Monitoring Climate Change using Satellites: Lessons from MSU

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UAH data from John Christy

Residual uncertainty work in collaboration with John Christy, Roy Spencer and David Parker

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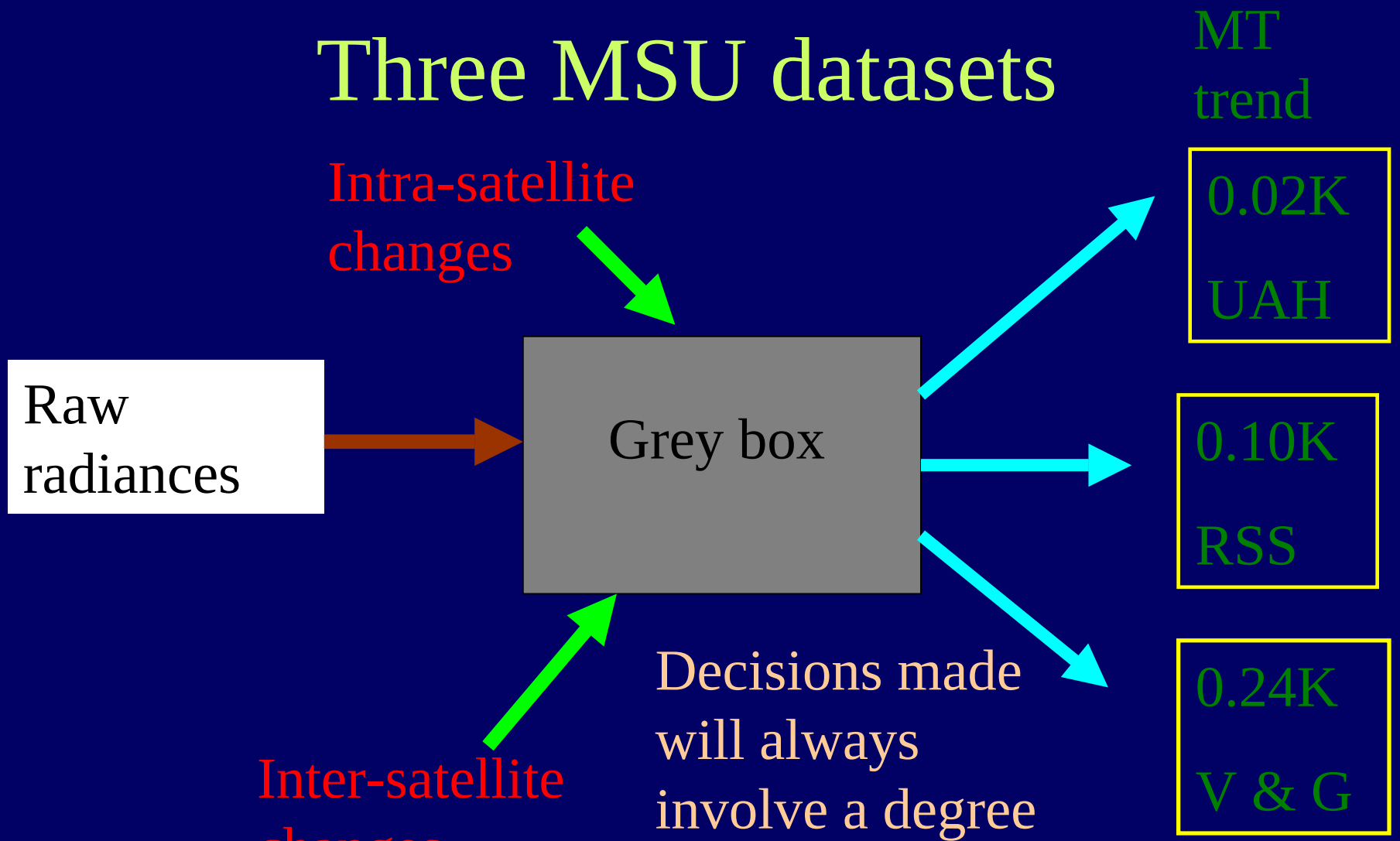
What is the problem?

- Forming a homogeneous series from several different satellites
- Corrections are required for:
  - Orbit decay -- satellite gets closer to Earth
    - » Only needed for LT retrieval and v. small uncert.
  - Diurnal drift -- satellites drift aliasing in the diurnal cycle
  - Instrument temperature.
    - » Conversion into brightness temperature has non-linear dependence on the satellite temperature.
  - Other intra-satellite bias.
    - » Any remaining biases removed.
  - Inter-satellite biases

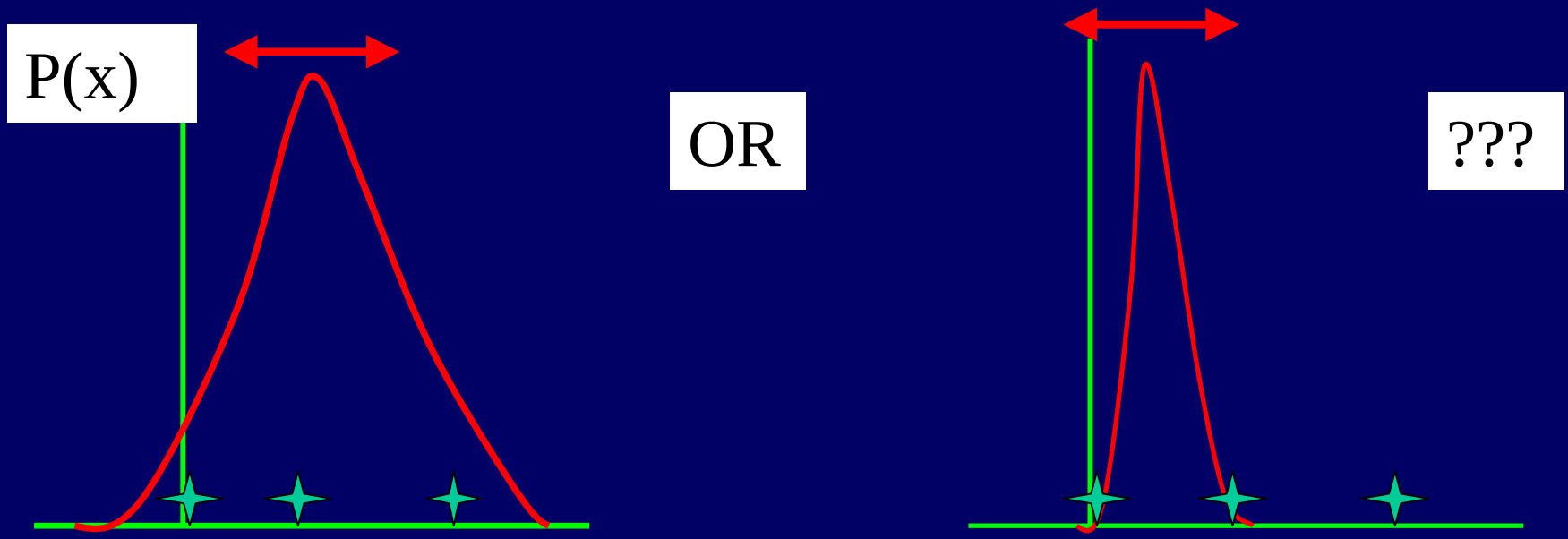
Dataset trend uncertainty

- Two sources:
  - Structural uncertainty
    - » the uncertainty introduced by the method chosen to go from raw radiances to a “homogeneous dataset”
  - Residual uncertainty
    - » Uncertainty inherent in the method in the presence of finite data.

Three MSU datasets



What is the true structural uncertainty?



Red is the PDF of best-guess global-mean trends for an infinite number of physically realistic treatments, green stars published estimates.

Which (L or R) is correct is important!

Are the datasets consistent?

- The respective published estimates with 2 sigma (residual only) uncertainty estimates are:
  - UAH: 0.02 +/-0.05 K / decade
  - RSS: 0.10 +/-0.02 K / decade
  - V & G: 0.24 +/-0.02 K / decade
- Implies either:

  1. some (all?) are physically implausible methods or

  2. that structural uncertainty is the major source of uncertainty (error!) and that this implicitly needs to be taken into account:
     - How? We are grossly under-sampling the structural uncertainty phase space.

Residual dataset uncertainty

- How were these uncertainty estimates derived?
  - Could they simply be under-estimated?
    - » Might a more realistic set of residual uncertainty estimates obviate the need to consider structural uncertainty because it is in fact unimportant?
- Concentrate on UAH as it has had most analysis applied to it, but similar principles will pertain to the other datasets.

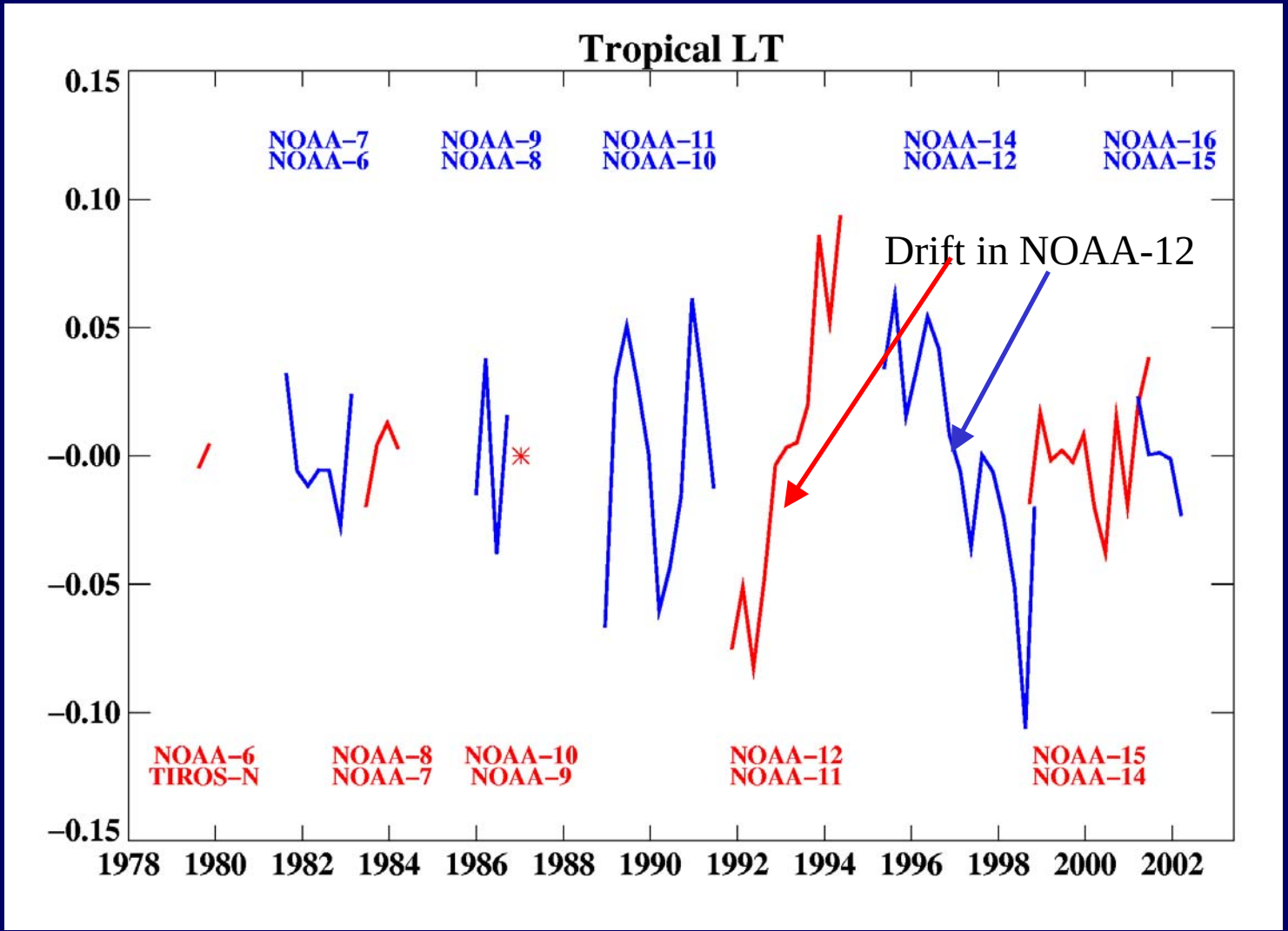
Internally and Externally derived error estimates

- Attempt to produce “internal” error estimates
  - “Model” the various components of treatment error to estimate total error.
    - » Need to get major error sources and be right about “model”
    - » Allows computation of any desired quantity.
    - » Independent
- Alternatively produce “external” error estimates
  - by comparison with radiosondes
    - » Need enough radiosonde data
    - » Need to assume error distribution (as sondes are sparse)
    - » Radiosondes contain errors!

Inter-Satellite bias

- Chosen as one example for internally derived estimate.
- Uncertainty in bias is normal expression for standard deviation ($\sigma/\sqrt{N}$) where N is the estimated dof.
- Estimate 1-σ error from 90-day averages (indep. data)
- Biases are cumulative.

LT Inter-Satellite differences



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Bias Uncertainties

Product	Tropics	Global
Pre NOAA-12	0.034	0.031
LT NOAA-12	0.052	0.037
post NOAA-12	0.021	0.015
MT	0.024	0.018
LS	0.071	0.063

Externally derived estimates

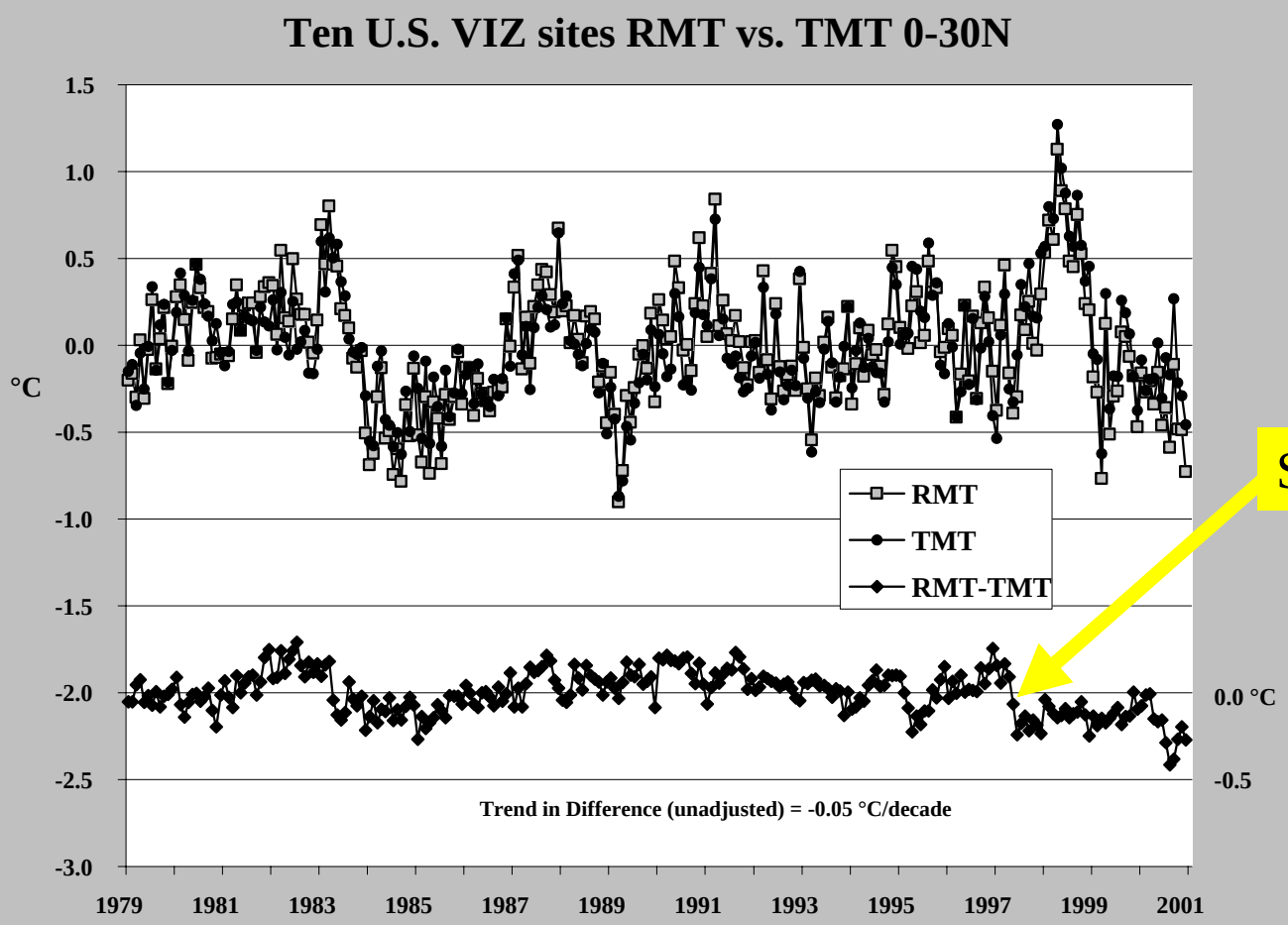
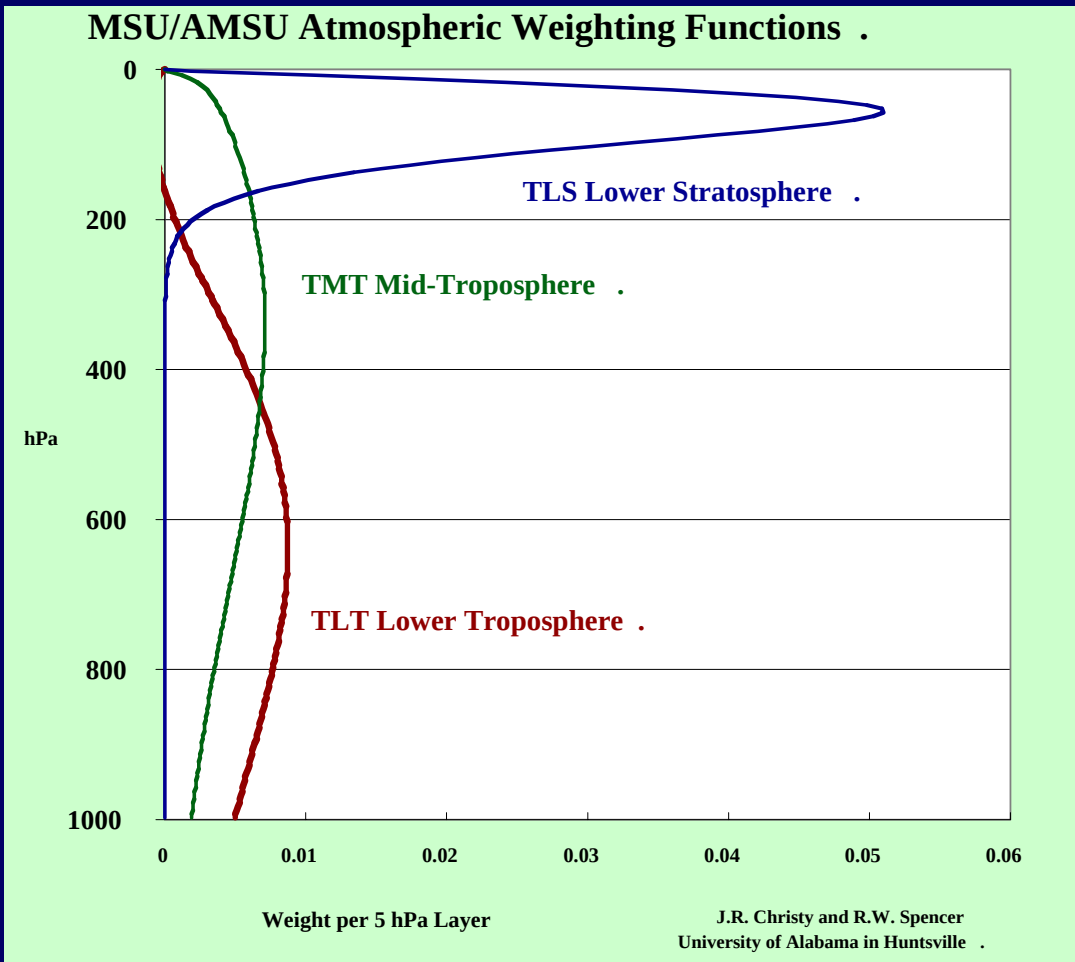


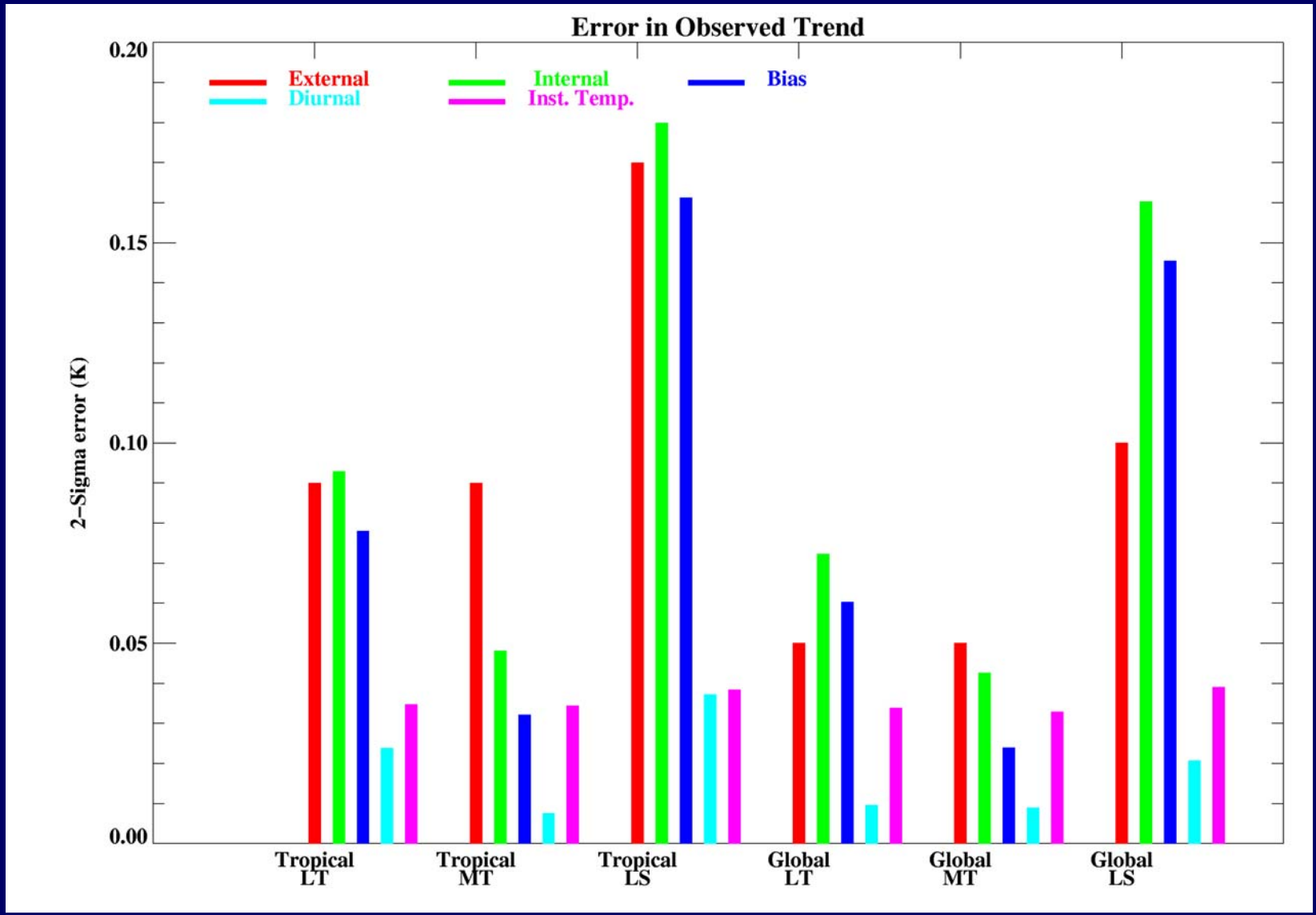
Fig. 5 Christy et al. 2003

Results

- Three products (LT, MT & LS)
- Two regions:
  - tropics (+/- 20^{o})
  - Global



Errors in the trend



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Residual errors

- Analysis of UAH shows that residual error estimates are not likely to be (at least grossly) underestimated.
- The two remaining MSU datasets need a thorough error analysis and this needs to be published.

Lessons?

- Critically important to place robust error estimates.
- But, structural uncertainty may be the major source of error: if so this is a big challenge!
- Having three independently produced estimates permits an in-depth analysis which is unlikely to be possible for other satellite datasets and will undoubtedly provide valuable information.

Just a satellite problem?

- What is happening to tropospheric temperatures fundamentally affects our understanding of climate change.
- Depending upon which MSU series you choose the answer changes absolutely.
- We desperately need a clear-cut and objectively based answer as to what the true trend is with error estimates!
- Needs expert input from the satellite, climate, reanalysis, and observational communities.