

Evolving Reference Networks and Integrated Satellite Data (Product) Validation

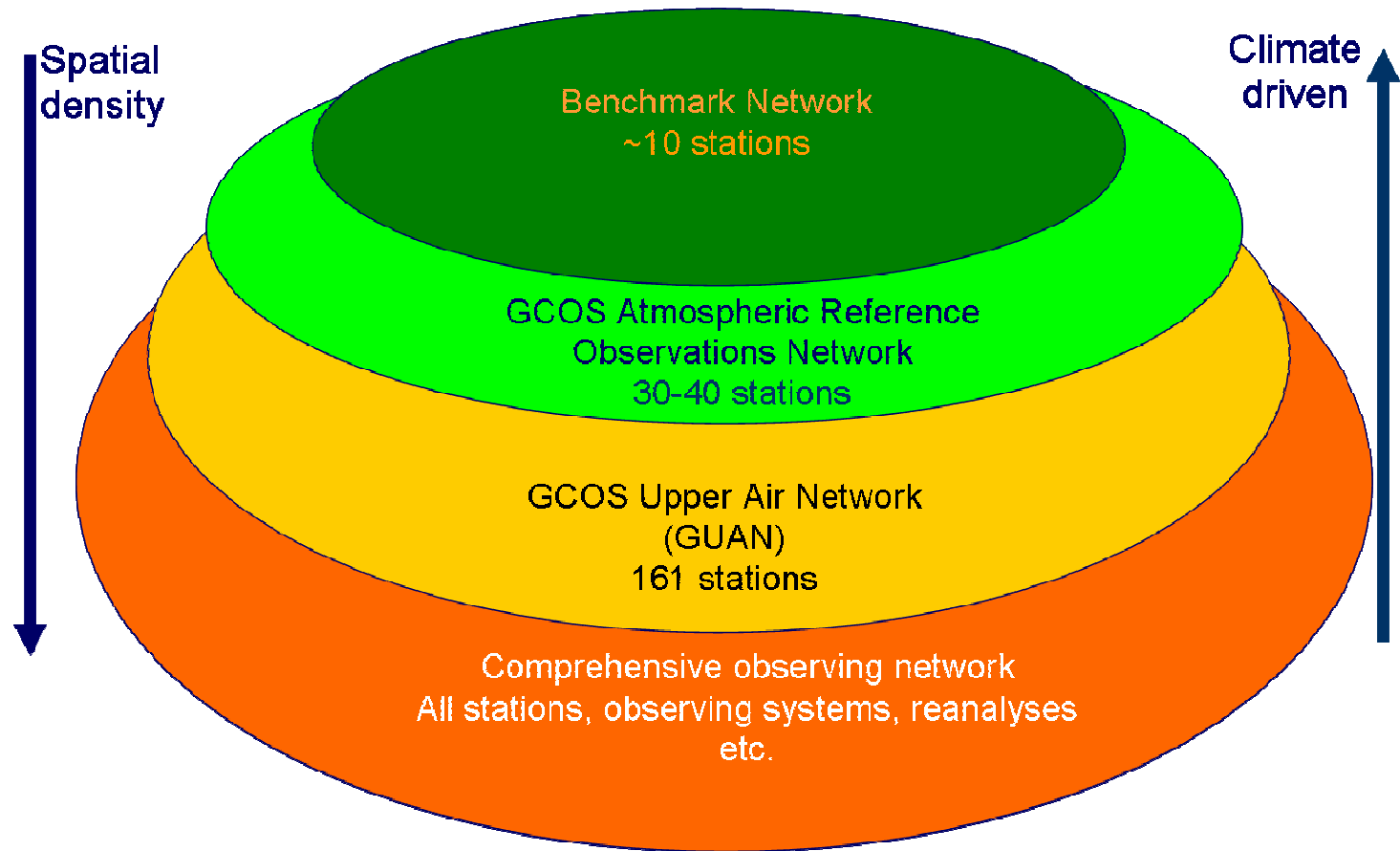
Tony Reale
NOAA/NESDIS
Center for **SaT**ellite **A**pplications and **R**esearch (STAR)
Operational Products Development Branch (OPDB)

[\(\[tony.reale@noaa.gov\]\(mailto:tony.reale@noaa.gov\)\)](mailto:tony.reale@noaa.gov)

15th International TOVS Study Conference
Maratea, Italy, Oct 4-10, 2006

Outline

- Evolving GCOS Atmospheric Reference Observations Network (GARON)
- Construction of Historical (TOVS) Psuedo-Reference Database (SEARCH)
- ATOVS Operational Data and Integrated Validation
- Expanded Integrated (Operational) Validation ... *in preparation for NPOESS via NOAA IPO award*



**GCOS Atmospheric Reference Observations Network
(GARON):
Justification, Requirements, Siting and Instrumentation Options**

Report (comments by Oct 15)

(http://hadobs.metoffice.com/aopc_wg_aro)

- Scientific Requirement
 - Climate record vs Measurement (uncertainty) record ...
 - Measurement Requirement Tables (Appendix-A)
- Network Operating Principles
 - Training, site (network) management, data management ... user
- Data and Instruments
 - Pressure, temperature, humidity and wind ... Priority 1
 - Srfc Radiation, microwave / infrared (AERI) sounder, clouds, trace gas, aerosol Priority 2
- Candidate Networks and Sites
- Sampling
 - Spatial ... global robustness ?
 - Temporal ... synoptic vs satellite coincident (“still an active area of ongoing debate”)
- Cal / Val

GARON Site CAL / Val

- “Sensor” and “calibration source” data **uncertainty** traceable to International System of Units standards.
- Residual **uncertainty** evaluated as a function of time.
 - Simultaneous measurement by independent sensors.
 - In the laboratory when the sensor can be retrieved.
 - In the operational environment when the sensor cannot be retrieved.
- Extended **uncertainty** computed and documented for every sensor and system.

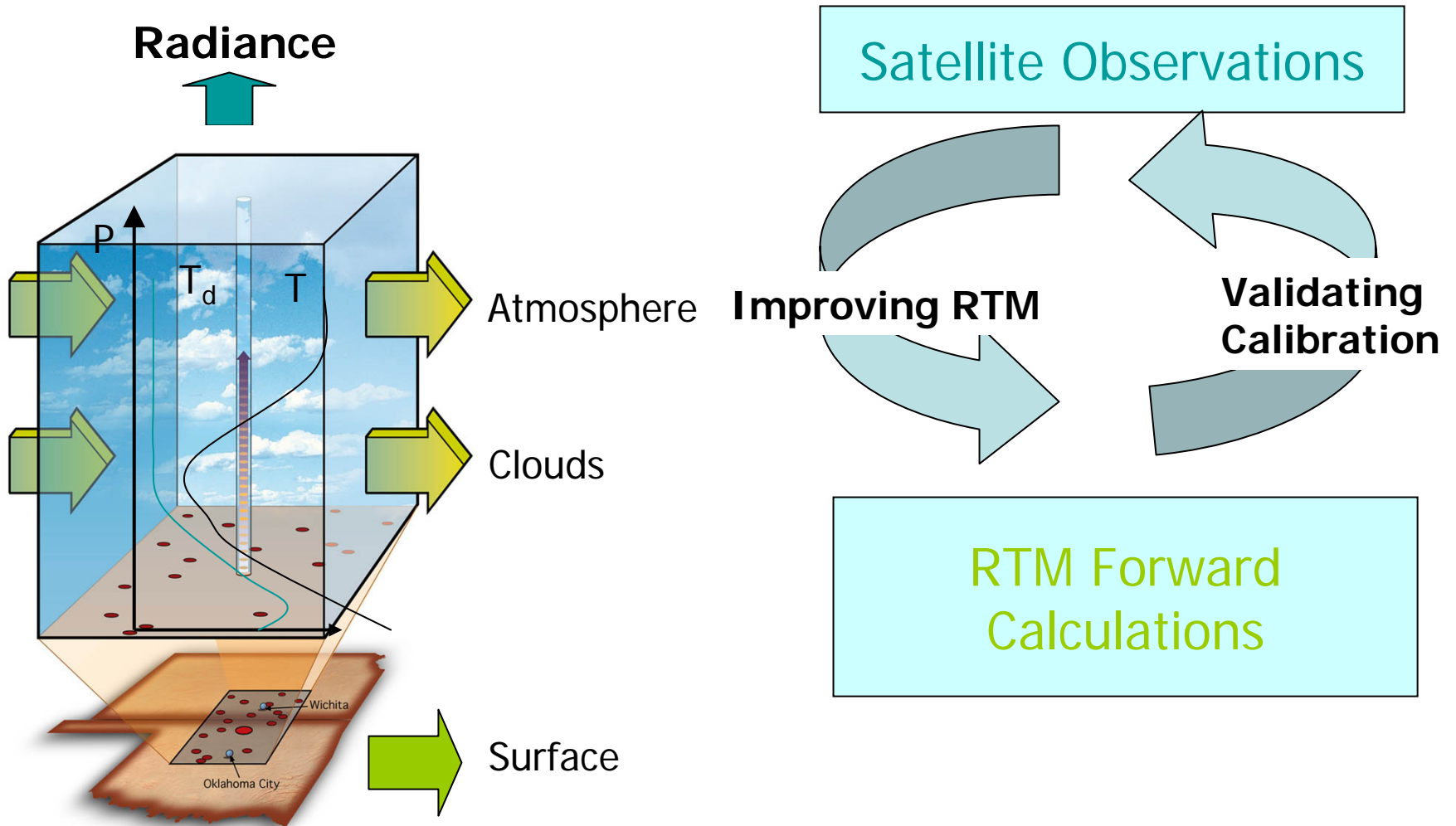
Candidate Networks...

- Baseline Surface Radiation Network (<http://bsrn.ethz.ch/>)
- Network for Detection of Atmospheric Composition Change (<http://www.ndacc.org/>)
- Aeronet (<http://aeronet.gsfc.nasa.gov/>)
- Global Atmospheric Watch ozone network
- International GNSS (Global Navigation Satellite Systems) Service (IGS) (see <http://igscb.jpl.nasa.gov/>)
- WMO Global Observing System
- The Atmospheric Radiation Measurement (ARM) Program (see <http://www.arm.gov/>)
- A number of individual national observatories
- The network of surface GPS total column water vapour instruments

... Initial Candidate Sites

- ARM sites (Tropical Western Pacific, Southern Great Plains, North Slope of Alaska) (<http://www.arm.gov/>, Ackerman and Stokes, 2003)
- Lindenberg, Germany (<http://www.dwd.de/en/FundE/Observator/MOL/MOL.htm>)
- Camborne, U.K., Payerne, Switzerland,
- Cabauw, Netherlands (<http://www.cesar-observatory.nl/>)
- Sodankylä, Finland (<http://www.sgo.fi/>)
- Heredia, Costa Rica
- Lauder, New Zealand
- Boulder / Denver, U.S.,
- Beltsville, U.S. (<http://meiyu.atmphys.howard.edu/beltsville/inde3.html>)

Radiance Validation at Reference Sites using RTM



Referencing The Past ... *TOVS*

Collocated TOVS and Radiosonde DataBase
compiled in support of
NOAA **Study Of Environmental ARctic CHange** Program
(SEARCH)

- “Complete” 1b-level records for TOVS HIRS and MSU
- 1b-level readers (Schweiger, Univ Wash...)
- WMO and Special radiosondes 1979-2003
- Collocated Observations (poleward 45N)
 - referenced to sounder measurements
- Data Management
 - *relational file structures*
- Users and Access
 - **Francis and Schweiger** ... compile RT bias (RTTOVS) and reprocess TOVS (ITPP-3I)
 - Plans for FTP and Web

“Global Climate Change” Proposal Submitted ... 3-years (*follow-up to SEARCH work*)

- Baseline SEARCH Expansion
 - Global
 - **TOVS SSU**, operational soundings
 - *DMSP, other ?*
 - TOVS N14 to 2006
 - **ATOVS (1998-onward)**
 - Special (simultaneous) TOVS and ATOVS (1998-2006) record
 - In-situ, Research,
- **Implement into ATOVS Product Operation ...**
- Serve as Baseline for NPOESS ... Reference Network
- User Access
 - FTP and Web

**Orient
Operational Product Environment
to Provide
Integrated Validation Datasets
and
Analysis**

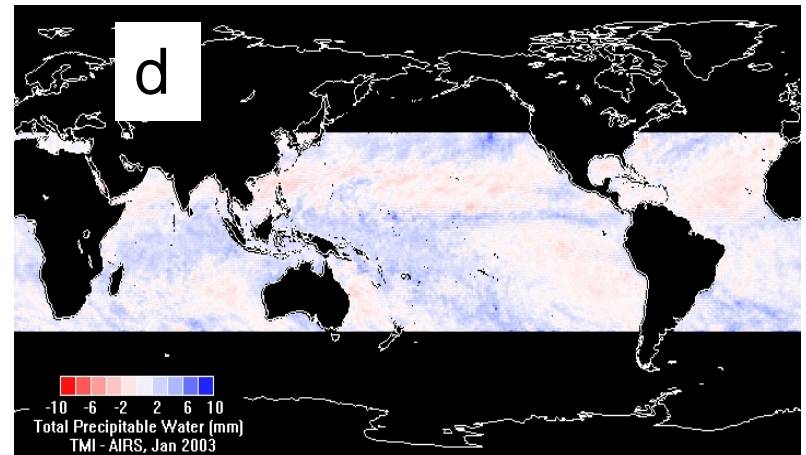
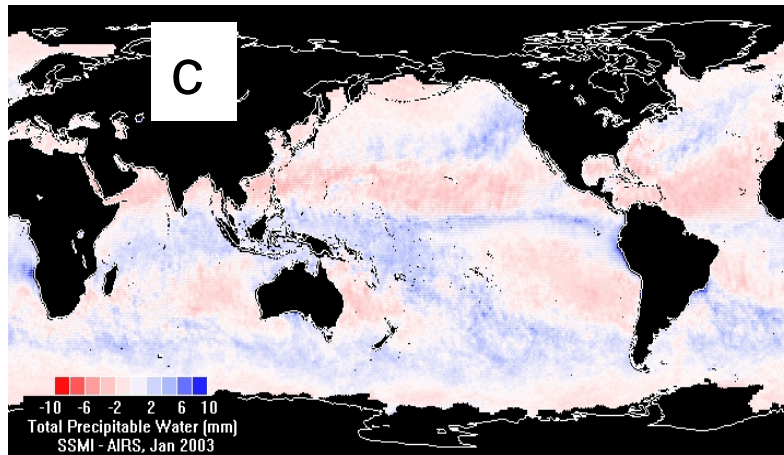
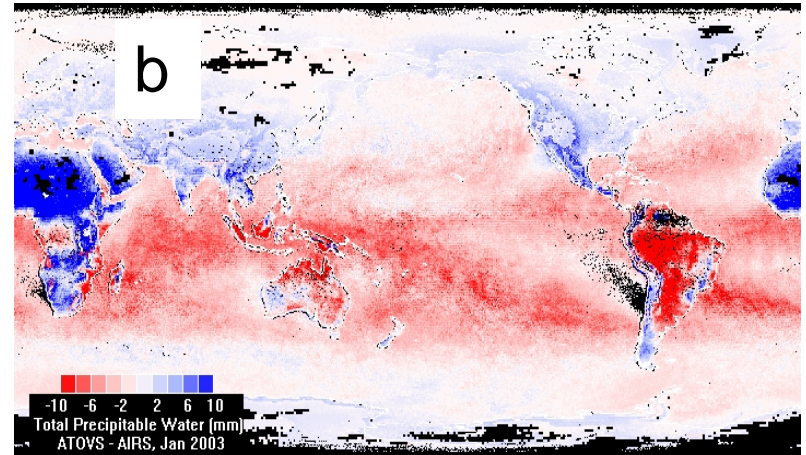
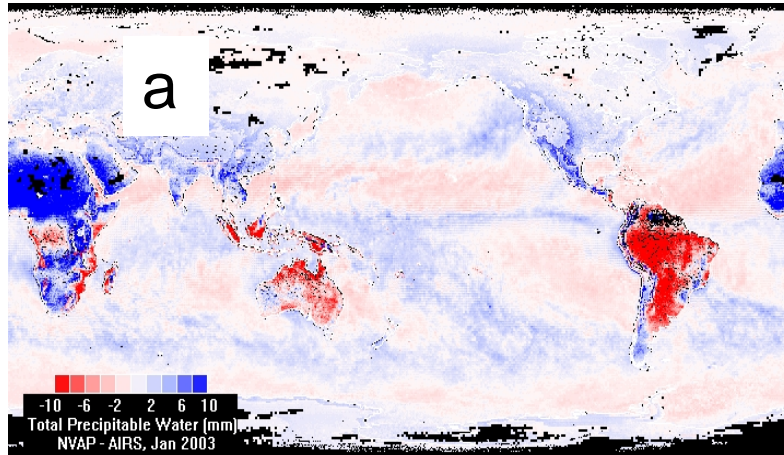
ATOVS Surface / Sounding Products

- *Incorporate MHS*
- *Integrate Microwave Integrated Retrieval (MIR) Products*
 - *TPW, CLW, Emissivity ... (Weng, Boukabara; talk 11.6)*
- Regression Guess replaces Library Search
 - Calculate First Guess Radiance (CRTM)
- Measurement (Radiance) Bias Adjustment
 - AMSU-A
 - MHS
 - HIRS
- *Integrate MIR Retrieval Solution (CRTM) per sounding (Paul Van Delst, Fuzhong Weng, Yong Han)*
 - *based on Guess Temp and Moisture*
- *Baseline for NPOESS (... AIRS and IASI... Thomas King talk 12.3)*
- Peripheral Upgrades
 - Limb-adjustment
 - Complete NWP Profile (Srfc data, +/- 90 minutes, 3hr fcst ...)

A PILOT STUDY OF SCIENTIFIC DATA STEWARDSHIP WITH GLOBAL WATER VAPOR

Thomas. H. Vonder Haar, *John M. Forsythe*, and Ron W. Kessler

1 Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO 80523



Red areas are moister, blue areas drier (−10 to +10 mm):

a) NVAP blended minus AIRS TPW.

b) ATOVS (NOAA-15 and-16) minus AIRS.

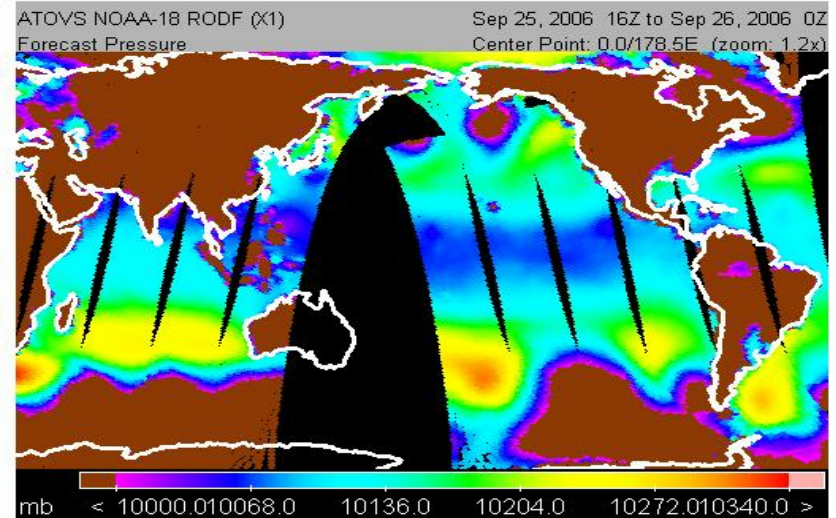
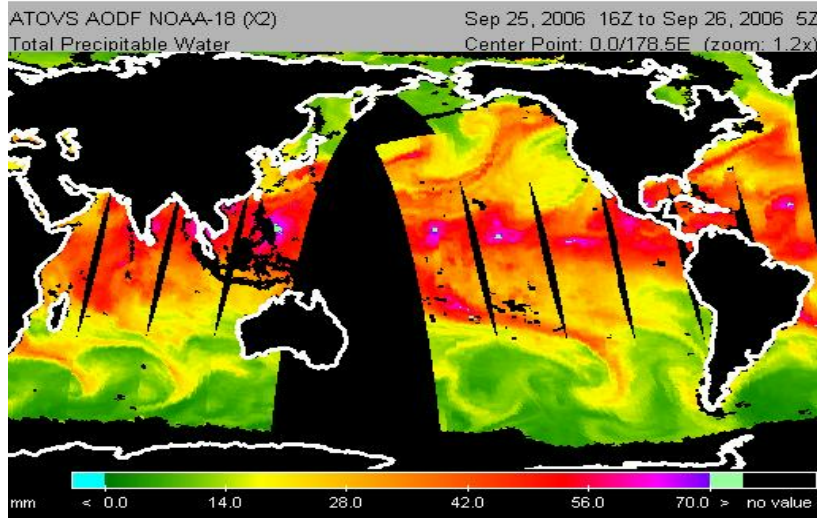
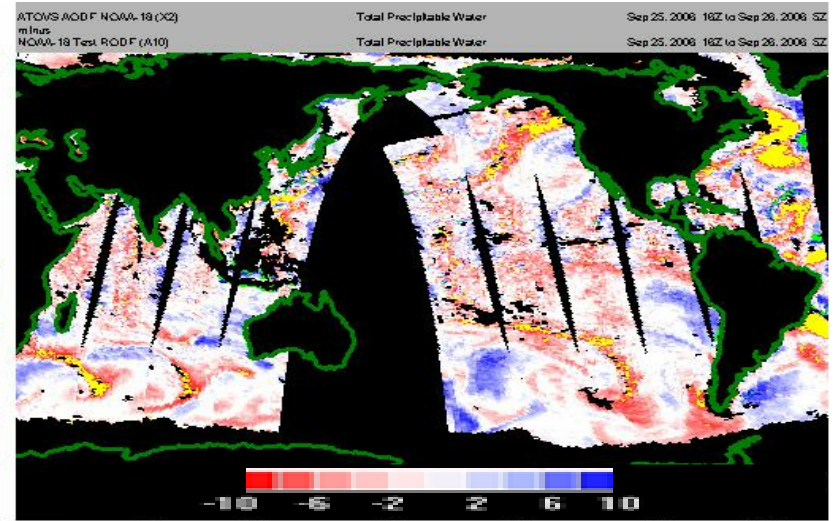
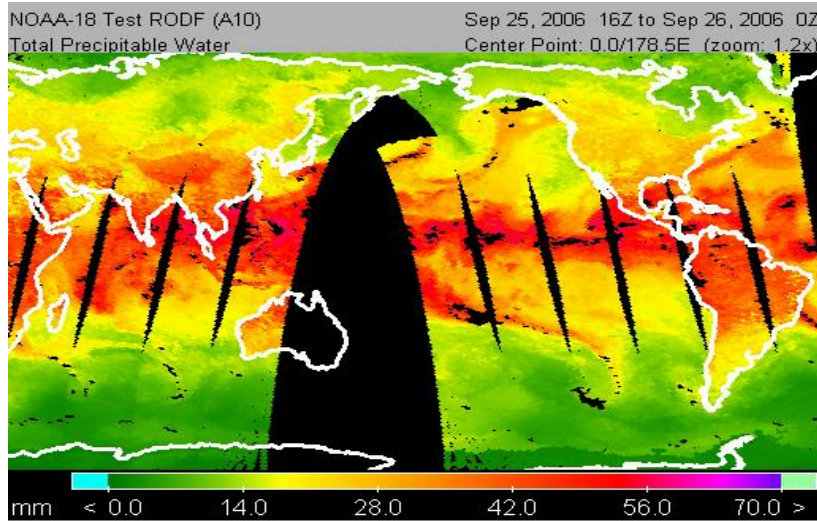
c) SSM/I (F-13 and F-14) minus AIRS

d) TMI minus AIRS.

... ATOVS sounding product use in climate studies ...???

ATOVS Integrated (to 1000mb) TPW

ATOVS - MIR

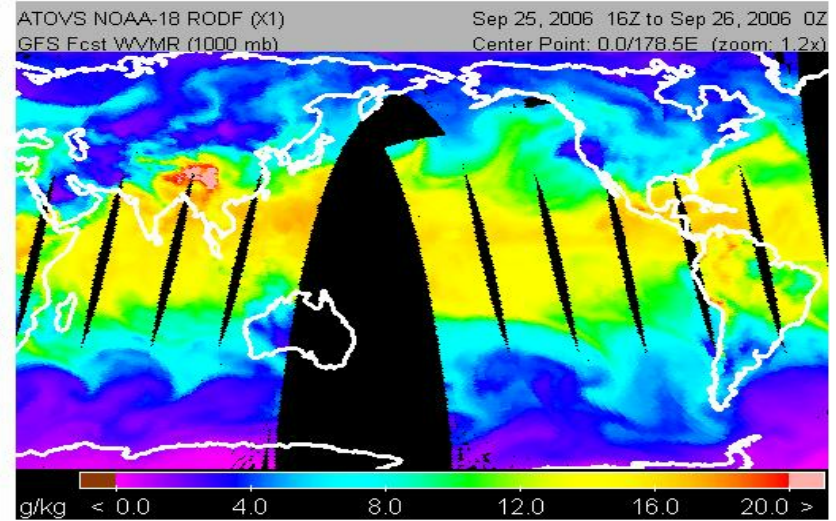
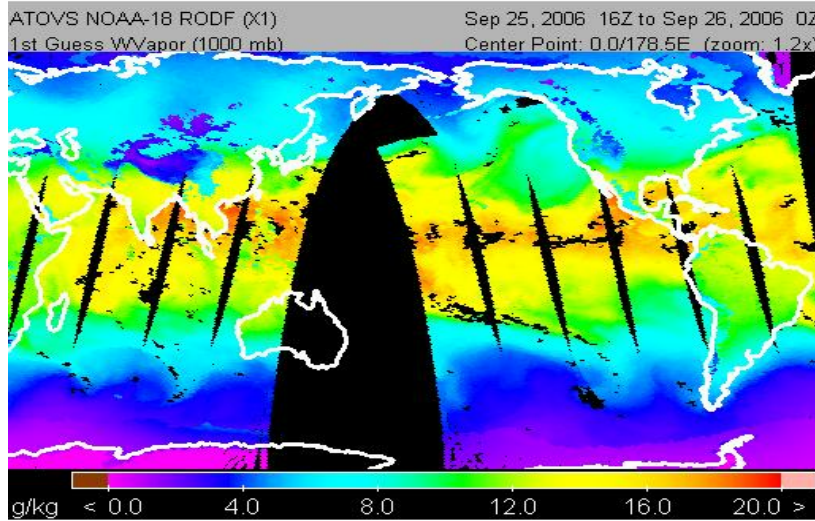
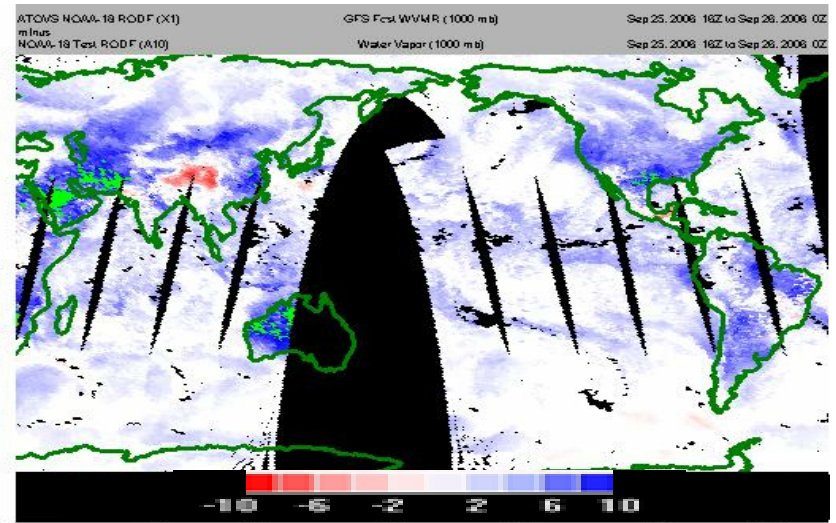
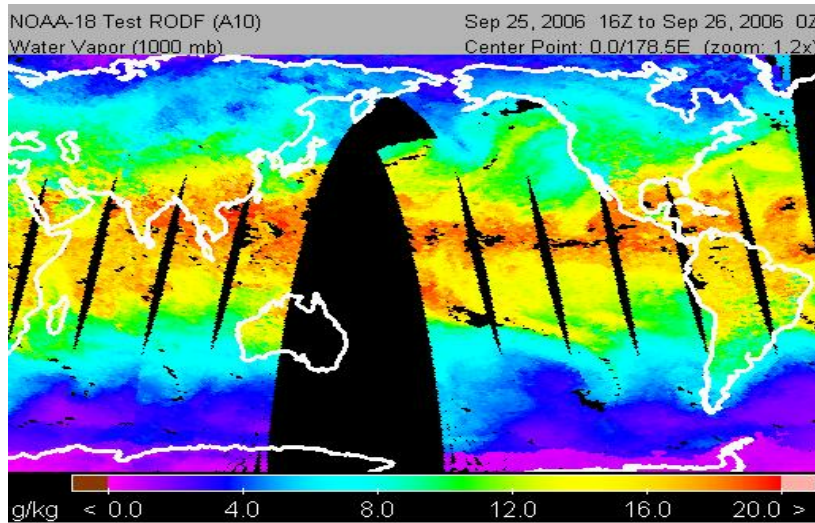


MIR TPW (to Srfc)

NWP Srfc Pressure >1000mb

ATOVS Oper WVMR @1000mb

ATOVS - NWP



ATOVS Test WVMR @1000mbTest

NWP WVMR @ 1000mb

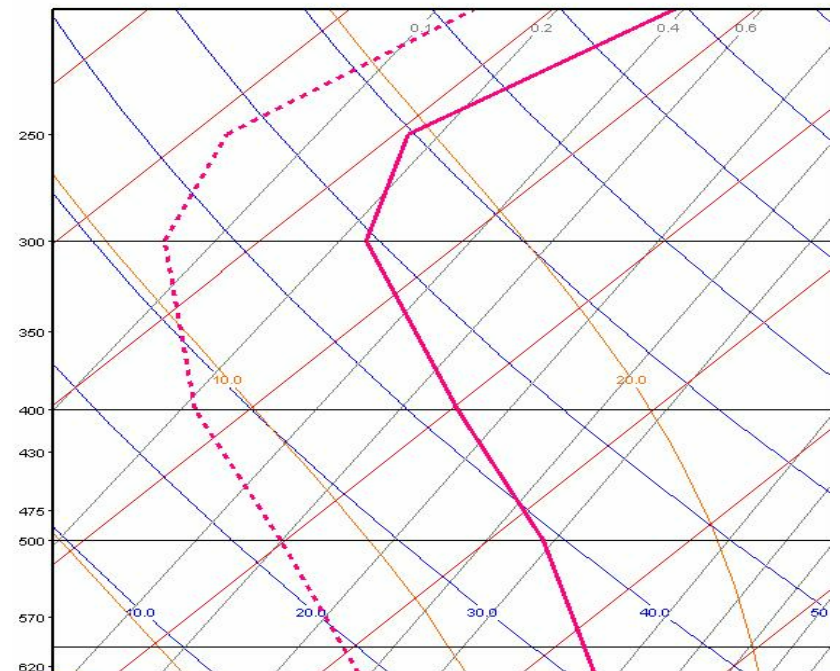
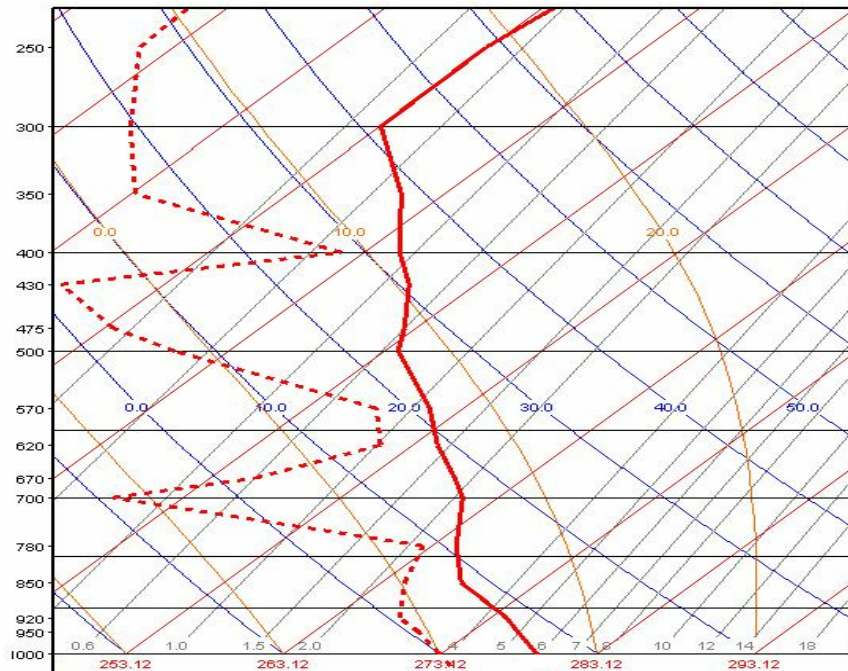
Orient to Integrated Data (Product) Validation

(Part-1)

- **Collocation DataBase Generation**
 - Reference to *Satellite Measurement (not Sounding)*
 - Expand Radiosonde Data stored
 - rad correction, drift parameters, updated instrument type
 - appended NWP, QC
 - *Moisture Profile QC*
 - **Expand** data platforms to include
 - AIRS, GOES, COSMIC,
 - In-situ (ie from ARM), ...
 - Research Experiment data
 - Relational Data Management (...*baseline SEARCH*)

Operational Procedures to Process, Screen and Collocate Radiosondes with NOAA Polar Satellite Observations

Reale and Tilley
2006



Examples of Radiosonde Moisture QC ...

Orient to Integrated Data (Product) Validation

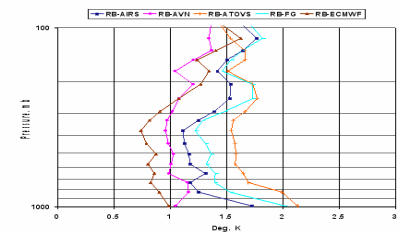
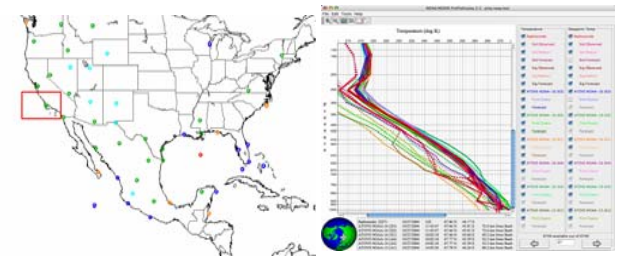
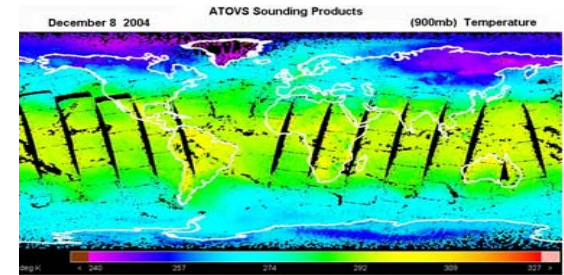
(Part-2)

- **Collocation DataBase Analysis**
 - Product vs Product
 - Radiance (Obs) vs Radiance (Obs)
 - Radiance (RTM) vs radiance (Obs)
 - Convergence studies,
 - Other ...

Enivronmental Data Graphic and Evaluation System (*EDGE*)

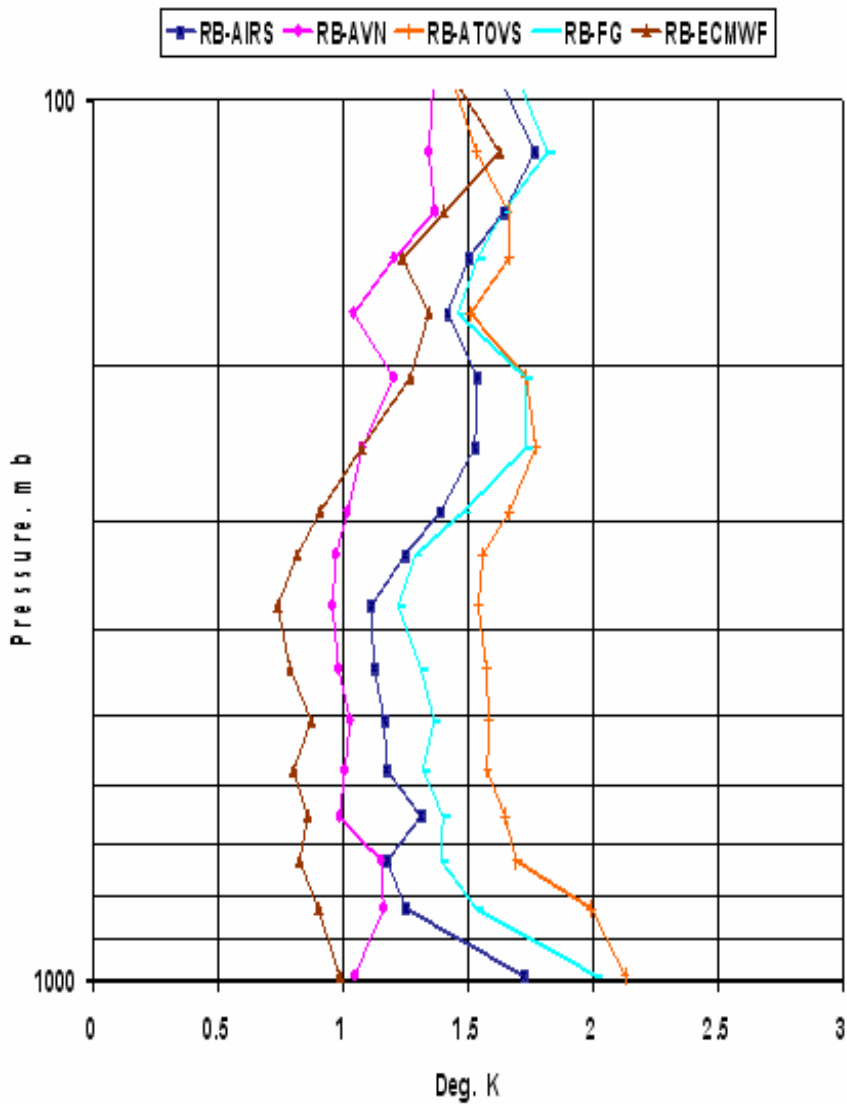
– Three (3) Major Sub-systems:

- *EDGEIS*: Horizontal Fields of Orbital Products data
- *Profile Display (PDISP)*: Collocated Multiple Platforms of Ground Truth vs Satellite Obs ... see SSSP web site
- *Vertical Statistics (VSTAT)*: Multiple Platform inter-Validation

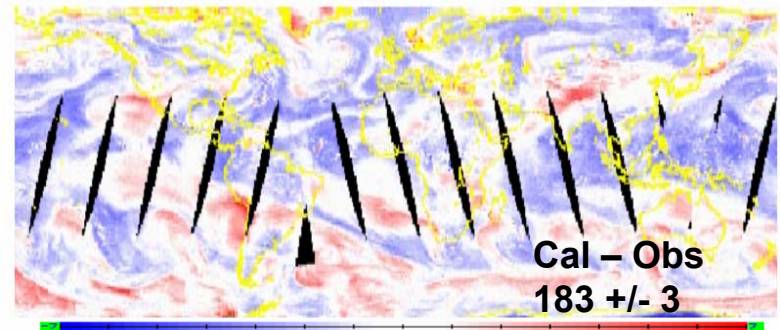
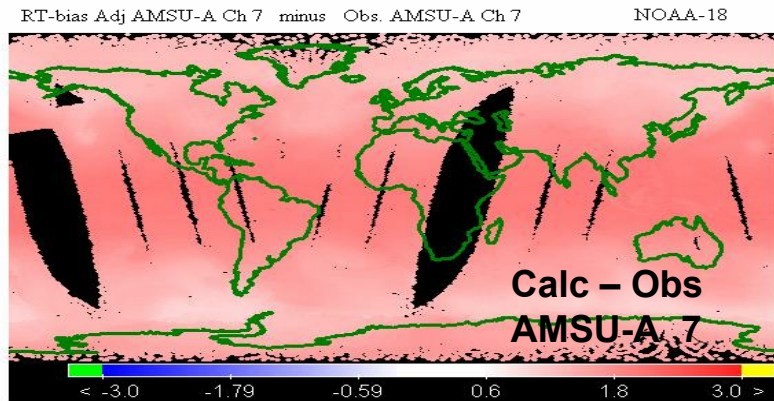
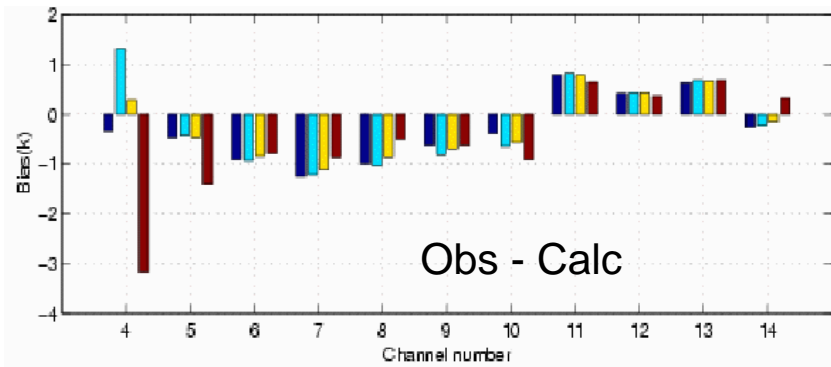


– *Vehicle for EUMETSAT/NOAA Collaboration for METOP*

- Cornerstone for NPOESS Validation Protocols ... (also see Lihang Zhou Poster B-17)

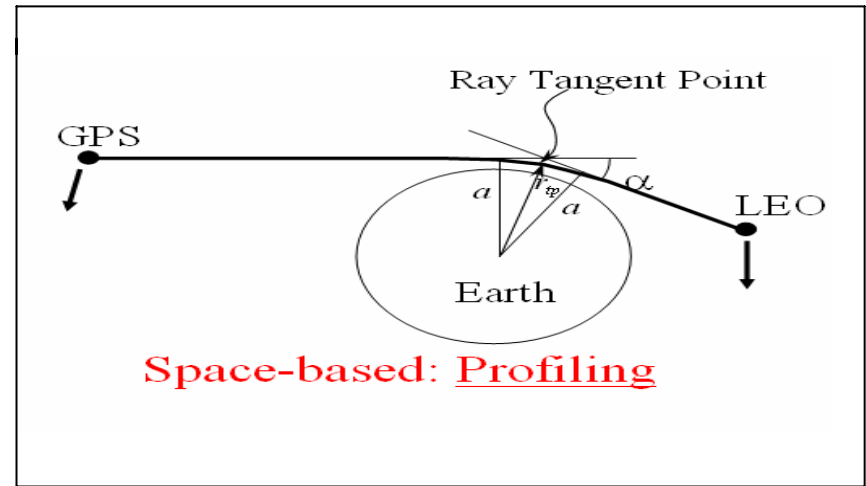
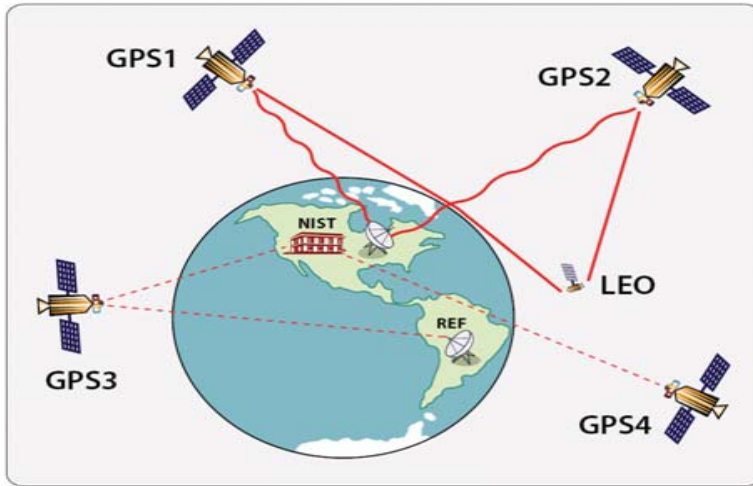


Multi-platform Product Comparison

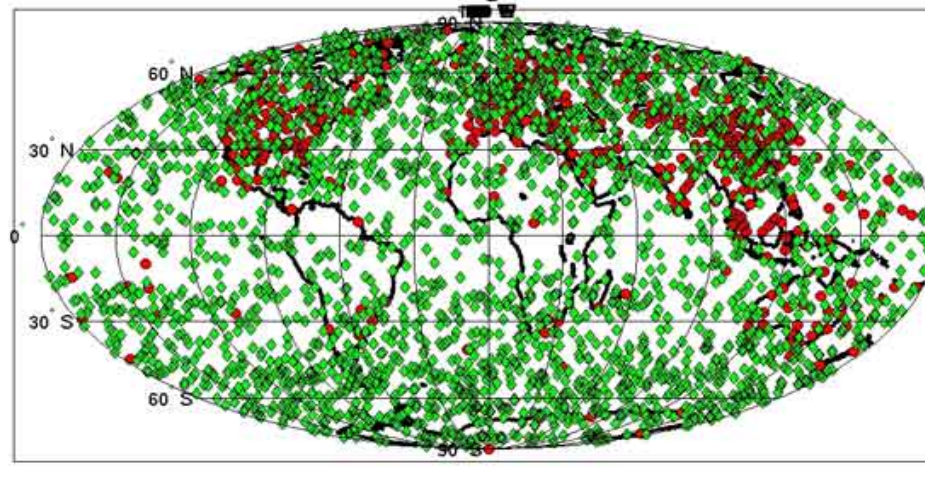


Multi-channel Radiance Comparison

C O S M I C



Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs



... the independent nature of *radio occultation soundings* make them highly complementary to other atmospheric sounding systems, such as infrared and microwave sounders ...

Eva Borbas (SSEC), Christian Rocken (UCAR), Jim Yoe (NOAA)

In-situ Observations



PEOPLE | SITE INDEX | HOME
 SEARCH

ABOUT ARM

ABOUT ACRF

SCIENCE

SITES

INSTRUMENTS

MEASUREMENTS

DATA

PUBLICATIONS

EDUCATION

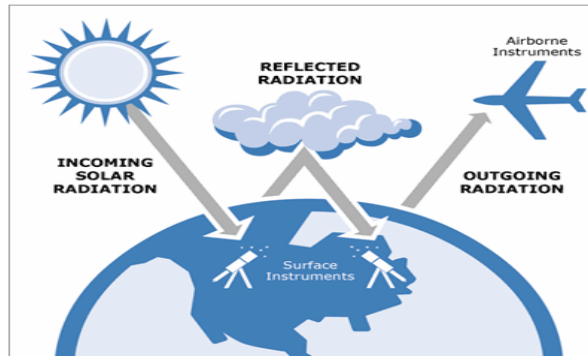
FORMS

[Alphabetized List](#)

[Measurement Categories](#)

Measurements

The Atmospheric Radiation Measurement (ARM) Program gathers a wide variety of measurements from many different sources. Each day, the [Data Archive](#) stores and distributes large quantities of data collected from these sources. Scientists then use these data to research atmospheric radiation balance and cloud feedback processes, which are critical elements of global climate change.



The ARM Program gathers cloud and radiation measurements from instruments on the ground, attached to aircraft, and sometimes placed on ships.

Measurement Categories

- [Shortwave Spectral Radiation](#)
- [Cloud Properties](#)
- [Surface Meteorology](#)
- [Atmospheric Profiling](#)
- [Surface Energy Flux](#)
- [Aerosols](#)
- [Atmospheric Carbon](#)
- [Airborne Platforms](#)
- [Longwave Spectral Radiation](#)
- [Longwave Broadband Radiation](#)
- [Shortwave Broadband Radiation](#)

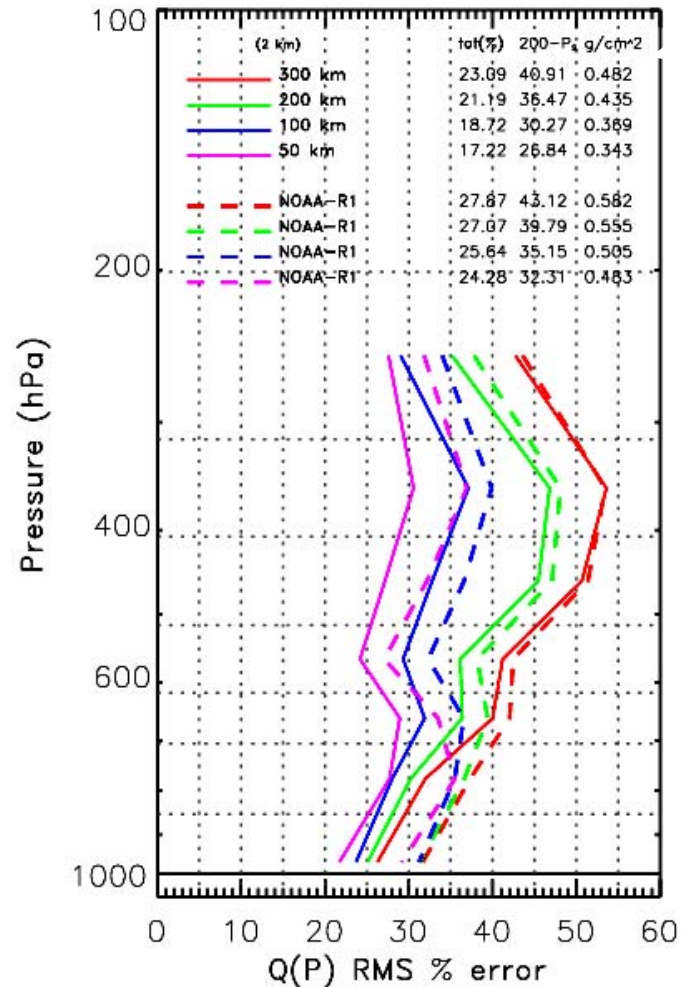
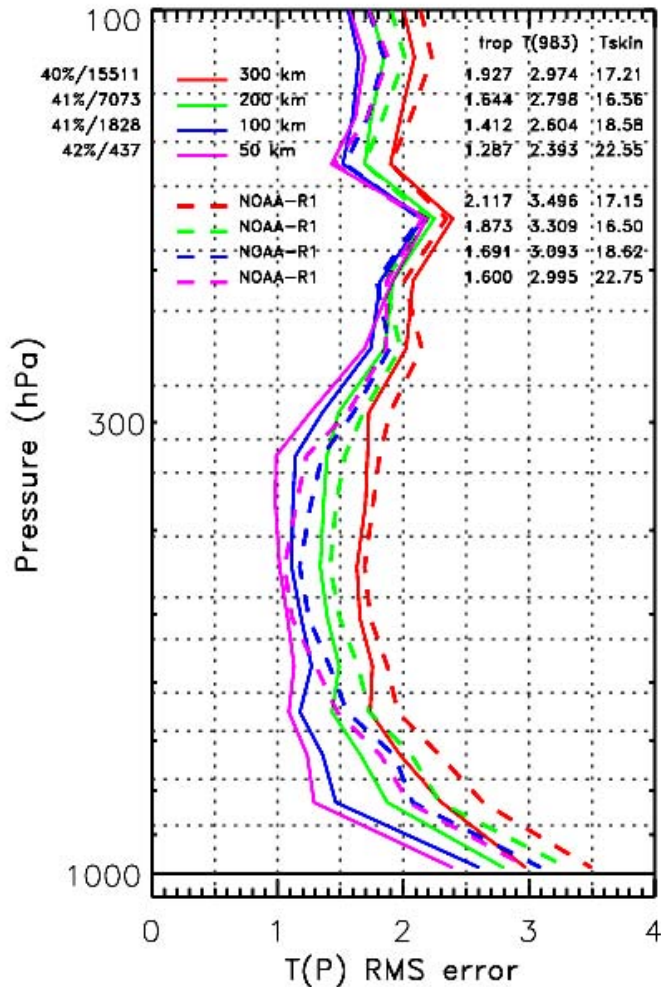
- **Atmospheric Profiling and Clouds**
 - **Microwave Radiometer (Column Integrated H2O)**
 - **Microwave Radiometer Profiler (T, H2O and CLW profiles @ 20-30 and 50-60 GHz)**
 - **GVR (183 +/- 1,3,7,14 gHz)**
 - **Raman Lidar (H2O Vapor, Cloud, Aerosol)**
 - **Radiosonde (Vaisala RS-92, dual humicap)**
 - **AERI (RT, Clouds , T, H2O and Trace Gas @ 3 -20 (25) Microns)**

Initiatives for Satellite Coincident Radiosonde Launches (RS-90) at ARM Site(s)

- continued NASA support for ARM (SGP, NSA, TWP) site radiosonde launches coincident with AIRS ... (Tobin, Revercomb SSEC, Wisconsin)
- pending agreement for to launch “144 extra sondes at SGP” coincident with polar ATOVS ... (Barry Lesht (ARM), Reale)
- studies to quantify impact of coincidence for GARON ... (*Menzel, Goldberg, Thorne and most recently Goodrich, Peterson*) ... possible funding opportunity
 - results from EOS-Aqua-AIRS
 - user community
 - other

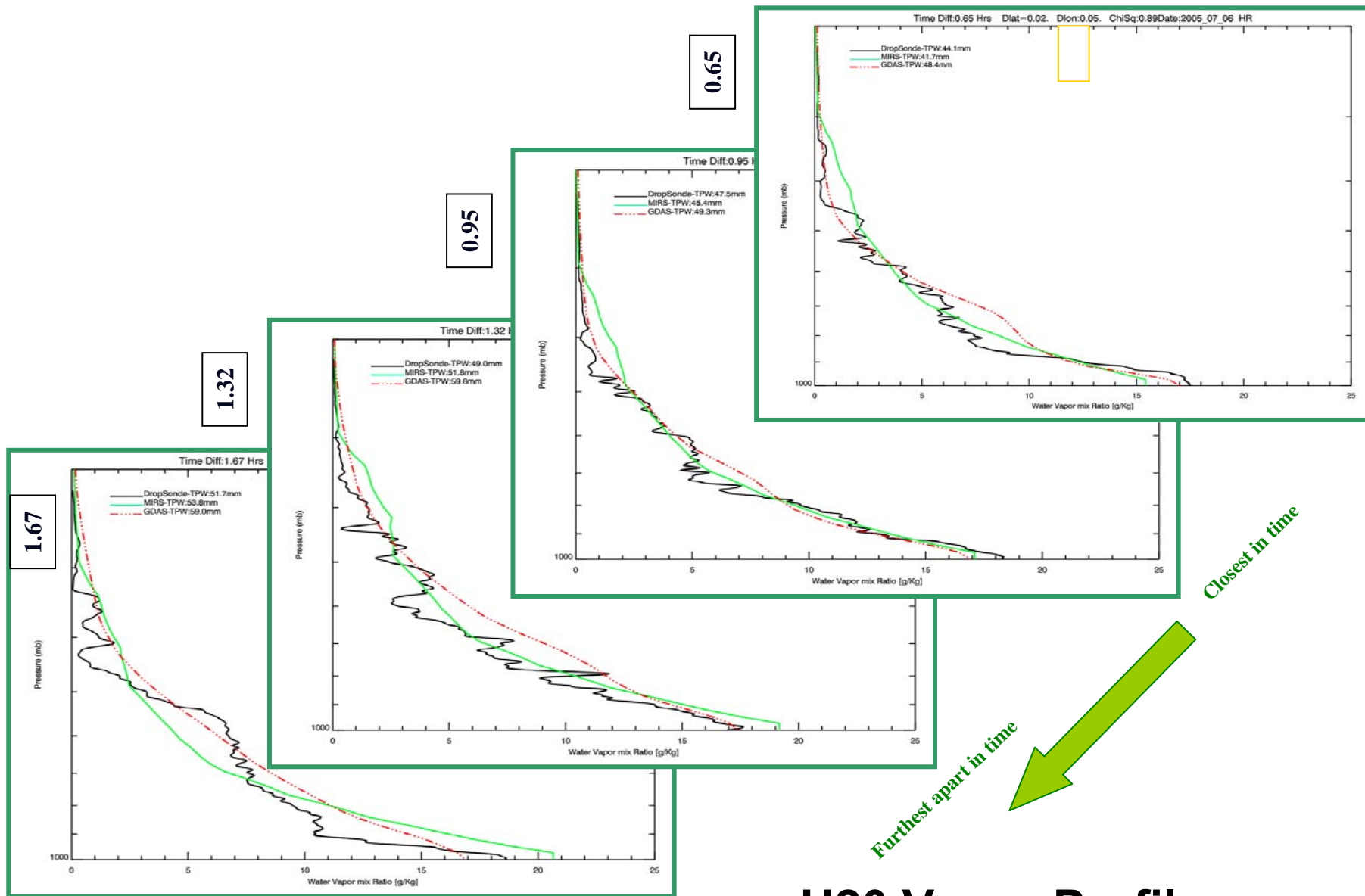
Spatial gradient in RS 90 radiosonde-retrieval RMS Comparison (ARM-SGP ... 97W, 36N)

Antonia Gambacorta (a) , Chris Barnet (b) , Dave Tobin © , Leslie Moy © , Scott Hannon (a) , Larrabee Strow (a) , Dave Whiteman (d)
AIRS Science Meeting, 9-27-2006



Temporal Gradient in Dropsonde – AMSU/MHS retrieval (MIR) Comparison

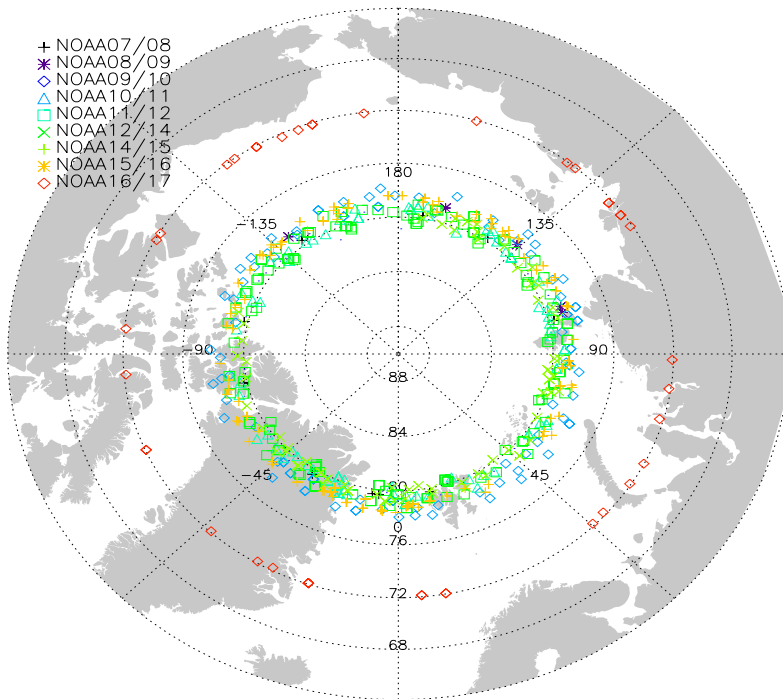
(Weng, Boukabara, Ferraro, Zhao; MIR, 9-30-2006)



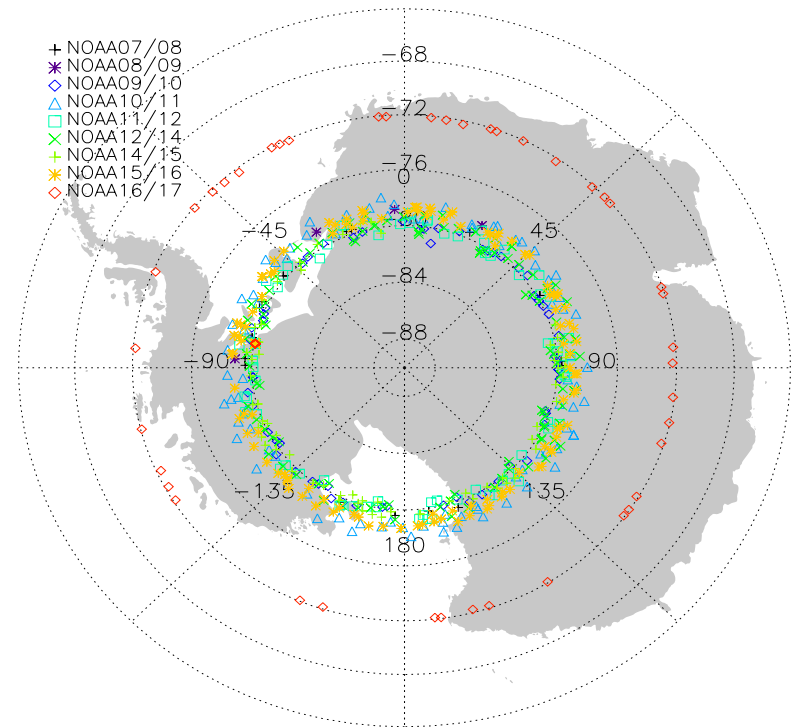
H2O Vapor Profiles

NOAA POES Simultaneous Nadir Overpasses (SNO) (... Cheng-Zhi Zhou)

Arctic



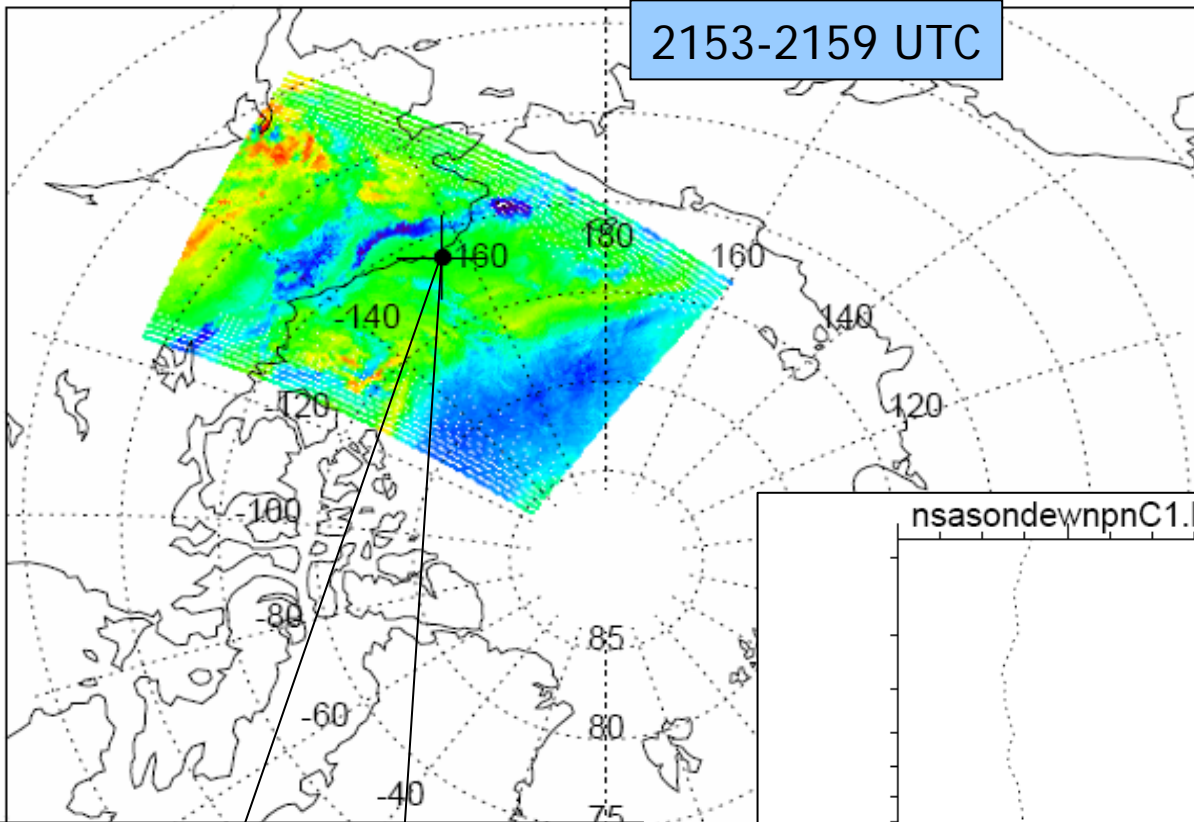
Antarctic



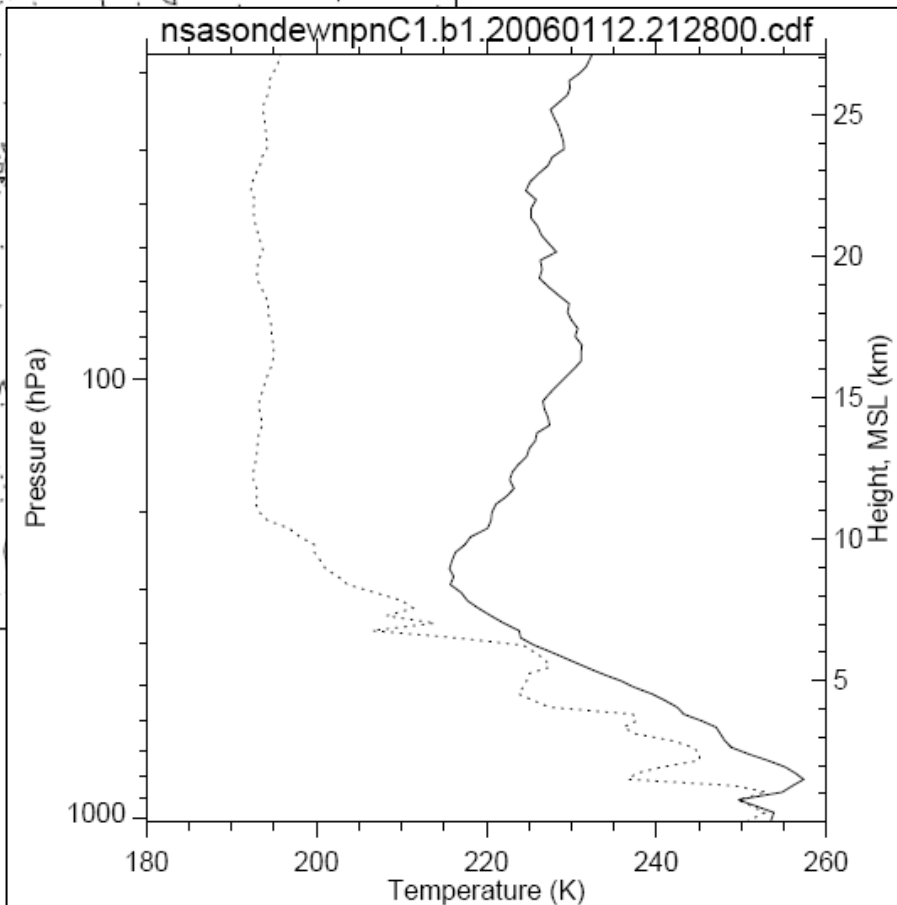
AIRS Ch 750

2153-2159 UTC

BT
263.14
259.70
256.25
252.81
249.36
245.92
242.47



2128 UTC



ARM North Slope of Alaska



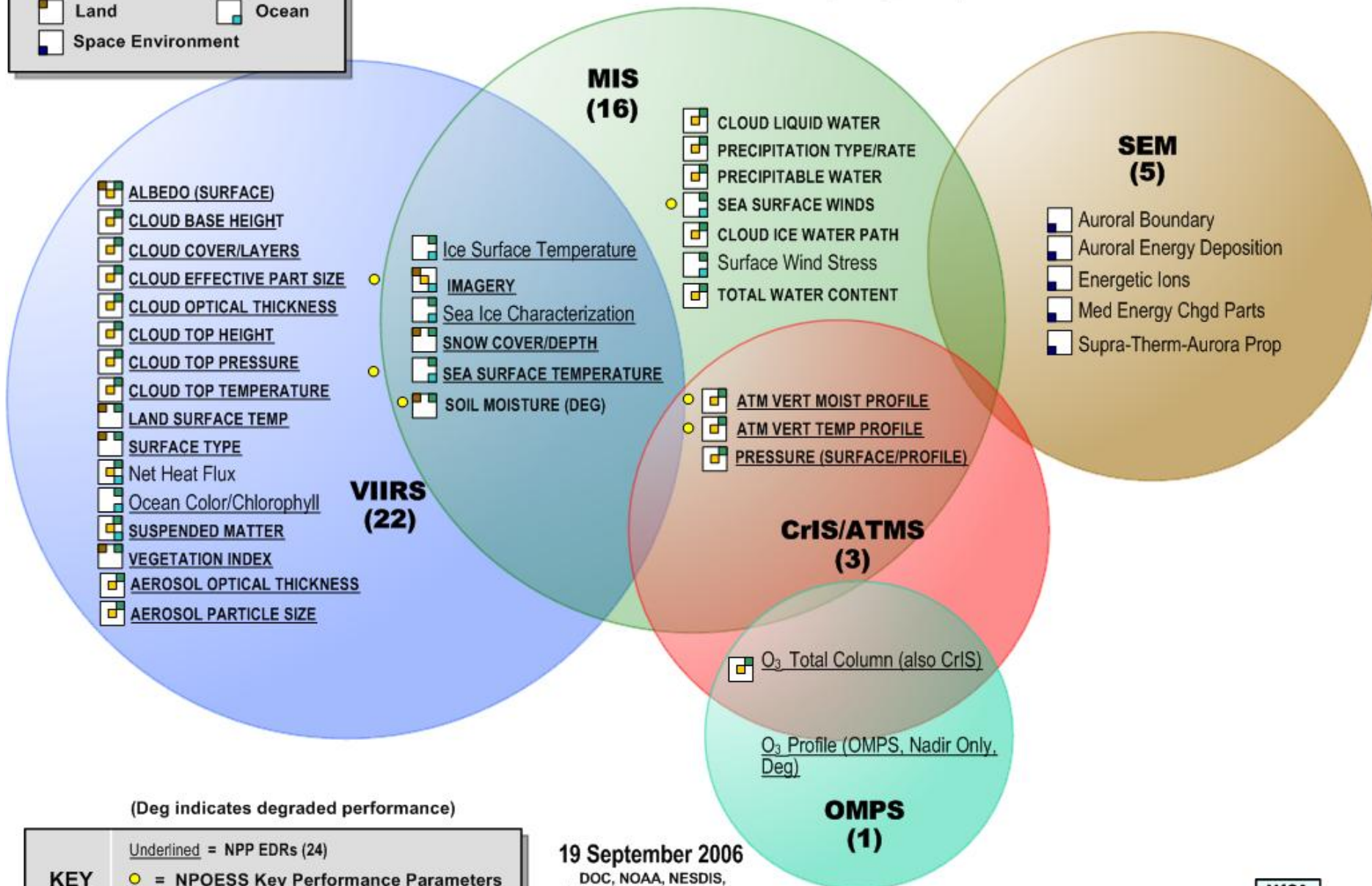


MISSION AREAS

-  Atmosphere
-  Climate
-  Land
-  Ocean
-  Space Environment

NPOESS Certified Program - 38 EDRs

(2 Degraded)



(Deg indicates degraded performance)

KEY	<u>Underlined</u> = NPP EDRs (24)
	● = NPOESS Key Performance Parameters
	BOLD CAPS = LRD Environmental Data Records

19 September 2006

DOC, NOAA, NESDIS,
Integrated Program Office
M. Bonadonna, M. Haas,
J. Whitcomb

Integrated Cal/Val System

(Weng, Cao ... Goldberg)



NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service



STAR – Center for Satellite Applications and Research
formerly ORA – Office of Research Applications



STAR > SMCD > SPB > Integrated Satellite Instrument Calibration/Validation System



Integrated Satellite Instrument Calibration/Validation System



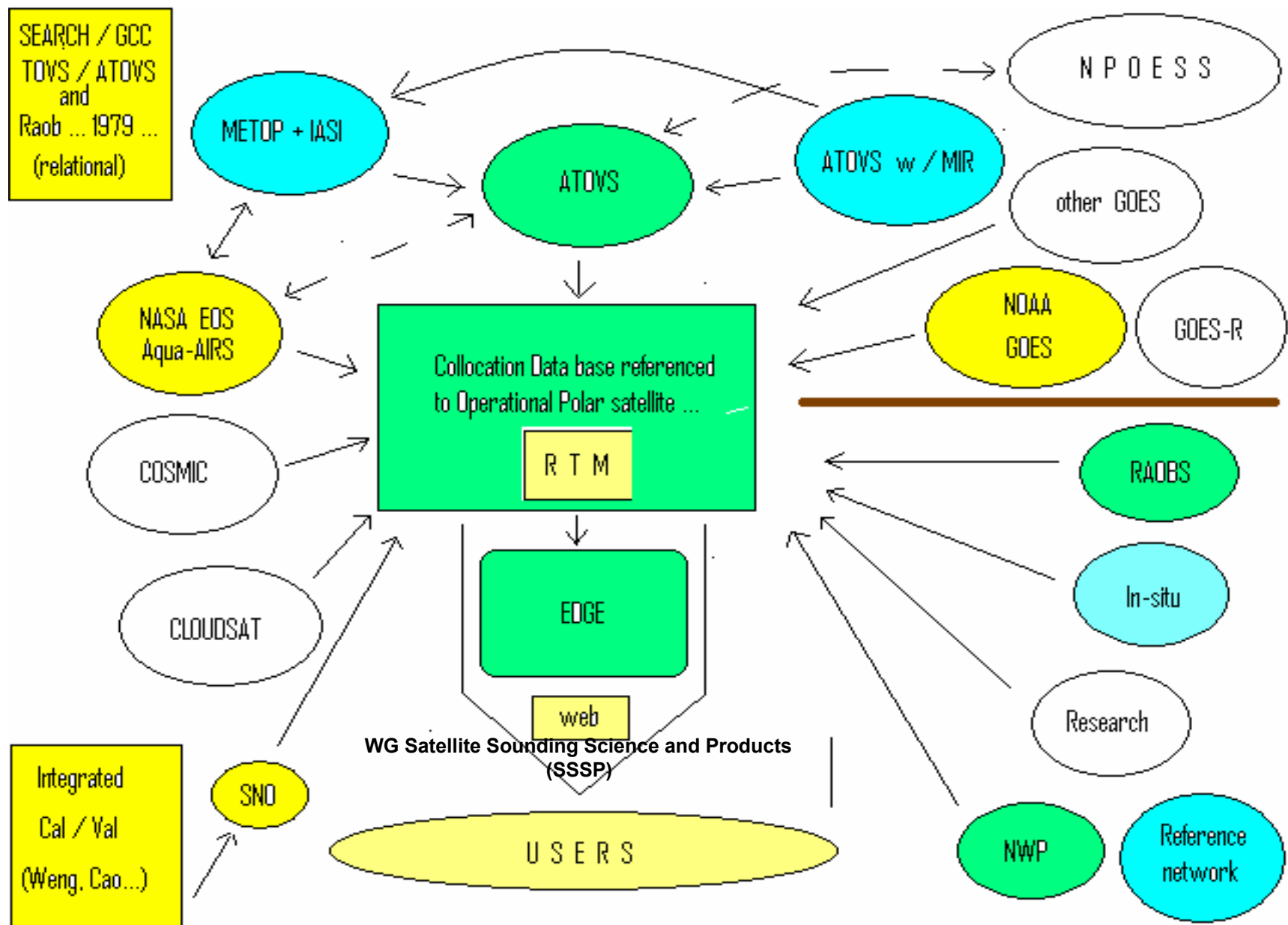
Introduction			
Microwave Sounders	> NOAA18/HIRS/4	>>	SNO Biases (N18 vs. N16)
Microwave Imagers	> NOAA17/HIRS/3	>>	SNO Biases (N17 vs. N16)
Infrared Sounders	> NOAA16/HIRS/3	>>	SNO Biases (N16 vs. Aqua)
Infrared Imagers	> METOP-A/HIRS/4	>>	SNO Predictions
Visible & Near Infrared Instruments	> METOP-A/IASI	>>	Instrument Performance Monitoring
Ultraviolet Instruments	> NPP/CrIS	>>	View Current Rad. Data
Projects	>> NPOESS/CrIS	>>	RTM at ARM Sites
Publications	>> GOES-10/Sounder	>>	NWP Ctr. Analysis
FAQ and Tools	>> GOES-11/Sounder	>>	Prelaunch Characterization
	>> GOES-12/Sounder		
	>> GOES-R/HES		
	>> Retrospective Cal.		

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<http://www.orbit.nesdis.noaa.gov>

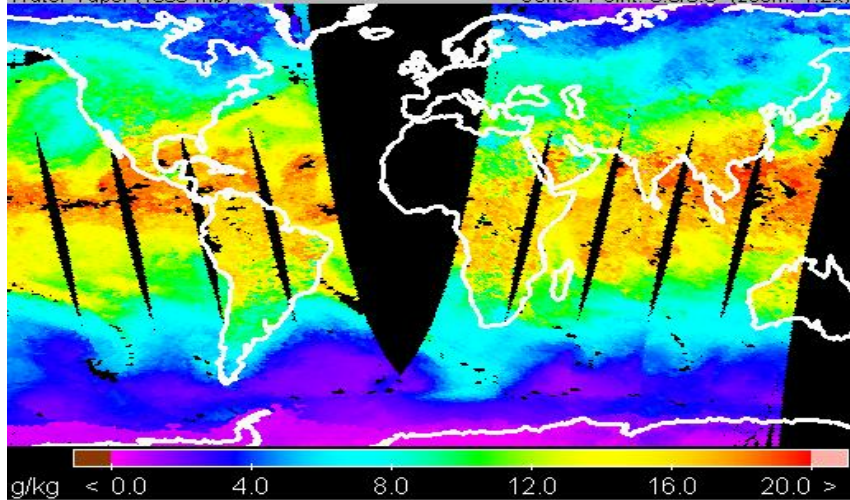
<http://www.orbit.nesdis.noaa.gov/smcd/spb/calibration/icvs/>

Integrated Operational Product Data Validation (NPOESS IPO Award)

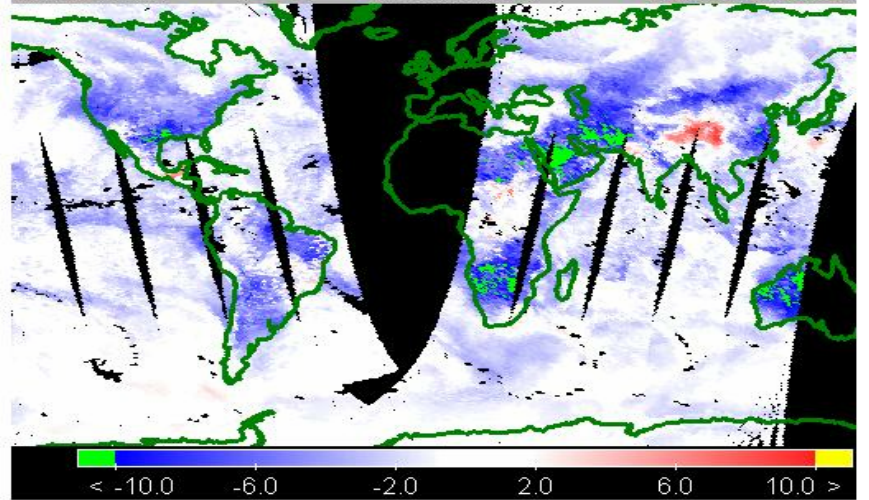


EXTRAS

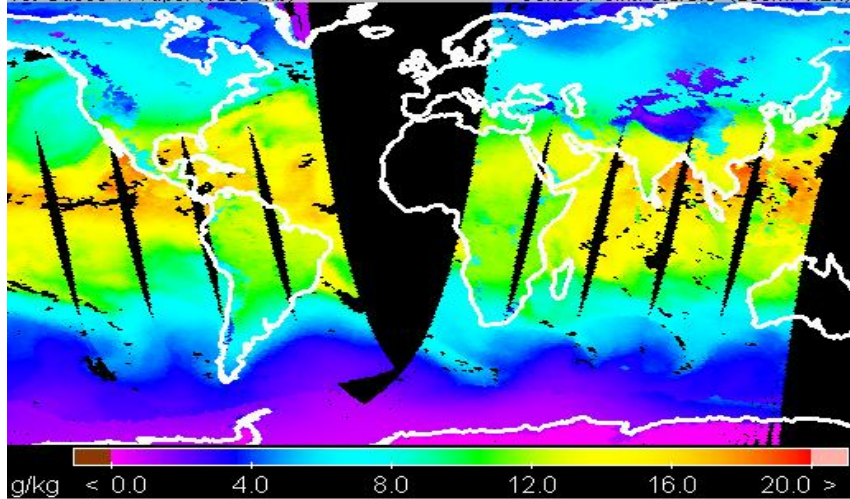
NOAA-18 Test RODF (A10) Sep 25, 2006 16Z to Sep 26, 2006 0Z
Water Vapor (1000 mb) Center Point: 0,0/0,0 (zoom: 1.2x)



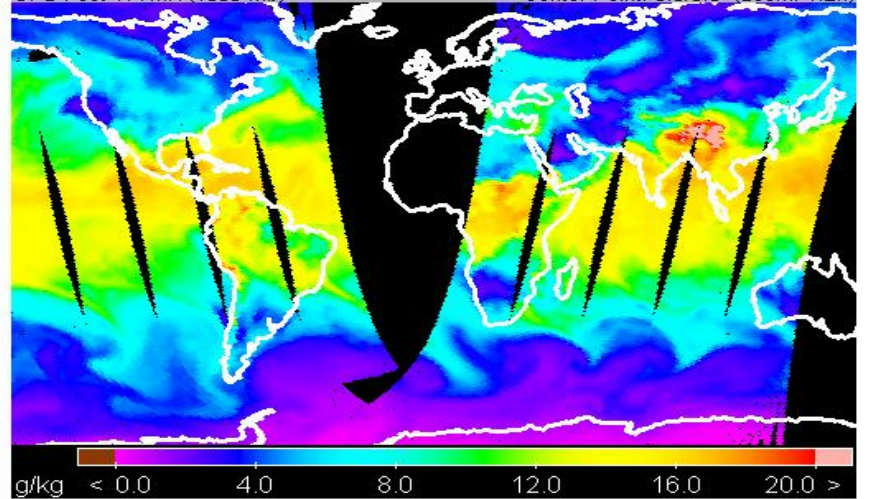
ATOVS NOAA-18 RODF (X1) GFS Fcst WVMR (1000 mb) Sep 25, 2006 16Z to Sep 26, 2006 0Z
m Inus NOAA-18 Test RODF (A10) Water Vapor (1000 mb) Sep 25, 2006 16Z to Sep 26, 2006 0Z



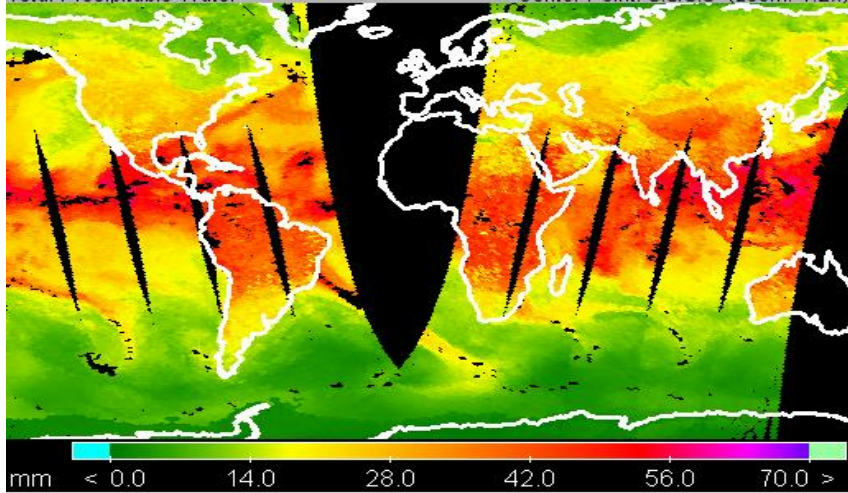
ATOVS NOAA-18 RODF (X1) Sep 25, 2006 16Z to Sep 26, 2006 0Z
1st Guess WVapor (1000 mb) Center Point: 0,0/0,0 (zoom: 1.2x)



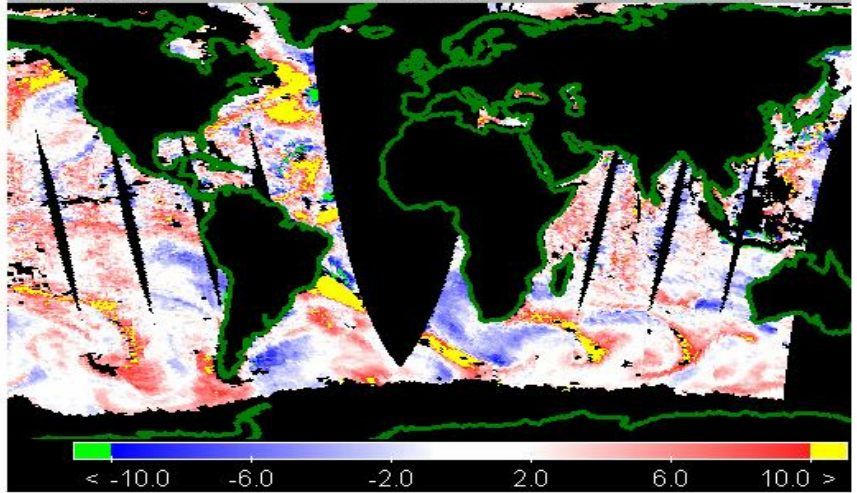
ATOVS NOAA-18 RODF (X1) Sep 25, 2006 16Z to Sep 26, 2006 0Z
GFS Fcst WVMR (1000 mb) Center Point: 0,0/0,0 (zoom: 1.2x)



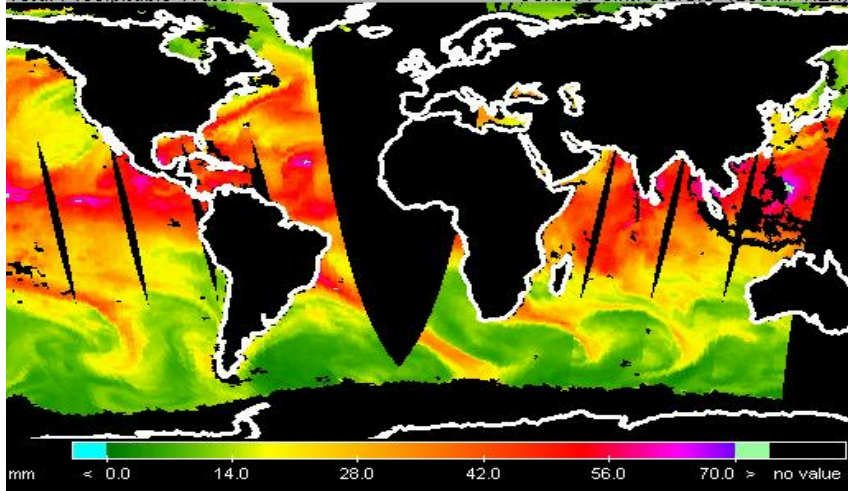
NOAA-18 Test RODF (A10) Sep 25, 2006 16Z to Sep 26, 2006 0Z
Total Precipitable Water Center Point: 0.0/0.0 (zoom: 1.2x)



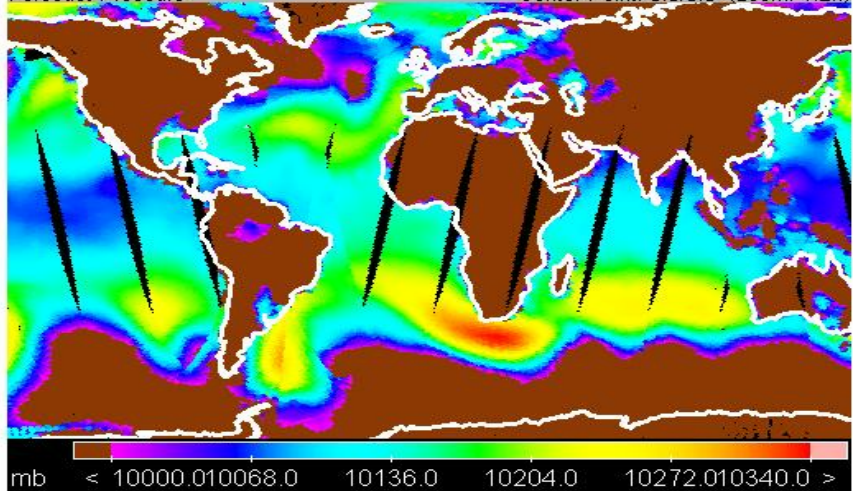
ATOVS AODF NOAA-18 (X2) Total Precipitable Water Sep 25, 2006 16Z to Sep 26, 2006 5Z
m Inus NOAA-18 Test RODF (A10) Total Precipitable Water Sep 25, 2006 16Z to Sep 26, 2006 5Z



ATOVS AODF NOAA-18 (X2) Sep 25, 2006 16Z to Sep 26, 2006 5Z
Total Precipitable Water Center Point: 0.0/0.0 (zoom: 1.2x)



ATOVS NOAA-18 RODF (X1) Sep 25, 2006 16Z to Sep 26, 2006 5Z
Forecast Pressure Center Point: 0.0/0.0 (zoom: 1.2x)



Potential Ground Sites



The NVAP dataset is a widely-used, global, daily, 1-degree resolution blended product suitable for studies of water vapor in the climate system (Randel et al, 1996; Simpson et al, 2001). NVAP contains layered water vapor fields as well as TPW fields. NVAP has layered precipitable water at 1000-700, 700 – 500, 500 – 300 and above 300 hPa.

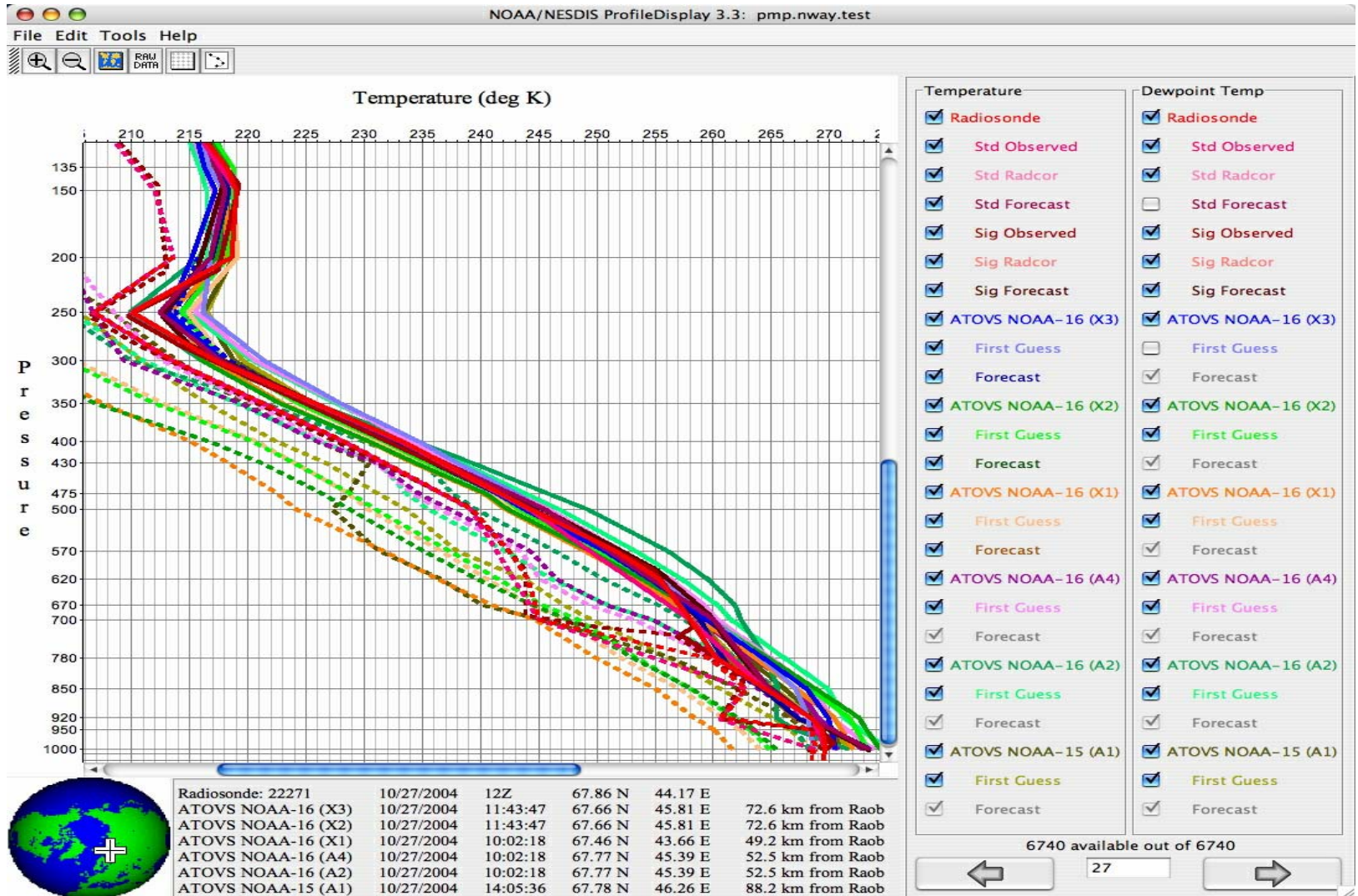
NVAP was constructed by blending observations from radiosondes, satellite sounder instruments (NOAA TIROS Operational Vertical Sounder (TOVS, or ATOVS after 1998)), and passive microwave radiometers (Special Sensor Microwave / Imager (SSM/I)). The TRMM Microwave Imager (TMI) was used for 2000-2001. Retrievals are performed on each dataset, and the results are then blended together to create a global merged field. NVAP currently covers the time period 1988 – 2001. Our goal in the creation of the global NVAP dataset to compare with AIRS is to achieve a product which mimics a withdrawal of the NVAP data from the NASA DAAC, as if it existed in 2003-2004.

NVAP data for 1988-2001 is available from the NASA Langley DAAC at:
http://eosweb.larc.nasa.gov/PRODOCS/nvap/table_nvap.html.

The comparison of TPW indicates that the ATOVS TPW field is an outlier from the other datasets. These results make it questionable whether the ATOVS sounding product should be used in climate studies. The ATOVS sounding product has historically been used in NVAP production, in particular to provide soundings over land and provide vertical structure.

AIRS validation and reprocessing is an ongoing process, so results from this study must be viewed in that light. As AIRS validation increases in maturity, it can be used in scientific data stewardship studies with greater confidence in the AIRS products.

Compare individual profiles from *Radiosonde*, *Satellite* and *NWP* platforms (PDISP)



MSOffice1 The slide illustrates the multiple profiles from different satellite product systems, for example, operational and test systems for NOAA-16, NOAA-15 and various NWP profiles that were appended to the satellite products data record during orbital processing, capable of being collocated with and evaluated against radiosonde observations.

Solid curves indicate temperature and dashed curves moisture profiles respectively.

Each profile source is color coded based on the legend on the right.

The file contains over 6700 collocations compiled over an approximate 30 day period, and available for statistical evaluations as shown in the next slide.

ORA, 12/14/2004

ARM Site Satellite Overpass Dedicated Radiosondes for FY2007

Draft recommendation letter, 3 August 2006

In the past several years, NASA has funded DoE's Atmospheric Radiation Measurement (ARM) program to provide special radiosonde launches which are coincident with EOS Aqua overpasses of the primary ARM sites (SGP, TWP and NSA). This has been a scientifically productive interagency cooperation. Due to the high accuracy requirements of atmospheric soundings from AIRS, such data is required for detailed and critical assessments of the satellite products. Examples of resulting work include the use of clear sky ensembles for radiative transfer model development and validation (Strow et al. 2006), assessment of upper level water vapor measurement accuracy (Miloshevich et al. 2006; Whiteman et al., 2006), and temperature and water vapor retrieval validation (Tobin et al. 2006). Making use of the ARM site facilities, previous studies to characterize the ARM measurements, and routine, on-going operations, the ARM site efforts are a cost effective and fundamental part of the EOS validation program. While other validation datasets provide complimentary information for satellite validation studies, the ARM site products are considered the "gold standard" for this work. The level of coincidence achieved markedly exceeds past efforts at this scale and quality. In addition to AIRS, the ARM site radiosondes have also been useful for Aqua MODIS and Aura TES studies.

To enable the development of long term and well-characterized Earth Science Data Records, we recommend that NASA support for these ARM site efforts continue. Specifically, we recommend that the same level of effort from the previous two years (i.e. 2 phases of radiosonde launches from each of the three primary ARM sites) be continued for FY2007. Considering inputs from all interested parties, a consensus plan will be developed in the near future detailing the timing and level of effort at each ARM site. In the future, we also recommend that these efforts be extended to include the advanced sounders IASI on METOP and CrIS on NPP and NPOESS; discussions with the NPP and IPO programs should be pursued to facilitate this.

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George Aumann, JPL

Tony Clough, AER (representing TES)

To: jimmy.voyles@arm.gov
Subject: A modest proposal...

Hi Jimmy,

Dan Rusk, Luci Walker, and I have been tracking down the source of 144 'extra' radiosondes that are at SGP. Luci has discovered that these were ordered for last year's AIRS experiment, but not delivered until afterwards. Because they were marked 'For AIRS' they were not included in our estimates of sondes needed for operations next year. Apparently we supported AIRS with sondes we already had in stock so, in a sense, these are extras. We could use them to offset future operational needs, but I was thinking that perhaps a better use might be to start a 'pilot' IOP to help Tony Reale at NOAA. As you certainly know by now, Rick Wegener has decided that the added cost of processing the NOAA satellite data that Tony has found for us would not offset the savings of cutting the SeaSpace contract and doing the extra soundings that Tony had requested.

Maybe we could use a few of these extra sondes and start a one-per-day extra sounding to match Tony's needs at the SGP only as a kind of demonstration. If he is happy with the result, perhaps we could then get support for a wider program. As you will recall, Tony was one of the more vocal ACRF supporters at the Seattle GCOS workshop.

Anyway, I don't have a personal stake, I just think it might be good for the program and wanted to mention it. Whatever you guys decide is of course fine with me. It seems that this would be less of a cold and complete turn down to Tony - that's all.

Best, Barry
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N P O E S S

VIIRS - vis/IR imager
CMIS - μ wave imager
CrIS - IR sounder
ATMS - μ wave sounder
SESS - space environment
OMPS - ozone
ADCS - data collection










SARSAT - search & rescue
APS - aerosol polarimeter
ERBS - Earth radiation
budget
SS - laser sensor
ALT - altimeter
TSIS - solar irradiance



NPOESS EDR-to-Sensor Mapping

55 Product Sets [EDR, RDR, SDR]

☆ Atmospheric Vertical Moisture Profile	Cloud Top Pressure	Precipitable Water
☆ Atmospheric Vertical Temp Profile	Cloud Top Temperature	Precipitation Type/Rate
☆ Imagery	Downward Longwave Radiance <i>(sfc)</i>	Pressure (Surface/Profile)
☆ Sea Surface Temperature	Downward Shortwave Radiance _(sfc)	Sea Ice Characterization
☆ Sea Surface Winds	Electric Field	Sea Surface Height/Topography
☆ Soil Moisture	Electron Density Profile	Snow Cover/Depth
Aerosol Optical Thickness	Energetic Ions	Solar Irradiance
Aerosol Particle Size	Geomagnetic Field	Supra-Thermal-Auroral Particles
Aerosol Refractive Index	Ice Surface Temperature	Surface Type
Albedo (Surface)	In-situ Plasma Fluctuations	Wind Stress
Auroral Boundary	In-situ Plasma Temperature	Suspended Matter
Auroral Energy Deposition	Ionospheric Scintillation	Total Water Content
Auroral Imagery	Medium Energy Charged Particles	Vegetation Index
Cloud Base Height	Land Surface Temperature	
Cloud Cover/Layers	Net Heat Flux	
Cloud Effective Particle Size	Net Solar Radiation (TOA)	
Cloud Ice Water Path	Neutral Density Profile	
Cloud Liquid Water	Color/Chlorophyll	
Cloud Optical Thickness	Ocean Wave Characteristics	
Cloud Particle Size/Distribution	Outgoing Longwave Radiation (TOA)	
Cloud Top Height	Ozone - Total Column/Profile	

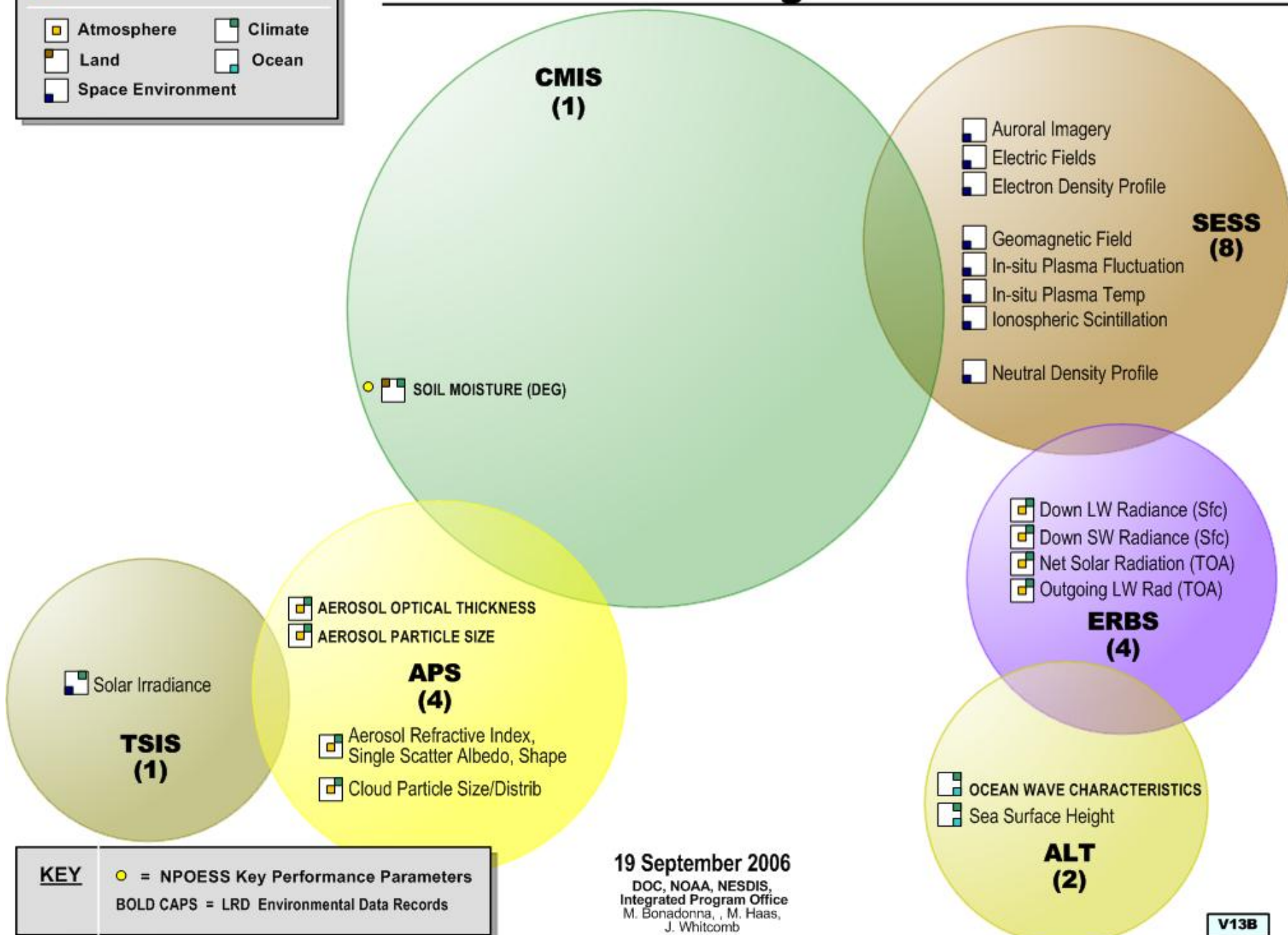
	VIIRS (23)
	CMIS (19)
	CrIS/ATMS (3)
	OMPS (1)
	SES (13)
	ERBS (5)
	TSIS (1)
	ALTIMETER (3)
	APS (4)

☆ Environmental Data Records (EDRs) with Key Performance Parameters


NPOESS Certified Program – Demanifested EDRs

MISSION AREAS

 Atmosphere	 Climate
 Land	 Ocean
 Space Environment	



KEY

-  = NPOESS Key Performance Parameters
- BOLD CAPS** = LRD Environmental Data Records

19 September 2006
 DOC, NOAA, NESDIS,
 Integrated Program Office
 M. Bonadonna, M. Haas,
 J. Whitcomb

(Deg indicates degraded performance)