Towards understanding the variability and trend in the radiation energy budget

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Acknowledgements:
John Dykema, Daniel Feldman, Seiji Kato,
Stephen Leroy, Hank Revercomb

CLARREO workshop, LASP, Boulder
2012-10-16

Transient variations in OLR

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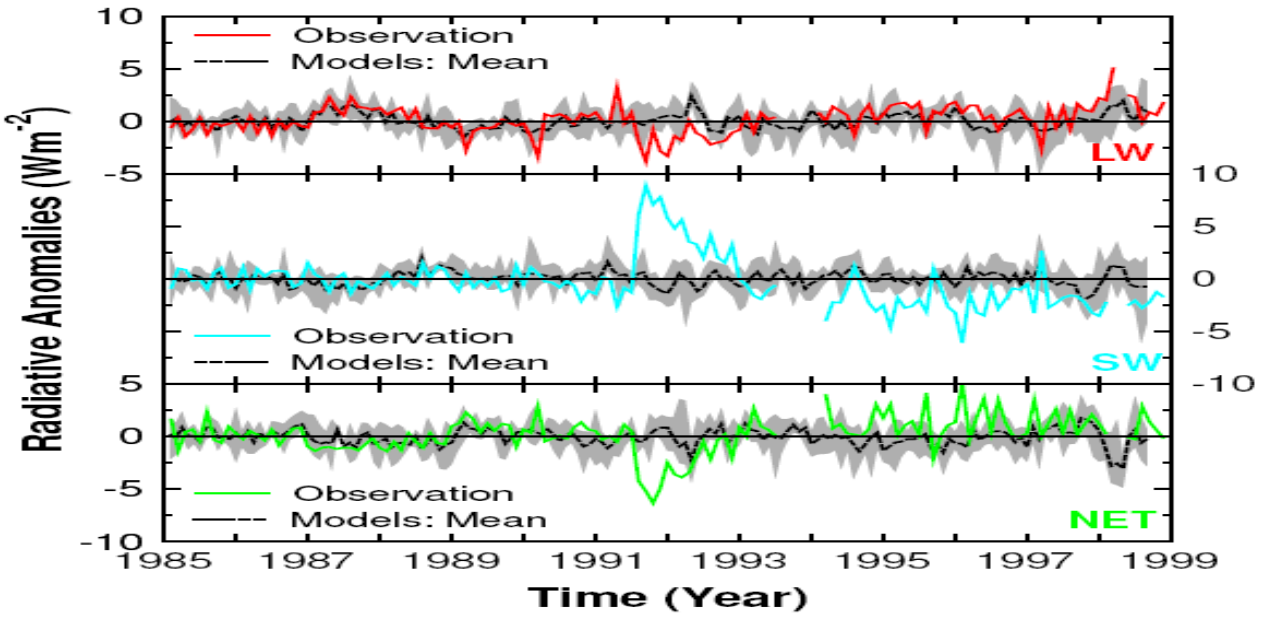
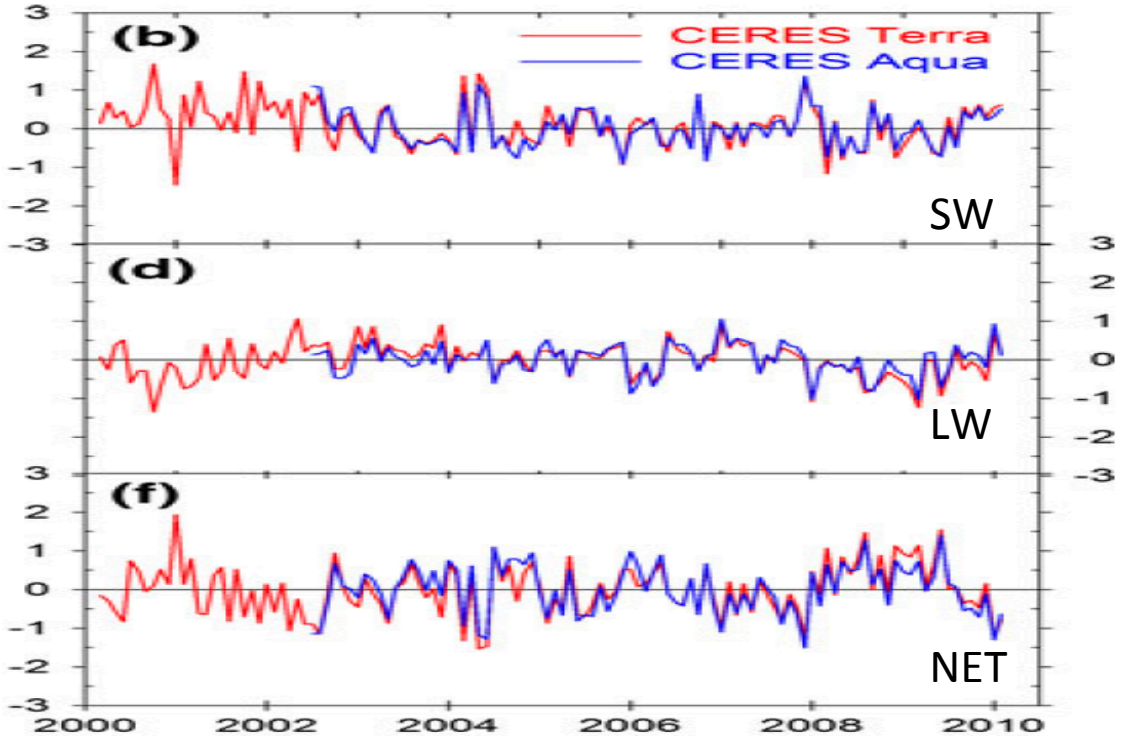
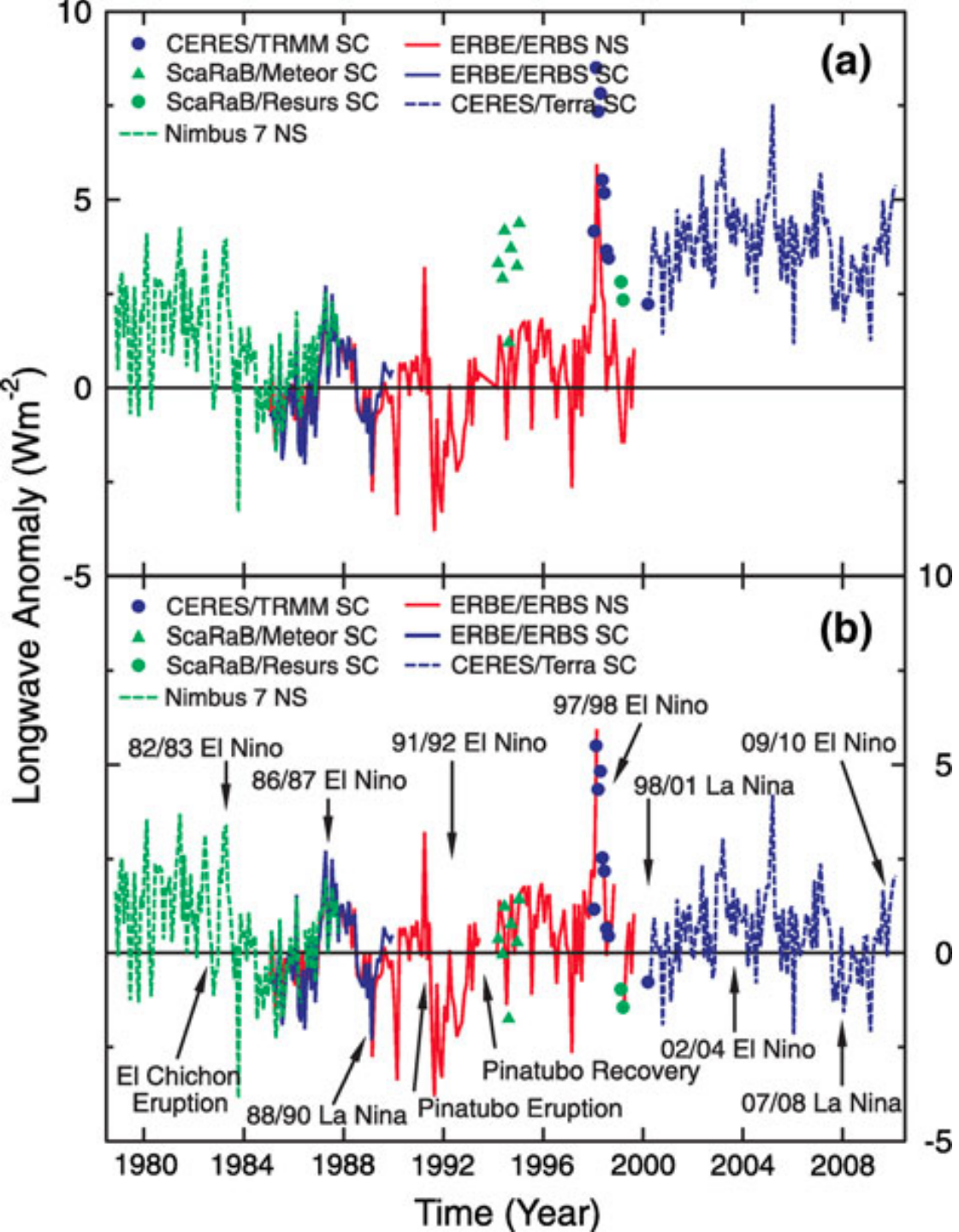


Observed OLR time series: lack of long-term trend

ERBE/ERBS
[Wong et al. 2006]



CERES
[Loeb et al. 2012]

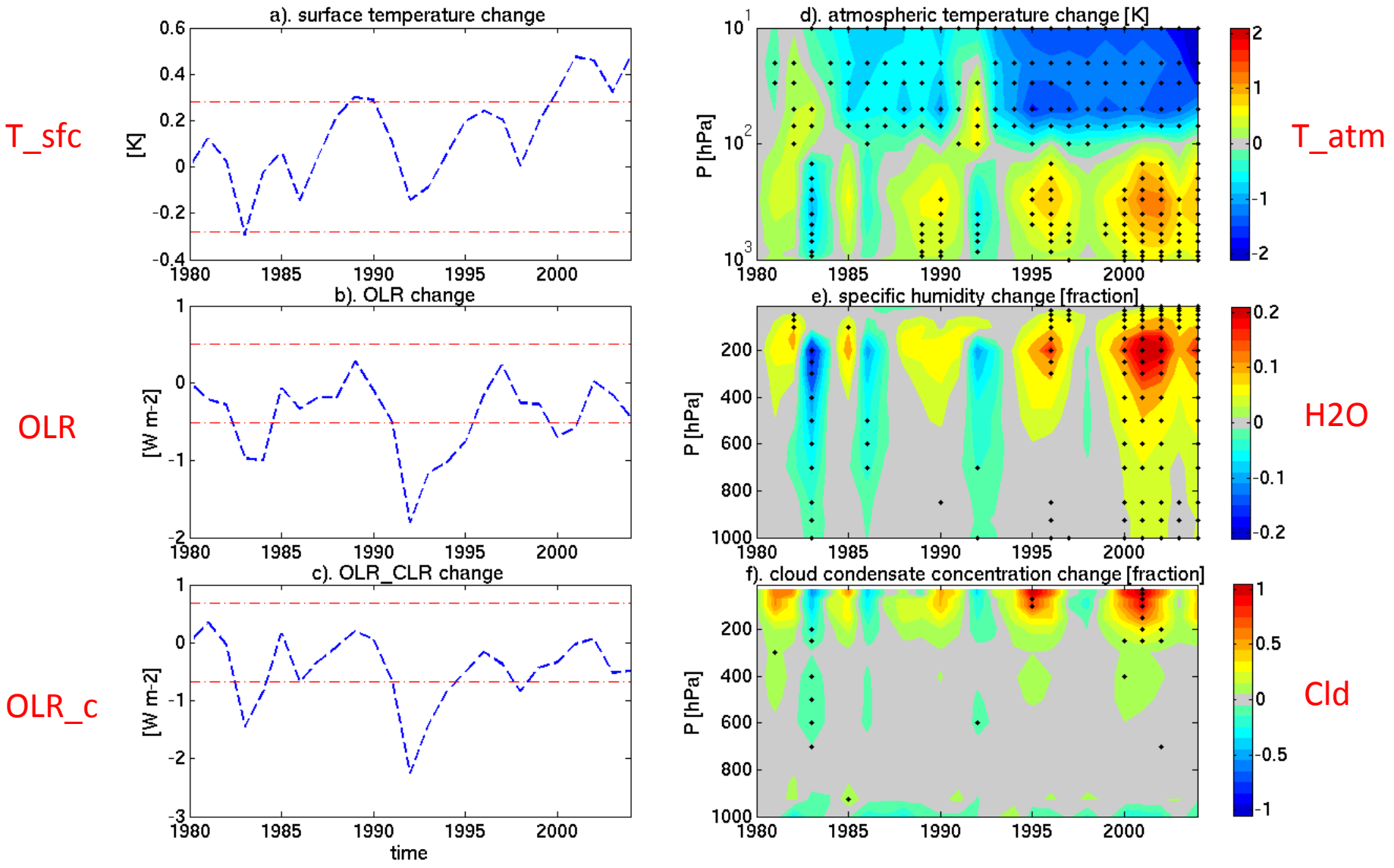


Inter-instrument biases

20S/N mean
[Loeb et al 2012]

No OLR trend also in some GCMs

(e.g., GFDL CM2, Huang&Ramaswamy 2009)

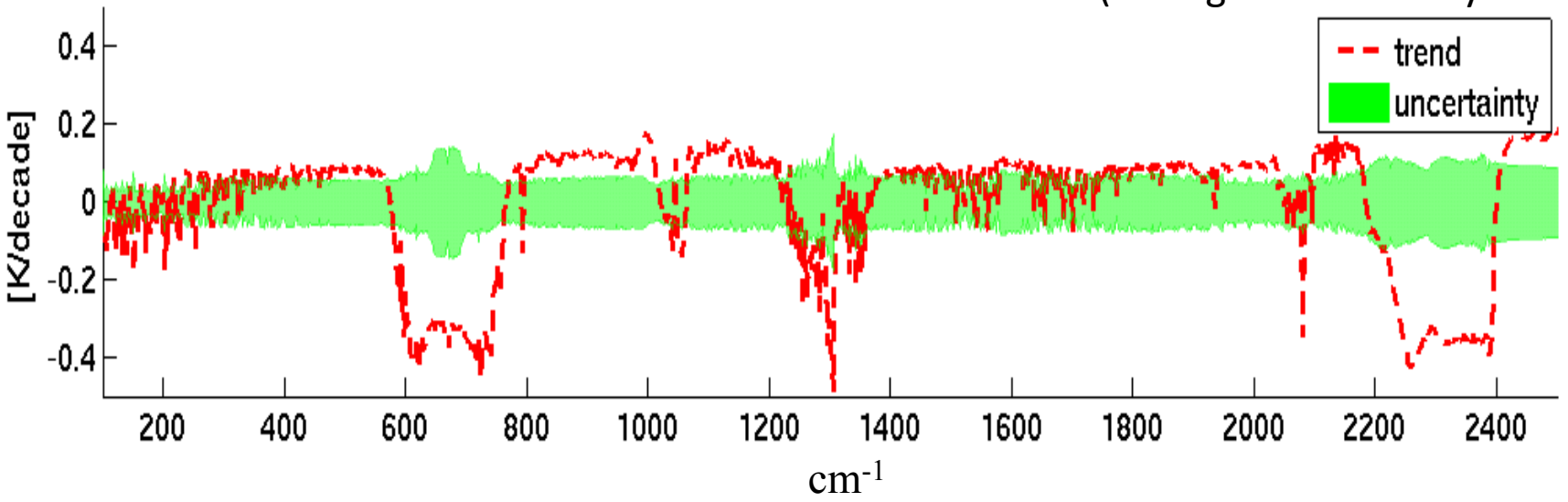


Blue lines and color contours: Evolution of the variables in the GCM simulation

Red dotted lines and black dots: anomaly (relative to 1980) larger than 3 times the Nat. Var.

Linear trends in radiances

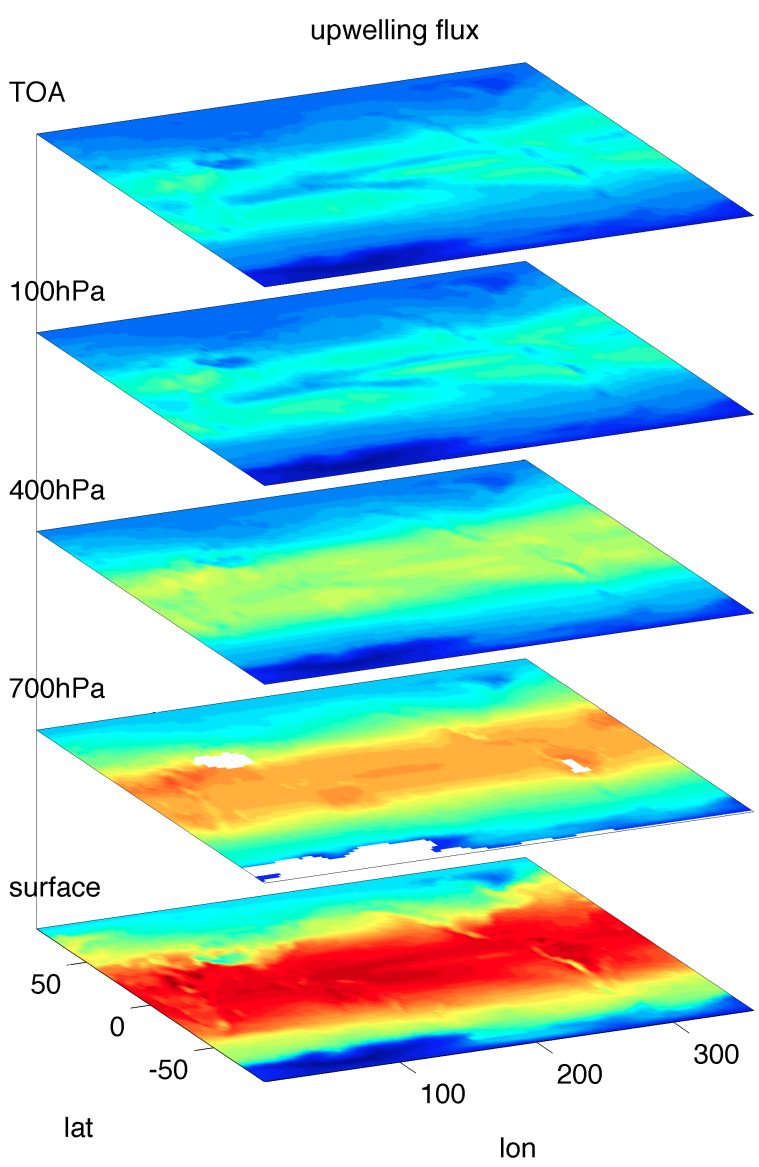
(Huang&Ramaswamy 2009)

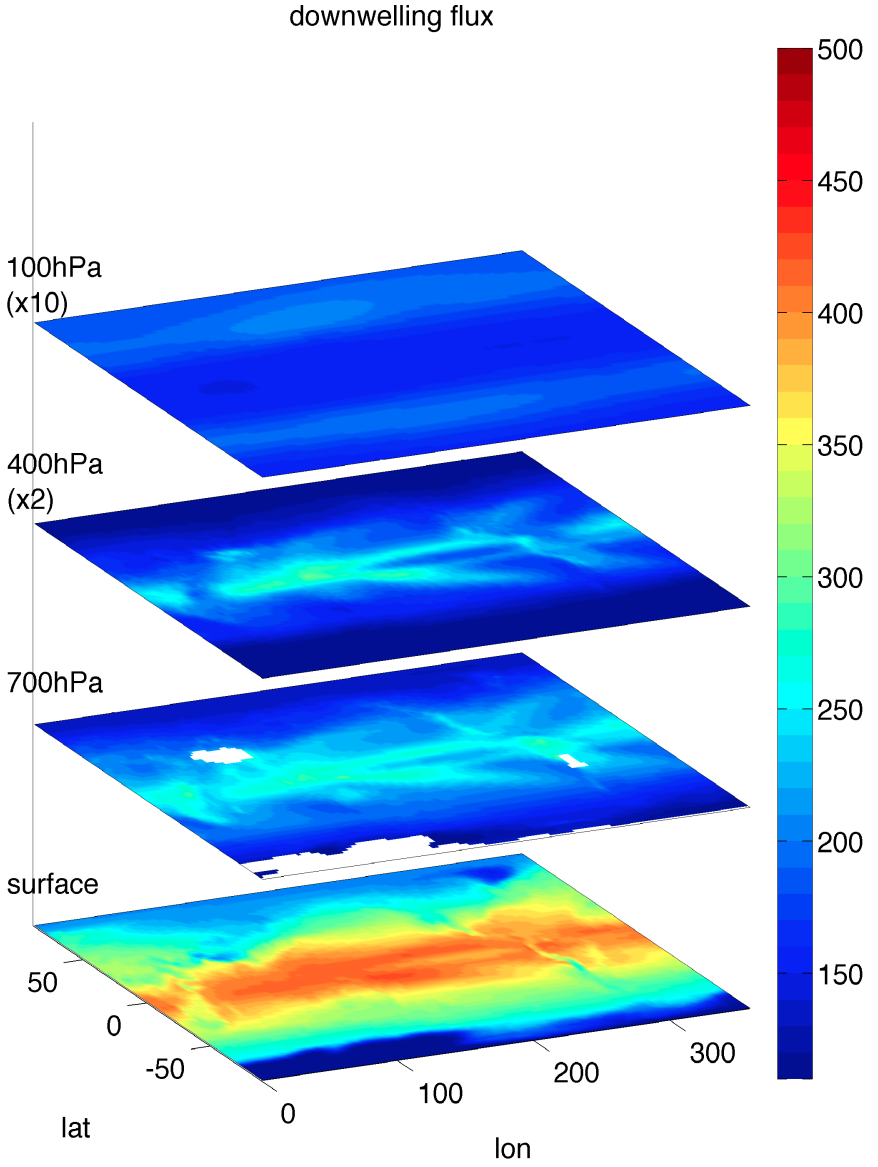


Spectral compensations result in OLR conservation:
Forcing (CO_2) – Warming (Window)
Feedback (H_2O) – Feedback (Temperature)

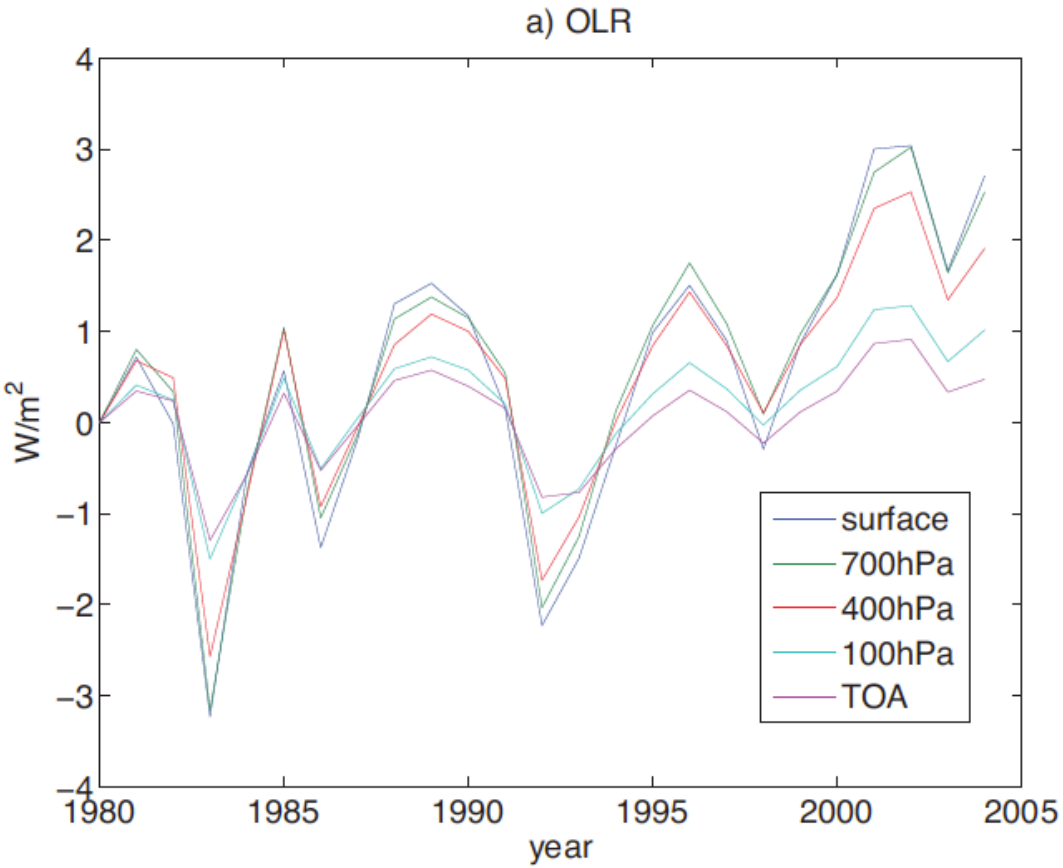
Vertical perspective

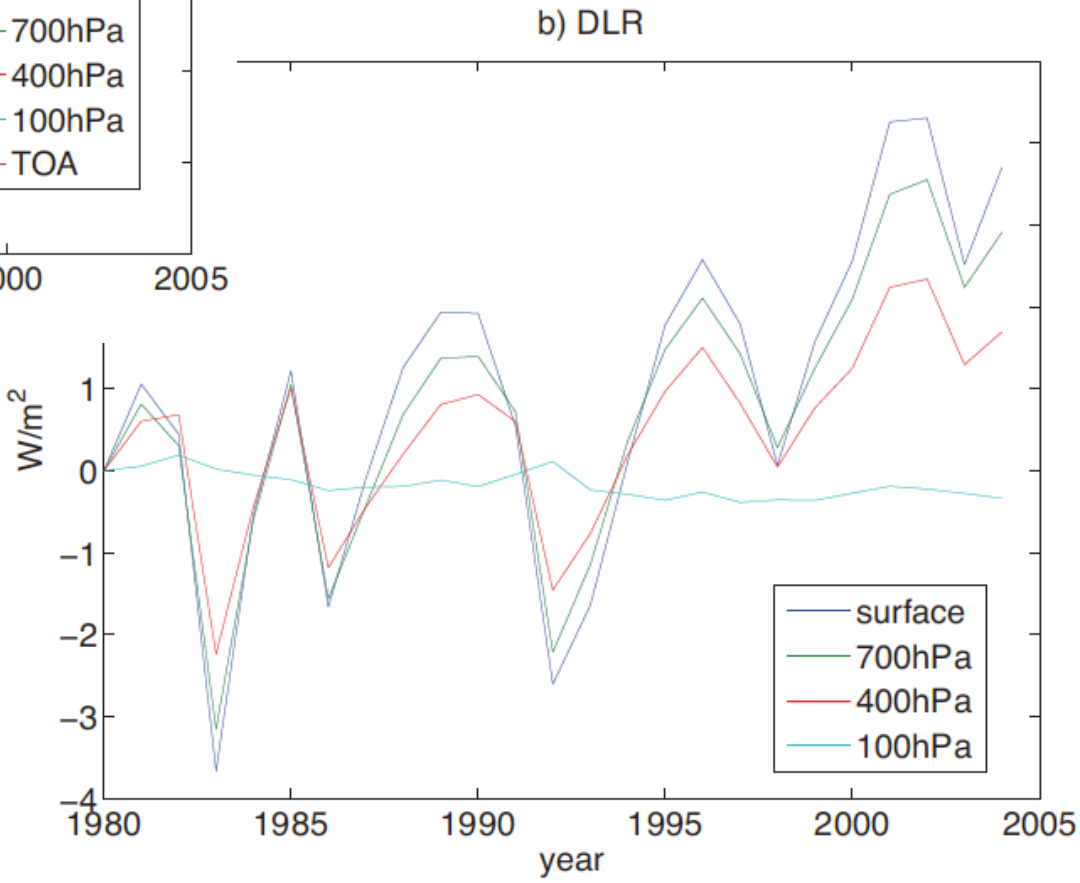
A simulated climatology of height-dependent atmos radiation [Huang 2012a]





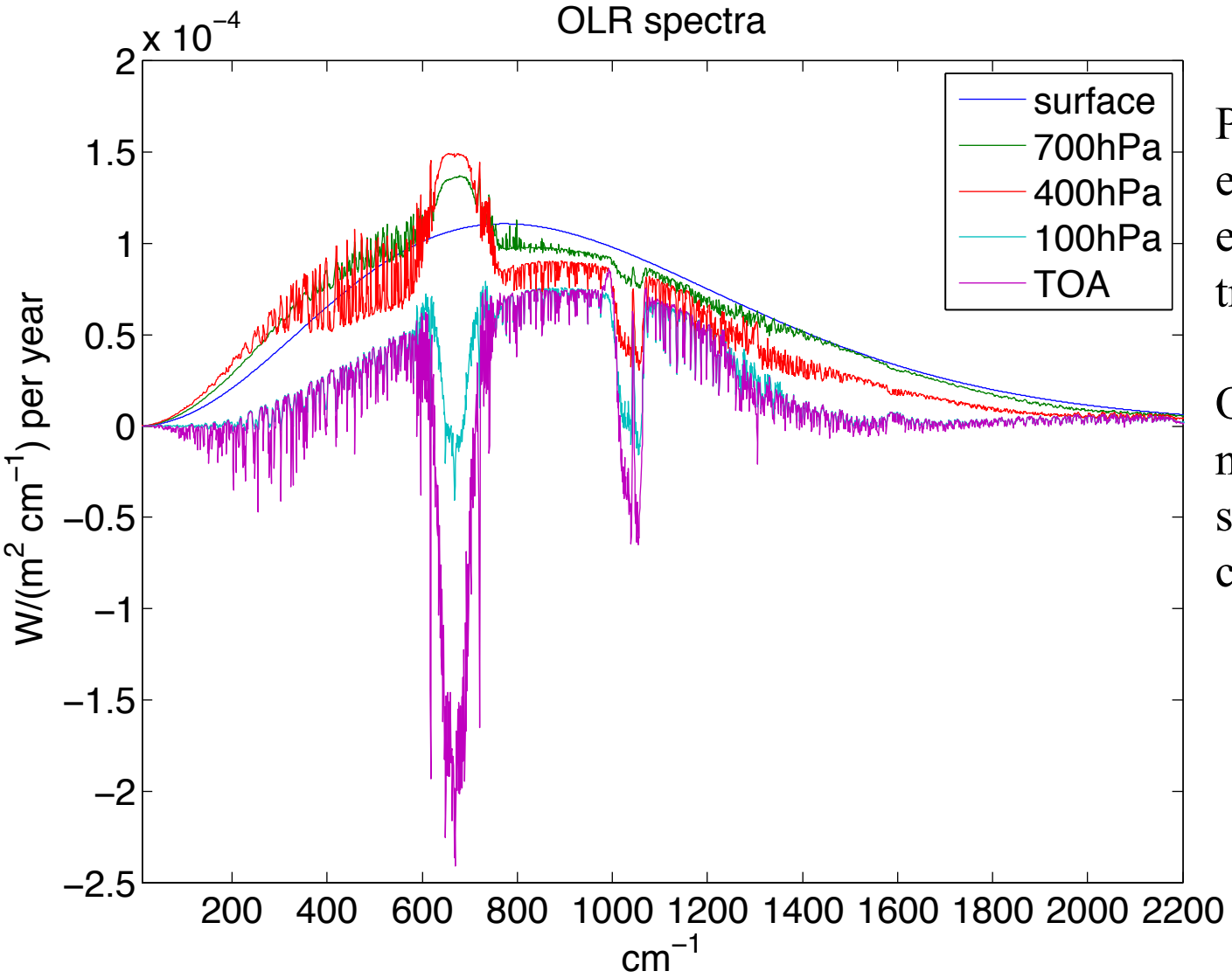
OLR and DLR time series





While R^+ at all surf/tropos levels increases, OLR largely conserves.
While R^- at all surf/tropos levels increases, stratos R^- decreases.

Vertical + spectral perspectives



Linear trends in global mean up-welling longwave radiation spectra

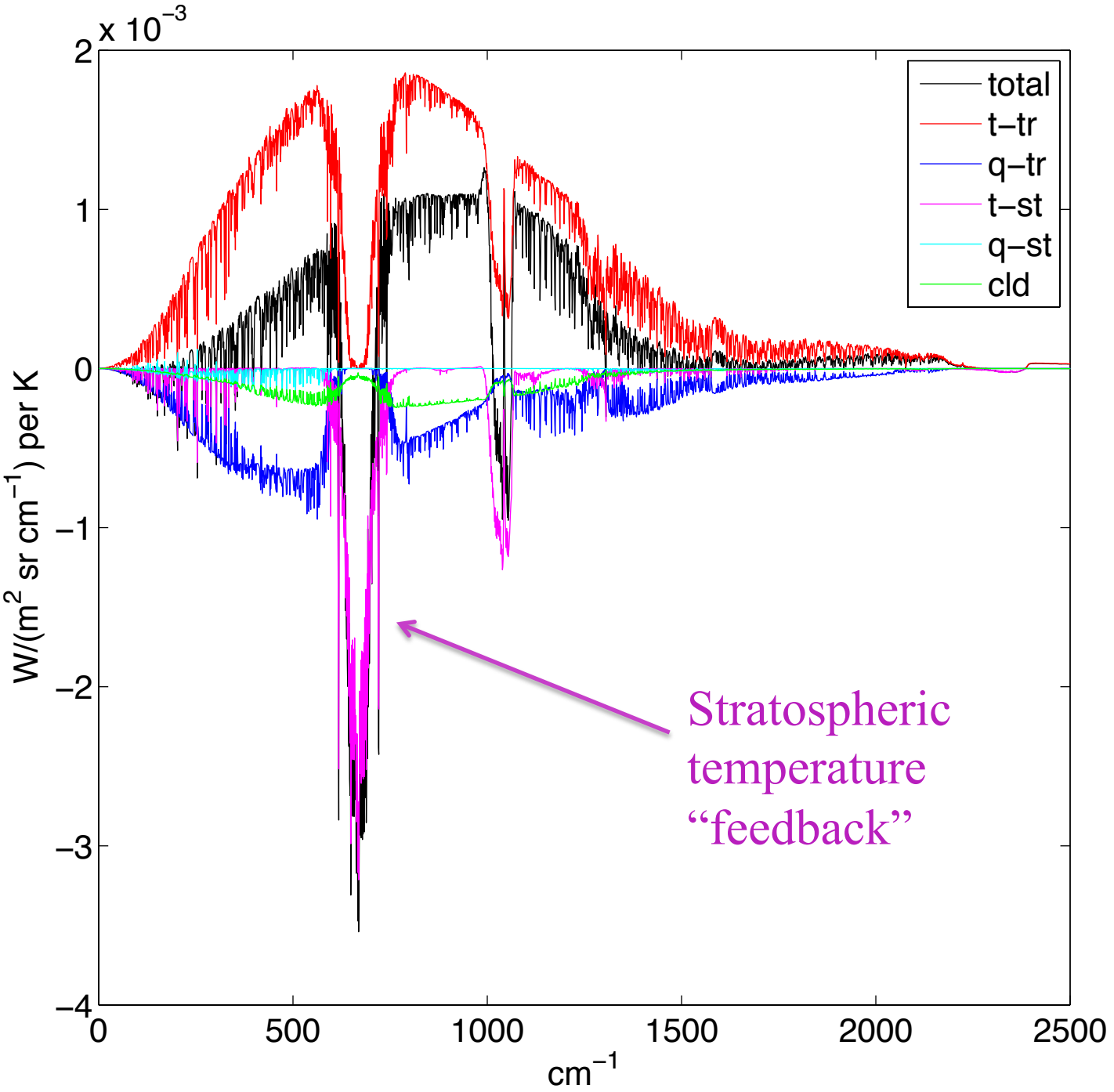
Planck effect exceeds opacity effect in the troposphere.

OLR conservation not possible without stratospheric contribution.

Longwave spectral feedbacks

Non-cloud feedbacks estimated by using a priori calculated spectral kernels;

Cloud feedback estimated by cloud-forcing adjustment technique [Soden et al 2008]

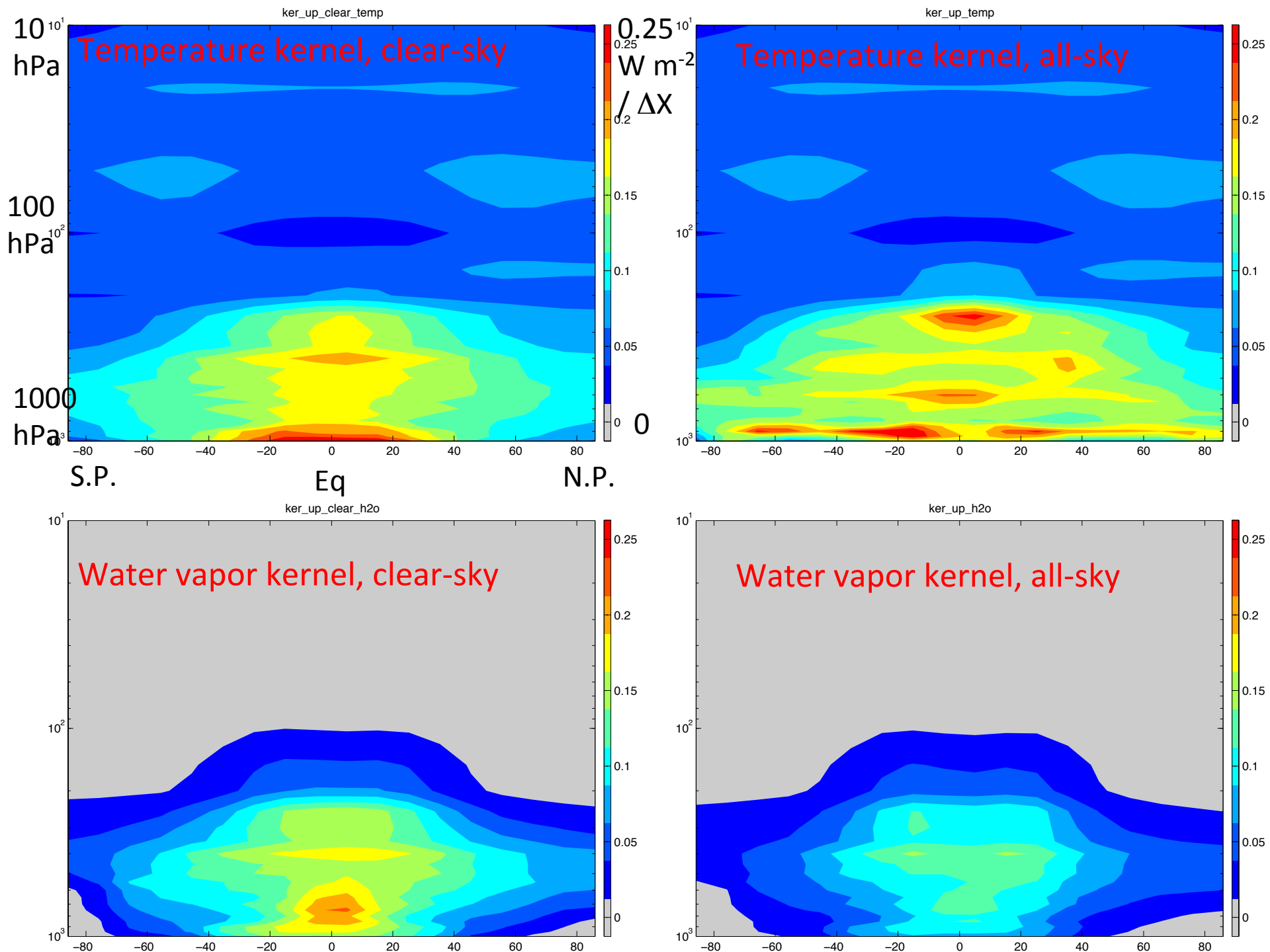


Spectral kernels

- CM2 atmosphere
- PRP done globally and 3-hourly for 1 year then monthly averaged to obtain: K(month,vertical-level, latitude,longitude,wavenumber)
- Temp: +1 K

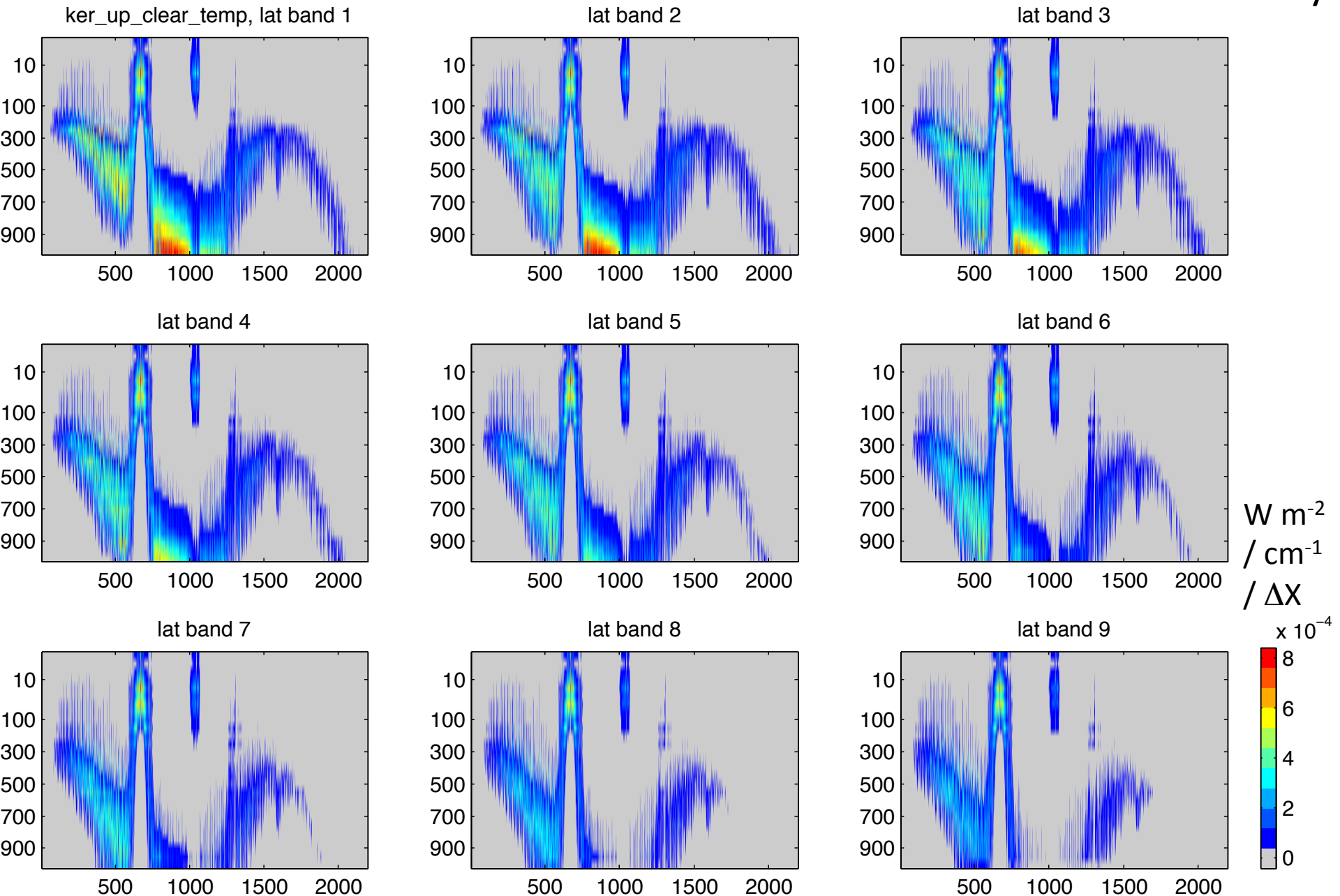
  H2O: specific humidity +10%

  (Cloud fraction/liquid/ice concentration: +10%)


ker_up_clear_temp
Temperature kernel, clear-sky
ker_up_temp
Temperature kernel, all-sky
0.25
W m-2
/ Δx
0
10 hPa
100 hPa
1000 hPa
S.P.
Eq
N.P.
ker_up_clear_h2o
Water vapor kernel, clear-sky
ker_up_h2o
Water vapor kernel, all-sky

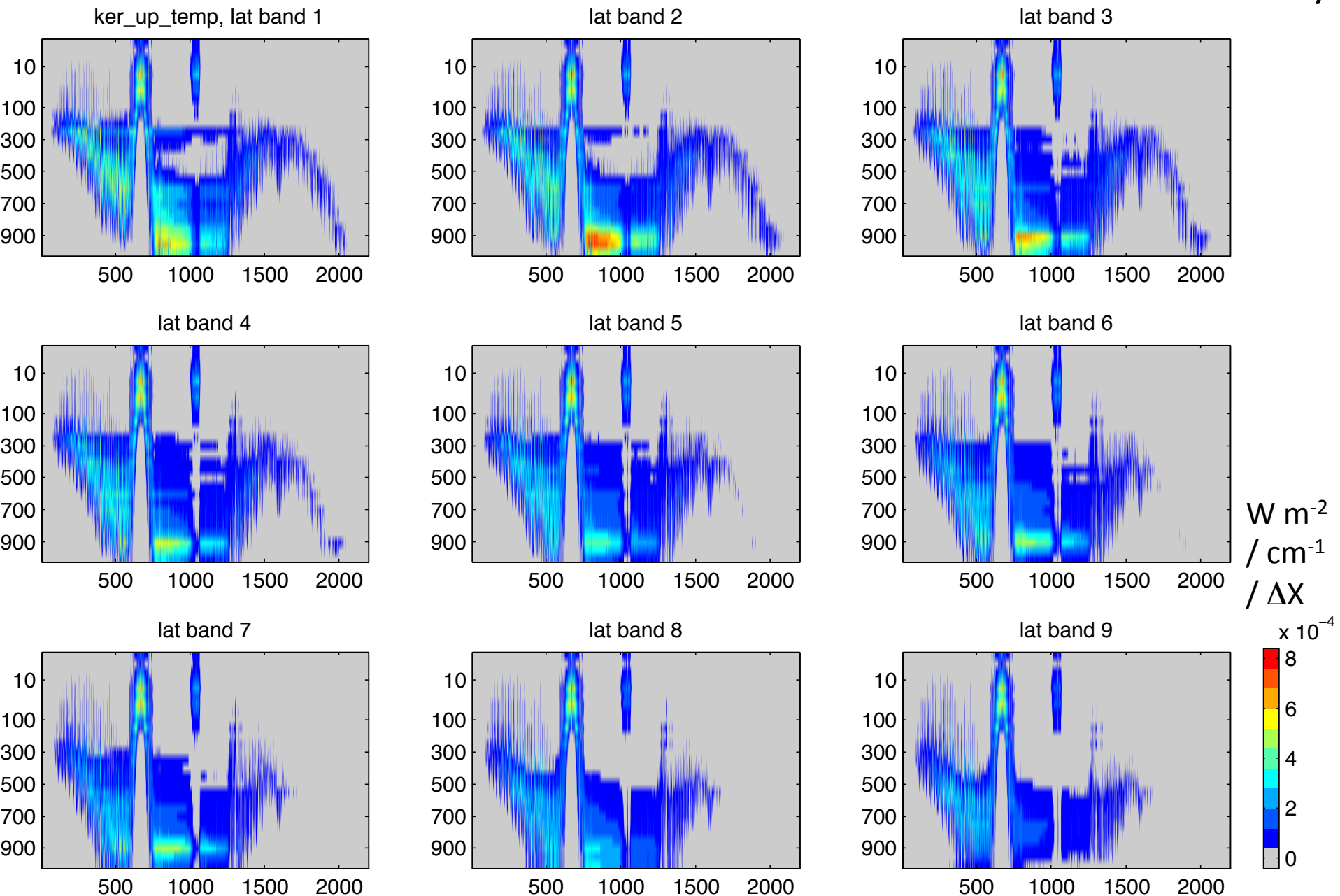
Zonal mean (equa. to pole) spectral kernels

temperature
clear-sky



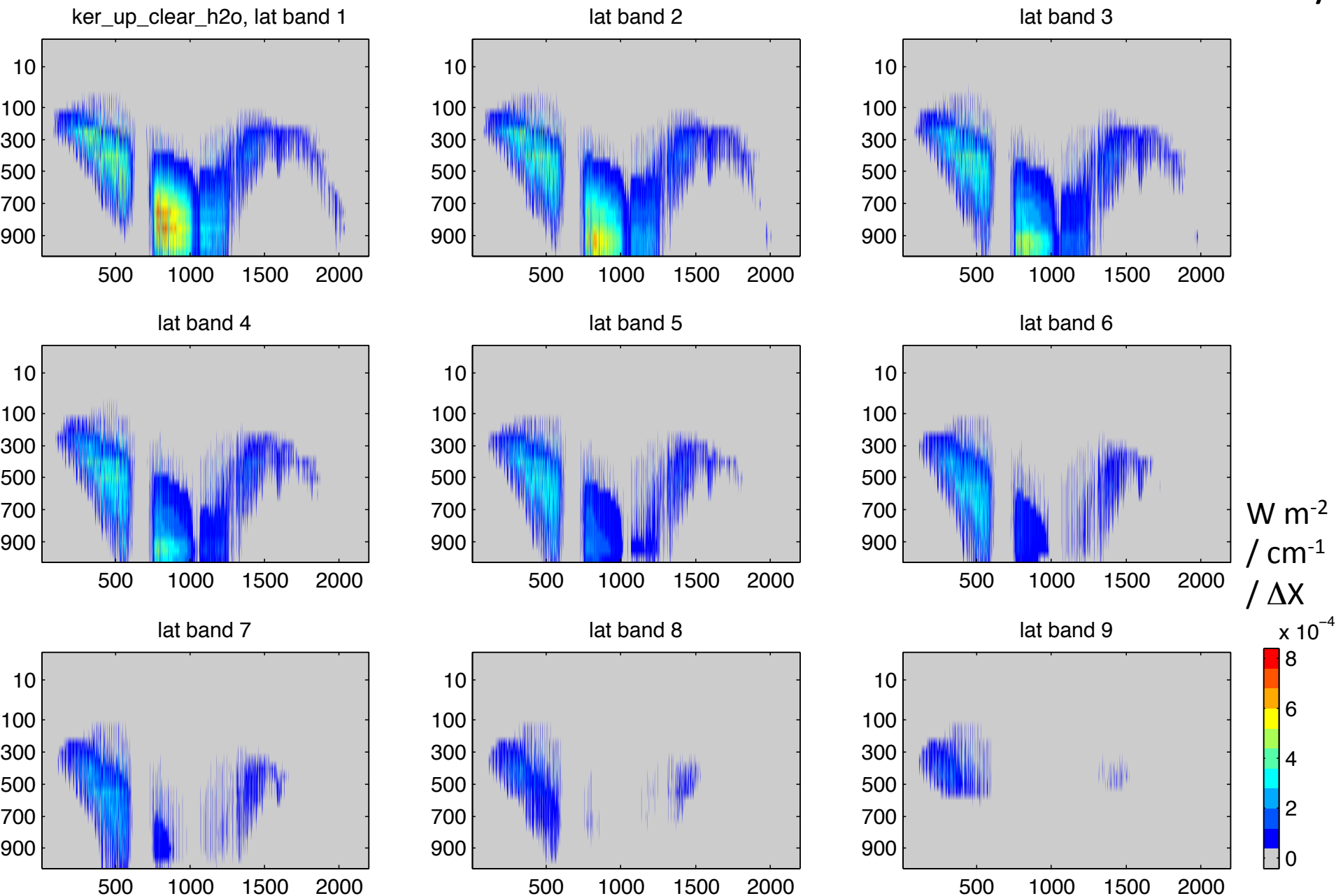
Zonal mean (equa. to pole) spectral kernels

temperature
all-sky



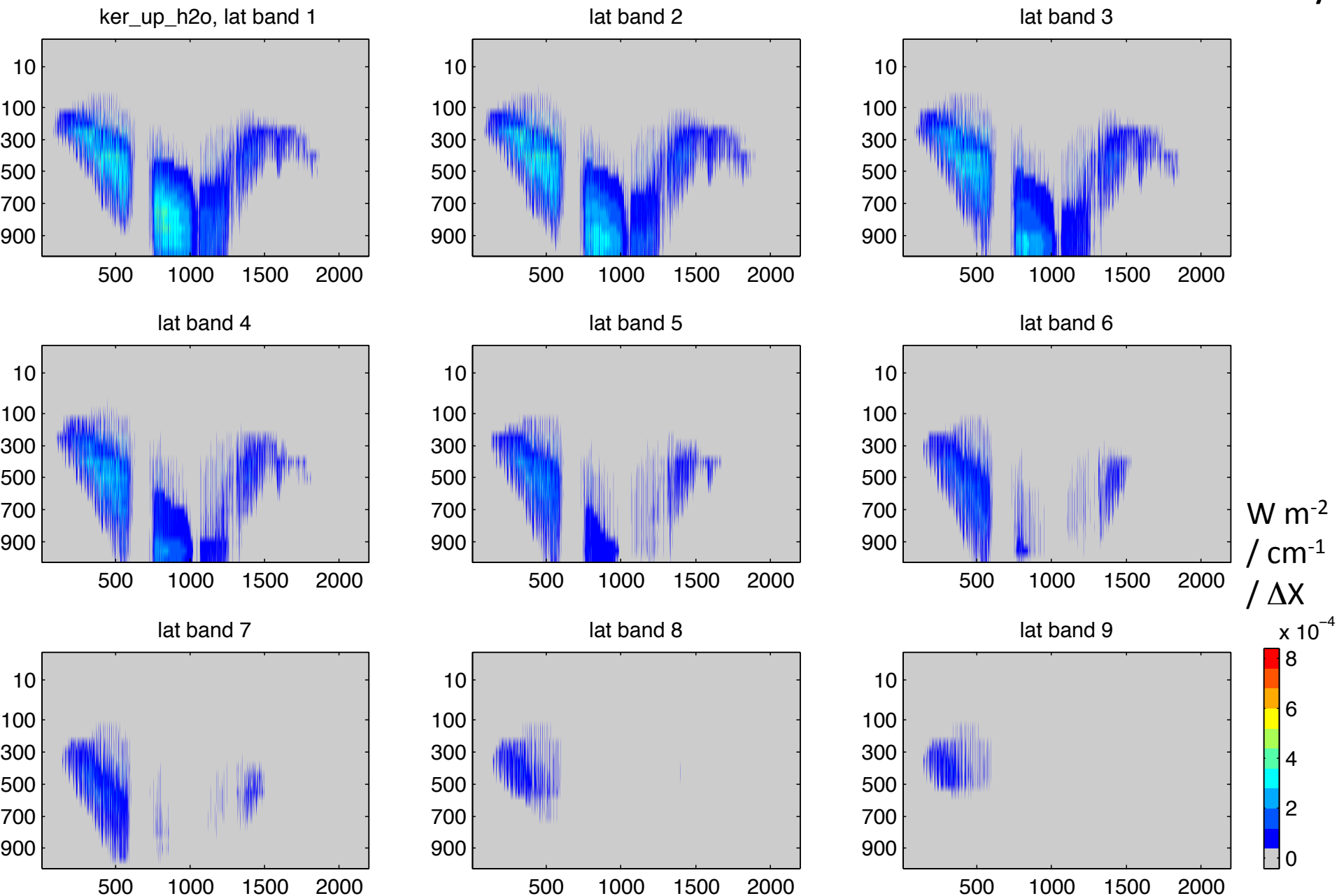
Zonal mean (equa. to pole) spectral kernels

Water vapor clear-sky



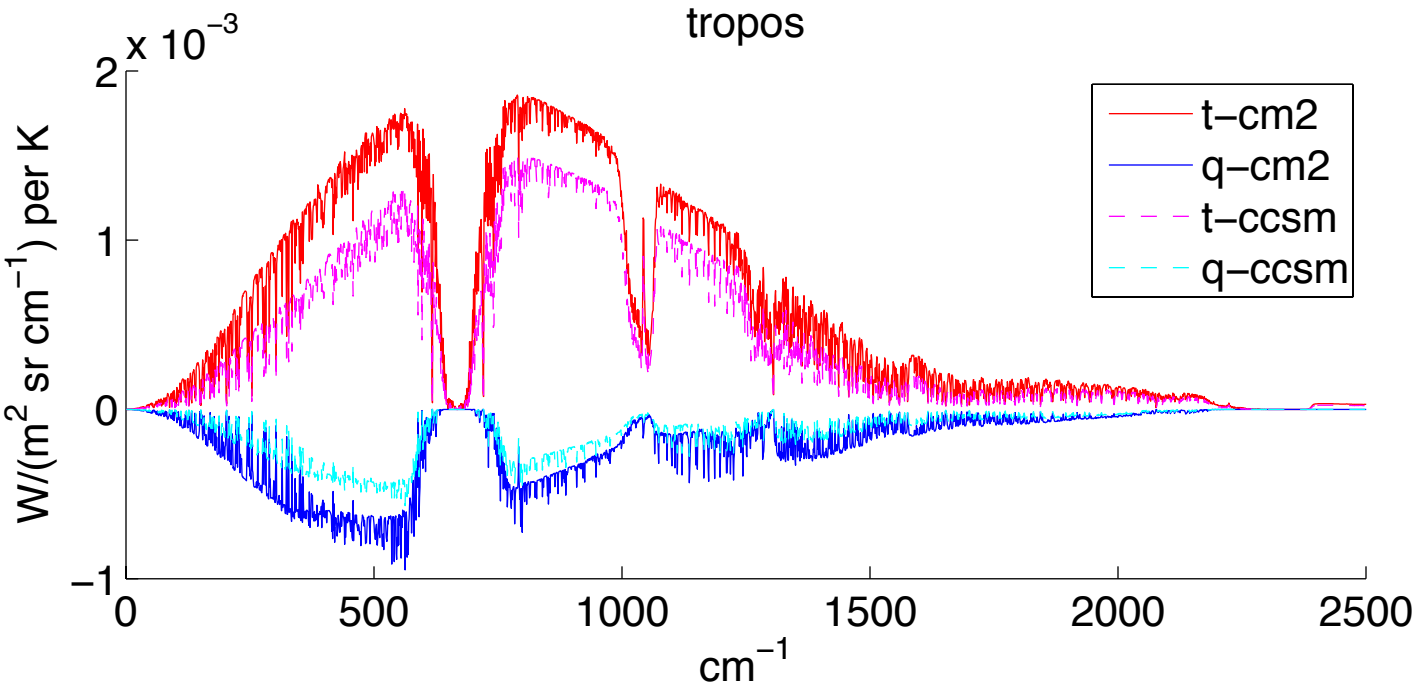
Zonal mean (equa. to pole) spectral kernels

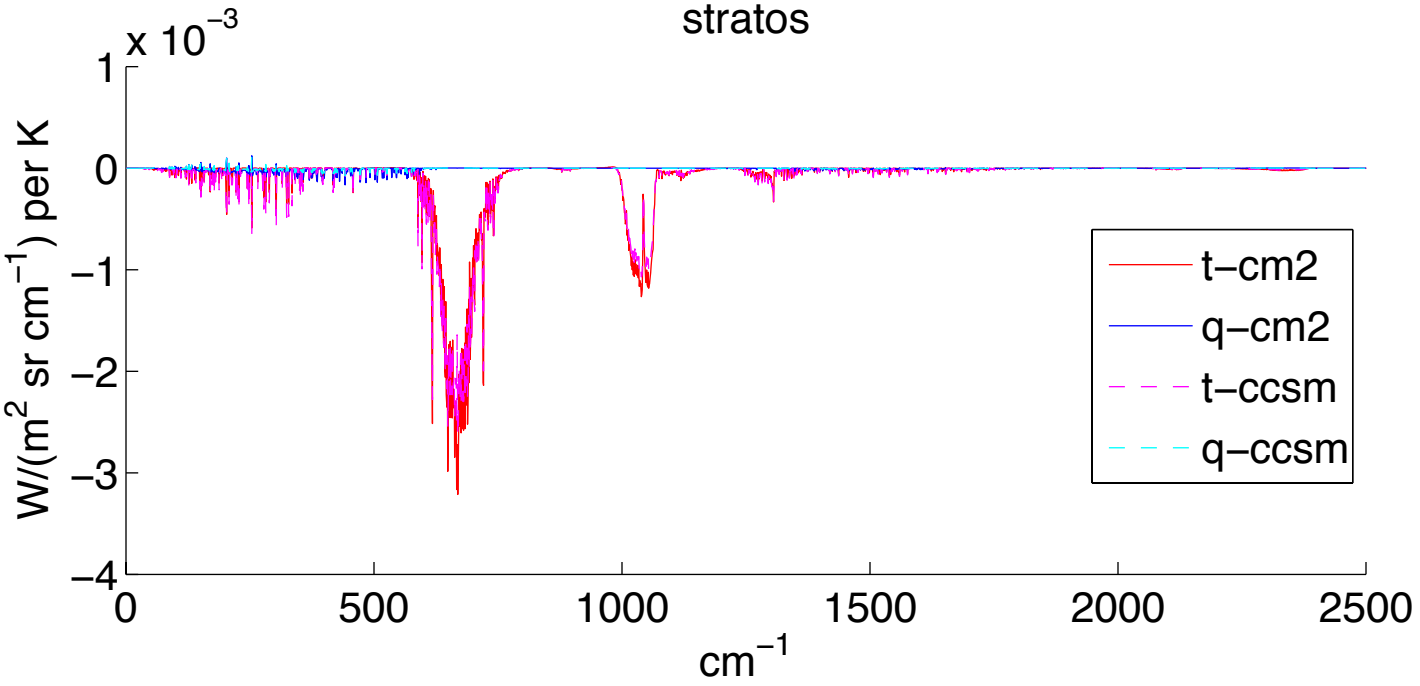
Water vapor
all-sky



CM2 vs. CCSM (personal commu. w/ D. Feldman)

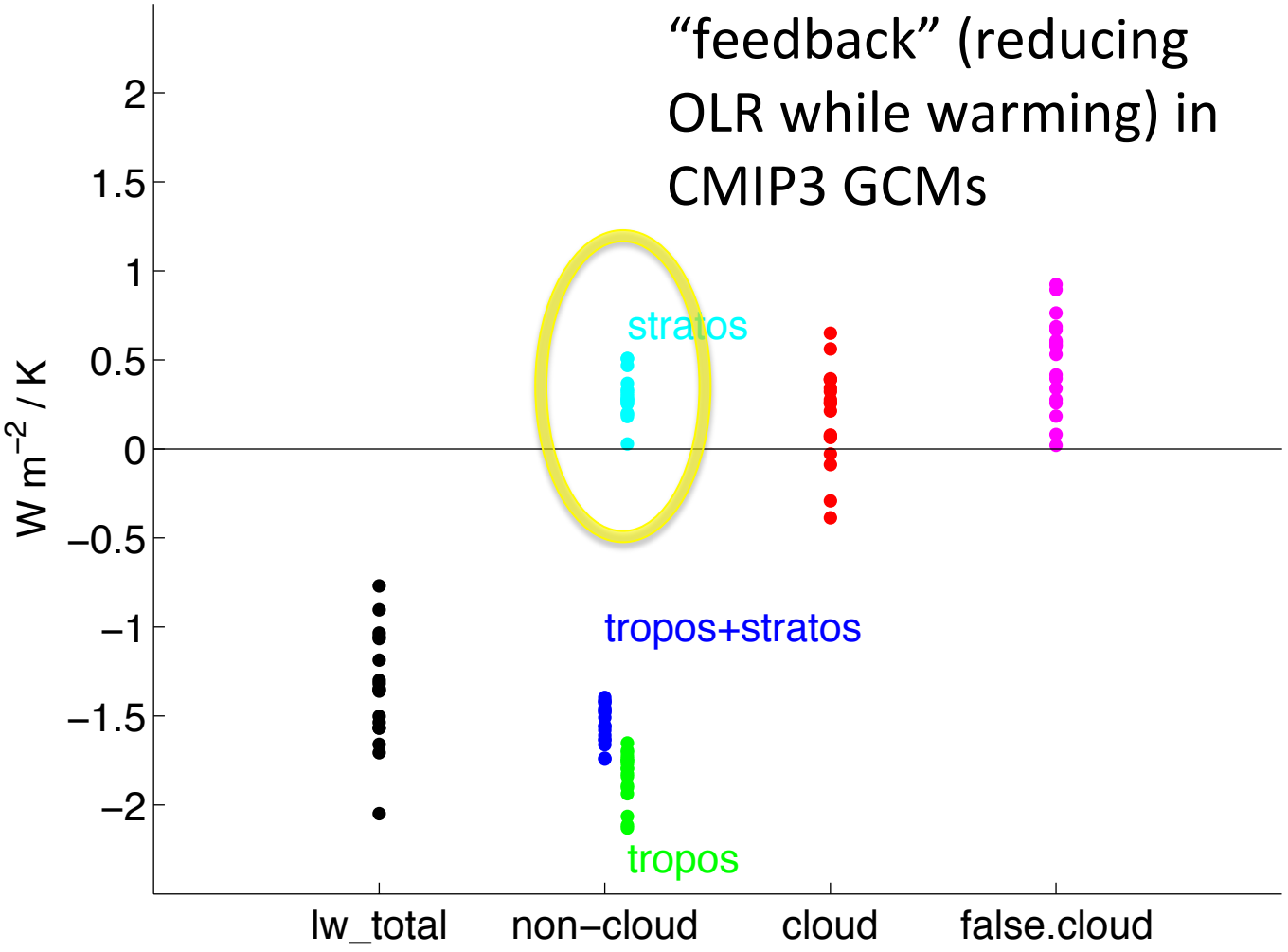
	CM2	CCSM
T-trp	-4.6	-3.3
q-trp	1.4	0.9
T-str	0.9	0.9
q-str	<0.1	<0.1





Other GCMs

Unanimously positive stratospheric "feedback" (reducing OLR while warming) in CMIP3 GCMs

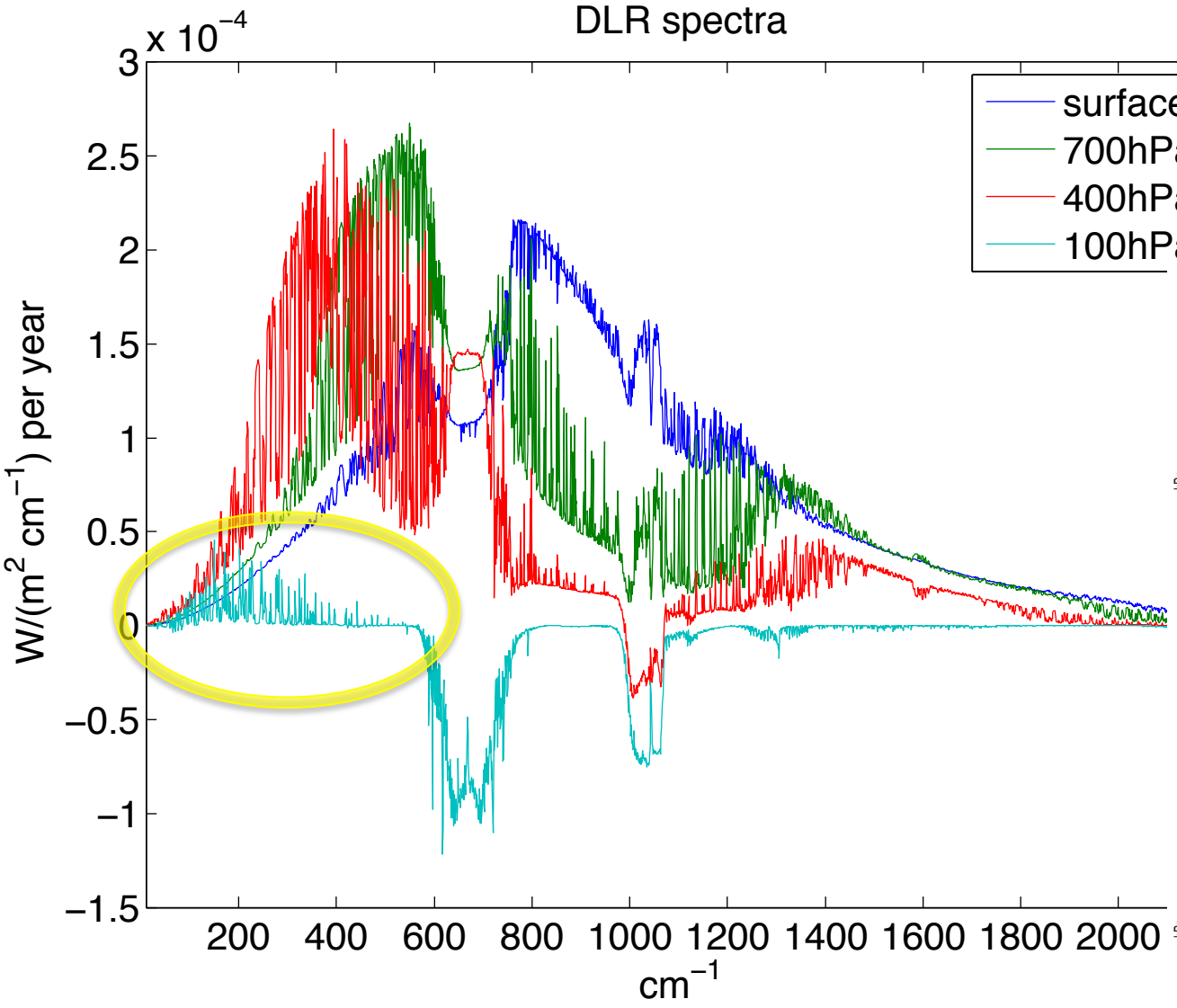


Based on 18 GCMs in A1B experiments [Huang 2012 b]

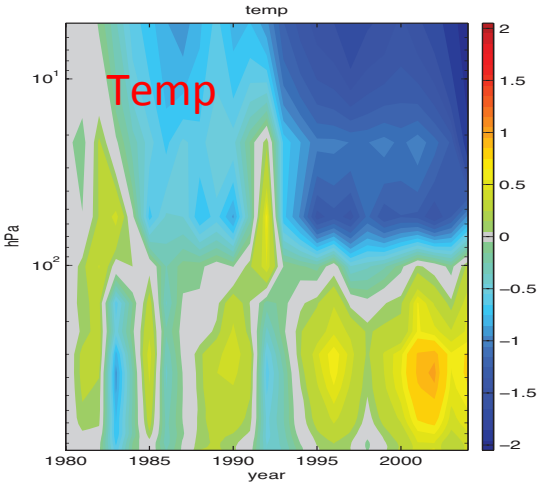
Summary

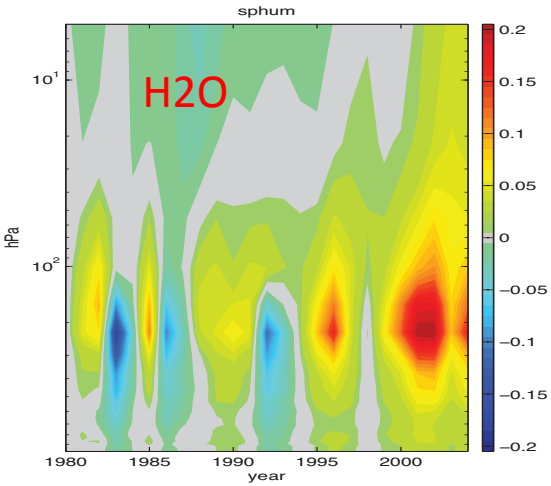
- Stratospheric temperature is an important factor that controls transient OLR variations
  - Forcing or feedback?
- Downwelling IR radiance at tropopause level affords an advantageous means for monitoring stratospheric water vapor
  - How to measure it? – S-HIS, FIRST?
- Strongest and soonest (t<10yr) to detect climate forcing/ feedback signals in OLR spectrum lie in the CO_2 band
  - Verified? Due to CO_2 or stratos T? Spectrally fingerprintable?

Vertical + spectral perspectives



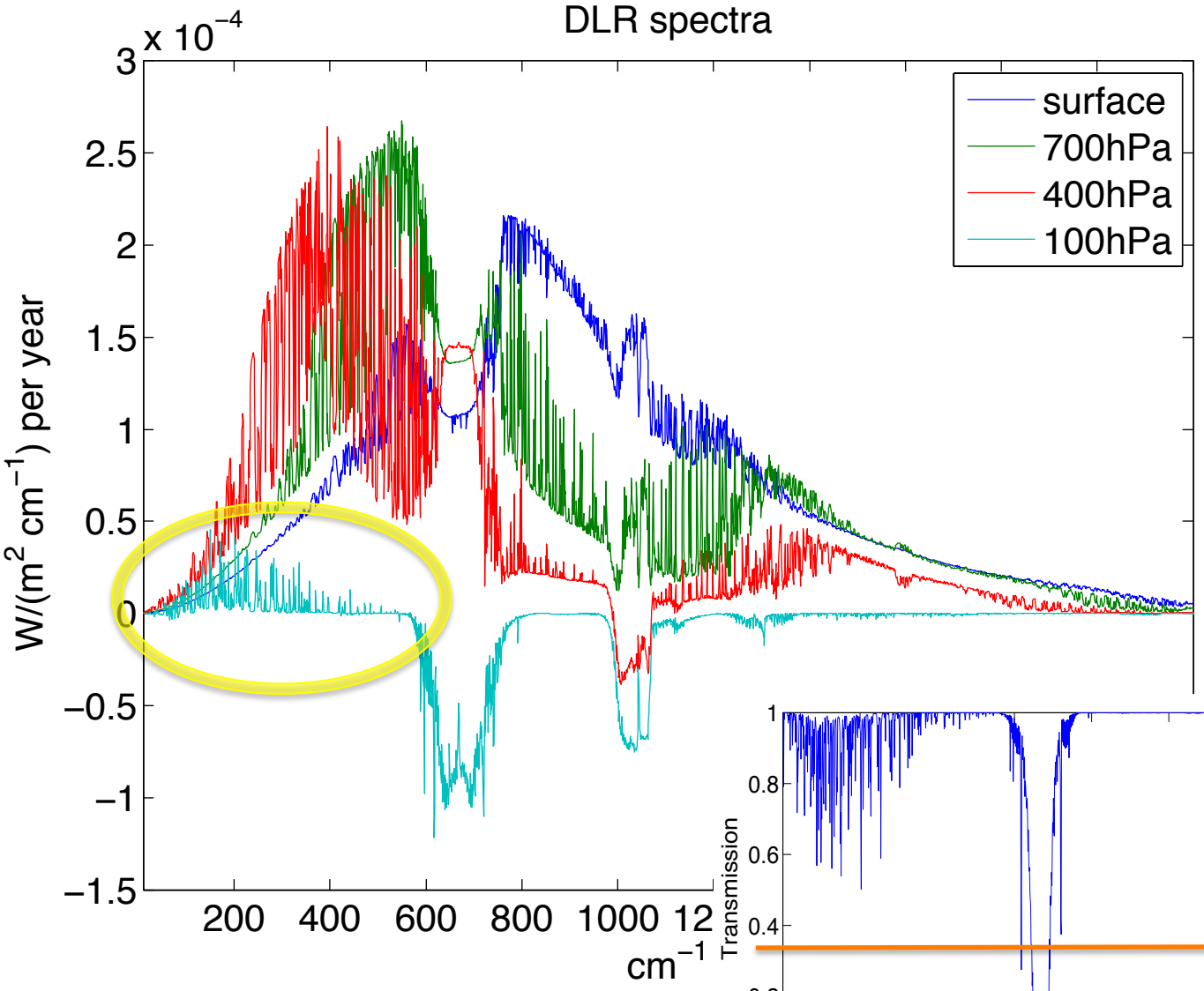
R⁻ (100hPa):
Distinct far IR signals





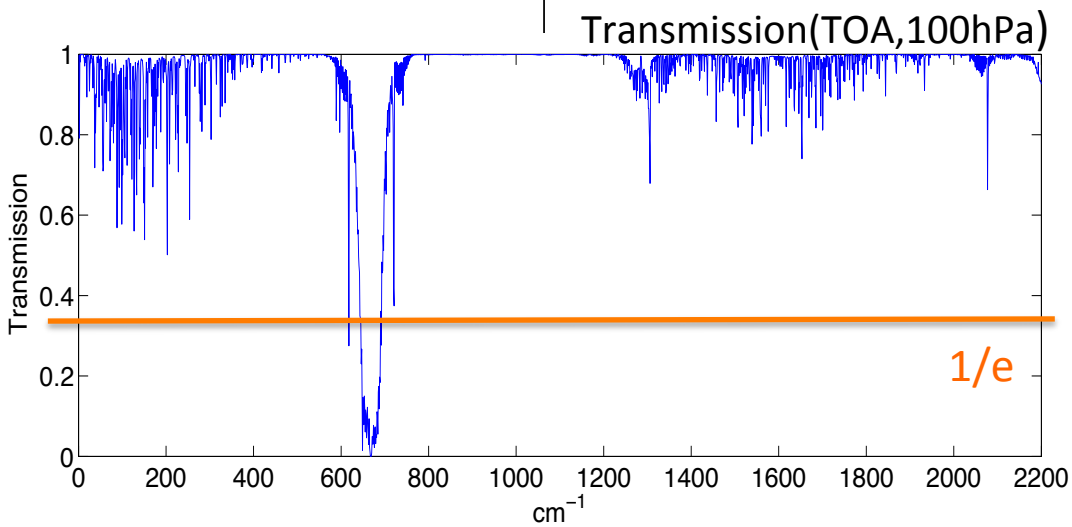
Linear trends in global mean down-welling longwave radiation spectra

Vertical + spectral perspectives

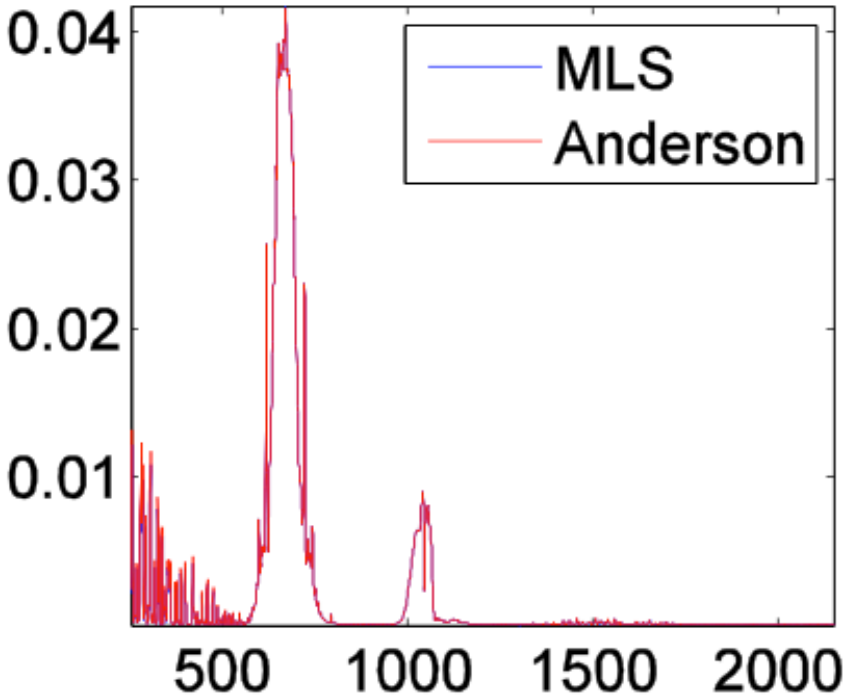


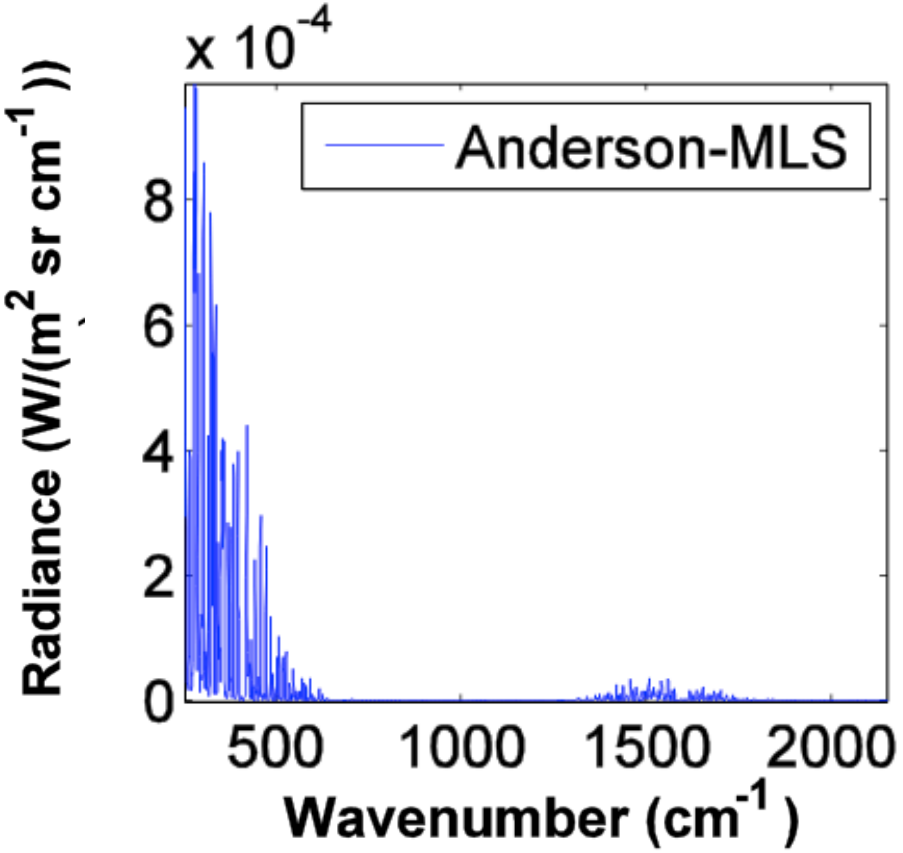
R⁻ (100hPa):
Distinct far IR signals

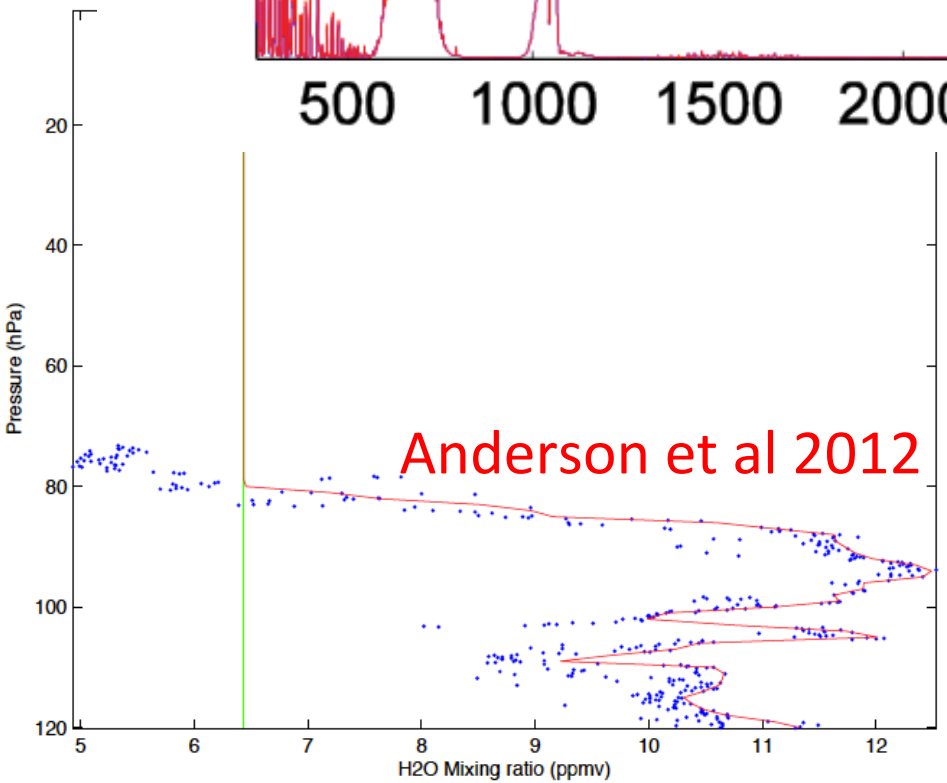
Opportunity for stratos H_2O monitoring?



Linear trends in global mean dow radiation spectra

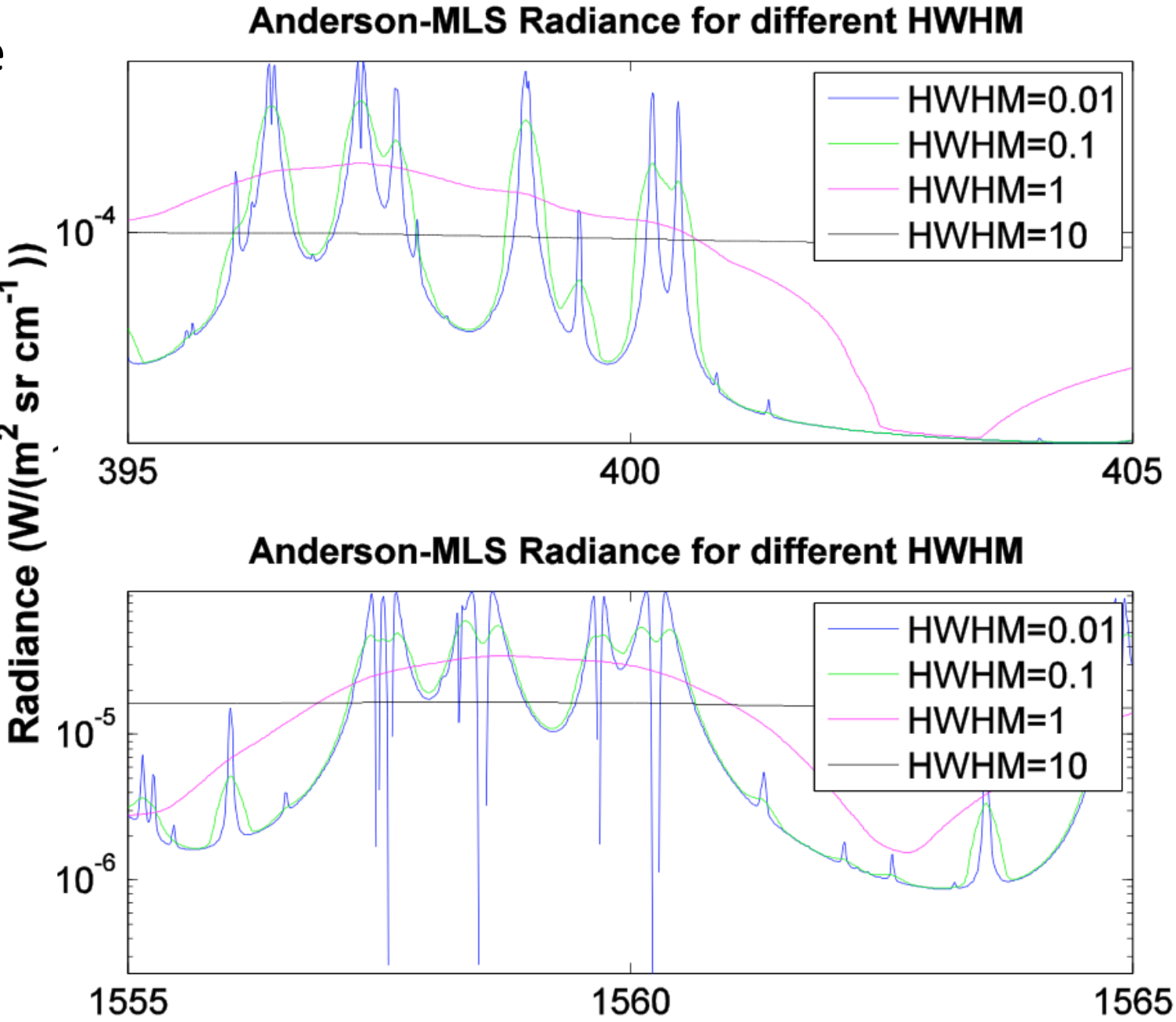


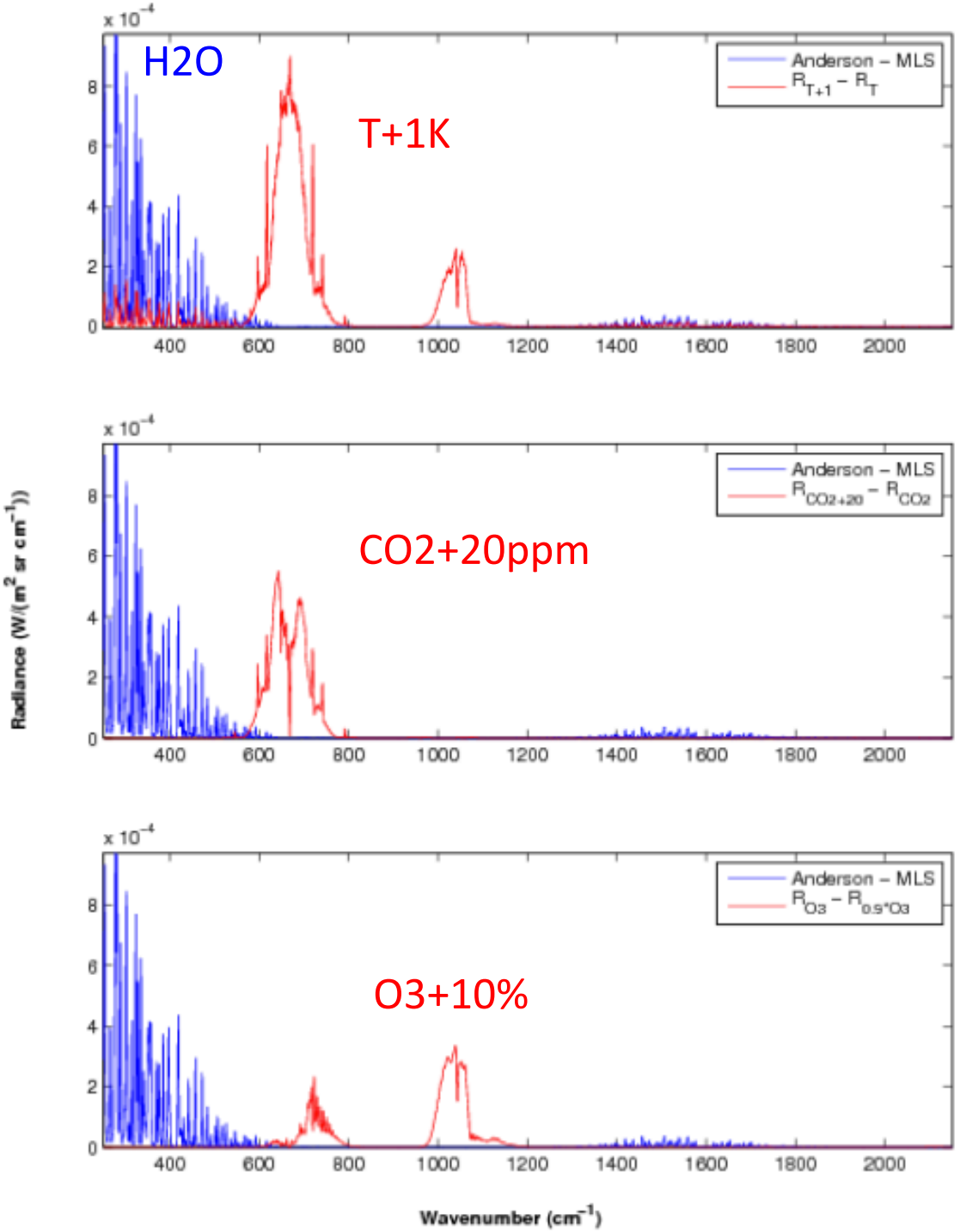




Spectral signatures of storm injected stratospheric H2O

Dependence on spectral resolution





H_2O signals can be well distinguished from T, CO_2 and O_3 signals.

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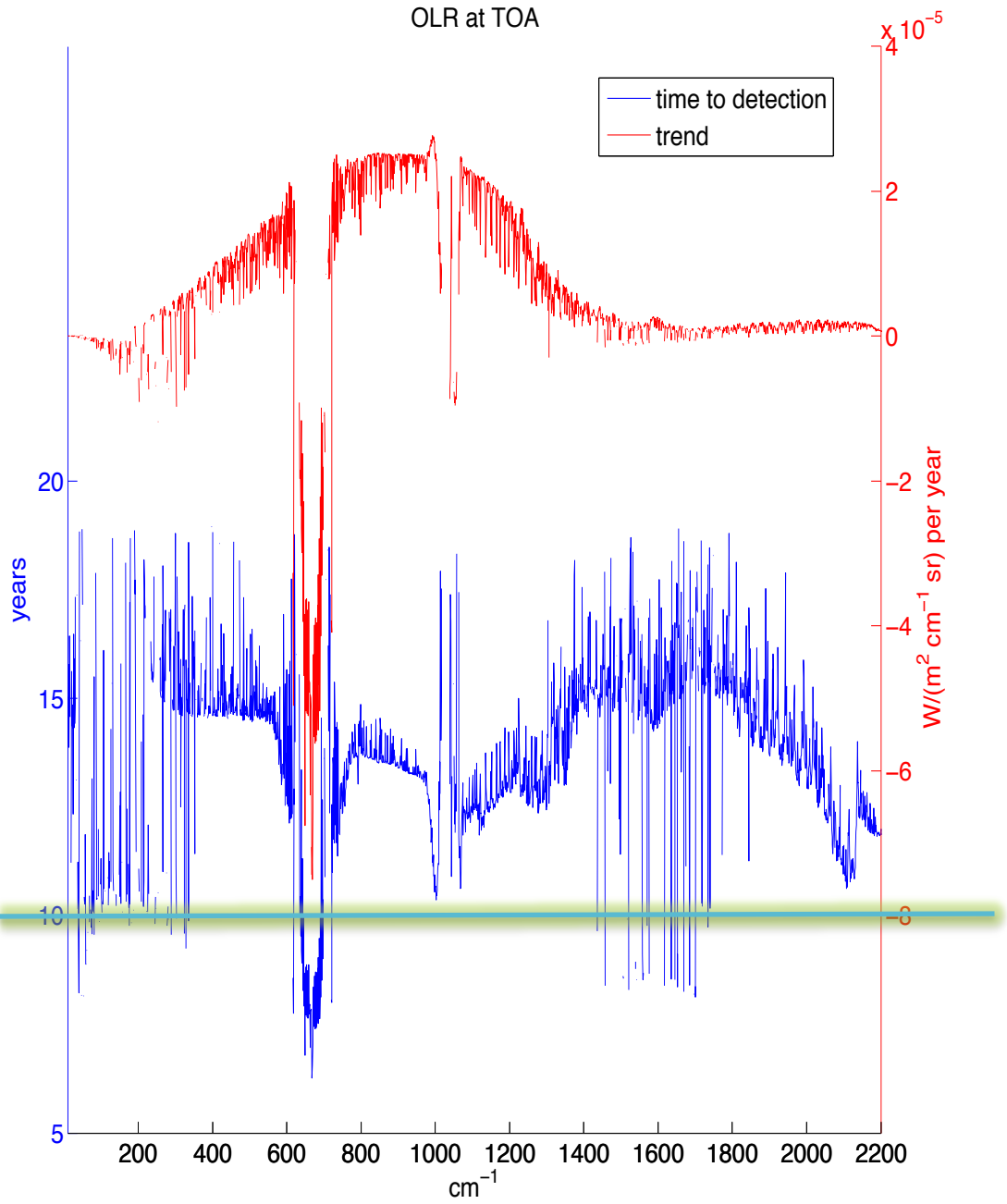
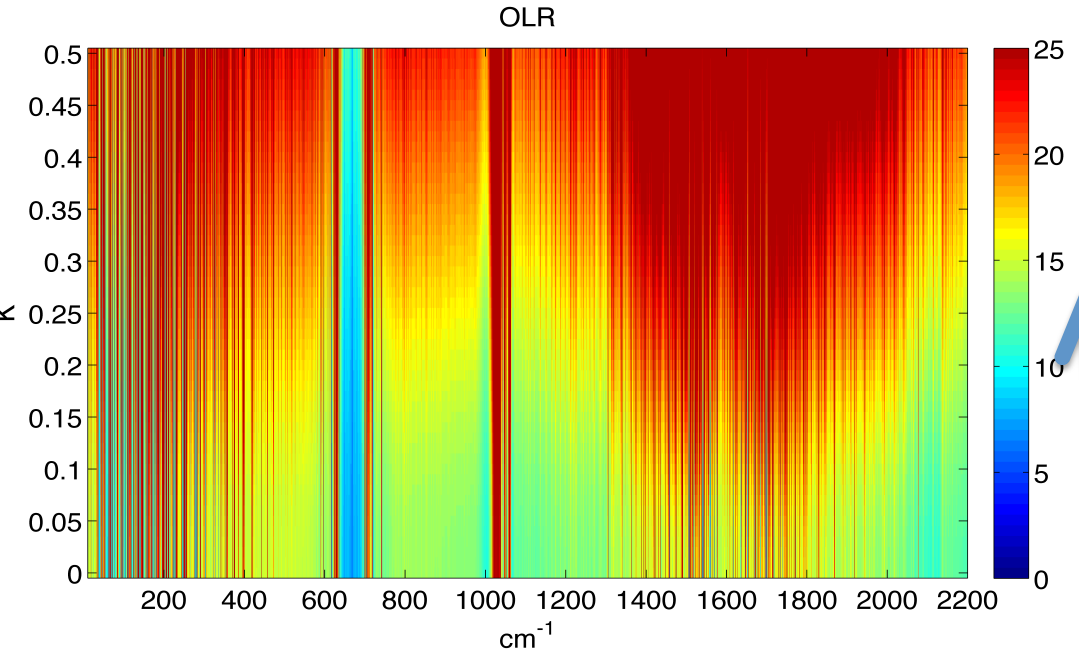
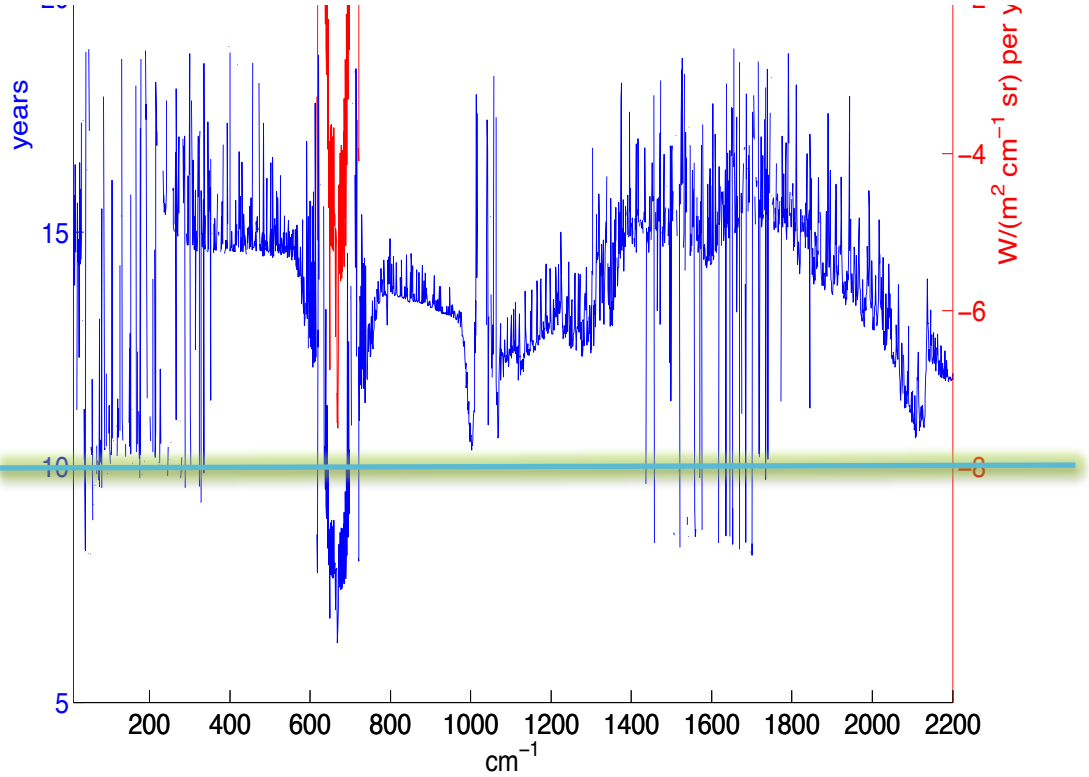


Time to detection (Huang 2012 a)

Strongest and soonest to detect climate change signals lie in the CO_2 band:
$t < 10$ yr : verifiable by AIRS

(Weatherhead formula: secular trend signal vs internal variability)





Time to detection (Huang 2012 a)

$$n^* \approx \left(\frac{3.3\sigma_N}{|\omega_o|}\frac{1+\phi}{1-\phi}\right)^{2/3}\left(1+\frac{\sigma_m^2}{\sigma_N^2}\right)^{1/3}$$

x-axis: wavenumber
y-axis: σ_m (instru. error: K)
contour: time to detection (years)

Monitoring forcing (CO_2, stratos. cooling) is little affected by instrument (in)accuracy;
Monitoring tropospheric feedbacks (H_2O vs T) is.

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End