Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Sounding Science at the Jet Propulsion Laboratory

Bjorn Lambrigtsen, Joao Teixeira, Eric Fetzer, Tom Pagano & many more
Jet Propulsion Laboratory, California Institute of Technology

JPL: 6000 employees
400 in Science
150 in Earth Science
20 in Sounding Science

ITSC-XXI, Darmstadt, November 29 - December 5, 2017

Sounding Science Themes

Focus on the troposphere

- "Moist thermodynamics": water vapor is the key variable
- Water cycle in the atmosphere: water vapor, clouds, precipitation
- Atmospheric processes controlling weather and climate; severe storms

Illuminated by tropospheric sounders & related sources

- IR sounders: AIRS, CrIS, IASI etc.; MW sounders: AMSU, ATMS etc.
- CYGNSS, GPSRO, GPS-met, raobs, buoys, aircraft

Science questions

- *How do small-scale weather processes interact with the large-scale thermodynamic environment?*
- *What controls the intensity, distribution and likelihood of convective storms, and how can we use satellite observations to improve modeling and prediction of important weather events?*
- *How well do climate models compare to observations, and how can we use global satellite observations to improve the models?*
- *What phenomena relevant to our research themes are not adequately observed and require new observing strategies and systems to be developed?*

Relevant WCRP grand challenges

- *Understanding and Predicting Weather and Climate Extremes:* Extreme weather processes, severe storms
- *Clouds, Circulation and Climate Sensitivity:* Cloud and water vapor processes
- *Water Availability:* Atmospheric branch of water cycle (water vapor, clouds, precipitation)

Sounding Science Groups at JPL

"Atmospheric Physics and Weather" group: Focus on AIRS

- *Has provided most of AIRS science support since 1980's*
- Has developed into a significant sounding-science research group
- Funded from NASA R&A (now 50%) , AIRS, S-NPP and other sources

Unique capabilities & expertise in Sounding Science

- *Complete range of expertise, from instruments to atmospheric research*
- Instruments & algorithms: AIRS, AMSU, CrIS, ATMS; L0→L3→climatology
- Data & data products: Thorough understanding; analysis & validation
- Research: Rich research program, high productivity re. published papers
  - In 3 years (2014-16): 24 first-authored papers + 145 co-authors

Related groups: Leverage and collaborations

- "Aerosols and Clouds" group: built around former MISR group
  - LES simulations; Cloud processes
- "Tropospheric Composition" group: built around former TES group
  - Retrieval algorithms, radiative transfer models
- "Stratosphere and Upper Troposphere" group: former MLS group
  - Upper tropospheric moisture; WRF simulations
- "Statistical Methods" group
  - Data fusion; machine learning methodologies
- JPL Climate Center
  - Modeling & model assessment; process studies

Atmospheric Physics and Weather group

Demographics

- 14 employees; 1 contractor; 2 postdocs (→ 5)

Business mix and funding base

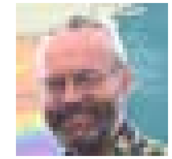
- 40%: AIRS and CrIMSS science support
- 50%: R&A
- 10%: Field campaigns, new developments, etc.

Expertise

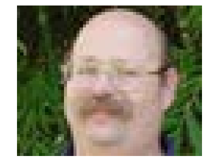
- Satellite systems; sounders; data characteristics
- Atmospheric science & research
- Retrieval algorithms; radiative transfer models; spectroscopy
- Simulations; OSSEs
- Future instrument & mission development

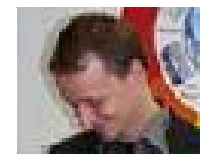
Themes & topics

- Water vapor; clouds
- Precipitation
- Tropical cyclones & severe storms
- Water resources/hydrology, droughts, fires
- Climate
- Trace gases & composition; CO_2
- Sensor technology & design














Sounder Analysis Capabilities

AIRS Project and SNPP-Sounder SIPS provide mission anchor

- Staff has broad knowledge of AIRS/AMSU and CrIS/ATMS instruments
- Large infrastructure for algorithm development, integration & testing
- Large database supporting product testing & validation
- Supports seamless transition from Aqua to S-NPP to JPSS

Our goal is to merge data across instruments and platforms

- Support unified algorithms, data fusion, advanced retrieval methods
- Integrate past/current/future sounder data into long-term record
- Develop collaborations with EUMETSAT and IASI

Atmospheric Physics and Weather group provides science anchor

- Broad knowledge and understanding of satellite data & their usage
- Understanding of science user needs from personal research experience

Partnerships complements local expertise

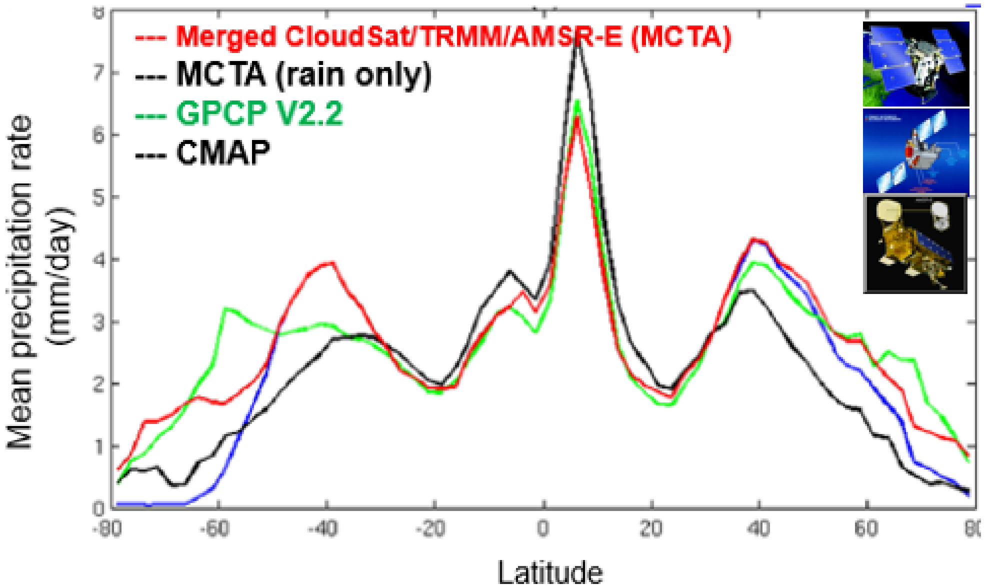
- Science teams: Algorithm & product development
- NASA/GSFC, MIT, NOAA & CIMSS: Instruments, algorithms, missions

JPL sponsors exploration of future directions

- Specialized sounders: *Solve the boundary layer problem*
- Geostationary sounders: *Provide time resolution of storm environment*
- Cubesats & Venture missions: *Address the cost & life-cycle problem*

Ali Behrangi: Precipitation, drought

Finding “missing” precipitation: An Update on the Oceanic Precipitation Rate



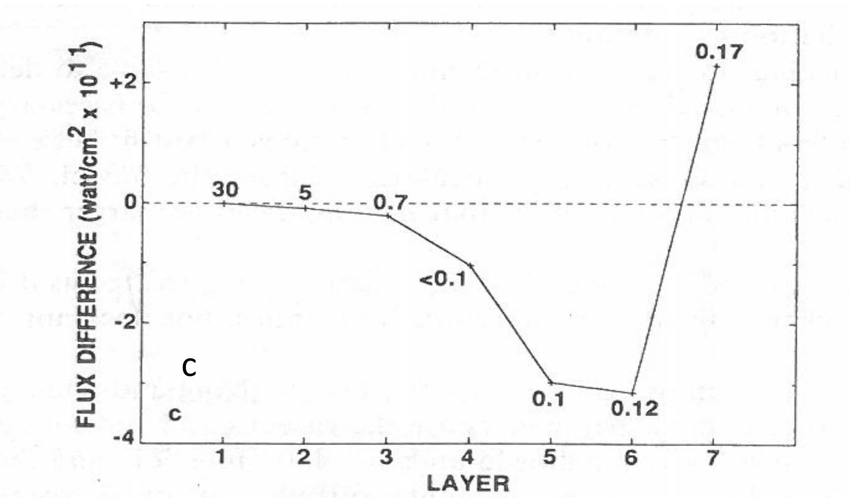
Zonal distribution of oceanic precipitation rate using the new combined estimate and comparison with popular precipitation products.

Reference :
Behrangi, A., G. Stephens, R. F. Adler, G. J. Huffman, B. Lambrigtsen, and M. Lebsock, 2014: An Update on the Oceanic Precipitation Rate and Its Zonal Distribution in Light of Advanced Observations from Space. *Journal of Climate*, **27,** 3957-3965.

- **Science Question:** The true amount of precipitation and its zonal distribution has been highly uncertain over ocean, mainly due to lack of ground observation and needed sensitivity from space.
- **Data & Results:** By merging histograms of CloudSat, TRMM , and AMSR-E precipitation data, the largest range of precipitation sensitivity was utilized to quantify snowfall and rainfall from drizzle to the most intense rates.
- **Significance:** Results show that 5 to10% of total precipitation is currently missed over ocean by the popular reference precipitation climatology products (e.g., GPCP and CMAP) and the zonal distribution of precipitation may have not been captured accurately. This is very important for water and energy budget closure studies.

Luke Chen: Spectroscopy, RTMs

The Correlated-k Method and related methods for broadband radiation calculations



Thermal flux divergence calculated by lbl(straight-line segments) and c-k(points) for a 7-layer model of atmosphere. The numbers against the points are percentage errors, 100(c-k – lbl)/lbl. Errors are generally within 1%, except for small radiative quantities such as in layer 1 (bottom of the model atmosphere), using 10 g values instead of thousands lines.

R. West, R. Goody, L. Chen, D. Crisp, The correlated-k method and related methods for broadband radiation calculations. Journal of Quantitative Spectroscopy and Radiative Transfer,Volume **111**, Issue **11**, July 2010, Pages 1672-1673.

To calculate broadband radiation both efficiently and accurately with a few absorption coefficients(k) that could represent typically tens of thousands of coefficients in a rigorous line-by-line(lbl) calculation for non-gray, vertically inhomogeneous scattering atmospheres.

Findings:

1)Errors are generally within 1% for c-k, other mapping transformation methods can achieve arbitrary accuracy relative to lbl.

2)Valid for strong-line and weak-line limits, and overlapping bands of gas mixture.

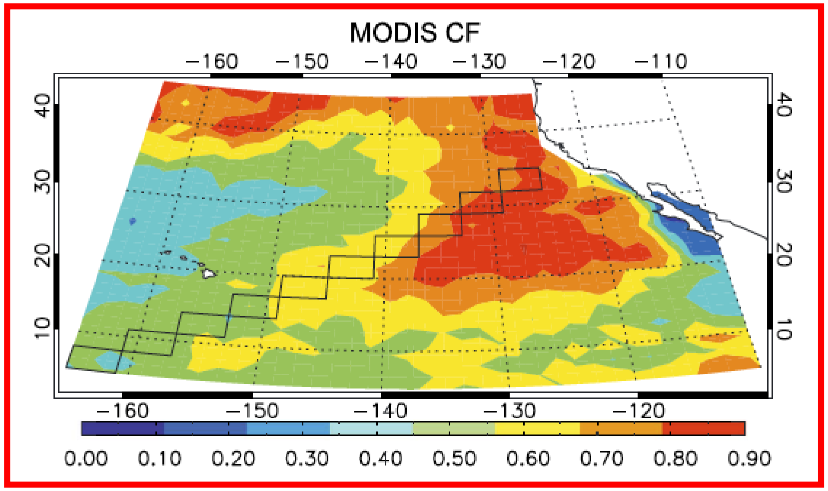
3)Temperature effect can be interpolated on a coarse grid.

Significance: well suited to iterative methods in the inversion of satellite radiances or numerical weather or climate models.

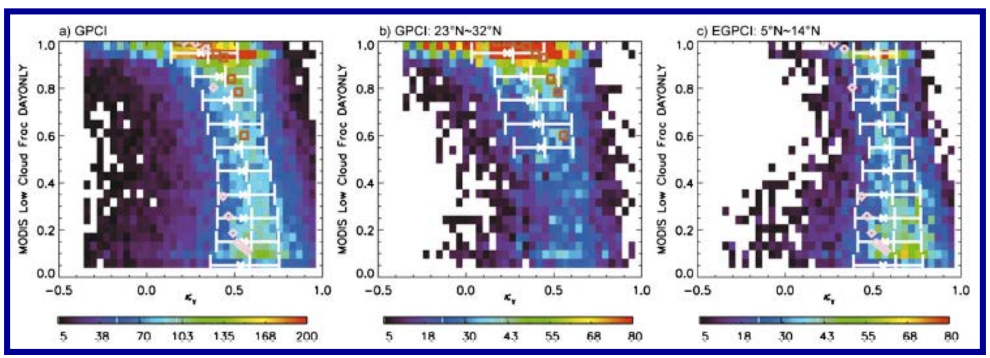
Eric Fetzer: Water vapor, merged data

AIRS Project Scientist

Merging Observations from the A-Train Constellation



MODIS cloud fraction



Boundary layer entrainment parameter from AIRS

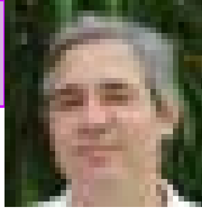
Problem: Relating clouds and thermodynamic structure observed simultaneously by A-Train instruments, and use the observations to test models.

Finding: Boundary layer clouds observed by MODIS are related to cloud top entrainment into the boundary layer estimated from AIRS temperature and water vapor retrievals. These are broadly consistent with model simulations.

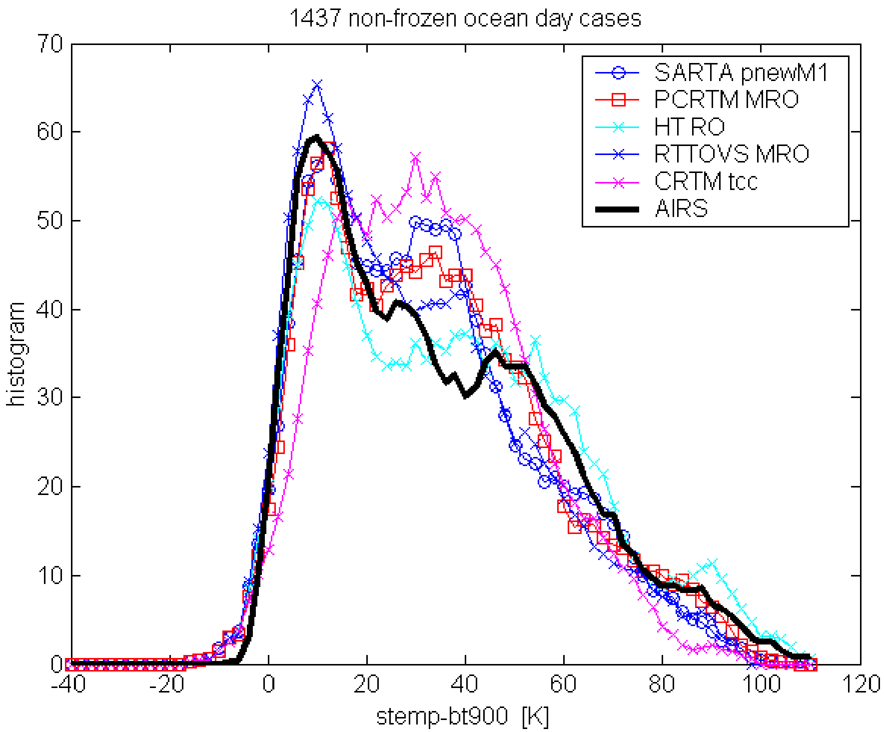
Significance: AIRS vertical resolution is sufficient to detect gradients associated with entrainment. The structure produced by large eddy simulation model are broadly consistent with observations, corroborating the model physics.

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.

Evan Fishbein: Simulations & RTMs



Evaluation of Cloudy Radiative Transfer Algorithms: 1. Performance Metrics



Comparison of probability density functions of surface skin temperature - 900 cm-1 brightness temperature for AIRS observations and several cloudy radiative transfer models.

Aumann, H.H, E. Fishbein, E. Manning, V. Naraj, C. Wilson, S. Machado, L. Strow, S. Havemann, X. Liu, Y. Yung, X. Haung, X. Chen, I. Moradi, A. Geer, Evaluation of cloudy RTAs: 1. Performance Metrics, submitted to JGR. 2017.

Problem: Thermal infrared cloudy-radiative transfer algorithms error characterization is poor.

Finding: Models and observations agree under heavily-clouded, high-cloud scenes, but not for heterogeneous scenes. Differences between calculated and observed radiances have contributions from uncertainty in cloud property characterization, including spatial distribution of cloud particles, overlap of clouds and implementation of cloud radiative properties in RTA. The contributions from specifying cloud physical and radiative transfer properties, specifically those not observationally constrained, dominate the error budget.

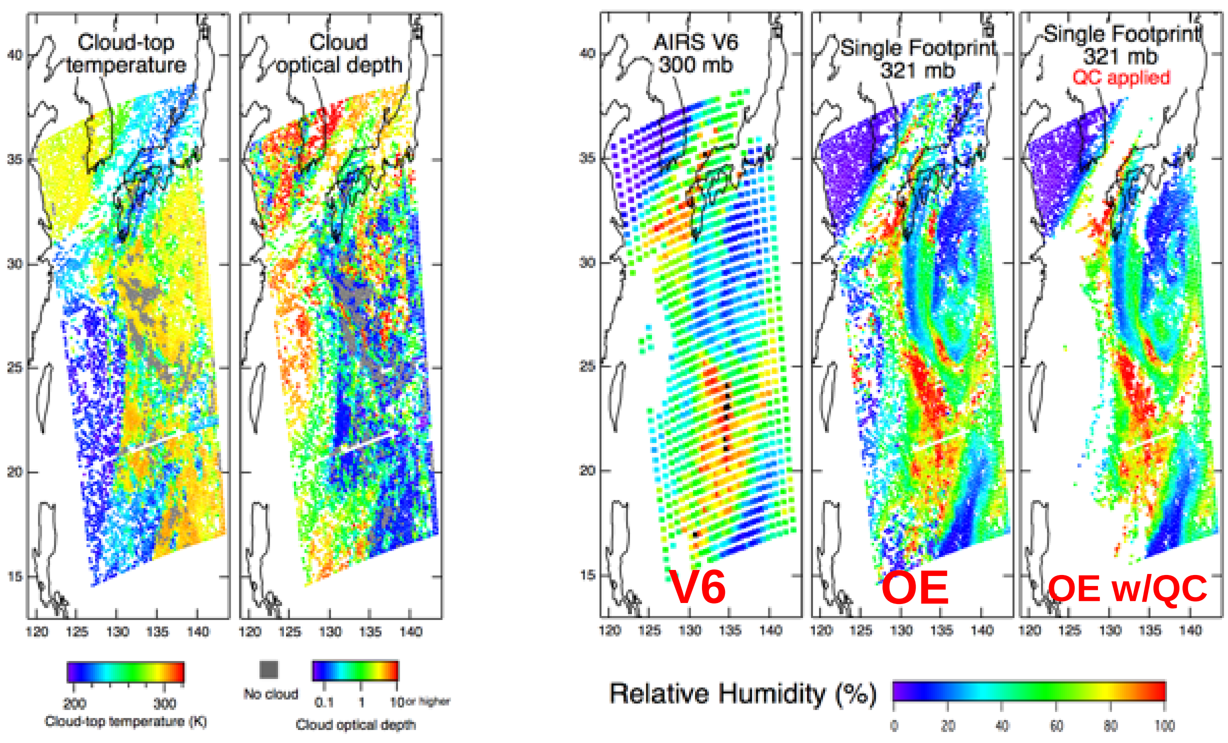
Significance: Assimilation of cloudy radiances in NWF need accurate radiance model errors and a better understanding of the trade-off between RTA model accuracy and performance.

Bill Irion: Retrieval systems

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*

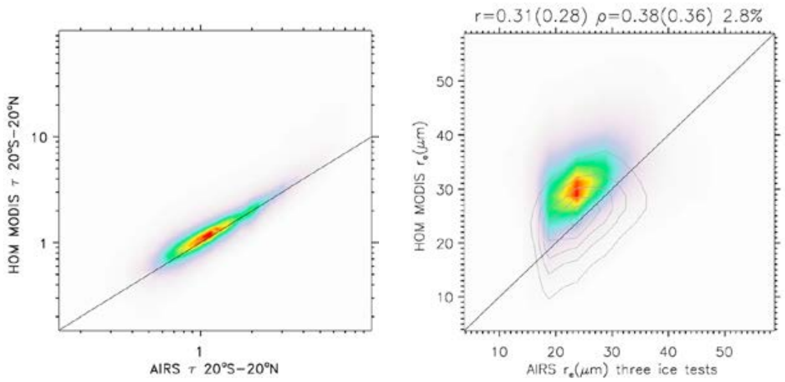
Granule 44
Sept 6, 2002
(Subtropical Western Pacific. Note tropical cyclone to west)



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

Brian Kahn: Clouds, dynamics

AIRS and MODIS ice cloud optical thickness and effective radius



The left panel shows the AIRS versus MODIS ice cloud optical thickness correlation. The right panel shows the AIRS versus MODIS ice cloud effective radius comparison for a subset of pixels with horizontally uniform ice cloud. The color shading indicates the comparisons for the MODIS 2.1 μm channel and contours for the MODIS 3.7 μm channel. The bias between AIRS and 3.7 μm is less than AIRS and 2.1 μm.

Problem: Ice cloud properties remain highly uncertain and are important for climate feedbacks. Questions remain about the consistency of AIRS and MODIS ice cloud property retrievals and how they should be utilized in research efforts.

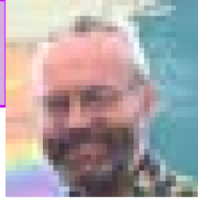
Finding: The correlations of optical thickness and effective radius between the two instruments are strong functions of horizontal cloud heterogeneity and vertical cloud structure, with highest correlations found in single-layer, horizontally homogeneous clouds over low-latitude oceans.

Significance: A difference of 5–10 μm remains in effective radius within the most homogeneous scenes identified, consistent with known radiative transfer differences in the visible and infrared bands. This suggests that the synergistic use of these instruments in a retrieval will yield vertical information on ice cloud effective radius.

Kahn, B. H., M. M. Schreier, Q. Yue, E. J. Fetzer, F. W. Irion, S. Platnick, C. Wang, S. L. Nasiri, and T. S. L'Ecuyer (2015), Pixel-scale assessment and uncertainty analysis of AIRS and MODIS ice cloud optical thickness and effective radius, *J. Geophys. Res.*, **120**, doi:10.1002/2015JD023950.

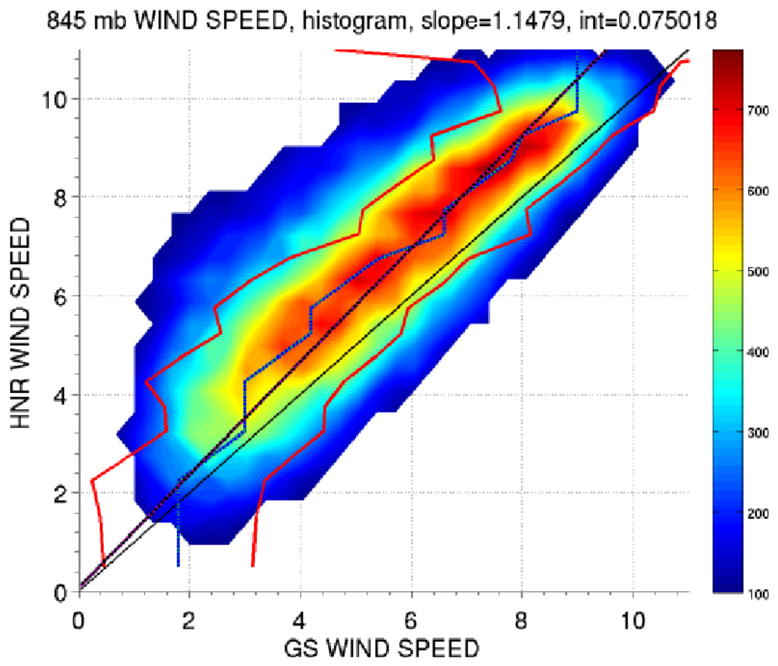
Supported by NASA Science of Terra and Aqua program under grant NNN13D455T.

Bjorn Lambrigtsen: MW remote sensing



Group Supervisor

Measuring tropospheric wind with microwave sounders



Histogram of simulated AMV wind speed (horizontal axis) vs. nature run “truth” (vertical axis at 845 mb

Lambrigten, B. et al.: All-Weather Tropospheric 3D Wind from Microwave Sounders. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. *In press*

Problem:

Tropospheric wind is currently poorly measured but is one of the most desired variables. Polar satellites do not provide frequent enough observations to provide reliable AMV feature tracking. Geostationary imagers track cloud tops only at uncertain heights. Geostationary IR sounders will not be able to penetrate clouds

Finding:

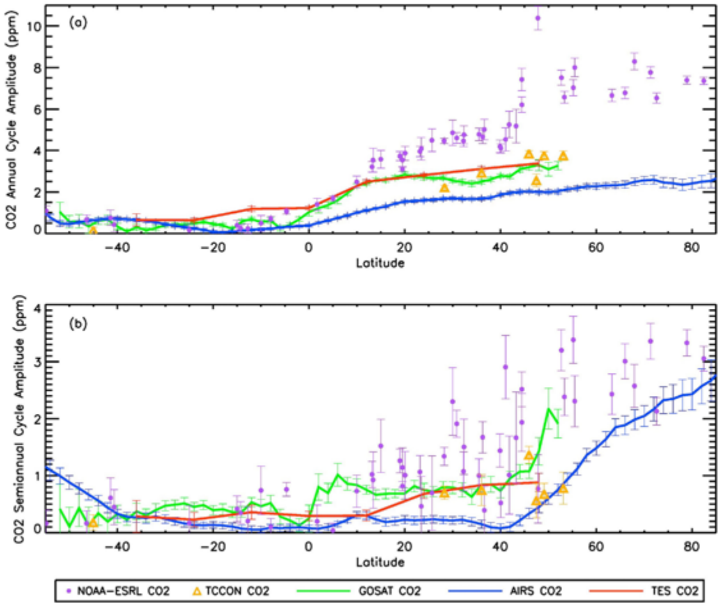
Two simulation studies found that tropospheric wind vectors can be derived by tracking water vapor features measured with microwave sounders with a precision of ±2 m/s (wind speed) and ±15° (wind direction) and negligible bias. With a geostationary microwave sounder, wind measurements can be obtained for the entire hemisphere below the satellite continuously and under all weather conditions with a temporal resolution of 15 minutes and spatial resolution of 25 km or better and vertical resolution of 2-3 km. Wind can also be measured as accurately with a cluster of 3-4 CubeSats spaced 5-10 minutes apart, but temporal and spatial sampling and coverage are not as favorable.

Significance:

The projected accuracy and precision using this method meet WMO requirements for tropospheric wind and will enable significant progress in atmospheric dynamics research and weather prediction, particularly in the tropics, where wind is typically non-geostrophic and therefore not derivable from temperature and pressure fields. A GEO/MW measurement system is particularly capable and could be a good match with a doppler lidar system.

Edward Olsen: AIRS CO_2

CO2 annual and samiannual cycles from multiple satellite retrievals and models



Latitudinal variation of CO2 annual and semiannual cycle amplitudes at the surface and at the different altitudes at which AIRS, GOSAT and TES are sensitive. NH amplitudes are greater than in the SH throughout the atmosphere.

Jiang, X., D. Crisp, E. T. Olsen, S. S. Kulawik, C. E. Miller, T. S. Pagano, M. Liang, and Y. L. Yung (2016), "CO2 annual and semiannual cycles from multiple satellite retrievals and models", Earth and Space Science, 3, 78–87, doi:10.1002/2014EA000045

Problem: How realistic are model simulations of the CO2 annual and semiannual cycles over the globe and at various altitude in the atmospheric column.

Finding: The latitude/altitude variation of the two CO2 cycles simulated by the MOZART-2 and CarbonTracker models agree well with the satellite observations.

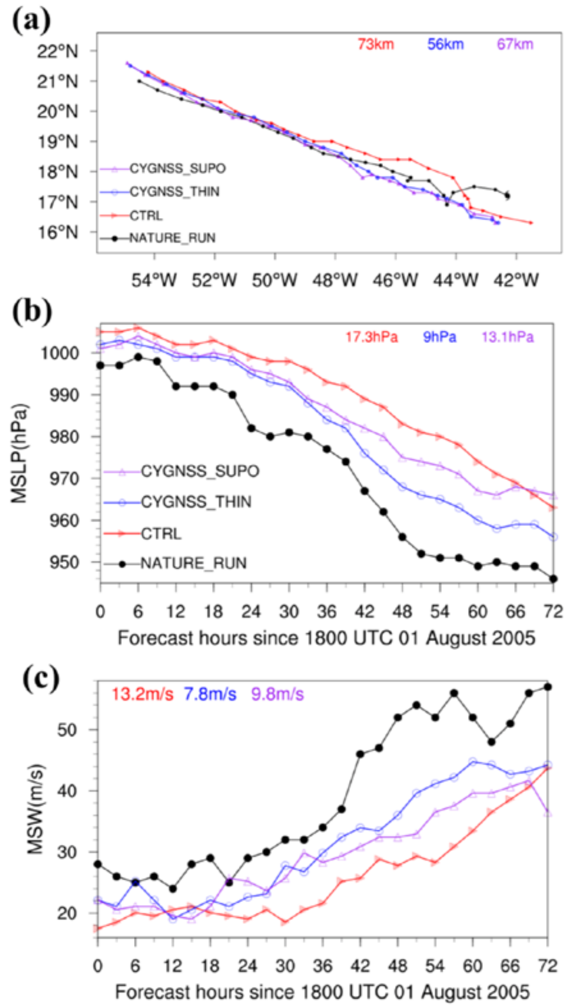
Significance: Comparison with observations can be used to diagnose deficiencies in the chemistry-transport models that are used to understand the global transport of CO2 through the atmosphere and ultimately the carbon budget..

Derek Posselt: DA & OSSEs

CYGNSS Deputy PI

Impact of CYGNSS Wind Speed Observations on Hurricane Forecasts

Time series of (a) track, (b) minimum sea level pressure, and (c) maximum surface wind between 18 UTC 01 and 18 UTC 04 August 2005 from CTRL and CYGNSS data assimilation experiments compared against the hurricane nature run. The colored numbers in (a) denote the averaged track errors during the first 36-hour forecast and in (b-c) represent the averaged absolute intensity errors during the whole simulation period (72-h) for the corresponding experiments.



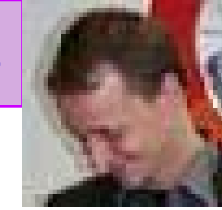
Zhang, S., Z. Pu, D. J. Posselt, and R. Atlas, 2017: Impact of CYGNSS ocean surface wind speeds on numerical simulations of a hurricane in observing system simulation experiments. J. Atmos. Ocn. Tech., 34, 375-383, doi: 10.1175/JTECH-D-16-0144.1.

Science Question: What impact will observations of surface wind speed from CYGNSS have on forecasts of tropical cyclone (TC) track and intensity? Will thinning or averaging of observations produce better results? These questions are addressed using an observing system simulation experiment.

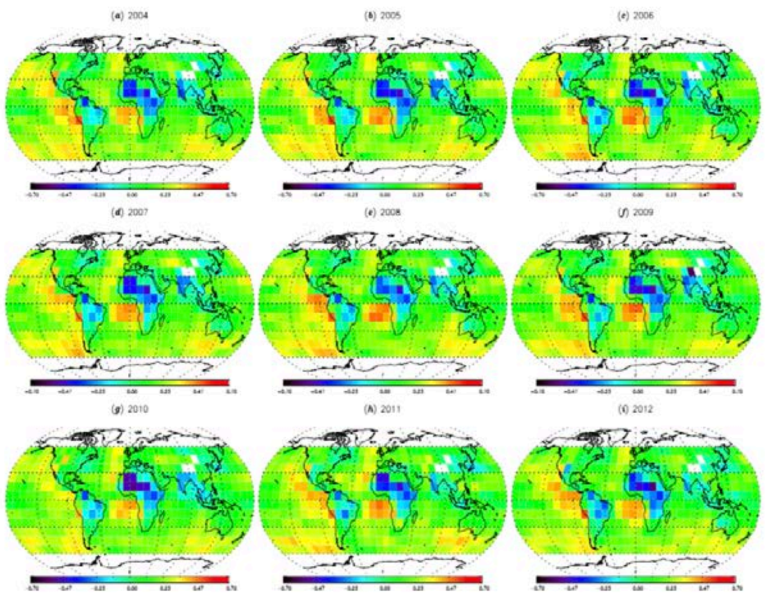
Results: Assimilation of CYGNSS surface wind speeds results in systematic improvements in TC forecast intensity and position. Thinning, rather than averaging, observations results in slightly better performance.

Significance: CYGNSS observations are expected to provide a significant improvement in forecasts of tropical cyclone intensity and position.

Mathias Schreier: Clouds, MW systems



Correlations between clouds and atmosphere using collocated AIRS and MODIS data



9 years of correlations between LTS and cloud fraction, based on collocated AIRS/MODIS observations

Problem: How to use collocated satellite data to test cloud parameterization approaches directly on a a global and decadal scale.

Finding: Cloud fraction based on lower tropospheric stability (LTS) shows the highest correlation with observations. But it still shows influence against ENSO-fluctuations. The commonly used maximum relative humidity shows bad correlations and strong influence by ENSO-fluctuations.

Significance: The approach proves the use of collocated satellite observations for simultaneous observation of atmosphere and clouds. It can be used to validate GCM parameterizations. The results show that LTS is the best approach to estimate low cloud fraction, even under ENSO-fluctuations. The commonly used maximum relative humidity cannot be verified as a good approach.

M. Schreier & K. Suselj (2016) Analysis of collocated AIRS and MODIS data: a global investigation of correlations between clouds and atmosphere in 2004–2012, International Journal of Remote Sensing, 37:11, 2524-2540, DOI: 10.1080/01431161.2016.1177244

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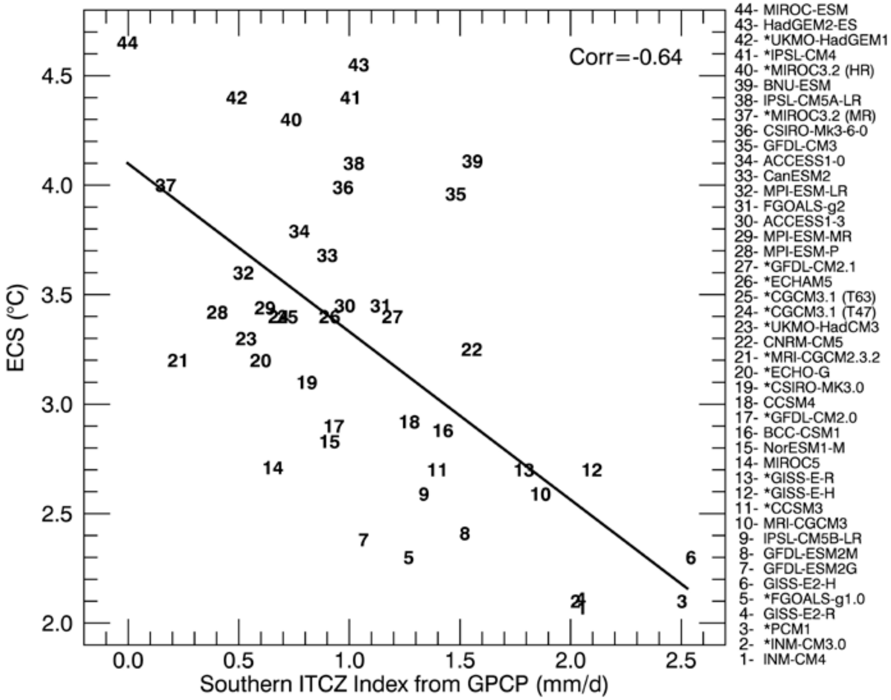
Baijun Tian: MJO, CMIP assessment

Constraining model climate sensitivity and bias with satellite observations



Scatter plot of the southern ITCZ index (x-axis) quantifying the double-ITCZ bias and the equilibrium climate sensitivity (ECS) (y-axis) in 44 global climate models from CMIP3/5.

Problem:

Despite decades of climate research and model development, two outstanding problems still plague the latest global climate models (GCMs): The double-intertropical convergence zone (ITCZ) bias and the 2−5 C spread of equilibrium climate sensitivity (ECS).

Finding:

Based on NASA satellite humidity data from Atmospheric Infrared Sounder (AIRS) and NASA satellite rainfall data from GPCP available in Obs4MIPs and 44 GCM outputs from Coupled Model Intercomparison Project Phases 3/5 (CMIP3/5) we show that the double-ITCZ bias and ECS in climate models are negatively correlated. The models with weak (strong) double-ITCZ biases have high (low) ECS values of ~4.1 (2.2) C.

Significance:

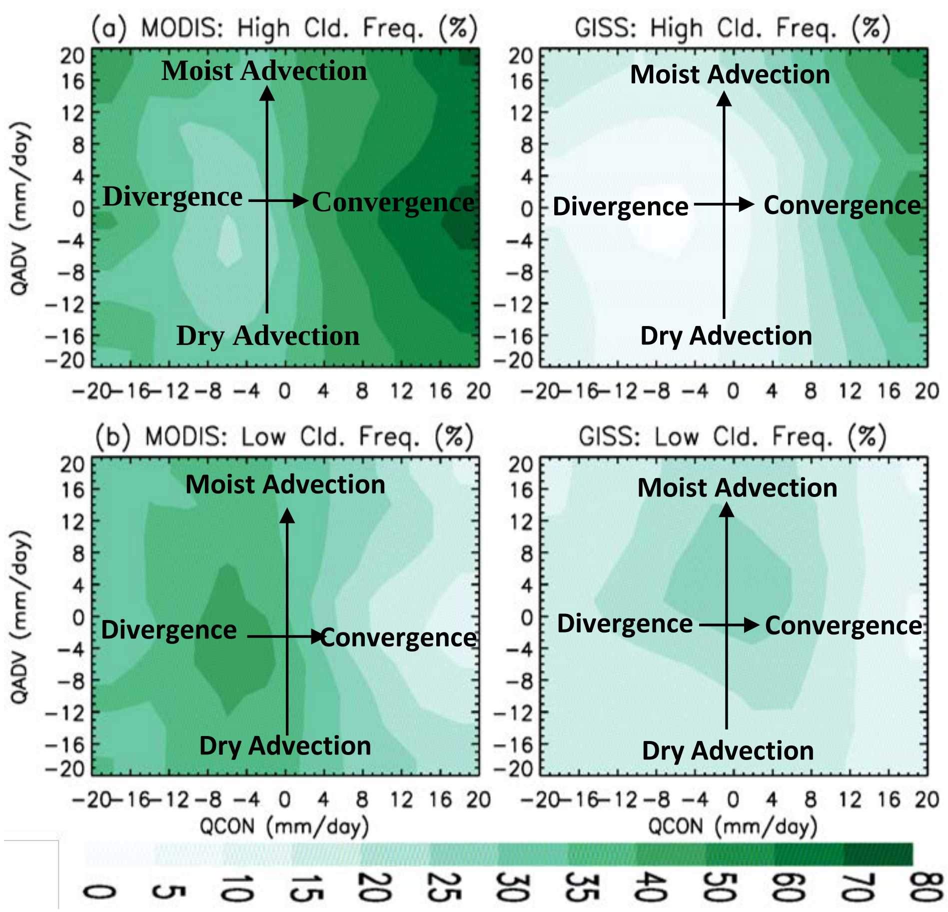
This indicates that 1) the double-ITCZ bias is a new emergent constraint for ECS based on which ECS might be in the higher end of its range (~4.0 C); 2) NASA AIRS humidity data and GPCP rainfall data in Obs4MIPs are very useful in improving climate models and future climate prediction.

Tian, B., 2015: Spread of model climate sensitivity linked to double-intertropical convergence zone bias. *Geophys. Res. Lett.*, 42, 4133-4141, doi:10.1002/2015GL064119.

Funding source: This work was supported by AIRS project at the NASA JPL/Caltech.

Sun Wong: Water/energy budget

Responses of Tropical Ocean Clouds to the Atmospheric Water Budget



Question

How do clouds in GISS E2 respond to moisture tendencies related to large-scale advection (QADV) and convergence (QCON)?

Findings:

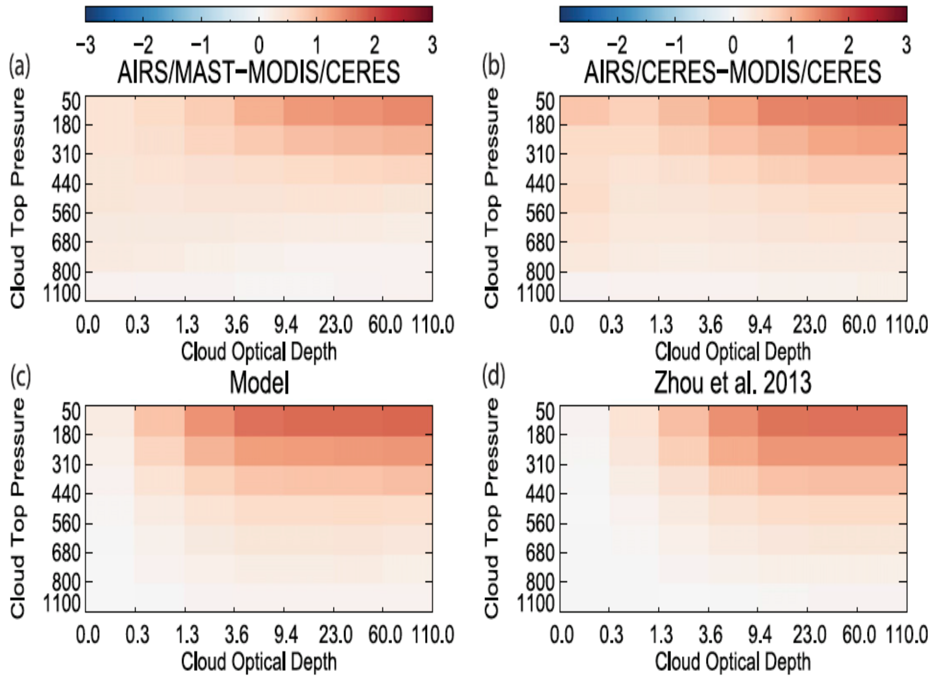
- (Top Panel) Compared to MODIS cloud occurrence frequencies, cumulus parameterization in GISS E2 provides proper high-level cloud (cloud top > ~6 km) dependence on large-scale moisture budget, with frequent high-level cloud occurrence in regimes of convergence (QCON > 0).
- (Bottom Panel) Low-level clouds (cloud top lower than ~3 km) in GISS E2 are located in a regime of mild moisture advection (QADV > 0 and QCON~0), while MODIS clouds occur most frequently in a regime of large-scale divergence (QCON < 0).
- GISS E2 has less frequent cloud occurrence with higher cloud optical thickness compared to MODIS, a problem also shared by many GCMs.

Wong, Del Genio, Wang, Kahn, Fetzer, and L'Ecuyer (J. Climate, Oct 1, 2016): Responses of tropical ocean clouds and precipitation to the large-scale circulation: Atmospheric-water-budget-related phase space and dynamical regimes, doi: 10.1175/JCLI-D-15-0712.1

Funding sources: NASA MAP, MEaSUREs, and PMM

Qing Yue: Cloud radiative feedback

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



CRKs (W m^{-2} $\%^{-1}$) obtained by different data and methods. (a) and (b): Obs.-CRKs using AIRS-MODIS-CERES data for different MODIS retrieval algorithms. (c) and (d): Fu-Liou model calculated CRKs based on satellite and model data as input, respectively.

Yue, Q., E. J. Fetzer, B. H. Kahn, M. Schreier, S. Wong, X. Huang, X. Chen, 2016, Observation-based Longwave Cloud Radiative Kernels Derived from the A-Train, J. Climate, 29(6), 2023–2040, doi: http://dx.doi.org/10.1175/JCLI-D-15-0257.1

Problem: Observation-based longwave cloud radiative kernels derived from pixel-scale collocated A-Train and MERRA data to estimate cloud feedback by cloud regime.

Finding: The observation-based CRKs show the TOA radiative sensitivity of cloud types to unit cloud fraction change as observed by the A-Train. Observations show a larger TOA radiative sensitivity for optically thin clouds than models.

Significance: A combination of observation-based CRKs with cloud changes observed by A-Train provides an estimate of the short-term cloud feedback by maintaining consistency between CRKs and cloud responses to climate variability.

Not just satellites: Hurricane field campaigns

Lambrigtsen, Schreier

HAMSR

The High-Altitude MMIC Sounding Radiometer is an airborne microwave sounder

- 25 channels around 50, 118 and 183 GHz
- Provides information about temperature, water vapor and rain
- Cross scanning with a scan angle of $\pm 60^o$
- Successfully flown in several campaigns (HS3, SHOUT, CalWater)
- PI: B. Lambrigtsen

SHOUT

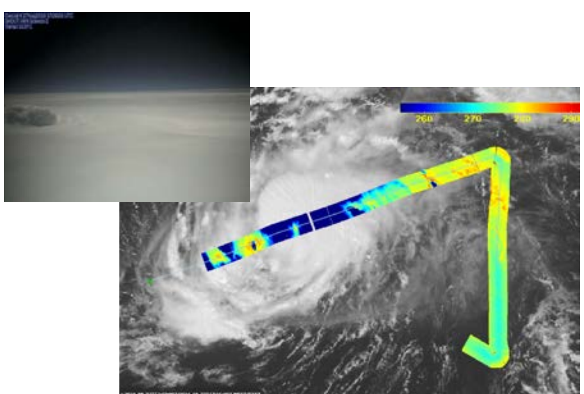
HAMSR is part of SHOUT (Sensing Hazards with Operational Unmanned Technology). The project is using the Global Hawk from Armstrong and Wallops to make targeted observations of tropical storms (TS) and hurricanes.

The Impact of SHOUT 2016

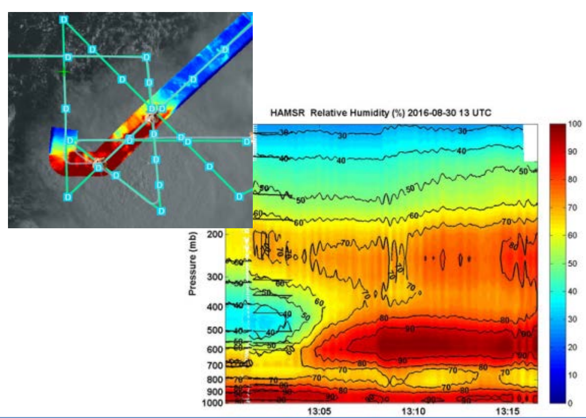
- From 08/24 - 09/02, SHOUT observed Gaston and Hermine, collecting valuable information during their transition from TS to hurricane
- The flight on 08/24 caused NHC to elevate Gaston from TS to hurricane, a first-ever case of forecast impact from targeted observations

HAMSR Observations during SHOUT 2016

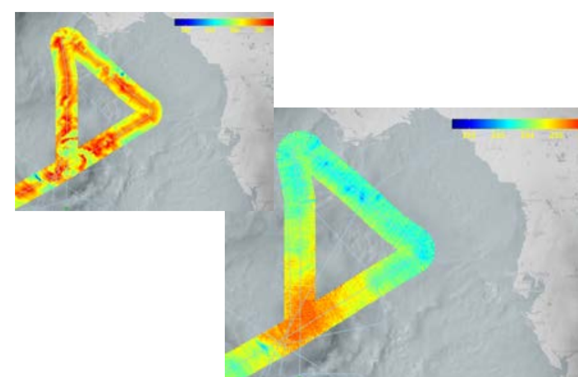
Hurricane Gaston, 27th August 2016
Passing the hurricane eye
GH-camera and HAMSR data at 50 Ghz



Tropical Storm Hermine, 29th August 2016
Flight over the core
real-time scattering index and retrieved RH



Tropical Storm Hermine, 31 August 2016
Observed surface and warm core anomaly
50 Ghz (surface) and 53.93 GHz (~250 mb)

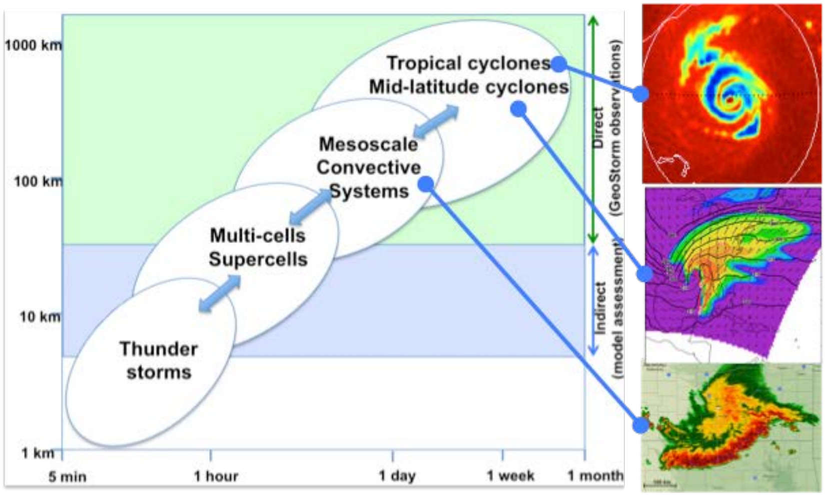


Future: A Geostationary Microwave Sounder?

GeoStorm (Venture EV-I concept)

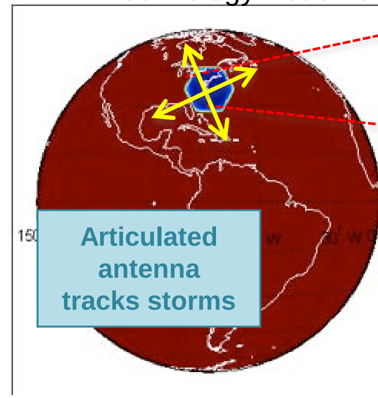
Lambrigtsen

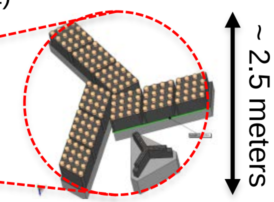
Objectives: Hurricanes & Severe Storms



Instrument: GeoSTAR-lite

- *Microwave sounder; Y-shaped steerable antenna, 2.5 m synthesized aperture.* Sensitivity: ~ 0.5 K. Spatial resolution: 35 km (118 GHz) and 25 km (183 GHz)
- Technology Readiness Level: 6

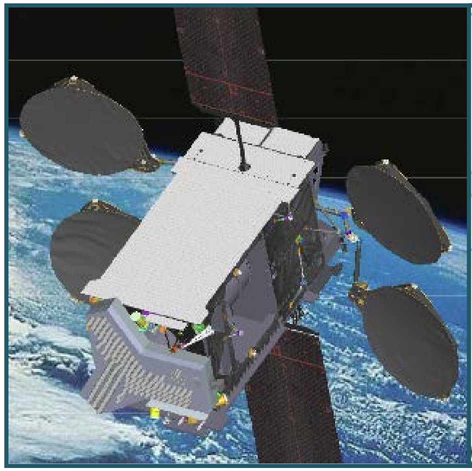


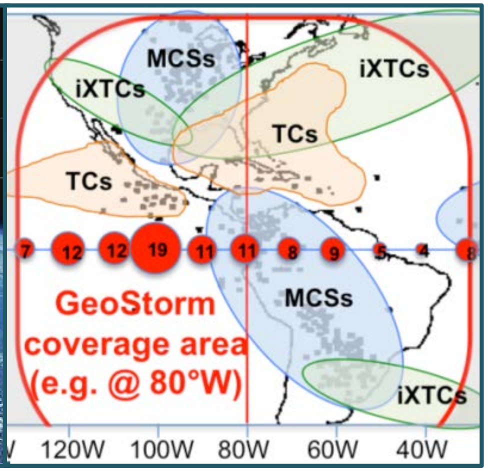


	CBE	CBE + Cont.
Mass	171 kg	222 kg
Power	199 W	259 W
Data Rate	< 100 kbps	< 150 kbps
Volume (m^3)	2.5 x 2.5 x 0.7	2.5 x 2.5 x 0.7

GeoStorm Highlights	
Targeted Observations	Life-cycle storm tracking
Time-Continuous Coverage	Capture dynamic processes Diurnal cycle fully resolved
Simultaneous Measurements	Temperature, humidity, clouds, rain, & wind
All-Weather	Penetrates clouds & rain
3D Observations	Cylindrical volume 1000 km in diam. & 15 km in height
Wide Coverage	Full Earth disk from GEO

Implementation: Hosted on GEO Comm-Sat

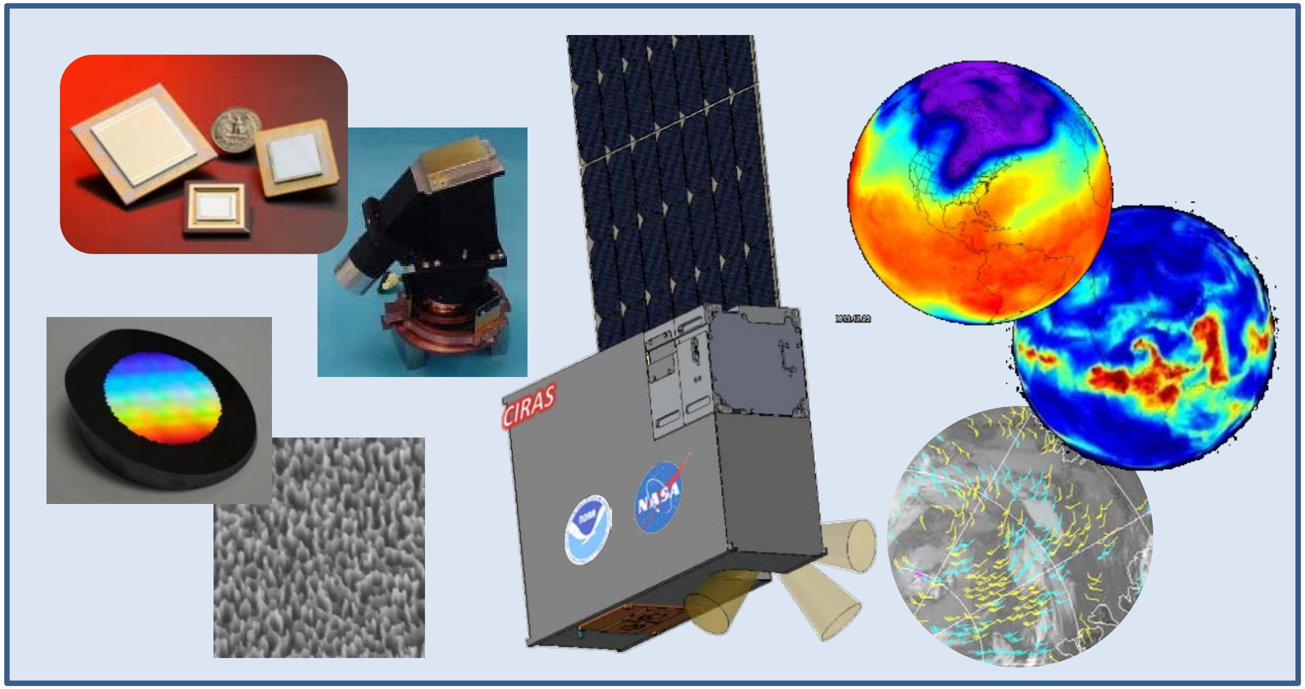




Future: A CubeSat IR sounder?

Pagano

CubeSat Infrared Atmospheric Sounder (CIRAS)



- *Hyperspectral Midwave Infrared (MWIR) Sounder*
- *Low Earth Orbit, 6U CubeSat, Launch TBD*
- *Key Technologies: Spectrometers, Detector, Blk Si.*
- *Lower Tropospheric Temperature Profiles*
- *Lower Tropospheric Water Vapor Profiles*
- *Goal: Experimental Demonstration of 3D Winds*
- *Status: On hold pending additional funding*

Spatial	
Orbit Altitude	450-600 km
Pushbroom SW	>1000 km
Horizontal Res'n	13.5 km
Spectral	
Method	Grating
Band 1	4.08-5.13 µm
Spectral Resolution	1.2 cm^{-1} – 2.0 cm^{-1}
Total Channels	625

Radiometric	
NEdT (@250K)	<0.25 K
Resources	
Size	6U Cubesat
Mass	13 kg
Power	28 W
Data Rate	0.3 Mbps

Assessment of Retrieval Algorithms

Integration: Support development of new/updated algorithms & SW

- Functional testing to diagnose problems ← (iterate) → Algorithm dev.
- Performance testing

Testing: Characterize as-built performance

- Verify performance claimed by algorithm developers: precision, accuracy
- Verify progress: New versions better than old
- Identify "issues" before users find them
- AIRS baseline system: New version (V7) now being assessed
- CrIMSS/S-NPP: Assessing joint AIRS-CrIMSS retrieval system
- AIRS research system: Assessing Irion's single-FOV system

Validation: Measure performance against "truth"

- Focused on regions and processes where independent truth is available
  - Independent of data sources used to support and verify algorithm development
- Complete characterization: Uncertainties, information content, etc.
  - Apply "VVUQ" paradigm
- "Absolute" sources: Dedicated raobs, GPSRO, buoys, land met stations, ARM CART, etc.
- "Relative" sources: Other satellite sensors: MODIS, AMSR, etc.
- Comparative analysis: Sounder results vs. reanalysis & forecast models
- Dissemination of results: Peer-reviewed papers; Summary web reports

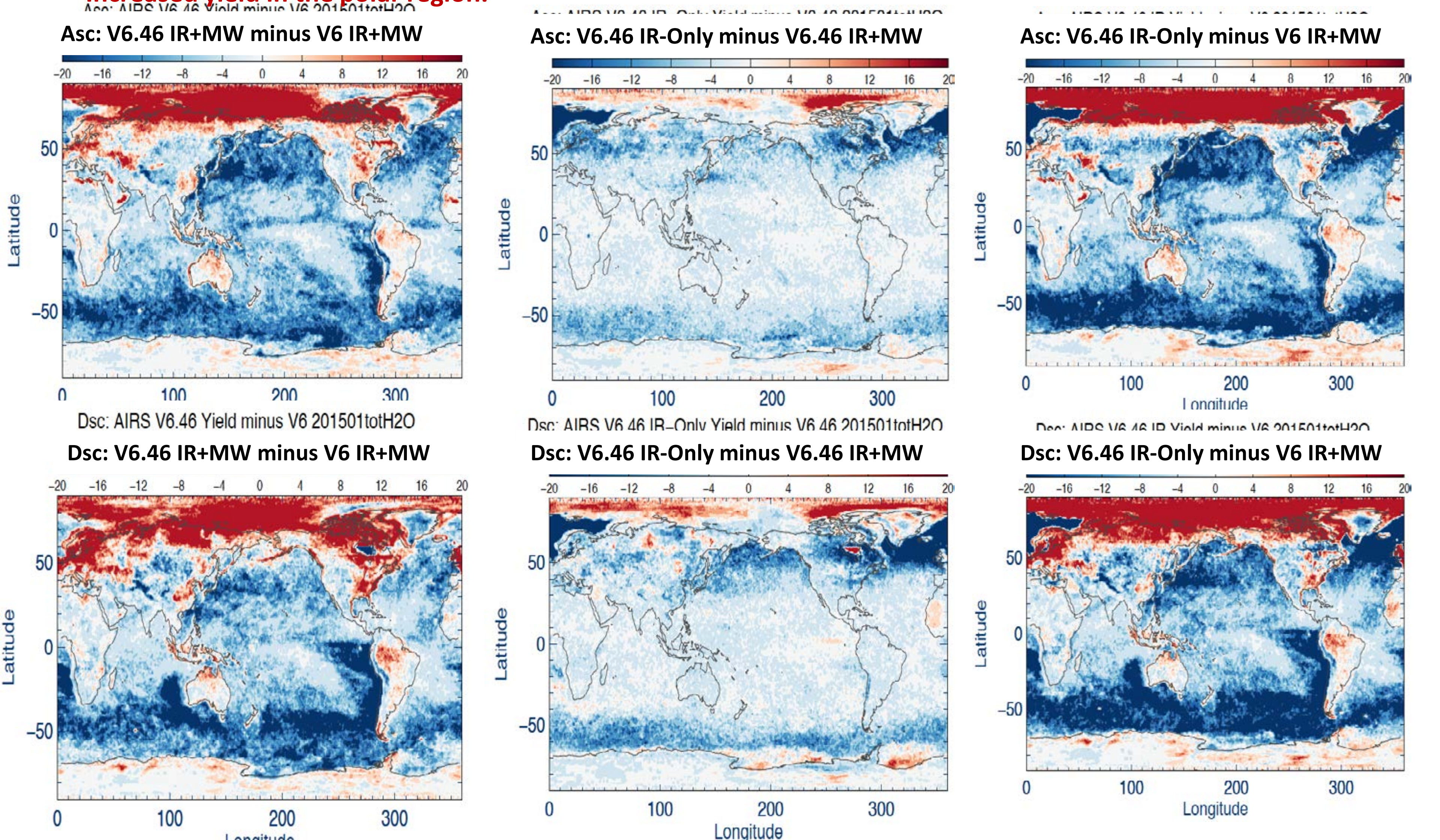
AIRS V7 Assessment: Tests, people, data

Variables	POC	Correlative Data	AIRS Data Used
L3 yield, totH2OVap and SST over ocean	Qing Yue	AMSR2	01 and 07, 2015
Surface Classes	Evan Manning Qing Yue	Snow and sea ice from National Snow and Ice Center	01 and 07, 2015
Total ozone and ozone profiles along the edge of the southern ozone hole	Evan Fishbein	18 ozonesondes launched from Dumont d'Urville station	18 granules over this station where departures from climatology are observed.
L2 temperature and water vapor profiles	Sun Wong	Operational sonde	01 and 07, 2015
L2 near surface T and Q over ocean	Luke Chen	ICOADS: Buoy and ship	01 and 07, 2015
L2 near surface T and Q over ocean	Luke Chen	MesoNet	01 and 07, 2015
L2 CC-Rad	Chris Wilson	MODIS clear sky radiances	01 and 07, 2015
L2 and L3 cloud	Brian Kahn	None	01 and 07, 2015

Example AIRS V7 testing: Yield

2015 January TPW Yield:

- **Decreased yield over ocean in the new versions, especially over subtropical low cloud and storm track regions.**
- **Increased yield in the polar region.**



Summary

Sounding science is thriving at JPL

- AIRS has been the focal point since late 1980's
- MLS, TES, MISR, OCO2 collaborations have broadened the scope
- S-NPP and JPSS represent "life after AIRS" → Continuity

AIRS analysis has spawned a vigorous research program

- Intimate understanding of measurements & data → Many papers
- Well funded through NASA's R&A program
  - Our proposal have been very competitive
- Publishing record is growing rapidly
- Collaborations with U.S. *and* European colleagues are highly valued

JPL environment facilitates development of new observing systems

- Easy to assemble a team of experts: *"Just go next door…"*
- JPL wins a large fraction of NASA proposal competitions
- Lively technology development program → New sensors & systems

JPL Sounder Team is a key "resource" for NASA

- Wide range of expertise covering all aspects of sounding science
- Provides anchor of broader sounding science activities
- Close coordination with NASA/GSFC, NOAA, CIMSS, MIT/LL