A satellite image showing two large, swirling hurricane systems over the ocean. The hurricane in the upper right is more developed, with a clear eye and dense cloud bands. The one in the lower left is also well-defined but appears slightly less intense. The surrounding ocean surface shows some smaller-scale wave patterns.

# Update on single-footprint retrievals and some new applications.

Bill Irion

Jet Propulsion Laboratory  
California Institute of Technology

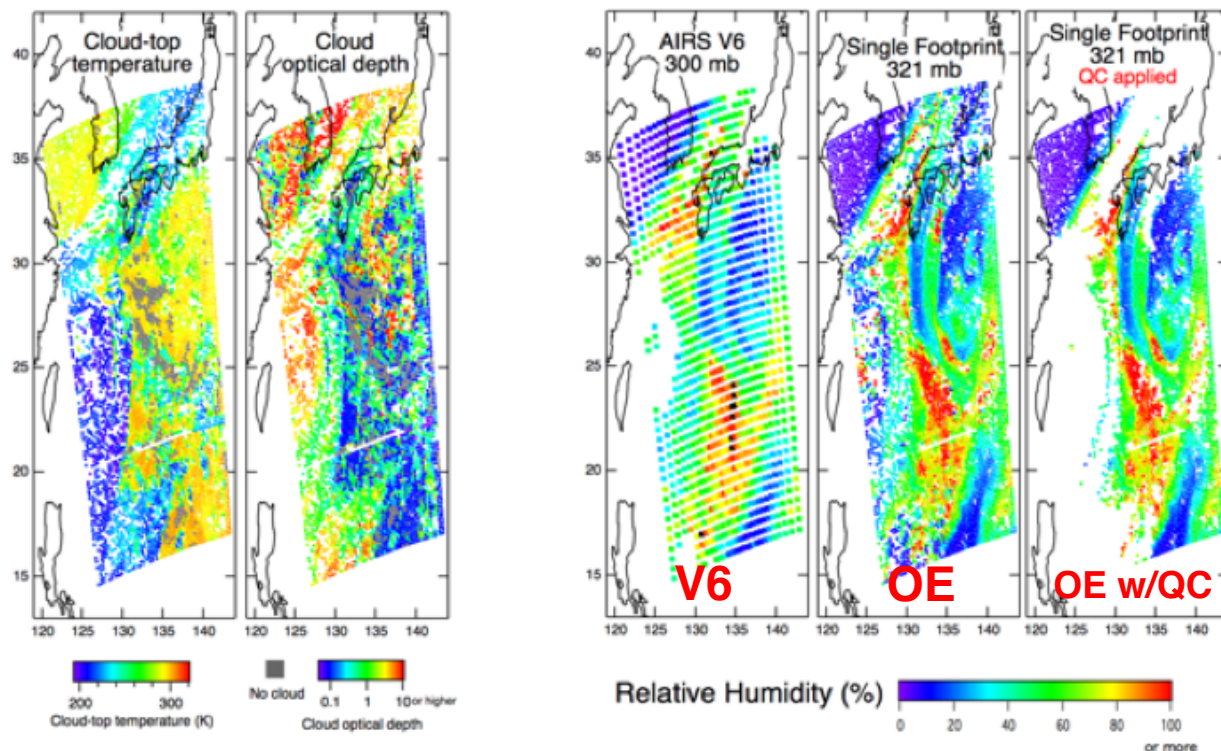
With thanks to Luke Chen,  
Jesse Dorrestijn, Eric Fetzer,  
Brian Kahn, Bjorn Lambrigtsen,  
Ed Olsen, Tom Pagano and  
Joao Teixeira

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Government Sponsorship acknowledged

# Single Footprint Retrievals from AIRS L1b Spectra

- Uses AIRS L1b directly – no microwave and **no cloud-clearing**
- 13.5 km horizontal resolution at nadir, but no retrieval below thick clouds
- SARTA forward model + Delta-4-Stream cloud calculation (*Strow et al.*, 2003; *Ou et al.*, 2013)
- Simultaneous optimal estimation retrieval (TES heritage; *Bowman et al.*, 2006)
  - surface temperature,
  - cloud-top temperature, cloud optical depth and particle size
  - profiles of temperature, water vapor
- MODIS L2 cloud properties (averaged on AIRS footprint) used as cloud *a priori*
- ECMWF 6hr analyses used for surface, temperature and water vapor profile *a priori*

Granule 44  
Sept 6, 2002  
(Subtropical Western  
Pacific. Note tropical  
cyclone to west)



*Irion, F. W., et al.: Single-footprint retrievals of temperature, water vapor and cloud properties from AIRS, Atmos. Meas. Tech. Discuss., in review, 2017.*

## Clouds often not realistic in current forward model in AIRS-OE

- Delta-4-Stream scattering code outputs cloud at only a single temperature, wedged into a single forward model layer.
  - OK for thin clouds, but upwelling radiance biases for thick clouds
  - Many failed retrievals above high thick clouds
- Maximum one cloud in an AIRS footprint
- No aerosol calculations
- Problems from scan angle biases in ozone 10 micron band using L1b directly

## Current work in progress is to adapt forward model of DeSouza-Machado et al. (“SARTA TwoSlab”) *Atmos. Meas. Tech. Discuss., in review, 2017*

- Ability to use 2 clouds or cloud/aerosol combination over multiple layers.
  - Would open up more footprints for retrieval
- Work in progress to integrate SARTA TwoSlab Fortran into AIRS-OE retrieval
  - Conversion from executable to callable subroutine finished, not tested.
  - Other changes to simplify code and speed-up execution speed.



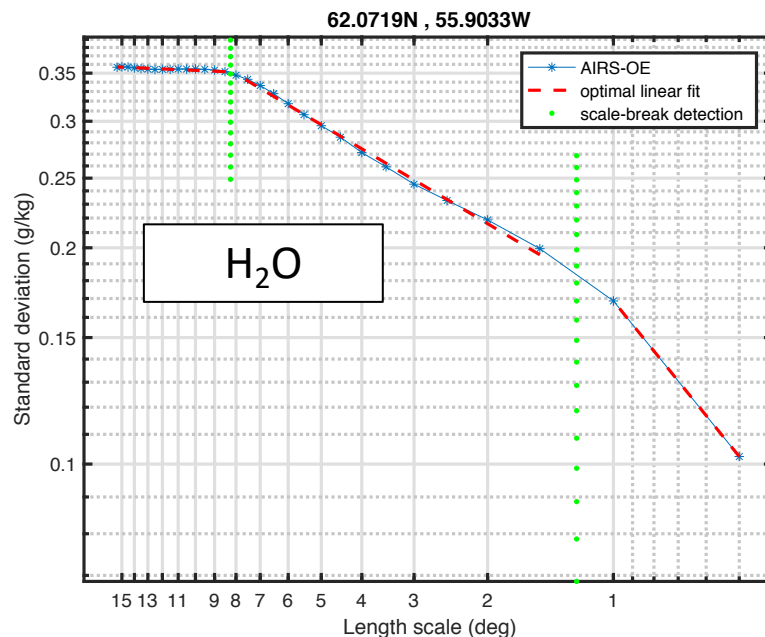
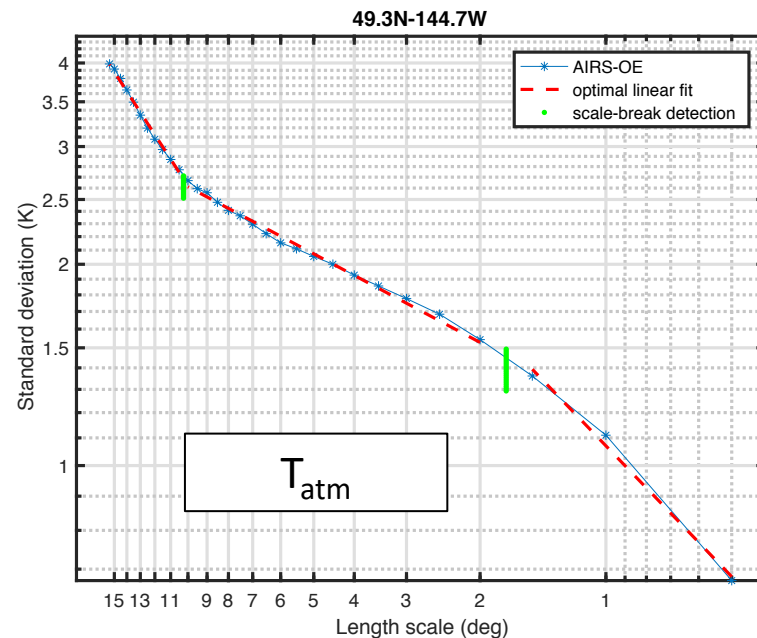
# Application of Single-Footprint Retrievals to Variance Scaling

*Dorrestijn et al.,  
in preparation, 2017*

Variance scaling is useful for parameterizing sub-grid variables in GCMs

Kahn and Teixeira [2009] produced a global climatology of variance scaling from AIRS (on the cloud-cleared footprint)

Dorrestijn et al. have detected scale breaks at less than 150 km using the single-footprint retrieval.

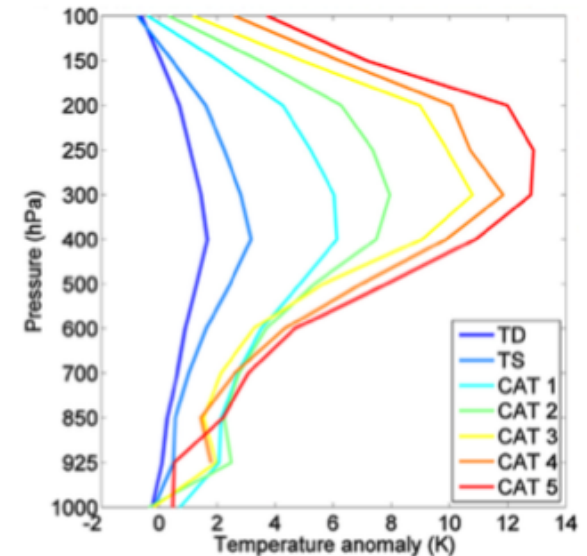
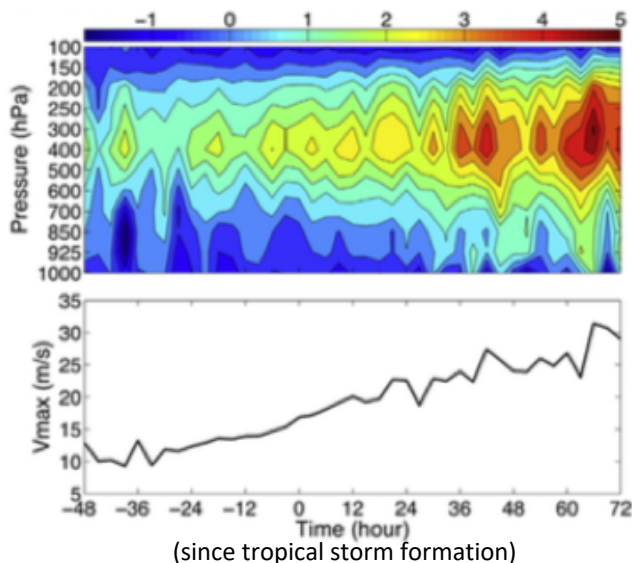


# Hurricane Eye $T_{\text{atm}}$ and $\text{H}_2\text{O}$ anomalies

- Eye temperatures tend to be warmer than undisturbed regions outside storm.
- Some studies above 300 mb (e.g., Durden, *Mon. Wea. Rev.*, 2013).

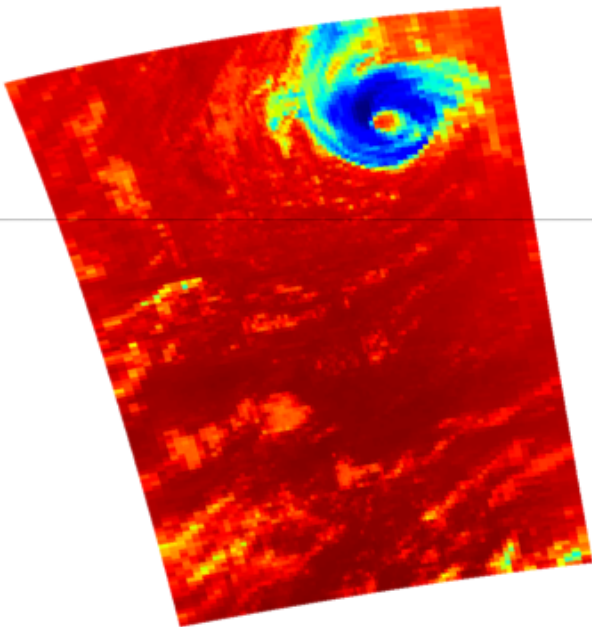
Temperature anomalies using AIRS V6 data.

Gao et al., *Dynam. Atmos. Oceans*, 2017



**Some eyes are big.  
Some eyes are small.**

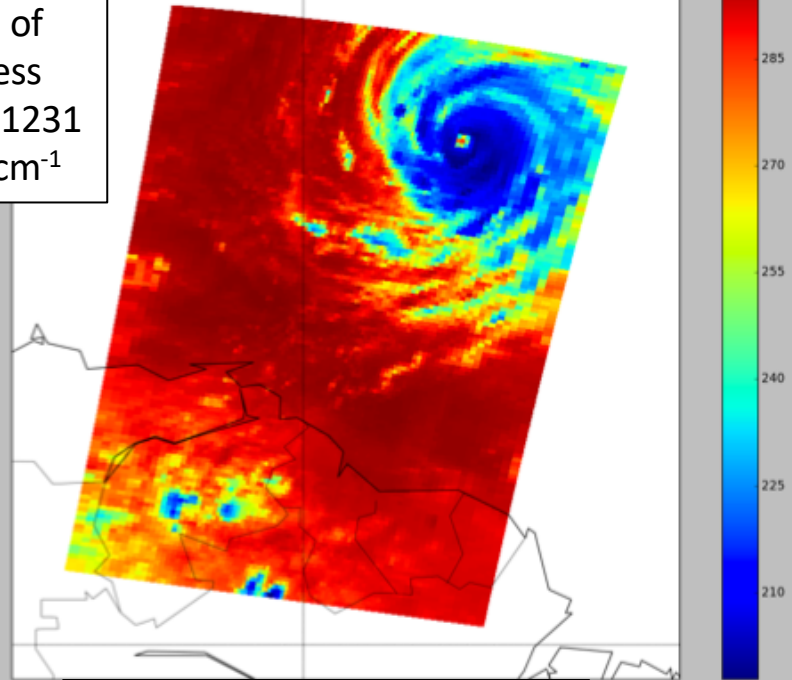
/archive/AIRSops/airs/gdaac/v5/2005/12/05/airbrad/AIRS.2005.12.05.157.L1B.AIRS\_Rad.v5.0.0.0.G07110231659.hdf



Epsilon 12/5/2005 (Cat 1)

Average of  
Brightness  
Temps for 1231  
and 960  $\text{cm}^{-1}$

/archive/AIRSops/airs/gdaac/v5/2010/09/15/airbrad/AIRS.2010.09.15.056.L1B.AIRS\_Rad.v5.0.0.0.G10258125331.hdf



Ivan 9/15/2010 (Cat 4)

# Methodology for preliminary analyses

*Can we do things here with single-footprints?*

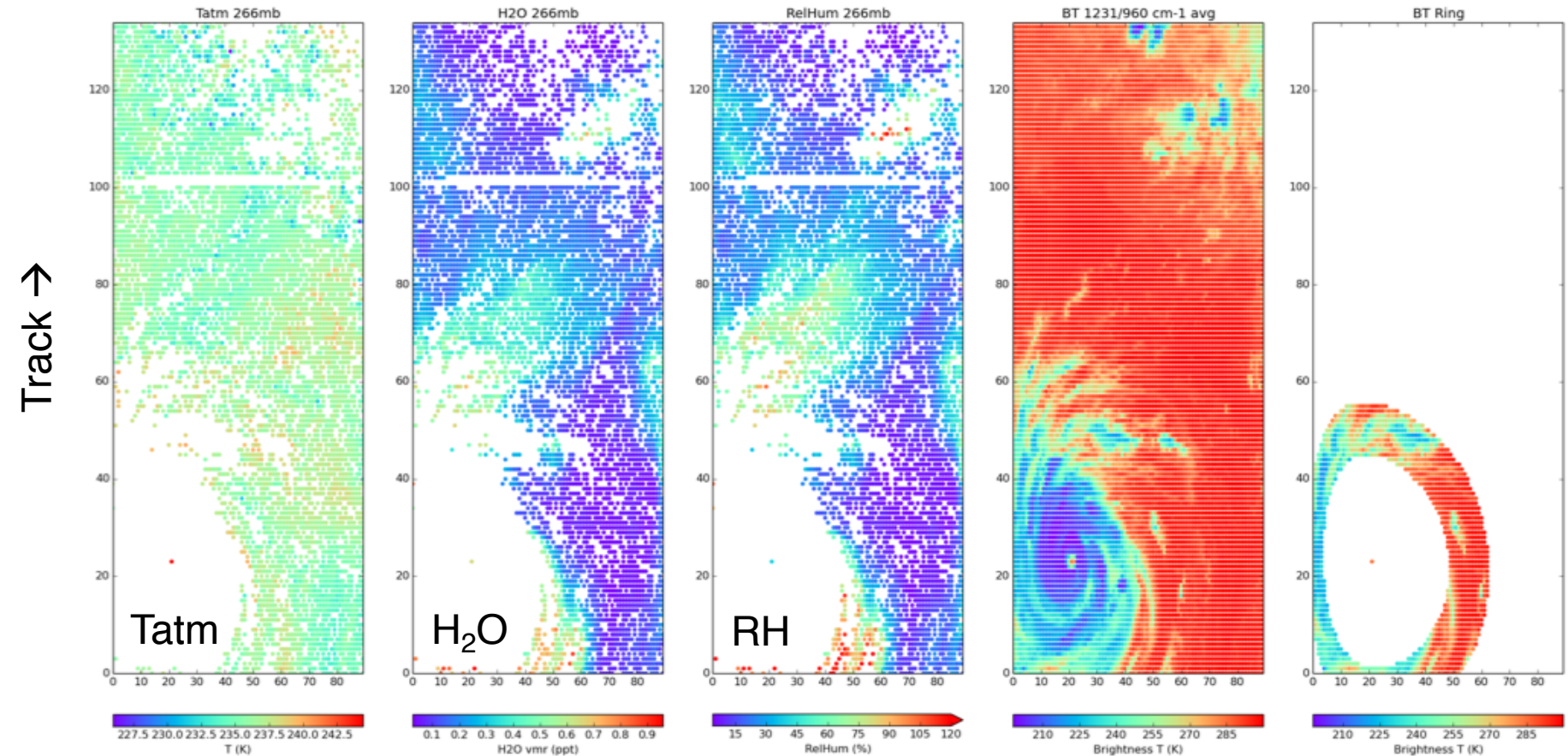
- Select candidate hurricane/cyclone observations from [tropicalcyclone.jpl.nasa.gov](http://tropicalcyclone.jpl.nasa.gov) (Thanks Luke!)
- Test retrievals in eye region using NN prior and window BTs for cloud-top temperature
- If successful, retrieve full granule (and often adjoining granule) using MODIS for cloud a priori and ECMWF for  $T_{\text{atm}}$ /H<sub>2</sub>O.
  - Might be better using neural net?
  - Surface pressure possibly wrong in interpolation.
- Get median eye profile for  $T_{\text{atm}}$  and H<sub>2</sub>O
- Get median difference between eye and ring 400-600 km outside eye
  - Use a better method to determine “undisturbed” region?

# Hurricane Ivan (Cat 4 at observation)

## 9/15/2010 Granule 56

OE Retrievals at 266 mb

Window channel BTs

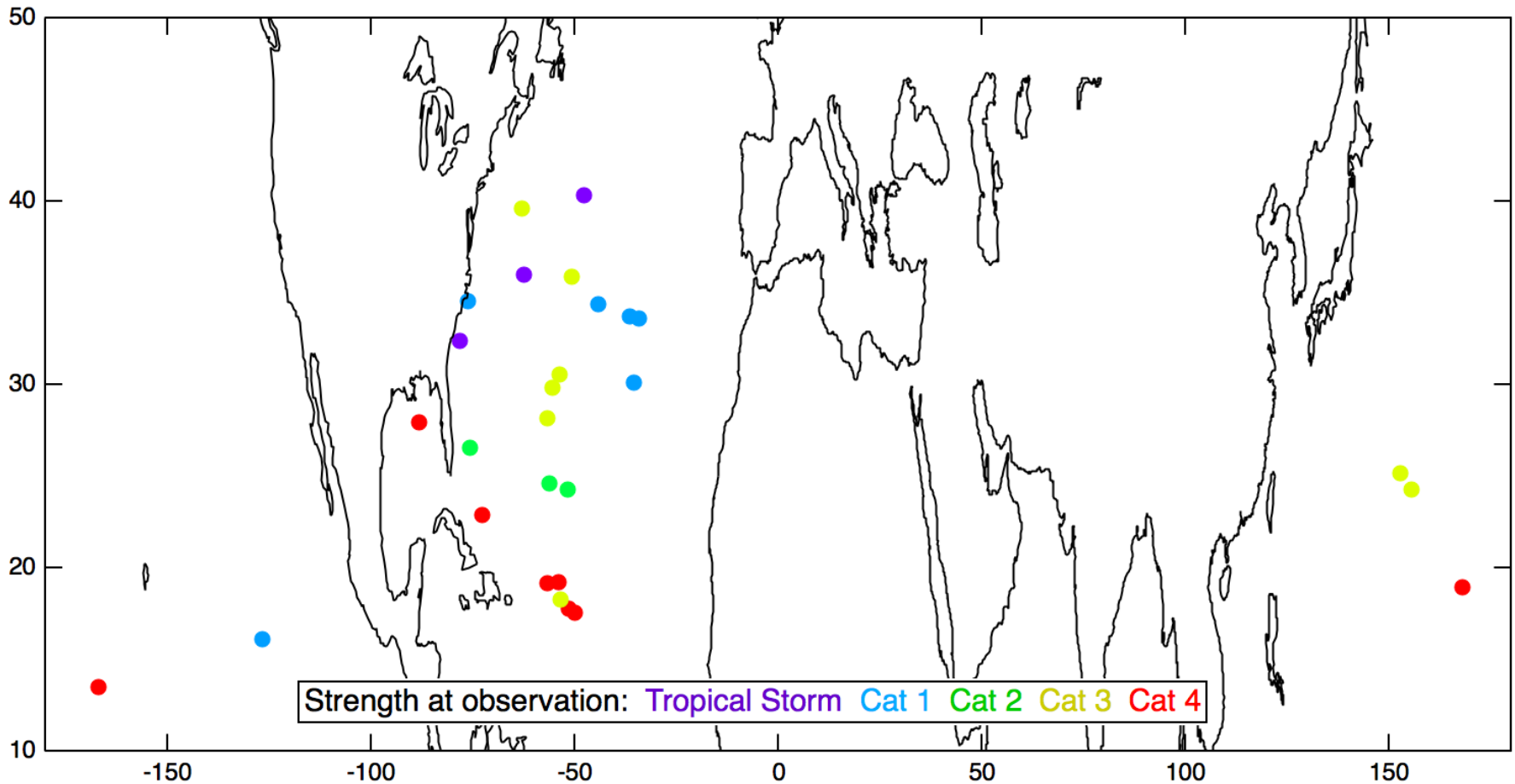


xTrack →

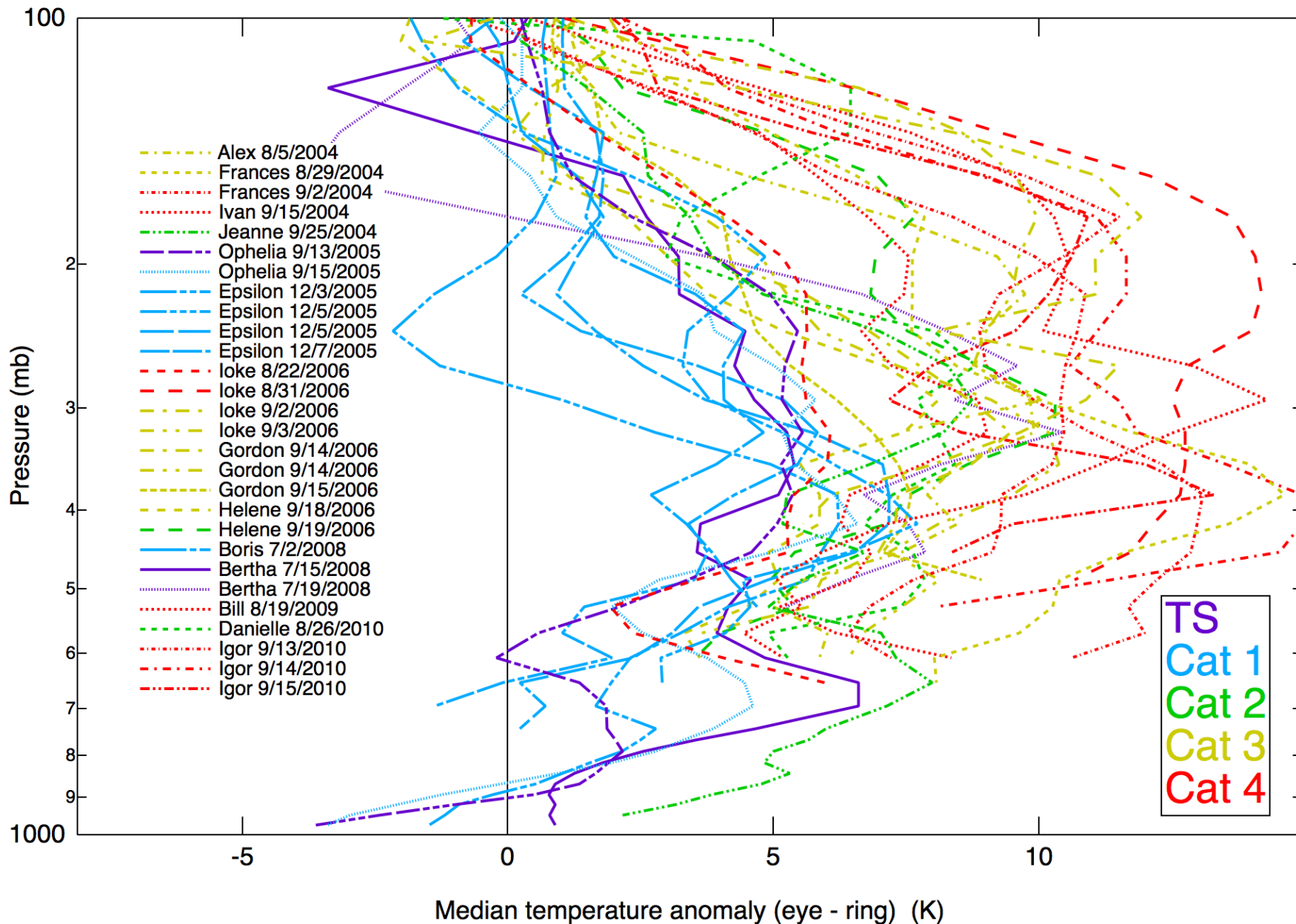


# 14 storms, 28 eyes successfully retrieved 2004-2010

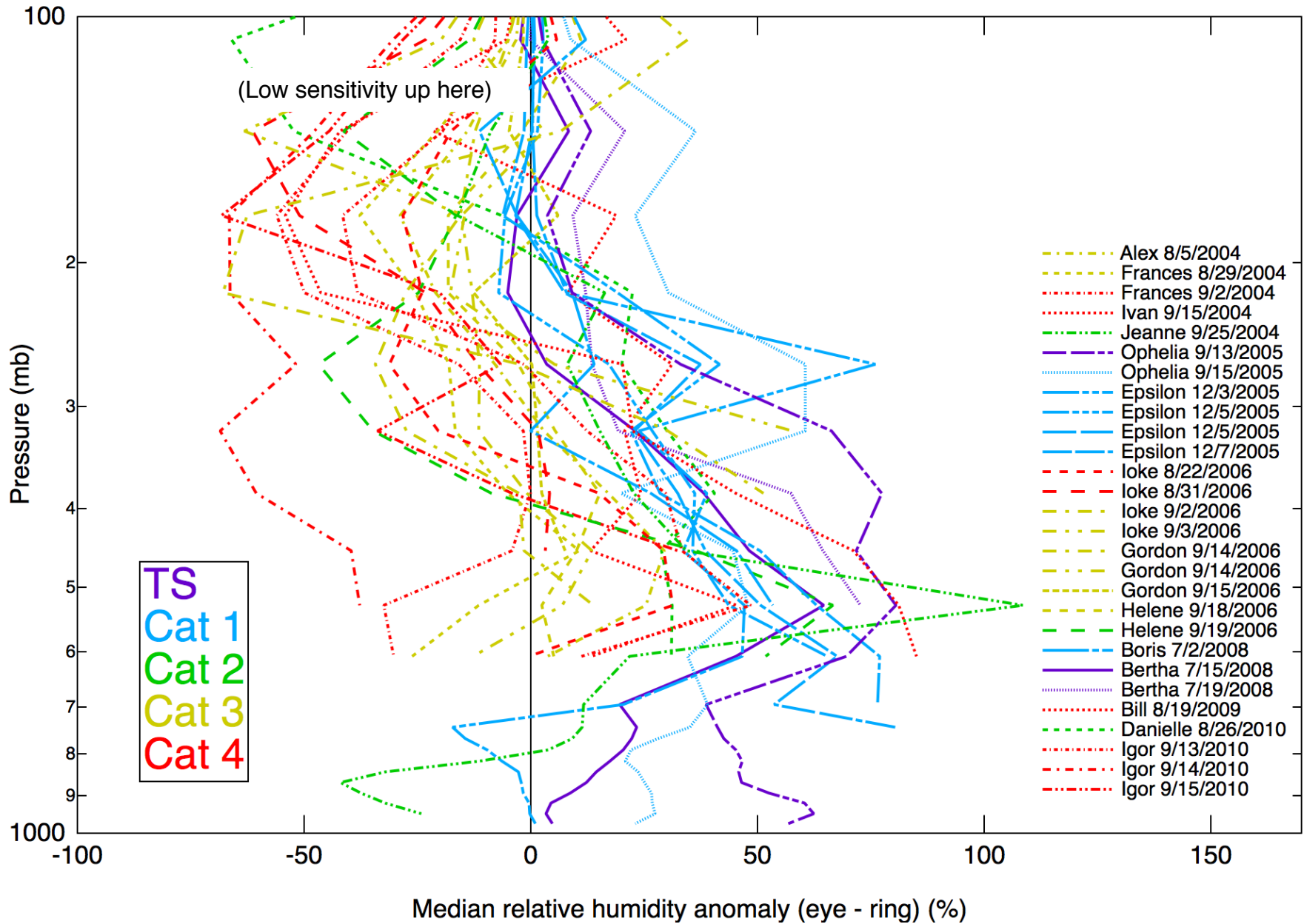
Still lots more to look at!



# Median temperature anomalies (eye – ring)



# Median relative humidity anomalies (eye – ring)



# Single-footprint retrievals from AIRS ...

- Can push variance studies to smaller length scales
- For hurricanes and cyclones ...
  - New insights the temperature/H<sub>2</sub>O/RH histories of hurricanes?
  - Can the improved spatial resolution be used to better understand the genesis of extreme events?
- Improved forward model can return more data above thick clouds and dusty regions.
- All of this needs validation!