TES effective CTP and OD: Simulations and Comparisons to MODIS and AIRS

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Outline

- Simulation results: expected sensitivity
- Case study examples
- Statistics compared with MODIS
- Statistics compared with AIRS
- Conclusions

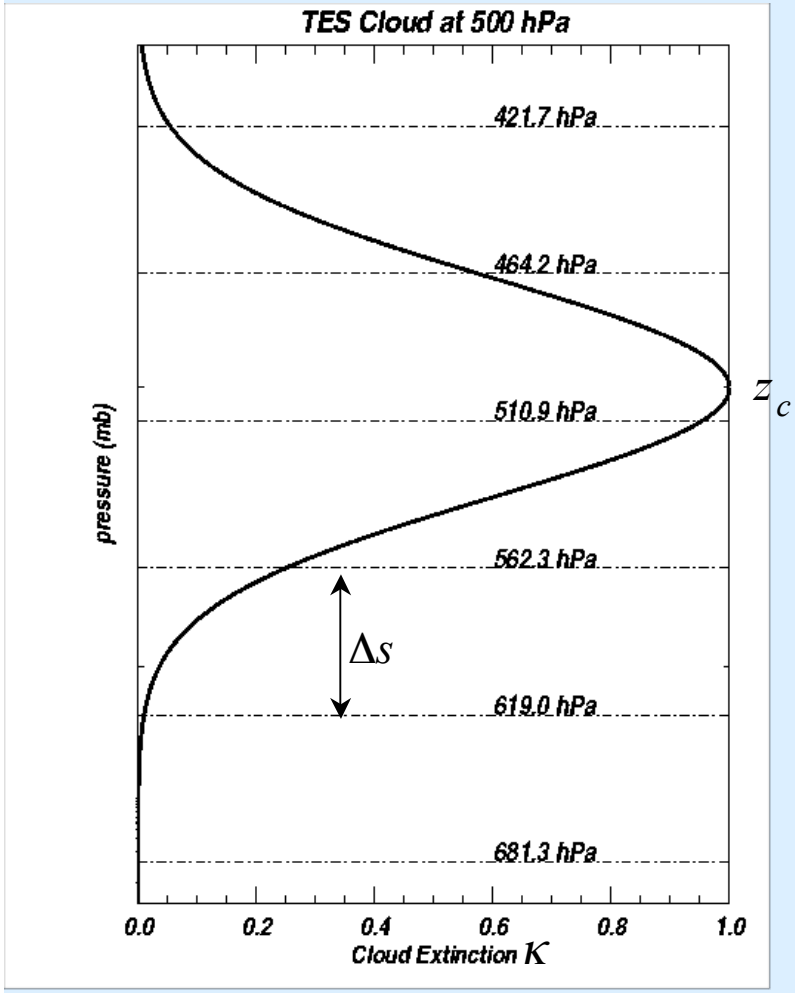
COMPARISON TO FORMER APPROACHES

Other instruments retrieve atmospheric parameters with clouds. AIRS, TOMS, OMI, MOPITT successfully retrieve in the presence of clouds

TES's approach is somewhat different than prior approaches

1) Parameterize clouds and place the effect of these parameters into our forward model
2) Retrieve cloud parameters like any other retrieved parameter, with an initial guess, *a priori*, constraint, and Jacobians
3) Error characterization *and effect of clouds on retrieved atmospheric species* is handled like any other retrieved parameter

TES CLOUD PARAMETERIZATION



- **Single cloud layer modeled as a Gaussian profile**
- **Absorption and scattering modeled with an effective tau discretized on a coarse frequency grid 25 – 100 cm^{-1}**

$$\tau_{\nu,z} = \kappa_\nu e^{-\beta(z-z_c)^2} \Delta s$$

Altitude

Effective extinction (25 frequency values)

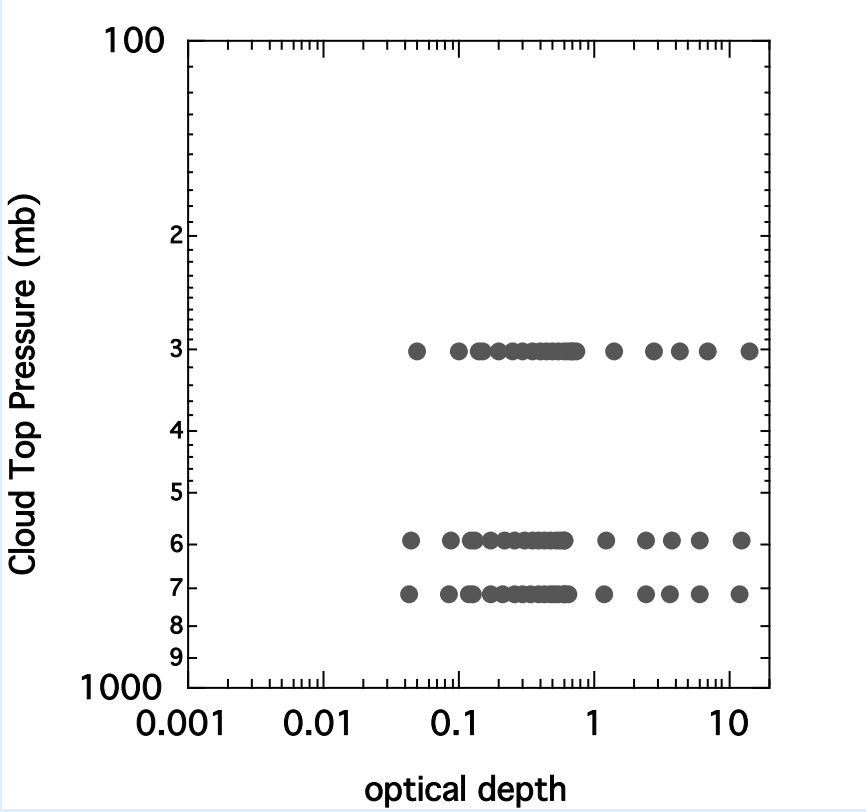
width parameter (fixed)

layer thickness

Initial guess: cloud pressure = 500 mb. Cloud extinction by Brightness temperatures between observed radiance and TES cloud-free initial guess

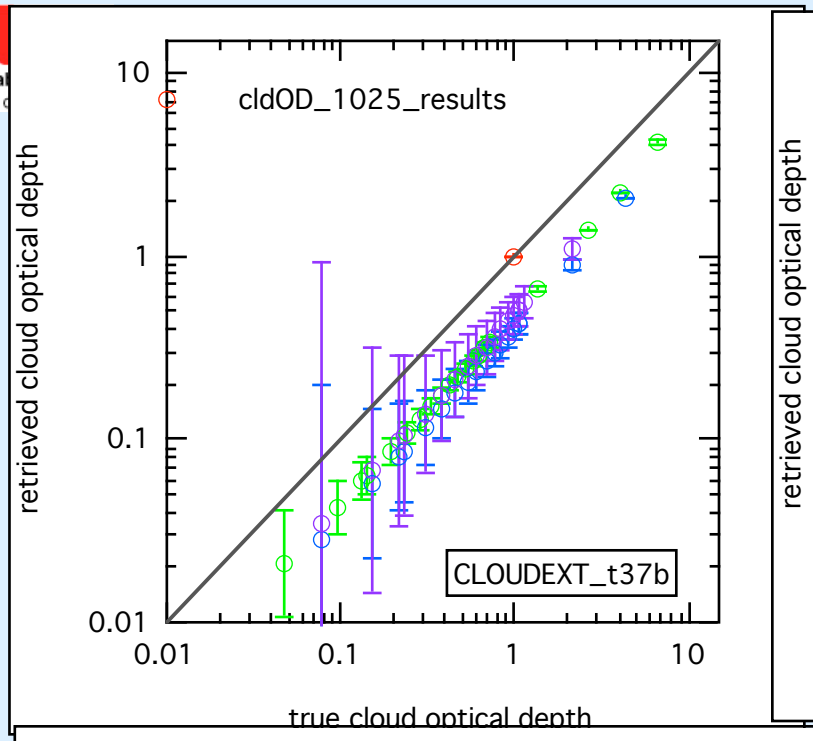
Simulation set

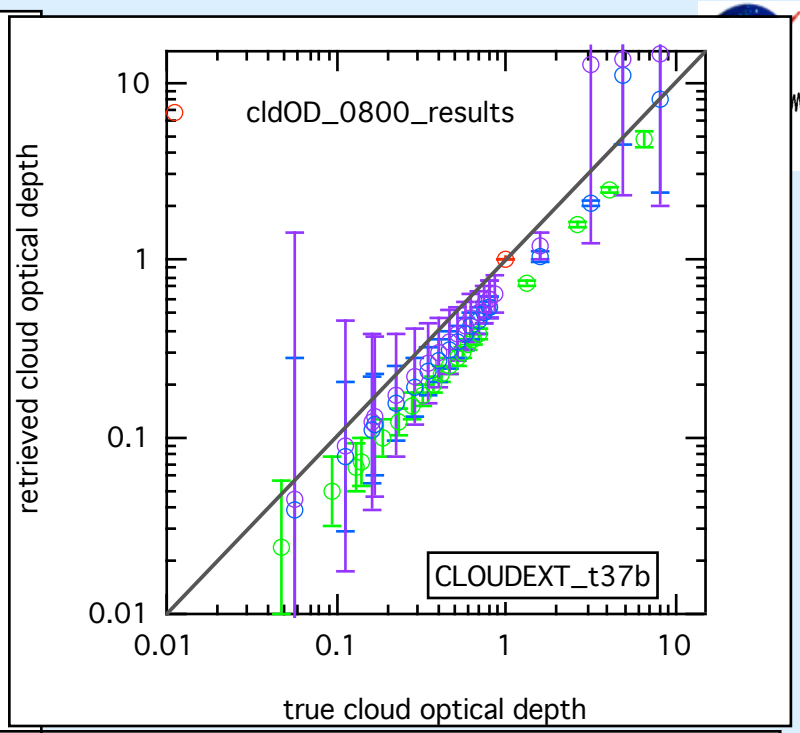
- 68 simulation cases with range of cloud optical depth from 0.005 to 15
- Used scattering and non-scattering clouds
- CHARTS used for scattering radiative transfer calculations
- Ice and water models with spectrally dependent extinction and single scatter albedo



Case 1 (t37b)

- Scattering, no noise in simulation
- Henley - Greenstein parameter of G = 0.76
- Find that cloud top pressure is well retrieved
- Can explain difference between input optical depth and retrieved effective optical depth with multiple scattering


cldOD_1025_results
CLOUDEXT_t37b
retrieved cloud optical depth
true cloud optical depth
10
1
0.1
0.01
0.01
0.1
1
10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CLOUDEXT_t37b
retrieved cloud optical depth
true cloud optical depth
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0.1
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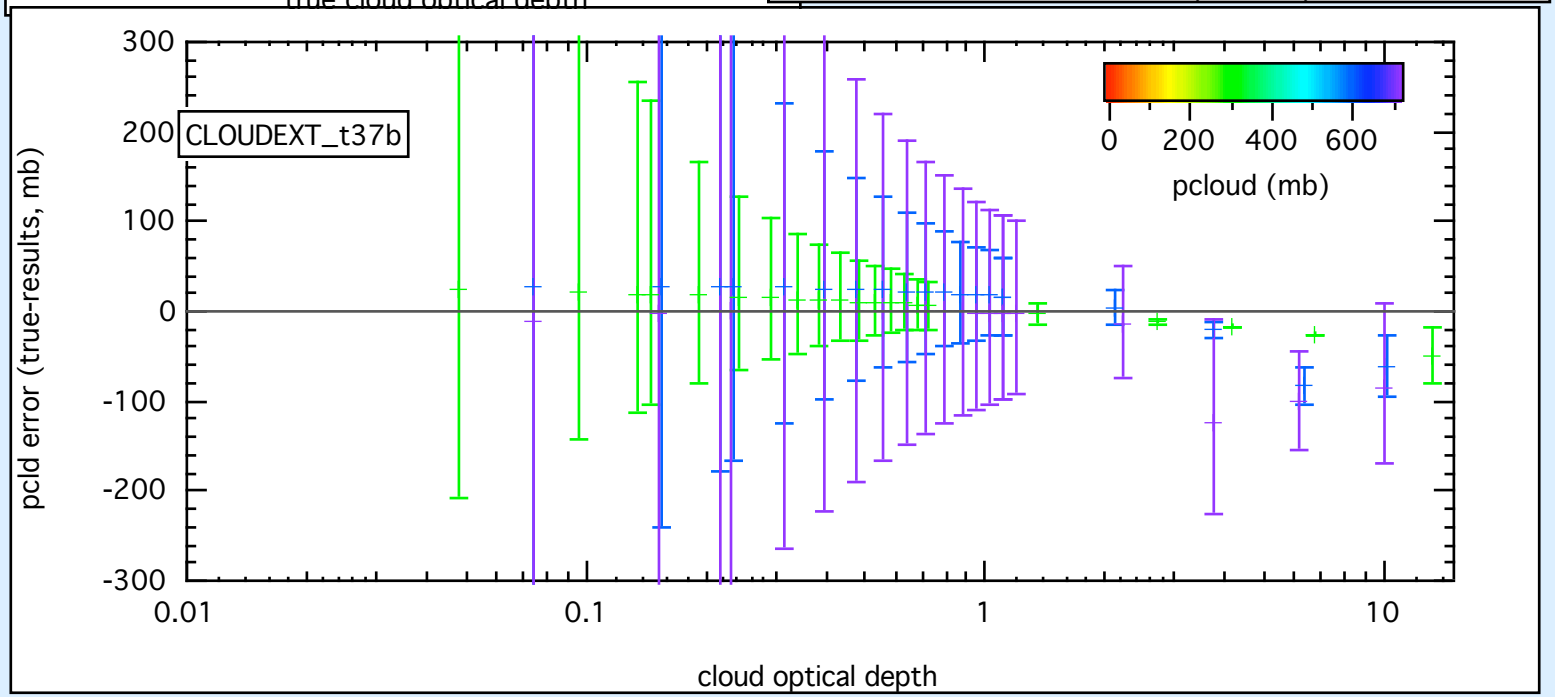
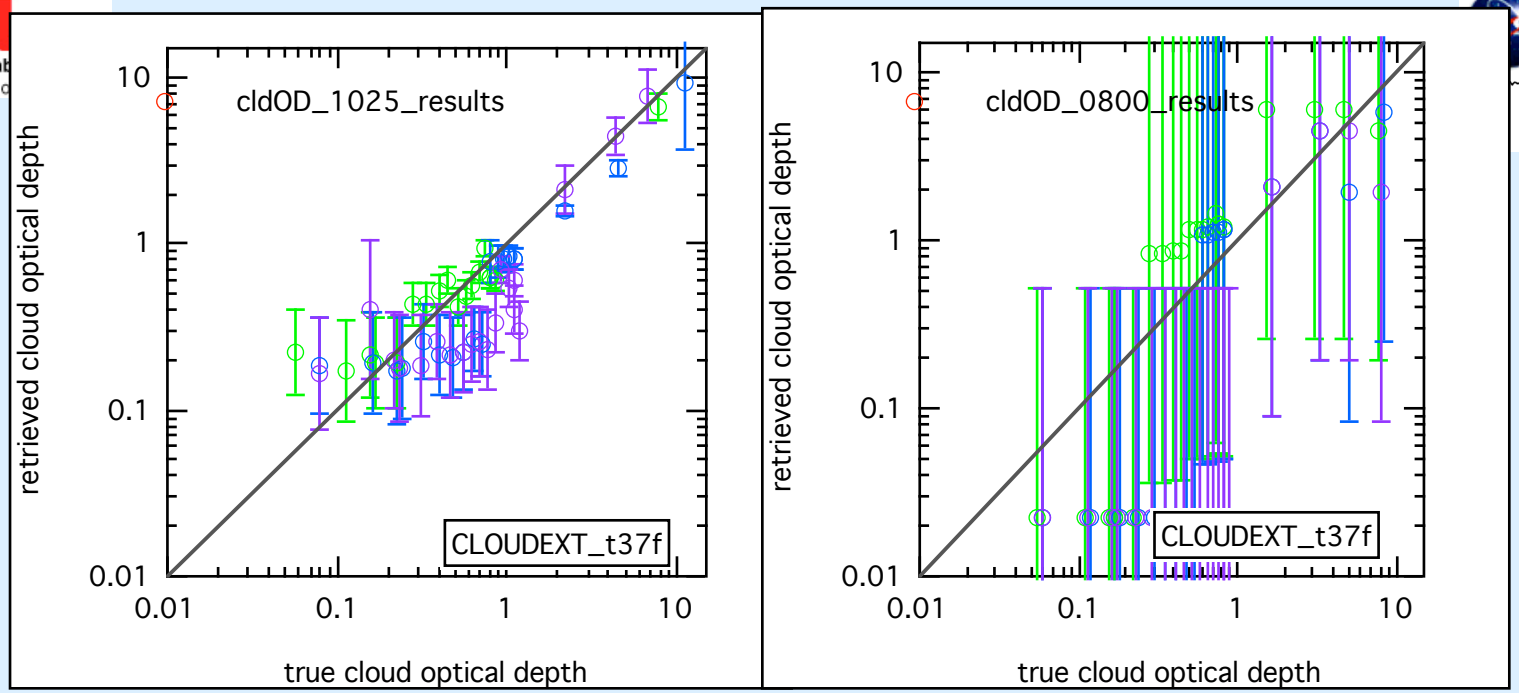

CLOUDEXT_t37b
pcloud (mb)
0
200
400
600
pcld error (true-results, mb)
cloud optical depth
300
200
100
0
-100
-200
-300
0.01
0.1
1
10

Case 2 (t37f)

- Noise in simulated radiance, scattering
- G = 0.76
- Find that cloud top pressure is well retrieved
- Note - optical depth only retrieved at 1025 cm-1
- For high clouds (300mb), optical depths greater than 0.1 well represented
- 700mb cloud optical depths not well retrieved when less than 1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CLOUDEXT_t37f
retrieved cloud optical depth
true cloud optical depth
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0.01
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1
10

cldOD_0800_results
CLOUDEXT_t37f
retrieved cloud optical depth
true cloud optical depth
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0.1
0.01
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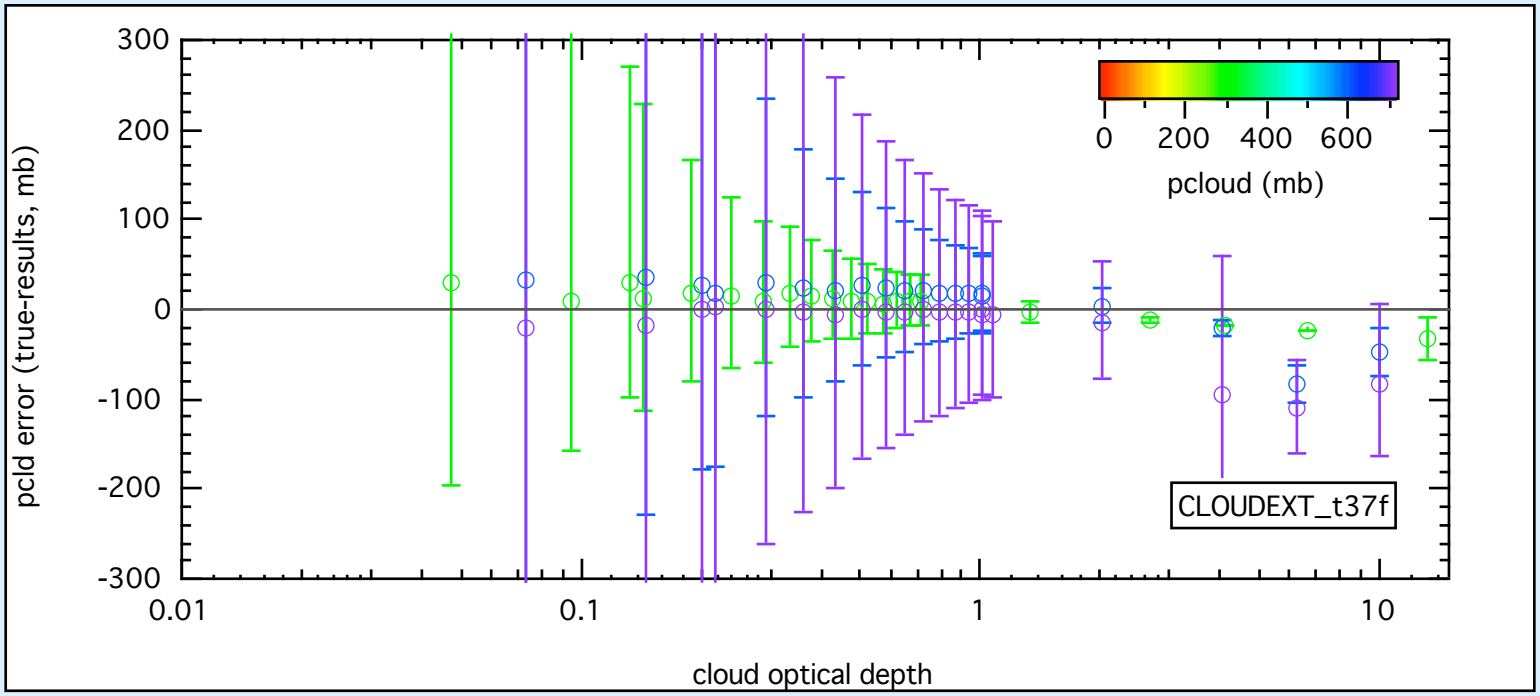

pcld error (true-results, mb)
cloud optical depth
CLOUDEXT_t37f
pcloud (mb)
0
200
400
600
300
200
100
0
-100
-200
-300
0.01
0.1
1
10

Additional simulations

- Original simulations approach integrates PCLOUD and CLOUDEXT retrieval with gas retrieval at each step
- Found that PCLOUD errors become large
- Exploring a strategy to retrieve PCLOUD only in first step, and then retrieve CLOUDEXT along with gas retrievals.

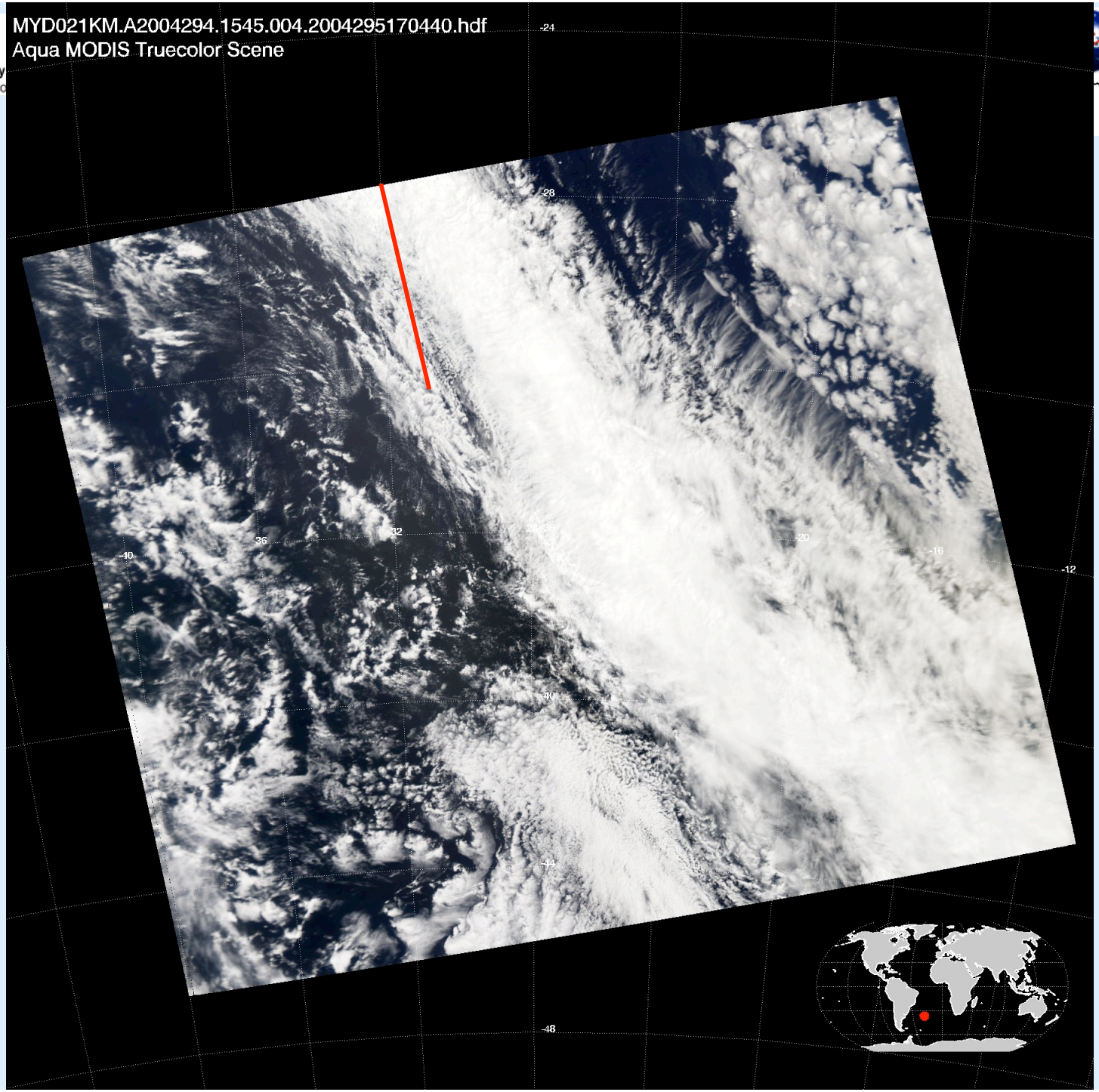
An example of observations

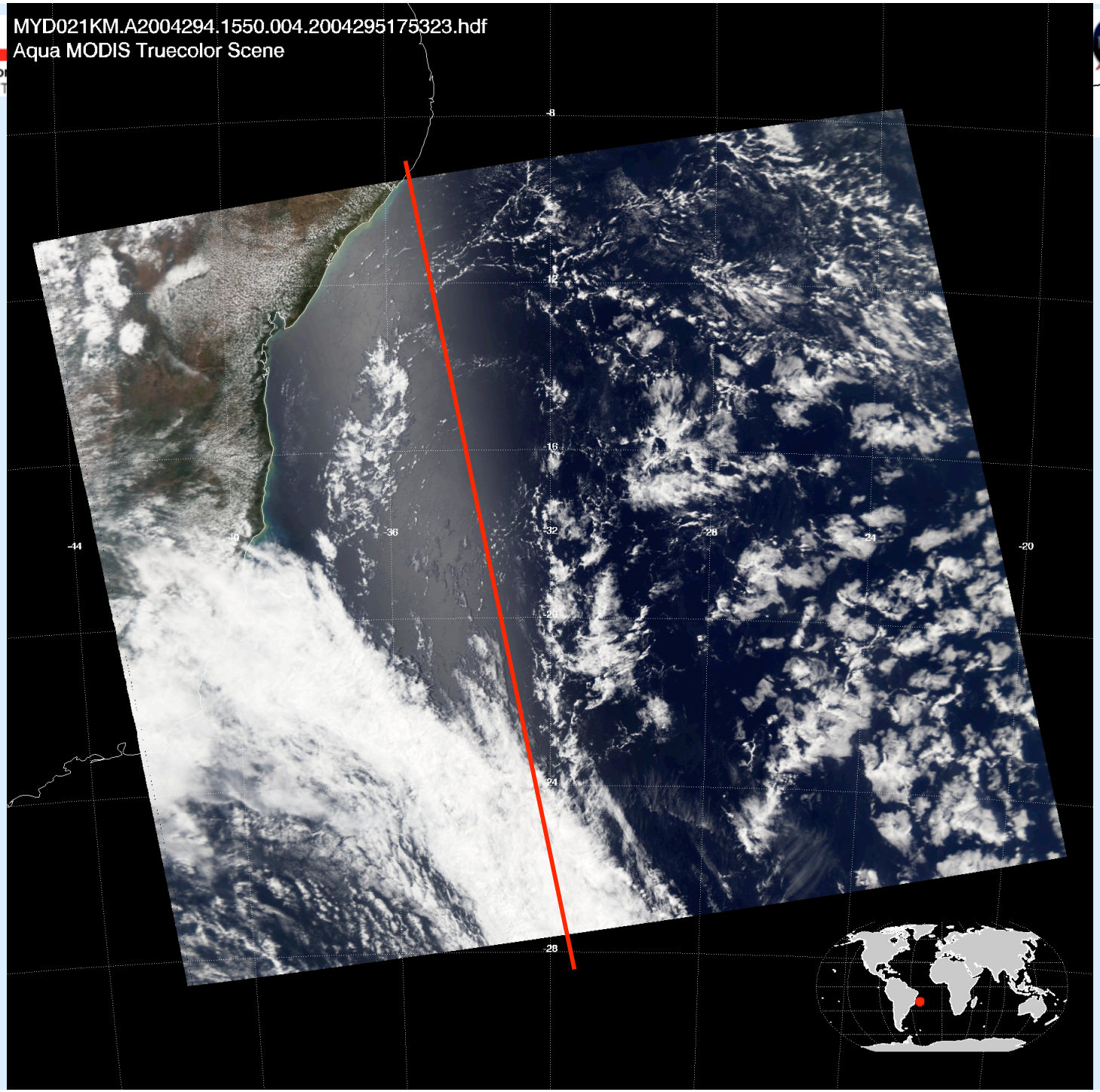
- TES step and stare
- MODIS visible images
- MODIS cloud top pressure
- AIRS cloud top pressure

The data sets

- TES
  - Step and stares
  - Data averaged over 16 pixels to 5km by 8km
  - Some screening based on ctp error and effective optical depth in later analysis
- AIRS
  - V4
  - Cloud top pressure for two layers in 45km footprint
- MODIS data
  - Cloud top pressure - 5km product day and night
  - Cloud optical depth - 1km product, daytime only
  - Calculate 'homogeneity' from optical depth in 5km by 5km area

Jet Propulsion Laboratory
California Institute of Techno

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Aqua MODIS Truecolor Scene
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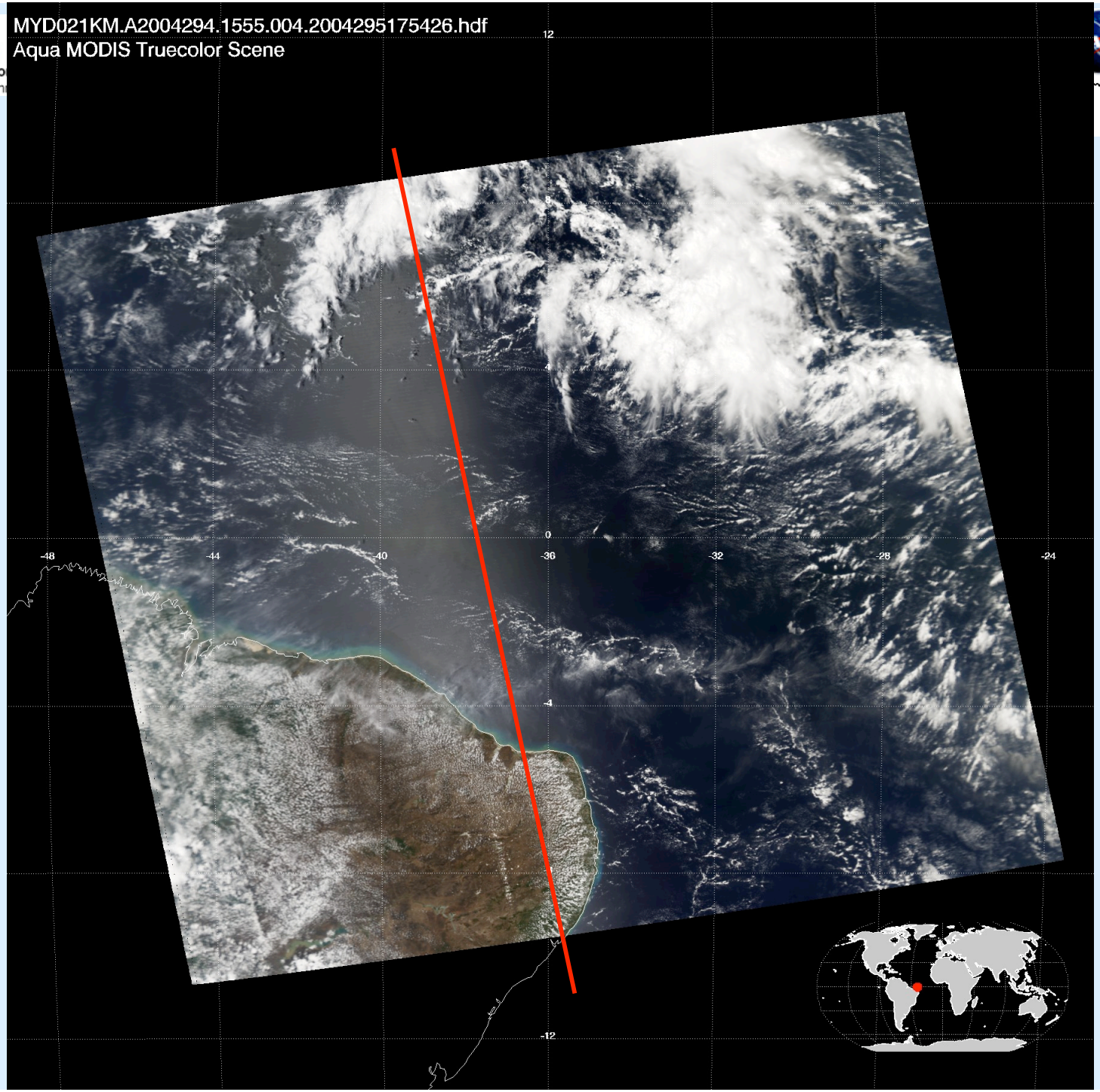
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Aqua MODIS Truecolor Scene
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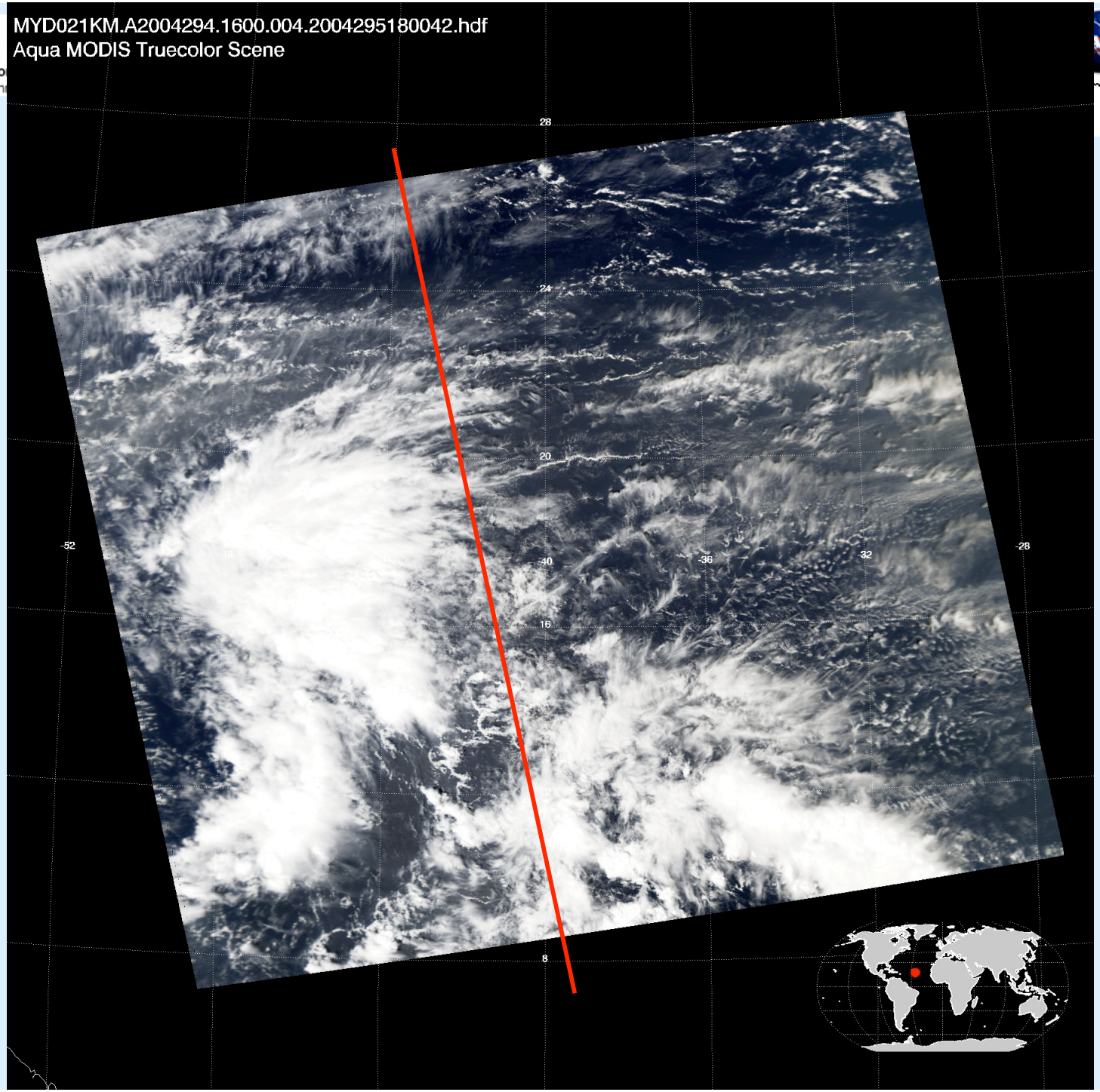
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Aqua MODIS Truecolor Scene
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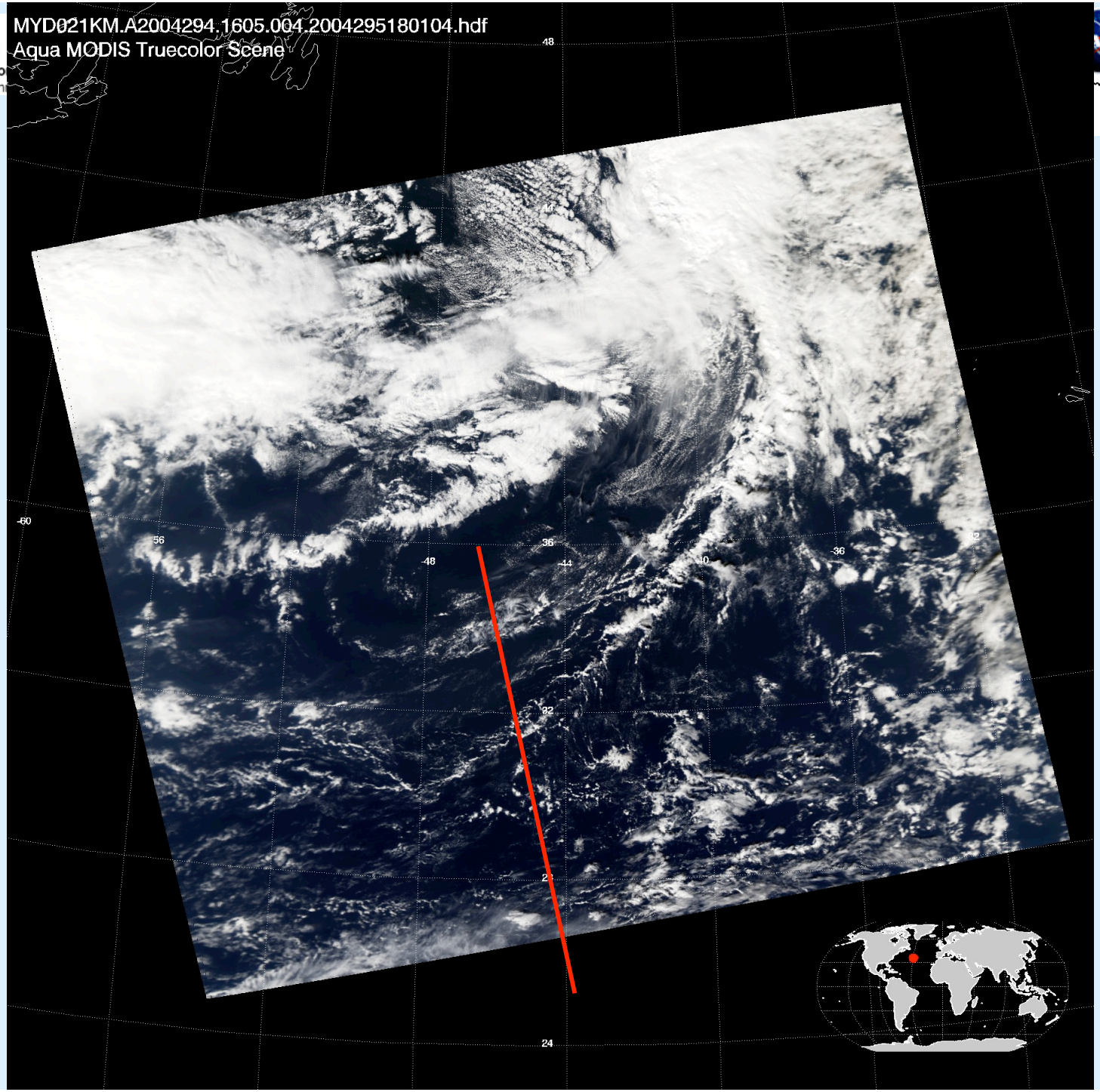
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Aqua MODIS Truecolor Scene
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-48
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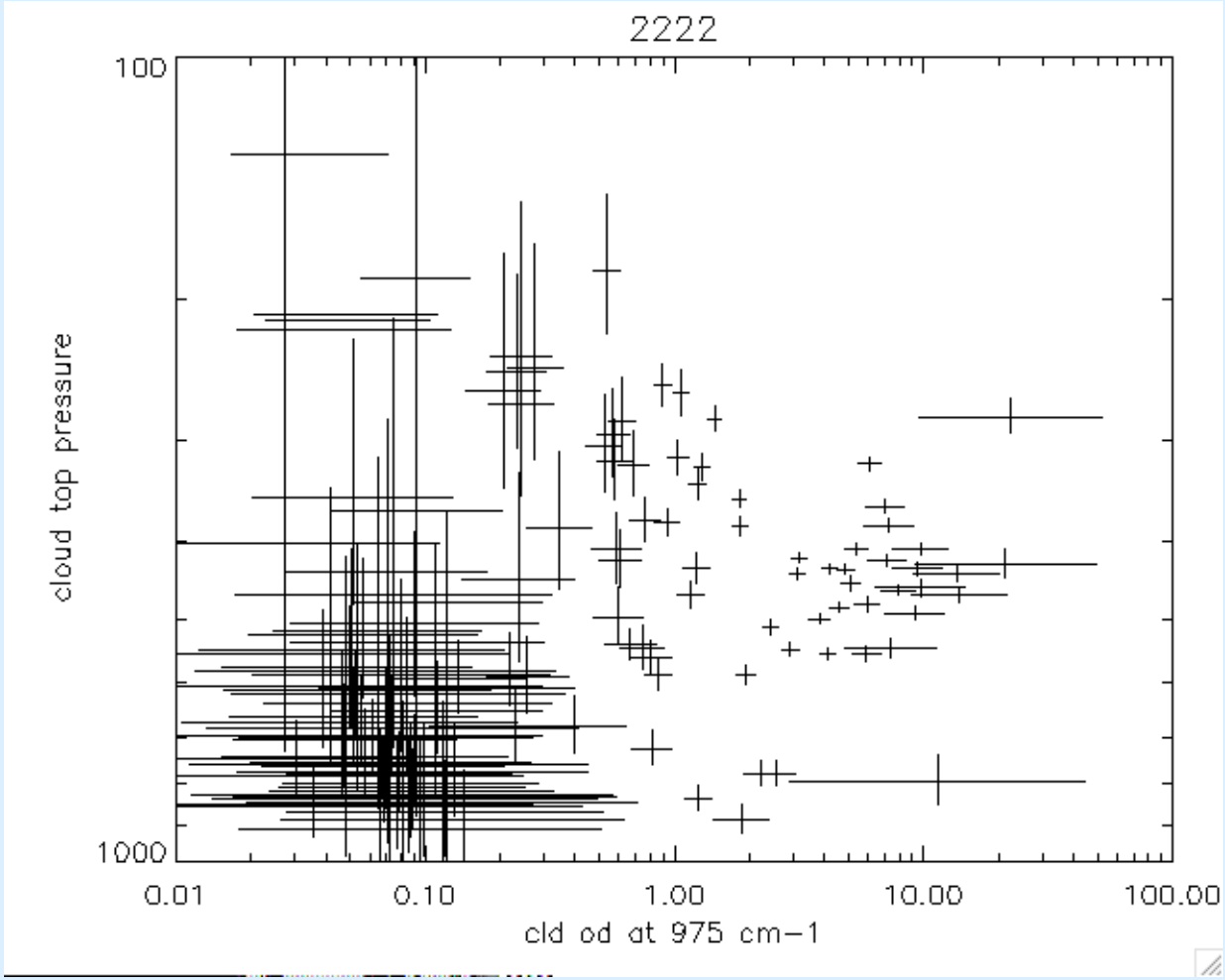
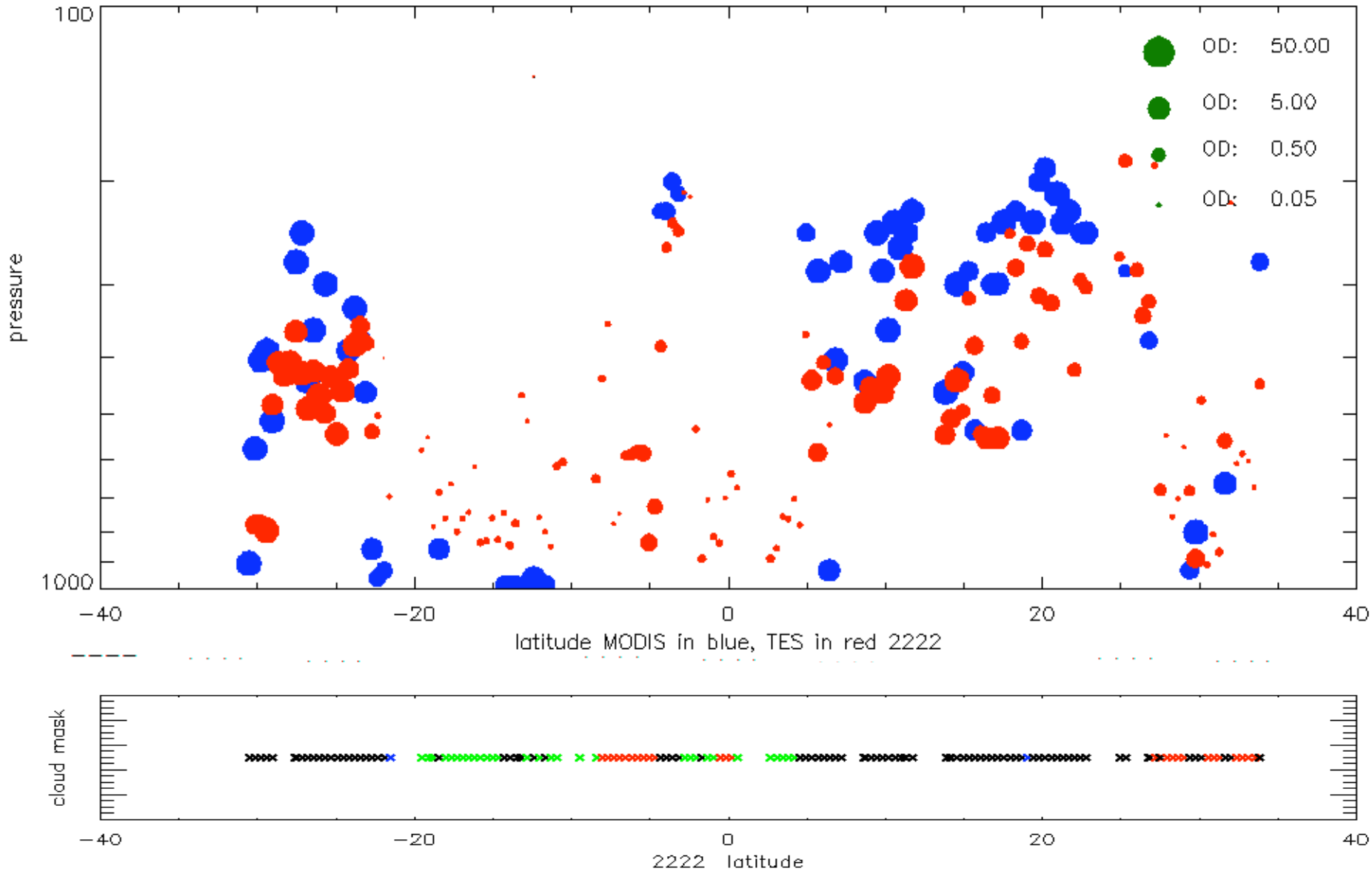
-36
32
24

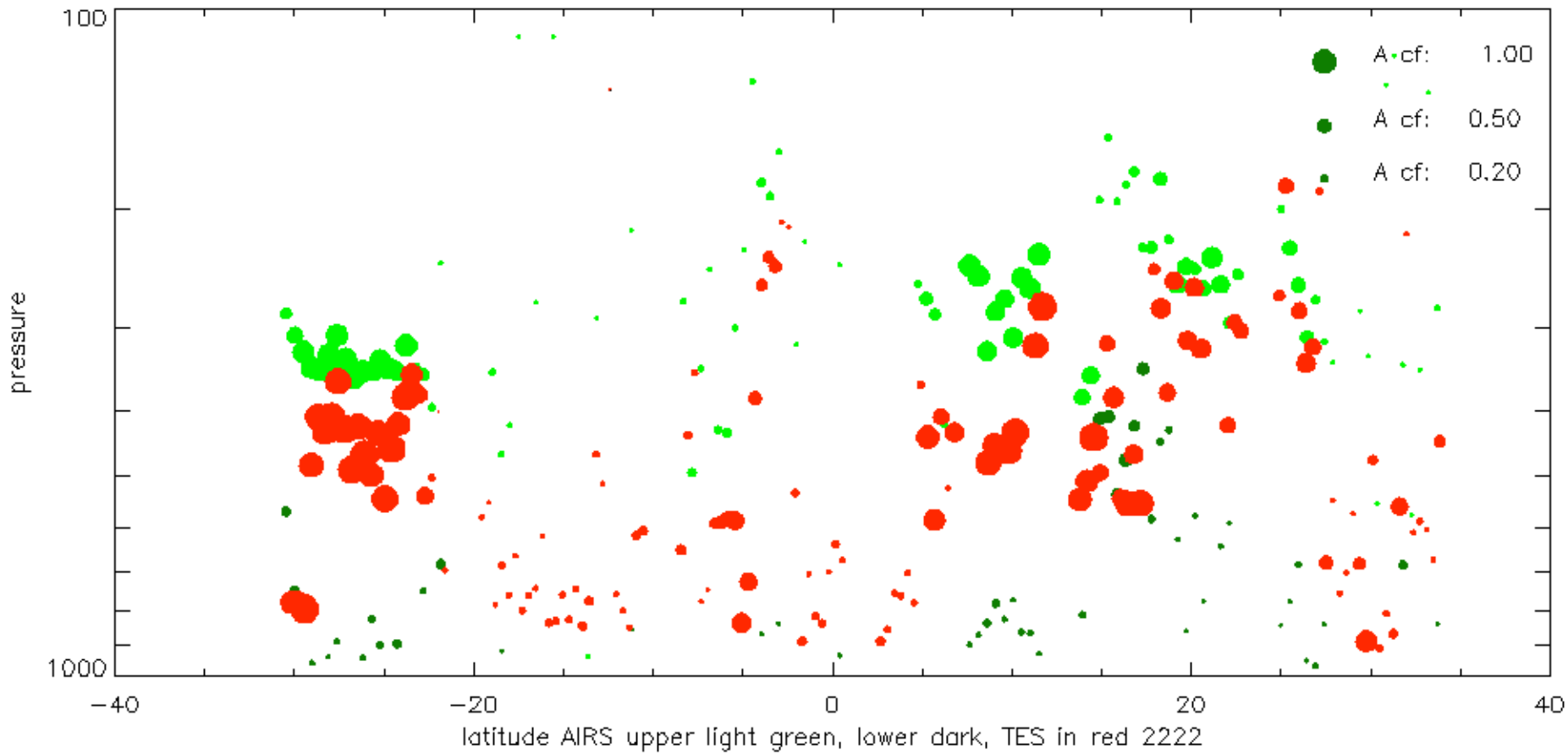
Small OD retrievals have very large estimated error



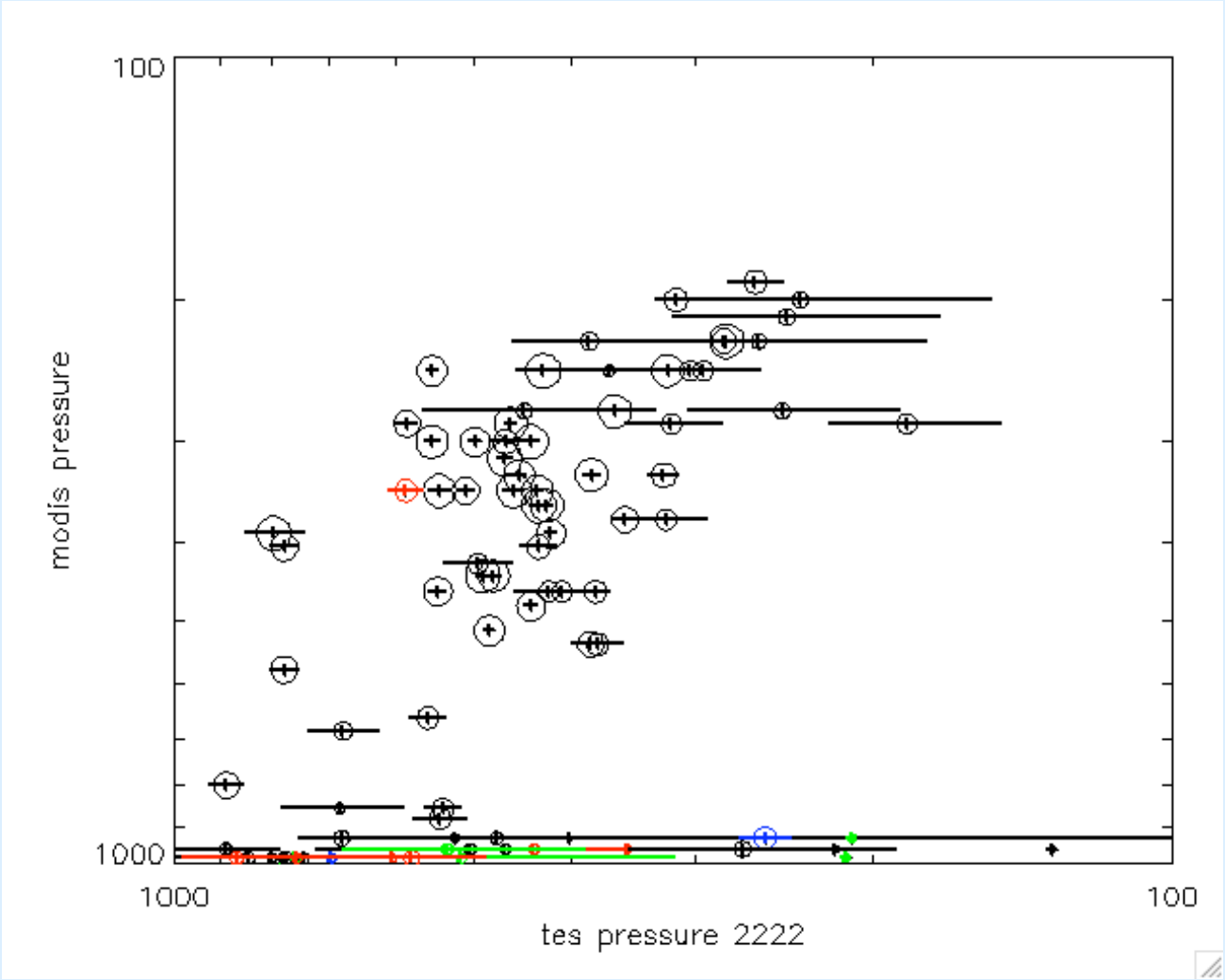
Tropics case - TES-MODIS



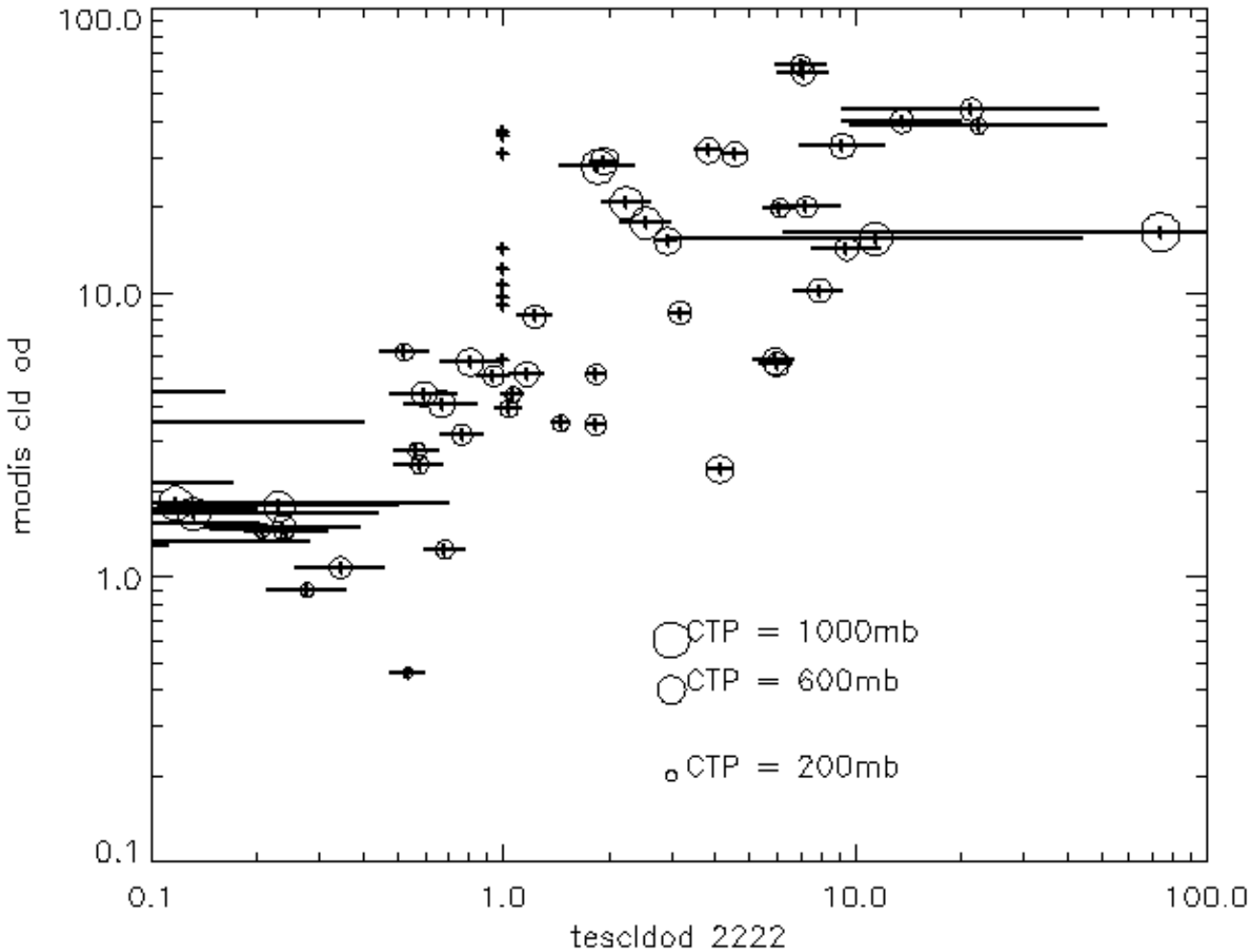
Tropics case - TES-AIRS



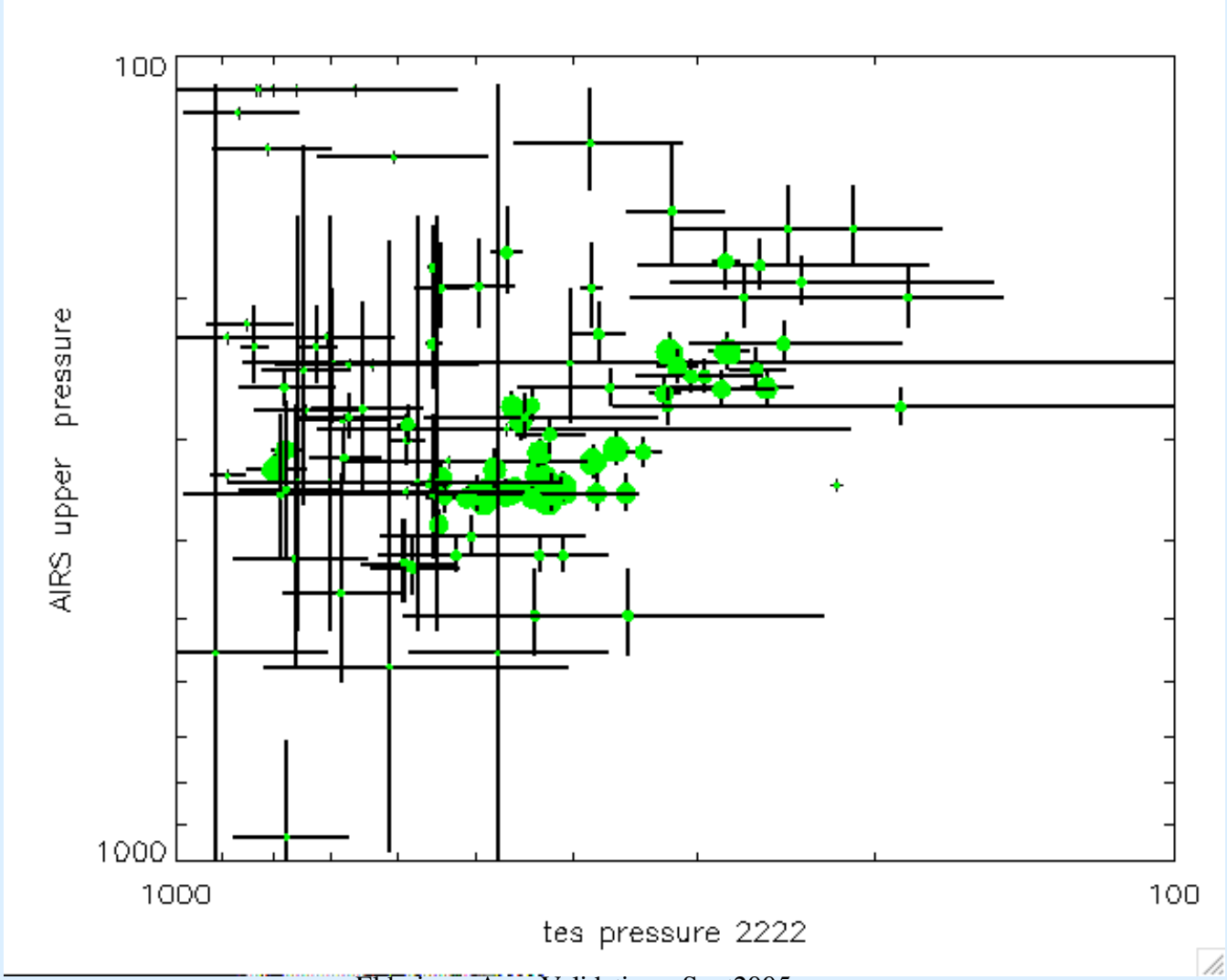
TES-MODIS cloud top pressure



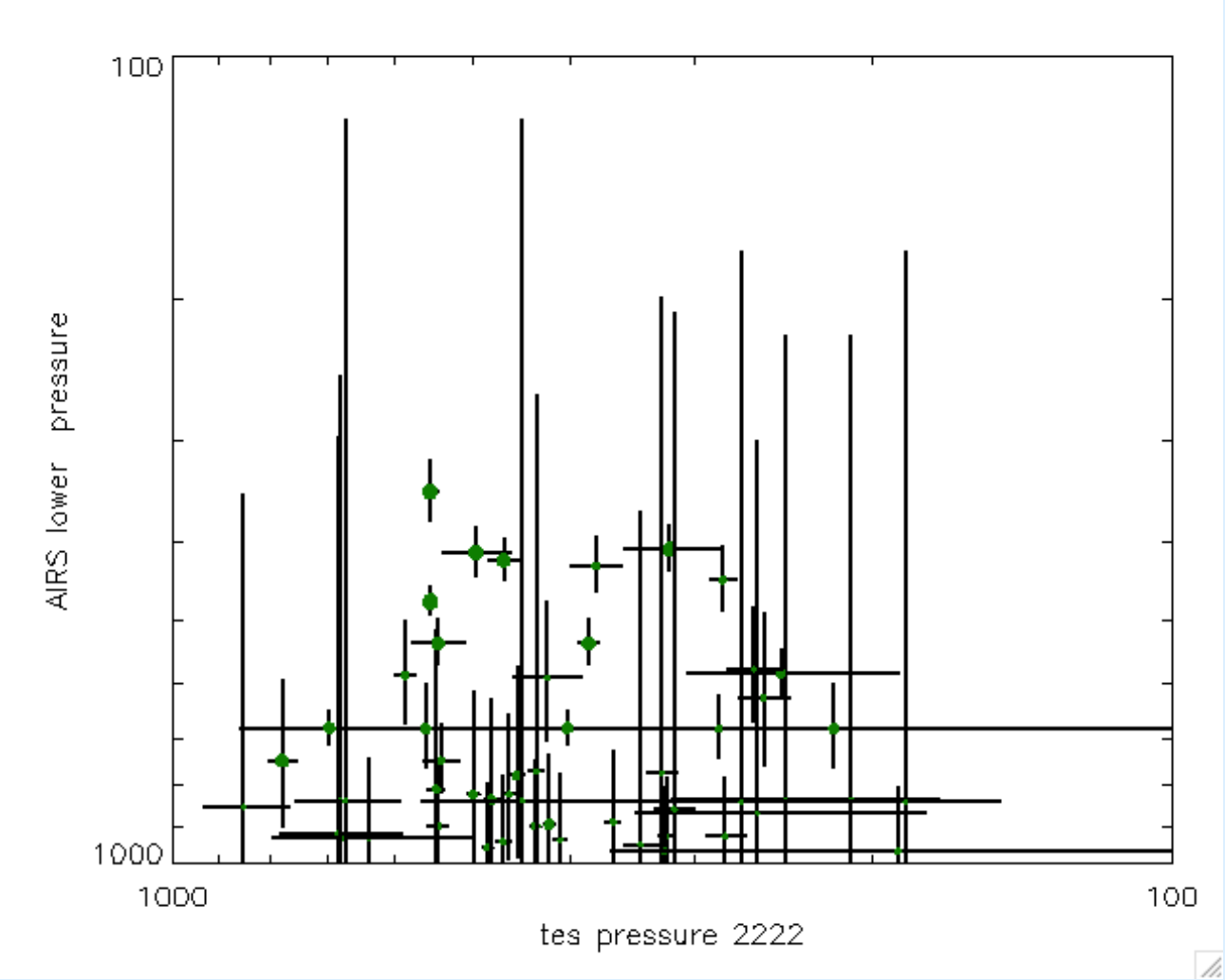
TES-MODIS optical depth



AIRS upper cloud pressure



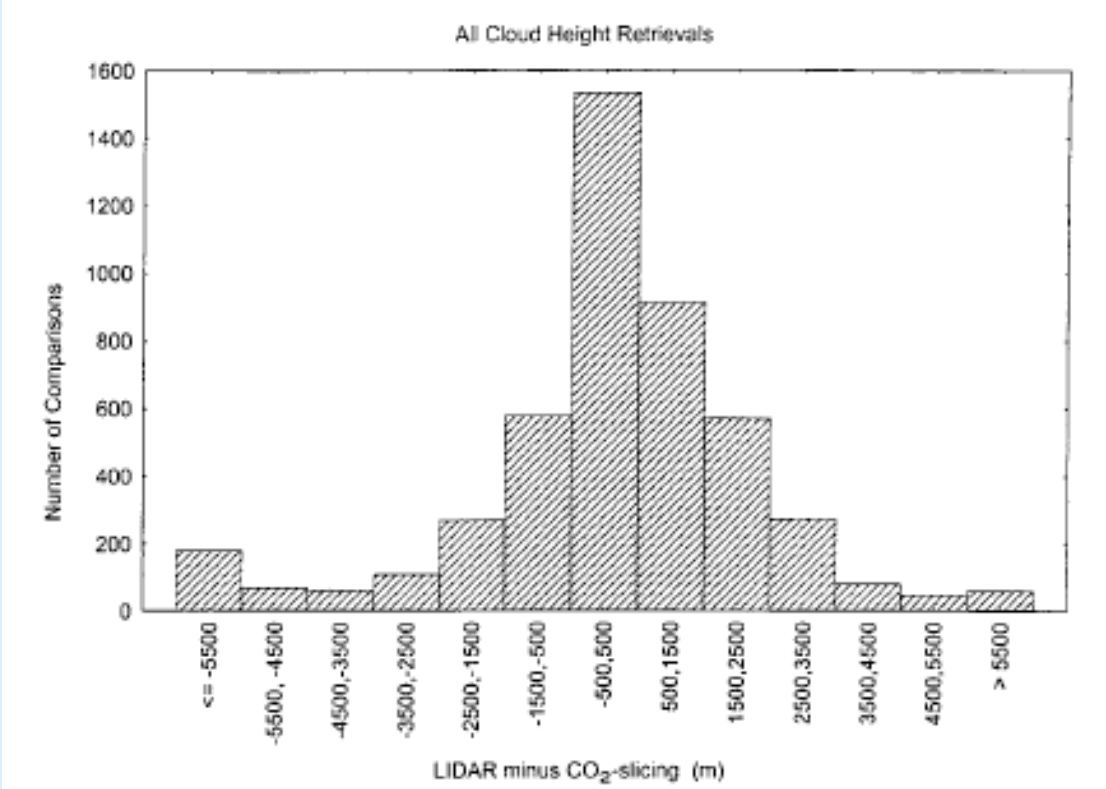
AIRS lower cloud layer



Statistical approach

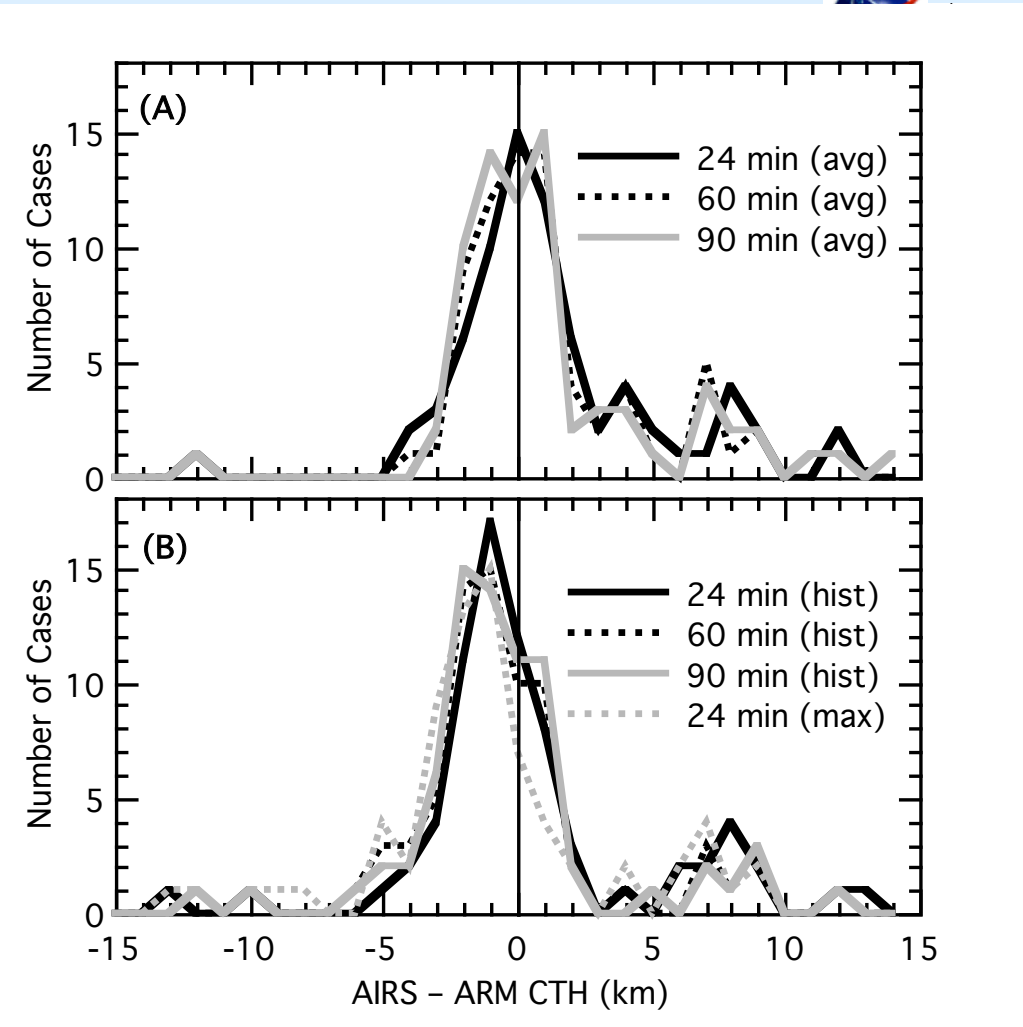
- MODIS and AIRS CTP verified with cloud lidar
- Gather statistics on TES-MODIS cloud top pressure differences over many observations
- Also look at variability of MODIS data over the footprint size
- Use data when MODIS is confidently cloudy
- Use if TES cldod err is less than 10Xod and PCLOUD error less than 100mb

MODIS cloud top pressure products



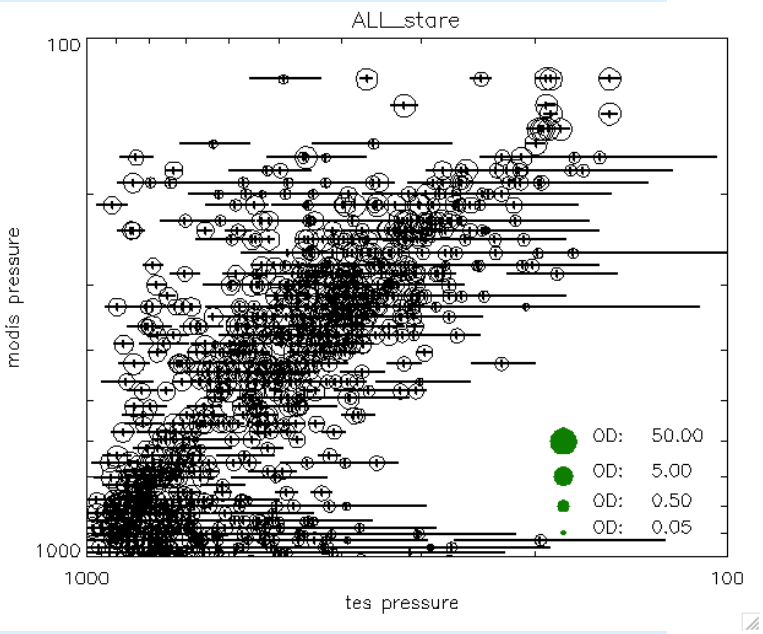
Histogram of differences for all comparisons between Cloud Lidar System (CLS) and CO_2-slicing of MODIS Airborne Simulator (MAS) coincident observations [*Frey et al., JGR*, 1999]

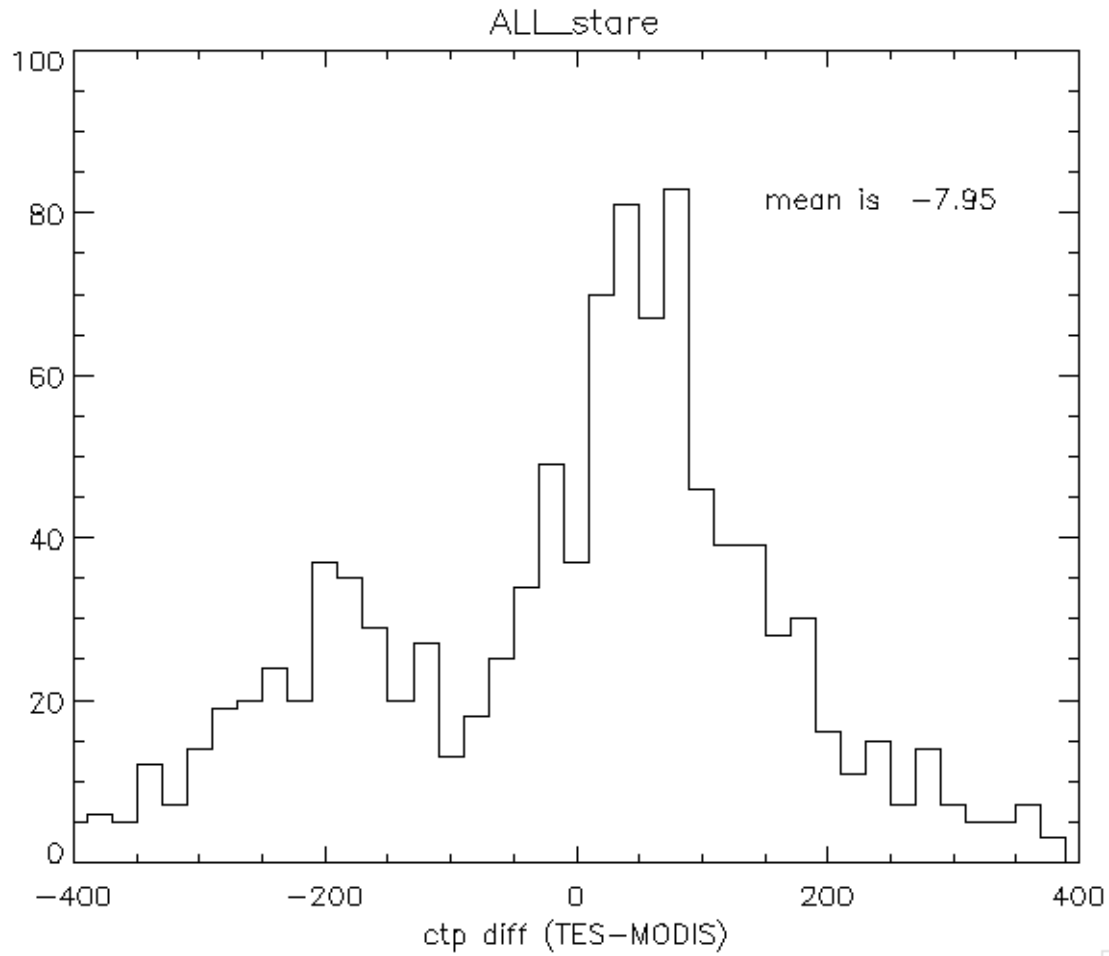
AIRS cloud top pressure



Histogram of differences between AIRS L2 CTP and ARM Manus Island ARSCL cloud boundaries.

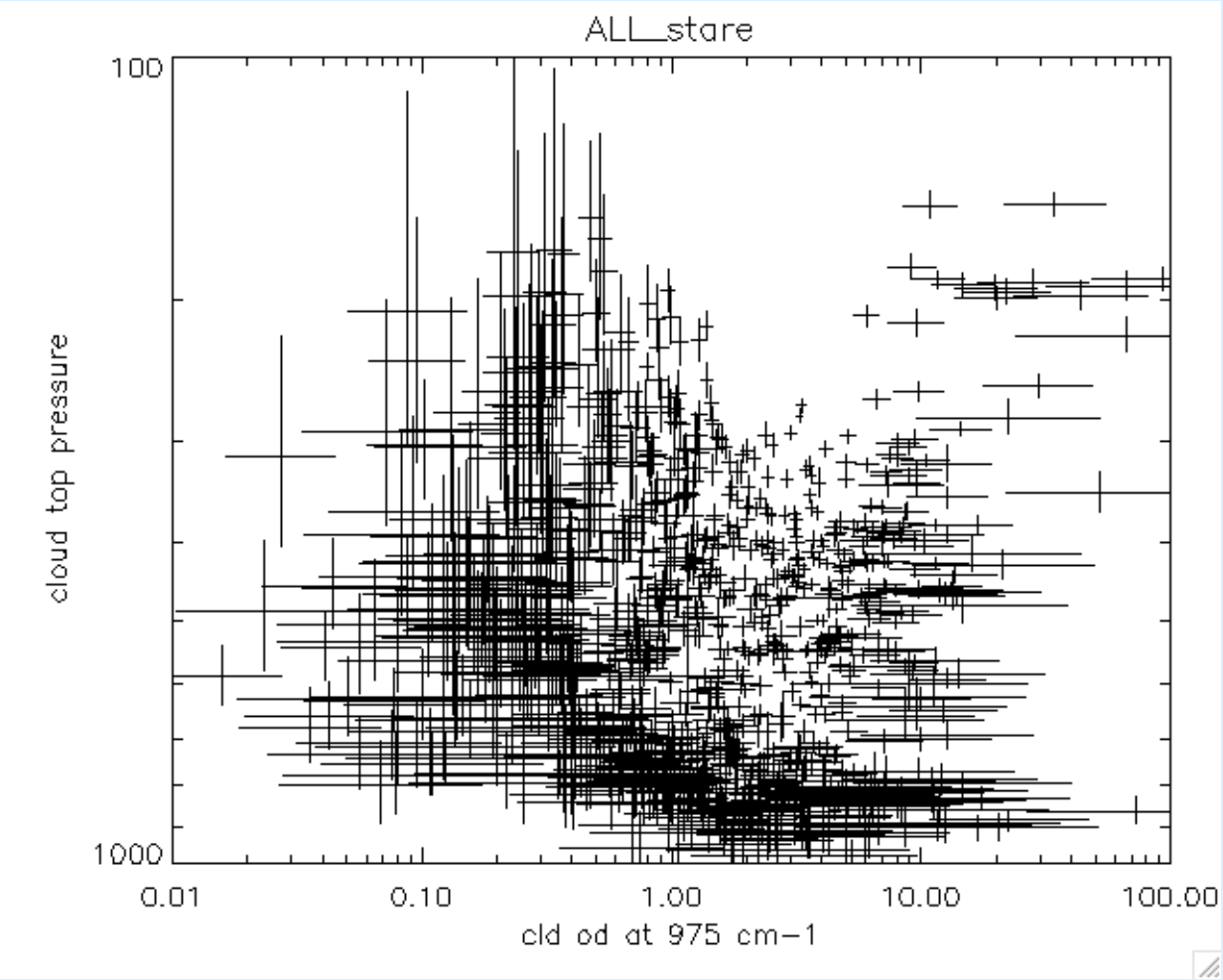
TES-MODIS CTP stats





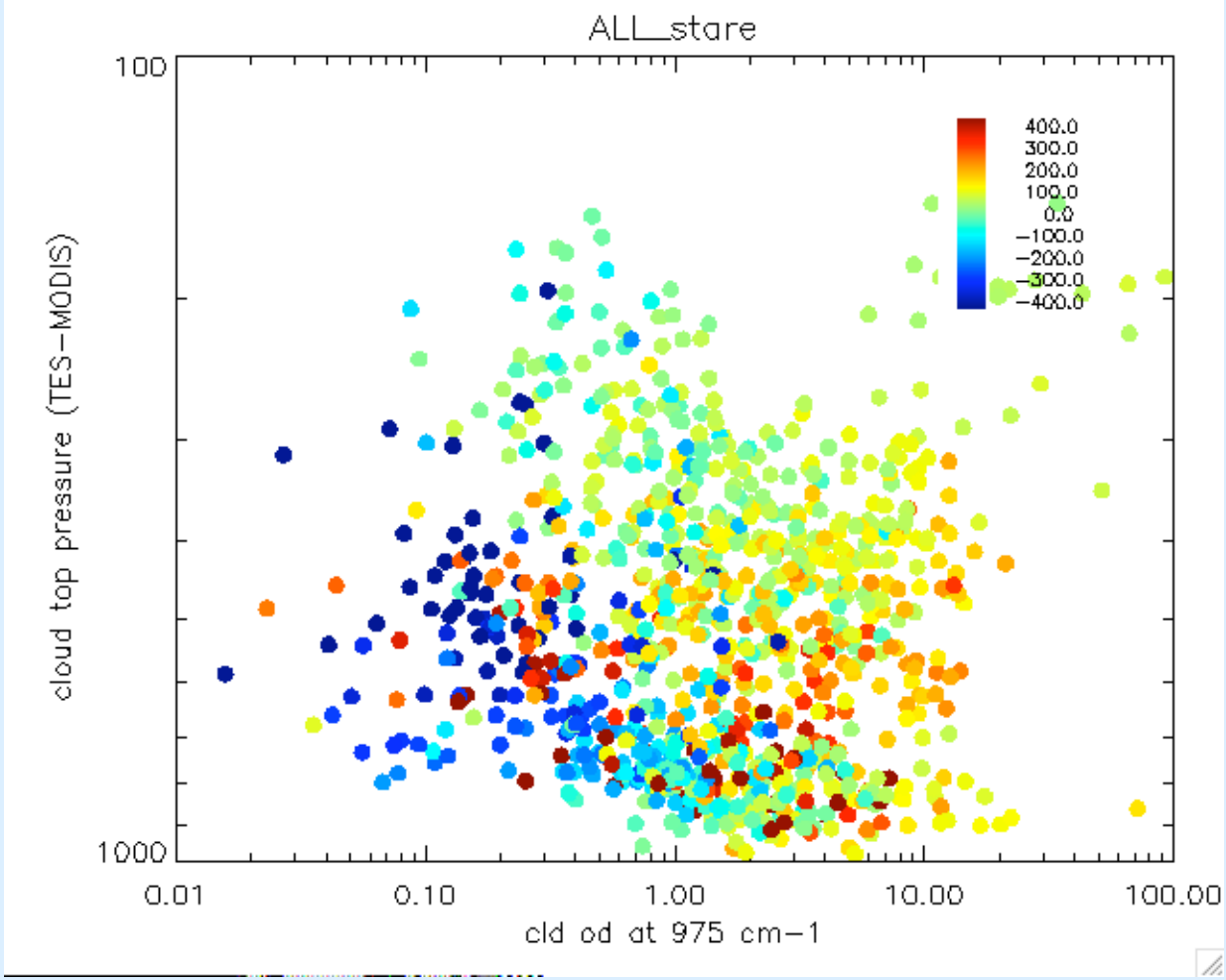
Differences in mb

Estimated errors for TES



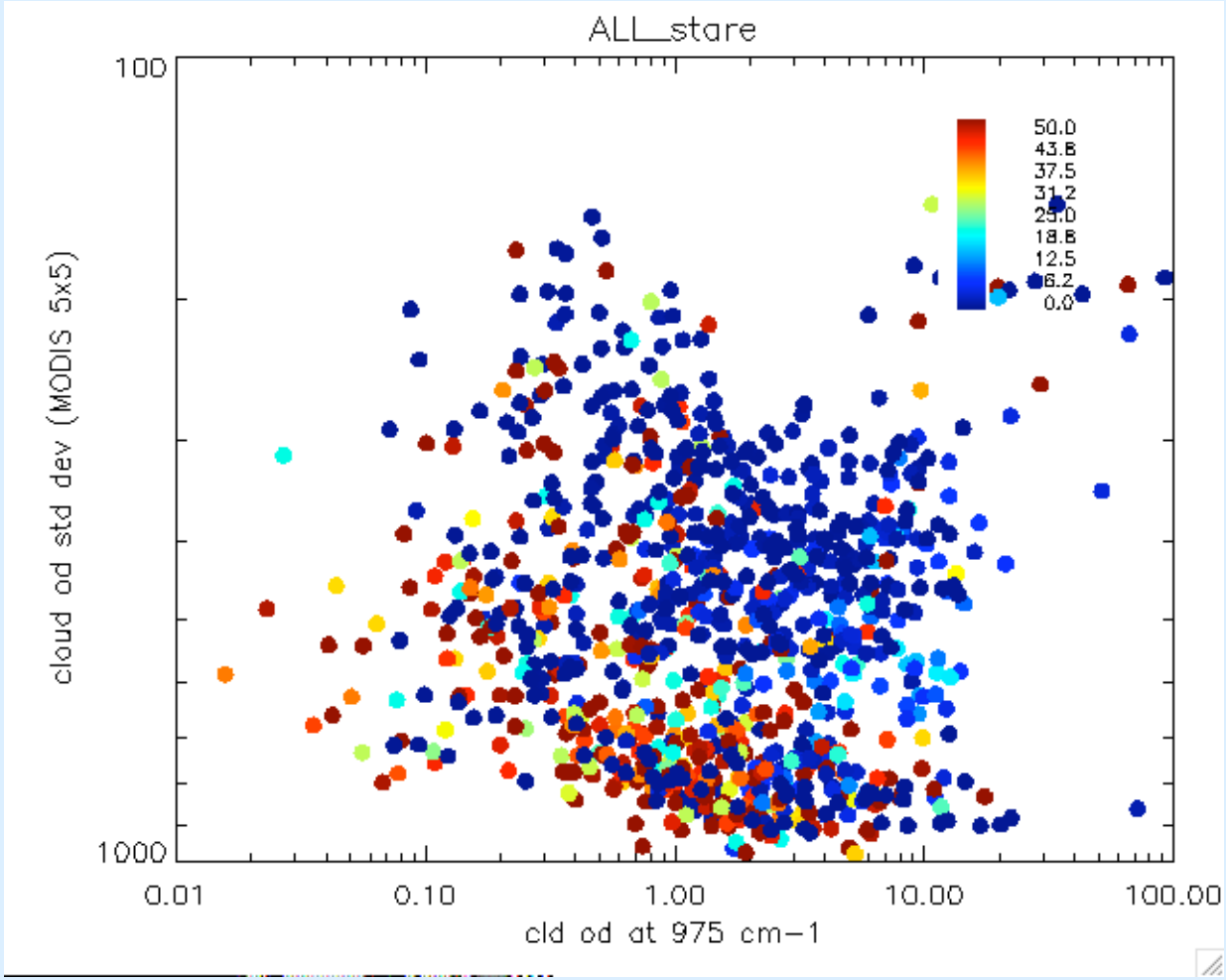
Small ctp differences where error estimates are small

- Differences in ctp small for higher clouds
- Clouds closer to surface and thinner are characterized differently by MODIS and TES



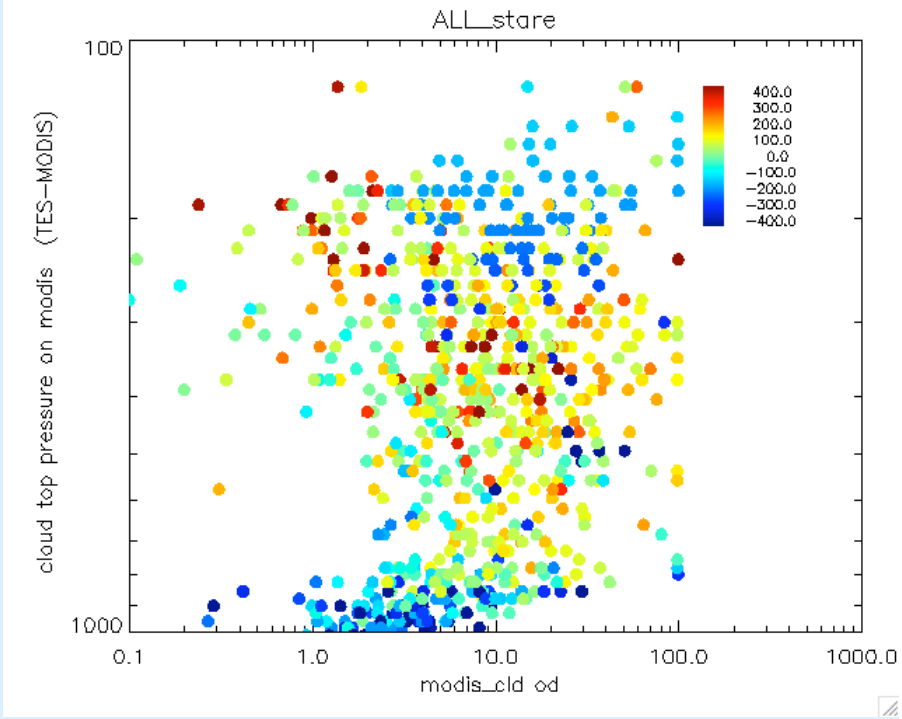
Homogeneous clouds

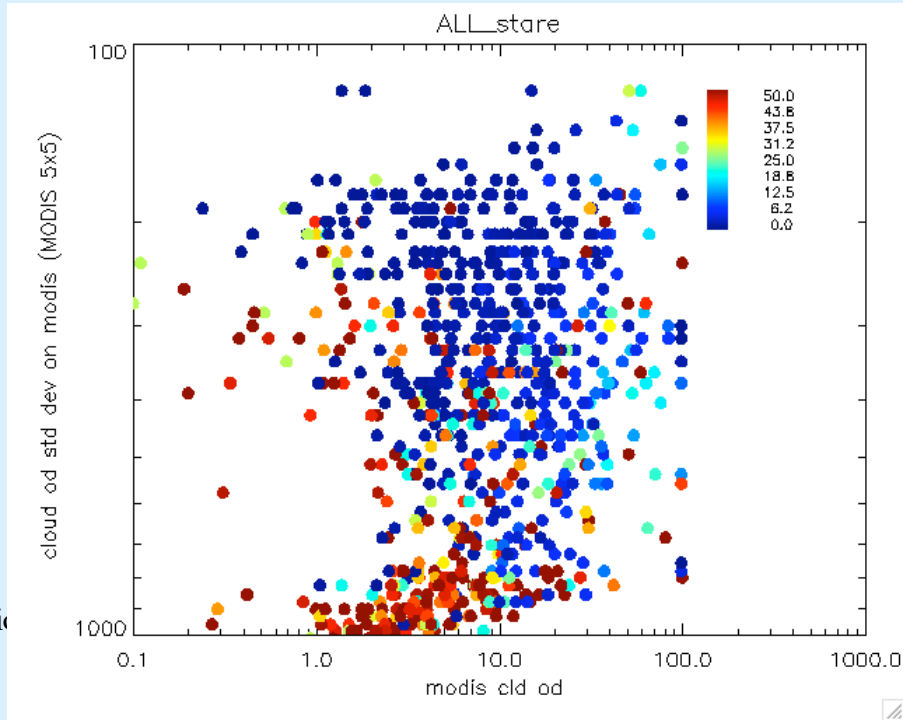
- The clouds that TES and MODIS characterize similarly have little variation in MODIS OD over 5km by 5km



MODIS characterization

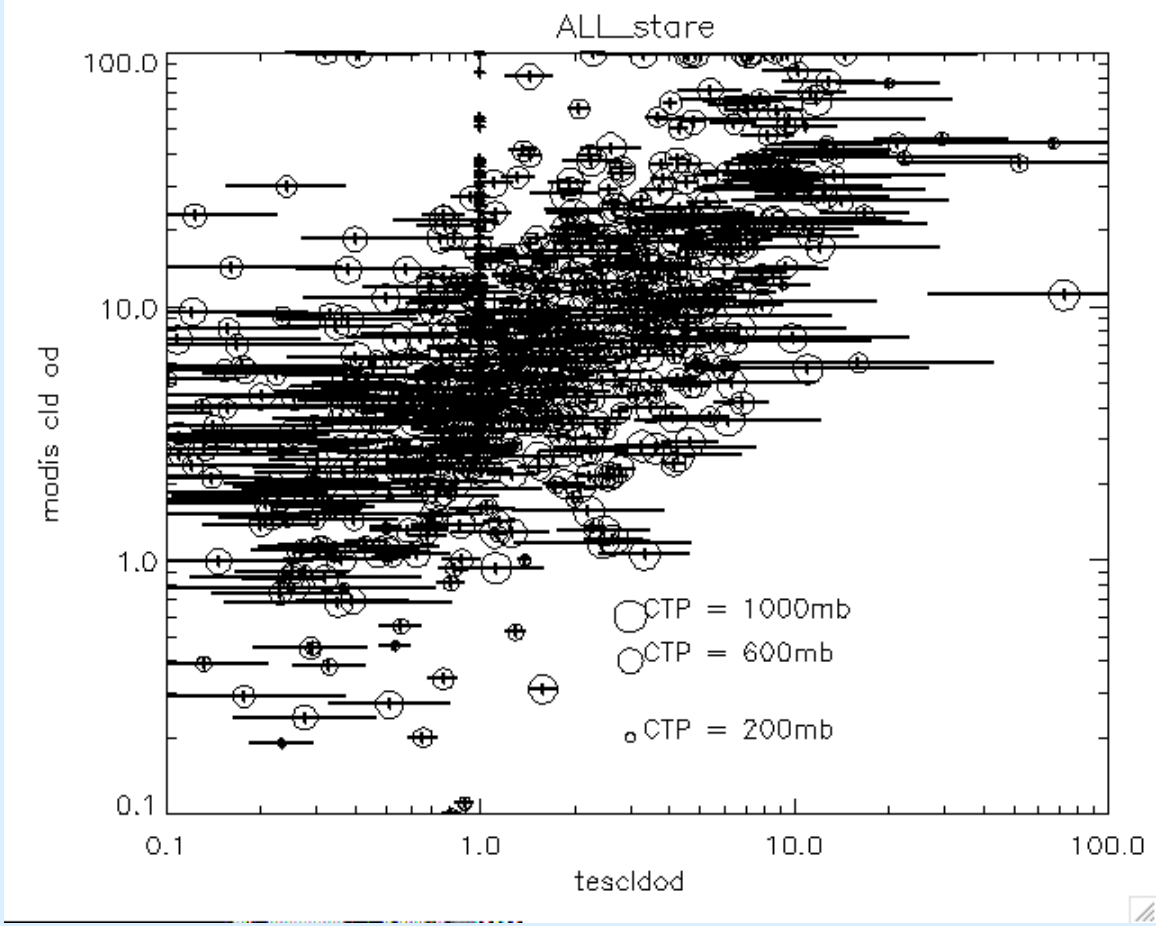
- TES and MODIS are different when MODIS places broken clouds near surface or places cloud above 200mb
- Can see impact of TES initial guess of 500mb, MODIS defaults to near surface cloud





Optical depth

- MODIS and TES see fundamentally different optical depth
- Will be difficult to verify TES retrieval with other measurements



Conclusions

- TES errors on retrieved effective cloud top pressure and effective optical depth are reasonable, based on physics, simulations, and differences with MODIS
- Effective optical depths consistent with MODIS
- Radiance residual is a strict test of optical depth for TES
- Would like to work with OMI team on comparisons