NOAA's Temperature Records: *A Foundation for Understanding Global Warming*

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Thursday, May 6, 2010 2:00 p.m. to 3:30 p.m.
U.S. Capitol Visitor Center Room SVC 208/200

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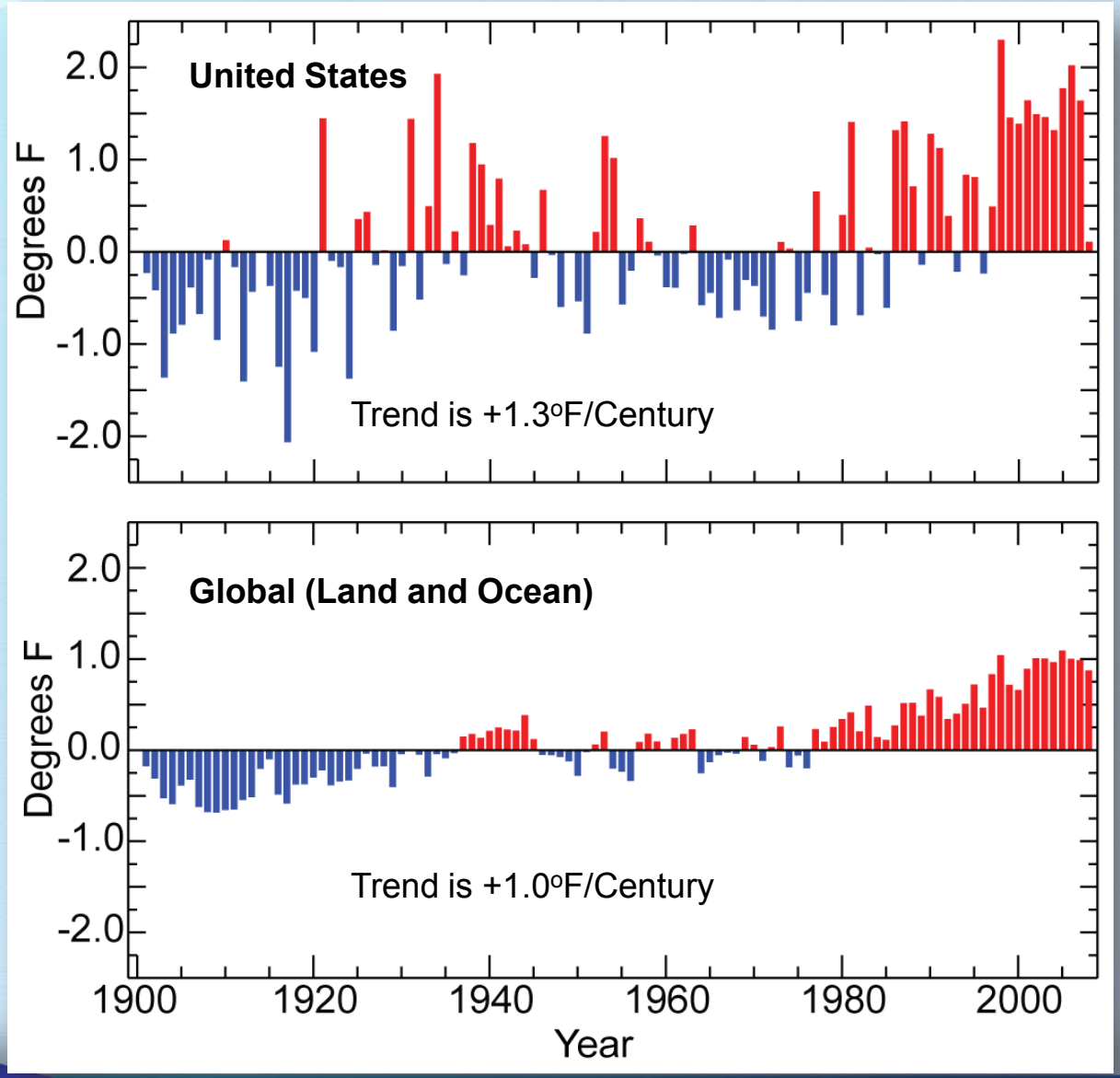
Outline

- **U.S. and Global temperatures**
- **NOAA's U.S. and global temperature calculations**
  - Evaluating robustness and reliability
- **Other measures of temperature change**

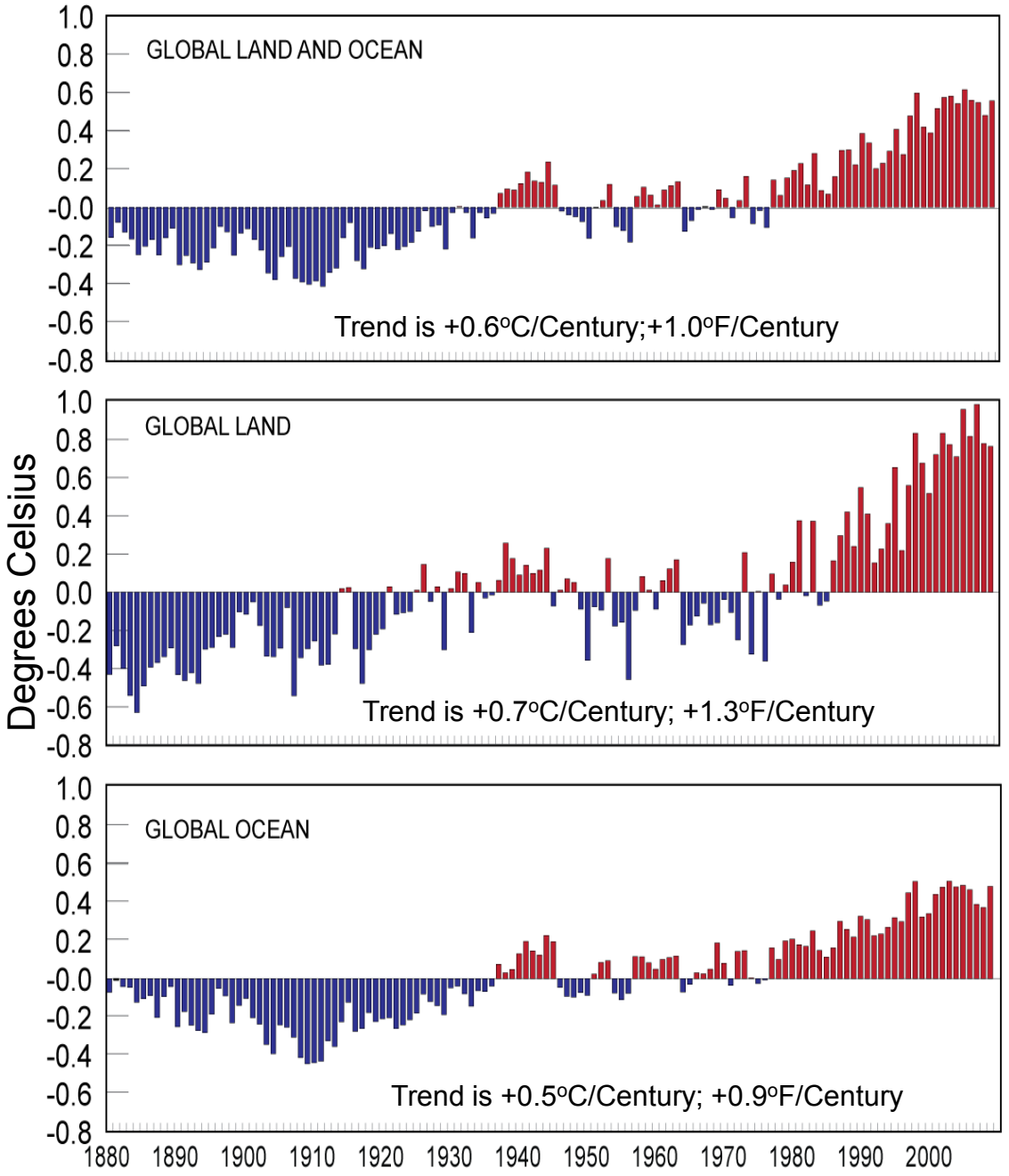
Annual Average Temperature

(Departure from the 1901-2000 Average)



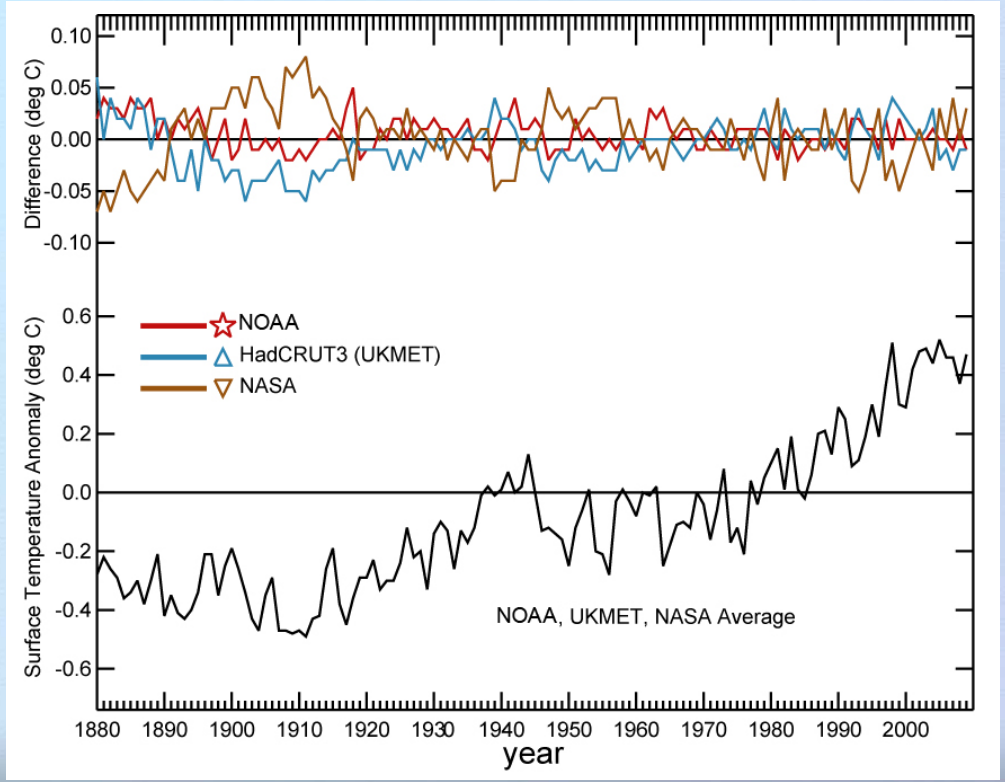
Jan-Dec Global Surface Average Temperature Anomalies

NCDC/NOAA/NESDIS (Smith *et al*., 2008)



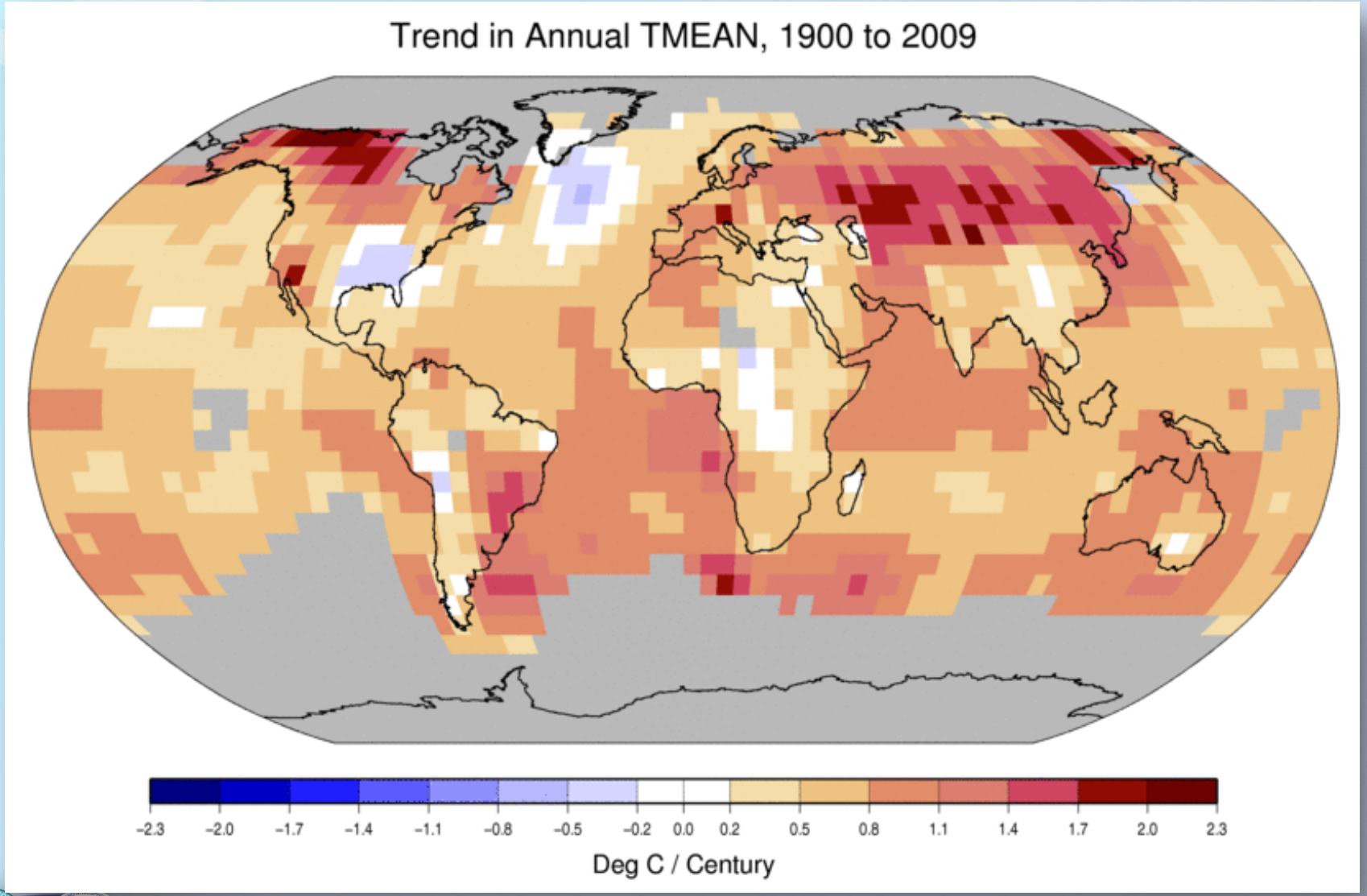
Three Institutions Produce Global Temperature

- **NASA Goddard Institute for Space Studies (NASA GISS)**
- **Meteorological Office (UKMET)**
- **NOAA/**National Climatic Data Center

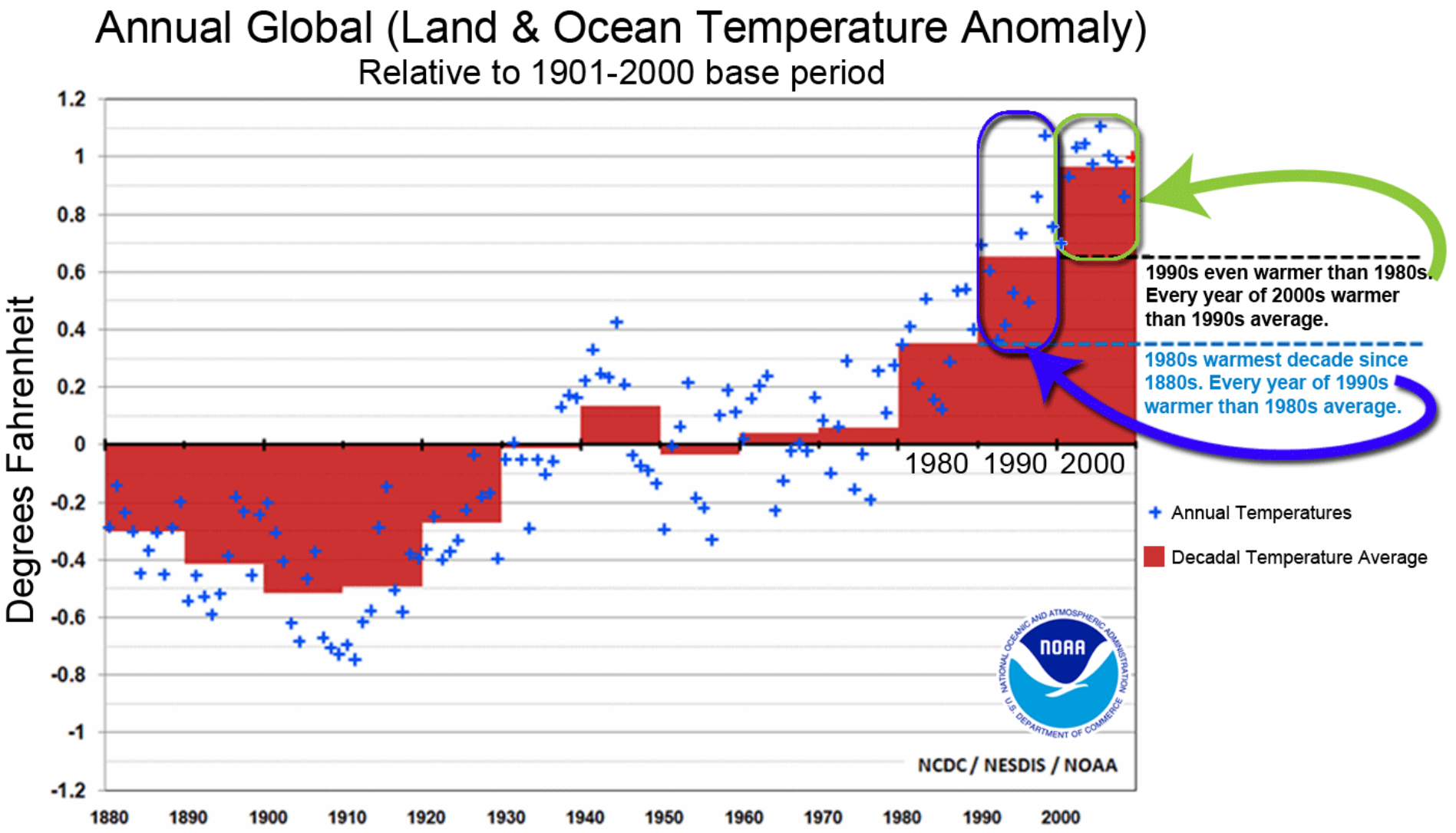


Adapted from the 2009 State of the Climate Report, figure by Kate Willett, UK Met Office

Global Warming is not Uniform Around the Globe



Has Global Warming Stopped?

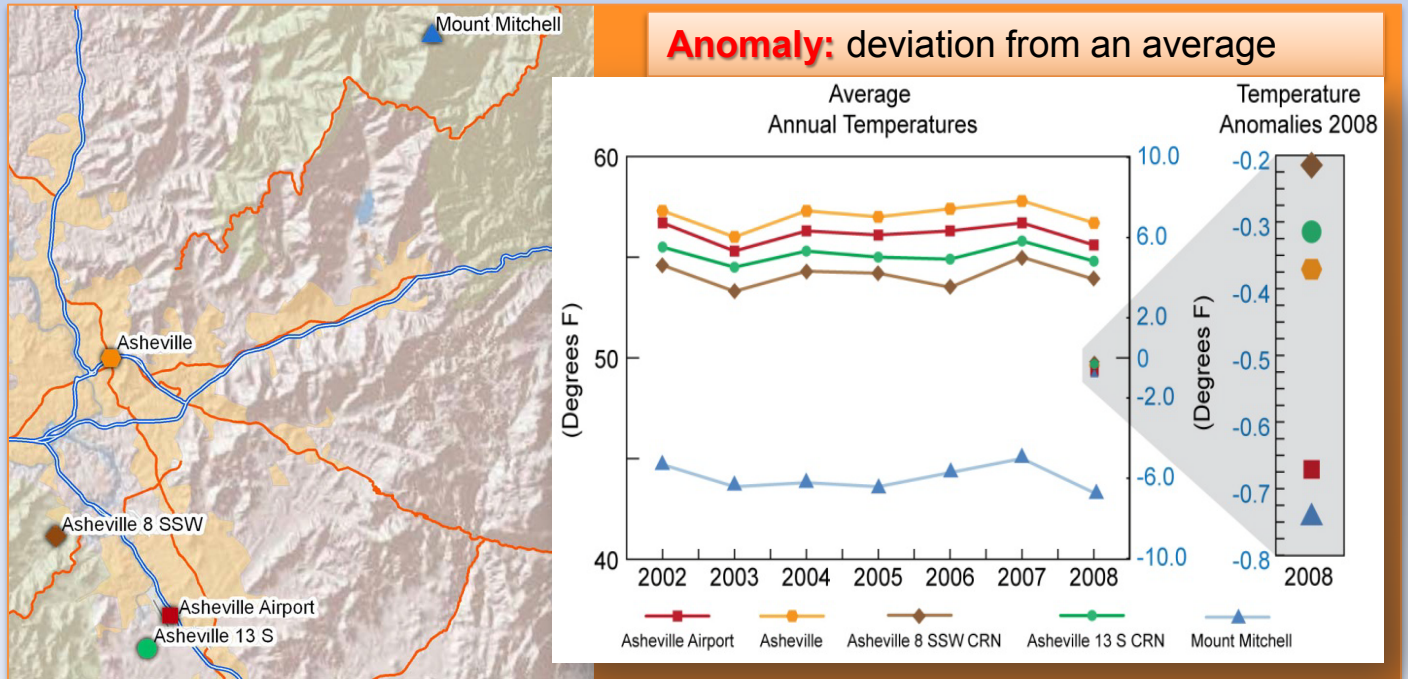


NOAA's U.S. Temperature Calculations & Evaluating of Robustness and Reliability

U.S. Temperatures

- **U.S. Historical Climatology Network**
  - 1200 stations in (USHCN) contiguous U.S.
    - Stations selected for their long-term data
  - Data undergo intensive assessment and corrections to remove artificial biases
  - Station anomalies (not absolute temperatures) are area-averaged to produce the final time series

NOAA Historical Climate Network, 20th Century

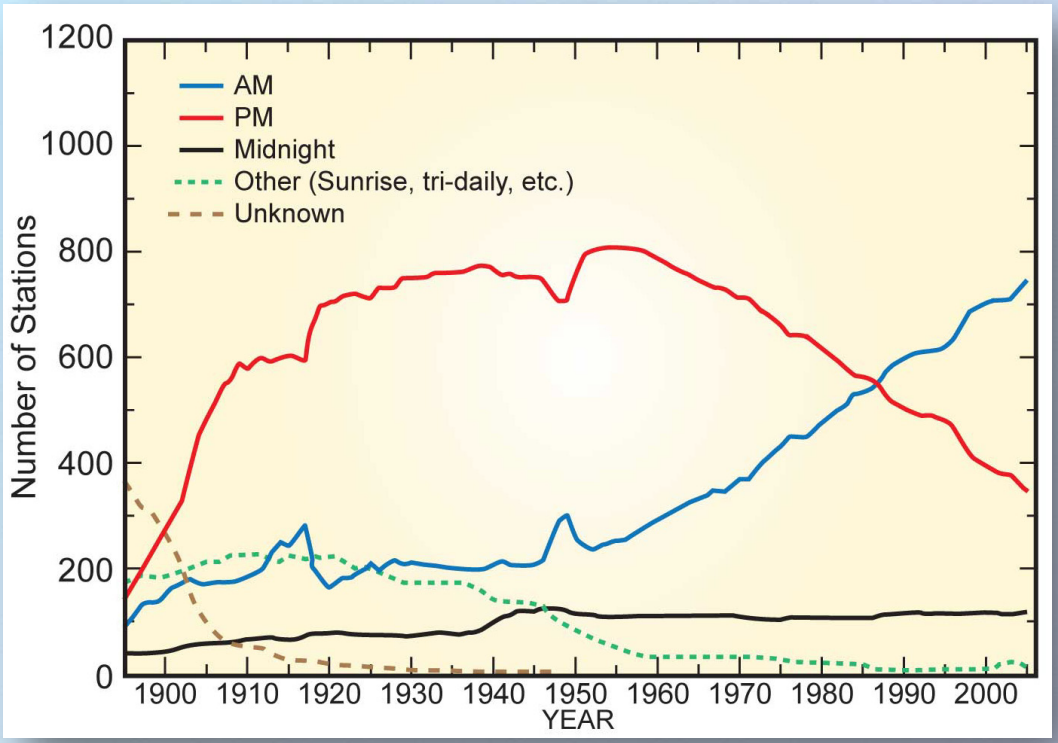


NOAA Climate Reference Network, 21st Century

Do Data Have to be Corrected?

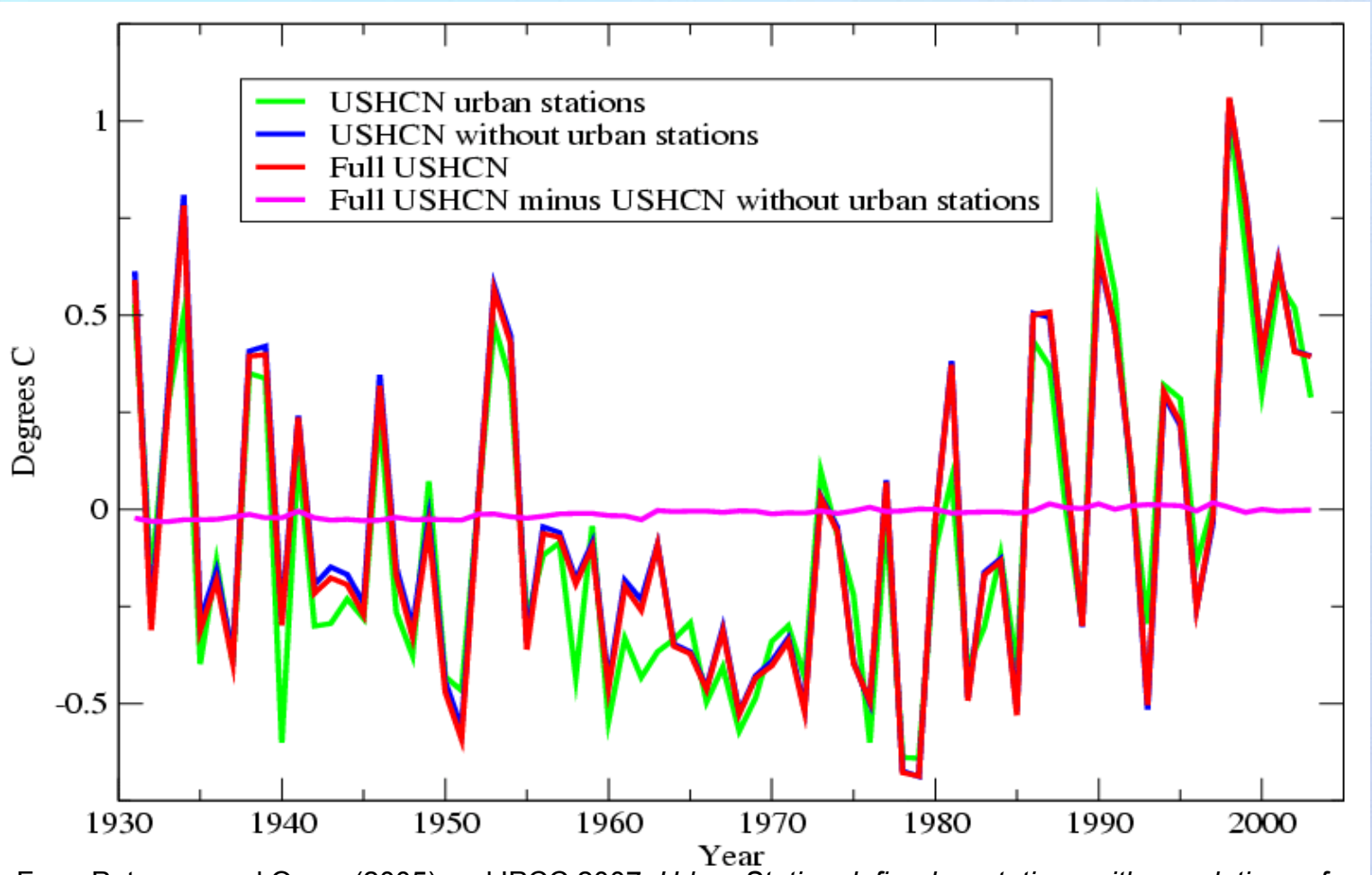
- **We correct for:**
  - Time of observation change (most significant)
  - Change in location or surroundings
  - Instrumentation change
- **Systematic changes are essential to assess:**
  - Observation times change
  - Station relocations, e.g., cities to outlying airports
  - Urbanization
- **Systematic changes are often comingled**

United States Observations



How Does Urbanization Impact the National Temperature Trend?

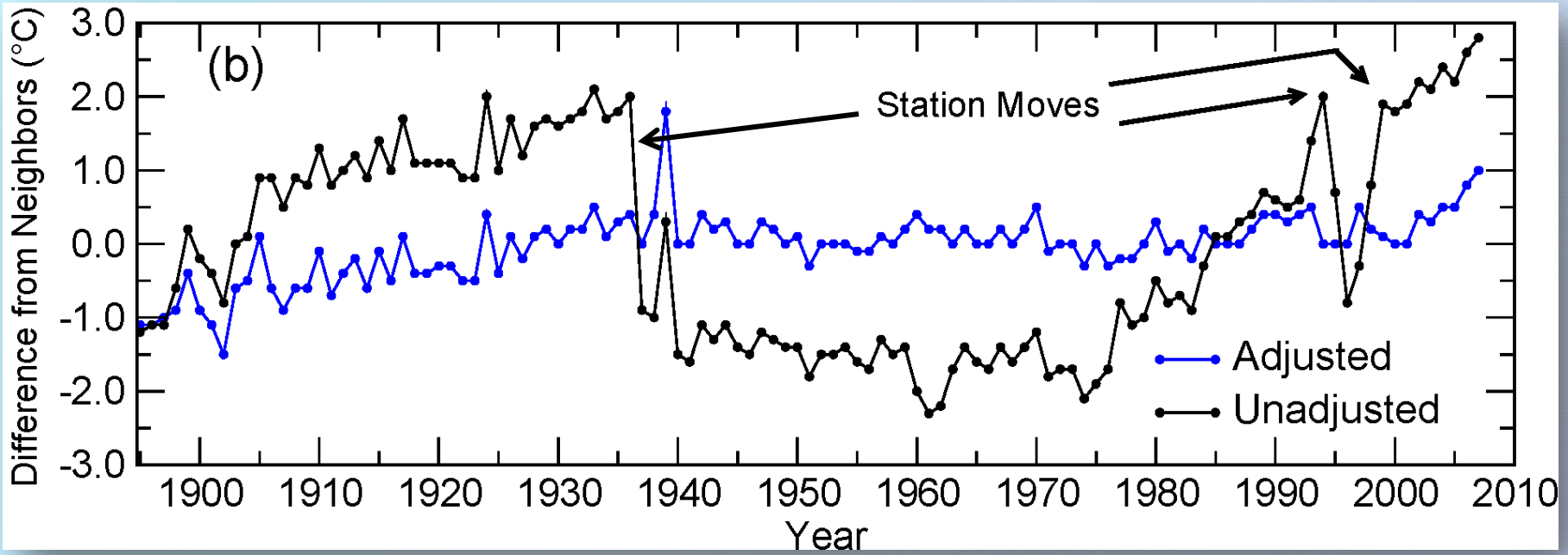
U.S. Mean Temperature Contiguous Anomaly Time Series



From Peterson and Owen (2005) and IPCC 2007. *Urban Station defined as stations with populations of over 30,000 people within 6 km of the station.*

How do we Address Changes in the Station Location and Instruments?

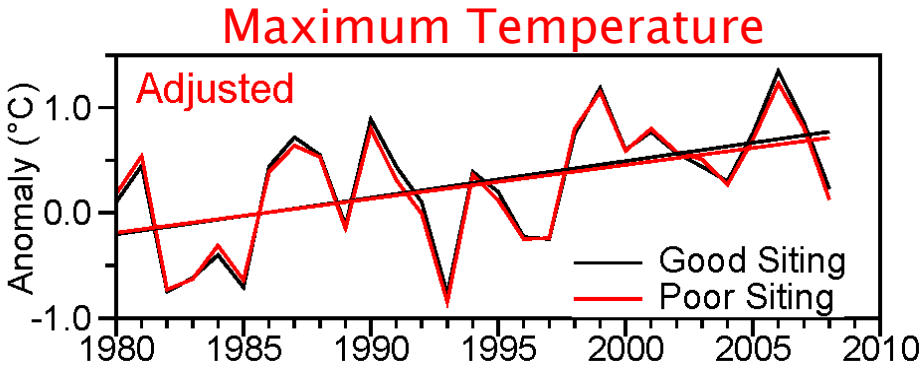
Reno, Nevada

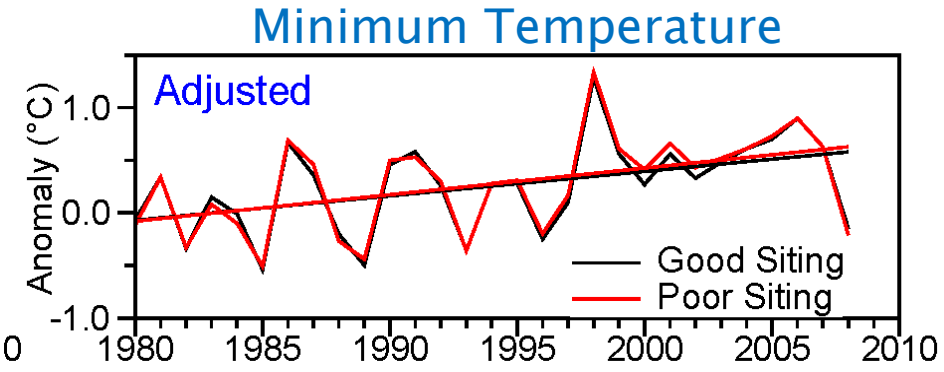


Example of the removal of the effect of instrument changes, station moves, and other unspecified influences (surface changes and other micro-enviroment) from climate record (Menne, et al., 2008)

Does Poor Station Siting Impact National Temperature Trends?

- **NOAA/NCDC compared trends from poorly-sited stations with trends from well-sited stations**
- **After adjusting for known biases related to instrumentation and observing changes:**
  - No evidence that the US temperature trend is inflated by poor siting of stations
  - Poor siting alone does not implicitly lead to significant observational errors in the trend

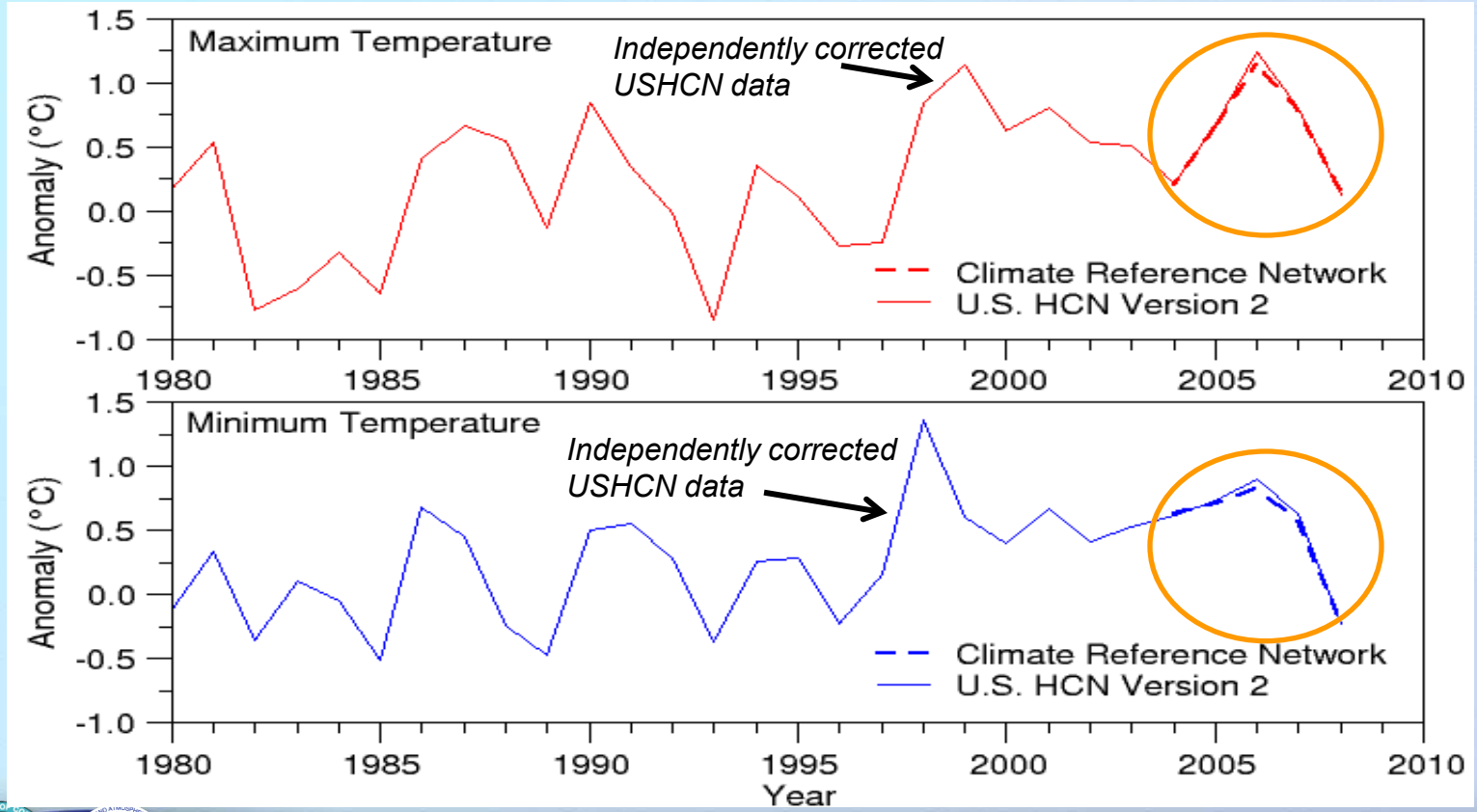




Menne, Matthew; Claude Williams; and Michael Palecki, 2010: On the Reliability of the U.S. Surface Temperature Records. Journal of Geophysical Research—Atmospheres.

The new Climate Reference Network (CRN) validates that old data are reliable

- CRN: 114 new state-of-the-art carefully sited observing stations
- Average difference between historic (U.S. HCN V2) and new network (CRN) is -0.03°C for annual maximum and minimum temperatures.

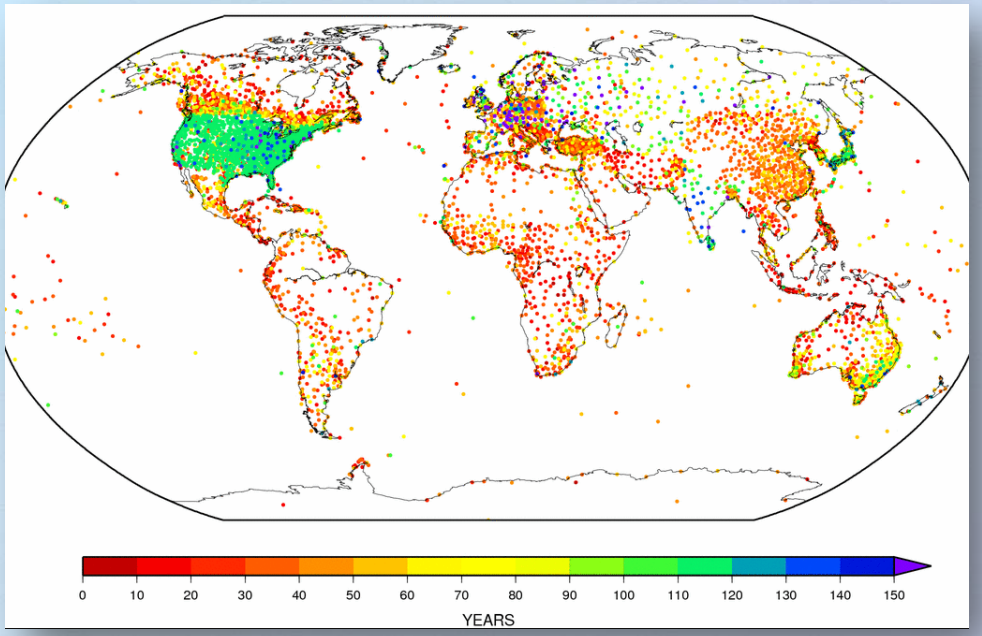


Adapted from Menne et al., 2010

NOAA's Global Temperature Estimates

GHCN-Monthly Land Surface Stations

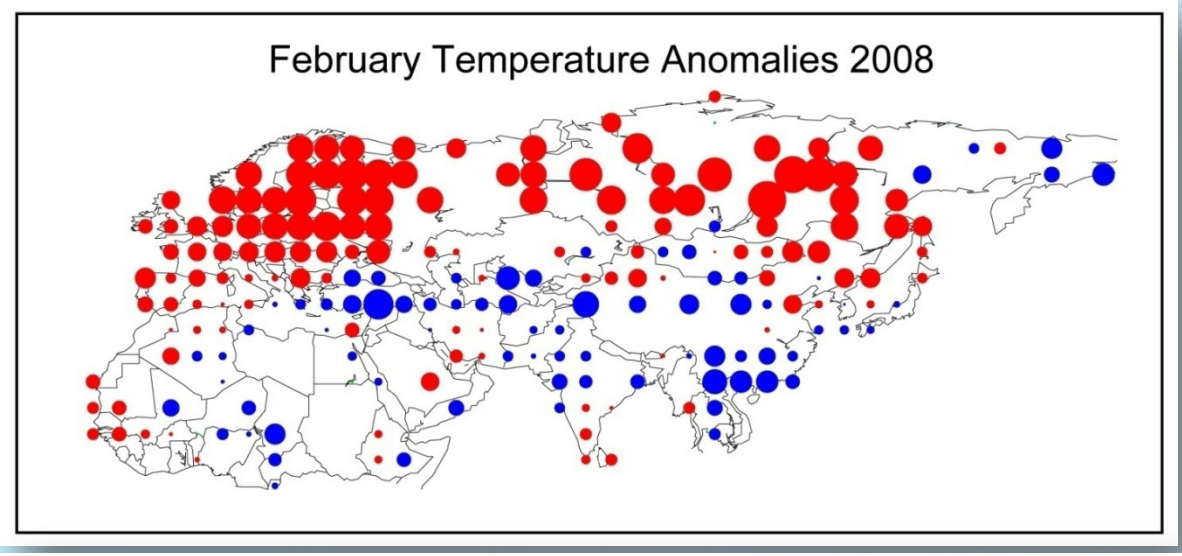
- **NOAA/NCDC monitors global land surface temperature using the Global Historical Climate Network (GHCN)**
  - Data set assembled over the past few decades
  - 7,280 stations
  - ~4,400 stations (at least 25 years of data) are used to calculate the global average temperature
- **Like the U.S. data they undergo corrections to errors in the raw data (systematic and random)**

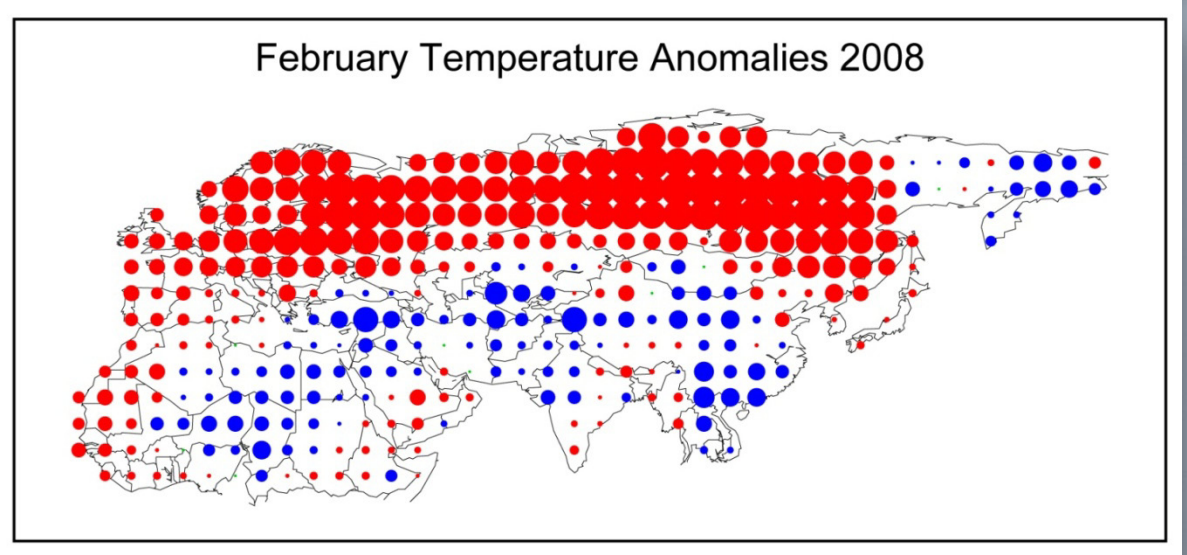


Number of years of data for each station in GHCN-Monthly mean temperature dataset

All GHCN data are available at www.ncdc.noaa.gov

Spatial Interpolation (Orthogonal Eigenvector Teleconnections) to Fill in Data Sparse Areas



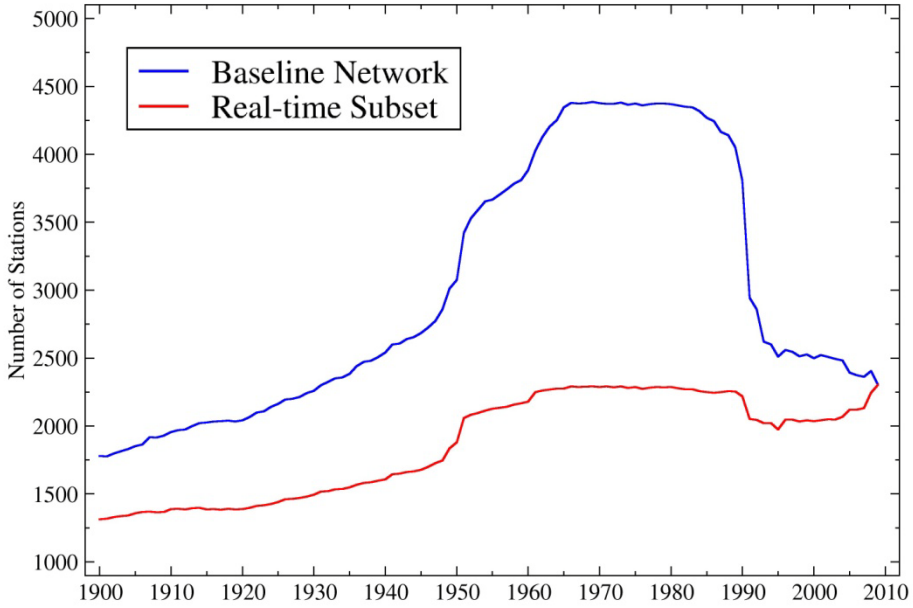


- Historical patterns of similar temperature anomalies are used to fill in missing gaps. Smith et. al., (2008)
- Ensures record reflects all areas, not just countries with good international data exchange

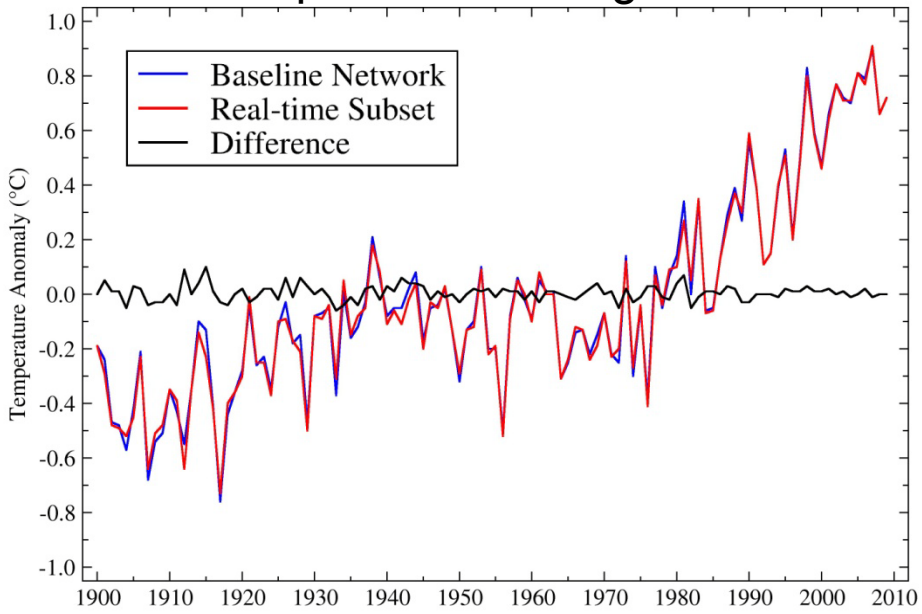
Is Decrease in Number of GHCN Stations in Recent Years a Problem?

- NCDC analyzed a subset of 2300 stations that are routinely updated
- No difference between temperature trends with full network and trends with the subset.
- Why use more stations?
  - To discern trends at finer resolution

Number of Stations Through Time

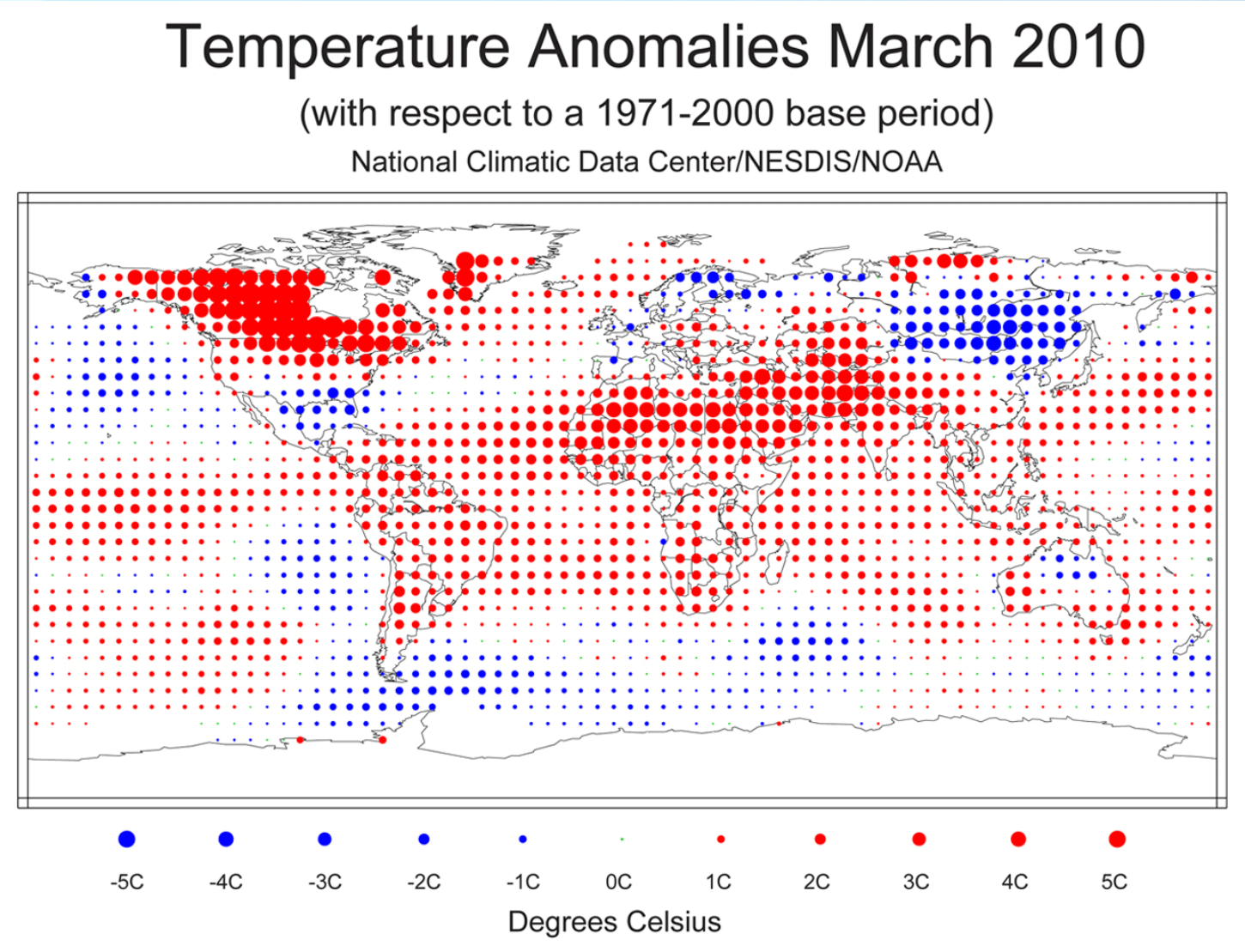


Temperature Through Time

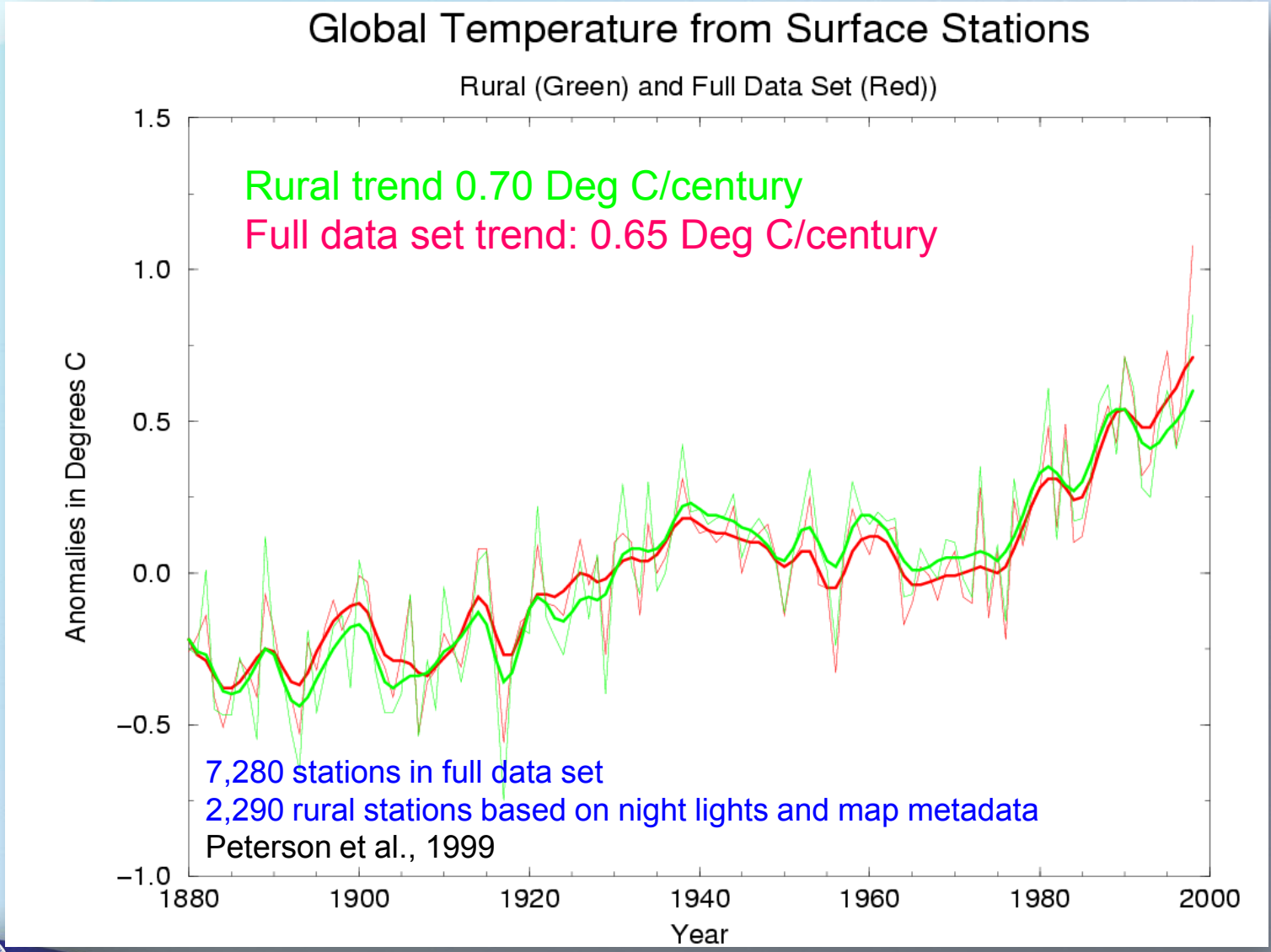


All GHCN data are available at www.ncdc.noaa.gov

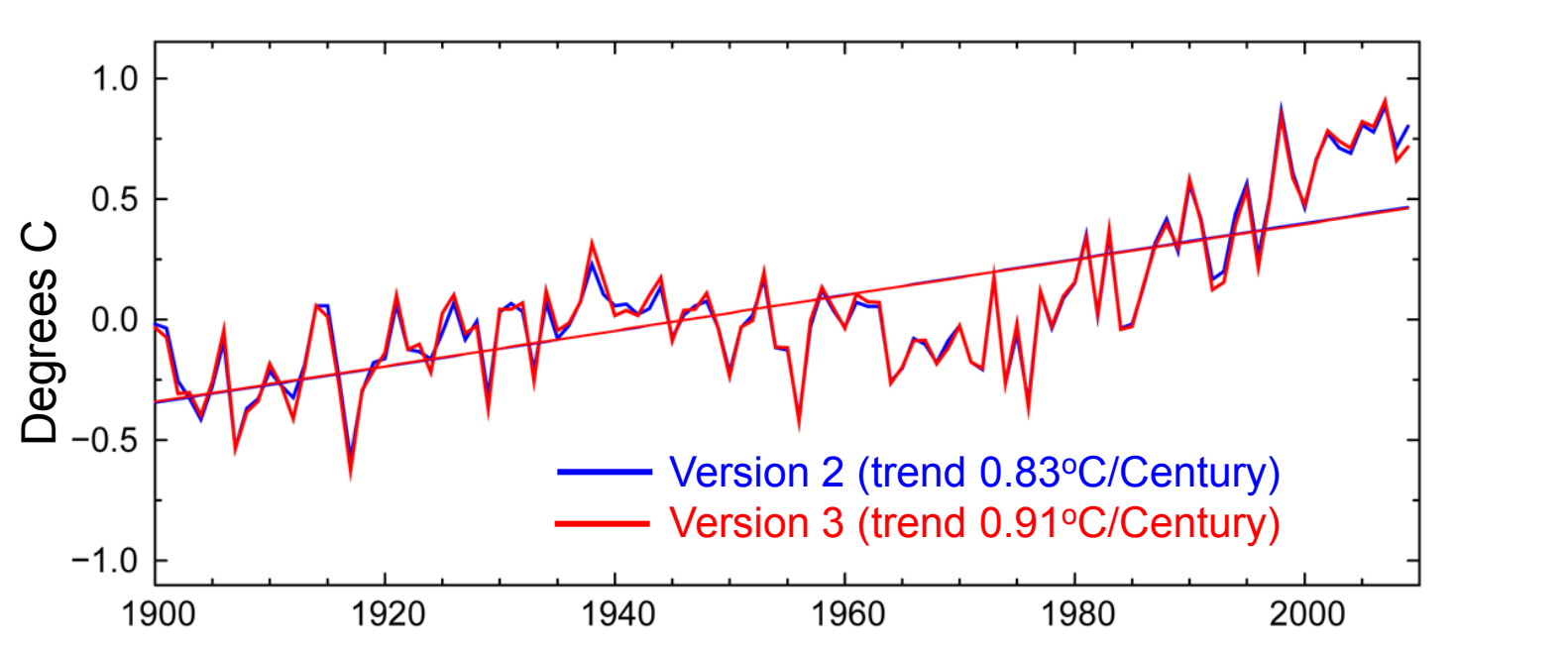
Land and Ocean Data are Blended Using Objective Methods



Does Urbanization Impact the Long-Term Global Temperature Trend?

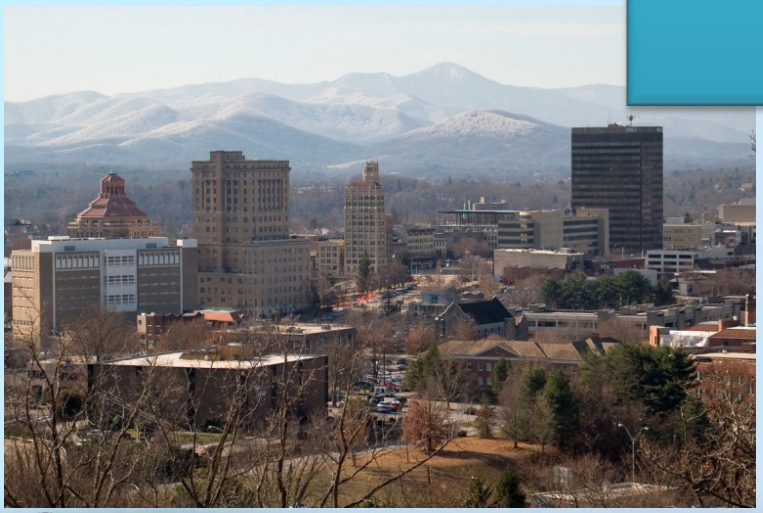


New Global (GHCN) Monthly Version 3 to Replace Version 2



- Correction methods: connected with those used in U.S. (Menne and Williams, 2009; Menne et al., 2010)
- Method inter-compared in international blind study indicated corrections are robust (Venem et al., 2010, Mestre et al., 2010)
- Confirms that global warming is robust

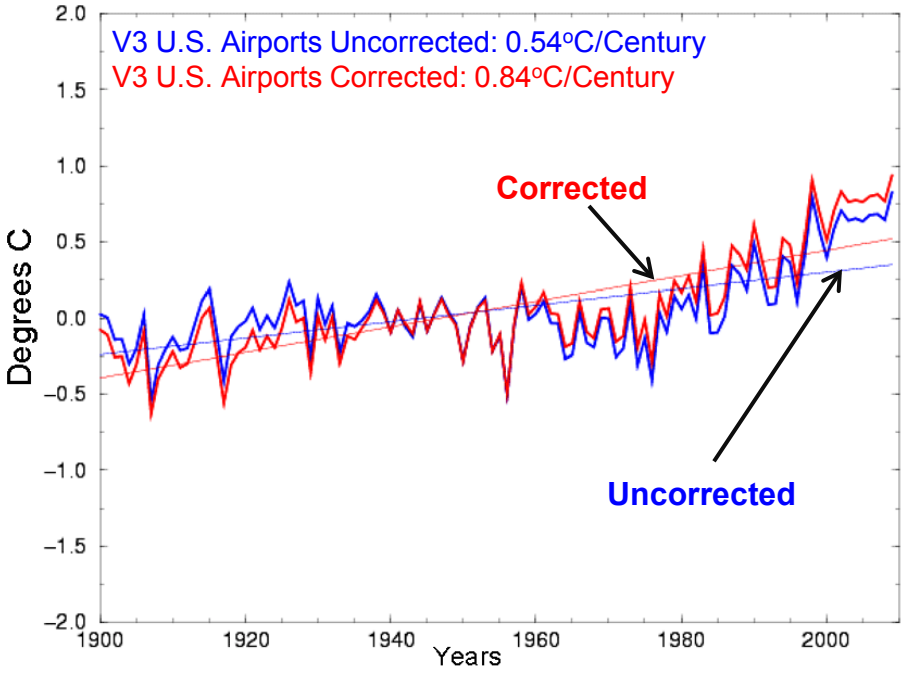
Mid 21st Century Systematic Moves of City Weather Stations to Airport Locations



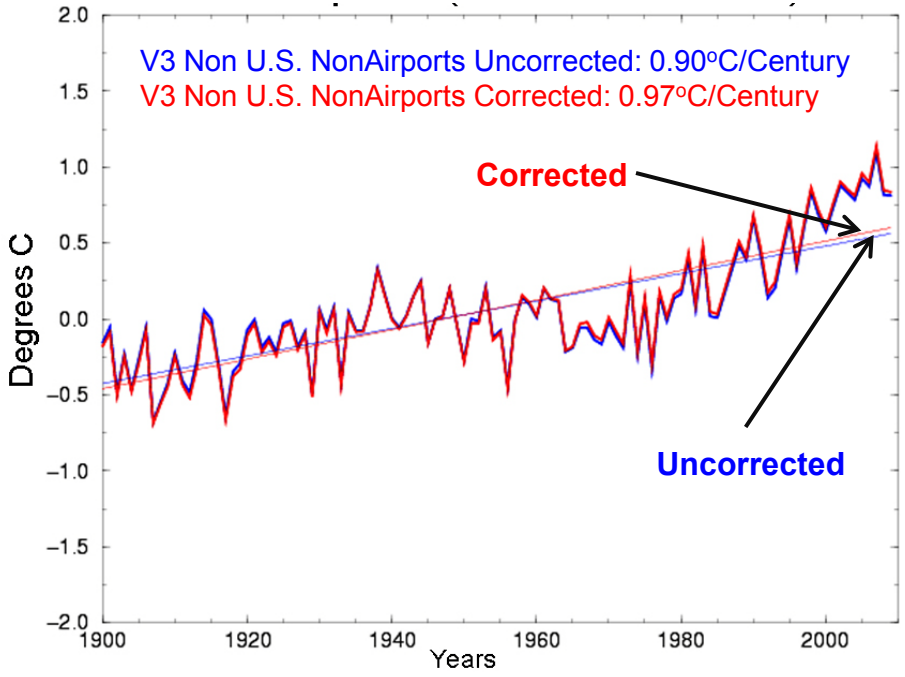
Airport versus Non-Airport Temperature Corrections

(Preliminary Results)

Airports (GHCN-Monthly Version 3)



Non-Airports (GHCN-Monthly Version 3)

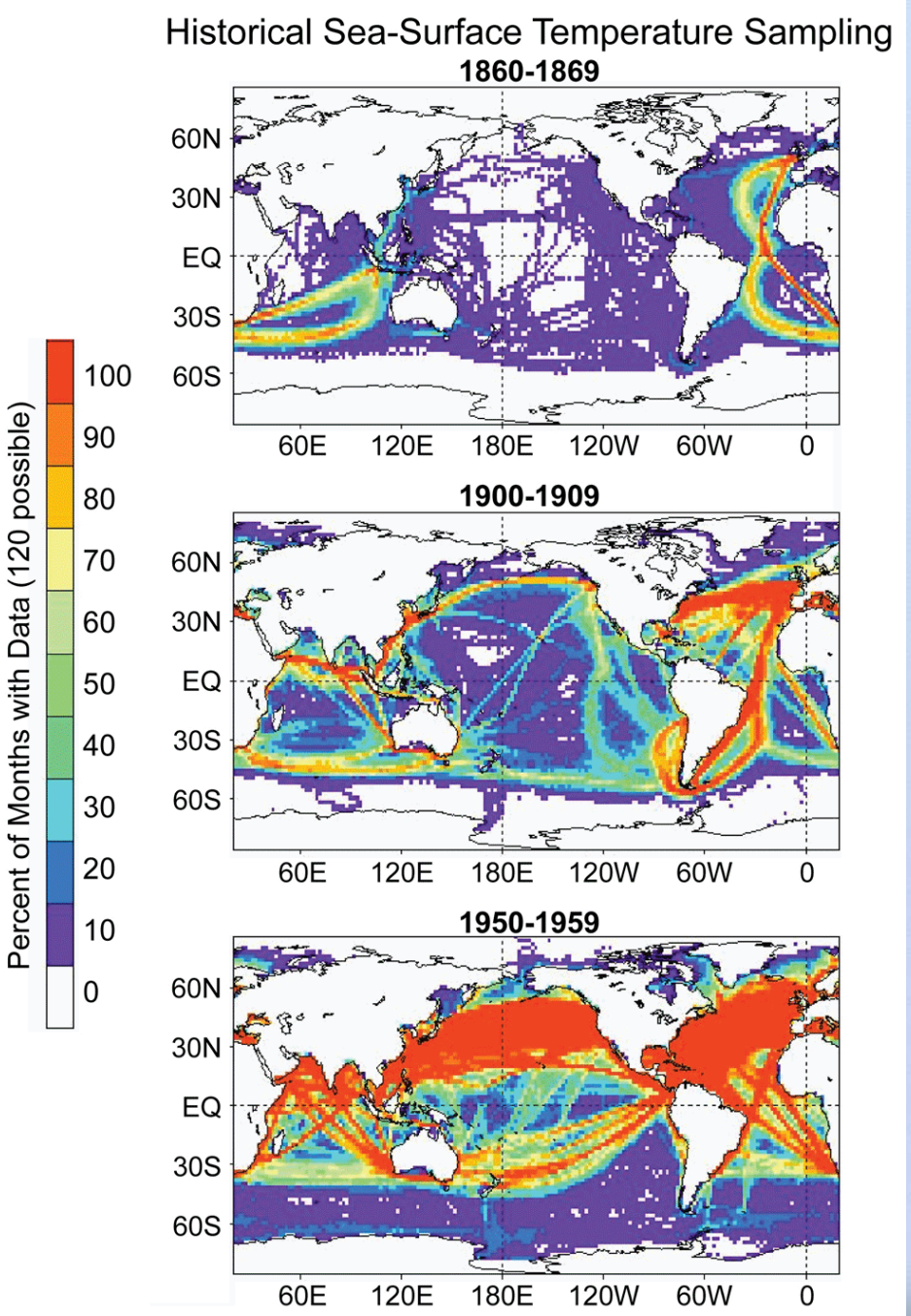


Preliminary Results Related to the Effects of Airport Relocations

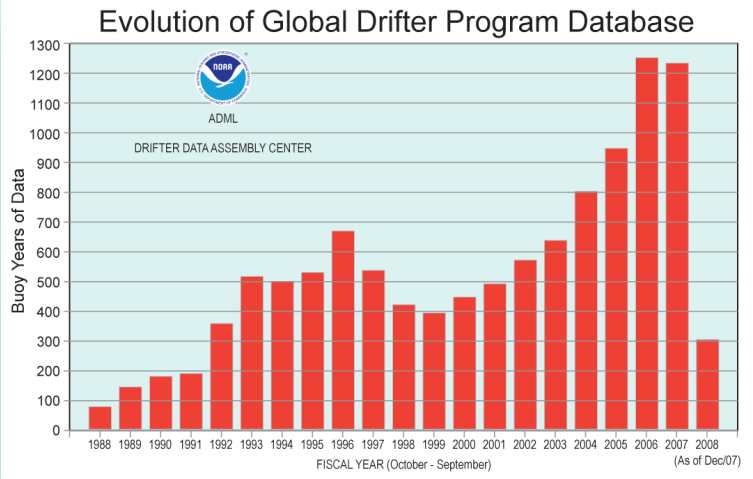
Relatively Many City to Airport Relocations			
1920-1980	Number of Stations	Raw Data	Corrected Data
Airports	951	-0.3°C/Century	0.0°C/Century
Others	2060	0.0°C/Century	0.0°C/Century

Historic Sea Surface Temperature *in situ* sampling density

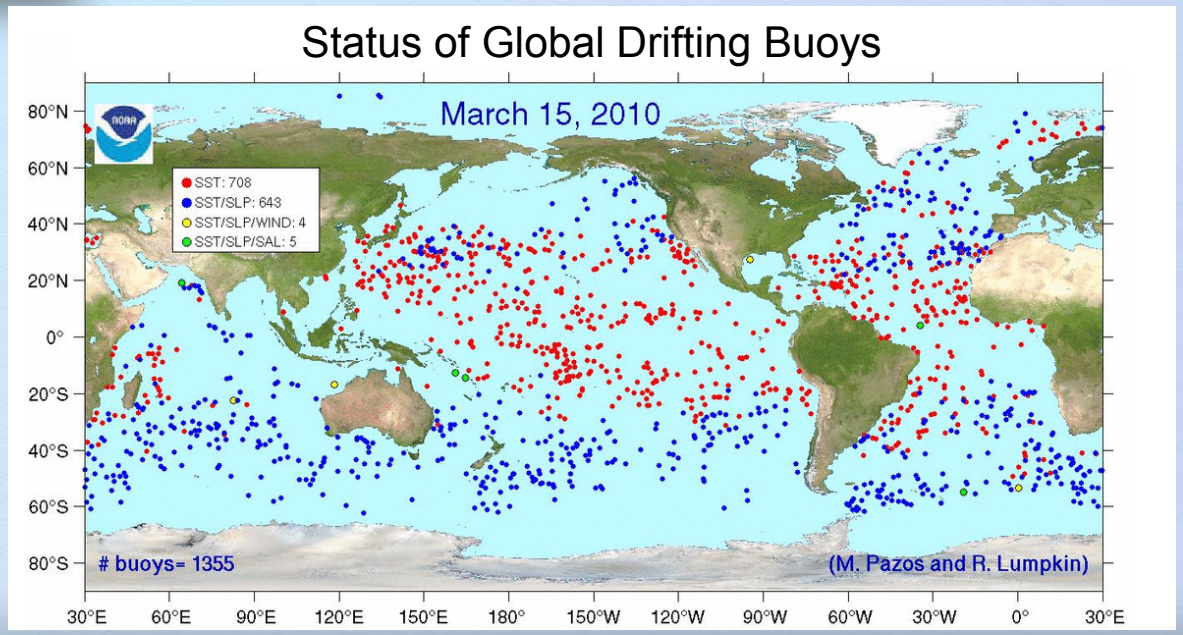
- Includes only areas with at least 1 observation/month
- Sampling changes related to century trends are at least 10 times smaller than observed global warming trends. (Karl et. al., 1993)



Corrections Related to Changes in Observing Method



- Since the late 1980s, the number of drifting buoys sending back SST data has increased dramatically.
- Recent analysis indicates buoys read a little colder than shipboard measurements



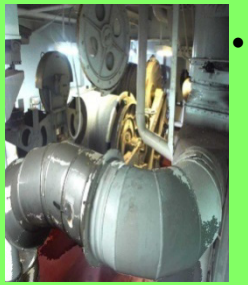
Historical Changes in Ocean Temperature Measurements (in situ)

BUCKETS. Lose heat via evaporation as they are hauled on deck

- Heat lost depends on the material
- Wooden buckets effectively insulated
- Canvas buckets lose a lot of heat
- Modern insulated buckets often made of rubber

ENGINE ROOM INTAKE

- Measurements made in ships' engine rooms
- They use water taken in to cool the engines
- Water warmed by engines producing warm bias

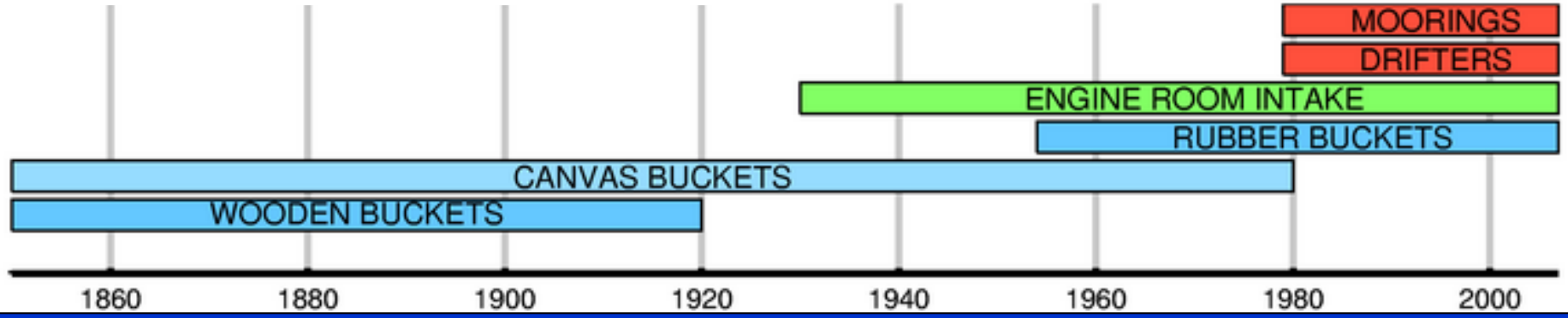


- Engine room intake produces warm bias and buckets produce cool bias- they tend to cancel

BUOYS

- Moored and drifting buoys
- Make regular, consistent observations

- Typically cold relative to ships

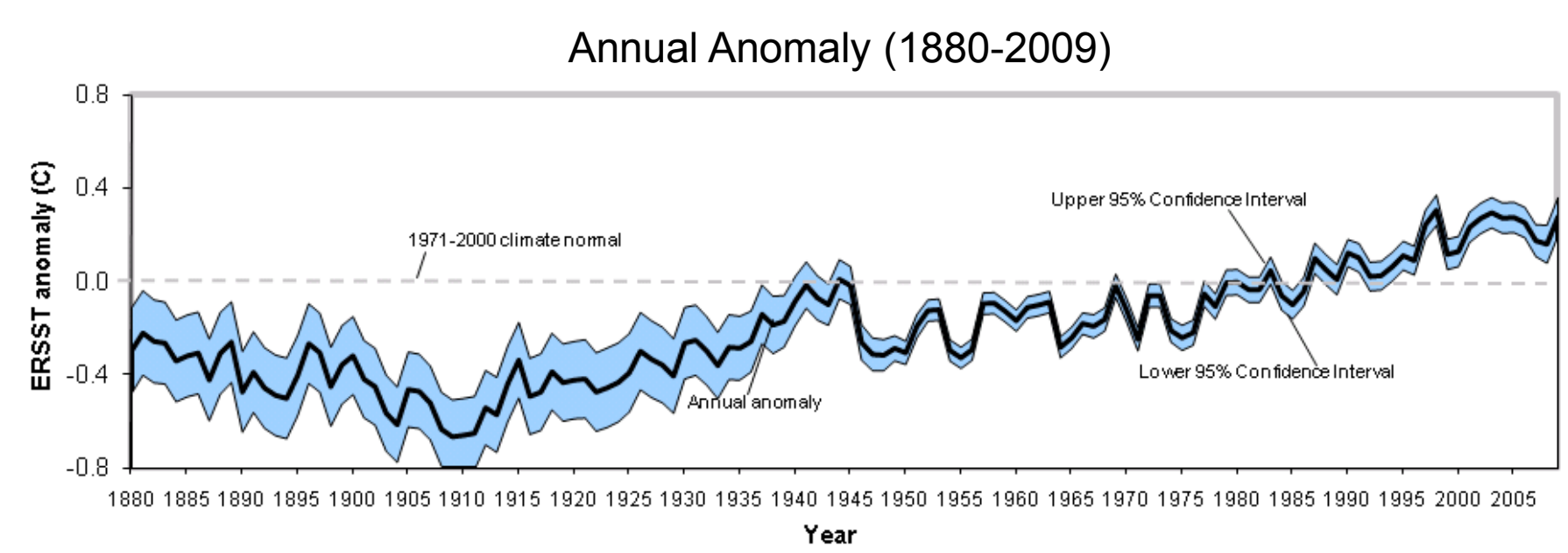


Adapted from: UK Met Office: Kennedy, Smith, Rayner & Parker

Uncertainty in Estimates of NOAA/NCDC Ocean Temperature Anomalies

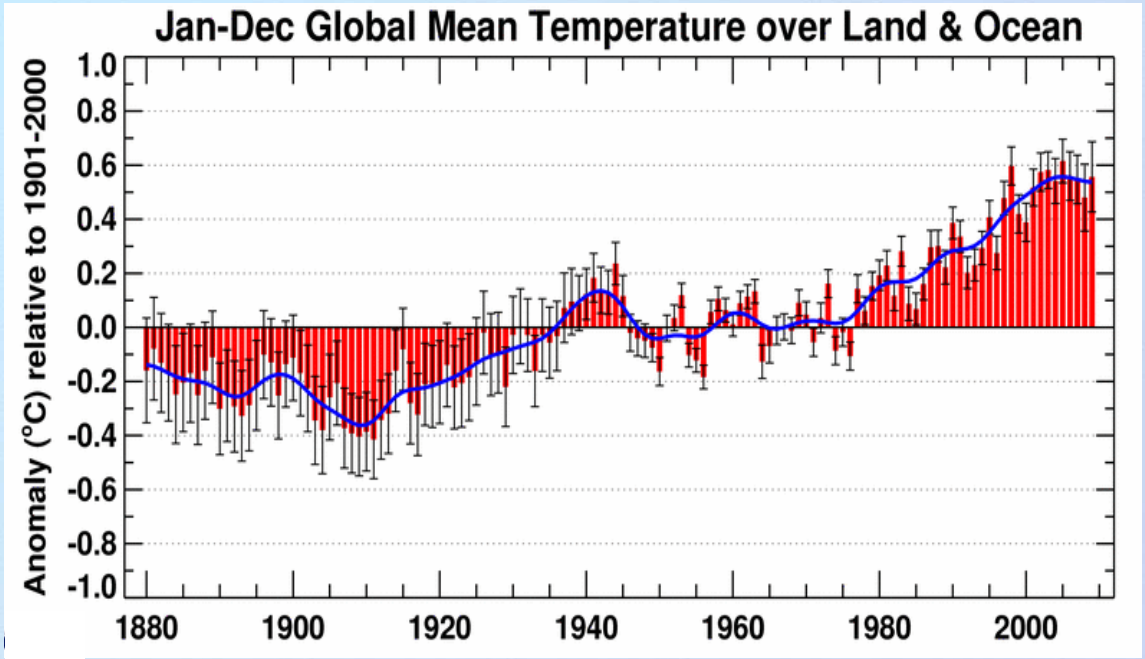
- From in situ data sources only
- Relative to 1971-2000 baseline
- From 60°N to 60°S

- Uncertainty based on
  - Observing methods
  - Sampling changes



How Large is the Uncertainty in Global Temperatures?

- Uncertainty in the global temperature is due to sampling, instrumental, and platform changes
- Uncertainties make it difficult to say with complete confidence that 2005 was warmer than 1998, for example.



- Uncertainties do not bring into question the century-scale and multi-decadal warming trend observed since 1880.

Other Indicators of Climate Change:

Lake/river thawing

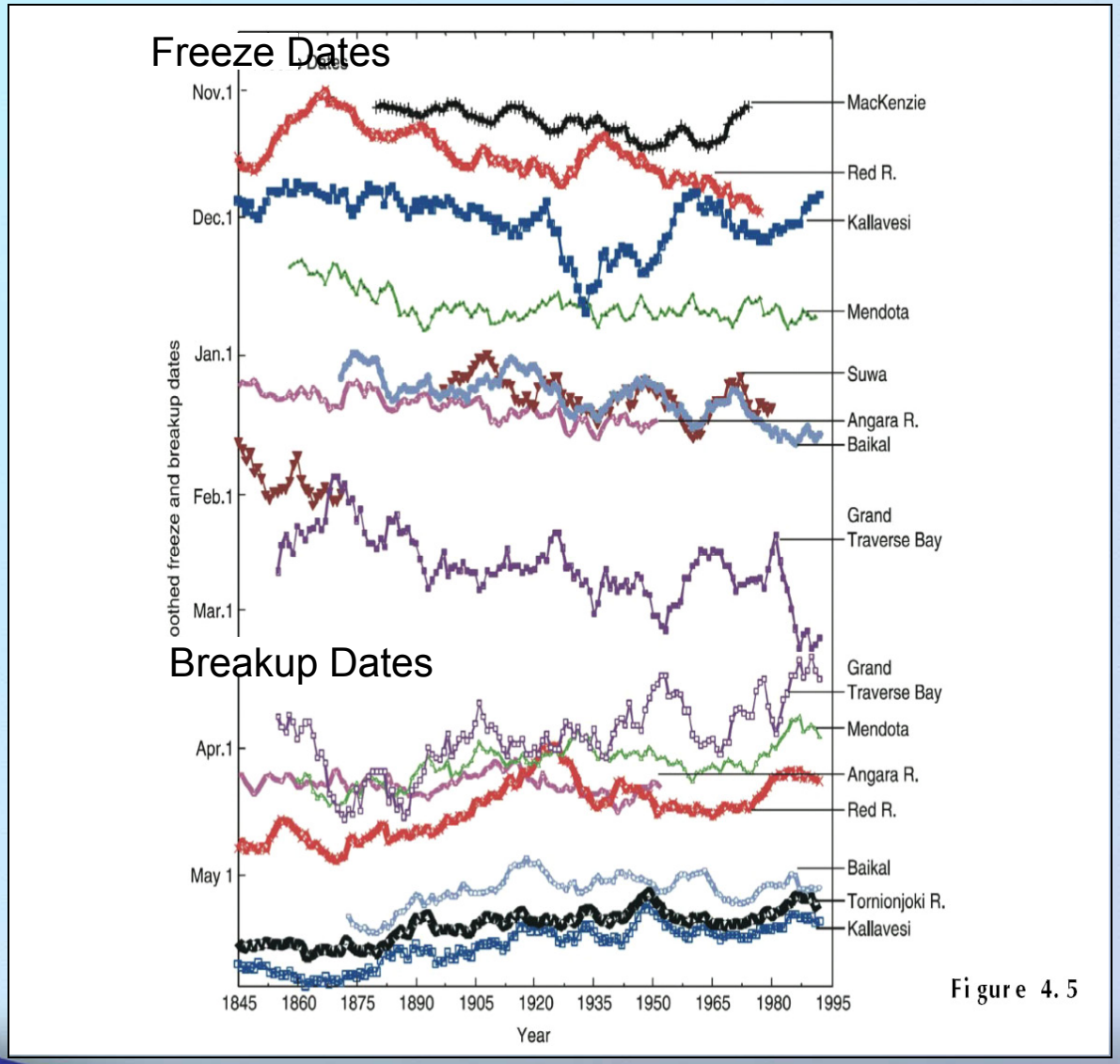
Glacial ice volume

Arctic sea ice

Ocean heat content

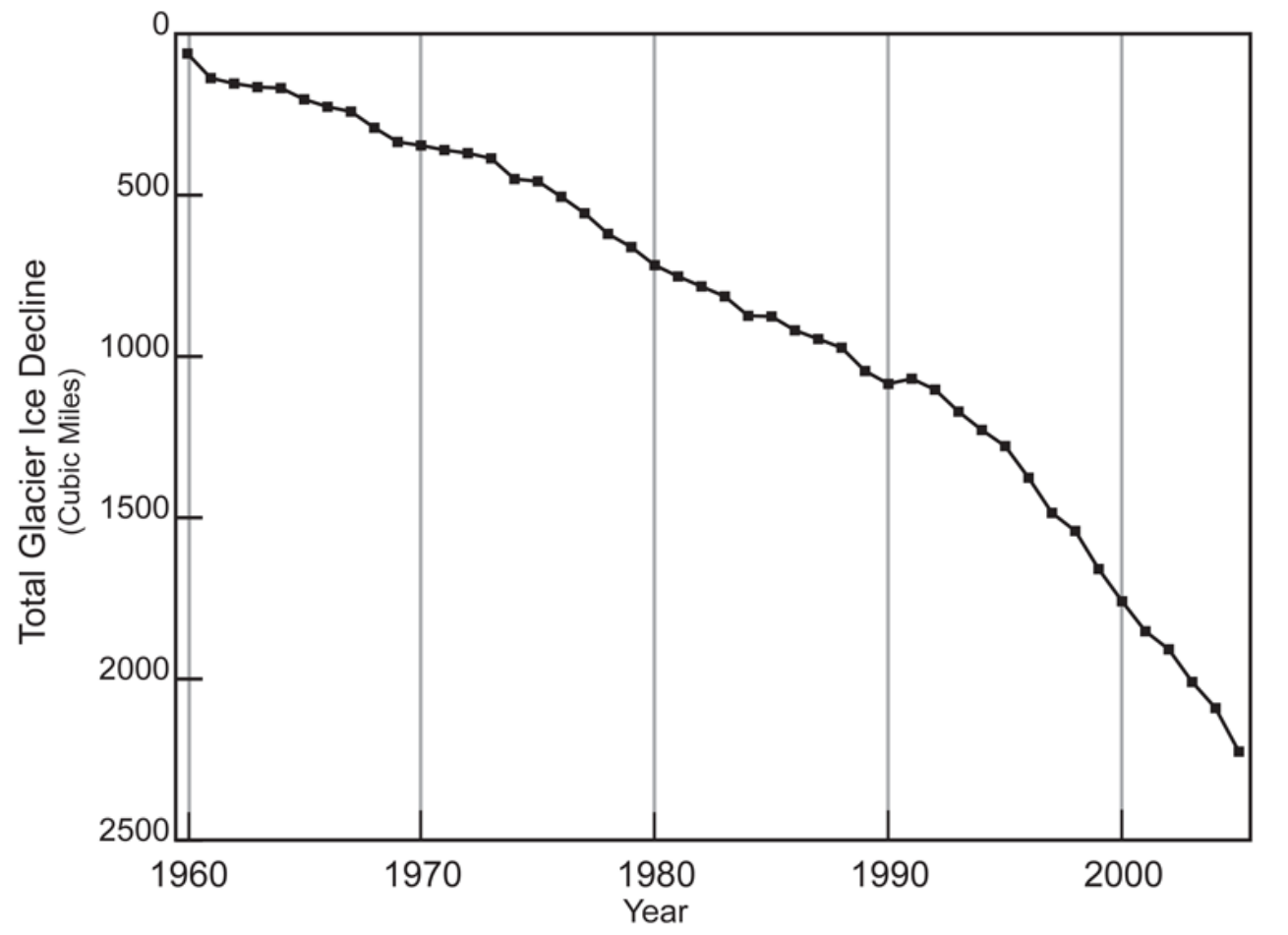
Plants and animal responses

Lakes and Rivers are Freezing Later and Thawing Earlier



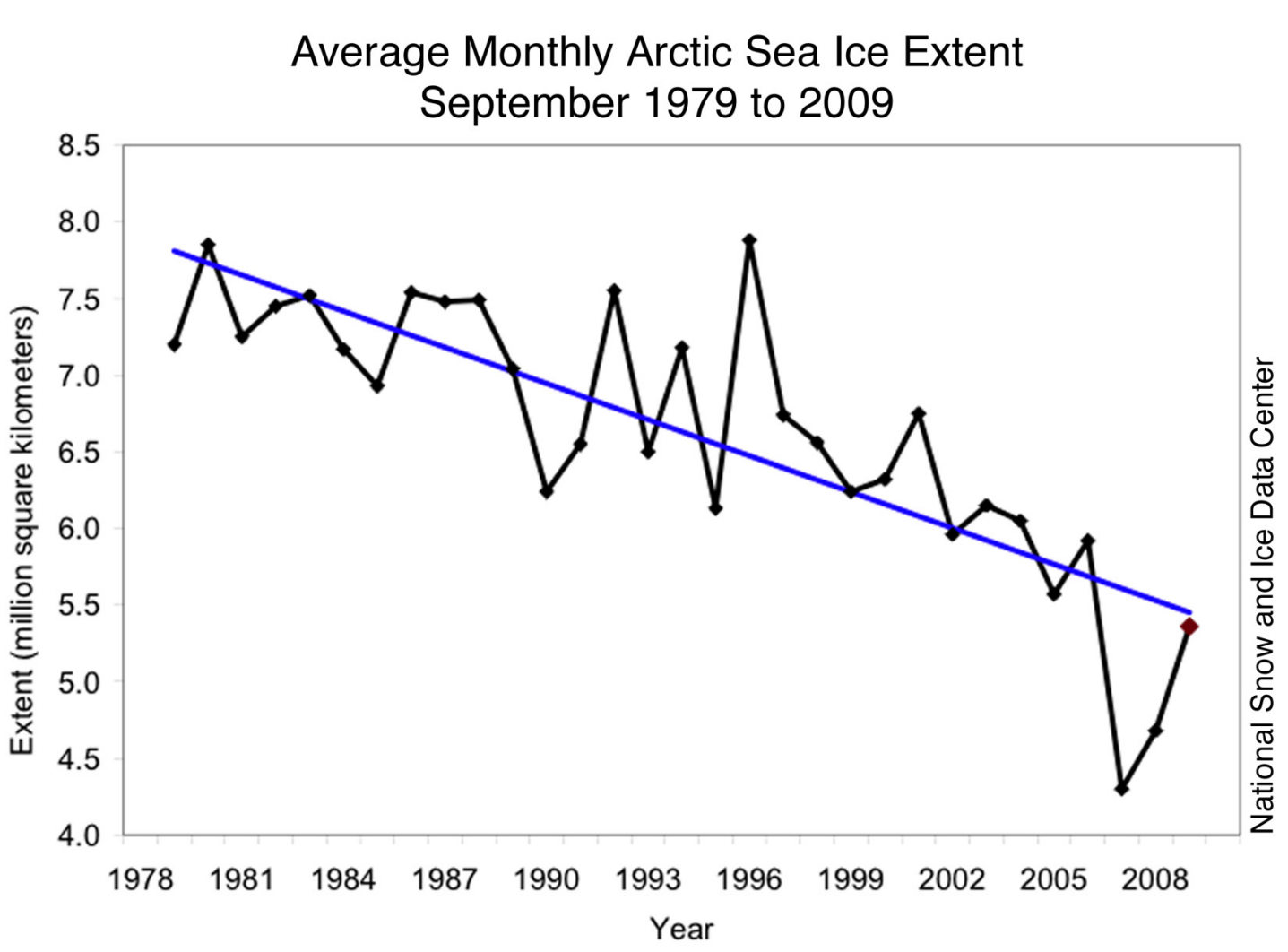
From IPCC, 2007

Glacial Ice Volume is Declining Over the Globe

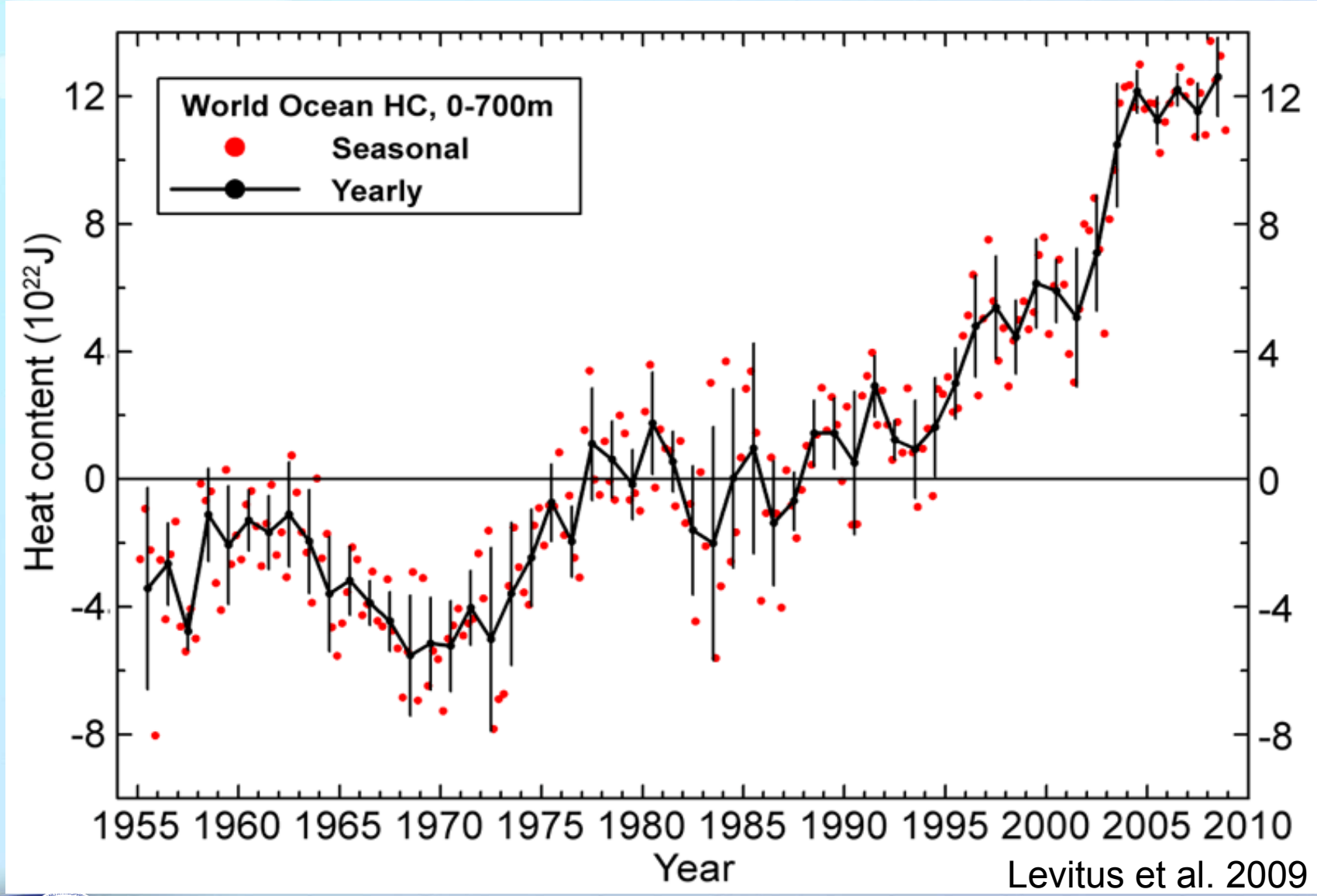


From the GCCI Report, 2009

Arctic Sea-Ice is Shrinking

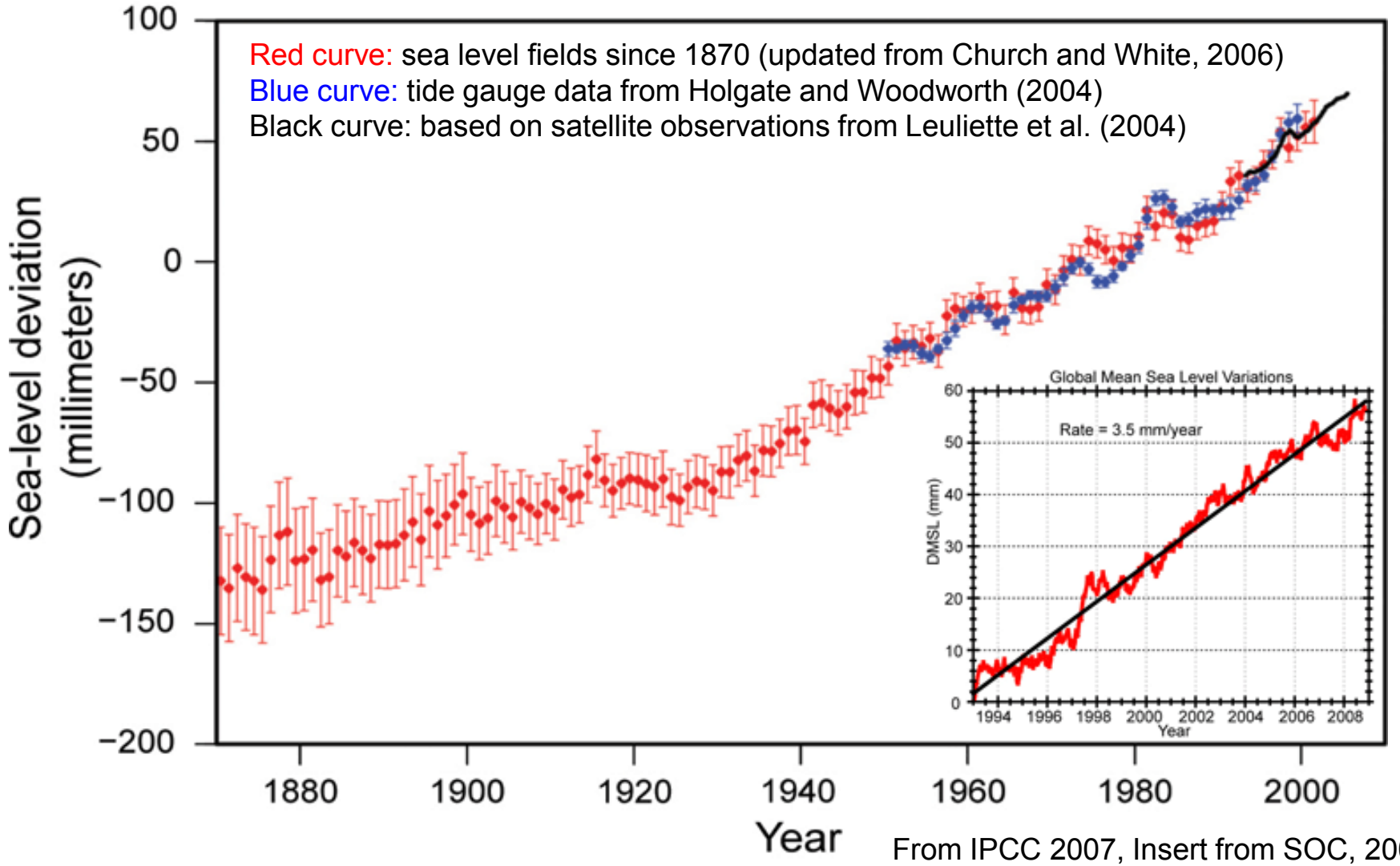


Ocean Heat Content is Increasing



Levitus et al. 2009

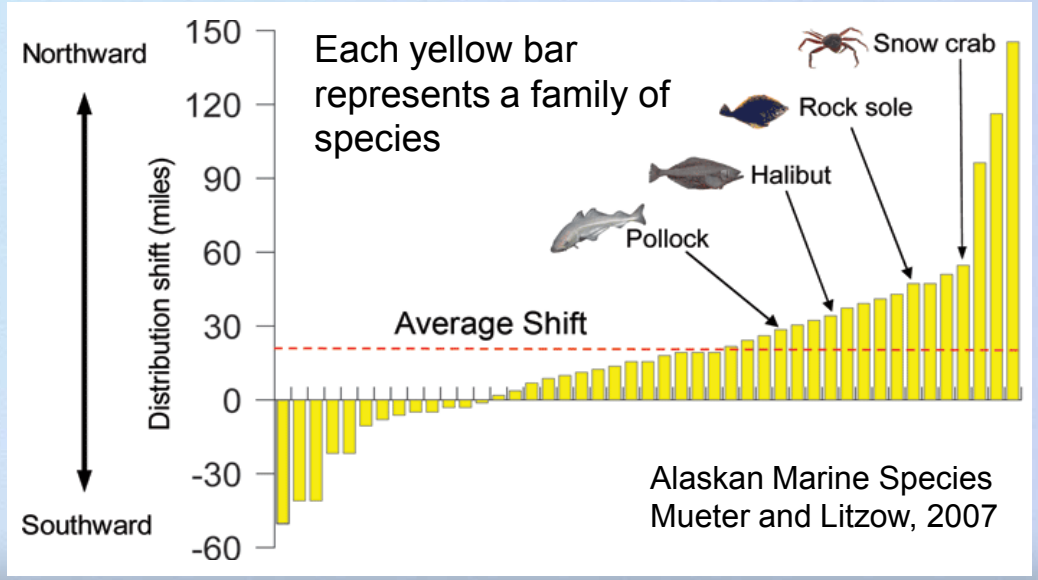
Sea-Level is Rising



From IPCC 2007, Insert from SOC, 2009

Plants and Animals are Acting as if it is Warming

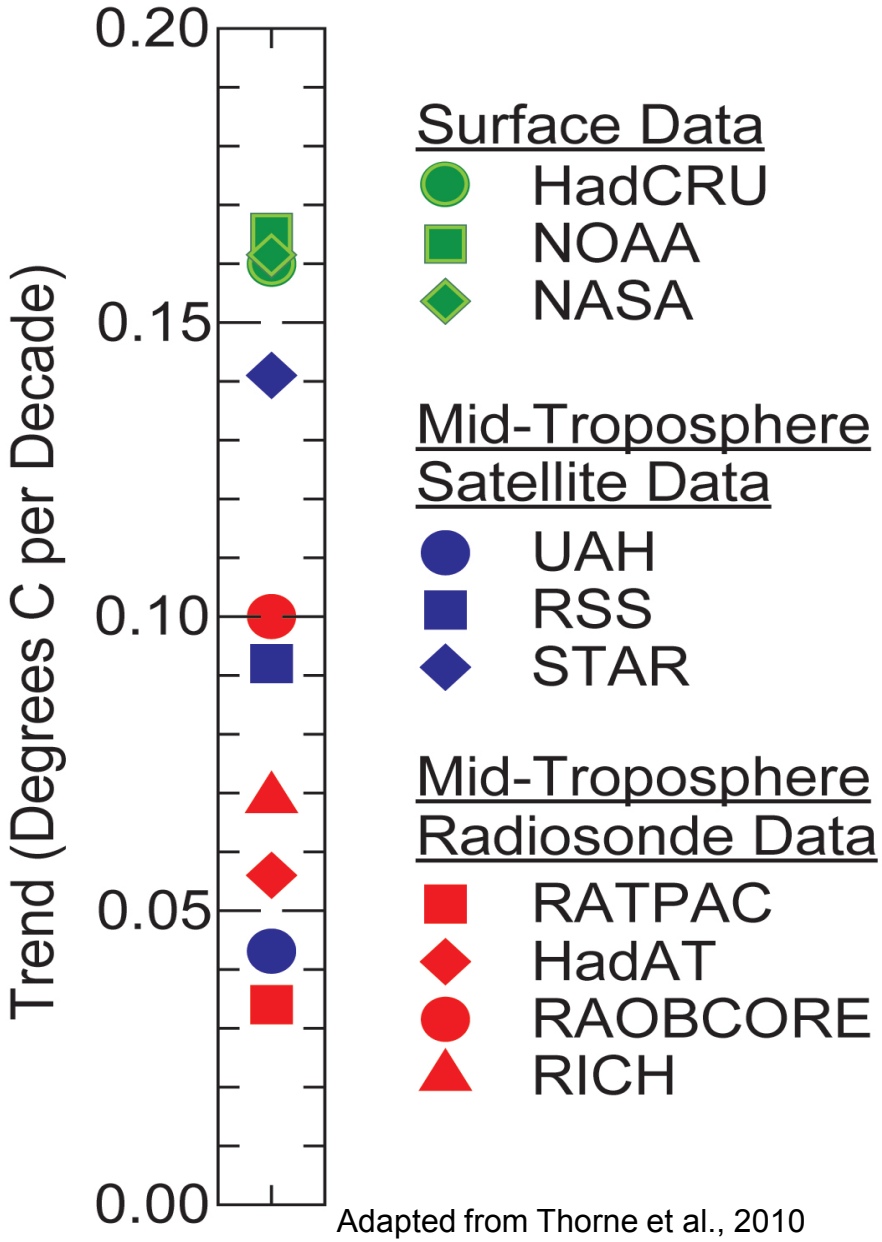
- **Plants are blooming 1-3 days/decade earlier**
  - "Altered timing of spring events has been reported for a broad multitude of species and locations" (IPCC 2007).
- **Animals species are moving poleward**
  - "Many studies of species abundances and distributions corroborate predicted systematic shifts related to changes in climatic regimes" (IPCC 2007)



From GCCI Report

Temperature Trends

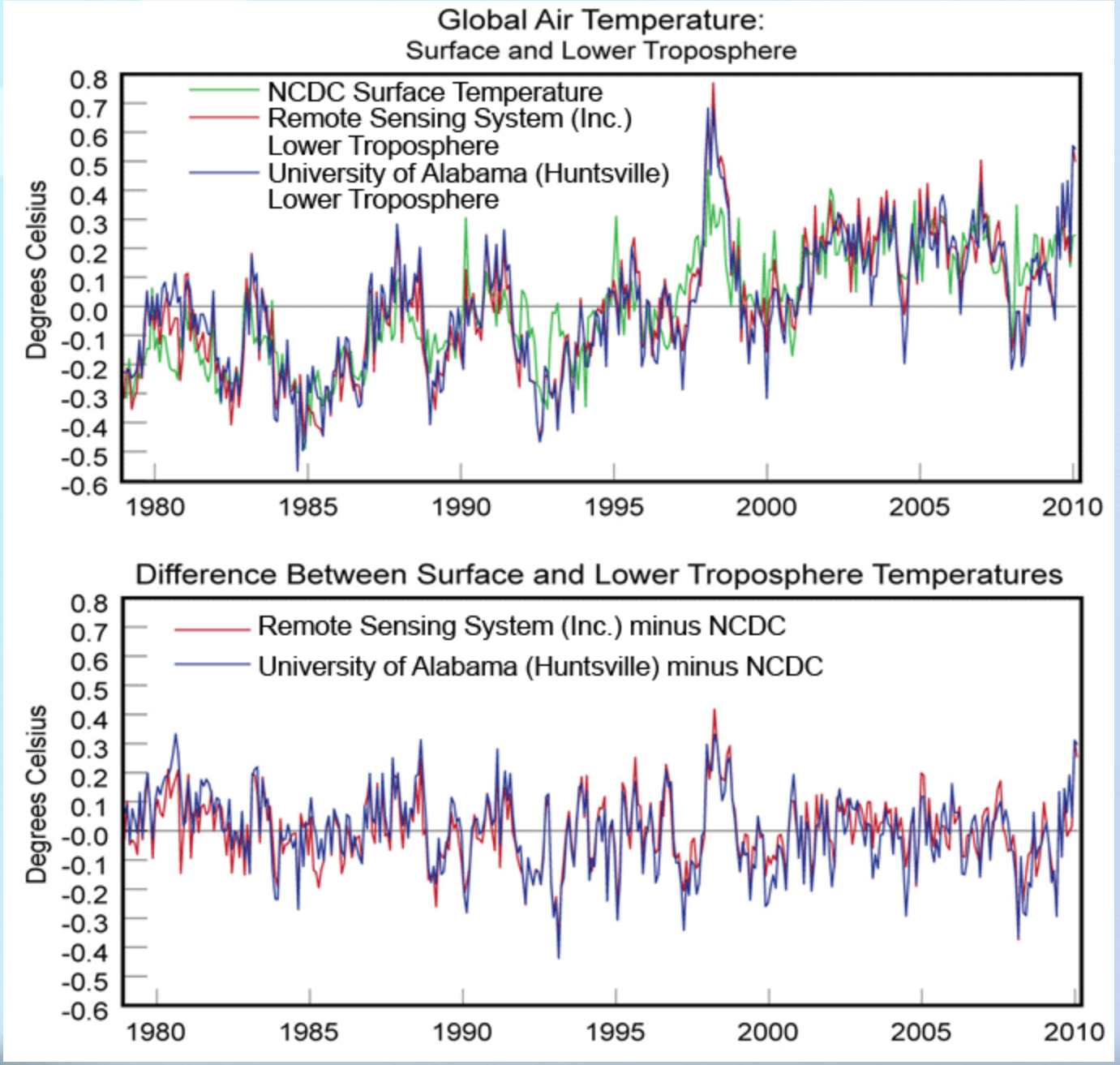
From 1979 through 2008



Adapted from Thorne et al., 2010

Larger Uncertainty Associated with Trends of Satellite Observations, and Balloons

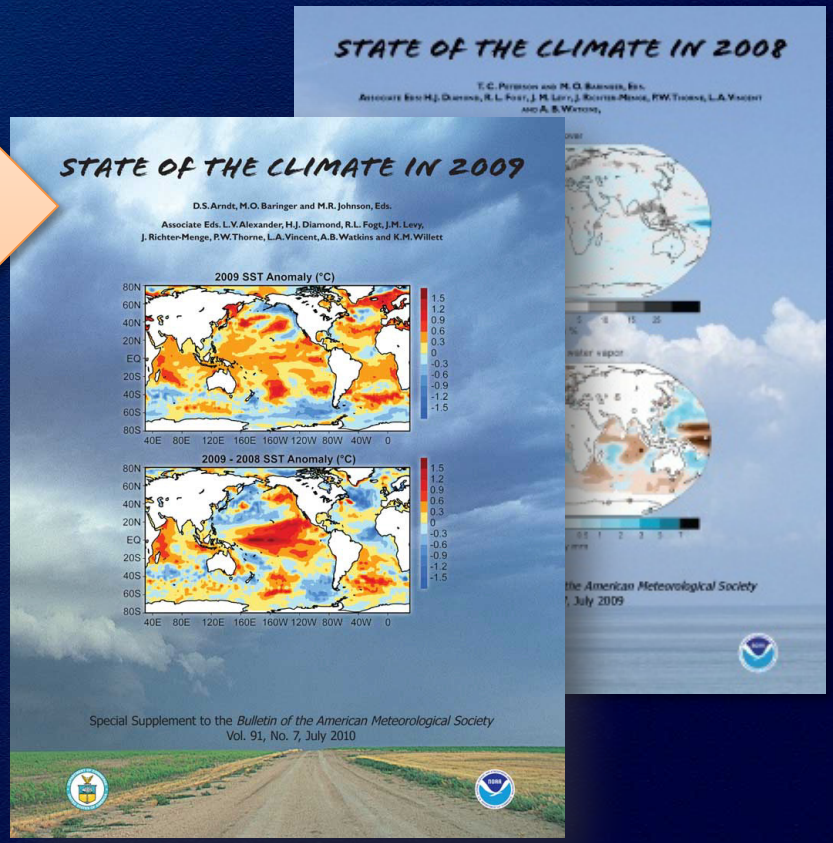
- **Surface temperature data agree very well**
  - With very different approaches to address time-dependent errors
- **Upper air data vary considerably**
  - Both satellite and radiosonde balloon data
  - A measure of structural uncertainty


Global Air Temperature:
Surface and Lower Troposphere
NCDC Surface Temperature
Remote Sensing System (Inc.)
Lower Troposphere
University of Alabama (Huntsville)
Lower Troposphere
Degrees Celsius
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1980
1985
1990
1995
2000
2005
2010
Difference Between Surface and Lower Troposphere Temperatures
Remote Sensing System (Inc.) minus NCDC
University of Alabama (Huntsville) minus NCDC
Degrees Celsius
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1980
1985
1990
1995
2000
2005
2010

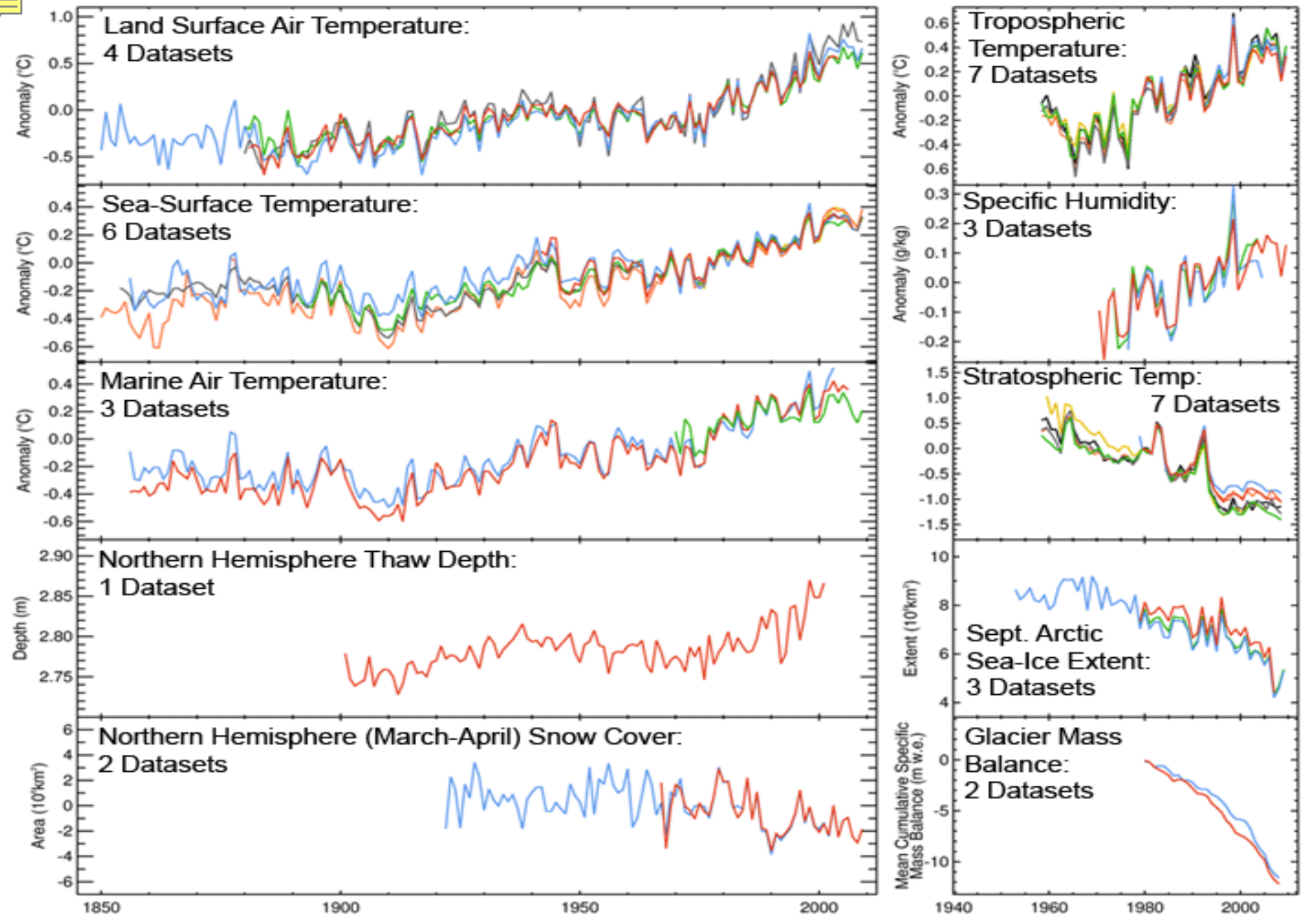
Please see the 2009 State of the Climate Report in July for more information:

http://www.ncdc.noaa.gov/bams-state-of-the-climate

2009 Report coming **July 2010**

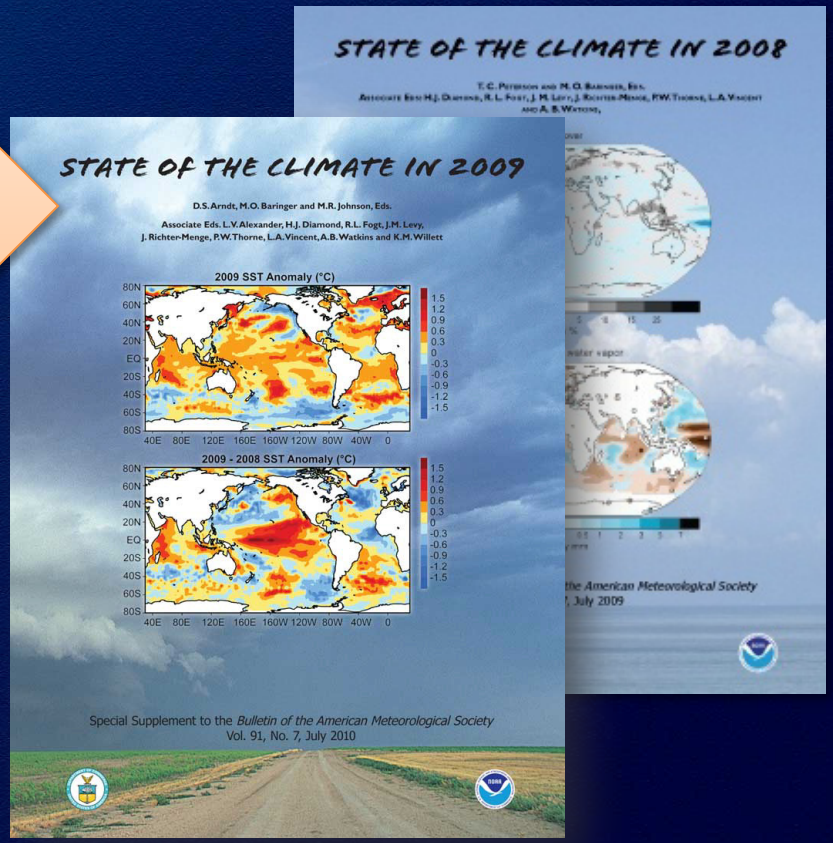


See previews on next slide


Land Surface Air Temperature:
4 Datasets
Anomaly (°C)
Sea-Surface Temperature:
6 Datasets
Anomaly (°C)
Marine Air Temperature:
3 Datasets
Anomaly (°C)
Northern Hemisphere Thaw Depth:
1 Dataset
Depth (m)
Northern Hemisphere (March-April) Snow Cover:
2 Datasets
Area (10⁶km²)
1850
1900
1950
2000
Tropospheric Temperature:
7 Datasets
Anomaly (°C)
Specific Humidity:
3 Datasets
Anomaly (g/kg)
Stratospheric Temp:
7 Datasets
Sept. Arctic Sea-Ice Extent:
3 Datasets
Extent (10⁶km²)
Glacier Mass Balance:
2 Datasets
Mean Cumulative Specific Mass Balance (m w.e.)
1940
1960
1980
2000

Thank you

2009 Report coming **July 2010**

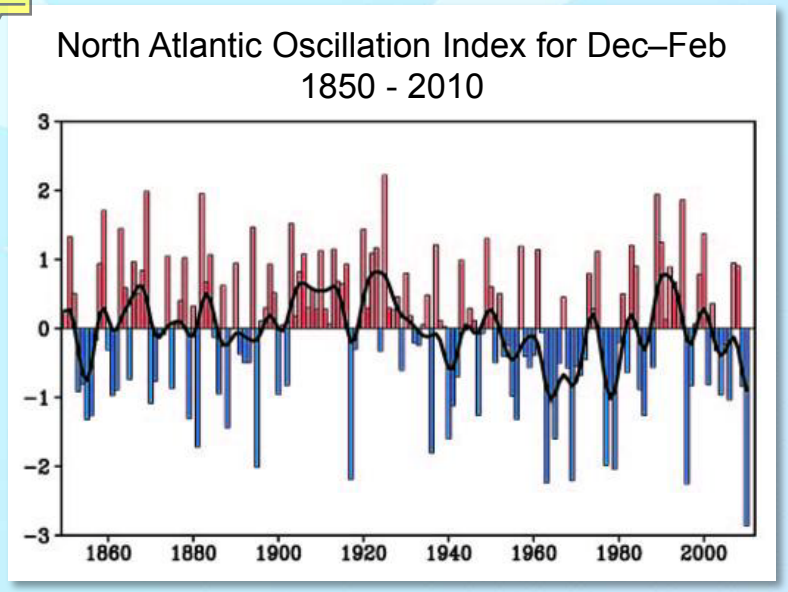


Questions?

BACK UP SLIDES

Preliminary Results Related to the Effects of Airport Relocations

Relatively Few City to Airport Relocations			
1980-2010	Number of Stations	Raw Data	Corrected Data
Airports	259	3.3°C/Century	3.1°C/Century
Others	259	3.0°C/Century	3.8°C/Century



Explaining Record Snows of Winter 2009/2010

NOAA El Nino Index