Atmospheric Temperature CDRs from Satellites

Science Overview & Current Challenges

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Workshop on Climate Data Records from Satellite Microwave Radiometry
22-24 March 2010 Silver Spring, MD

Outline

- Upper-air T as a climate change indicator
- T CDRs from MSU and SSU observations
- Value of *in situ* observations
- SPARC Temperature Trends Panel
- Recommendations for NOAA CDR efforts

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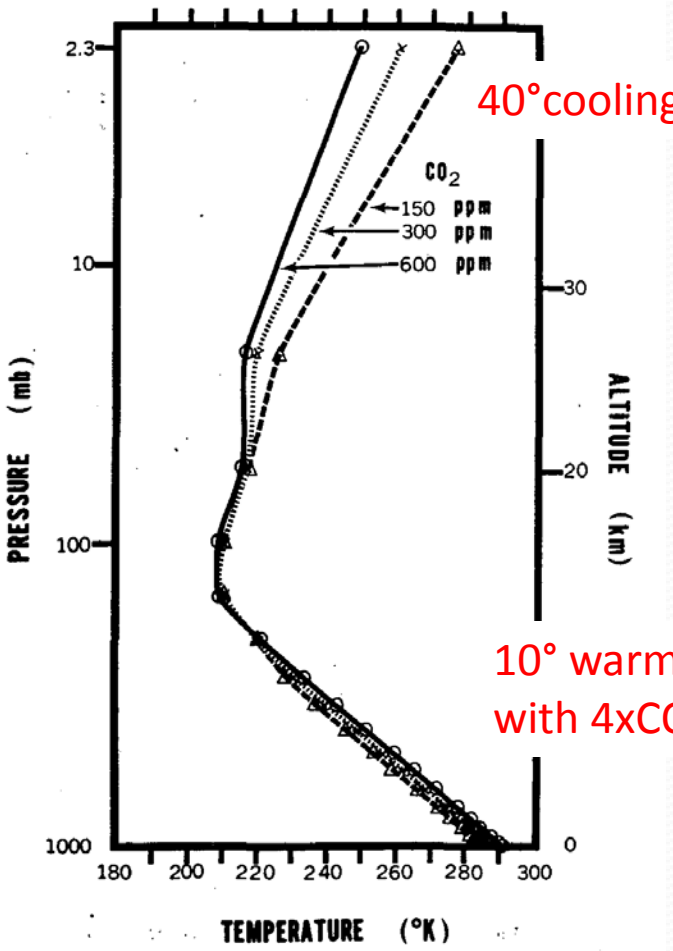
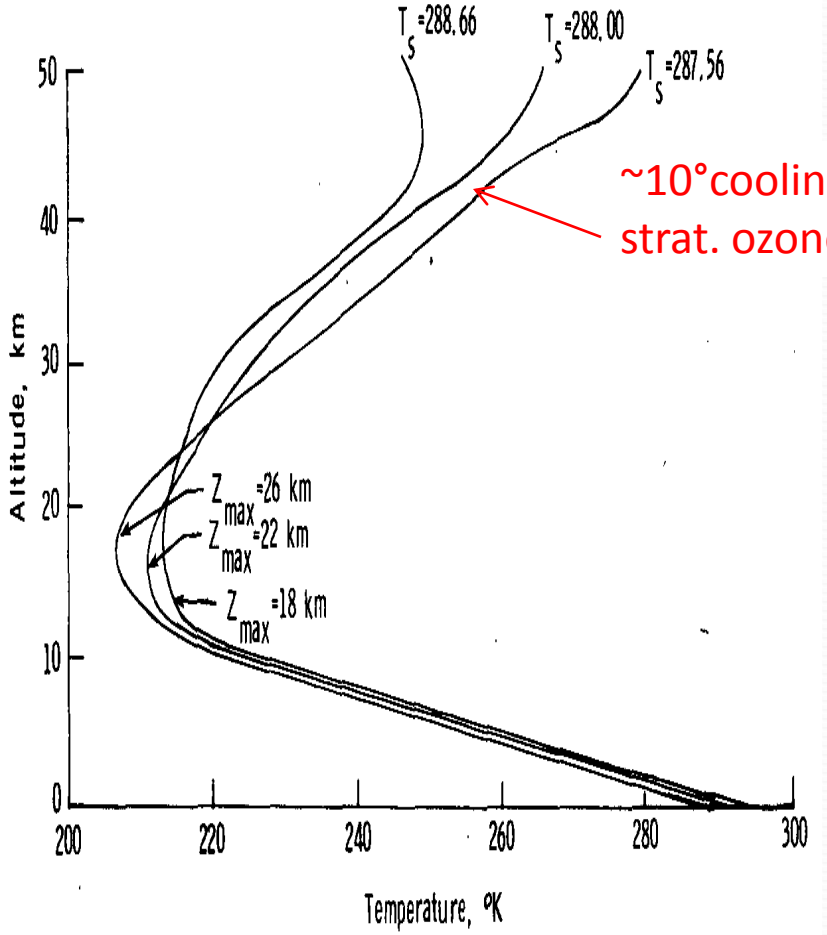
Early model projected T changes



40°cooling

10° warming with $4xCO_2$

Manabe and Wetherald (JAS, 1967)

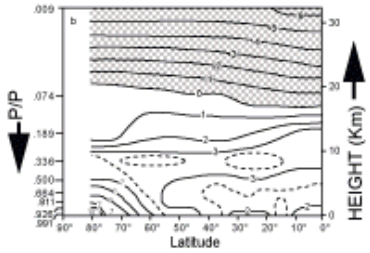


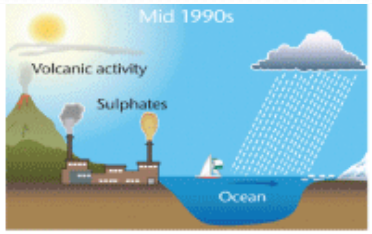
~10°cooling with strat. ozone loss

Ramanathan et al. (JAS, 1976)

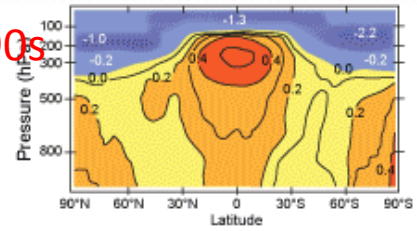
Consistent projections over time

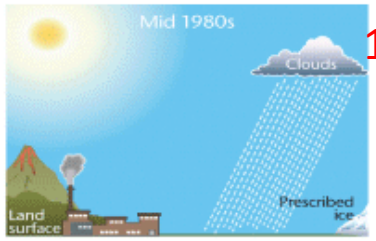
1970s



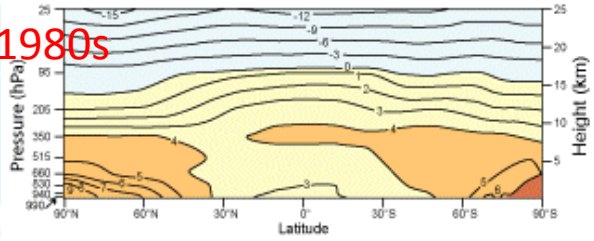


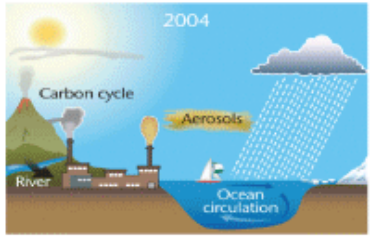
1990s



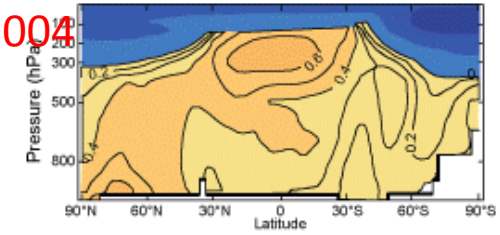


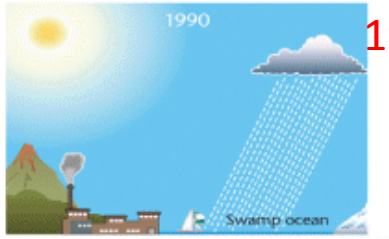
1980s



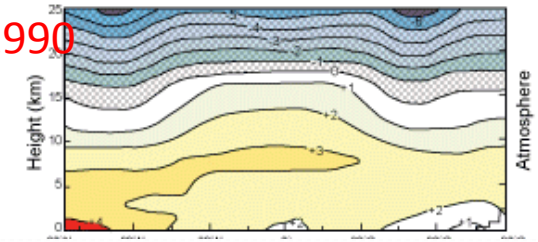


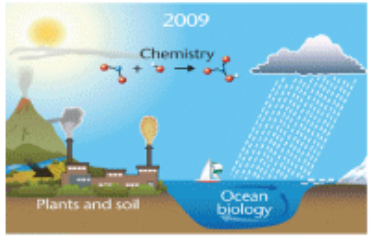
2004



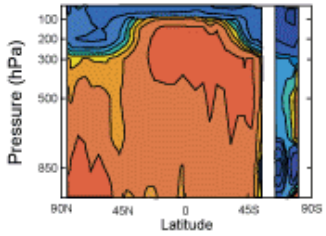


1990





2009



NOAA GFDL models

Manabe and Wetherald (1975)

Manabe (1983)

Manabe et al. (1994)

UK Met Office/Hadley Centre models

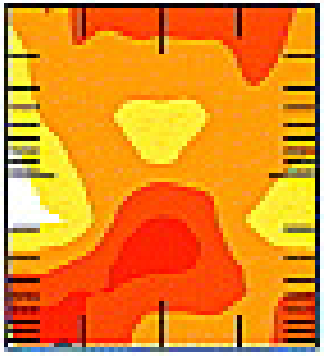
Tett et al. (1996)

Tett et al. (2002)

Stott et al. (2006)

Distinctive patterns of T trends

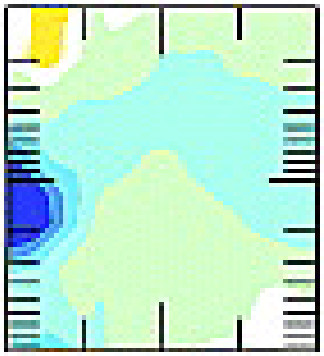
Greenhouse Gases



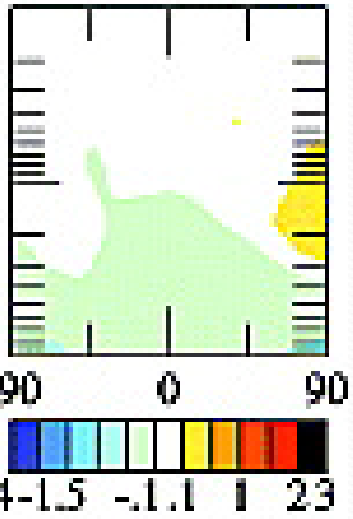
Solar

Strat. Water Vapor

Strat. Aerosols



Ozone

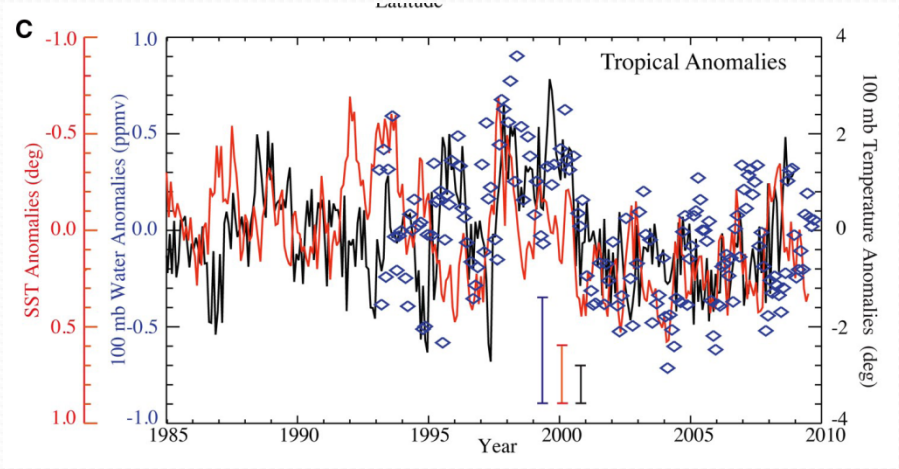


Trop. Aerosols

- Hansen et al. (JGR, 2002)

Importance of tropopause T

- Tropopause height/pressure as indicator of climate change
- Tropical cold point temperature related to stratospheric water vapor
- Multiple tropopauses indicators of dynamical processes
- Require high vertical resolution observations



100 mb T in warm pool region, from Japanese reanalysis, as surrogate for cold point

Solomon et al. (Science 2010)

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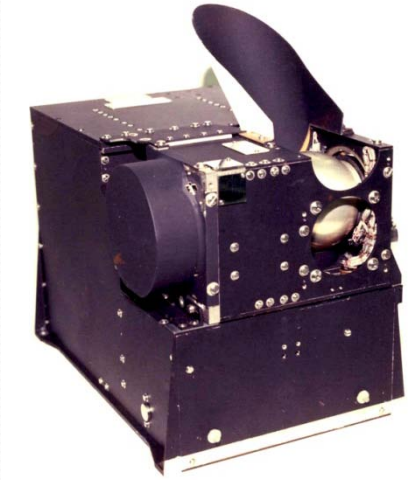
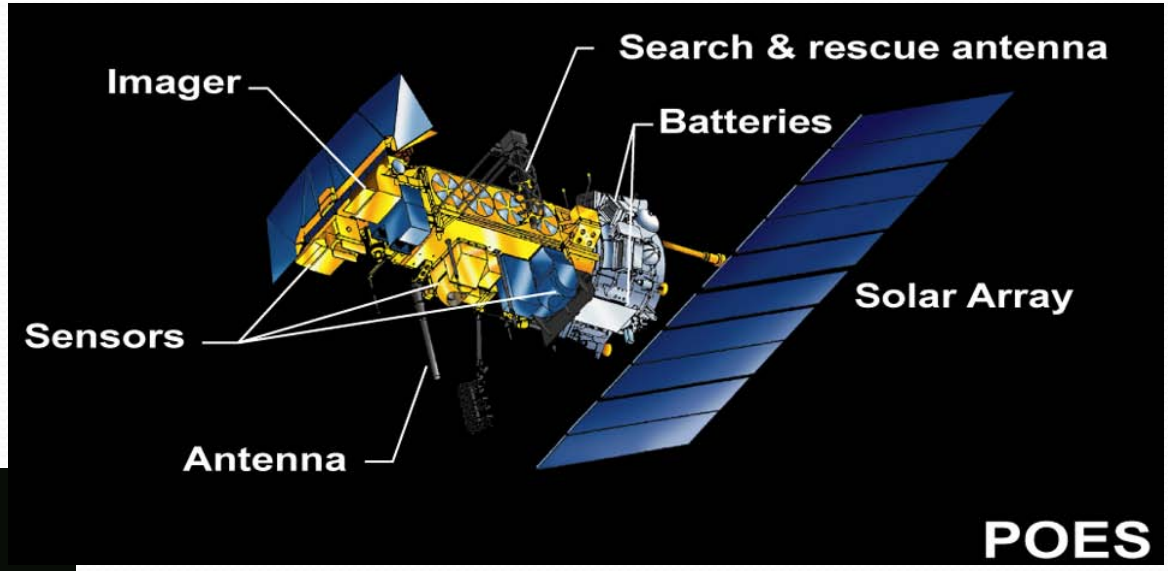
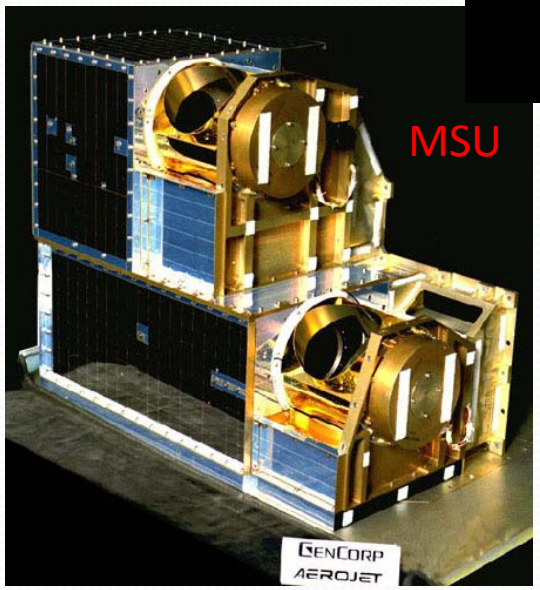
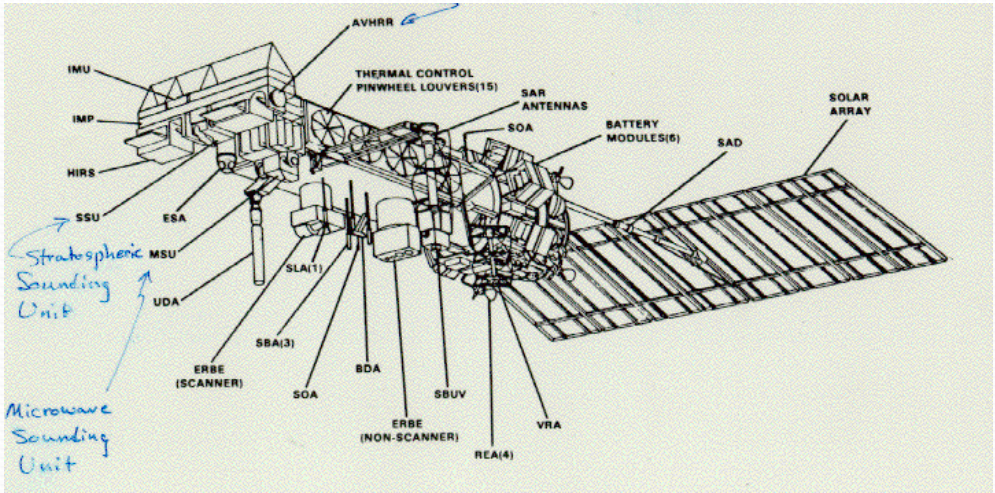
Microwave Sounding Unit & Stratospheric Sounding Unit



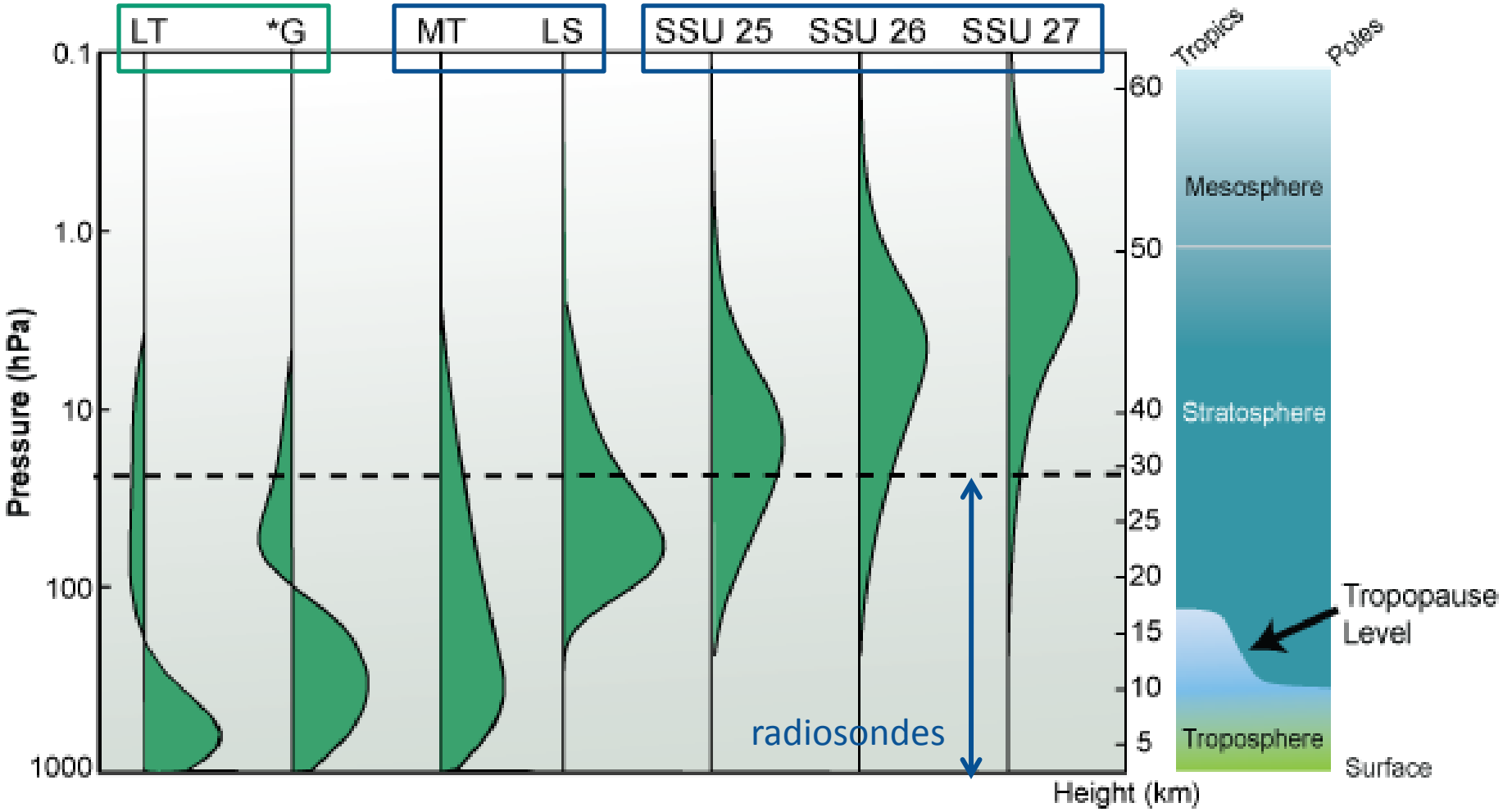
SSU



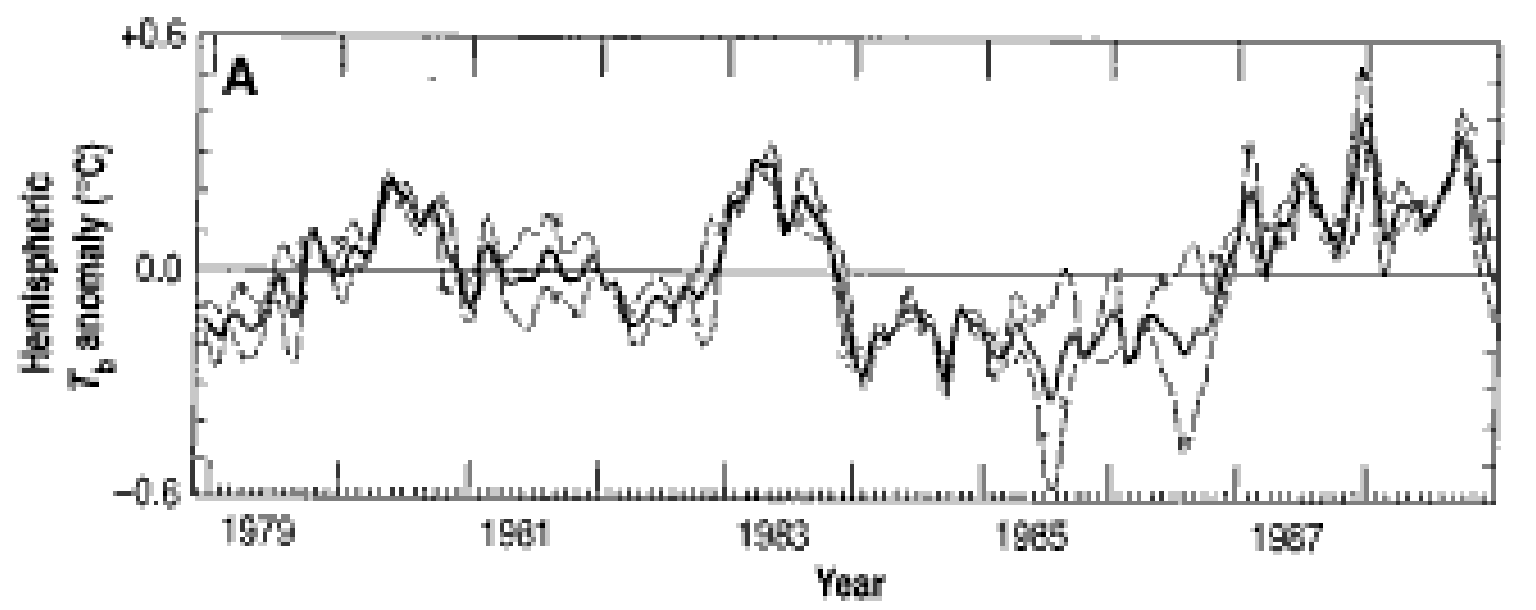




MSU & SSU vertical sampling

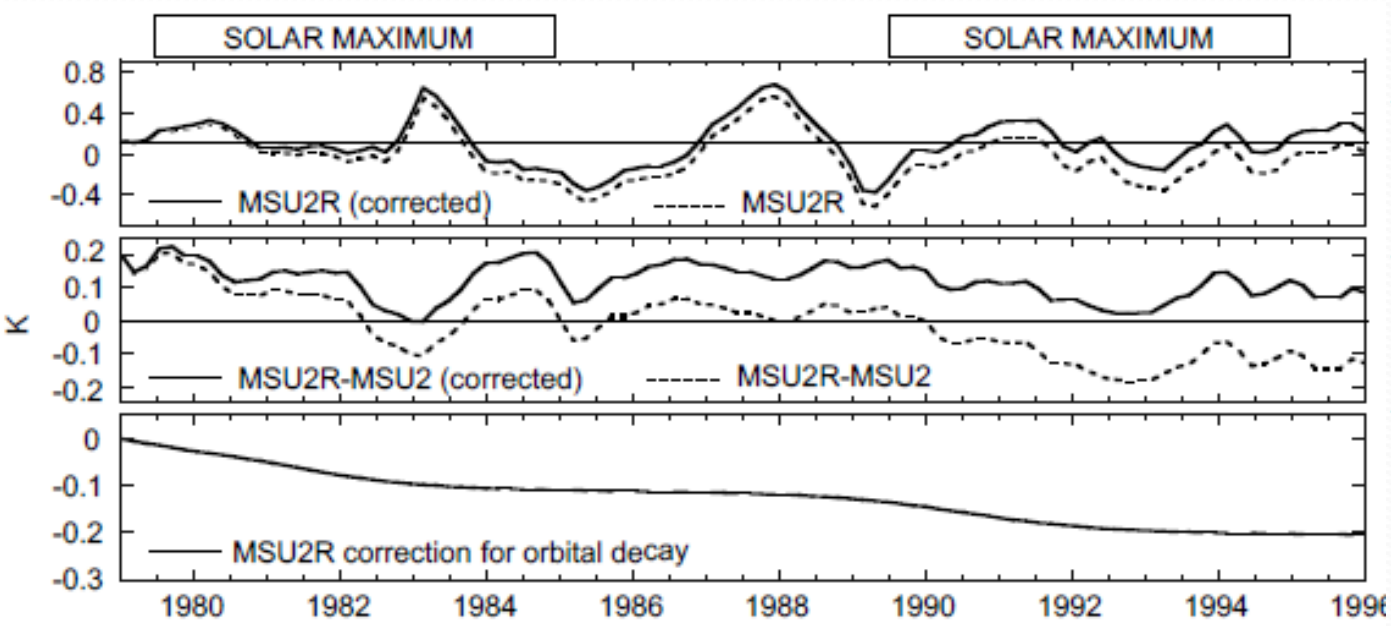


CDRs from MSU



Spencer and Christy (Science, 1990)

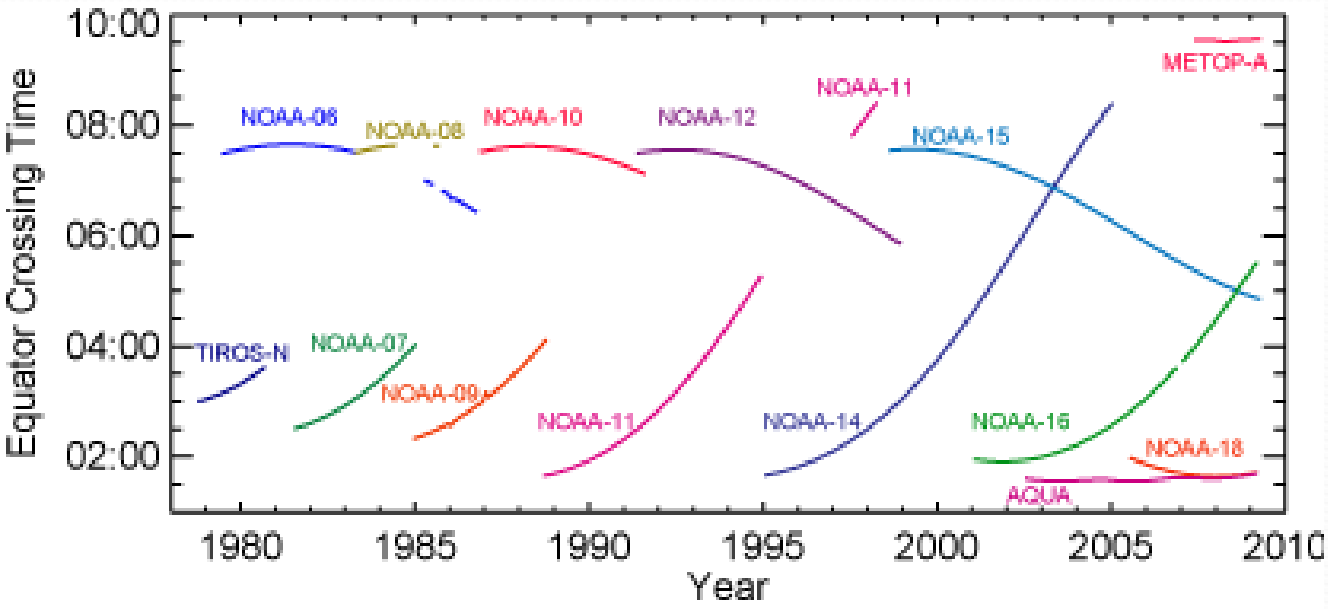
MSU data homogeneity



- Orbital decay due to drag
- Affects off-nadir views
- Spurious cooling trend in LT product

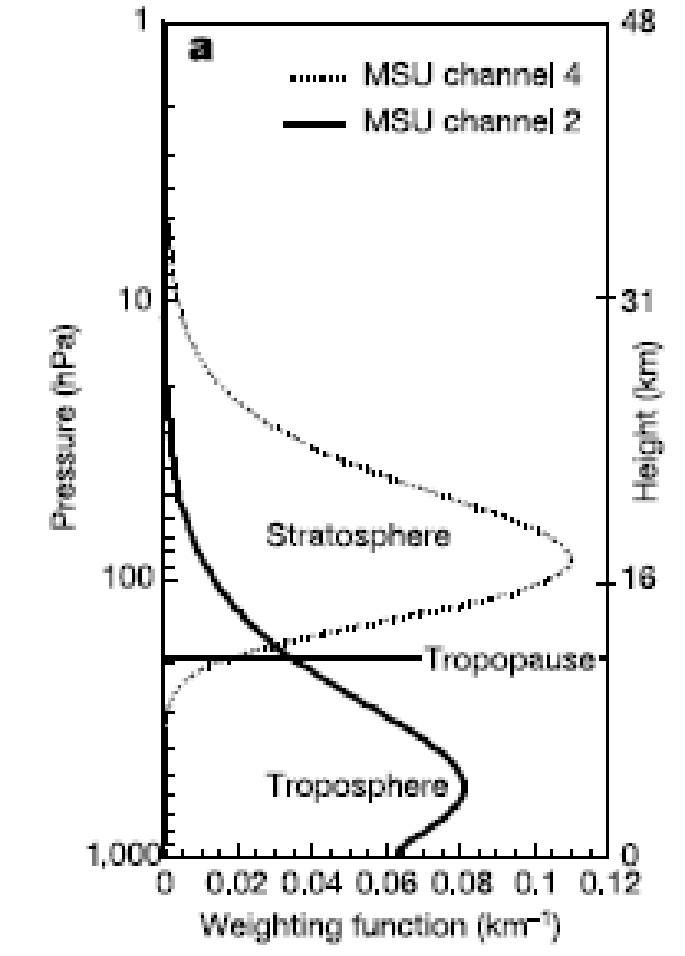
Wentz and Schabel (Nature, 1998)

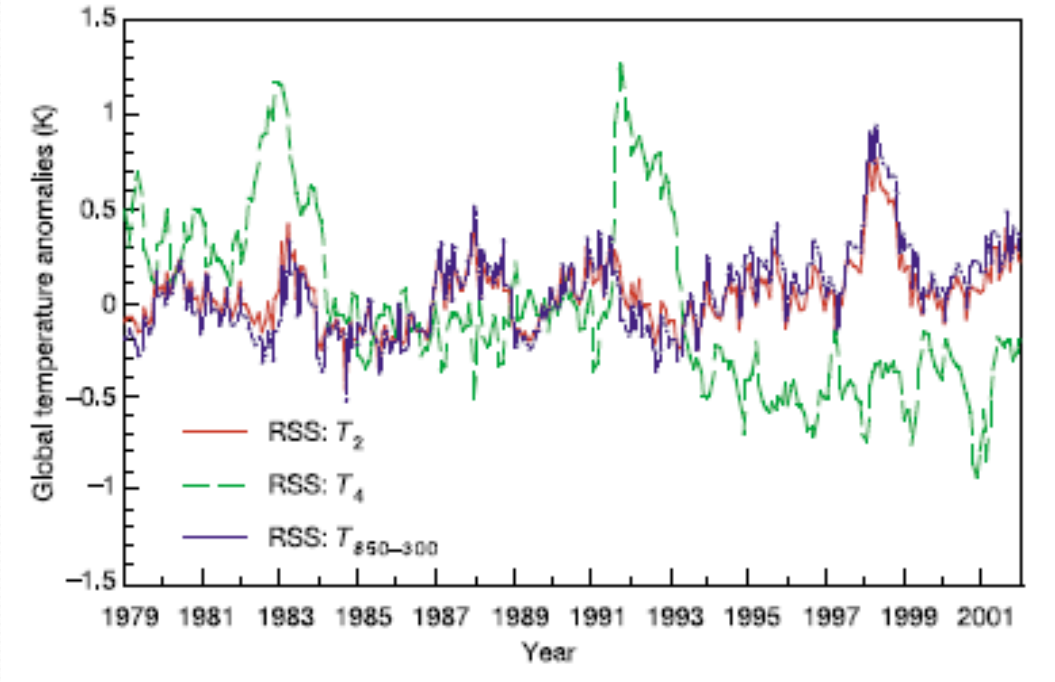
MSU data homogeneity



- Various approaches to address LECT drift and changes in platform
- Overlapping observations available for MSU, not for SSU

Stratospheric influence on MSU

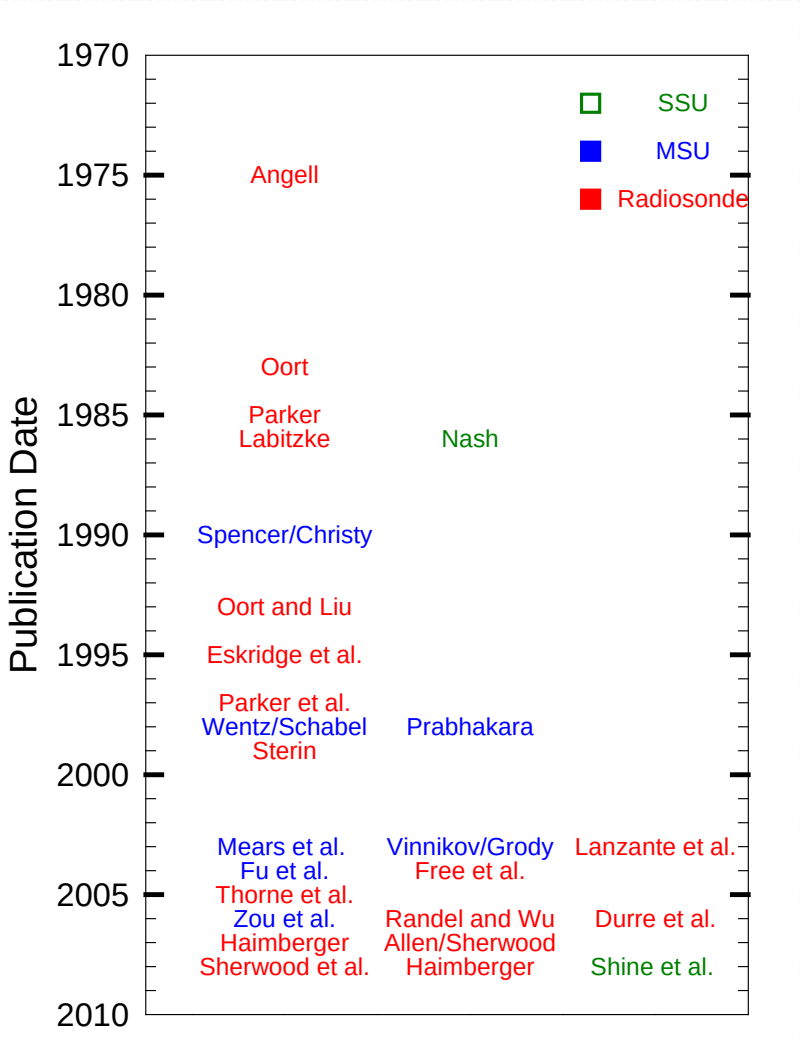




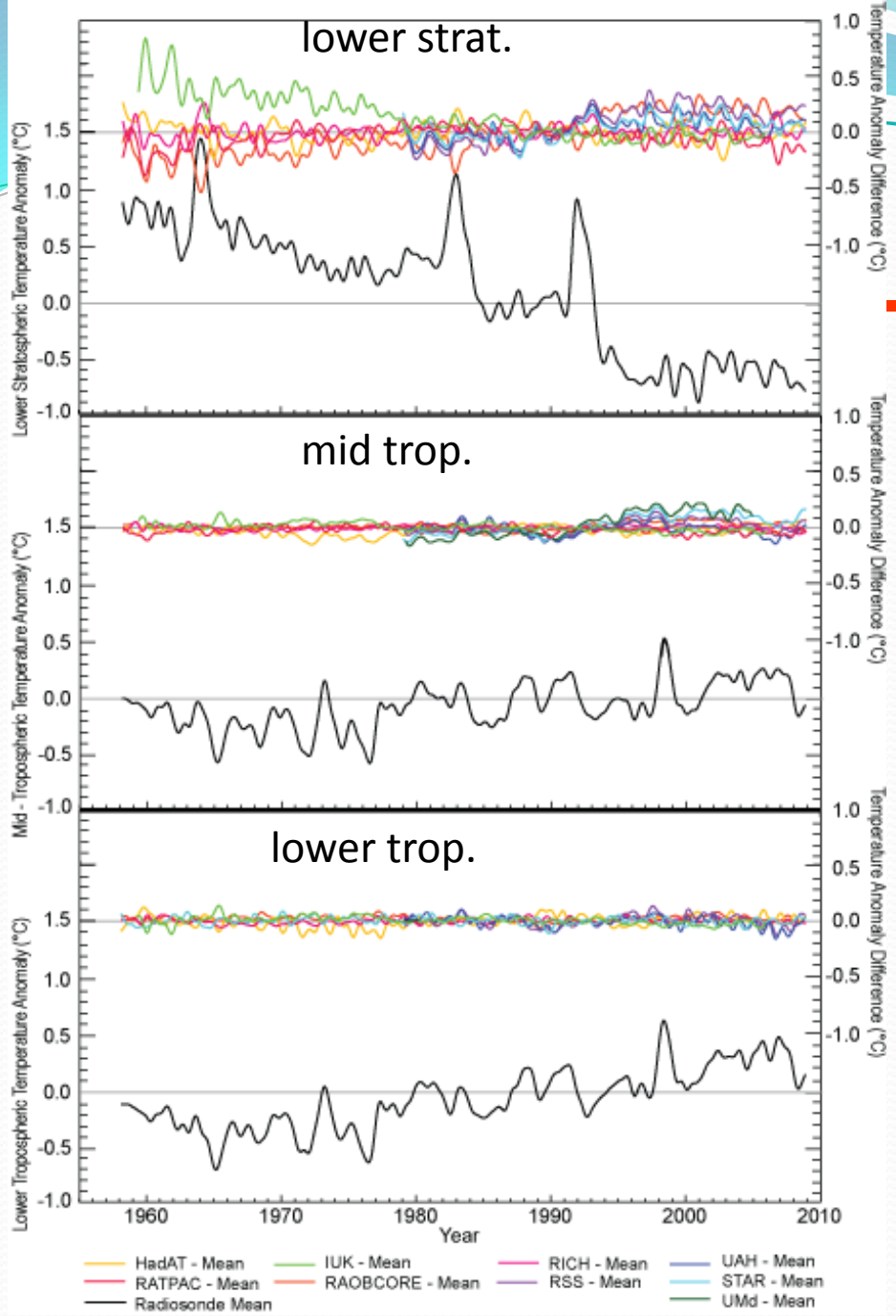
$T(850\text{-}300\ hPa) = a_0 + a_2T(MT) - a_4T(LS)$

Fu et al. (Nature, 2004)

Proliferation of T datasets



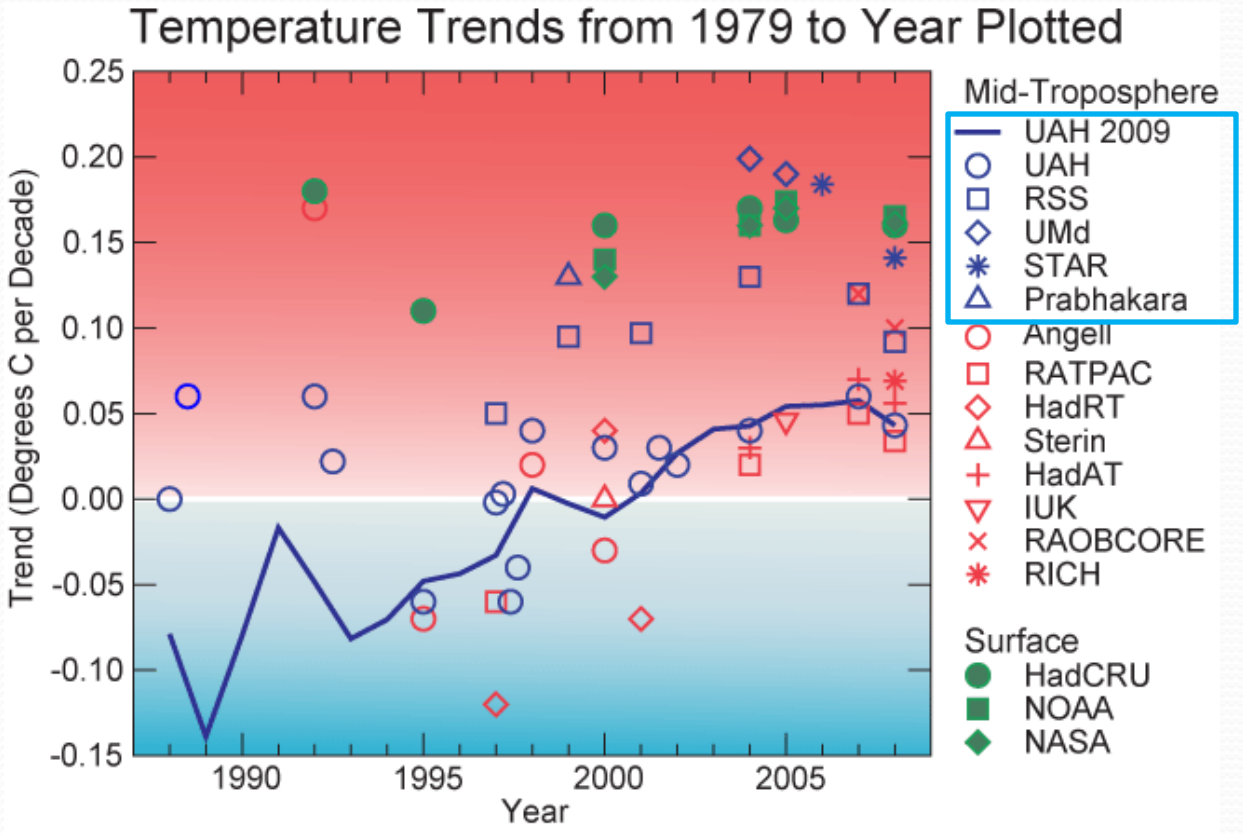
- Multiple, independent attempts to homogenize
- Each has strengths/weaknesses
- None “reference” quality
- More radiosonde products than MSU
- More MSU than SSU



T signals & noise

- *State of the Climate in 2008* (BAMS, 2009)
- Less agreement among stratospheric time series than tropospheric

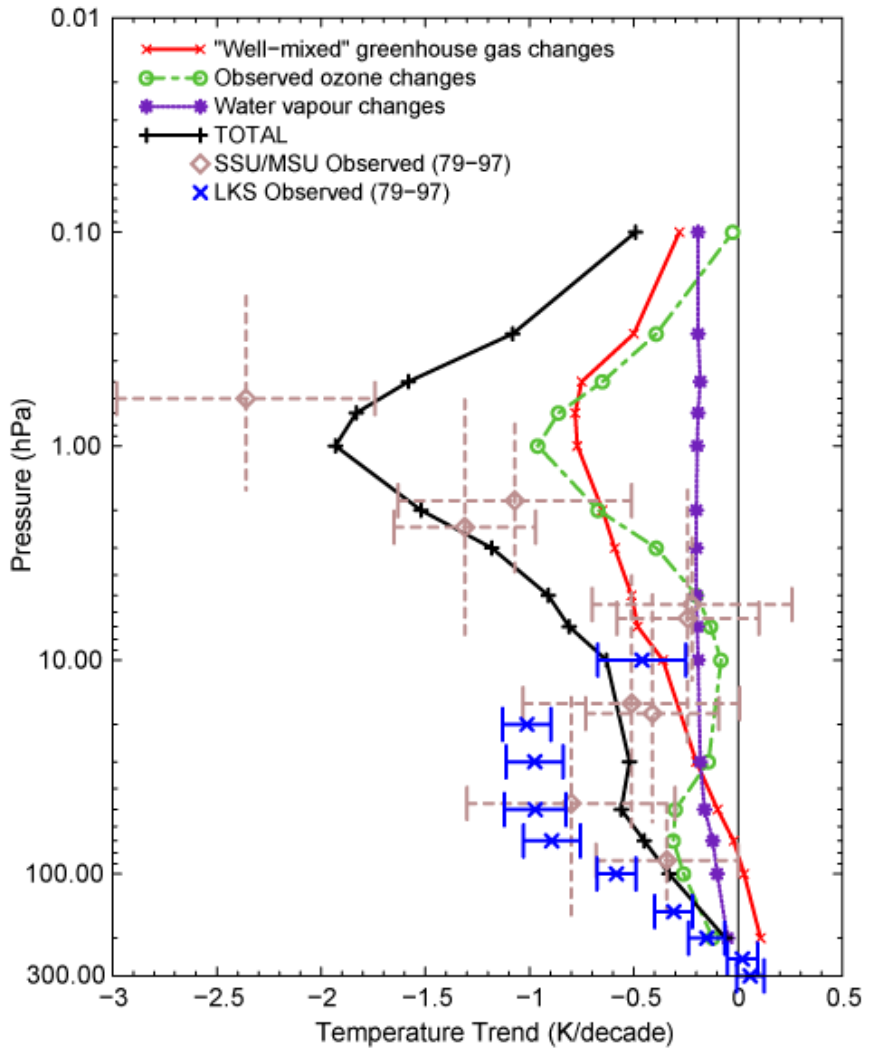
Trends in T trends



- UAH 2009 shows increasing warming with time
- Compare UAH 2009 with earlier versions
- Compare UAH and other MSU
- More warming in recent (adjusted) radiosonde datasets
- Consistency of surface datasets
- Overall convergence

Thorne et al. (submitted)

Stratospheric T trends

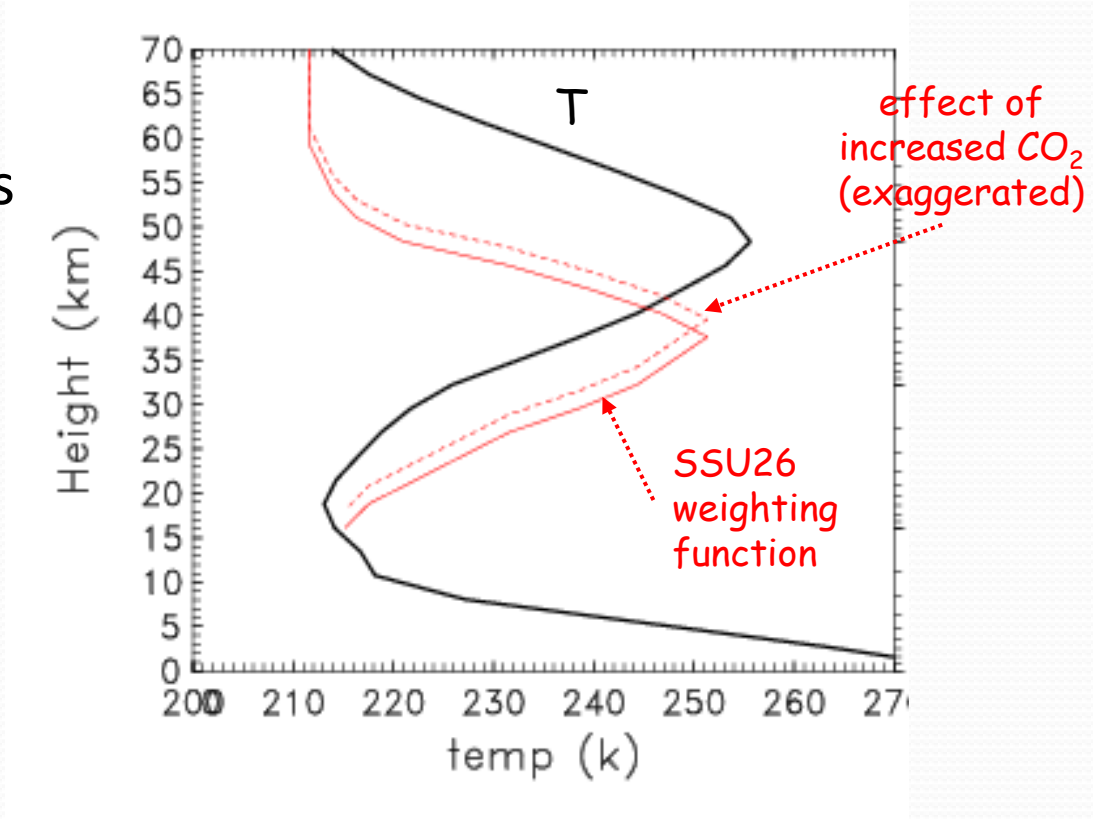


- Limited model results
- Limited observational data, none “climate quality”
- Poor agreement at various levels

Shine et al. (QJRMS, 2003)

Re-examination of SSU data

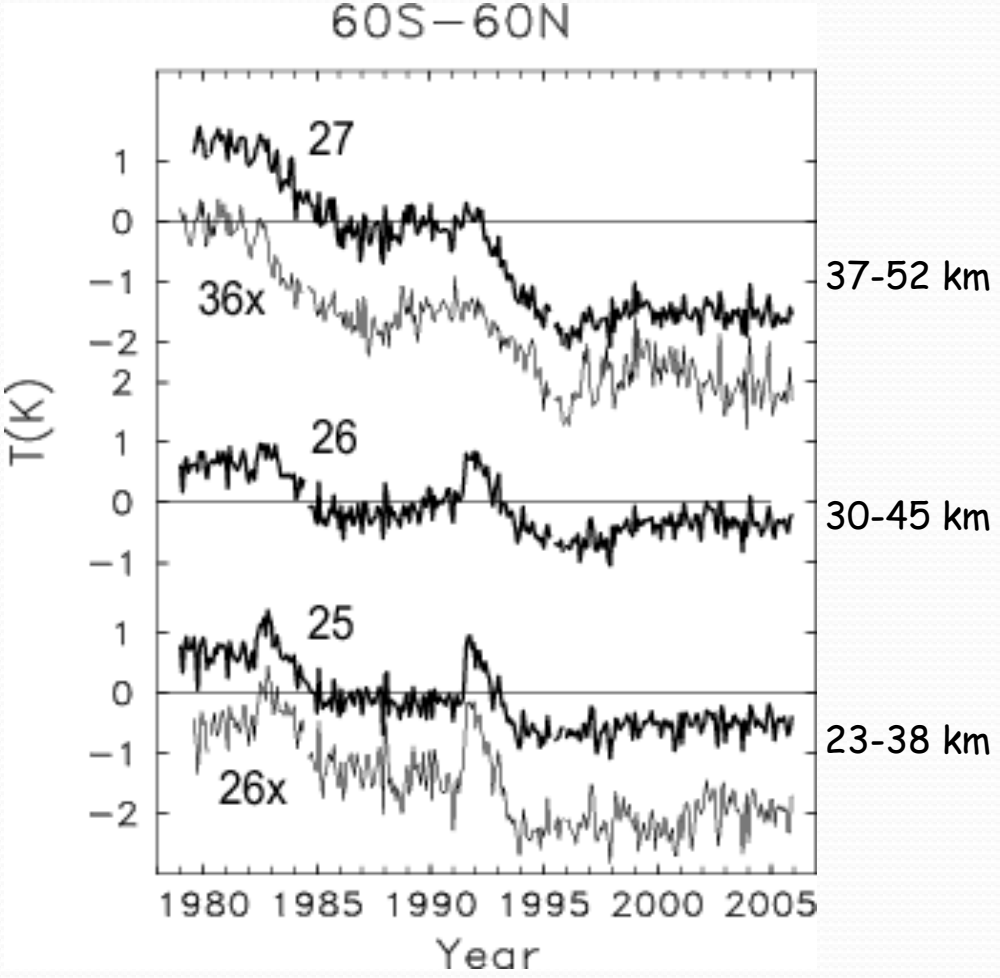
- SSU measures in 15 µm CO_2 band
- Effect of CO_2 increase is to elevate weighting functions
- Apparent trends ~0.3 K/decade



Shine et al. (GRL, 2008)

Stratospheric Temperature Evolution

- Overall cooling
- Punctuated by El Chichón and Pinatubo warmings
- Step-like behavior
- Flat since 1995
- Data quality questions, especially regarding “X channels”
- Difficulties in creating SSU CDRs due to
  - Lack of overlap data
  - Time series based on zonal anomalies – hard to reconstruct
  - Minimal literature



Randel et al. (JGR, 2009)

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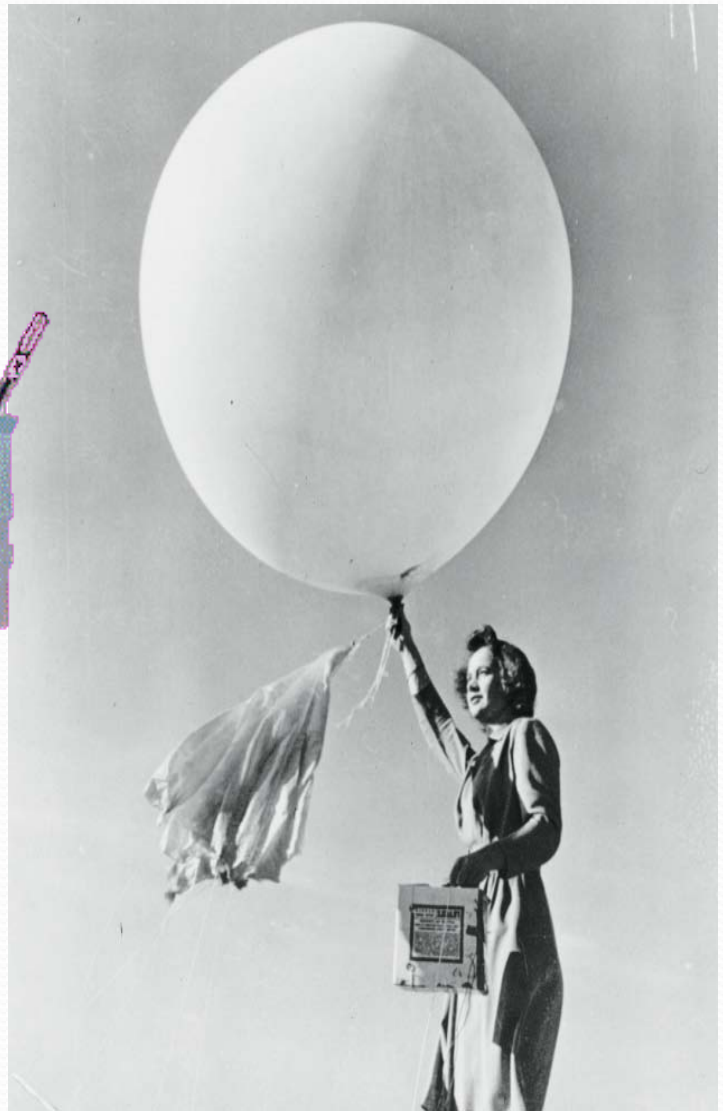
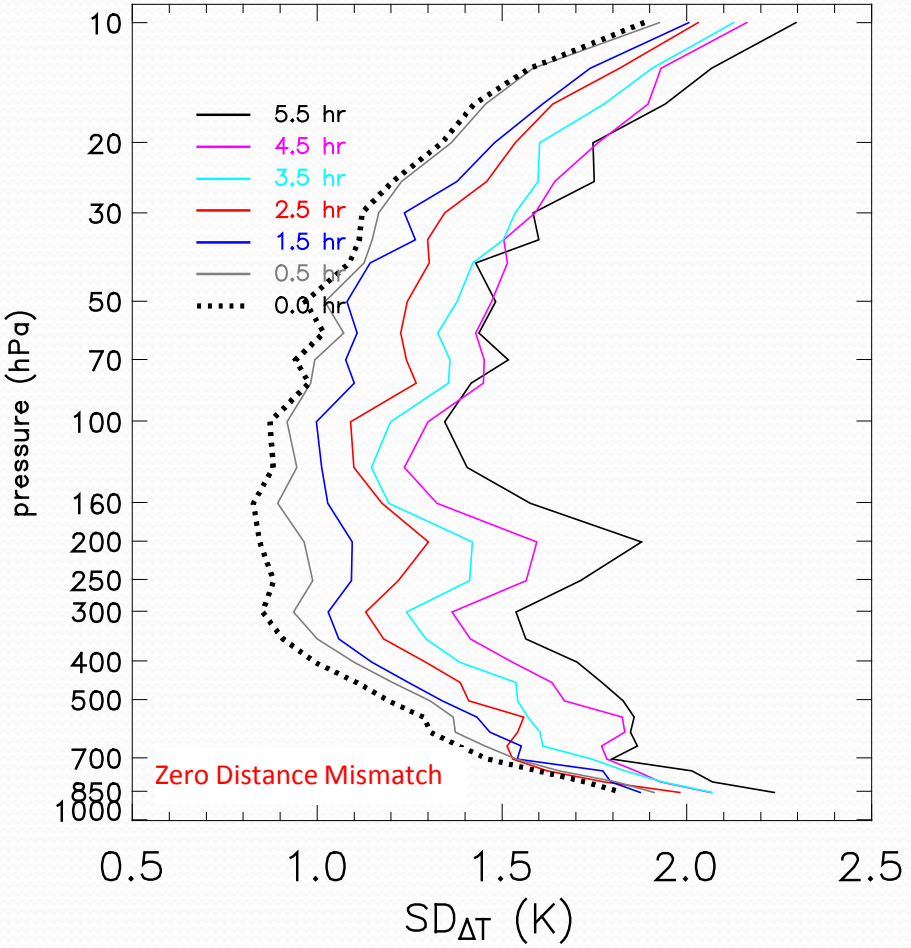
Radiosondes



Satellite CDR cal/val

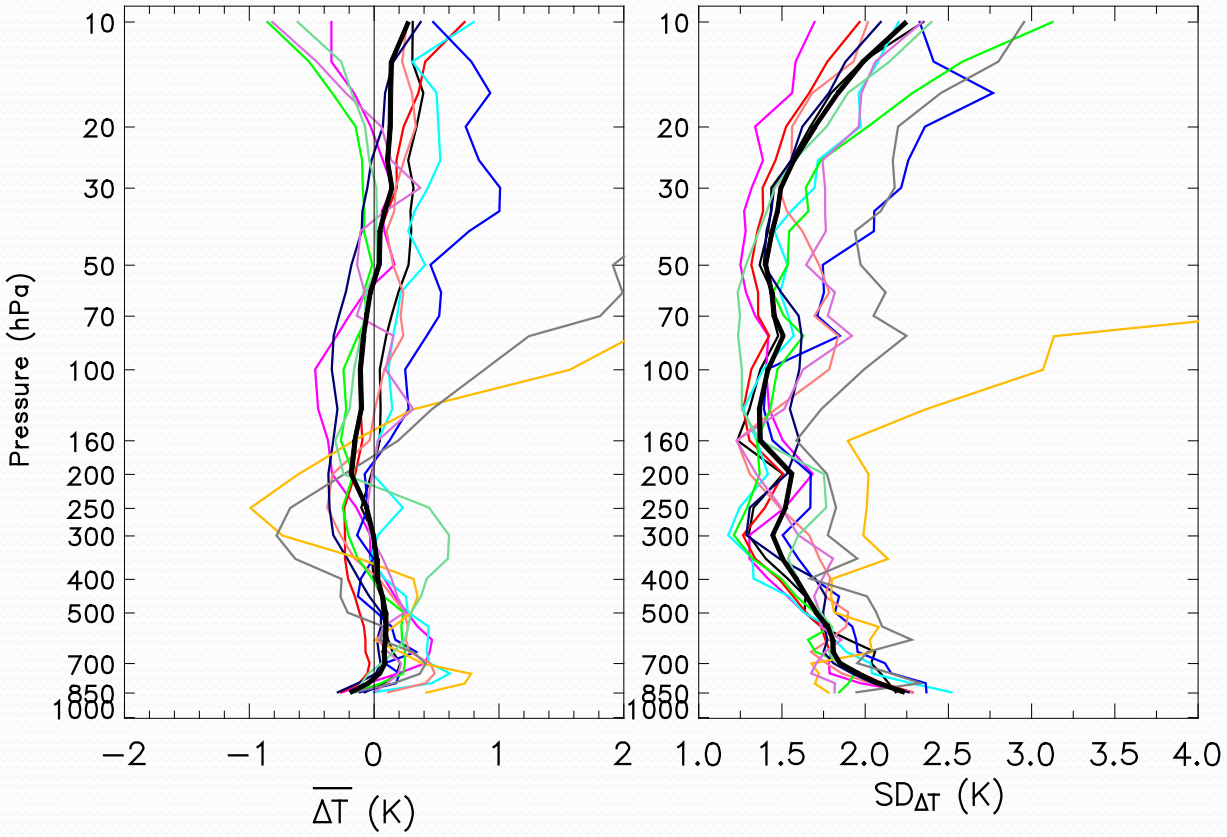
- COSMIC and radiosonde T profiles from NPROVS
- Effects of imperfect collocation on cal/val statistics



Sun et al. (in preparation)

Identifying radiosonde differences

- COSMIC vs radiosonde
- See also He et al. (GRL, 2009)



Sun et al. (in preparation)

Radiosonde data homogeneity

- Time series affected by
  - Instrument changes
  - Data processing and corrections
  - Station moves
- Care needed in comparing satellite CDRs to radiosondes

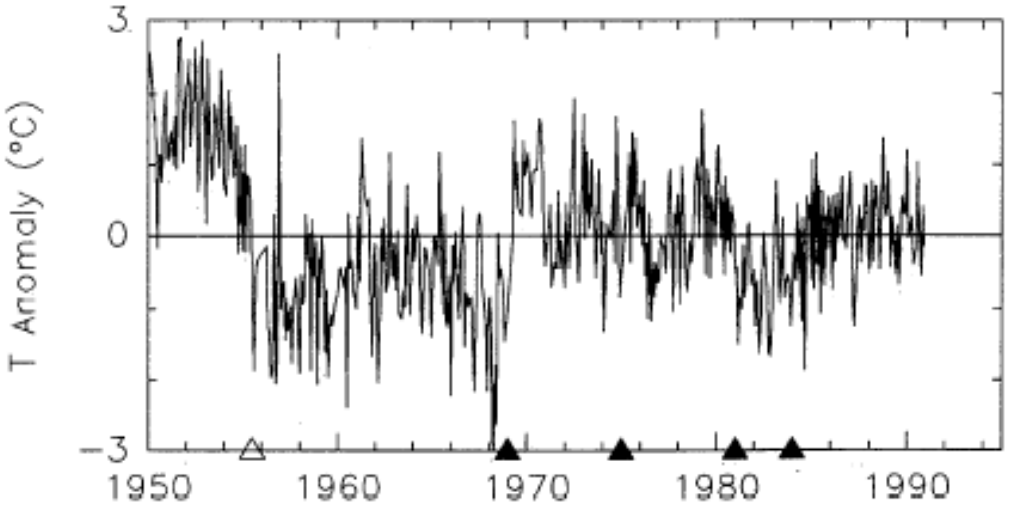
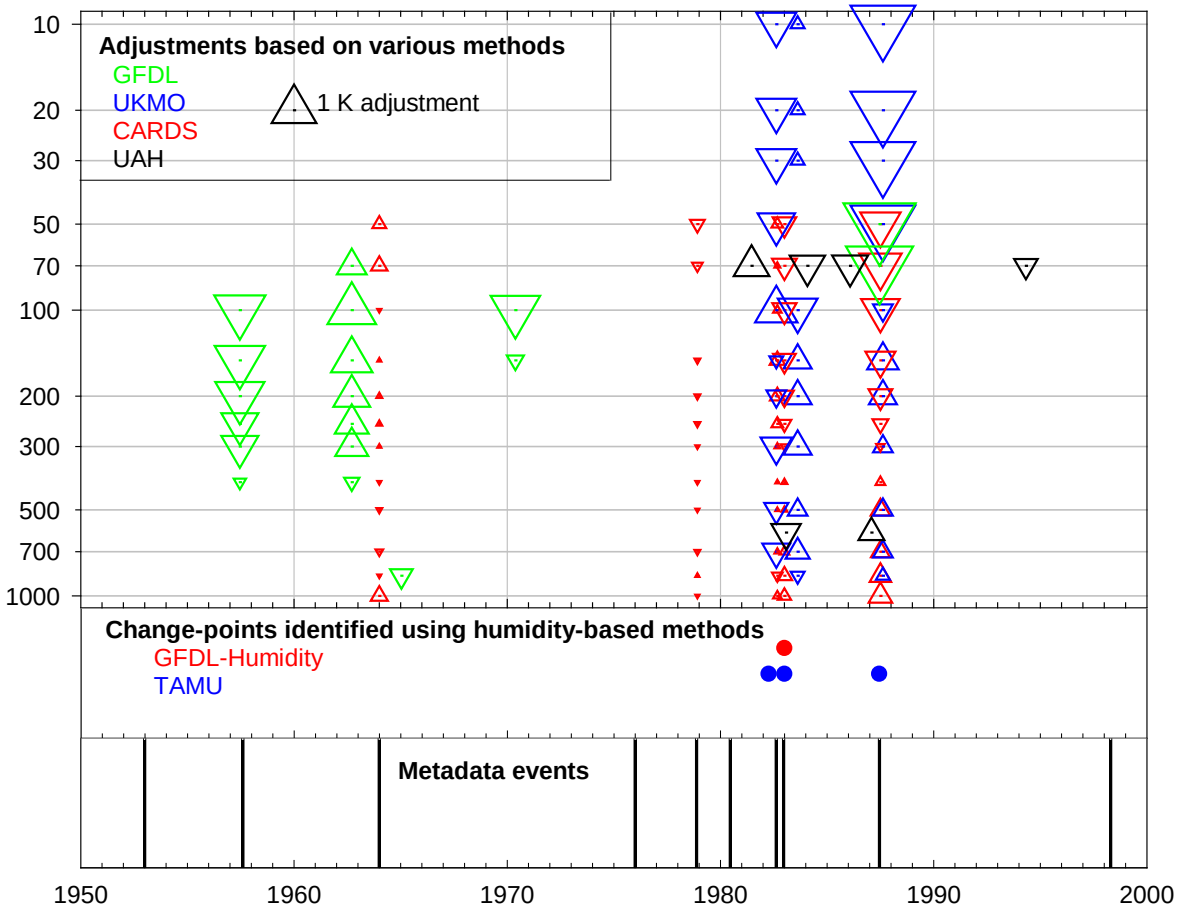


Figure 3. Time series of 200-hPa monthly temperature anomalies at Hong Kong. Open arrow shows date of change in radiation corrections, while solid arrows show dates of known radiosonde type changes, as noted in the text.

Gaffen (JGR, 1994)

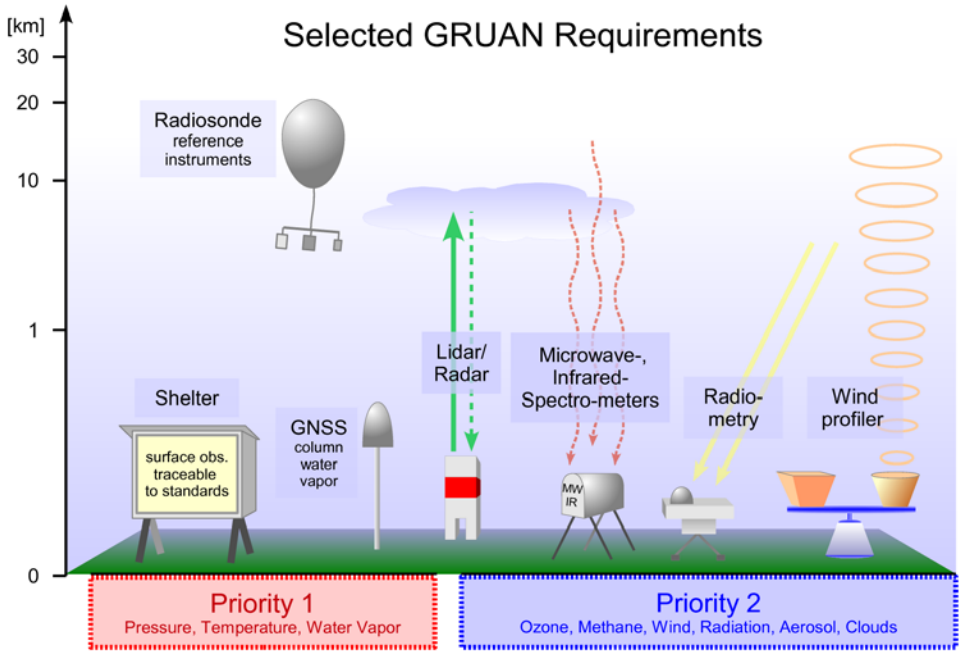
Homogenization challenge

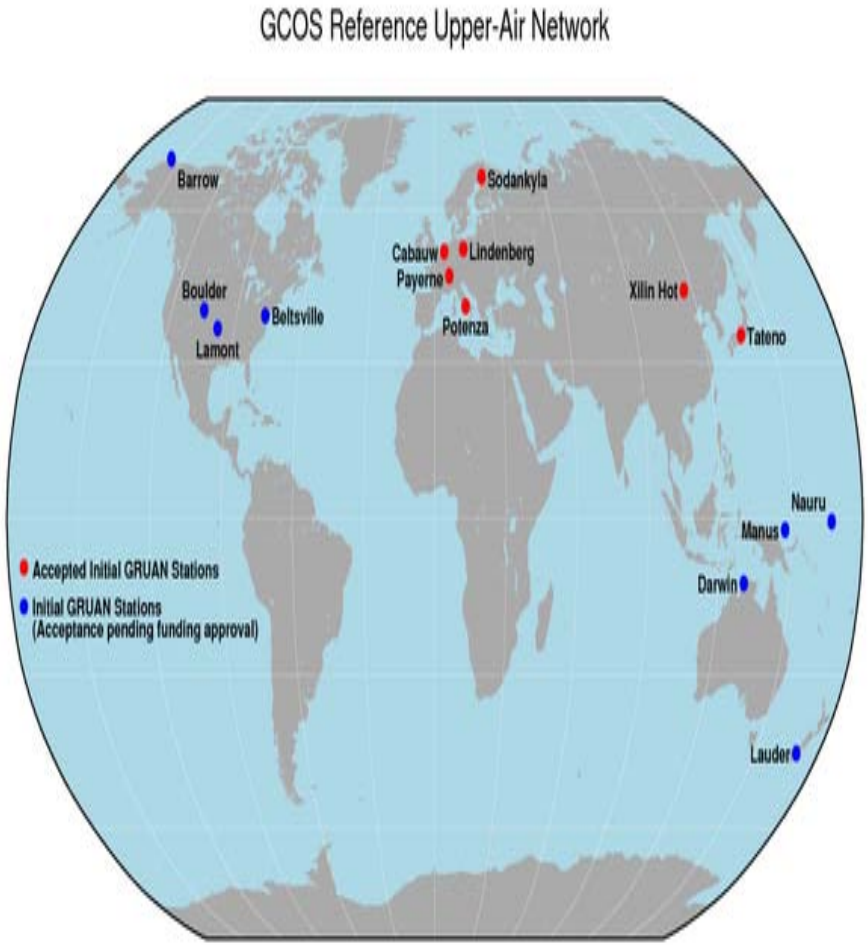
- 2000 workshop compared approaches by several groups
- Example from Darwin, Australia
- A tough assignment!



Free et al. (BAMS, 2002)

Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN)





GRUAN interested in strengthening connection to satellite community

Seidel et al. (BAMS, 2009)

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SPARC T Trends Panel

- SPARC = WCRP Stratospheric Processes and the Role in Climate program
- Temperature Trends Panel – intl. team, since ~ 1995
- Chair – Bill Randel, NCAR
- Reviews and assessments
  - **WMO Scientific Assessment of Ozone Depletion: 1998**, WMO Global Ozone Research and Monitoring Project Report N°. 44, Geneva, 1999.
  - Ramaswamy, V., M.-L. Chanin, J. Angell, J. Barnett, D. Gaffen, M. Gelman, P. Keckhut, Y. Koshelkov, K. Labitzke, J.-J. R. Lin, A. O'Neill, J. Nash, W. Randel, R. Rood, K. Shine, M. Shiotani, and R. Swinbank, **Stratospheric temperature trends: observations and model simulations**. *Reviews of Geophysics*, 39(1), 71-122, 2001.
  - Shine, K.P., M.S. Bourqui, P.M.de F. Forster, S.H.E. Hare, U. Langematz, P. Braesicke, V. Grewe, C. Schnadt, C.A. Smith, J.D. Haigh, J. Austin,, N. Buchart, D. Shindell, W.J. Randel, T. Nagashima, R.W. Portman, S. Solomon, D.J. Seidel, J. Lanzante, S. Klein, V. Ramaswamy, M.D. Schwarzkopf, 2003: **A comparison of model-predicted trends in stratospheric temperatures**. *Quart. J. Royal. Meteor. Soc.*, 129, 1565-1588.
  - Randel, W.J., K.P. Shine, J. Austin, J.Barnett, C. Claud, N.P. Gillett., P. Keckhut, U. Langematz, R. Lin, C. Long, C. Mears, A. Miller, J. Nash, D.J. Seidel, D.W.J. Thompson, F. Wu and S. Yoden, 2009: **An update of observed stratospheric temperature trends.** *J.Geophys. Res.*, 114.

SPARC T Trends Panel

- Current Foci
  - Lidar observations
  - SSU and AMSU (AIRS, other ???)
  - Analysis of Chemistry-Climate Model Validation Activity (CCMVal) simulations
  - Detection and attribution of stratospheric T change
  - **All Depend on Satellite T CDRs**

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Recommendations

- Adhere to GCOS climate monitoring principles
- Judiciously use *in situ* data in comparisons with satellite CDRs
- Foster closer, more active connection with GRUAN and other in situ networks meant to support satellite CDRs
- CDRs for tropopause characteristics would be useful
- Support multiple, independent CDR construction efforts for a given dataset
- Continue and expand efforts to rehabilitate SSU data and combine SSU and AMSU

Thank you!