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Inland Water Temperature: An Ideal Indicator for the National Climate Assessment

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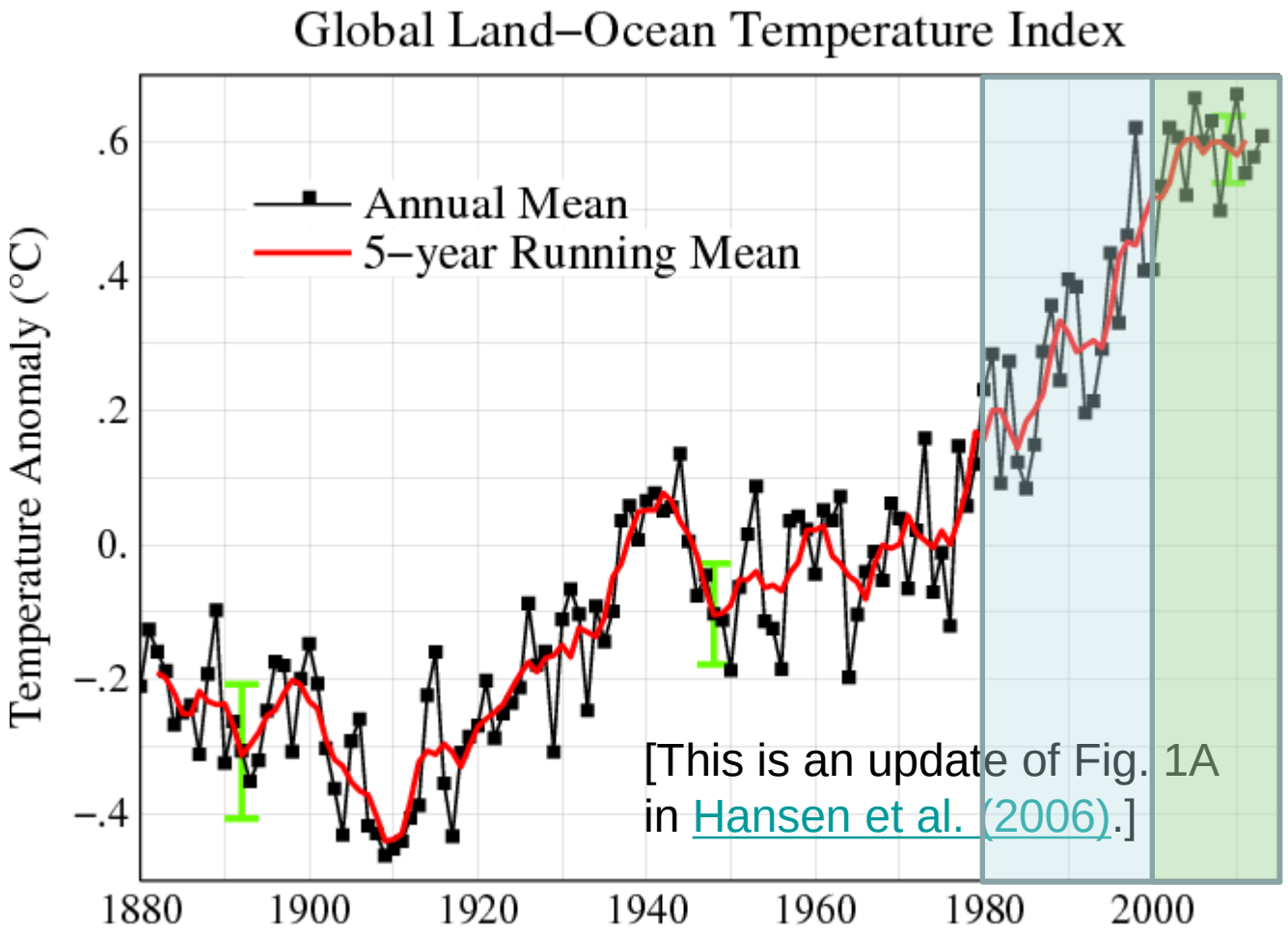
Introduction

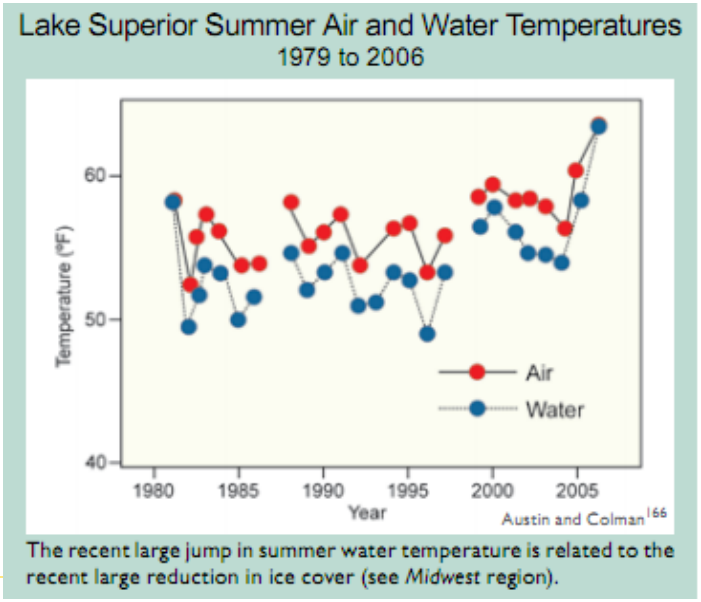
Line plot of global mean land-ocean temperature index, 1880 to present, with the base period 1951-1980. The dotted black line is the annual mean and the solid red line is the five-year mean. The green bars show uncertainty estimates.

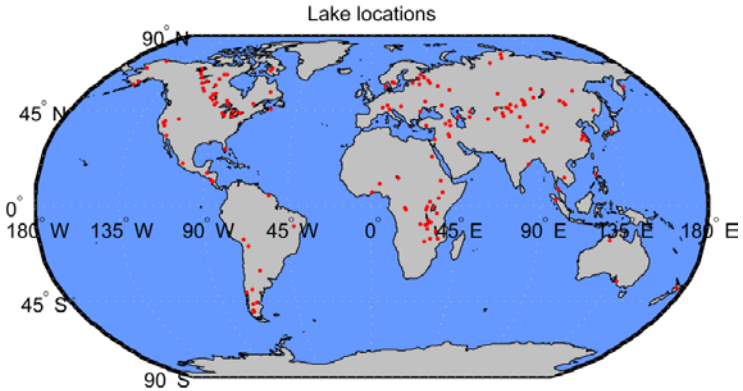


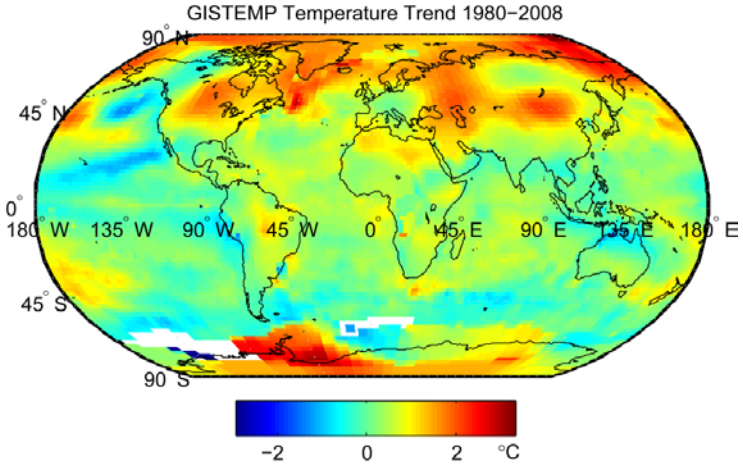
[This is an update of Fig. 1A in Hansen et al. (2006).]

Introduction

- The Idea
  - Temperatures of lakes and reservoirs are good indicators of climate trends
  - Existing in situ data is insufficient in space and time
  - Nearly 30-year record of satellite thermal infrared imagery available





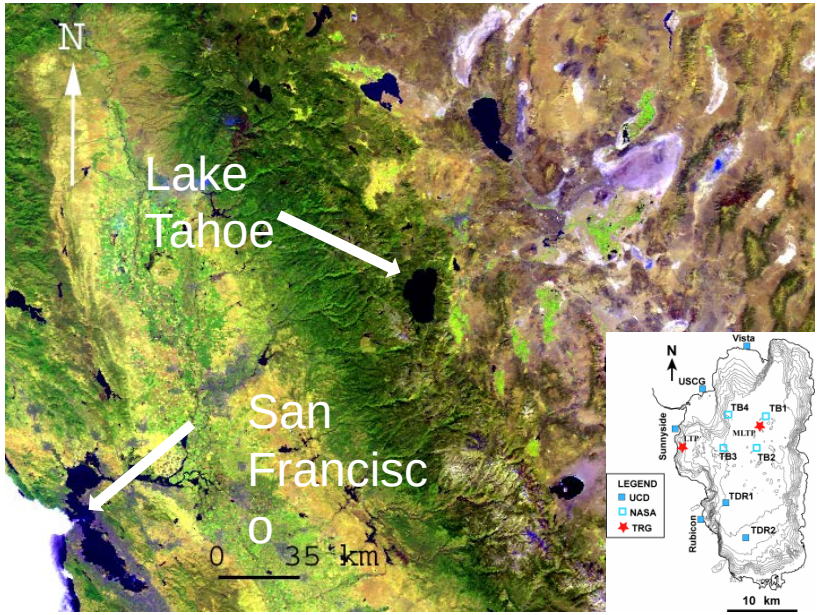


Early work by Austin and Colman for Lake Superior

Project Objectives

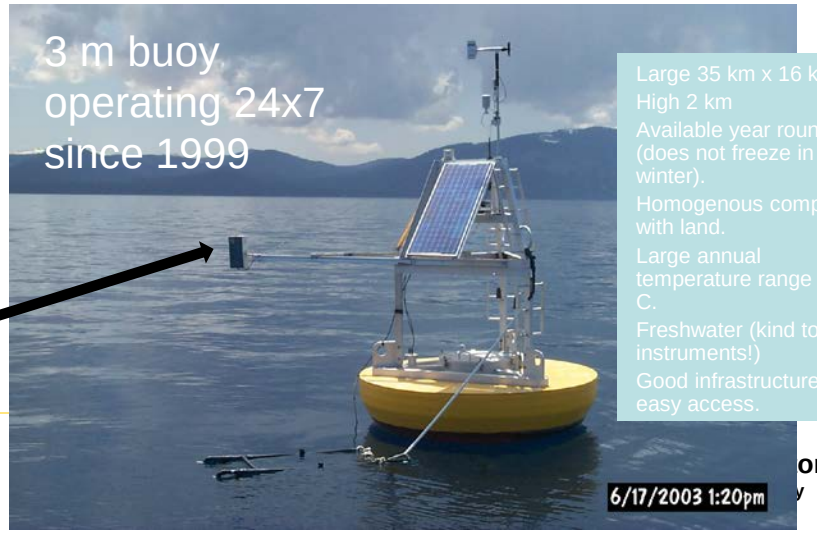
- Extend the temperature time-series to all of the North American inland water bodies that are sufficiently large to be studied using 1-km resolution satellite data for the last three decades.
- Relate changes in the thermal behavior of the water bodies to changes in surface air temperature data.
- Develop ecologically relevant indicators that are meaningful to the general public and summarize the data and make it available for the National Climate Assessment writing teams.
- Compare the regional trends in surface temperature derived from satellite-based and *in situ* observations to those in the CMIP5/IPCC model simulations/projections.
- Predict future changes in inland water body surface temperatures based on comparisons with the models and detailed observations from *in situ* monitoring sites.

Validation of Satellite Data



Methodology:

- 4 buoys on large, high lake, each buoy is 1 km from shore and nearest buoy.
- Each buoy has custom thermal infrared radiometer operating 24x7 and associated meteorological measurements.
- Extract skin temperature from radiometer at time of overpass and propagate to top of atmosphere with radiative transfer model.
- Convolve to instrument system response functions and compare to satellite instrument measured value.



Large 35 km x 16 km
High 2 km
Available year round (does not freeze in winter).
Homogenous compared with land.
Large annual temperature range 5-25 C.
Freshwater (kind to instruments!)
Good infrastructure and easy access.

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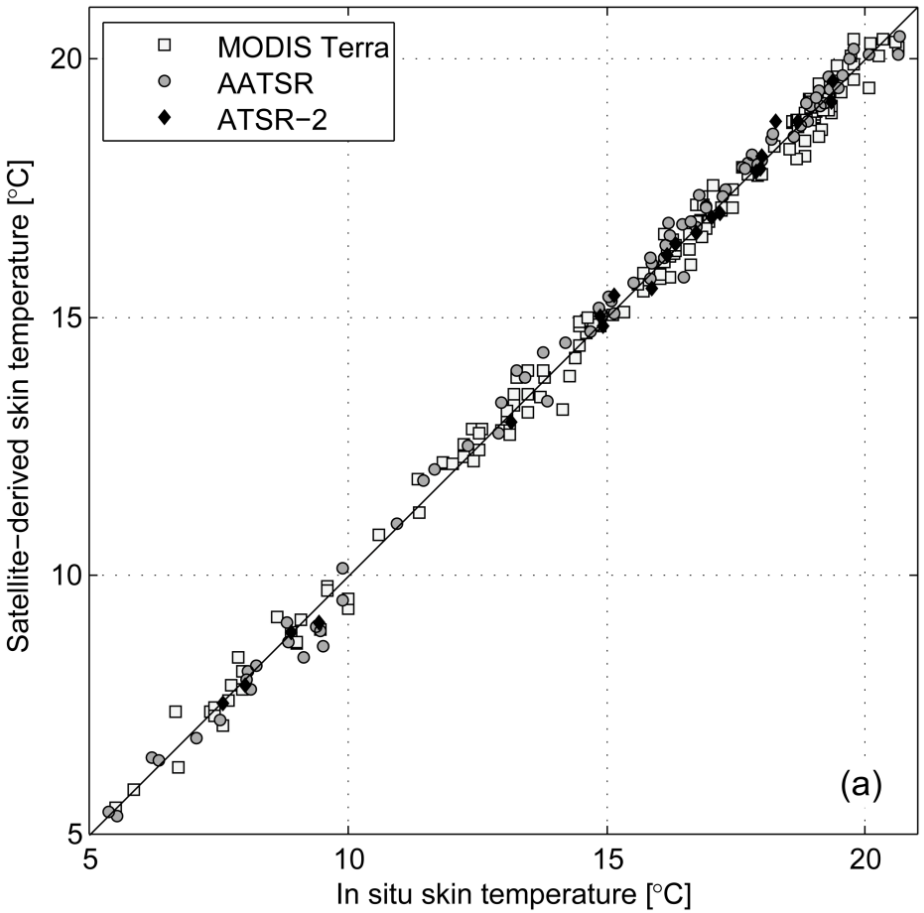
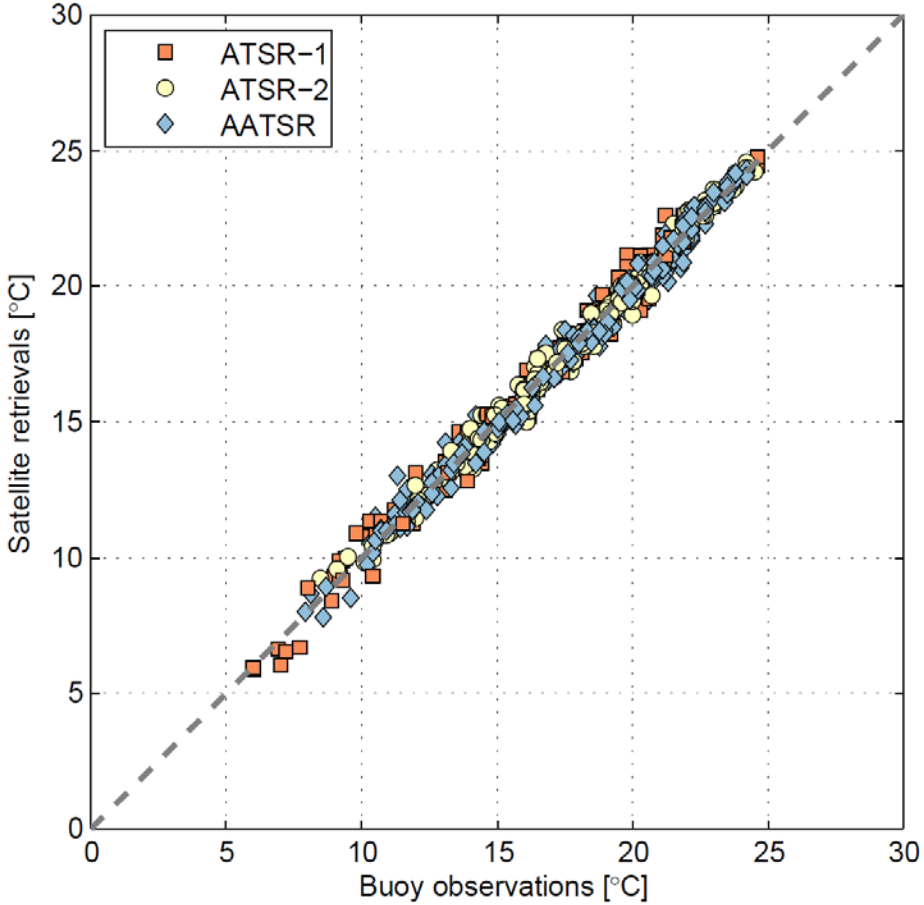
Results: Lake Tahoe Validation



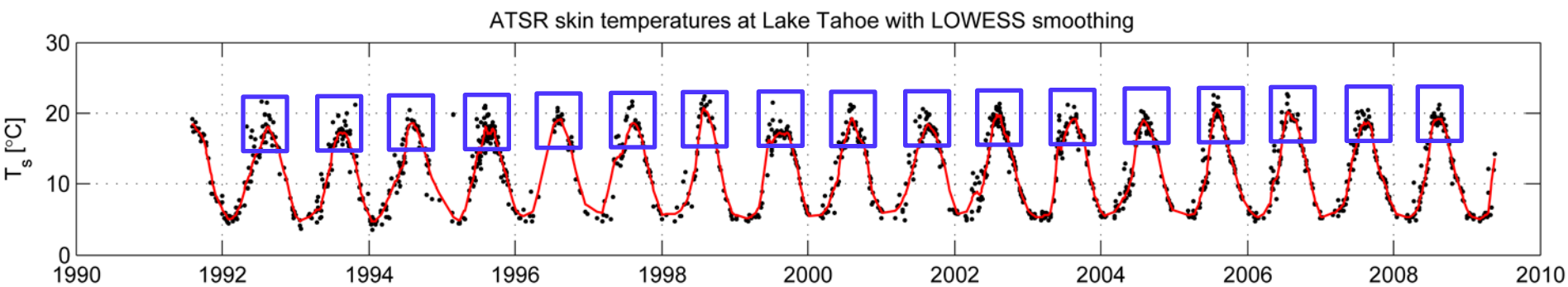


Schneider et al. (2009). Satellite observations indicate rapid warming trend for lakes in California and Nevada. *Geophysical Research Letters*, in print

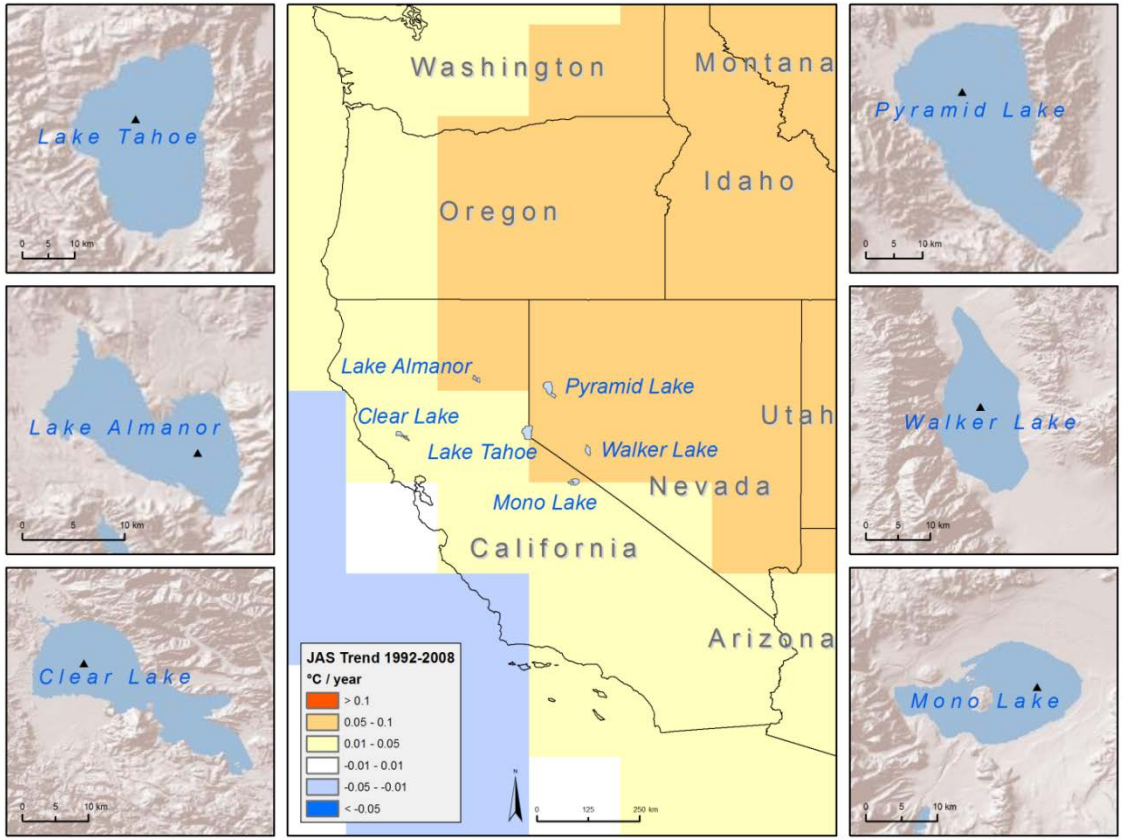
Standard error = 0.2 K

Data and Methods

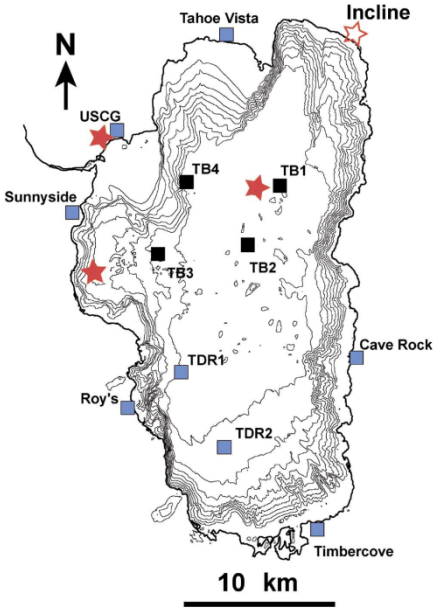
- Thermal infrared data from two sensor series
  - Moderate Resolution Imaging Spectroradiometer (MODIS)
  - Along-Track Scanning Radiometer (ATSR)
- Data extraction
- Cloud masking
- Atmospheric correction
- Computation of summer time (JAS) means
- Weighted linear regression analysis and uncertainty analysis

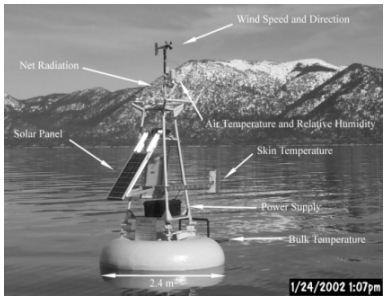


California/Nevada case study



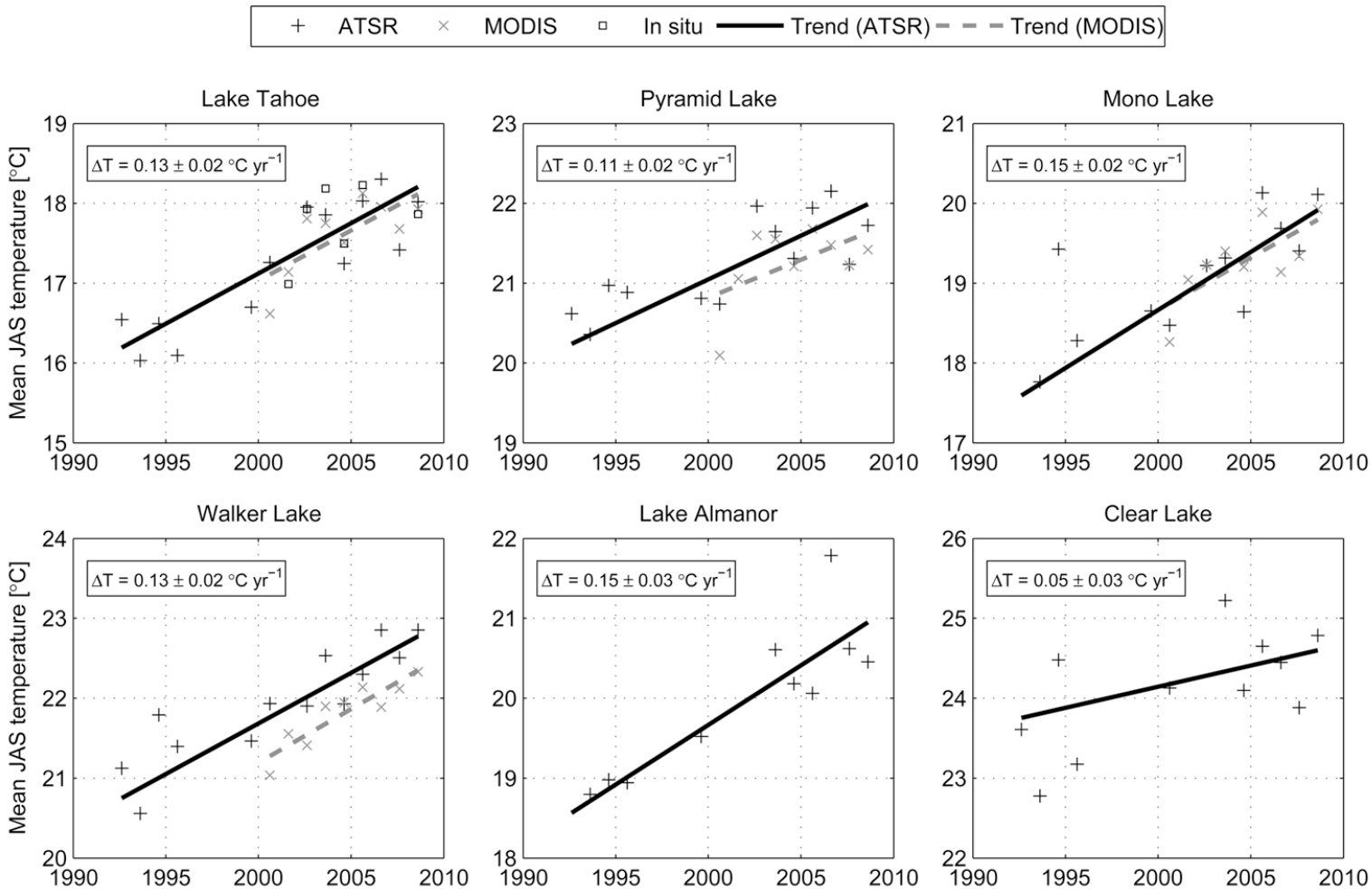
A preliminary case study was carried out for six lakes in California and Nevada. The center panel shows the lake locations and the GISTEMP (Hansen et al., 1999) summertime temperature change between 1991 and 2008.





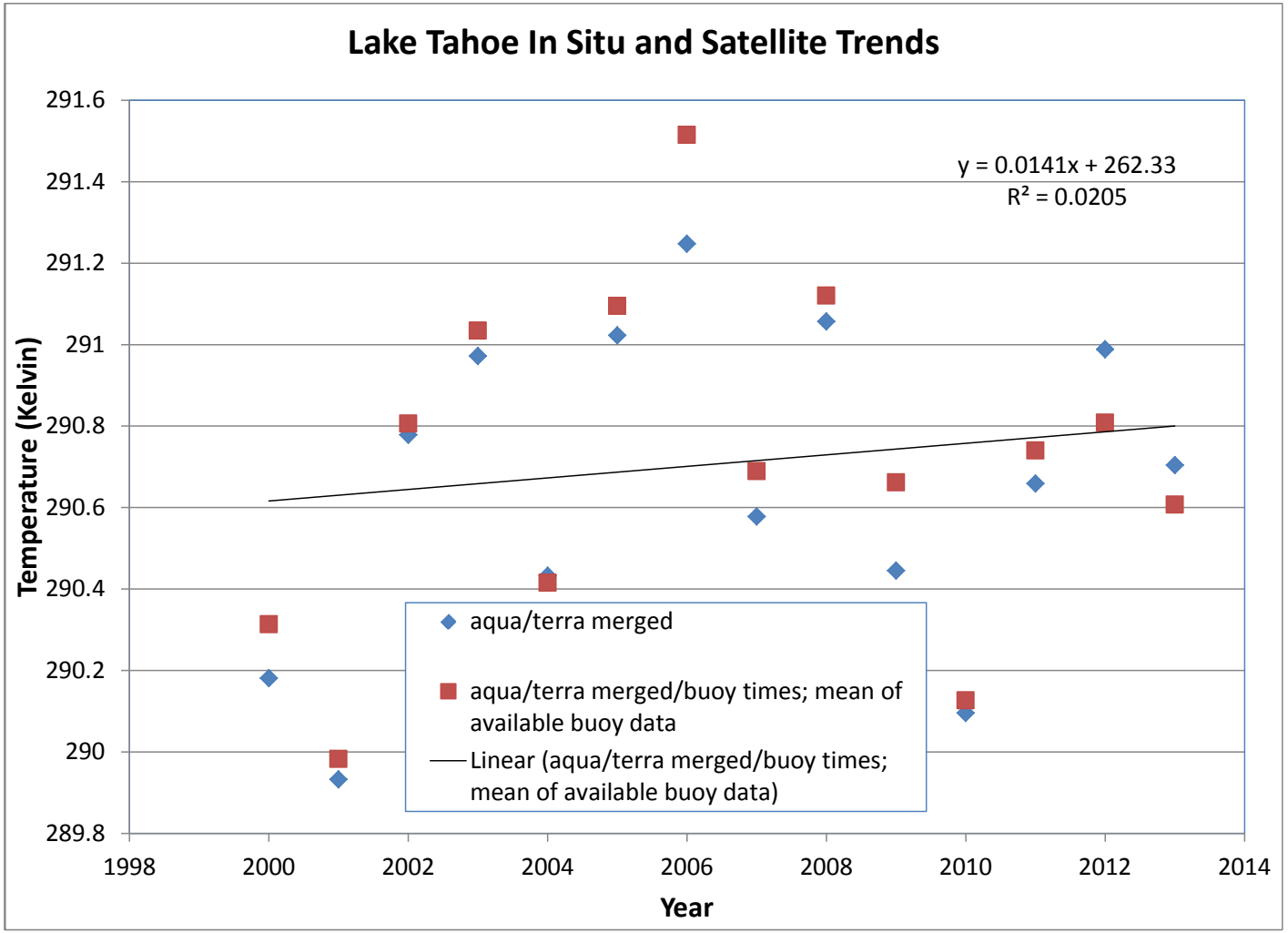
In situ measurements at 4 buoys at Lake Tahoe were used to develop algorithms and validate the results

Summertime (JAS) trends since 1991-2008

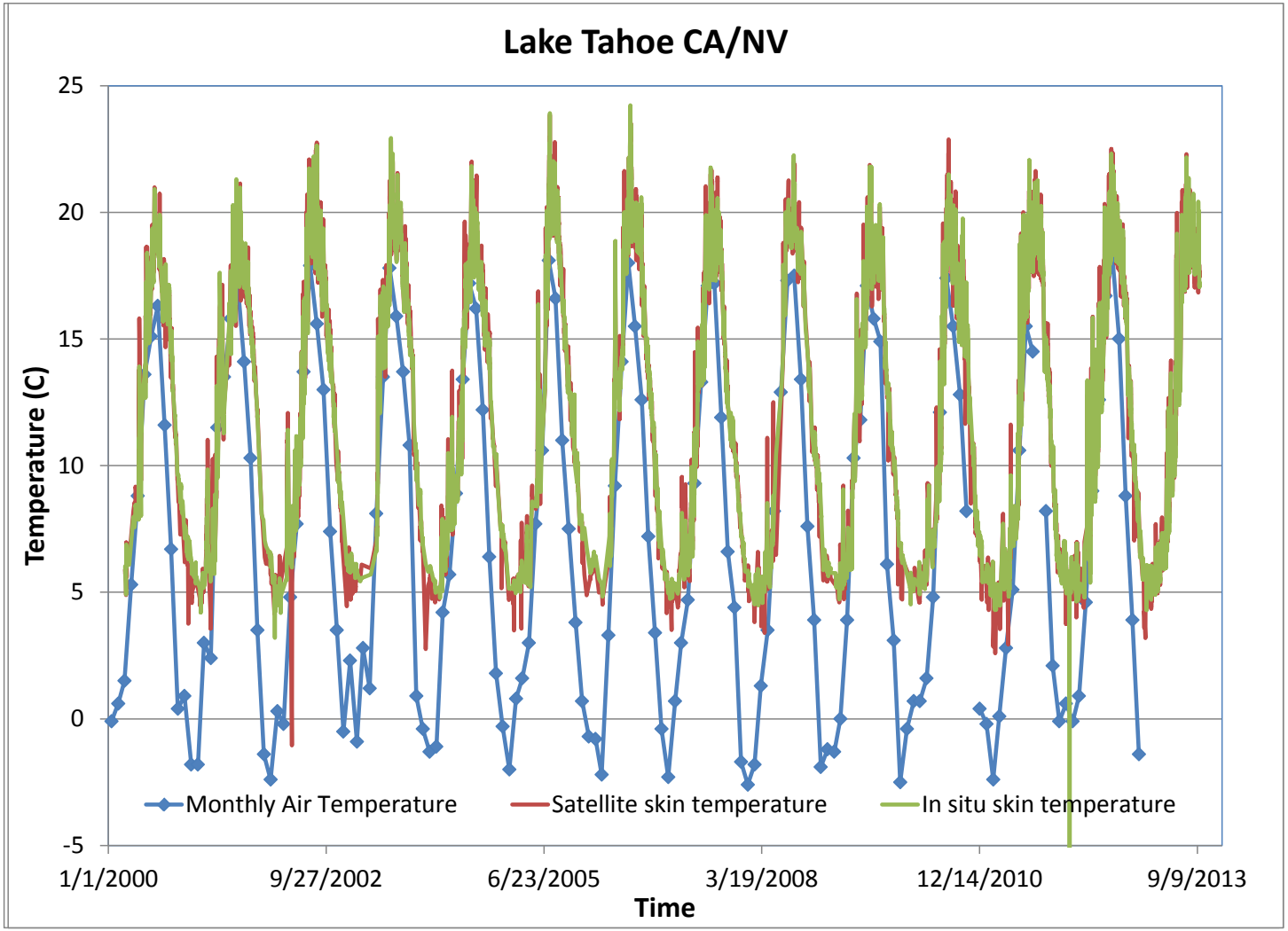


Schneider et al. (2009). Satellite observations indicate rapid warming trend for lakes in California and Nevada. *Geophysical Research Letters*

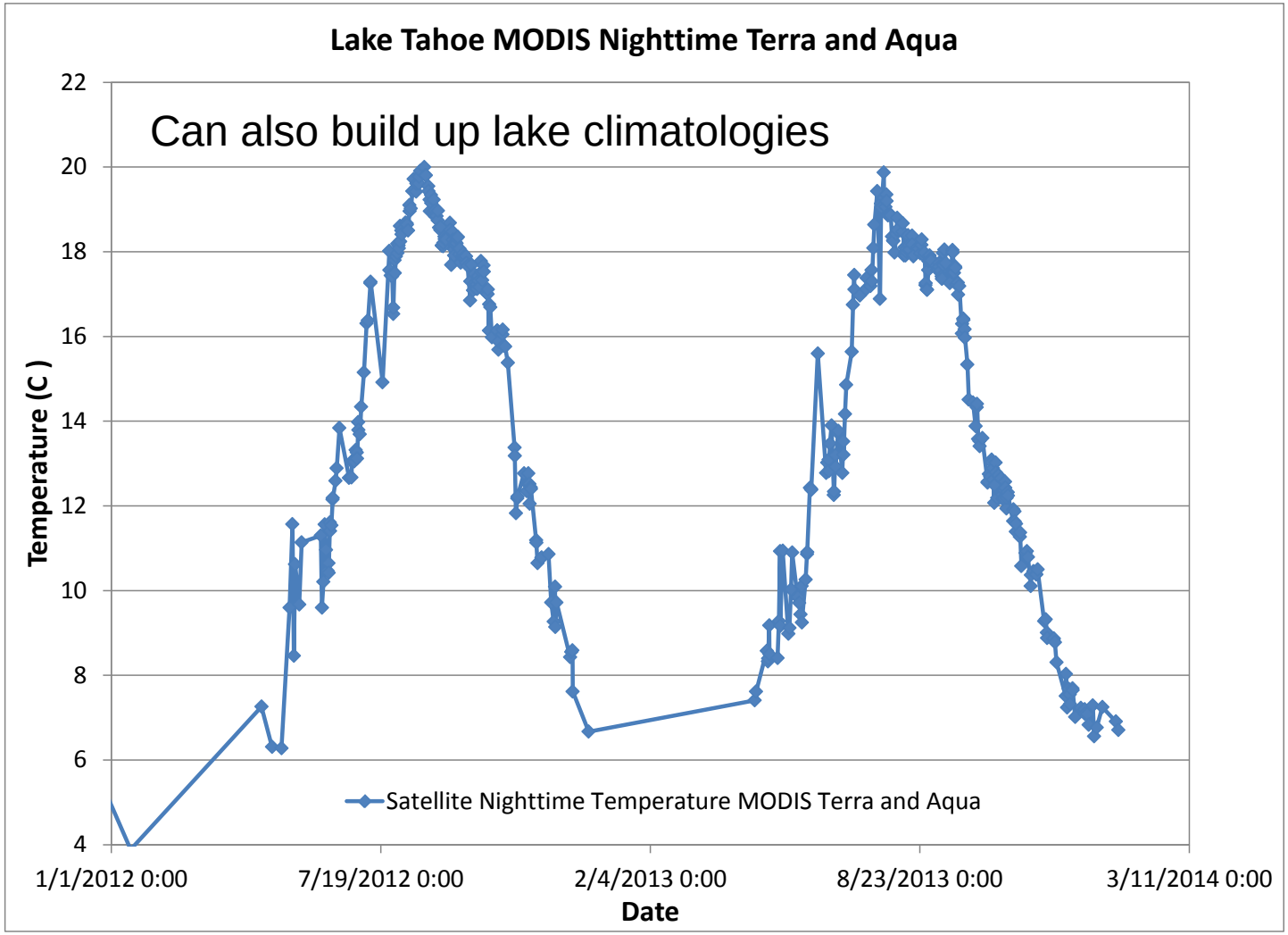
The Importance of Record Length



What about Air Temperatue



More than Trends - Climatologies



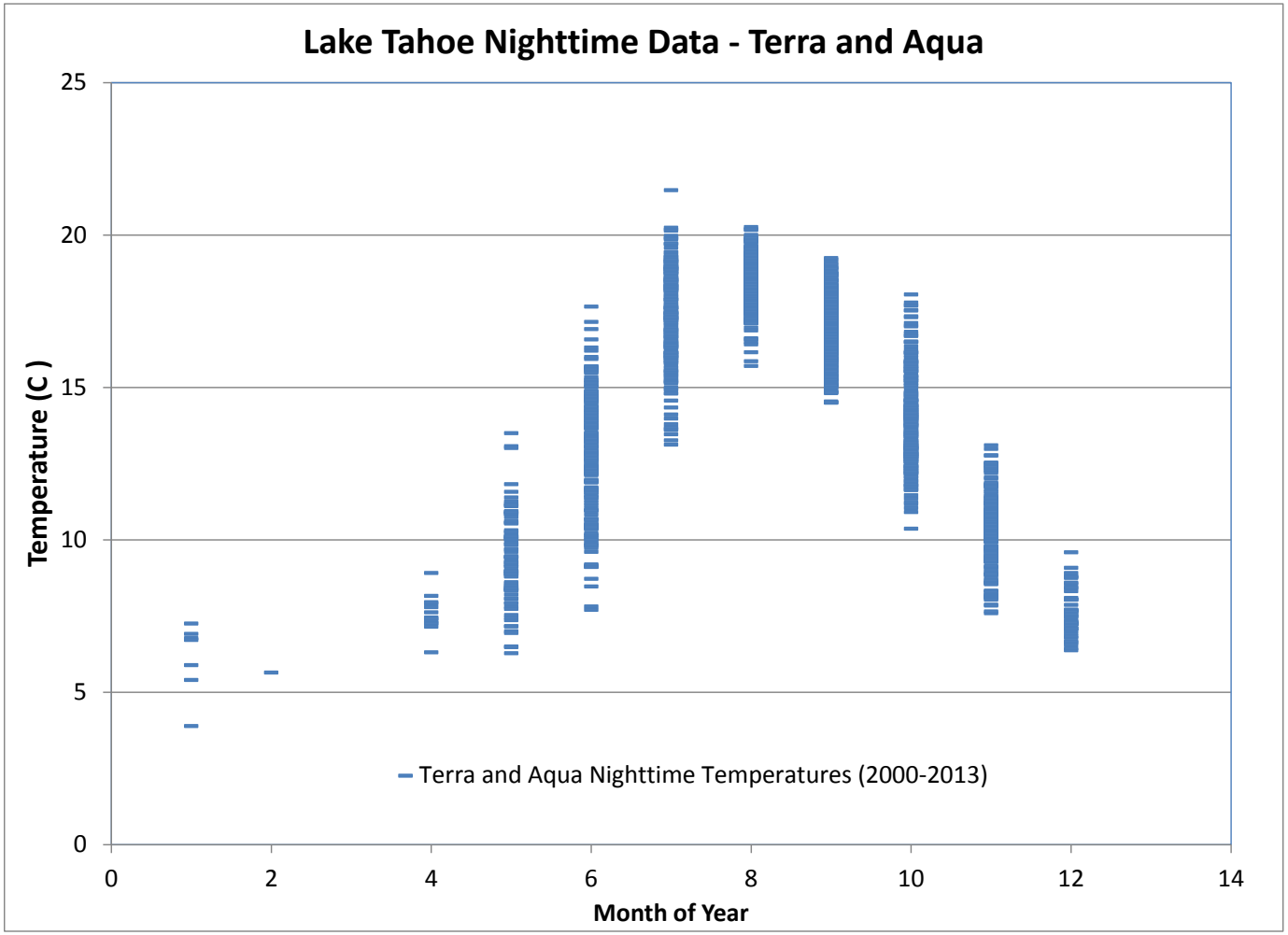
Climatologies and Ecological Indicators

Is it an unusually hot month?

When was the temperature above 4C?

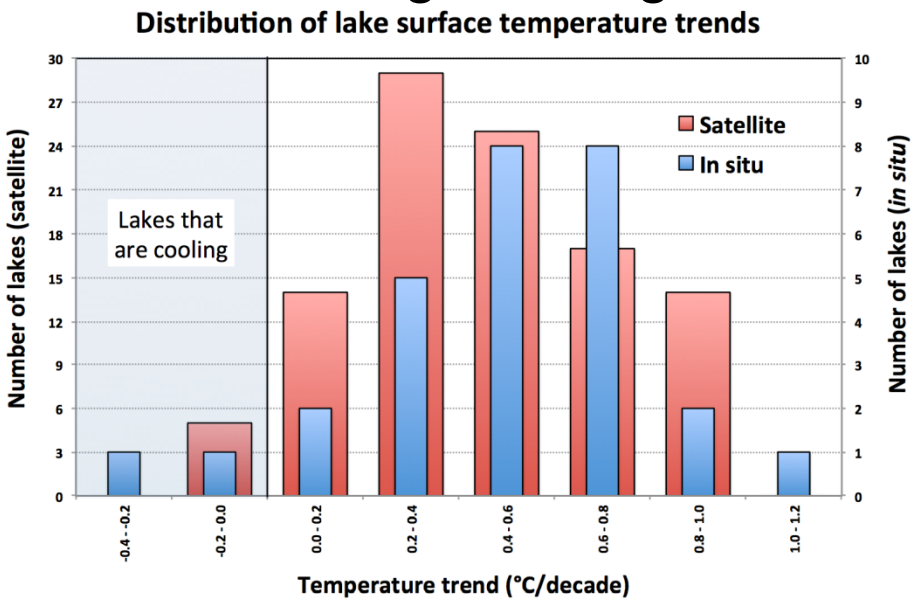
What was the maximum summertime temperature?

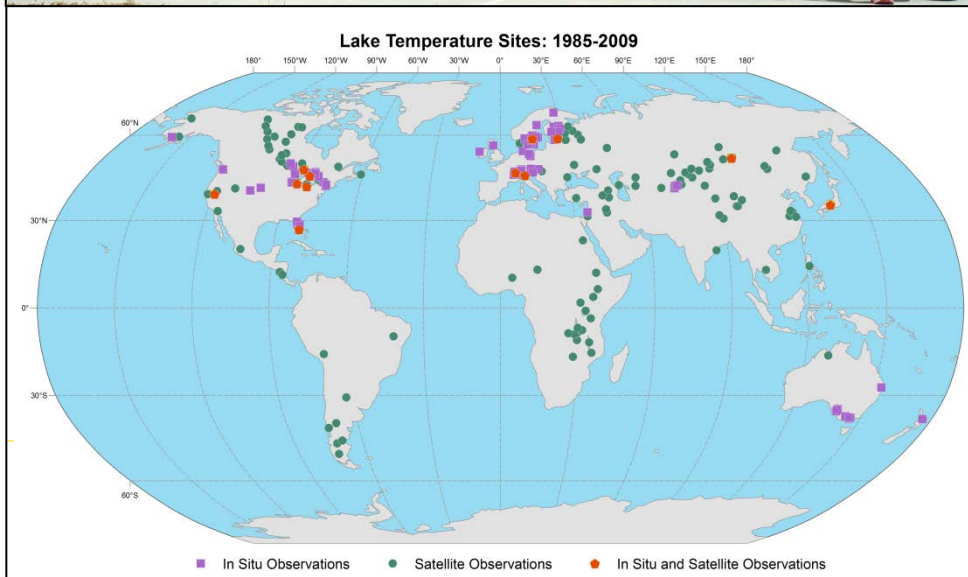
How long was the stratified Period?



Global Lake Temperature Collaboration (GLTC):

What are the patterns, mechanisms, and impacts of global lake warming / cooling?





Summary and Conclusions

- Satellite thermal data provides a rich record of changes in surface temperature since 1980.
- After 2000 have excellent validation and data access. Need to improve access to earlier data and validate them
- Currently extending time series first created in 2009 to present day (AVHRR, ATSRx, MODIS). Could add other datasets e.g. VIIRS.
- Incorporating higher resolution AVHRR data over North America available from direct broadcast to increase number of lakes.
- Relating changes in the thermal behavior of the water bodies to changes in surface air temperature data.
- Exploring ecologically relevant indicators that are meaningful to the general public and summarize the data and make it available for the National Climate Assessment writing teams.
- Have not discussed but also comparing regional trends to model predictions

Comments?

Questions?

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Lake Gjende, Norway, August 2008, courtesy Philipp Schneider