Optimal Detection of CHAMP and COSMIC Radio Occultation Data

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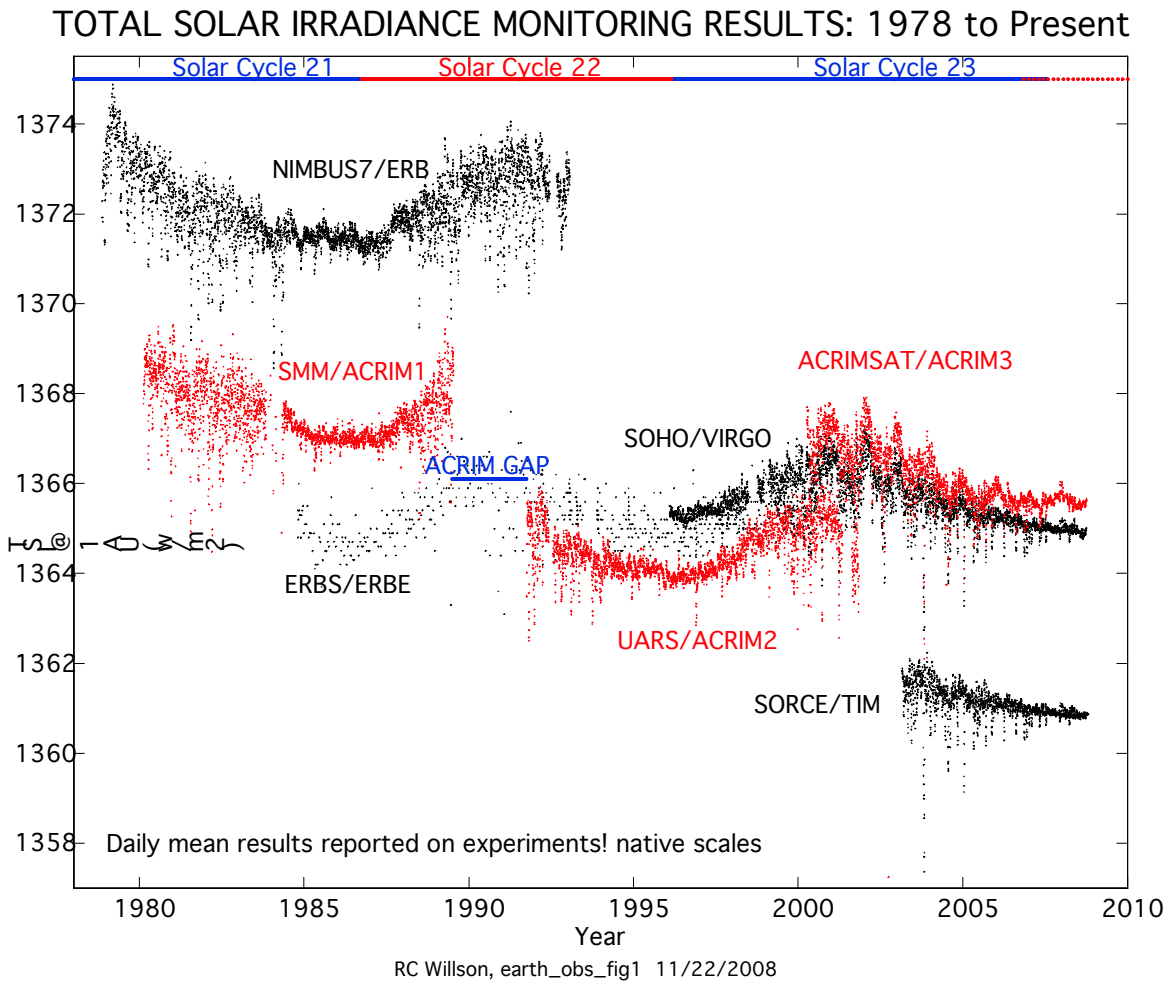
Outline

- Background
- Processing
  - JPL
  - Harvard
  - Mapping
- Optimal detection approach
  - Inference
  - Optimization
- Conclusions

Background: SI traceability, Insensitive to Breaks



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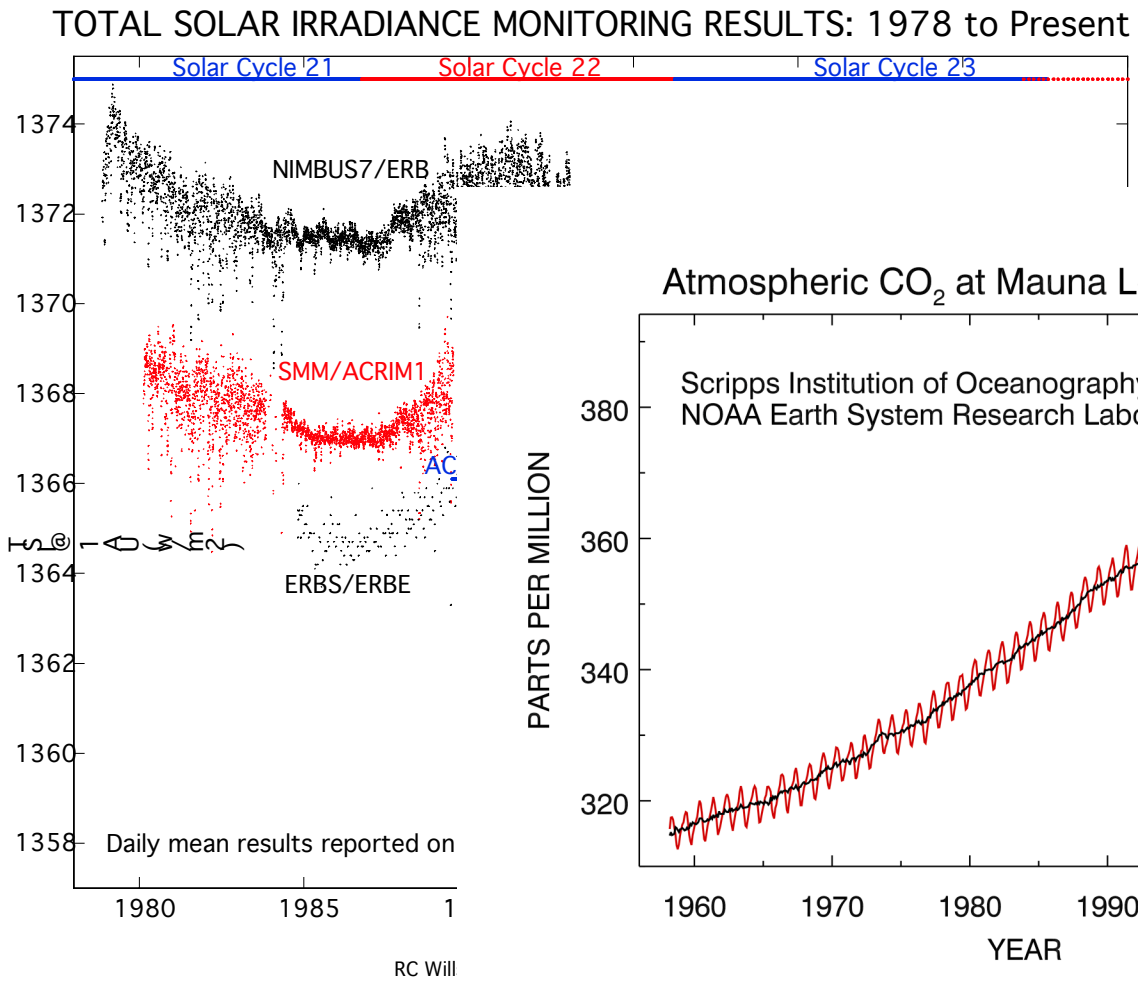
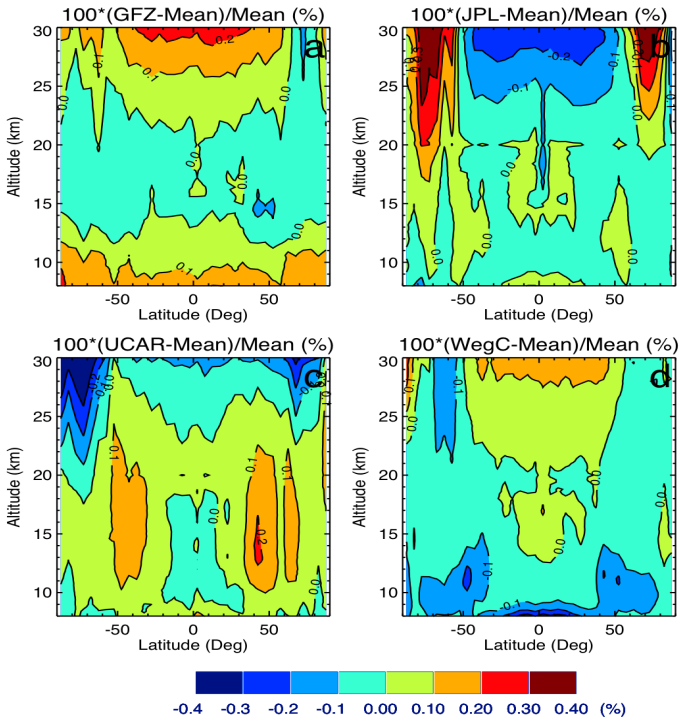
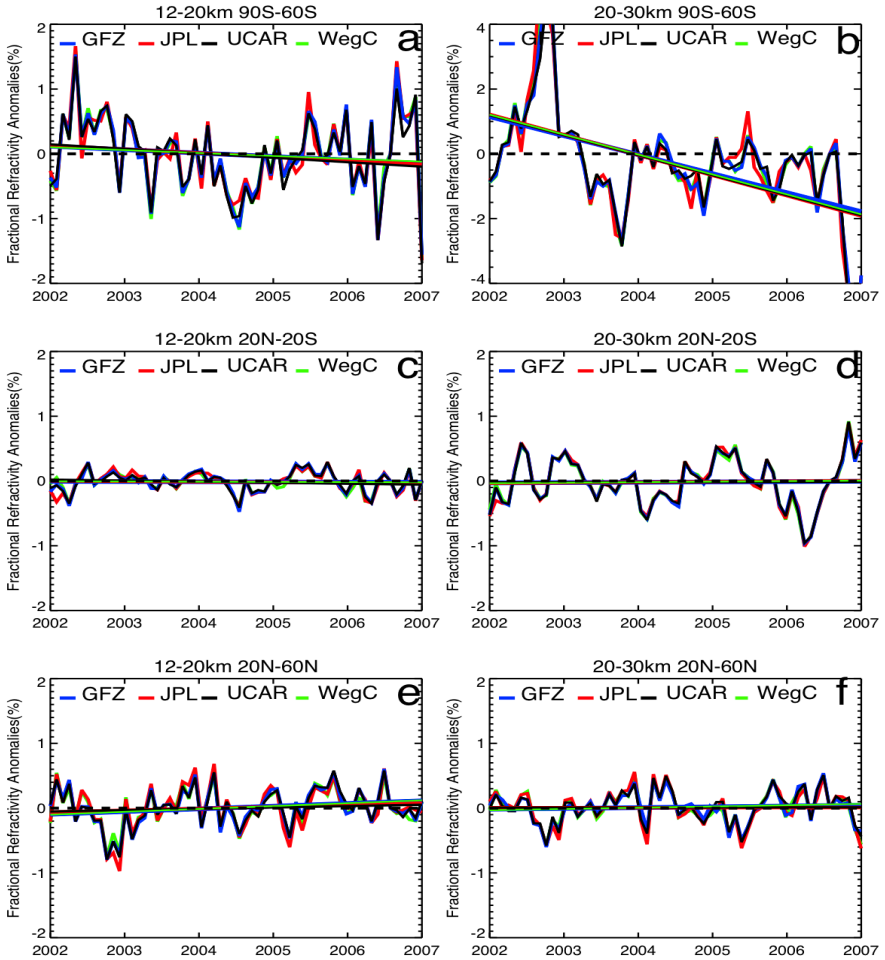


Background: SI Traceability, Robust Trends

Robust trends

Ho et al., *J. Geophys. Res.*, 2009.



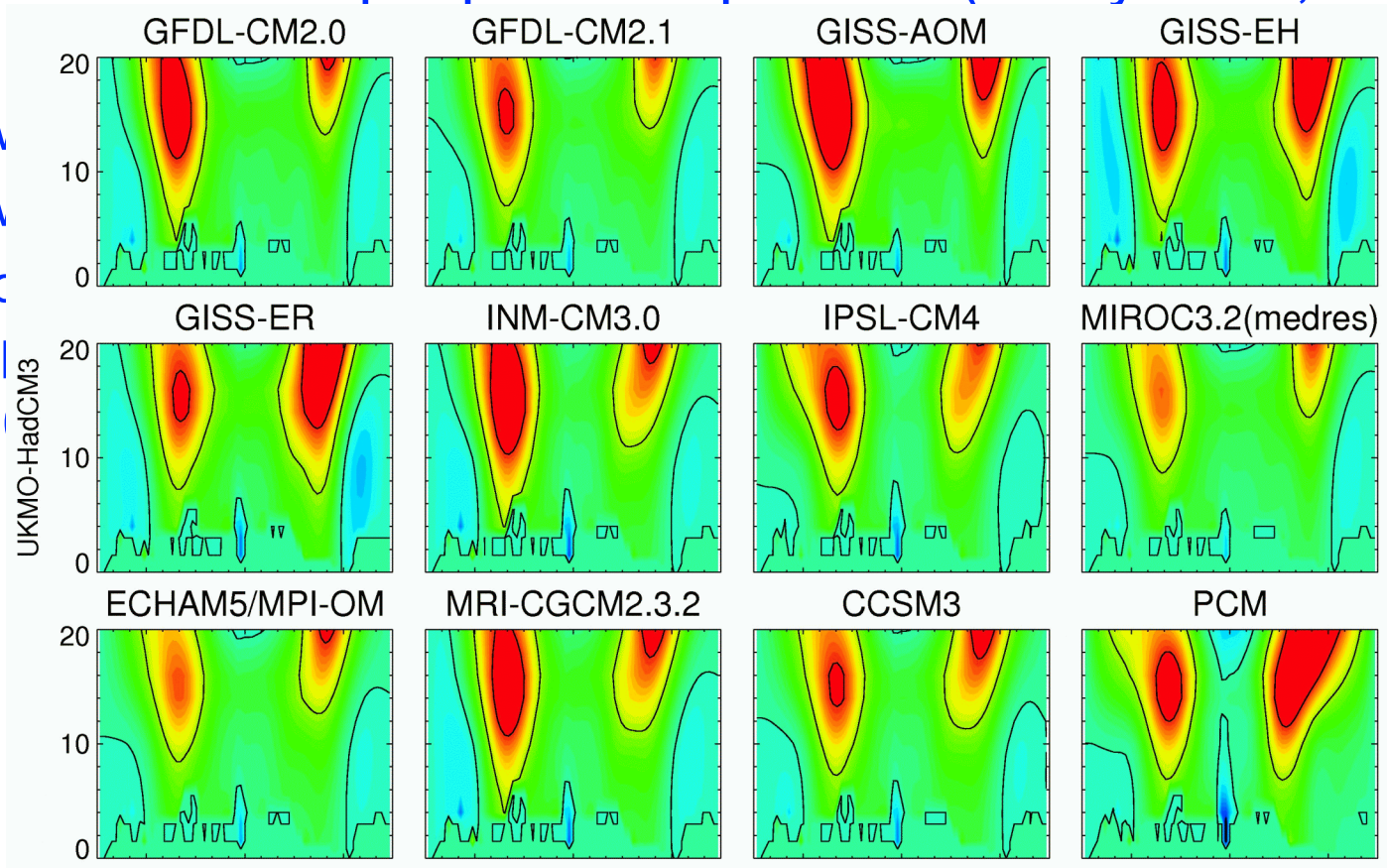


Background: Climate Monitoring

- Dry pressure & tropospheric expansion (Leroy et al., *JGR,* 2007)
  - Downward integral of refractivity in RO processing
  - Upward integral of temperature in atmosphere
  - Above mid-troposphere, same as pressure, geopotential
  - SNR 2 detection time of 10 years, as also in Ringer & Healy (2008)

Background: Climate Monitoring

- Dry pressure & tropospheric expansion (Leroy et al., *JGR,*
  - Dov
  - Upv
  - Abc
  - SNI (20



Optimal Detection: Inference

$$\mathbf{F} = \left(\Sigma_{\text{var}} + \Sigma_{d\mathbf{d}/d\alpha}\right)^{-1}\mathbf{S}\left[\overline{\mathbf{S}}^{T}\left(\Sigma_{\text{var}} + \Sigma_{d\mathbf{d}/d\alpha}\right)^{-1}\overline{\mathbf{S}}\right]^{-1}$$

$$\mathbf{s}_i = d\mathbf{g}/d\alpha_i, \quad \Sigma_{d\mathbf{d}/d\alpha} = \sum_{i,j}\left\langle \frac{d\alpha_i}{dt}\frac{d\alpha_j}{dt}\delta\mathbf{s}_i\delta\mathbf{s}_j^{T}\right\rangle_{\text{models}}$$

$$\frac{d\alpha}{dt} = \frac{d}{dt}\left(\mathbf{F}^{T}\mathbf{d}(t)\right)$$

Define scalar according to your interest—link regional trends to global data. Link any variable to arbitrary data.

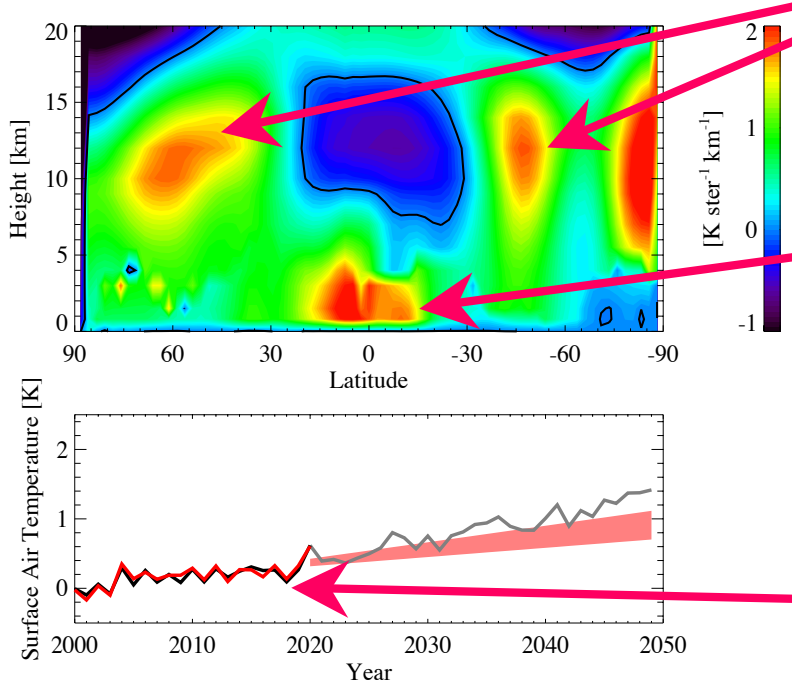
Physically robust—there is significant agreement between models that the indicator's trend is strongly related to the target scalar's trend, and

Quiet—they are associated with minimal naturally occurring inter-annual variability.

Leroy and Anderson, *J. Climate,* 2010.

Optimal Detection: Inference (Leroy, OPAC-3)

α = global average surface air temperature, $\boldsymbol{d}$ = GPS RO dry pressure [height]



Poleward migration of jet streams

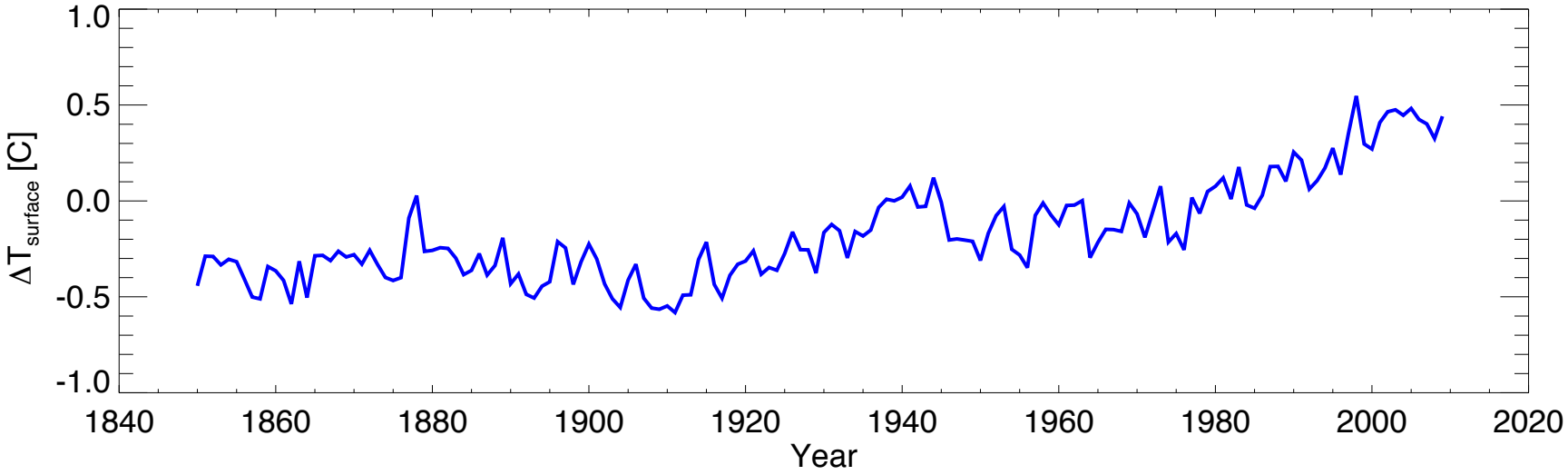
Increased tropical humidity

Near perfect tracking of global average surface air temperature

Strategy

- Lon-lat grid in upper troposphere
  - Avoid wet-dry ambiguity
  - Thermal expansion of troposphere strongly related to surface air temperature trends
  - Potential optimization from spatial pattern
- Use two wholly independent retrieval systems
- Map data using Bayesian interpolation
  - Multi-day bins to resolve spatial structures; longer for CHAMP; shorter for COSMIC
  - Monthly climatologies
- Error analysis by comparison to ERA Interim as truth

The Record


1.0
0.5
0.0
-0.5
-1.0
ΔT surface [C]
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year

Processing: JPL and Harvard (MEG)

Jet Propulsion Laboratory (Hajj et al. 2002, Ho et al. 2009)

- GIPSY orbits; double differencing
- Backpropagation, canonical transform (type 1) below 30 km
- Smoothing: 1km above 20km, 200m below.
- Exponential bending angle extrapolation above 50km; *T* from ECMWF at 40km

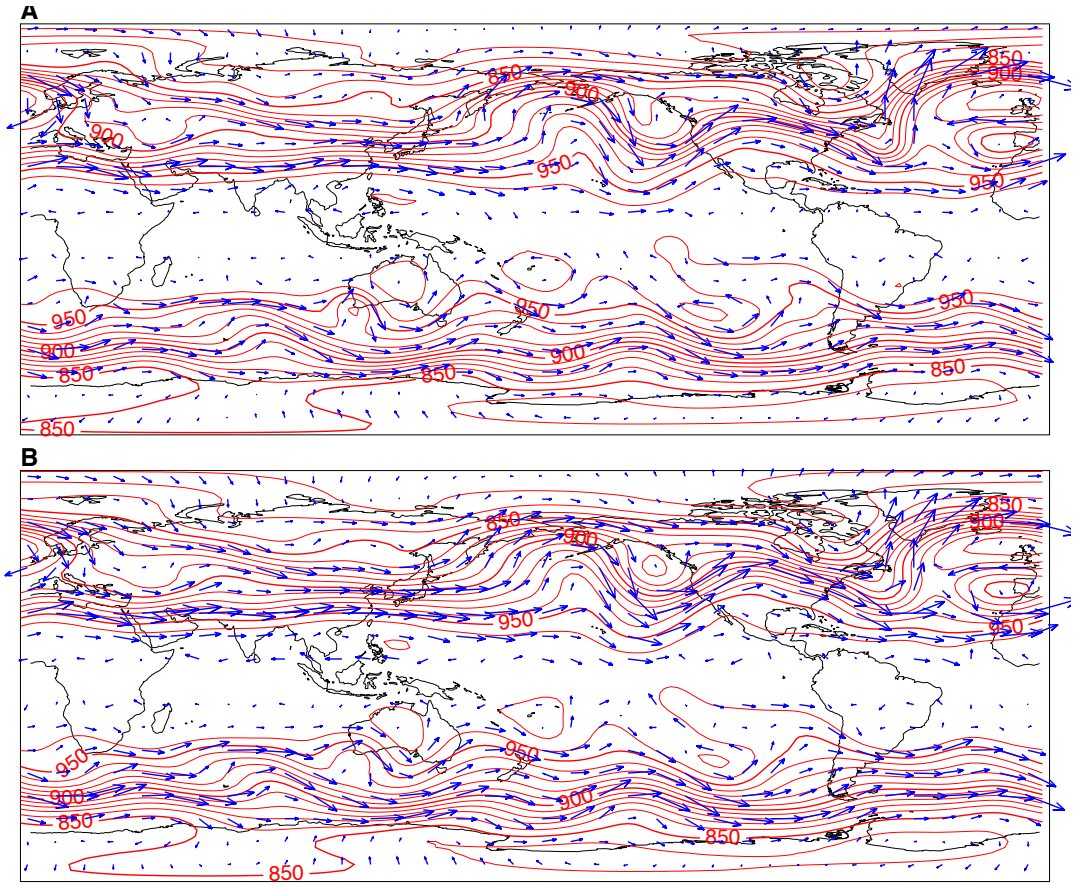
Harvard/Gorbunov (Gorbunov et al. 2010)

- UCAR calibration
- Canonical transform (type 2)
- Smoothing: 200m
- Scaled MSIS background, to match ECMWF temperature; *p*=0 at 150km

Mapping: Bayesian Interpolation

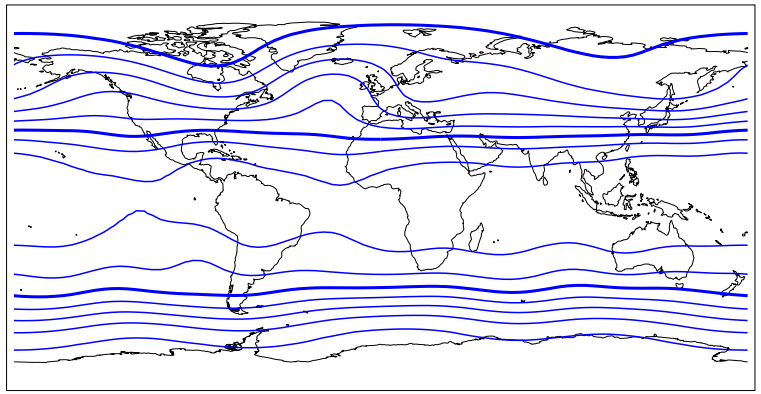
- Fit using a spherical harmonic basis without over-fitting
- Find optimal binning time, optimal penalty
- Find effective horizontal resolution

Leroy (1997), Leroy & Ao (in progress)

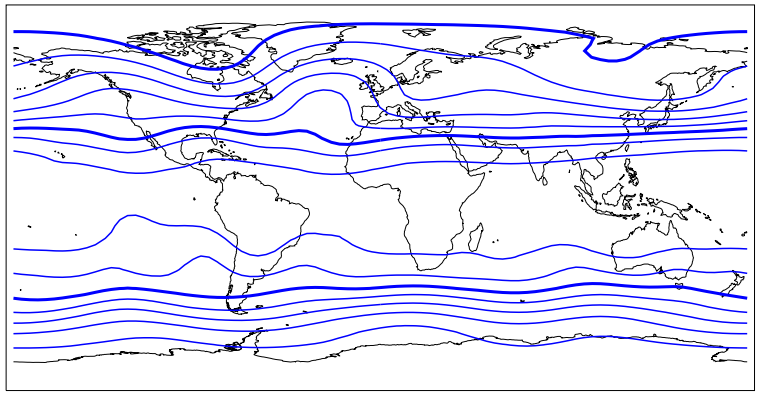


A Quick Check

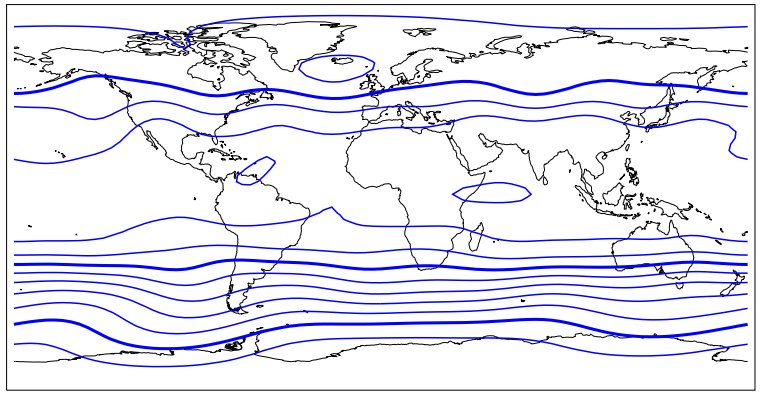
Occultations, February, 2005



ERA Interim, February, 2005



Occultations, July, 2009



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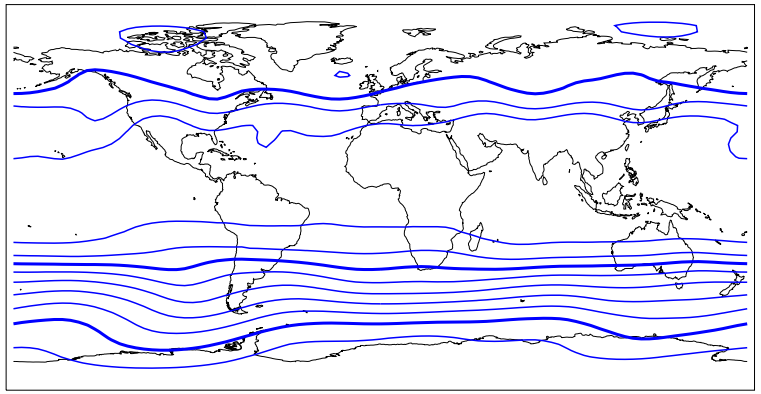
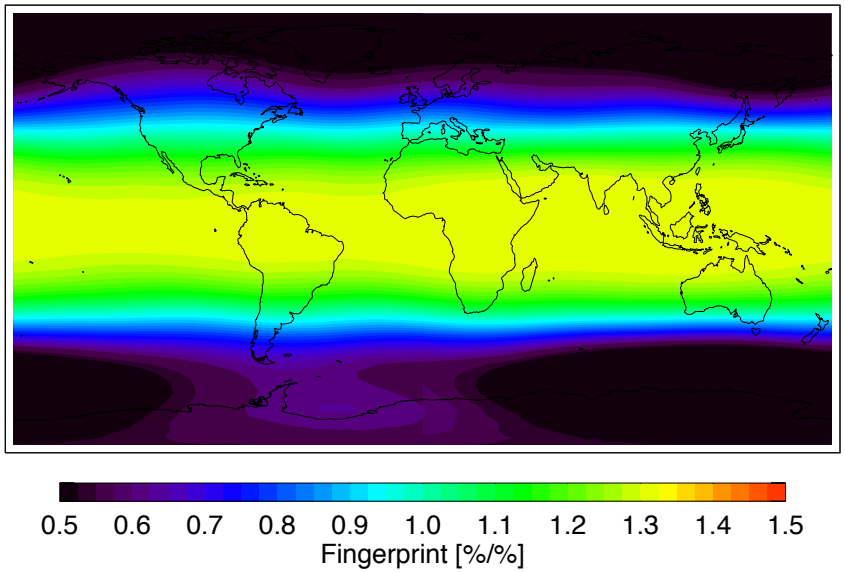


200m contour interval

Log Dry Pressure at 20 km (JPL)



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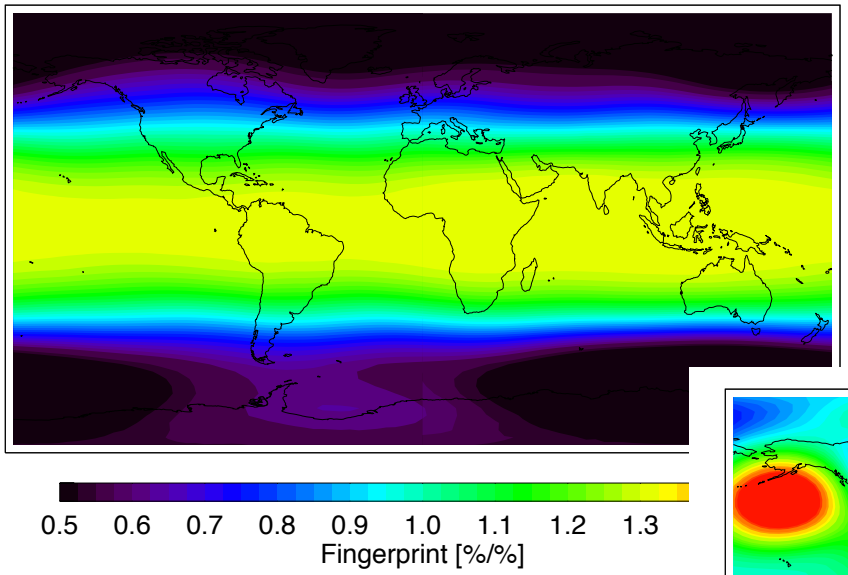
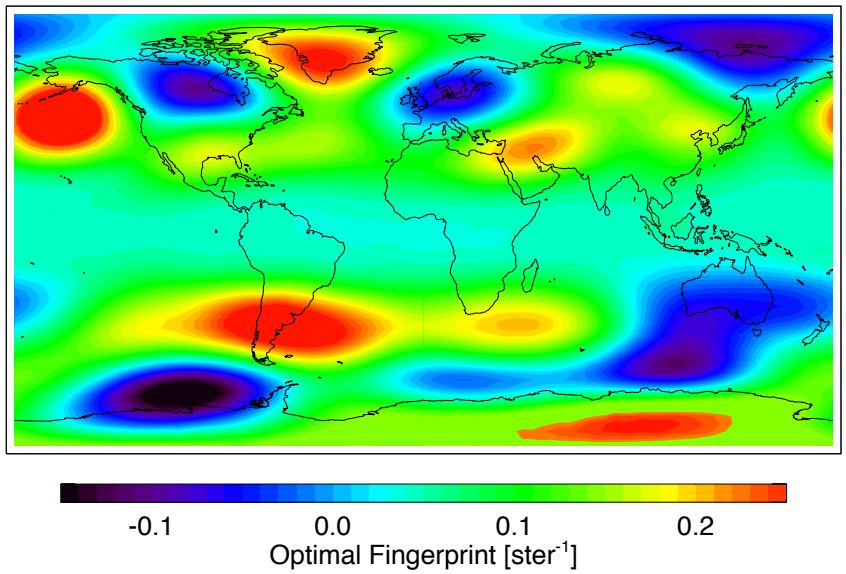
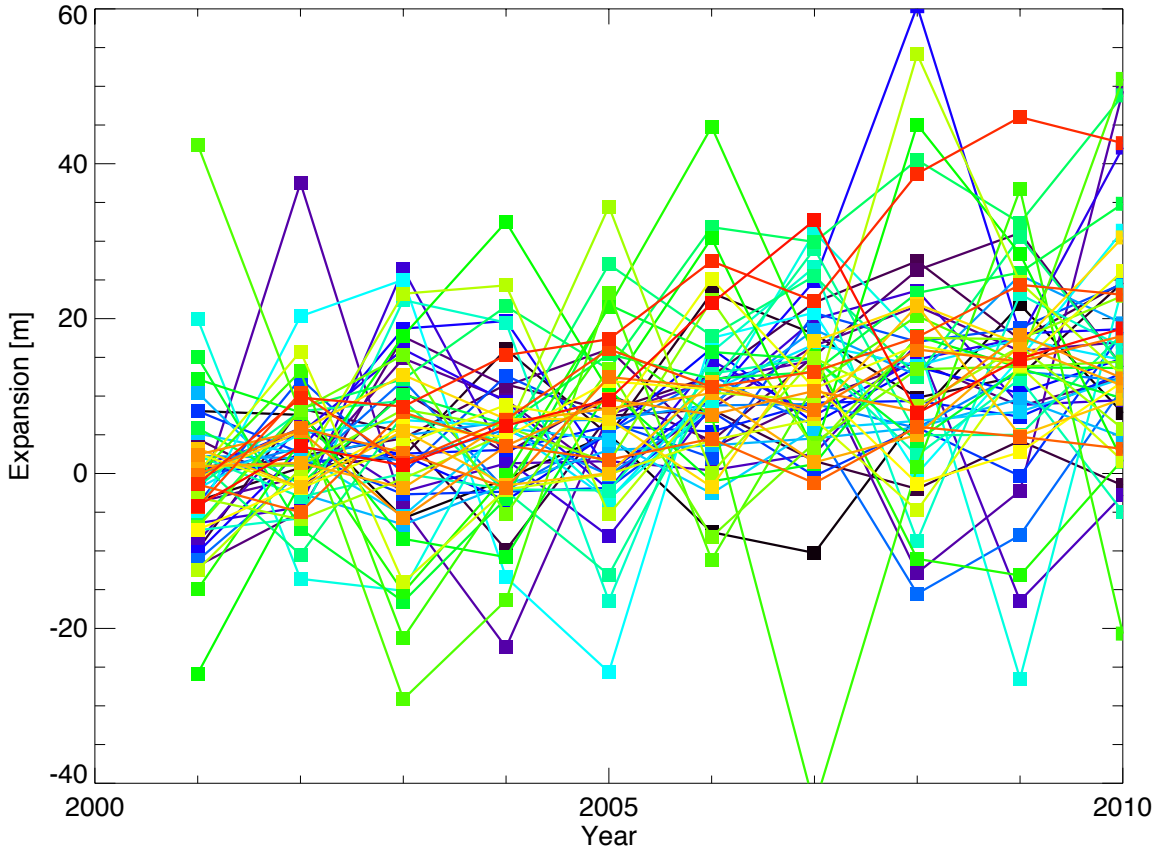




Log Dry Pressure: Optimal Detection



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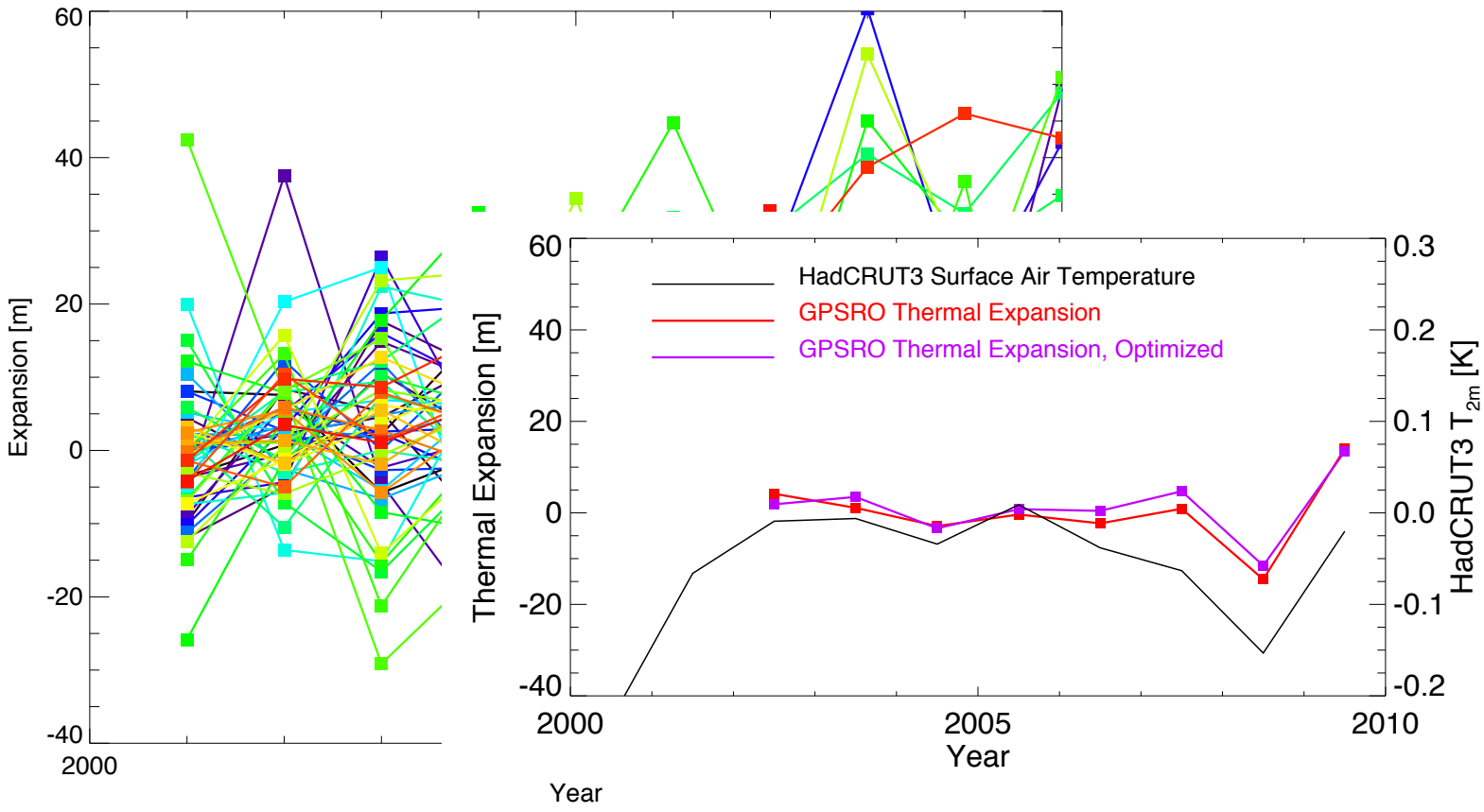
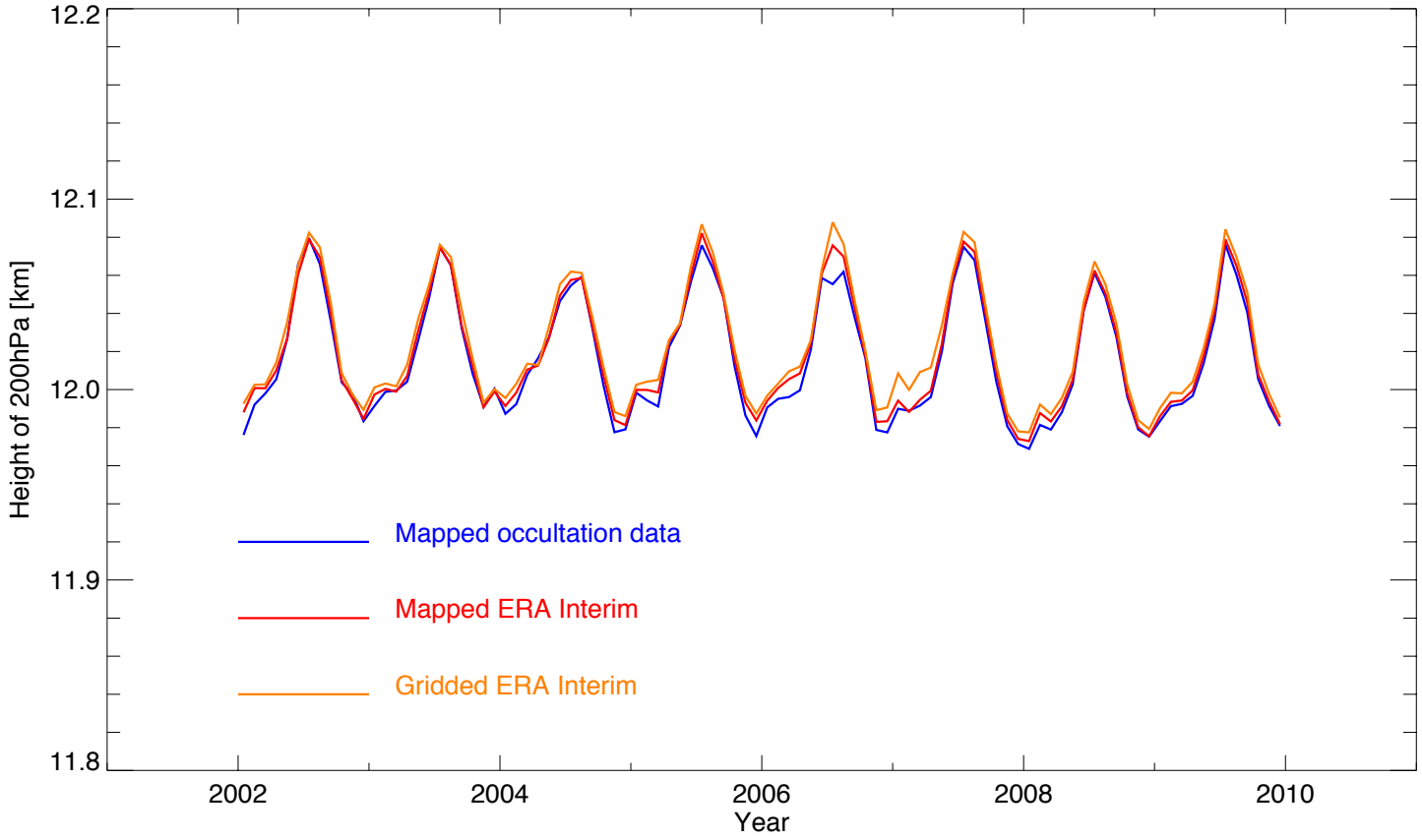
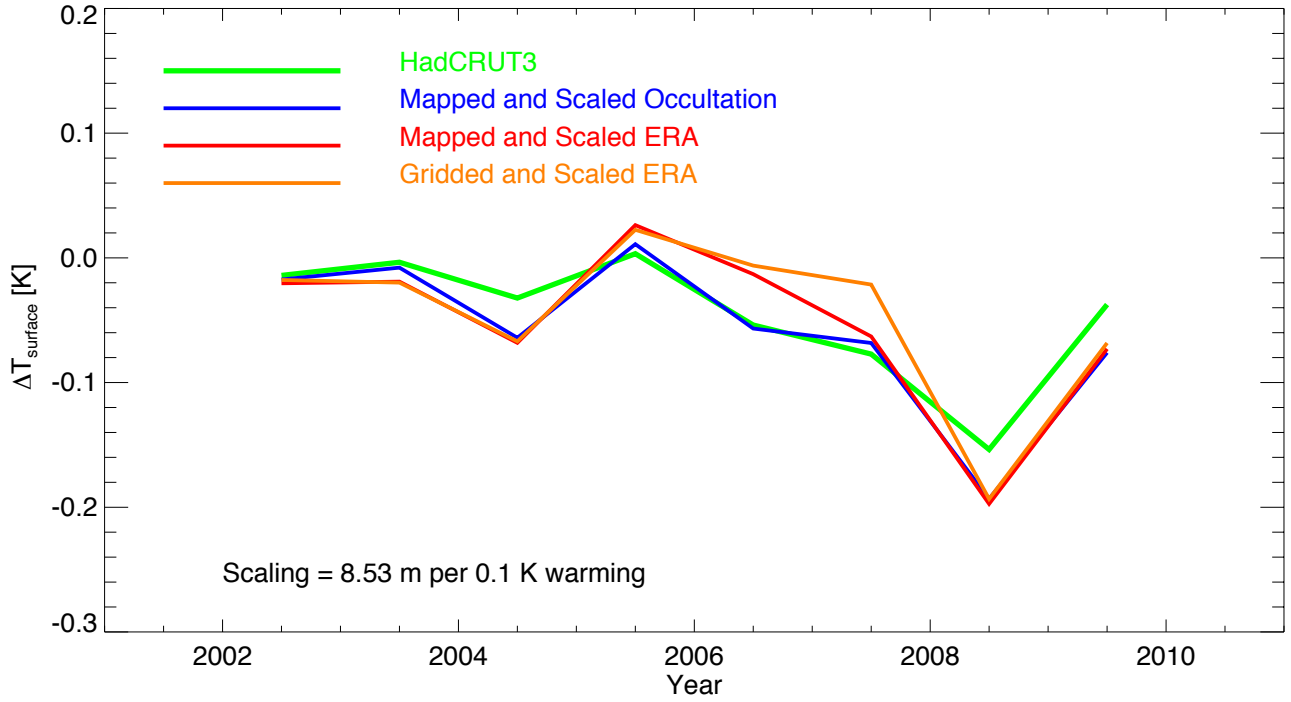


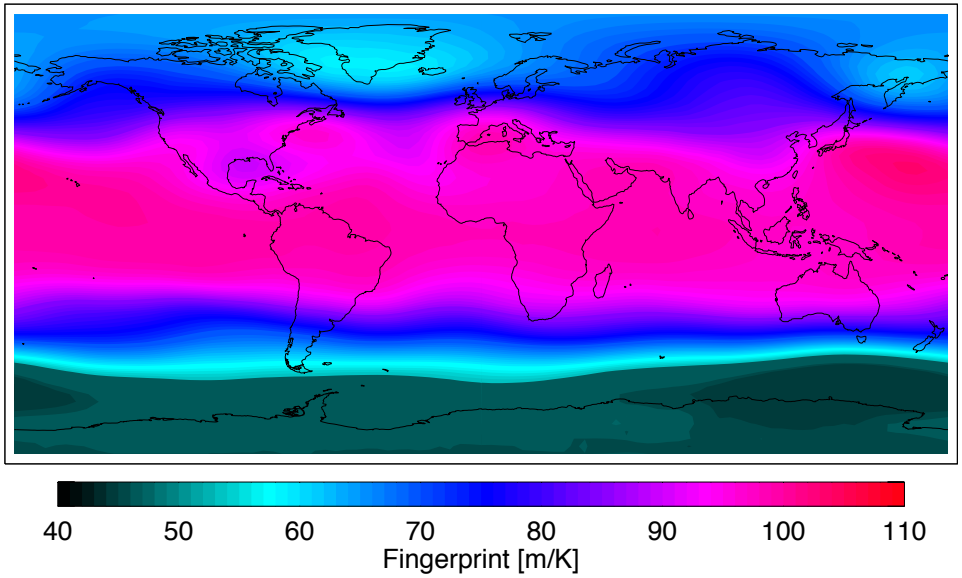
Tropospheric Expansion (Harvard)



Inference by Scaling



Tropospheric Expansion Fingerprint



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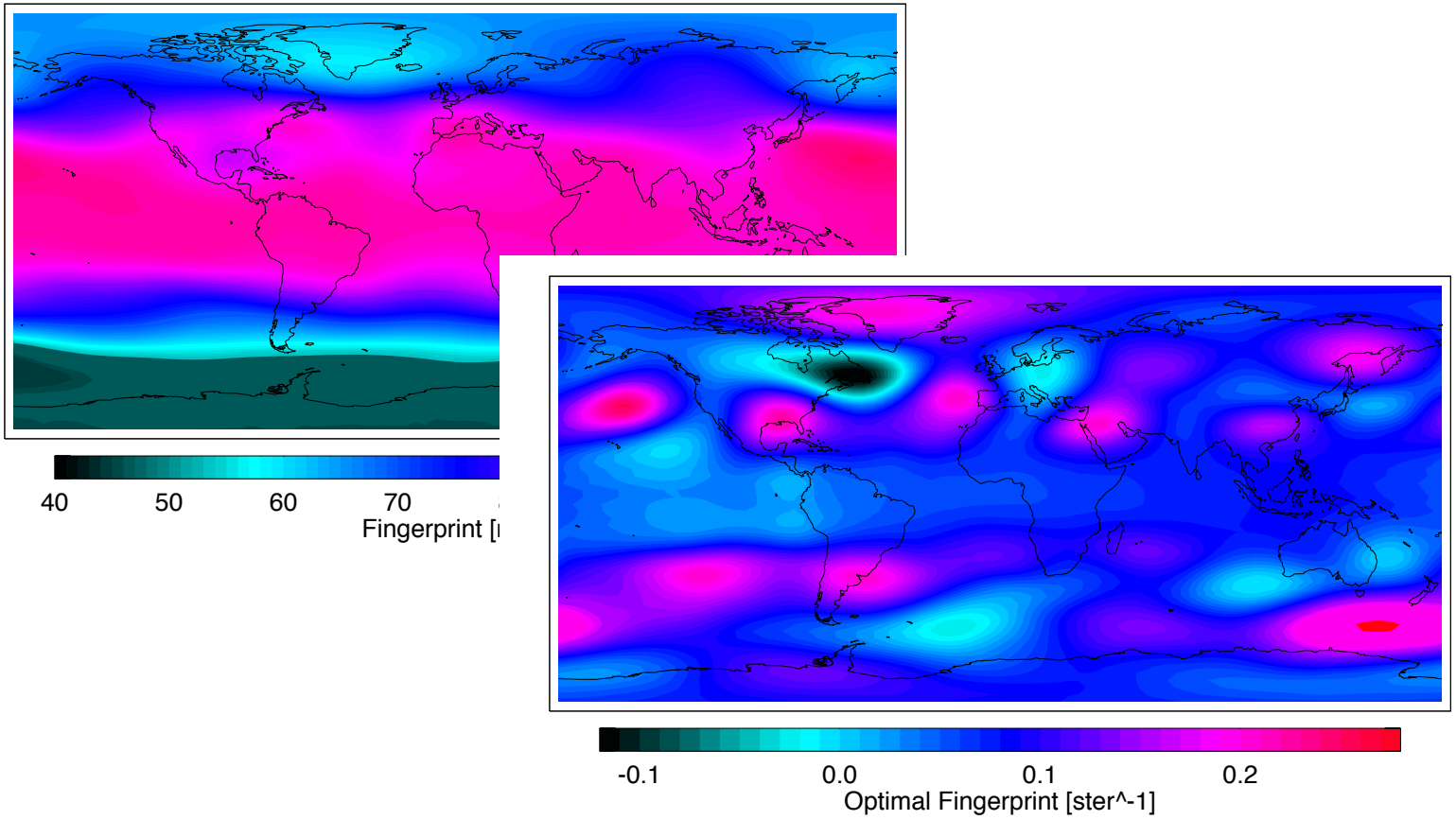
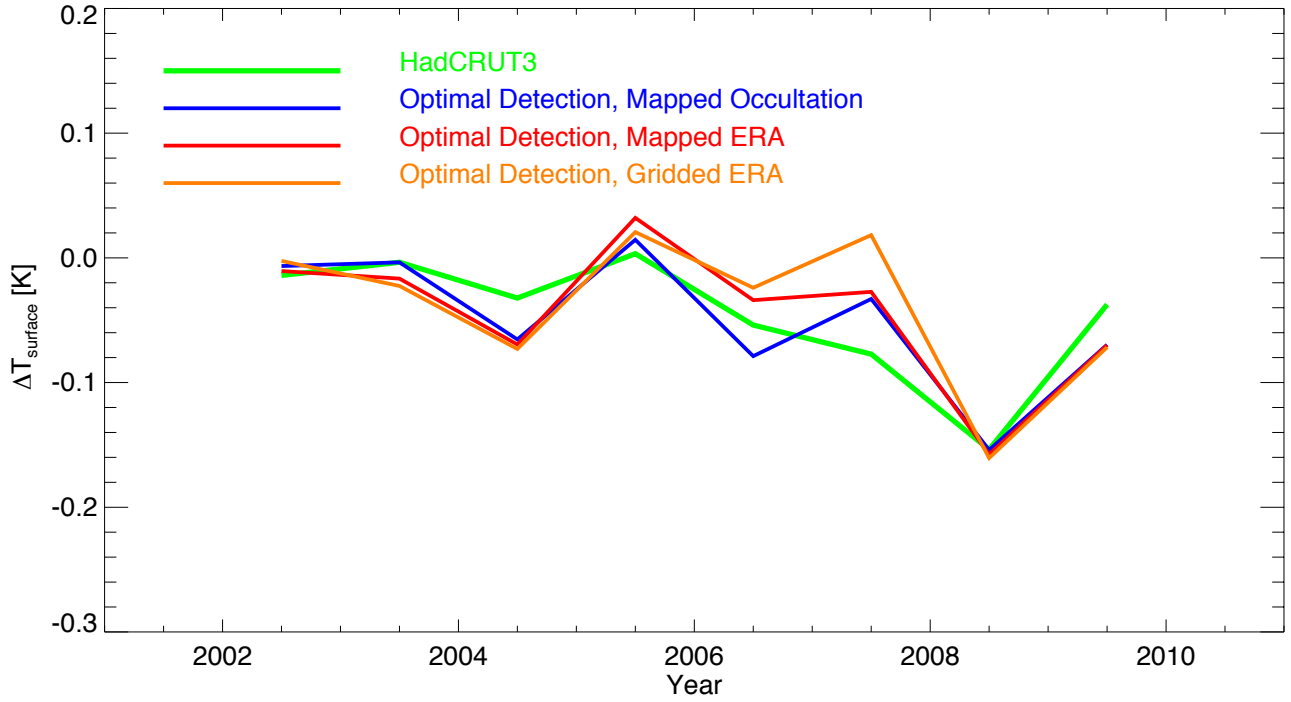


Inferring Temperature Change



Summary

- No statistically significant trend over CHAMP-COSMIC time era
- From dry pressure at 20 km, indication that surface air record steadily biasing negative over last three years
- From height at 200 hPa, no indication of bias
- No optimization to be had in radio occultation data

- Possible over-fitting in Bayesian mapping and problems in winter; still subject to testing
- Perform parallel studies, JPL and Harvard
- Still possible to test relationship of surface air temperature anomaly with radio occultation anomaly to address water vapor and lapse rate feedbacks