Trends in Upper Air Temperature in the Era of Aqua

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Climate Monitoring and Change Science

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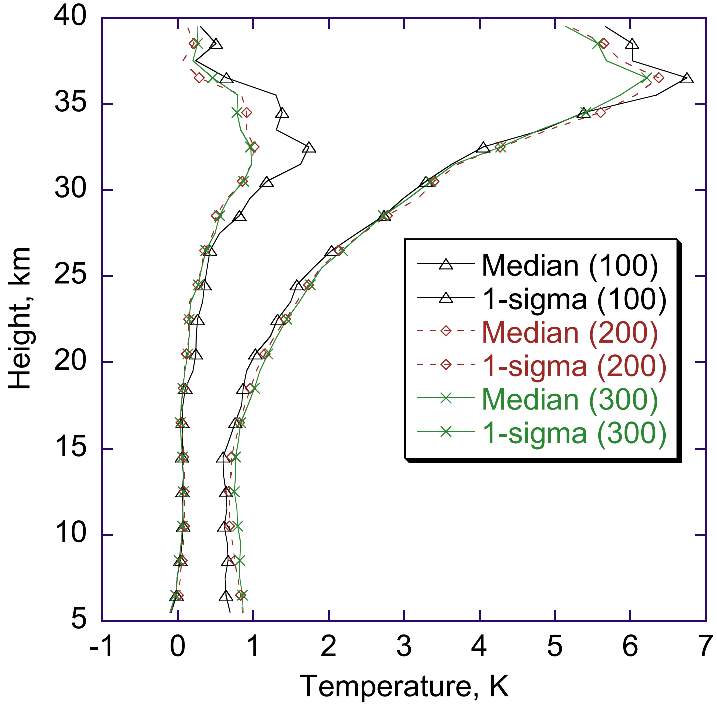
Data sources

- GPS Radio Occultation: JPL genesis level 3
  - CHAMP (2001-2009), ~200 daily soundings
  - COSMIC (2007-2014), ~2500 daily soundings
  - Bayesian interpolation/spherical harmonic fitting: 14^{th} degree for CHAMP, 20^{th} degree for COSMIC (2007-2014)
  - Vertical resolution 5 hPa (~100 m)
- Infrared: AIRS level 3, version 6
  - Neural net based on ECMWF analyses
  - Combined infrared and microwave ("AIRX")
  - Infrared only ("AIRS")
  - Version 5 leaves too many gaps

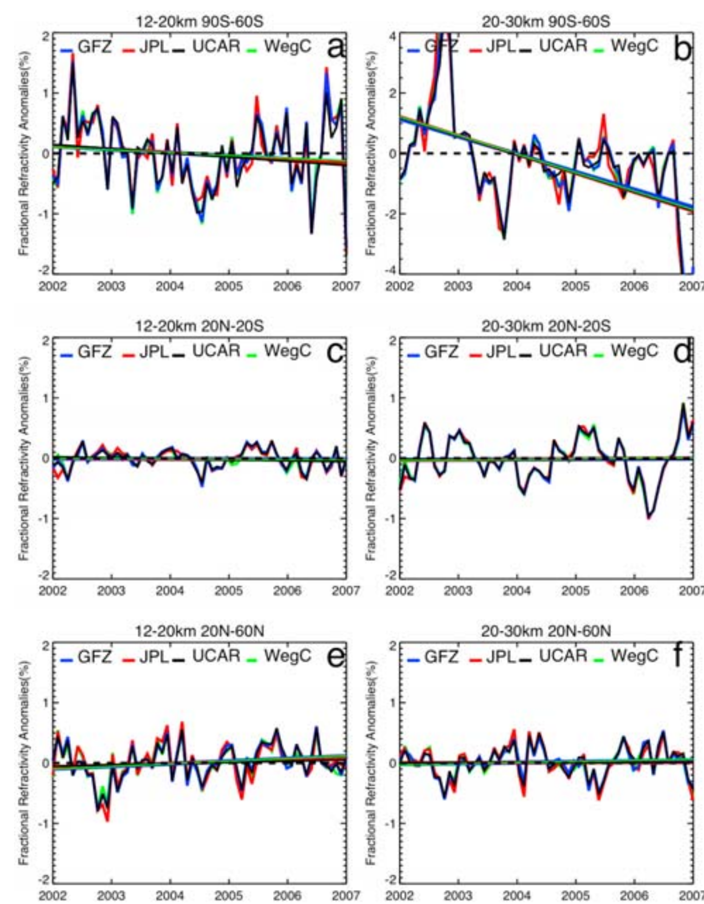
Background: GPS RO

CHAMP vs. SAC-C temperature



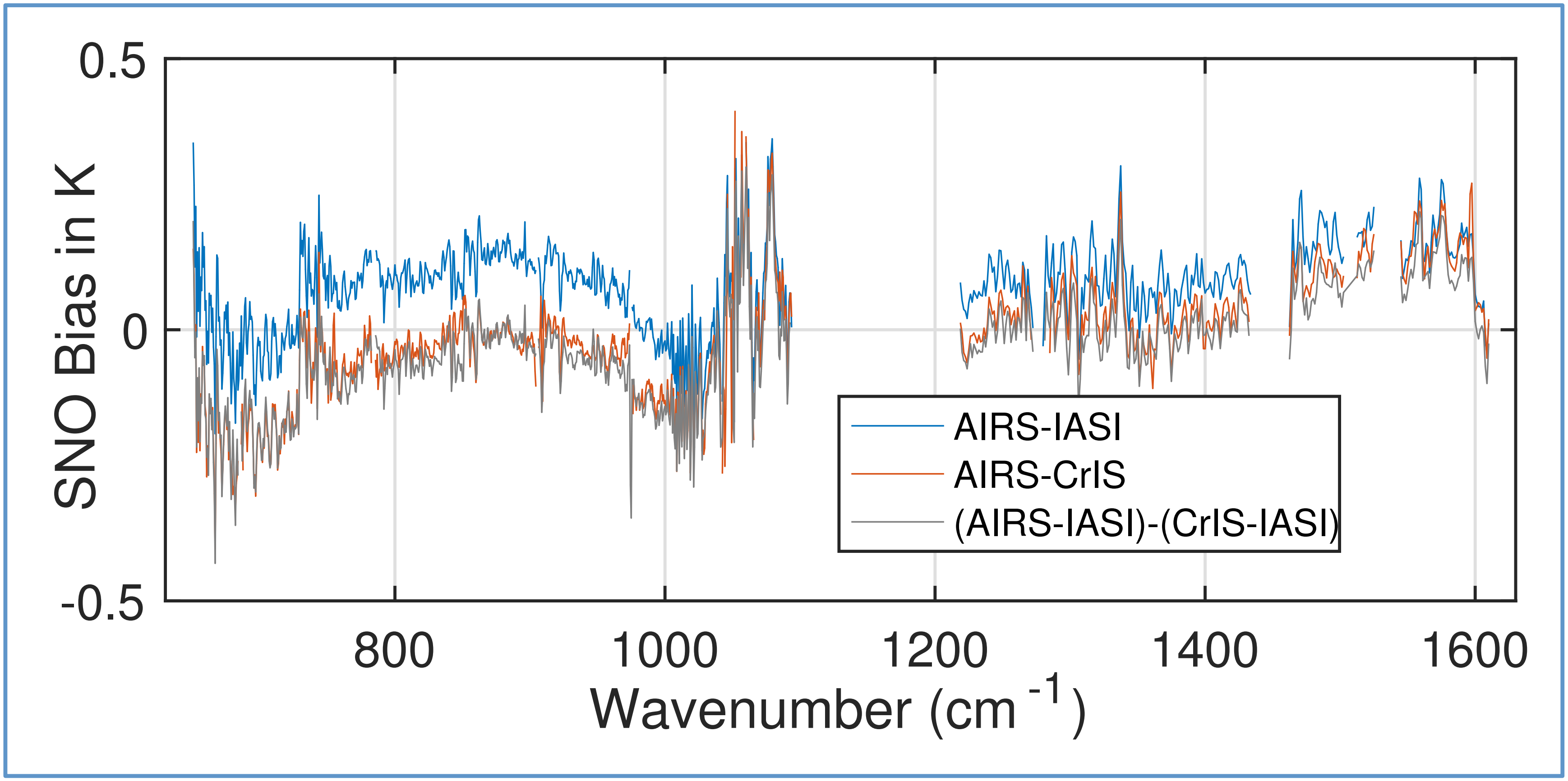
Hajj et al., JGR, 2004

Four different retrieval centers



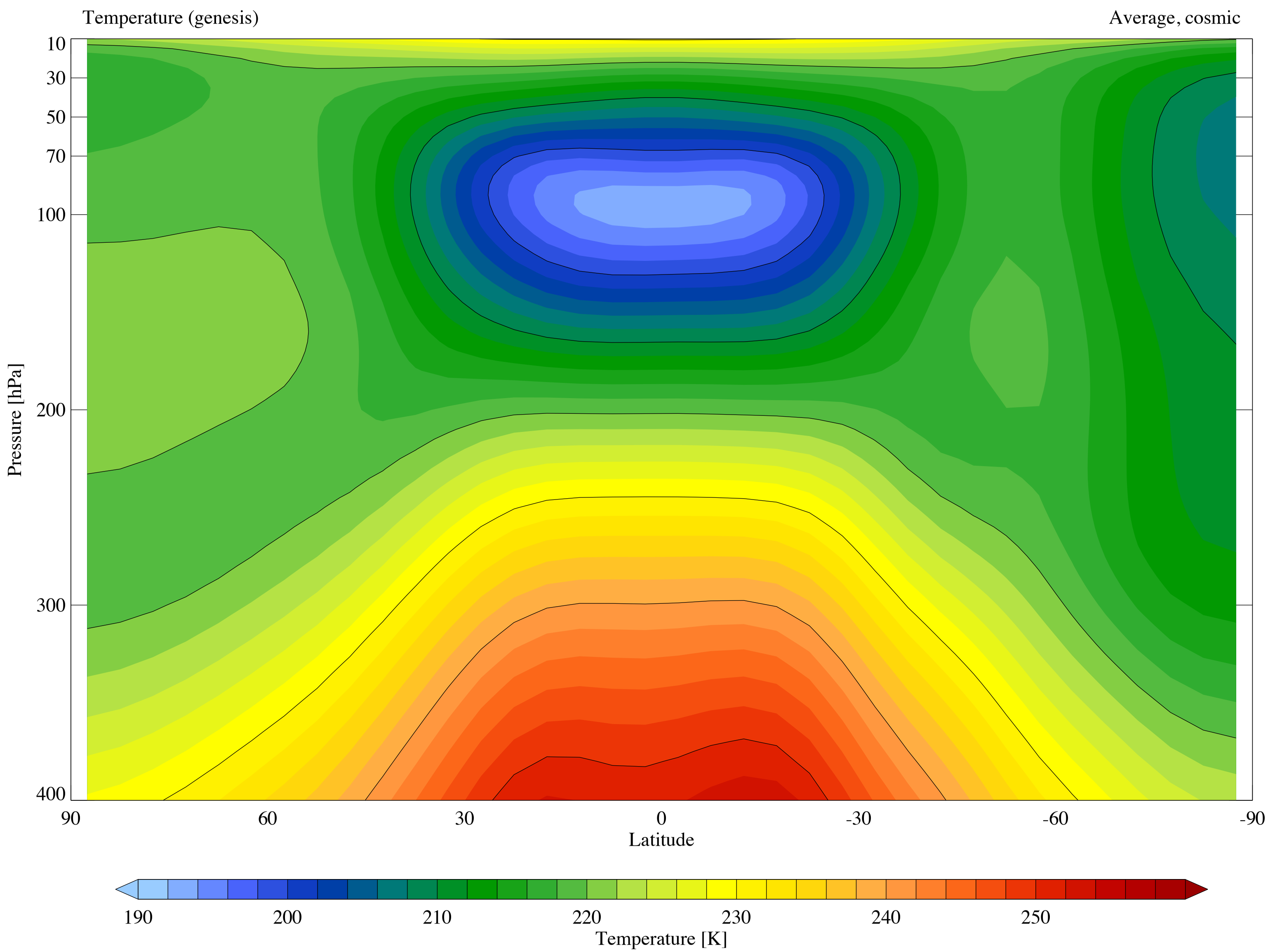
Ho et al., JGR, 2009

Infrared Inter-calibration

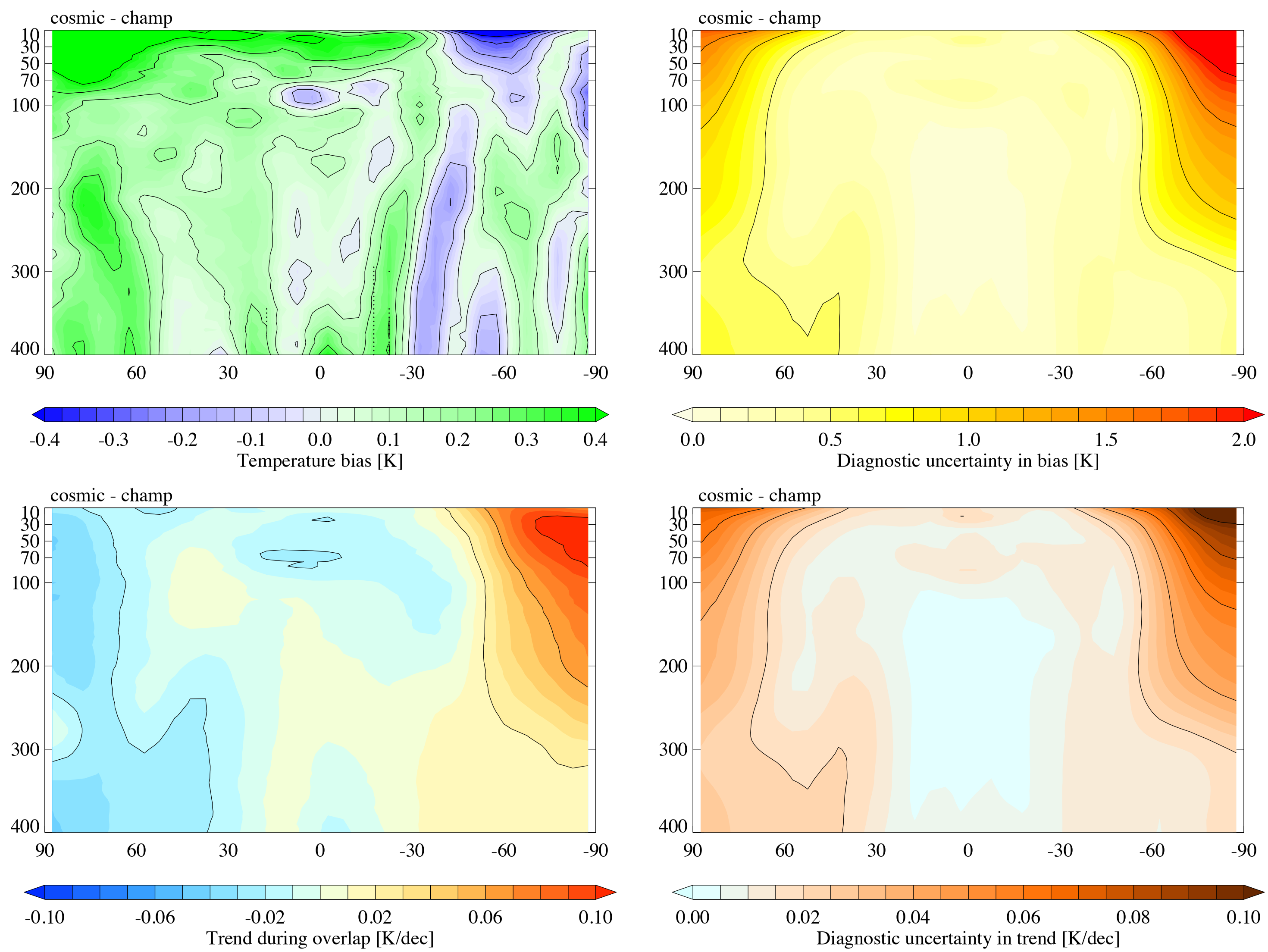


Courtesy Larrabee Strow

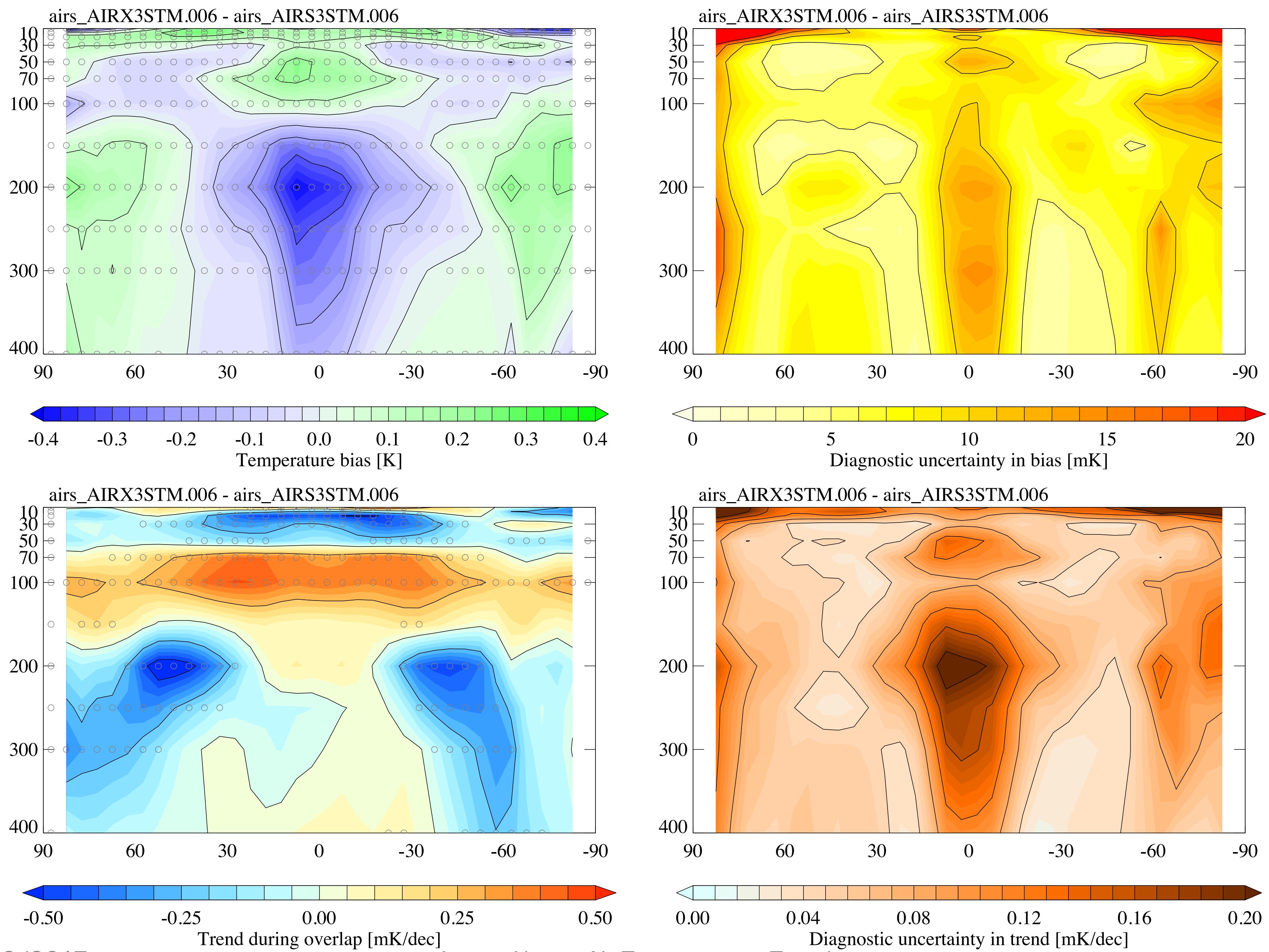
Background temperature: GPS RO (COSMIC)



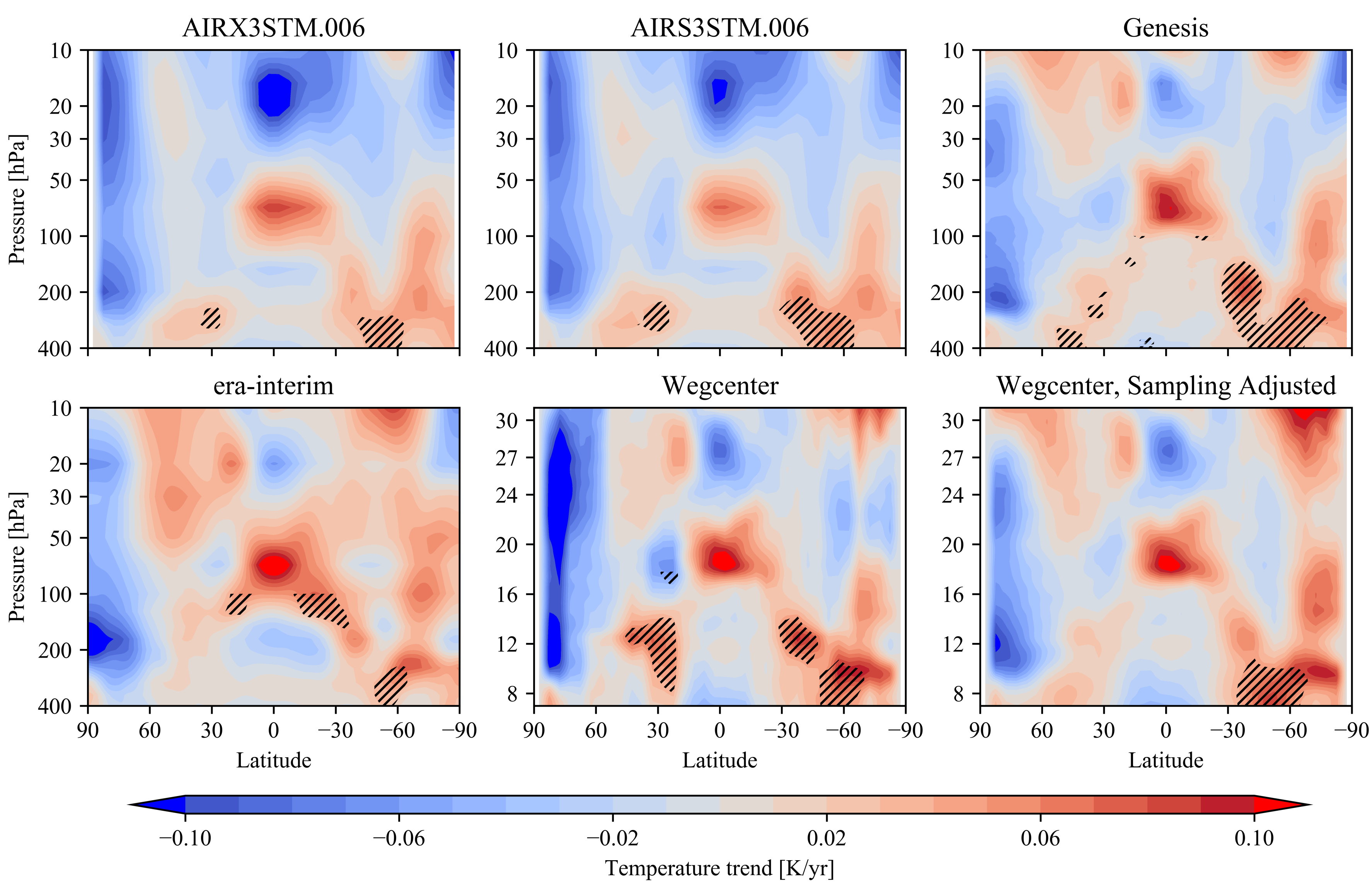
CHAMP and COSMIC Overlap



AIRS level 3 biases



Upper Air Temperature Trends (2003-2014)



Time-series

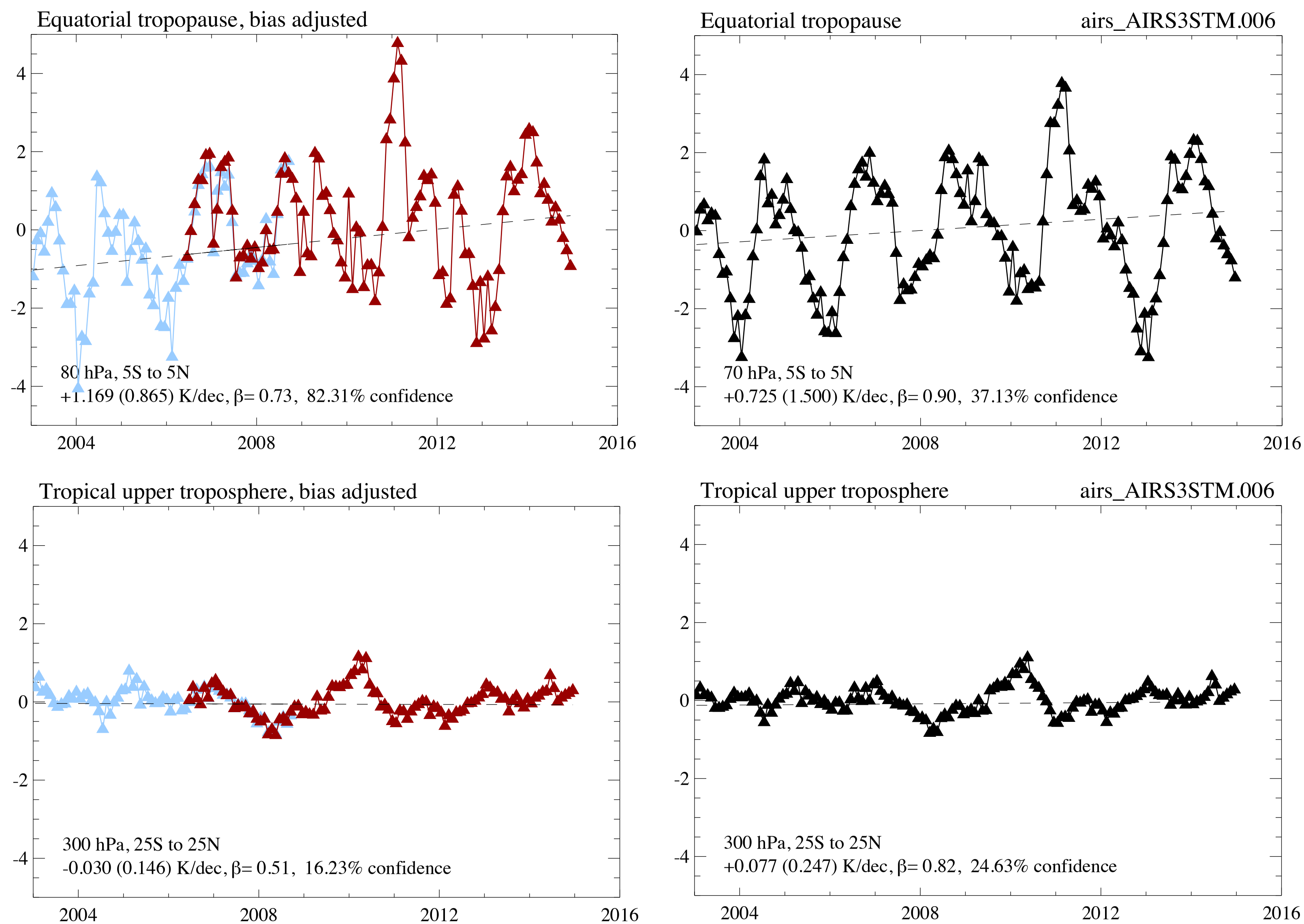
GPS RO (bias-adjusted)

AIRS (infrared-only)

Equatorial tropopause

QBO!!

Tropical upper troposphere



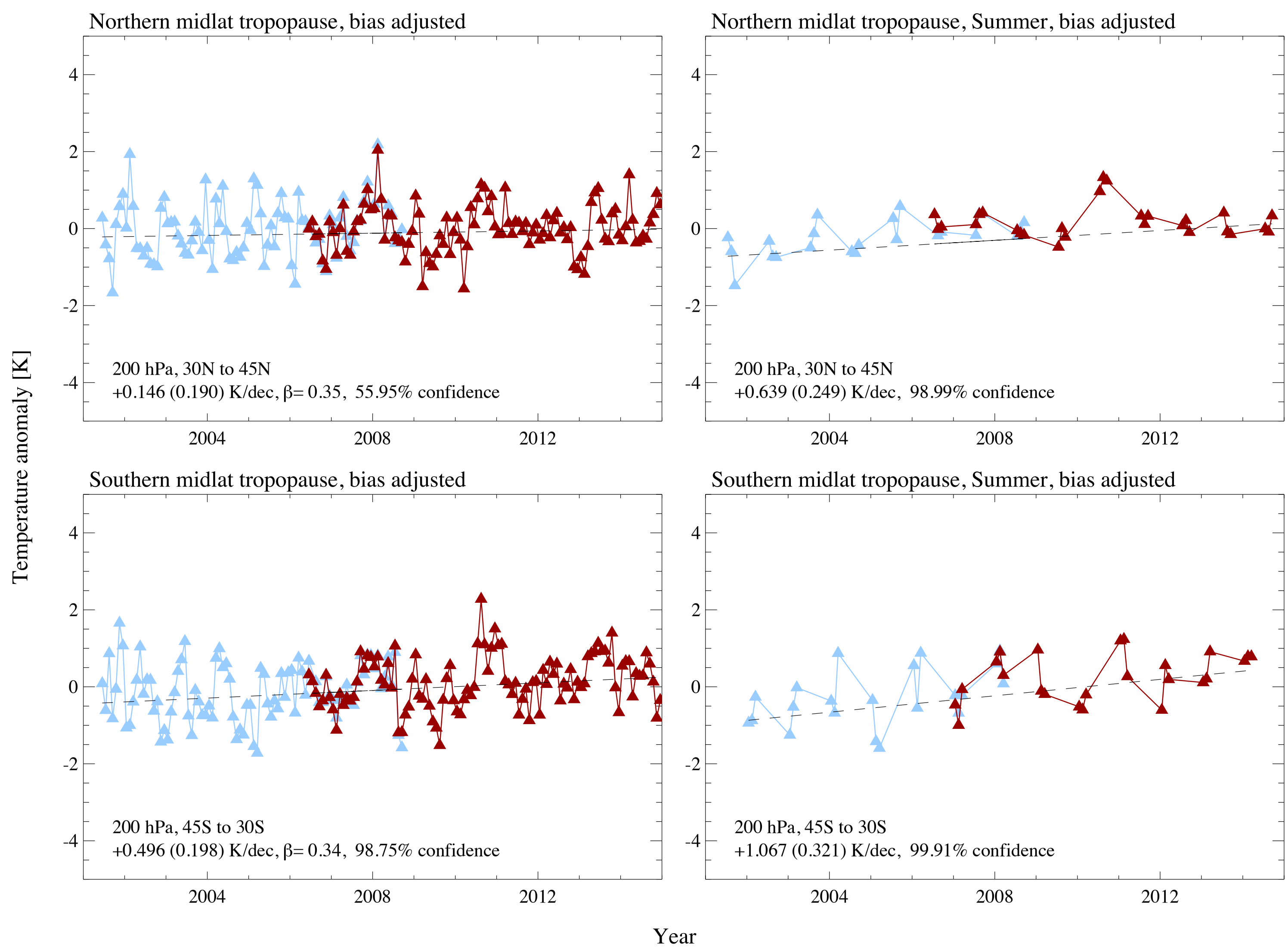
More time-series (RO only)

All seasons

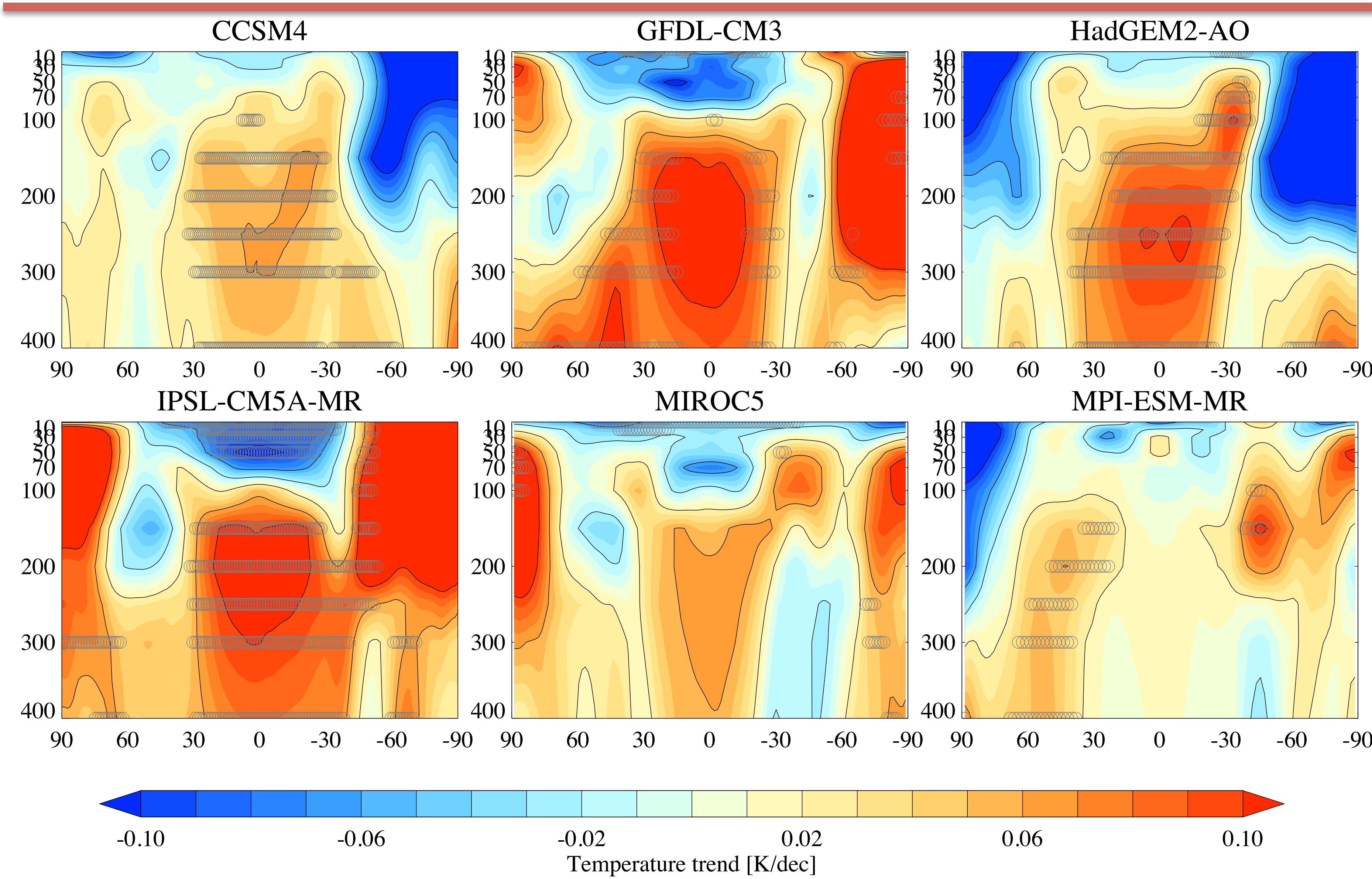
Summer only

Northern subtropics and mid-latitudes

Southern subtropics and mid-latitudes

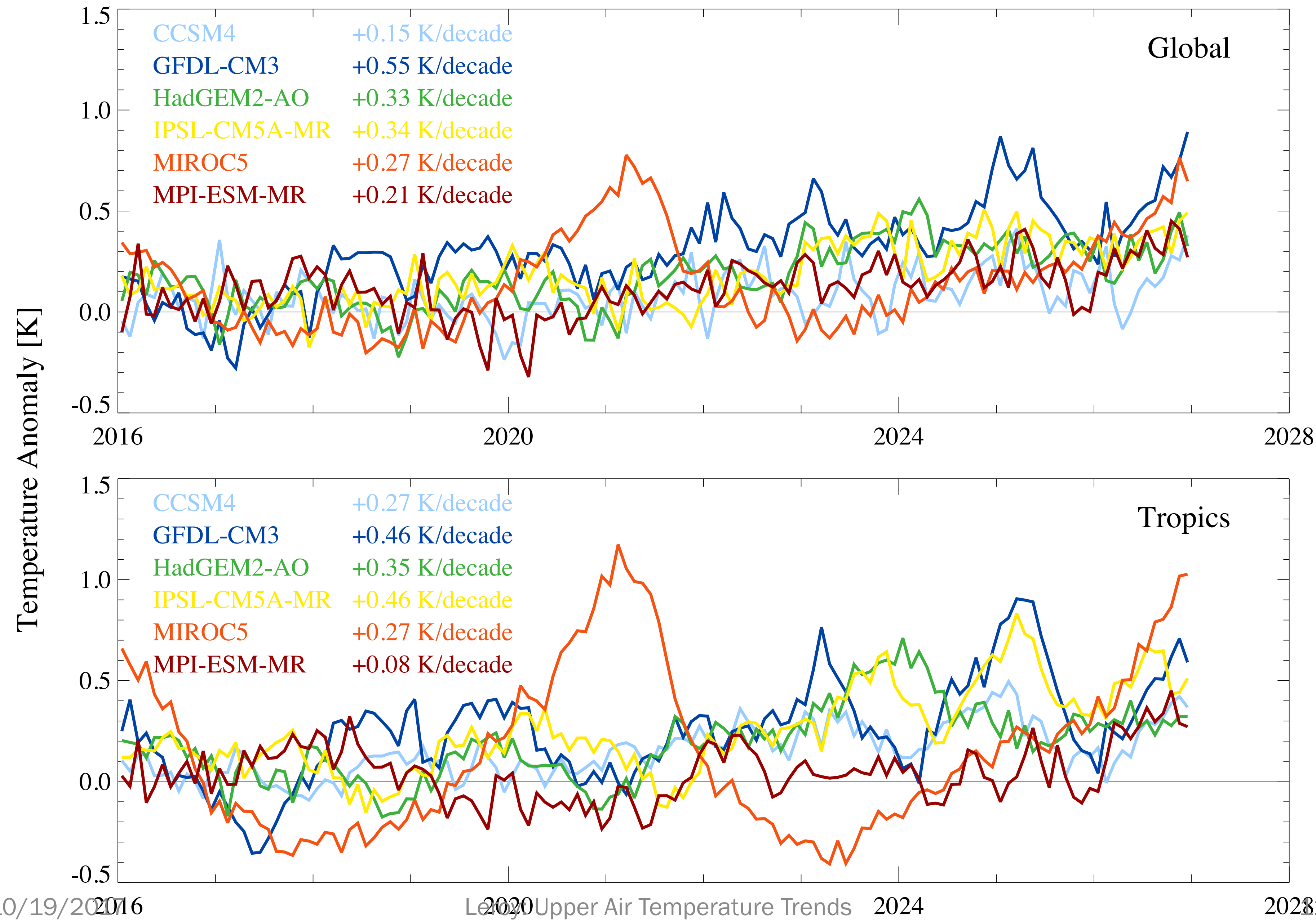


CMIP5 (rcp45)

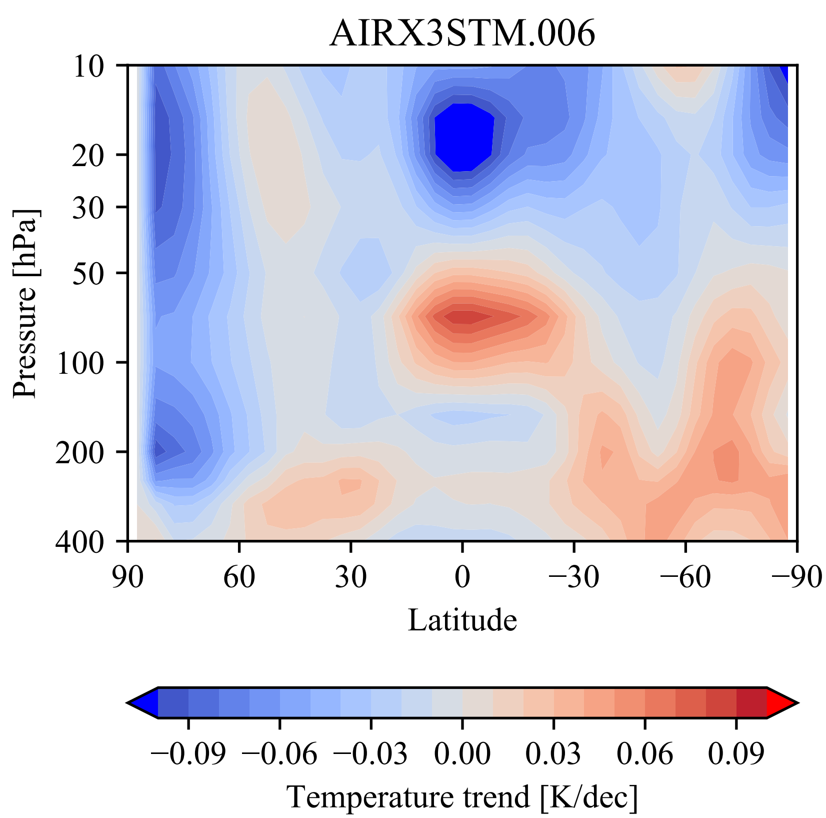


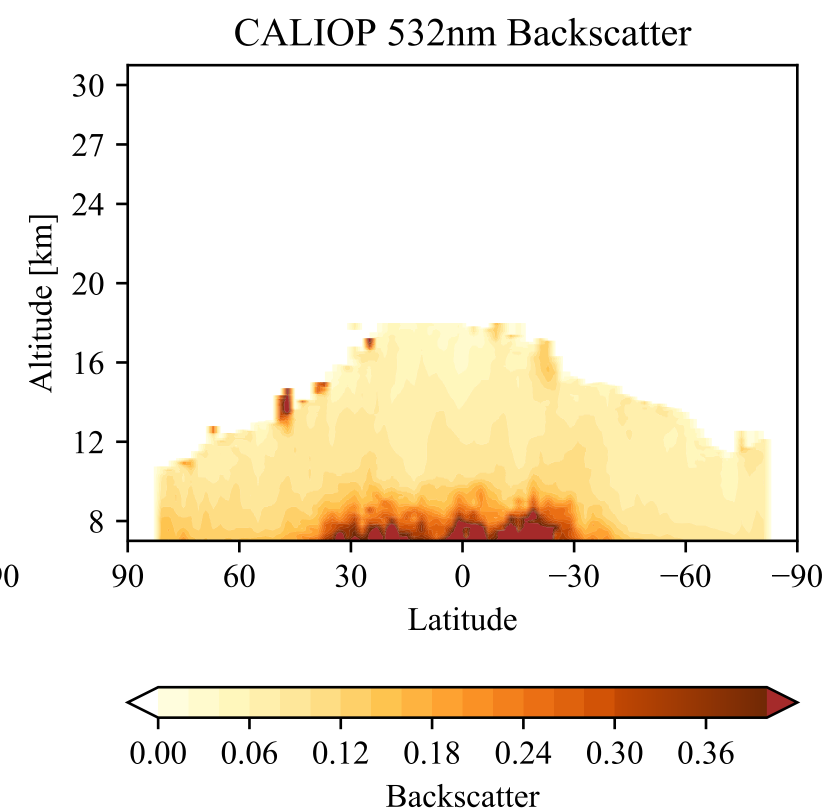
CCSM4
GFDL-CM3
HadGEM2-AO
IPSL-CM5A-MR
MIROC5
MPI-ESM-MR
10
30
50
70
100
200
300
400
90
60
30
0
-30
-60
-90
-0.10
-0.06
-0.02
0.02
0.06
0.10
Temperature trend [K/dec]

CMIP5 (rcp45)


Temperature Anomaly [K]
Global
CCSM4 +0.15 K/decade
GFDL-CM3 +0.55 K/decade
HadGEM2-AO +0.33 K/decade
IPSL-CM5A-MR +0.34 K/decade
MIROC5 +0.27 K/decade
MPI-ESM-MR +0.21 K/decade
Tropics
CCSM4 +0.27 K/decade
GFDL-CM3 +0.46 K/decade
HadGEM2-AO +0.35 K/decade
IPSL-CM5A-MR +0.46 K/decade
MIROC5 +0.27 K/decade
MPI-ESM-MR +0.08 K/decade
1.5
1.0
0.5
0.0
-0.5
2016
2020
2024
2028

CALIPSO Clouds





Conclusions

- Great care is required in constructing level 3 products of GPS RO data: non-uniform sampling is a problem.
- Bias drifts in AIRS level 3 products are ~ 0.5 mK/decade.
- Spatial pattern amplitude of temperature trends in AIRS is suspect.
  - Corruption by high cirrus?
  - Trouble with calibration in extremely cold conditions?
- Poleward migration of jet streams, even when no tropical warming. Possibility to test hypothesis for tropical width and widening.

Thank you.

Background

Motivation

- GPS Radio Occultation is now a 16-year uninterrupted record
  - Accurate by traceability to the international definition of the second
  - Sensitive to UTLS temperature unambiguously
  - Trends in temperature insensitive to retrieval system, satellite platform
- AIRS is now a 14-year uninterrupted record
  - Stable according to inter-calibration, target scene viewing
  - Sensitive to UTLS temperature but with cloud ambiguity
  - Sensitivity to retrieval system unknown

Theory for Width of Tropics

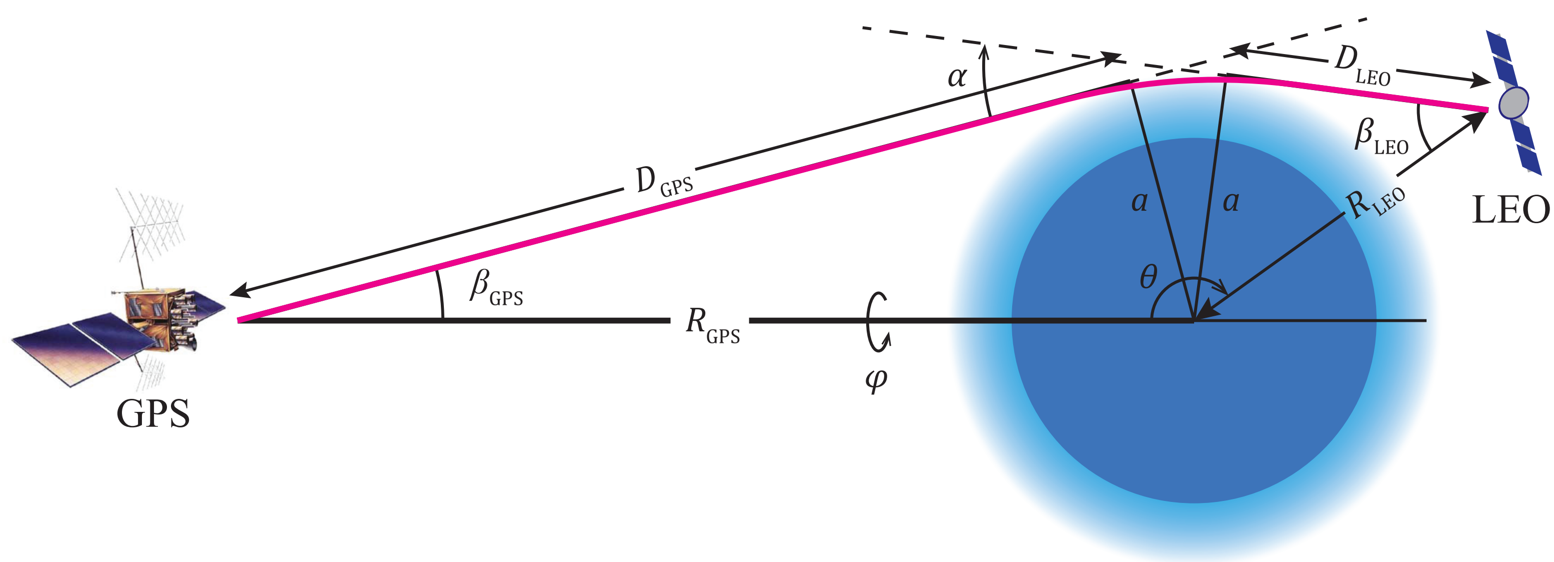
- Held and Hou 1980, steady, inviscid, closed circulation:

$$\phi_H \sim \left(\frac{gH_t}{\Omega^2 a^2} \frac{\Delta_h}{\theta_0} \right)^{1/2}$$

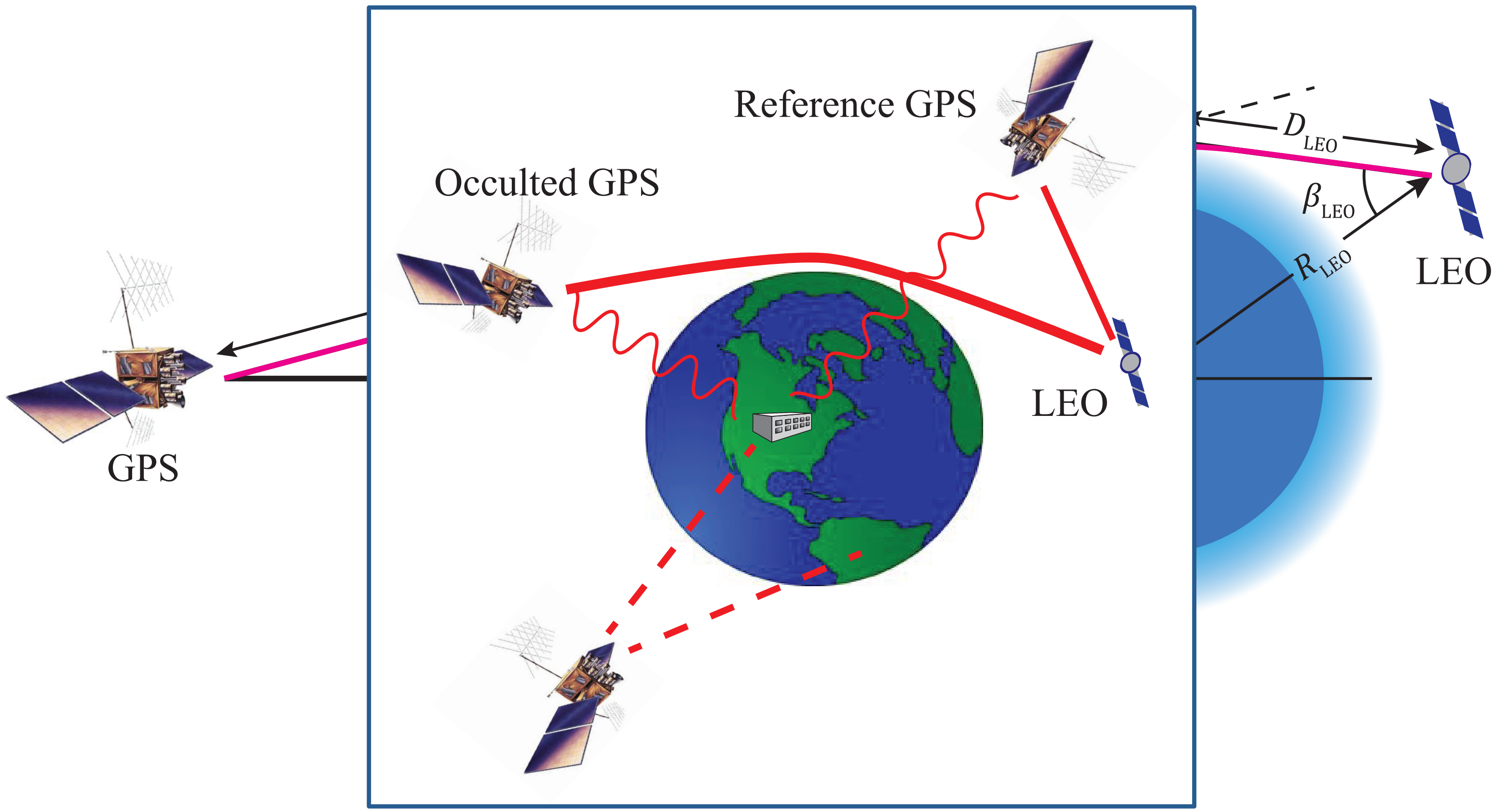
- Held 2000, taking eddies into consideration:

$$\phi_H \propto \left(\frac{NH_e}{\Omega^2 a} \right)^{1/3}$$

Radio Occultation

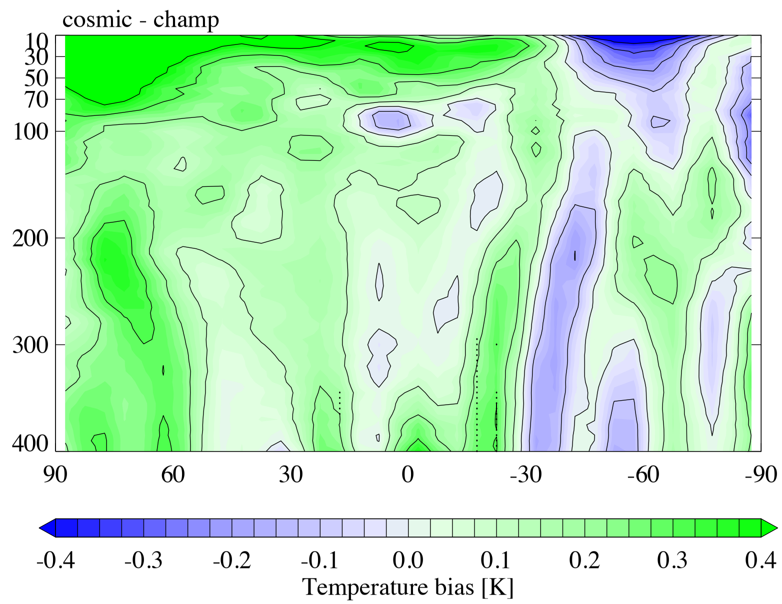


Radio Occultation

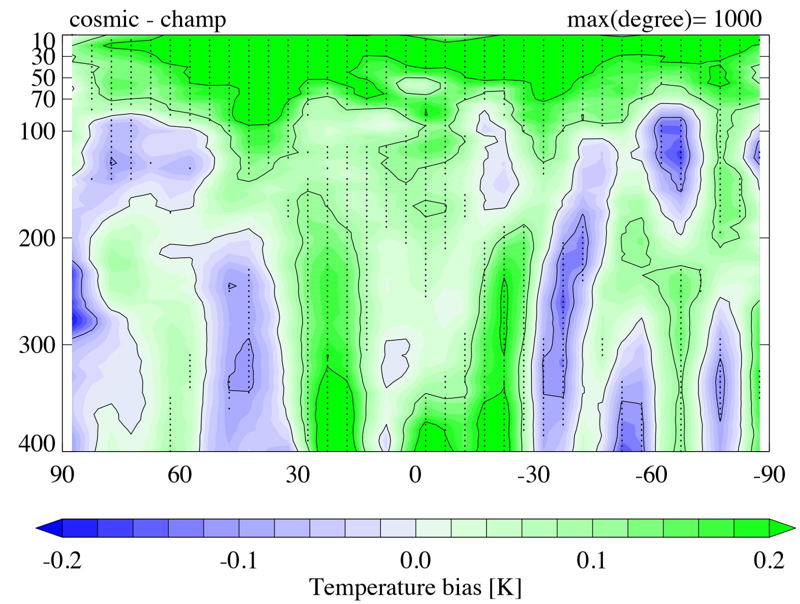


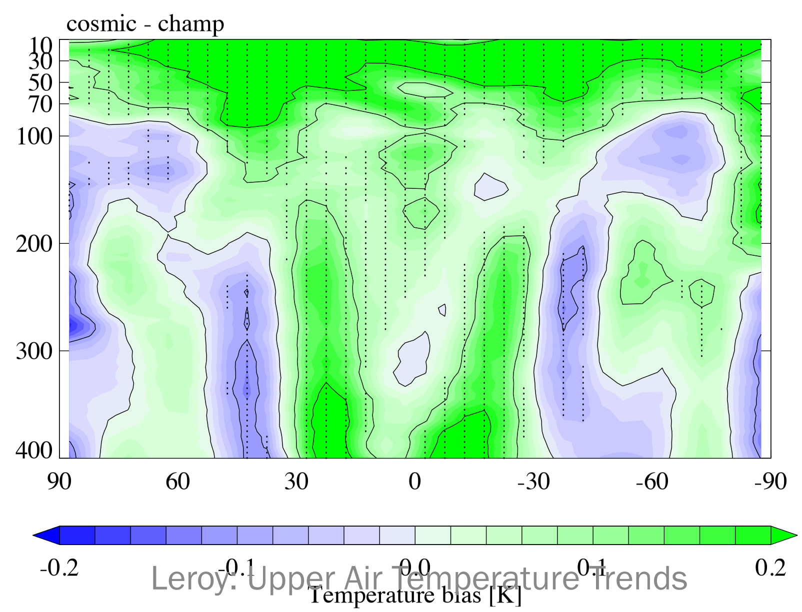
Spherical harmonic truncation bias

Bias: genesis climatology (gridded)



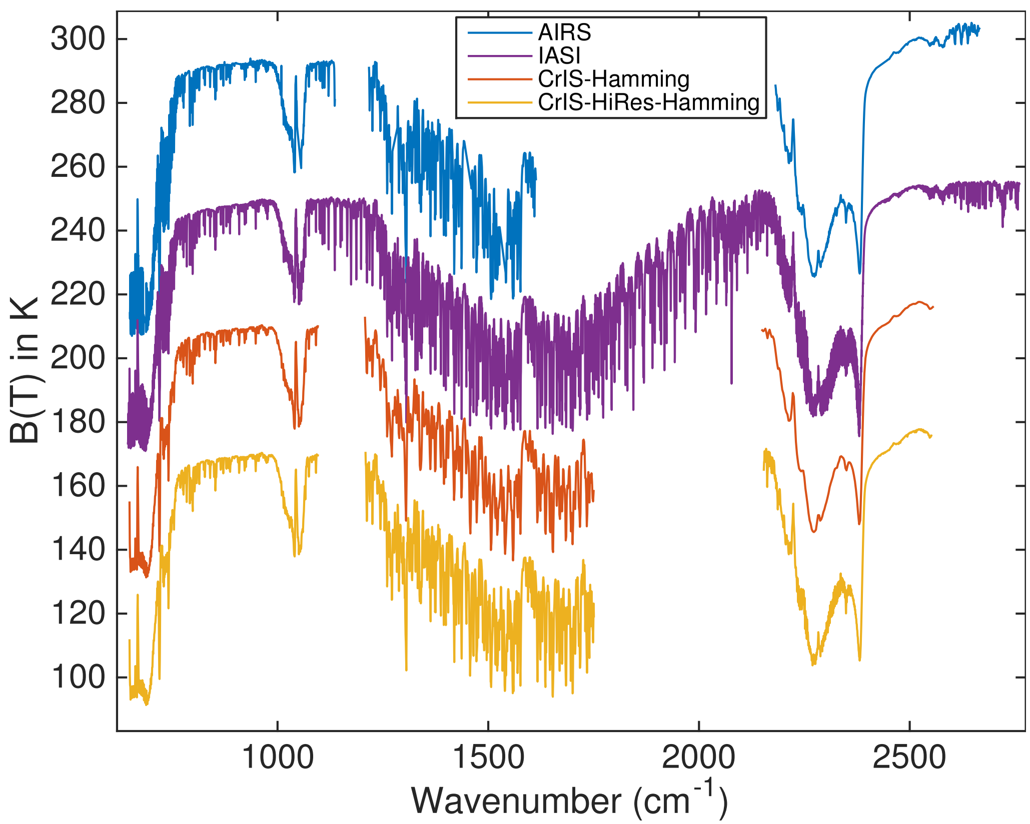
Full truncation (overlap period)





14th degree truncation (overlap period)

Infrared Spectrum



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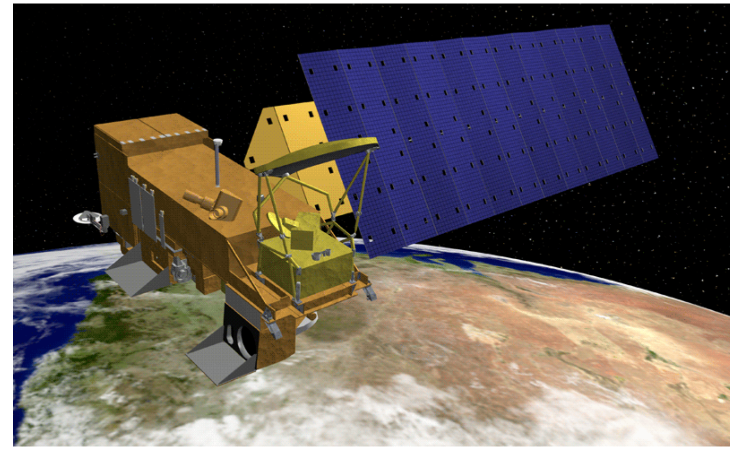
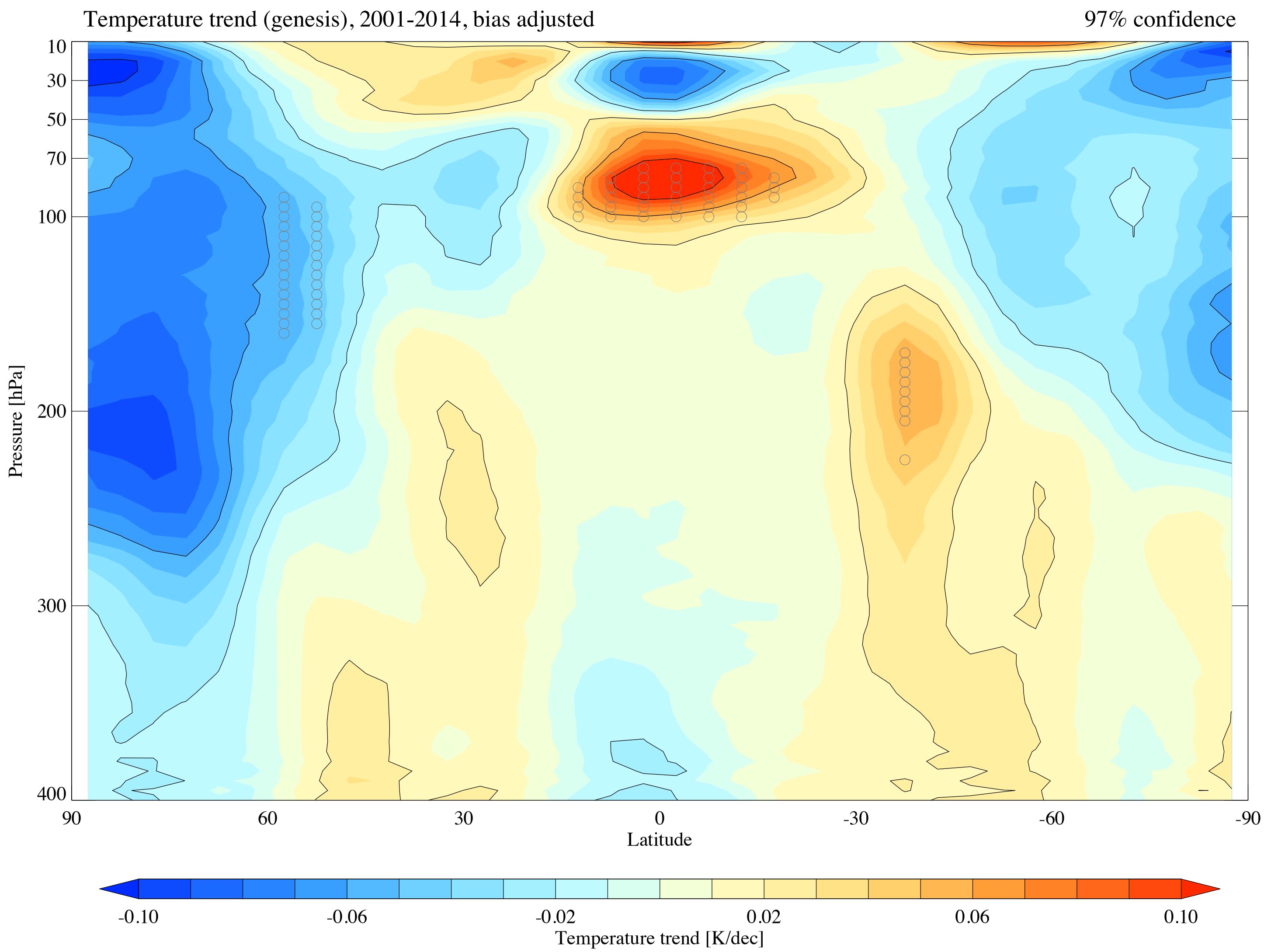
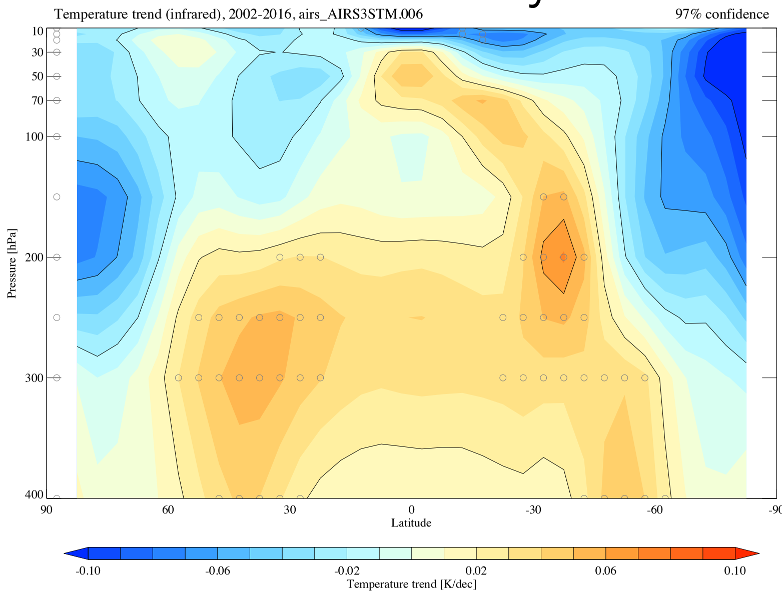


GPS RO trend, bias-corrected

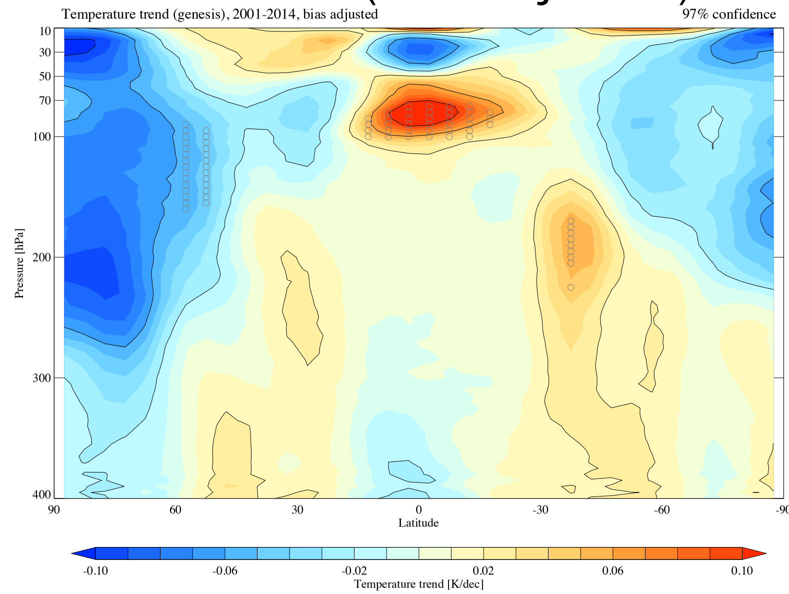


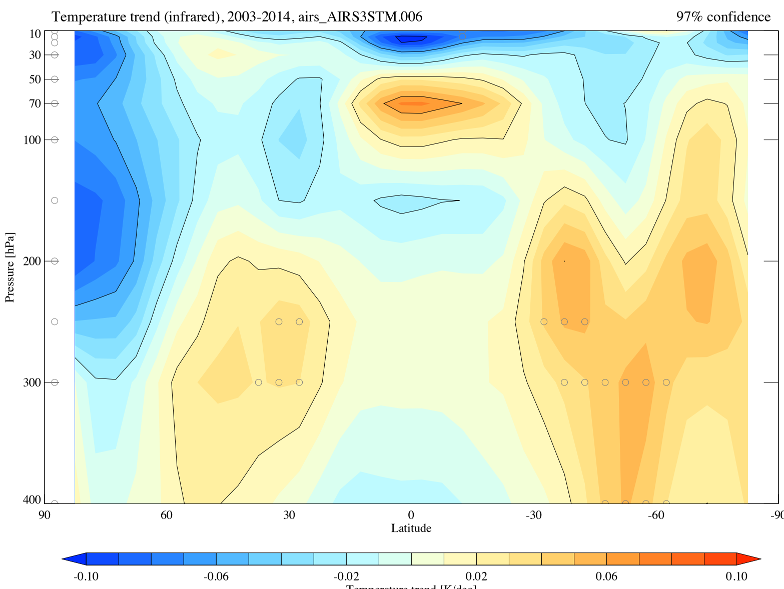
AIRS level 3 trends

AIRS infrared-only retrieval



GPS RO (bias-adjusted)





Overlap,
2003-2014