Climate studies using 12+ years of AIRS radiances

UMBC AN HONORS UNIVERSITY IN MARYLAND

S. De Souza-Machado[1], L. L. Strow[1], A. Tangborn[1], C. Hepplewhite[1], H. Motteler[1], S. Buczkowski[1], P. Schou[1]

[1]Joint Center for Earth System Technology, Univ. of Maryland Baltimore County

JCET UMBC NASA-GSFC

1 AIRS instrument

- AIRS: Grating spectrometer sounder on EOS-AQUA, 2378 channels with spectral resolution ~0.5-2.0 cm^{-1} from 650-2665 cm^{-1}. 1:30 am/pm orbit. AIRS operational for 12+ years, intensively validated.
- Look at zonally averaged radiance changes from two different subsets
  - Calibration Stability DataSet which are clear-sky scenes over ocean
  - All-sky scenes along the nadir track, ocean/land

AIRS, IASI, CrIS producing low noise, highly accurate spectra for 12+ years. Can be used for trending at climate level of WV, temperature and trace gases 12 years not enough for climate, so at this stage we are mostly testing AIRS observations against ERA re-analysis fields

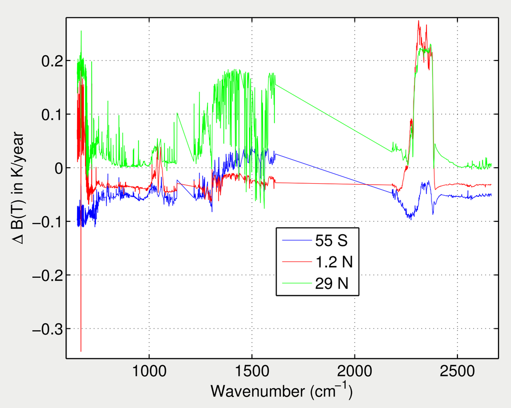
Also examine gridded (4x4 °grids) AIRS radiance data for evidence of stochastic forcing

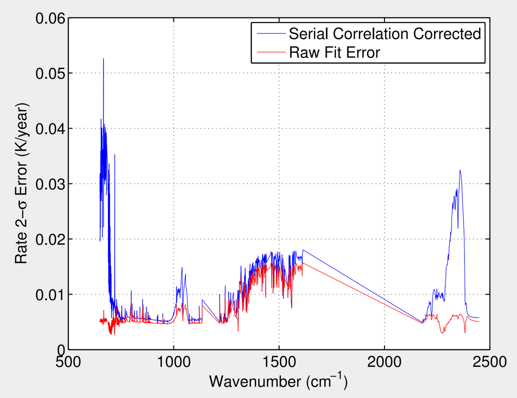
2 Approach for trends

- Create zonally averaged daily subsets (all i=1 .. 2378 channels)
- Match to re-analysis T(z), WV(z), stemp (and cloud fields) from ERA-Interim
- Find linear trend (dBT/dt) from time-series
- The linear trends $b_i(\nu)$ of the AIRS spectral radiances are used to retrieve a variety of geophysical trends using an optimal estimation retrieval approach
- Clear sky bins span about ± 70 deg, narrowest bins at tropics
- All-sky zonal bins are 5 deg wide, spanning -90S to +90N, over land/ocean

3. Calibration Stability Data Set

Graphs showing (L) sample clear sky rates and (R) fitting errors

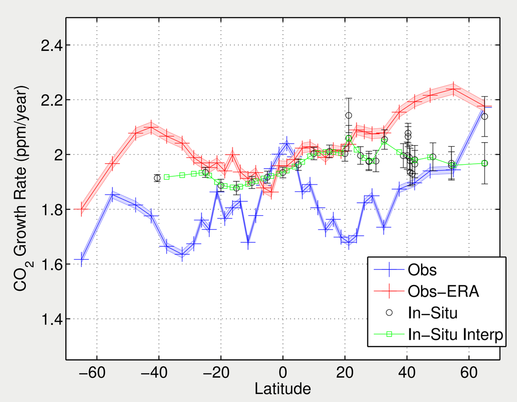


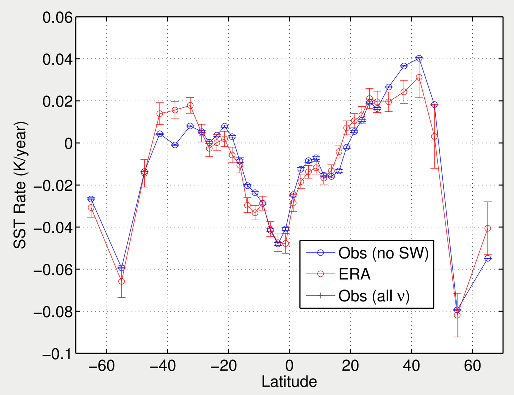


4. CO_2 and Surface Temp results

Graphs showing (L) CO2 rates and (R) surface temp rates

CO_2 rates have highly accurate global reference data. BUT CO_2, T(z) Jacobian vary Co-Linearly, so need to do an Obs-correction to accurately fit CO_2 rates



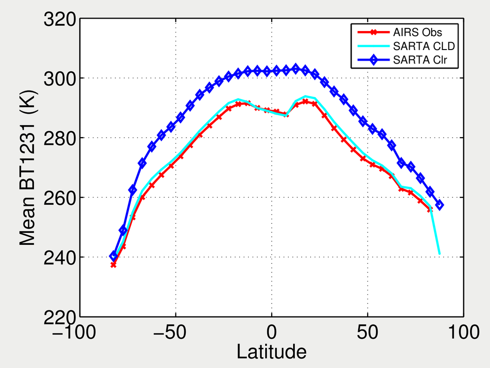


- red : CO_2 trends after Obs-correction
- Retrieved SST Rates versus ERA rates

5. All-Sky rate retrievals

- Cloud/geophysical Jacobians from ERA
- Minor gas, cloud parameters (OD/size for liquid, ice clouds)
- Zero A-priori, Tikhonov L_1 regularization.

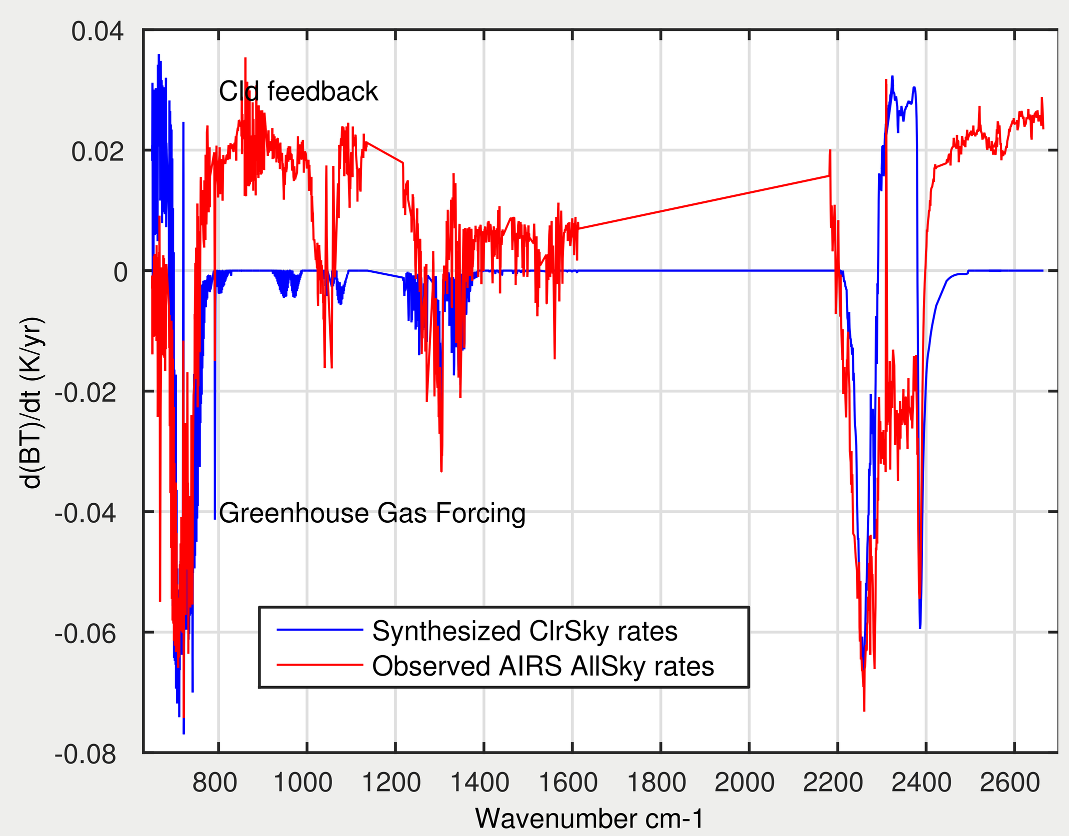
Approach works as on average, **scenes are almost-clear!!!!** (10 K cloud effect)



BT (K) at 1231 cm^{-1} vs Latitude

6.Greenhouse Effect

Greenhouse Spectral Changes in Radiative Forcing

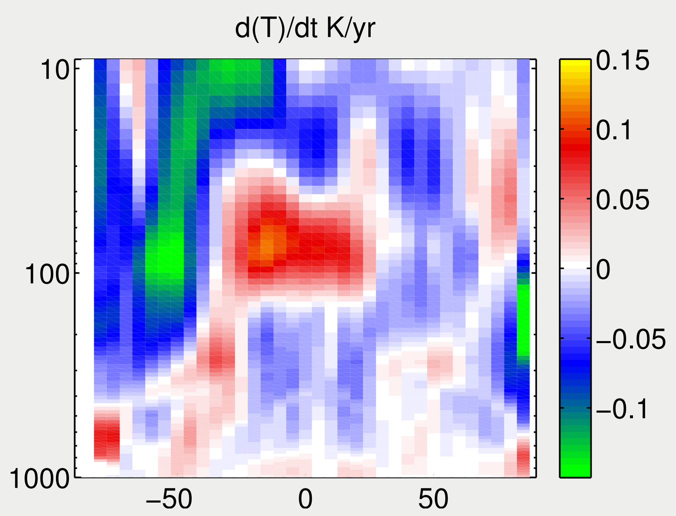


Red curve is AIRS allsky rates, averged over whole globe
Blue curve is global synthesized clear sky rates
The negative trends from 650 cm^{-1} to 800 cm^{-1} are due to CO_2 increases, which decrease radiation to space
The 800 cm^{-1}- 1200 cm^{-1} positive trends could be cloud feedbacks

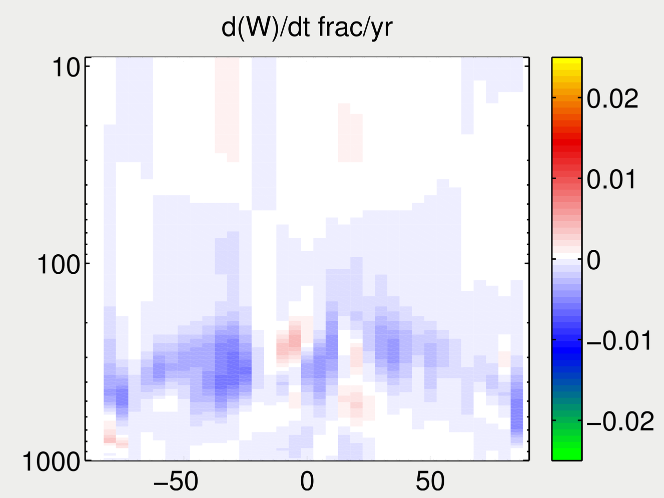
7. T(z) and WV(z) All-Sky rate retrievals

Geophysical rates derived from AIRS all-sky radiance trends (UMBC-AIRS) agree better with re-analysis (ERA and MERRA) rates, than with AIRS L3 rates. The L3 product is derived from AIRS L2 retrievals.

T(z) rate from UMBC-AIRS

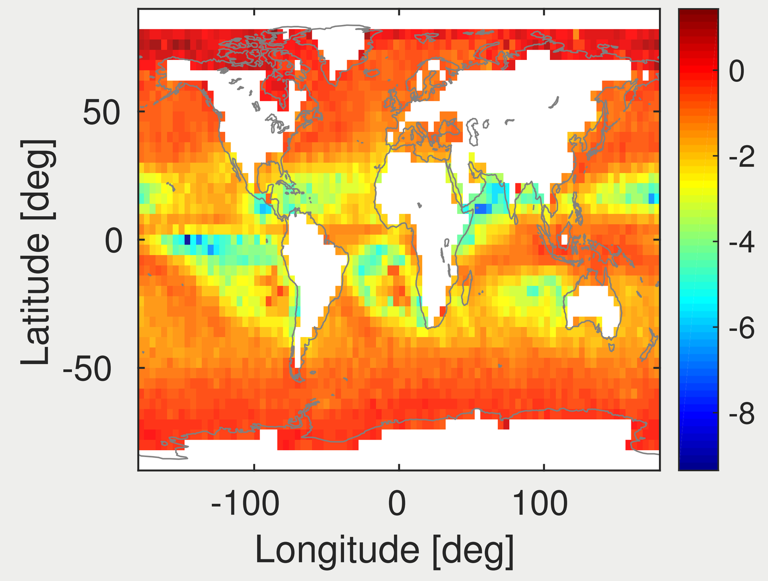


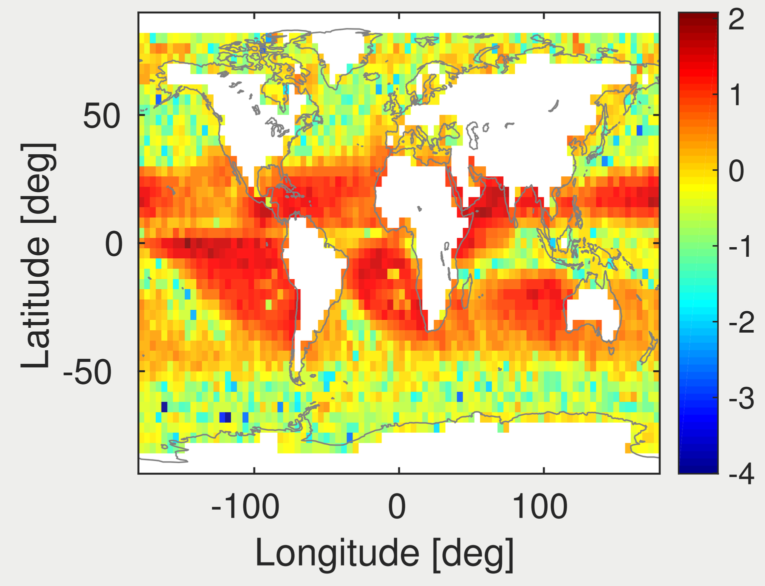
WV(z) rate from UMBC-AIRS



8. Skewness and Kurtosis of window channel centered at 1231 cm^{-1}

(L) Skewness and (R) log_{10}(Kurtosis) shown on a 4 × 4 grid. Regions of high Skewness and Kurtosis are where non-Gaussian extreme events are more likely.





9. Theoretical Background

- Physical processes can be separated into into fast and slow modes. The slow modes are deterministically represented while the fast modes are approximated by a state dependent noise process.
  The system can then be modeled by a stochastic different equations (SDE):

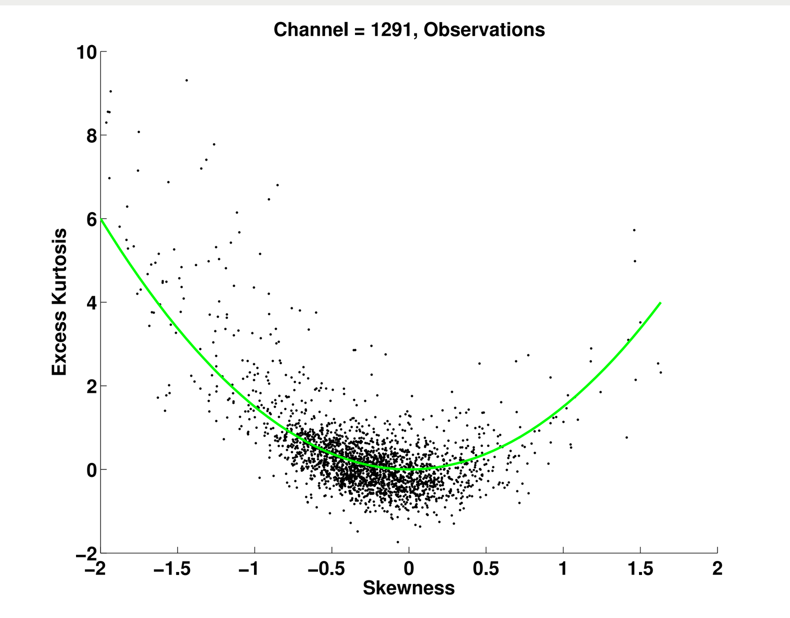
$$\frac{dx}{dt} = A(x) + B(x)\eta(t) \quad (1)$$

  Here the slow processes are described by $A(x)$ and $B(x)\eta(t)$ is an approximation to the fast processes where $\eta(t)$ is a noise vector. The stochastic forcing is then state dependent (through $B(x)$) which has been shown to be one possible scenario that leads to non-Gaussian PDFs.
- When Correlated Additive and Multiplicative (CAM) noise is present, the stochastic model of Equation 1 yields a relationship between the excess kurtosis ($K = < x >^4 / \sigma^4 - 3$) and skewness ($S = < x >^3 / \sigma^3$):

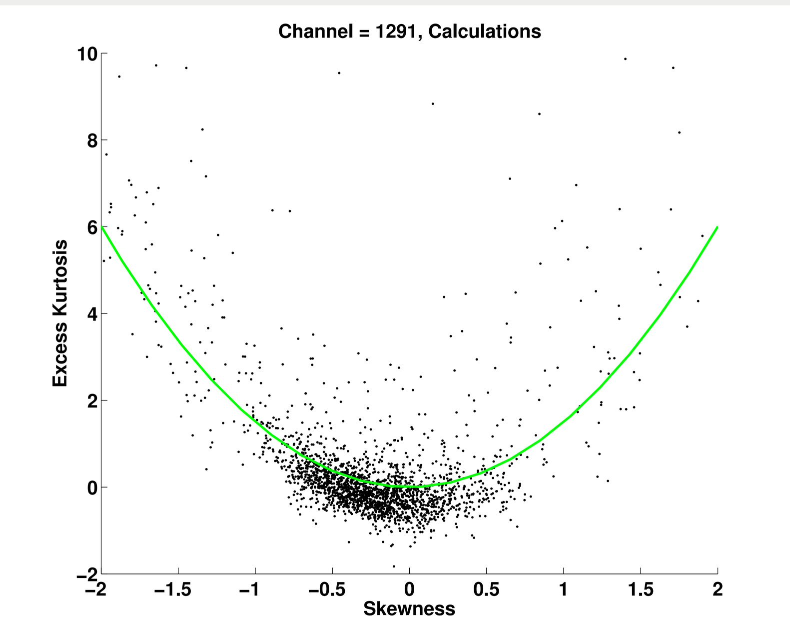
$$K \geq \frac{3}{2}S^2 - r \quad (2)$$

10. Skewness vs. Kurtosis for 1231 cm^{-1} channel

AIRS observations



BT Calculations from ERA



Clear sky 1231 cm^{-1} Observations and ERA simulations look very similar. There are a number of data points below the curve; this possibly arises from using a simple model to describe complex multidimensional dynamics.