Linear trends and closures of 10-year observations of AIRS stratospheric channels

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Outline

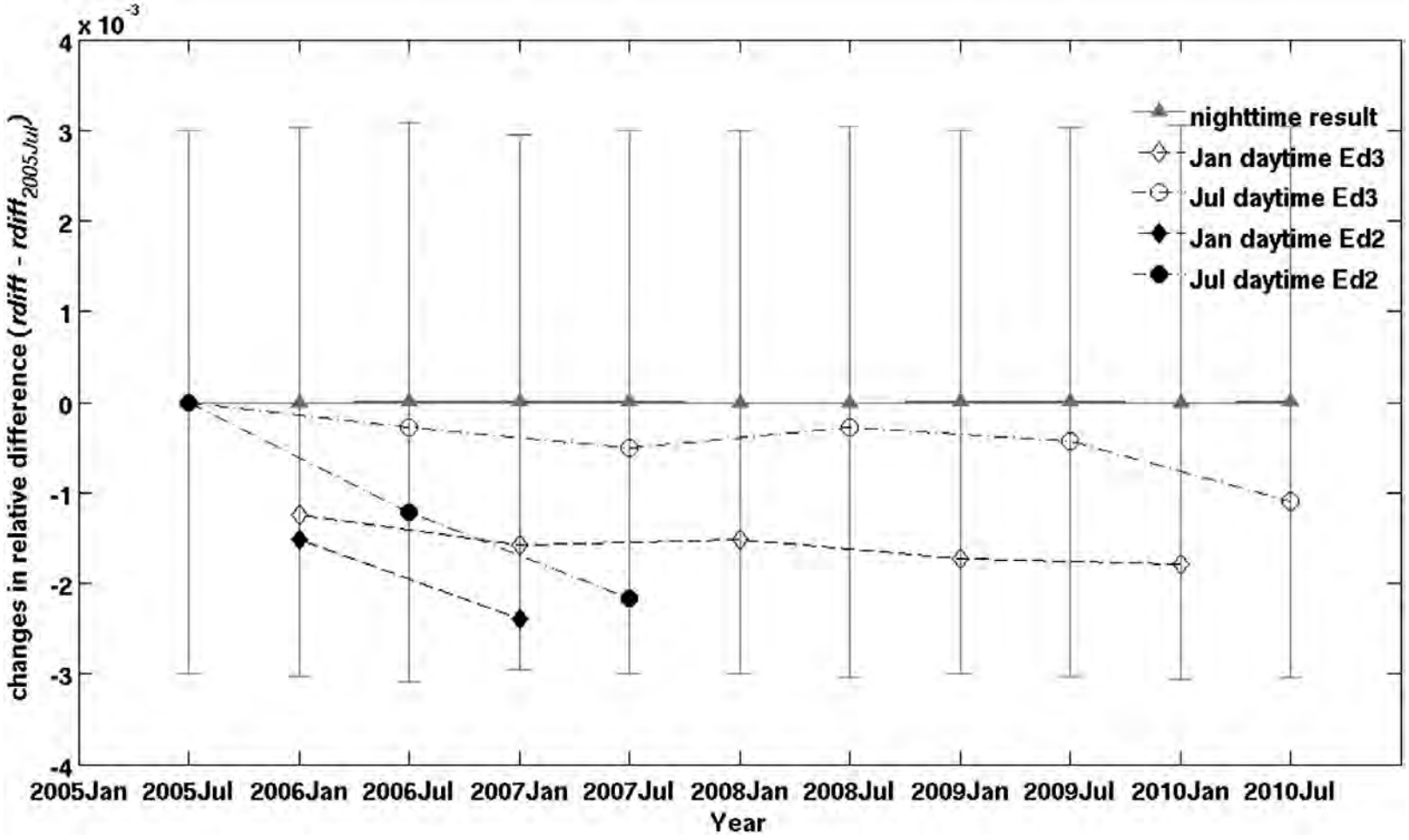
- Motivations
  - What can AIRS radiances tell us about the secular trend in the stratosphere?
- Trend Analysis
  - AIRS observations
  - Synthetic radiances: GFDL AM3 runs, ECMWF ERA-interim
- Closure Studies
- Outlooks

Pan, F., X. L. Huang, H. Guo, L. L. Strow, Linear trends and closures of 10-year observations of AIRS stratospheric channels, *Journal of Climate*, in press.

AIRS Radiances

- Collected from a single instrument over 10+ years with proved radiometric calibration and stability
  - Vs. stitching MSU/AMSU data records
  - ~3 Millions of spectra per day
- How to make use of this in trend analysis?

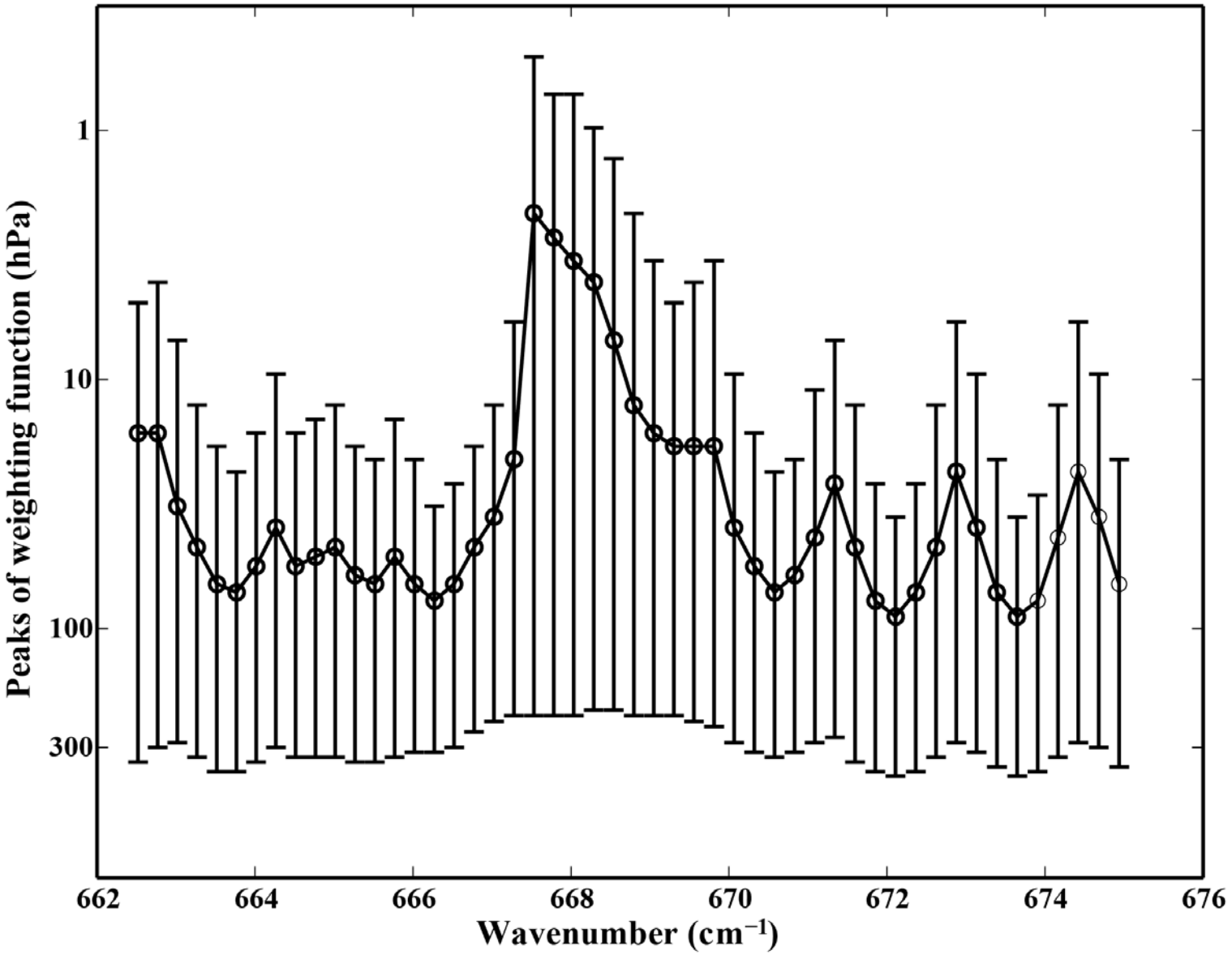
An example: assessing CERES SSF performances from Ed2 to Ed3



(Huang, Loeb, and Chuang, JTECH, 2012)

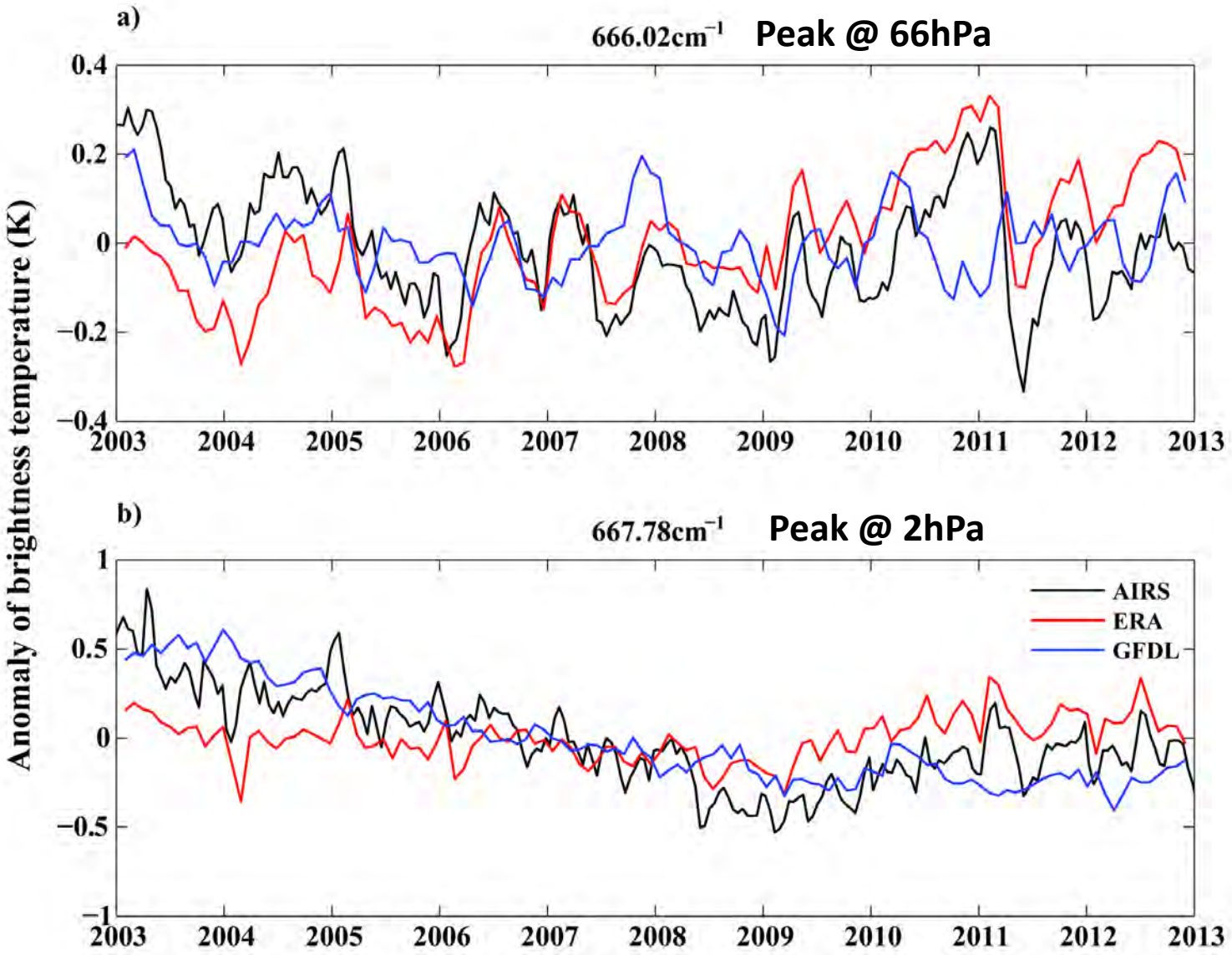
Data and method (I)

- AIRS radiance processing
  - Near real-time archiving of AIRS L1 nadir-view radiances onto $2.5^{o}\times2^{o}$ grids
    - 16-day average for Aqua repeating cycle
    - Quality controls for each spectrum (Huang & Yung, 2005)
  - This study focuses on channels in the CO_2 v_2 band sensitive to stratospheric emissions
    - 50 channels in total


Peaks of weighting function (hPa)
1
10
100
300
662
664
666
668
670
672
674
676
Wavenumber (cm⁻¹)

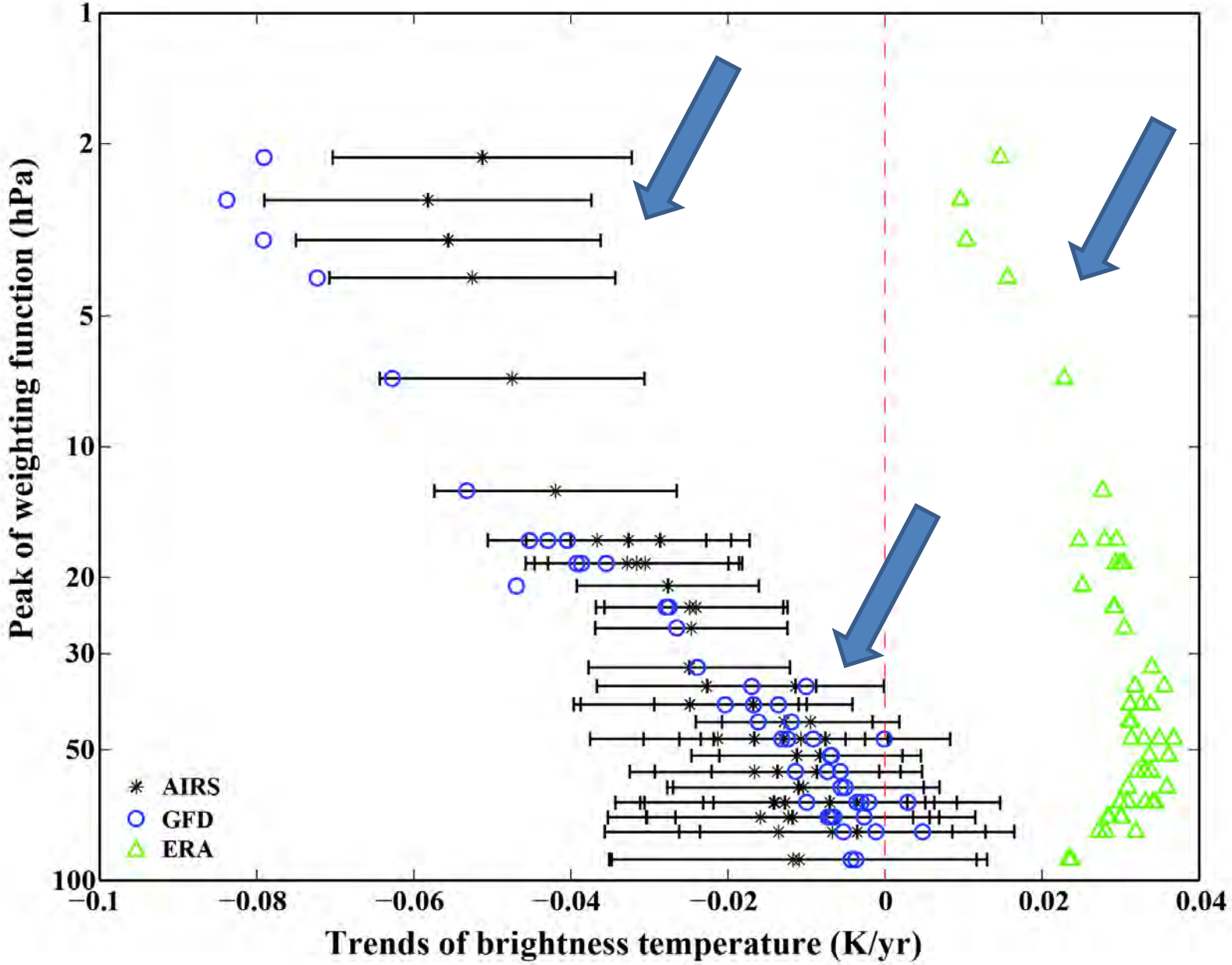
Data and method (2)

- GFDL AM3
  - Top at 0.01 hPa
  - Forced by observed SST, CO_2, and TSI
- ERA-Interim Reanalysis
- Synthetic radiances
  - Sample the 6-hourly output according to AIRS nadir-view trajectories
  - PCRTM to obtain synthetic AIRS radiances
- Trend analysis
  - Take auto-correlation into account for the confidence interval and significance level


a)
666.02cm^{-1}
Peak @ 66hPa
0.4
0.2
0
−0.2
−0.4
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
b)
667.78cm^{-1}
Peak @ 2hPa
1
0.5
0
−0.5
−1
AIRS
ERA
GFDL
Anomaly of brightness temperature (K)

Trend analysis of the global-mean L-1 radiances

Linear trends based on 2003-2013 data

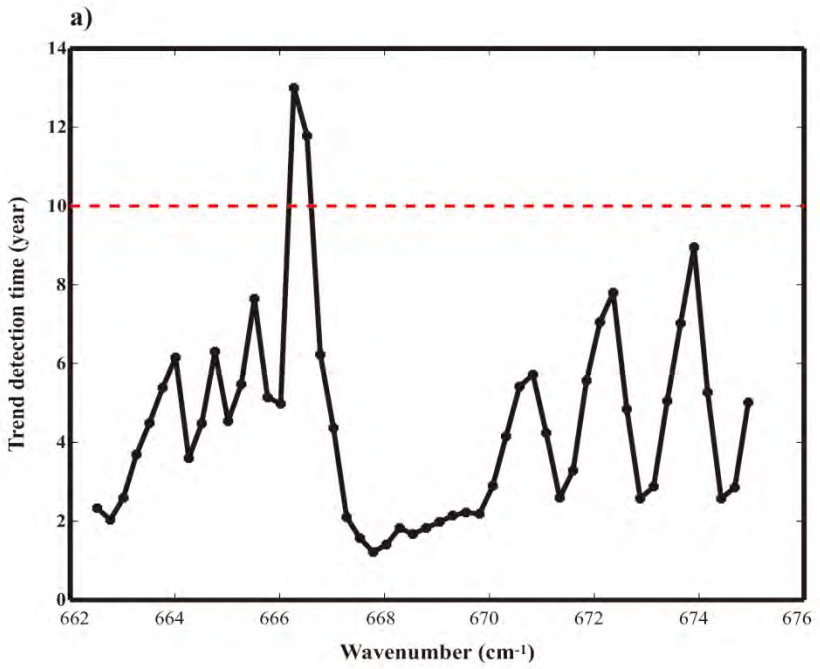


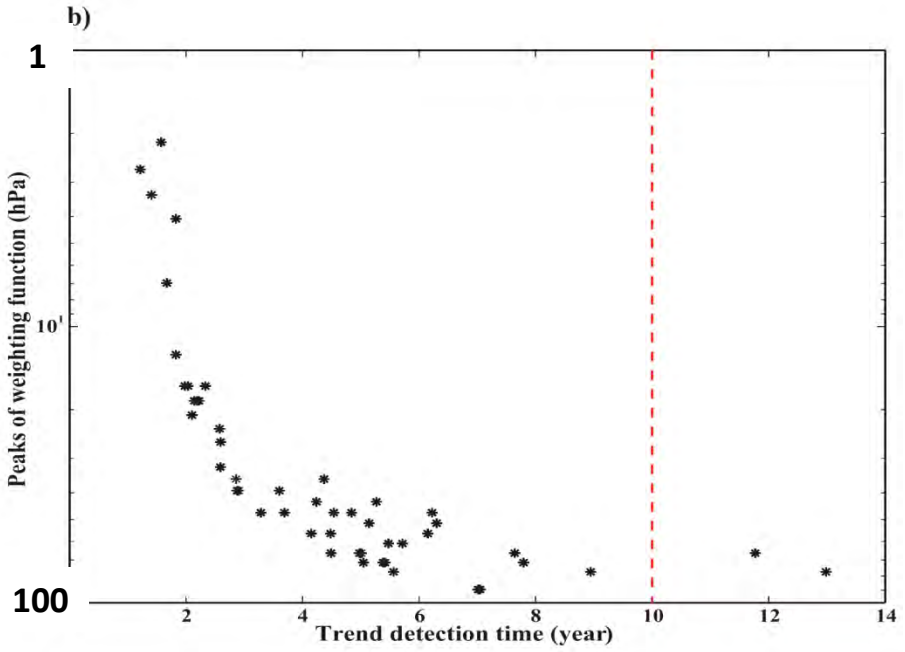
How likely to detect a statistically significant trend with such 10-year data?

$$n = \left[\frac{12 s^2}{m_{est}^2} \sigma_{\text{var}}^2 \tau_{\text{var}} \right]^{1/3} \left(1 + f^2\right)^{1/3}$$

Leroy (2008)

Natural variability estimated from a 500-year GFDL CM3 control run





A closure study

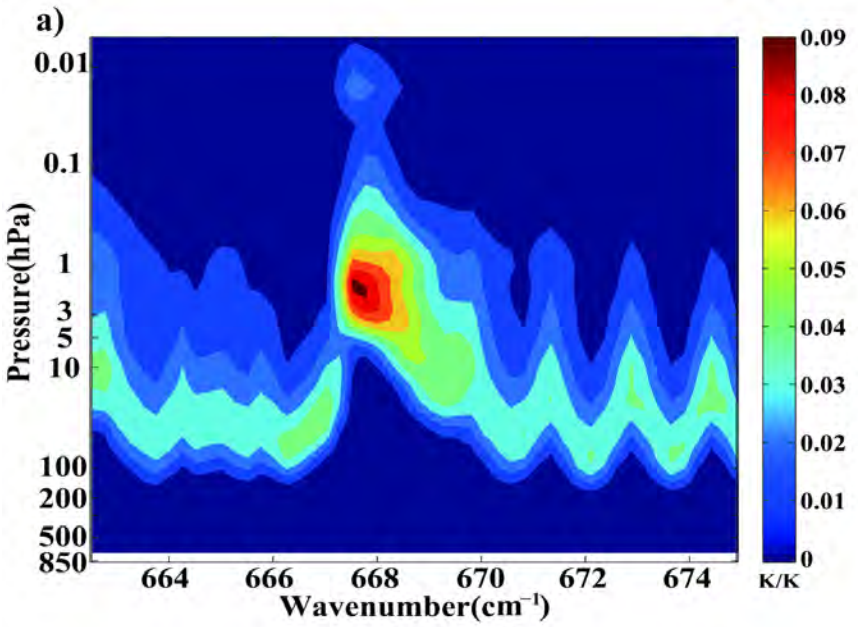
- To what extents do the trends of L1 radiances agrees with the trends of L2 retrieved geophysical parameters?

$$\Delta_t BT_\upsilon = \frac{\partial f_\upsilon}{\partial Ts}\Delta_t Ts + \sum_i \frac{\partial f_\upsilon}{\partial T_a^i}\Delta_t T_a^i + \sum_i \frac{\partial f_\upsilon}{\partial H_2O^i}\Delta_t H_2O^i + \frac{\partial f_\upsilon}{\partial CO_2}\Delta_t CO_2 + \text{Residual}$$

- The partial derivatives: a spectral radiative kernel approach (Huang et al., 2014, GRL)
  - Using 3-hourly output to compute the radiative partial perturbation for each (lat, lon)
  - Average onto the longer time scale

Huang, X. L., X. H. Chen, B. J. Soden, X. Liu, The spectral dimension of longwave feedbacks in the CMIP3 and CMIP5 experiments, *Geophys. Res. Letts.*, 41, doi:10.1002/2014GL061938, 2014.

Spectral Radiative Kernels



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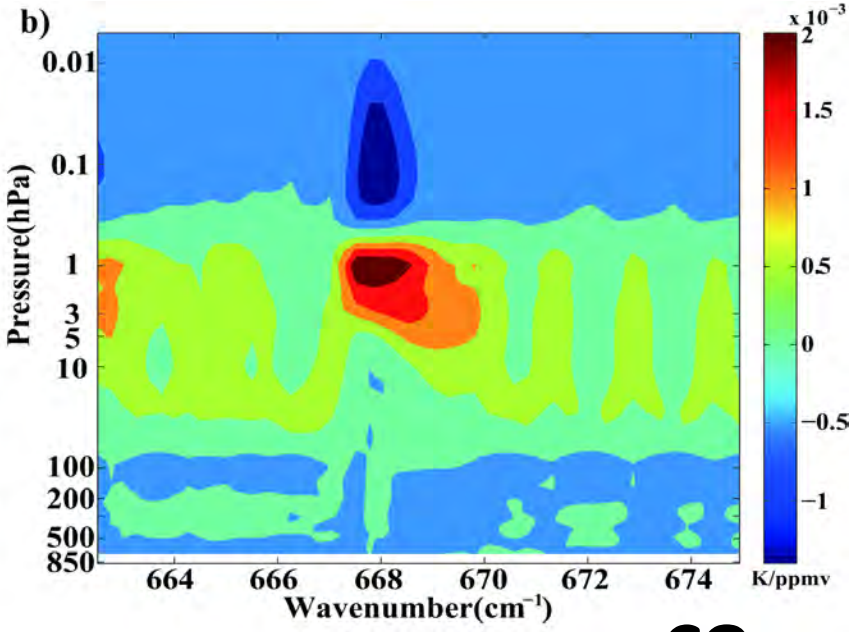
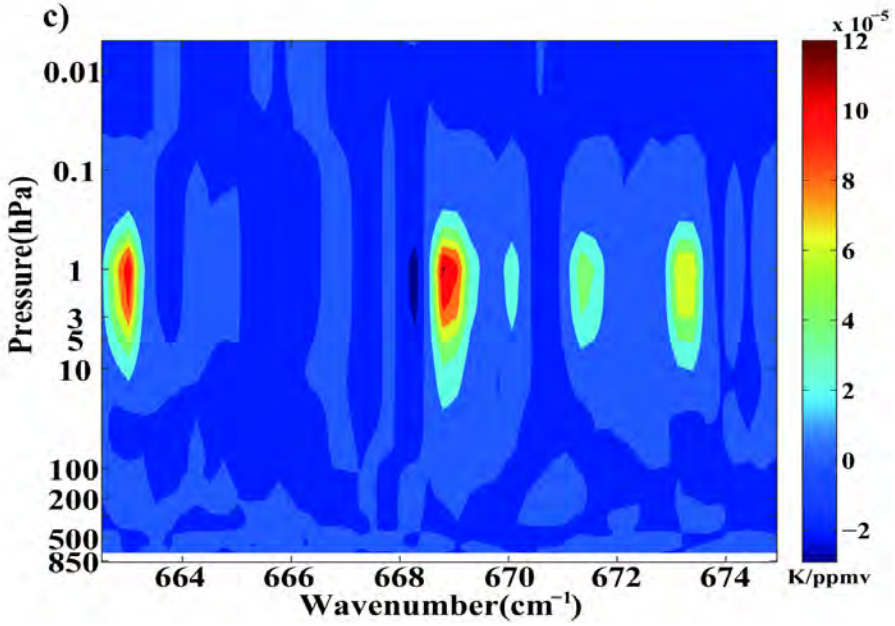
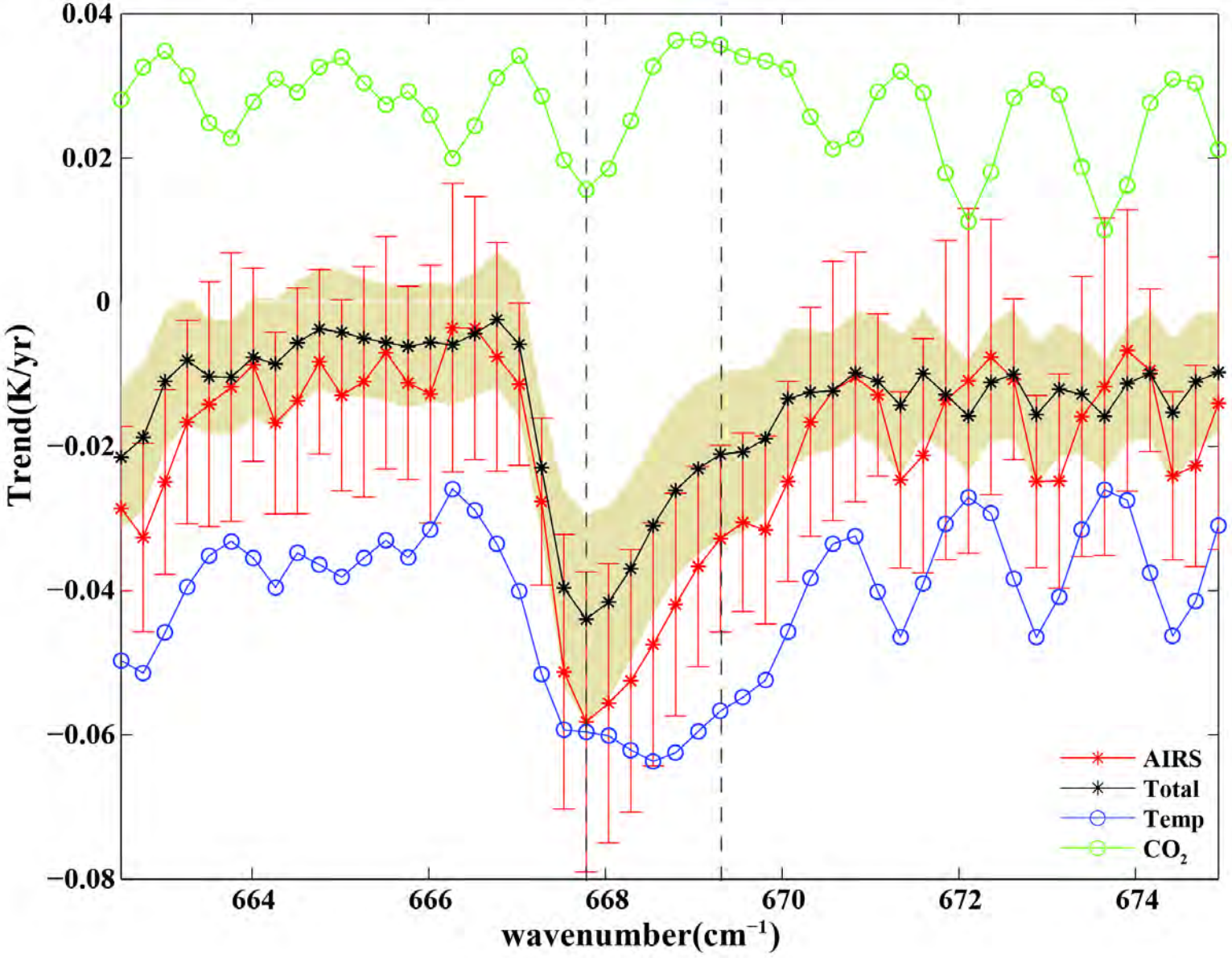


CO_2



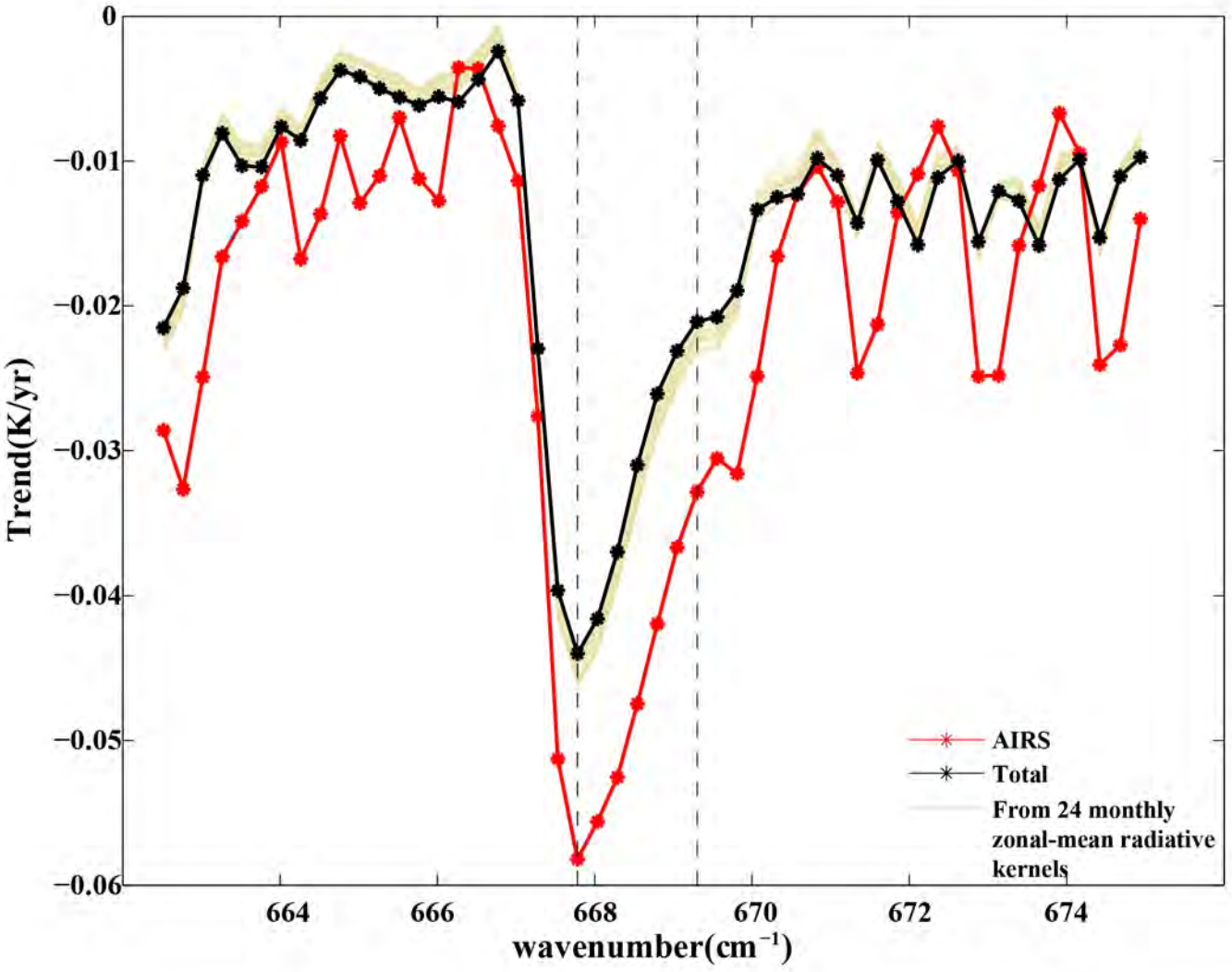
H_2O

Results


0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
Trend(K/yr)
664
666
668
670
672
674
wavenumber(cm⁻¹)
AIRS
Total
Temp
CO2

Conclusions and Discussions

- Statistically significant trends can be derived from 10 years of AIRS radiances
  - Discrepancies exist between observed and modeled trends
- Trends of L1 radiances and L2 temperature are largely consistent with each other, at least in terms of global mean. Discrepancies exist in 668-669 cm^{-1}.
- Future plans
  - Trends of different latitudes: linkage to change of BDC circulation
  - Formal detection and attribution studies


0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
Trend(K/yr)
664
666
668
670
672
674
wavenumber(cm^{-1})
AIRS
Total
From 24 monthly zonal-mean radiative kernels

Trends of the tropical stratosphere