

# The need for a Climate Observing System

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OR:

How I spent my summer vacation  
working on:

# The Presidential Climate Research Initiative

Special thanks to Tom Karl and Tom Spence



# We do NOT have an adequate Climate Observing System!

Instead we rely on an eclectic mix of observations taken for other purposes. But we can not create an observing system just for Climate!

Therefore observations **MUST** serve multiple purposes.

Observations justified (and paid for) primarily for weather or seasonal-to-interannual prediction must serve other purposes too.

With a little more care, they can serve climate change and decadal needs.

Archival, stewardship, and management of and access to the data are also essential components that must be included in costs of funding the activity.

# A Scientific Strategy for Climate Monitoring

There is compelling evidence that the climate is changing. We argue about the degree, nature and cause of the climate variations and whether there is a change, but the only way to settle these arguments is with solid information.

This requires

- **improved observations** of the **state variables** and **forcings**,
- the means to **process** these and understand them,
- the ability to set them in a coherent physical (and chemical and biological) framework with **models**.

Meanwhile, the information is also extremely valuable for other purposes including a myriad of **practical applications** for business, industry, government, and the general public.

Climate change will occur,  
whether or not slowed by mitigation measures.

Hence improved description of changes as they happen and reliable predictions of climate for several planning horizons into the future, ranging from seasons to decades, become absolute imperatives.

Further we argue that there is a need for much more than “what if” scenarios-driven projections of future climate, such as produced by IPCC, and instead climate predictions as an **initial value** problem are crucial.

These demands have implications for climate observations and modeling, and for climate research.

## *Climate monitoring requires a long-term commitment to quality and stability.*

- Many of the climate-related **signals are small**, obscured by natural variability.
- There must be an active program of **research** and **analysis** utilizing climate data sets to ensure the data are state-of-the-art and meet requirements.
- Climate research and monitoring requires an **integrated strategy** of land/ocean/atmosphere observations, including both in situ and remote sensing platforms, and modeling and analysis.

## **Observing system** means a comprehensive approach, including

- **Climate observations** from both space-based and in situ platforms taken in ways that address climate needs and adhere to the ten principles outlined by the NRC (1999).
- A **global telecommunications network** and satellite data telemetry capacity to enable data and products to be disseminated.
- A climate observations **analysis** capability that produces global and regional analyses of products for the atmosphere, oceans, land surface and hydrology, and the cryosphere.
- **Four dimensional data assimilation** capabilities that process the multivariate data in a physically consistent framework to enable production of the analyses: for the atmosphere and oceans, land surface etc
- **Global climate models** that encompass all parts of the climate system and which are utilized in data assimilation and in making ensemble predictions.
- A climate observations **oversight and monitoring center** that tracks the performance of observations, the gathering of the data, and the processing system. This center must have **resources** and influence to fix problems and be a prominent climate voice when observational systems are established, such as for weather purposes or in establishing requirements for instruments on satellites.

## Observations have many uses:

The need for continuing, long-term data on climate is related to prudent **stewardship of resources** and the **protection of life and property**. Good management suggests that without the capacity to monitor, measure, and predict changes in the climate system, policy makers in both the public and the private sectors, as well as individual citizens will make long-term commitments and decisions related to vital life and property issues in the absence of critical information.

Access to knowledge concerning current climate and long-term projections of climate change will **improve decision making** regarding the economy by corporations, state and local governments, and individual citizens.

## Research observations:

Climate observations will continue to require a blend of both **monitoring and process-oriented** observing systems.

- Understanding specific climate-related **processes** (which may in turn require decadal-scale measurements) is essential for **improving climate models**.

Process observations are many and varied and in the research domain:

Serve as a pilot for sustained observations:

**issue of technology transfer**

**(esp: NASA→NOAA space-based)**

## Climate Data Records

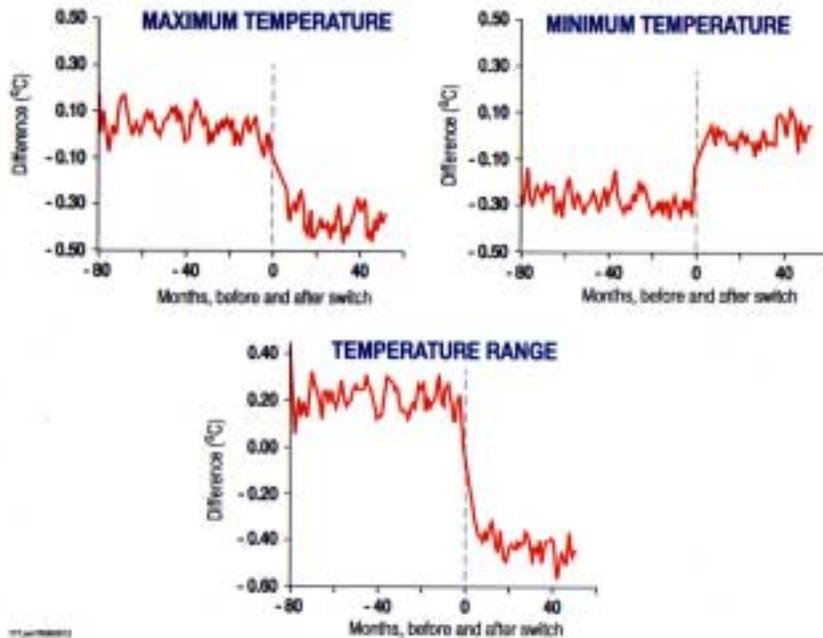
Surface and *in situ* observations, often associated with weather networks, have provided the most important data so far for the detection and attribution of causes of global climate change.

**Long-term consistency does not exist.**

Instead heroic reconstruction attempts are made to quantify and minimize space- and time-dependent biases and try to produce continuity of records.

Surface data are also used in a variety of applications to reduce climate-related risk to life and property, and act as anchor points for validating space-based measurements.

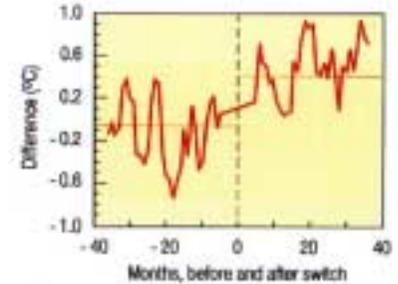
## Estimated Bias Introduced by New Sensors in NOAA's 6000 Station Cooperative Network



## Effects of Changing Instruments from HO63 Series to HO83 Series

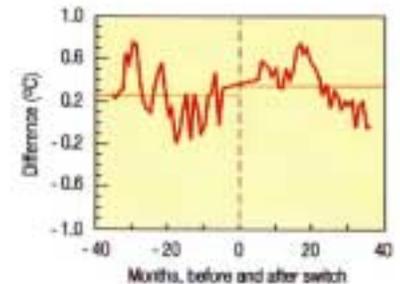
### MAXIMUM TEMPERATURE

Average difference:  
+ 0.50 °C

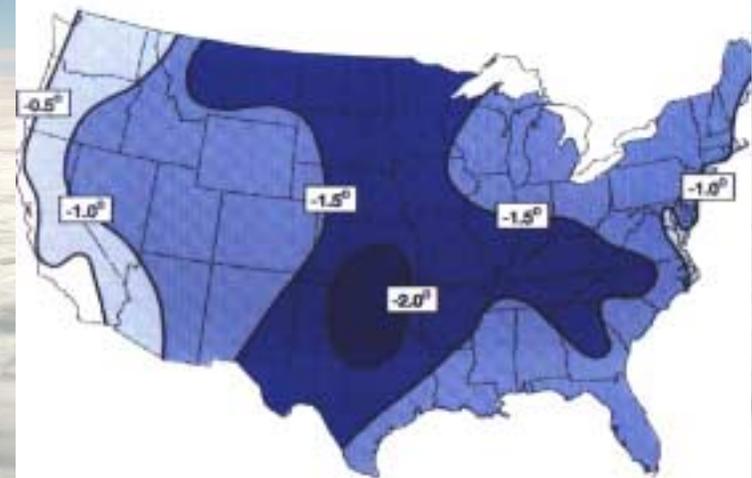


### MINIMUM TEMPERATURE

Average difference:  
maybe + 0.10 °C

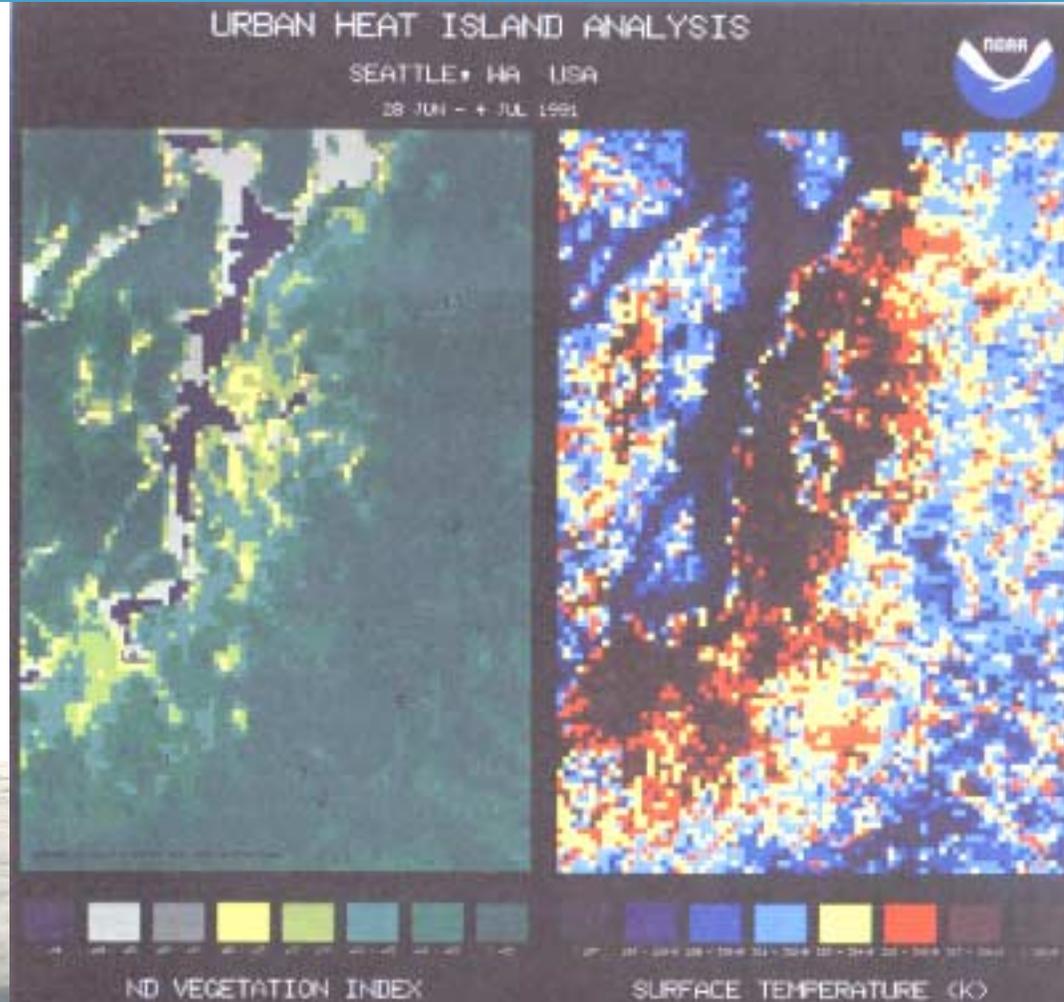
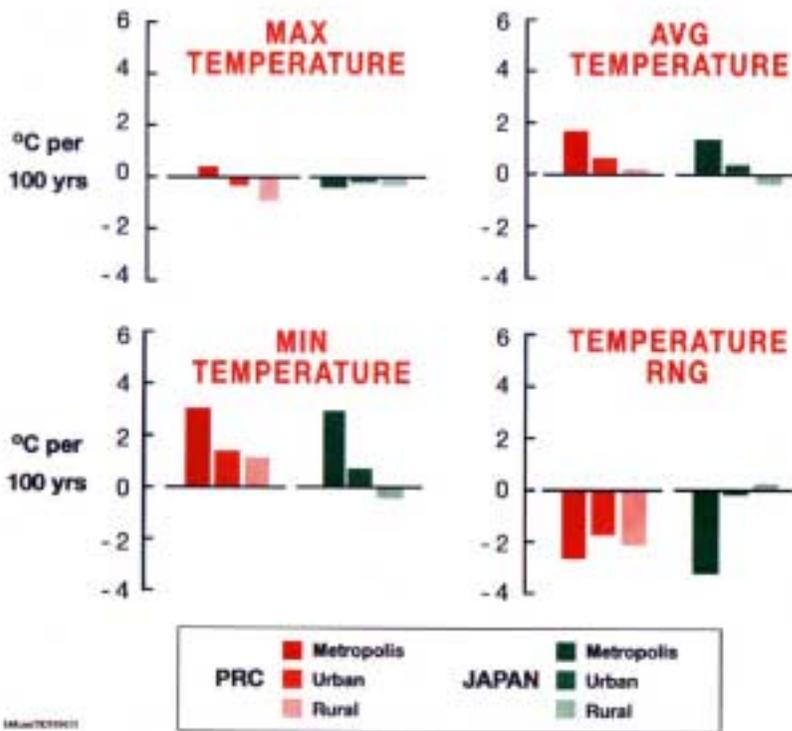


**Change in the average March temperatures (°C) resulting from changing the time of observation from 5 P.M. to 7 A.M. local time.**

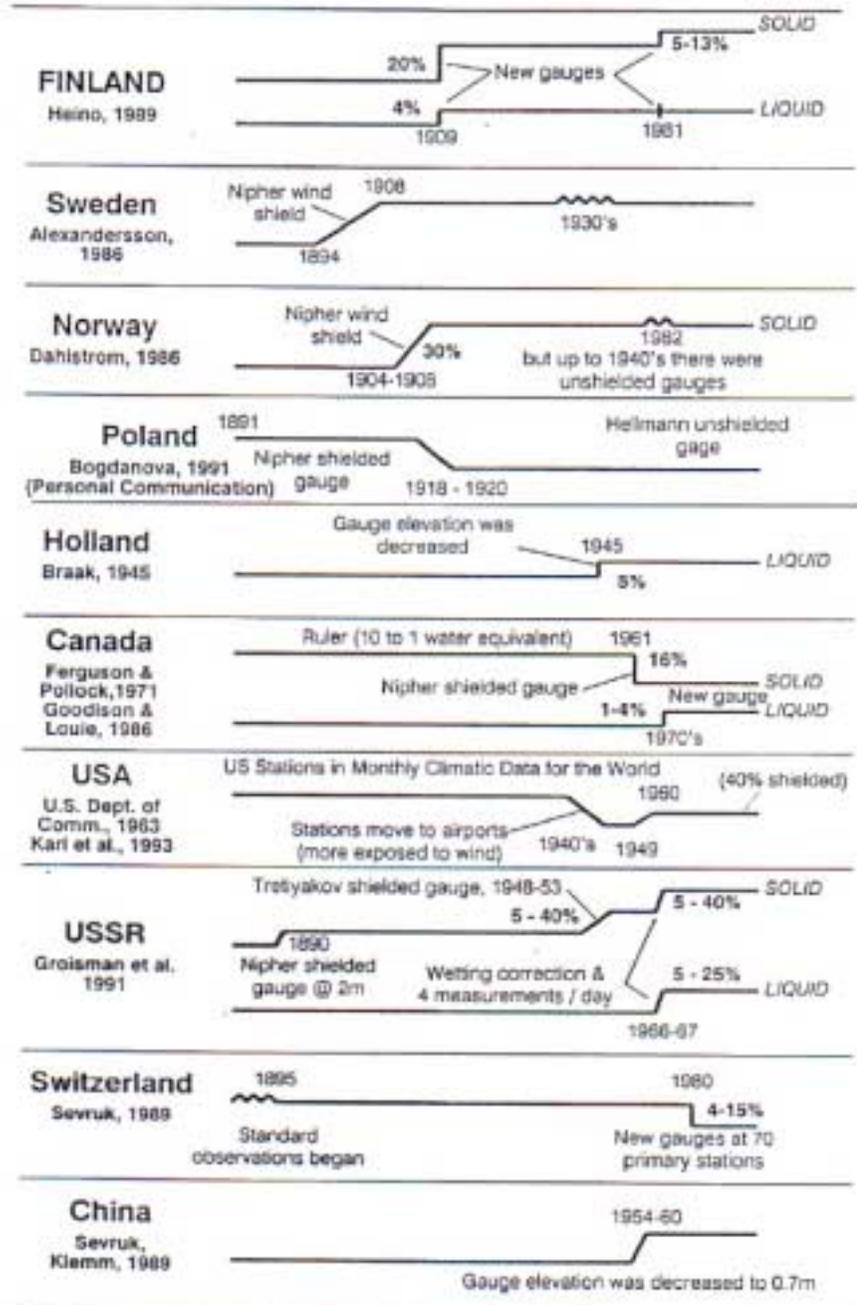


# Urban Heat Island effects

## Land use vs temperature



# Precipitation discontinuities

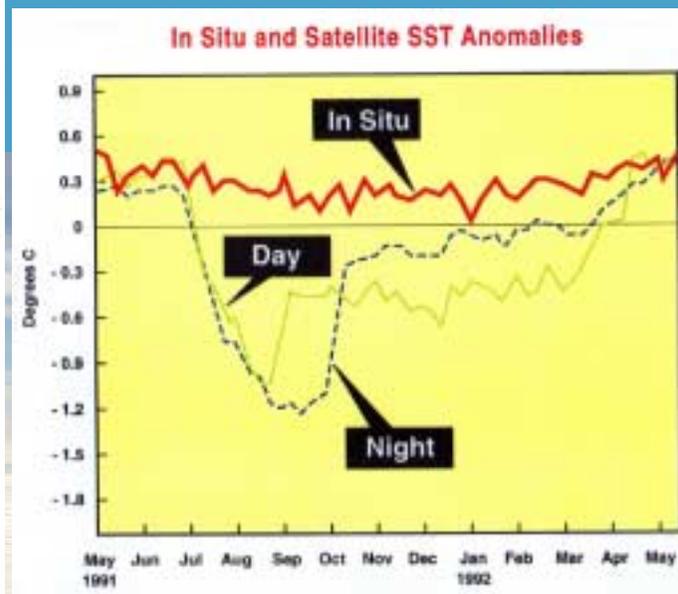
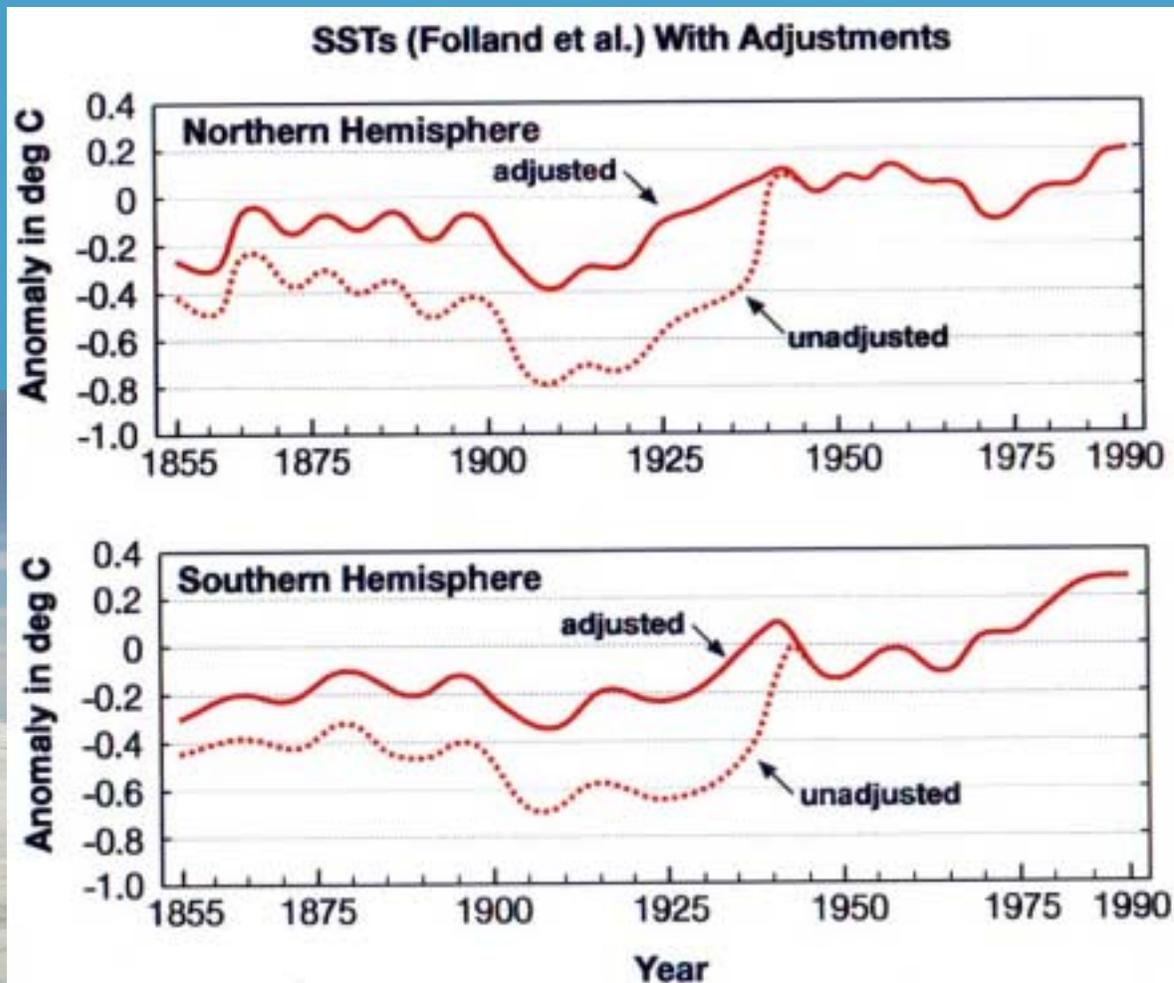


Courtesy P. Groisman

# SST changes:

From buckets to engine intakes

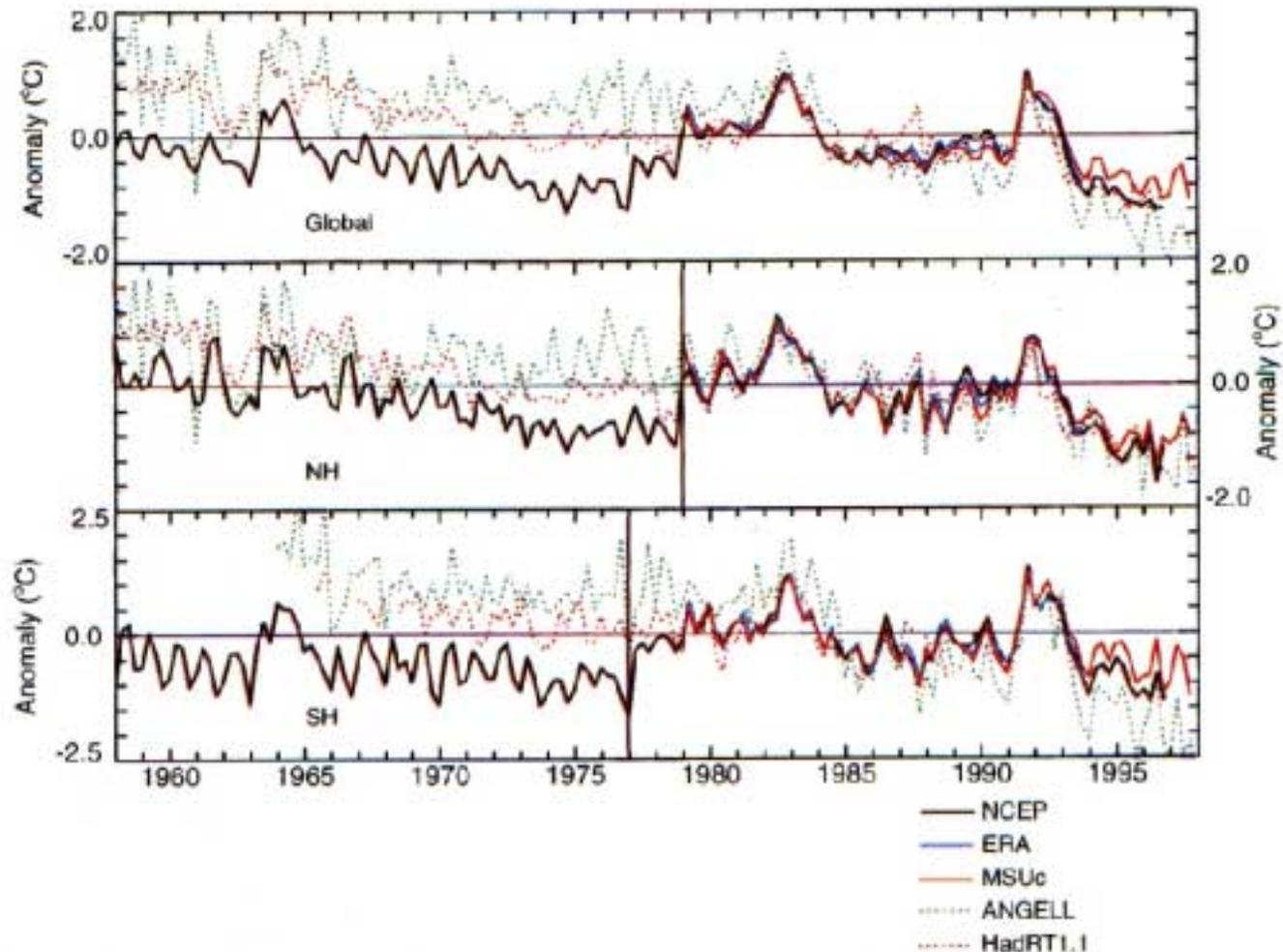
Due to  
Mt Pinatubo  
aerosol effects  
on satellite  
measurements



# Changes in lower stratosphere temperatures in NCEP reanalysis due to satellite observations introduced at time of vertical lines

SANTER ET AL: UNCERTAINTIES IN TEMPERATURE CHANGE ESTIMATES

5309



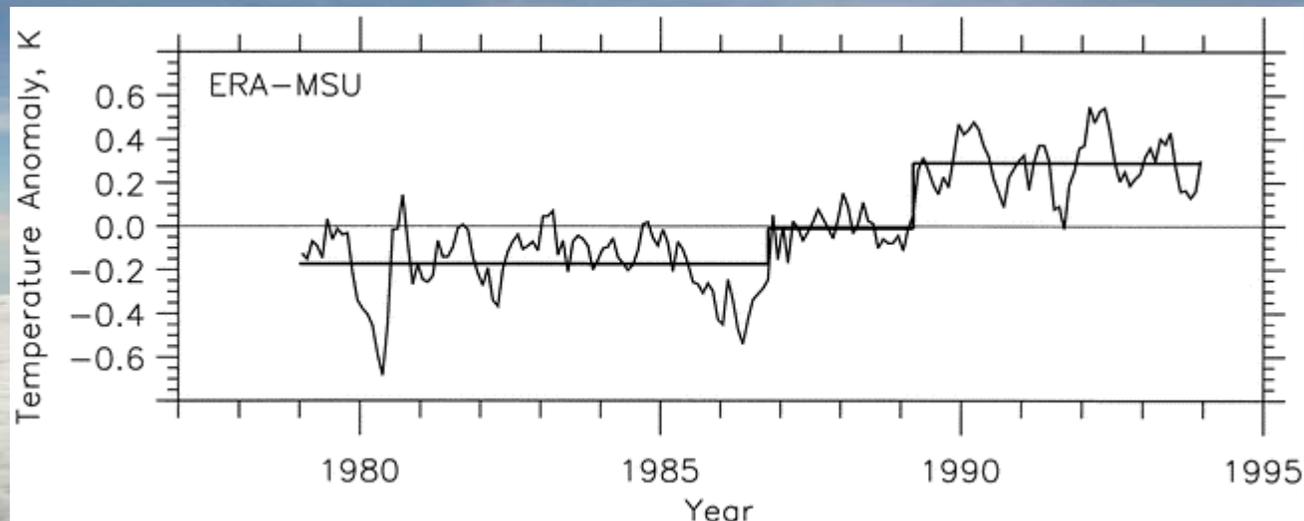
# Problems occur in assimilating satellite data

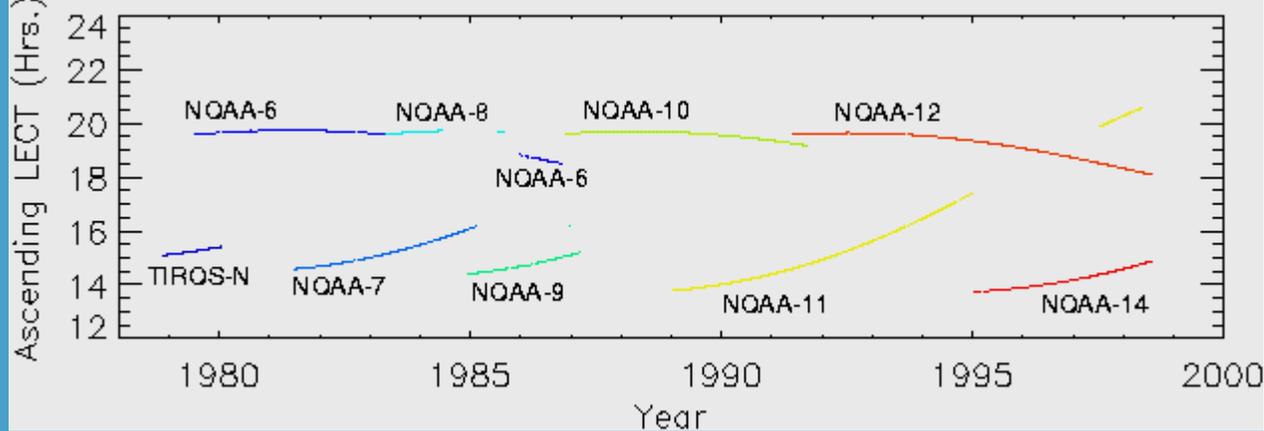
- Spurious variability from cloud clearing problems in 1980
- Spurious changes from satellite transitions and bad data

Only 1 satellite: 1986-87

2 Nov 1986: solar flare interference

February 1989: change in satellites





## Example: Satellite based observations

- Satellites typically last 3-5 years and have to be replaced
- Orbits decay
- Equator crossing times change
- New satellite orbits differ
- Instrument calibrations drift and can be changed by launch
- Interference can occur from other instruments
- Need is for stable orbits
- May require boosters
- Need sufficient sampling of diurnal cycle
- Launch on schedule, not on failure, to ensure overlap
- Calibrations required
- Ground truth validation required

## Climate Data Records

A major effort is required to produce satisfactory climate data records from operational data.

Over the past decade a number of **basic principles** have been endorsed by the National Research Council (NRC) in 1999, the United Nations Framework Convention on Climate Change, and in recommendations for a Global Climate Observing System.

1. **Management of Network Change:** Assess how and the extent to which a proposed change could influence the existing and future climatology.
2. **Parallel Testing:** Operate the old system simultaneously with the replacement system.
3. **Metadata:** Fully document each observing system and its operating procedures
4. **Data Quality and Continuity:** Assess data quality and homogeneity as a part of routine operation procedures.
5. **Integrated Environmental Assessment:** Anticipate the use of data in the development of environmental assessments.
6. **Historical Significance:** Maintain operation of observing systems that have provided homogeneous data sets over a period of many decades to a century or more.
7. **Complementary Data:** Give the highest priority in the design and implementation of new sites or instrumentation within an observing system to data-poor regions, poorly observed variables, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. **Climate Requirements:** Give network designers, operators, and instrument engineer's climate monitoring requirements at the outset of network design.
9. **Continuity of Purpose:** Maintain a stable, long-term commitment to these observations, and develop a clear transition plan from serving research needs to serving operational purposes.
10. **Data and Metadata Access:** Develop data management systems that facilitate access, use, and interpretation of data and products by users.

# Links to Climate Modeling and Prediction

The monitoring program must be combined with **analysis and generation of products**, including assimilation of the data into an operational climate model. Without this step there is neither feedback to the monitoring program nor expert information on the data for the climate services.

## Initializing Operational Climate Prediction

In addition to tracking climate changes as they happen and providing information based upon resulting analyses, the observations are vital to establish the **initial state** of the climate system monthly.

For climate predictions, the initial state of the atmosphere is less critical. For predictions of a season to a year or so, the **upper ocean heat content** is most critical; **soil moisture** and state of **surface vegetation** over land are also important.

The mass, extent, thickness and state of **sea ice and snow cover** are vital along with other aspects of the land surface.

On longer time scales, information throughout the **ocean** is essential.

Information on systematic changes to the atmosphere (especially its composition and influences from volcanic eruptions) as well as external **forcings**, such as from changes in the sun, is also needed.

# Data Assimilation and Reanalysis

The synthesis of the observations through data assimilation using sophisticated models is extremely effective.

The models provide a consistent dynamical framework that helps with quality control. **A substantial research effort is required to capitalize on new observations**, especially from space.

## Reprocessing

Desirable to take advantage of improved processing methods and to eliminate errors.

Model **reanalysis** of past data can incorporate all kinds of data and information, including space-based radiances and ground-based observations, for ocean and atmosphere.

Reanalysis makes it possible to eliminate biases in the climate record attributed to model changes.

**Research needed:** the information is spotty (single level, single profile), the error characteristics and covariances of the field may not be adequately known, and computational restrictions exist.

The highest priority recommendation is to establish an organization **with responsibilities for operational climate monitoring and prediction.**

Essential infrastructure has to be established to ensure the integrity and continuity of the observations, their analysis into products, and links to modeling and research activities. The need is for systematic, objective, continuous observations of both state variables and forcings of the climate system.

In particular, the entity should provide a central facility with oversight of the **health of the observing system** and resources to build and sustain a climate observing system operating under the 10 guideline principles. It would have a new management structure, authority and infrastructure and should be responsible for a line of products for use in all aspects of climate, and oversight of management, access and archival of the data.

# The infrastructure and commitment required

The National Weather Service provides one model. Elements include the **observing** system, the **telecommunications** system, the **global data processing** system, and the **product dissemination** system.

Also close integration **internationally**: data freely and openly exchanged.

- The distributed observations around the world are funneled to national, then regional, and then to world meteorological centers, which produce high level analyses, develop products and forecasts, and disseminate these to the data producers. Quid pro quo!

An alternative model of the essential **infrastructure**:

In addition:

- Should ensure the **integrity and continuity** of the observations.
- Systematic, objective continuous **observations** of state variables and forcings with a commitment to the continuity of record.
- Strong links to **research and development**.
- Long-term **stewardship of the data**.

- Continually assess the **health** of the observing system: **Oversight** of all observations made for climate.
- Implementation of the ten climate **monitoring principles** and the management guidelines required to implement them.
- Take **actions** to redress deficiencies, correct problems and ensure continuity. Requires resources.
- Ensure that all observations are utilized in real time and operational **products** are developed to help in quality control.
- Links to other **users and uses** of the data, especially 4DDA.
- Generation of initial fields for ensemble prediction.
- **Free and open** access and exchange of data; real time access. Dissemination of products. Archival and stewardship of data.
- Ongoing reprocessing and **reanalysis** of data.
- An **advisory committee** of outside experts.
- Links to research
- Continual **dialog** between those who make observations and those who use them concerning the utility, quality, and problems with observations and to foster their continuation.
- **Ability to adapt and evolve** the system for new technologies, lower costs, new variables.
- Represent the US in **international** planning and agreements.

*A system is needed to assure that the data and information necessary to adequately monitor climate will be delivered.*

*Some important operating principles include:*

1. Adequate **support** should be available for changes to instrumentation in the context of maintaining a long-term climate record.
2. **Stable** support is an essential characteristic of a climate observing system. Since this is to be a sustained activity, inflationary increases should be programmed into budget requests.
3. **Contingency plans** should be made for resource shortfalls so that operation of the system is not compromised.
4. Observing system activities should be regularly **reviewed**.
5. Activities should produce annual **plans** documenting accomplishments, future activities, and projected spending.
6. Operating cost increases or other factors often require flexibility and adjustments by the system operators to maintain data flow while long-term solutions are sought. In making such adjustments, **priorities**, from highest to lowest, should be:
  - a) Data collection and archiving
  - b) Distribution of the raw data in near-real time
  - c) Quality control in delayed mode and archiving of data sets
  - d) Development and maintenance of data access tools (e.g. web sites)
  - e) Follow-on processing to produce analyses and reanalyses

**The climate is changing: It is likely to continue to change!**  
Regardless of the success of mitigation actions:

**We need a comprehensive information system to:**

- Observe and track the climate changes and forcings as they occur.
- Analyze global products (with models)
- Understand the changes and their origins
- Validate and improve models
- Initialize models; predict future developments
- Assess impacts regionally: on environment, human activities and sectors such as agriculture, energy, fisheries, water resources, etc.

**Such a system will be invaluable regardless of magnitude of global warming**