Capturing trends and low-frequency variations in reanalyses

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Phil Jones (CRU)
Ben Santer (PCMDI)
Kevin Trenberth (NCAR)

Capturing realistic trends: the problems

- **Observations have biases, and these biases change over time**
  - e.g. daytime warm bias in radiosonde measurements of stratospheric temperature
- **Models have biases, and changes in observational coverage over time may change the extent to which observations correct these biases**
  - e.g. 1970s transition of southern-hemisphere observing system
- **Data assimilation can introduce biases that depend on observational coverage**
  - e.g. humidity/rainfall problem over tropical oceans in ERA-40

Christy, Seidel and Sherwood (2006)
Chapter 2, US CCSP Report on Temperature Trends

c) Operational Reanalyses

Operational reanalyses (hereafter simply "re-analyses") will be discussed here in Chapter 2, but trends derived from them are presented only sparingly in the following chapters because of evidence that they are not always reliable, even during the recent period. All authors expressed concern regarding reanalyses trends, a concern that ranged from unanimous agreement that stratospheric trends were likely spurious to mixed levels of confidence regarding tropospheric trends (see chapter 3). Surface temperature trends are a separate issue as reanalyses values are indirectly estimated rather than observed (see below).

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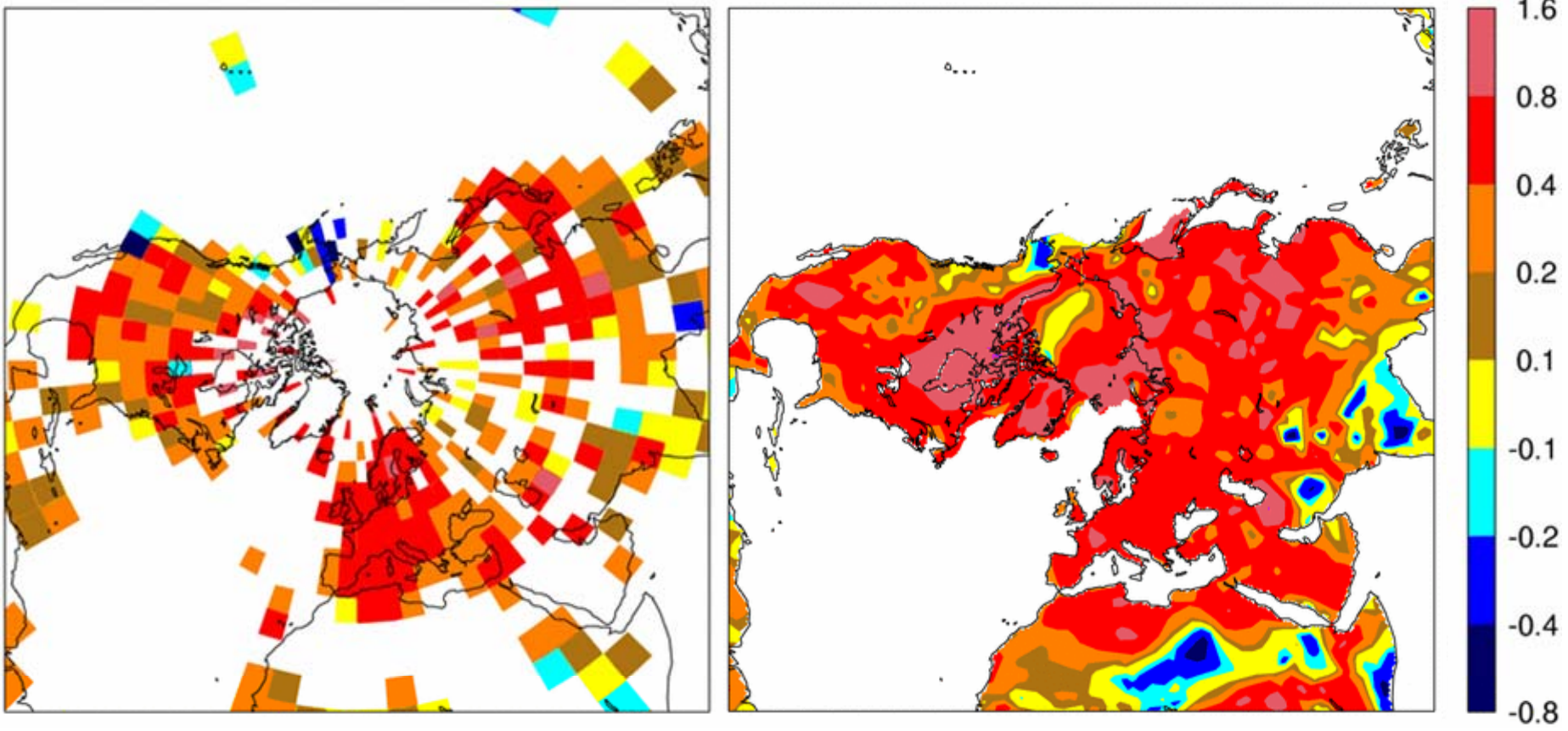
Linear trend in two-metre temperature (1979-2001)

Mean over land: 0.30°C/decade

Mean over land: 0.32°C/decade

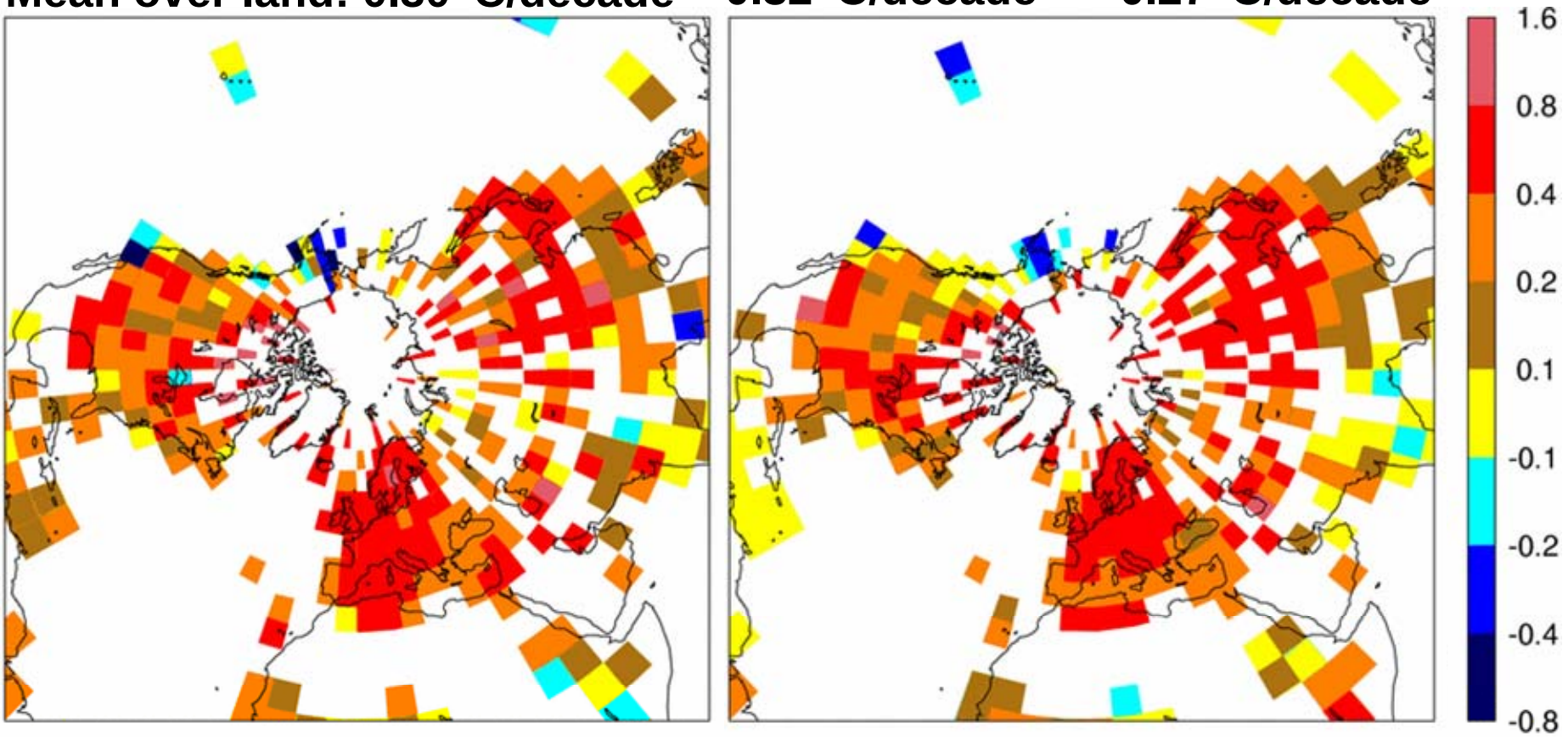


Based on monthly CLIMAT station data (CRUTEM2v; Jones and Moberg, 2003)

Based on ERA-40 reanalysis of SYNOP data (Simmons et al., 2004)

Linear trend in two-metre temperature (1979-2001)

Mean over land: 0.30°C/decade **0.32°C/decade → 0.27°C/decade**

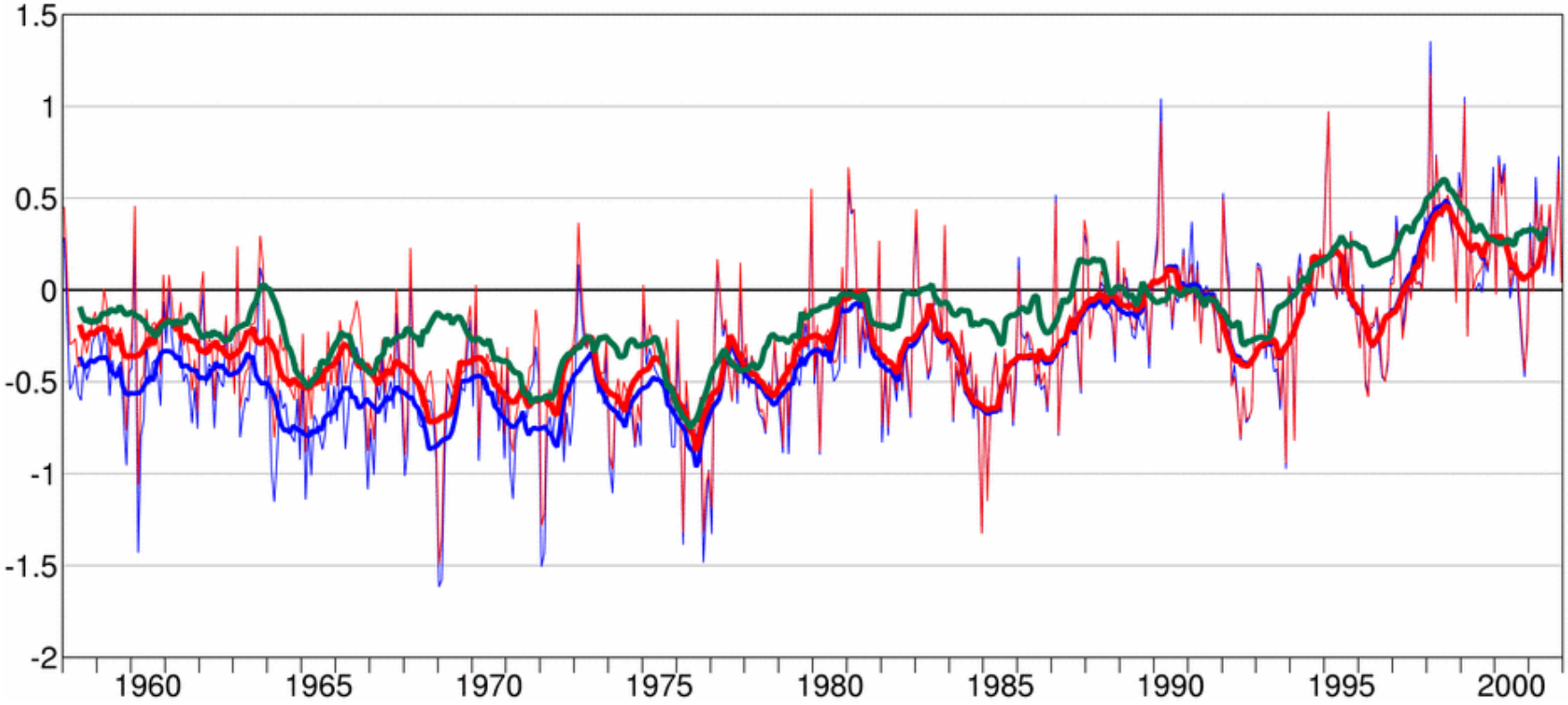


Based on monthly CLIMAT station data (CRUTEM2v; Jones and Moberg, 2003)

Based on ERA-40 reanalysis of SYNOP data, sub-sampled to match CRUTEM2V

Comparison of reanalysis and land-station values

Surface air temperature anomaly (°C) with respect to 1987-2001



Based on monthly CLIMAT data (Jones and Moberg, 2003)

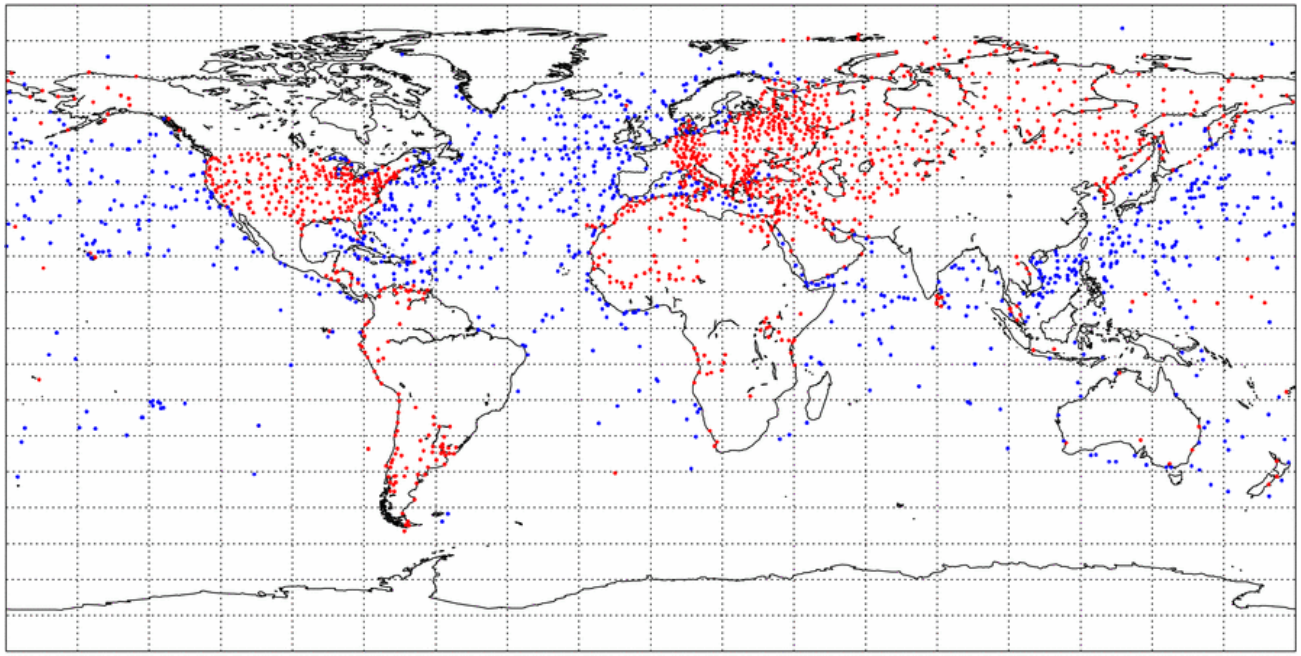
Based on ERA-40 reanalysis of SYNOP data

Based on simulation using ERA-40 model and SST/sea-ice (plotted relative to ERA-40 reanalysis mean for 1987-2001)

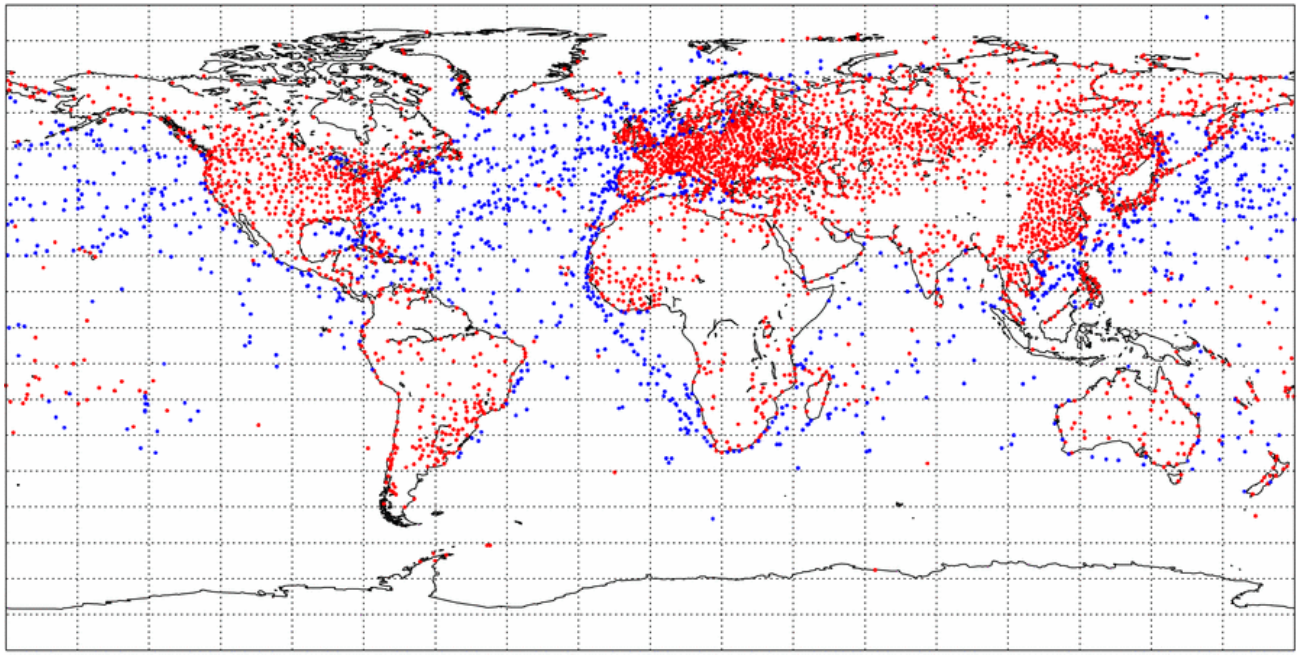
SYNOP and SHIP data available to ERA-40

a

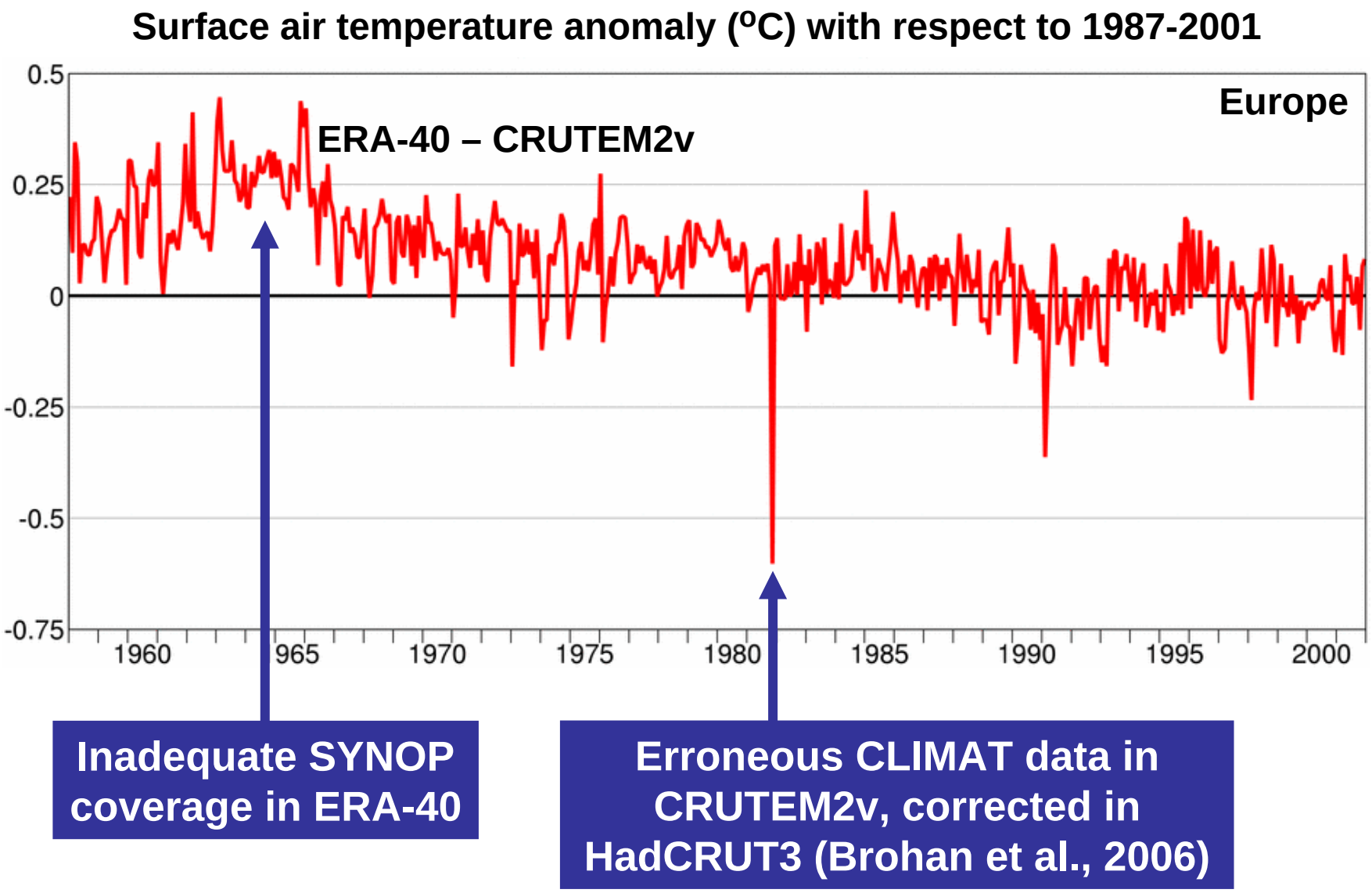
09-15UTC
1 July 1966



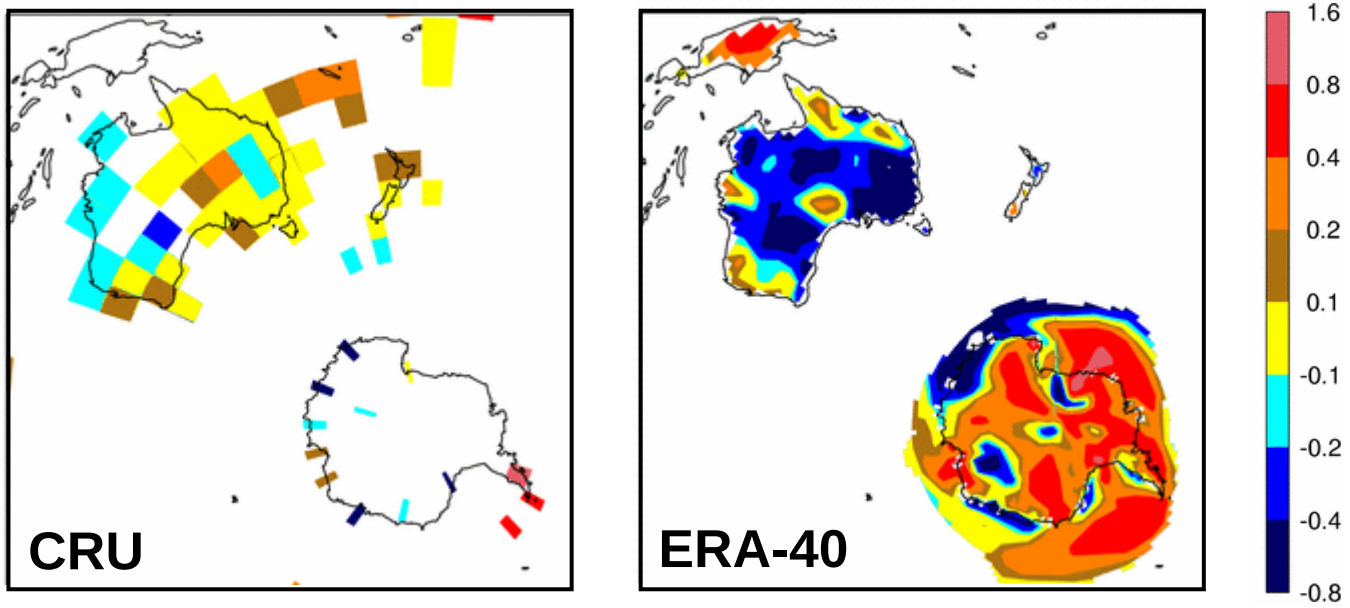
09-15UTC
1 July 1967



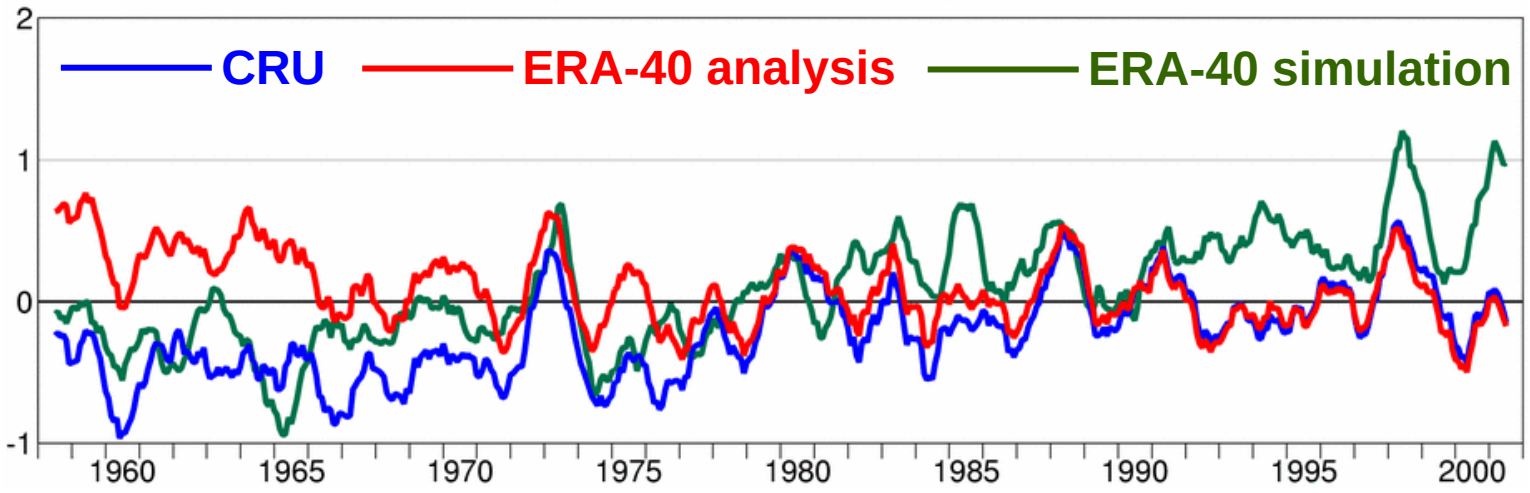
Comparison of reanalysis and land-station values



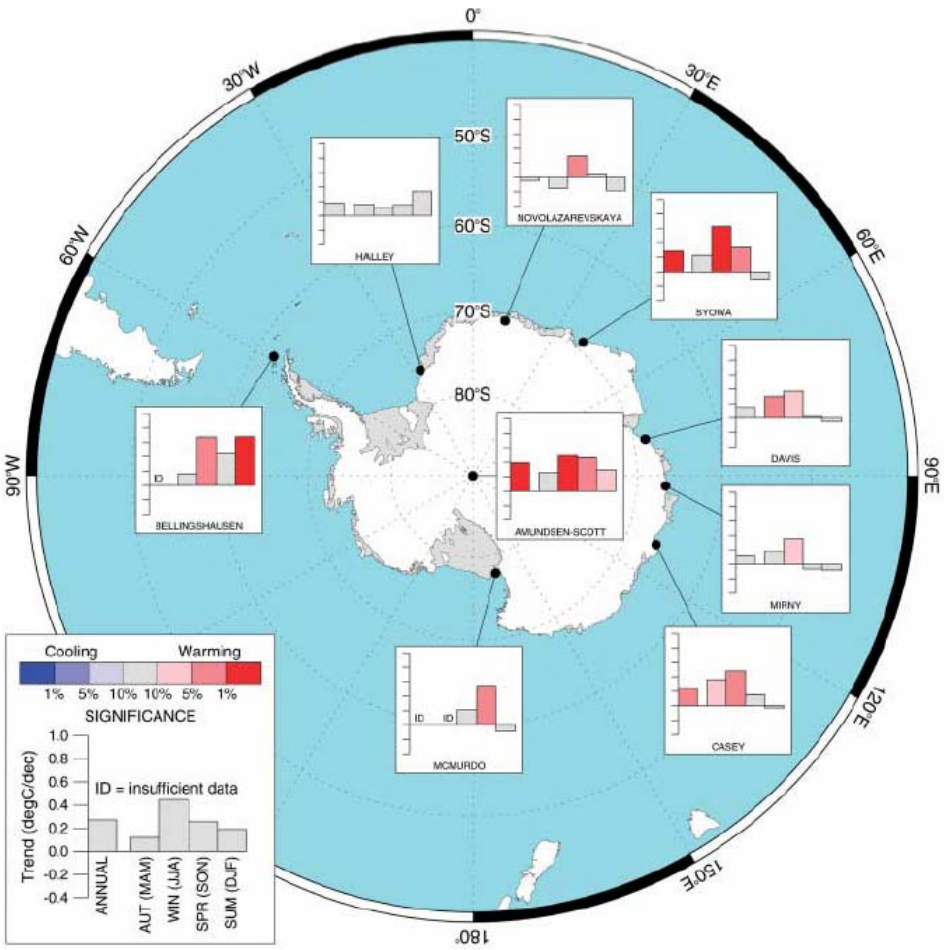
Linear trend in two-metre temperature (ºC/decade; 1979-2001)

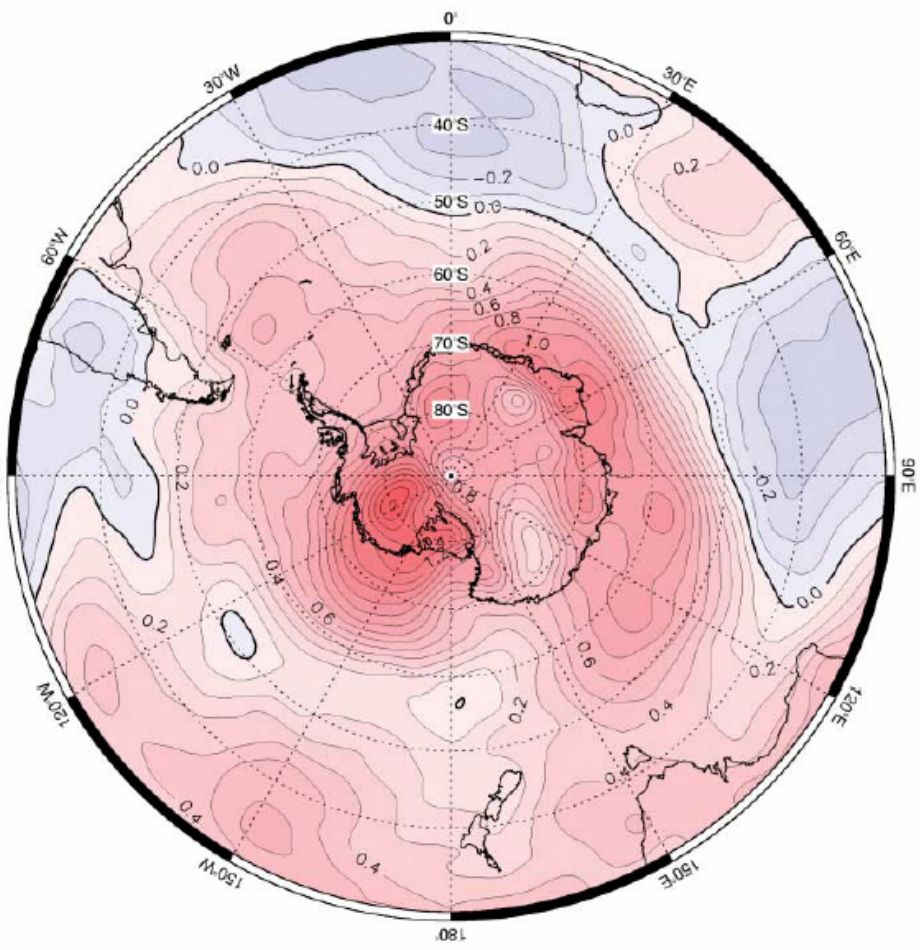


Surface air temperature anomaly (ºC; wrt 1987-2001) for Australia



Antarctic warming at 500hPa

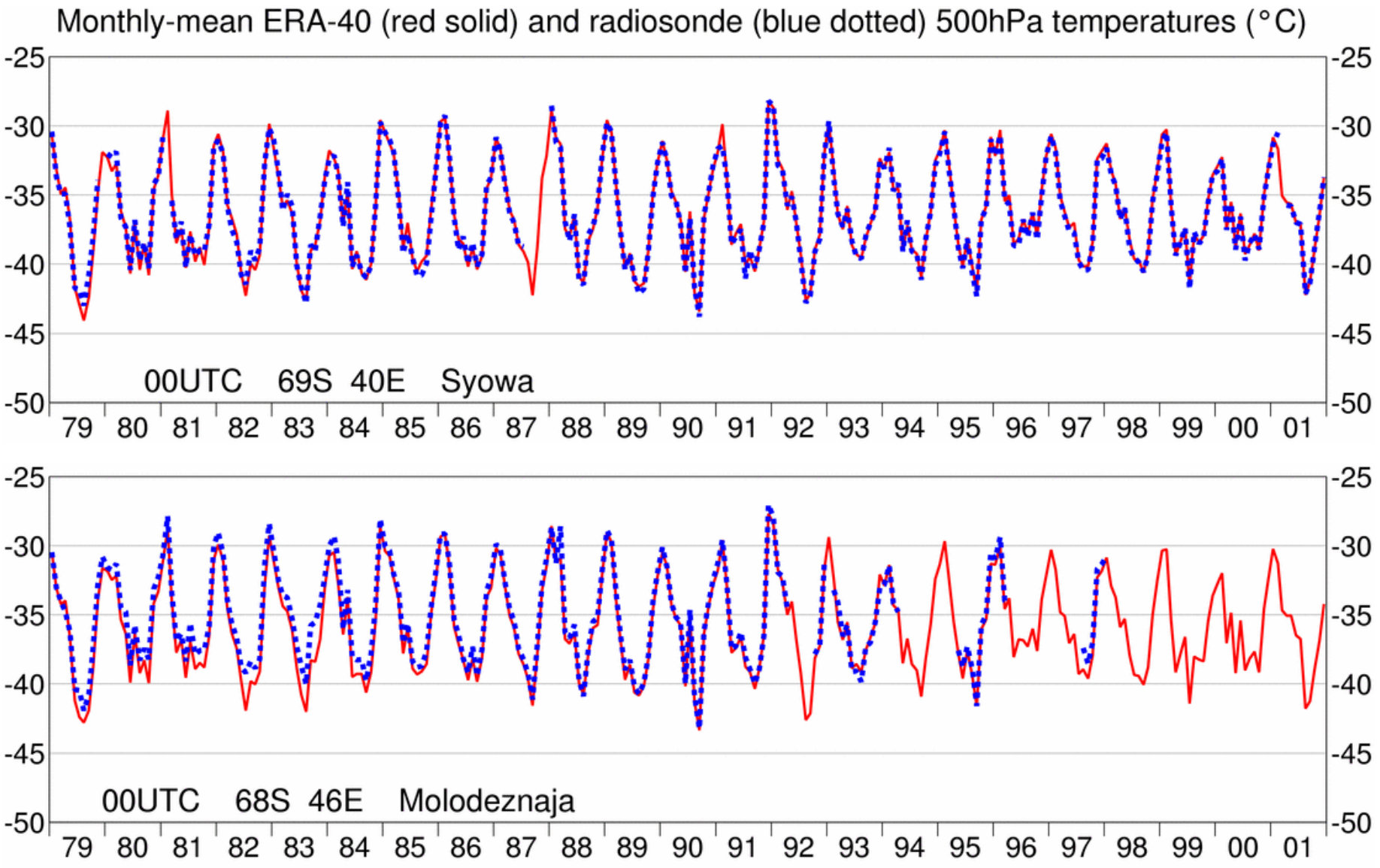




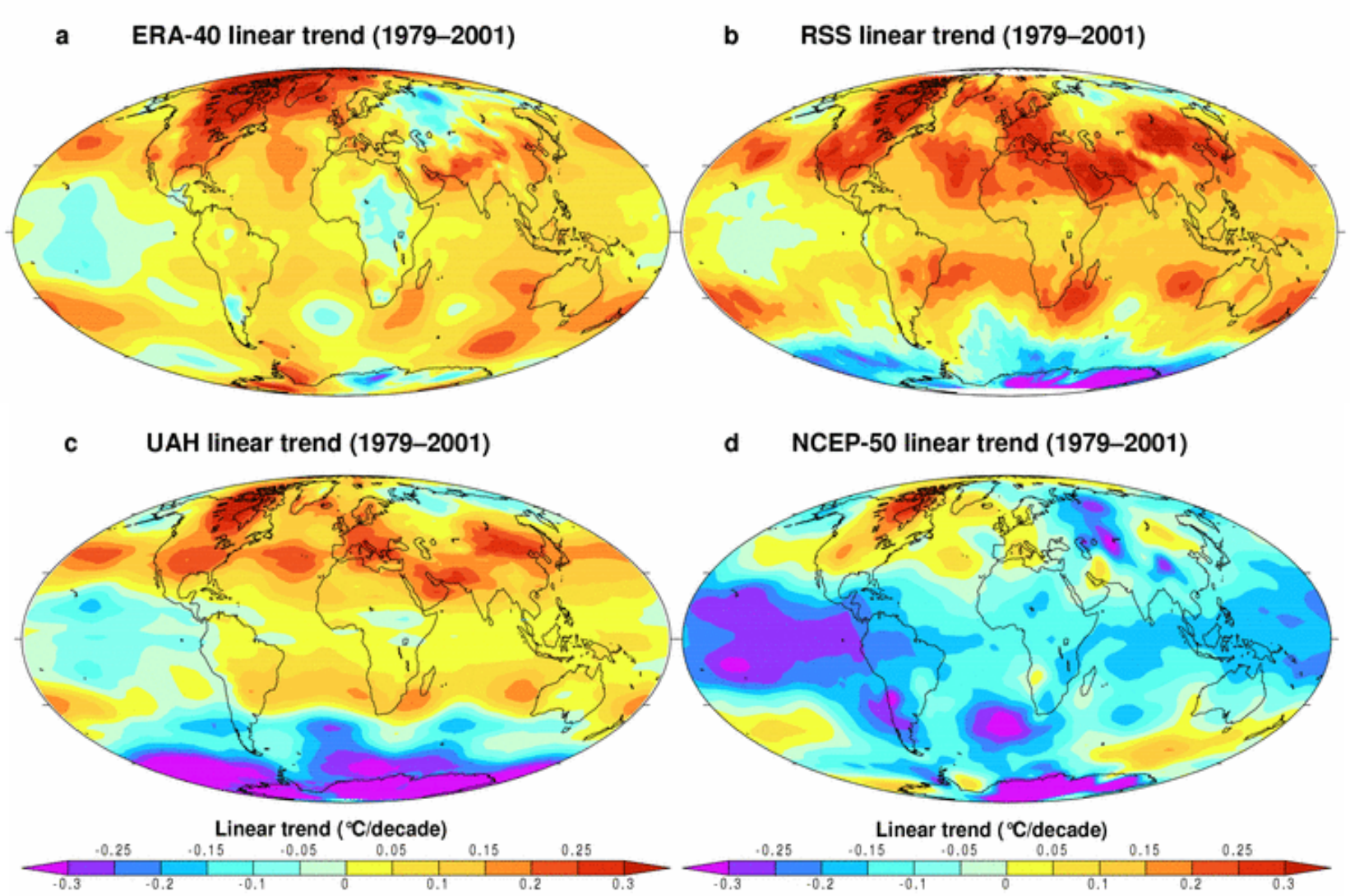
Radiosondes **ERA-40**

Turner et al. (2006)

500hPa temperature fits for Antarctic stations

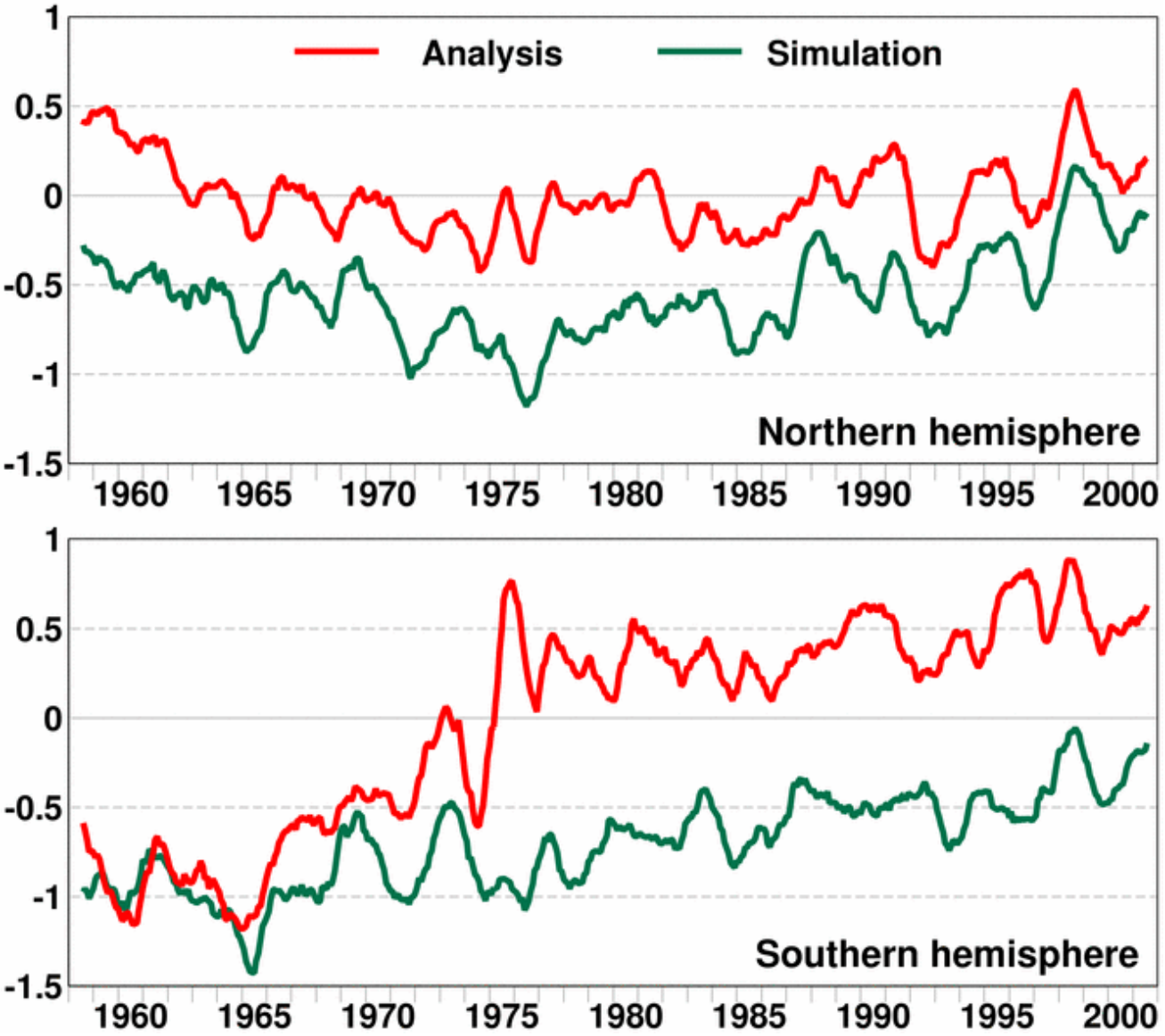


Linear trends 1979-2001 in MSU-2 temperatures

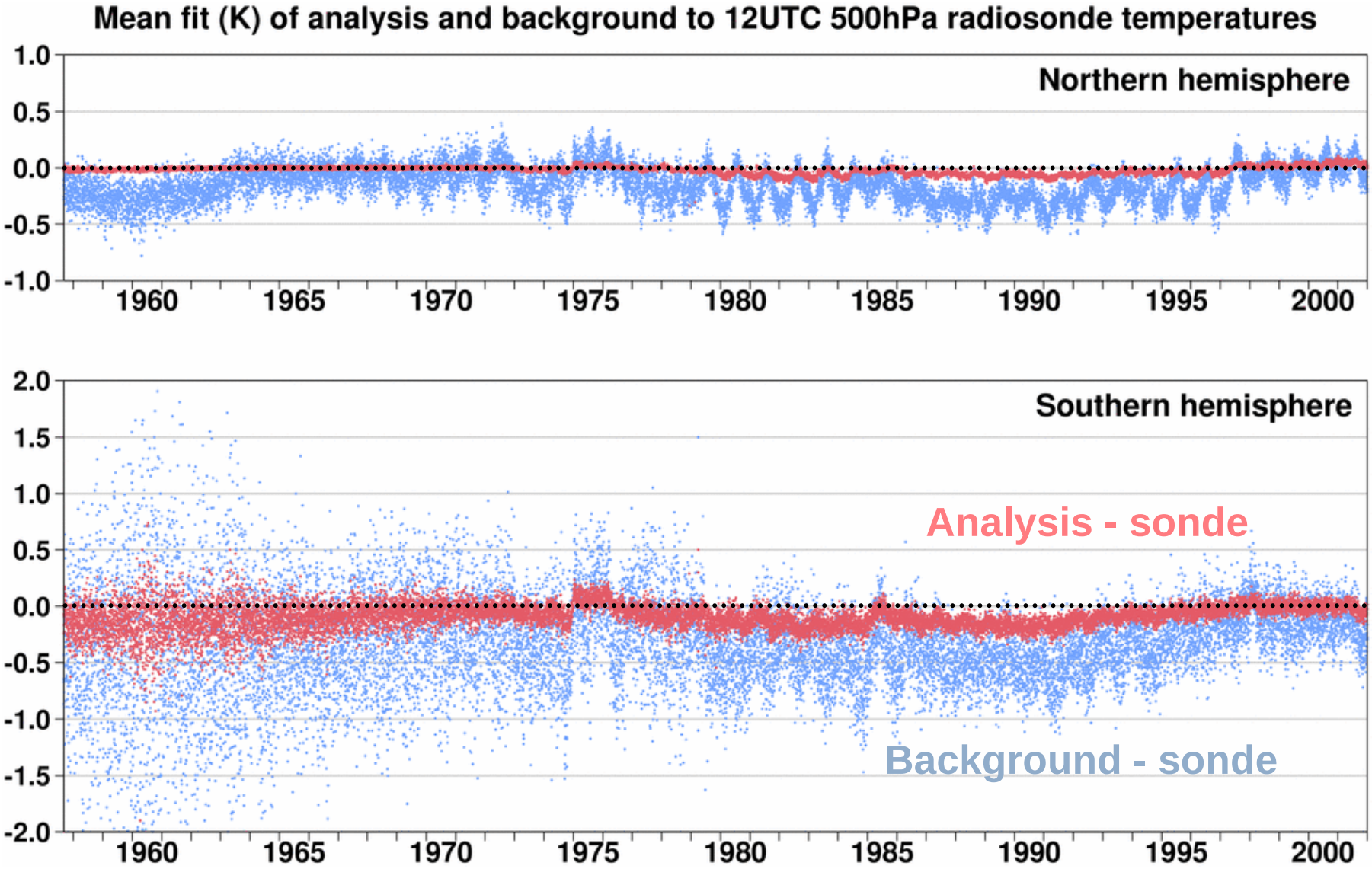


From Santer et al. (2004)

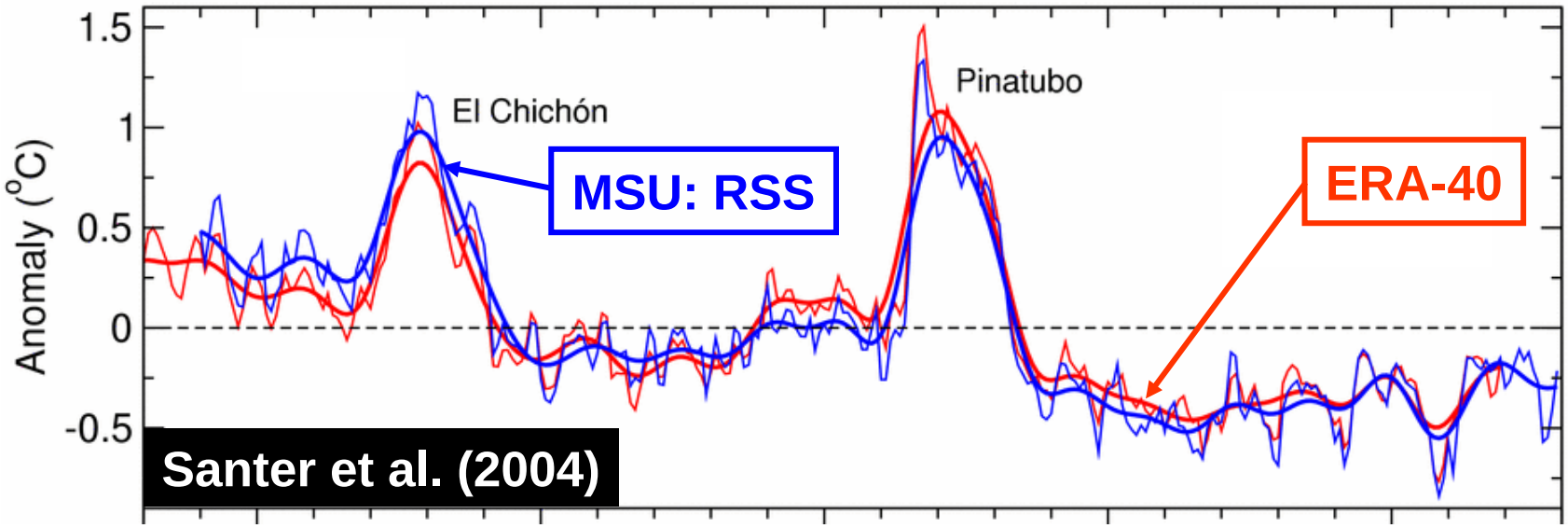
500hPa temperature anomaly
(relative to ERA-40 analysis for 1958-2001)

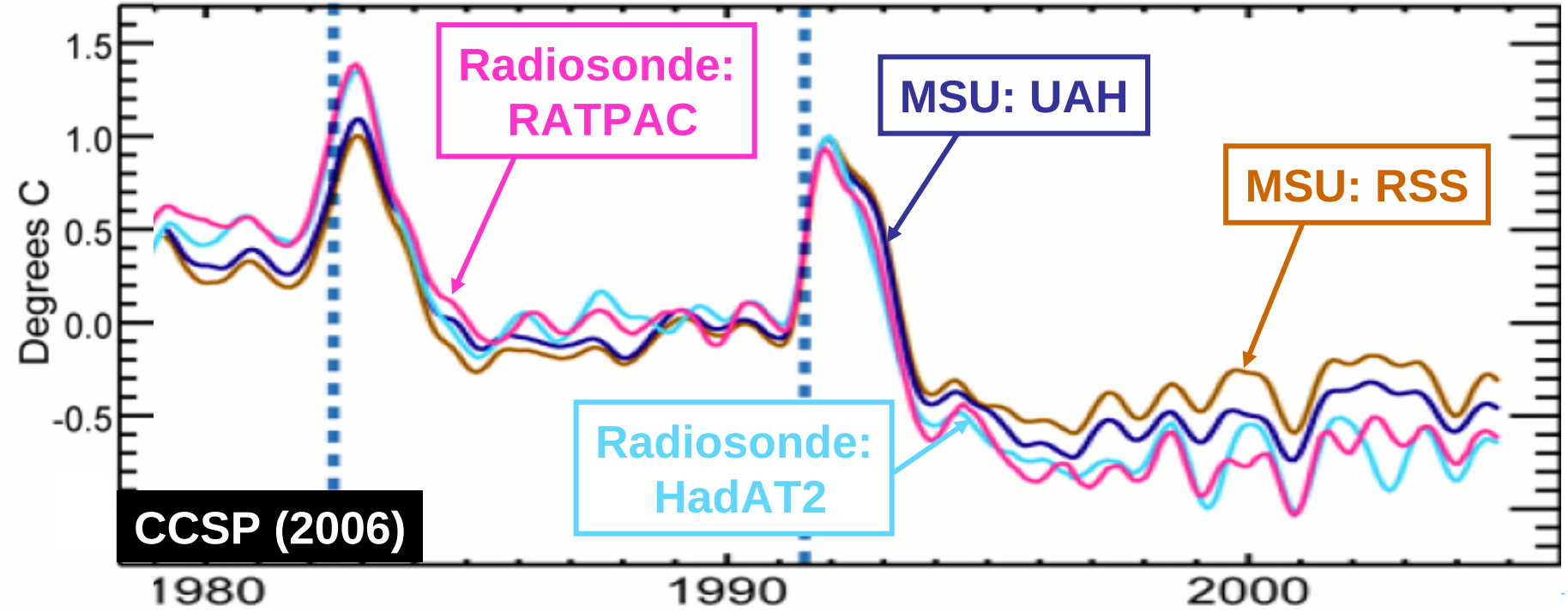


500hPa temperature differences

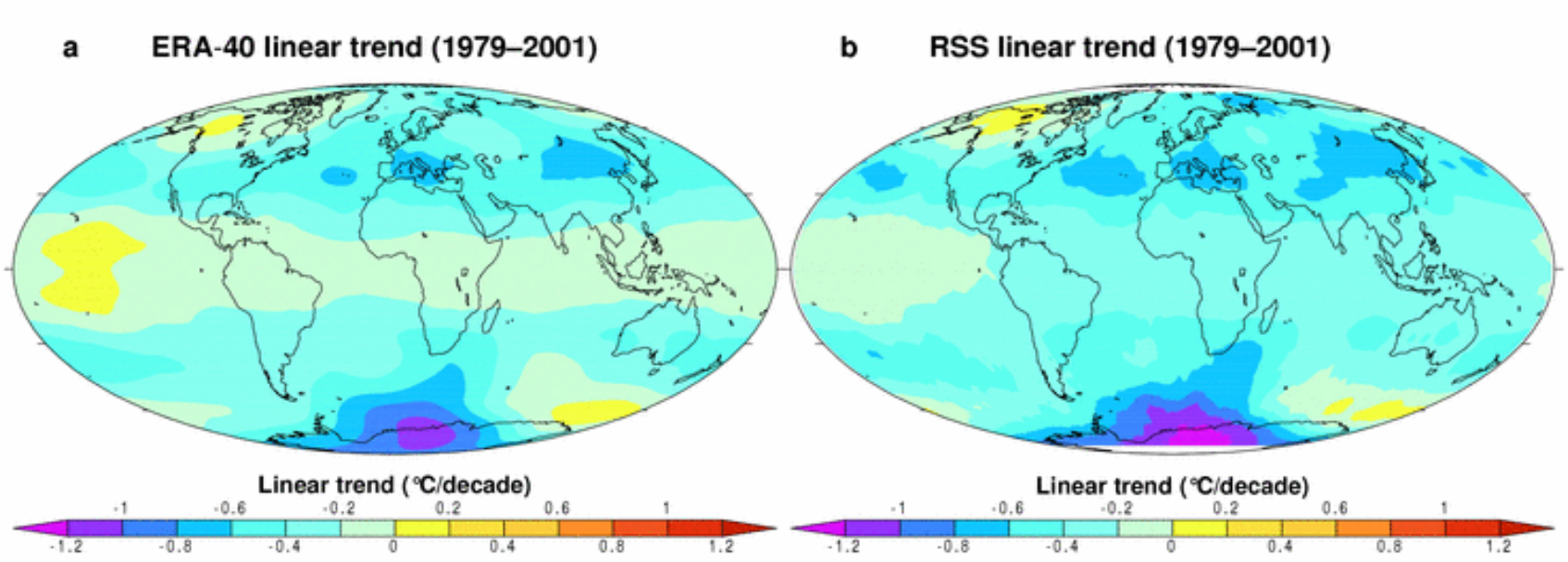


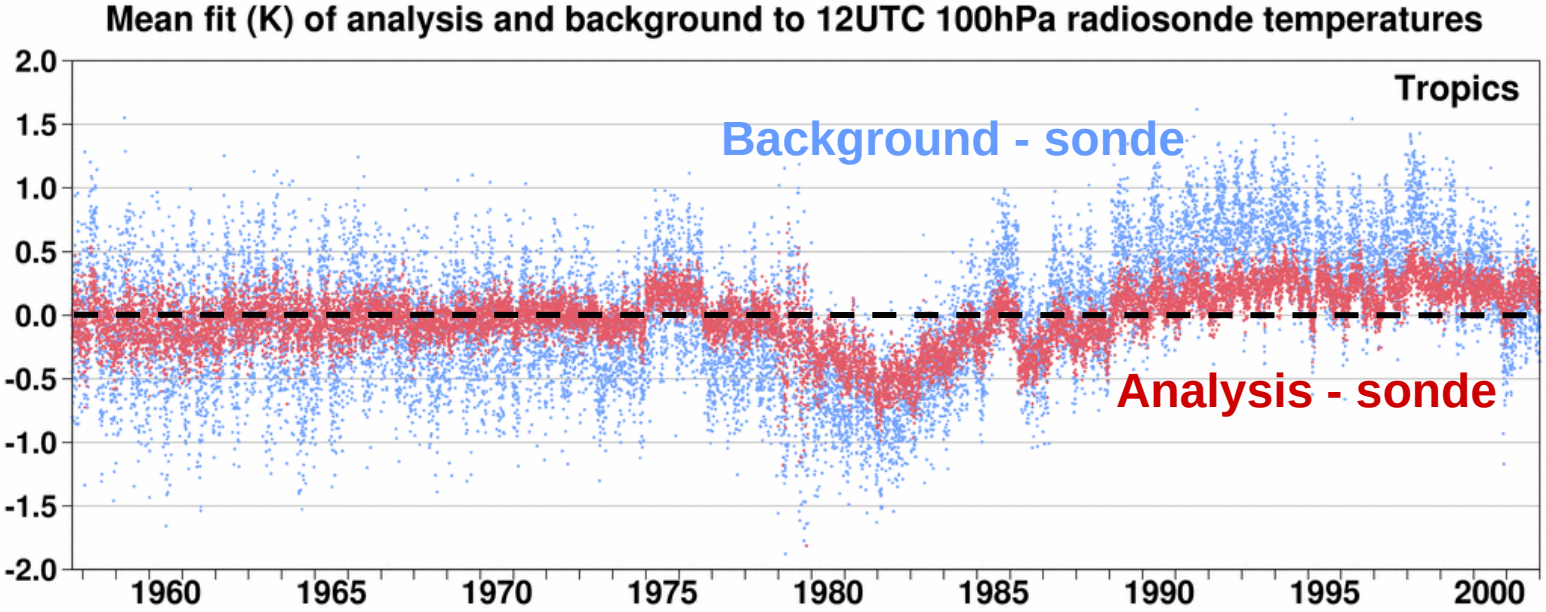
Trend and variability in lower stratospheric temperature



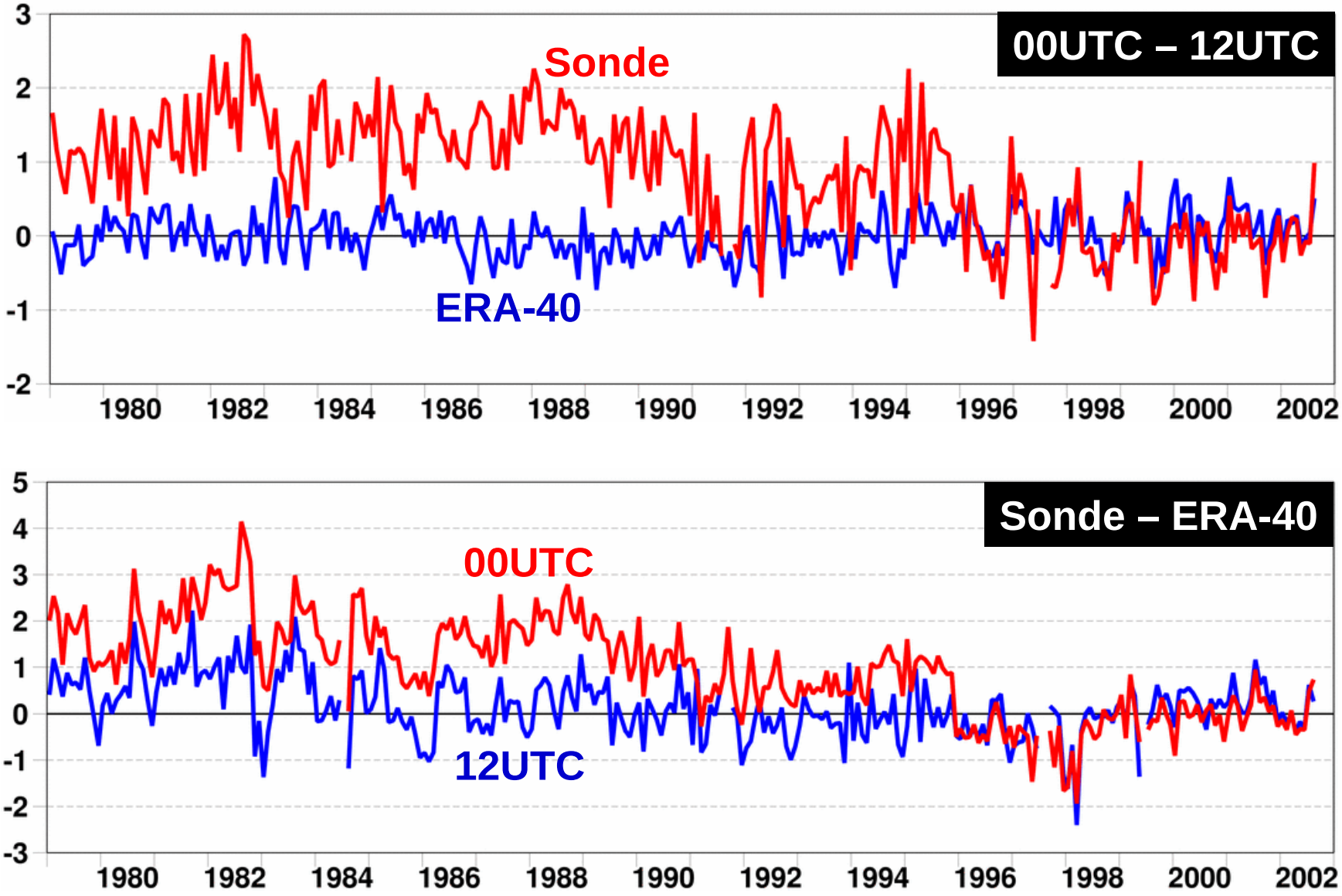


Linear trends 1979-2001 in MSU-4 temperatures

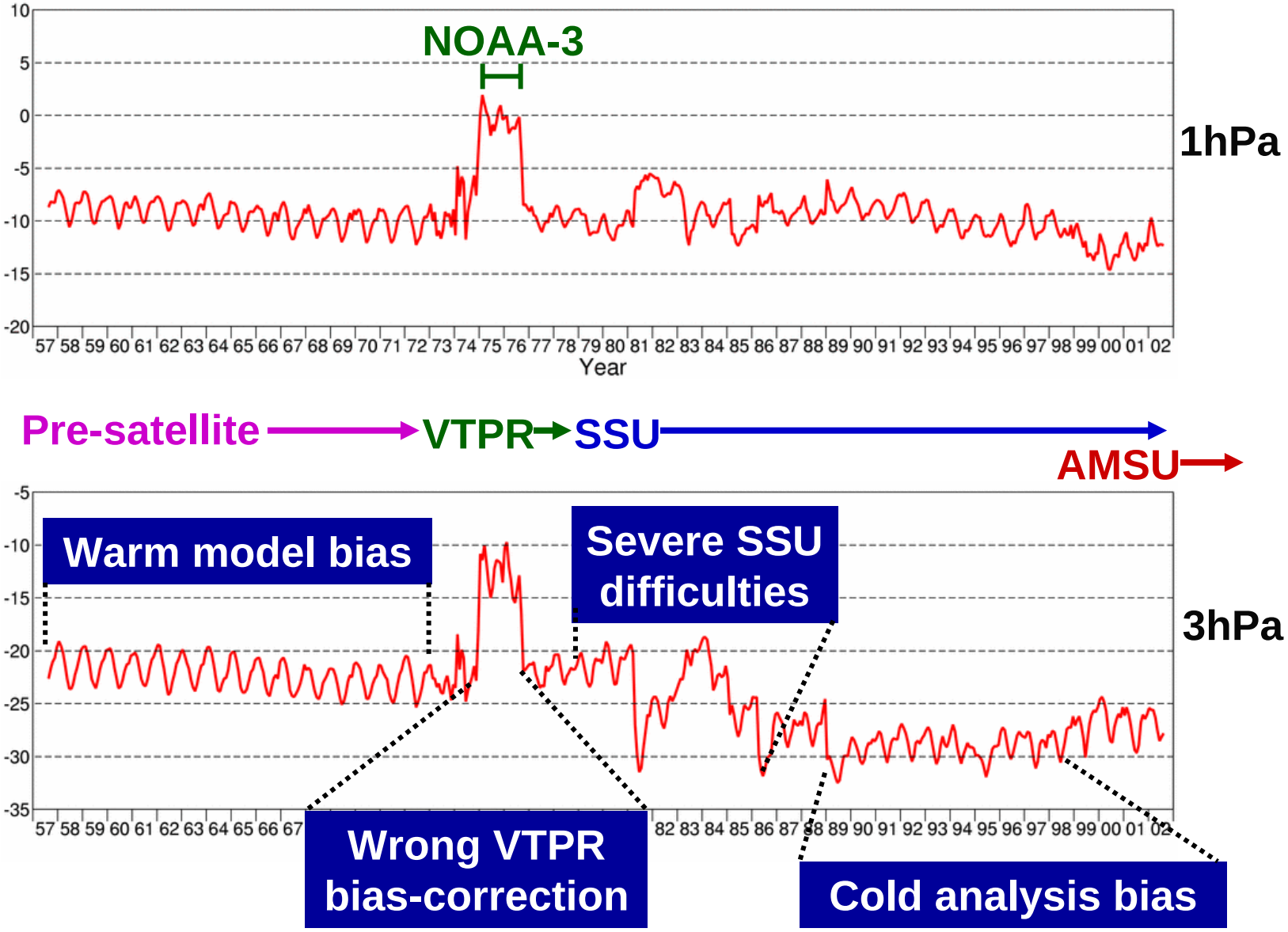




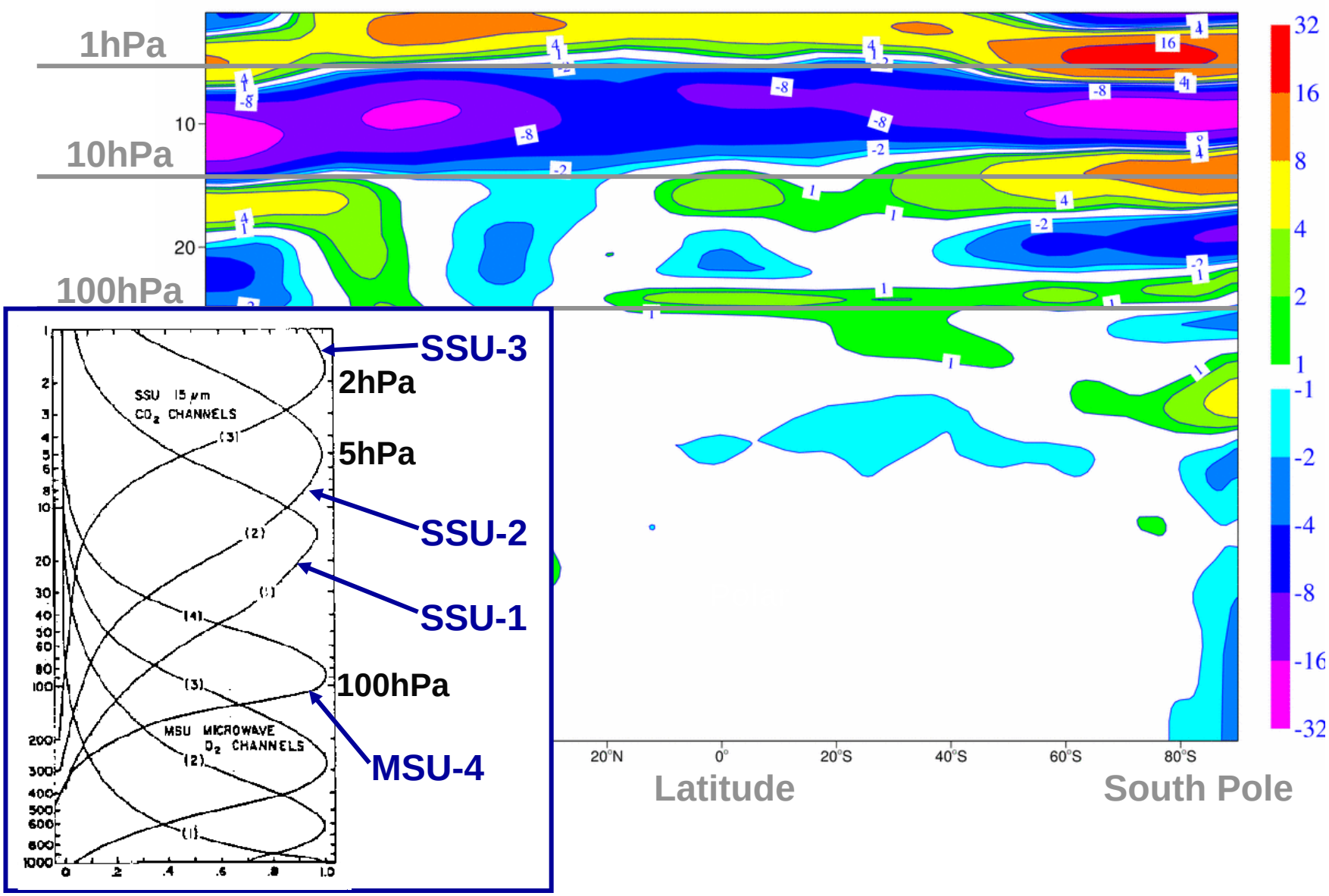
Monthly-mean 100hPa temperatures (^{O}C) from radiosondes and reanalyses at 14S 171W (American Samoa)



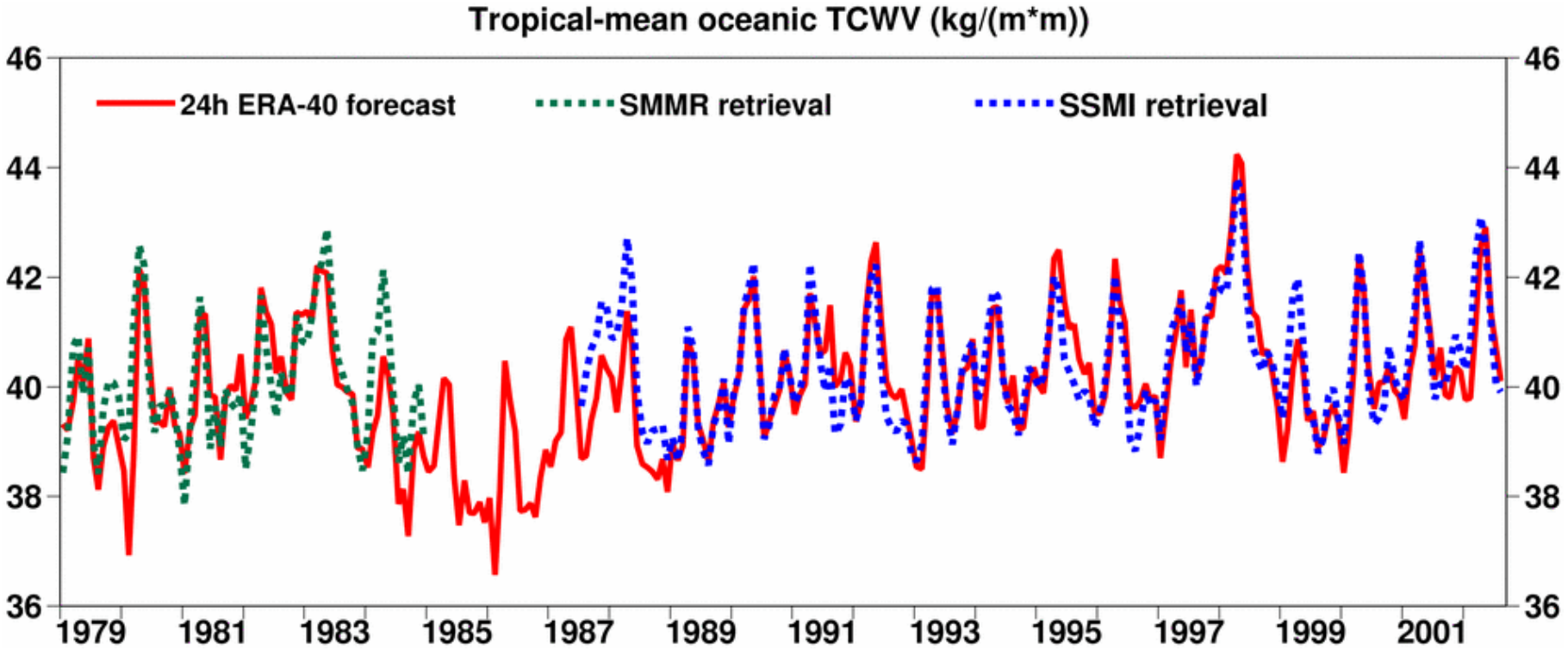
Global-mean temperature at 1hPa and 3hPa



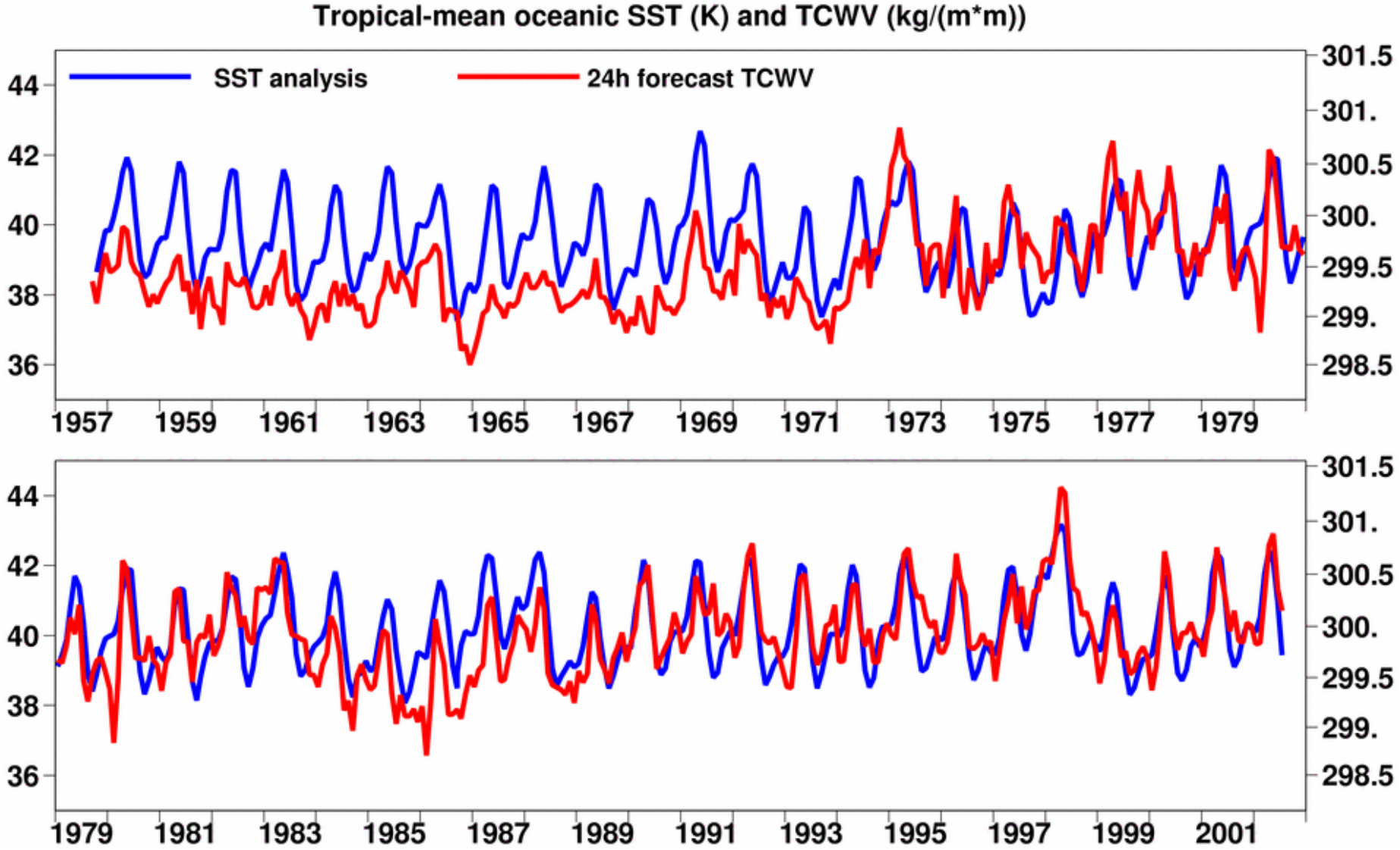
Zonal-mean temperature difference
January 1989 – January 1981



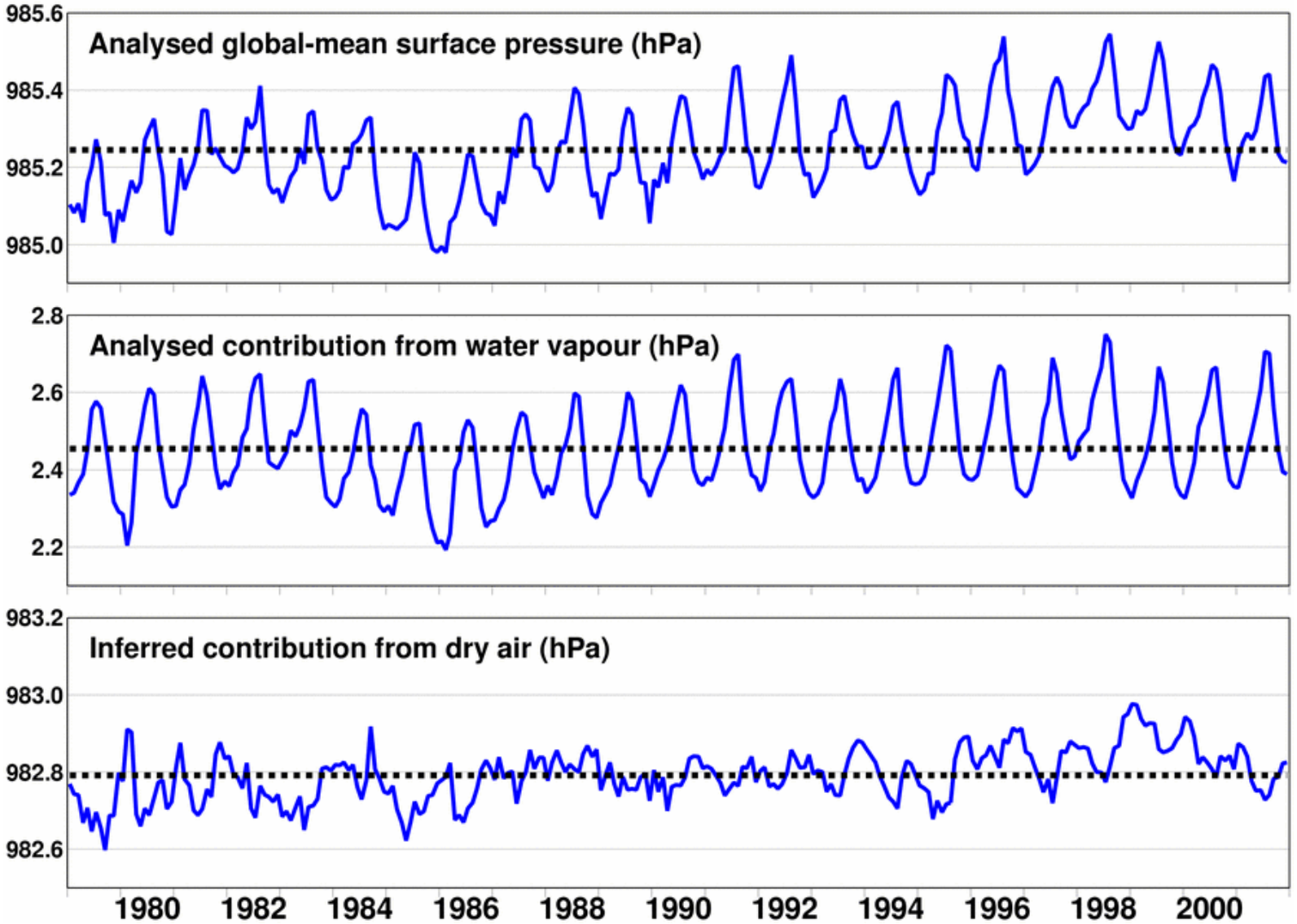
Tropical water-vapour content



Aspects of tropical humidity analysis



Consistency of surface-pressure and humidity analysis
Trenberth and Smith (2005)



In summary

- **Reanalysis does have a role to play in the study of recent climate trends**
- **It can help in the detection and correction of problems in the instrumental record**
- **ERA-40 represents a clear step forward from the NCEP/NCAR reanalysis for the depiction of trends**
- **Insights into deficiencies are provided by analysis and background fits to observations, analysis increments and comparisons with simulations**
- **There is considerable potential for improvement of reanalysis – more so than for improvement of the database of past observations?**

What will lead to better trends in future reanalyses?

- **The passage of time**
  - will limit impact of (or enable us to avoid) the problematic early-satellite period
  - will see gradually increasing impact from new and improved observations, such as from radio occultation
- **Reduction of bias in background forecasts**
  - from better basic climatology of the assimilating model
  - from better time-variation of radiatively active constituents
  - from improvements to the data assimilation process
- **Better handling of remaining model biases in data assimilation**
  - apply model bias term estimated from most recent period

What will lead to better trends in future reanalyses?

- **Better correction of biases in observations**
  - homogenization and SZA-dependent correction of radiosonde data
  - variational correction of radiance biases
- **Better observation operators**
  - forward radiative transfer model for SSU
  - incorporation of volcanic aerosol effects for HIRS radiances
- **Better quality control of observations**
  - deciding when and when not to use data from specific instruments/channels
- **Better collection of observations**
  - such as filling gaps in pre-1967 SYNOPS, pre-1977 snow cover
- **Time-variation in observation/background error variances**
  - giving more weight to pre-1979 southern hemisphere radiosondes