Using AIRS PDFs to study climate variability 2002-2015

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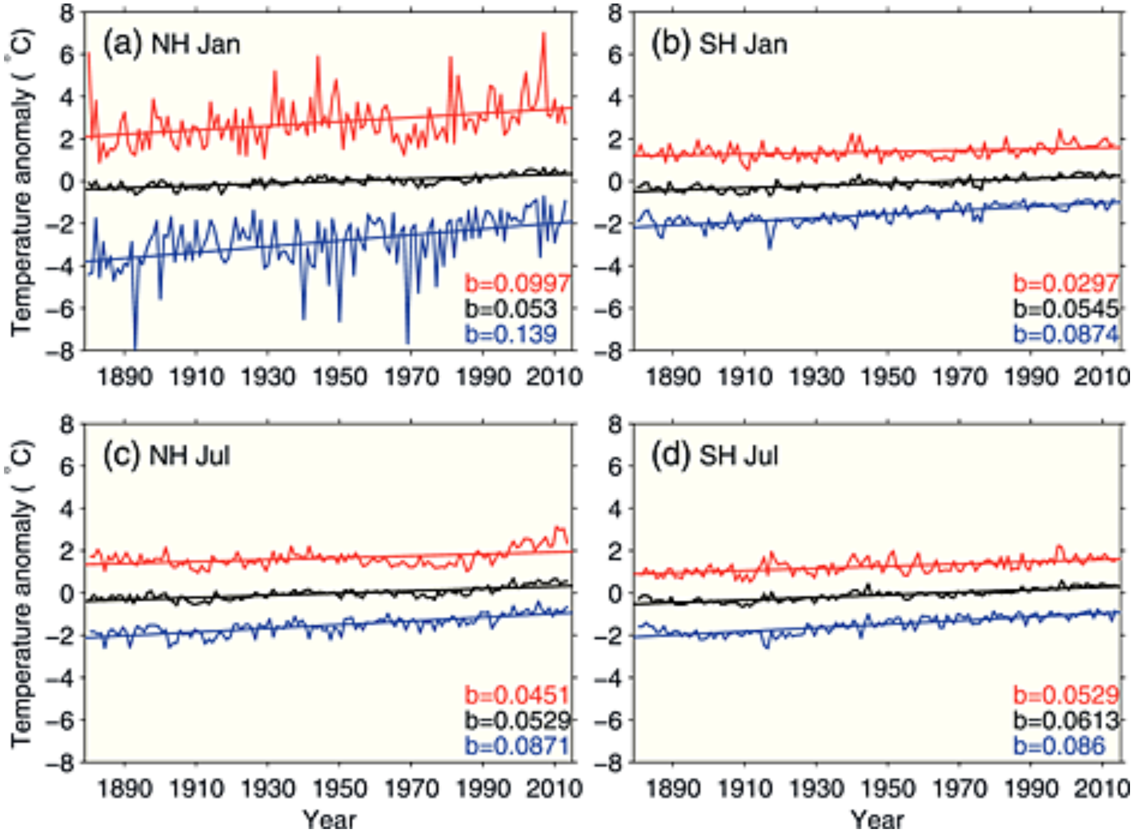
Talk Outline

- Motivation for studying climate extremes using PDFs
- Stochastic forcing and climate variability
- PDFs and extreme events.
- AIRS all-sky PDFs – effect of clouds
- Changes to PDFs over 13 years
- Conclusions

Extreme events and Climate

- Extremes can change at significantly different rates than mean for geophysical processes.
- Example (Robeson, et al., GRL, 2014) shows combined SST and overland air temperatures (HadCRUT4)

Red – 95%
Black – 50%
Blue – 5%



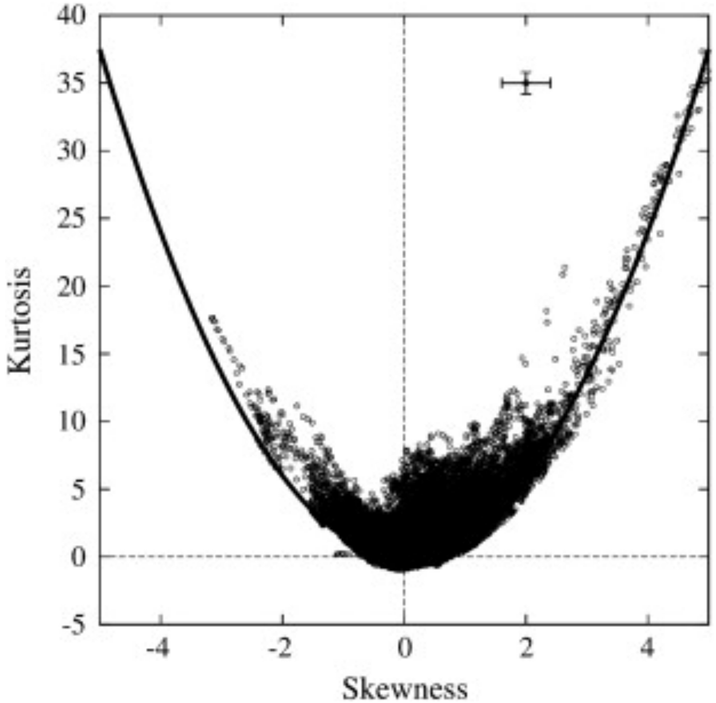
What is the cause of these different rates?

Stochastic forcing

Sura (2011) has shown that 30 years of SST data, binned by lat/lon has higher moments that obey:

$$K > (3/2)\, S^2 - r$$

Where
S = Skewness (3rd moment); K = Kurtosis – 3 (4th moment)
r = constant that depends on degree of spatial correlation in the forcing.

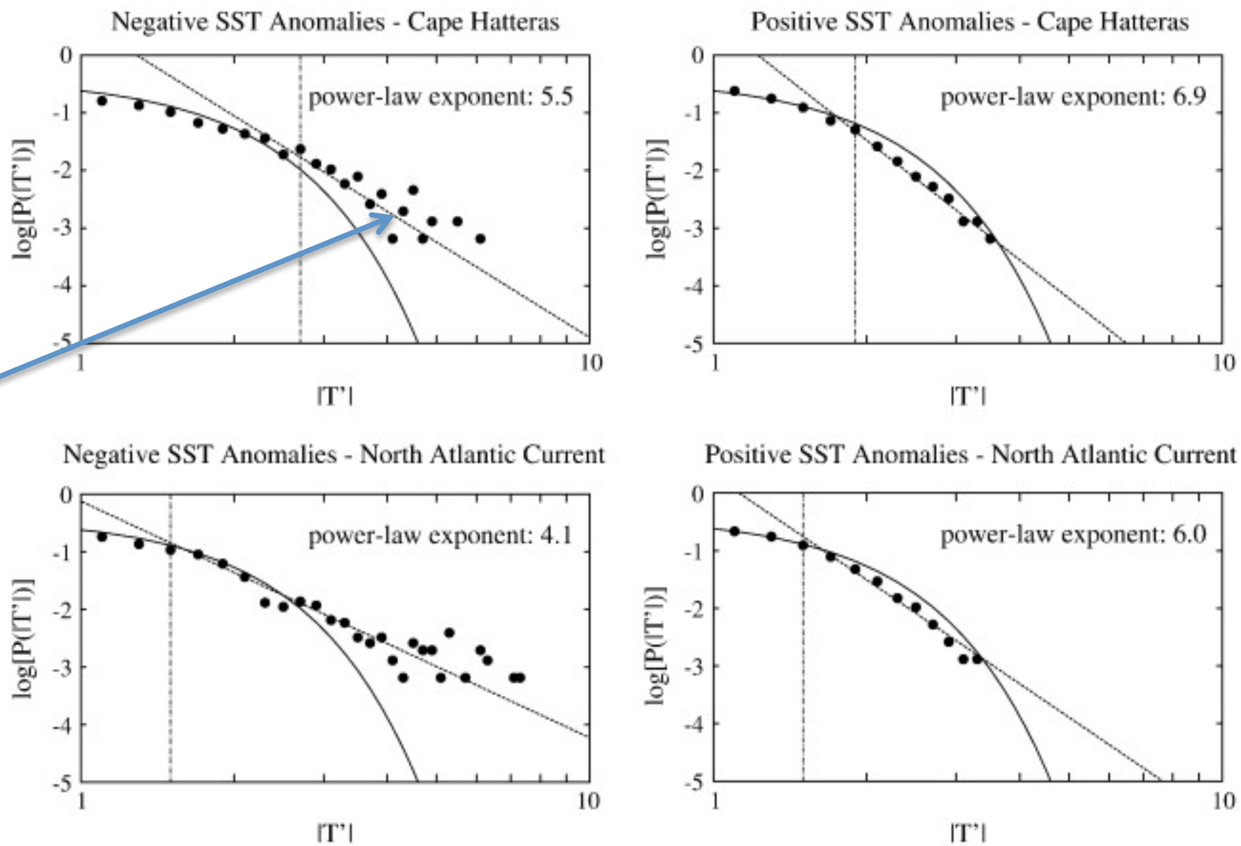


- Each dot represents a lat/lon grid box.
- Gaussian statistics would result in a single dot at (0,0).

Why is this important?

Probability Density Function (PDF) tails

Log scale extreme edges of PDFs for SST from Sura (2011)



Extreme tail results in more occurrences than for Gaussian.

What is stochastic forcing in geophysics?

- Forcing that occurs on timescales << observed process timescale.
- This results in multiplicative stochastic forcing (slow × fast)
- Particularly important in Non-linear dynamics (wind speed x temp gradient).

Some example:

- SST (and ENSO) ⬄ Surface winds
- Greenland Ice sheet cover ⬄ pulsing of fresh and salt water.

AIRS radiance measurements and ERA simulated radiances

From DeSouza-Machado, et al., submitted to Applied Meteorology and Climatology, 2015

Clear sky scenes, over oceans, analyzed for 2002-2012

662 cm^{-1} Upper Stratosphere Ozone

754 cm^{-1} Mid-tropospheric temperature

1024 cm^{-1} Stratospheric Ozone

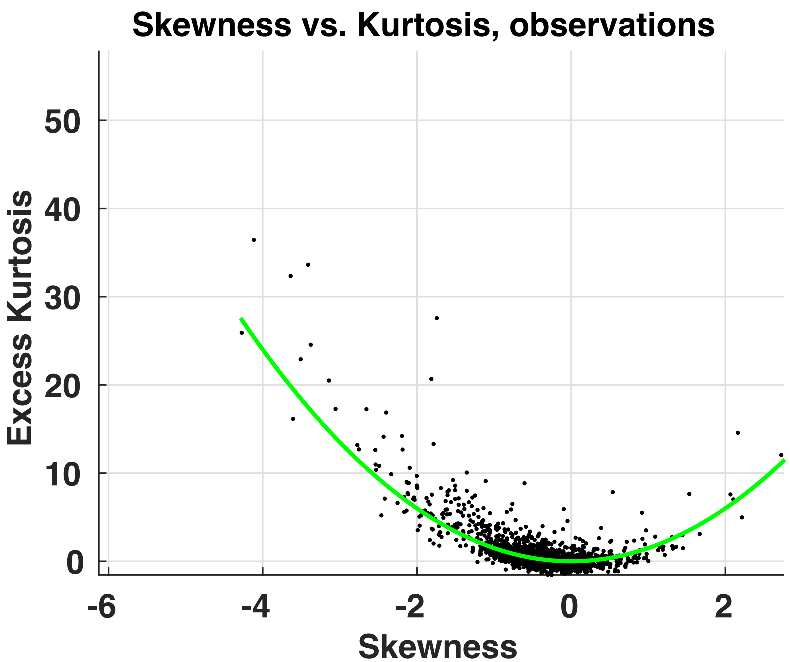
1231 cm^{-1} Surface temperature and lower tropospheric humidty

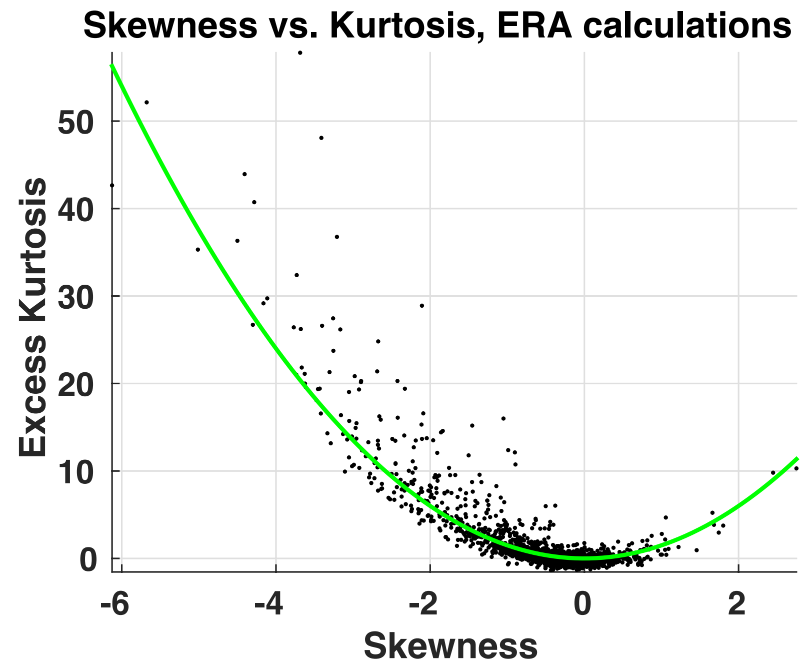
1344 cm^{-1} Lower tropospheric humidity

1420 cm^{-1} Upper trop./lower strat. Humidty

Do these channels all exhibit the same statistical behavior?

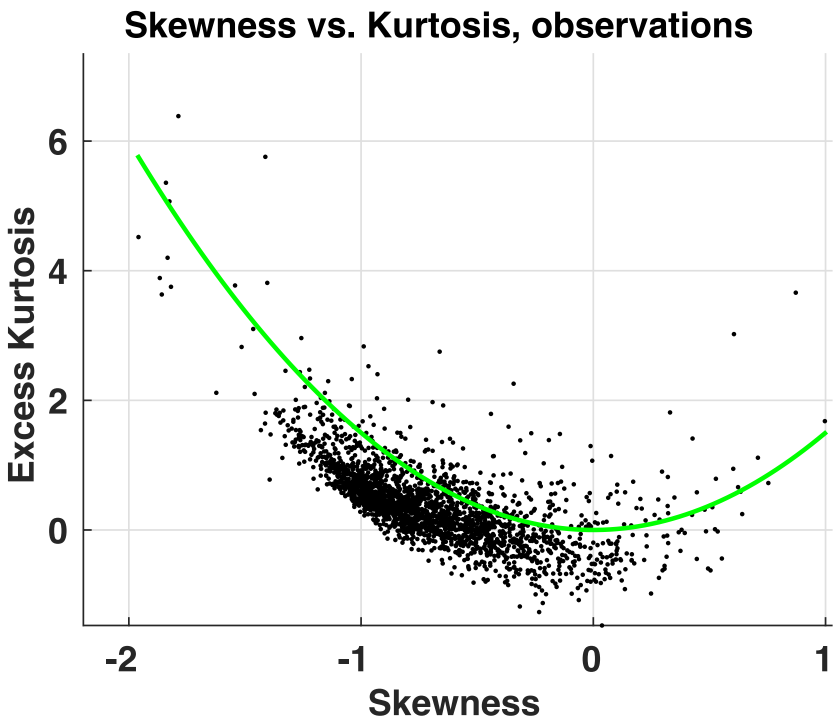
1231 cm^{-1} (Surface temp and WV)

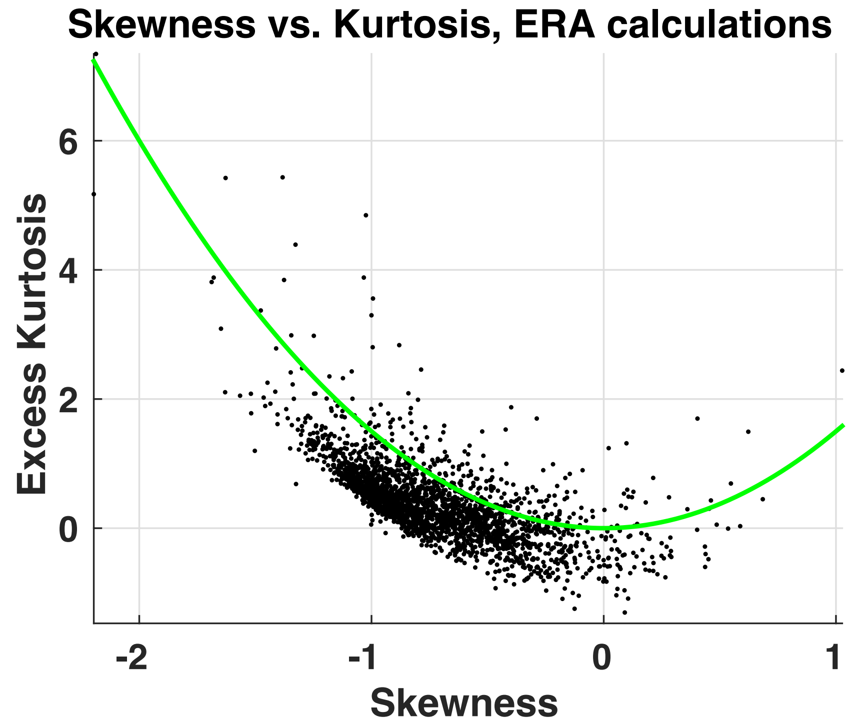




- Both AIRS and ERA radiances conform to the $K > 1.5\ S^2 - r$ statistics.
- ERA appears to have more negatively skewed regions => effect of WV?
- An expected result due to the sensitivity to SST

1024 cm^{-1} (Stratospheric Ozone)

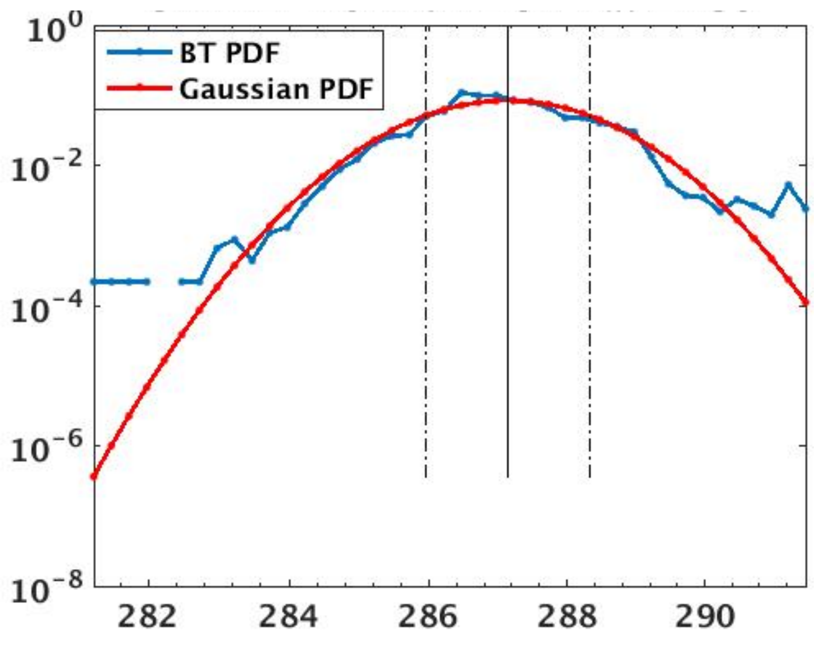




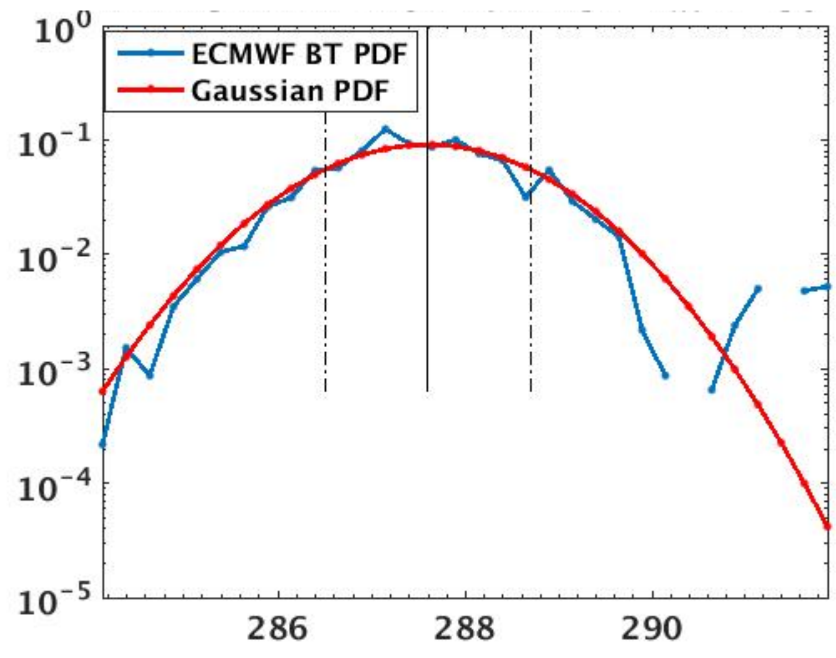
- Statistics in most of the regions fall below the 1.5S^2 curve
- Possibly weaker stochastic forcing or stronger spatial correlation

PDF for 1231 cm^{-1} (34E, 38S), DJF

Obs



ERA

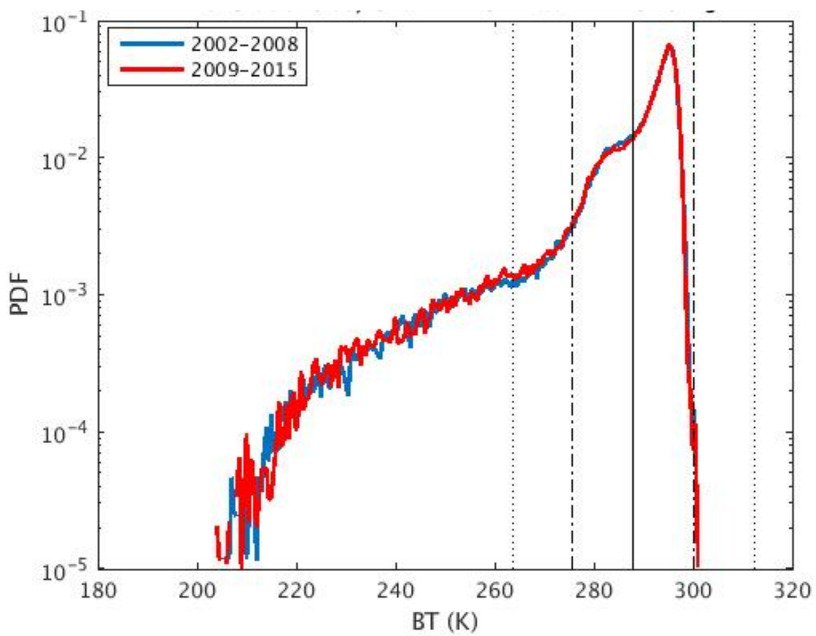


- Both Obs and ERA show hot side tails, but more well defined in Obs
- Cold side tail in Obs only. Could be due to differences in Trop WV.

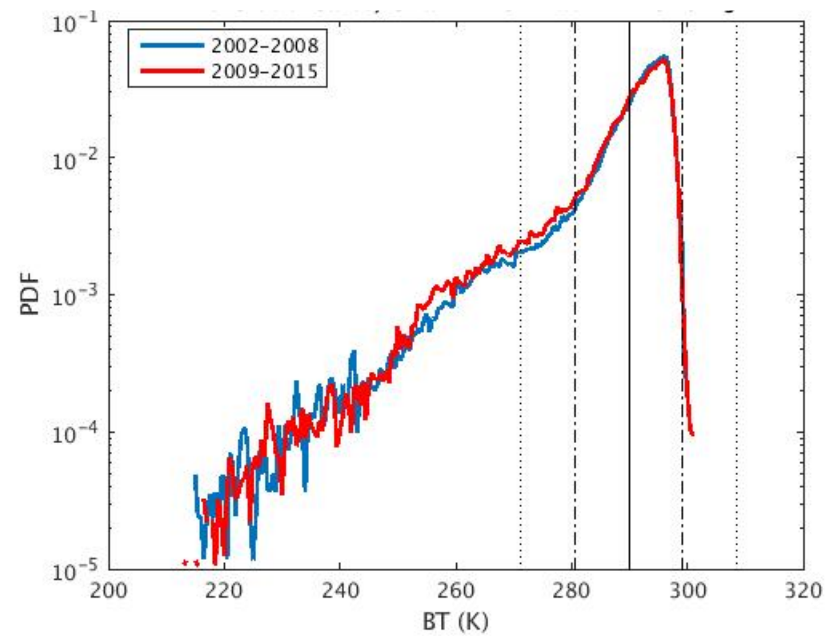
All-sky PDFs – change over 15 years

1231 cm^{-1} (Surface temperature and WV)

Obs



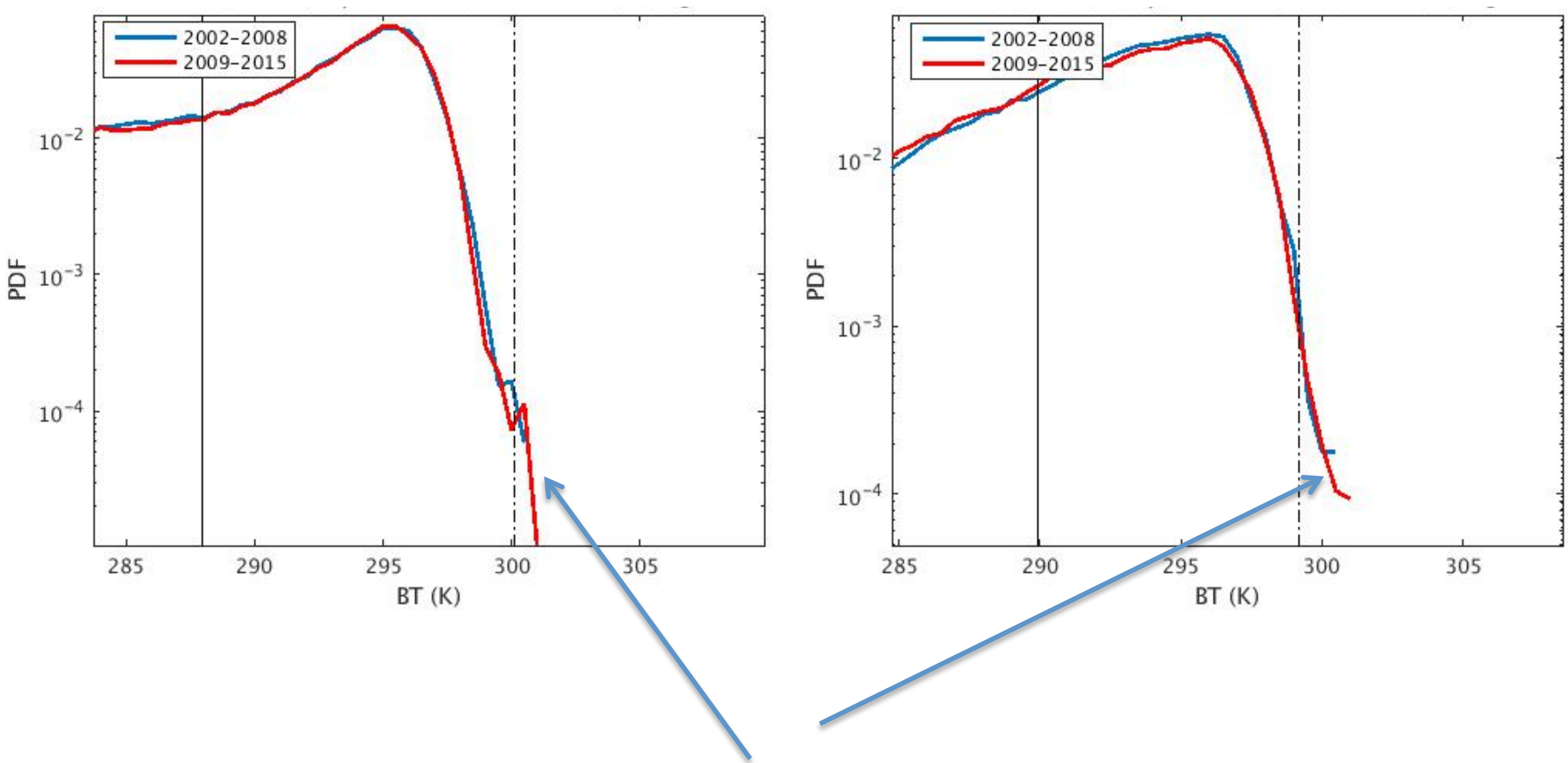
ERA



- Some differences at lower temperatures (clouds)
- More change in ERA than in Obs in the 250-270K region
- Focus on Hot tail extremes

Zoom in on hot extremes:

Obs ERA



Both AIRS and ERA show some increase in extremes for 1231 cm^{-1}

Conclusions and Future Work

- Evidence for stochastic forcing of climate variability in AIRS radiance data.
- Comparisons with ERA show larger differences in the extremes than in the mean.
- Changes to PDFs are relatively small over the 13 years of AIRS data, with larger changes in the PDF tails.
- Future Work: Linear rates of extreme events and connecting these to mean changes – How are mean change amplify extreme events?