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A Multi-Sensor Water Vapor, Temperature and Cloud Climate Data Record: Status of our MEaSUREs 2012 Project

Eric Fetzer, Evan Fishbein, Hook Hua, Brian Kahn, Alex Guillaume, Bjorn Lambrigtsen, Gerald Manipon Mathias Schreier, Bob Stachnik, Brian Wilson, Sun Wong and Qing Yue

Jet Propulsion Laboratory, California Institute of Technology

AIRS Science Team Meeting, Caltech

March 22, 2016

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Our Team

- ***Science***: Eric Fetzer, Alex Guillaume, Bob Stachnik, Sun Wong, Qing Yue (also Bjorn, Brian K. and Evan F.).

- ***Technology***: Hook Hua, Gerald Manipon and Brian Wilson.

What We Proposed

Our primary objectives:

- **Incorporate all A-Train water vapor, including small-scale, horizontal and vertical water vapor structure from MODIS and GPS.**
- **Use MODIS cloud classification that is collocated at the pixel-scale over the full AIRS/AMSU swath.**
- **Extend summaries to PDFs/higher order moments of water vapor sorted by cloud classes**
- **Establish robust, scale-dependent statistical relationships between cloud, temperature, and water vapor PDFs for the climate modeling community**

We will also:

- **Update our current data record to new CloudSat/CALIPSO cloud classification.**
- **Provide merged AIRS and MLS water vapor profiles using averaging kernels.**
- **Include temperature and water vapor from models (ECMWF) and reanalyses (MERRA).**
- **Classify METOP-A and NOAA satellite water vapor with AVHRR during SNOs.**
- **Compare with the NVAP-M water vapor climatologies.**
- **Use existing data sources and mature algorithms, and document processing algorithms.**

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MEaSUREs 2007: A Multi-Sensor Water Vapor Climate Data Record Using Cloud Classification

PI: Eric Fetzer, Jet Propulsion Laboratory

Objectives

- Create a complete and consistent record of water vapor from the A-Train satellite constellation.
- Merge with water vapor observations obtained prior to the A-Train period, and with observations obtained from non-A-Train sensors.
- Quantify the effects of cloud variability on water vapor changes over years to decades.

Approach

- Use independent cloud and water vapor observations to characterize long-term changes in climate states.
- Reconcile observations between A-Train sensors, and from other observing systems.

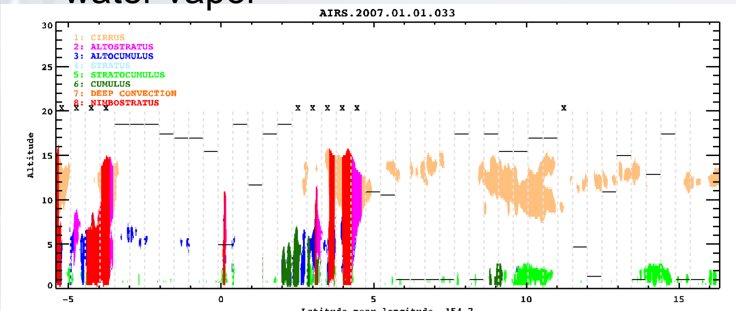
Co-Is/Partners

Co-Is: Evan F. Fishbein, Brian D. Wilson, Joao Teixeira, Brian H. Kahn, Bjorn H. Lambrigtsen, William G. Read, JPL. Tim Barnett, Scripps

•This work is coordinated with the NASA Water Vapor (NVAP) project lead by Thomas Vonder Haar of Colorado State University.

Datasets Used

- CloudSat cloud classes and properties.
- AIRS, MLS and AMSR-E temperature and water vapor



X,--: AIRS sounding depth
Colors: CloudSat cloud classes

Products

- AIRS, AMSR-E and MLS Level 2 water vapor retrievals matched to CloudSat cloud classes.
  - Delivered to GES DIS fall 2010.
- Summary L3 data products showing water vapor variability in cloud classes.
  - Delivery in Fall 2012.

Science Application

- A long-term record of atmospheric water vapor and clouds is needed for detection of trends in the atmospheric hydrologic cycle.

13 February 2012

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Major differences from our MEaSUREs 2007 Project

- ✓ Apply ISCCP-type classification to MODIS for all AIRS/AMSU, AMSR-E and MLS fields of view.
- ✓ Include all A-Train water vapor and temperature, not just along the CloudSat/CALIPSO track.
- ✓ Look at fine-scale variability in MODIS and GPS-RO water vapor.
- Begin comparing A-Train with IASI.

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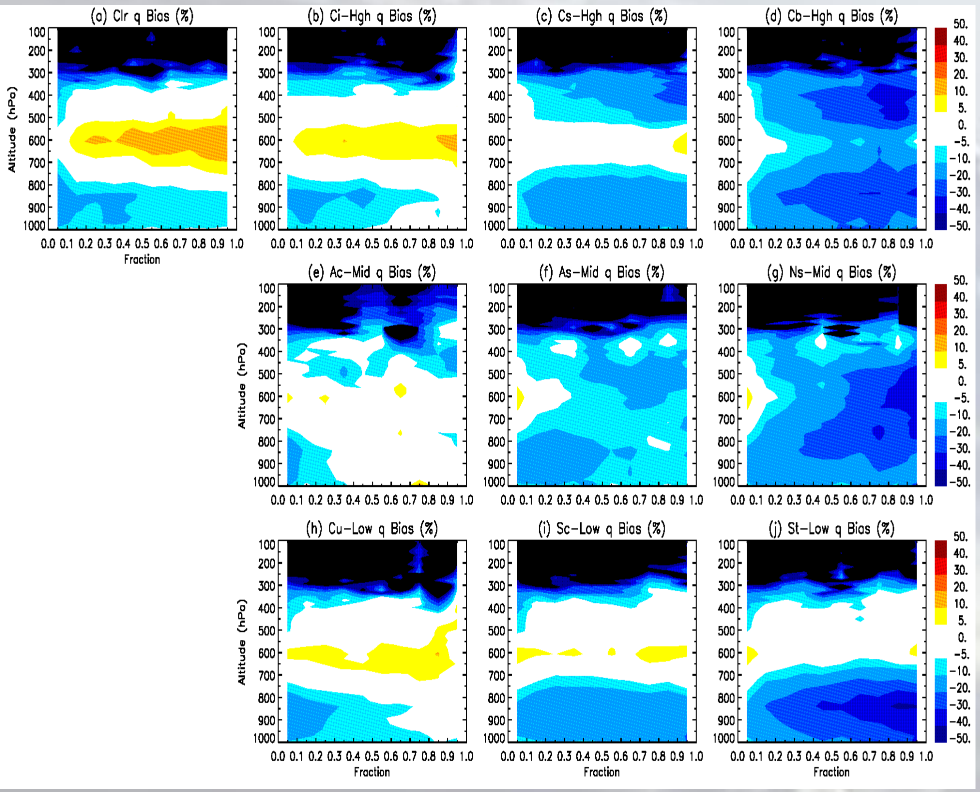
Cloud-Induced Uncertainties in AIRS and ECMWF Temperature and Specific Humidity (Sun Wong)



Profiles of specific humidity biases against radiosonde measurements as functions of cloud fraction of each cloud type in an AIRS/AMSU field of view. The cloud types are clear sky (Clr), cirrus (Ci), cirrostratus (Cs), deep convection (Cb), altocumulus (Ac), altostratus(As), nimbostratus (Ns), cumulus (Cu), stratocumulus (Sc), and Stratus (St).

- **Question**

How do clouds introduce retrieval biases into AIRS temperature and water vapor profiles?

- **Findings**

Biases are small compared to radiosonde measurements above clouds or when the clouds are thin, but increase when thicker clouds present

- **Relevance**

AIRS is used in climate studies and many applications related to societal impact (e.g., weather forecasts and prediction of potential of mosquito-based disease). Quantifying uncertainty is essential for both non-expert and expert users.

Supported by NASA's Earth System Data Record Uncertainty Analysis and MEaSUREs programs, PI: E. Fetzer

Wong, Fetzer, Schreier, Manipon, Fishbein, Kahn, Yue, and Irion –JGR-Atmosphere (2015 March)

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Estimating AIRS Biases using ECMWF

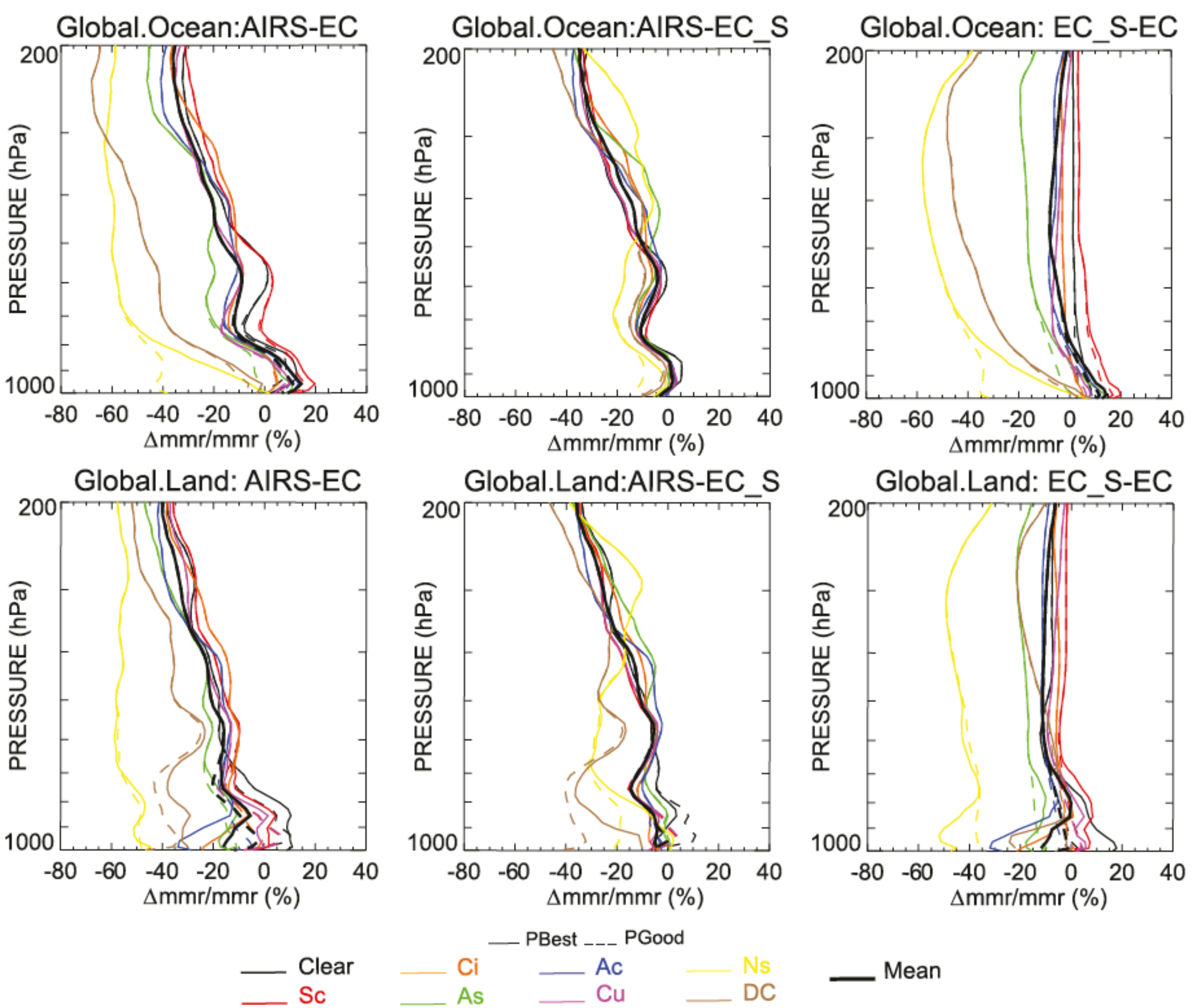

FIG. 7. Relative differences of q for (left) AIRS − EC, (center) AIRS − EC-S, and (right) EC-S − EC for the global (top) ocean and (bottom) land. The percentages are relative to EC, EC-S, and EC means for three columns, respectively.

Yue, Q., E. J. Fetzer, B. H. Kahn, S. Wong, G. Manipon, A. Guillaume and B. Wilson (2013), Cloud-state-dependent sampling in AIRS observations based on CloudSat cloud classification, *J. Climate*, 26, 8357–8377.

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Estimating sampling biases using reanalyses

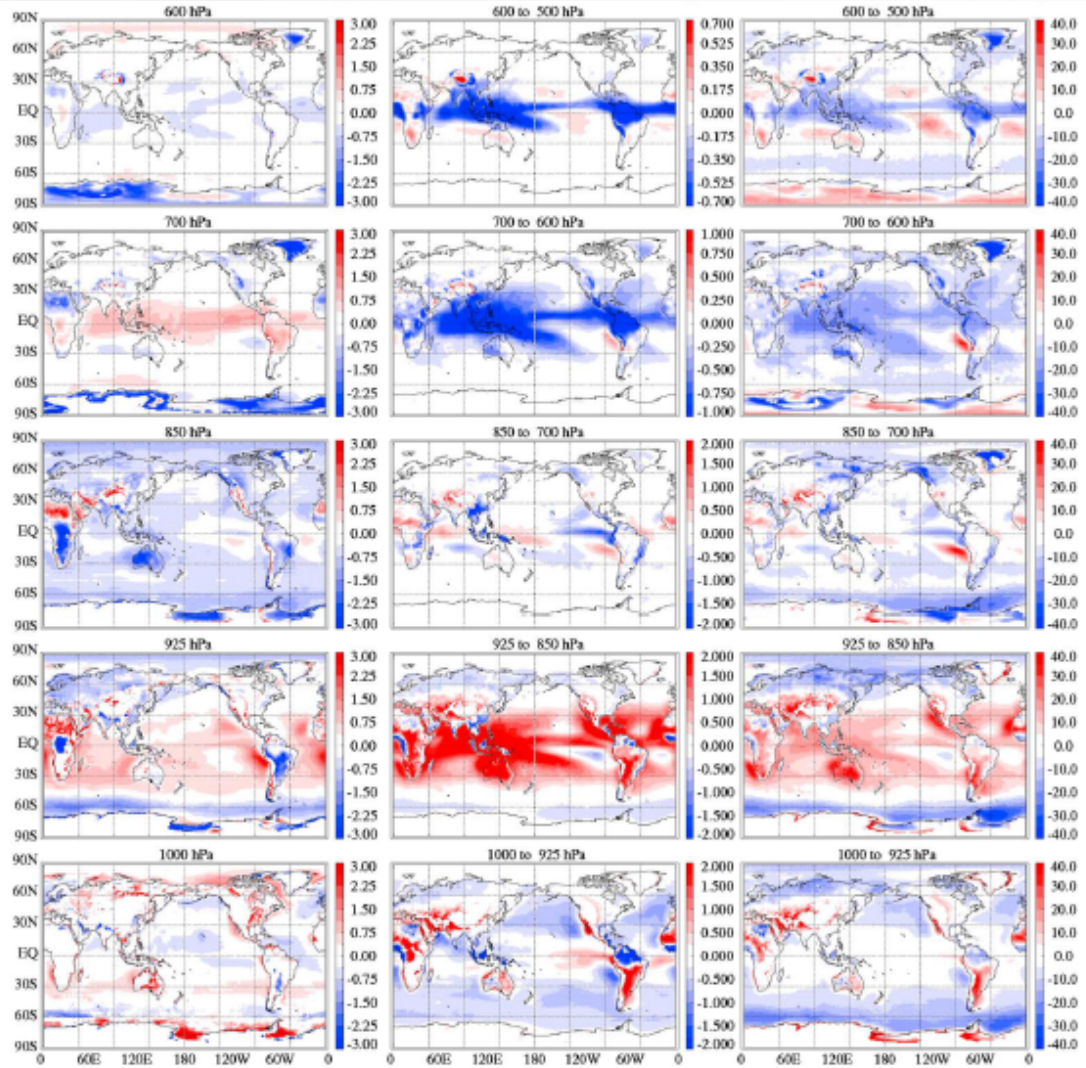

Figure 7. Differences between similarly sampled AIRS/AMSU-A and MERRA (AIRS/AMSU-A–MERRA sampled like AIRS/AMSU-A [MSAQC]) climatologies of air temperature in Kelvins, water vapor mixing ratio in g/kg, and percent difference of water vapor mixing ratio, from left to right. These differences are an estimate of the combined measurement uncertainty of AIRS/AMSU-A and MERRA at the locations where AIRS/AMSU-A is able to obtain observations.

Hearty, T. J., A. Savtchenko, B. Tian, E. Fetzer, Y. L. Yung, M. Theobald, B. Vollmer, E. Fishbein, and Y.-I. Won (2014), Estimating sampling biases and measurement uncertainties of AIRS/AMSU-A temperature and water vapor observations using MERRA reanalysis, *J. Geophys. Res. Atmos.*, *119*, doi:10.1002/2013JD021205.

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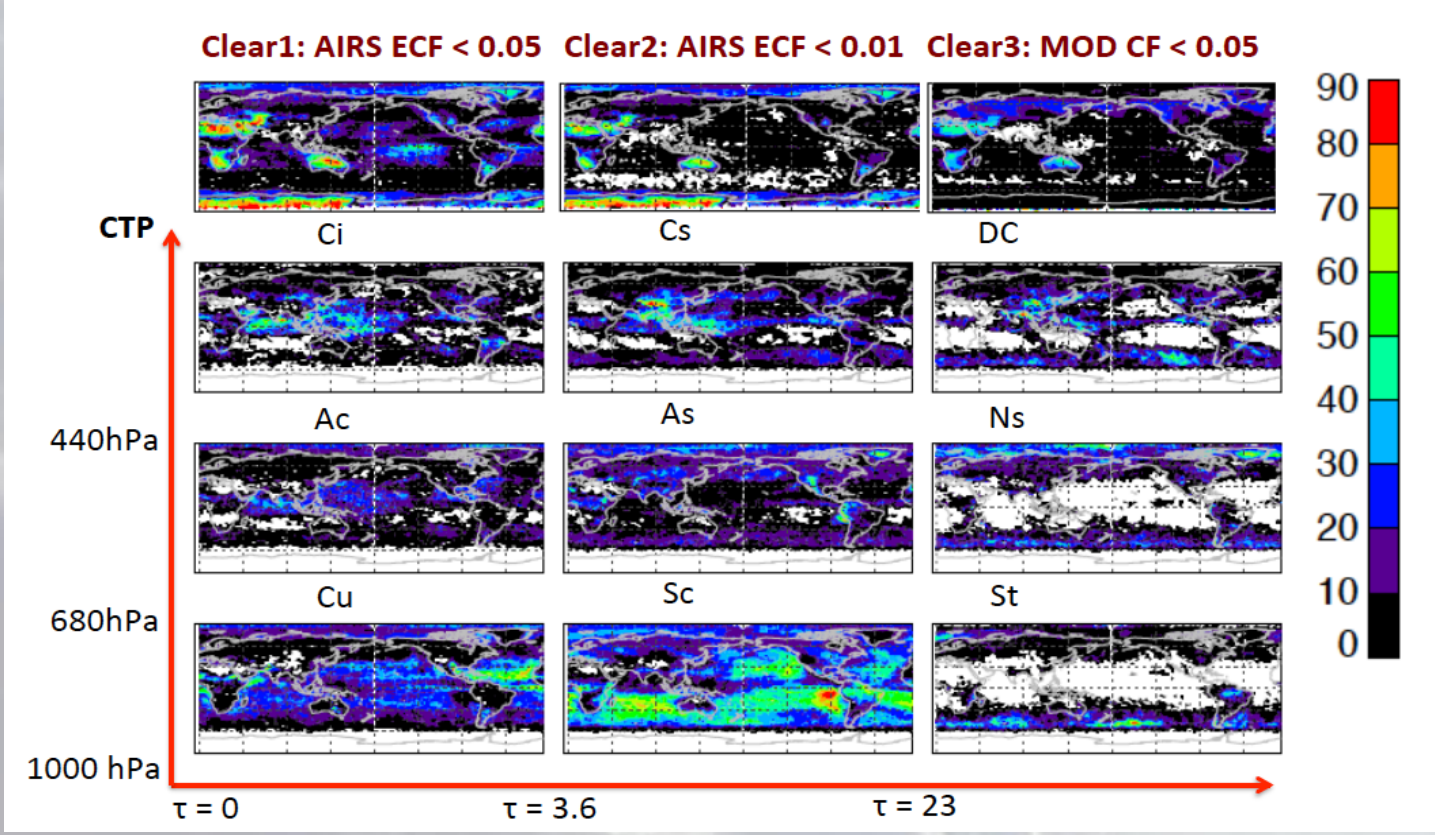
Observation-based Longwave Cloud Radiative Kernels Derived from the A-Train

Yue et al. (2016) *J. Clim., accepted.*



The global distributions of the occurrence frequencies for the three clear sky thresholds (top row) and the occurrence frequencies for the 3×3 ISCCP-defined cloud types for July 2009. The cloud types are defined using a histogram of cloud top pressure (CTP) and optical depth (τ) from MAST-MODIS data. The bin edges of CTP and τ are indicated along the red axis. Color bar shows percentage (%).

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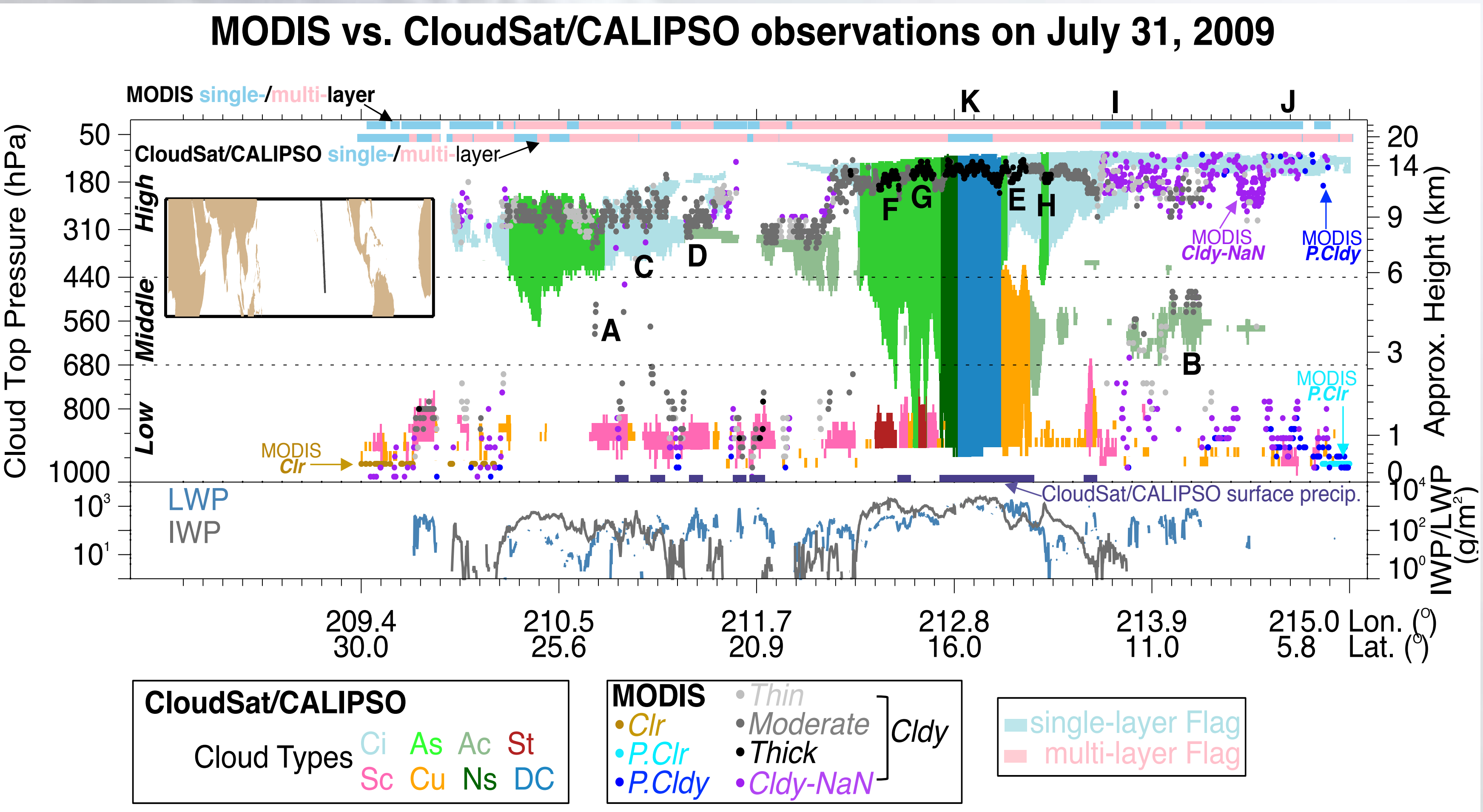
Comparing CloudSat/CALIPSO with MODIS clouds



T. Wang, E. J. Fetzer, S. Wong and Q. Yue (2016), Interpretation of MODIS Cloud Images by CloudSat/CALIPSO Cloud Vertical Profile, *in preparation*.

Water Vapor from GPS-RO and AIRS with MODIS cloud classification

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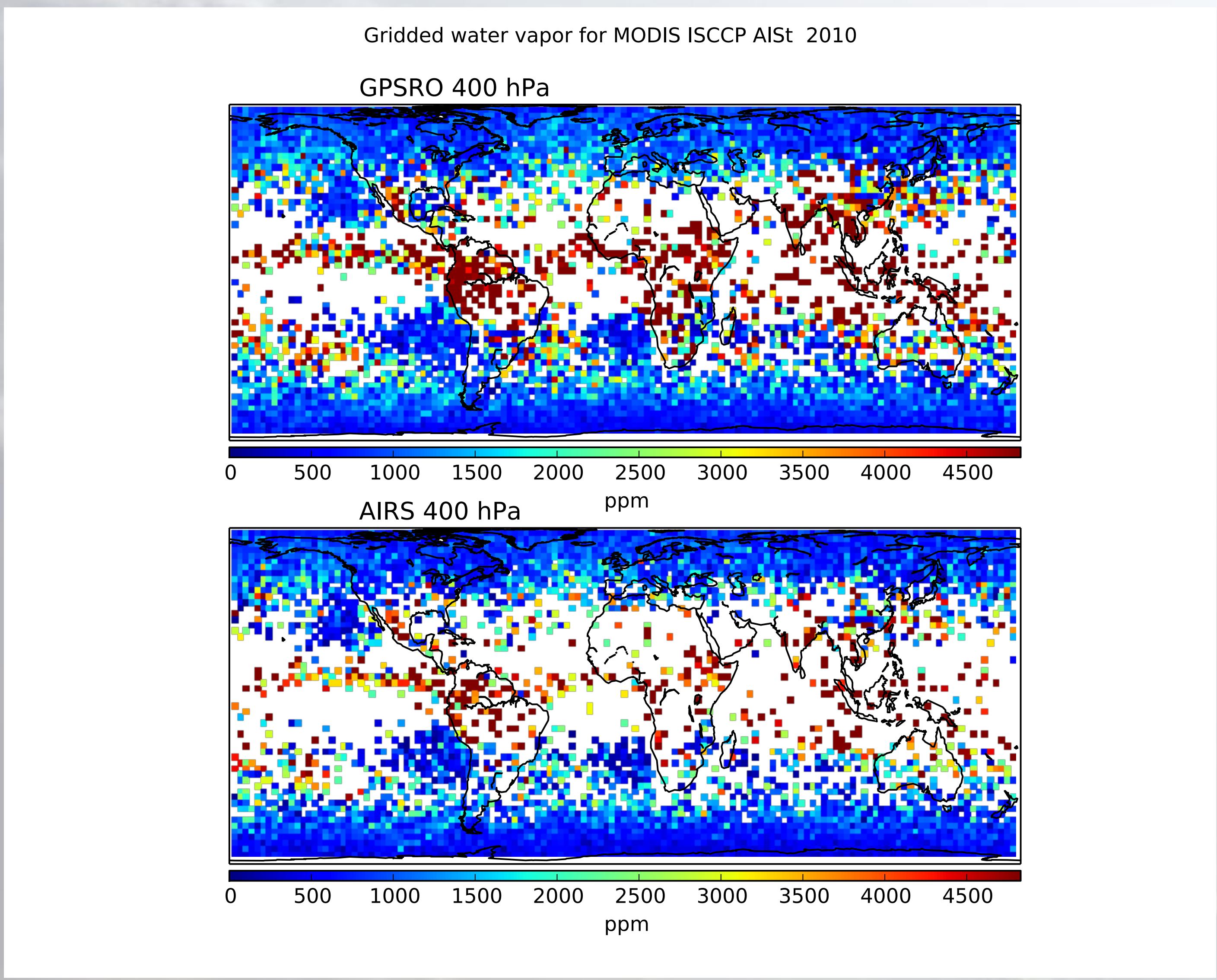

Image by Bob Stachnik.

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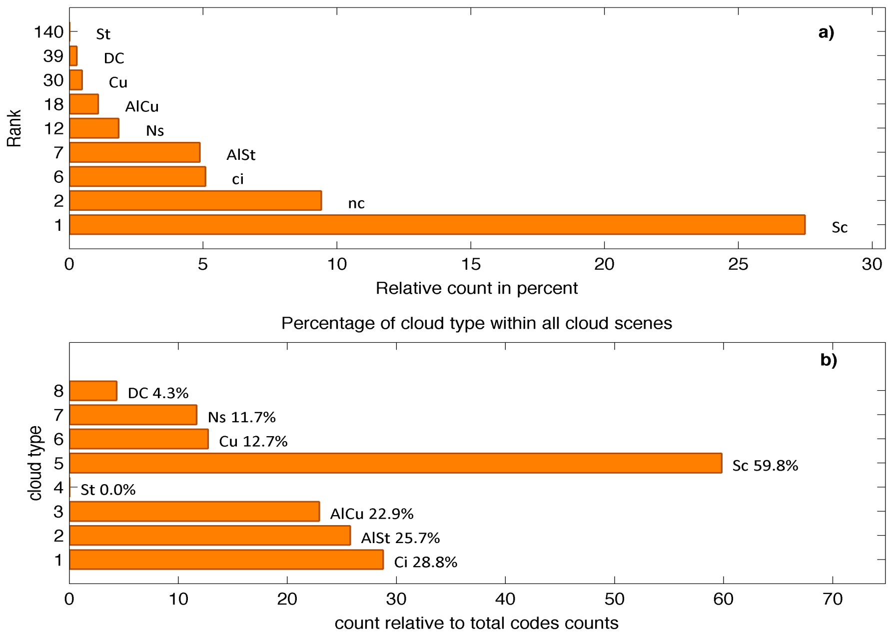
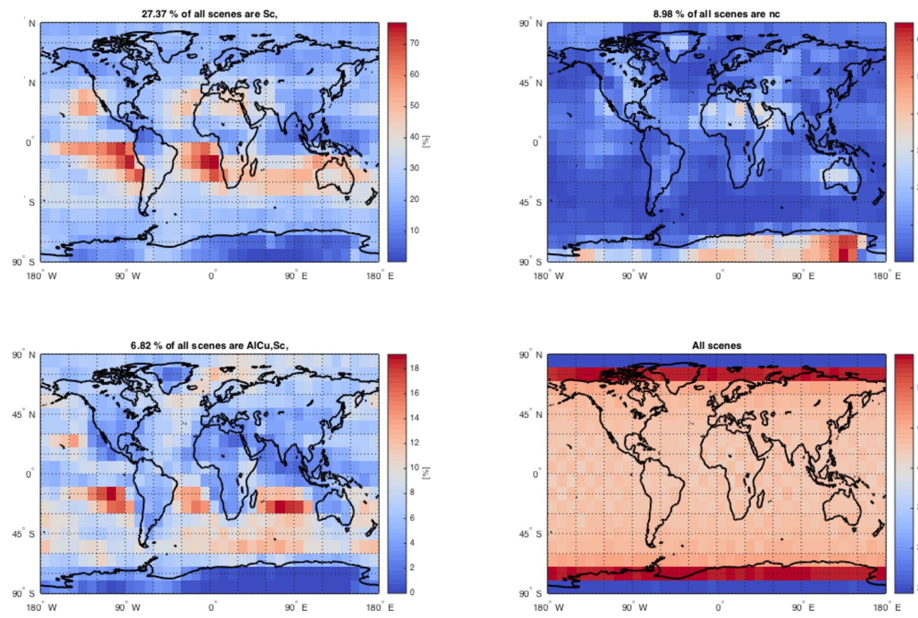
Looking at Cloud Frequency in CloudSat



a) Selection of all observed single cloud scenes among all observed mixed scenes. b) Single cloud type contained in all cloud scenes relative to the total number of observed scenes.



Geographic distribution of three of the most observed scenes (see Figure 1). The bottom right corner figure shows the cumulative counts of all observed scenes over the globe. The count of the {Sc}, {nc} and {AlCu, Sc} scenes have been normalized by the corresponding grid cell count in the lower right figure, and thus, are indicated in percent on the right side of each of the three scene figure.

In preparation, A. Guillaume et al.

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Technology

- **Use AIRS-MODIS match-ups to process the entire A-Train record in the Amazon Cloud.**
- **Costs are MUCH lower than even a single processing cluster.**
- **Our project prototyped the OCO-2 Cloud processing.**

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Future (Realistic) Work

- **Finish the AIRS-MODIS match-ups and summarization.**
  - ***Include reconciling with CloudSat and CloudSat/CALIPSO.***
- **Complete long-term climatologies, including MLS and AMSR-E.**
- **Continue with GPS-RO water vapor in-cloud water vapor and MODIS fine-scale horizontal variability.**
- **Move on to IASI and AIRS/AMSU matches.**

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Conclusions

- **We are reaching our main objective of AIRS/AMSU matched to MODIS cloud types**
  - ***Processing is underway.***
  - ***Still need to summarize temperature and water vapor over the A-Train period.***
- **Starting to include fine-scale information from GPS-RO and MODIS.**
- **Need to look at A-Train and S-NPP simultaneous nadir overpasses.**