# Studying Changes in PDFs of Selected AIRS channels

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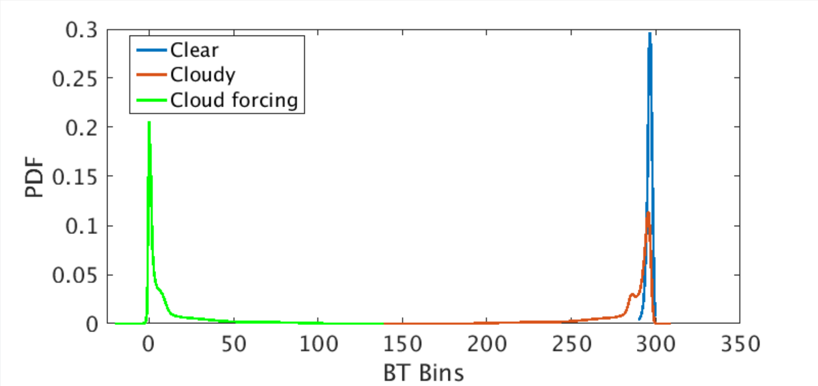
# Overview

- AIRS has now made 14 years of high quality TOA radiance measurements
- We have previously shown that the instrument stability is sufficient to determine linear rates surface temp., column $CO_2$, temp. and wv profiles
- We have also shown that probability density functions (PDFs) of clear sky PDFs can provide insight into non-Gaussian climate variability and stochastic forcing of the atmosphere
- In this talk, we further show how PDFs can provide information on the rate of change that would be missed when looking at changes to mean properties
- We focus on a single channel ($1231 cm^{-1}$), sensitive to surface temp., column water and clouds.
- Observations are allsky, night, over land and ocean

# AIRS Obs, Clear Calcs and Cloud Forcing PDFs at the equator

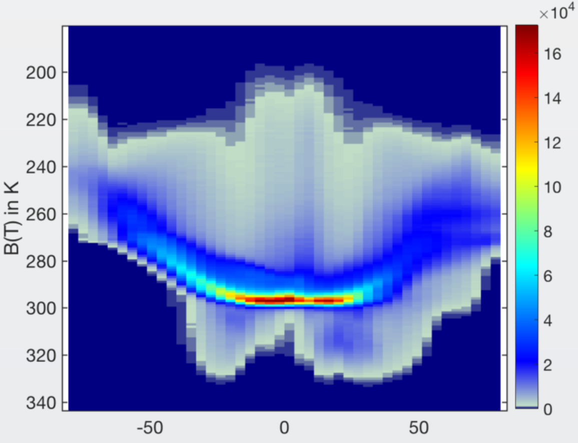
Over ocean, night time



# Mean PDF from 13 years of allsky observations from $1231 cm^{-1}$, all latitudes.

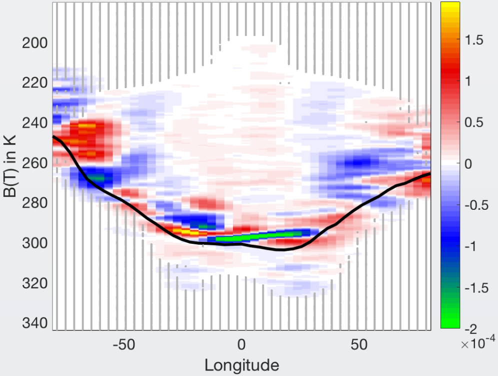
Window channel sensitive to surface temperature, clouds and column water vapor

- PDF scale is indicated by the colorbar. The x and y axes show the latitude and BT bins.



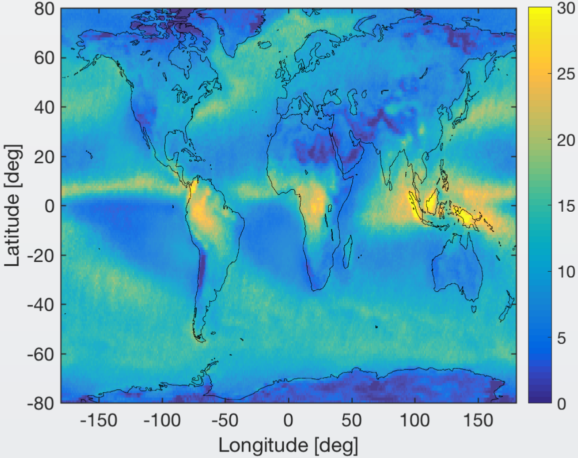
# Rate of change in BT PDF for 1231$cm^{-1}$

- Linear rate from regression of 1231$cm^{-1}$ PDF.
- PDF rate shows how occurences of a particular BT range are changing per year.
- Color bar scale shows whether BT is increasing.
- Gray lines are where rate < uncertainty



# Cloud radiative effect

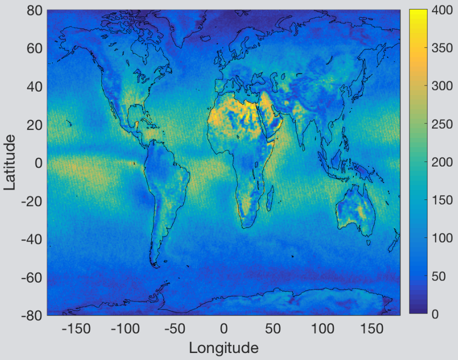
- Mean cloud forcing over 13 years.
- Clear Calculated Bt - Obs using ERA.
- Averaged on 1x0.5 degree grid.



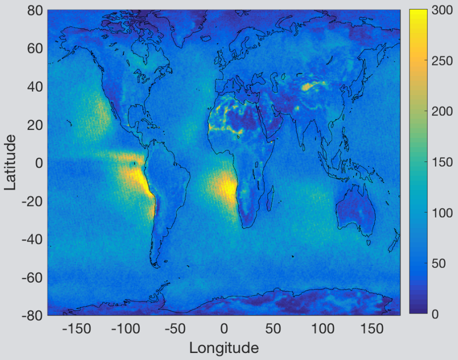
# Observation count for cloud forcing ranges

- Observations per pixel.
- 1% of data over 13 years.

1-5 K



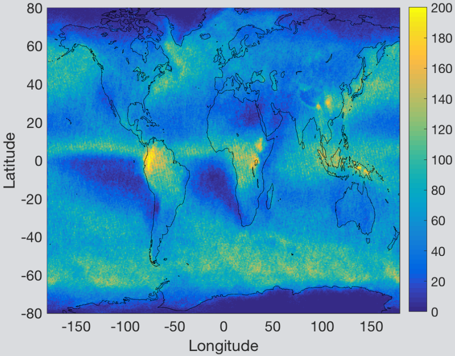

5-15 K



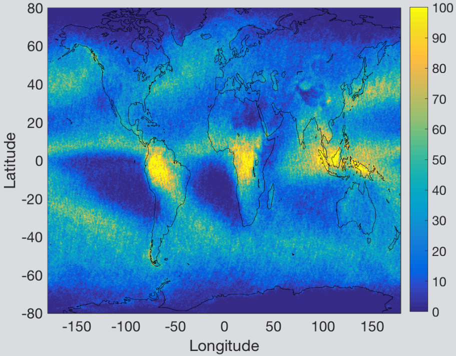
# Observation count - continued

- Observations per pixel.
- 1% of data over 13 years.

15-30 K

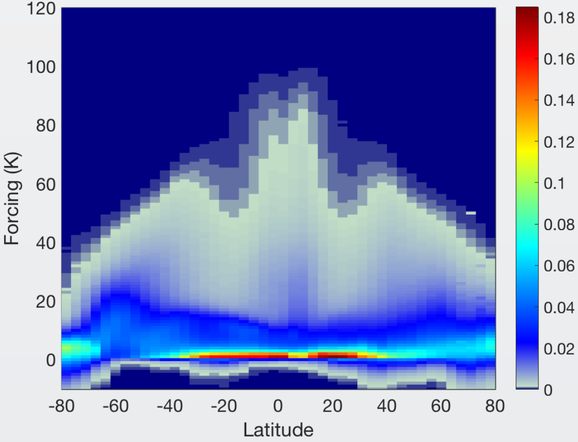



30-45 K



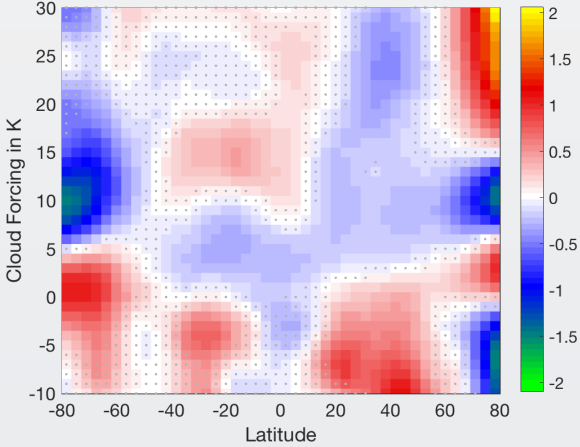
# Mean Cloud Forcing over 13 years, zonal average

- Color bar indicates PDF value.
- Large values indicate deep convective clouds.
- Values near zero indicate clear sky.



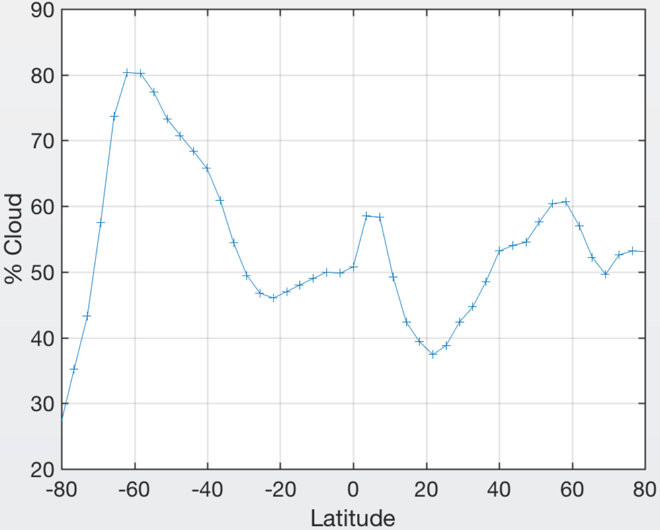
# Percent rate of change in cloud forcing ($1231 cm^{-1}$).

- Rates form linear regression of cloud forcing over 13 yrs
- Color scale indicates percent change in PDF per year
- Regions with dots have uncertainty greater than rate



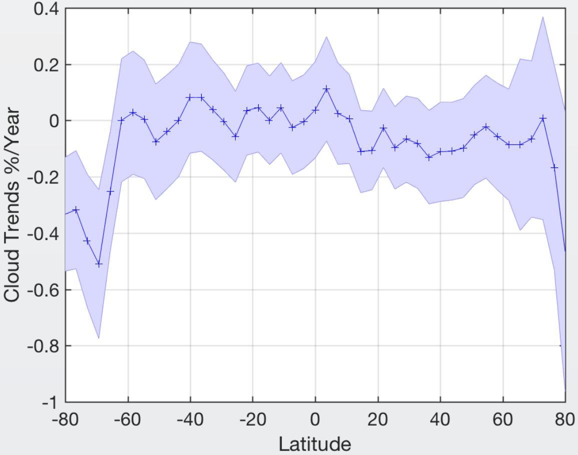
# Mean Total Cloud Fraction over 13 years

- Sum of cloud forcing PDFs from 5K to maximum



# Percent rate in change of cloud fraction

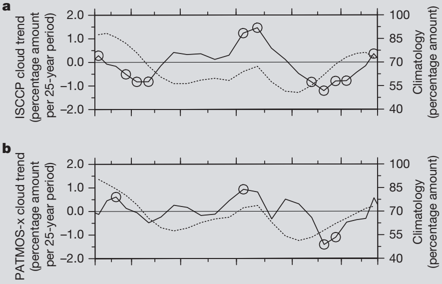
- Sum rate of change in cloud forcing from 5 K to maximum
- Uncertainty from linear regression



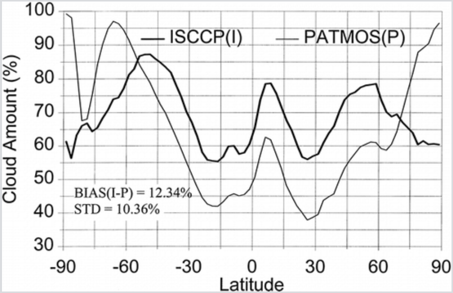
# Imager determination of cloud fraction

- ISCCP = count how many cloudy 5 km pixels there are in a 280 km region, seen by satellite? http://isccp.giss.nasa.gov/cloudtypes.html
- PATMOS : from AVHRR, cf from tests using IR/NR/VIS channels (Foster et. al., Remote Sens. 2016, 8(5), 424; doi:10.3390/rs8050424)

Norris (Nature 2016)



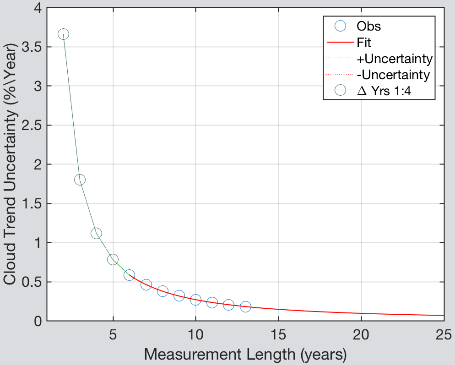

Stowe (JGR 1997)



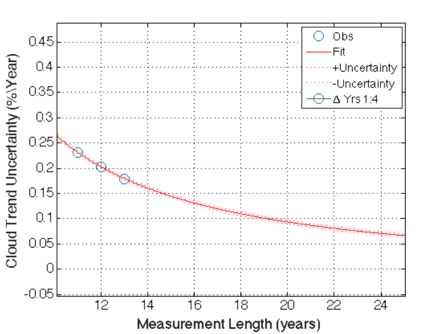
# Reduction of Uncertainties over Time

- Linear regression errors decrease with longer data sets
- We calculate the regression errors for 1-13 year linear fits and extrapolate to 25 years

## 25 years




## Zoom to last 15 years



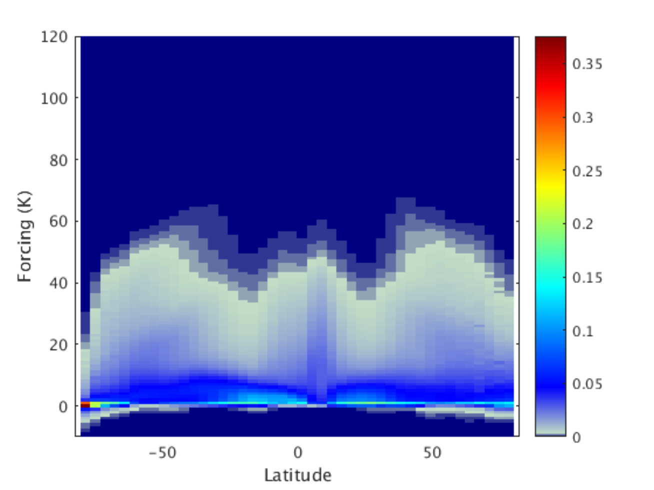
# Conclusions

- AIRS can give you high-quality pseudo-veritcal cloud percent changes, and we are starting to reach climate level measurements
- Linear rates of cloud forcing can be used to obtain cloud fraction rate dependence on latitude and level
- Longer term IR observation records should lead to higher accuracy
- Introduced a simple and easily implemented definition of partial cloudiness that agrees with eg ISCCP and PATMOS
- Preliminary results, more work needed

# Welcome, William

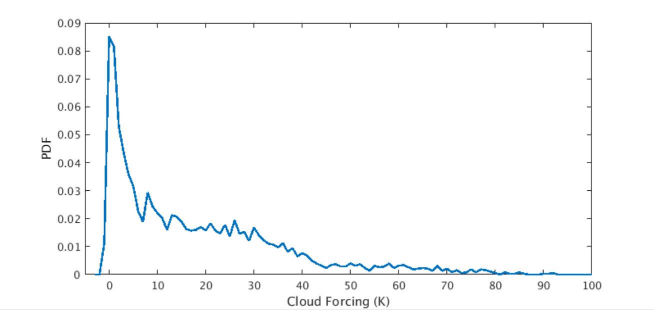
# Cloud Forcing PDF with ERA Calcs, Ocean Only

- Shows much less negative forcing over oceans



# Cloud forcing PDF at equator, ERA Calcs, one month

- Sum of these PDF values gives the cloud fraction.



# Cloud forcing rates, ERA Calcs, ocean only

- Shows high clouds increasing over tropics and northern mid-lat.