free ice will be blown around the lake by strong surface winds, changing the pattern of ice distribution from day to day. Smaller lakes and pond complexes exhibit different freeze-up and break-up patterns. Many small shallow lakes will ice over early in the winter, while nearby deeper lakes do not freeze over until later, if at all.

MODIS images from the 2004-05 ice season are presented in Plates 4.1 and 4.2 for Lake Clark and Iliamna Lake. Notes in the captions for each plate are examples of various ice and environmental features the interpreter is likely to encounter while evaluating ice conditions on lakes in SWAN.

1. Indicator lakes for ice cover in SWAN at the MODIS resolution include (Plate 4.3):

- Brooks/Naknek Lakes complex (Katmai NPP)
- Lake Clark (Lake Clark NPP)
- Lake Grosvenor (Katmai NPP)
- Lake Colville (Katmai NPP)
- Telaquana Lake (Lake Clark NPP)
- Twin Lakes (Lake Clark NPP)
- Kukalek (Katmai NPP
- Nonvianuk (Katmai NPP)
- Becharof and Iliamna on the Alaska Peninsula
- Tustemena and Skilac on the Kenai Peninsula
- Beluga and Chakachamna Lakes in the Alaska Range
- Complexes of small lakes in the lower Susitna Valley and the northern Kenai Peninsula
- Bristol Bay

2. Interpretation of lake ice cover. Examine the calibrated radiance images and make ocular estimates of ice cover on lakes listed above in 10% increments. For each day and each lake or complex, record the data in a file as shown in Table 4.3 (excel file for Julian day/lake). Note cloud cover (c) if clouds cover lake. Frequently, clouds will cover part, but not all of the SWAN region. If you can’t see a specific lake, try the next day (and the next), until you can find a cloud-free image over the lake. Sometimes you can interpret ice and water through scattered or thin clouds.

3. Digital Calibration. Periodically, check your ocular estimates with a digital calibration of an image. Select a (relatively) clear date with partial ice cover on lakes across the region as your calibration image. This is accomplished by masking out the lakes of interest, making an “ice

classification” by density slicing, and calculating % of signatures which should represent ice and water.

- Select a lake(s) that are cloud and shadow free; only water and ice
- Use registered swath MOD02 data
- Use lake masks created at the raster size of your data
- In ArcMap: add mask files and IR band of MOD02 image, (01 band)
- Clip out lake using raster calculator
    - Outfile name = con([lakemask) > 0, [NearIRband file])
    - Evaluate, say YES if projection error
- Display lake→symbolize→classification (3-7 classes depending on ice)
- View histogram, set breaks
    - Water is approximately 100-1250
    - Ice should be > 1250
- Color code image—check that it seems realistic for water and ice patterns
- Raster calculation to make a binary image
    - Output = lake mask > 1250
- View attribute table for this grid to count number of cells that are ice
    - (ice = 1)
    - Total lake area = 1s and 0s
- Calculate % of ice for total lake area
    - # pixels =1/total number of pixels in lake
- Compare with ocular estimate, adjust estimates accordingly
- Document for files, including date, interpreter and image date.
- If any actual verification data exist, compare with image conditions (check with pilots in area, go fly around yourself)

Interpret ice season metrics
Required software: ENVI, Excel

Examine the lakes using the interpretation criteria outlined in section 4.6.2 and Plates 4.1 and 4.2. Determine the date(s) of initial freeze-up (ice on part of lake(s)), final freeze-up (ice over whole lake), beginning break-up (ice pans or wet ice), final break-up (no ice, all open water), and lengths of freeze-up season, ice-on season, break-up season and ice-free season (the following summer). Record these metrics for each lake or lake complex individually. The data set for each cycle of seasons will appear as in Table 4.4. In time, there should be sufficient data to establish the range of natural variability, and to conduct trend analysis to see if there are long term trends in ice seasons.

Initial freeze-up	≥10% ice cover on lake
Freeze-up season	final – initial dates (number of days)
Final freeze-up	>90% ice cover
Ice on season	beginning break-up – final freeze-up (- interim days in winter)
Beginning break-up	≤90% ice cover, often leads or cracks appearing, wet blue ice
Break-up season	final break-up – beginning break-up
Final break-up	<10% ice cover on open water
Ice free season	Final break-up to initial freeze-up

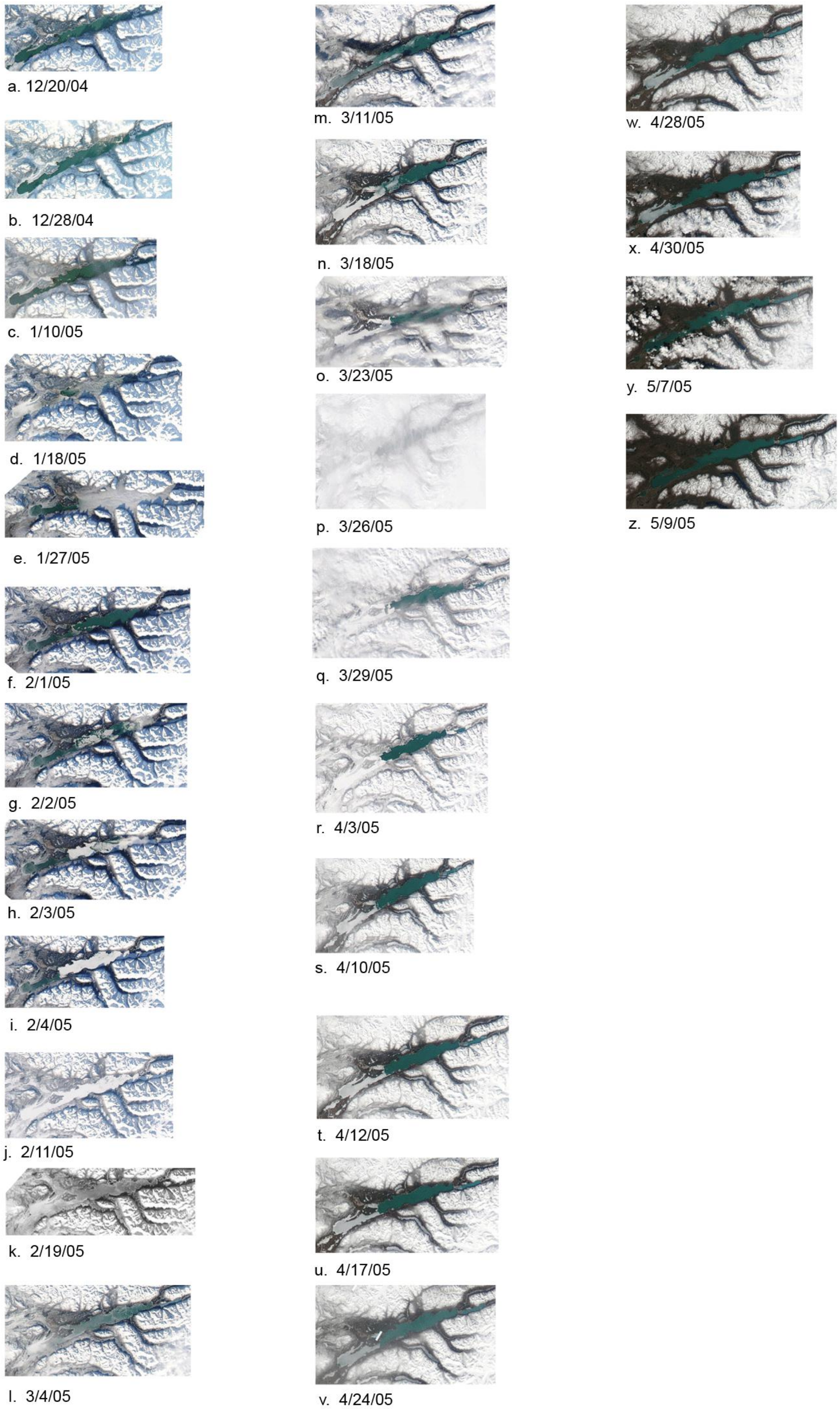


Plate 4.1. 2004-05 Ice season for Lake Clark.

Plate 4.1. Ice season on Lake Clark, Dec 2004-May 2005. These subimages are taken from Rapidfire images which are not geometrically corrected. Therefore, ice coverage estimates pertain to these images only, and may be significantly different when using geocorrected calibrated radiance images. The images in the plate are full data resolution. Although features may be difficult to see on a printed plate, expand or zoom the digital file to observe features noted in the captions. *These are examples for illustration only.*

a. Dec 20, 2004. Solstice on Lake Clark. The only ice is in upper Chulitna and Portage Bays. Remainder of lake is open water. Note mountain shadows across lake.

b. Dec 28, 2004. Ice covers Chulitna and Portage Bays around Keys Point. Light fog on lake near Portage Creek. Kontrashibuna is still open water. Ice cover 10%. Record as initial freeze-up.

c. Jan 10, 2005. Ice patterns similar to Dec 28, 2004. Ice cover 10%.

d. Jan 18, 2005. Ice with new snow on lower Lake Clark below Cape Shiskin. Open water shows outboard of Port Alsworth; low fog covers upper Lake Clark. Little Lake Clark is frozen over and snow covered. Ice cover approximately 30%, assuming open water below fog.

e. Jan 27, 2005. New ice on western Lake Clark; note white cracks in ice. Probably open water from lower Keys Point up to Port Alsworth. Fog over upper lake and valleys.

f. Feb 1, 2005. New ice (no snow) on most of lower lake west of Port Alsworth. Ice pans on lake west of Tommy Island. Open water on middle and upper Lake Clark. Kontrashibuna iced over. Ice cover 30-40%.

g. Feb 2, 2005. Ice pans on middle Lake Clark expanding and coalescing. Fog at upper end. Ice cover 70%.

h. Feb 3, 2005 Ice cover nearly complete; 90%.

i. Feb 4, 2005. Ice cover complete 100%; freeze-up date.

j. Feb 11, 2005 Ice cover complete. New snow from storm Feb 5-9.

k. Feb 19, 2005. (note—b/w image), ice cover wind swept. Snow blown to western end.

l. Mar 4, 2005. Several storms since Feb 19. Windswept “blue ice”.

m. Mar 11, 2005. Beginning of break-up. “Blue” ice on lower and middle Lake Clark. Open water or very wet ice on upper Lake Clark. Scattered clouds over lake (note shadows.)

n. Mar 18, 2005. New snow on ice at lower end of lake. Middle Lake Clark breaking up—large ice pans and wet blue ice. Ice cover approximately 60%. Blue ice on Little Lake Clark.

o. Mar 23, 2005. Some ice outboard of Port Alsworth has refrozen since March 18. Middle and upper Lake Clark generally ice free. Thin clouds over most of scene. Ice cover less than 50%. New snow on Little Lake Clark ice.

p. Mar 26, 2005. Scene covered by thin clouds. Barely interpretable as open water in mid-upper lake, snow covered ice on lower lake.

q. Mar 29, 2005. Open water mid-upper Lake Clark. Large pans breaking off east of Cape Shishkin. Solid ice cover on lower lake. Ice approximately 40%. Little Lake Clark starting to break-up.

r. Apr 3, 2005. Ice pans coalesced and refroze east of Cape Shishkin. Ice still about 40%. Little Lake Clark about half open water. Kontrashibuna still ice covered. Note open patch at outlet of Lake Clark.

s. Apr 10, 2005. Continued slow break-up between Cape Shishkin and Port Alsworth. Ice on lower lake has faint bluish cast. Ice cover pushing 30%.

t. Apr 12, 2005. Similar to Apr 10. Note higher lakes Kontrashibuna and Upper Tazimina starting to develop blue ice. Little Lake Clark almost completely ice free.

u. Apr 17, 2005. Similar to Apr. 10.

v. Apr 24, 2005. Lower lake still ice bound. Note westward retreat of ice in channel between Cape Shishkin and southeast shore of Lake Clark.

w. Apr 28, 2005. Ice in lower lake getting fairly rotten. Ice cover less than 30%. Upper Kontrashibuna and Tazimina Lakes breaking up.

x. Apr 30, 2005. Similar to Apr 28, but ice is “bluer” and has open patches in lower lake. Ice cover still about 30%. Kijik still frozen.

y. May 7, 2005. Clouds covered the scene during the first week in May, preventing pin pointing the exact day of break-up. Completely ice free on this date. Record as open water. Kontrashibuna, Taziminas, Kijik all open. Lots of cumulus clouds and shadows.

z. May 9, 2005. Nice cloud free day showing all lakes except Long Lake as open water.

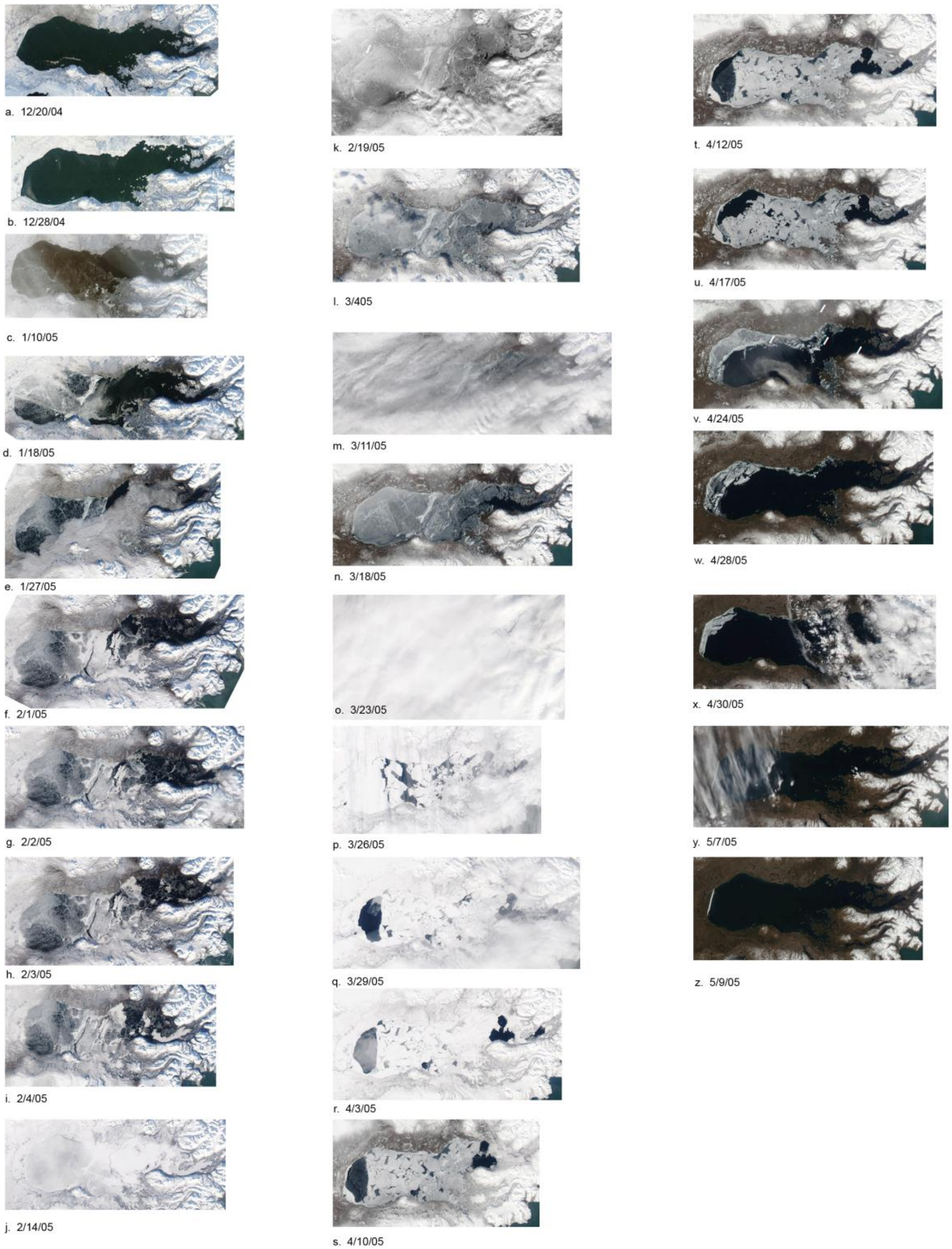


Plate 4.2. 2004-05 Ice season for Iliamna Lake.

Plate 4.2. Ice season on Iliama Lake, Dec 2004-May 2005.

These subimages are taken from Rapidfire images which are not geometrically corrected. Therefore, ice coverage estimates pertain to these images only, and may be significantly different when using geocorrected calibrated radiance images. The images in the plate are full data resolution. Although features may be difficult to see on a printed plate, expand or zoom the digital file to observe features noted in the captions. *These are examples for illustration only*.

- a. Dec 20, 2004. Open water with cloud strings near south shore.
- b. Dec 28, 2004. Early skims of ice near outlet at western end. Ice <10%.
- c. Jan 10, 2005. Very new ice on western end/middle of lake. Thin clouds. Ice 50-60%. Record as initial freeze-up.
- d. Jan 18, 2005. Ice thickening, but pushed westward by wind. Freezing in around islands at upper end. Swirls of broken ice off Kaknonak. Thin clouds on western end. Ice 40-50%.
- e. Jan 27, 2005. Ice formation moving east. Upper and south lake covered with low fog. Difficult to estimate ice cover; probably about 50%.
- f. Feb 1, 2005. Ice breaking and refreezing in middle section; western section pretty stable. Ice scrim forming among islands at upper end. Ice cover 60-70%.
- g. Feb 2, 2005. Continued ice formation near middle, especially near mouth of Newhalen River. Ice cover 70-80%.
- h. Feb 3, 2005. Ice extent about same as Feb 2, but more stable on north shore. Cover 80%.
- i. Feb 4, 2005. Continued ice development, especially Pile Bay. Ice cover 90%.
- j. Feb 11, 2005. Complete ice cover except tiny holes near south shore. A storm Feb 5-9 covered area with new snow. Record as freeze-up.
- k. Feb 19, 2005. Wind swept ice still mostly intact. Note that holes from Feb 11 are slightly larger. Ice cover still pretty much complete.
- l. Mar 4, 2005. Continued wind swept ice cover since Feb 19. Ice cover still >>90%.
- m. Mar 11, 2005. Cloud covered; difficult to interpret beyond appearance that ice is still intact.
- n. Mar 18, 2005. Beginning of break-up. Large open area along south shore at eastern end and Pile Bay. Large cracks and pans forming at eastern end. Ice cover 80-90%.
- o. Mar 23, 2005. Cloudy. Appears to be new snow on ice.
- p. Mar 26, 2005. Thin clouds, but break-up clearly visible. Open water is black, many large pans and leads. New snow on ice. Note opening at outlet. Ice cover 50-60%.
- q. Mar 29, 2005. Continued break-up and rearrangement of large ice pans. Note large area of open water (a polyna?) at western end, and refrozen pans immediately east of it. Also note beginning of characteristic “three leaf clover” open water at upper end. Ice 70%. Thin clouds.
- r. Apr 3, 2005. New ice reforming in western open water area. “Clover” more definitive, upper Pile Bay open, while channel off Porcupine Island has refrozen. Ice cover back up to 80%.
- s. Apr 10, 2005. Much of lake refrozen; new ice covers western polyna and Pile Bay. Ice cover back to 90+%.
- t. Apr 12, 2005. Break-up resumes. Polyna open on northern shore, “clover” and Pile Bay open water. Ice cover 80-90%.
- u. Apr 17, 2005. Continued break-up across lake. Large areas of open water on northwestern shore, note rearrangement of ice pans. Upper open clover merged with Pile Bay. Ice 70-80%.
- v. Apr 24, 2005. Movement of ice pans by wind and possible new ice along northwestern shore. Thin crescent of clouds on south shore. Ice 30%.
- w. Apr 28, 2005. Continued break-up of western ice pack. Leads and large pans. Most ice gone from south and eastern end. Ice cover 20%.
- x. Apr 30, 2005. Last of the ice pushed onto western shore. Clouds across middle and eastern end of lake. Ice cover 10%.
- y. May 7, 2005. Last remnant of ice along western shore. Clouds scattered over western end. Record as open water; ice cover about 2%.
- z. May 9, 2005. Nice cloud free day with tiny remnant of ice on western shore.

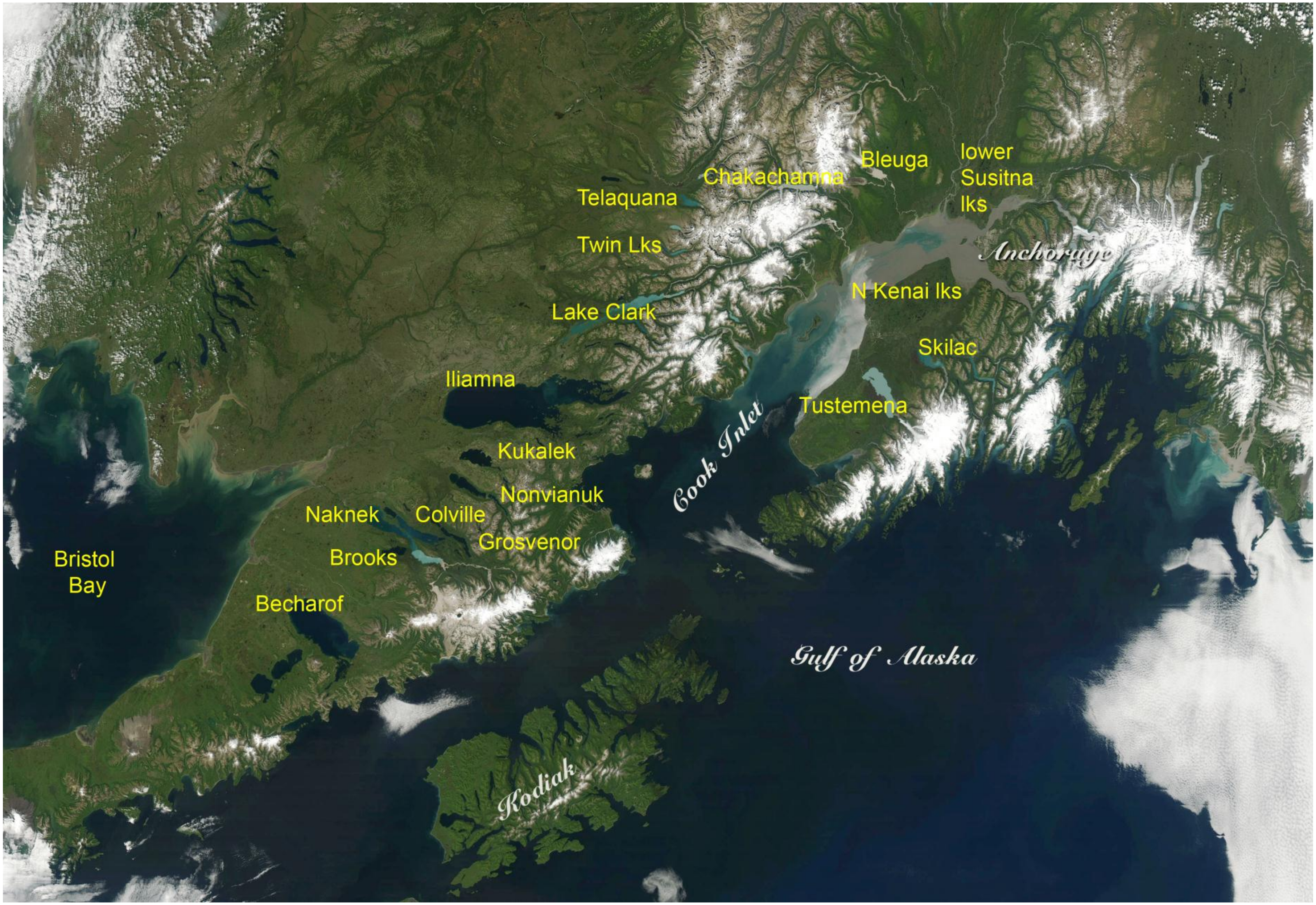


Plate 4. 3. Locations of lakes for ice cover monitoring in SWAN. MODIS image August 11, 2005

c=clouds; #=%ice; blank-not interpretable or not on image

year	Jul day	date	Iliamna	Lake Clark	Twin Lks	Skilac	Tustemena	Notes, other observations
2005	364	30-Dec						
2005	365	31-Dec						
2006	4	4-Jan	5	10	80	0	0	
2006	5	5-Jan	c	10	80	0	0	
2006	6	6-Jan						
2006	7	7-Jan						
2006	8	8-Jan						
2006	9	9-Jan						
2006	10	10-Jan						
2006	11	11-Jan	c	c	c	c	c	
2006	12	12-Jan						
2006	13	13-Jan	50, ice pans	40	c	50	0	Augustine multiple ash clouds drifting SE
2006	14	14-Jan						
2006	15	15-Jan						
2006	16	16-Jan						
2006	17	17-Jan	40, big ice pans	20	c	100	30	Arctic high meets Pacific low at Ak Pen along Aleutian Mtns
2006	18	18-Jan	70	c	100	c	c	ash to west of Augustine, over east end of Illiamna
2006	19	19-Jan	70, ice pans	50	100	100	c	Augustine has steam plume, Tustemena, Lk Clark, Iliamna all partially frozen
2006	20	20-Jan						
2006	21	21-Jan						
2006	22	22-Jan						
2006	23	23-Jan	100	100	100	100	50	Cloud streaks N and S of Ak Pen
2006	24	24-Jan	100	100	100	100	100	Ice in Bering Sea south fo Aklun Mtns, Bristol Bay to Pilot Pt
2006	25	25-Jan						
2006	26	26-Jan	100	100	100	100	100	King's Bay, PWS frozen over
2006	27	27-Jan						
2006	28	28-Jan	100	c	c	100	100	Cloud streaks across Bering Sea and Ak Pen, low in Gulf,
2006	29	29-Jan	100	100	100	c	c	Augustine plume blowing up through clouds, blowing SW,
2006	30	30-Jan	100	100	100	100	100	Augustine plume blowing NE; ash deposits (?) S of Kamishak Bay
2006	31	31-Jan						
2006	32	1-Feb	100	100	100	c	100	Great cloud streaks off Bering Sea, Ice in Bering Sea reaches south of Naknek.
2006	33	2-Feb	100	100	100	100	100	Augustine plume blowing west, Bristol Bay iced down to Aniakcha
2006	34	3-Feb	c	c	c	100	100	Copper R delta--appears to be ground water flow out ot delta gravels
2006	35	4-Feb						
2006	36	5-Feb						
2006	37	6-Feb						
2006	38	7-Feb						
2006	39	8-Feb	c	c	100	100	100	Skilac and Tustemena blown mostly snowfree, blue ice
2006	40	9-Feb	c	c	c	c	c	
2006	41	10-Feb						
2006	42	11-Feb						
2006	43	12-Feb	c	c	c	c	c	
2006	44	13-Feb						
2006	45	14-Feb	c	100	c	100	100	Skilac & Tustemena wind blown, blue ice, King's Bay frozen
2006	46	15-Feb	c	c	c	100	100	watch Skilac--breaking up around upper landing?
2006	47	16-Feb	100	80	100?	90	100	very new ice on most lakes
2006	48	17-Feb						
2006	49	18-Feb						
2006	50	19-Feb						
2006	51	20-Feb	c	c	c	60	90	
2006	52	21-Feb	100	c	c	60	90	Skilac freezing, thin ice Tust, Illiamna, Becharof
2006	53	22-Feb	100	100	c	60	100	Skilac just freezing, Tust thin ice, Naknek and Illiamna thin ice
2006	54	23-Feb						

2006	55	24-Feb	100	100	100	95	100	Skilac nearly frozen over, west end still blue
2006	56	25-Feb						
2006	57	26-Feb	c	c	c	100	100	East end of Skilac still grey--just frozen

Table 4. 3. Example of data record for ice cover. Ice season 2005-06.

Years of ice cycle 2004-05												
	dates by Julian calendar								**Number of Days**			
Lake	**initial freeze-up**	**Interium melting/ freezing**		**final freeze-up**	**beginning break-up**	**Interium melting/ freezing**		**final break-up**	**length of freeze-up**	**length of ice-on or cover season**	**length of break-up season**	**length of ice-free season (following summer)**
Lake Clark	362			035	070			127	38	35	57	203
Iliamna	010			042	077	100	102	127	30	35	48	203
Tustemena												
Skilac												
Bleuga												
Chakachamna												
Twin Lakes												
Ice Cycle 2005-06												
Lake Clark	330			023	131			142	28	108	11	193
Iliamna	330			023	134			149	28	111	15	
Tustemena												
Skilac												
Bleuga												
Chakachamna												
Twin Lakes												

Table 4.4. Example data reporting for lake freeze-up/break-up cycle.

4.9. Compare to other years

For example, Figure 4.9 illustrates the differences between 8-day calibrated radiance for Feb 18-25 from 2001 and 2004. It is obvious that there is considerably more snow and ice in 2004, with Lake Iliamna and Lake Clark under ice and snow.

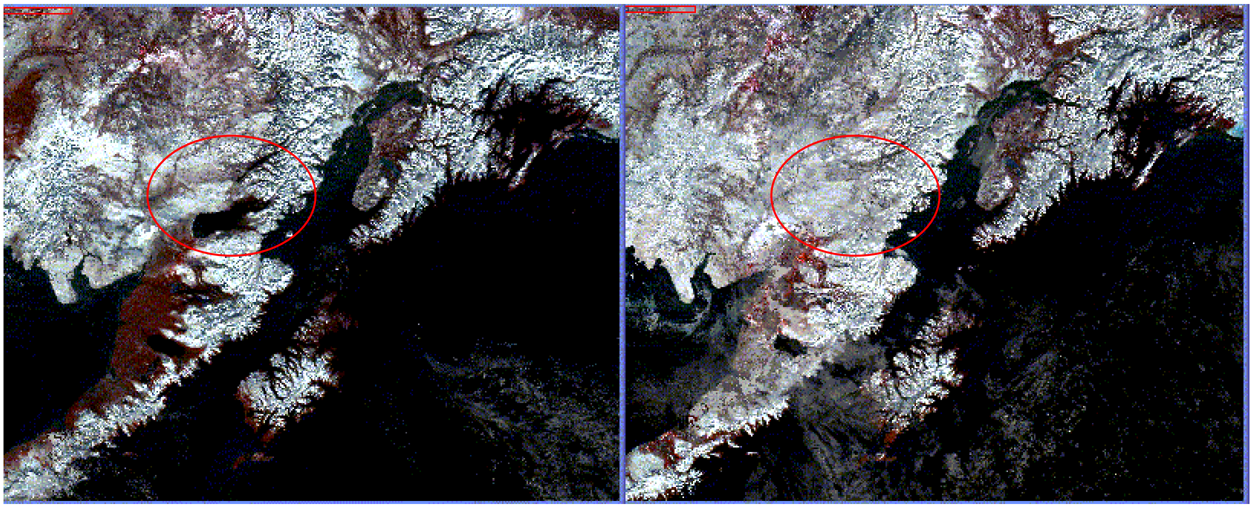


Figure 4. 9. Differences in ice cover on Illimna Lake between Feb. 18-25, 2001 (left) and 2004 (right).

When comparing same-date imagery from two (or more) different years, it is helpful to link the display windows from the two years. This is performed in the following manner.

- Open and display a specified date's calibrated radiance data using ENVI software (SOP 4.6.2).
- Open and display the same date from another year using a second display window.
    - ➢ To open a new display window, click on the display selection button (Fig. 4.10), and select New Display.
    - ➢ A new display will then be available to for the second year of data.

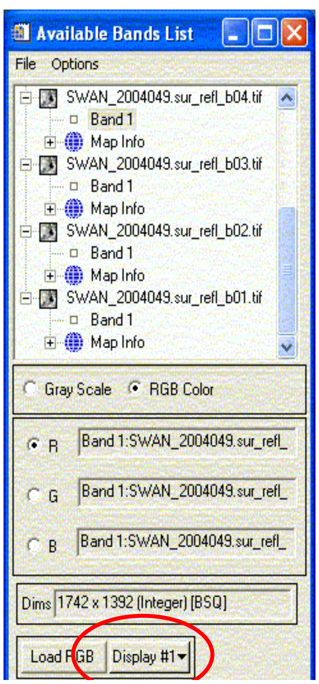


Figure 4. 11. Specify new display window for year 2.

After the two images are displayed, they may be linked by right mouse-clicking in either window and selecting "Link Displays…". Multiple displays may be linked in this way (assuming that they are georeferenced in the same manner). After they are linked, the zoom boxes may be moved with the mouse for any one window and they will move in an identical manner in the linked windows.

Reporting

Annual summary reports and synthesis reports that outline trends in landscape processes will describe the metrics shown in Table 4.5.

Vital sign	Metrics
Lake ice	For a given lake: • date of initial freeze-up • date of final freeze-up - continuous ice • date of initial break-up • end of break-up-- ice-free • duration of freeze-up season • duration of ice season • duration of break-up season • duration of ice-free season • range of freeze-up and break-up dates, seasonal durations across SWAN region

Table 4.5. Reporting summary for lake ice metrics.

Literature Cited

Jeffries, M.O., K. Morris and N. Kozlenko. 2005. Ice Characteristics and Processes, and Remote Sensing of Frozen Rivers and Lakes. *in* Duguay, C.R., and Pietroniero, A. eds., Remote Sensing in Northern Hydrology: Washington, DC, American Geophysical Union, AGU Monograph.

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SOP 5: Data Management-NPS

Satellite-Derived Measures of Landscape Processes
Southwest Alaska Network

Standard Operating Procedure (SOP) # 5

Data Management-NPS

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

Data Management Procedures

4-1. Directory Structure and File Naming

The images and interpreted derivatives will be stored under the following directory structure:

Drive name:\AREA\SENSOR_ProductType(or metric)_TimePeriod

i. Year

a. Files

Drive name will be the drive letter (e.g, D:\, J:\) plus any higher level directories (e.g., J:\SWAN\Remote_Sensing)

AREA will be the geographic area of interest, usually “SWAN”, but may also be “AllAlaska”, or other networks or areas of interest.

SENSOR will be “MODIS” or “ASTER”

ProductType will include

SNOW
SurfRef500
SurfRef250
VI
CalRad500
CalRad250
Phenology
SnowCover
LakeIce

TimePeriod will be the time period represented. Currently these include

daily
8day
16day

Year subdirectories will be the calendar year

File names will use the following convention:

a. Image file names :

AREA_YearJulianDay.ProductType_IdentifyingInformation.FileType

b. Input files and output files such as .txt or .prm files for automated processing are named by their scripts, or provided by USGS EROS. These will reside in the appropriate year directory.

- **AREA** will usually be "SWAN", but may also be "AllAlaska" or other networks or areas of interest.

- **YearJulianDay** will be four digit year followed by the three digit Julian day. Remember that for multiple day composites, the Julian day is the first day of the composite.

- **ProductType** will be sur_refl, cal_rad, VI, etc. Many of these files will be named during the mosaicking and reprojecting by the MRTs, as discussed in SOPs 2 and 5.

- **IdentifyingInformation** will vary depending on the stage of processing the file represents. The MRT will append the band number in this position. Other likely information may include enhancements, band stacks, stretches, density slices, smoothing, or a host of interpretation processing. There will often be multiple fields in the filename for this information.

- **FileType** will be the three letter suffix which identifies the file type. These often identify the program that generated the file, such as .doc for Word files, or .xls for excel spreadsheets. Many of the data files will be GeoTiff or Tiff (.tif) files generated by the MRT, ENVI and/or Photoshop during processing. Files downloaded from the LP DAAC will be .hdf or .aux.hdf. These are the raw MODIS files before they are processed by the MRT. Standard ENVI files will not have a suffix, but will be paired with a header (.hdr) file.

Although the SWAN Data Management Plan recommends that there be no periods (.) in filename, the raw datafiles and many of the products from the scripts have periods in the names. Use the underline (_) in file and directory names as specified above.

4-2. Metadata

Metadata will follow the FGDC (Federal Geographic Data Committee) format. One metadata record per product type (cf. 4-1) will be produced to meet the FGDC Content Standards for Digital Geospatial Metadata (CSDGM). The metadata records should cite this protocol in the “Larger Work Citation” An example of an acceptable metadata file is attached as Appendix 2.

A metadata file will be put in each product type directory (cf. 4-1), and will apply to all images in those directories. The only variable for subdirectories will be the date the data were originally acquired by the satellites. See the SWAN Data Management Plan, Sections 8.2 and 8.4, for SWAN standards for documentation of spatial data sets. Metadata for interpreted products will document the procedures used to analyze and interpret the images. Essential documentation such as algorithms, output files, or spatial analyses may reside in different systems and formats, and could potentially be overlooked when distributing or applying the data. Depending on the project, documentation may need to include details on data models or algorithms used, procedures for data synthesis, and associated input and output files. Data use and data request histories, and secondary research or publications resulting from long-term monitoring projects, may also need to be tracked (cf. SWAN Data Management Plan 2005, Section 8.6.2). As the protocols are developed, vital signs documentation will be tested and will evolve to combine metadata needs and ease of use.

4-3. Operational and Archiving File Management

Raw files will be downloaded from the LP and NSIDC DAACs and LAADS to a working computer (e.g., external drive, D:\). Reprojected, mosaicked files (.tif) will be transferred to the SWAN file server (J:\). It may not be practical to use the J:\SWAN server for operational processing because the NPS network is too slow to process large image files. Final MODIS products will be archived on the AKRO data file server (X:\). The directory and file structure should be set up on each involved computer to mirror the structure outlined in procedure 1 above. Filenames will follow the conventions outlined in procedure 4-1. These conventions will allow for easier transfer to the SWAN server.

Each of the data processing scenarios will require the creation of temporary files that will not be needed for long-term monitoring of the SWAN. To preserve disk space and to keep the organization of the system at a manageable level, these temporary files should be deleted as necessary. The suggested life-span of the temporary files will be: 1) raw data products (for both standard and non-standard processing) – 3 months, and 2) temporary data products (that result from data analysis procedures) – 1 month. The raw data products are easily identifiable as they have the *.hdf file extension. A regular examination of the file folders will be necessary to identify the files, and they may then be deleted if they exceed the life-span criteria. The temporary data products resulting from data analysis procedures will be identifiable only by the personnel who are conducting the exploratory data analysis. It is their responsibility to make the judgment concerning the files that are necessary to maintain.

Different standard products will have varying schedules for transfer to the AKRO data file server (X: drive) for archiving. Images for each product should be copied to the AKRO data file server after the raw products have been mosaicked and reprojected to the Albers Conical Equal Area (Alaska Albers) projection. Products from the Data Pool will be downloaded and pre-processed within several weeks of initial satellite acquisition and will be inserted into their appropriate directories at that time. Files recording annual or seasonal metrics such as vegetation, snow or ice phenology will be transferred to the AKRO data file server annually. Original raw data and interim processing products will not be archived by SWAN. The raw data are archived by the EOS Data Gateway, and if necessary, can be retrieved and processed with procedures in Appendix 3.

Non-standard products will be archived on the AKRO data file server in their appropriate product type directories. Daily and composited images of surface reflectance will be archived after mosaicking and reprojecting into Albers Conical Equal Area (Alaska Albers) projection. Key downstream products will also be archived, including accompanying metadata that documents the procedures used to analyze and interpret the images.

4-4. Backup Procedures

System backups are managed by the Alaska Regional Information Technology staff as described in the SWAN Data Management Plan, Section 11.5. Additional backups of working documents, etc. may be performed by SWAN staff as needed.

SOP 6: Changes to SOP

Satellite-Derived Measures of Landscape Processes
Southwest Alaska Network

Standard Operating Procedure (SOP) # 6

Changes to SOPs

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

This Standard Operating Procedure outlines the documentation of changes to the protocol narrative and accompanying SOPs. Anyone editing the protocol narrative or any one of the SOPs must follow these procedures, as indicated by Oakley et al. (2003).

Revision Procedures:

1. All edits will require review for clarity and technical soundness. Small changes or additions to existing methods will be reviewed by SWAN staff. However, if a complete change in methods becomes necessary, an outside review will be required. Regional and national NPS staff with expertise in remote sensing and data analysis, and/or external specialists, will be utilized as reviewers.

2. Edits to the protocol will be tracked in the Revision History Log that accompanies the protocol narrative and each SOP. Version numbers assigned to each edited draft should reflect the magnitude of changes therein: major changes will be designated by whole number increases (e.g., Version 1.0 to Version 2.0, etc.) and minor changes by tenths (e.g., Version 1.1 to Version 1.2, etc.). With each round of changes to the protocol narrative or SOPs, the following information should be recorded in the associated Revision History Log: the previous version number, new version number, date of revision, author of the revision, paragraph(s) and page(s) where changes appear, and the rationale for each change.

3. The Data Manager must be informed regarding changes to the protocol narrative or SOP so that the new version number can be incorporated in the metadata of the project database. The database may have to be edited by the Data Manager to accompany changes in the protocol narrative and SOPs.

4. The Data Manager will post new versions of the protocol on the internet and notify via e-mail individuals known to have a previous version.

5. MODIS data production experiences infrequent changes in the “collection” or version number, as production algorithms are modified. When these changes occur, the NASA philosophy is to re-process the entire data collection, dating back to February, 2000. However, when these reprocessing events occur, in some cases the reprocessed data are no longer comparable to the older (existing) version. When this occurs, SWAN personnel should consult with the producers of this protocol to determine a strategy for continuous updating of the databases that are a result of this protocol.

Appendix 1: Albers Projection Parameters and Spatial Subset for the SWAN

Alaska Albers Conical Equal Area:

Units:	Meters
Datum:	NAD83
Parameters:	
Central Meridian	-154.0
Latitude of Origin	50.0
1st Standard Parallel	55.0
2nd Standard Parallel	65.0

Spatial Subset for the SWAN:

Upper Left:	62.0 Latitude , -160.0 Longitude
Lower Right:	56.0 Latitude , -146.0 Longitude

Appendix 2: Example of Metadata for MODIS Calibrated Radiance Images

Identification_Information:
Citation:
Citation_Information:
Originator: NPS, Southwest Alaska Monitoring Network
Publication_Date: Unpublished Material
Title: MODIS Calibrated Radiance Images for Southwest Alaska
Geospatial_Data_Presentation_Form: remote-sensing image
Online_Linkage: \\IFW7NR-NPSTEMP\I$\\SWAN\MODIS_CalRad\
Larger_Work_Citation:
Citation_Information:
Originator: Reed B, Budde M, Spencer P, Miller A.
Publication_Date: December 15, 2006
Title: Satellite-Derived Measures of Landscape Processes Monitoring Protocol for the Southwest Alaska Network

Description:
Abstract:
MODIS Calibrated Radiance products for the Southwest Alaska Network (SWAN) are created from MOD02 MODIS data available through the LAADS (Level 1 and Atmosphere Archive and Distribution System) at NASA Goddard Space Flight Center. These images are used to monitor landscape-scale processes across the SWAN region. Swaths for the SWAN region are downloaded from the LAADS website (http://ladsweb.nascom.nasa.gov/), mosaicked and reprojected to Albers Conical Equal Area (Alaska Albers). Band numbers and corresponding wavelengths are:

Band	
1	620 - 670 μm
2	841 - 876

Purpose: These images were created to provide large spatial scale, fine temporal scale data for the SWAN vital signs monitoring program.
Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: February, 2000
Ending_Date: present
Currentness_Reference: ground condition
Status:
Progress: In work
Maintenance_and_Update_Frequency: Continually
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -160
East_Bounding_Coordinate: -146
North_Bounding_Coordinate: 62
South_Bounding_Coordinate: 56

Keywords:
Theme:
Theme_Keyword_Thesaurus: none
Theme_Keyword: Inventory and Monitoring Program
Theme_Keyword: MODIS images
Theme_Keyword: Calibrated Radiance
Theme_Keyword: Landscape Processes
Theme_Keyword: monitoring

Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: Imagery
Place:
Place_Keyword_Thesaurus: National Park System Unit Name Thesaurus
Place_Keyword: Alagnak Wild River
Place_Keyword: Aniakchak National Monument and Preserve
Place_Keyword: Katmai National Park and Preserve
Place_Keyword: Kenai Fjords National Park
Place_Keyword: Lake Clark National Park and Preserve
Place_Keyword: Southwest Alaska Network
Place:
Place_Keyword_Thesaurus: National Park System Unit Code Thesaurus
Place_Keyword: ALAG
Place_Keyword: ANIA
Place_Keyword: KATM
Place_Keyword: KEFJ
Place_Keyword: LACL
Place_Keyword: SWAN
Place:
Place_Keyword_Thesaurus: none
Place_Keyword: Katmai
Place_Keyword: Lake Clark
Place_Keyword: Kenai Fjords
Place_Keyword: Aniakchak
Place_Keyword: Southwest Alaska
Place_Keyword: Kenai Peninsula
Place_Keyword: Kodiak
Place_Keyword: Alaska Peninsula
Place_Keyword: Cook Inlet
Place_Keyword: Naknek Lake
Place_Keyword: Tustemena
Place_Keyword: Skilac
Place_Keyword: Beluga
Place_Keyword: Chakachamna
Place_Keyword: Twin Lakes
Place_Keyword: Susitna Valley
Place_Keyword: Bristol Bay
Place_Keyword: Kvichak Bay
Place_Keyword: Kujulik Bay
Place_Keyword: Shelikof Strait
Place_Keyword: Becharof
Place_Keyword: Southcentral Alaska
Place_Keyword: Lake and Peninsula Borough
Place_Keyword: Kodiak Island Borough
Place_Keyword: Kenai Peninsula Borough
Place_Keyword: Becharof National Wildlife Refuge
Place_Keyword: Kodiak National Wildlife Refuge
Place_Keyword: Alaska Peninsula National Wildlife Refuge
Place_Keyword: Prince William Sound
Place_Keyword: Anchorage
Place_Keyword: Port Alsworth
Place_Keyword: Kenai
Place_Keyword: Homer
Place_Keyword: Seward
Place_Keyword: King Salmon
Place_Keyword: Port Heiden

Place_Keyword: Port Moller
Place_Keyword: Chignik
Place_Keyword: Dillingham
Place_Keyword: Karluk
Place_Keyword: Naknek
Place_Keyword: Egegik
Place_Keyword: Ugashik
Place_Keyword: Pilot Point
Place_Keyword: Iliamna

Access_Constraints: none
Use_Constraints: none
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Page Spencer
Contact_Organization: NPS, Alaska Regional Office
Contact_Position: Ecologist
Contact_Voice_Telephone: 907-644-3448
Contact_Electronic_Mail_Address: Page_spencer@nps.gov
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.0.0.535
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: Spectral accuracy within limits of MOD02 processing
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report: within 300 m Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: NA

Lineage:
Process_Step:
Process_Description: Complete processing of these images is documented in the Protocol for Satellite-Derived Measures of Landscape Processes. Calibrated Radiance images are the MOD02 MODIS data generated by NASA Goddard . The images in the SWAN archive are derived from V005 processing, initiated by NASA Goddard in fall 2006. All MODIS acquisitions are being reprocessed as V005. MOD02 granules over SWAN are acquired from theLAADS, mosaicked and reprojected using the MODIS Swath Reprojection Tool.
Process_Date: varies, updated continuously
Cloud_Cover: varies

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Raster
Raster_Object_Information:
Raster_Object_Type: Pixel
Row_Count: 2783
Column_Count: 3483
Vertical_Count: 1
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area (Alaska Albers)
Albers_Conical_Equal_Area:
Standard_Parallel: 55.000000
Standard_Parallel: 65.000000
Longitude_of_Central_Meridian: -154.000000

Latitude_of_Projection_Origin: 50.000000
False_Easting: 0.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: row and column
Coordinate_Representation:
Abscissa_Resolution: 250.000000
Ordinate_Resolution: 250.000000
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: NPS Southwest Alaska Monitoring Network
Contact_Position: SWAN Data Manager
Contact_Address:
Address: 240 W 5th Ave
City: Anchorage
State_or_Province: AK
Postal_Code: 99501
Country: USA
Contact_Voice_Telephone: 907-644-3684

Resource_Description: SWAN Server:\SWAN\MODIS_CalRad\
Distribution_Liability:
The National Park Service shall not be held liable for improper or incorrect use of the data described and/or contained herein. These data and related graphics (i.e. "GIF or JPG" format files) are not legal documents and are not intended to be used as such. The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data, as outlined in particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data. The National Park Service gives no warranty, expressed or implied, as to the accuracy, reliability, or completeness of these data. It is strongly recommended that these data are directly acquired from an NPS server and not indirectly through other sources which may have changed the data in some way. Although these data have been processed successfully on computer systems at the National Park Service, no warranty expressed or implied is made regarding the utility of the data on other systems for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data.

Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: TIFF
Transfer_Size: 18.510
Fees: none
Metadata_Reference_Information:
Metadata_Date: 20051205
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:

Contact_Person: Page Spencer
Contact_Organization: NPS, Alaska Regional Office
Contact_Address:
Address_Type: 240 West 5th Avenue
City: Anchorage
State_or_Province: Alaska
Postal_Code: 99501
Contact_Voice_Telephone: 907-644-3448
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Extensions:
Online_Linkage: http://www.esri.com/metadata/esriprof80.html
Profile_Name: ESRI Metadata Profile

Appendix 3: Grid data for Surface Reflectance Processing

Revision History Log:

Previous Version #	*Revision Date*	*Author*	*Changes Made*	*Reason for Change*	*New Version #*

This Appendix explains the procedures for browsing, acquiring and processing MODIS surface reflectance images that are not included in the procedures outlined in SOPs 2-4. Surface reflectance (MOD09) products are processed to remove the effects of the atmosphere so that multiple dates of images can be directly compared with each other. An aerosol correction is applied to remove variations due to water vapor, particulates and smoke. MOD09 data are projected into geographic tiles which can be mosaicked into the area of interest.

A3.1. Data Browse

There are several browse facilities for MODIS data. The easiest one to use is the Rapidfire site maintained by NASA Goddard: http://rapidfire.sci.gsfc.nasa.gov/production/.

Browse the thumbnails and select desired dates and locations as described in SOP 4.1.

A3.2. Data Order

Order through the EOS Data Gateway (http://LPDAAC.usgs.gov/main.asp)

a. On the left side of the window: Data Access box, select EOS Data Gateway
b. At the screen for the "Earth Observing System Data Gateway:, register yourself as a User. This will (usually) make ordering faster since they will have a record of your address and other such data.) After the first time, enter as a registered user.
c. On the left side of the "Primary Data Search" window: Search and Order box, select Search Creation
d. You will have the "Choose Keywords for One or More Categories" screen. You will use this to choose the desired data products and the spatial tiles that cover the SWAN region.

Choose Data Sets

a. Select "By Categories/Attributes" button
b. Highlight "Data Set" and press the "Choose Keywords for>>" button
c. The screen for "Keyword Selection: Data Set" appears. In the window for "Data Set list 3:" highlight the desired data sets. This window allows you to select both Aqua and Terra data sets. Select the V004 data sets when available. You can select surface reflectance daily or multiple-day composites, snow products and Vegetation Indices
d. MOD09 products are listed as:

MODIS/Aqua (or Terra) Surface Reflectance Daily L2G Global 250m SIN GRID V004

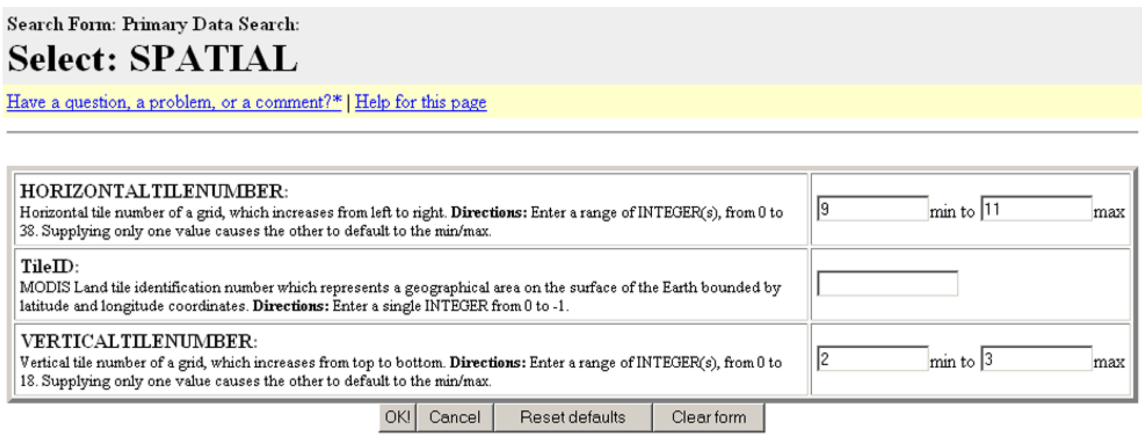
e. After selecting desired data sets, click OK! This returns you to the "Choose Keywords for One or More Categories. Your selected data sets should be displayed in the Data Set window.

Choose Spatial Area by tile

1. Return to choose keywords window and select "spatial", which is at the bottom of the list. Click on "Choose Keywords for>>"
2. A new screen appears asking for tile numbers:

   SWAN tile numbers are: Horizontal 9, 10 and 11 and
   Vertical 2 and 3

   Fill these in and press OK (Fig A3.1).



Search Form: Primary Data Search:

Select: SPATIAL

Have a question, a problem, or a comment?* | Help for this page

HORIZONTALTILENUMBER: Horizontal tile number of a grid, which increases from left to right. **Directions:** Enter a range of INTEGER(s), from 0 to 38. Supplying only one value causes the other to default to the min/max.	9 min to 11 max
TileID: MODIS Land tile identification number which represents a geographical area on the surface of the Earth bounded by latitude and longitude coordinates. **Directions:** Enter a single INTEGER from 0 to -1.	
VERTICALTILENUMBER: Vertical tile number of a grid, which increases from top to bottom. **Directions:** Enter a range of INTEGER(s), from 0 to 18. Supplying only one value causes the other to default to the min/max.	2 min to 3 max

OK! | Cancel | Reset defaults | Clear form

Figure A3.1. Selecting spatial search area by tile.

Choose A Data Search Type: select "Primary Data Search"

At this point the upper part of your search window should look similar to Fig. A3.2:

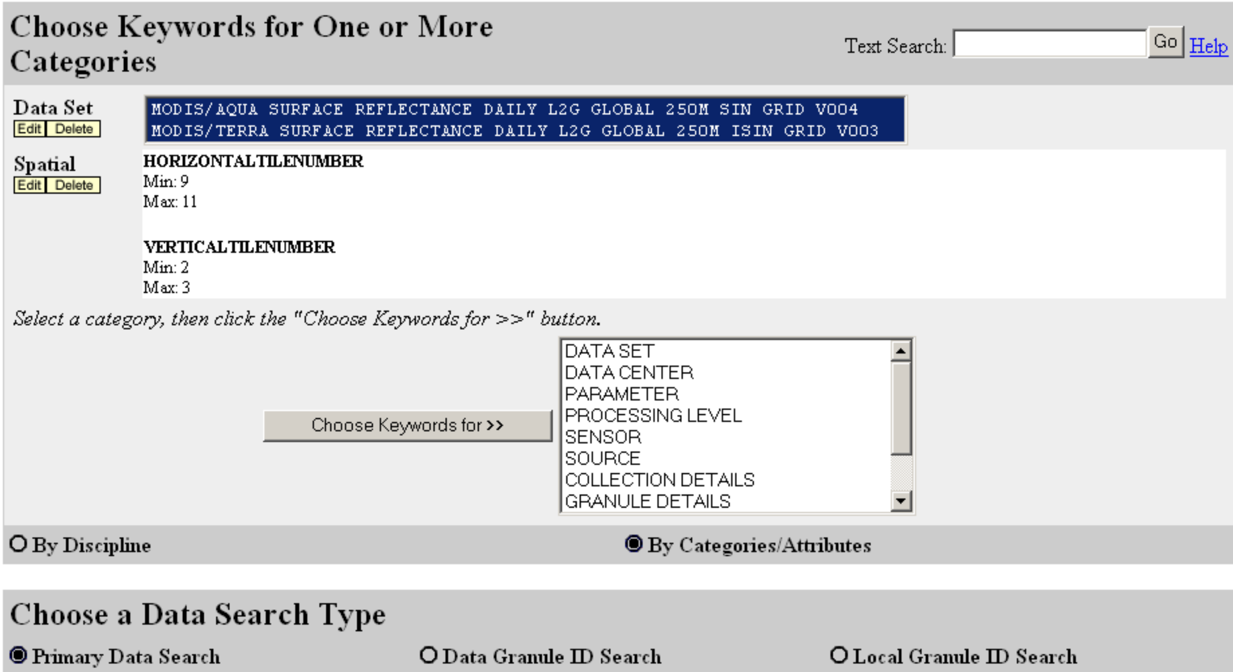


Figure A3.2. Primary data search window.

Choose Date/Time Range

Enter desired date(s) by standard date nomenclature or Julian date ranges. Remember if you are searching for multi-date composites that the date you will enter is the first date in the time series (Fig A3.3.).

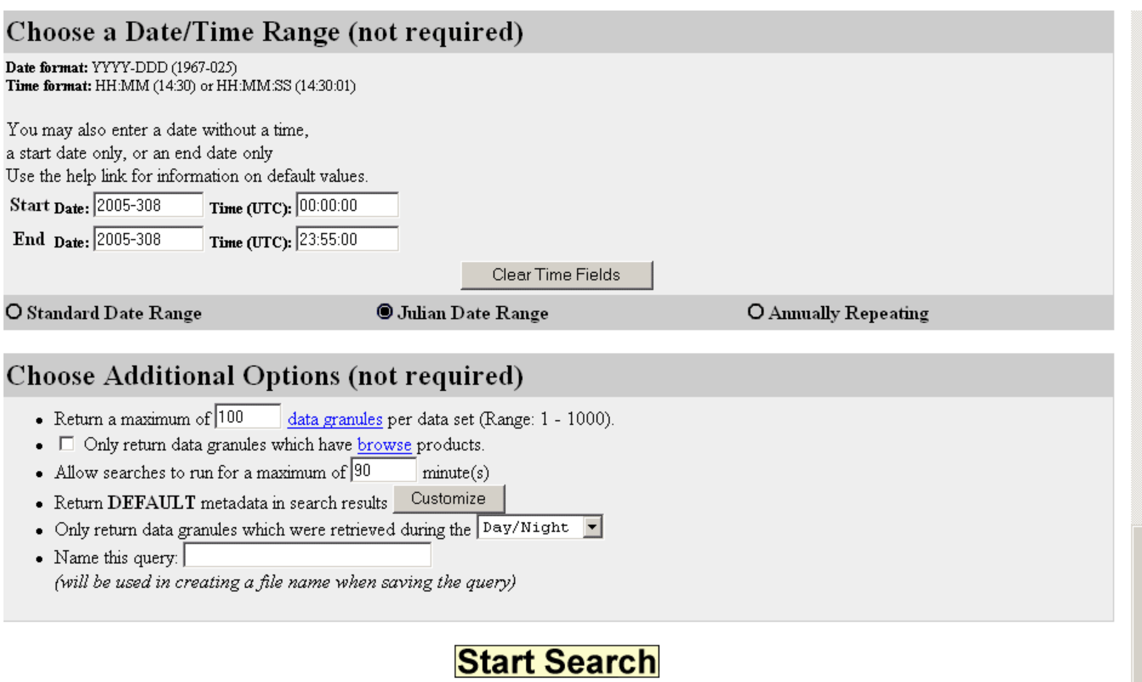
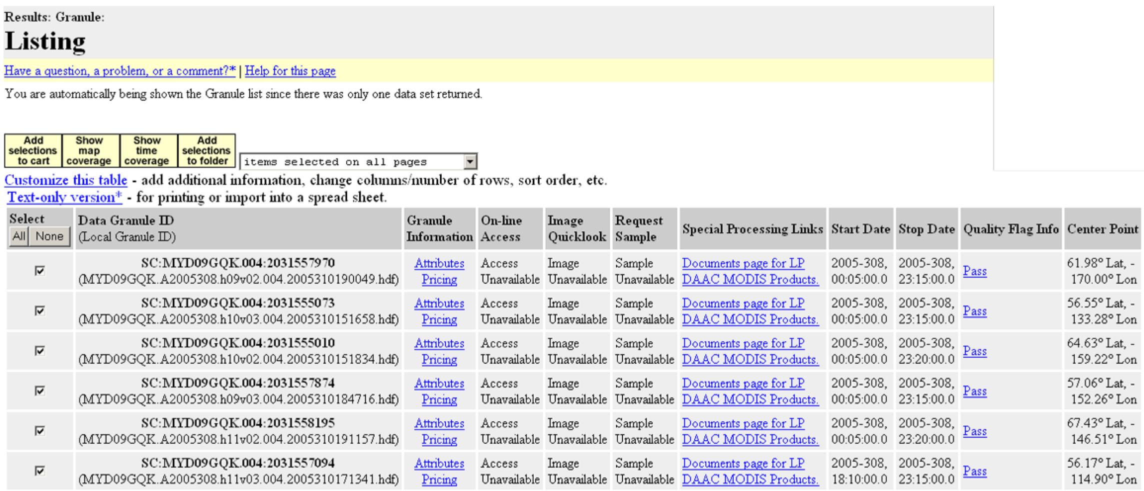


Figure A3.3. Selecting Date/Time range for data search.

3. Press “Start Search”
4. The “Search in progress” screen appears to track the search progress. When completed, a “Listing” screen appears with each file displayed. Click a check mark in the selection box of each file you want. In the example below, a search was done for the 250 meter surface reflectance data (MOD09GQK) for SWAN tiles for Julian day 308, 2005. I have selected the six SWAN tiles for day 308 (November 4, 2005). After selection is finished, press “Add selections to cart” (Fig A3.4).


Results: Granule:

Listing

Have a question, a problem, or a comment?* | Help for this page

You are automatically being shown the Granule list since there was only one data set returned.

Add selections to cart | Show map coverage | Show time coverage | Add selections to folder | items selected on all pages

Customize this table - add additional information, change columns/number of rows, sort order, etc.

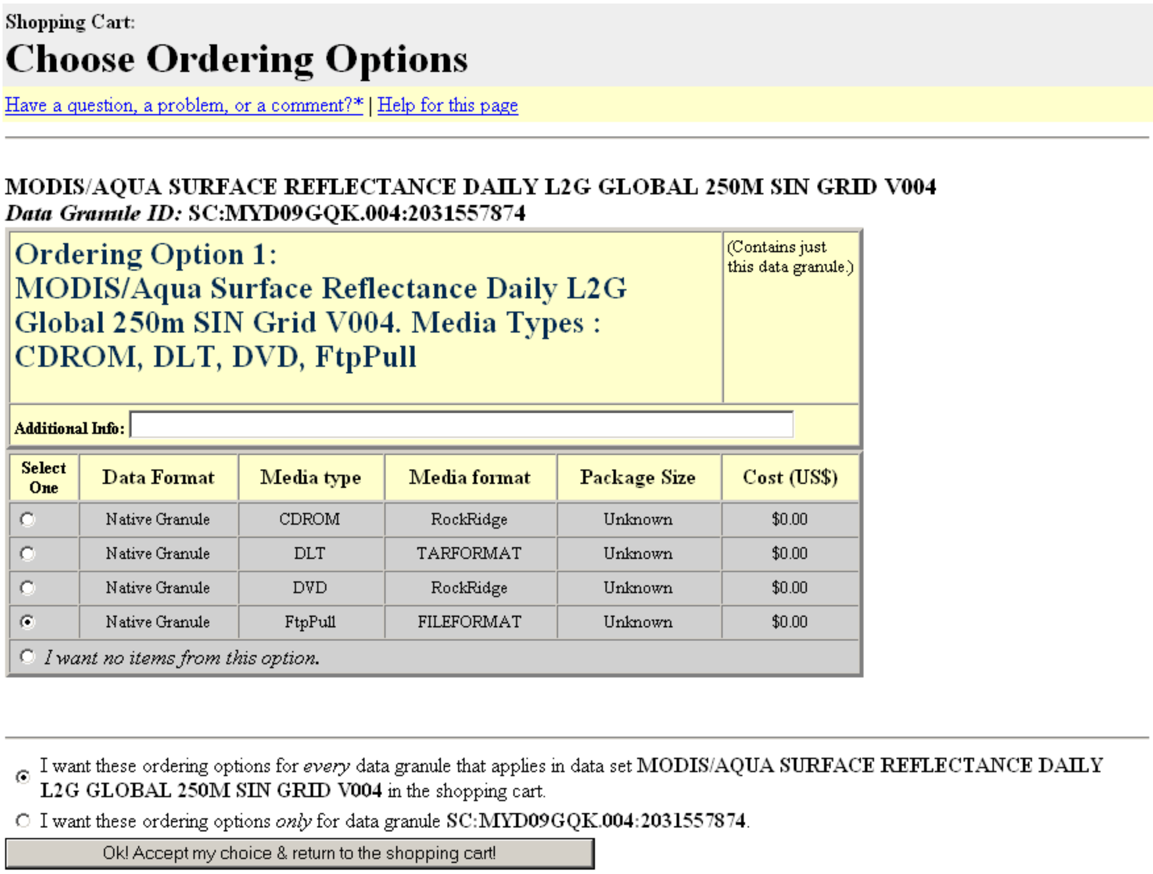
Text-only version* - for printing or import into a spread sheet.

Select (All / None)	Data Granule ID (Local Granule ID)	Granule Information	On-line Access	Image Quicklook	Request Sample	Special Processing Links	Start Date	Stop Date	Quality Flag Info	Center Point
☑	SC:MYD09GQK.004:2031557970 (MYD09GQK.A2005308.h09v02.004.2005310190049.hdf)	Attributes Pricing	Access Unavailable	Image Unavailable	Sample Unavailable	Documents page for LP DAAC MODIS Products.	2005-308, 00:05:00.0	2005-308, 23:15:00.0	Pass	61.98° Lat, -170.00° Lon
☑	SC:MYD09GQK.004:2031555073 (MYD09GQK.A2005308.h10v03.004.2005310151658.hdf)	Attributes Pricing	Access Unavailable	Image Unavailable	Sample Unavailable	Documents page for LP DAAC MODIS Products.	2005-308, 00:05:00.0	2005-308, 23:15:00.0	Pass	56.55° Lat, -133.28° Lon
☑	SC:MYD09GQK.004:2031555010 (MYD09GQK.A2005308.h10v02.004.2005310151834.hdf)	Attributes Pricing	Access Unavailable	Image Unavailable	Sample Unavailable	Documents page for LP DAAC MODIS Products.	2005-308, 00:05:00.0	2005-308, 23:20:00.0	Pass	64.63° Lat, -159.22° Lon
☑	SC:MYD09GQK.004:2031557874 (MYD09GQK.A2005308.h09v03.004.2005310184716.hdf)	Attributes Pricing	Access Unavailable	Image Unavailable	Sample Unavailable	Documents page for LP DAAC MODIS Products.	2005-308, 00:05:00.0	2005-308, 23:15:00.0	Pass	57.06° Lat, -152.26° Lon
☑	SC:MYD09GQK.004:2031558195 (MYD09GQK.A2005308.h11v02.004.2005310191157.hdf)	Attributes Pricing	Access Unavailable	Image Unavailable	Sample Unavailable	Documents page for LP DAAC MODIS Products.	2005-308, 00:05:00.0	2005-308, 23:20:00.0	Pass	67.43° Lat, -146.51° Lon
☑	SC:MYD09GQK.004:2031557094 (MYD09GQK.A2005308.h11v03.004.2005310171341.hdf)	Attributes Pricing	Access Unavailable	Image Unavailable	Sample Unavailable	Documents page for LP DAAC MODIS Products.	2005-308, 18:10:00.0	2005-308, 23:15:00.0	Pass	56.17° Lat, -114.90° Lon

Figure A3.4. Selecting tiles and adding to cart.

5. The “Data Quality Summary” page appears. Run to bottom of screen and click the “Accept-Continue to Shopping Cart” button.
6. The shopping cart contents are displayed on the screen labeled “Step 1: Choose Ordering Options”

   Click the yellow box in front of the top file box that says “ordering options”. The “Choose Ordering Options” screen appears. Select the button near the bottom, which reads “FtpPull” in the Media type column. Be sure the top button for “I want these ordering options for every data granule….” is marked. Click “OK! Accept my choice and return to shopping cart!” (Fig A3.5).


Shopping Cart:

Choose Ordering Options

Have a question, a problem, or a comment?* | Help for this page

MODIS/AQUA SURFACE REFLECTANCE DAILY L2G GLOBAL 250M SIN GRID V004
Data Granule ID: SC:MYD09GQK.004:2031557874

Ordering Option 1:
MODIS/Aqua Surface Reflectance Daily L2G Global 250m SIN Grid V004. Media Types : CDROM, DLT, DVD, FtpPull

(Contains just this data granule.)

Additional Info:

Select One	Data Format	Media type	Media format	Package Size	Cost (US$)
○	Native Granule	CDROM	RockRidge	Unknown	$0.00
○	Native Granule	DLT	TARFORMAT	Unknown	$0.00
○	Native Granule	DVD	RockRidge	Unknown	$0.00
◉	Native Granule	FtpPull	FILEFORMAT	Unknown	$0.00
○	*I want no items from this option.*				

◉ I want these ordering options for *every* data granule that applies in data set MODIS/AQUA SURFACE REFLECTANCE DAILY L2G GLOBAL 250M SIN GRID V004 in the shopping cart.

○ I want these ordering options *only* for data granule SC:MYD09GQK.004:2031557874.

Ok! Accept my choice & return to the shopping cart!

Figure A3.5. Choosing ordering options.

7. This returns you to the Step 1 screen. Each file should have an order option of FtpPull in the left column. Press "Go to Step 2: Order Form"

If you are a registered user, the Step 2: Order Form screen should be filled out for you. If you are working as "Guest", you will have to fill out the form. When finished, press "Submit Order Now!"

8. The "Order in Progress" screen appears, followed by the "Order Submitted" screen. If all goes well, you should get an email soon from edc that verifies your order. A second email will be sent within minutes to hours, depending on the size of your order and the workload at the EOS gateway. Save the second email (from CM SHARED (CM Code Delivery) because it has the instructions for the data download.

A3.3. Data Download

d. You will need ftp software to get your data from the LP DAAC. Either use the regular FTP command that comes with Windows, or download one you prefer. . DO NOT USE WINDOWS COPY and PASTE commands—it takes a long time and the connection will often time out.

e. When the email comes from CM SHARED, look near the bottom of the second page below the line of +++++s. You need the FTPHOST and the FTPDIR lines:

```
++++++++++

ORDERID: 0300371885
REQUESTID: 0300557018
USERSTRING:
FINISHED: 11/22/2005 19:24:09

MEDIATYPE: FtpPull
MEDIAFORMAT: FILEFORMAT
FTPHOST: e0dps01u.ecs.nasa.gov
FTPDIR: /PullDir/0300557018nwGIFA
```

f. Open a DOS Command window: Start→All Programs→Accessories→Command Prompt

   Change (cd) to the directory on your computer where you want to save your files

   Example: > cd {*name of directory}*

   Note: For help using DOS, type "help" at the > prompt, and a list of commands will appear. The command cd .. will take you up up a level in the directory tree structure, and that cd pathname will take you down or across the directory tree structure.

   ncftp to the FTPHOST site:

   Example: ncftp e0dps01u.ecs.nasa.gov

   cd to the FTPDIR

   Example: cd /PullDir/0300557018nwGIFA

   Dir to list files. There should be two files for every tile you ordered: a *.hdf file and a *.hdf.xml file.

   get all the files:

   Example: mget *.*

g. The files will start downloading. The ETA: counter shows approximate time remaining for that file. This process can take a long time. If a connection is fast, you may get them within an hour.. This is a good thing to do at the end of the day. DO NOT CLOSE the DOS WINDOW! If all goes well and the connection doesn't break, you should have your files by the next day (Fig A3.6).

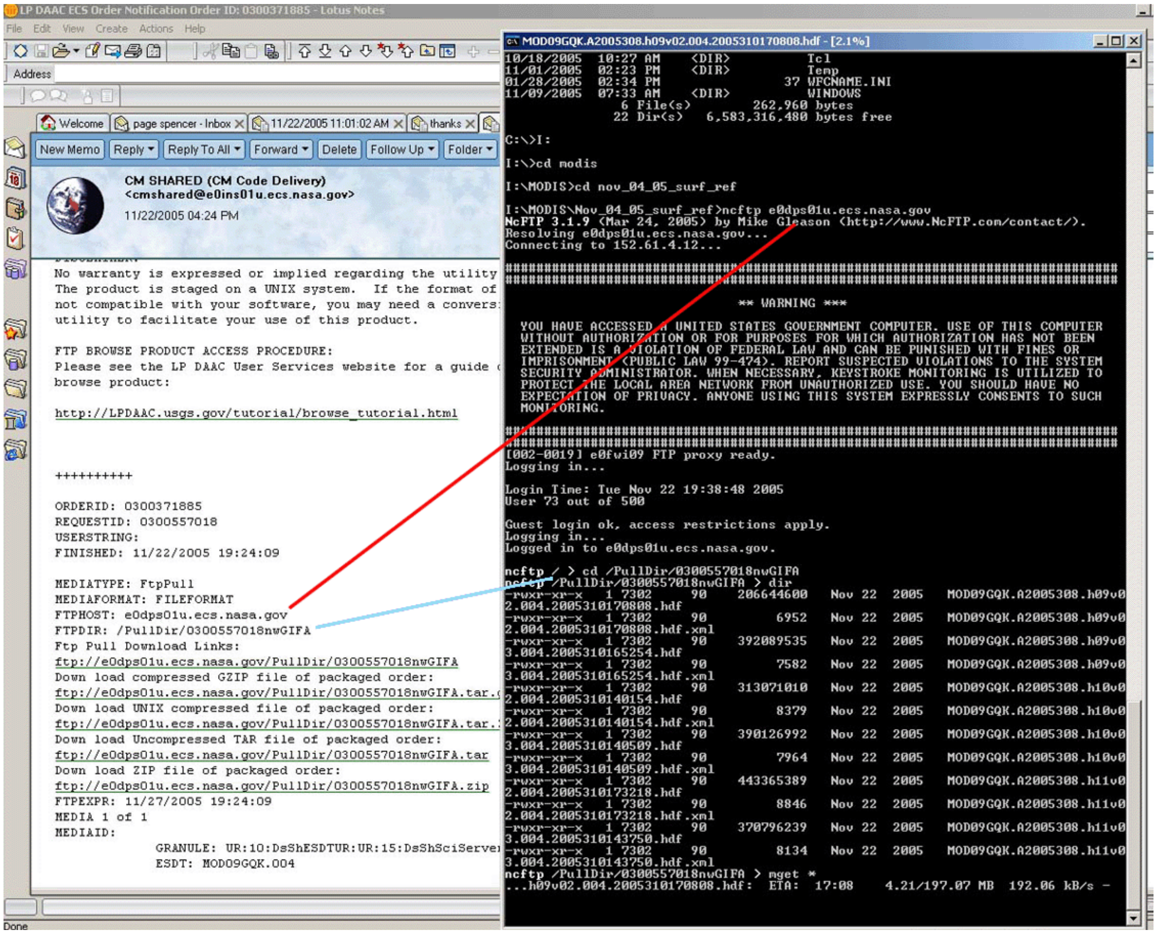


Figure A3.6. FTP Download of LPDAAC data.

A3.4. Data Processing

A3.4.1. Mosaic and Reproject the tiles into a geometrically corrected image of the SWAN Region.

You will need the MODIS Reprojection tool (MRT) for this step. Download the MRT from the EROS LP DAAC page: http://LP DAAC.usgs.gov/main.asp and install it on your machine using the handy "User's Manual". See SOP # 1 for further details about installing the software. NOTE—don't use any spaces in your paths or filenames or this software will not work.

Run the MRT using the shortcut you created during installation. A black window labeled ModisTool.bat comes up, quickly followed by the ModisTool GUI. Fill out the GUI screen as follows:

1) **Open Input File** -- browse to the directory where you saved the downloaded tile files (hdf files). Select the desired tiles.
2) The **Input File Info** box is populated by the MRT. All the bands in your hdf tile files are displayed in the "Selected Bands" box on the right. Put the files you DON'T want over in the "Available Bands" box on the left by selecting them and pressing the << button. You should keep the bands labeled xxx_b01_, xxx_b02_, up to xxx_b07_.

These bands are the spectral data, and the b# corresponds to the band number of the MODIS sensor. See http://LPDAAC.usgs.gov/modis/table2.asp or Table 1 in the Protocol Narrative for a listing of band numbers and their corresponding wavelength ranges.

3) **Spatial Subset**: Input lat/long
   UL corner is 62 latitude, -160 longitude
   LR corner is 56 latitude, -146 longitude
4) These are the boundaries of the SWAN region.
5) **Specify Output File**: browse to directory where you are putting projected files and specify file name. Be sure to add the .tif to the filename. The MRT will add the band number and product type to whatever you specify as a root file name.
6) **Output file type** is GEOTIFF
7) **Resampling Type** is Nearest Neighbor
8) **Output Projection Type** is Albers Equal Area
9) **Edit Projection Parameters**:

SMajor : 0.0	**SMinor** : 0.0	**STDPR1** : 55.0
STDPR2 : 65.0	**CentMer** : -154.0	**OriginLat** : 50.0
FE : 0.0	**FN** : 0 .0	**Datum** : NAD83

10) **Output pixel size** is whatever you ordered (250m, 500m or 1000m)

Press Run button. A Status window appears and tracks the processing for each band. Mosaicking is done first, followed by reprojecting. The MRT writes the final files to the directory and name specified in the Output File window. You will have a geotif image for each spectral band you specified in the Selected bands window (Fig A3.7).

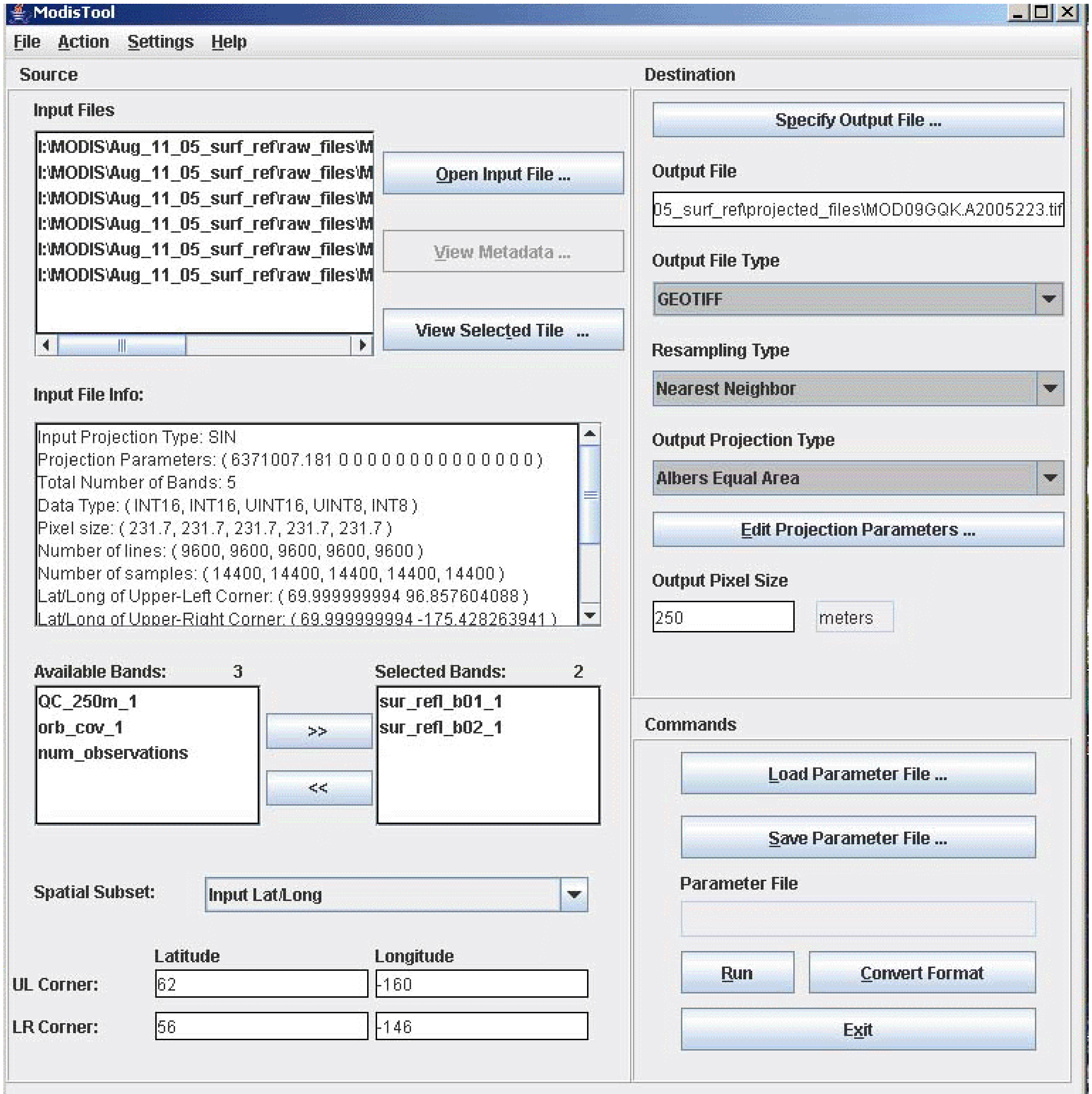


Figure A3.7. MRT Graphical User Interface for data processing.

A3.5. Composite single band images into multi-band image and enhance for manual interpretation.

This step uses ENVI software to stack the images into a single file. You can use ENVI for further enhancing, or export a tif file for enhancing with a package such as Photoshop. Using ENVI retains the geographic location capability, so the image can be used in various GIS or further image analysis functions. Using Photoshop creates a color image where the red/green/blue channels are no longer spectral data, but simply color values of a picture. Use Photoshop to pretty up a picture for simple interpretation, posters or publications where the actual spectral data values are no longer needed.

Open ENVI

1. (in the Main ENVI menu) File→open image file. Select desired bands from geometrically corrected list. Display as natural color or false color infra-red composite. Natural color can be done using the 500m or 1000 m data with seven bands. CIR can be created using the two bands in 250m data, or the seven band data. Specify appropriate bands from the available bands list and load RGB.

Natural color		
	Red gun	band 1
	Green gun	band 4
	Blue gun	band 3
Color Infra red		
	Red gun	band 2
	Green gun	band 1
	Blue gun	band 4 (or repeat band 1 with 250m data)

2. (in the Main ENVI menu) File→Save file as→ENVI standard The ENVI standard file will be a flat binary file with an associated header file (*.hdr). Stack as many bands in the file as you will want to work with. If working with the 250m data, which has only two bands, you can duplicate band one to give an easily displayed CIR image. Your resultant file will be a multi-band image of the SWAN Region. You can use this to proceed with ENVI processing, including various stretches and other enhancements.

3. (In the Display Image Menu) Enhance Using the scroll window as the target, the preprogrammed stretches for Linear 2% and the Square Root make a quick and often useful enhancement. Another useful enhancement is in the Main ENVI Menu: Transform→Photographic Stretch. This stretch has cleaned up images with several "foggy" bands and results in a clean appearing image.

For finer tuning of specific features, use the interactive stretching at the bottom of the menu. In the histogram window menu:
Stretch_Type→Piecewise Linear
Add nodes to the white stretch line in the histogram with the middle mouse button
Options→Edit Piecewise Linear
Enter new (output) values for each node in the right column (LUT Val)

4. If you want a picture to work with in Photoshop or other graphics packages, Powerpoint or documents, you need to export the file in a format those packages can utilize.

Right mouse click in the display window. In the resultant window, select "Save image as". Under "Output File Type, select desired format (tif, bmp, jpg). You can open the resultant picture in Photoshop and use the Image Adjustments functions to enhance the color balance, brightness and contrast. Photoshop is also a good place to add non-geographic graphics and some text and create quality output products.

A3.6. Creating an image of the entire state of Alaska

1. Data Order. When specifying the spatial tiles for a data search and order, collect all of the following tiles. You may need to conduct this part of the search more than once and add them to your order incrementally.

h06v03	h11v02
h07v03	h11v03
h08v03	h12v01
h09v02	h12v02
h09v03	h12v03
h10v02	h13v01
h10v03	h13v02
h28v03	h29v03

2. Data reprojection and tile mosaicking: When mosaicking and reprojecting the tiles, you will need to do it in three pieces and mosaic them together in ENVI or display them together in ArcMap.

H06 through h13 all projected into one piece east of the -180 longitude (date line).
H28v03 in a separate piece west of 180 longitude
H29v03 in another separate piece west of 180 longitude

When you process the big set of tiles east of the dateline (H06-H13) in the MODIS MRT, do NOT specify a spatial subset. Let it default to the full extent of the tiles. Use the usual parameters for editing the projection parameters. This should result in a large file for mainland Alaska plus the eastern Aleutians, and two smaller files for the western Aleutians for every band you process.

3. Mosaicking of three subimages.

In ENVI—at main menu
Basic Tools→Mosaicking→Georeferenced→Import→Import files and edit properties
Select or browse to your mainland image. After it displays in the little image window, select another smaller file. Then the last one. They should each display in the mosaicking window. Be sure to keep the same spectral stretch for all three files. Use the appropriate value for background pixels to set to transparent so you don't have black patches in your mosaic.
Then go to File→apply in the mosaicking window. Specify an output image name.
Proceed to display and stretch and marvel at the image as you have been doing with SWAN images.

If you don't need to have the image all in one big file, you can go into ArcMap and load all three files. They will be displayed in the correct relative position, but they are still three separate pieces. However, you can overlay vectors on them and create useful maps.