RECONCILING TROPOSPHERIC TEMPERATURE TRENDS FROM THE MICROWAVE SOUNDING UNIT

Stephen Po-Chedley
NOAA STAR Seminar Series
COGS Presentation

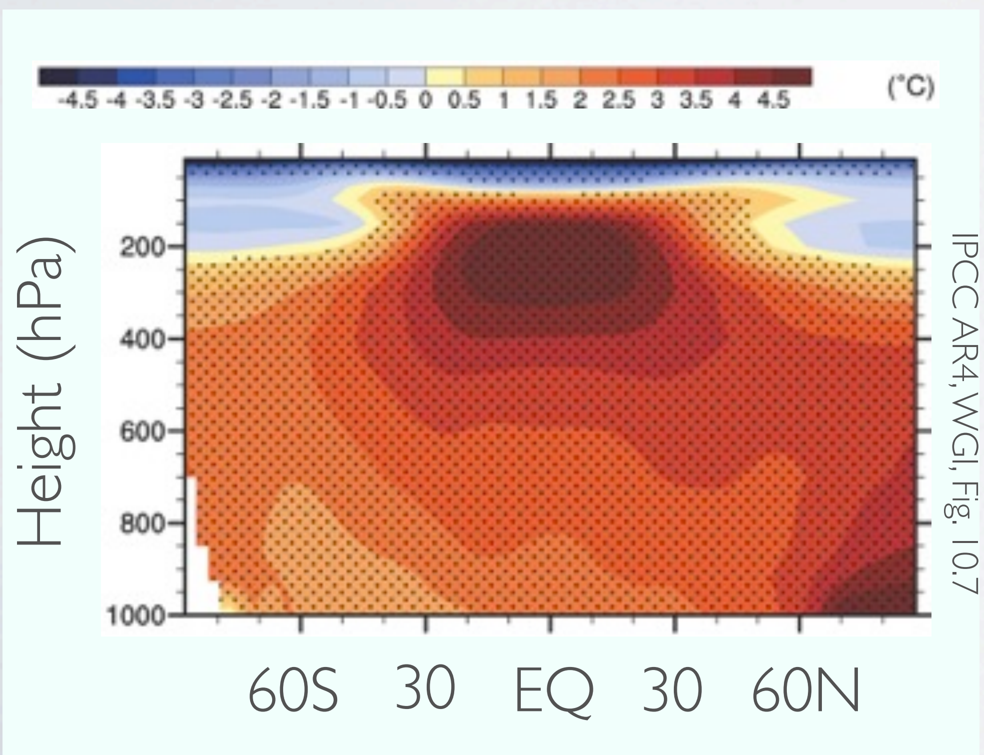
AGENDA

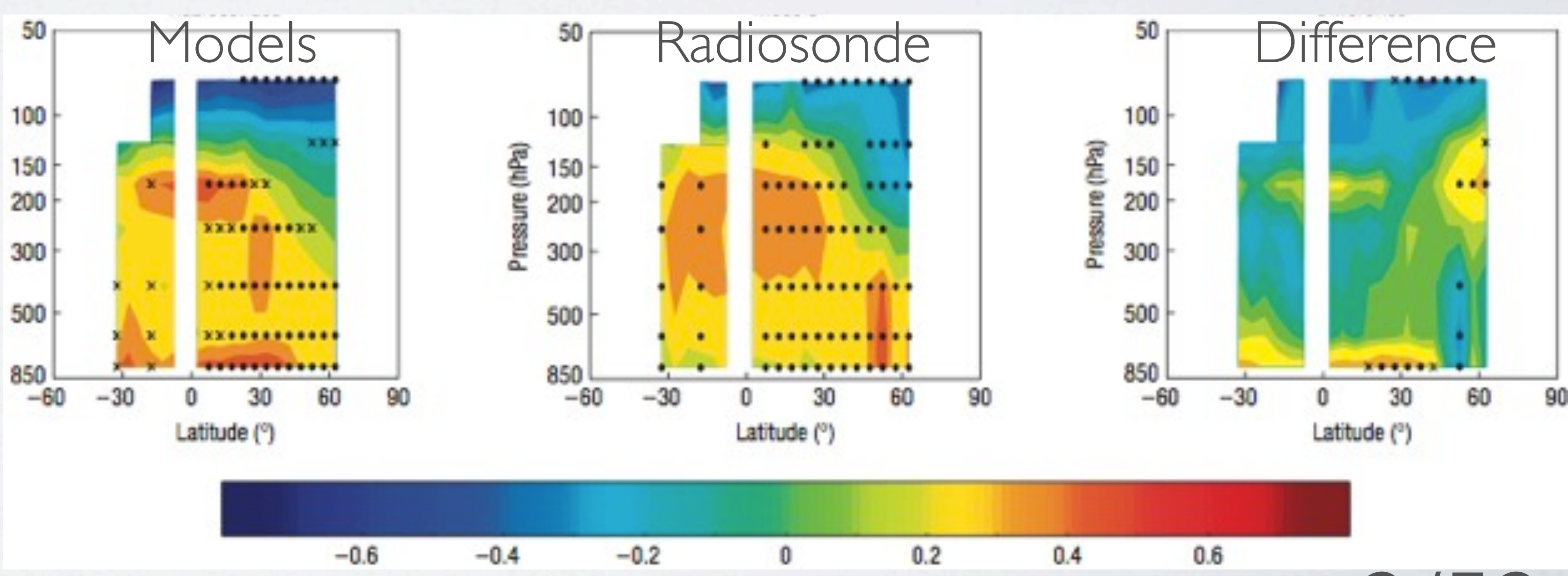
- Motivation.
- Microwave sounding unit discrepancies.
- NOAA-09.
- Other differences.
- Conclusions?

Motivation.

- Observations are an important check for models.
- Models predict temperature amplification in the tropics.
- Only some observations demonstrate amplification.

21st Century Warming.





Allen and Sherwood, 2008.

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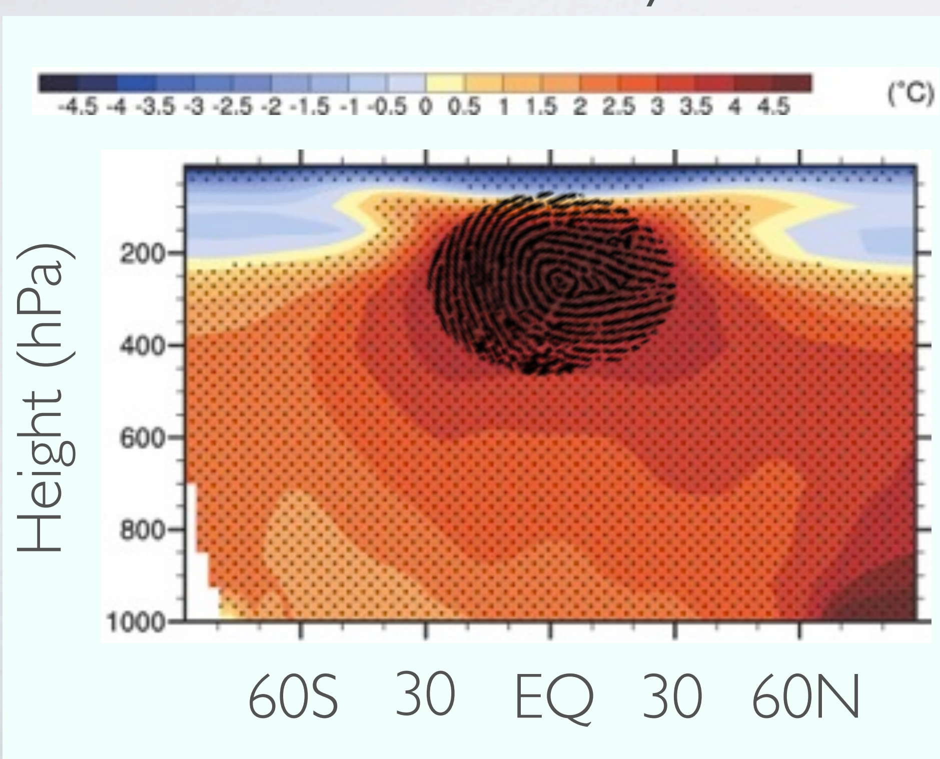
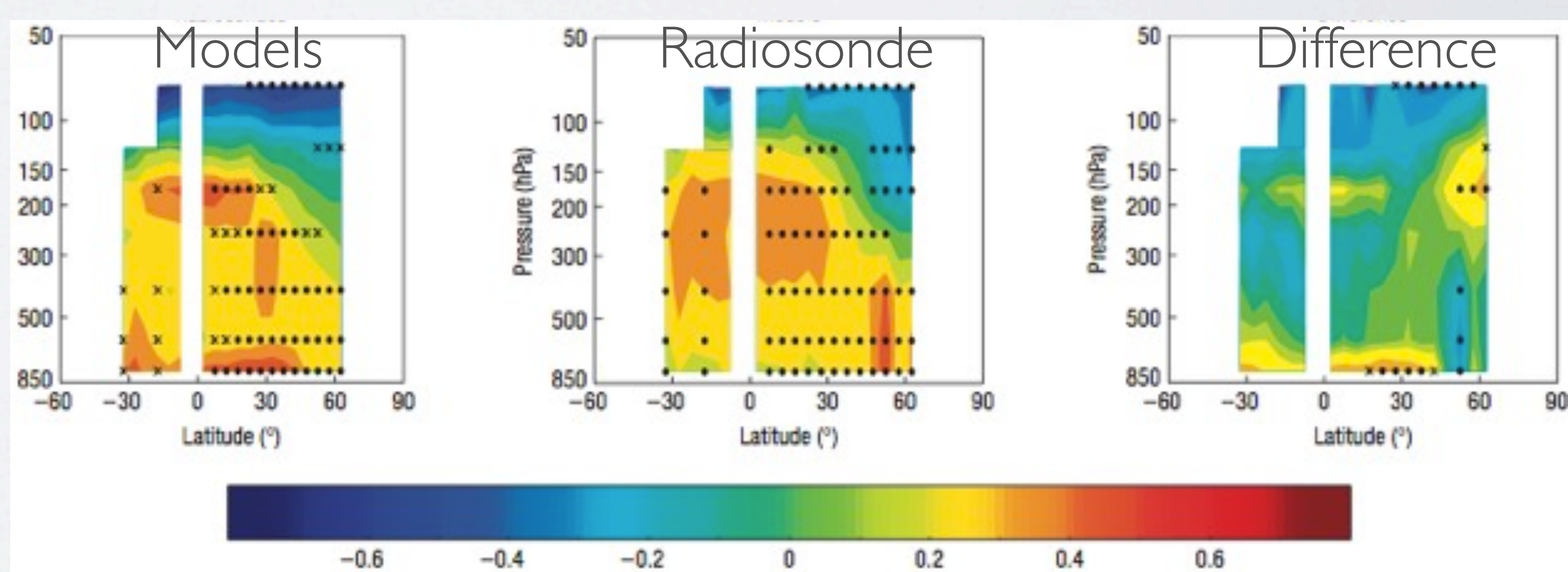


IPCC AR4, WGI, Fig. 10.7



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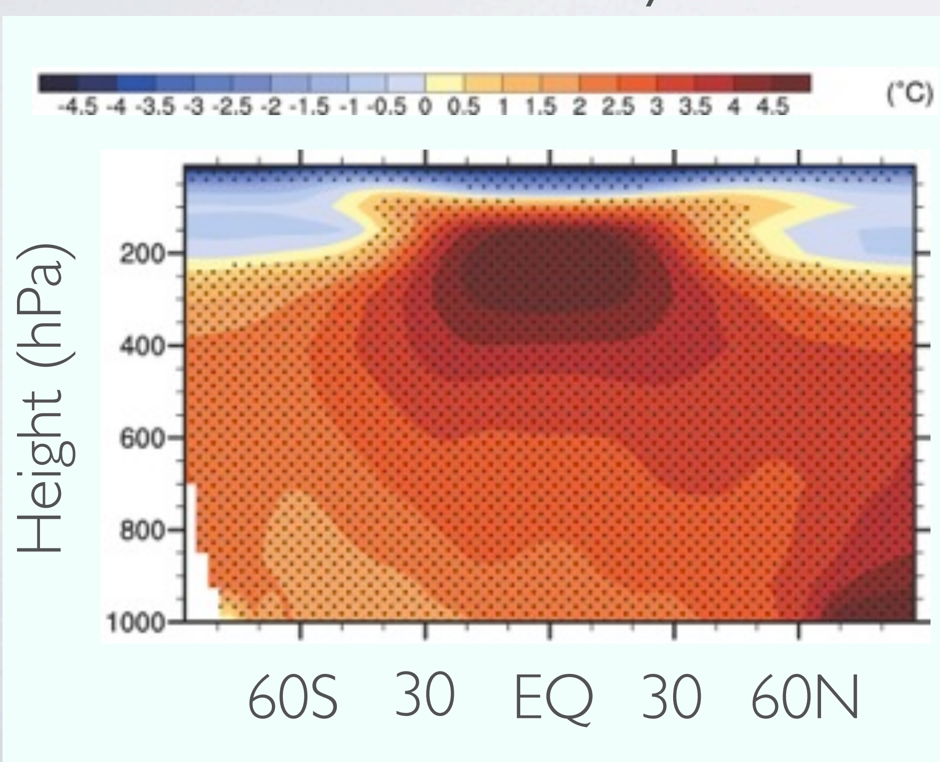
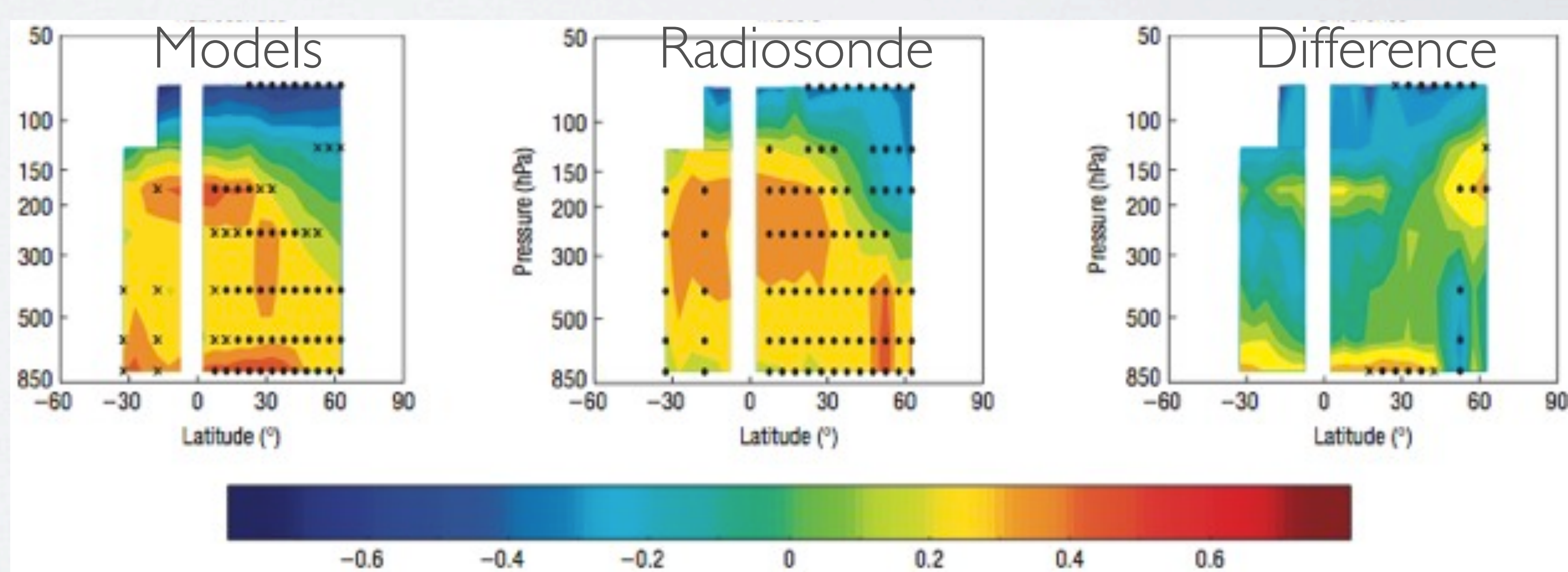


IPCC AR4, WGI, Fig. 10.7

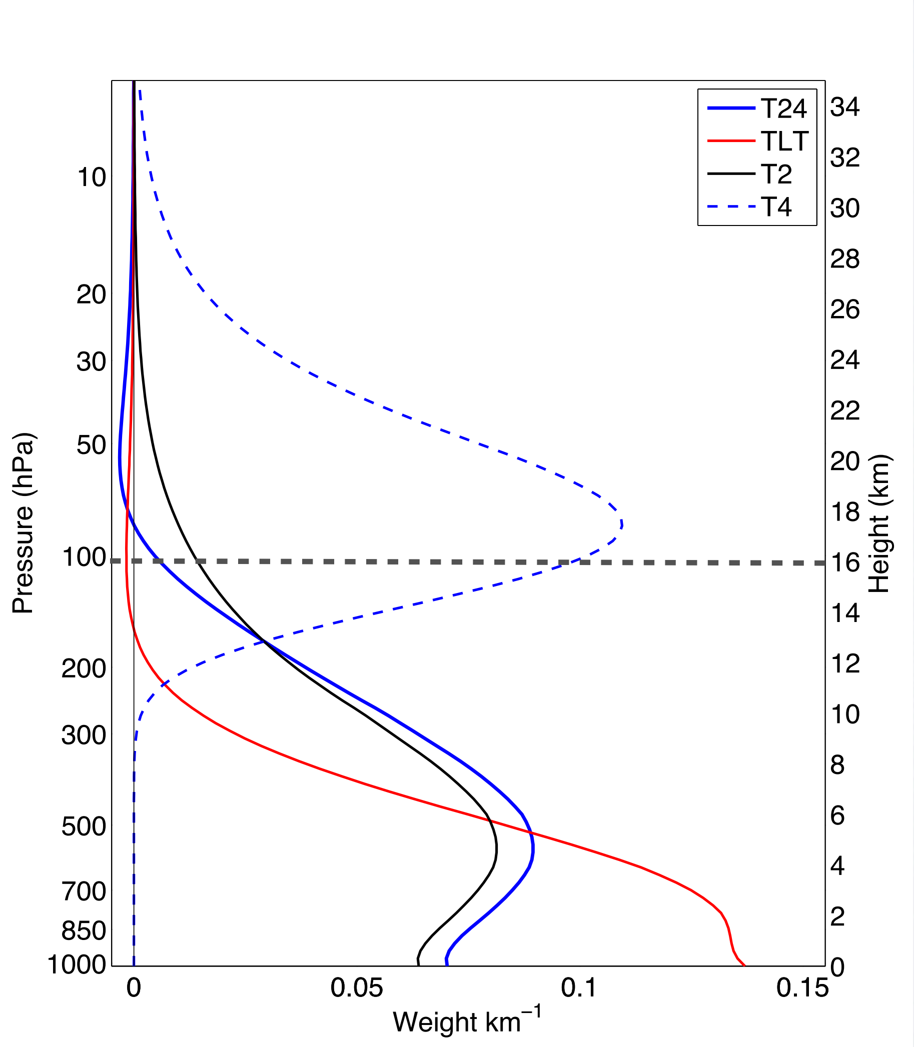
Anthropogenic Fingerprint.



Allen and Sherwood, 2008.

Motivation.

- How do we measure temperature in the atmosphere?
- Microwave Sounding Unit (MSU)
- Global coverage, 1979 - present
- NOAA STAR (v2.0), RSS (v3.3), and UAH (v5.3)



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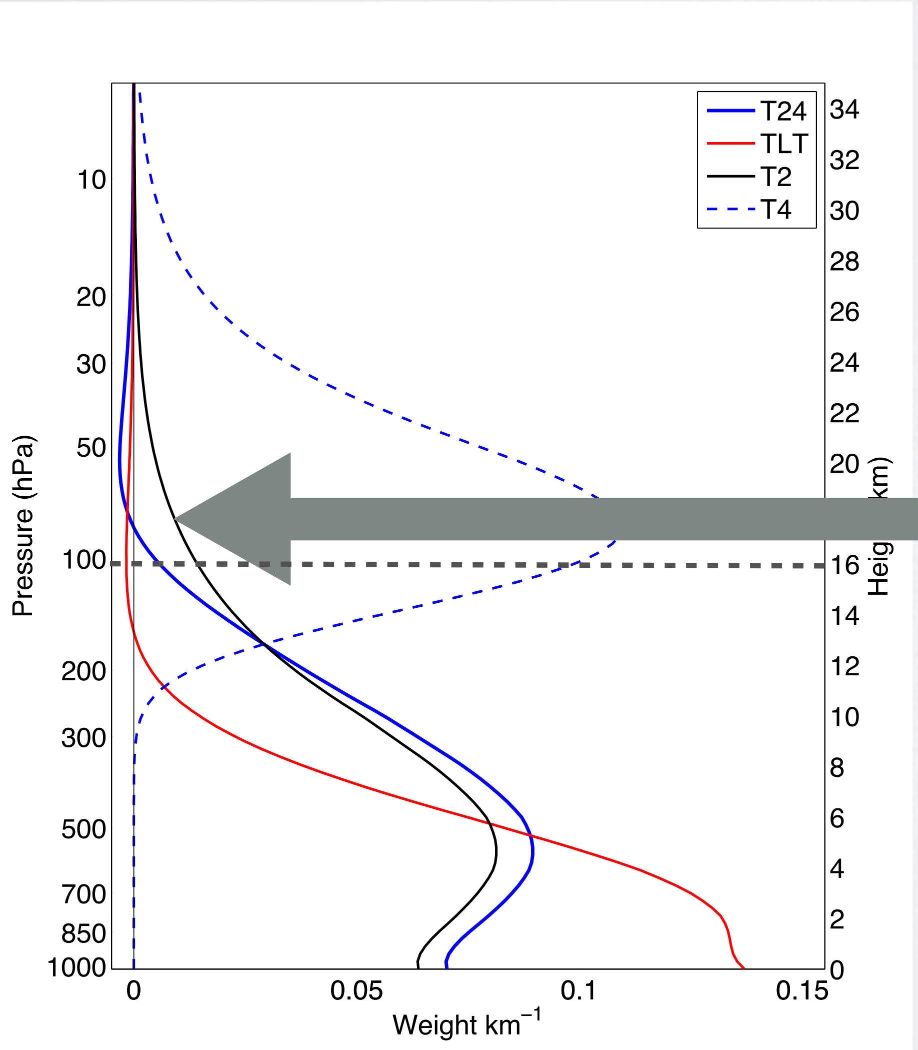
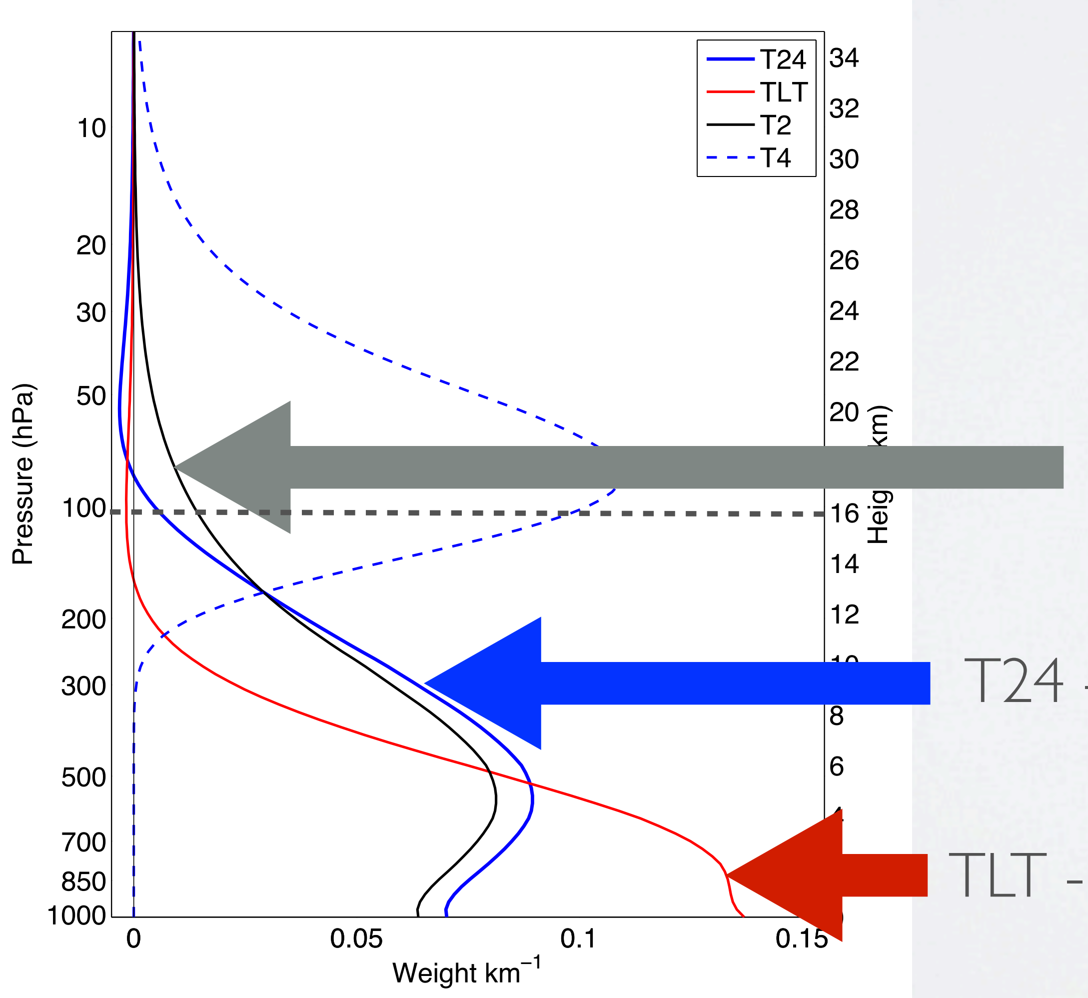


TMT (T2)

Motivation.

- How do we measure temperature in the atmosphere?
- Microwave Sounding Unit (MSU)
- Global coverage, 1979 - present
- NOAA STAR (v2.0), RSS (v3.3), and UAH (v5.3)



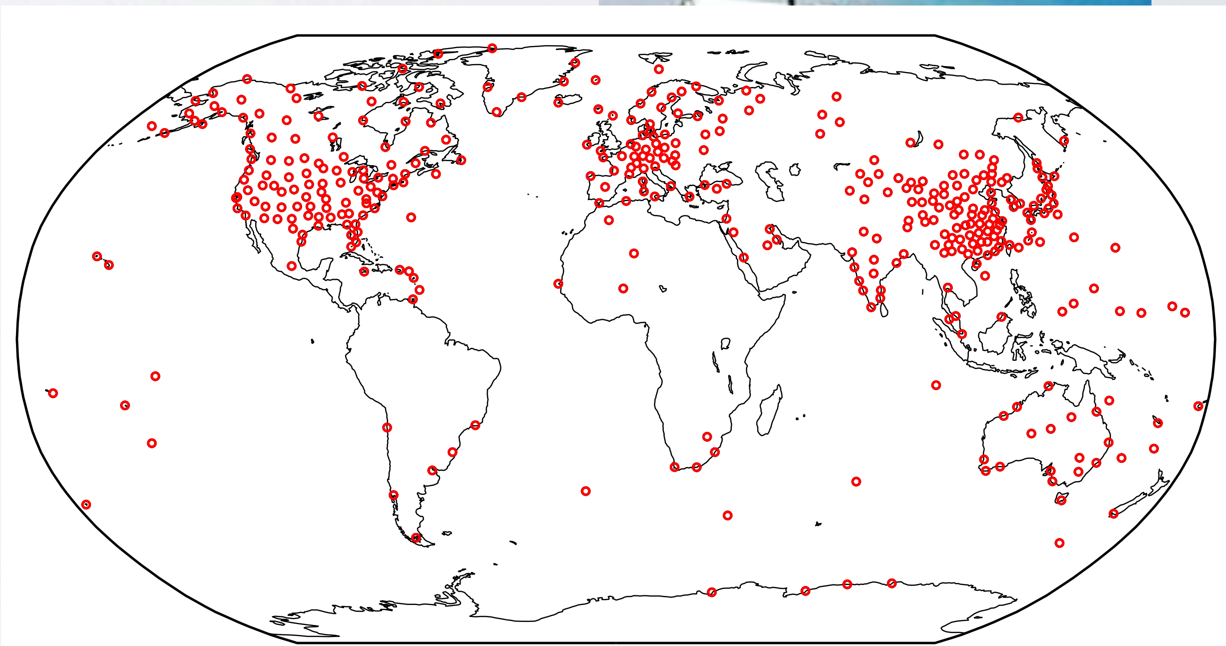
TMT (T2)

T24 - "Full Troposphere"

TLT - "Lower Troposphere"

Motivation.

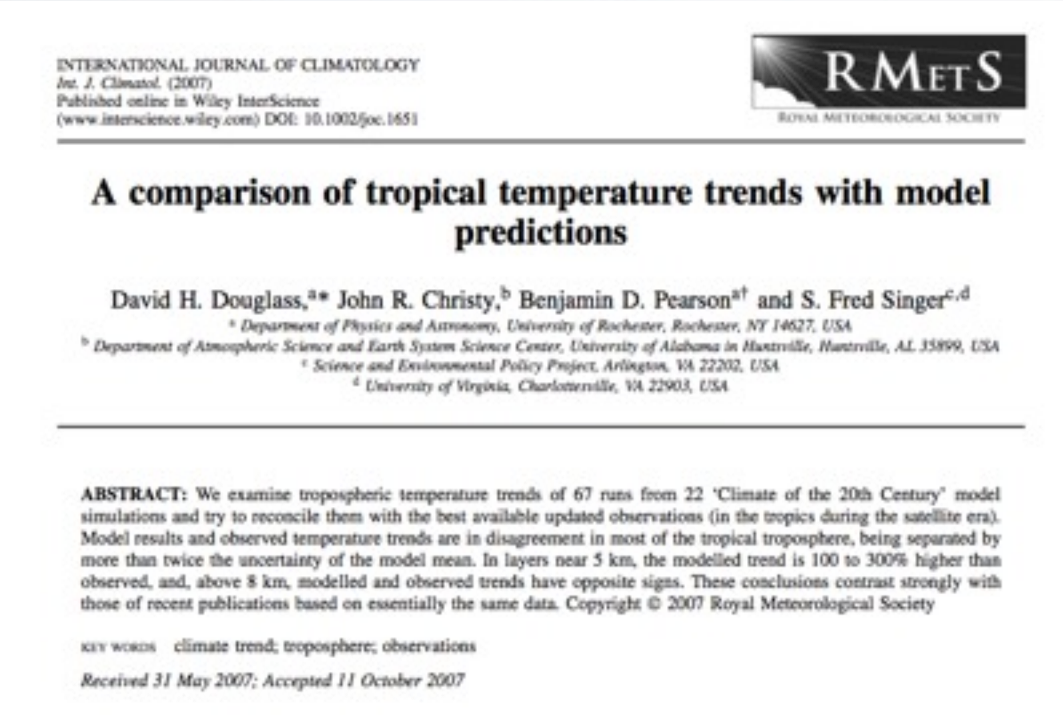
- How do we measure temperature in the atmosphere?
- Radiosondes (weather balloon)
- Direct measurement of temperature
- Large biases due to solar heating effects
- Patchy coverage
- Measurements at discrete levels



Motivation.

- Temperature trends derived from radiosondes and satellites have led people to question "the fingerprint" and models.

- A battle in the literature has followed surrounding temperature trends.



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RMetS
ROYAL METEOROLOGICAL SOCIETY

A comparison of tropical temperature trends with model predictions

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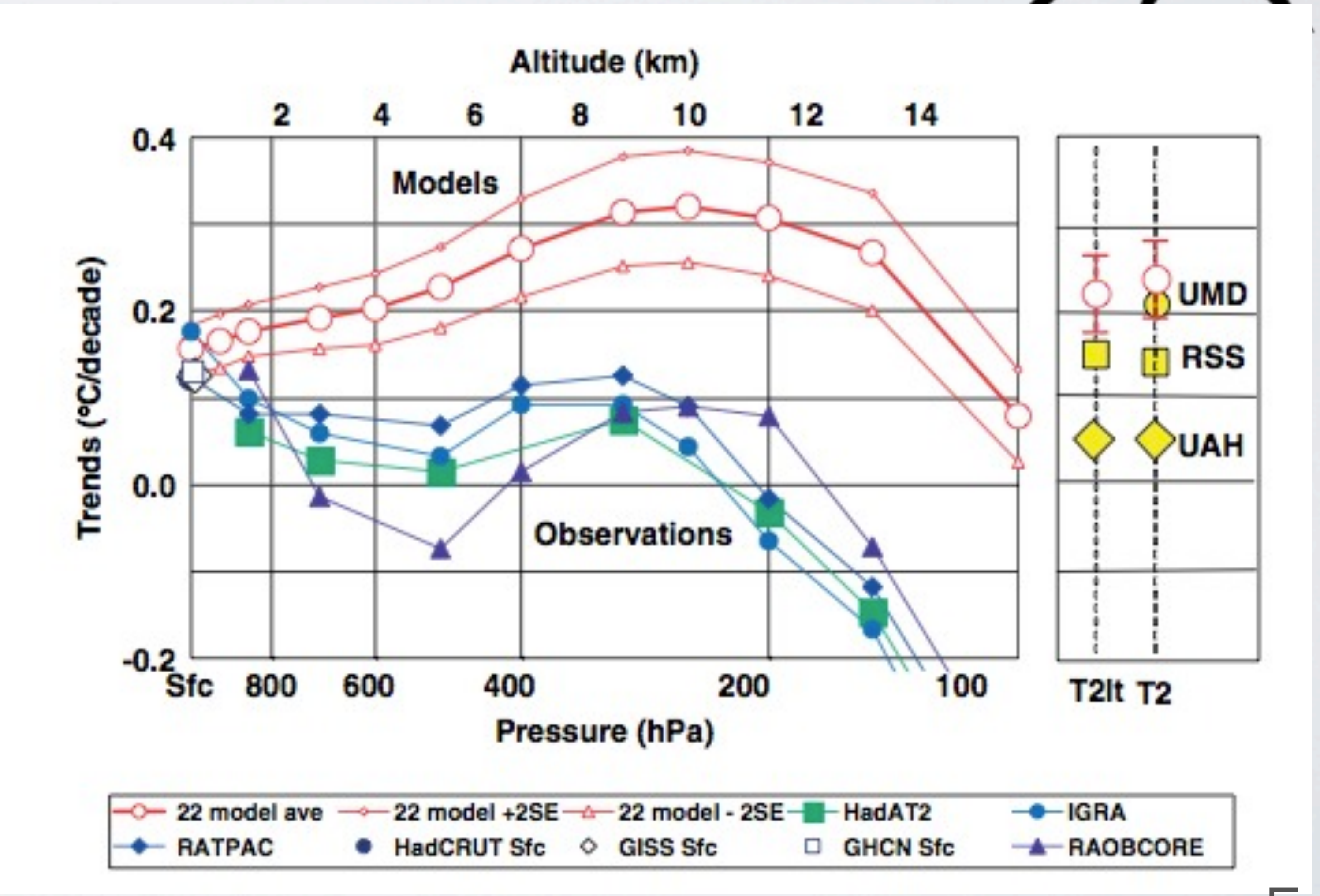
[b] *Department of Atmospheric Science and Earth System Science Center, University of Alabama in Huntsville, Huntsville, AL 35899, USA*
[c] *Science and Environmental Policy Project, Arlington, VA 22202, USA*
[d] *University of Virginia, Charlottesville, VA 22903, USA*

ABSTRACT: We examine tropospheric temperature trends of 67 runs from 22 'Climate of the 20th Century' model simulations and try to reconcile them with the best available updated observations (in the tropics during the satellite era). Model results and observed temperature trends are in disagreement in most of the tropical troposphere, being separated by more than twice the uncertainty of the model mean. In layers near 5 km, the modelled trend is 100 to 300% higher than observed, and, above 8 km, modelled and observed trends have opposite signs. These conclusions contrast strongly with those of recent publications based on essentially the same data. Copyright © 2007 Royal Meteorological Society

KEY WORDS climate trend; troposphere; observations

Received 31 May 2007; Accepted 11 October 2007



* Singer, 2008: "[This information] clearly falsifies the hypothesis of anthropogenic global warming" (quote, CES)

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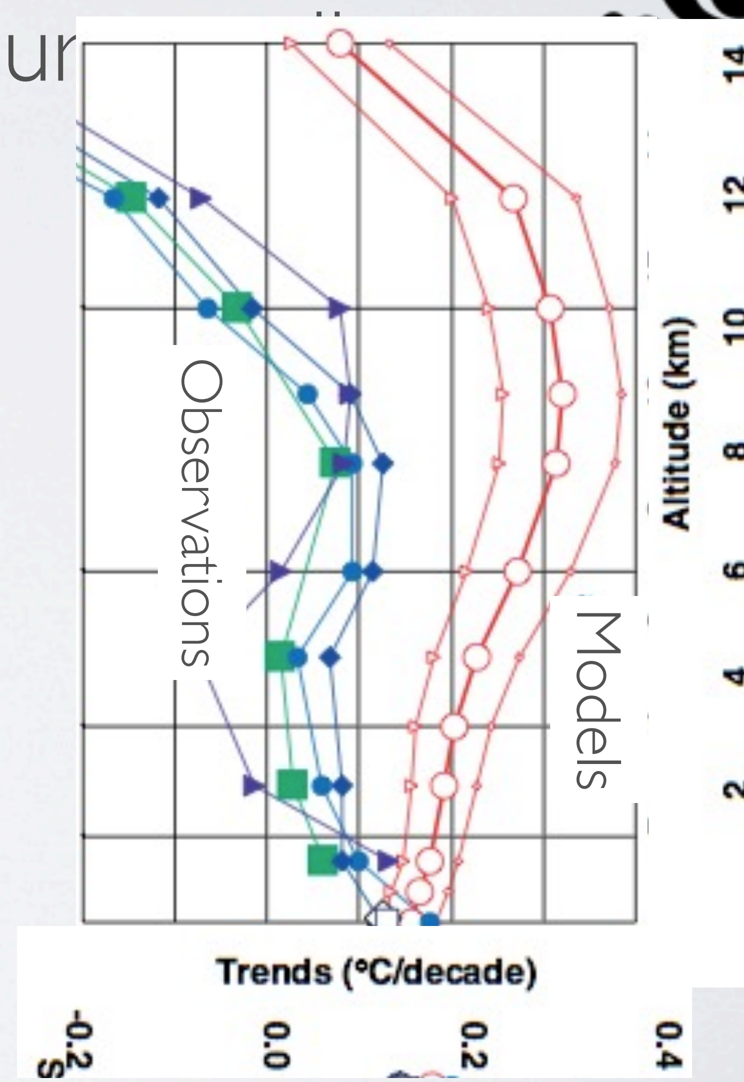

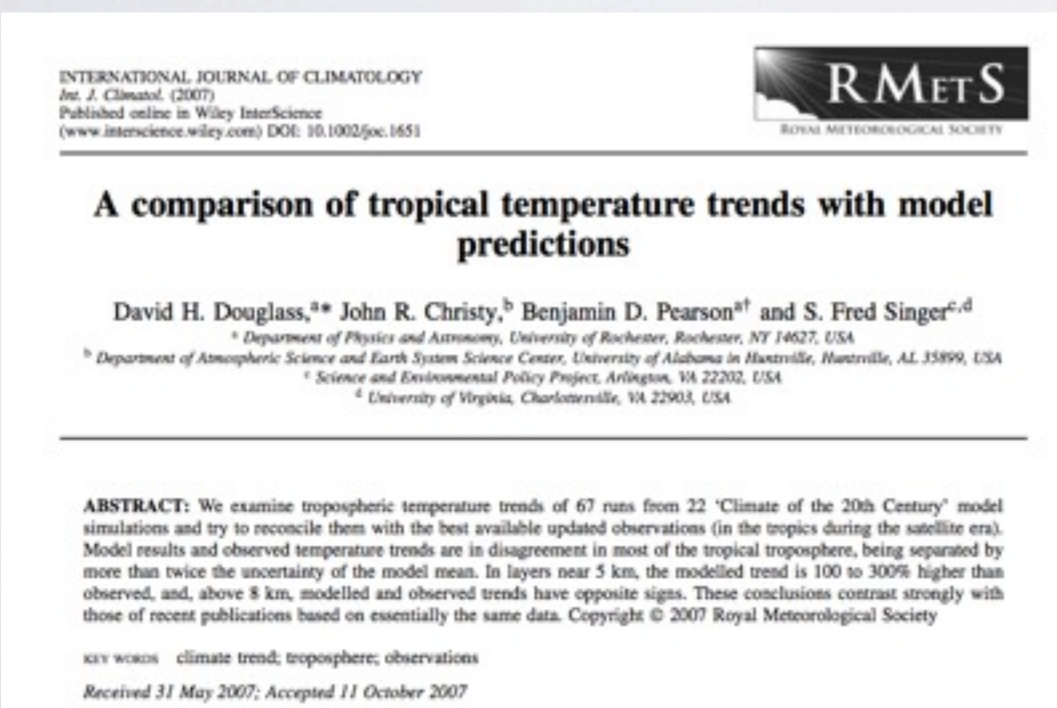

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Motivation.

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We have tested the proposition that greenhouse model simulations and trend observations can be reconciled. Our conclusion is that the present evidence, with the application of a robust statistical test, supports rejection of this proposition. (The use of tropical tropospheric temperature trends as a metric for this test is important, as this region represents the CEL and provides a clear signature of the trajectory of the climate system under enhanced greenhouse forcing.) On the whole, the evidence indicates that model trends in the troposphere are very likely inconsistent with observations that indicate that, since 1979, there is no significant long-term amplification factor relative to the surface. If these results continue to be supported, then future projections of temperature change, as depicted in the present suite of climate models, are likely too high.

In summary, the debate in this field revolves around the idea of discrepancy in surface and tropospheric trends in the tropics where vertical convection dominates heat transfer. Models are very consistent, as this article demonstrates, in showing a significant difference between surface and tropospheric trends, with tropospheric temperature trends warming faster than the surface. What is new in this article is the determination of a very robust estimate of the magnitude of the model trends at each atmospheric layer. These are compared with several equally robust updated estimates of trends from observations which disagree with trends from the models.

The last 25 years constitute a period of more complete and accurate observations and more realistic modelling efforts. Yet the models are seen to disagree with the observations. We suggest, therefore, that projections of future climate based on these models be viewed with much caution.

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Motivation.

- Turns out Douglass et al. applied a biased statistical test.
- Did not account for autocorrelation and used older versions of radiosonde datasets (when new ones were available).

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Consistency of modelled and observed temperature trends in the tropical troposphere

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[b] *U.K. Meteorological Office Hadley Centre, Exeter, EX1 3PB, UK*
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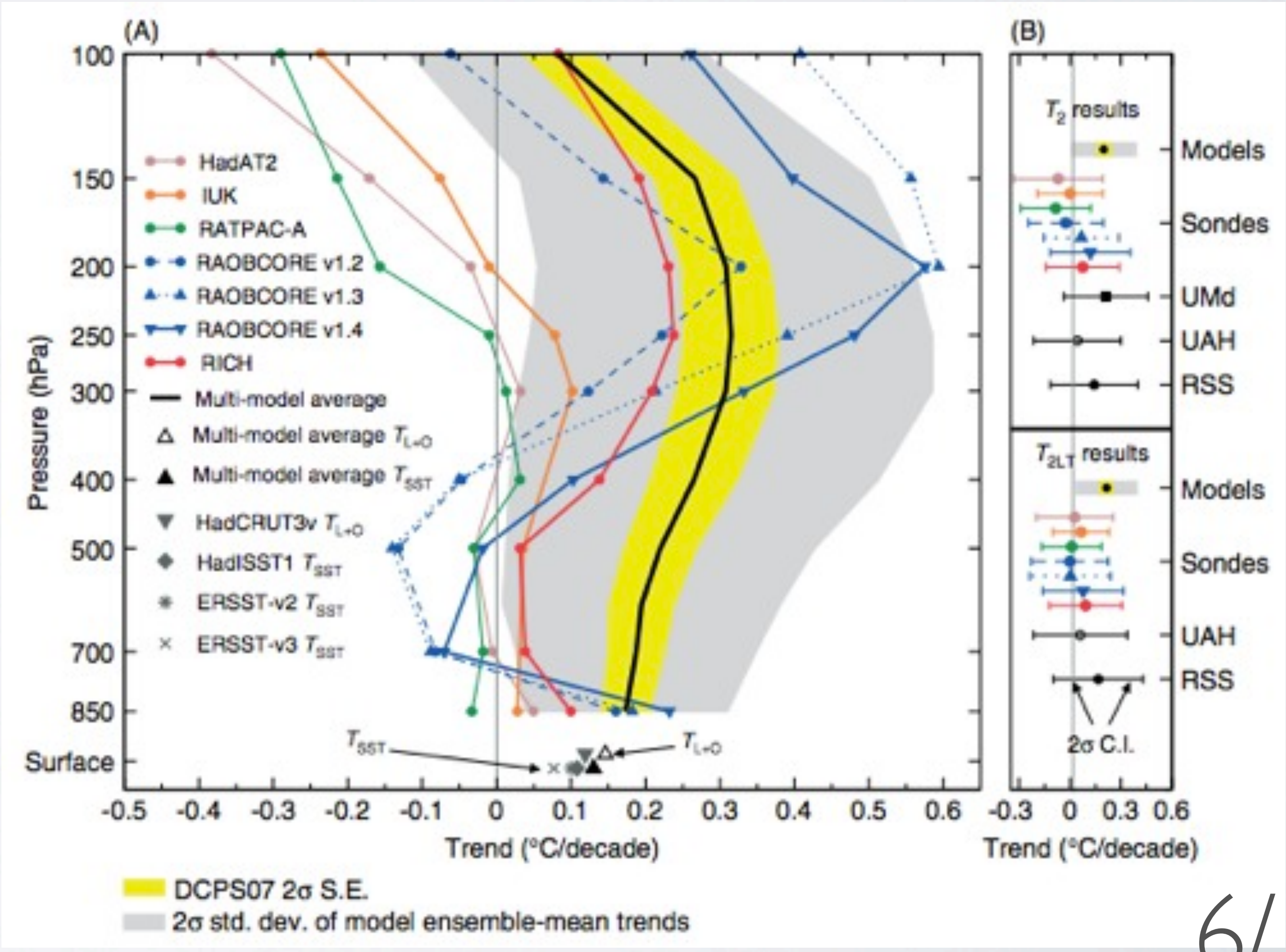
[l] *Yale University, New Haven, CT 06520, USA*

ABSTRACT: A recent report of the U.S. Climate Change Science Program (CCSP) identified a '*potentially serious inconsistency*' between modelled and observed trends in tropical lapse rates (Karl *et al.*, 2006). Early versions of satellite and radiosonde datasets suggested that the tropical surface had warmed more than the troposphere, while climate models consistently showed tropospheric amplification of surface warming in response to human-caused increases in well-mixed greenhouse gases (GHGs). We revisit such comparisons here using new observational estimates of surface and tropospheric temperature changes. We find that there is no longer a serious discrepancy between modelled and observed trends in tropical lapse rates.

This emerging reconciliation of models and observations has two primary explanations. First, because of changes in the treatment of buoy and satellite information, new surface temperature datasets yield slightly reduced tropical warming relative to earlier versions. Second, recently developed satellite and radiosonde datasets show larger warming of the tropical lower troposphere. In the case of a new satellite dataset from Remote Sensing Systems (RSS), enhanced warming is due to an improved procedure of adjusting for inter-satellite biases. When the RSS-derived tropospheric temperature trend is compared with four different observed estimates of surface temperature change, the surface warming is invariably amplified in the tropical troposphere, consistent with model results. Even if we use data from a second satellite dataset with smaller tropospheric warming than in RSS, observed tropical lapse rate trends are not significantly different from those in all other model simulations.



Motivation.

But disagreement looms...

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Article

What Do Observational Datasets Say about Modeled Tropospheric Temperature Trends since 1979?

John R. Christy [1,*], Benjamin Herman [2], Roger Pielke, Sr. [3], Philip Klotzbach [4], Richard T. McNider [1], Justin J. Hnilo [1], Roy W. Spencer [1], Thomas Chase [3] and David Douglass [5]

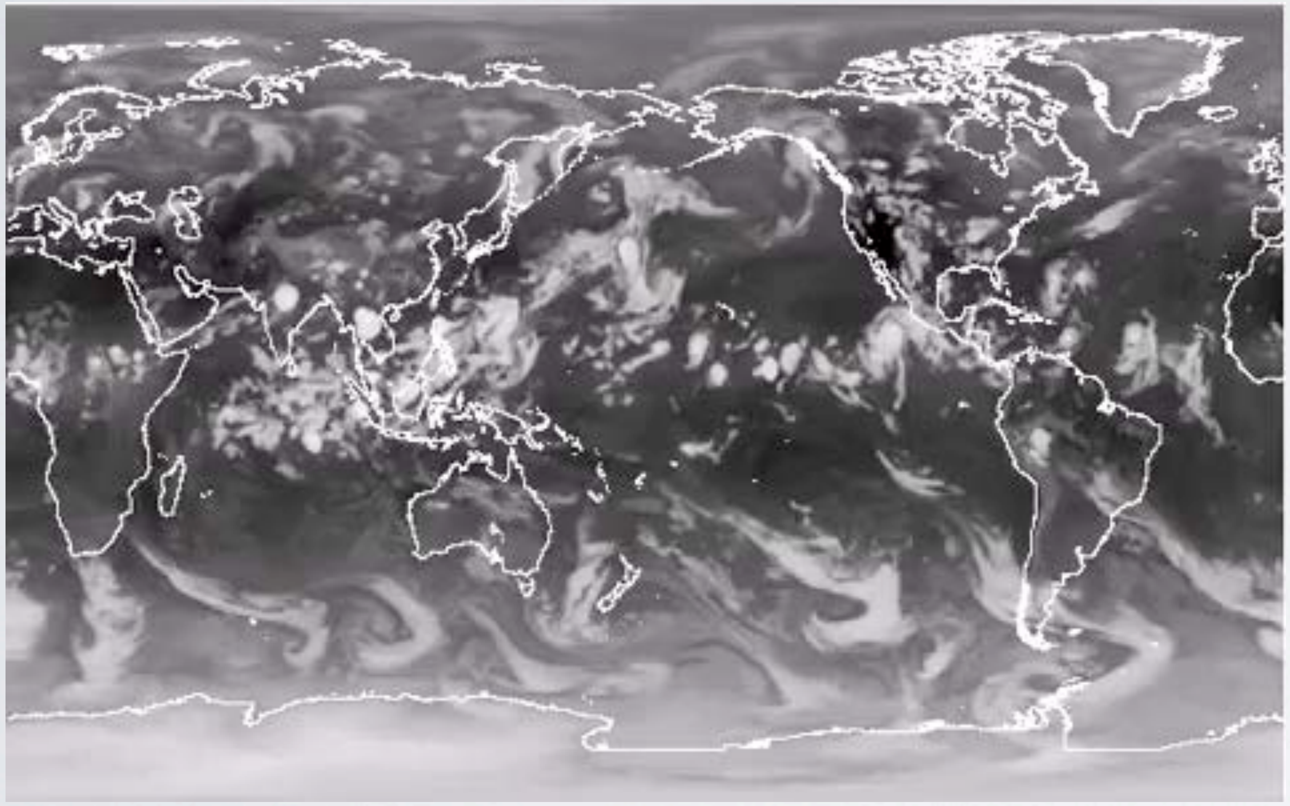
Motivation.

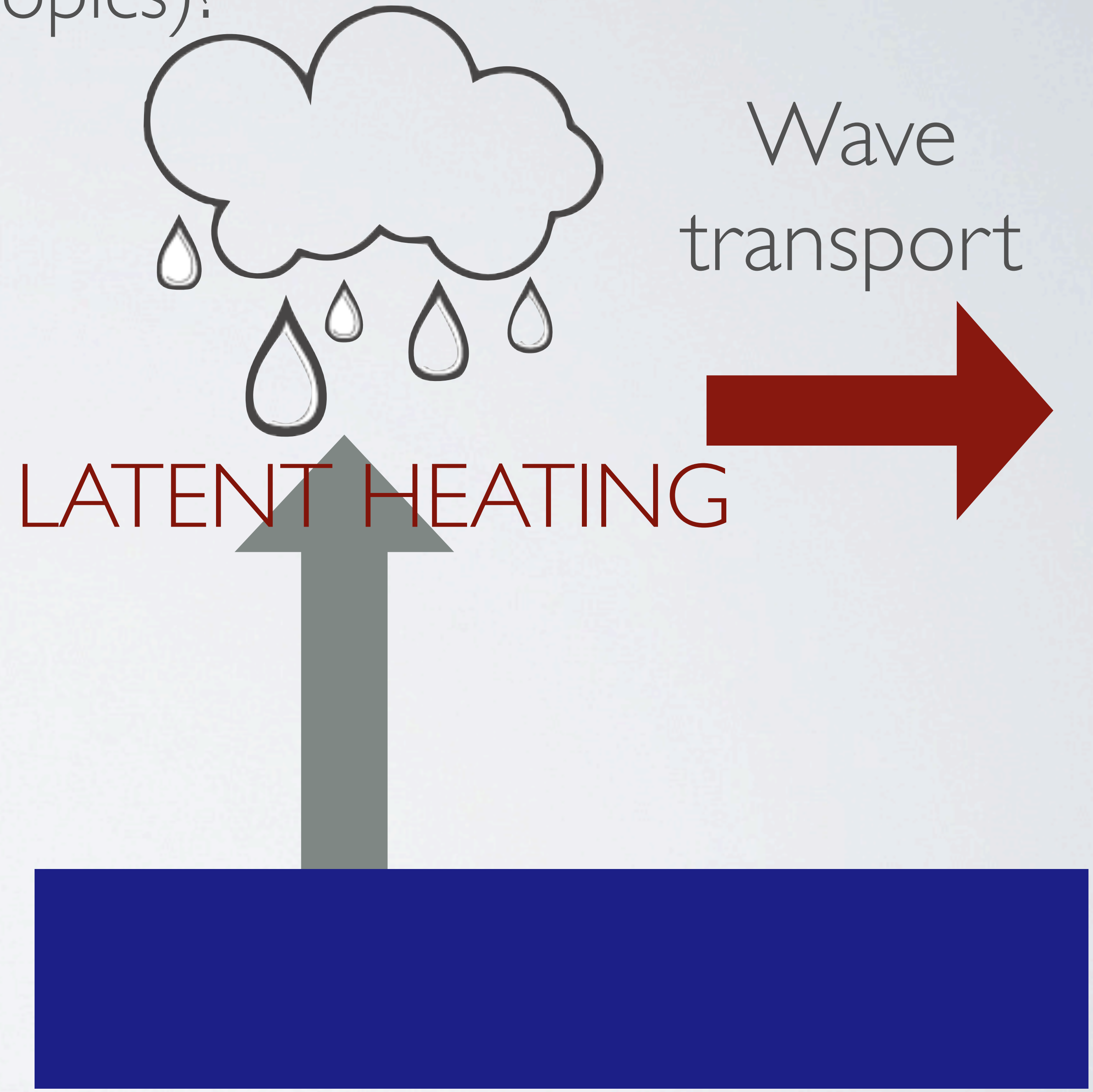
But disagreement looms...

Abstract: Updated tropical lower tropospheric temperature datasets covering the period 1979–2009 are presented and assessed for accuracy based upon recent publications and several analyses conducted here. We conclude that the lower tropospheric temperature (T_{LT}) trend over these 31 years is +0.09 ± 0.03 °C decade^{-1}. Given that the surface temperature (T_{sfc}) trends from three different groups agree extremely closely among themselves (~ +0.12 °C decade^{-1}) this indicates that the "scaling ratio" (*SR*, or ratio of atmospheric trend to surface trend: T_{LT}/T_{sfc}) of the observations is ~0.8 ± 0.3. This is significantly different from the average *SR* calculated from the IPCC AR4 model simulations which is ~1.4. This result indicates the majority of AR4 simulations tend to portray significantly greater warming in the troposphere relative to the surface than is found in observations. The *SR*, as an internal, normalized metric of model behavior, largely avoids the confounding influence of short-term fluctuations such as El Niños which make direct comparison of trend magnitudes less confident, even over multi-decadal periods.

Motivation.

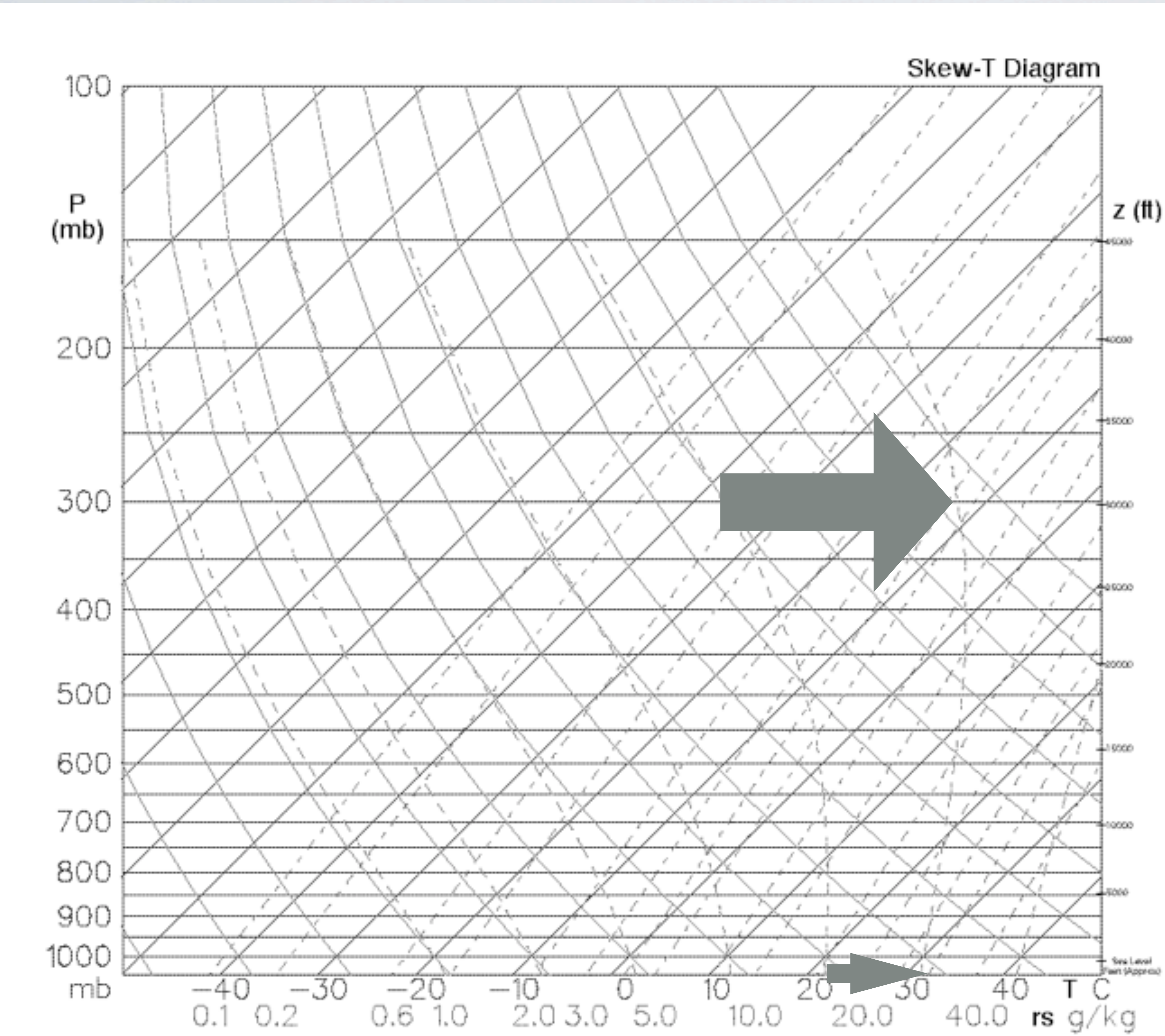
- What does theory say (in the tropics)?

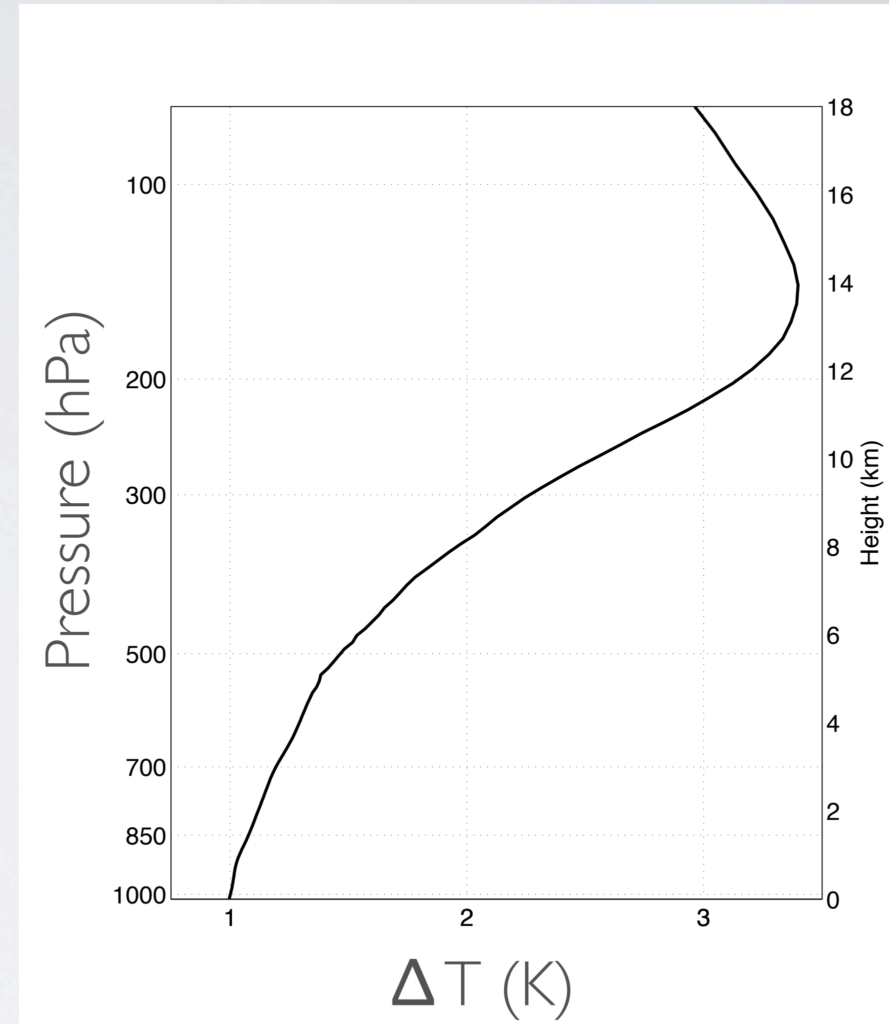




- Tropics maintain a moist adiabatic lapse rate in the free troposphere

Motivation.





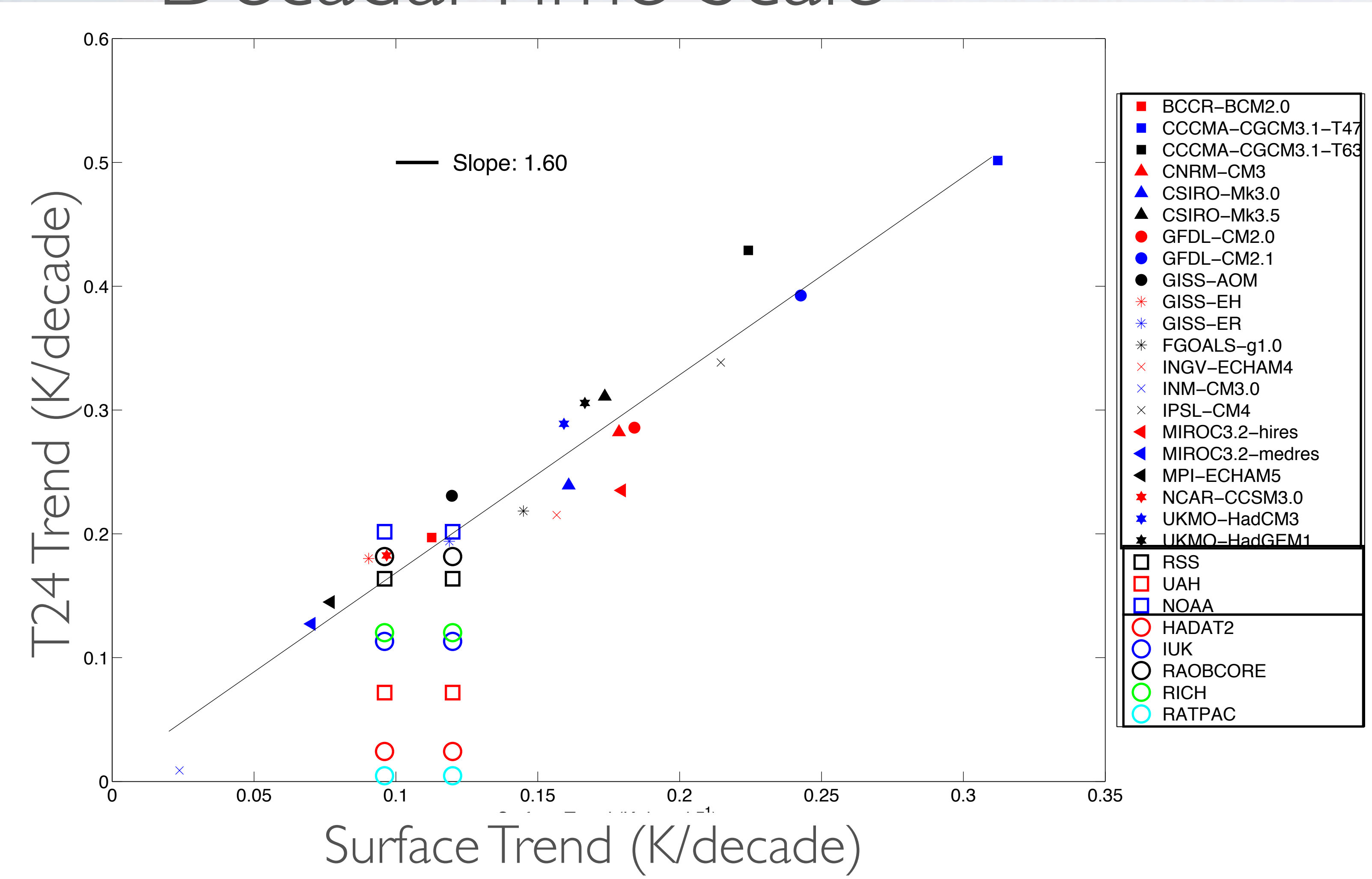
T24 = 1.75x**Δ**Surface

TLT = 1.29x**Δ**Surface

Motivation.

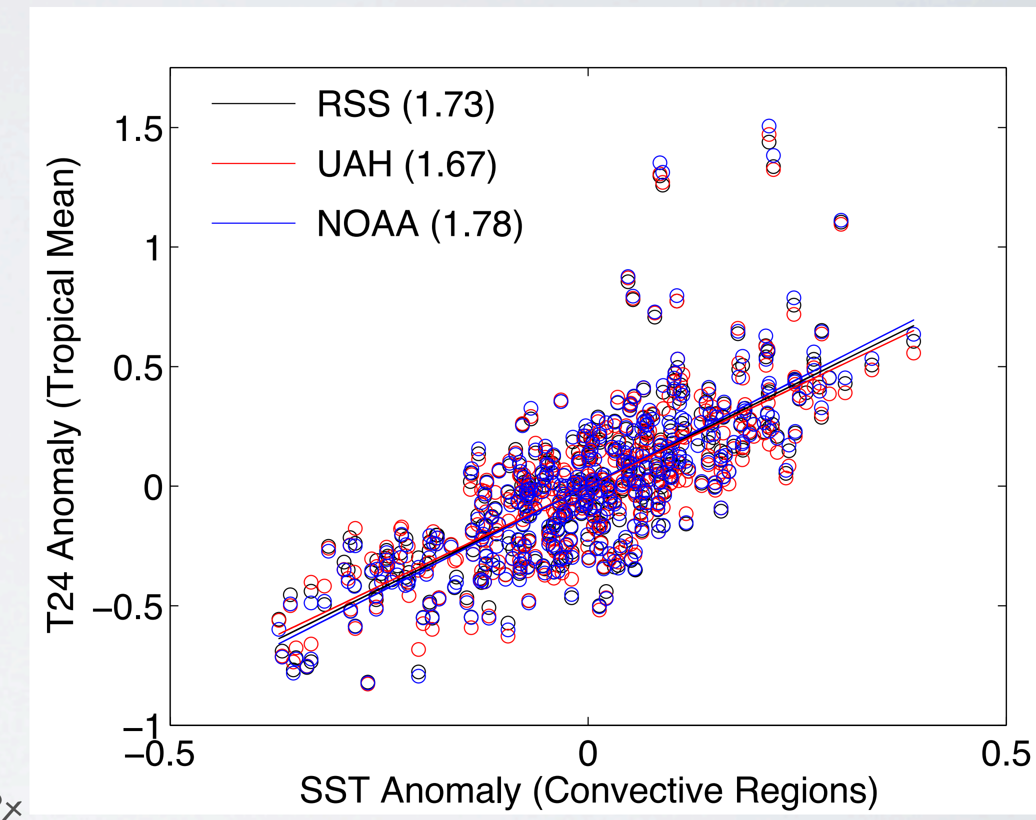
- There is an incongruence with amplification on different time scales.

Decadal Time Scale



Tropical (20N-S), 1979 - 2000
* See Santer et al, 2005

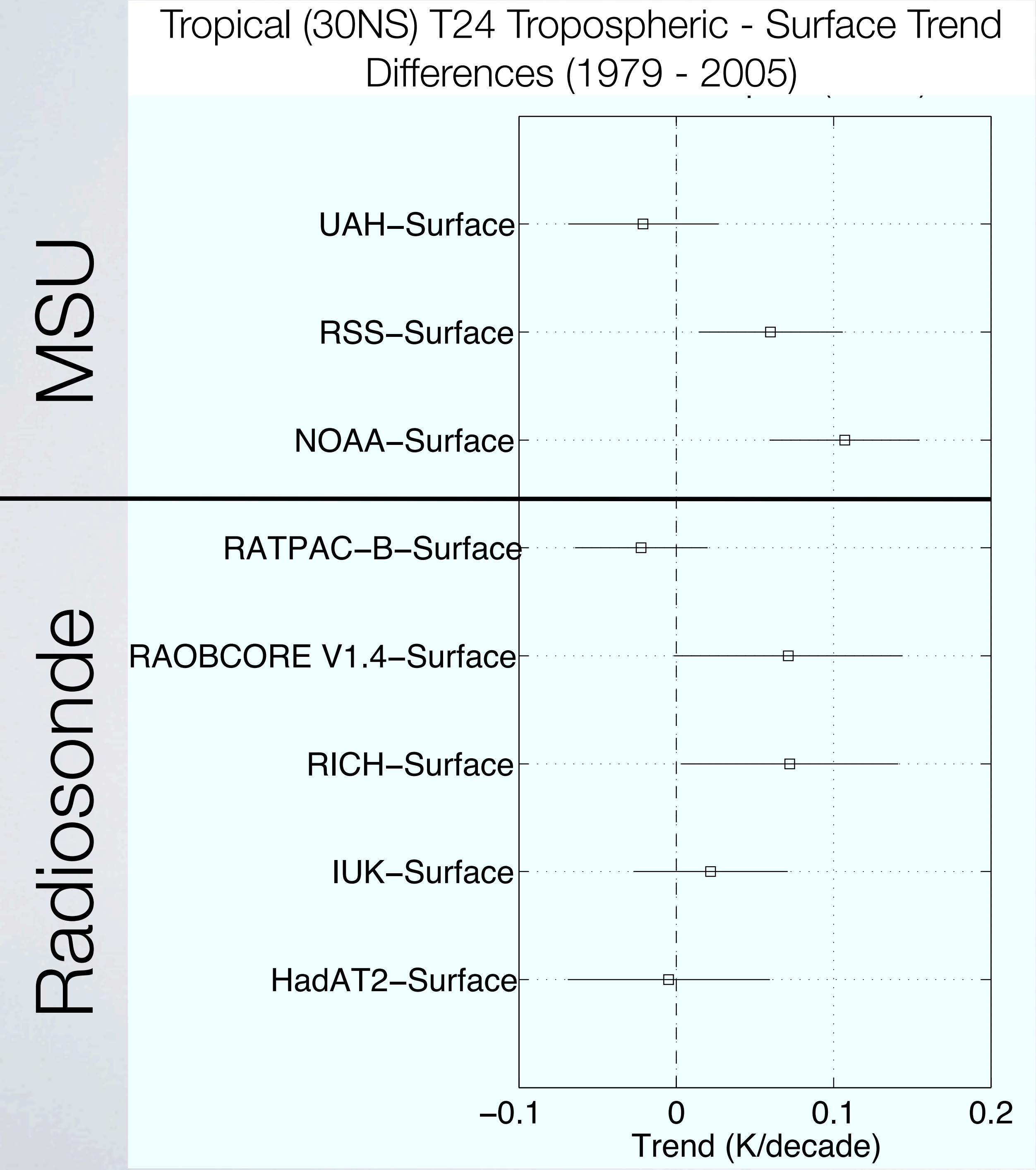
Interannual



1979 - 2009 (ERSST, GPCP)
* See Sobel et al, 2002

MSU discrepancies.

- There are still large discrepancies in observational trend estimates.



Each group uses the exact same raw data!

Why are they different?

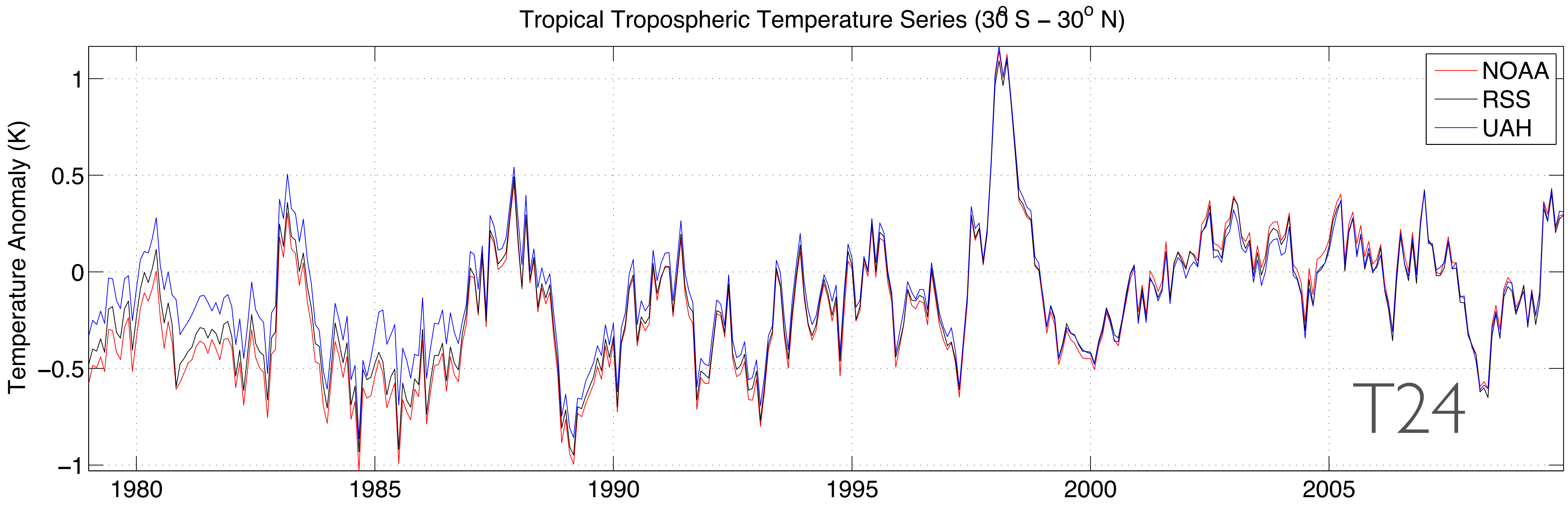
MSU discrepancies.

Table 1.1: Current least squares linear trend values (1979 - 2011) for NOAA, RSS, and UAH for various channels in units of K decade^{-1}.

Channel	Region	NOAA	RSS	UAH
TLT	Global	N/A	0.139	0.137
	Tropical	N/A	0.125	0.072
T24	Global	0.197	0.141	0.113
	Tropical	0.177	0.138	0.075
TMT	Global	0.130	0.083	0.048
	Tropical	0.131	0.101	0.040
TLS	Global	-0.322	-0.302	-0.382
	Tropical	-0.324	-0.264	-0.313

MSU discrepancies.

- Where are differences in tropospheric temperature measurements?



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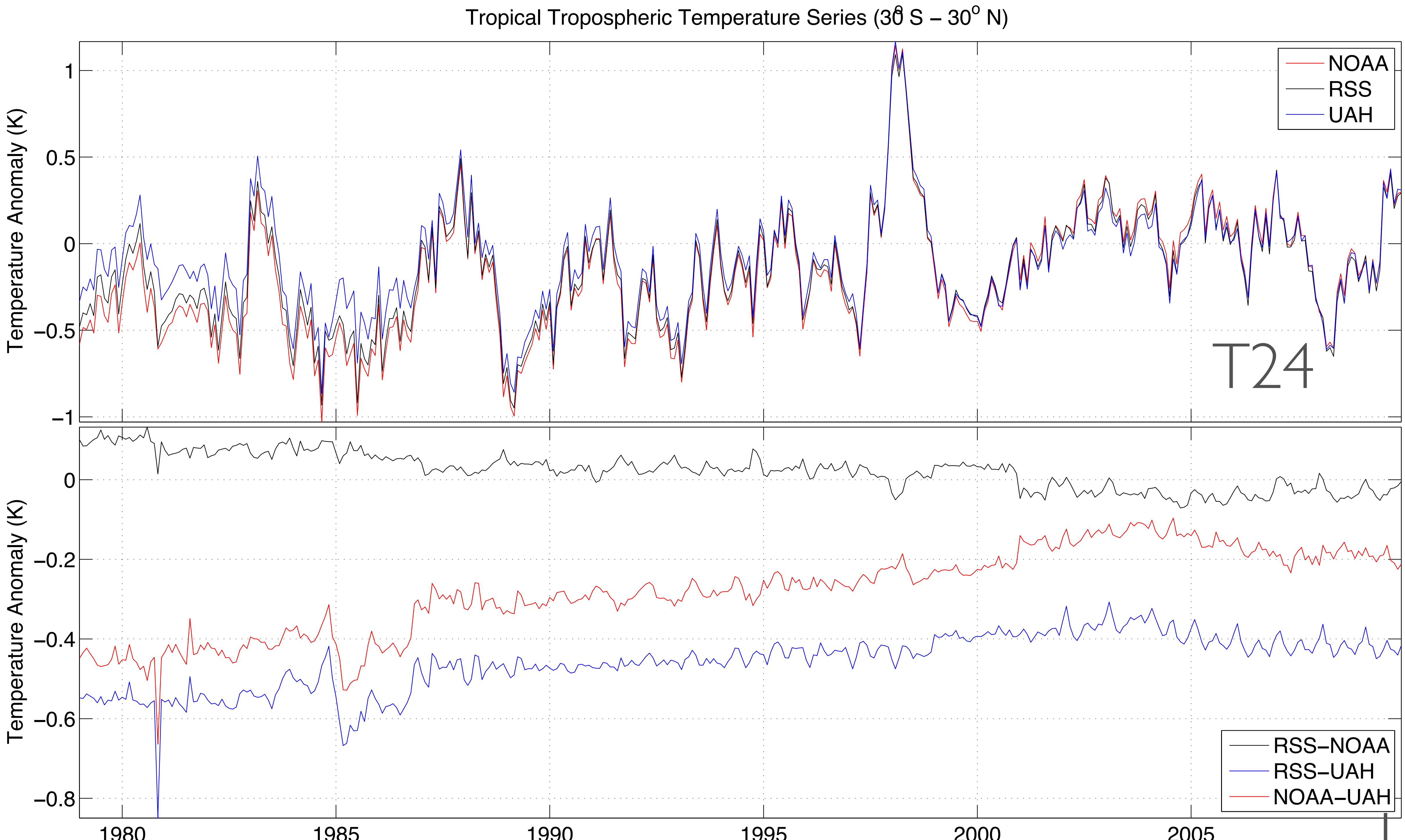

MSU discrepancies.

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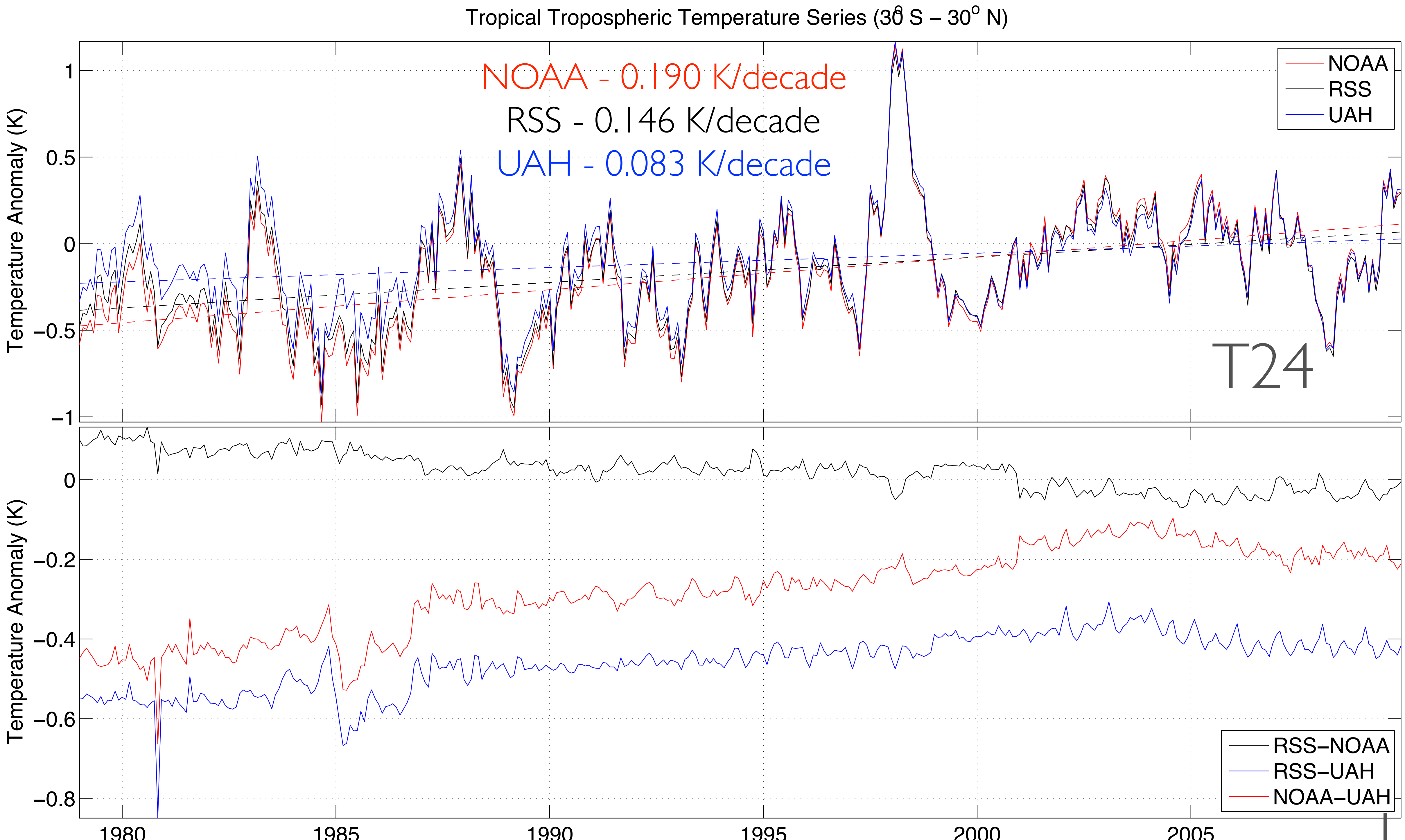
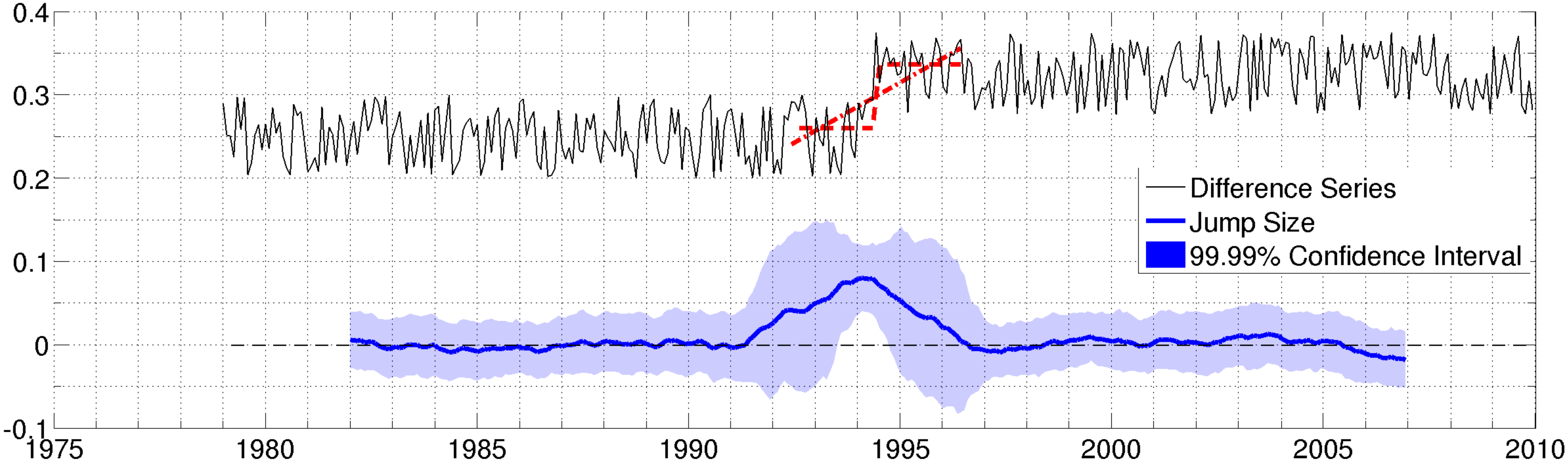


MSU discrepancies.

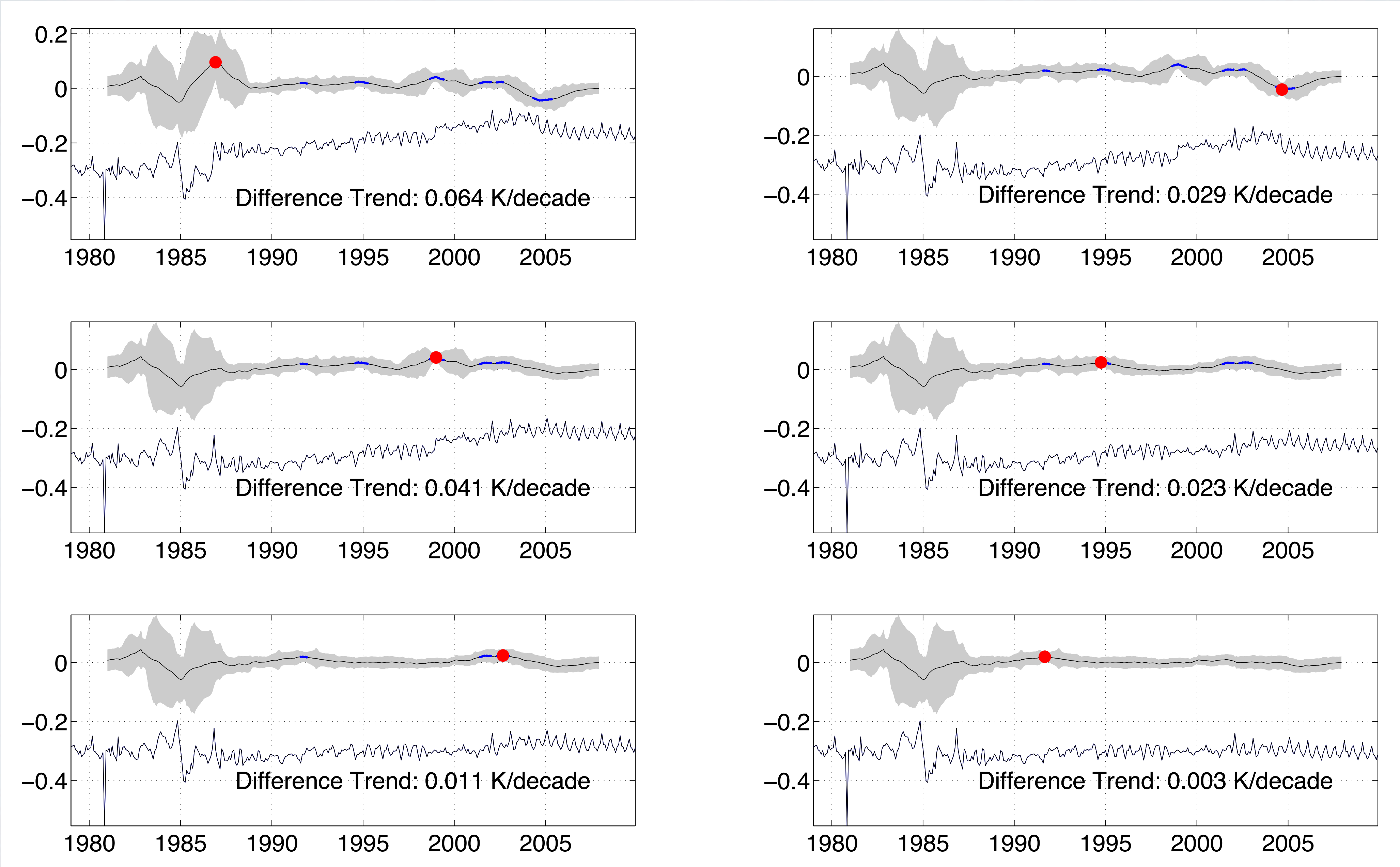
- Figuring out where the "jumps" are.



$$T_B = \sum_{t+1}^{t+k} \frac{T_{diff}(t)}{k} - \sum_{t-k}^{t-1} \frac{T_{diff}(t)}{k}$$

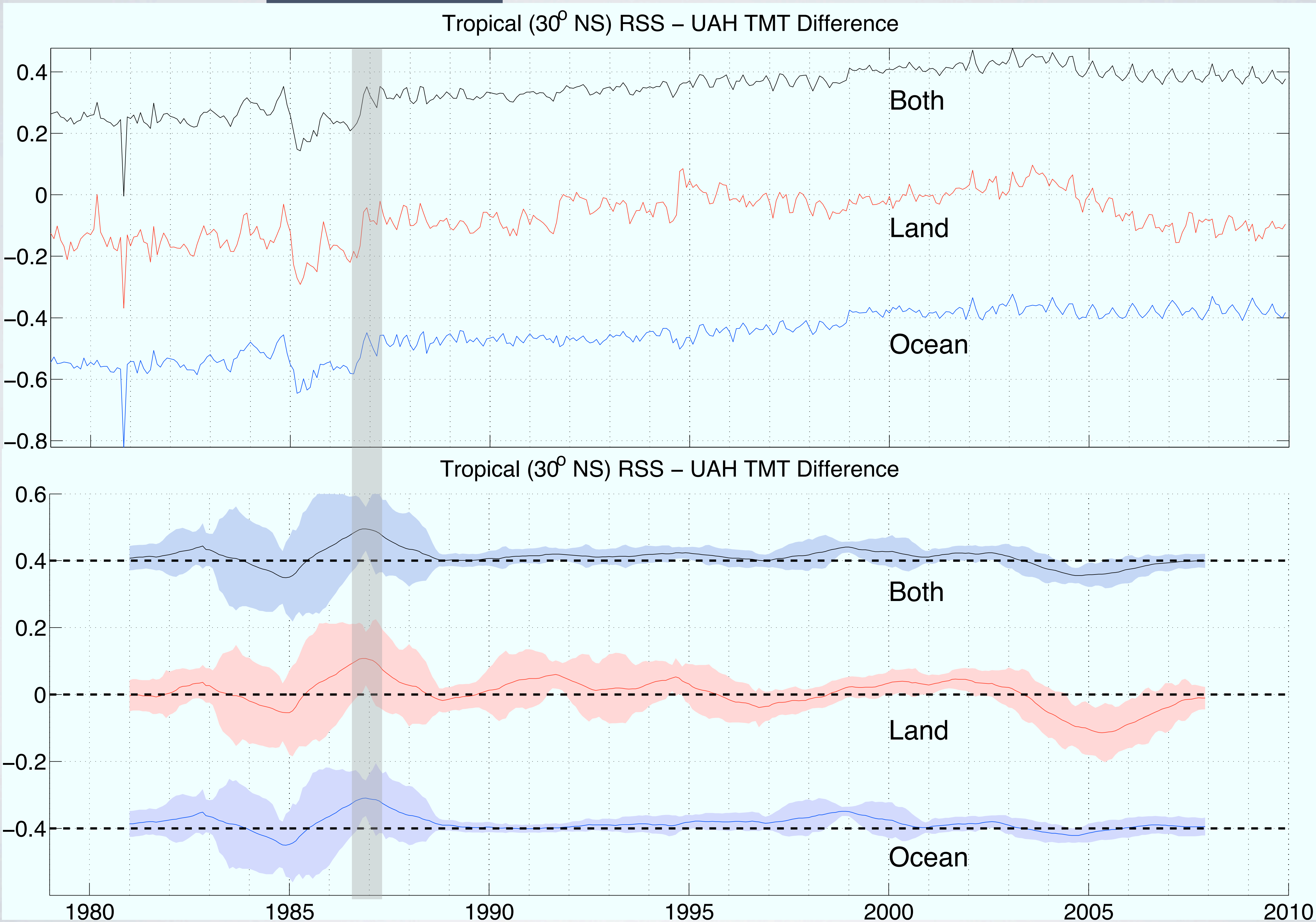
MSU discrepancies.

- Can reconciling "jumps" reconcile trends?



RSS T24 - UAH T24 (tropics)

MSU discrepancies.

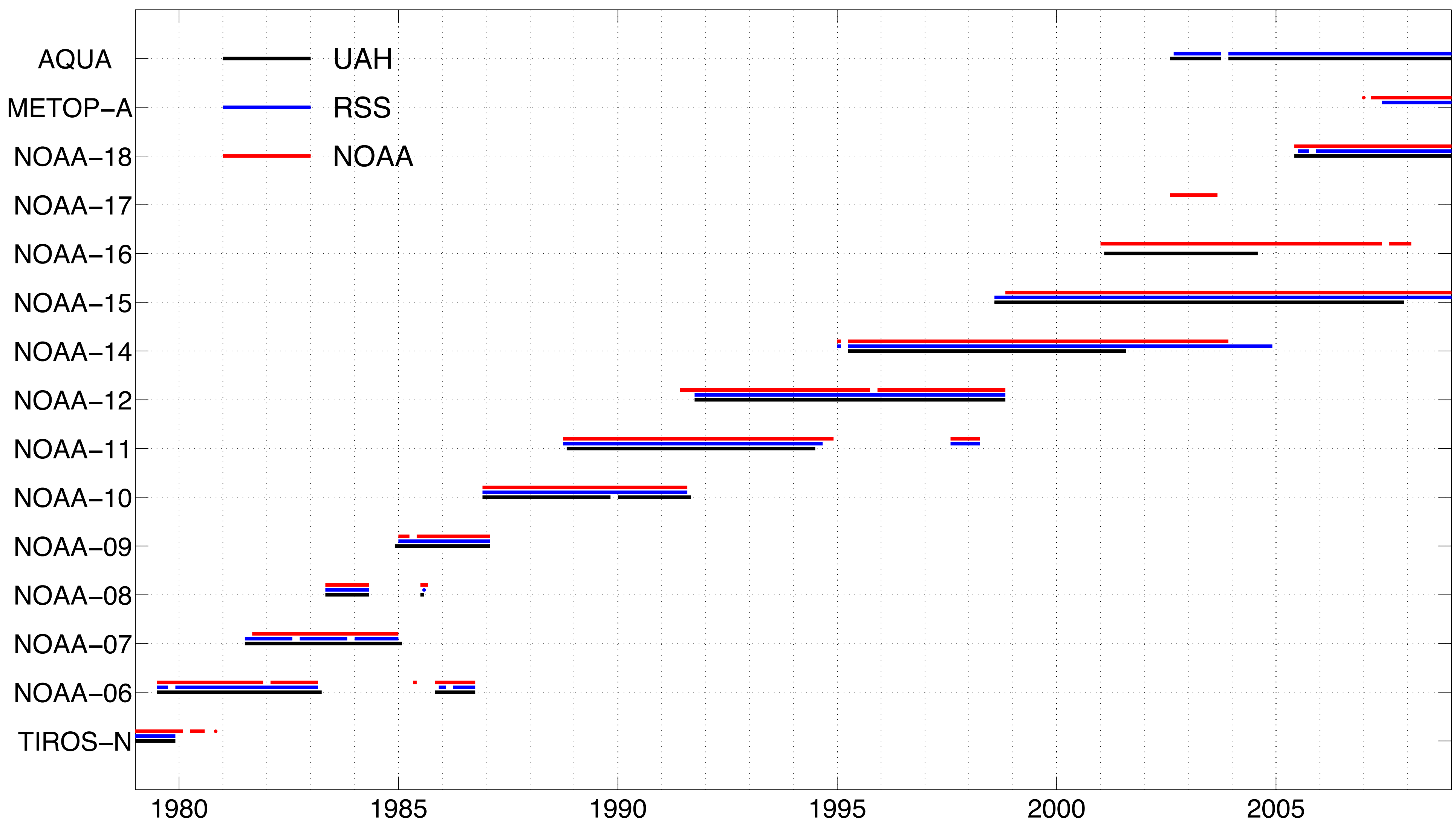


MSU discrepancies.

Why would two datasets with the exact same data suddenly disagree?

MSU discrepancies.

- Complicated merging process...



MSU discrepancies.

- Complicated merging process...

Science 2005

The Effect of Diurnal Correction on Satellite-Derived Lower Tropospheric Temperature

Carl A. Mears and Frank J. Wentz

ıts of decadal-scale temperature change in the lower cooling relative to Earth's surface in the tropics. Such ıal correction to prevent drifts in the satellites' mea- g spurious trends. We have derived a diurnal correc- of the opposite sign from that previously applied. ion in the calculation of lower tropospheric tem- crowave measurements, we find tropical warming at the surface and in our satellite-derived version of temperature.

Effects of orbital decay on satellite-derived lower-tropospheric temperature trends

Frank J. Wentz & Matthias Schabel

Remote Sensing Systems, 438 First Street, Suite 200, Santa Rosa, California 95401 USA

The 17-year lower-tropospheric temperature record derived from the satellite Microwave Sounding Unit (MSU)[1–3] shows a globa cooling trend, from 1979 to 1995, of –0.05 K per decade at ar altitude of about 3.5 km (refs 4, 5). Air temperatures measured a the Earth's surface, in contrast, have risen by approximately +0.13 K per decade over the same period[4,6]. The two temperature records are derived from measurements of different physica parameters, and thus are not directly comparable. In fact, the lower stratosphere is cooling substantially (by about –0.5 K pe decade)[5], so the warming trend seen at the surface is expected to diminish with altitude and change into a cooling trend at some point in the troposphere. Even so, it has been suggested that the cooling trend seen in the satellite data is excessive[4,7,8]. The difficulty in reconciling the information from these differen sources has sparked a debate in the climate community abou possible instrumental problems and the existence of globa warming[4,7,9]. Here we identify an artificial cooling trend in the satellite-derived temperature series caused by previously neglected orbital-decay effects. We find a new, corrected estimate of +0.07 K per decade for the MSU-based temperature trend which is in closer agreement with surface temperatures. We also find that the reported[7] cooling of the lower troposphere, relative to the middle troposphere, is another artefact caused by uncor- rected orbital-decay effects.

Nature 1998

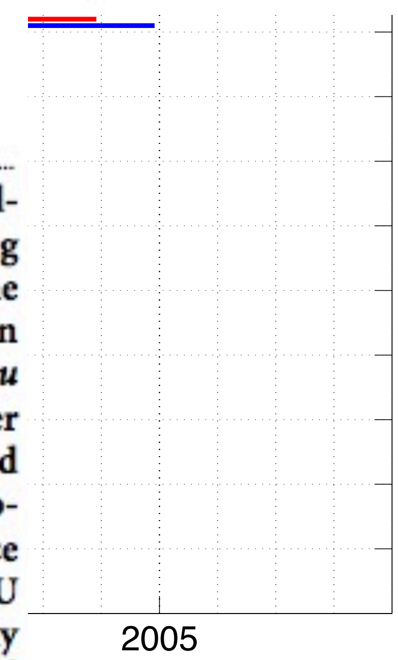
Nature 2004

Contribution of stratospheric cooling to satellite-inferred tropospheric temperature trends

Qiang Fu[1], Celeste M. Johanson[1], Stephen G. Warren[1] & Dian J. Seidel[2]

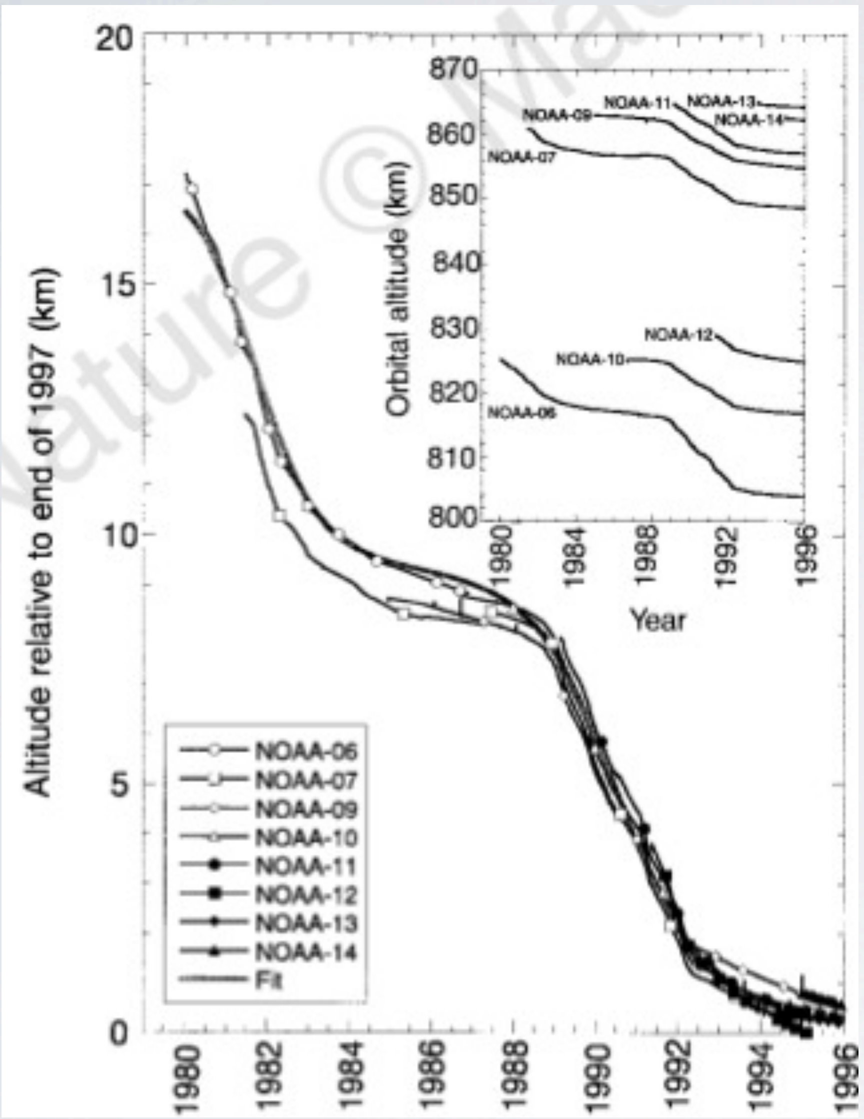
[1]*Department of Atmospheric Sciences, University of Washington, Seattle, Washington 98195, USA*
[2]*NOAA Air Resources Laboratory, Silver Spring, Maryland 20910, USA*

From 1979 to 2001, temperatures observed globally by the mid-tropospheric channel of the satellite-borne Microwave Sounding Unit (MSU channel 2), as well as the inferred temperatures in the lower troposphere, show only small warming trends of less than 0.1 K per decade (refs 1–3). Surface temperatures based on *in situ* observations however, exhibit a larger warming of ~0.17 K per decade (refs 4, 5), and global climate models forced by combined anthropogenic and natural factors project an increase in tropo- spheric temperatures that is somewhat larger than the surface temperature increase[6–8]. Here we show that trends in MSU channel 2 temperatures are weak because the instrument partly records stratospheric temperatures whose large cooling trend[9] offsets the contributions of tropospheric warming. We quantify the stratospheric contribution to MSU channel 2 temperatures using MSU channel 4, which records only stratospheric tempera-

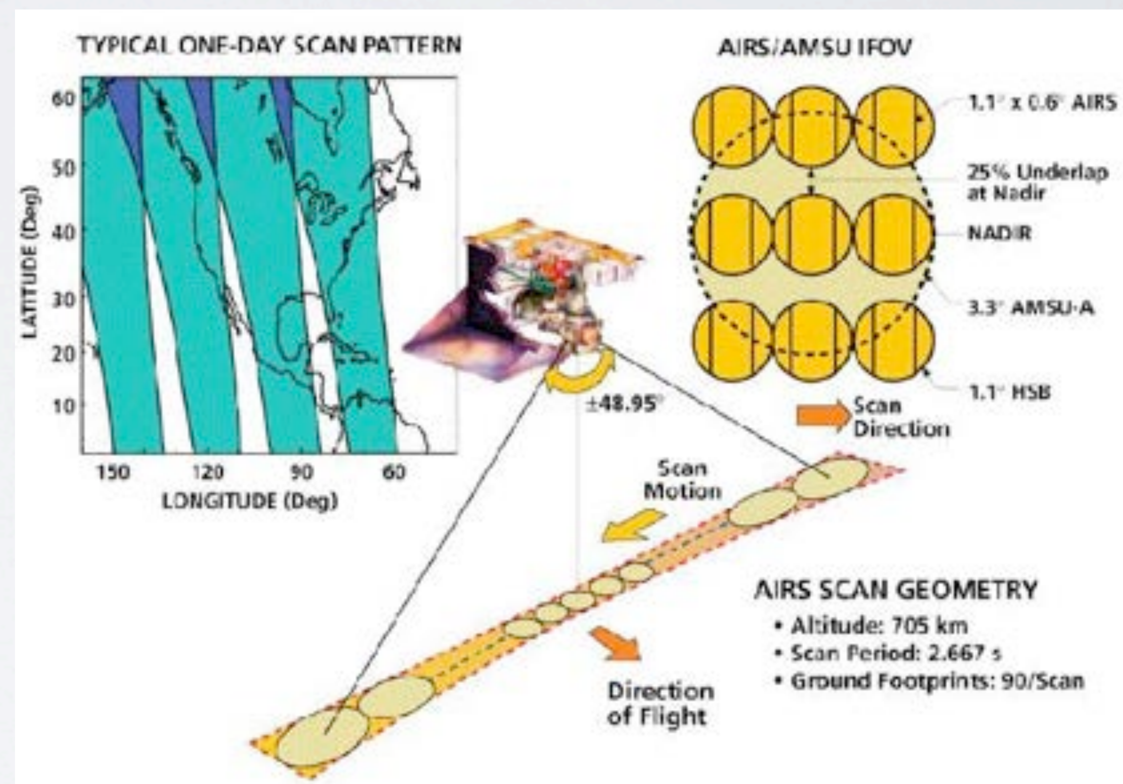


MSU discrepancies.

Orbital decay?



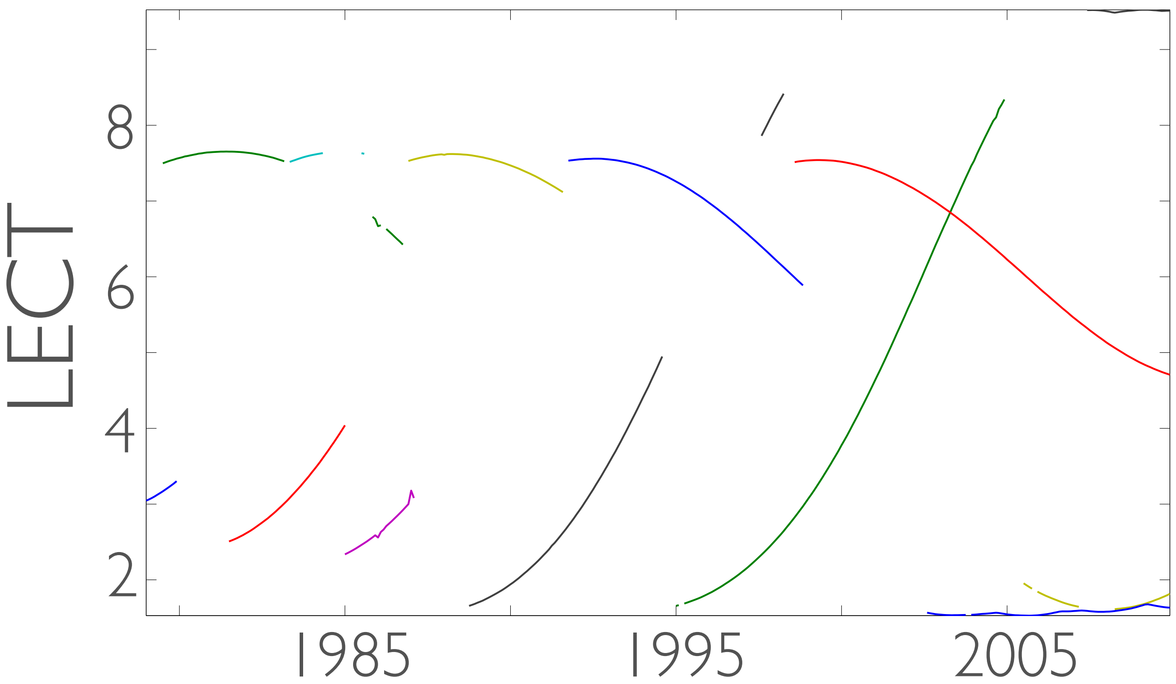
Wentz and Schabel, 1998

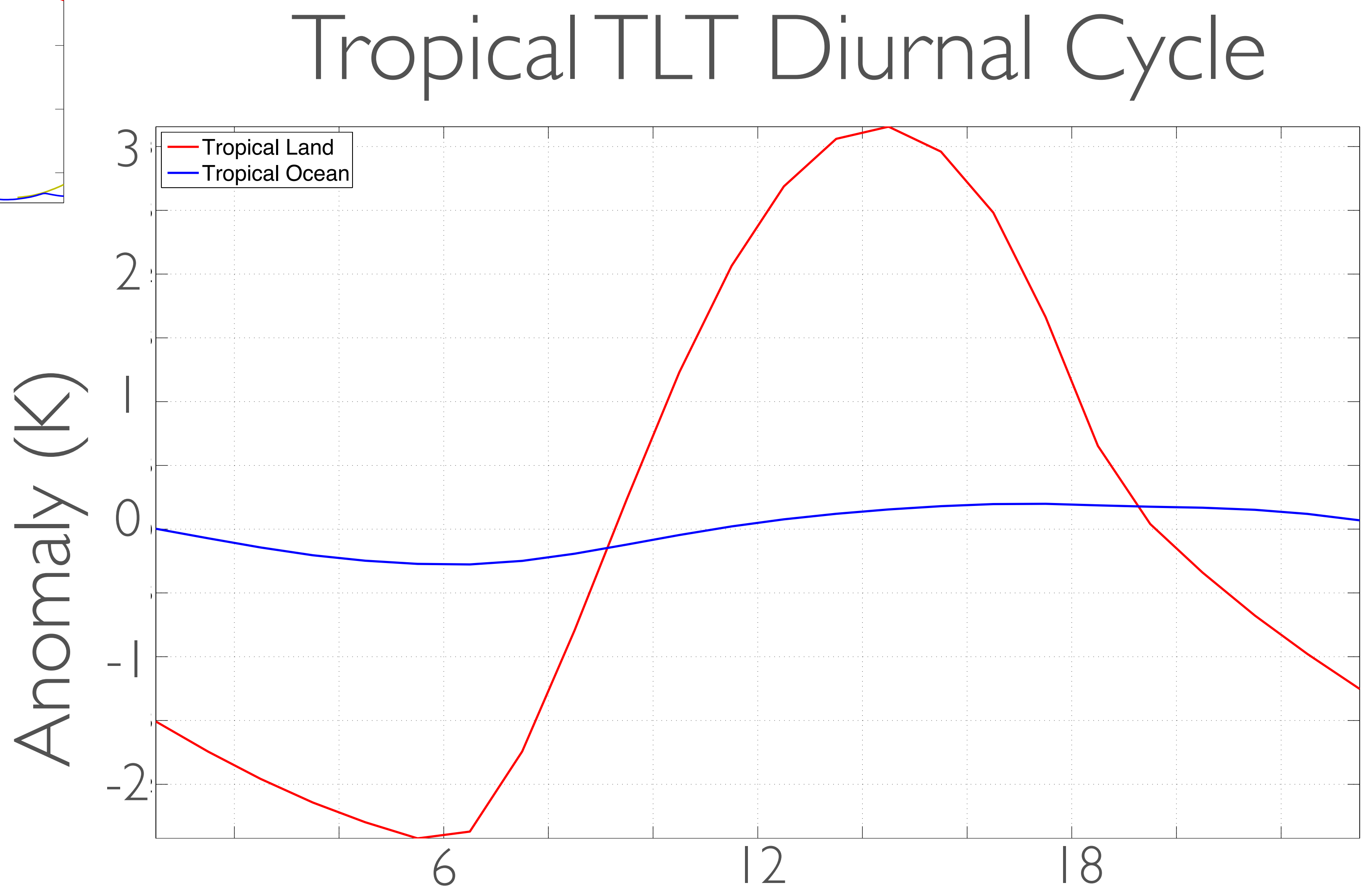


TLT = 4*NADIR - 3*LIMB

MSU discrepancies.

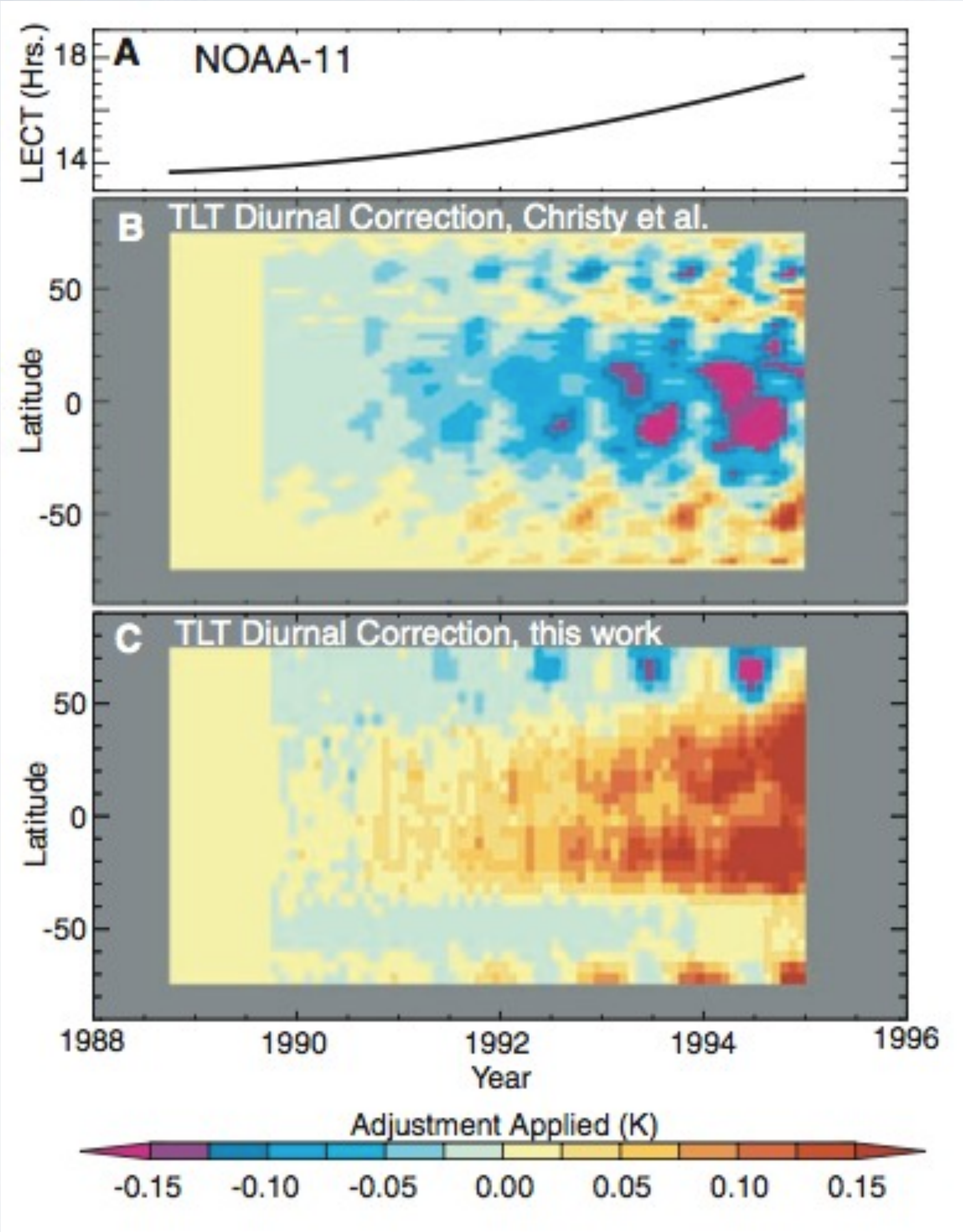
Diurnal correction differences?





Courtesy RSS (CCSM3)

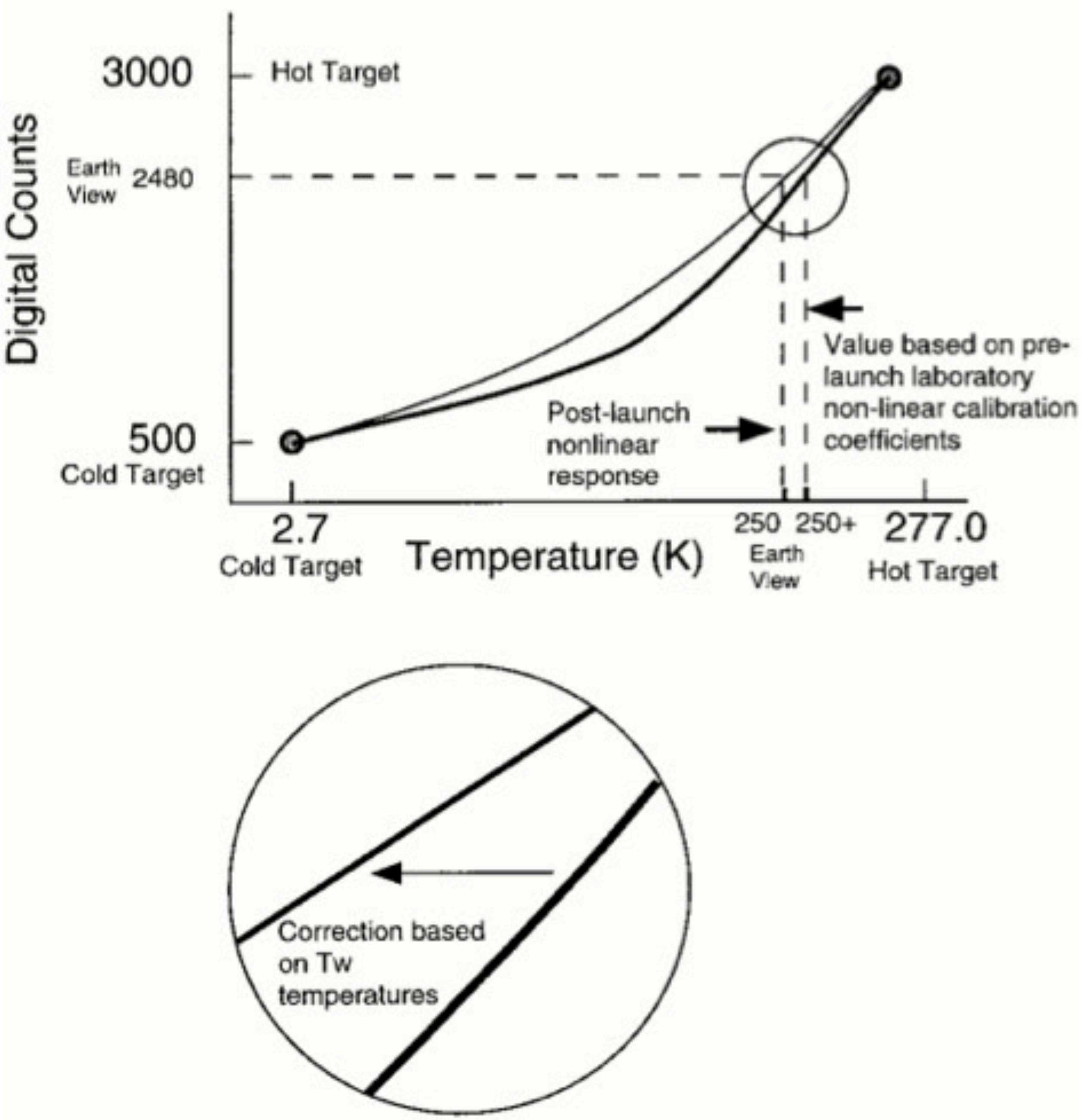
MSU discrepancies.



Mears et al, 2005

Diurnal correction differences?

MSU discrepancies.



Something else?

$$T_{Earth} = T_{MEAS} - \alpha T_{TARGET} + C + \varepsilon$$

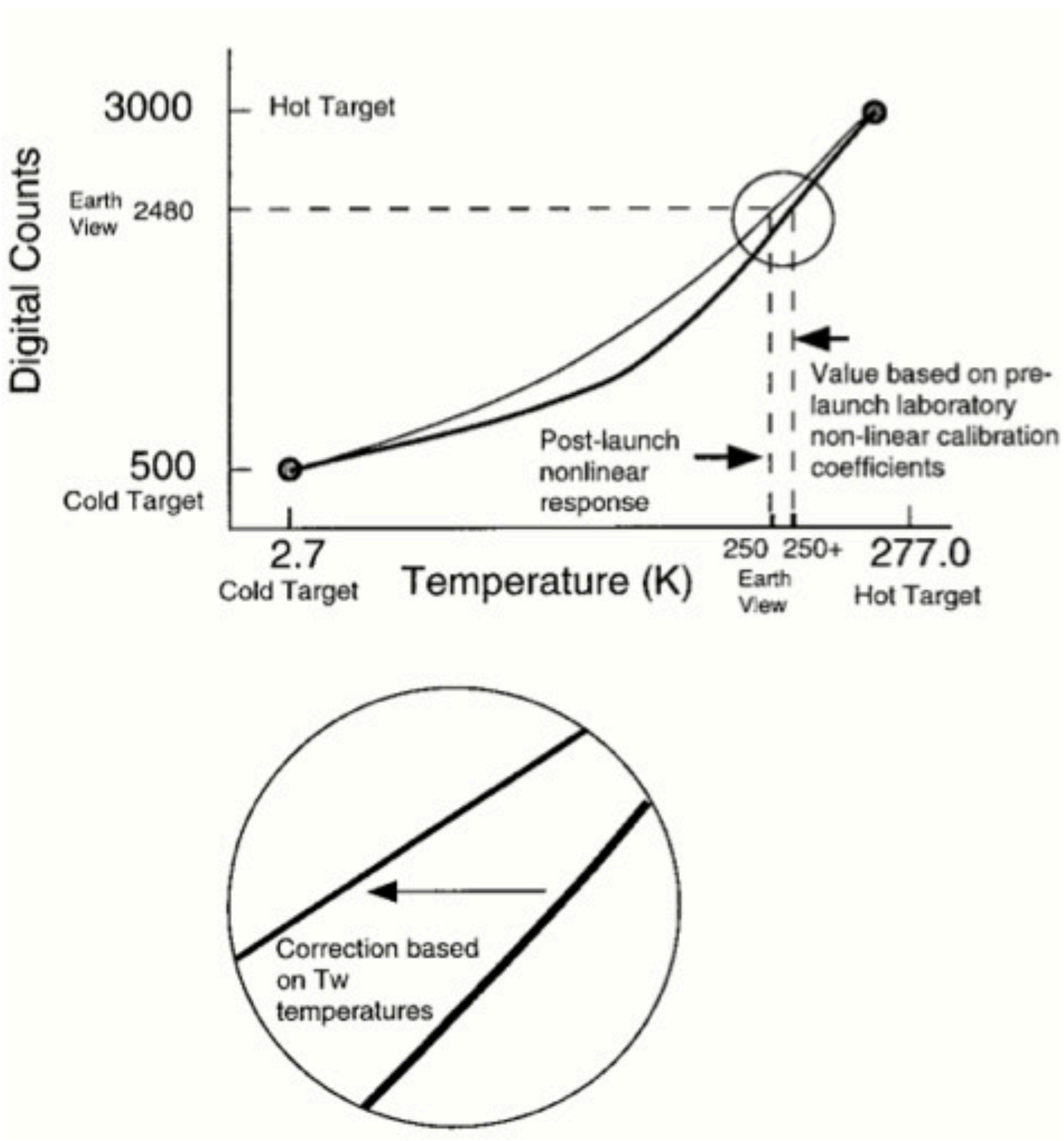
Target factor

Constant bias

Other errors

Christy et al, 2000; Mears et al, 2003; Zou et al, 2009

NOAA-09.



Something else?

$$T_{Earth} = T_{MEAS} - \alpha T_{TARGET} + C + \varepsilon$$

Target factor

Constant bias

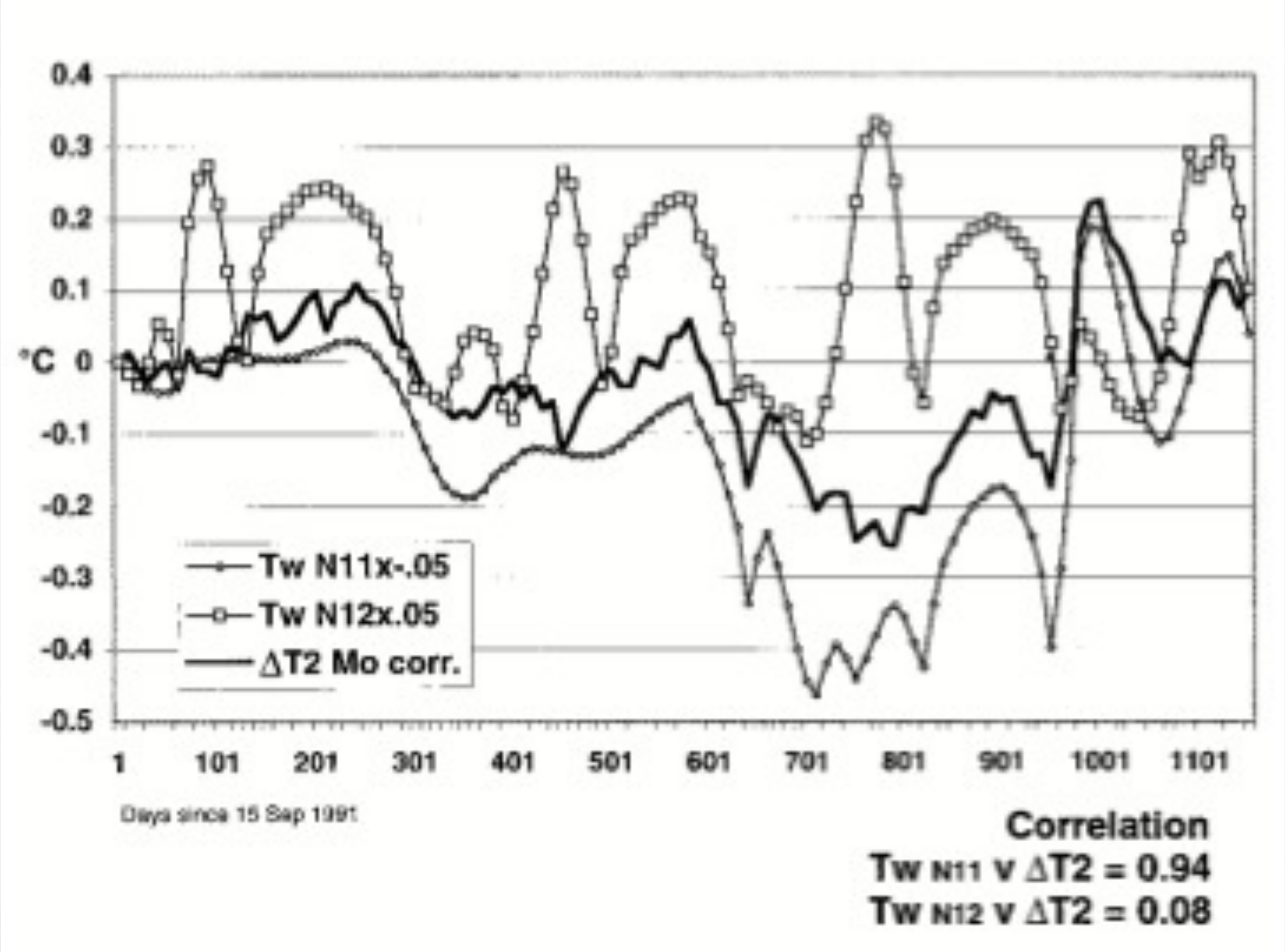
Other errors

Christy et al, 2000; Mears et al, 2003; Zou et al, 2009

NOAA-09.

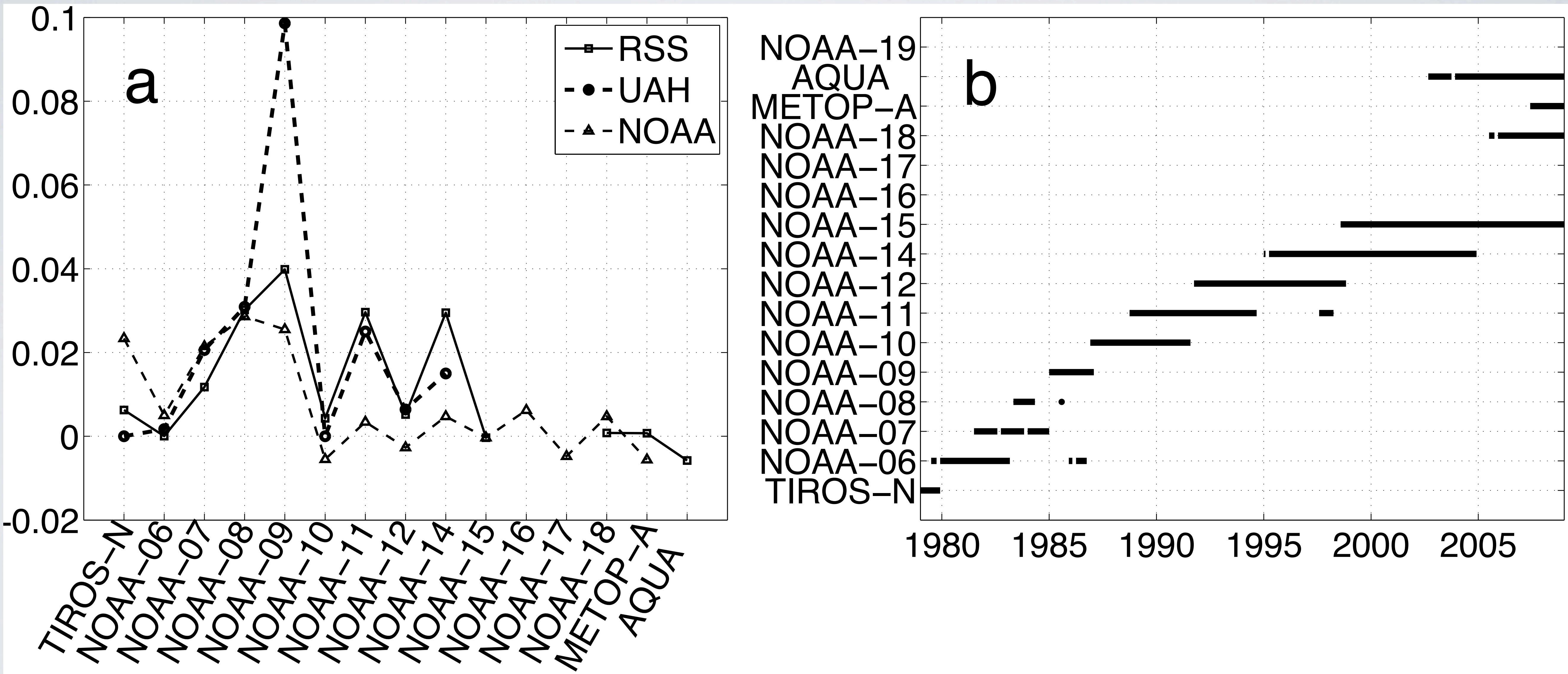
$$\Delta T_{m,n} = T_{W,m} \times \alpha_m + T_{W,n} \times \alpha_n + A_{m,n}$$

One equation for each time step and each pair of satellites used.



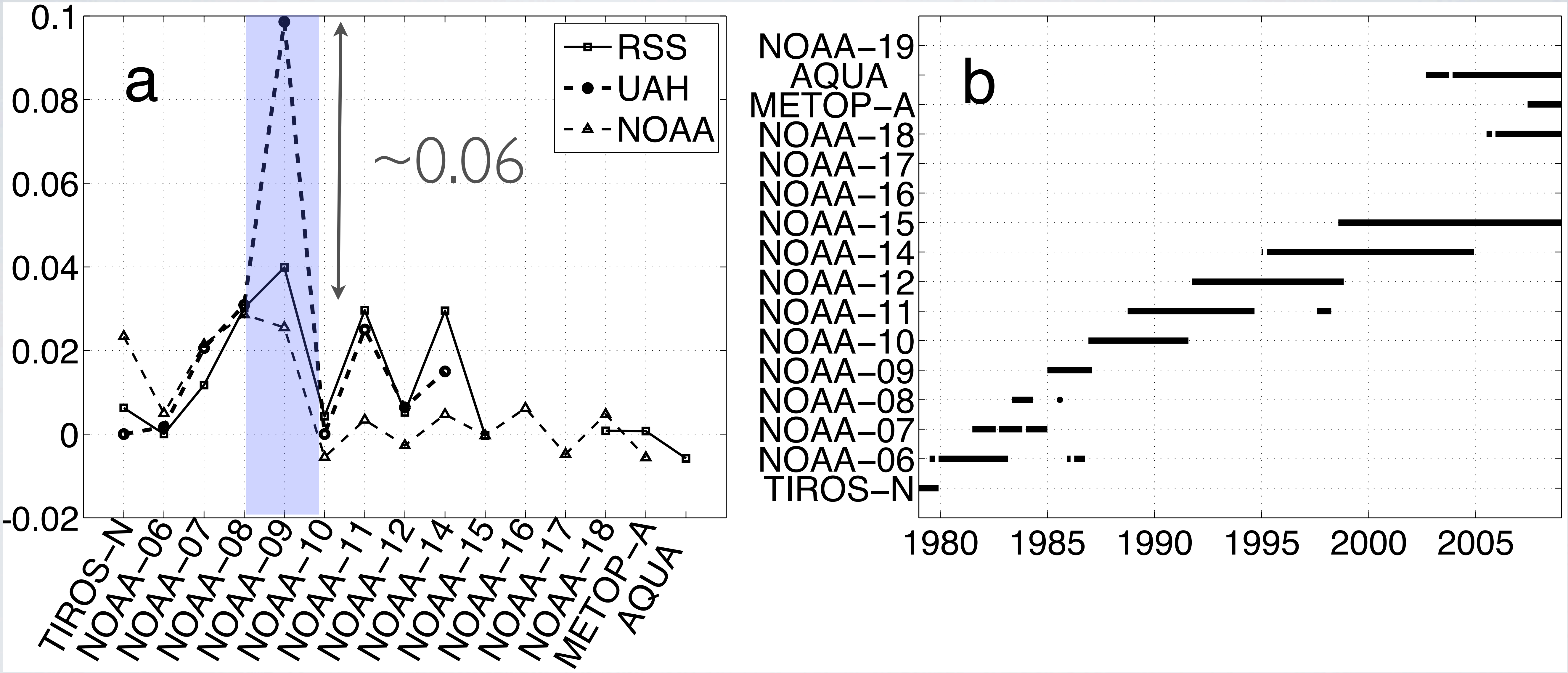
Christy et al, 2000

NOAA-09.



α-factor

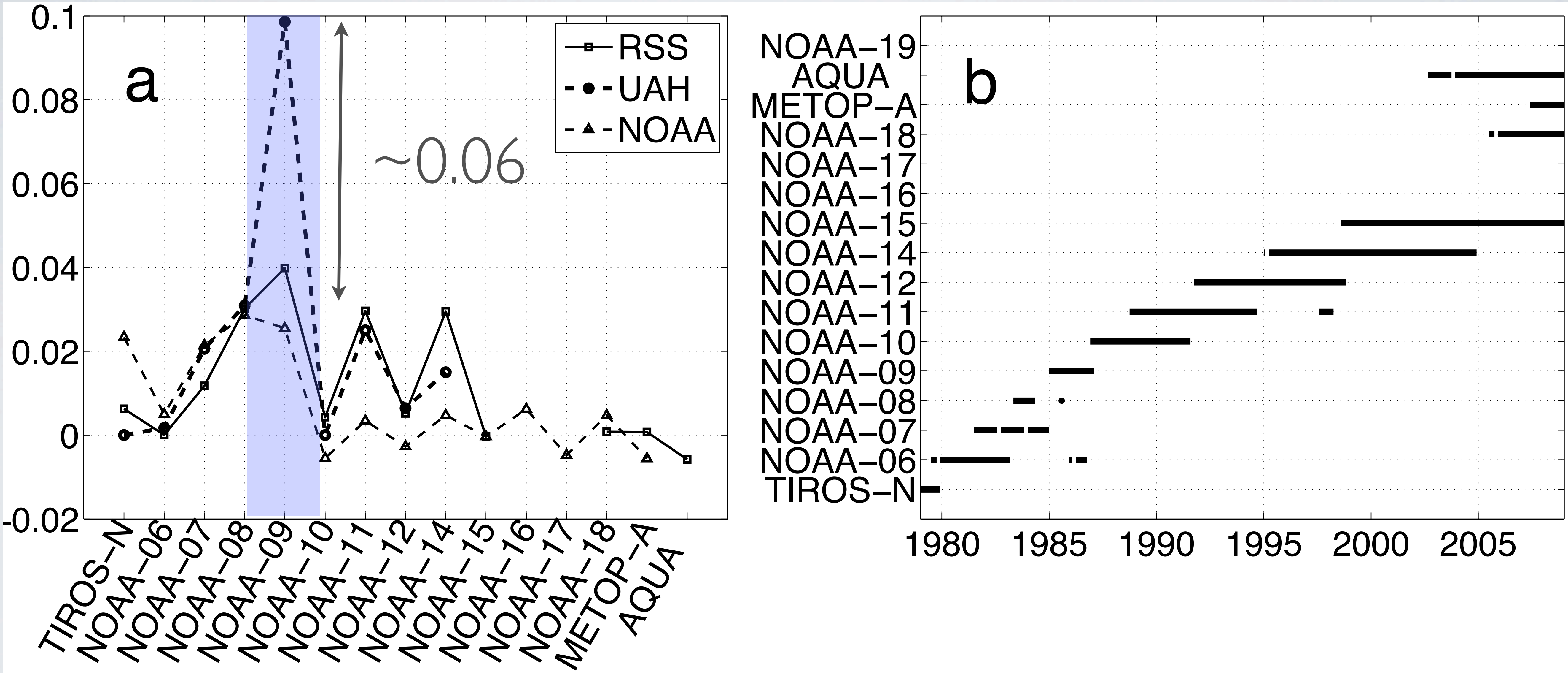
NOAA-09.



α-factor

NOAA-09.

This difference has been considered a structural uncertainty



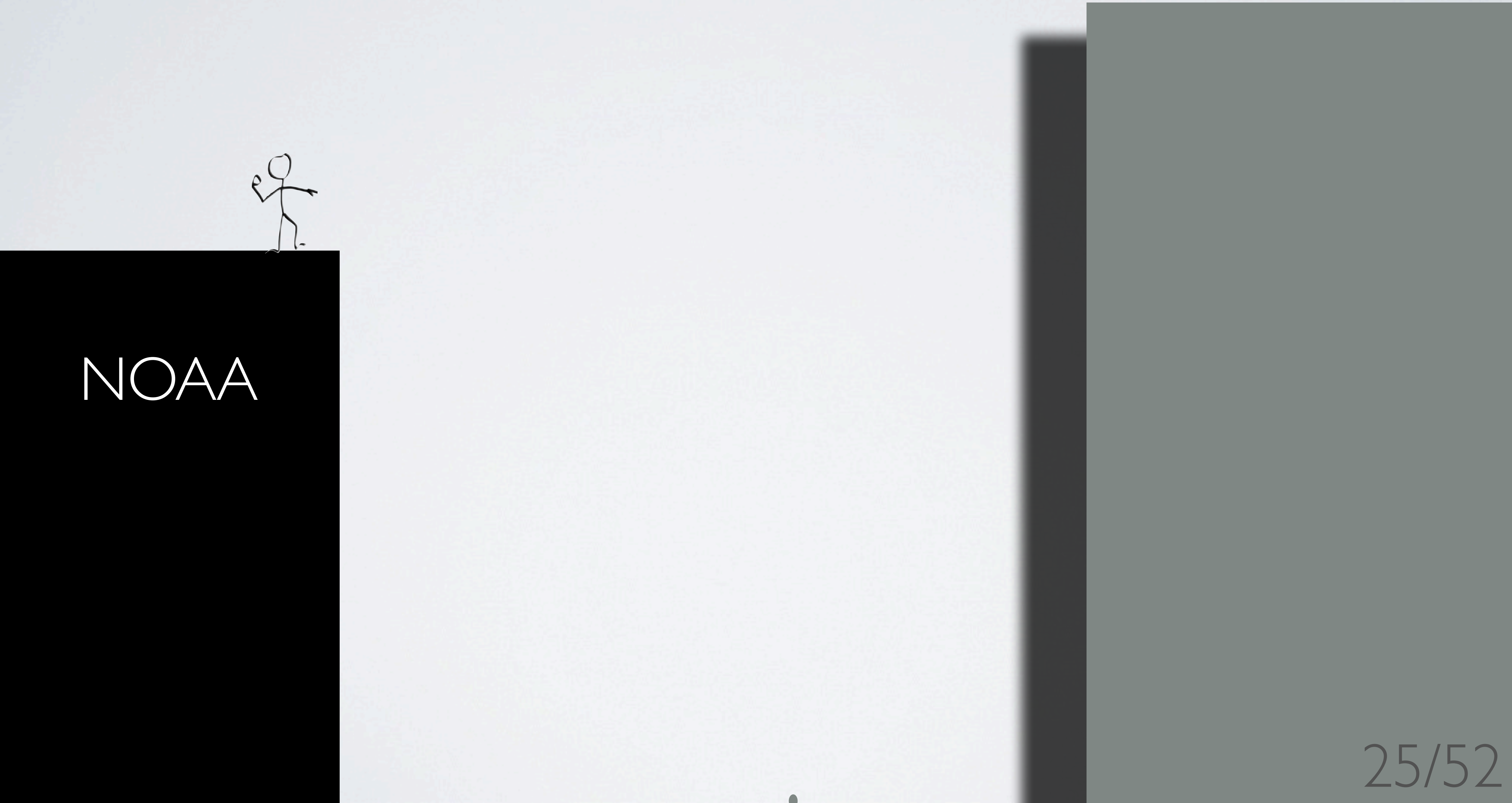
α-factor

NOAA-09.

NOAA

NOAA-09.

NOAA-09.



NOAA-09.

$$H=1/2gt^2$$

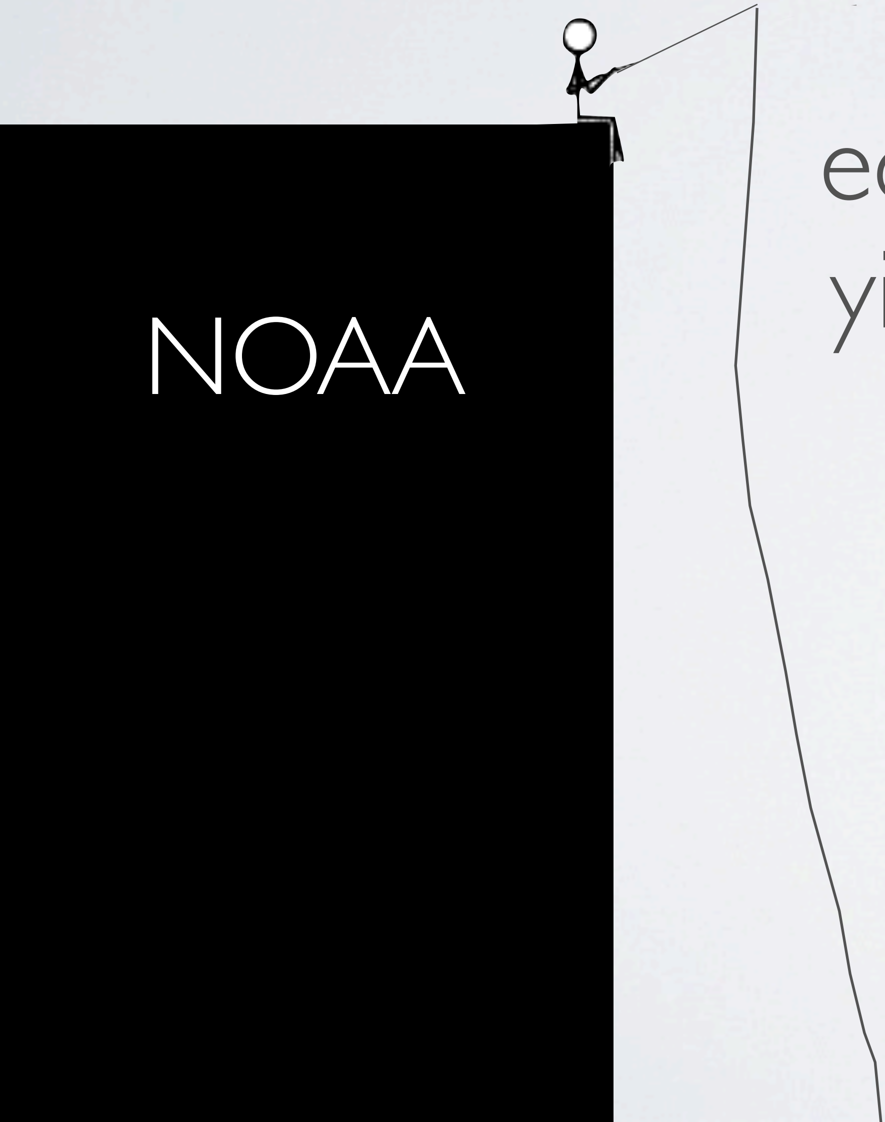
NOAA

NOAA-09.

NOAA

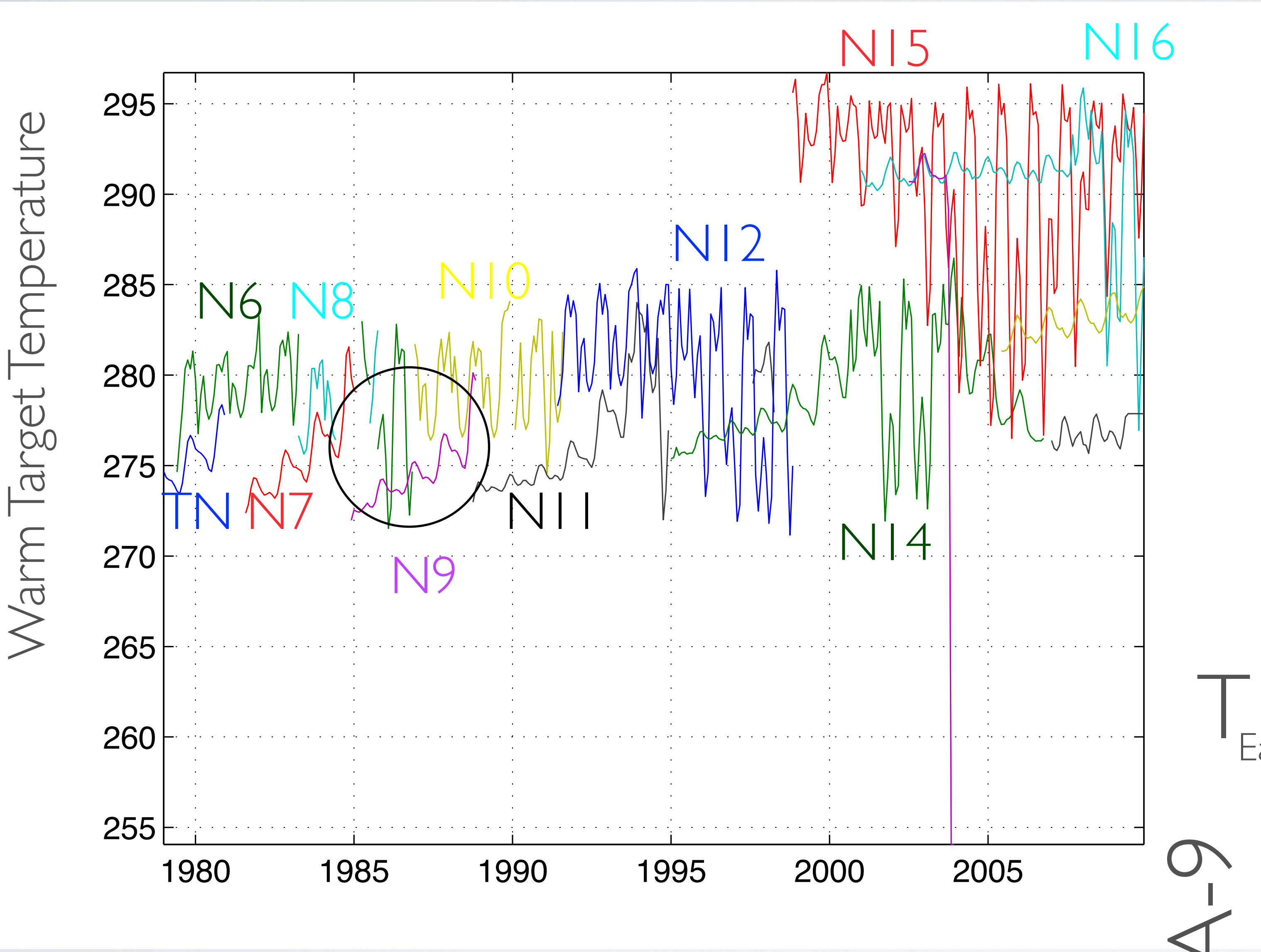
NOAA-09.

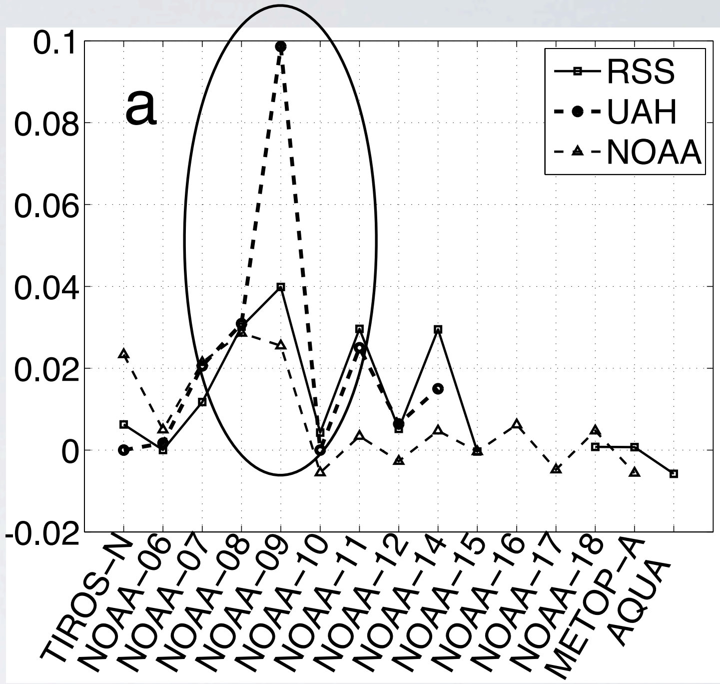
NOAA-09.



Structural uncertainty results when two equally valid methods yield different results.

NOAA-09.





NOAA-9

$$T_{Earth} = T_{MEAS} - \alpha T_{TARGET} + C + \varepsilon$$

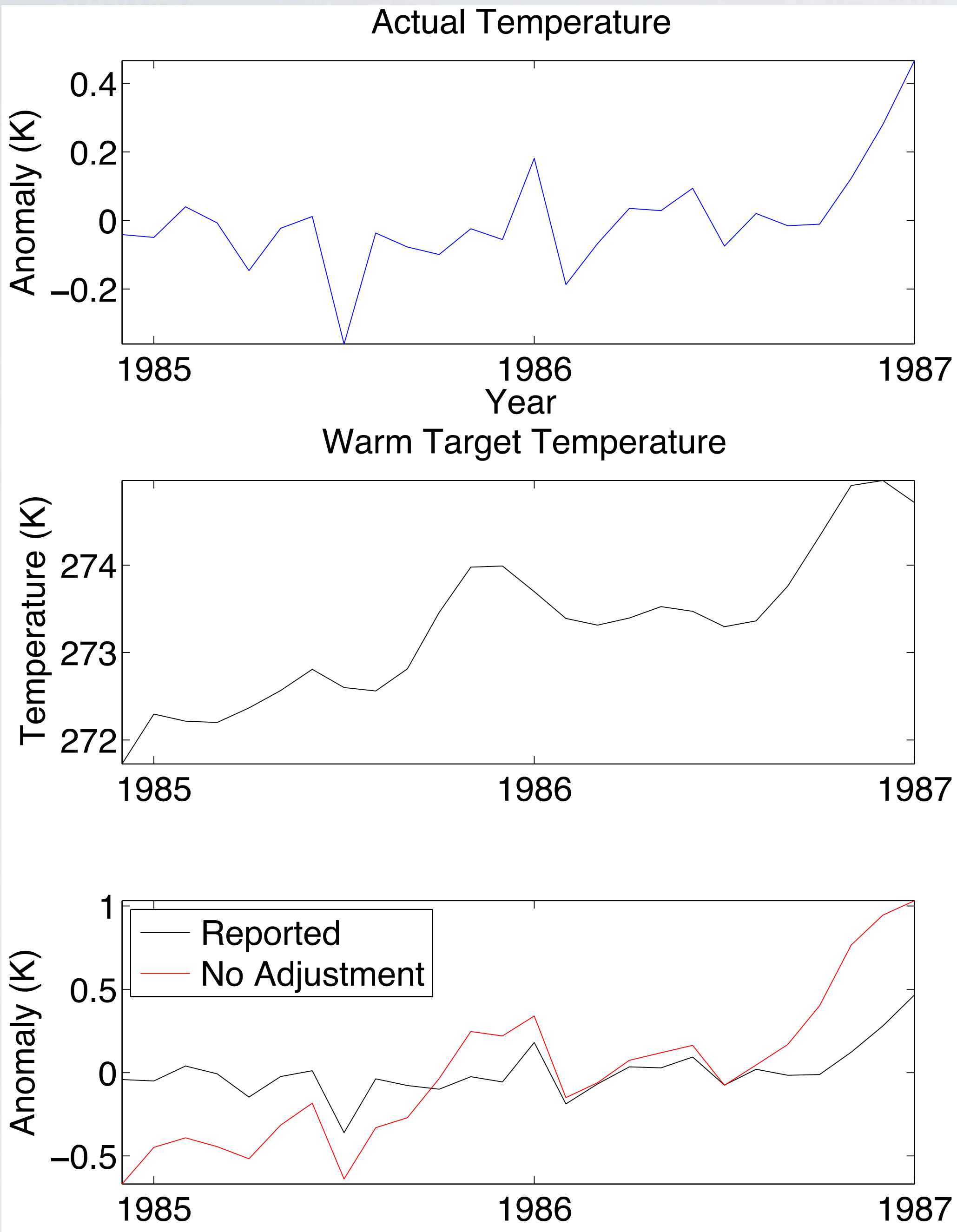
$$\Delta T_{Earth} = \Delta\alpha\Delta T$$

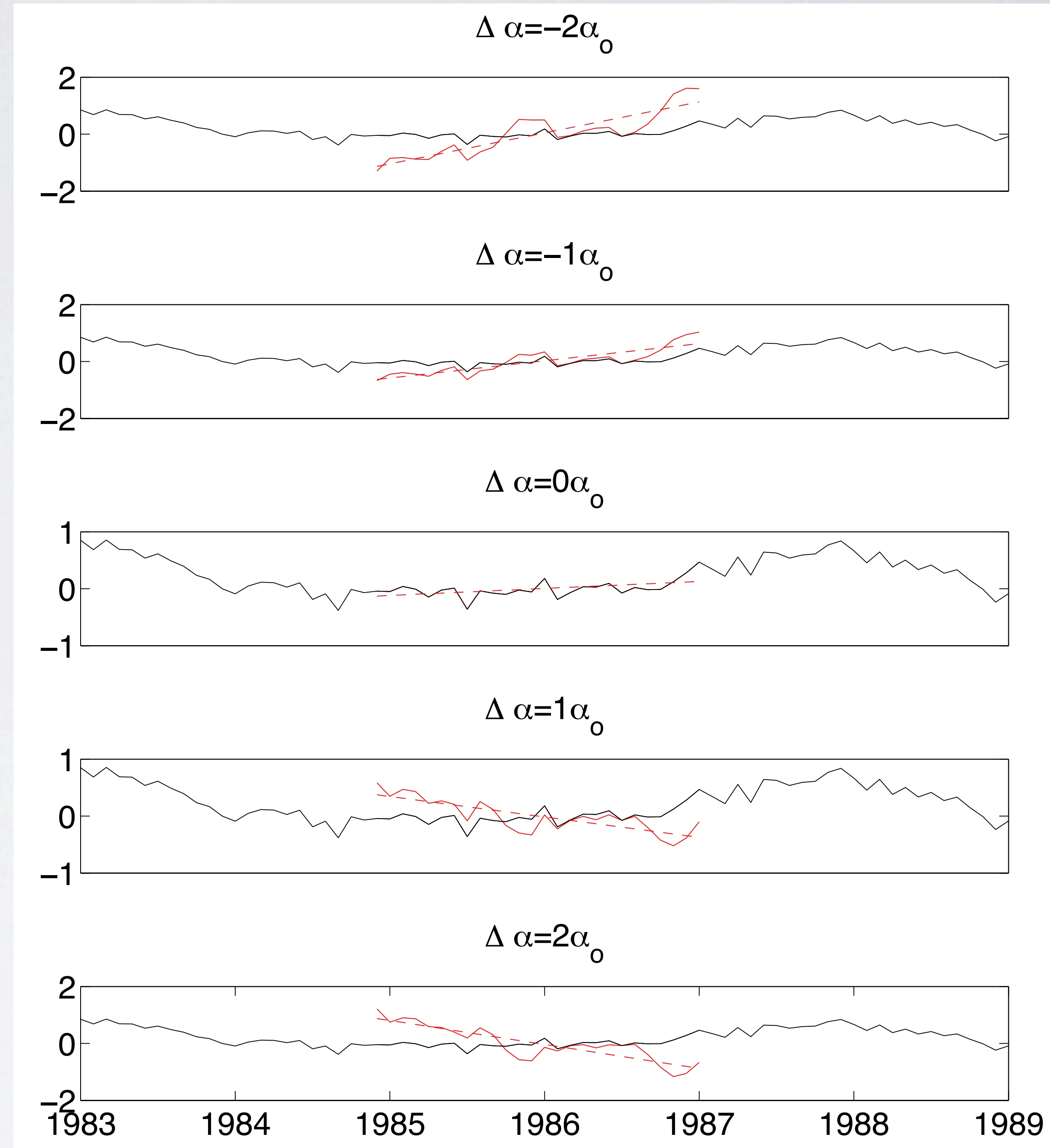
$$\Delta T_{Earth} \sim 0.06 * 2.5K$$

$$\Delta T_{Earth} \sim 0.15K$$

NOAA-09.

* exaggerated for example



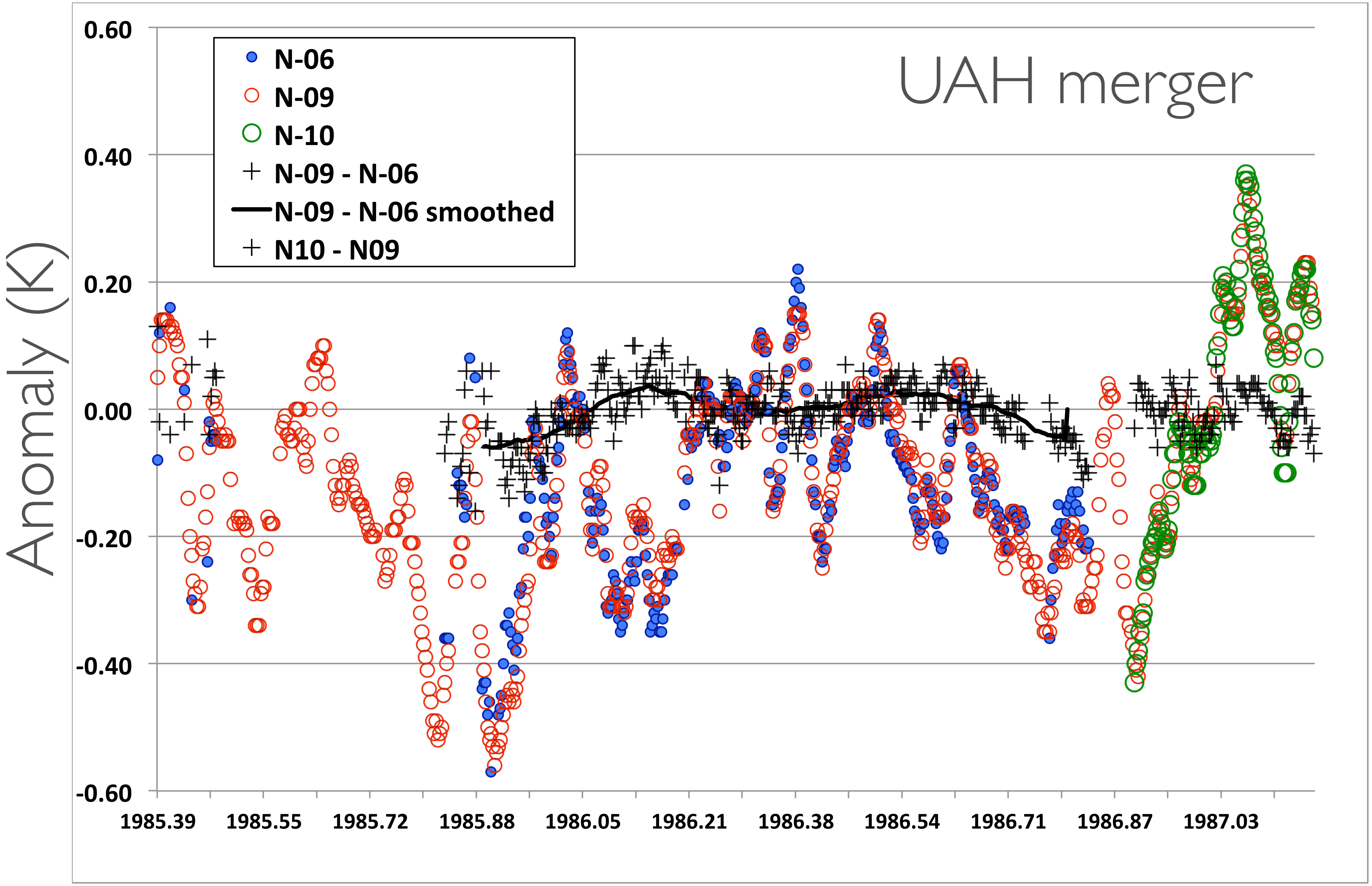


$$T_{Earth} = T_{MEAS} - \alpha T_{TARGET} + C + \varepsilon$$

(red line) T_{TARGET}

(blue line) T_{Earth} (black line) $T_{Reported}$

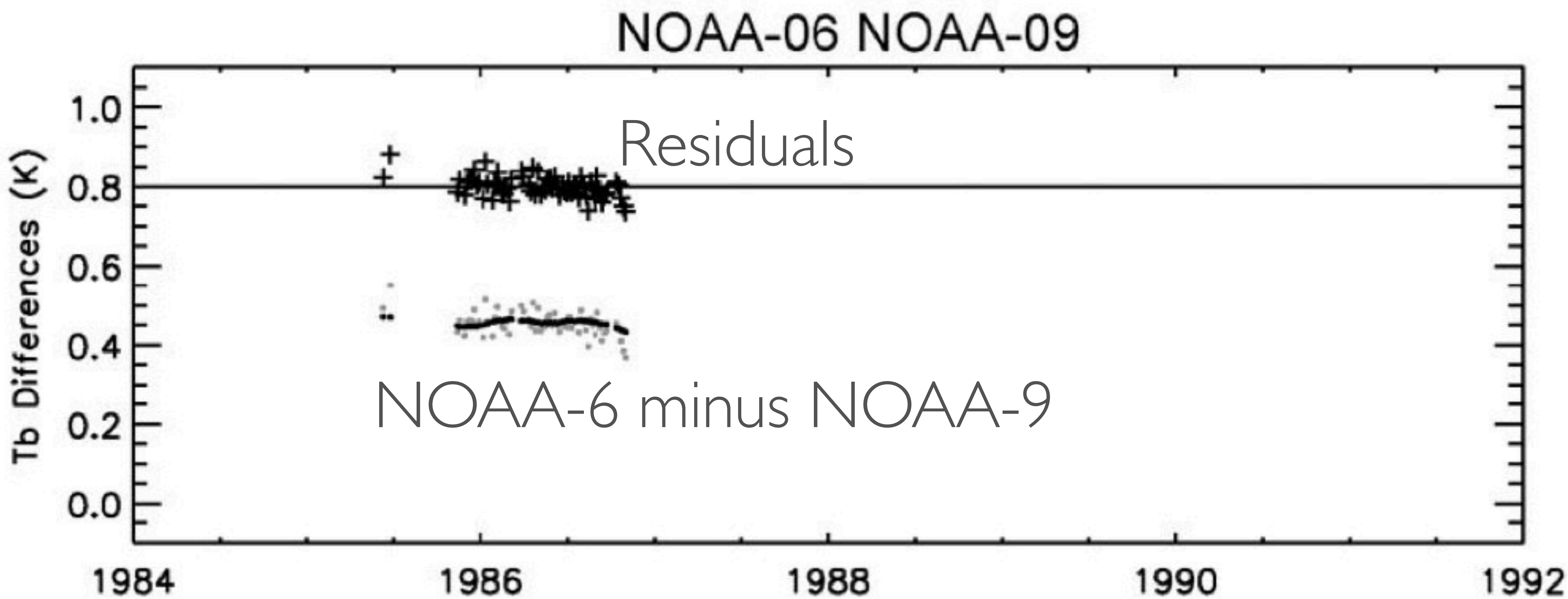
NOAA-09.



John Christy, personal communication

NOAA-09.

RSS merger



Mears et al, 2003

NOAA-9 Target Factor

	RSS	UAH
Target Factor	0.0399	0.0986
Residual NOAA-9/ NOAA-6 Trend	0.04 K/year	0.00 K/year
Satellites used	N6, N7, N8, N9, N10	N6, N9, N10
Area used	Ocean only	Land + Ocean
Smoothing	5 day	60 - 120 day

NOAA-09.

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UAH target factor is 2 times larger than that used for any other satellite

NOAA-09.

NOAA-9 Target Factor

	RSS	UAH
Target Factor	0.0399	0.0986
Residual NOAA-9/ NOAA-6 Trend	0.04 K/year	0.00 K/year
Satellites used	N6, N7, N8, N9, N10	N6, N9, N10
Area used	Ocean only	Land + Ocean
Smoothing	5 day	60 - 120 day

RSS leaves a larger residual trend between NOAA-6 and NOAA-9

NOAA-09.

NOAA-9 Target Factor

	RSS	UAH
Target Factor	0.0399	0.0986
Residual NOAA-9/ NOAA-6 Trend	0.04 K/year	0.00 K/year
Satellites used	N6, N7, N8, N9, N10	N6, N9, N10
Area used	Ocean only	Land + Ocean
Smoothing	5 day	60 - 120 day

RSS utilizes more satellites to constrain the target factor value

NOAA-09.

NOAA-9 Target Factor

	RSS	UAH
Target Factor	0.0399	0.0986
Residual NOAA-9/ NOAA-6 Trend	0.04 K/year	0.00 K/year
Satellites used	N6, N7, N8, N9, N10	N6, N9, N10
Area used	Ocean only	Land + Ocean
Smoothing	5 day	60 - 120 day

RSS uses only oceanic regions, which minimizes the influence of the diurnal cycle correction

NOAA-9 Target Factor

	RSS	UAH
Target Factor	0.0399	0.0986
Residual NOAA-9/ NOAA-6 Trend	0.04 K/year	0.00 K/year
Satellites used	N6, N7, N8, N9, N10	N6, N9, N10
Area used	Ocean only	Land + Ocean
Smoothing	5 day	60 - 120 day

Smoothing has seemingly small effects

Is there a way forward?

NOAA-09.

Reported Error

$$T = T_o + \Delta T$$

Signal

NOAA-09.

Reported — Error

$$T = T_o + \Delta T$$

Signal

$$T_{MSU} - T_R = (T_o + \Delta T_{MSU}) - (T_o + \Delta T_R)$$

NOAA-09.

Reported   Error

$$T = T_o + \Delta T$$

Signal

$$T_{MSU} - T_R = (T_o + \Delta T_{MSU}) - (T_o + \Delta T_R)$$

$$T_{MSU} - T_R = \Delta T_{MSU} - \Delta T_R$$

NOAA-09.

Reported Error

$$T = T_o + \Delta T$$

Signal

$$T_{MSU} - T_R = (T_o + \Delta T_{MSU}) - (T_o + \Delta T_R)$$

$$T_{MSU} - T_R = \Delta T_{MSU} - \Delta T_R \quad \left(\Delta T_{MSU} = -\Delta\alpha_i T_{TARGET,i} + \epsilon_i\right)$$

NOAA-09.

Reported Error

$$T = T_o + \Delta T$$

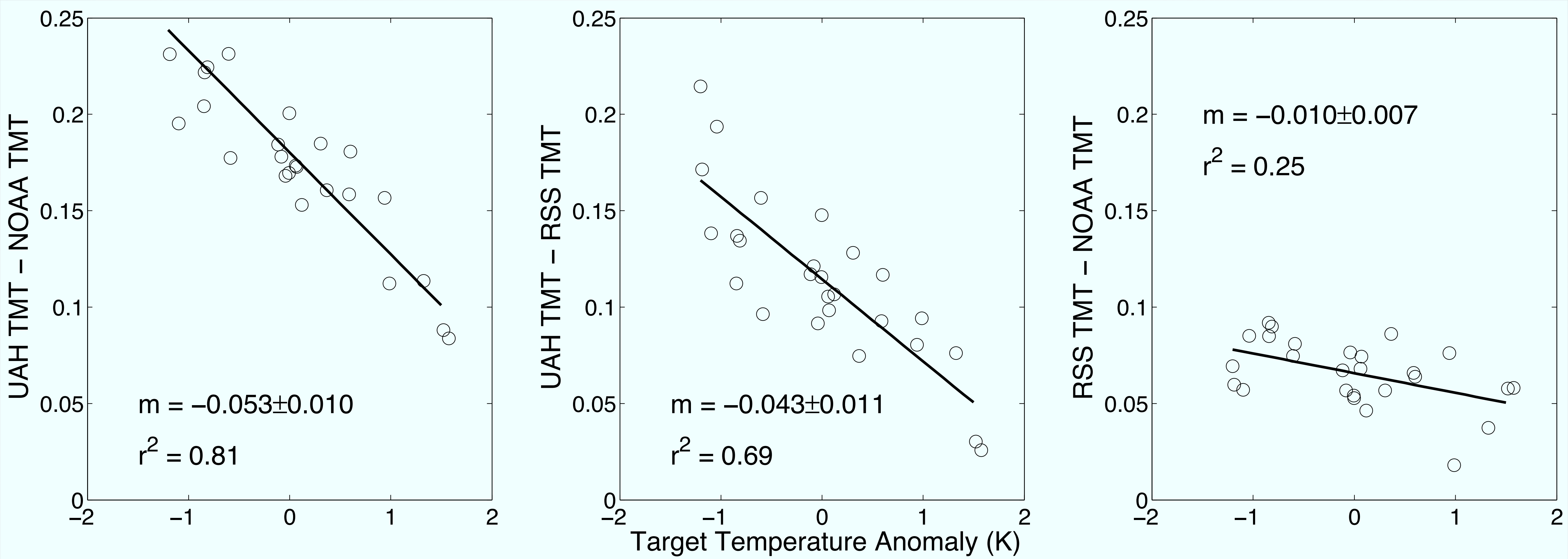
Signal

$$T_{MSU} - T_R = (T_o + \Delta T_{MSU}) - (T_o + \Delta T_R)$$

$$T_{MSU} - T_R = \Delta T_{MSU} - \Delta T_R \quad \left(\Delta T_{MSU} = -\Delta\alpha_i T_{TARGET,i} + \epsilon_i\right)$$

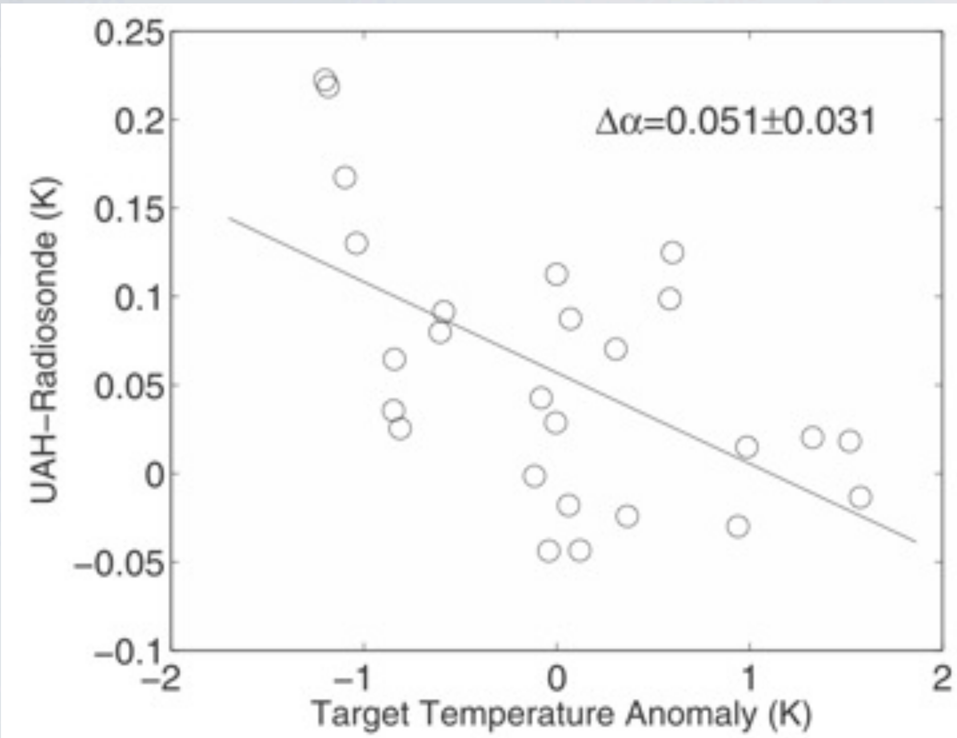
Regress versus the Target Temperature

NOAA-09.



UAH TMT – NOAA TMT
m = –0.053±0.010
r2 = 0.81
UAH TMT – RSS TMT
m = –0.043±0.011
r2 = 0.69
RSS TMT – NOAA TMT
m = –0.010±0.007
r2 = 0.25
Target Temperature Anomaly (K)

NOAA-09.



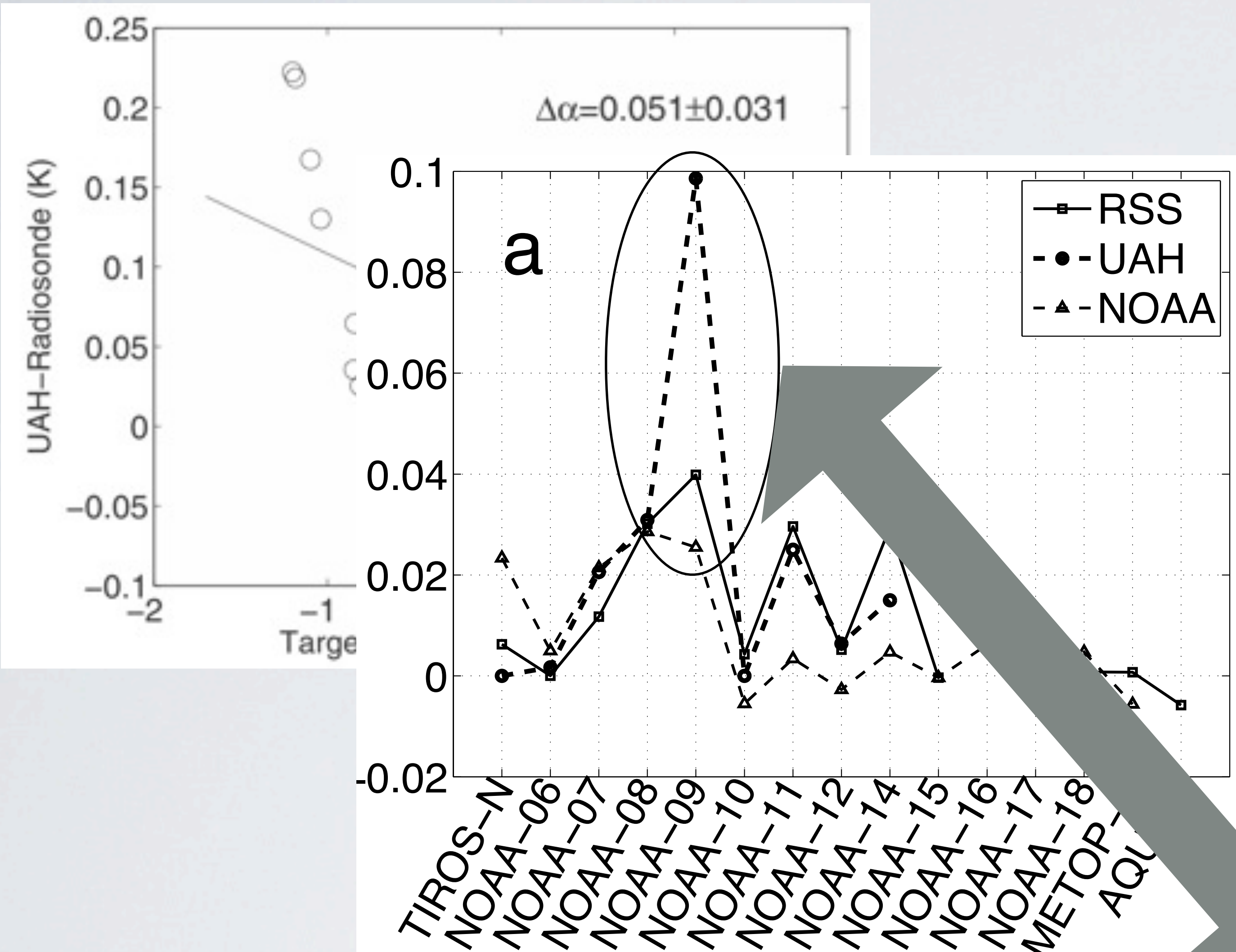
r-values

REFERENCE	NOAA	RSS	UAH
HadAT2	−0.157	−0.208	−0.399*
IUK	0.062	0.024	−0.425*
RICH	−0.237	−0.332	−0.501*
RAOBCORE	−0.206	−0.299	−0.477*
RATPAC	−0.244	−0.334	−0.672*
Radiosonde mean	−0.181	−0.272	−0.543*

REFERENCE	UAH $\Delta\alpha_9$
HadAT2	0.041 ± 0.039
IUK	0.038 ± 0.032
RICH	0.056 ± 0.037
RAOBCORE	0.051 ± 0.036
RATPAC	0.071 ± 0.026
Radiosonde mean	0.051 ± 0.031

UAH radiances are significantly influenced by the temperature of the satellite itself.

NOAA-09.



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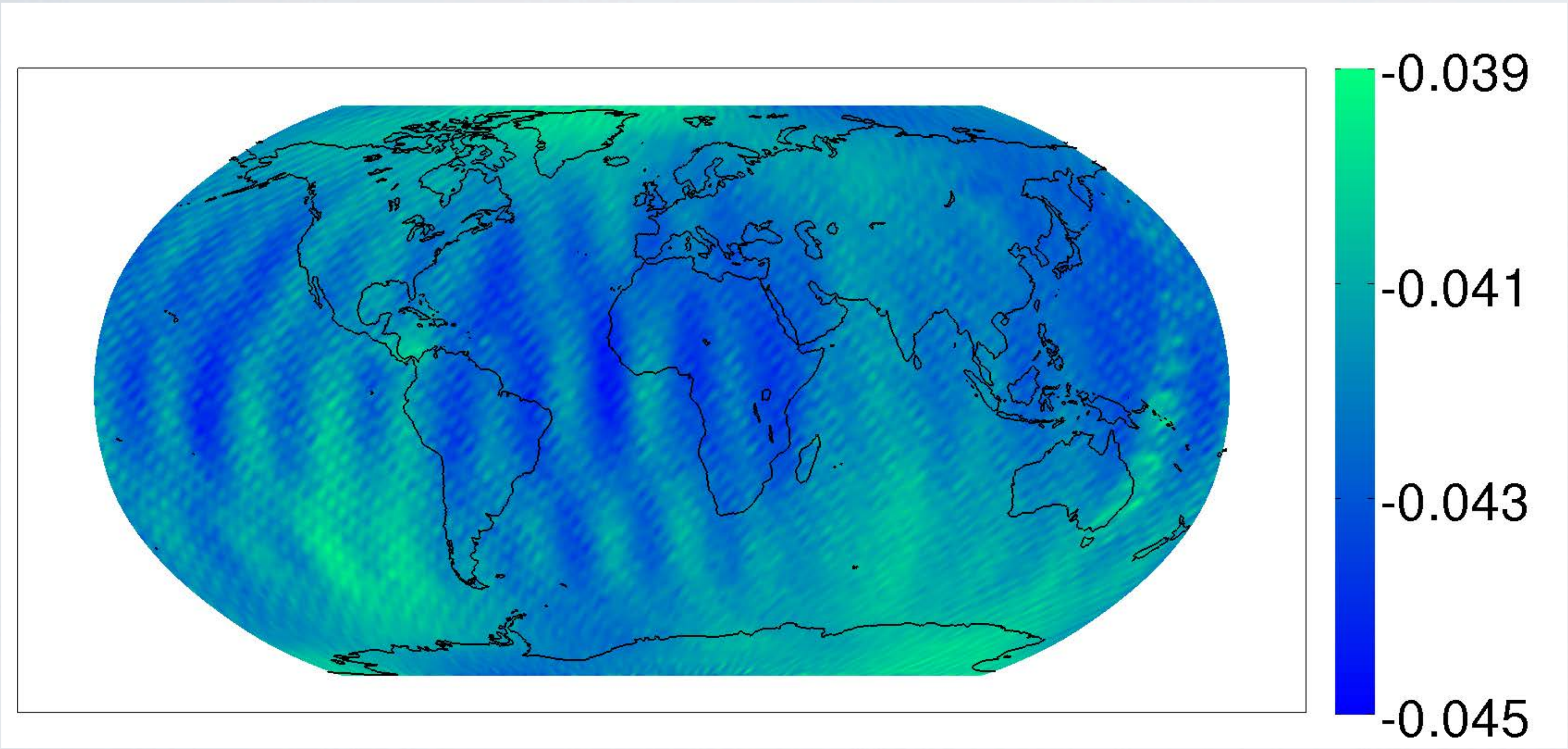
UAH radiances are significantly influenced by the temperature of the satellite itself.

NOAA-09.

What is the impact of this bias?



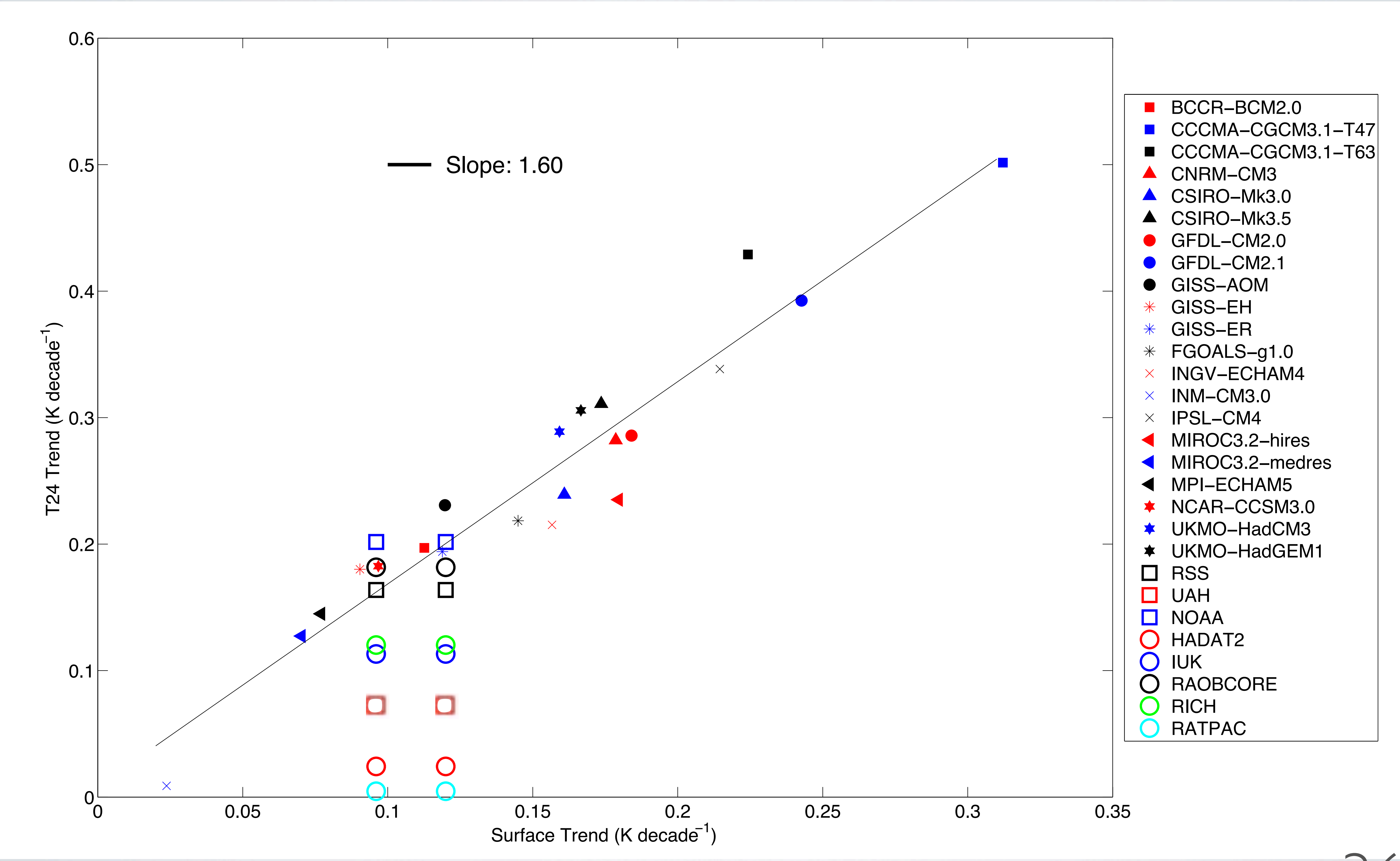
TMT Trends

NOAA	0.127
RSS	0.080
UAH	0.038
Adj. UAH	0.080

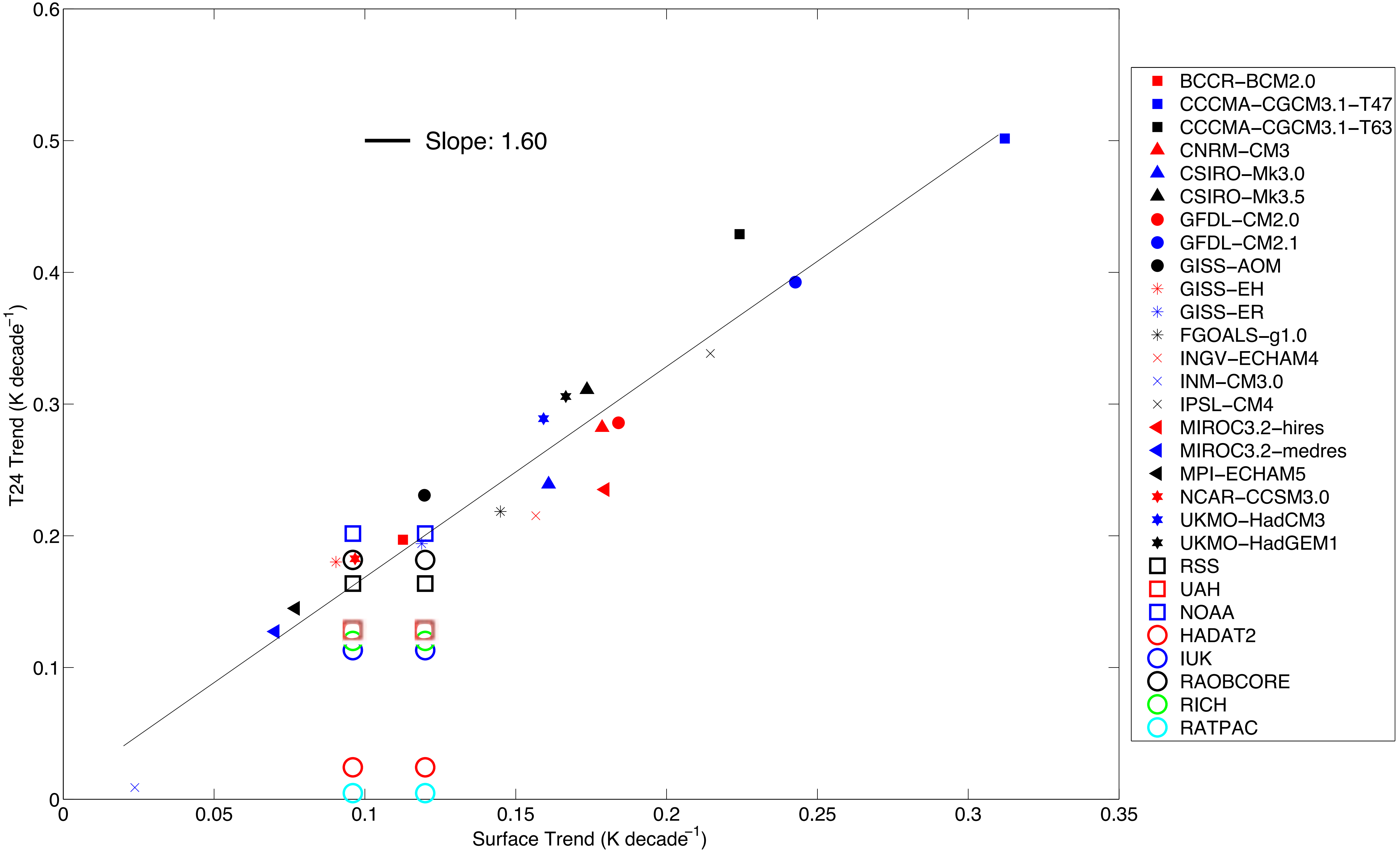
(all in K/decade)

47 % of UAH-NOAA Difference
All of UAH-RSS Difference

NOAA-09.

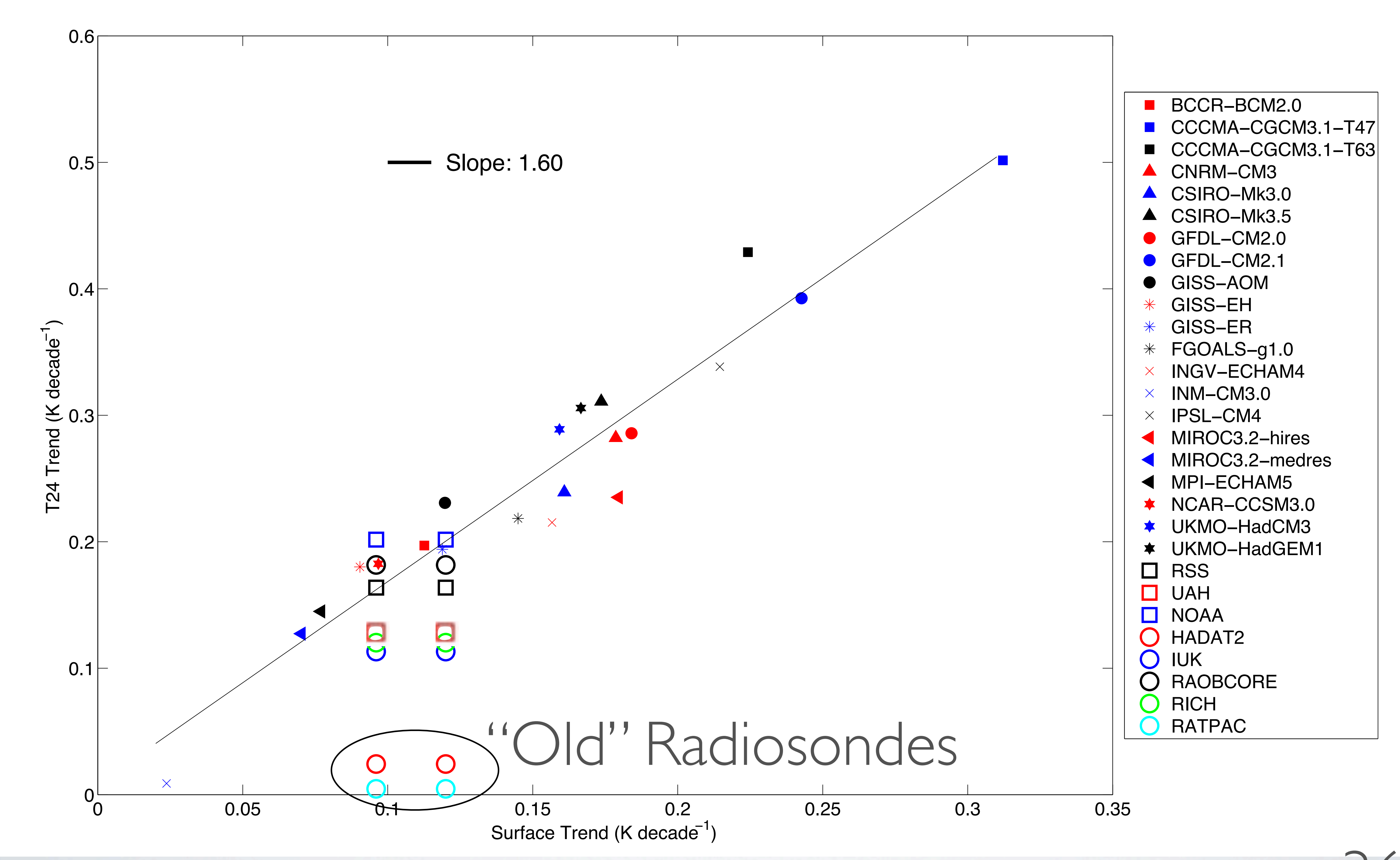

Slope: 1.60
T24 Trend (K decade^{-1})
Surface Trend (K decade^{-1})
0
0.1
0.2
0.3
0.4
0.5
0.6
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
BCCR–BCM2.0
CCCMA–CGCM3.1–T47
CCCMA–CGCM3.1–T63
CNRM–CM3
CSIRO–Mk3.0
CSIRO–Mk3.5
GFDL–CM2.0
GFDL–CM2.1
GISS–AOM
GISS–EH
GISS–ER
FGOALS–g1.0
INGV–ECHAM4
INM–CM3.0
IPSL–CM4
MIROC3.2–hires
MIROC3.2–medres
MPI–ECHAM5
NCAR–CCSM3.0
UKMO–HadCM3
UKMO–HadGEM1
RSS
UAH
NOAA
HADAT2
IUK
RAOBCORE
RICH
RATPAC

NOAA-09.



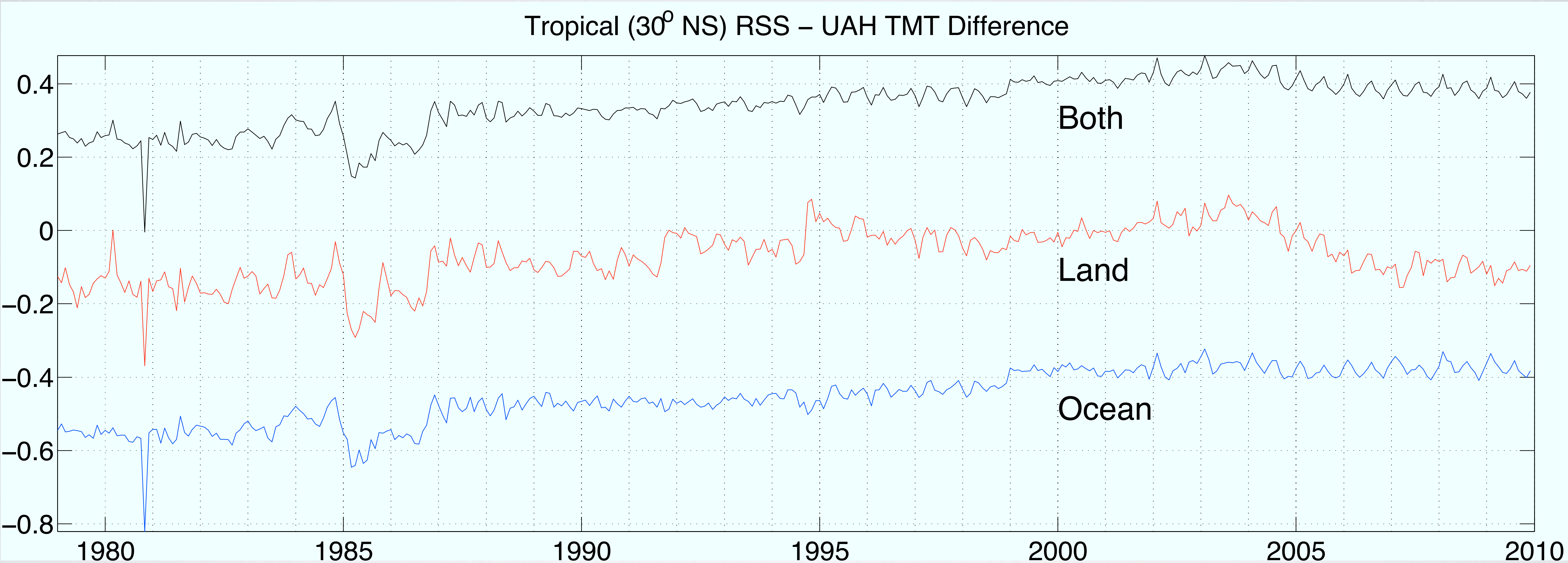
Slope: 1.60
T24 Trend (K decade⁻¹)
Surface Trend (K decade⁻¹)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
BCCR–BCM2.0
CCCMA–CGCM3.1–T47
CCCMA–CGCM3.1–T63
CNRM–CM3
CSIRO–Mk3.0
CSIRO–Mk3.5
GFDL–CM2.0
GFDL–CM2.1
GISS–AOM
GISS–EH
GISS–ER
FGOALS–g1.0
INGV–ECHAM4
INM–CM3.0
IPSL–CM4
MIROC3.2–hires
MIROC3.2–medres
MPI–ECHAM5
NCAR–CCSM3.0
UKMO–HadCM3
UKMO–HadGEM1
RSS
UAH
NOAA
HADAT2
IUK
RAOBCORE
RICH
RATPAC

NOAA-09.



Slope: 1.60
"Old" Radiosondes
T24 Trend (K decade^{-1})
Surface Trend (K decade^{-1})
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.1
0.2
0.3
0.4
0.5
0.6
BCCR–BCM2.0
CCCMA–CGCM3.1–T47
CCCMA–CGCM3.1–T63
CNRM–CM3
CSIRO–Mk3.0
CSIRO–Mk3.5
GFDL–CM2.0
GFDL–CM2.1
GISS–AOM
GISS–EH
GISS–ER
FGOALS–g1.0
INGV–ECHAM4
INM–CM3.0
IPSL–CM4
MIROC3.2–hires
MIROC3.2–medres
MPI–ECHAM5
NCAR–CCSM3.0
UKMO–HadCM3
UKMO–HadGEM1
RSS
UAH
NOAA
HADAT2
IUK
RAOBCORE
RICH
RATPAC

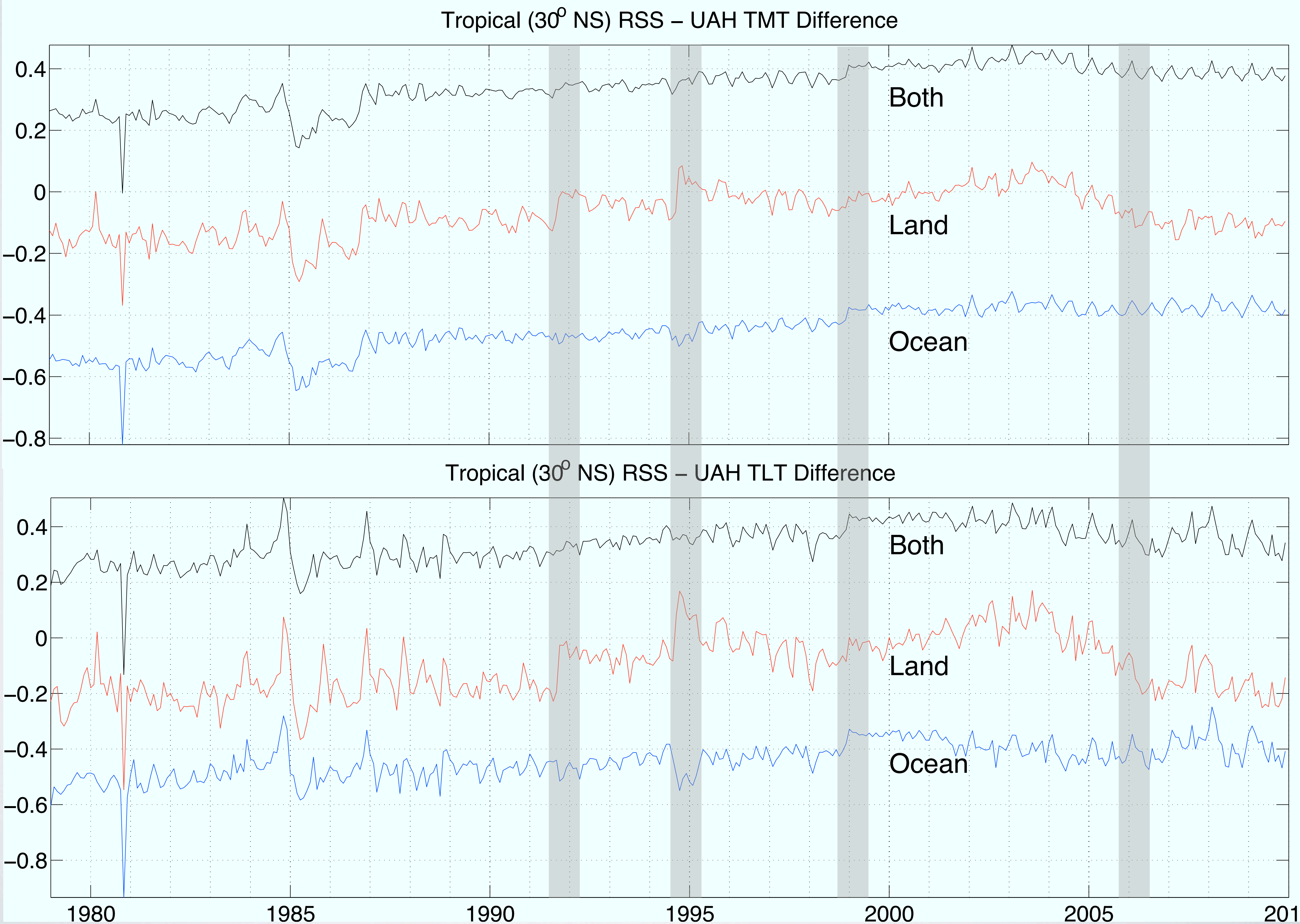
Other discrepancies.



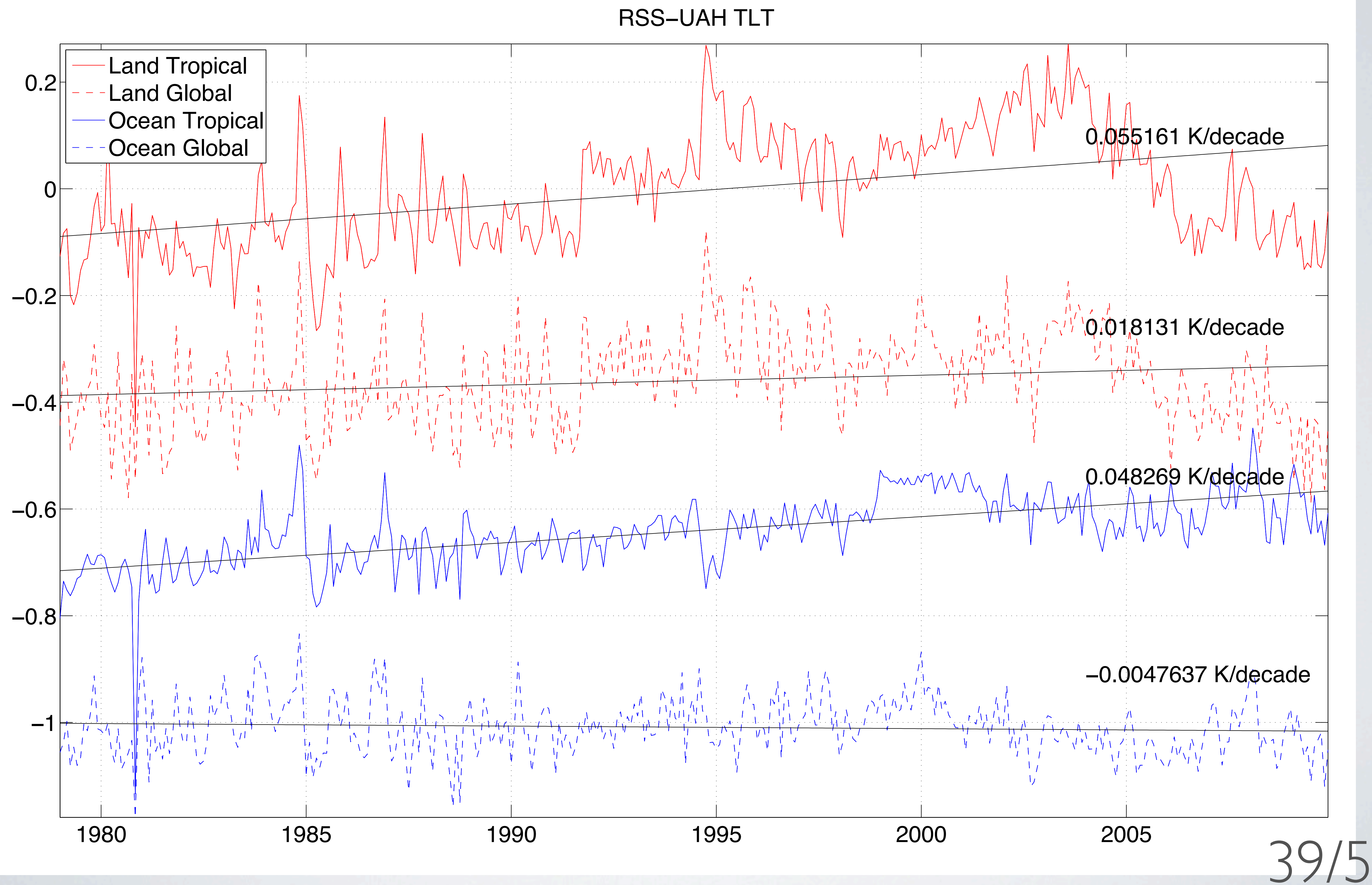
NOAA-9 addresses some of the differences.
What about the others?

Other discrepancies.

TLT versus TMT

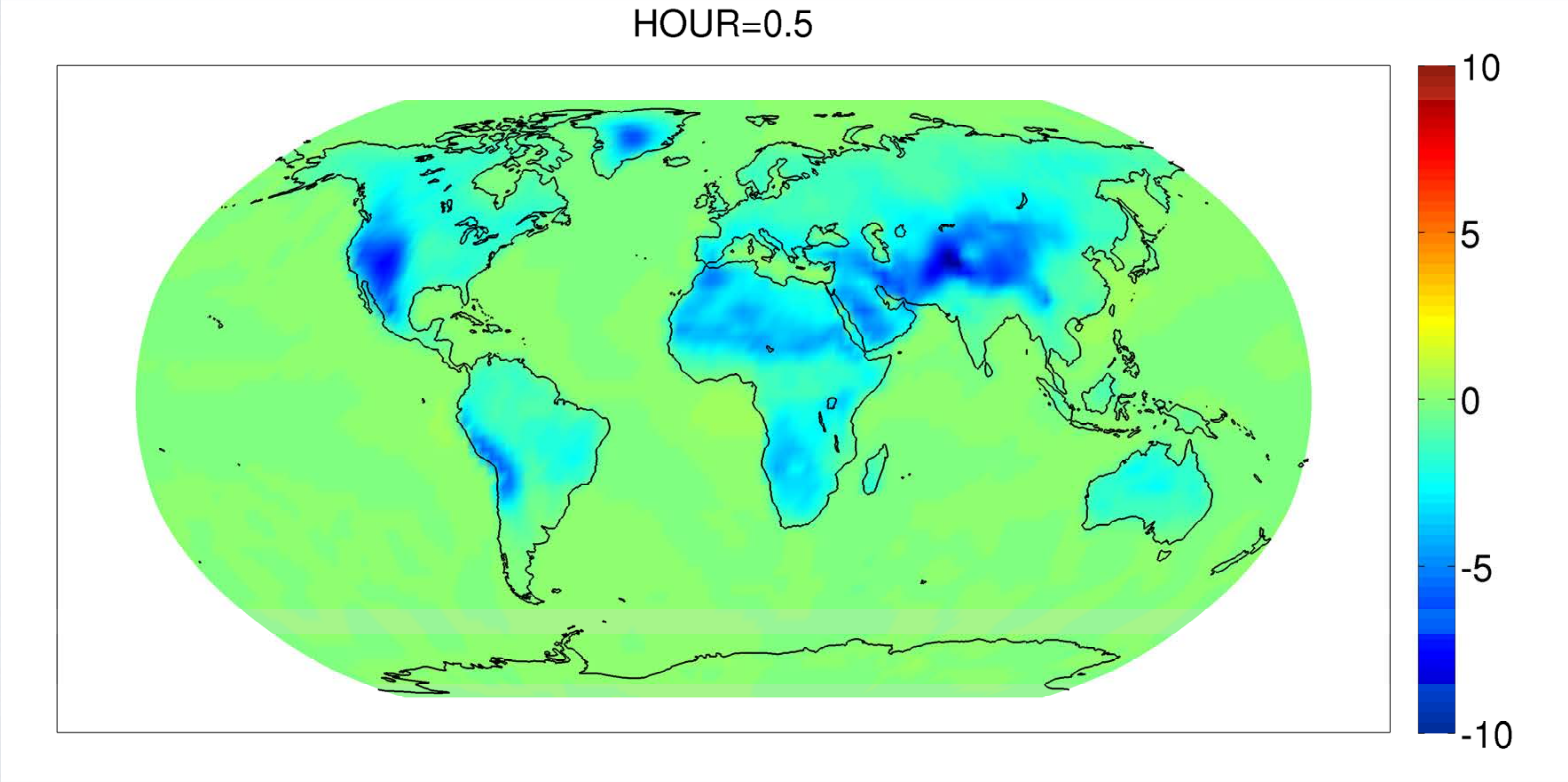


Other discrepancies.



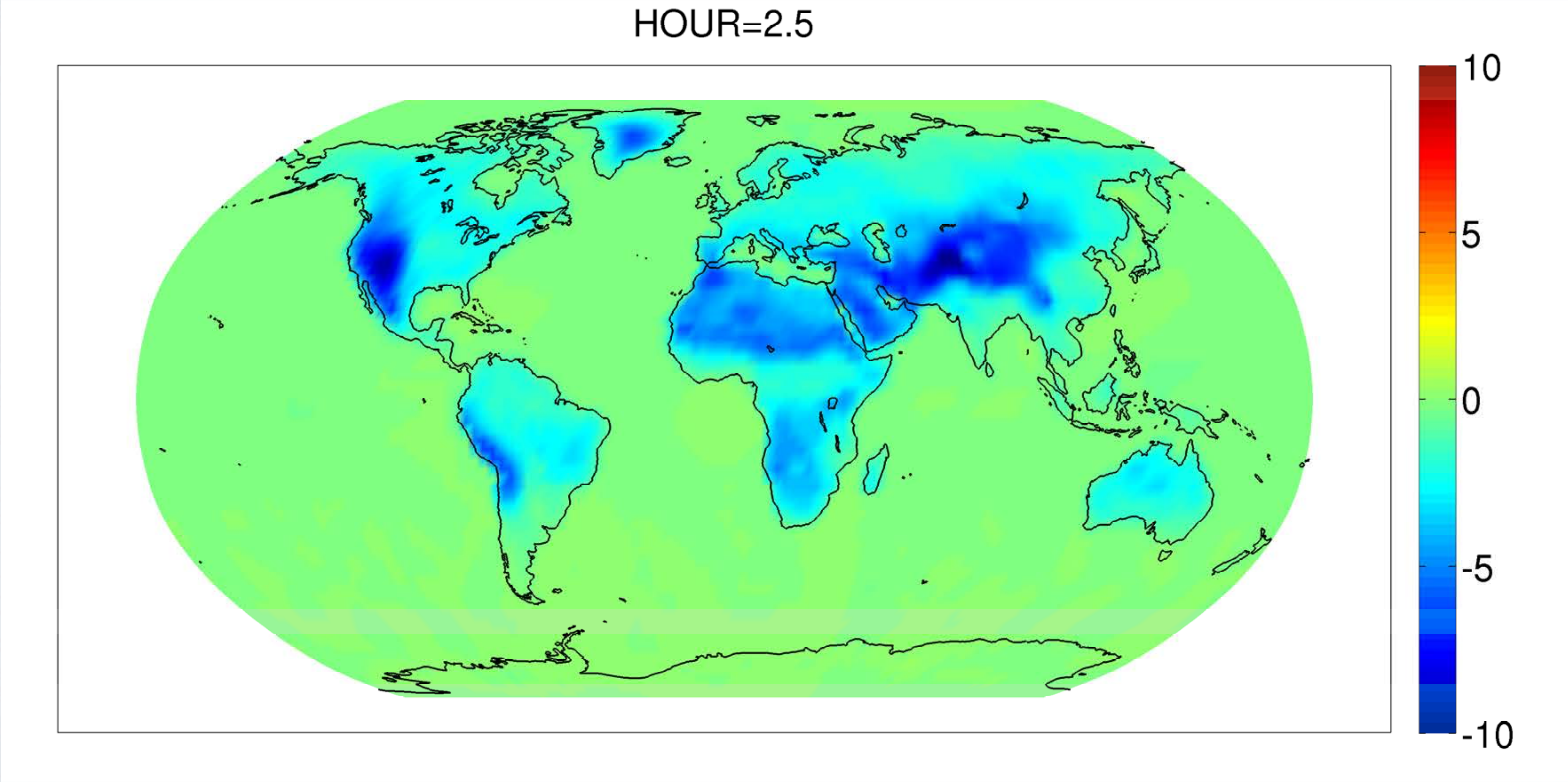
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



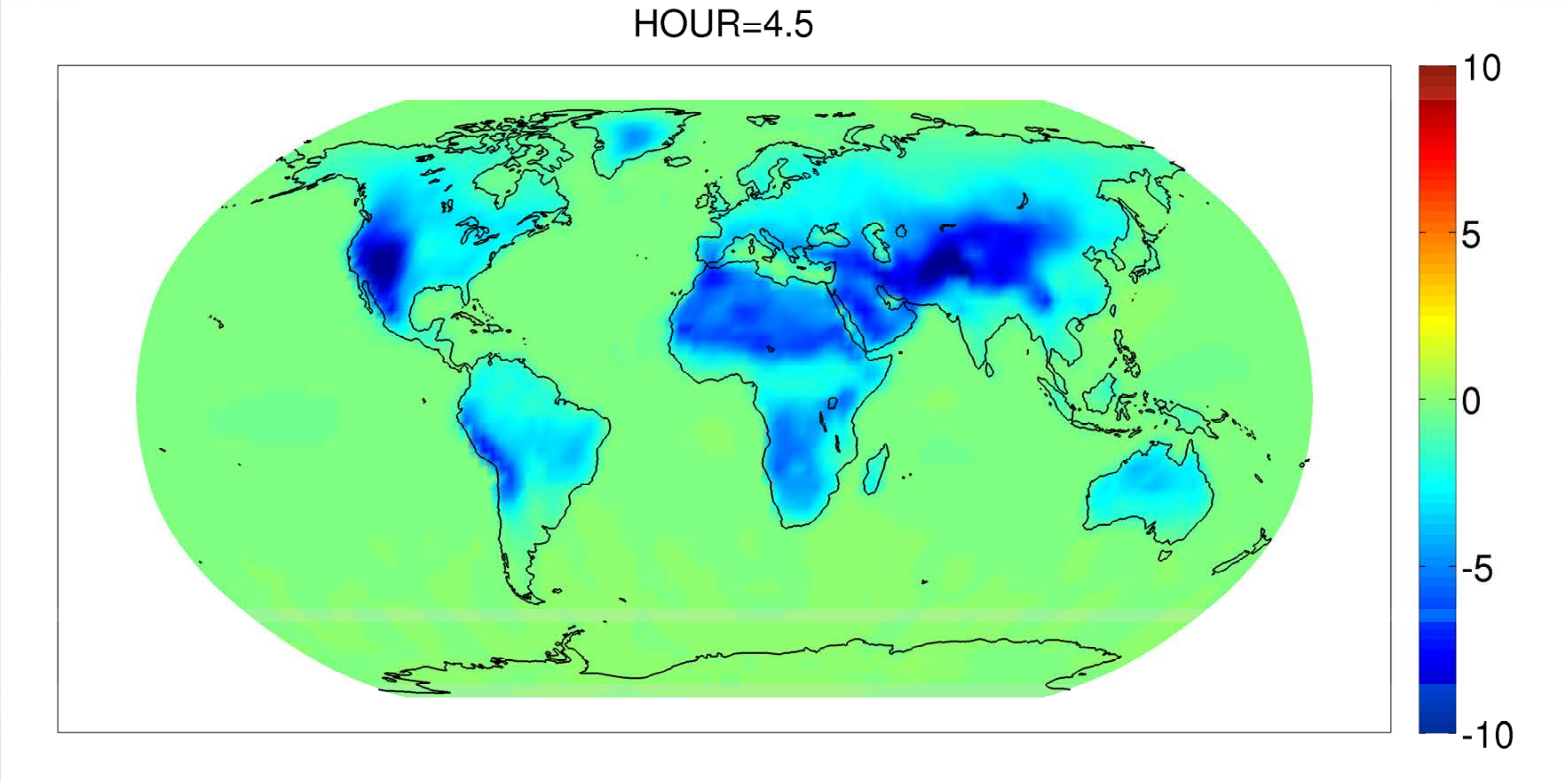
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



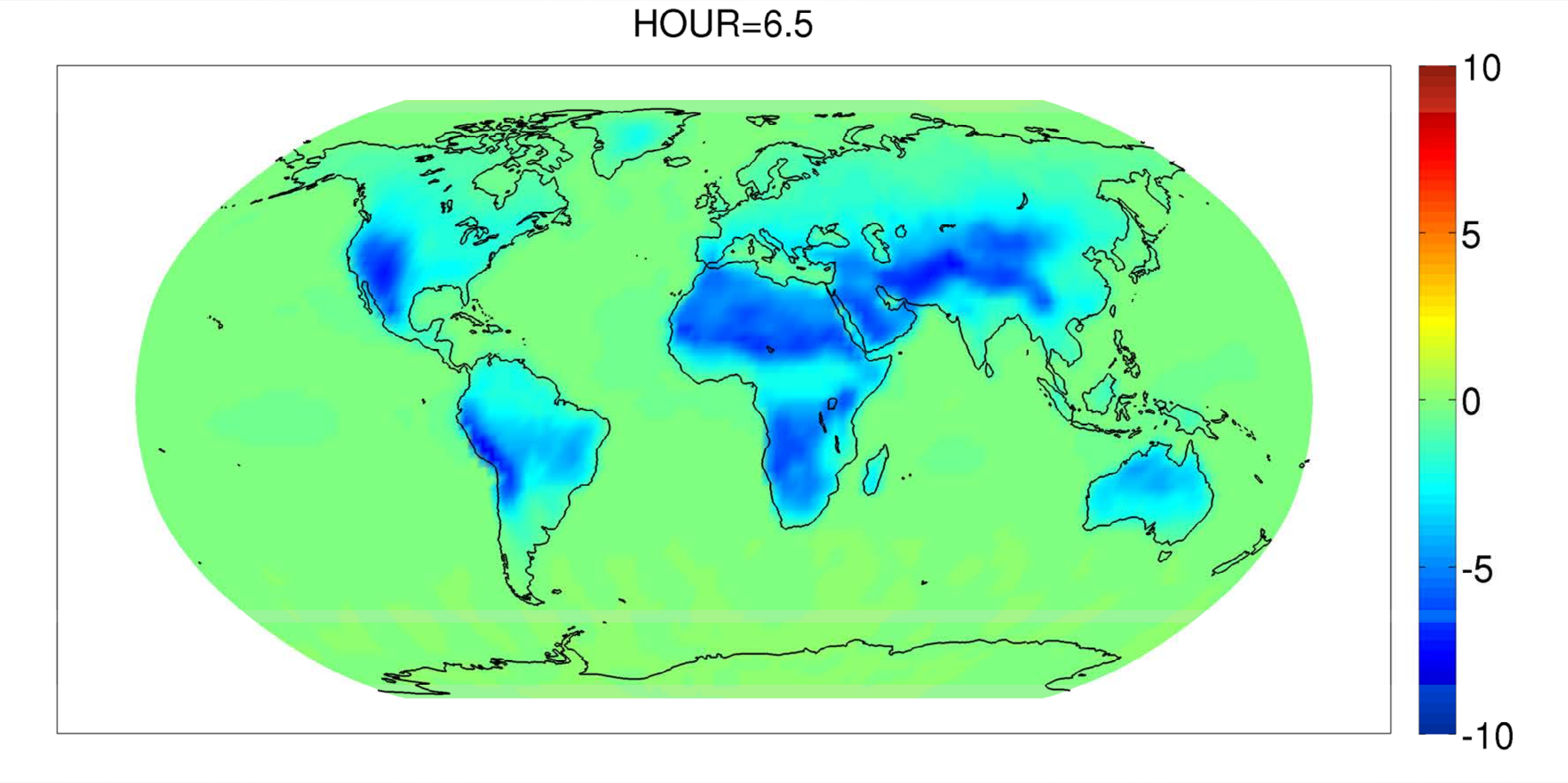
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



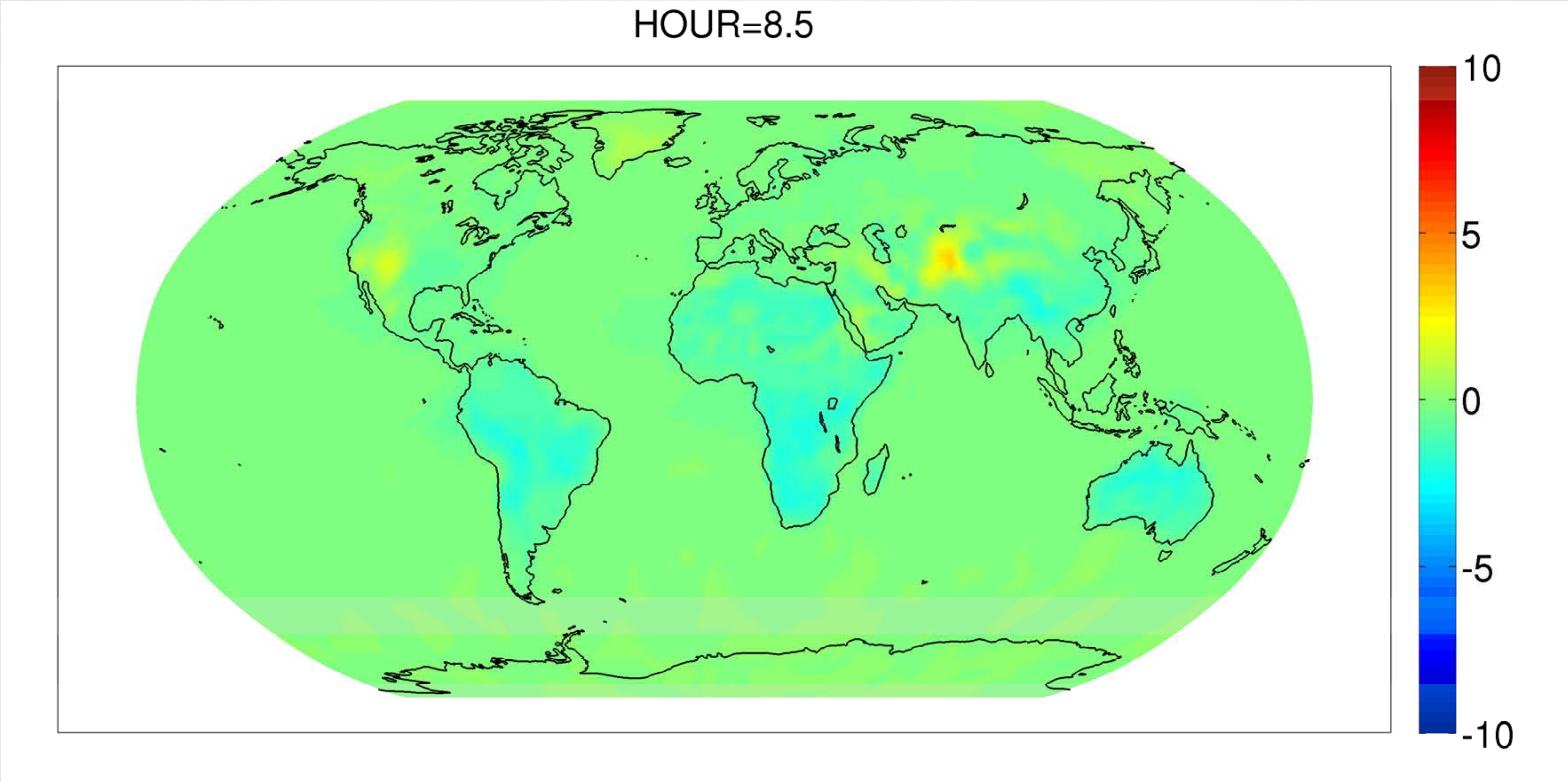
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



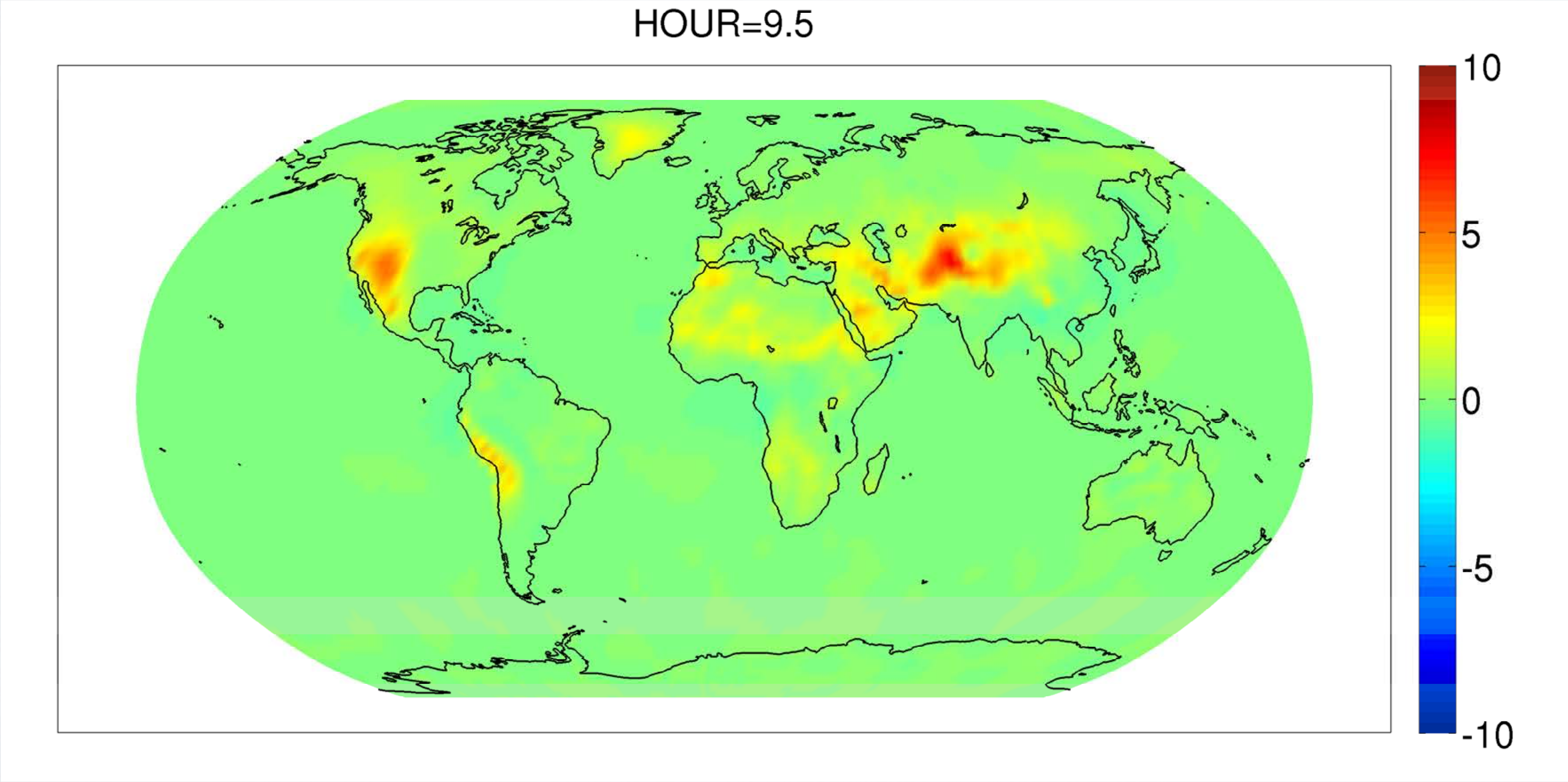
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



Other discrepancies.

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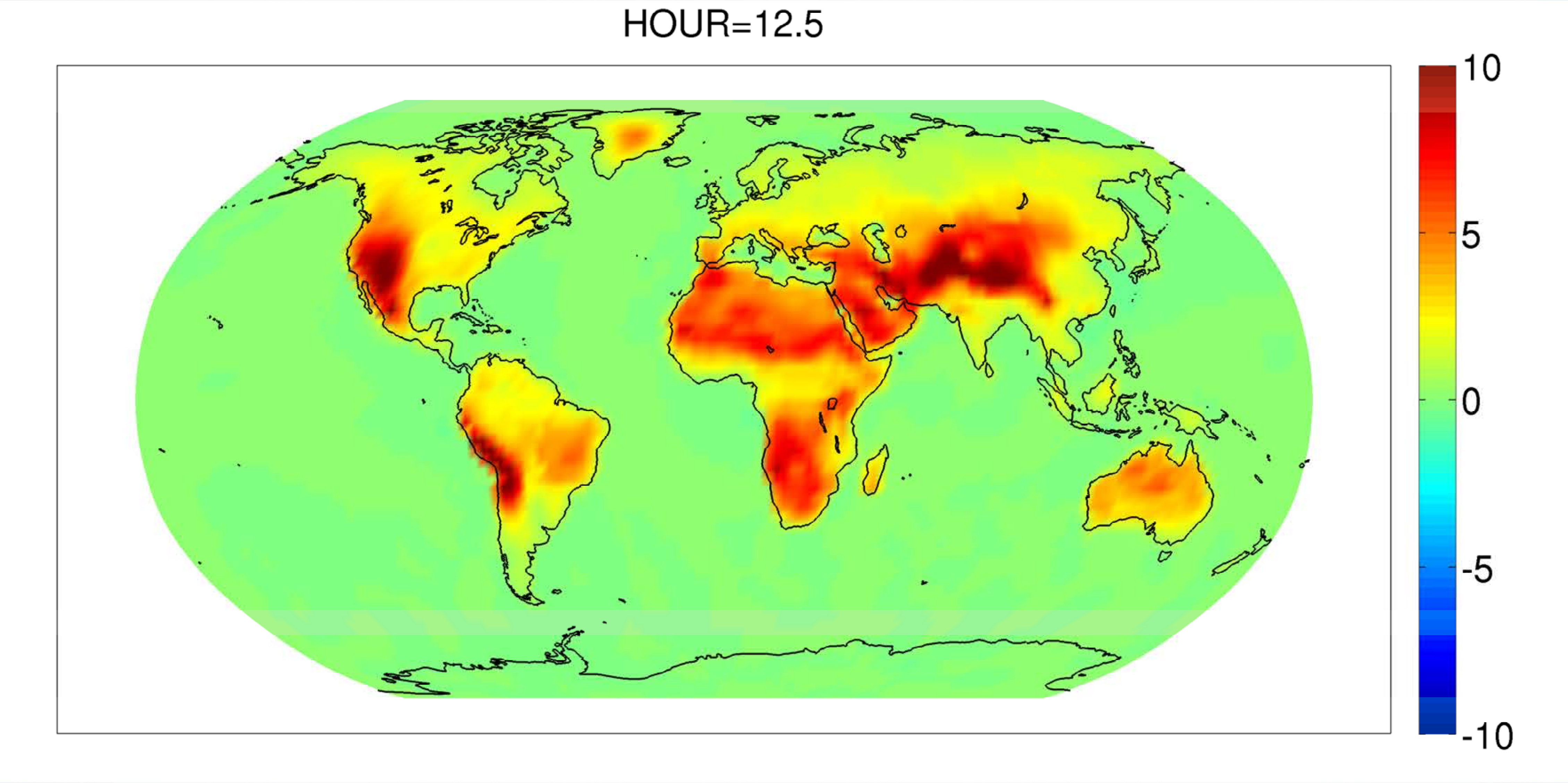

Other discrepancies.

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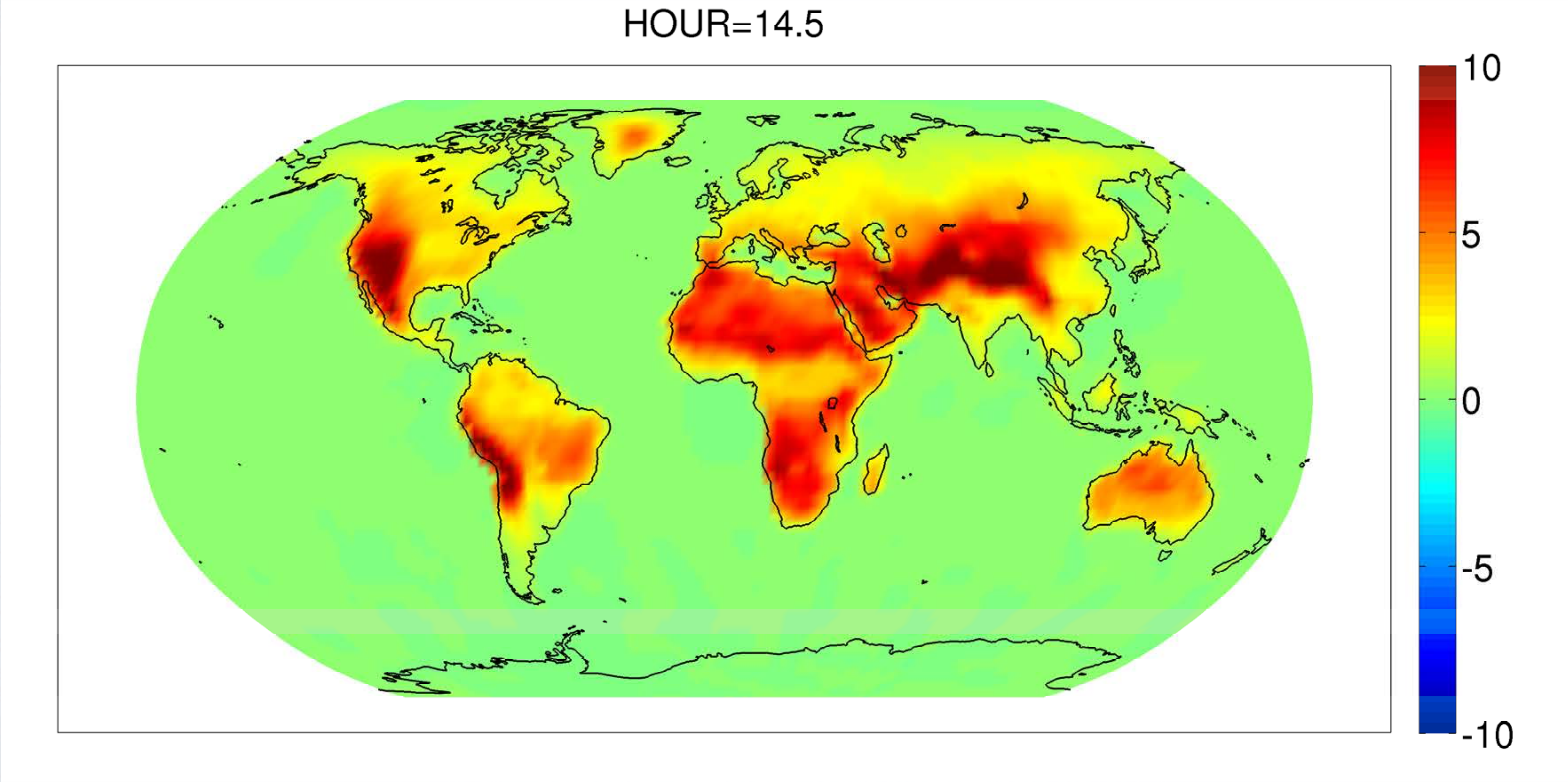

Other discrepancies.

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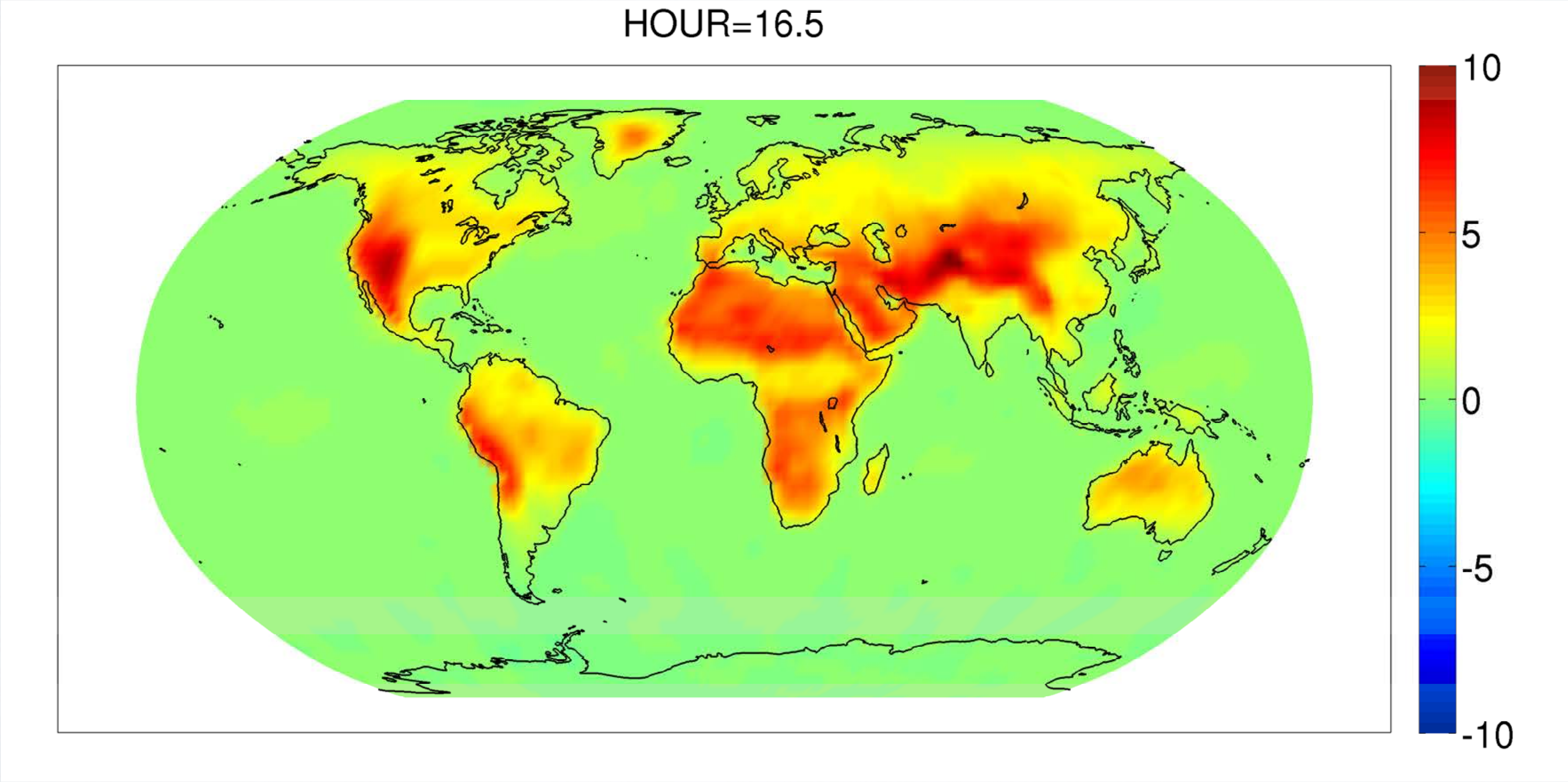
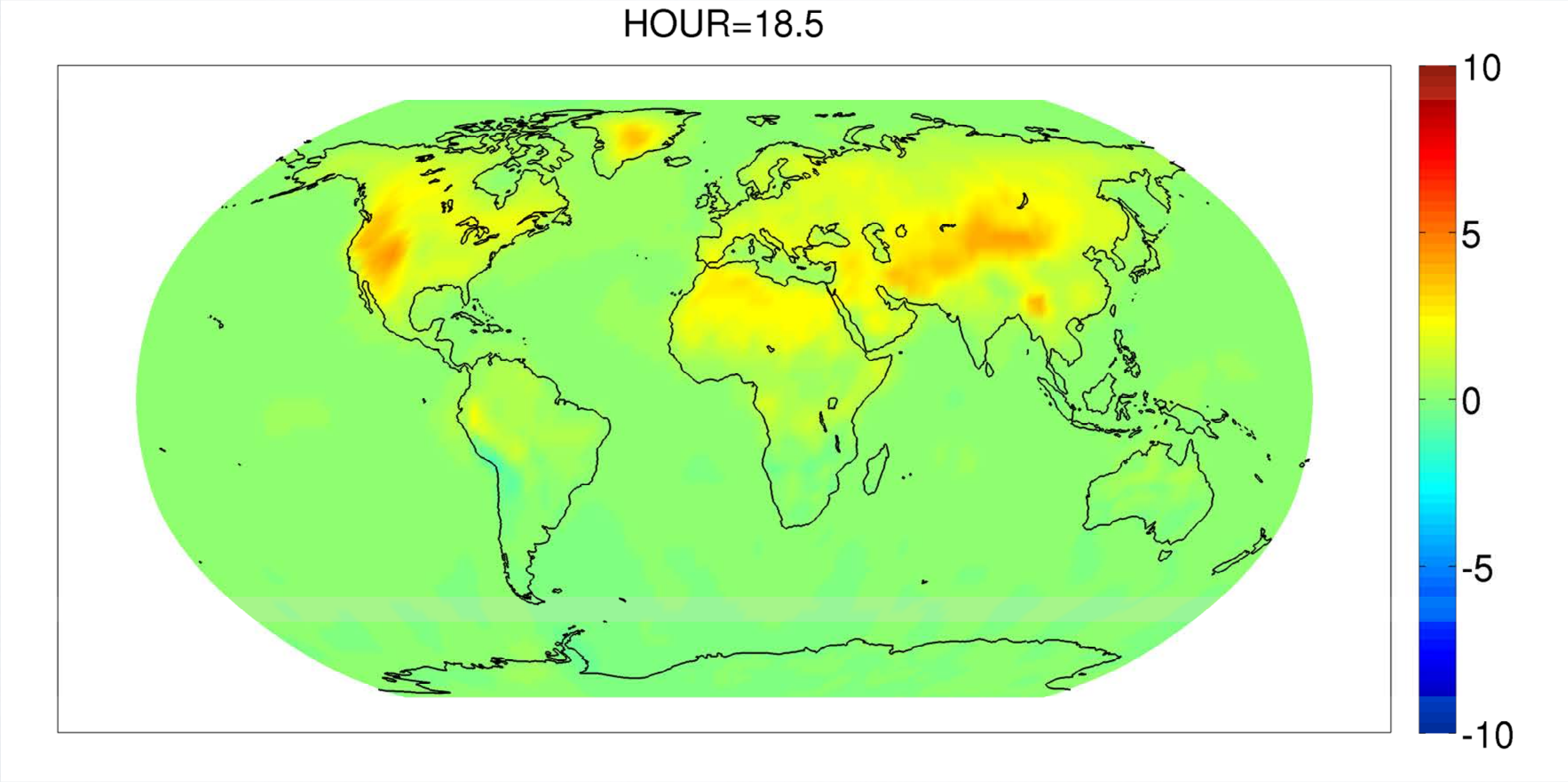


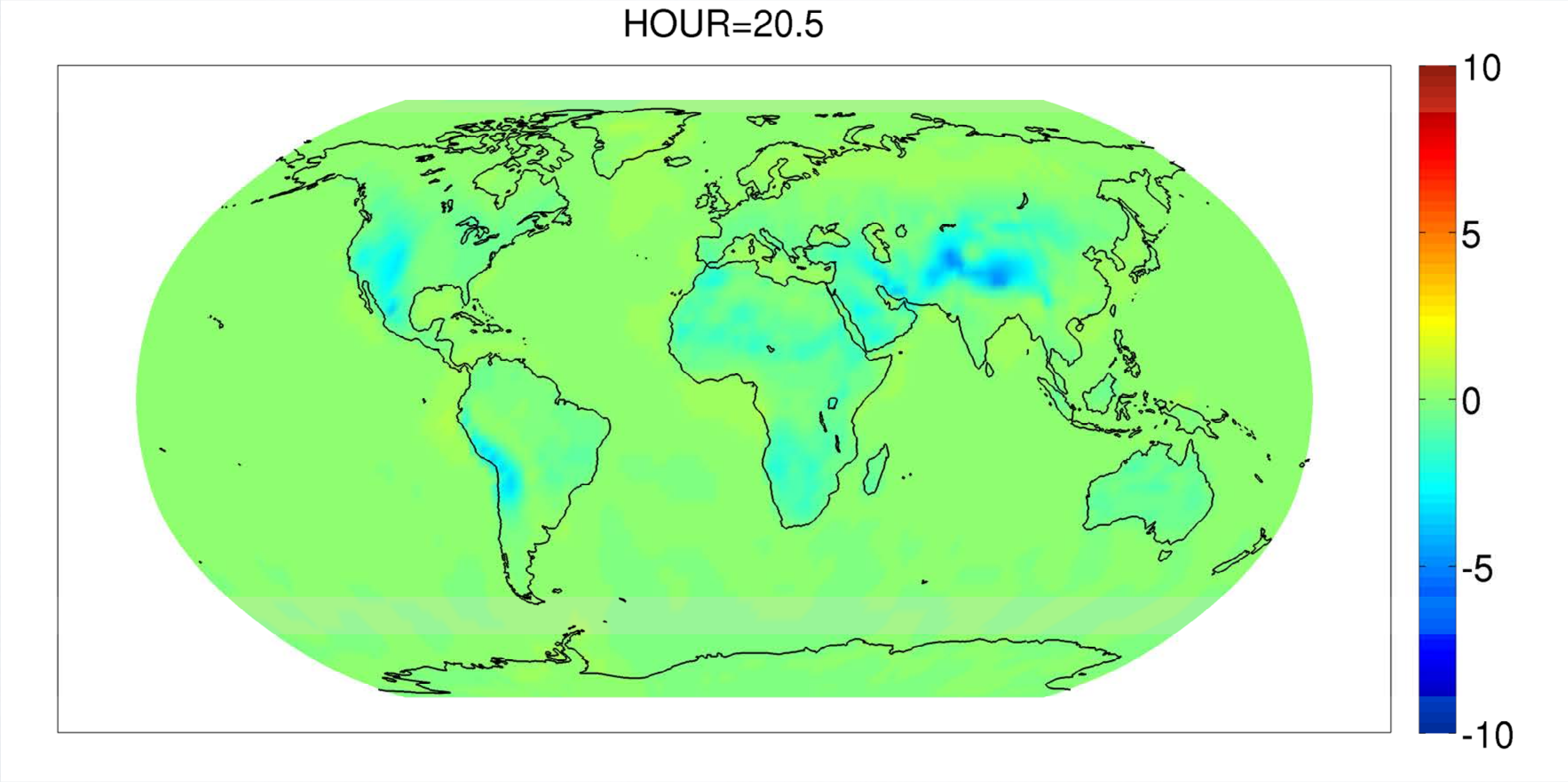
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)



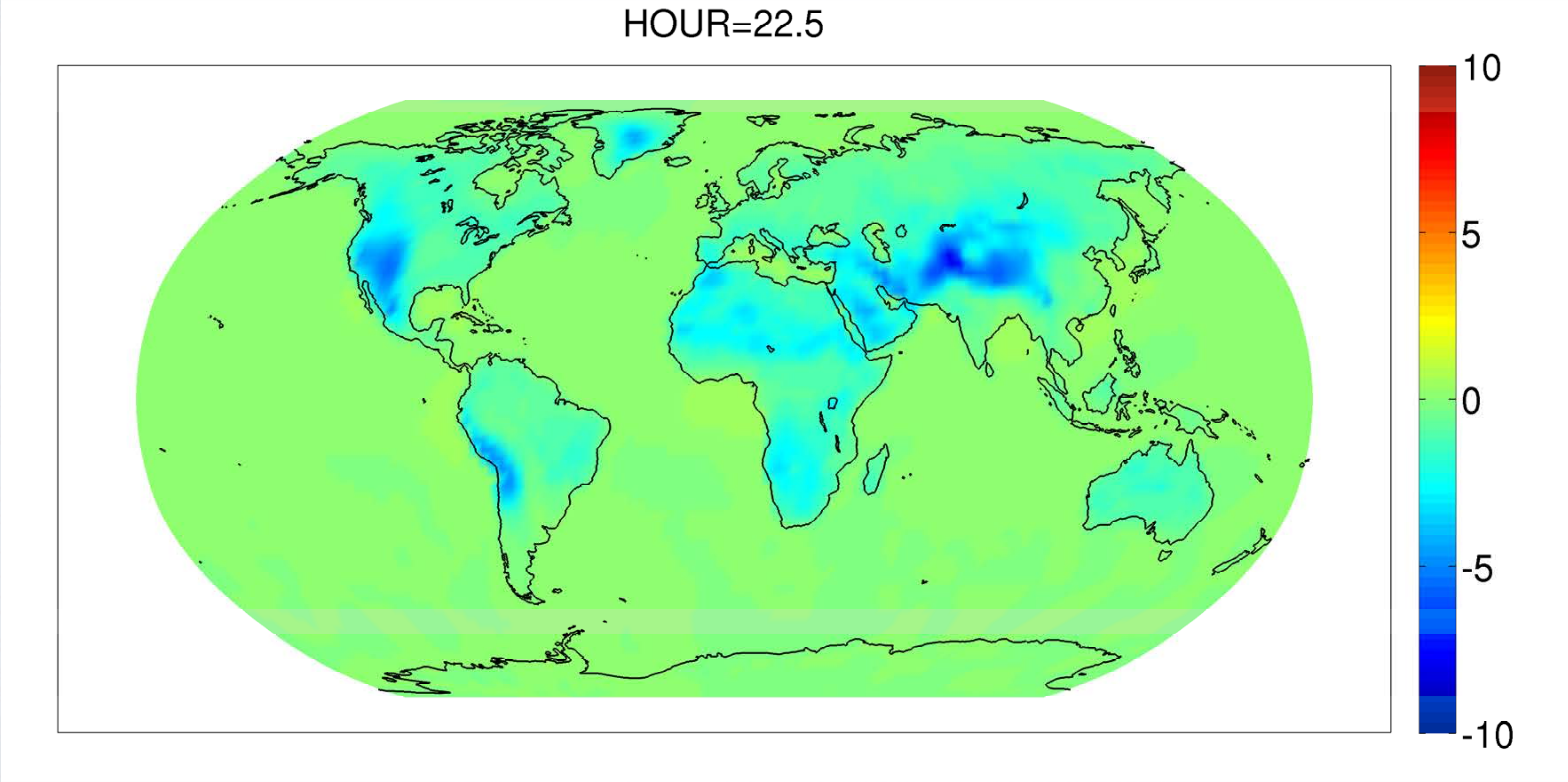
Other discrepancies.

CCSM3.0 TLT Diurnal Cycle (RSS)

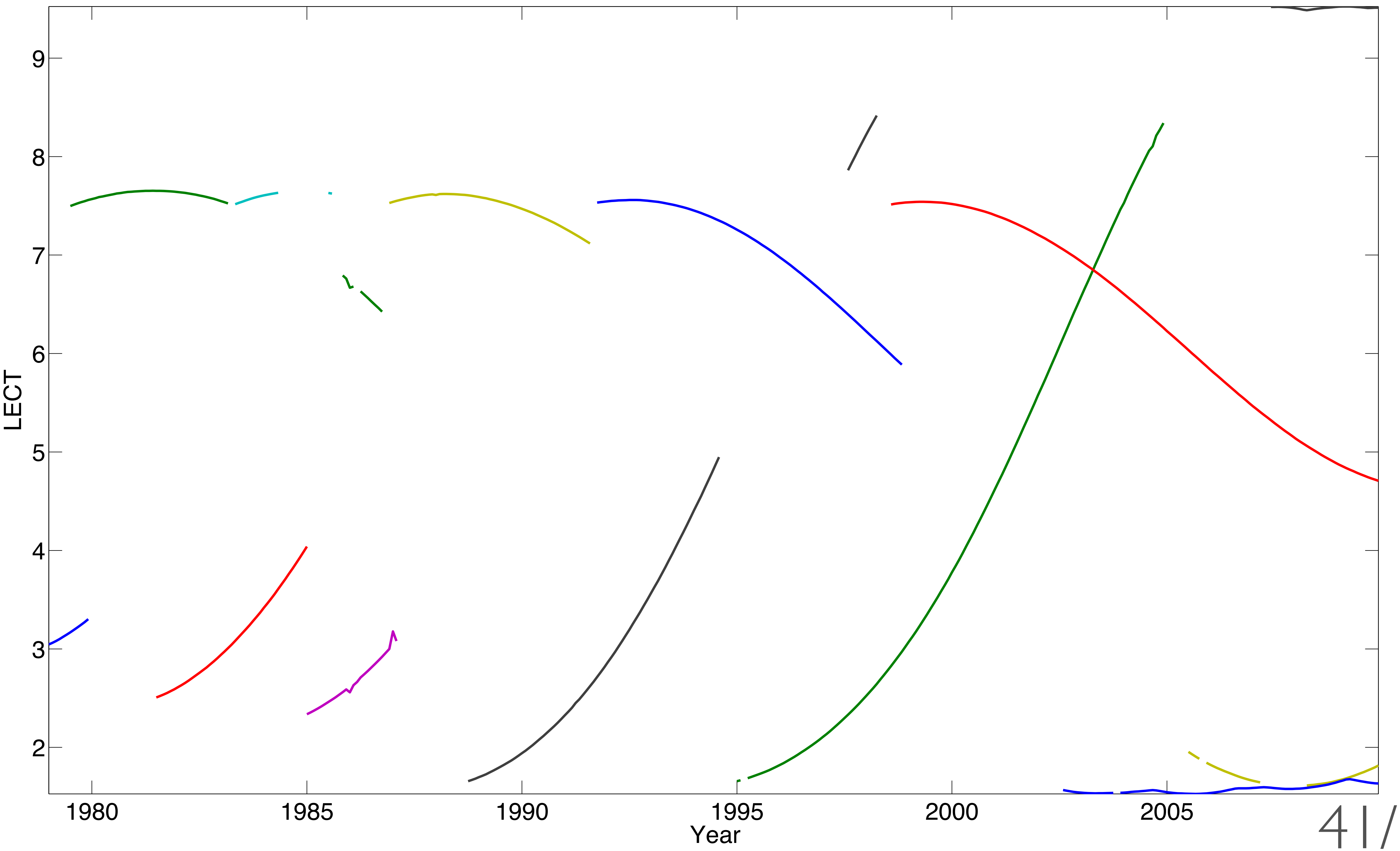


Other discrepancies.

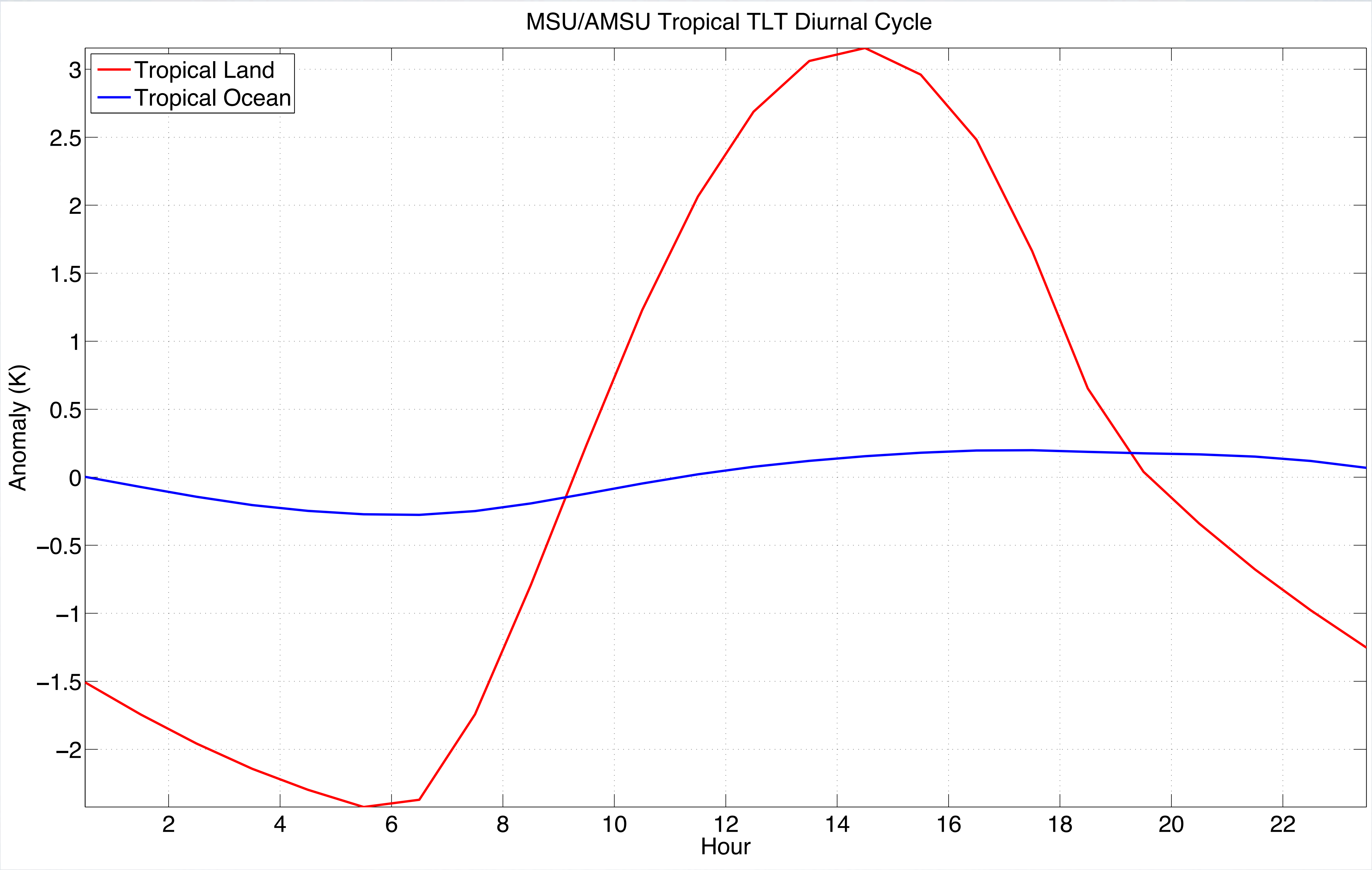
CCSM3.0 TLT Diurnal Cycle (RSS)



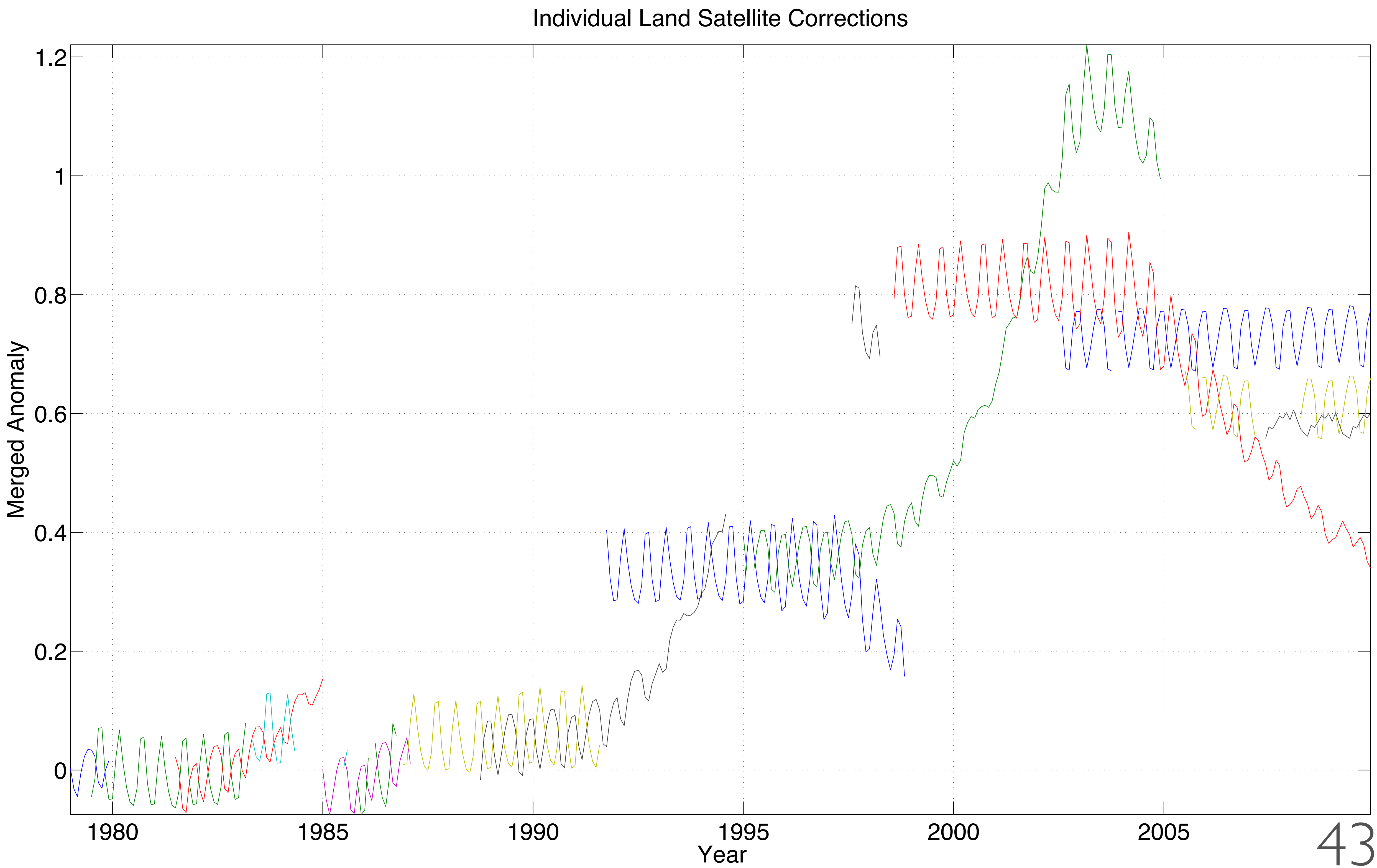
Other discrepancies.



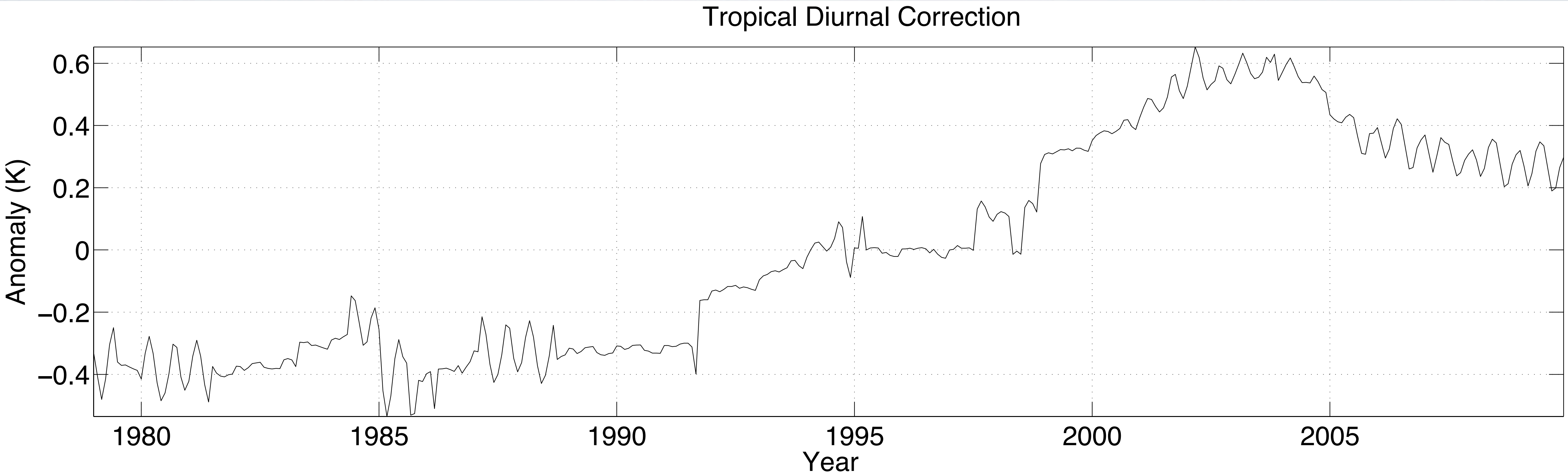
Other discrepancies.



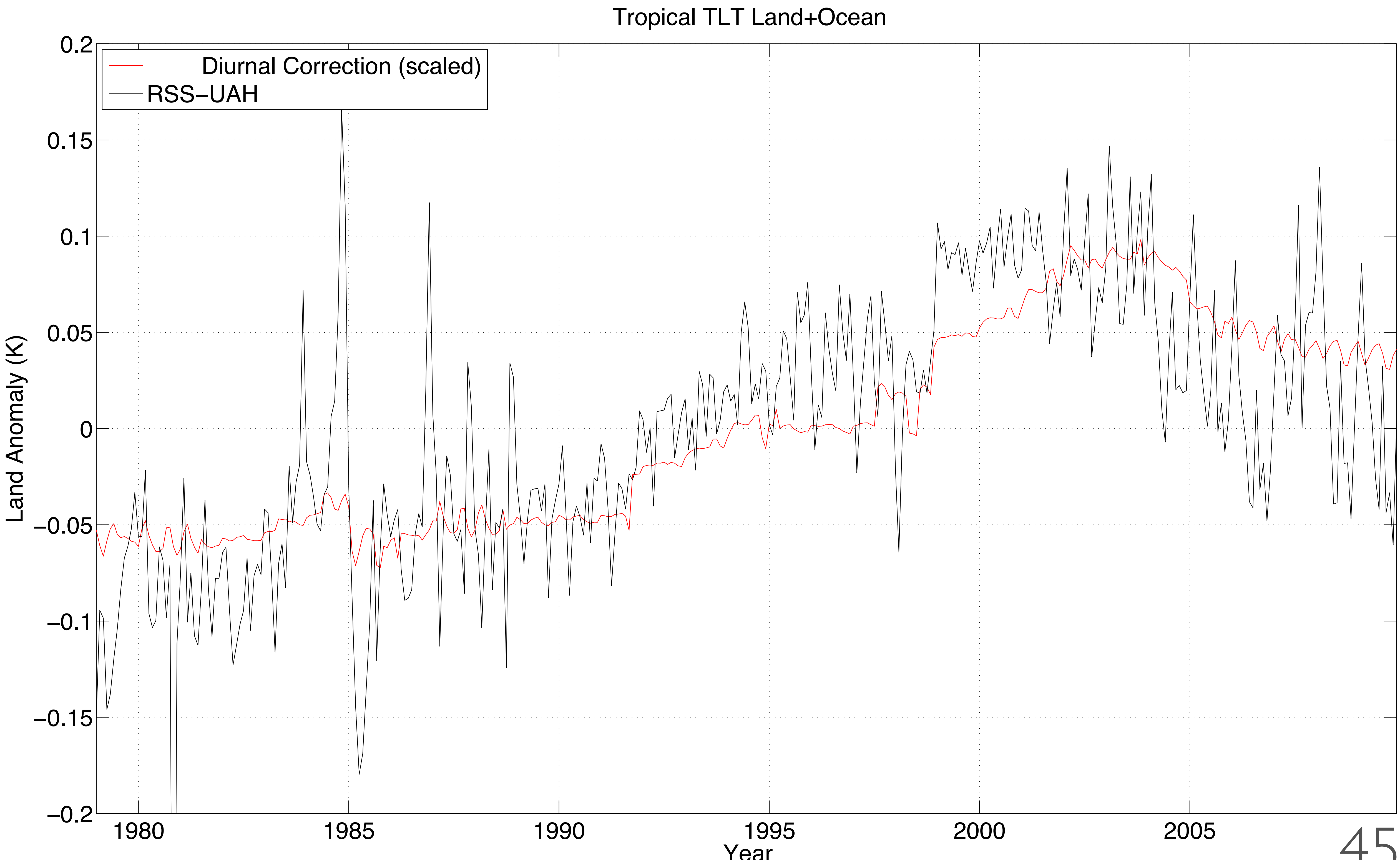
Other discrepancies.



Other discrepancies.



Other discrepancies.



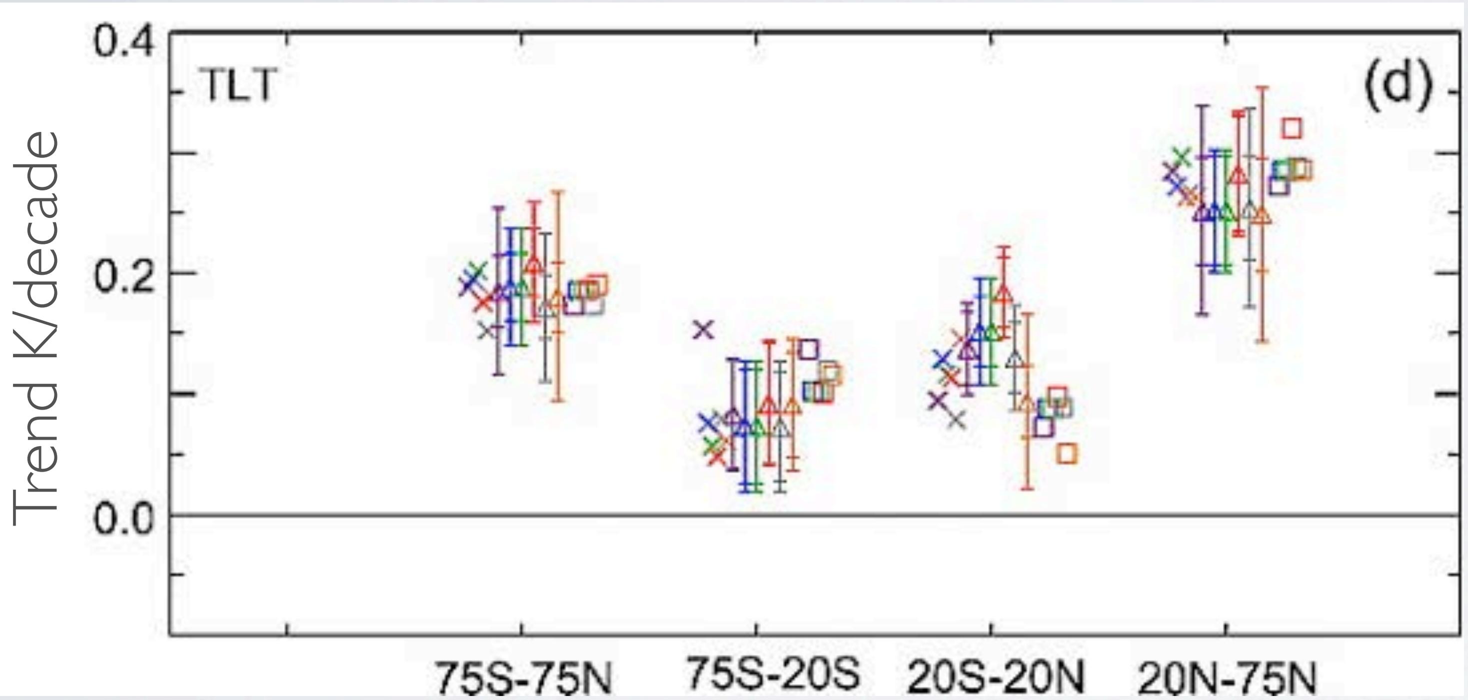
Other discrepancies.

- The effect of the diurnal cycle drift can be similar to warm target effect
- Diagnosing drifts in the diurnal cycle correction or warm target temperature is important in reconciling trends
- No perfect reference
- Some studies using radiosondes (e.g. Randall and Herman, 2008; Christy et al. 2010) indicate that the diurnal drift correction for RSS is too large for TLT
- Over long time scales, radiosondes are a less reliable reference

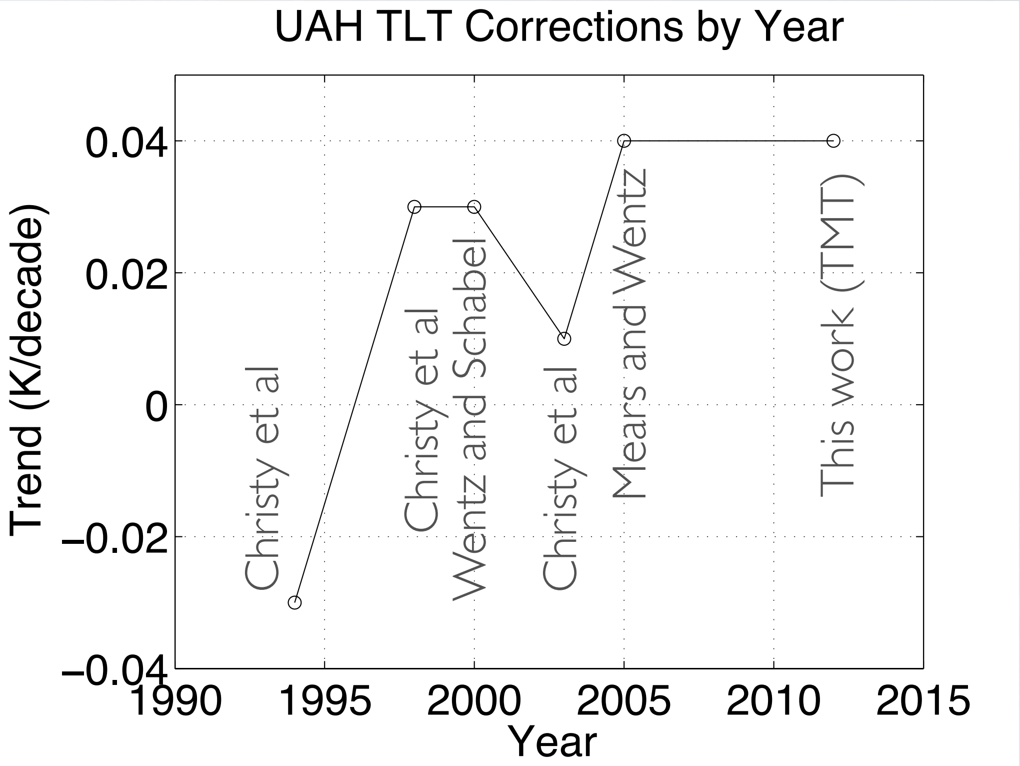
Conclusions Part I.

- UAH has a significant bias that reduces the mid-tropospheric trend
  - The UAH merging procedure is biased
- UAH should increase ~0.04 K/decade
- There is evidence that tropical differences are related to the treatment of diurnal drift

Conclusions Part II.



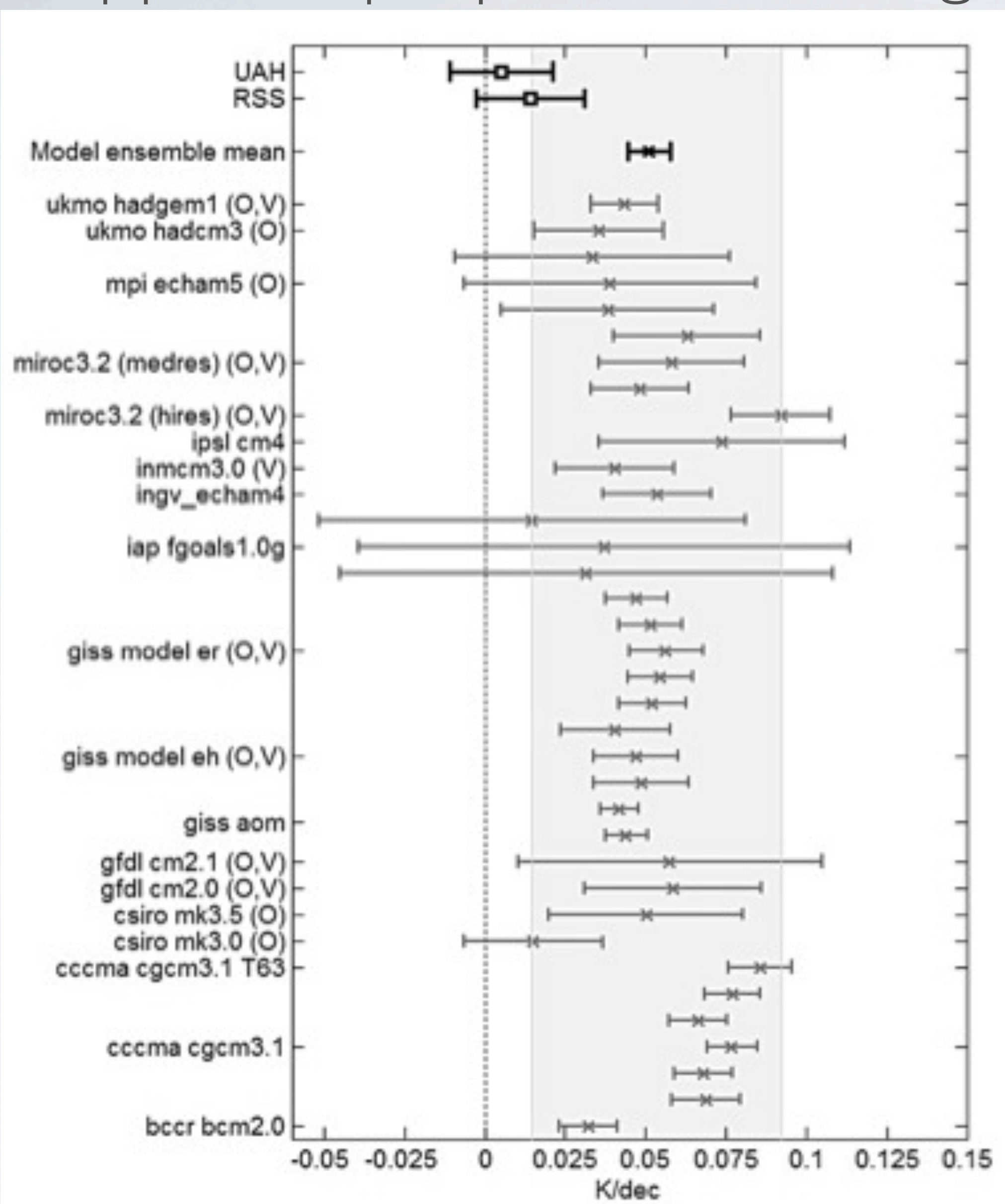
Mears et al, 2011



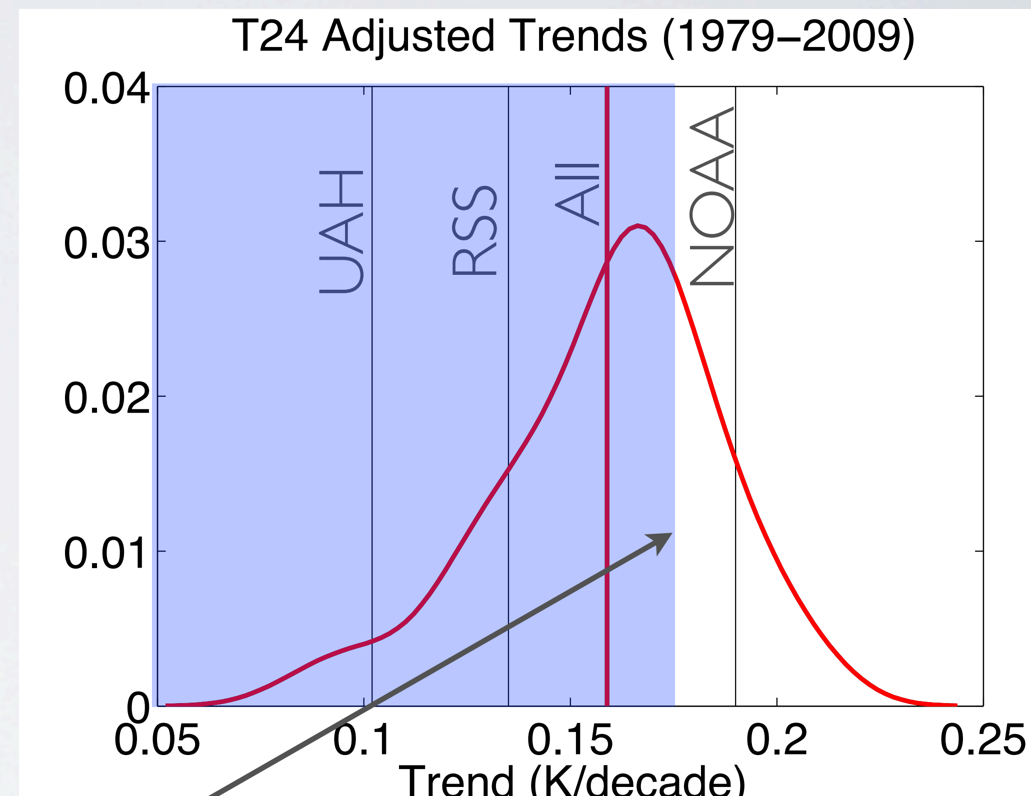
Uncertainties are large...

Conclusions Part III.

Upper Tropospheric Warming



Fu et al, 2011



Model Estimated Warming

Similar to Thorne et al, 2011

But maybe models are overestimating amplification...

Future work.

- Continue to work on diurnal drift discrepancy
- Explore differences between CMIP5 and observations
  - Amplification
  - Land/Ocean differences
  - Stability changes between the mid- and upper-troposphere
  - Mean tropical temperature profile

Thank you!

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Questions?