Thermal Response of Western Alaska Lakes and Lagoons to Past, Present and Future Changes in Climate and an Emerging Alaska Lake and Lagoon Temperature Network (ALLTNET)

Support provided by the Western Alaska Landscape Conservation Cooperative

In collaboration with:

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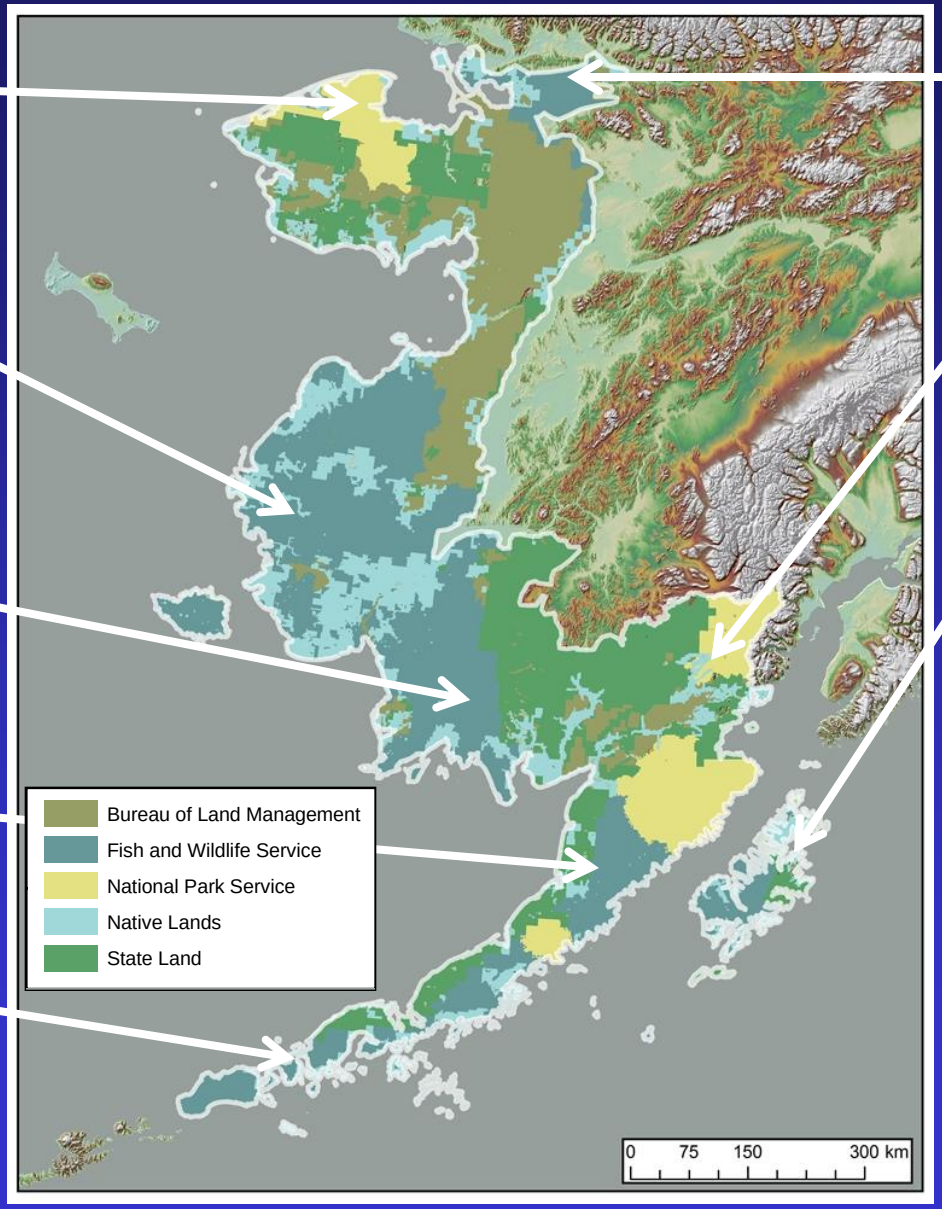

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Other Partners:
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Importance of Monitoring Water Temperature

1. Important Indicators of Climate Change: Water temperature variations represent an integrated response to climate change (e.g., due to solar radiation, air temperature, wind, etc.)

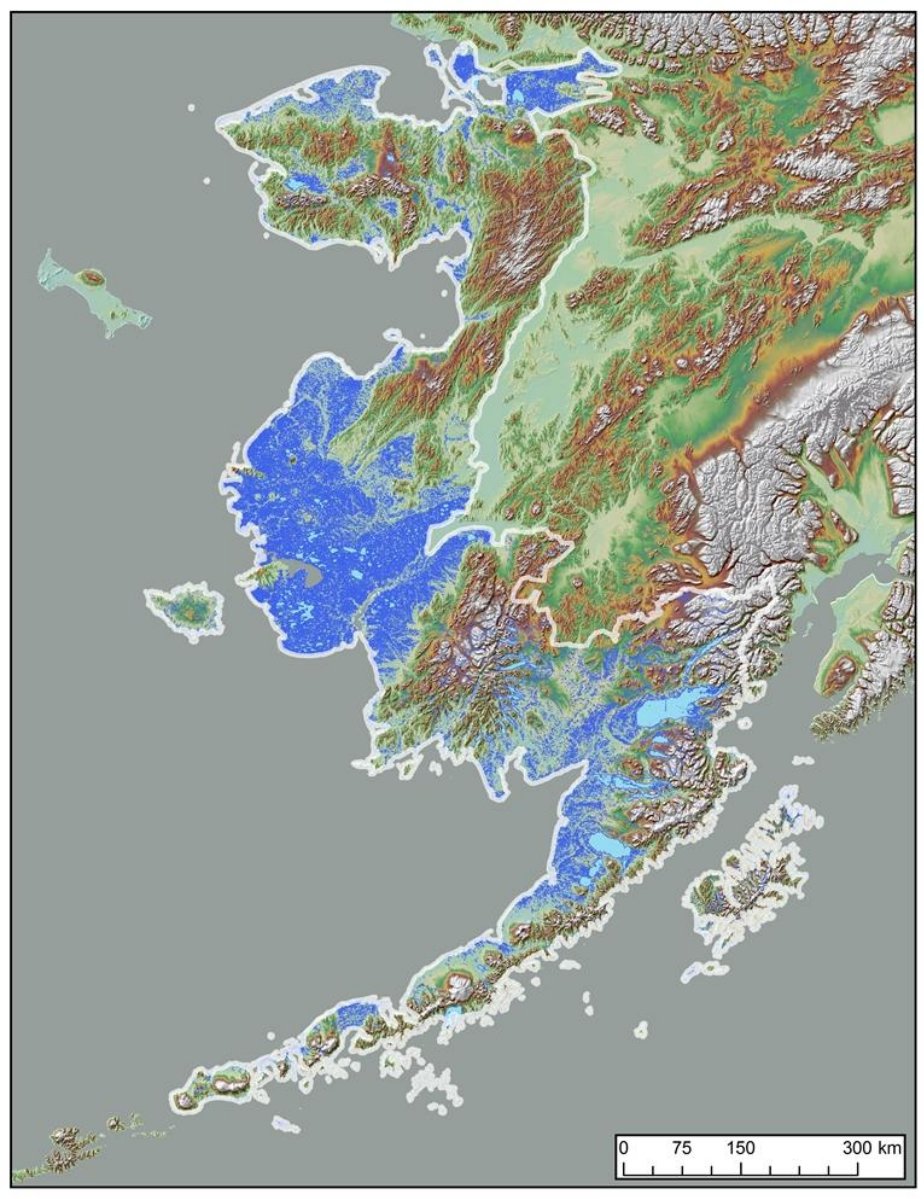
2. Driver of Ecological Processes: Nearly all important ecosystem processes are mediated by temperature including lake productivity (algal blooms, macrophyte growth, etc), decomposition, evaporation and other gas emissions, and biogeochemical reactions

3. Control of Habitat Suitability and Biological Optimums: Nearly all organisms have optimum temperature ranges for survival, growth, and reproductive success such that shifts in temperature or temperature variability can cause changes in species abundance and community composition.

4. Impact on Permafrost : For lakes set in permafrost, thermal regimes control talik development and shoreline erosion

Why Study Lakes in Western Alaska?

- 8% of the surface area of western Alaska is lake
- 48% of the lakes in Alaska are found in the study region
- 53% of the lake area in Alaska found in study region
- 7 of the 10 largest lakes in Alaska are found in study region
- Region was heavily glaciated during the Pleistocene (50%)
- Region is underlain by varying forms of permafrost (77%)



Primary Goals and Objectives

1. Remote Sensing: Reconstruct summertime lake and lagoon surface temperature trends for water bodies larger than 50 km^2 back to 1985, and larger than 10 km^2 back to 2001 with remotely sensed imagery

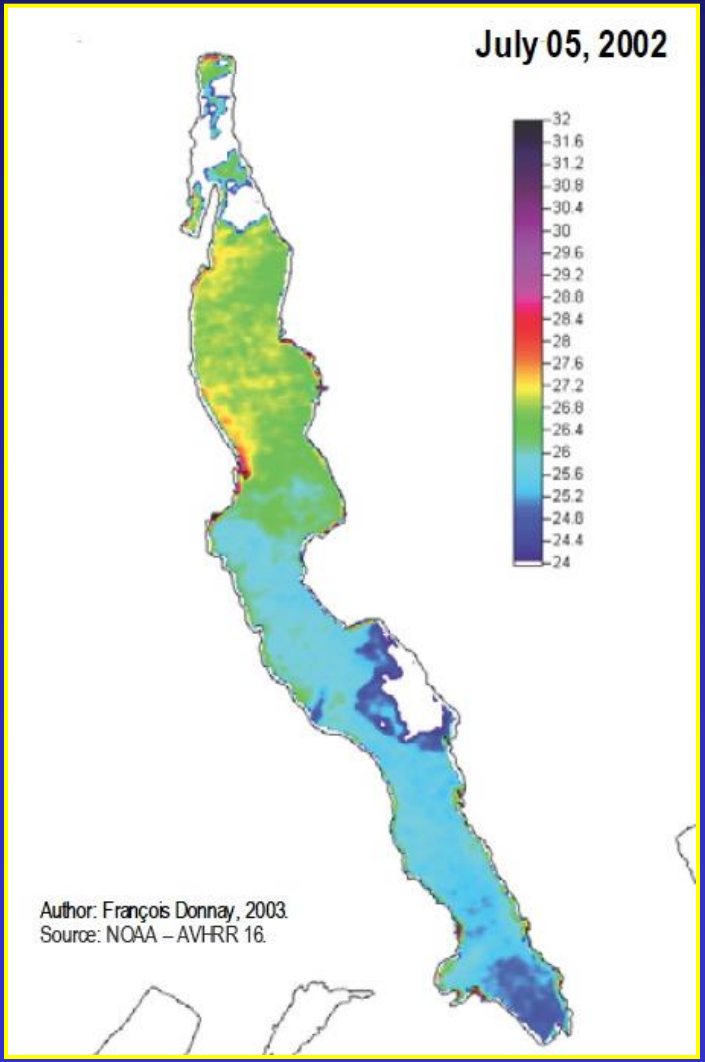
2. Field Data Collection: Deploy lake temperature thermistors in 40 water bodies during the summer of 2012

3. Modeling and Forecasting: Develop a predictive model using relations between *in situ* data, remotely sensed data, and nearby meteorological data to forecast lake and lagoon surface temperature trends out to 2025, 2050, and 2100 based on a series of GCM scenarios

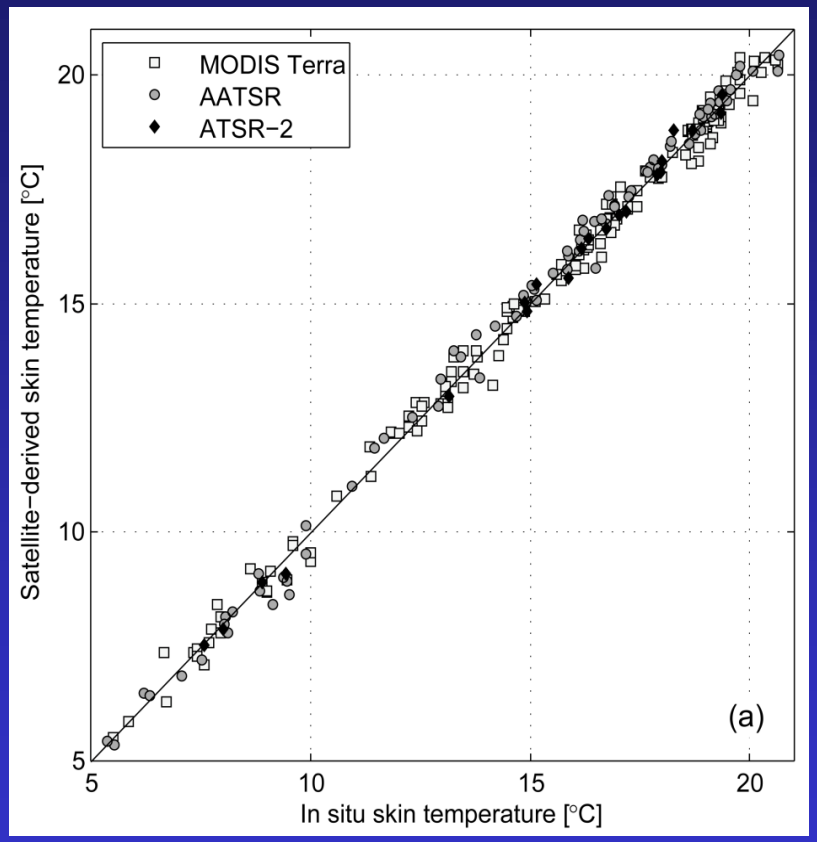
4. Establish a Long-term Lake Monitoring Network: Establish a long-term monitoring network aimed at measuring lake and lagoon temperatures in a variety of lake types and depths

1. Remote Sensing: Three key platforms

- Advanced Very High Resolution Radiometer (AVHRR)
  - 1981/1985 through present
- Series of Along-Track Scanning Radiometers (ATSR)
  - ATSR (1991 through 1997)
  - ATSR-2 (1996 through 2003)
  - AATSR (2002 through present)
- Moderate Resolution Imaging Spectroradiometer (MODIS)
  - Terra (2000 through present)
  - Aqua (2002 through present)



1. Remote Sensing: Validation of Methodology

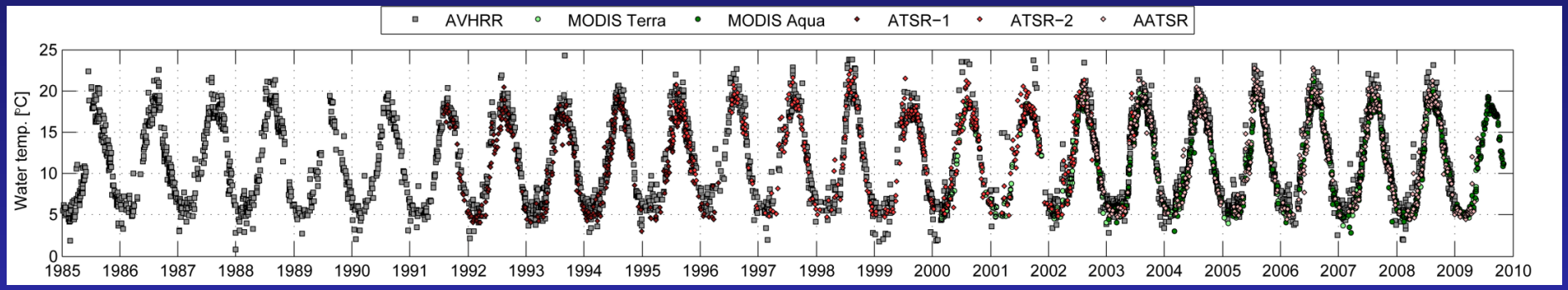


Schneider et al. (2009), Satellite observations indicate rapid warming trend for lakes in California and Nevada. Geophys. Res. Lett., 36, L22402, doi:10.1029/2009GL040846.

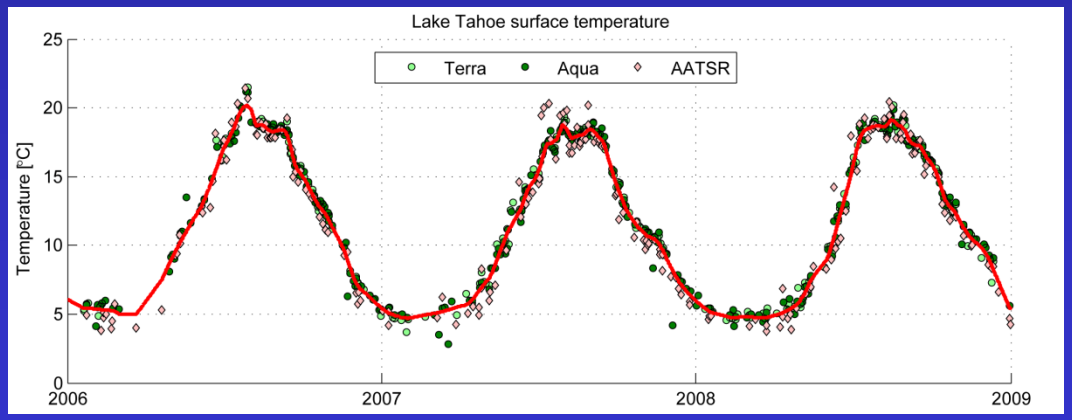
- Long-term archive of thermal infrared satellite imagery can be used to quantify temporal changes in lake temperatures
- Individual retrievals are accurate up to 0.2 ºC
- Long-term trends can be determined with an accuracy of 0.004 ºC/yr

1. Remote Sensing: Potential Outputs

Skin Temperature retrievals from 1985 to present

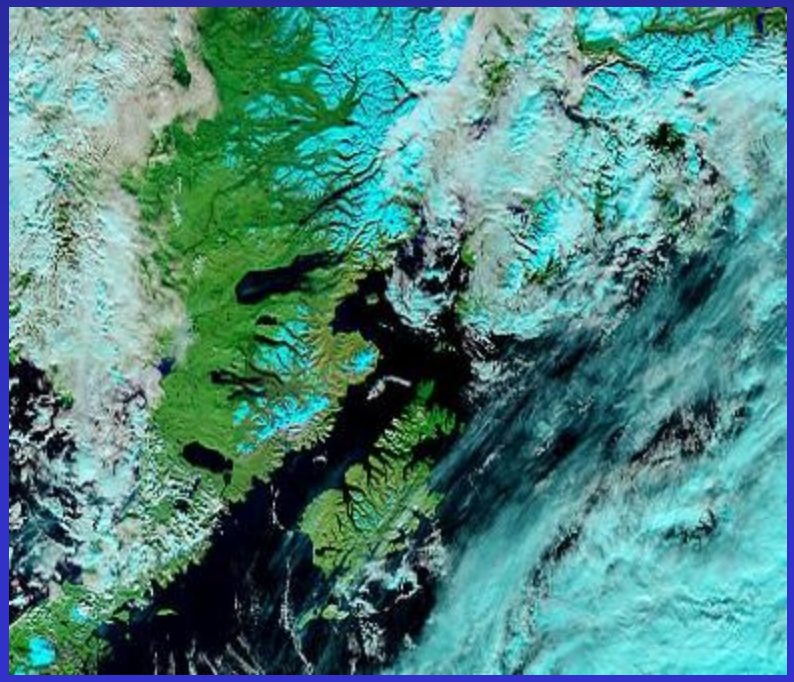


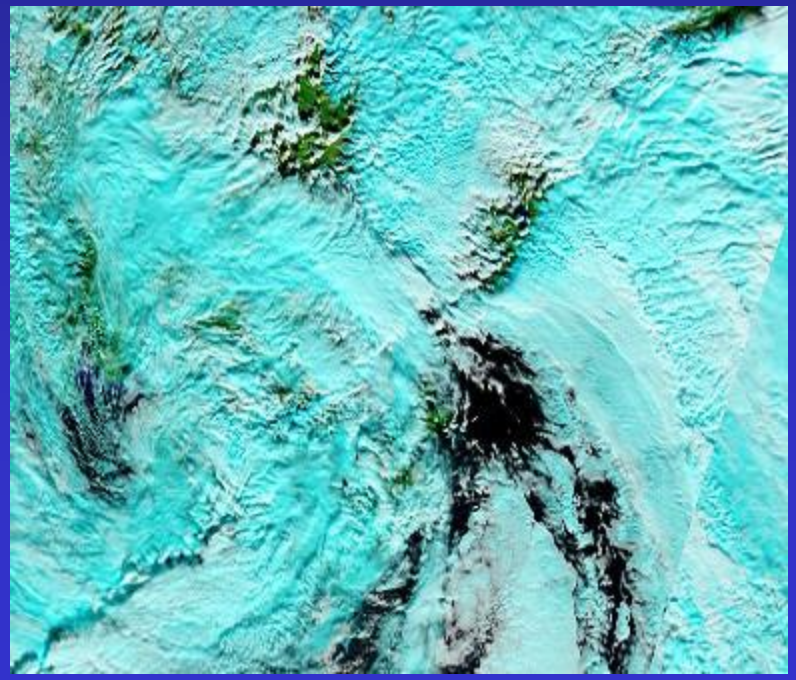
Locally weighted regression to obtain continuous temperature estimate



1. Remote Sensing: Challenges in Alaska

- Currently lacking a series of lake surface temperatures for temperature retrieval validation for region
- Many lakes are either too small or narrowly shaped for analysis with remotely sensed imagery
- Western Alaska is a cloudy place…



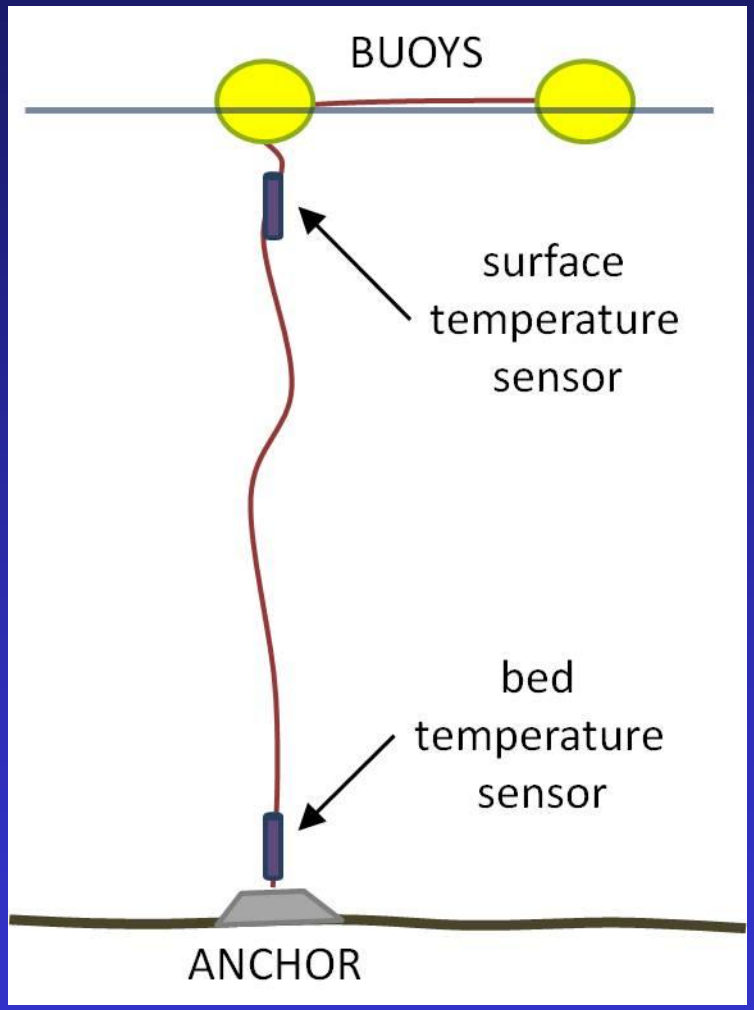


2. Field Data Collection: Data loggers

- Data loggers will deployed in approximately 30 lakes and 10 lagoons greater than 10km^2 in area in 2012 for validation purposes and establishing relations with local met station data

- Loggers will be positioned at surface and bed in water bodies shallower than 10 m

- In a series of lakes deeper than 20 m we will deploy sensors according to SWAN protocols in collaboration with ongoing efforts in Southwest AK



3. Modeling: Apply Energy Balance Model

- Use energy balance model calibrated to in situ and remote sensing data to forecast lake temperature regimes using downscaled GCM output

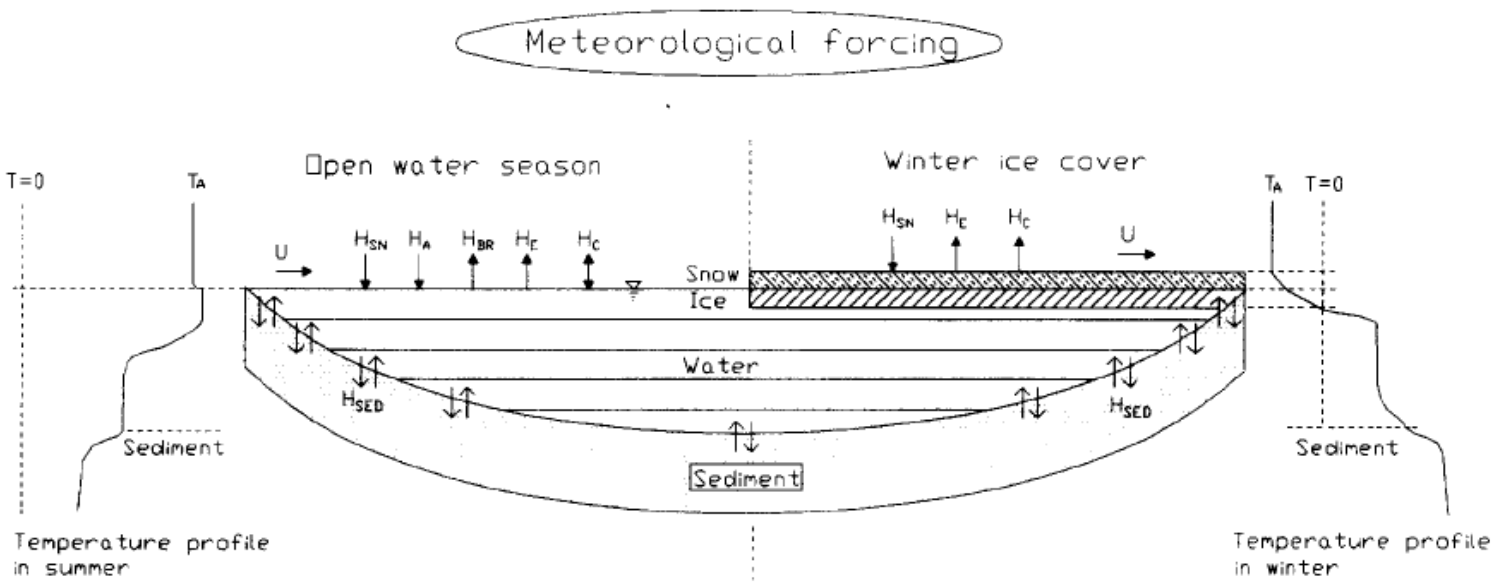


Fig. 1. Schematic of a stratified lake showing heat transfer components and temperature profiles in summer and winter.

$Q_S = Q_{SW} + Q_{LW} + Q_H + Q_L + Q_G$

Fang and Stefan 1996 *Cold Regions Science and Technology*

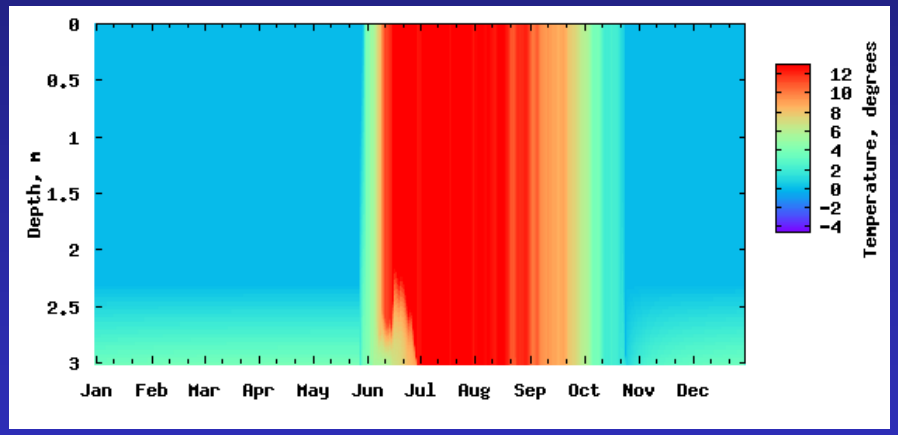
Data Inputs: Lake geometry and daily air temperature, relative humidity, solar radiation, wind speed, surface air pressure, precipitation, and cloud cover

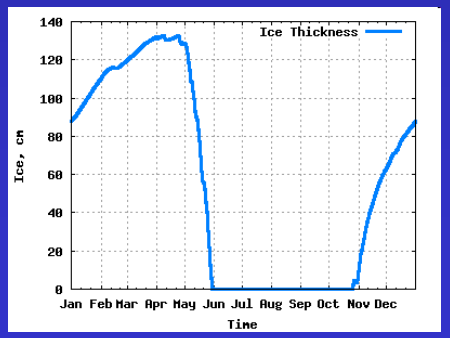
3. Modeling: One-dimensional lake models

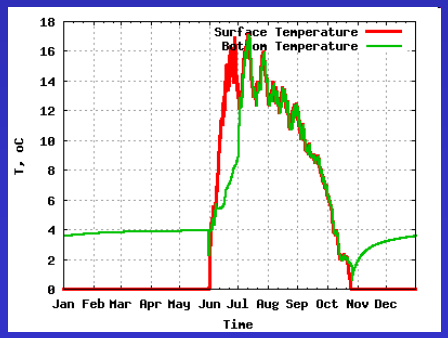
- Two models capable of handling GCM and RCM projections:

FLake and MyLake

Imuruk Lake





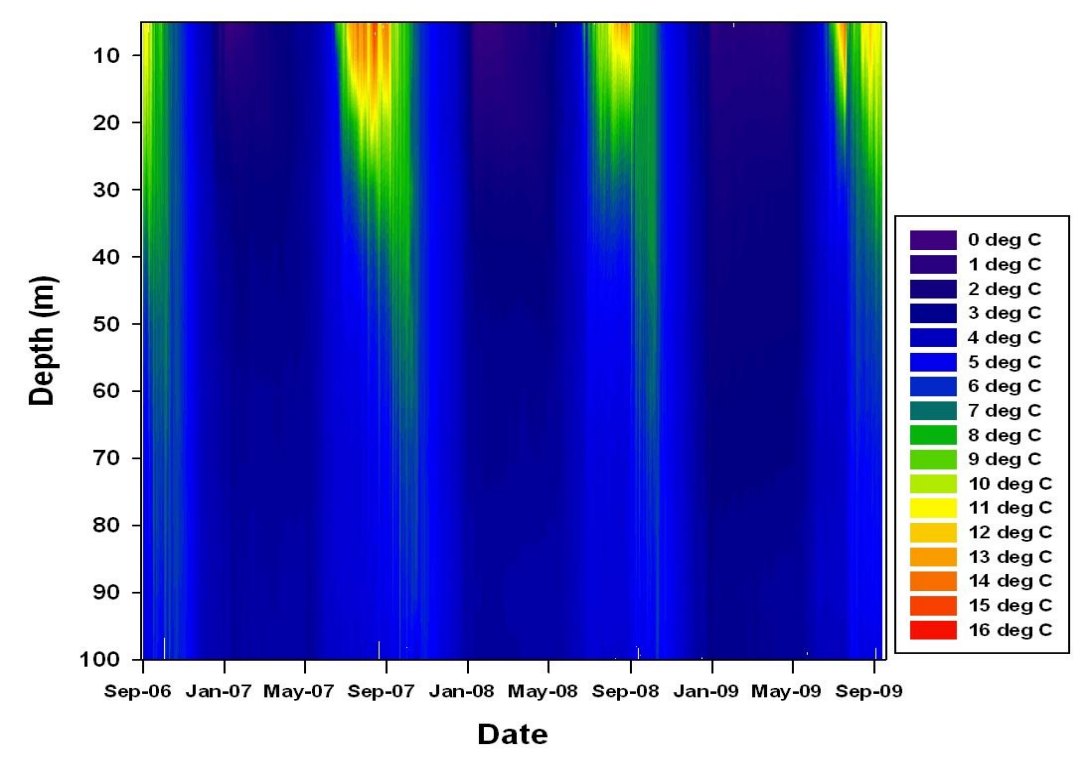


http://www.flake.igb-berlin.de/

4. Lake Temperature Monitoring Network

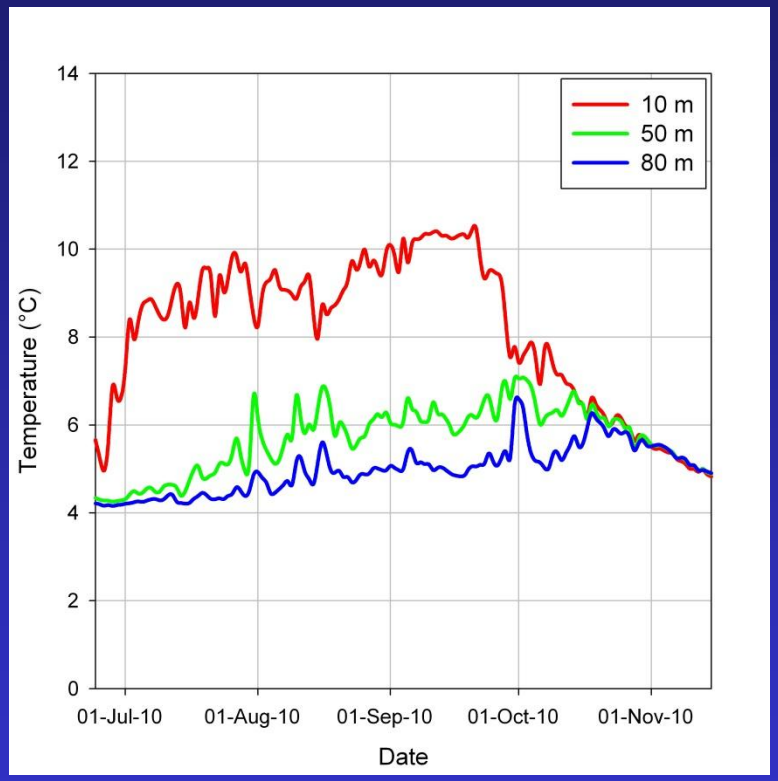
- While models and remotely sensed information are great…”real” measurements acquired over long periods of time are still essential and allow for interesting temporal and spatial comparisons

Lake Clark thermistor array time series



4. Monitoring Network: Deep Lake Comparison

Lake Clark

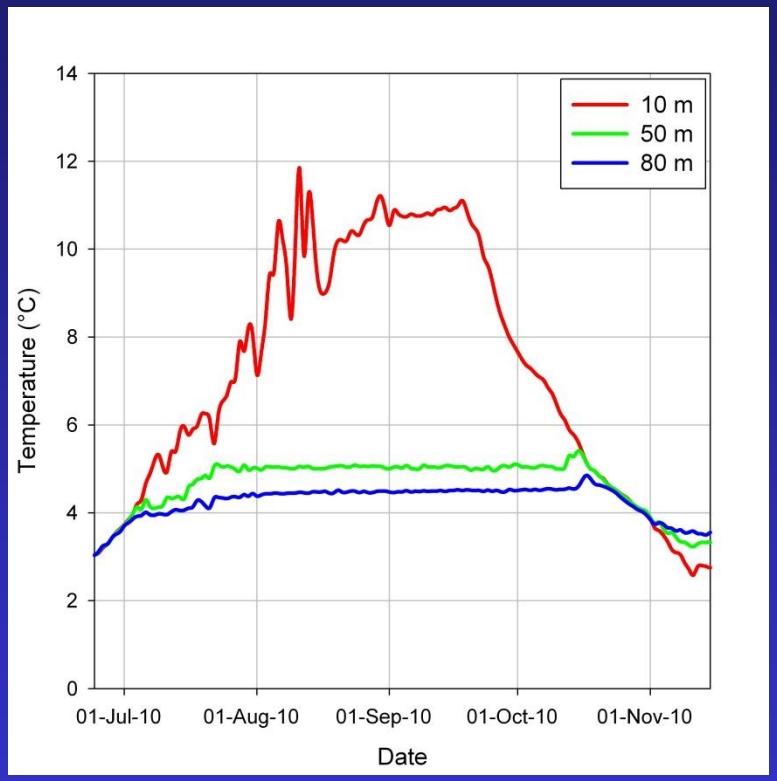


Latitude: 60.2˚

SD: 2 to 4 m

Subject to severe winds

Devil Mountain Maar Lake



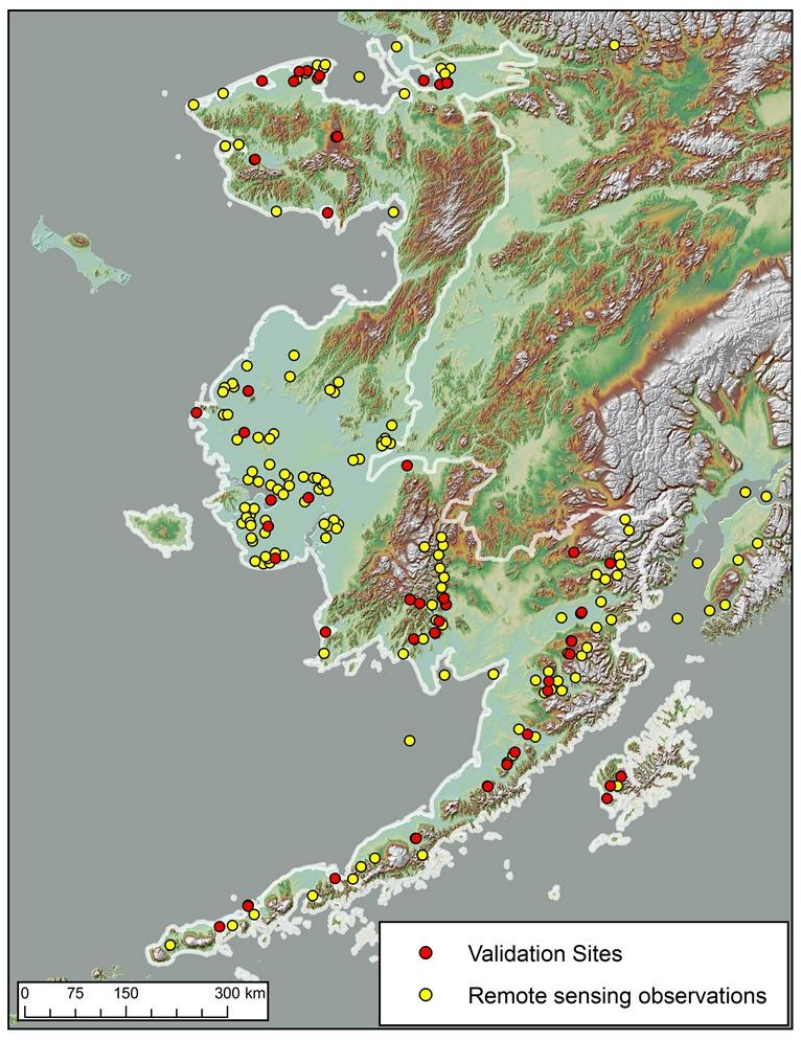
Latitude: 66.4˚

SD: 13 m

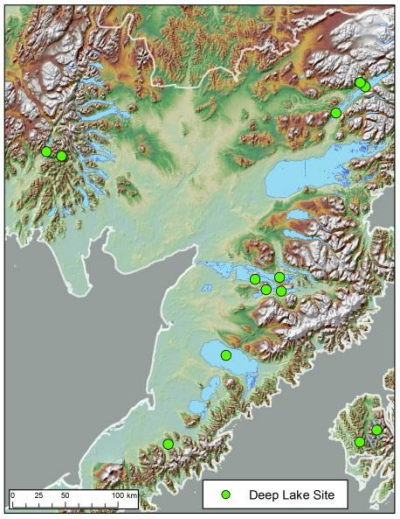
Protected from severe winds

An Emerging Alaska Lake and Lagoon Temperature Network

Large Lake Surface Temperatures



Deep Lake Thermistor Arrays

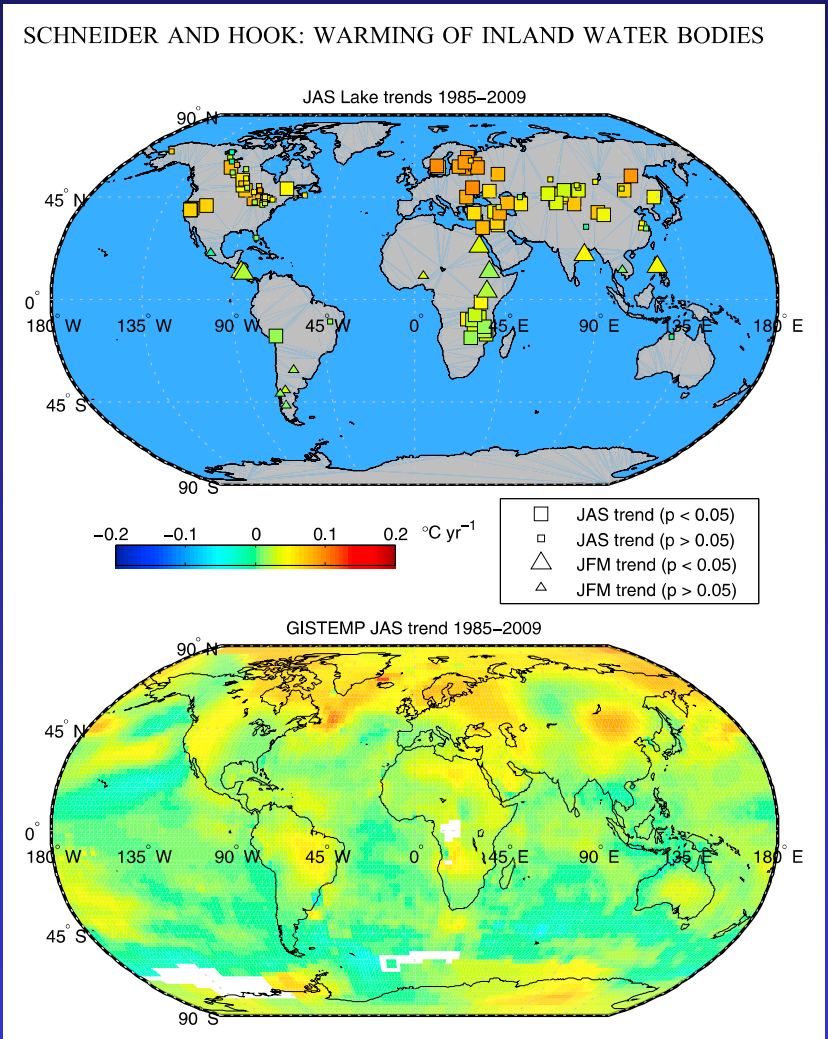


Other Alaska Lakes and Lagoons with Data?

- North Slope – NSF CALON
- YKD – Craig Ely Group
- Wood River System - Schindler Lab
- Yukon Flats NWR
- Interior Alaska Parklands

Larger Contributions

- Recent studies have revealed substantial warming of lakes worldwide with a maximum rate of 1.0° C/decade from 1985 to 2009
- Only one lake from Alaska in this global assessment and few Arctic lakes
- Global Lake Temperature Collaboration (GLTC) - our project will provide useful information to this effort consisting of 50 investigators spread around the globe
- Our project will also provide data to the CAFF - Freshwater Ecosystems Monitoring Group



Questions and Contact Info

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