Characterizing the Impact of Hyperspectral Infrared Radiances near Clouds on Global Atmospheric Analyses

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Cloud Height Estimation Errors

Only Infrared radiances unaffected by clouds are assimilated

- cloud-free (all channels)
- cloudy, but unaffected (only channels sensing above cloud)

QC determines the cloud height and screens channels whose weighting functions are sensitive to the retrieved cloud height

In the GSI data assimilation algorithm, a minimum residual method (Eyre and Menzel 1989) is used to determine the cloud height

- Assumptions in this method are fundamental sources of error:
  - Single layer clouds; Infinitesimally thin, black clouds; treated as fractionally gray
- Background biases can propagate into the retrieval
  - Both with respect to variational bias correction and uncorrected observation departures

Forecast Impact of Cloud Contamination

The misassessment of cloud height can result in the cloud signals being erroneously projected on the mass (T & q) fields

To quantify this source of error:

- **Observation Departures (bias corrected)**
  - Observed minus Forecasted Brightness Temperature (O-F)
- **Adjoint-Based Observation Impacts**
  - A 24 hour forecast error projected onto the observations of its initial analysis using the adjoints of the forecast model and assimilation system
  - The measure is a moist energy norm (u, v, T, p_s , q_v → J/kg)
  - This method is run routinely in GMAO ops at 0000 UTC
  - **A negative value equates a reduction in error, so NEGATIVE = GOOD**

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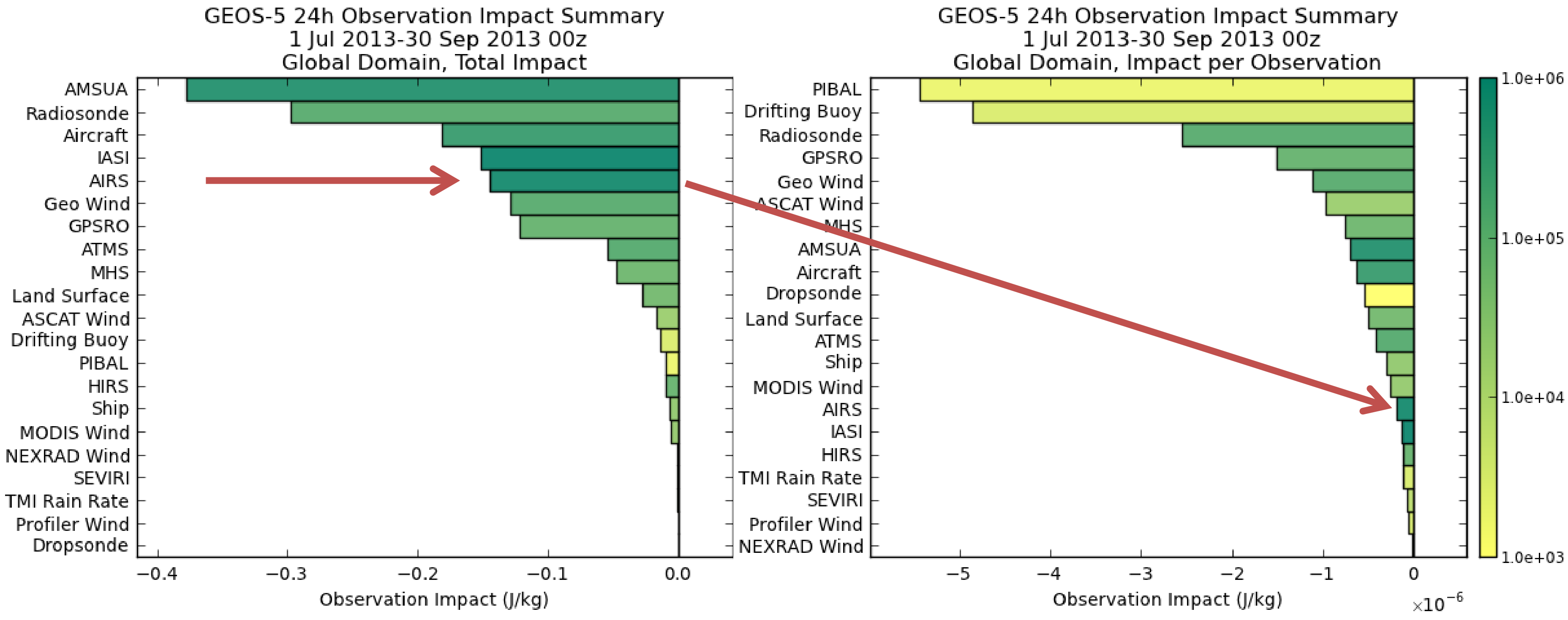
Impact of AIRS

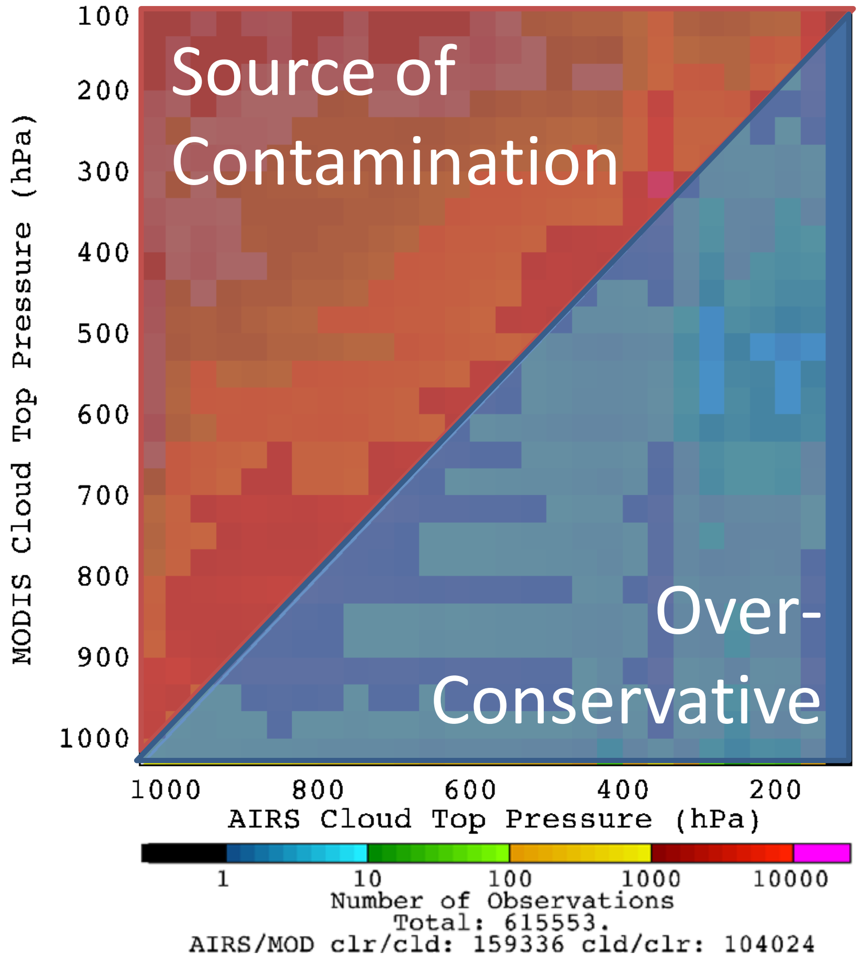


AIRS is generally larger than any single AMSU-A

Per radiance, AIRS is significantly less than AMSU-A

- Assumed as redundancy, but can cloud signals get past QC?

AIRS CTP vs. MODIS High CTP



1 Jul-30 Sept 2013

Comparing:

- AIRS Cld Top Pressure (CTP)
  - ~15 km
- MODIS MYD06 CTP
  - 5 km, coincident 3x3
  - highest CTP reported

Considering observations as function of cloud fraction shows biases in confident (opaque) and uncertain (variant) areas of cloudiness

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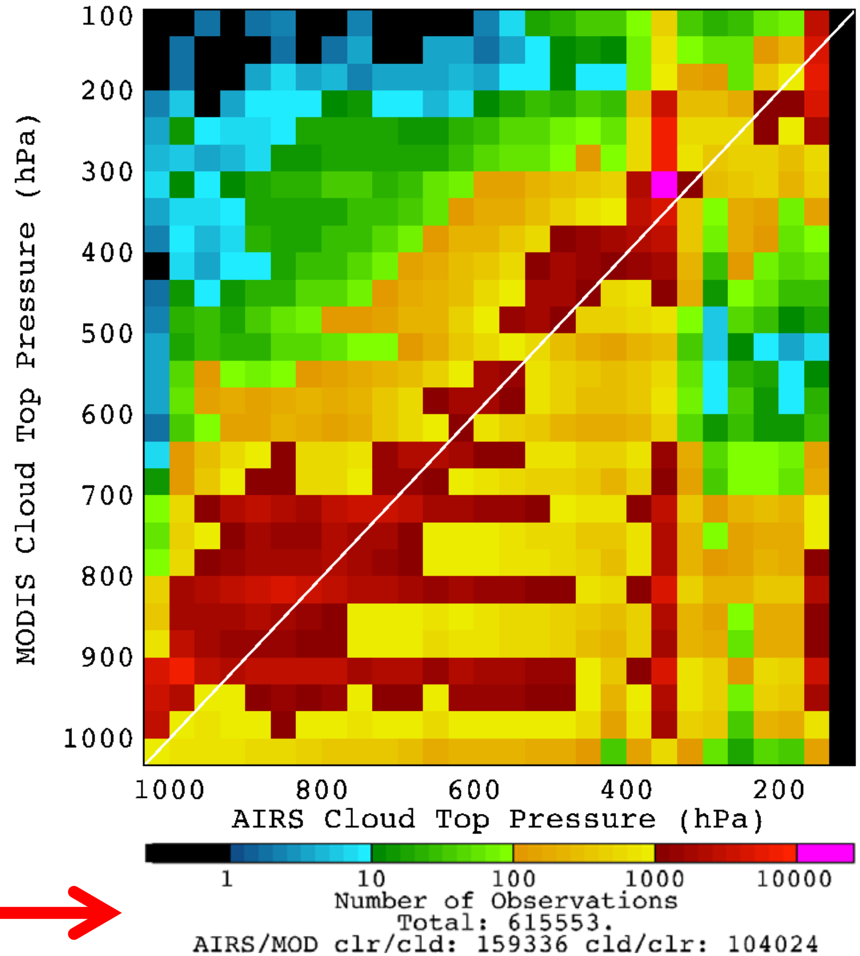

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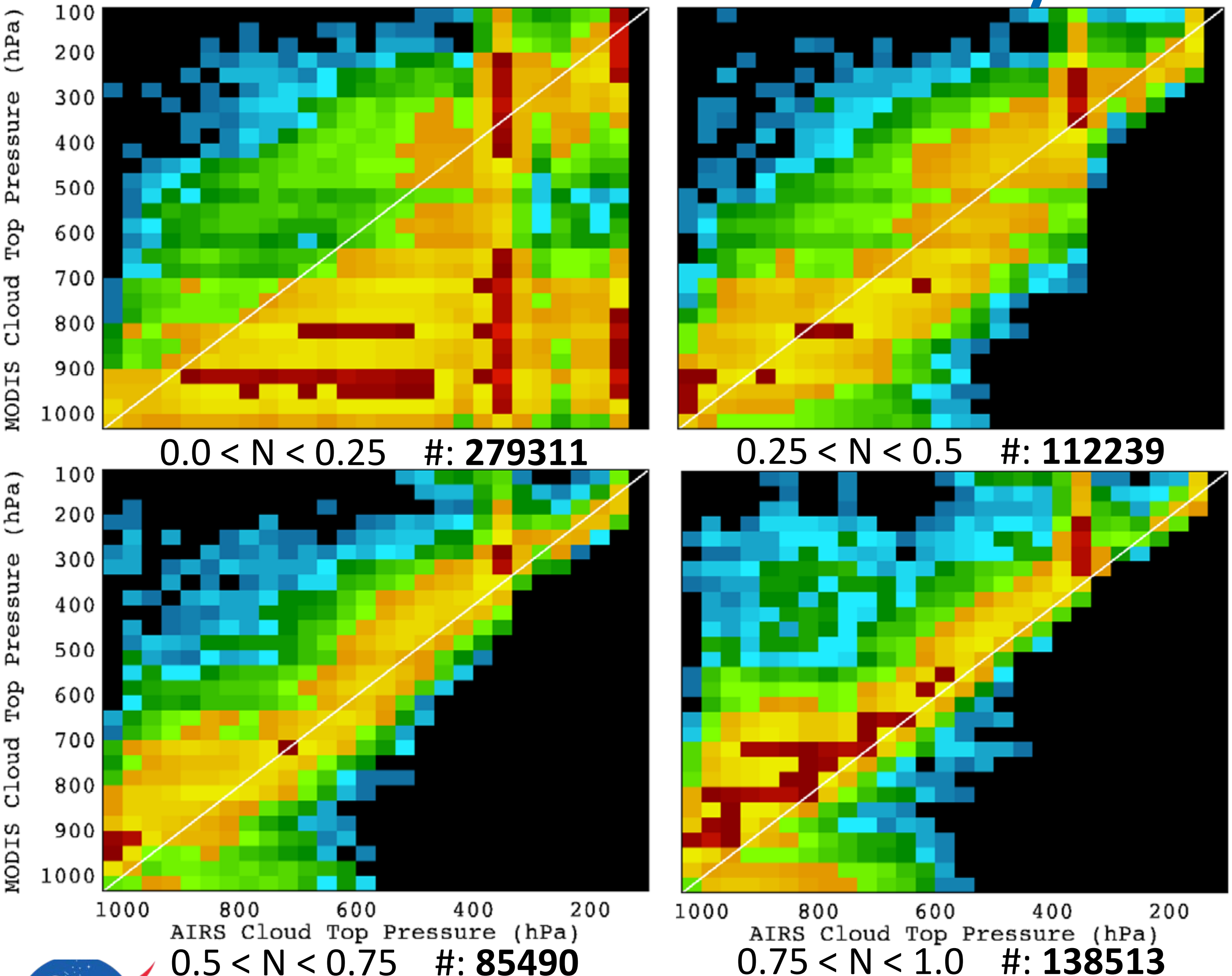
AIRS v. MODIS CTP by Fraction



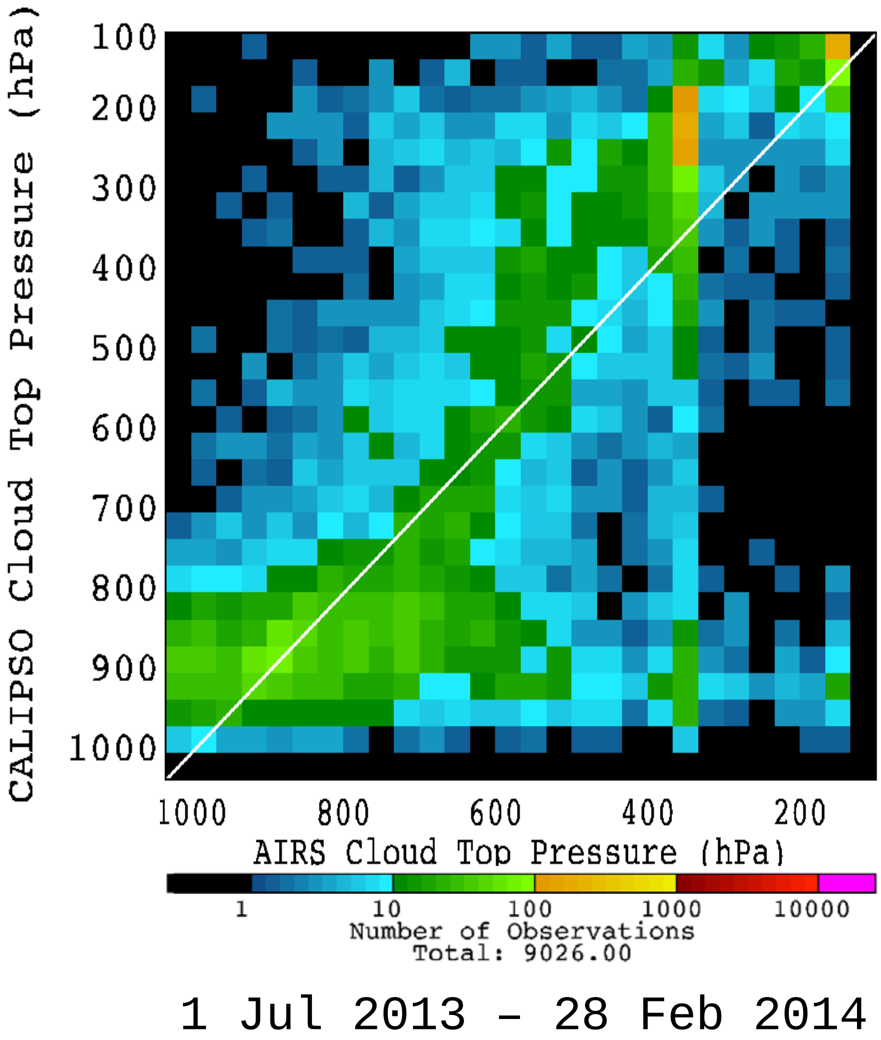
MODIS CTP uncertain > 700 hPa and in low fraction

Conservative in areas of low fraction

Apparent bias in areas of high fraction

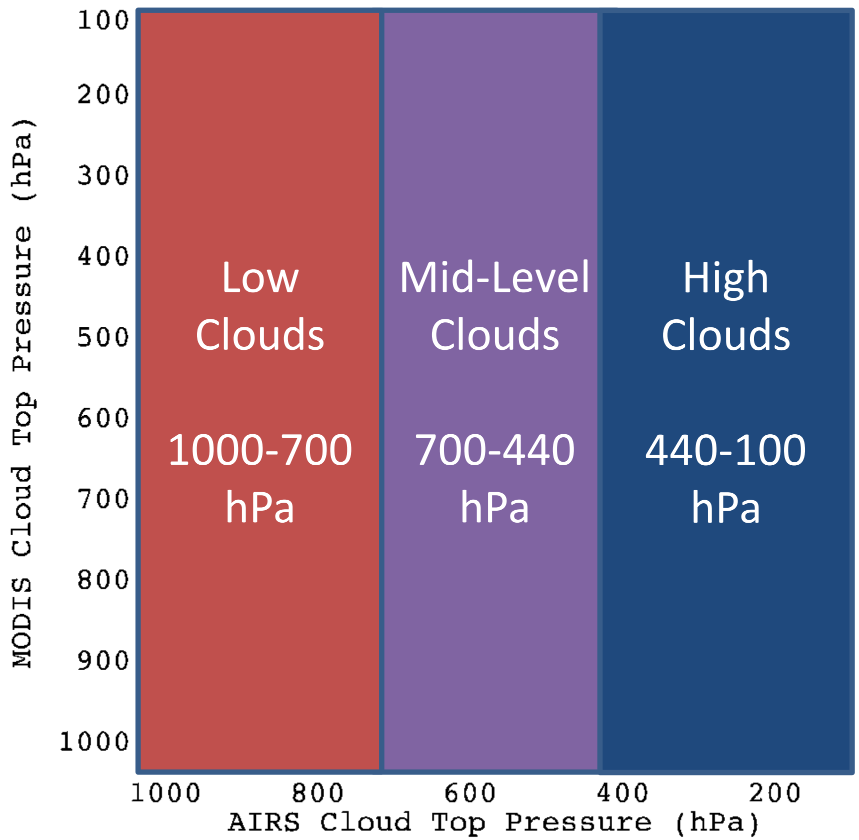
More low fraction observations by design

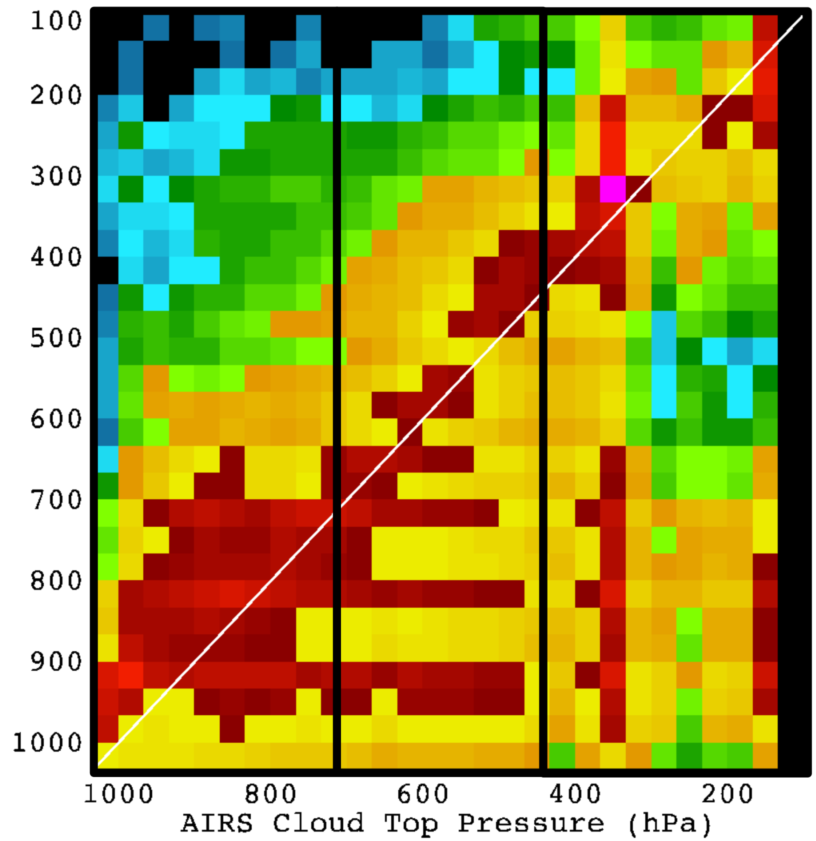
AIRS CTP vs. CALIPSO Highest CTP



- Compared against L2 CALIPSO-CALIOP determined CTP (1 km, V3-30)
- Similar trends, but reduction in lower-troposphere contamination (600-800 hPa)
- Includes poles, but separation was considered
  - No distinct polar signals
- Likely sampling issues (spatial and temporal)

AIRS CTP vs. MODIS High CTP





Clouds classified into (roughly) ISSCP height classifications as a function of AIRS Cloud Top Pressure

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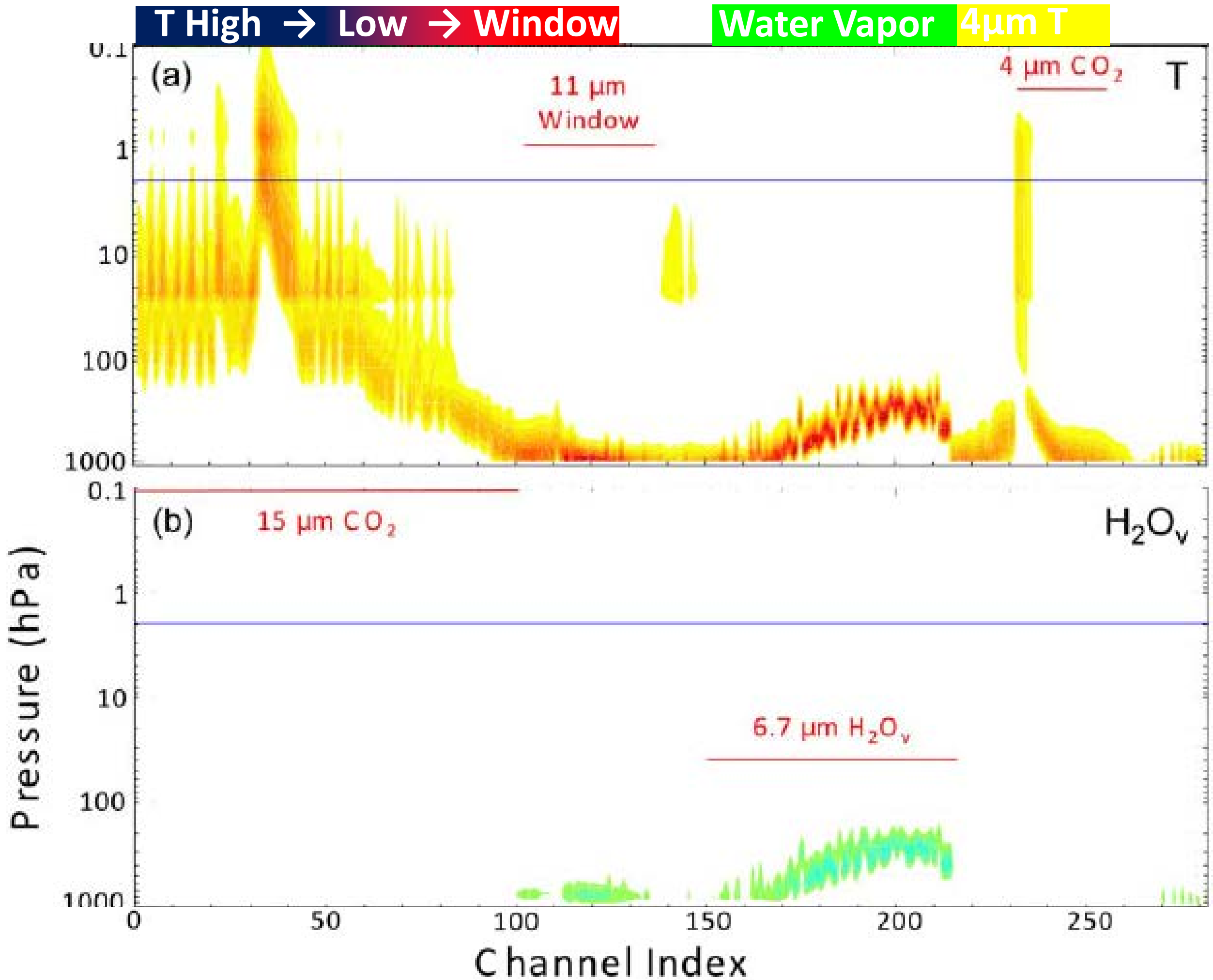
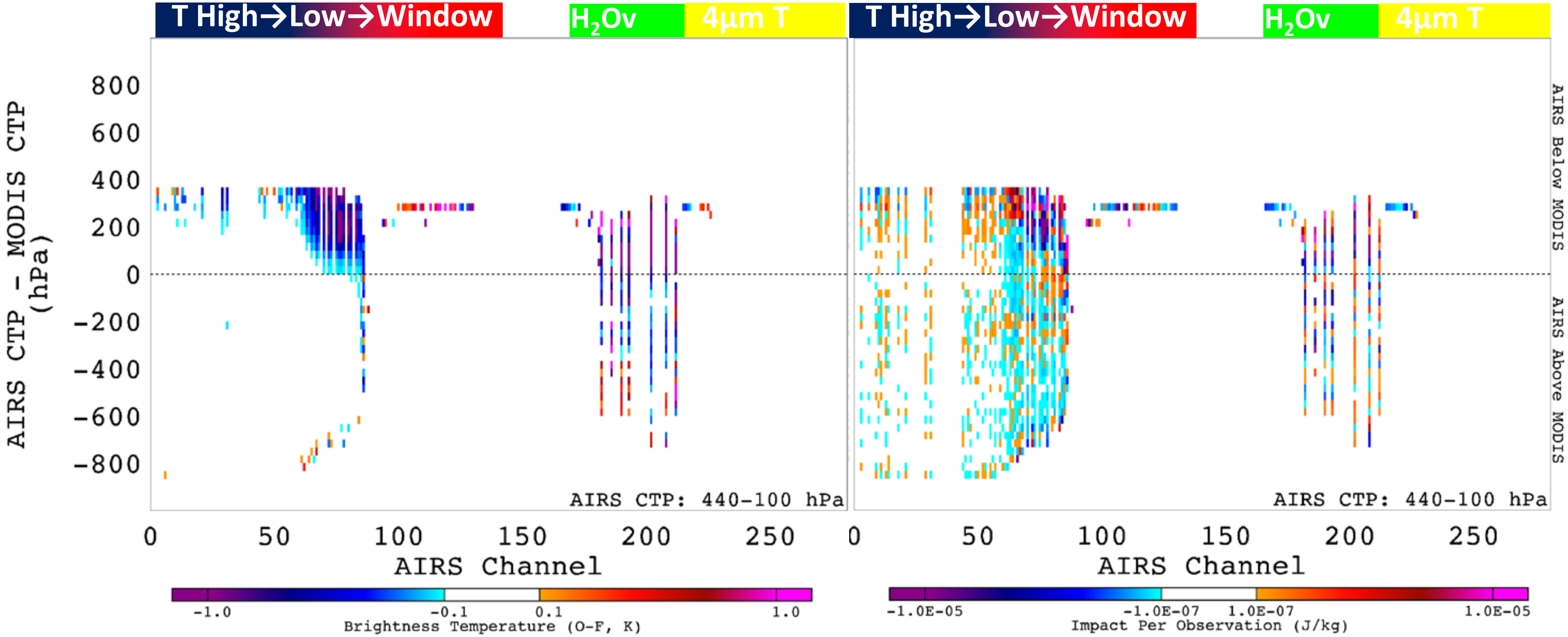
Channel Sensitivity



AIRS Jacobians for temperature and water vapor

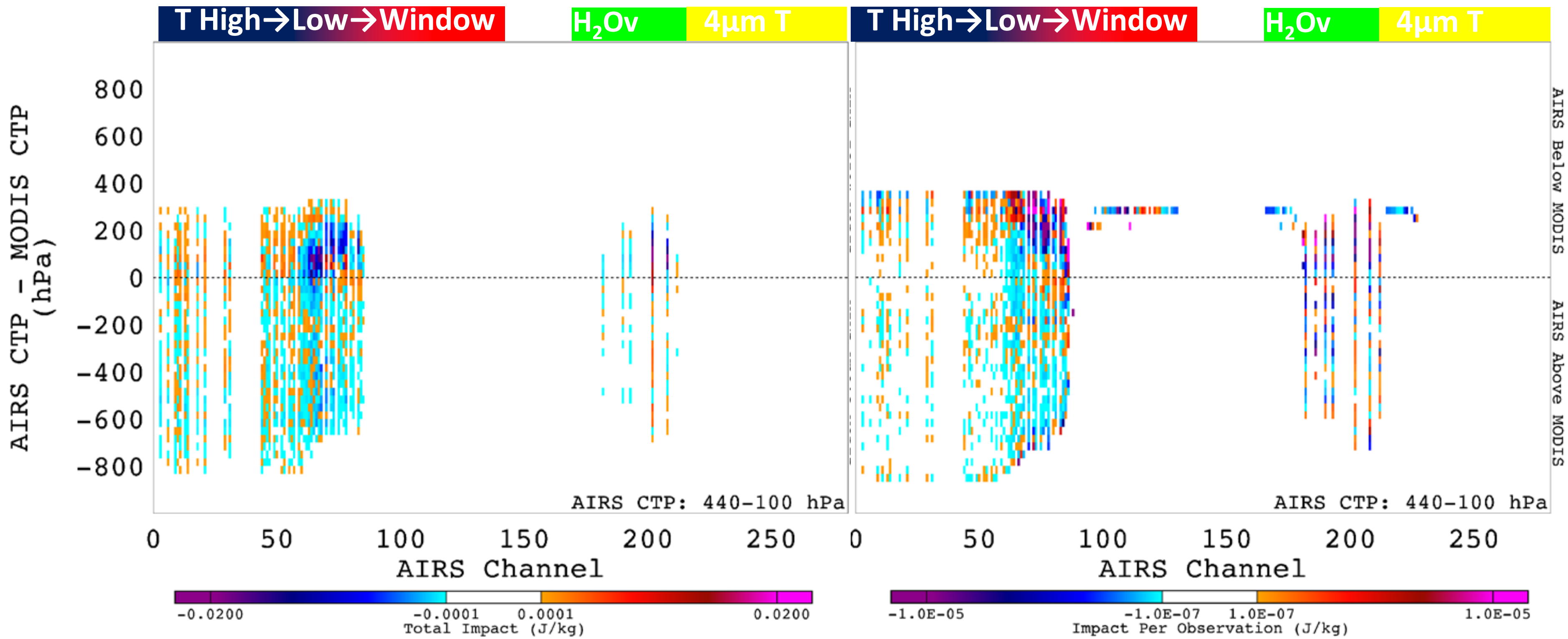
The top color bar will serve as reference for the remaining plots

Observation Impact – High Clouds



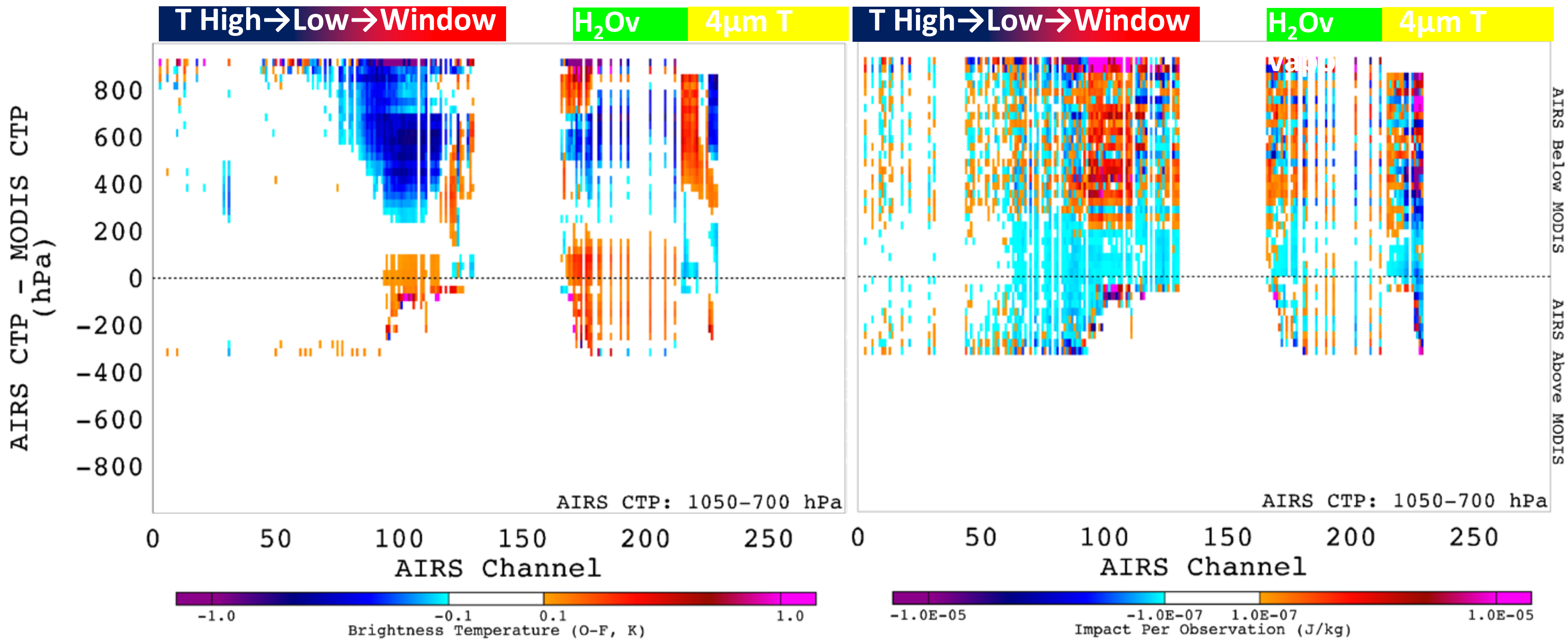
- Negative O-F signal apparent where MODIS/AIRS disagree most towards contamination
- Small count relative to total, but show inconsistent impact per observation in this region

Observation Impact – High Clouds



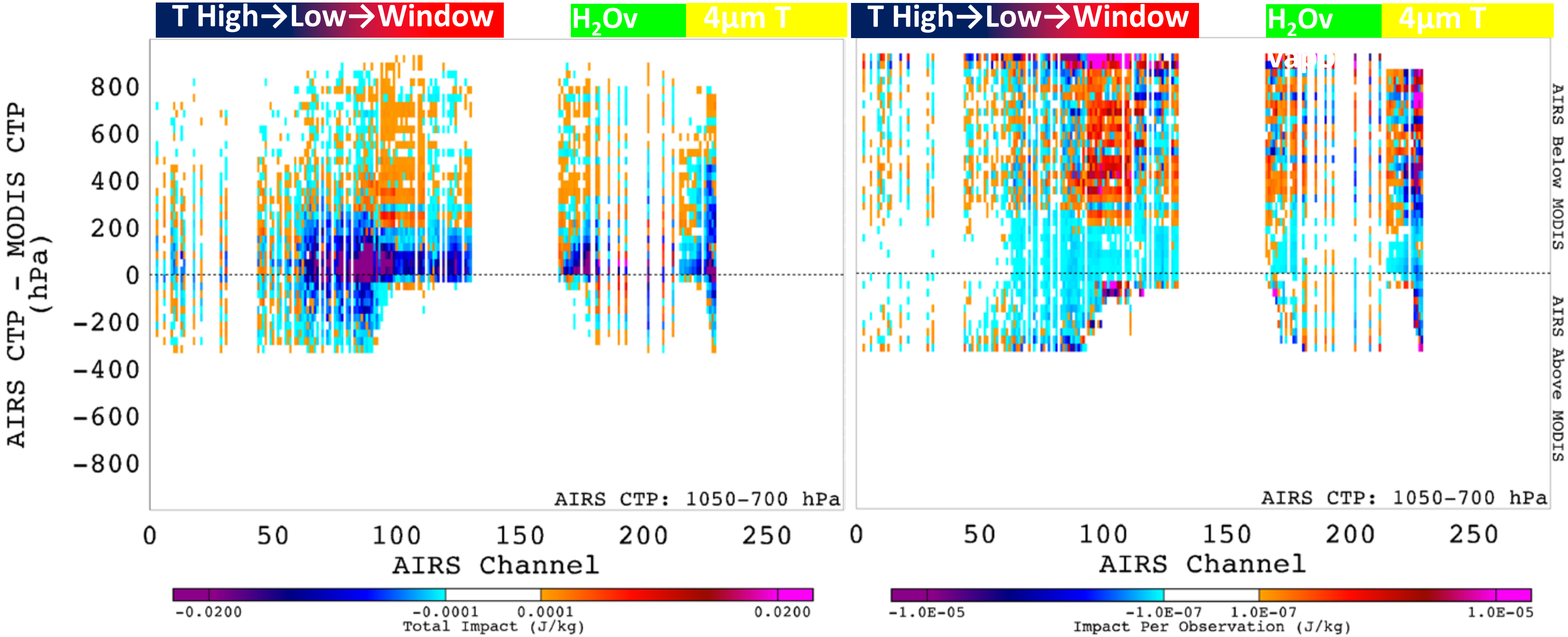
- Channels less effected by these high clouds (< 50) show more neutral impact – effect of the metric
  - Negative signal (~50-75) more apparent with larger sample size

Observation Impact – Low Clouds



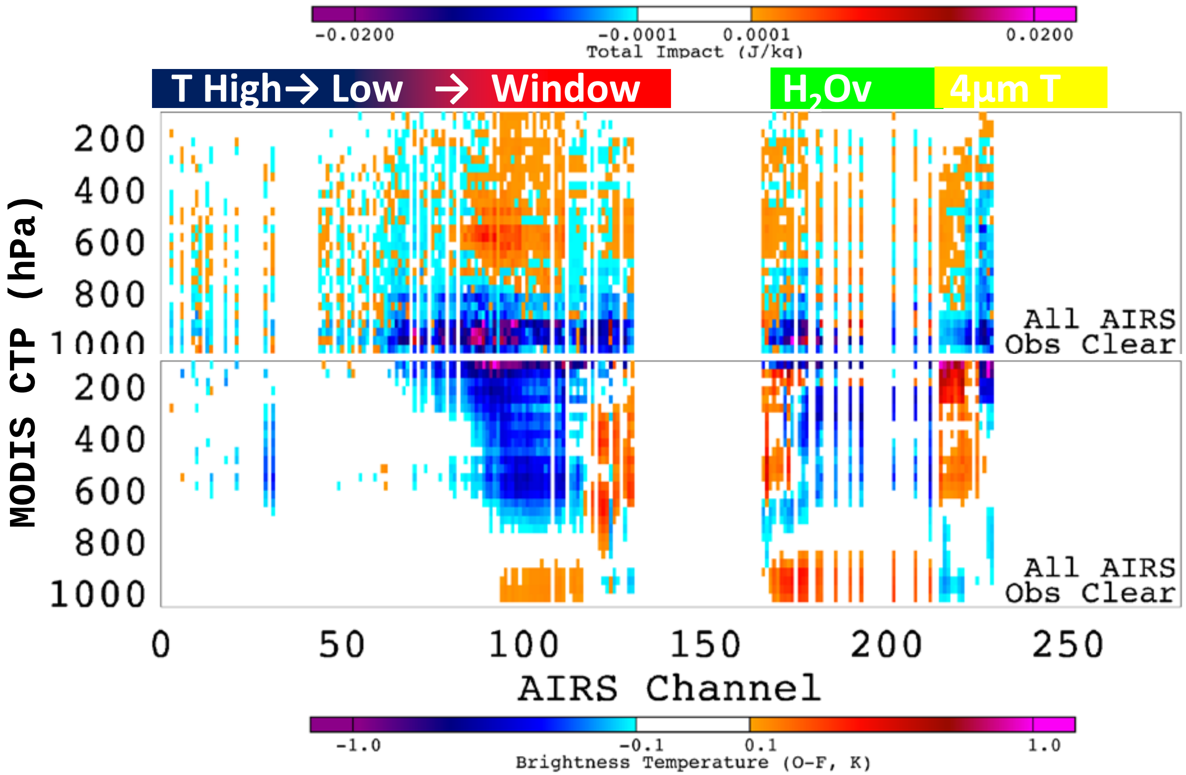
- Cloud signal again apparent
- Positive O-F bias in areas of agreement – potentially a feedback of cloud contamination having an effect on bias correction
- Impact per observation strongly negative in areas of cloud contamination

Observation Impact – Low Clouds



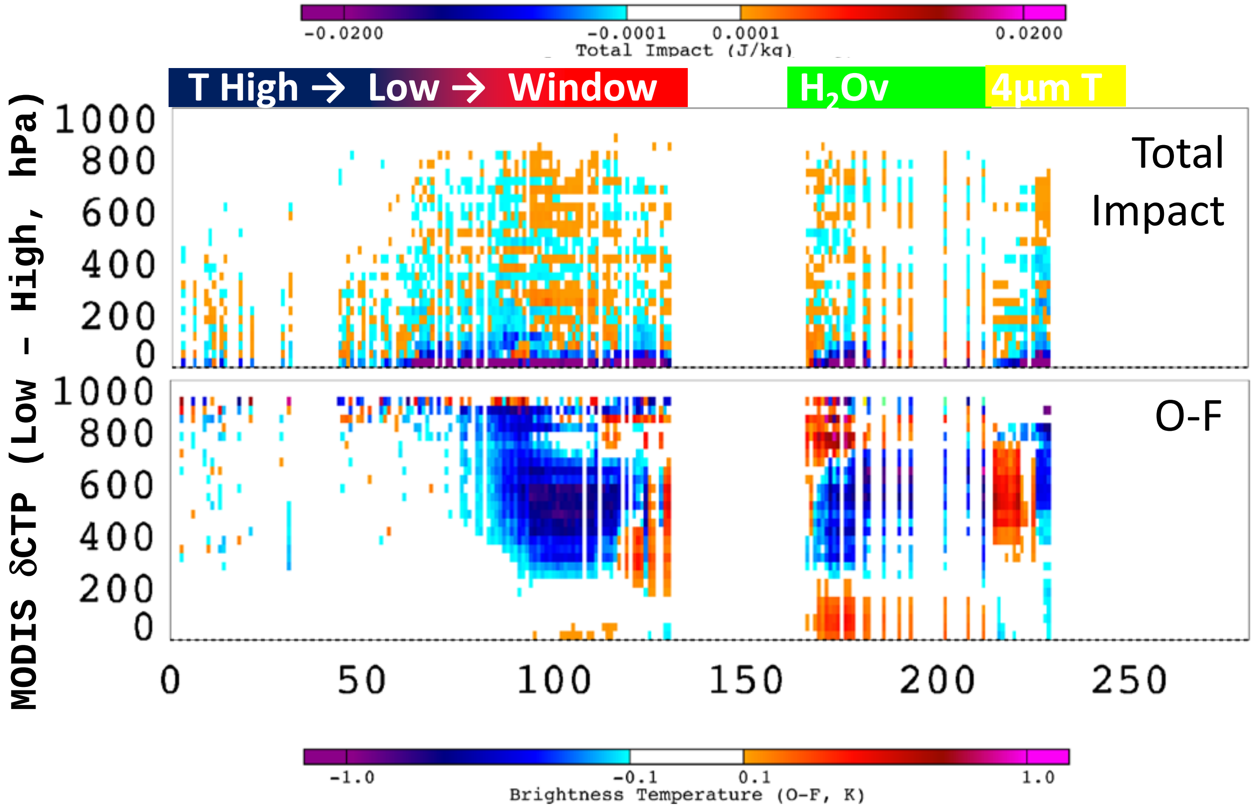
- Misrepresentation of low clouds relative to MODIS show clear increase in error for channels sensitive to low clouds
- There is a real chance that thin cirrus over small clouds can be a source of error
- Magnitude of total degradation due to clouds becomes much more significant w.r.t. overall positive impact

AIRS 'Clear'/MODIS Cloudy Observations



- Cloud signal again apparent, and largest magnitude of total degradation
- Warm O-F signal near sfc again

Heterogeneity in AIRS Observations



- Observations with notable subscale variability generally degrade, and have a negative O-F signal.
- This is using MODIS, which has many of the same limitations as AIRS.
  - Expansion to include CALIPSO was attempted, but an adequate sample couldn't be assembled
  - IASI clusters?

Conclusions/Future Work

- Readdress with v6 MODIS cloud retrievals
- Incorporation of CALIPSO dataset ongoing attempt to overcome issues with MODIS data
  - Even though different algorithms, MYD06 v5 (CO2 Slicing/IR Window) and GSI (MinRes) algorithms build on same assumptions
- An assimilation study incorporating MODIS CTPs to eliminate potential sources of contamination
  - In addition to impact assessment, it would help to quantify the effect that cloud contamination has on variational bias correction
- Ultimately, this helps quantify an issue that has been acknowledged
  - Tom Auligne has done some work with multilevel cloud retrievals in the GSI, and many data streams have subscale imagery information
- This work is providing a level of verification necessary to continue efforts to assimilate cloud-affected IR observations