Plans for a multidecadal satellite record of water vapor, temperature and clouds

Eric Fetzer, Hook Hua, Brian Kahn, Gerald Manipon, Paul Staten, Qing Yue, Chi Ao, Mathias Schreier, Brian Wilson and Robert Stachnik

Also

Sun Wong, Van Dang, Joao Teixeira, Bill Read, Tim Barnett,…

Jet Propulsion Laboratory, California Institute of Technology

Atmospheric Infrared Sounder Science Team Meeting

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- **Martha Maiden (retired).**
- **Ramesh Kakar (retiring).**
- **Lucia Tsaoussi**

Our Latest NASA MEaSUREs Project

ROSES 2017 MEASURES
NRA NNH17ZDA001N MULTIDECADAL WATER VAPOR, TEMPERATURE AND CLOUDS

A Multidecadal Satellite Record of Water Vapor, Temperature and Clouds

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The Third of Three Related MEaSUREs Projects

2007

ROSES 2006 — MEaSUREs
NRA NNH06ZDA001N — WATER VAPOR CLIMATE RECORD

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

Eric J. Fetzer, Evan F. Fishbein, Brian D. Wilson, Joao Teixeira, Brian H. Kahn, Bjorn H. Lambrigtsen, William G. Read and Tim Barnett

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3 Facilities and Equipment
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4.1 JPL Direct Labor
5 Biographical Sketch
5.1 Principal Investig
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6 Current and Pending Supp

2012

ROSES 2012 — MAKING ESDRS FOR USE IN RESEARCH ENVIRONMENTS
NRA NNH12ZDA001N-MEASURES — WATER VAPOR, TEMPERATURE AND CLOUDS

A Multi-Sensor Water Vapor, Temperature and Cloud Climate Data Record

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2017

ROSES 2017 — MEASURES
NRA NNH17ZDA001N — MULTIDECADAL WATER VAPOR, TEMPERATURE AND CLOUDS

A Multidecadal Satellite Record of Water Vapor, Temperature and Clouds

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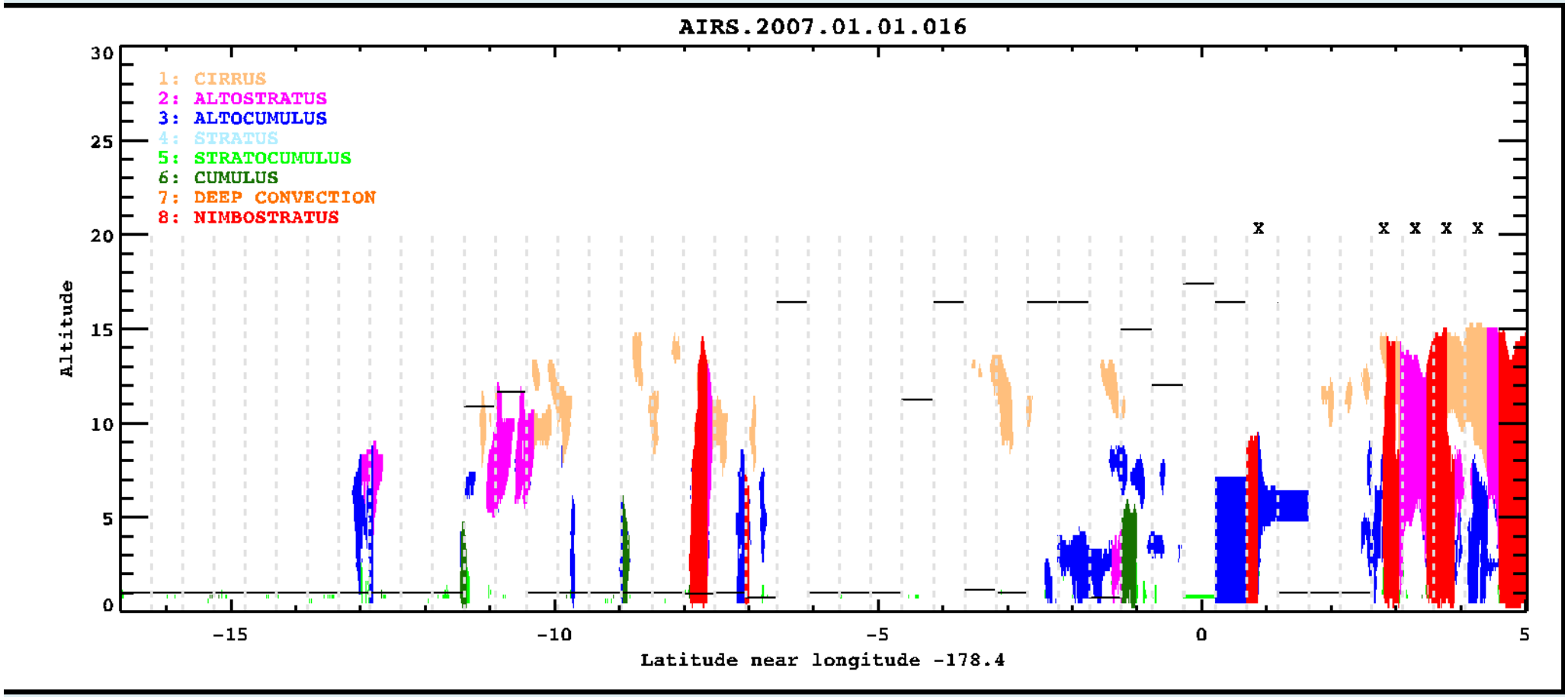
Historical Motivation (ca. 2006): Relationship between CloudSat Clouds and AIRS V4 Retrievals

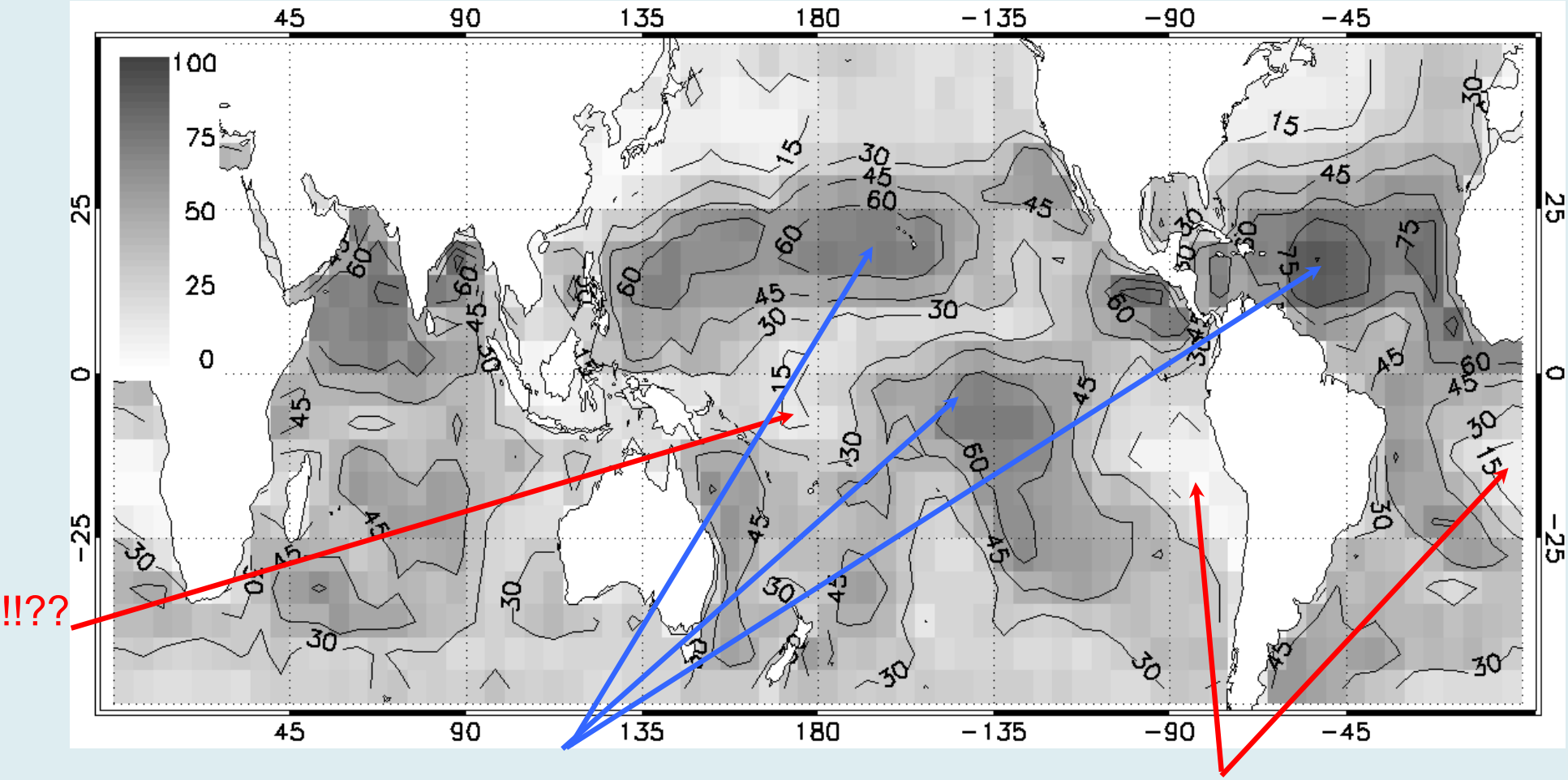


Black lines: AIRS 'best' retrieval altitude
X: no AIRS tropospheric profiling.

More Motivation:

AIRS retrieval yields vary with location

Fraction of 'good' retrievals (percent)



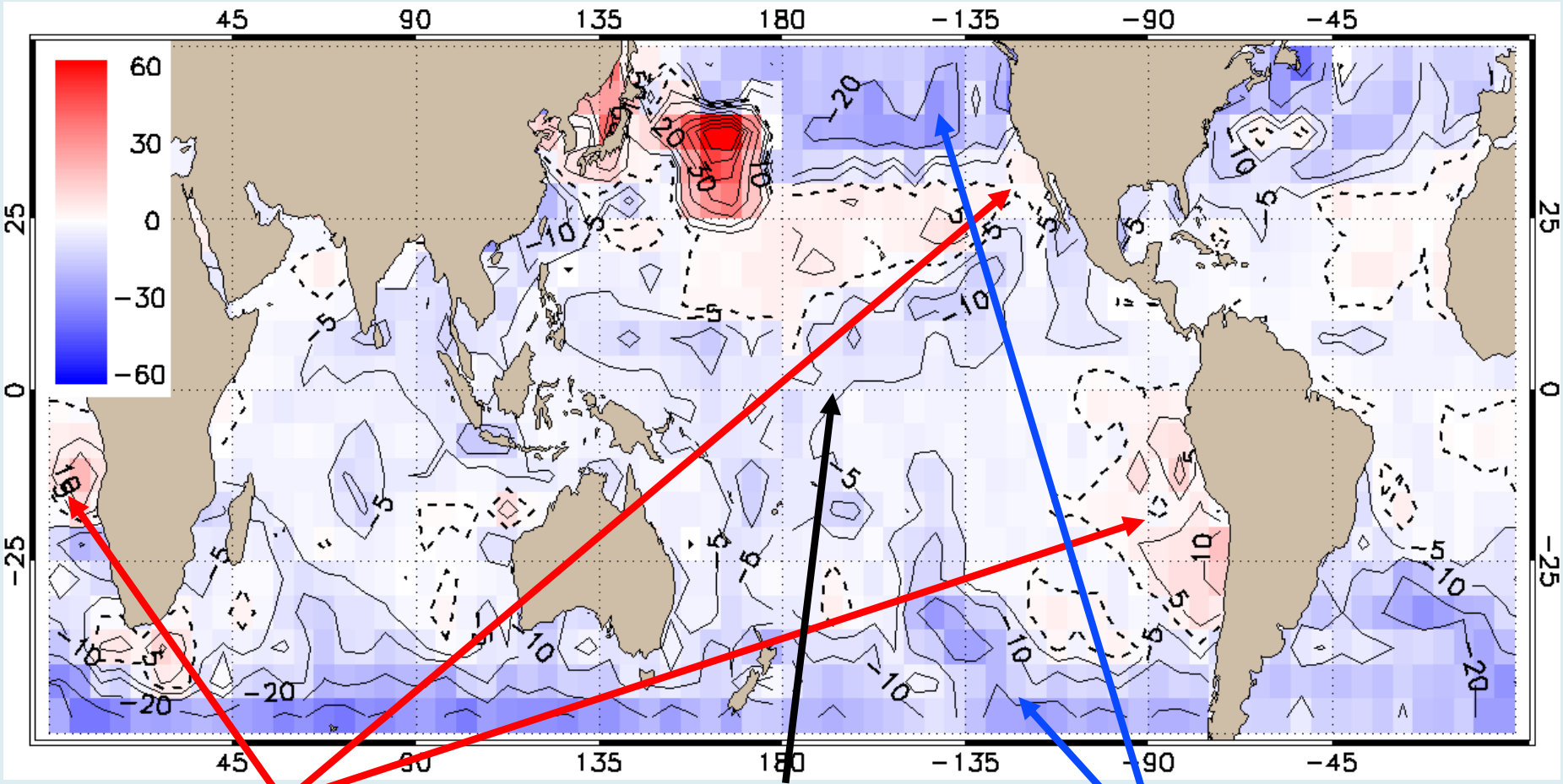
Highest yields in trade cumulus.

Poorer coverage in stratocumulus.

From: Fetzer, E. J., B. H. Lambrigtsen, A. Eldering, H. H. Aumann, and M. T. Chahine (2006), Biases in total precipitable water vapor climatologies from Atmospheric Infrared Sounder and Advanced Microwave Scanning Radiometer, *J. Geophys. Res., 111*, D09S16, doi:10.1029/2005JD006598

Even More Motivation:

Percent Differences in Mean AIRS and AMSR-E Water Vapor Climatologies
AIRS can be drier OR wetter than AMSR-E
25 Dec 2002 to 15 Jan 2003



AIRS climatology is *wetter* than AMSR-E in stratus regions

Small difference in tropics !!??

AIRS climatology is *drier* than AMSR-E at high latitudes

From Fetzer et al., 2004.

Our First Project
MEaSUREs 2007

- **Match AIRS to CloudSat and analyze.**
- **Deliver matched data sets.**

Estimating sampling biases using reanalyses (independent of cloud state).

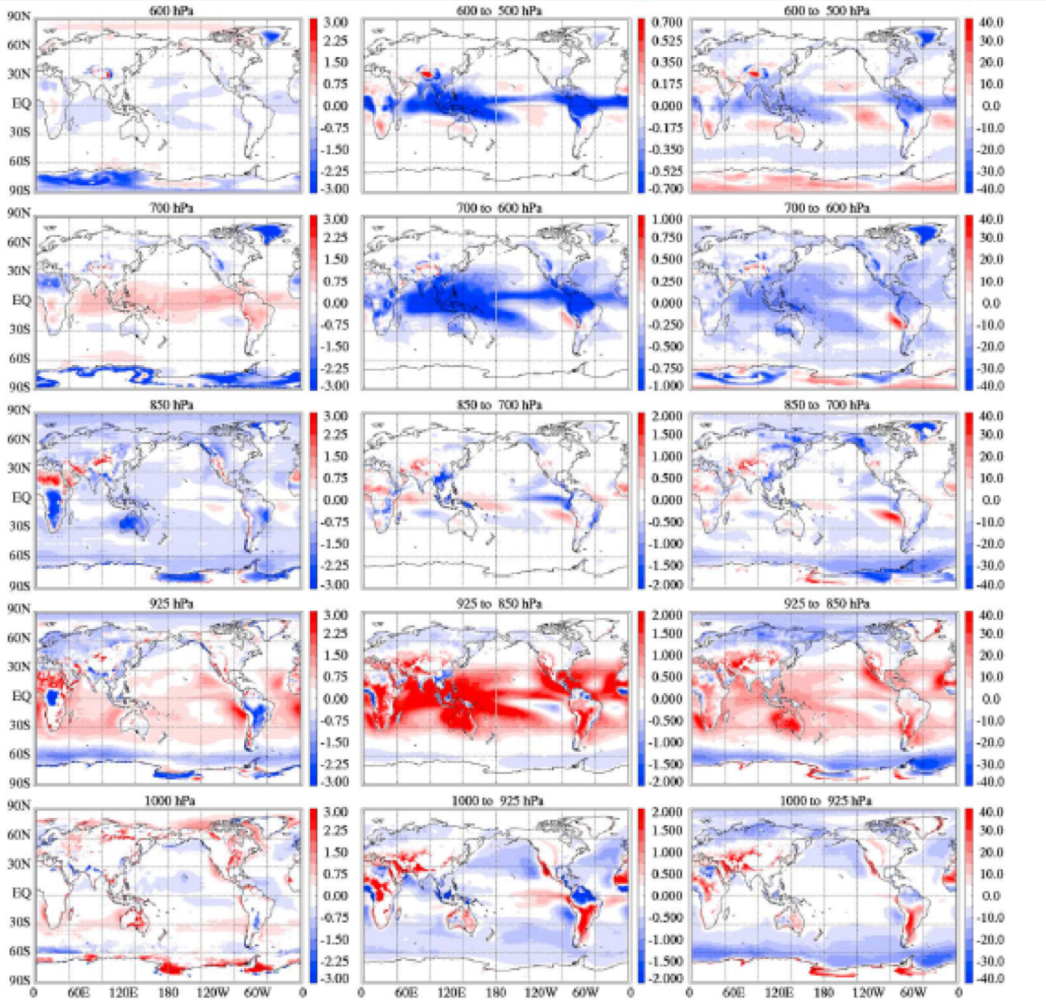


Figure 7. Differences between similarly sampled AIRS/AMSU-A and MERRA (AIRS/AMSU-A–MERRA sampled like AIRS/AMSU-A [MSAQC]) climatologies of air temperature in Kelvins, water vapor mixing ratio in g/kg, and percent difference of water vapor mixing ratio, from left to right. These differences are an estimate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

Estimating AIRS Sampling Biases Using ECMWF and CloudSat Cloud State

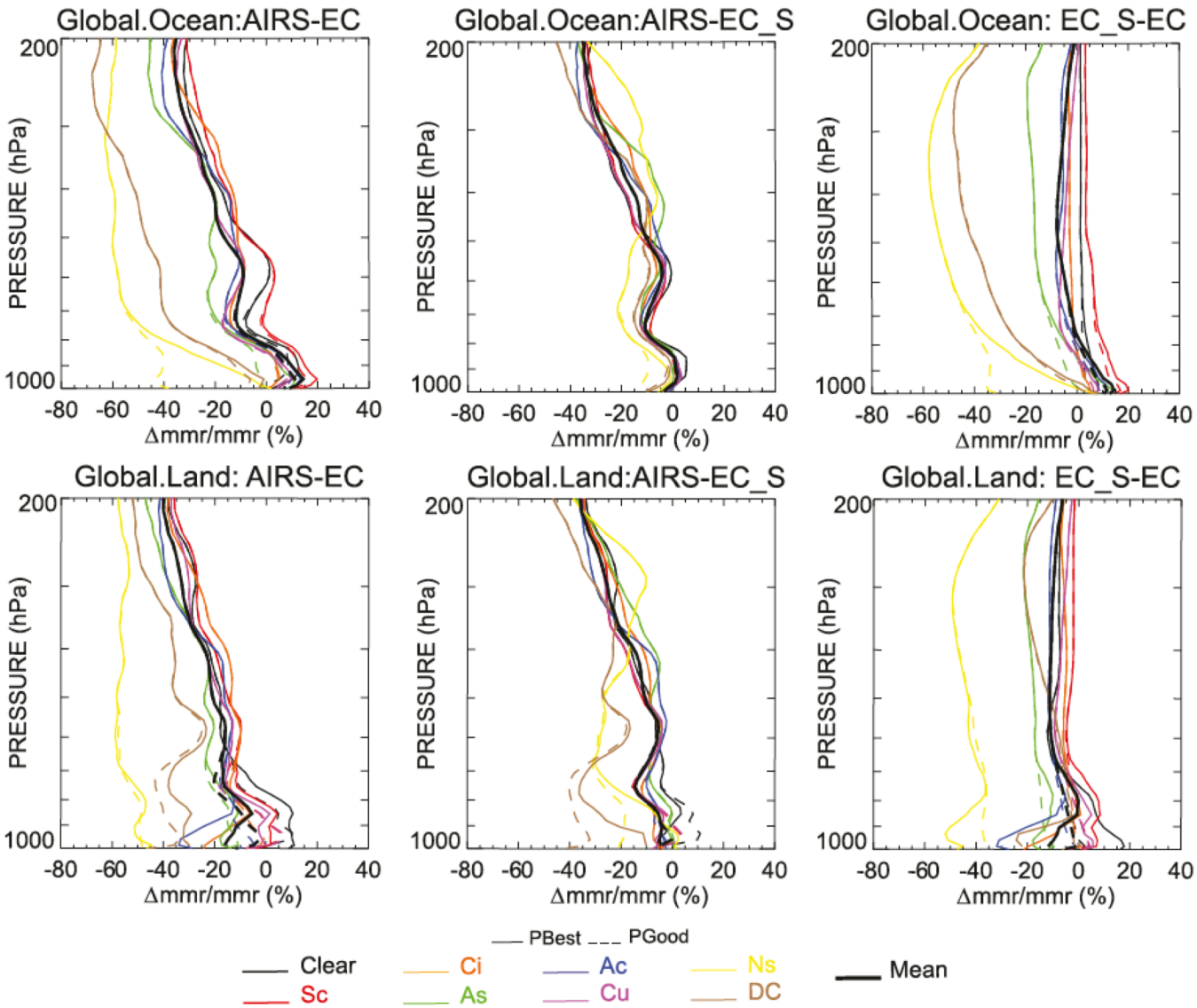


FIG. 7. Relative differences of q for (left) AIRS − EC, (center) AIRS − EC-S, and (right) EC-S − EC for the global (top) ocean and (bottom) land. The percentages are relative to EC, EC-S, and EC means for three columns, respectively.

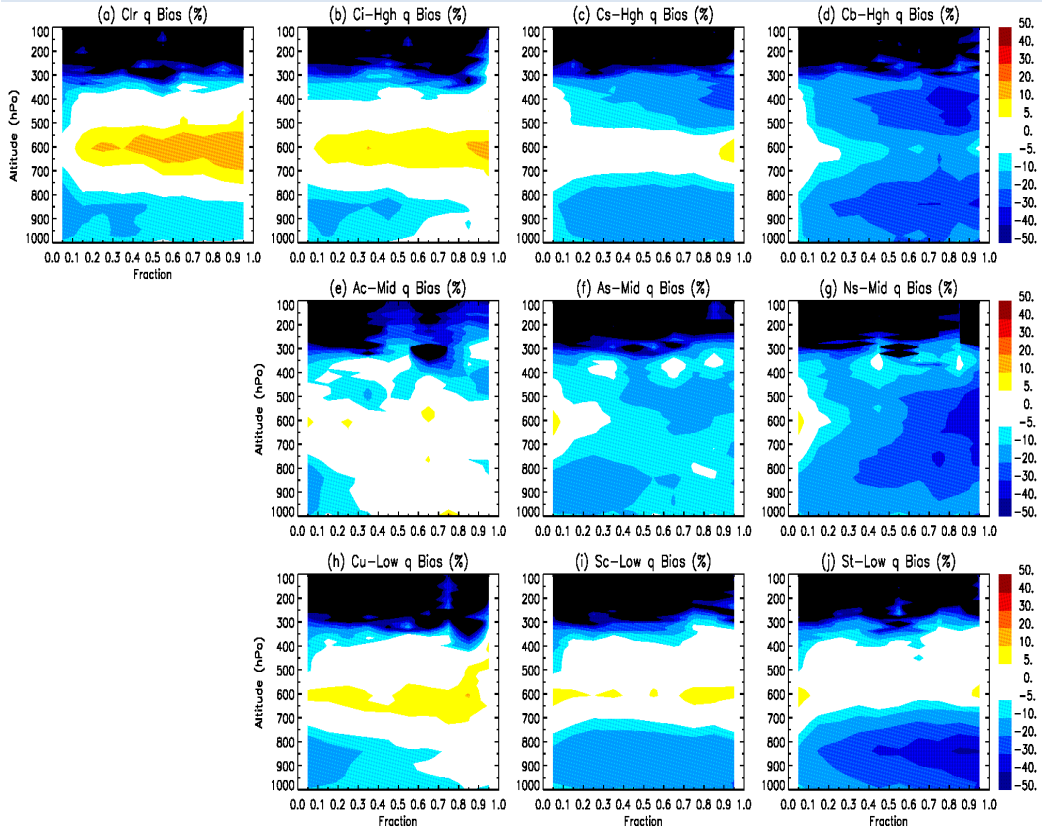
Yue, Q., E. J. Fetzer, B. H. Kahn, S. Wong, G. Manipon, A. Guillaume and B. Wilson (2013), Cloud-state-dependent sampling in AIRS observations based on CloudSat cloud classification, *J. Climate*, 26, 8357–8377.

Our Second Project
MEaSUREs 2012

- **Consider AIRS and CloudSat/CALIPSO (not just CloudSat).**
- **Include AIRS-MODIS matches.**
  - **About 30 times more data than CloudSat alone.**
- **Produce AIRS-MLS matches as in Liang et al. (2011) for profiles from surface to middle atmosphere.**
- **Match AMSR-E to MODIS.**

Deliver data sets to and make publicly available through the Goddard DAAC

Example: 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

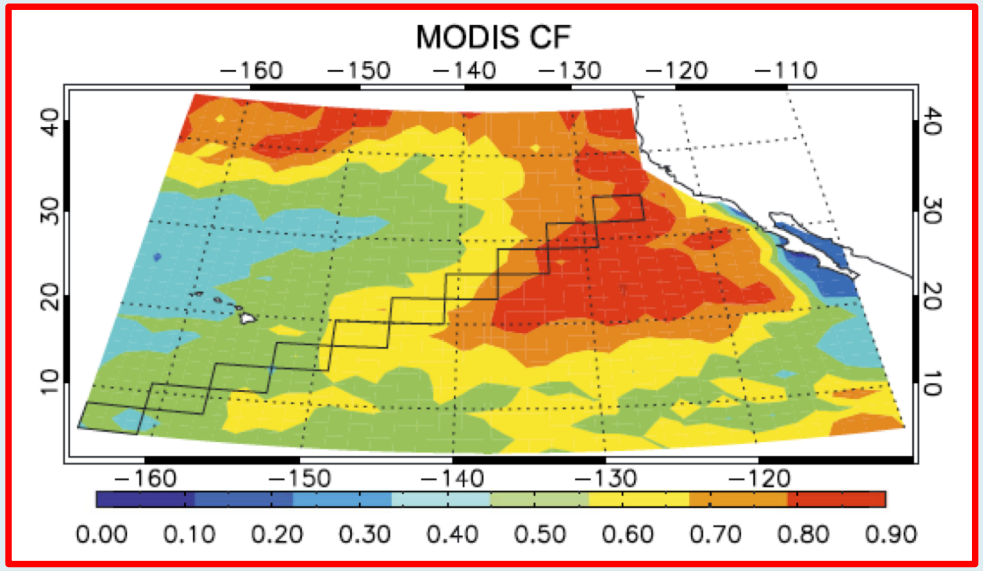
- **Relevance**

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

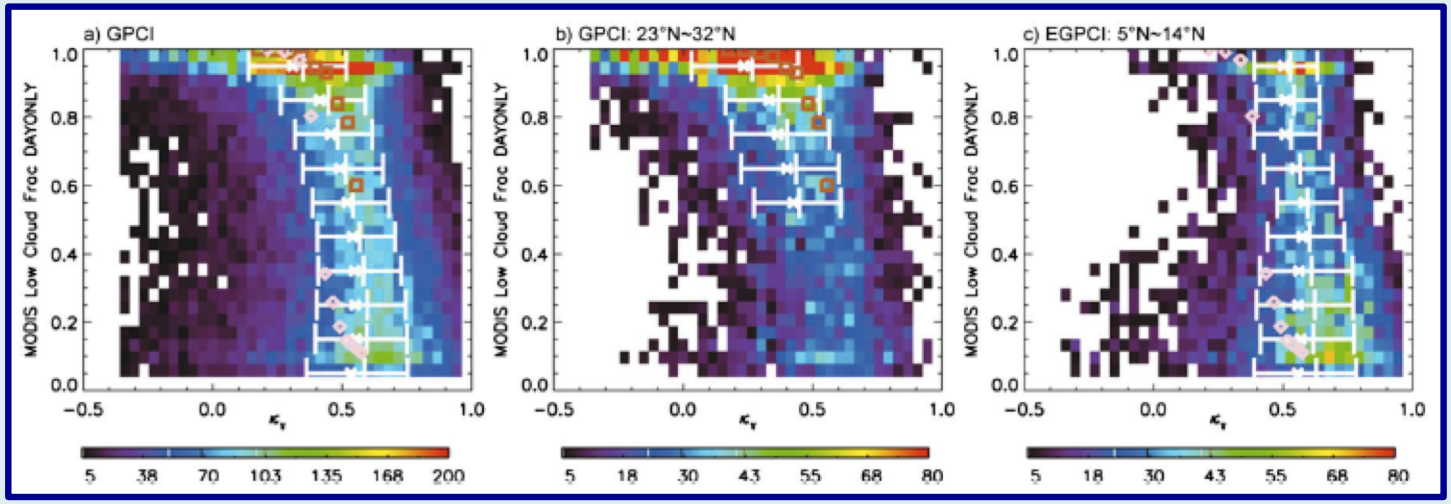
Wong, Fetzer, Schreier, Manipon, Fishbein, Kahn, Yue, and Irion –JGR-Atmosphere (2015 March)

Observing Boundary Layer Structure with AIRS and MODIS



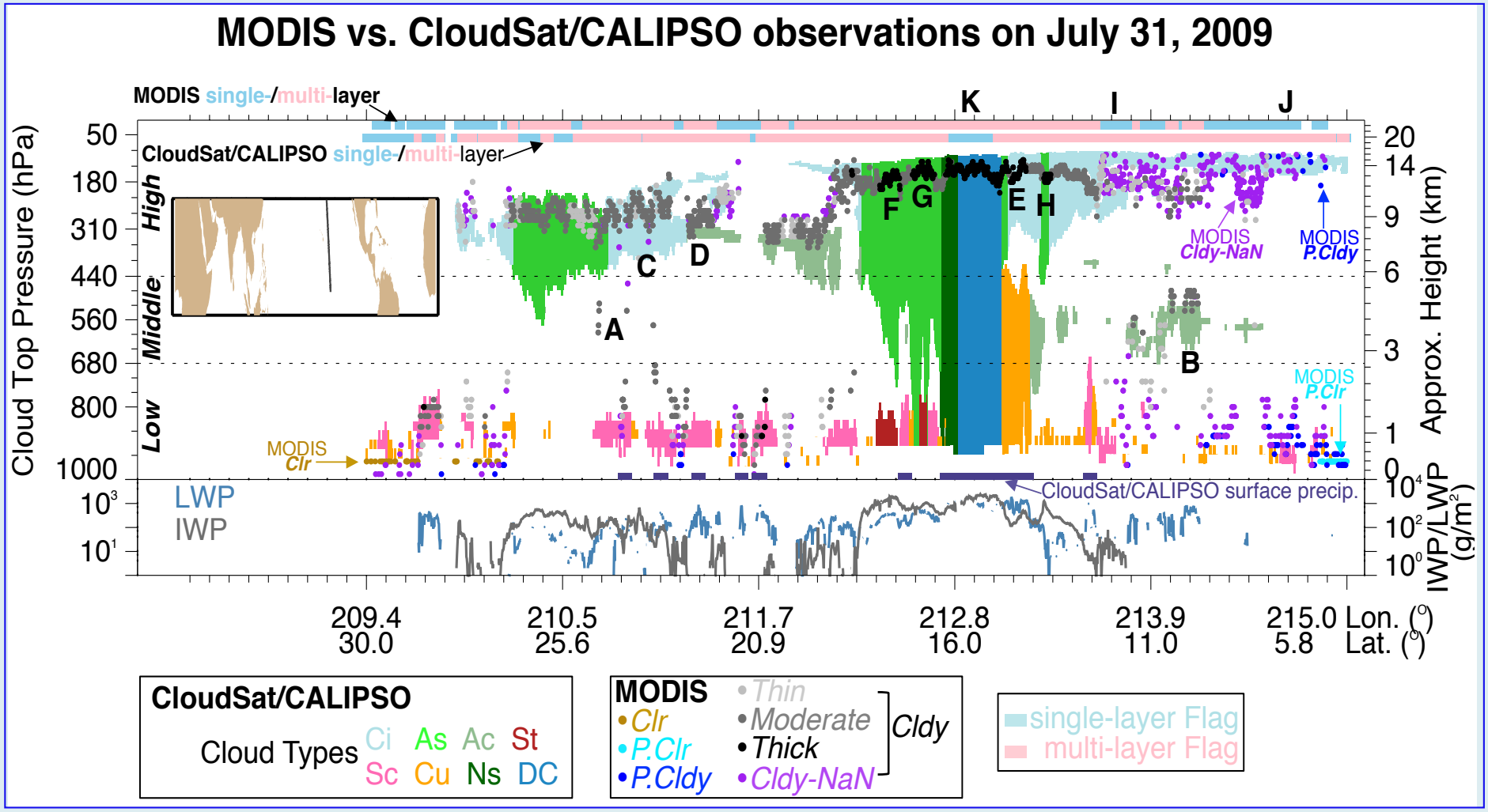
MODIS cloud fraction

Boundary layer entrainment parameter from AIRS



Yue, Q., B. H. Kahn, H. Xiao, M. M. Schreier, E. J. Fetzer, J. Teixeira, and K. Suselj (2013), Transitions of cloud-topped marine boundary layers characterized by AIRS, MODIS, and a large eddy simulation model, *J. Geophys. Res. Atmos., 118,* 8598–8611, doi:10.1002/jgrd.50676.

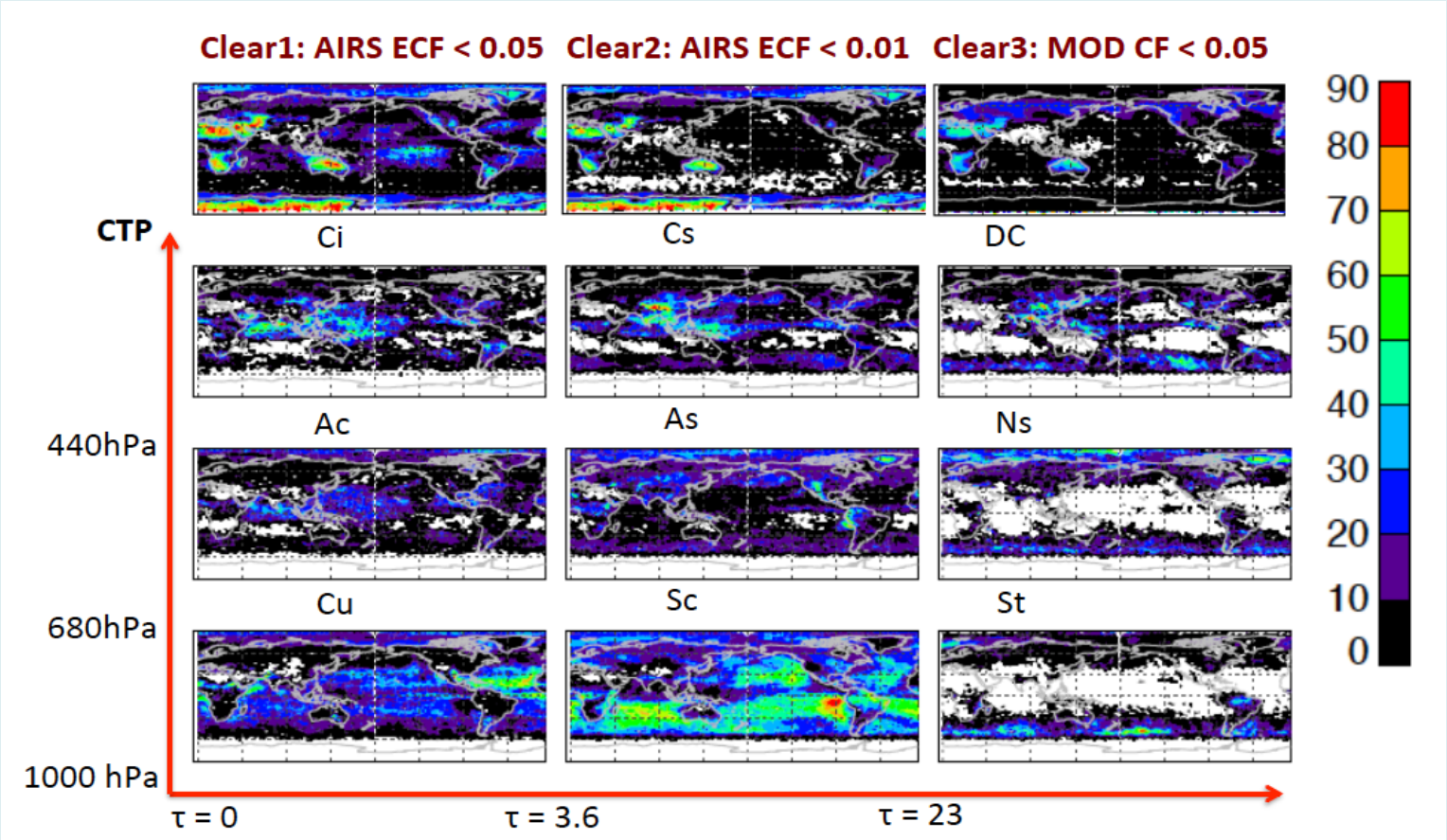
Comparing CloudSat/CALIPSO and MODIS clouds



Wang, T., E. J. Fetzer, S. Wong, B. H. Kahn, and Q. Yue (2016), Validation of MODIS cloud mask and multilayer flag using CloudSat-CALIPSO cloud profiles and a cross-reference of their cloud classifications, *J. Geophys. Res. Atmos., 121,* doi:10.1002/2016JD025239.

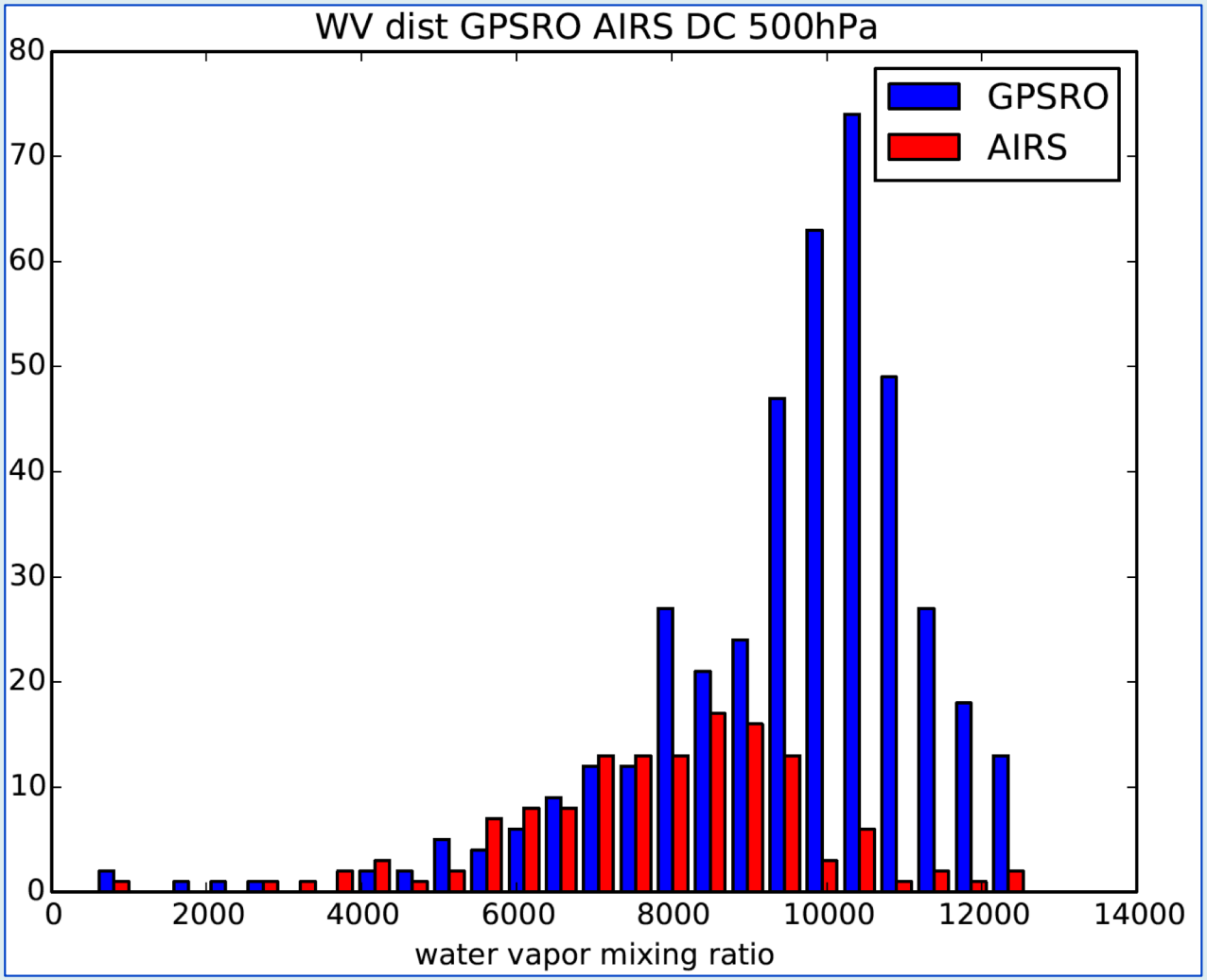
Spin-off: Observation-based Longwave Cloud Radiative Kernels Derived from the A-Train

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



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 (%).

GPS Provides Unique Information Inside Clouds



Collocated GPS-RO and AIRS 500 hPa water vapor in MODIS deep convective clouds.

Bob Stachnik, JPL

Our Next Project: What We're Doing

Our primary objectives:

- Assemble water vapor and temperature information from all nadir sounders and from collocated GPS-RO soundings since 1998.
- Use coincident cloud observations from imagers at the pixel-scale to classify cloud state for every sounding.
- Generate and compare statistical summaries from multiple satellites.
- Examine and compare physical processes as represented by different observing systems, including the effects of clouds on sampling.
- Quantify information from microwave soundings for clouds opaque to infrared radiation.

We will also:

- Place soundings and cloud classes in a common format.
- Update our current A-Train record of AIRS matched to CloudSat/CALIPSO and MODIS cloud state.
- Update merged AIRS and MLS water vapor profiles using averaging kernels.
- Use existing data sources, mature algorithms and processing system, and document data sets and processing algorithms.

Data Sources

Table 1-1. A-Train continuity products for the period May 2002 to present.

Temperature/Water Vapor Data Sources	Cloud Data Sources	Approximate total size (TB)
AIRS/AMSU/HSB* suite in A-Train	CloudSat/CALIPSO	7
	MODIS	96.3
AMSR-E and AMSR2 in A-Train	CloudSat/CALIPSO	3.9
	MODIS	96.3
Merged AIRS-MLS*	MODIS-AIRS matches	0.6
Constellation GPS-RO	MODIS	96.9

*Processing for AIRS and AIRS-MLS products is only 2018 forward.

Table 1-2. Data sources outside A-Train.

Temperature/Water Vapor Data Sources	Cloud Data Sources	Launch Date	Approx. total size (TB)
HIRS-3/AMSU-A/AMSU-B suite on NOAA-15	AVHRR/3	May 1998	1.4
HIRS-3/AMSU-A, -B suite on NOAA-16	AVHRR/3	September 2000	1.2
HIRS-3/AMSU-A/AMSU-B suite on NOAA-17	AVHRR/3	June 2002	1.1
HIRS-3/AMSU-A/MHS suite on NOAA-18	AVHRR/3	May 2005	0.9
HIRS-4/AMSU-A/MHS suite on NOAA-19	AVHRR/3	November 2008	0.7
IASI/ HIRS-4/AMSU-A/MHS on Metop-A	AVHRR/3	October 2006	8.6
IASI/ HIRS-4/AMSU-A/MHS on Metop-B	AVHRR/3	September 2012	4
CrIMSS suite on S-NPP	VIIRS	October 2012	0.7
Constellation GPS-RO	All collocated AVHRR and VIIRS.	May 1998	7

*

***Co-I Paul Staten, Indiana U. and former JPL postdoc with Brian Kahn.**

Summary and Conclusions

- **More than a decade of overlapping hyperspectral IR sounder coverage from five (soon six) instruments.**
  - **Even longer for microwave instruments.**
  - **Longer still for HIRS.**
- **All sounders have collocated imagers.**
- **Many processes are revealed by considering sounders and imagers simultaneously.**

- **Considering clouds can simplify data merger from different sounders**