The Evidence for Anthropogenic Climate Change (ACC)

Mark Berliner Ohio State U
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Joint Statistical Meetings: Miami
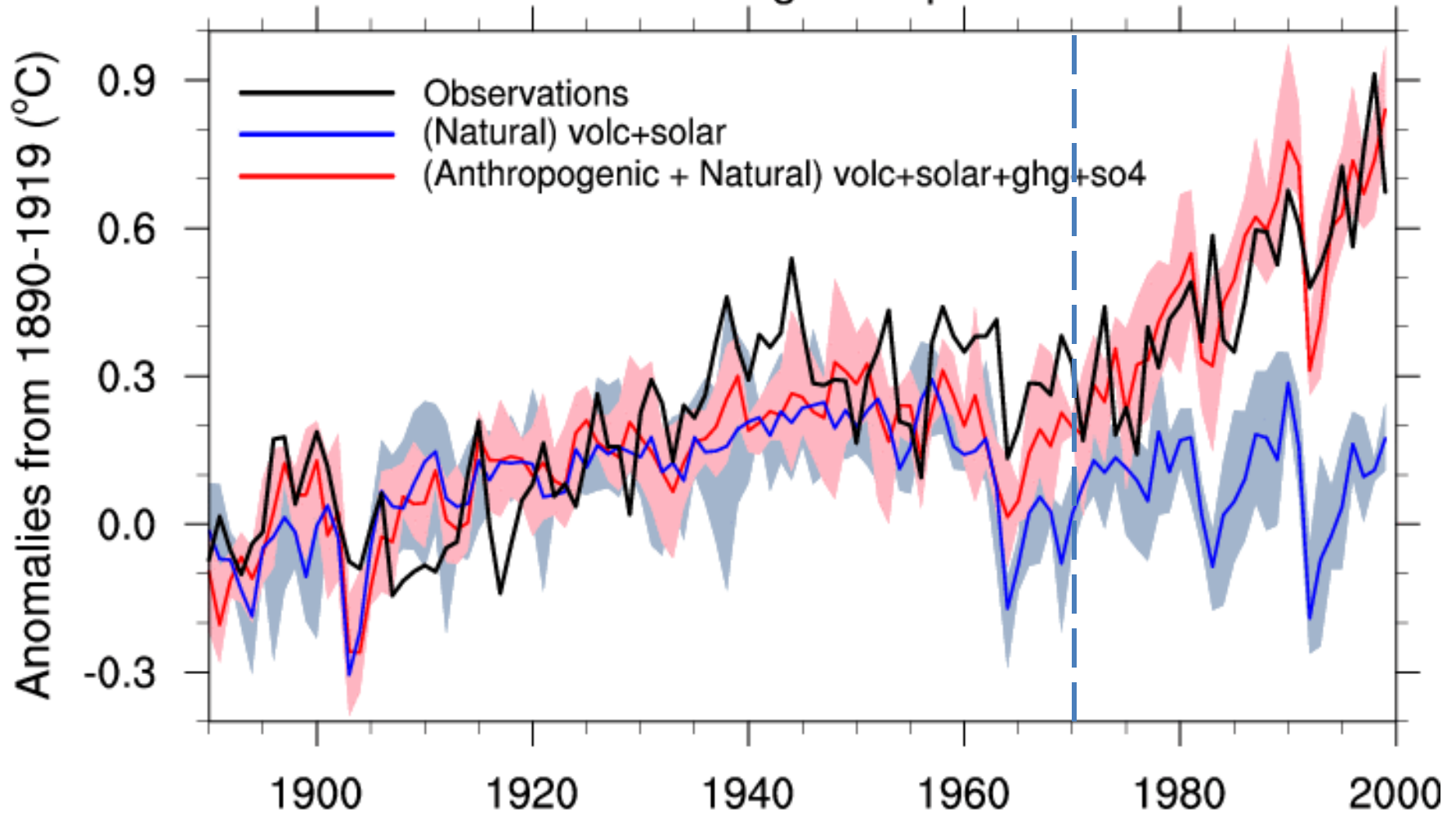
Three Points

1. **Science**
   - ➢ **Basic arguments for global warming**
        Greenhouse effect
   - ➢ **Climate models**

Natural forcings do not account for observed 20th century warming after 1970

Global Average Temperature

Meehl et al, 2004: J. Climate.

2. Anthropogenic influences

➢ **Greenhouse gas emissions**

CO_2 , methane …

➢ **Aerosols**

cooling

➢ **Land use**

cities, deforestation, agriculture, water "management"

Complex interactions

3. Observations: Since 1970

Rise in:

Global surface temperatures

Tropospheric temperatures

Global SSTs, ocean temp's

Global sea level

Water vapor

Rainfall intensity

Precipitation extratropics

Hurricane intensity

Drought

High temperatures extremes

Heat waves

Decrease in:

NH Snow extent

Arctic sea ice

Glaciers

Cold temp's

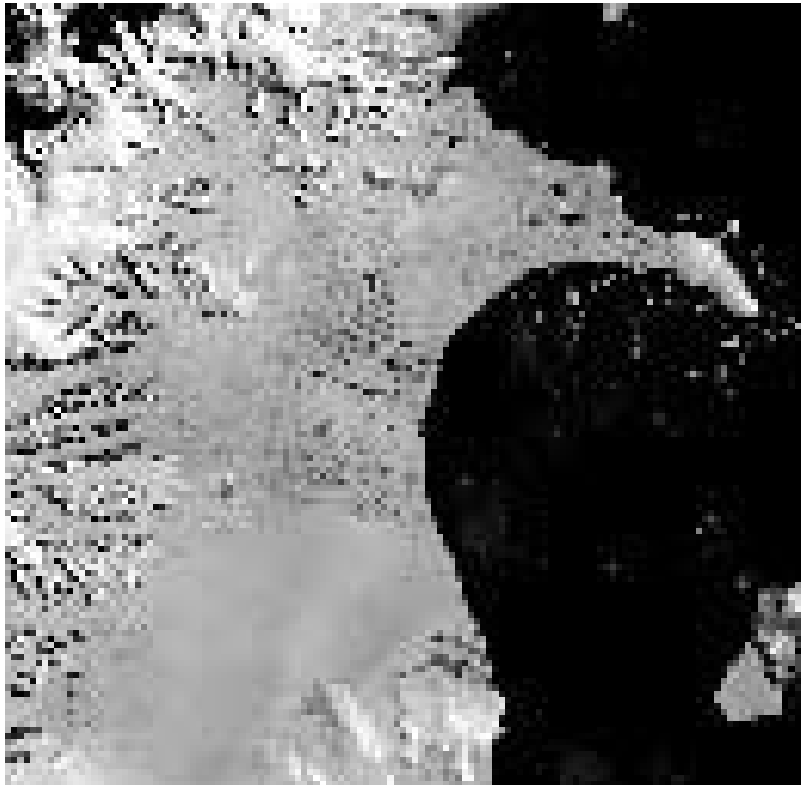# Ice: Arctic, Antarctica, Greenland all display changes

1941

2004
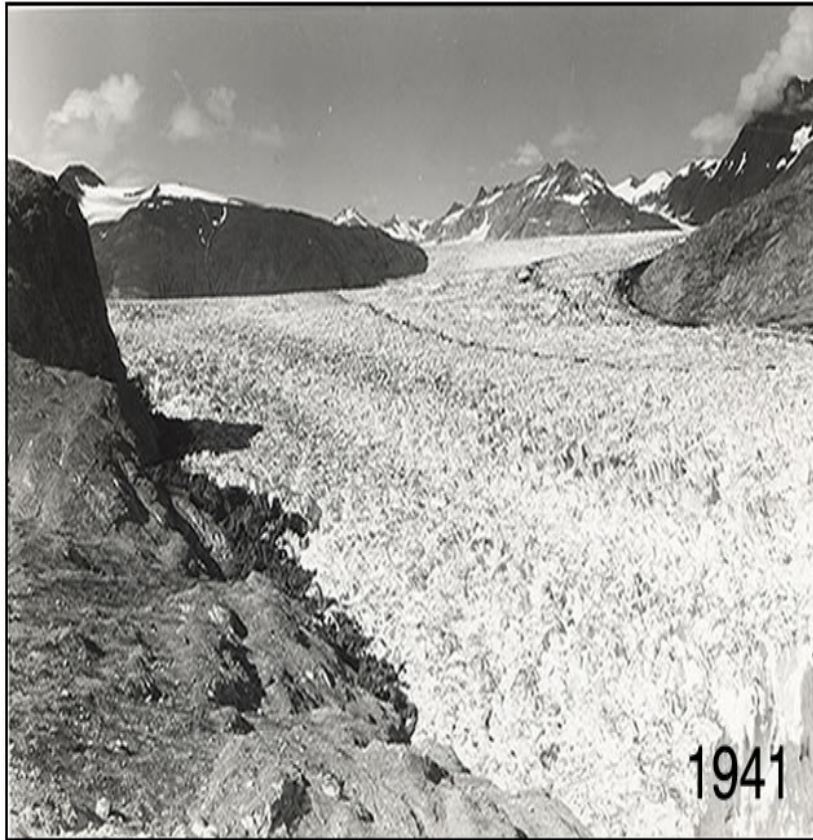
Larsen B Ice Shelf 2002 Collapse
In 35 days, 3,250km^2 ;   200m thick was lost
(Rhode Island: 2717km^2)

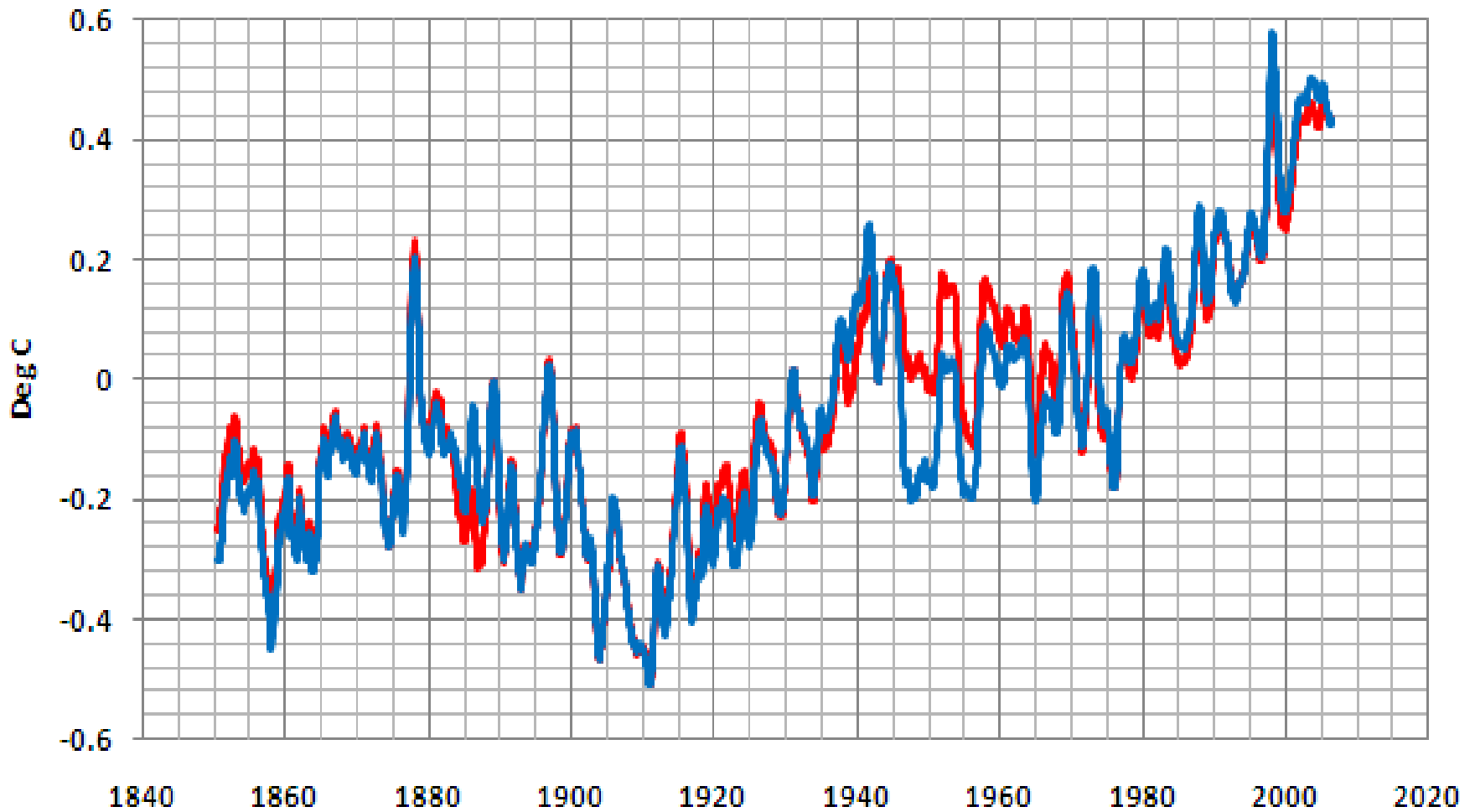31 Jan   5 Mar

Hadley Centre Global SST Dataset Comparison
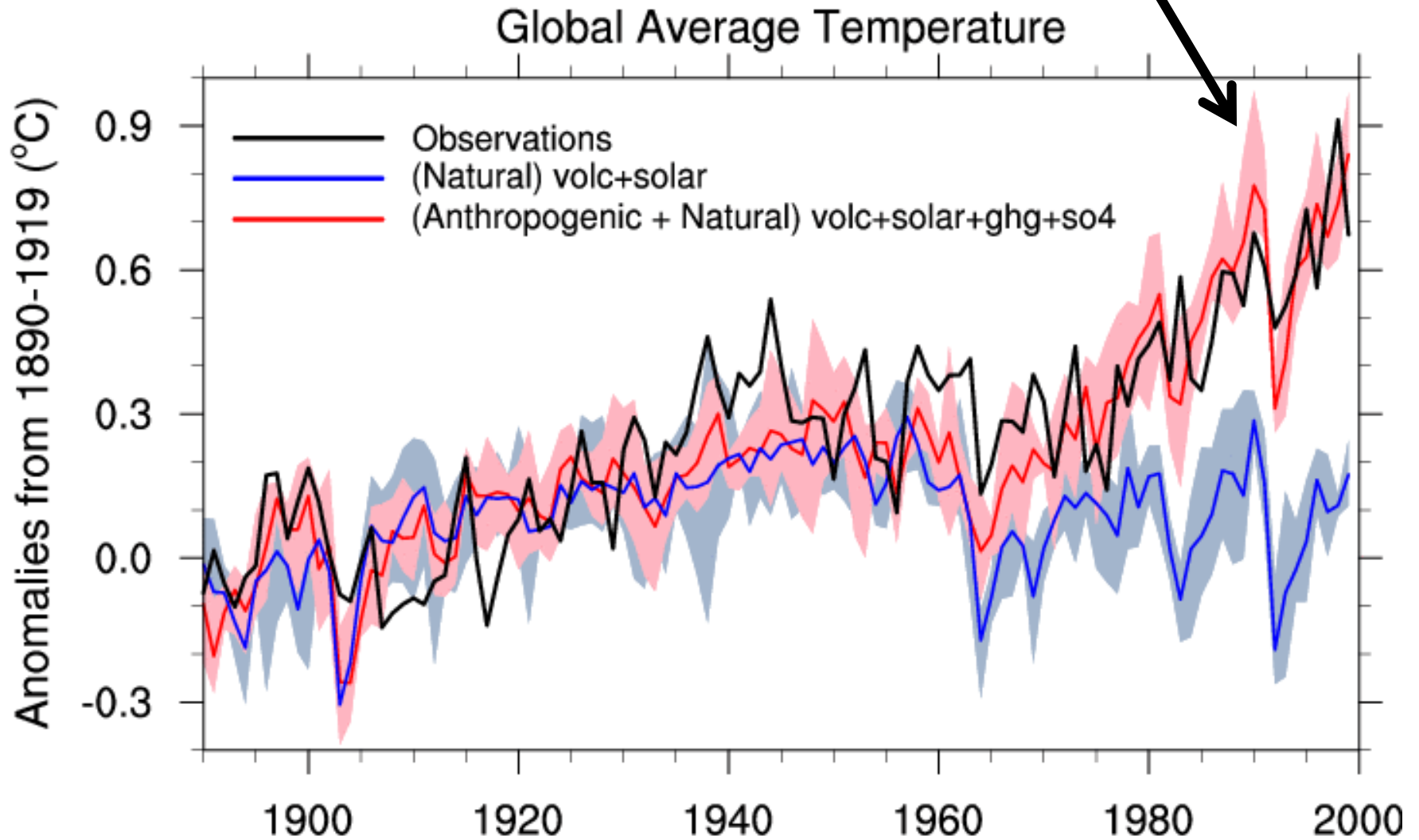HADSST3, HADSST2
Smoothed w/ 13-Month Filter
Jan 1850 to Dec 2006

Issues about the Evidence

1. Science
   - ➢ Basic arguments for global warming
     - Very loose quantification
   - ➢ Climate models: Flaws in
     - models
     - analyses of output

Ensemble Means and Variances; Intervals?

Global Average Temperature

Meehl et al, 2004: J. Climate.

Issues about the Evidence

3. **Observations**

   ➤ **Measurement error**

   Measurement -> various manipulations
   -> data point

   ➤ **Representativeness**

   ➤ **Replication is rare**

   ➤ **Spatial-temporal analyses**

Inference and Decision Making

- "Statistical significance"; causal inference:
  - *One* experimental unit
  - Practical versus statistical significance
    - Many sources of variation lead to: "confounding" and "lurking variables"
    Ex) two hypotheses
  1) Hurricane (and tornado) outbreaks associated with La Nina events
  2) ACC impact ENSO and add to the severity/intensity of storm events

Two (of Several) Conundra

1) Massive datasets, but sometimes "few relevant observations"
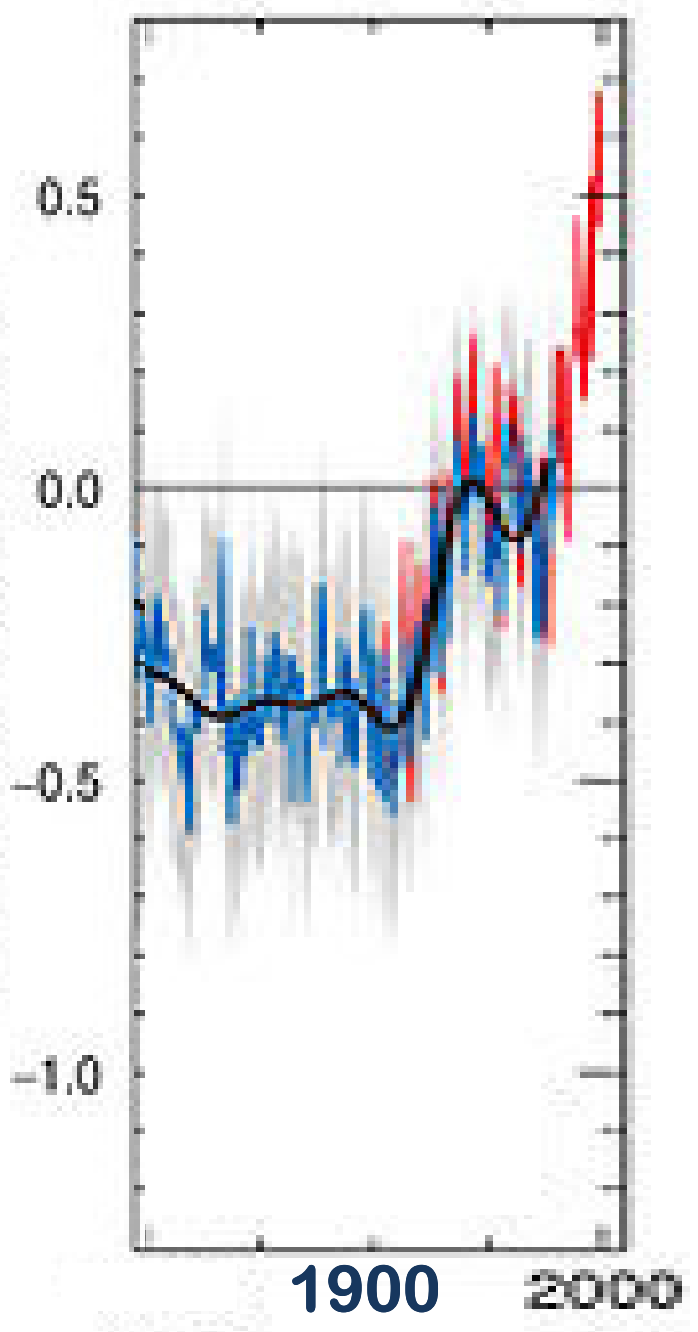
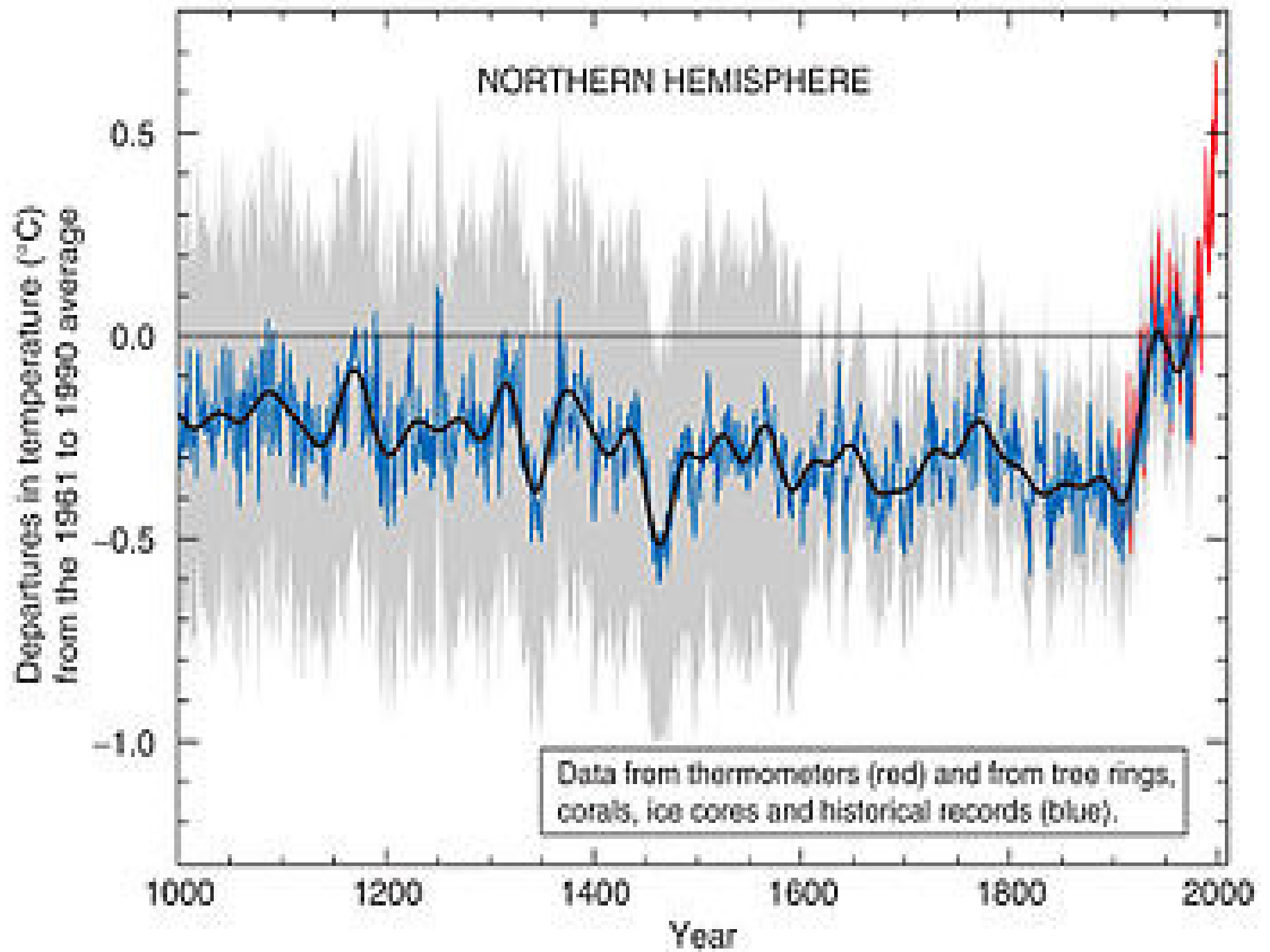   ENSO: 5 year cycle (quasiperiodic):

   13 La Nina events since 1950 [ ]

   7   "   "   1904 to 1950 [ )

2) Separating ACC from natural variation is difficult due to interaction of space-time scales with data quality

NORTHERN HEMISPHERE

Data from thermometers (red) and from tree rings, corals, ice cores and historical records (blue).

Inference and Decision Making

- **Prediction is very hard**
  - **Need models**
  - **Low probability; high impact events**
  - **Tipping points (?)**
- **Many players**
  - **Economic cost to US, Europe, … versus Bangladesh, Polynesia, …**
  - **US Southwest versus US East, Midwest**
  - **Social – economic groups**
- **My Conclusion: Combining information leads to strong weight of evidence for ACC & need for action**

- Climate data (raw)
- Climate data (processed)
- Paleo-data
- Paleo Reconstructions (including code)
- Large-scale model (Reanalysis) output
- Large-scale model (GCM) output
- Model codes (GCMs)
- Model codes (other)
- Data Visualisation and Analysis
- Master Repositories of climate and other Earth Science data

Climate data (raw)

[GHCN v.2](#) (Global Historical Climate Network: weather station records from around the world, temperature and precipitation)

USHCN US. Historical Climate Network ([v.1](#) and [v.2](#))

World Monthly Surface Station Climatology [UCAR](#)

Antarctic [weather stations](#)

European weather stations ([ECA](#))

Italian Meterological Society [IMS](#)

Satellite feeds ([AMSU](#), [SORCE](#) (Solar irradiance), [NASA A-train](#), [Ocean Color](#))

Tide Gauges ([Proudman Oceanographic Lab](#))

[World Glacier Monitoring Service](#)

[Argo float data](#)

[International Comprehensive Ocean/Atmosphere Data Set (ICOADS)](#) (Oceanic in situ observations)

[AERONET](#) Aerosol information

[Arctic data](#) from the Cooperative Arctic Data and Information Service (CADIS)

Climate data (processed)
- Surface temperature anomalies (GISTEMP (see also Clear Climate Code), HadCRU
  (alternate site), NOAA NCDC, JMA, BEST)
- Satellite temperatures (MSU) (UAH, RSS, Zou et al)
- Sea surface temperatures (Reynolds et al, OI)
- Stratospheric temperature
- Sea ice (Cryosphere Today, NSIDC, JAXA, Bremen, Arctic-Roos, DMI)
- Radiosondes (RAOBCORE, HadAT, U. Wyoming, RATPAC, IUK, Sterin (CDIAC), Angell (CDIAC))
- Cloud and radiation products (ISCCP, CERES-ERBE)
- Sea level (U. Colorado, NOAA)
- Aerosols (AEROCOM, GACP)
- Greenhouse Gases (AGGI at NOAA, CO2 Mauna Loa, World Data Center for Greenhouse Gases, AIRS CO2 data (2003+))
- AHVRR data as used in Steig et al (2009)
- Snow Cover (Rutgers)
- GLIMS glacier database
- Ocean Heat Content (NODC)
- Ocean CO_2 (CDIAC)
- GCOS Essential Climate Variables Index
- NOAA Climate Indicators State of the Climate 2009

Model codes (GCMs)

Downloadable codes for some of the GCMs.

GISS ModelE (AR4 version, current snapshot)

NCAR CCSM(Version 3.0, CCM3 (older vintage))

EdGCM Windows based version of an older GISS model.

Uni. Hamburg (SAM, PUMA and PLASIM)

NEMO Ocean Model

GFDL Models

MIT GCM

Master Repositories of Climate Data

Much bigger indexes of data sources:

Global Change Master Directory (GSFC)

PAGES data portal

NCDC (National Climate Data Center)

IPCC Data

Carbon Dioxide Information Analysis Center, Oak Ridge National Lab: Atmospheric trace gas concentrations, historical carbon emissions, and more

CRU Data holdings

Hadley Centre Observational holdings