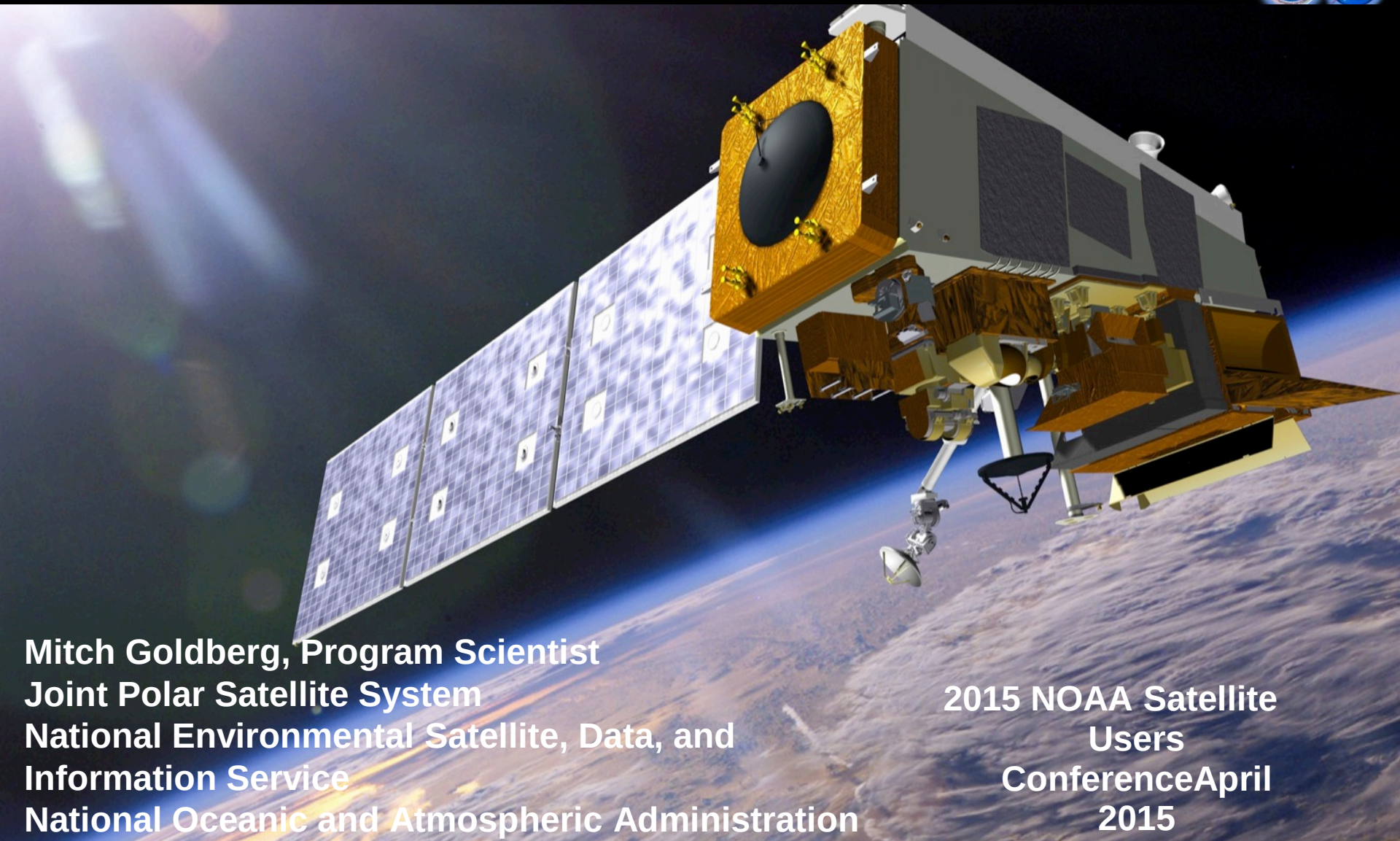
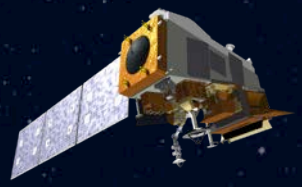
CriS and ATMS Applications



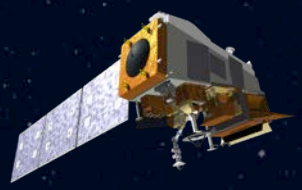
Mitch Goldberg, Program Scientist
Joint Polar Satellite System
National Environmental Satellite, Data, and Information Service
National Oceanic and Atmospheric Administration

2015 NOAA Satellite Users ConferenceApril 2015



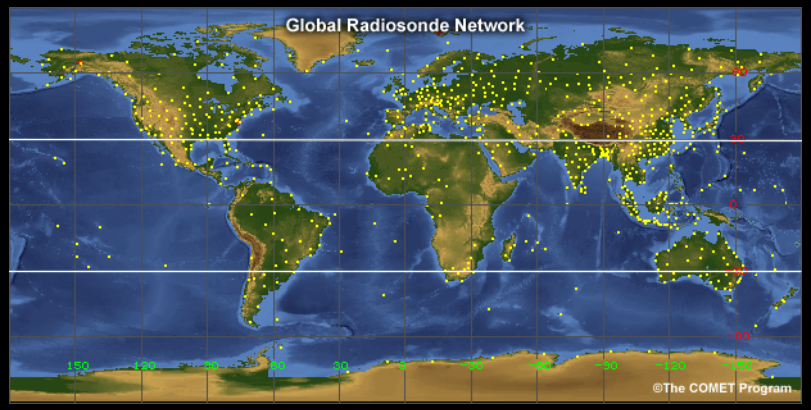
Topics

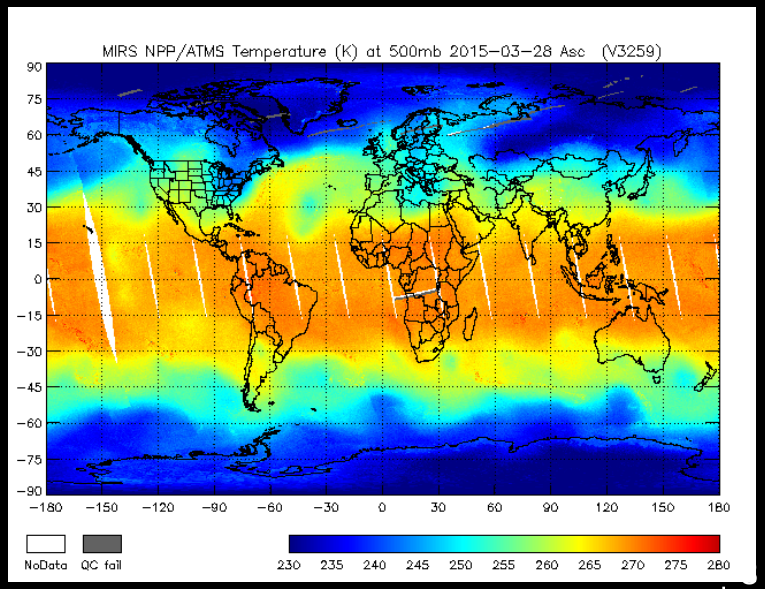
- What is a sounder?
- Overview of ATMS and CrIS Instruments
- Instrument Performance
- Products
- Applications



Sounder -Background

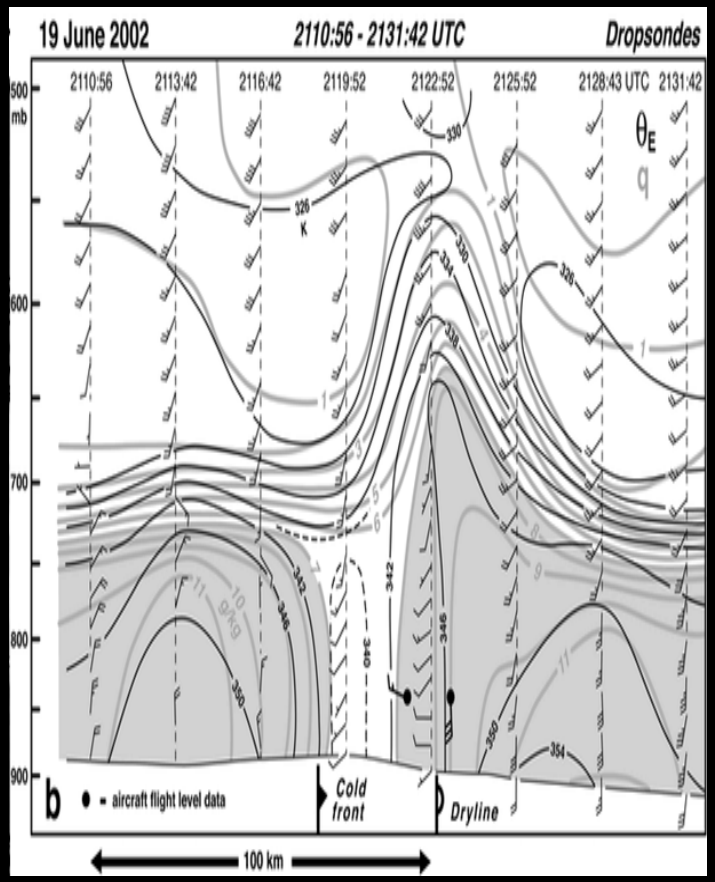
- The key observables for weather forecasting are atmospheric temperature, water vapor, pressure and wind profiles.
- In early 20th century a global coordinated effort initiated the radiosonde weather balloon network.
- Satellite were developed to cover the entire globe with sounding information

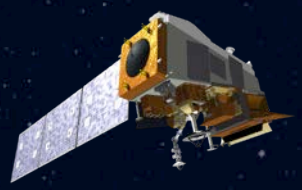




Meteorology 101

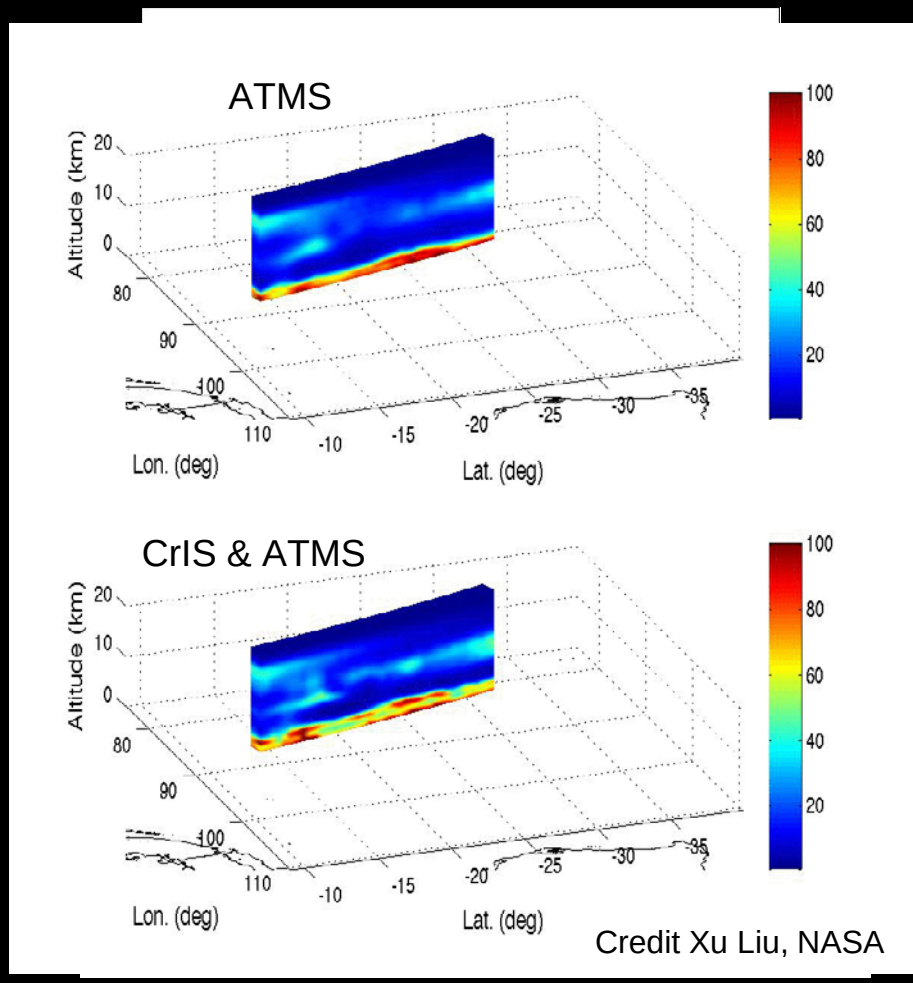
- Vertical distribution of temperature and water vapor drives weather patterns because their gradients drives atmospheric motion influences all weather conditions



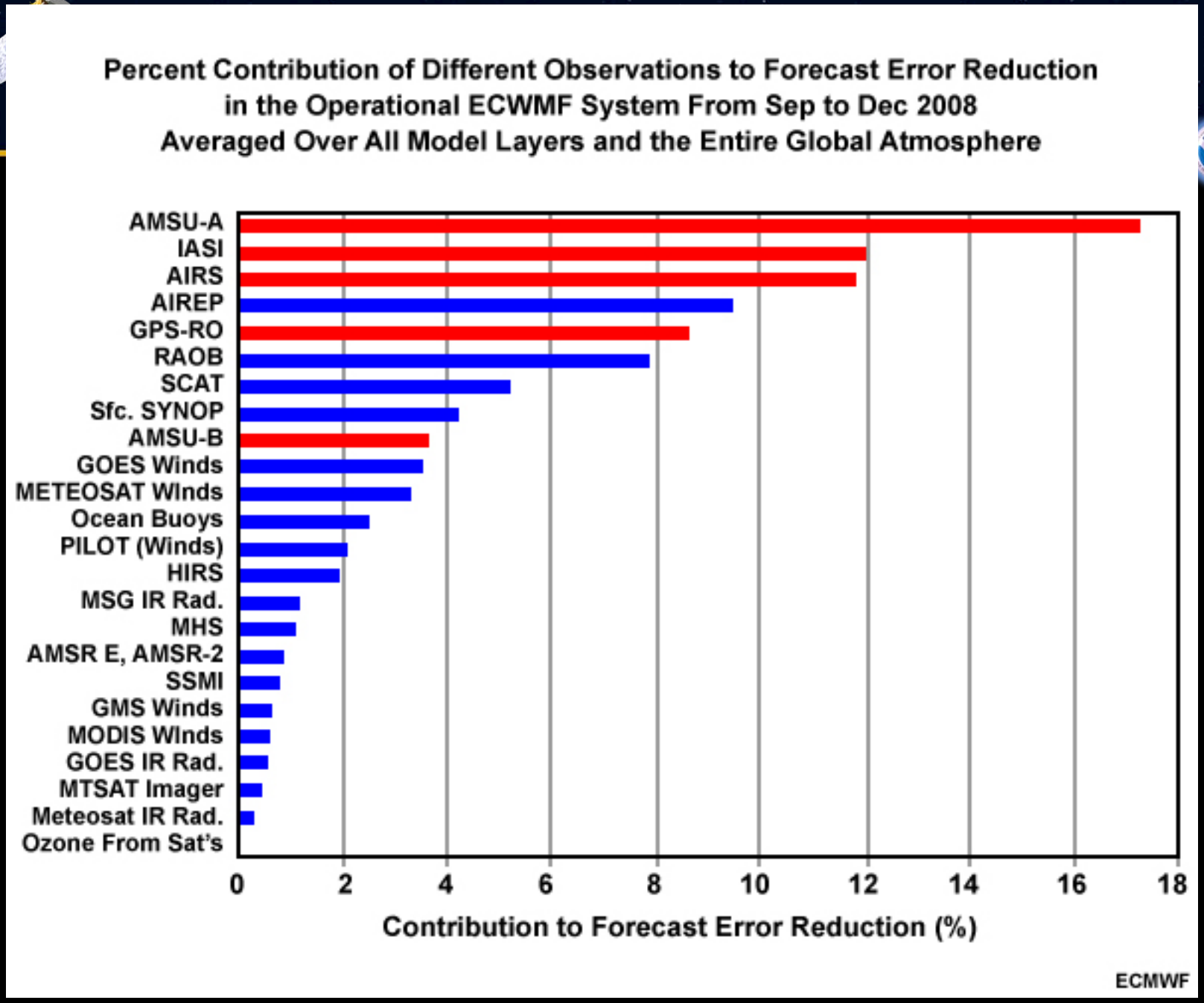


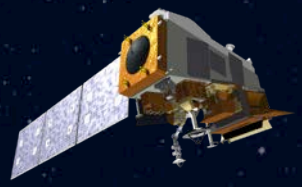
Temperature and Water Vapor Soundings from Satellites

- Satellite observes outgoing radiation from the Earth's surface and atmosphere
- For temperature, we use the infrared and microwave part of the outgoing radiation because in this region there is absorption of radiation due to relatively fixed gases – CO2 (infrared) and O2 (microwave)
- For water vapor, there are H2O absorption lines in both infrared and microwave
- In the infrared there are more absorption lines providing higher vertical resolution but is impacted by clouds.
- In the microwave the spectral resolution is coarser resulting in poorer vertical resolution but not impacted to clouds, except for precipitation



Credit Xu Liu, NASA

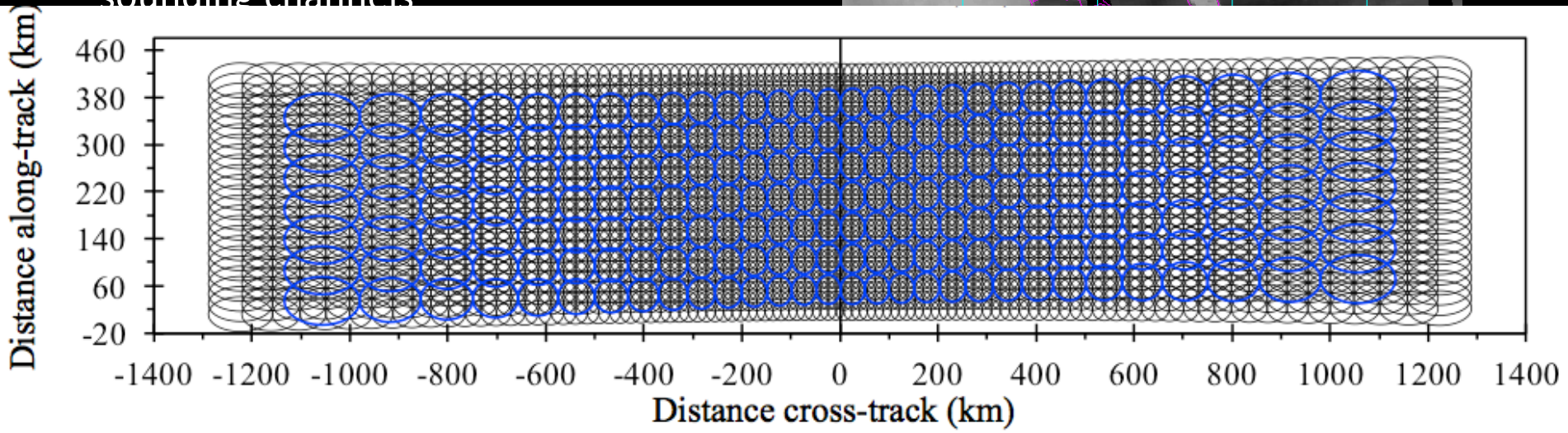

Percent Contribution of Different Observations to Forecast Error Reduction
in the Operational ECWMF System From Sep to Dec 2008
Averaged Over All Model Layers and the Entire Global Atmosphere
AMSU-A
IASI
AIRS
AIREP
GPS-RO
RAOB
SCAT
Sfc. SYNOP
AMSU-B
GOES Winds
METEOSAT Winds
Ocean Buoys
PILOT (Winds)
HIRS
MSG IR Rad.
MHS
AMSR E, AMSR-2
SSMI
GMS Winds
MODIS Winds
GOES IR Rad.
MTSAT Imager
Meteosat IR Rad.
Ozone From Sat's
0
2
4
6
8
10
12
14
16
18
Contribution to Forecast Error Reduction (%)
ECMWF



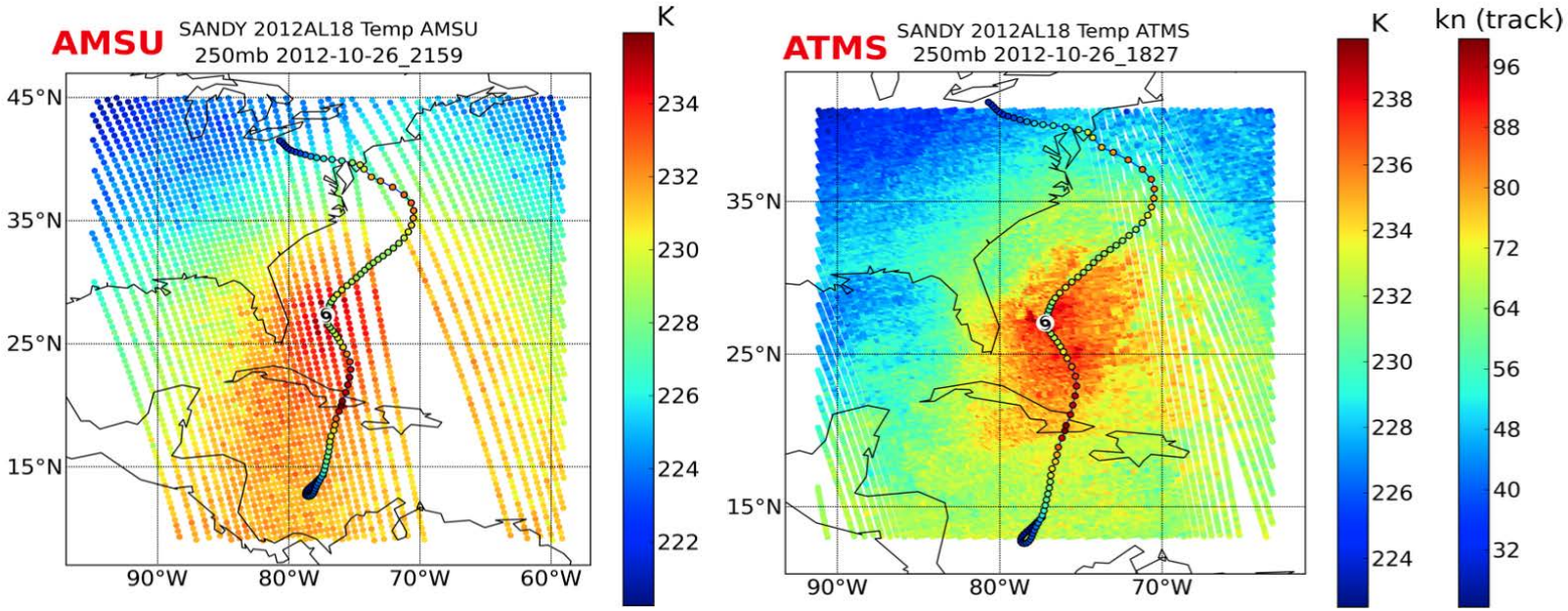
ATMS - Advanced Technology Microwave Sounder

Advanced Features

- Three instruments (AMSU-A1, AMSU-A2 and MHS) in one instrument – less power and weight
- Better spatial resolution (~48 to 32 km) for key temperature sounding channels



Resolution: ATMS vs AMSU



ATMS:

- higher resolution
- wider swath
- much smaller gaps between passes

- Increased horizontal resolution potentially beneficial for high gradient phenomena (such as hurricanes)

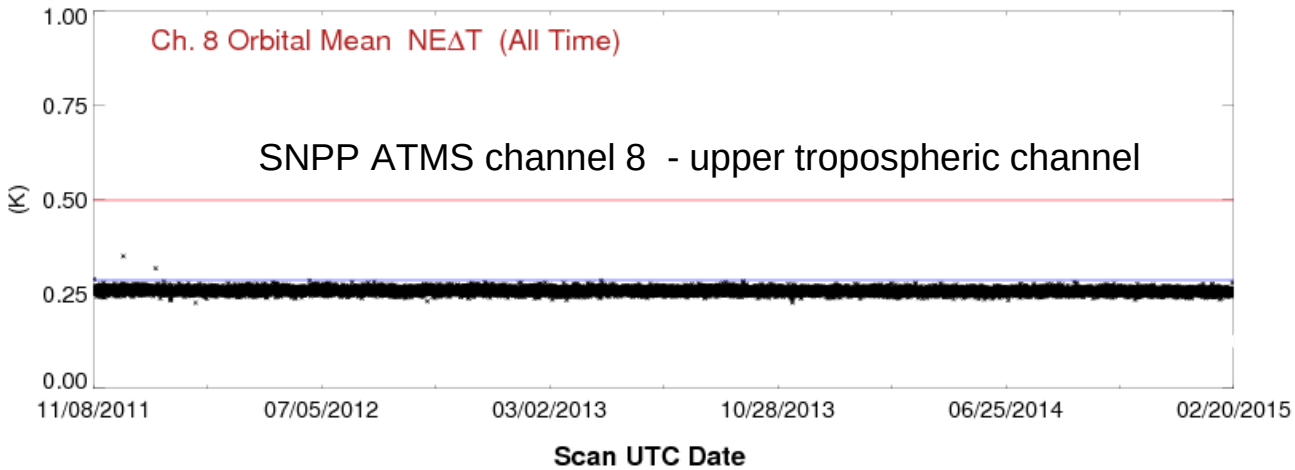
Spectral Differences: ATMS vs. AMSU/MHS

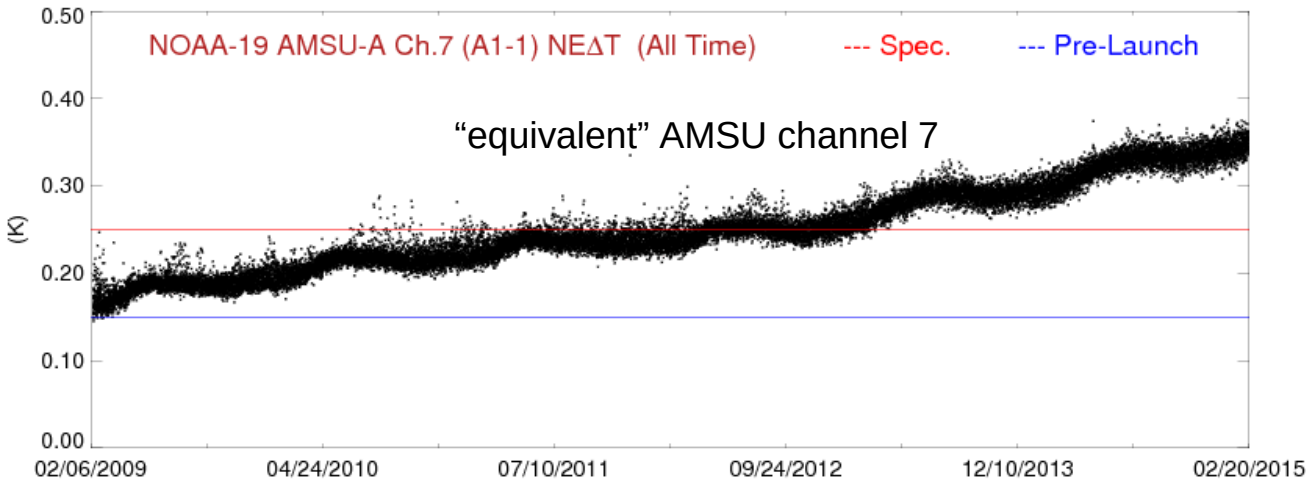
	AMSU/MHS			ATMS		
	Ch	GHz	Pol	Ch	GHz	Pol
AMSU-A	1	23.8	QV	1	23.8	QV
	2	31.399	QV	2	31.4	QV
	3	50.299	QV	3	50.3	QH
				4	51.76	QH
	4	52.8	QV	5	52.8	QH
	5	53.595 ± 0.115	QH	6	53.596 ± 0.115	QH
	6	54.4	QH	7	54.4	QH
	7	54.94	QV	8	54.94	QH
	8	55.5	QH	9	55.5	QH
	9	fo = 57.29	QH	10	fo = 57.29	QH
	10	fo ± 0.217	QH	11	fo±0.3222±0.217	QH
	11	fo±0.3222±0.048	QH	12	fo± 0.3222±0.048	QH
	12	fo ±0.3222±0.022	QH	13	fo±0.3222±0.022	QH
	13	fo± 0.3222±0.010	QH	14	fo±0.3222 ±0.010	QH
	14	fo±0.3222±0.0045	QH	15	fo± 0.3222±0.0045	QH
MHS	15	89.0	QV			
	16	89.0	QV	16	88.2	QV
	17	157.0	QV	17	165.5	QH
	18	183.31 ± 1	QH	18	183.31 ± 7	QH
	19	183.31 ± 3	QH	19	183.31 ± 4.5	QH
	20	191.31	QV	20	183.31 ± 3	QH
				21	183.31 ± 1.8	QH
				22	183.31 ± 1	QH

- **ATMS has 22 channels and AMSU/MHS have 20, with polarization differences between some channels**
  - **QV = Quasi-vertical; polarization vector is parallel to the scan plane at nadir**
  - **QH = Quasi-horizontal; polarization vector is perpendicular to the scan plane at nadir**

- Exact match to AMSU/MHS
- Only Polarization different
- Unique Passband
- Unique Passband, and Pol. different from closest AMSU/MHS channels

ATMS is outperforming AMSU in noise and long-term stability

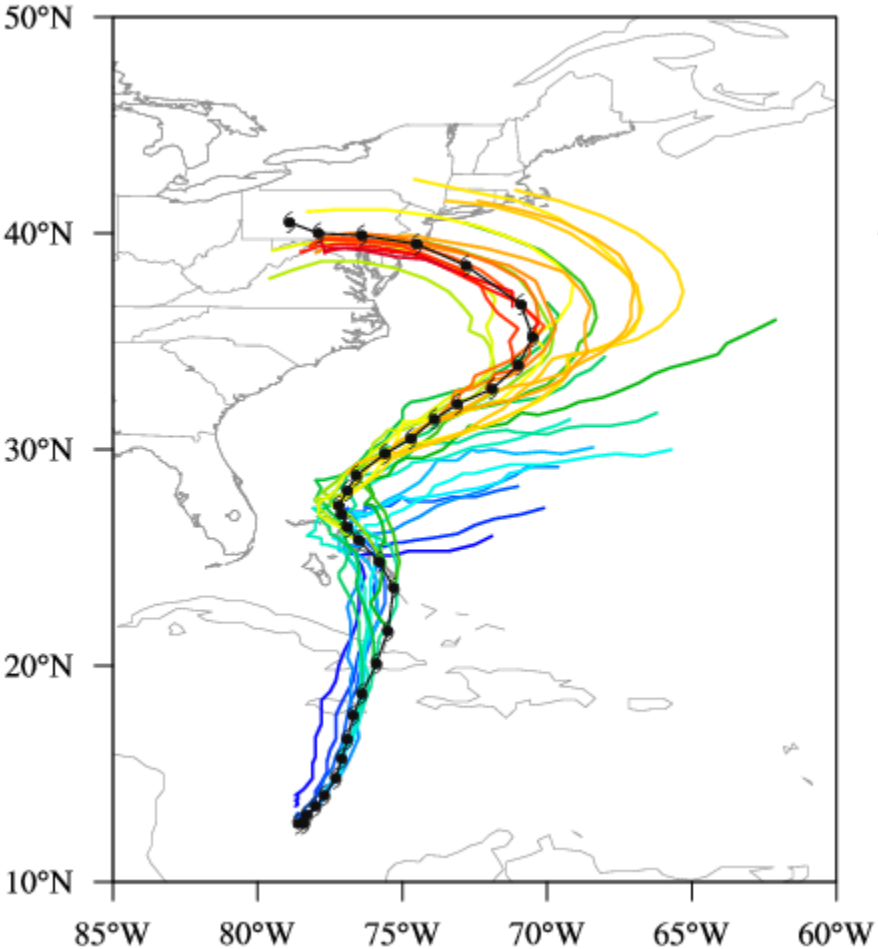




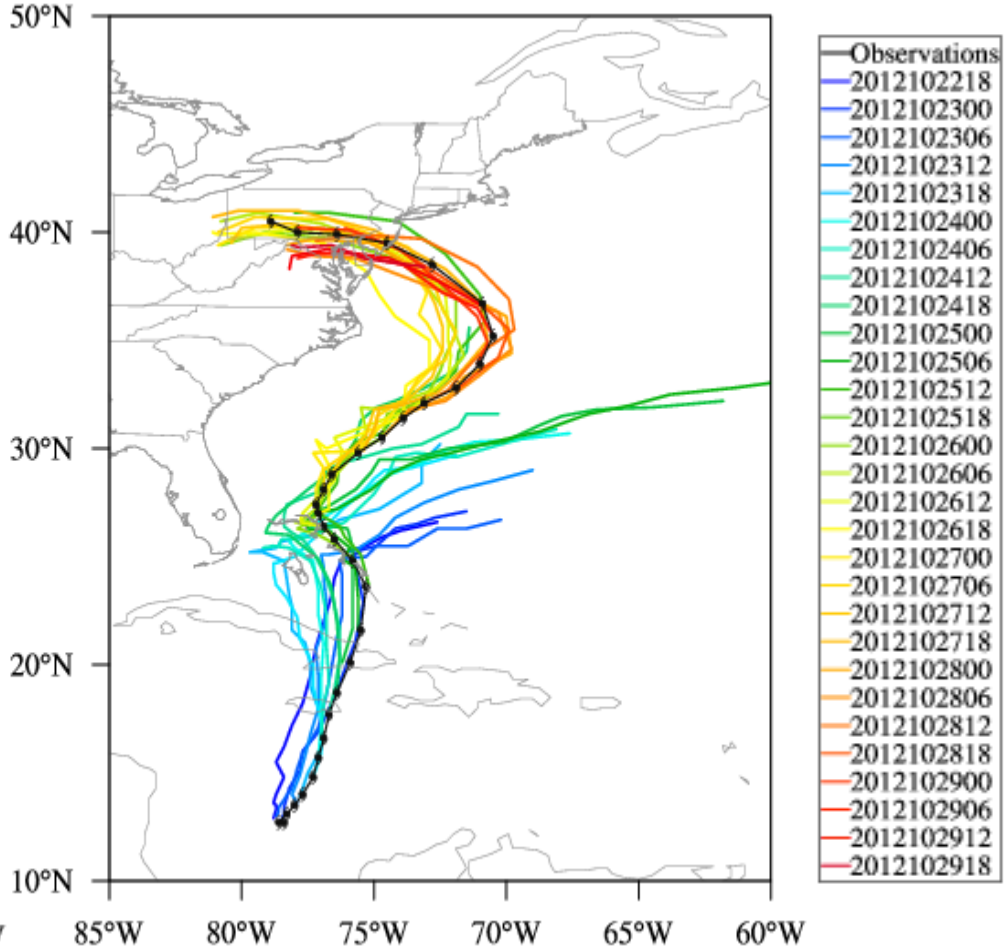
Direct Assimilation of ATMS into Models

Experimental results showing improvements in Sandy track forecasts from Hurricane Weather Research Forecast model with ATMS

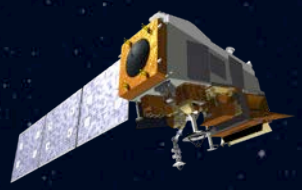
HWRF-NCEP Operational



Modified HWRF-NCEP with ATMS



Thanks to Fuzhong Weng



S-NPP and JPSS Data Products

VIIRS (24)
ALBEDO (SURFACE)
CLOUD BASE HEIGHT
CLOUD COVER/LAYERS
CLOUD EFFECTIVE PART SIZE
CLOUD OPTICAL THICKNESS
CLOUD TOP HEIGHT
CLOUD TOP PRESSURE
CLOUD TOP TEMPERATURE
ICE SURFACE TEMPERATURE
OCEAN COLOR/CHLOROPHYLL
SUSPENDED MATTER
VEGETATION INDEX, FRACTION, HEALTH
AEROSOL OPTICAL THICKNESS
AEROSOL PARTICLE SIZE
ACTIVE FIRES
POLAR WINDS
IMAGERY
SEA ICE CHARACTERIZATION
SNOW COVER
SEA SURFACE TEMPERATURE
LAND SURFACE TEMP
SURFACE TYPE

CrIS/ATMS (3)
ATM VERT MOIST PROFILE
ATM VERT TEMP PROFILE
CARBON (CO2, CH4, CO)
OUTGOING LONGWAVE RADIATION

OMPS (2)
O_3 TOTAL COLUMN
O_3 NADIR PROFILE
SO2 and Aerosol Index

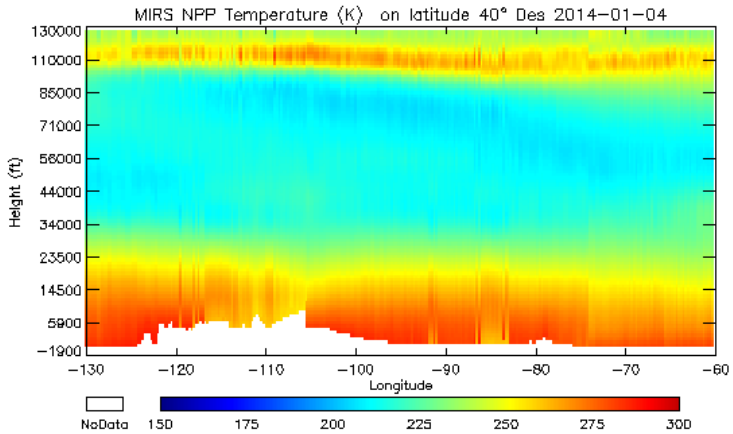
ATMS (11)
CLOUD LIQUID WATER
PRECIPITATION RATE
PRECIPITABLE WATER
LAND SURFACE EMISSIVITY
ICE WATER PATH
LAND SURFACE TEMPERATURE
SEA ICE CONCENTRATION
SNOW COVER
SNOW WATER EQUIVALENT
ATM TEMPERATURE PROFILE
ATM MOISTURE PROFILE

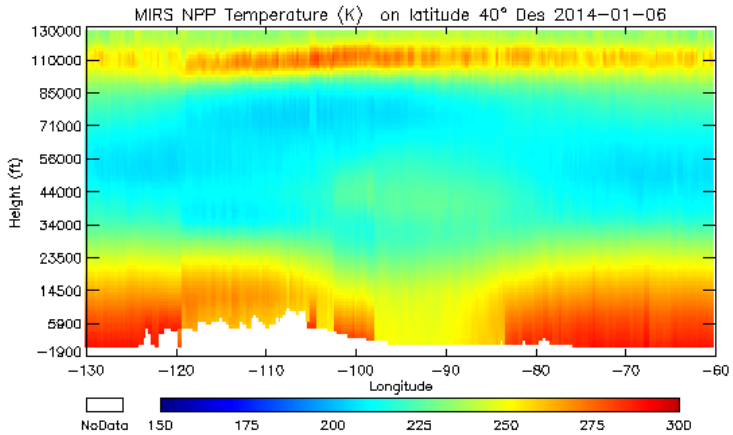
GCOM AMSR-2 (11)
CLOUD LIQUID WATER
PRECIPITATION TYPE/RATE
PRECIPITABLE WATER
SEA SURFACE WINDS SPEED
SOIL MOISTURE
SNOW WATER EQUIVALENT
IMAGERY
SEA ICE CHARACTERIZATION
SNOW COVER/DEPTH
SEA SURFACE TEMPERATURE
SURFACE TYPE

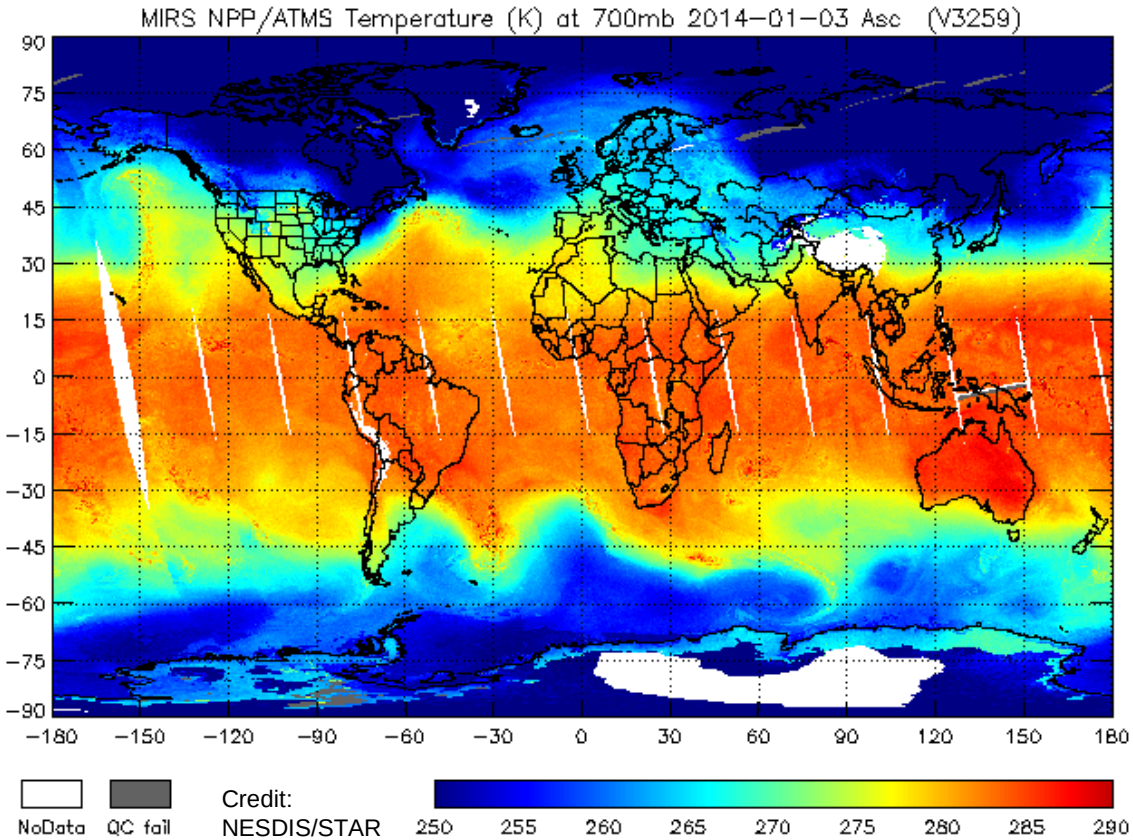
CERES(1)
RDRs

Data available through PDA , CLASS, and Direct Readout

January 2014



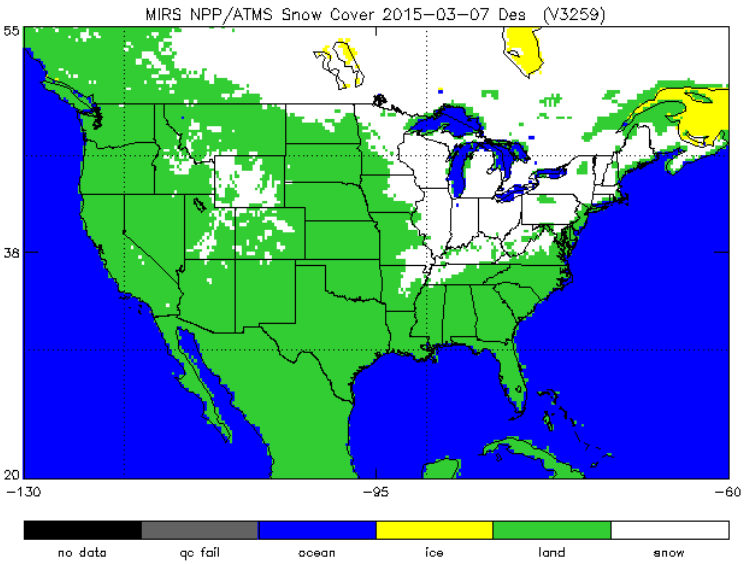


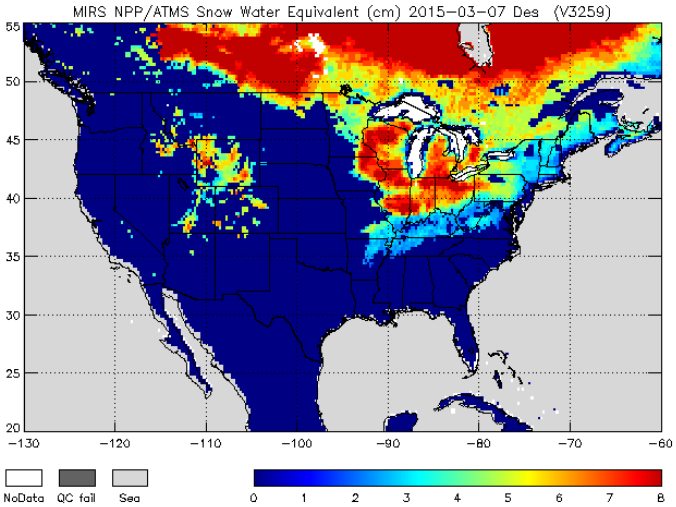


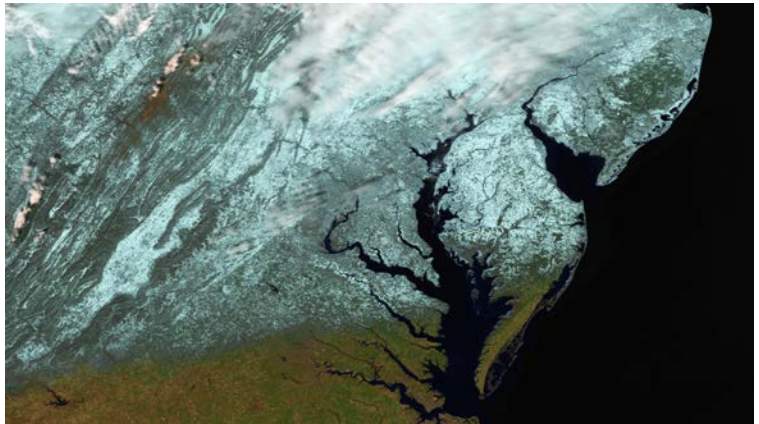
ATMS penetration of clouds reveals the transport of the Polar Vortex that impacted the US with large swath of record cold temperatures. The peak for DC area was 1/7/14. Above left are vertical cross-sections of temperature comparing January 4 with January 6, showing normal air temperature at ~ 23000 feet (-45 to -10 F, Winter) reached the surface on 1/6/14.

ATMS EDRs supports hydrological applications

- **Precipitable water & cloud liquid water**
- **Precipitation type and rate**
- **Snow cover and sea ice characterization**
- **Snow water equivalent**
- **Land surface temperature**
- **Land/Surface type**

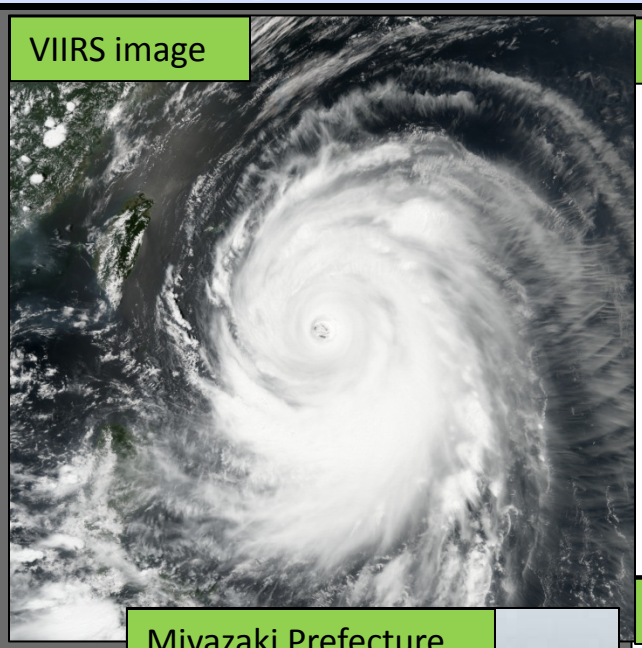




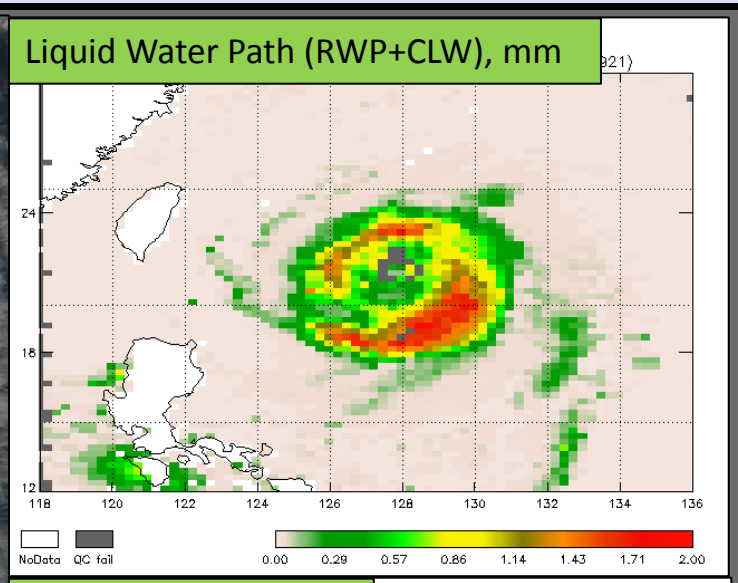


MiRS V11 Rainfall: Typhoon Neoguri on 7 July 2014

VIIRS image



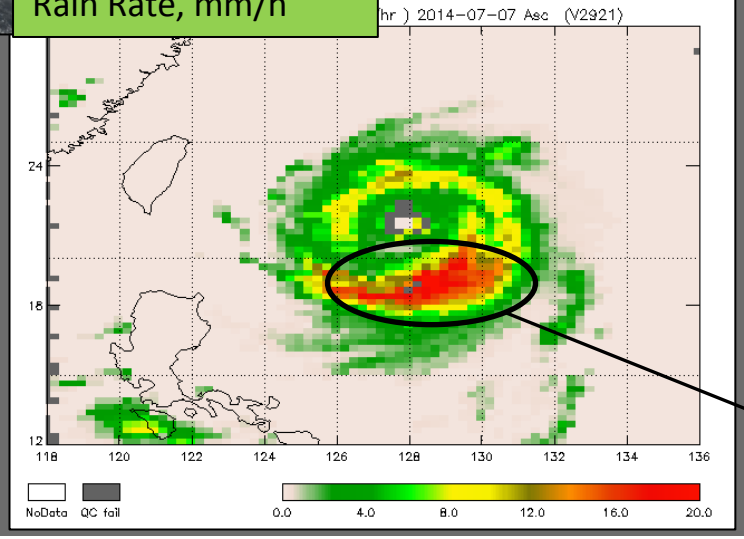
Liquid Water Path (RWP+CLW), mm



- SNPP/ATMS data
- Cyclone impacted Okinawa on 8 July

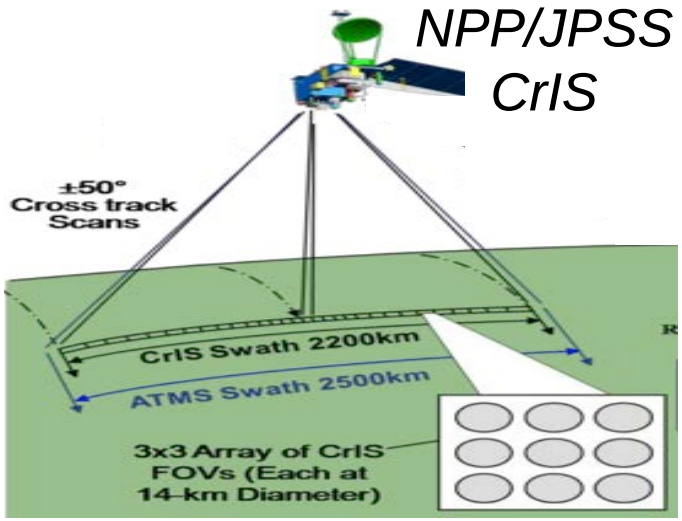
Miyazaki Prefecture

Rain Rate, mm/h

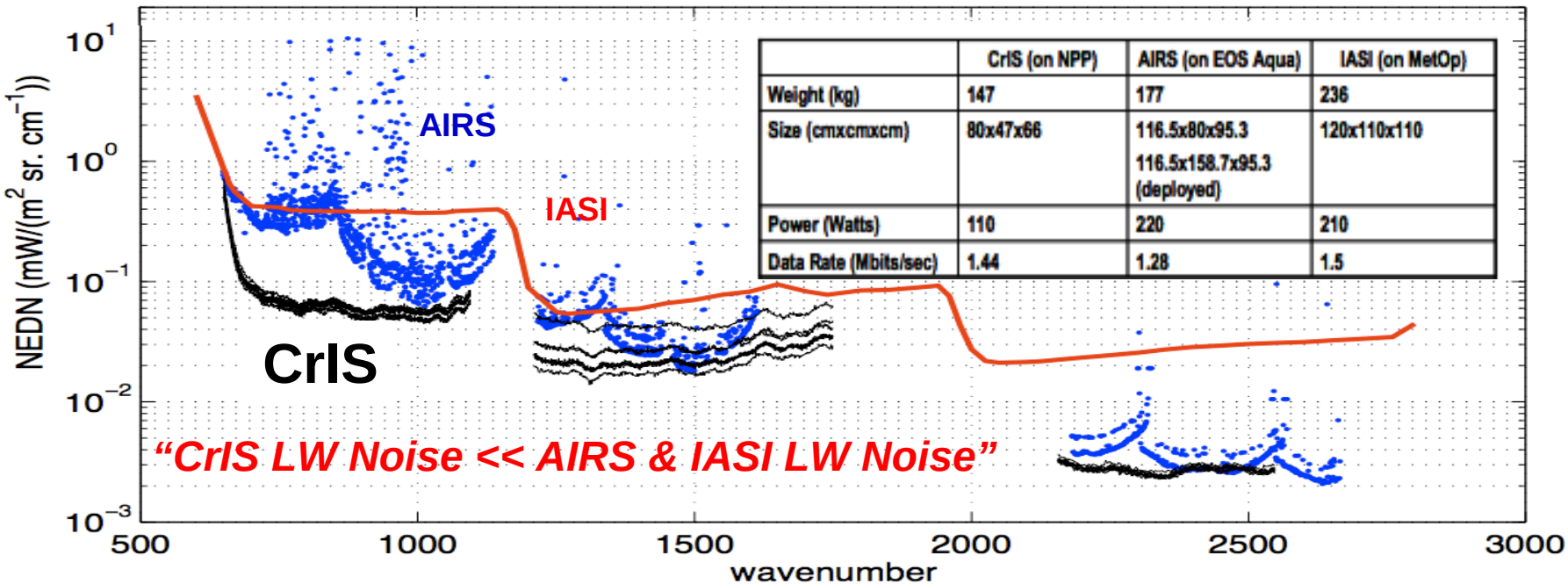


RR > 20 mm/h consistent with reports post-landfall (e.g. 340 mm in 24 h)

Cross-Track Infrared Sounder (CrIS)



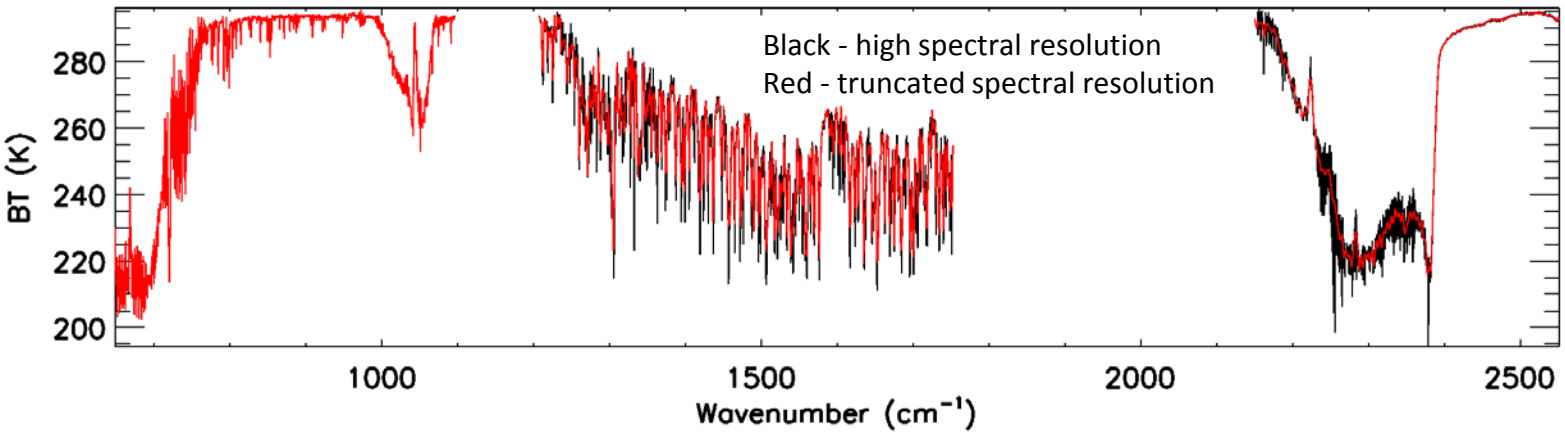
- Michelson Interferometer: 0.625,1.25, 2.5cm^{-1} (resolving power of 1000)
- Spectral range: 660-2600 cm^{-1}
- 3 x 3 HdCdTe focal plane passively cooled (4-stages) to 85K
- Focal plane 27 detectors, 1305 spectral channels
- 310 K Blackbody and space view provides radiometric calibration
- NEDT ranges from 0.05 K to 0. 5 K



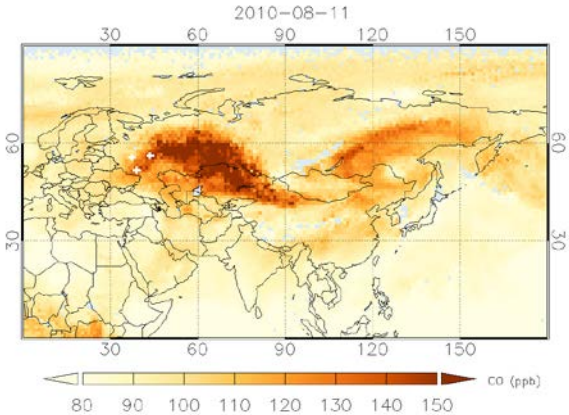
	CrIS (on NPP)	AIRS (on EOS Aqua)	IASI (on MetOp)
Weight (kg)	147	177	236
Size (cmxcmxcm)	80x47x66	116.5x80x95.3 116.5x158.7x95.3 (deployed)	120x110x110
Power (Watts)	110	220	210
Data Rate (Mbits/sec)	1.44	1.28	1.5

December 2014
CrIS Full Spectral Resolution

On 12/4/15 – full interferograms are now being transmitted from the SNPP instead of them being truncated on the spacecraft

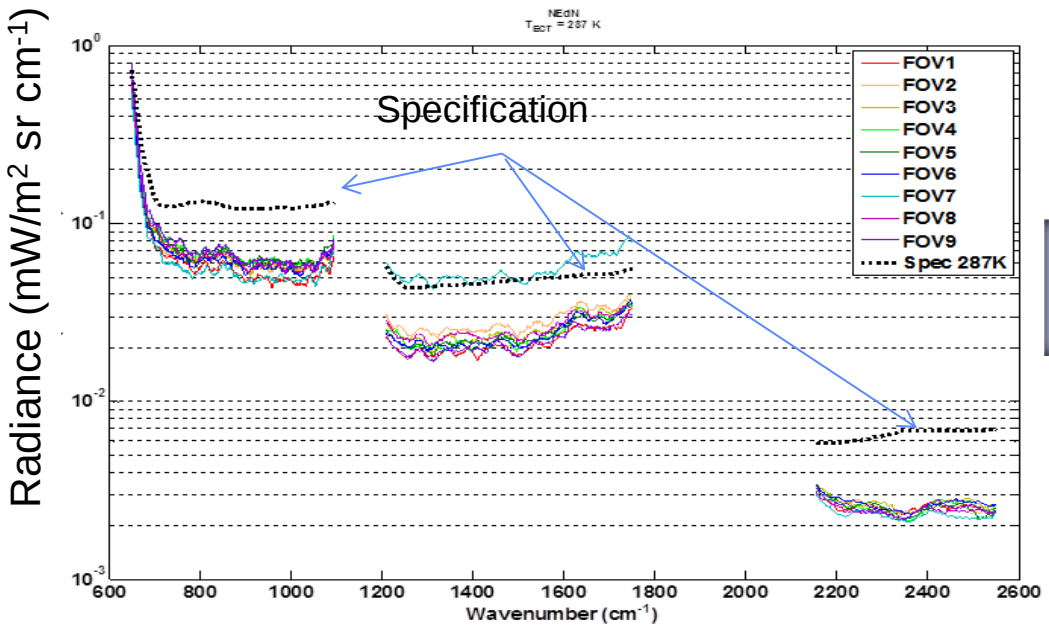


Benefit: higher spectral resolution in the water vapor IR band and in the shortwave IR band. CO requirements cannot be met without high spectral resolution. Higher spectral resolution water vapor spectral lines will improve water vapor soundings in upper troposphere.



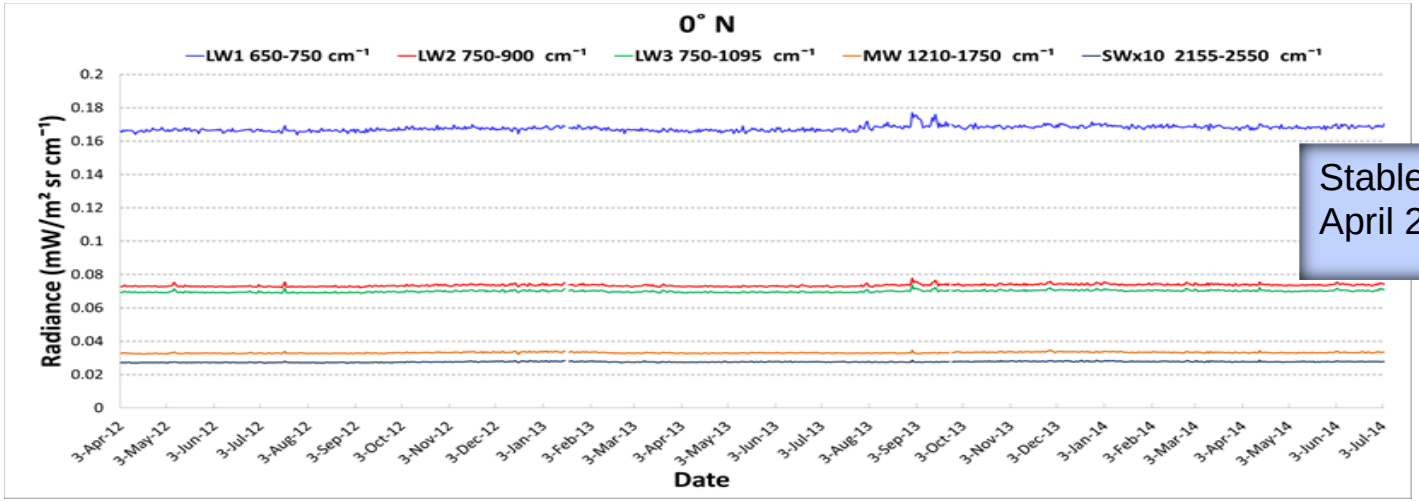
AIRS CO for 2010 Russian Fire, CRIS CO will have the same performance

CrIS Noise (NEdN)



The noise levels substantially better than specification

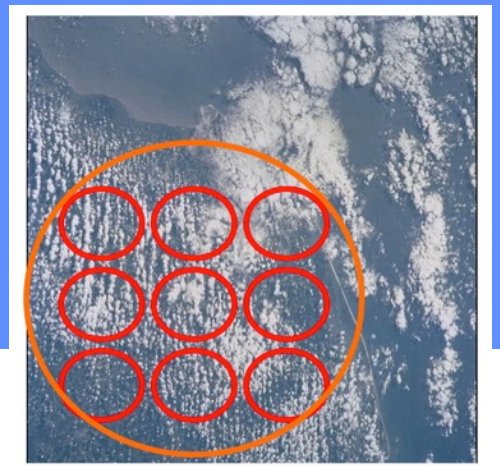
Credit: Yong Han (NOAA)



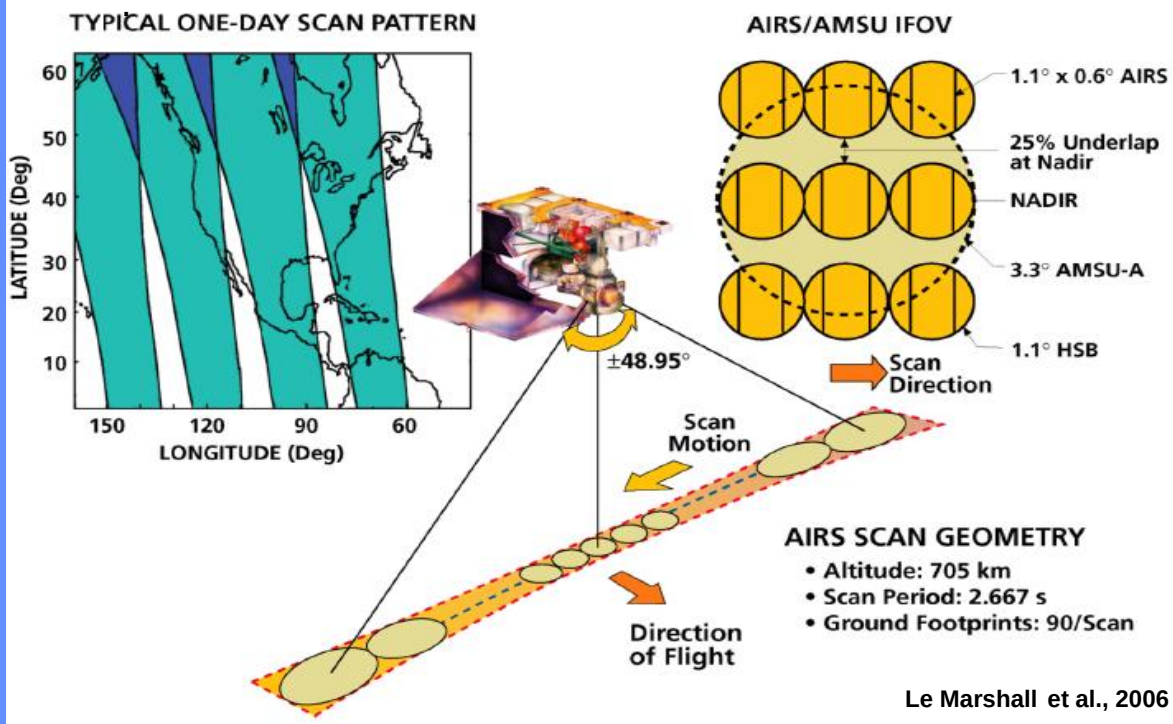
Stable NEdN
April 2012 to July 2014

Sounding Strategy in Cloudy Scenes

- Sounding is performed on 50 km a field of regard (FOR)
- FOR is currently defined by the size of the microwave sounder footprint
- IASI/AMSU has 4 IR FOV's per FOR
- AIRS/AMSU & CrIS/ATMS have 9 IR FOV's per FOR
- ATMS is spatially over-sampled can emulate an AMSU FOV

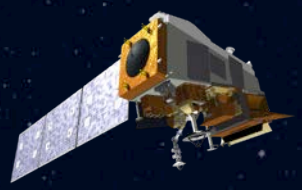


Co-locate infrared and microwave instruments



Le Marshall et al., 2006

AIRS, IASI, and CrIS all acquire 324,000 FOR's per day!



S-NPP and JPSS Data Products

VIIRS (24)
ALBEDO (SURFACE)
CLOUD BASE HEIGHT
CLOUD COVER/LAYERS
CLOUD EFFECTIVE PART SIZE
CLOUD OPTICAL THICKNESS
CLOUD TOP HEIGHT
CLOUD TOP PRESSURE
CLOUD TOP TEMPERATURE
ICE SURFACE TEMPERATURE
OCEAN COLOR/CHLOROPHYLL
SUSPENDED MATTER
VEGETATION INDEX, FRACTION, HEALTH
AEROSOL OPTICAL THICKNESS
AEROSOL PARTICLE SIZE
ACTIVE FIRES
POLAR WINDS
IMAGERY
SEA ICE CHARACTERIZATION
SNOW COVER
SEA SURFACE TEMPERATURE
LAND SURFACE TEMP
SURFACE TYPE

CrIS/ATMS (3)
ATM VERT MOIST PROFILE
ATM VERT TEMP PROFILE
CARBON (CO2, CH4, CO)
OUTGOING LONGWAVE RADIATION

OMPS (2)
O_3 TOTAL COLUMN
O_3 NADIR PROFILE
SO2 and Aerosol Index

ATMS (11)
CLOUD LIQUID WATER
PRECIPITATION RATE
PRECIPITABLE WATER
LAND SURFACE EMISSIVITY
ICE WATER PATH
LAND SURFACE TEMPERATURE
SEA ICE CONCENTRATION
SNOW COVER
SNOW WATER EQUIVALENT
ATM TEMPERATURE PROFILE
ATM MOISTURE PROFILE

CERES(1)
RDRs

GCOM AMSR-2 (11)
CLOUD LIQUID WATER
PRECIPITATION TYPE/RATE
PRECIPITABLE WATER
SEA SURFACE WINDS SPEED
SOIL MOISTURE
SNOW WATER EQUIVALENT
IMAGERY
SEA ICE CHARACTERIZATION
SNOW COVER/DEPTH
SEA SURFACE TEMPERATURE
SURFACE TYPE

Data available through PDA , CLASS, and Direct Readout

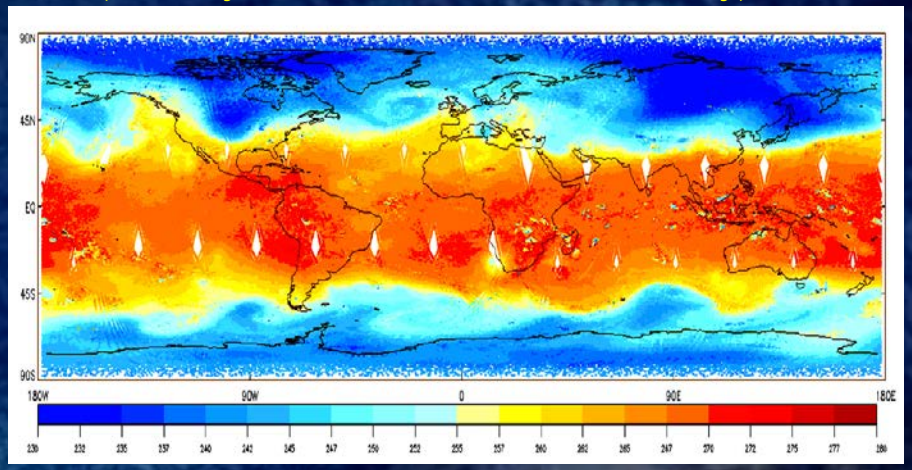
List of operational retrieval products

Credit: Gambacorta, Liu, Reale, Nalli, Barnet…..

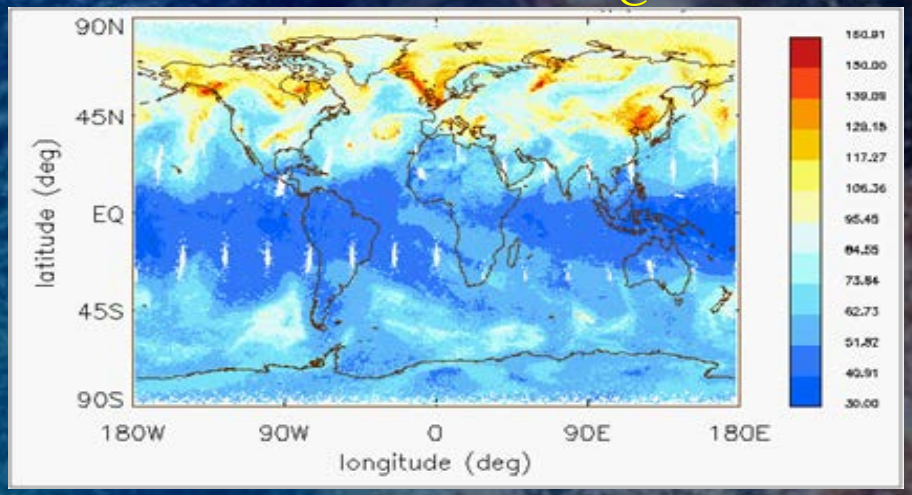
Retrieval Products

Cloud Cleared Radiances	660-750 cm-1 2200-2400 cm-1
Cloud fraction and Top Pressure	660-750 cm-1
Surface temperature	window
Temperature	660-750 cm-1 2200-2400 cm-1
Water Vapor	780 – 1090 cm-1 1200-1750 cm-1
O3	990 – 1070 cm-1
CO	2155 – 2220 cm-1
CH4	1220-1350 cm-1
CO2	660-760 cm-1
N2O	1290-1300cm-1 2190-2240cm-1
HNO3	760-1320cm-1
SO2	1343-1383cm-1

NUCAPS Temperature retrieval @ 500mb
(January 5th 2014 Polar Vortex Anomaly)



NUCAPS Ozone retrieval @ 500mb

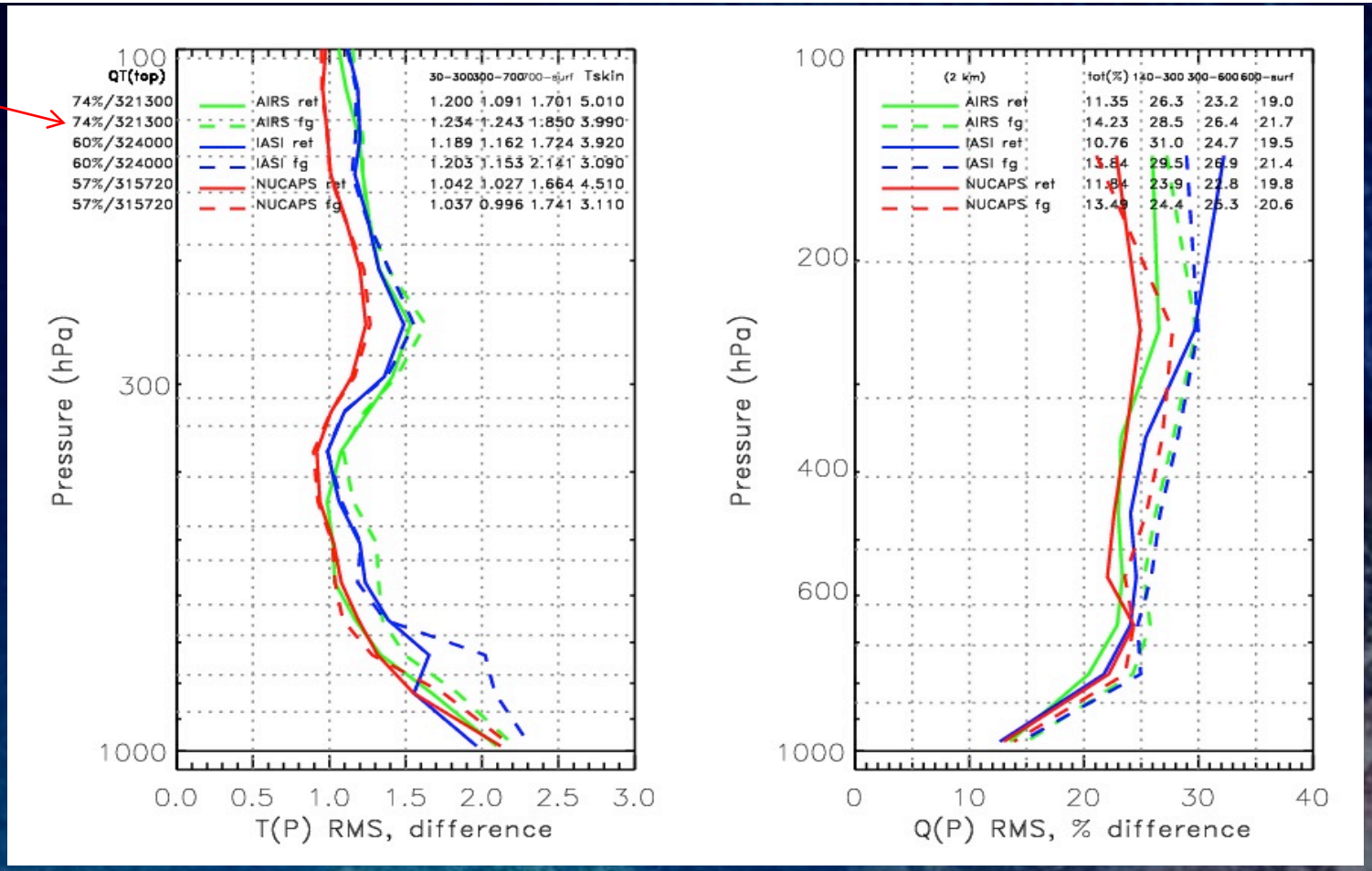


CrIS IASI AIRS

Global RMS Statistics vs ECMWF Analysis

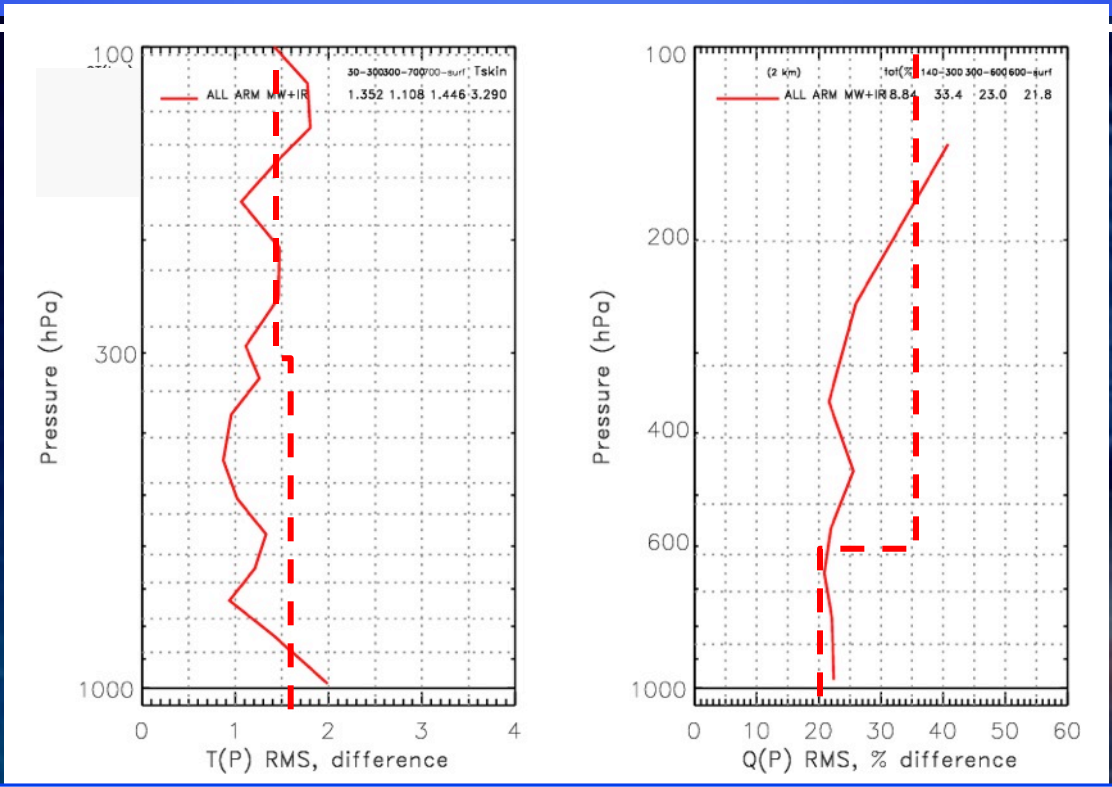
(dash lines = first guess)

Acceptance Yield



- Retrieval performance is stable and consistent across the three platforms.
- CrIS comparable to AIRS and IASI (10+ year maturity systems)
- Physical retrieval (solid) shows significant departure from first guess (dash line)

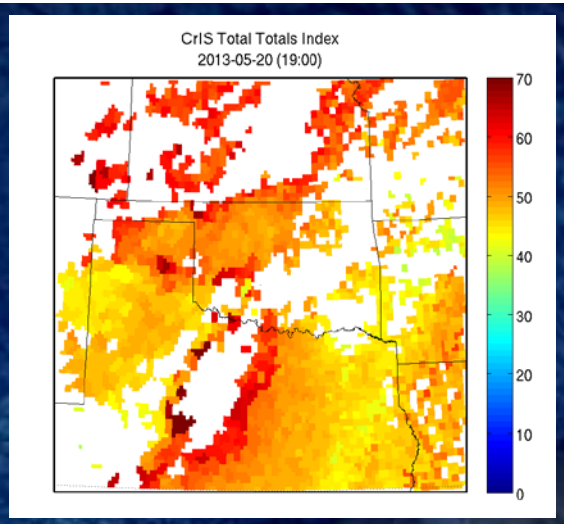
NUCAPS MW+IR
RMS Statistics vs ARM TWP, SGP, NSA Dedicated RAOBs



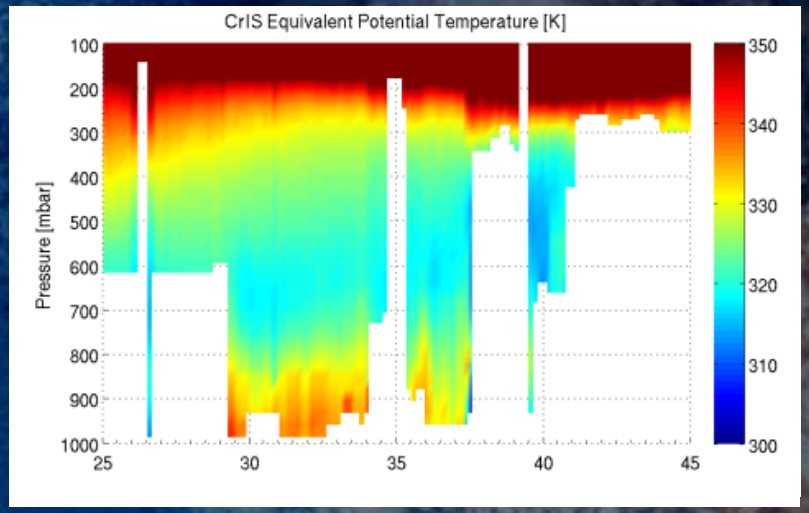
SUMMARY ON MW+IR RESULTS vs JPSS L1RD REQUIREMENTS					
MW+IR TEMPERATURE	RESULTS	JPSS L1RD	MW+IR WATER VAPOR	RESULTS	JPSS L1RD
30 – 300mb	1.35K	1.5K	100 - 600mb	28.2%	35%
300mb - SURF	1.25K	1.6K	600mb -SURF	21.8%	20%

CrIS Applications

- Assessing convective instability for potential of severe weather by NWS
- Outgoing longwave radiation for a variety of precipitation and tropical dynamical diagnostics applications by the NOAA Climate Prediction Center
- CriS – OMPS blended ozone for night-time ozone products
- Transport of CO from fires and pollution. SO2 plumes from volcanoes.



> 60 Liklihood of Moderate Thunderstorms With scattered severe t-storms



AWIPS-2 NUCAPS Training on Youtube
Thanks to Scott Lindstrom, Chris Barnet, Brian Motta and others

jpss.noaa.gov

Home | About JPSS ▾ | Science ▾ | User Community ▾ | Outreach ▾ | Media ▾ | Resources ▾

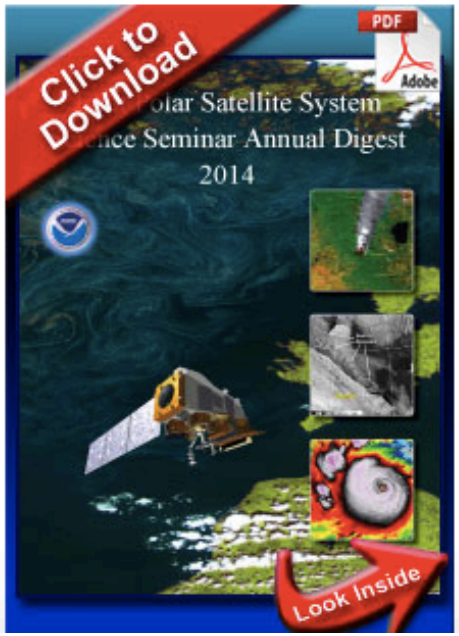
Science Seminar Annual Digest

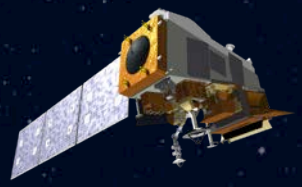
On behalf of the Joint Polar Satellite System (JPSS) Program Science, it is my pleasure to share with you our science digests, which are a collection of technical articles generated from a series of monthly science seminars. The digests capture the importance of the close collaborative efforts between product developers and key users to conceptualize and develop new products that help improve the use of JPSS data to enhance key services, such as forecasting of severe weather events and environmental monitoring of land, ocean and the cryosphere. I would like to thank our federal staff, private sector support staff, and university partners whose contributions and dedicated efforts have made JPSS a big success.

The JPSS program is committed to ensuring that its user community is prepared to utilize the satellite imagery and data available from JPSS – the United States' next generation polar-orbiting operational environmental satellite system. JPSS provides environmental observations which are used in a wide range of application areas that include severe weather, hazards, aviation, ocean, coastal, land, imagery and data assimilation.

2013

2014





Summary

- Both CrIS and ATMS are critical for forecasting – at all scales – particularly for the 3-7 day weather forecast.
- ATMS provides rain and snow rates, ice and snow cover information, and snow water equivalent
- CrIS provides soundings for real-time instability assessments, and trace gases for monitoring greenhouse gases and their transport.
- Both sensors have low noise and excellent long-term stability that will enable more accurate climate change monitoring.
- The sounding products (NUCAPS and MIRS) are available through the NOAA operational product generation system for global data and the CSPP Direct Readout Software.