Uses of Satellite Data for Monitoring and Forecasts of Hurricane and Coastal Precipitation

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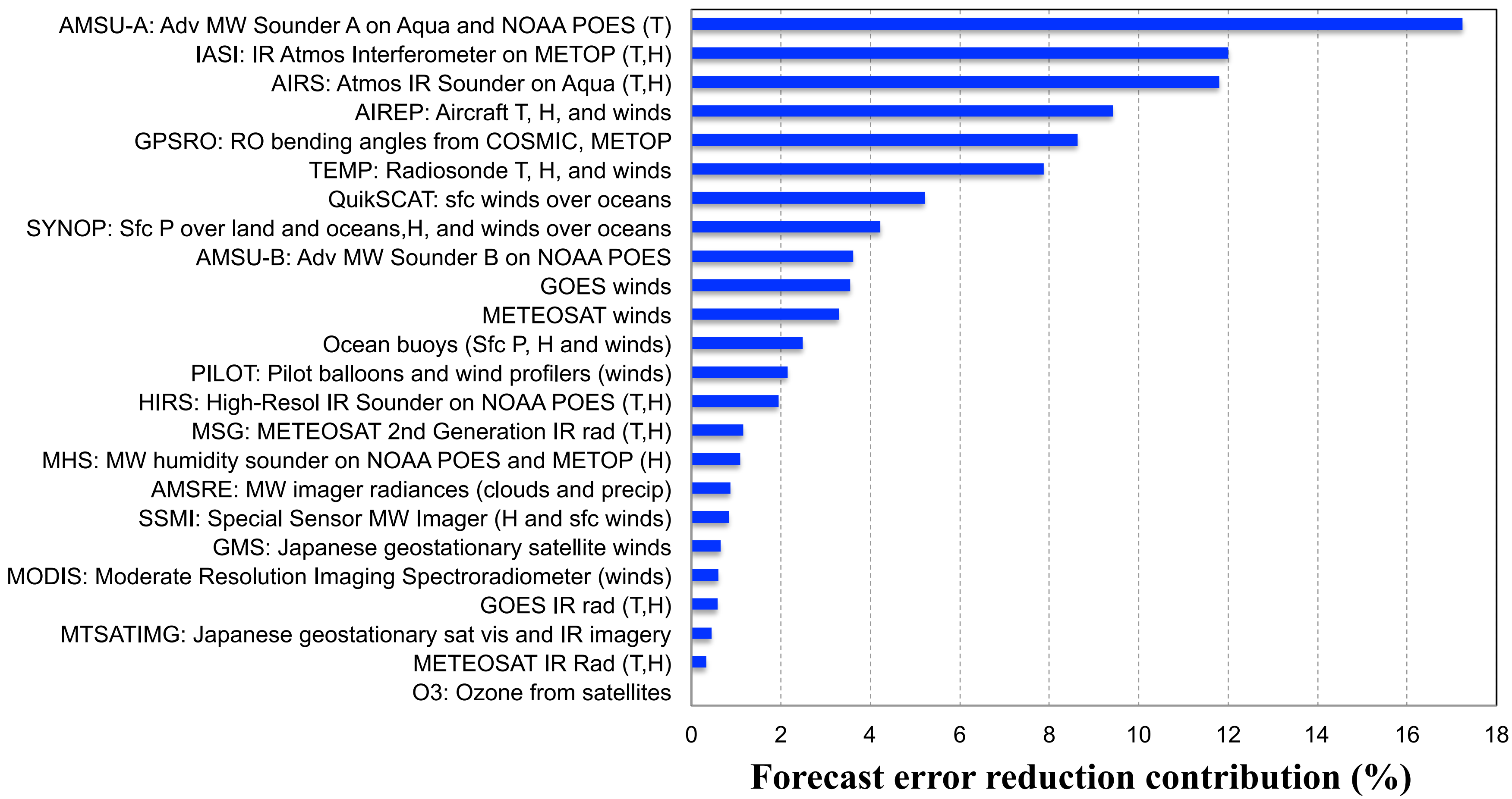
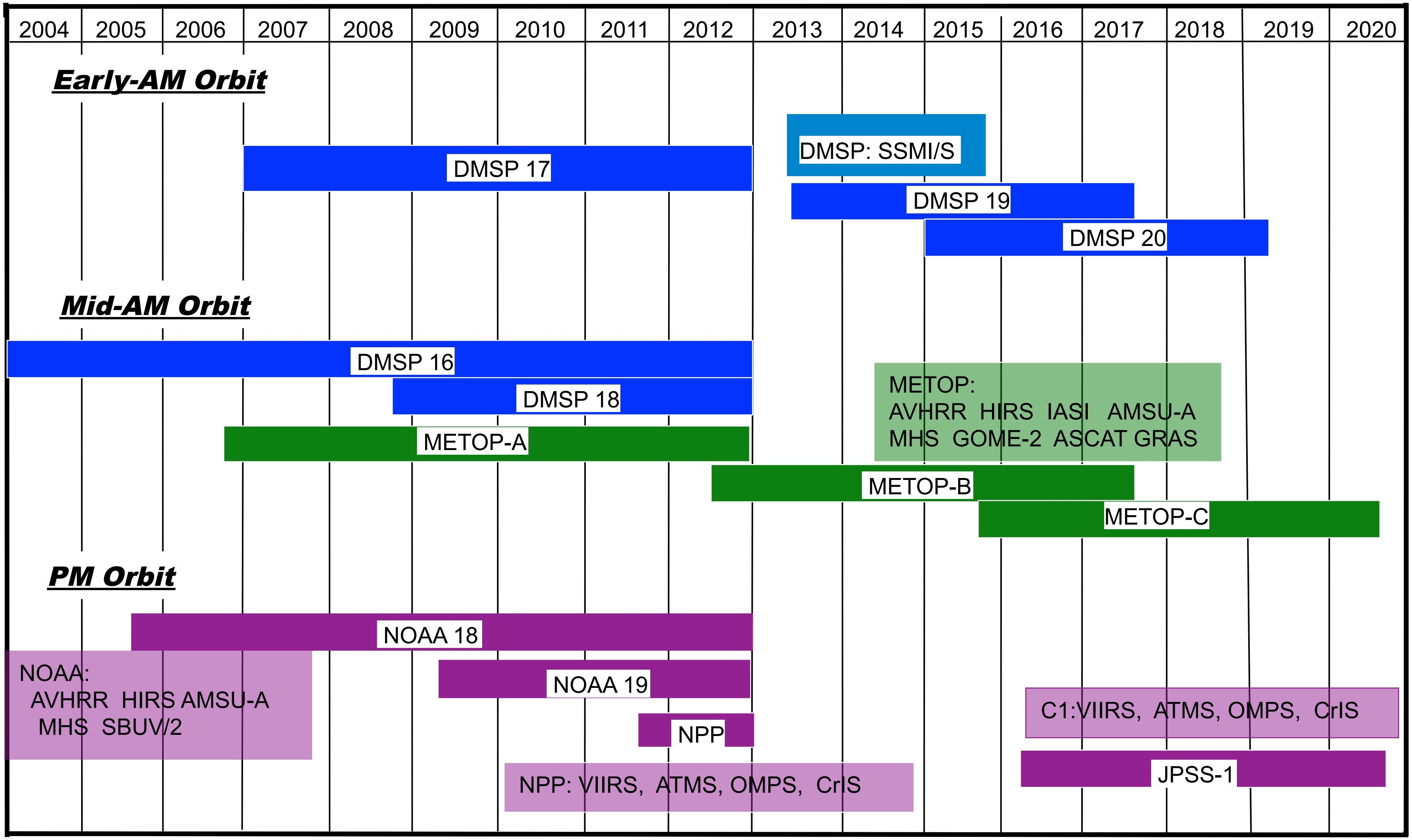
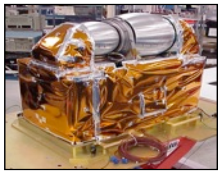
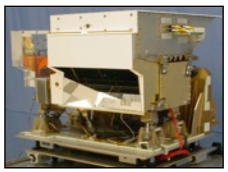
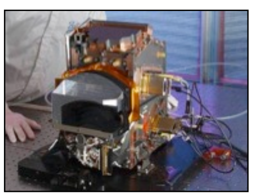
Impacts of Satellite Data on Global Medium-Range Weather Forecasts



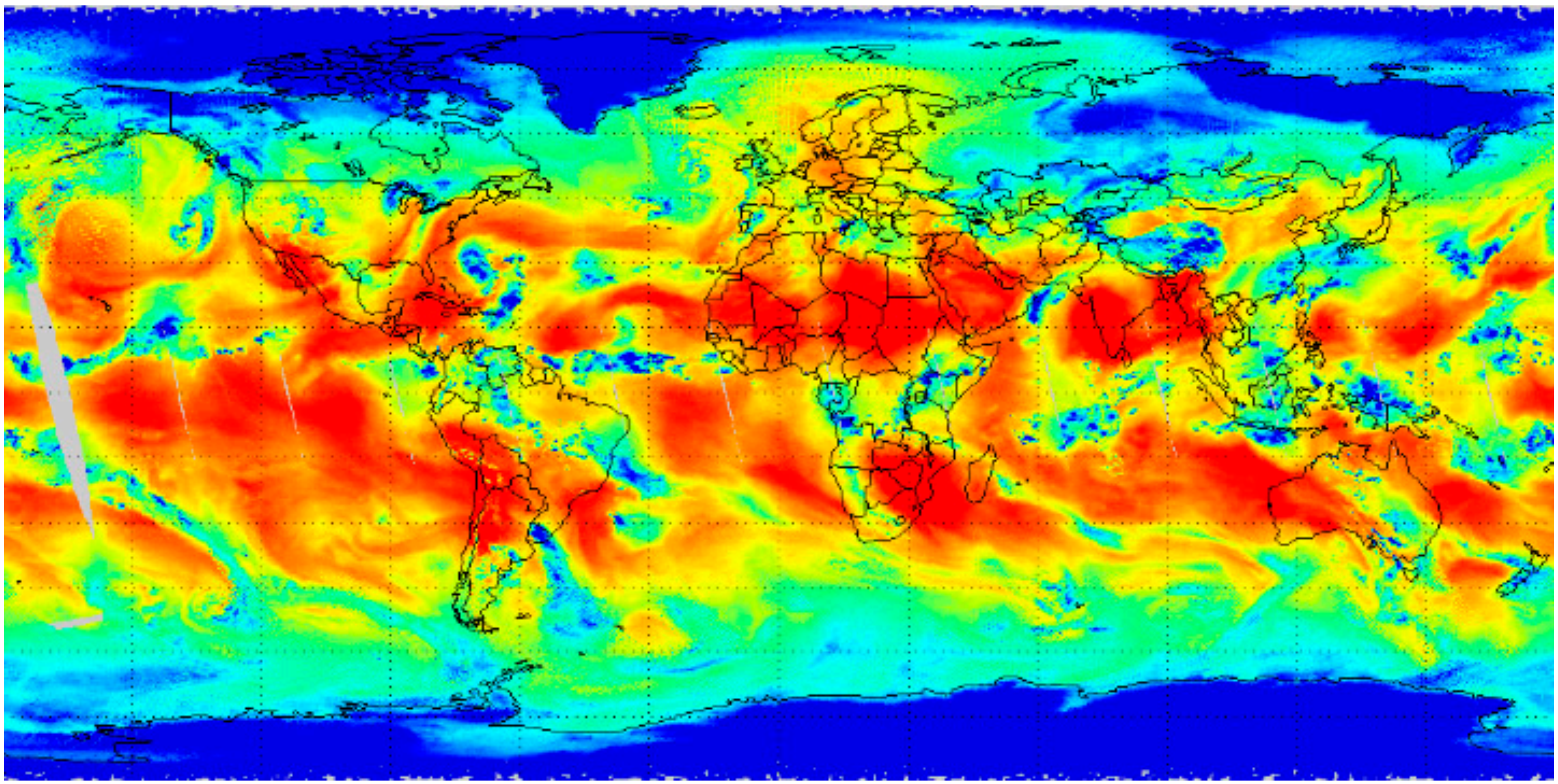
NOAA/METOP/DMSP Satellite System



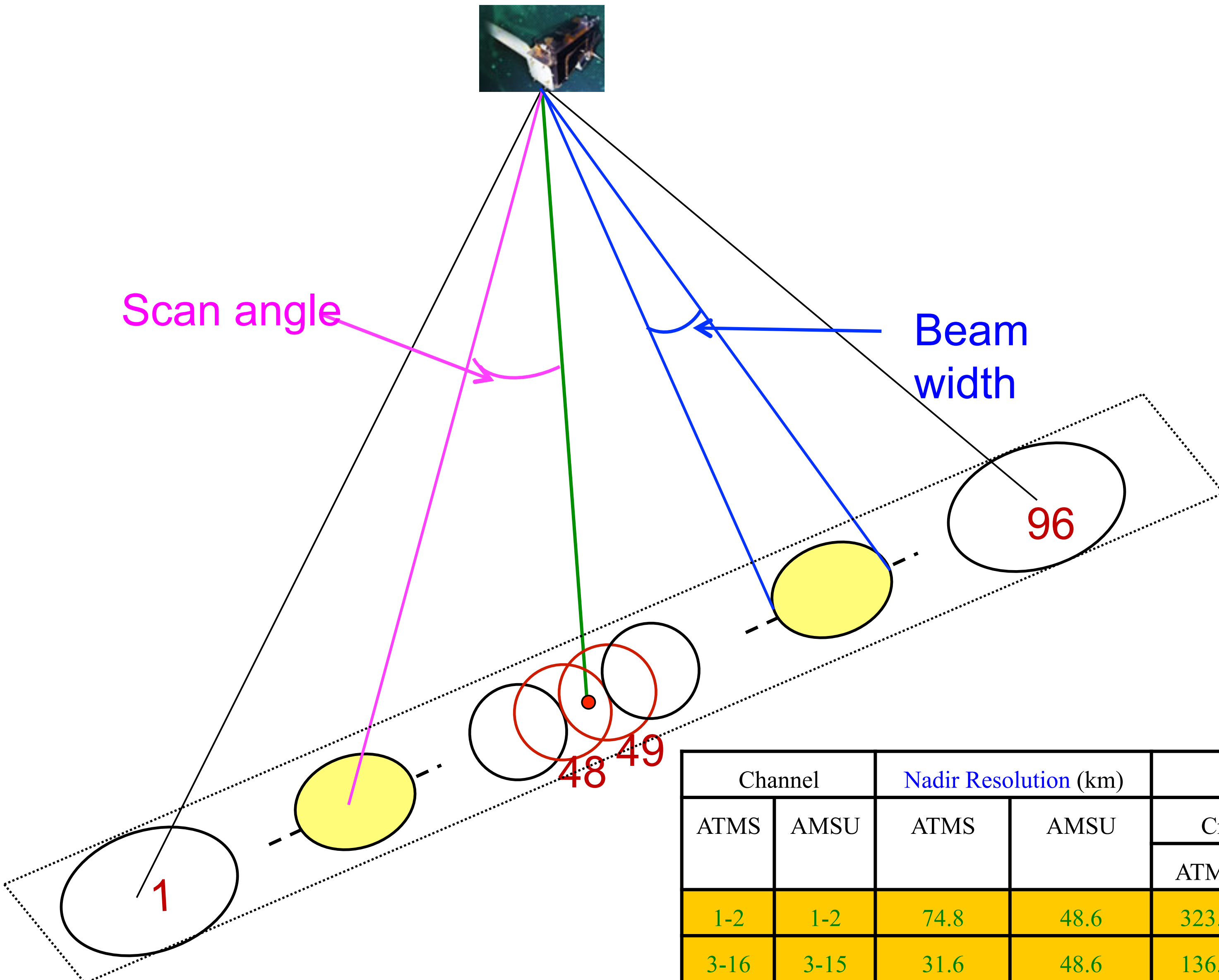
Suomi NPP Instruments

NPP/JPSS Instrument		Measurement
	**ATMS** - Advanced Technology Microwave Sounder	ATMS and CrIS together provide high vertical resolution **temperature** and **water vapor information needed to maintain and improve forecast skill** out to 5 to 7 days in advance for extreme weather events, including hurricanes and severe weather outbreaks
	**CrIS** - Cross-track Infrared Sounder	
	**VIIRS** – Visible Infrared Imager Radiometer Suite	VIIRS provides many **critical imagery products** including snow/ice cover, clouds, fog, aerosols, fire, smoke plumes, vegetation health, phytoplankton abundance/chlorophyll
	**OMPS** - Ozone Mapping and Profiler Suite	Ozone spectrometers for **monitoring ozone** hole and recovery of stratospheric ozone and for UV index forecasts
	**CERES** - Clouds and the Earth's Radiant Energy System	Scanning radiometer which supports studies of Earth Radiation Budget

The First ATMS Image at 183GHz

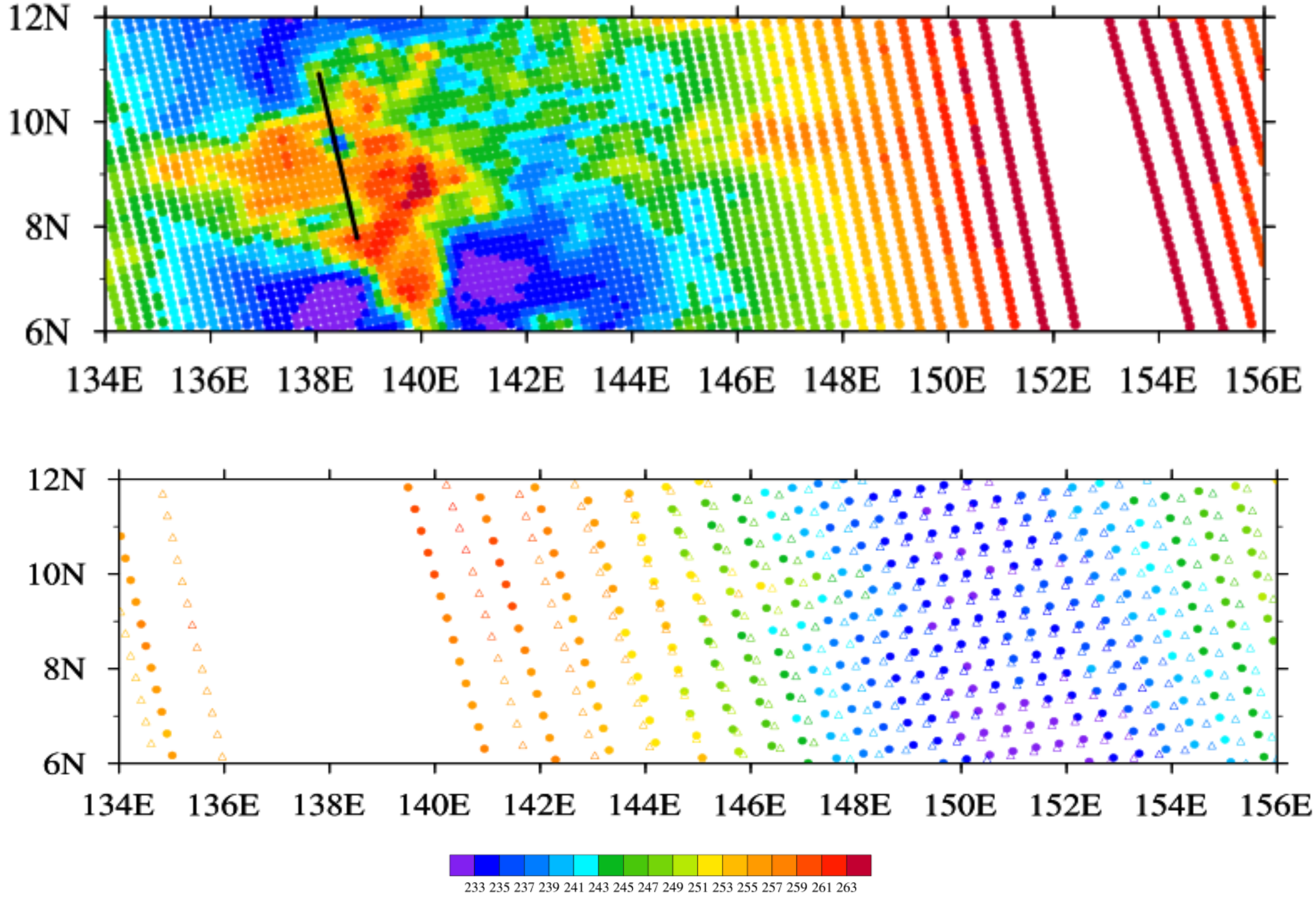


ATMS Scan Angle and Beam Width



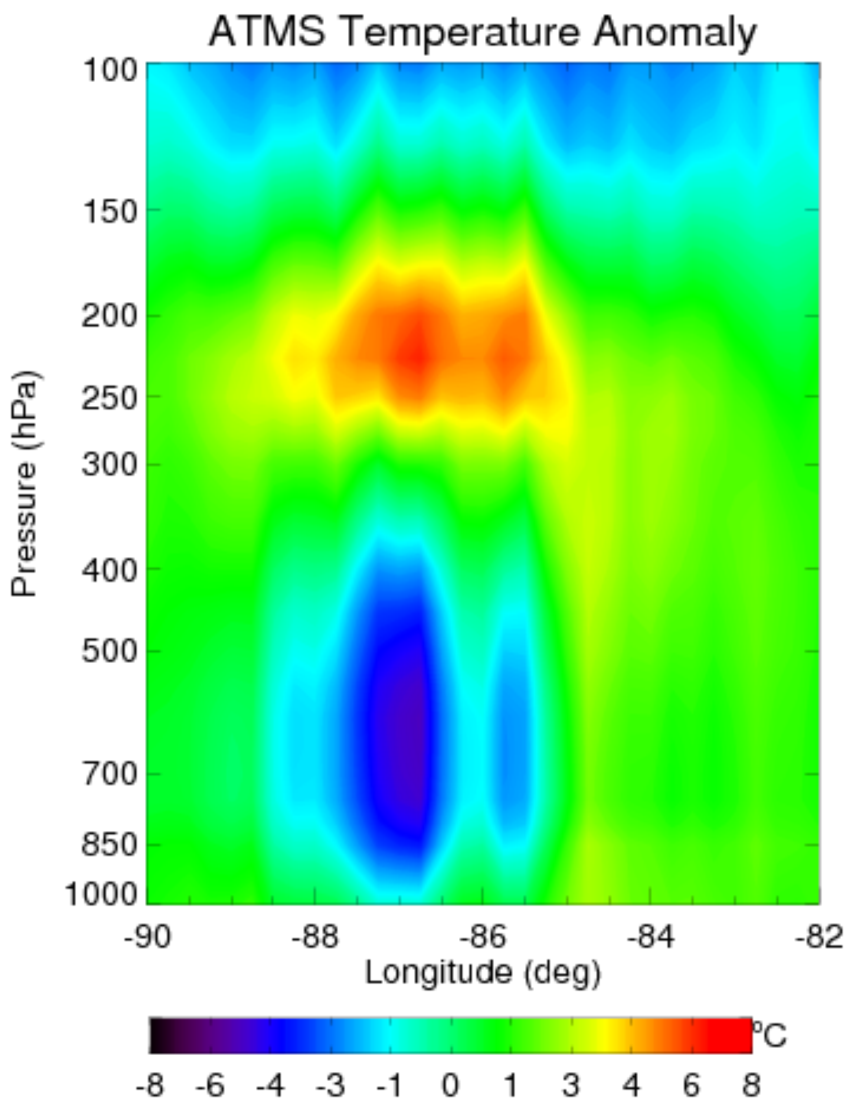
Channel		Nadir Resolution (km)		Outmost FOV size (km)			
ATMS	AMSU	ATMS	AMSU	Cross-track		Along-track	
				ATMS	AMSU	ATMS	AMSU
1-2	1-2	74.8	48.6	323.1	155.2	141.8	85.6
3-16	3-15	31.6	48.6	136.7	155.2	60.0	85.6
17-22	16-20	15.8	16.2	68.4	58.9	30.0	29.4

Comparison of Spatial Temperature Structure between ATMS and AMSU-A (CH2)

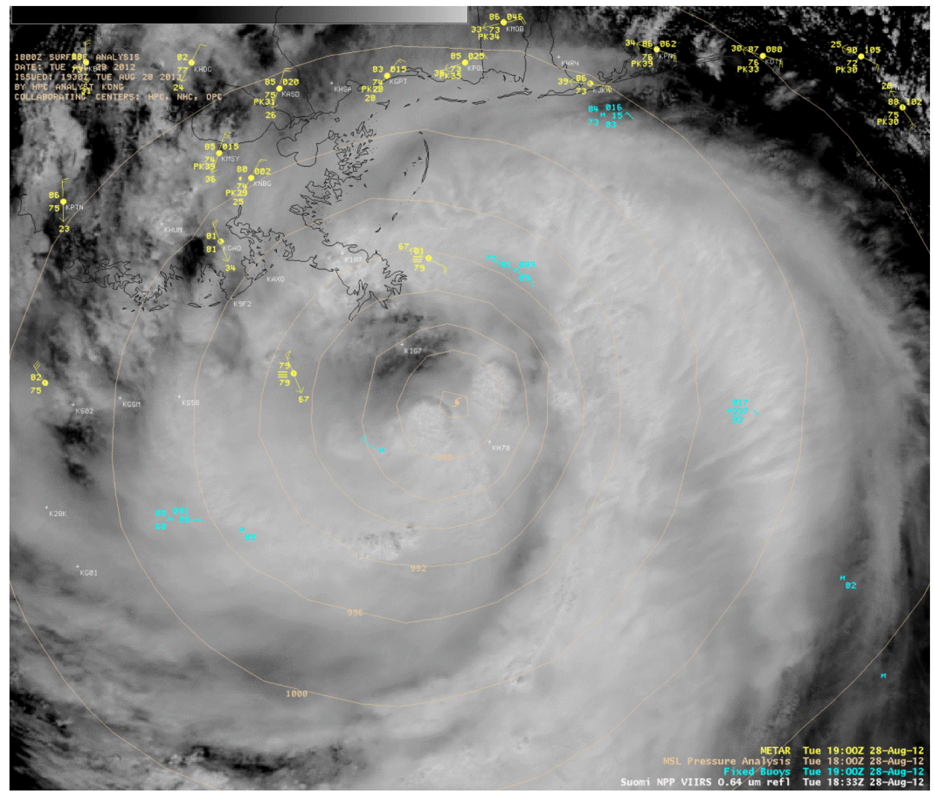


NPP ATMS and VIIRS Imager and Products

Warm Core Cross section along 26.0 N



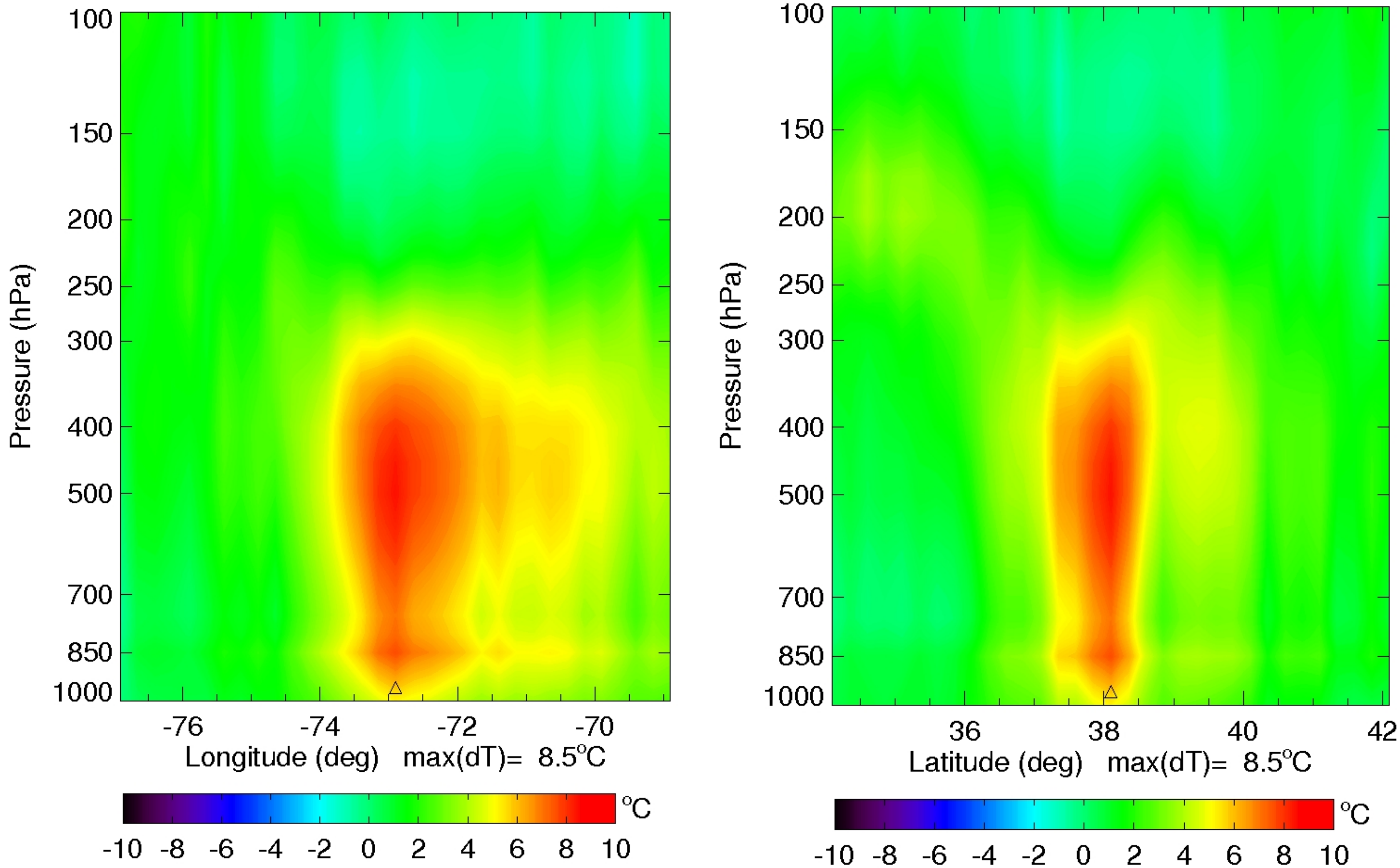
VIIRS 0.64 µm visible and 11.45 µm IR images at 18:33 UTC, 28 Aug 2012



METAR, MSL Pressure, and Buoys information included

Hurricane Sandy Warm Core Anomaly
Ascending 1730 UTC, 29 October 2012

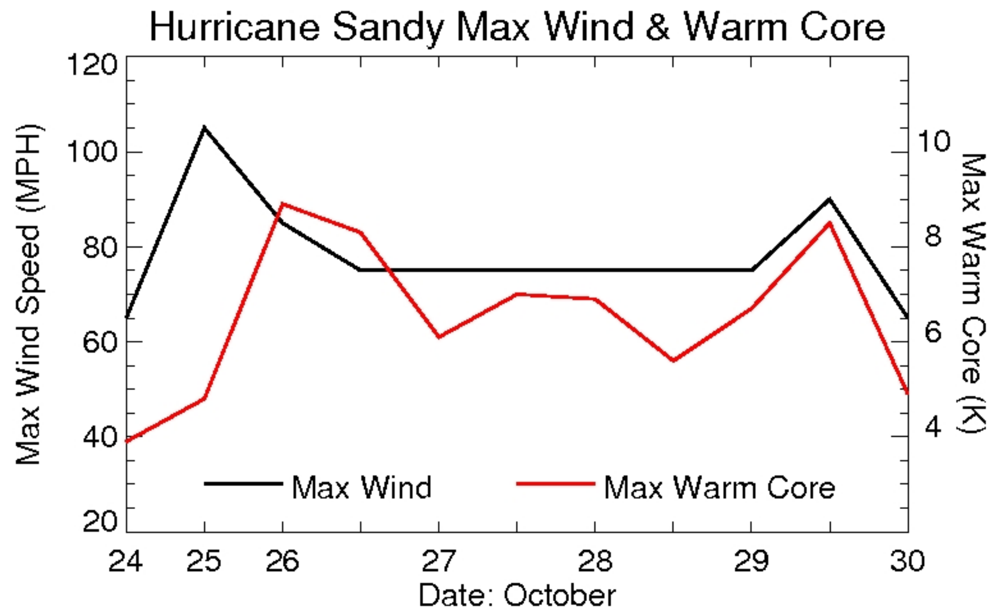
At 1800 UTC Oct 29 Max Wind: 90 MPH, Min Pressure: 940 hPa

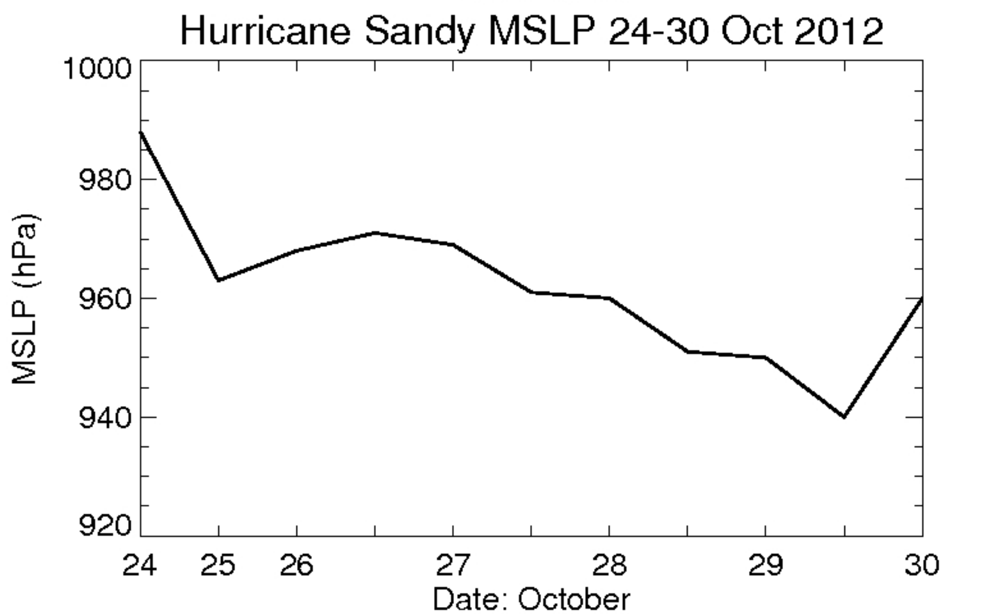


Cross section along Latitude 38.1 N

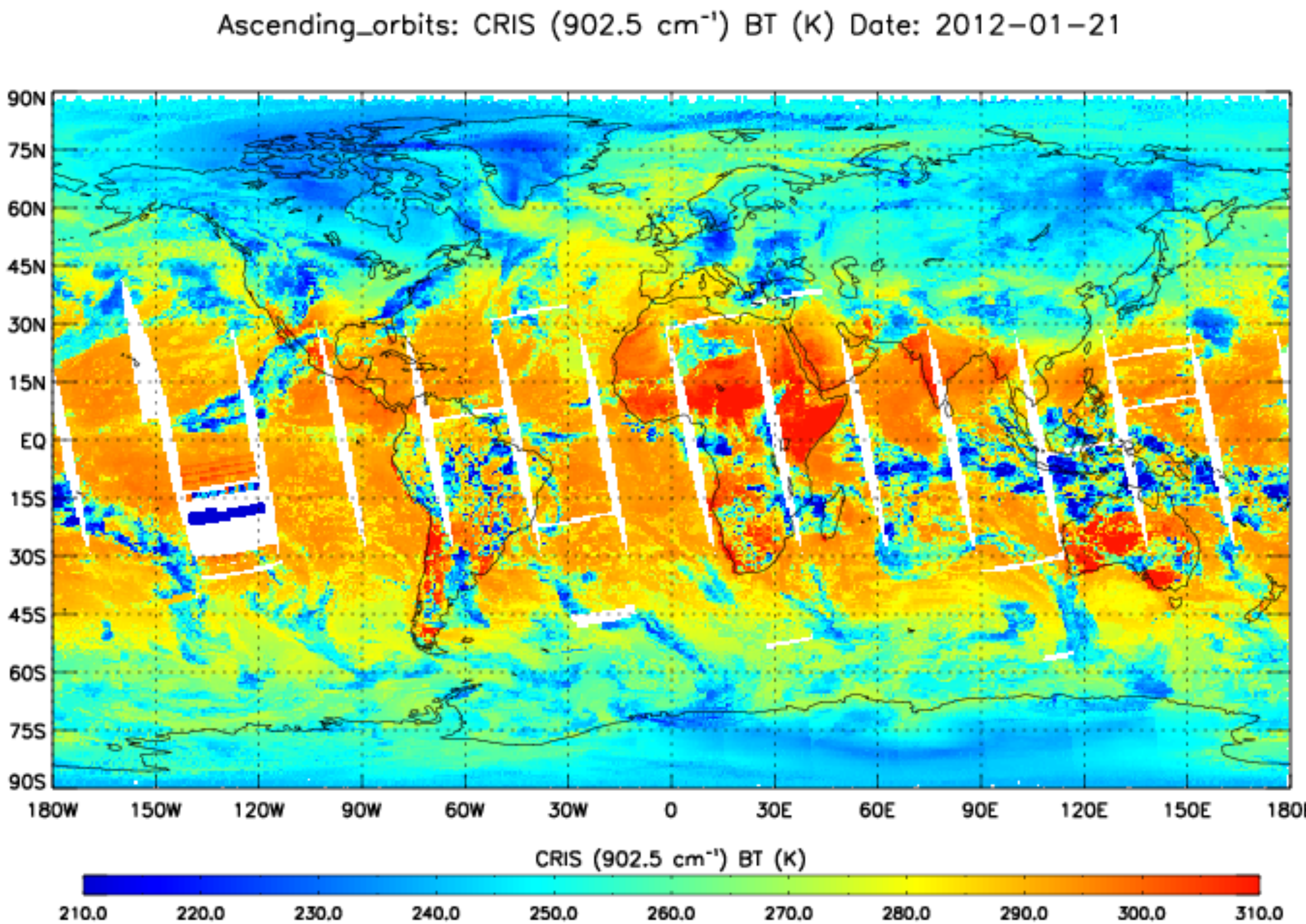
Cross section along Longitude 72.9 W

Sandy Max Wind, Warm Core and MSLP

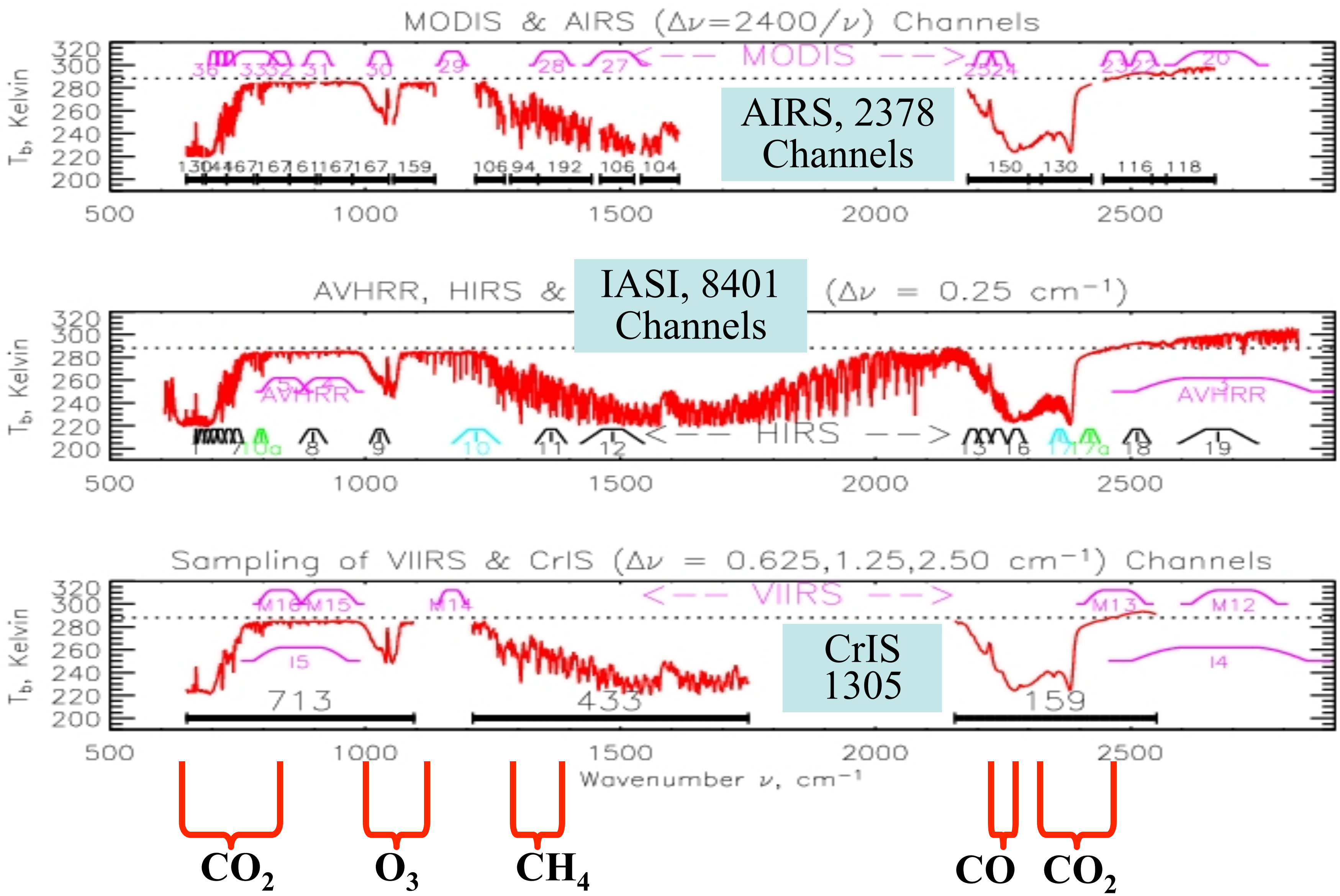




The First Light CrIS Image



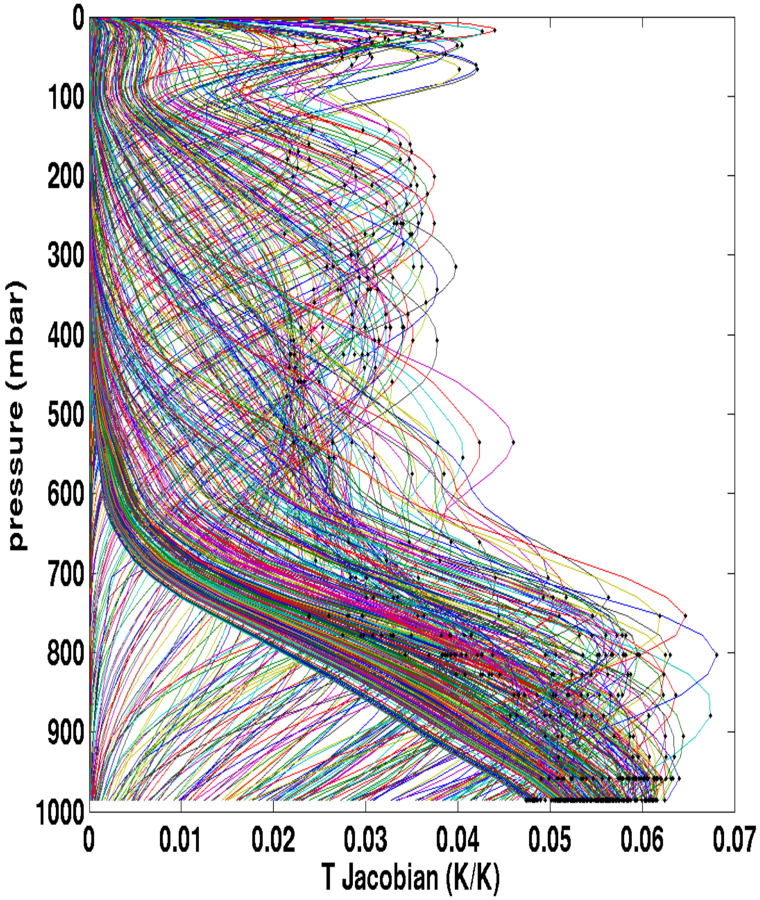
Spectral Coverage of Thermal Sounders (Example BT's for AIRS, IASI, & CrIS)



Example of T(p) & q(p) Channel Kernel Functions

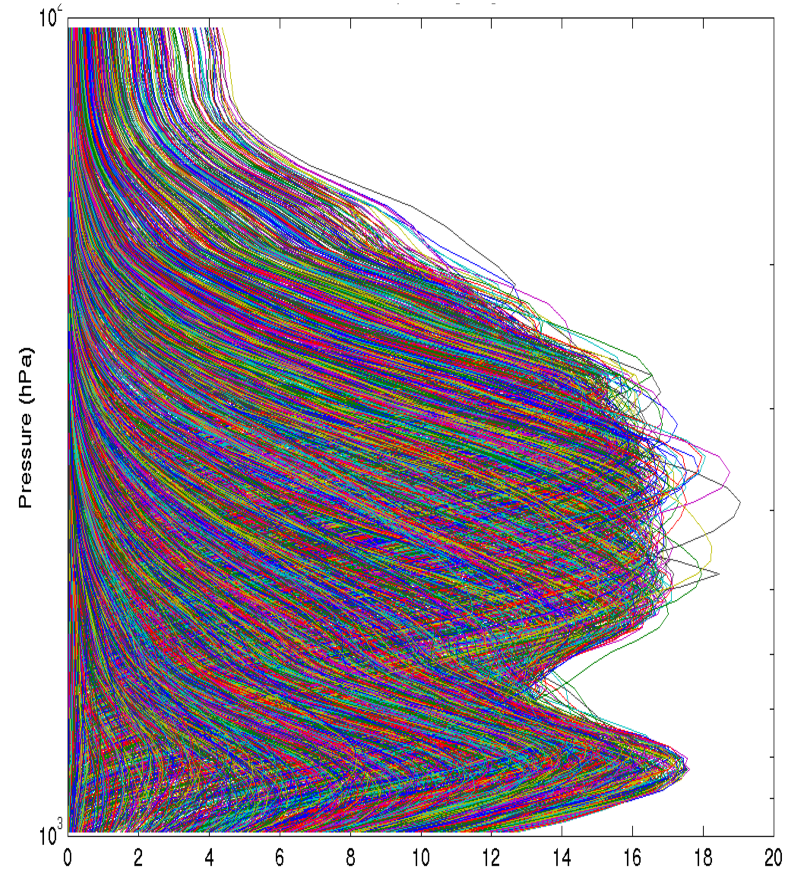
AIRS 15 μm (650-800 cm-1) band

K = dR/dT

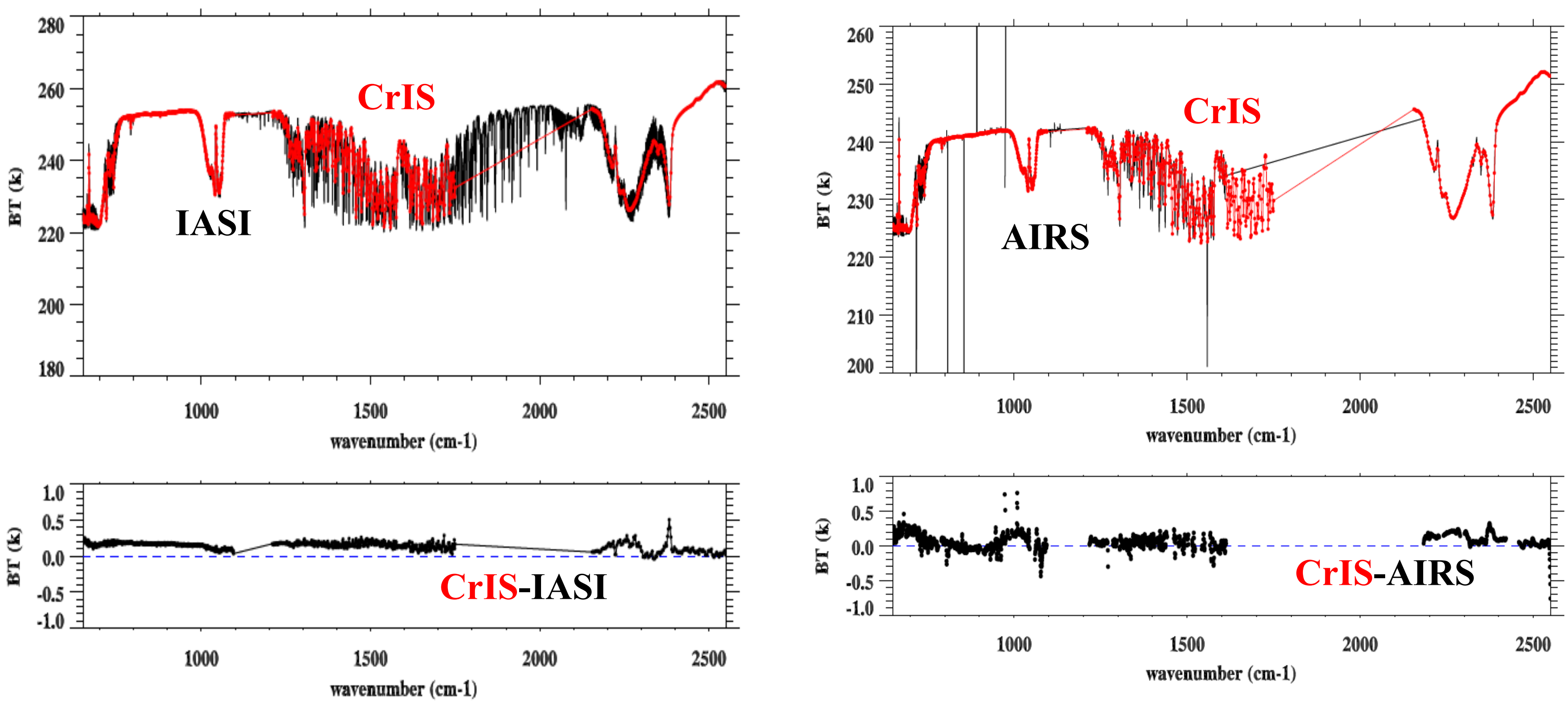


AIRS 6.7 μm (1200-1600 cm^{-1}) band

K = dR/dq



CrIS Radiometric Calibration: Compared to AIRS and IASI

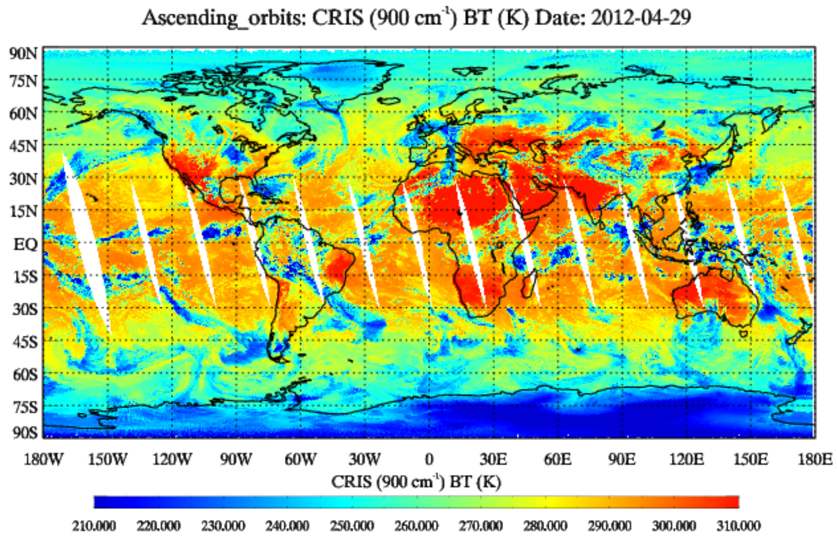


CrIS has about 0.2K warm bias wrt IASI and no bias wrt AIRS from SNO collocated data sets. In the analysis, IASI data was de-apodized to obtain the original interferogram data and are then resampled using CrIS spectrum resolution, and FFT back to get CrIS like radiances

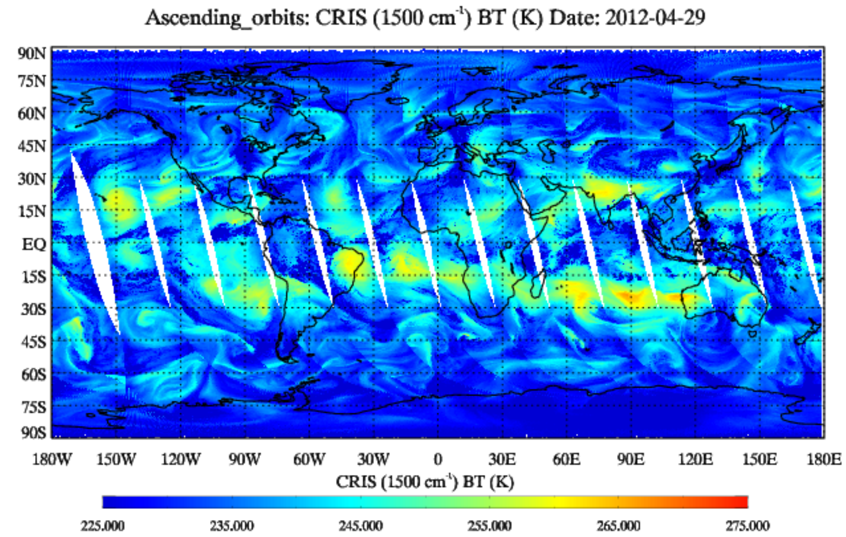
Courtesy of Likun Wang, STAR

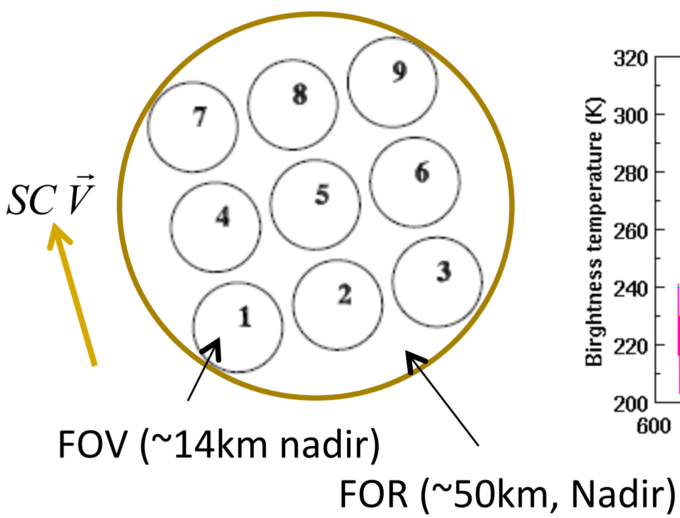
CrIS SDR Spectra and Global Coverage

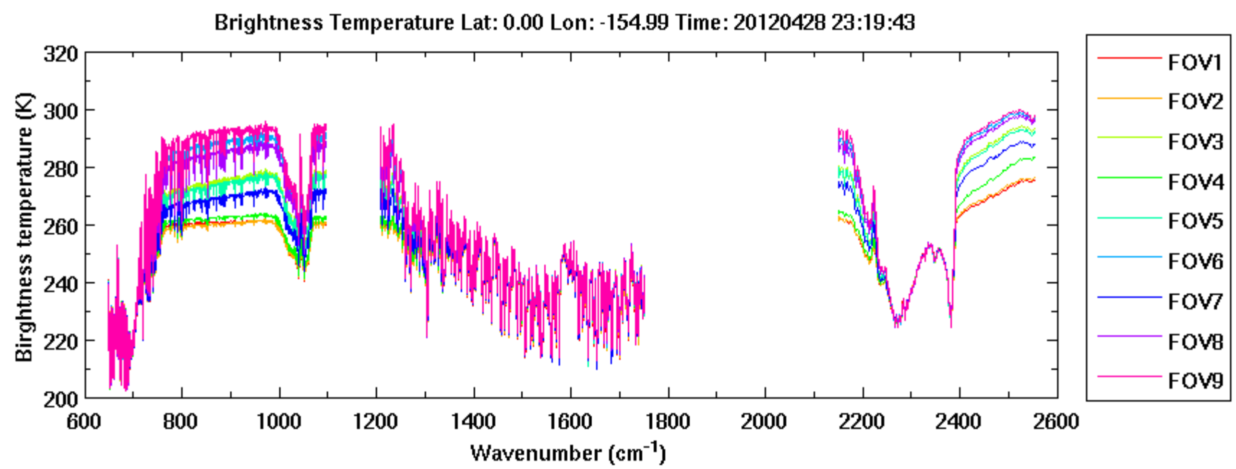
Window Channel



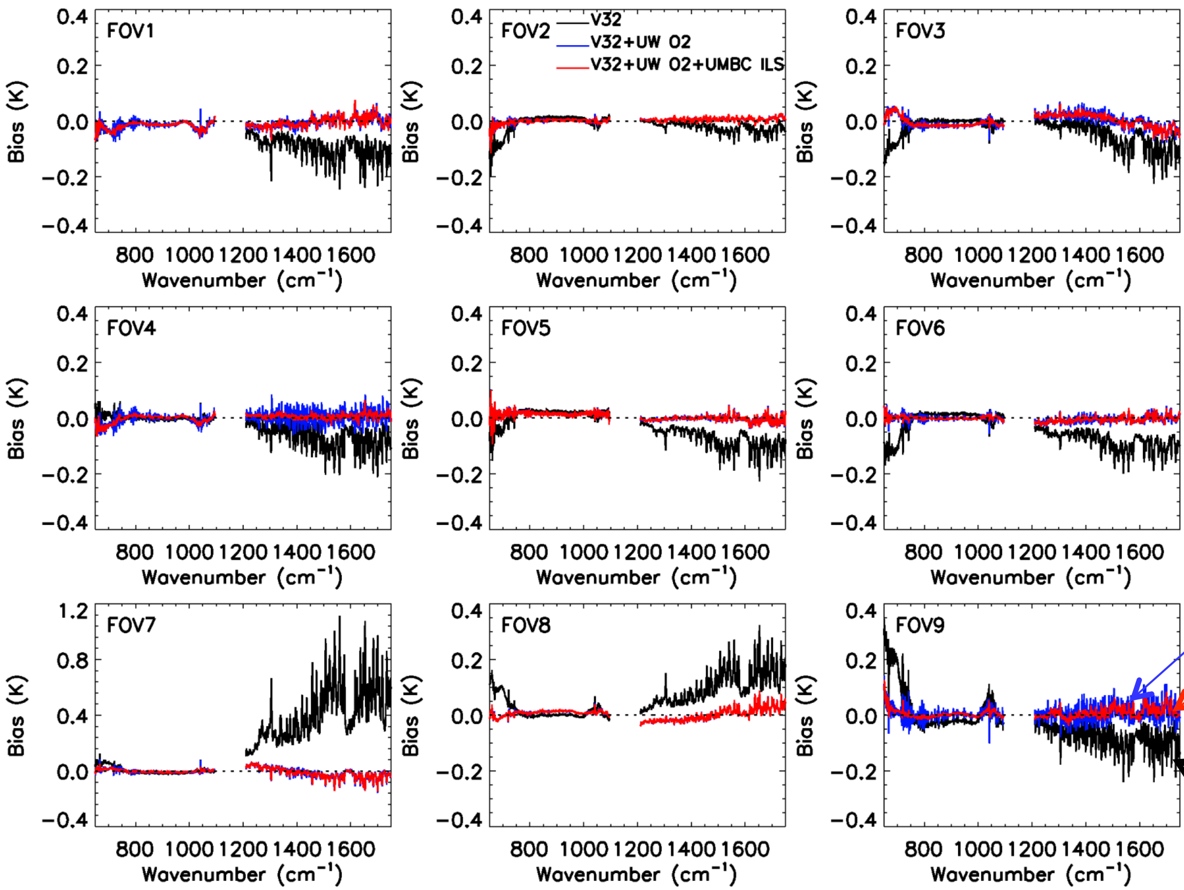
Water vapor Channel







CrIS Individual FOV Bias wrt NWP Simulations



Total clear sky observation points ~400000

Blue: after nonlinearity coefficient change but before spectral coefficient change

Red: after nonlinearity coefficient and spectral coefficient changes

Black: before nonlinearity and spectral coefficient changes

$$BIAS_{FOVi} = \overline{(Obs - CRTM)_{FOV_i}} - \overline{(Obs - CRTM)_{all}}$$

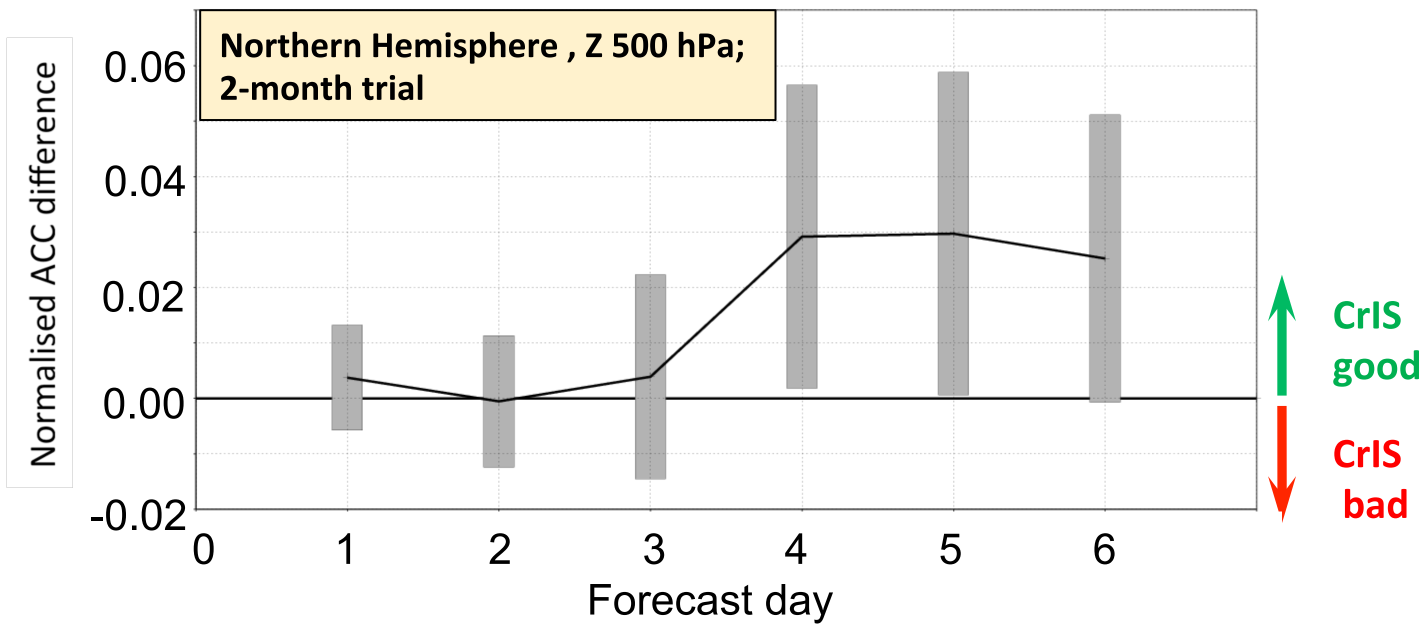
The achieved uniformity of the spectral and radiometric uncertainties cross the 9 FOVs is important for NWP to maximize the use of the radiance data

Courtesy of Yong Chen, STAR

Forecast Impact of CrIS in ECMWF

Radiance observations from CrIS have only been available since 26 June 2012 and thus forecast impact experiments are **not yet mature**.

However, preliminary results suggest that assimilating just 57 key temperature sounding channels from **CrIS in addition to AIRS and IASI** can improve forecasts compared to the control.

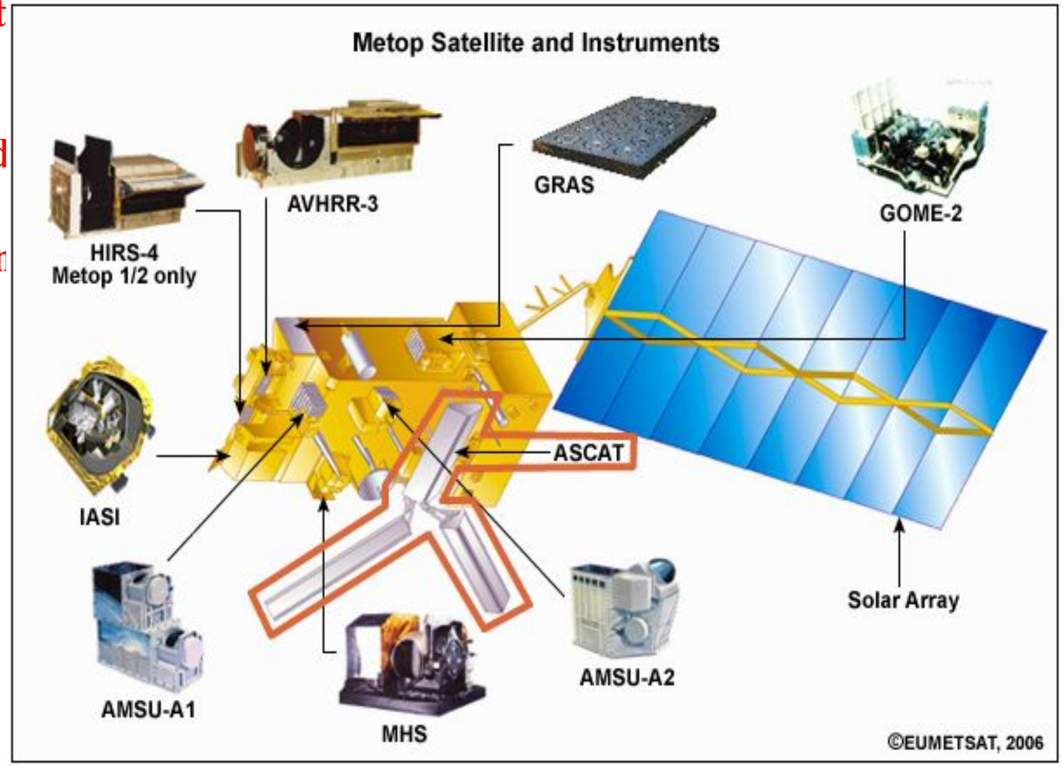


Note that the orbit of NPP is on top of that of AQUA (13:30) so **CrIS and AIRS data are used in close proximity** – work continues to optimise analysis weights.

From Niels Bormann, ECMWF

MetOp Instruments

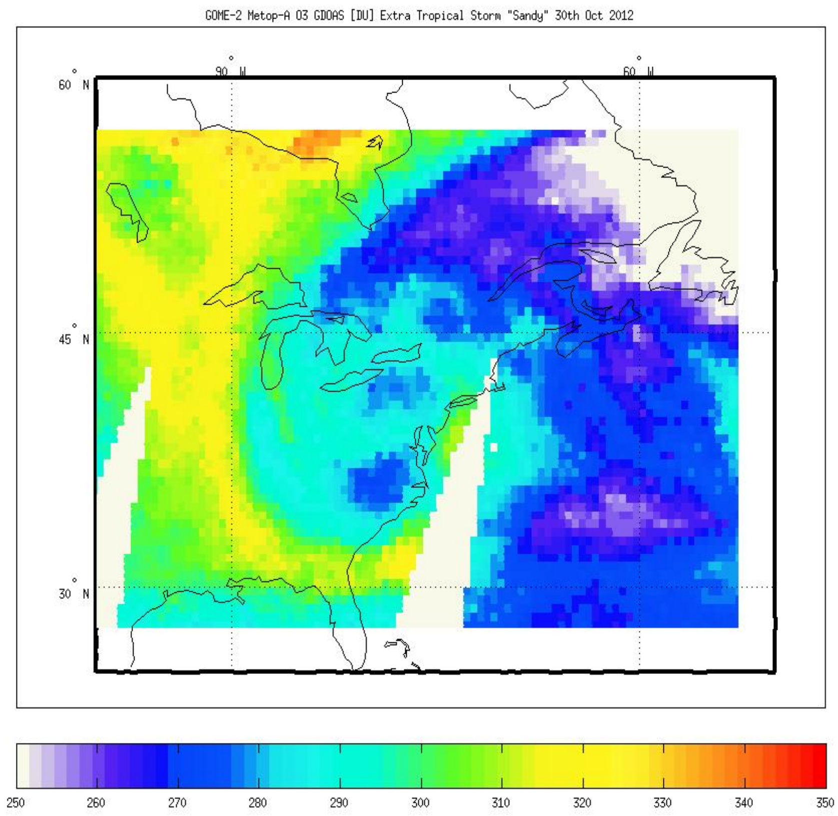
- AVHRR/3 - Advanced Very High Resolut Radiometer
- HIRS/4 - High Resolution Infrared Sound
- AMSU-A - Advanced Microwave Soundir Units-A1/A2
- MHS - Microwave Humidity Sounder
- ASCAT - Advanced Scatterometer
- GOME-2 - Global Ozone Monitoring Experiment-2
- IASI - Infrared Atmospheric Sounding Interferometer
- GRAS - The GNSS (Global Navigation Satellite System) Receiver for Atmospheric Sounding (GRAS)



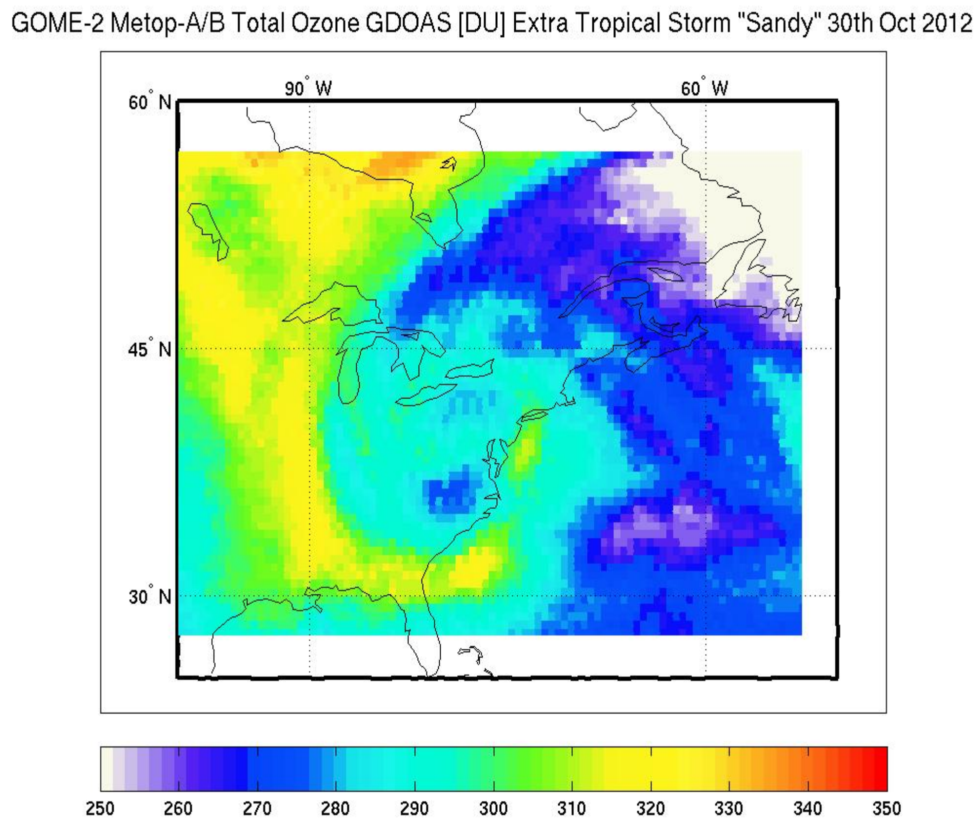
Highlighted instruments in red are the common ones which are also on board of NOAA satellites

Ozone Perturbation during Hurricane Event: An Example of METOP GOME-2

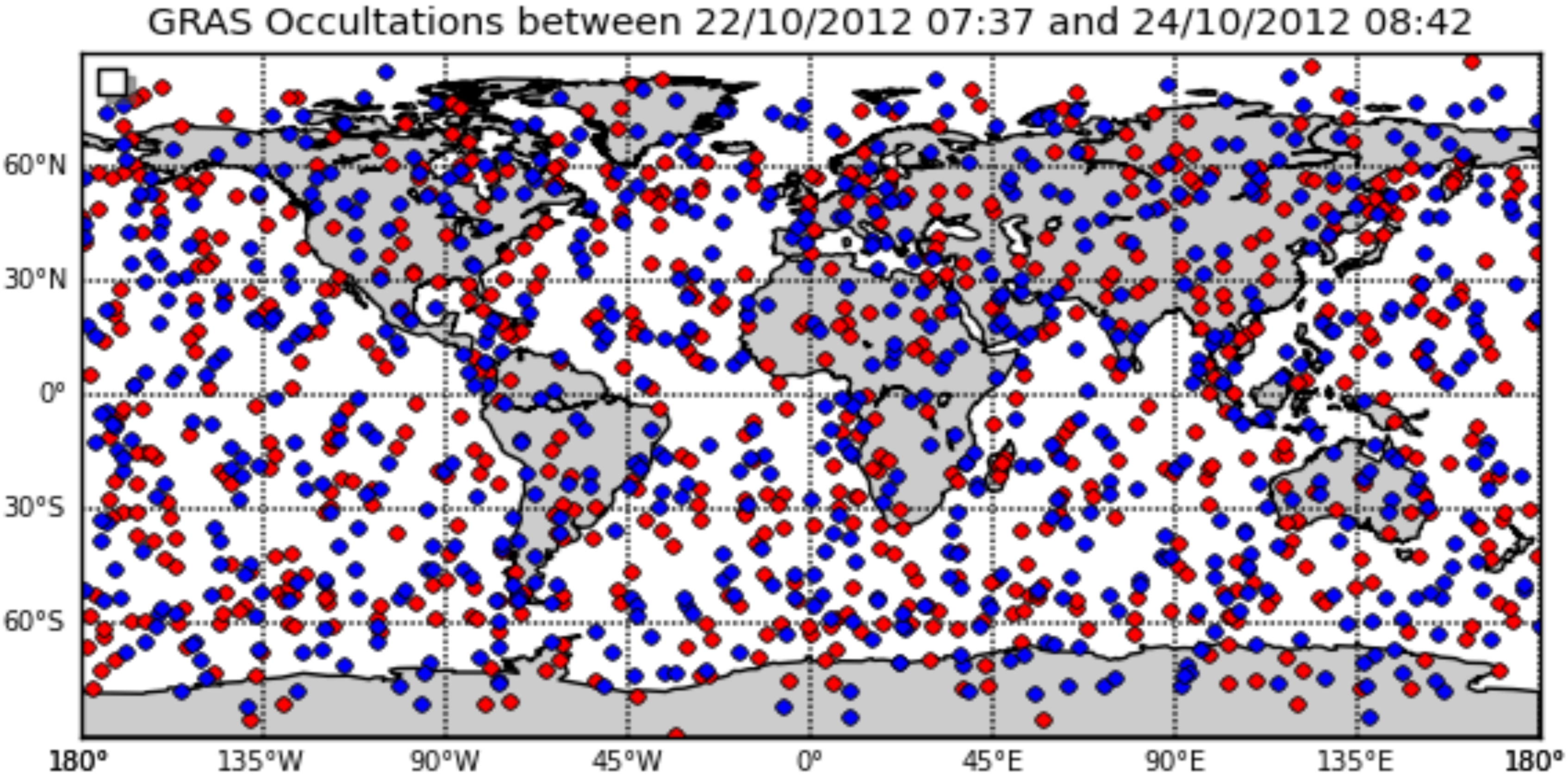
Metop-A



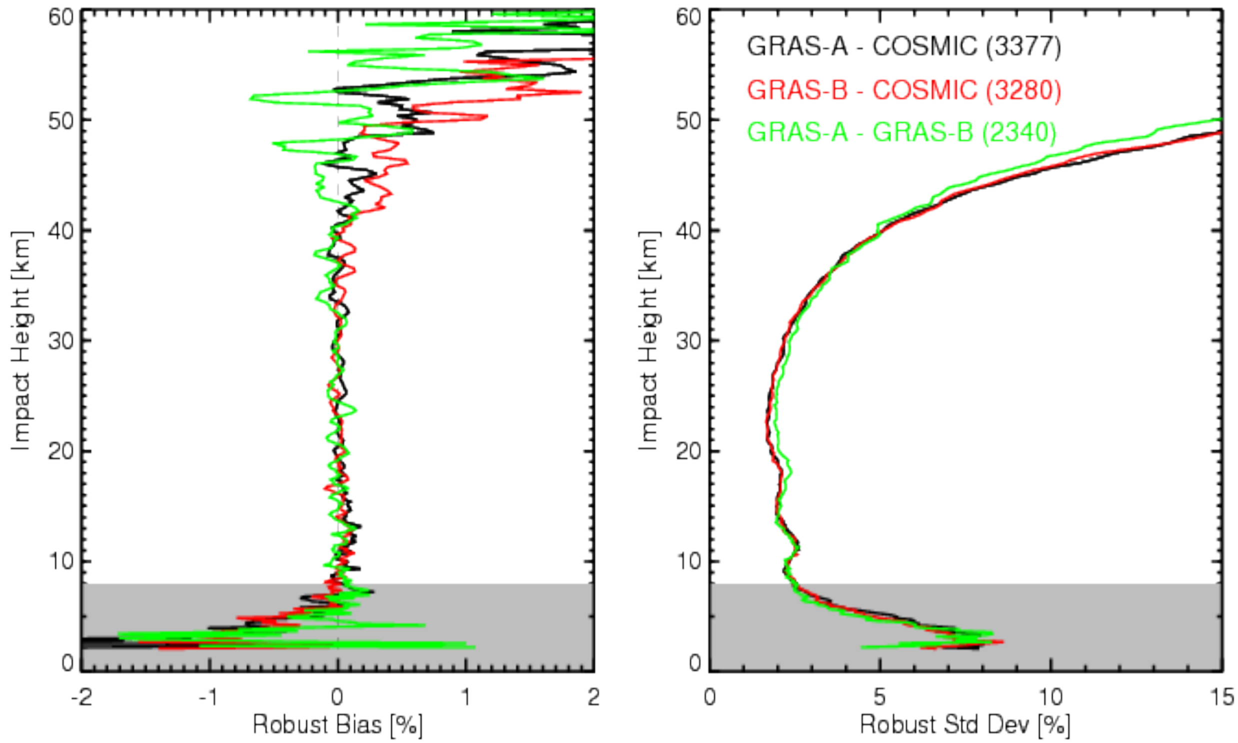
Metop-A and Metop-B



GPSRO Measurements: Example Metop-B GRAS

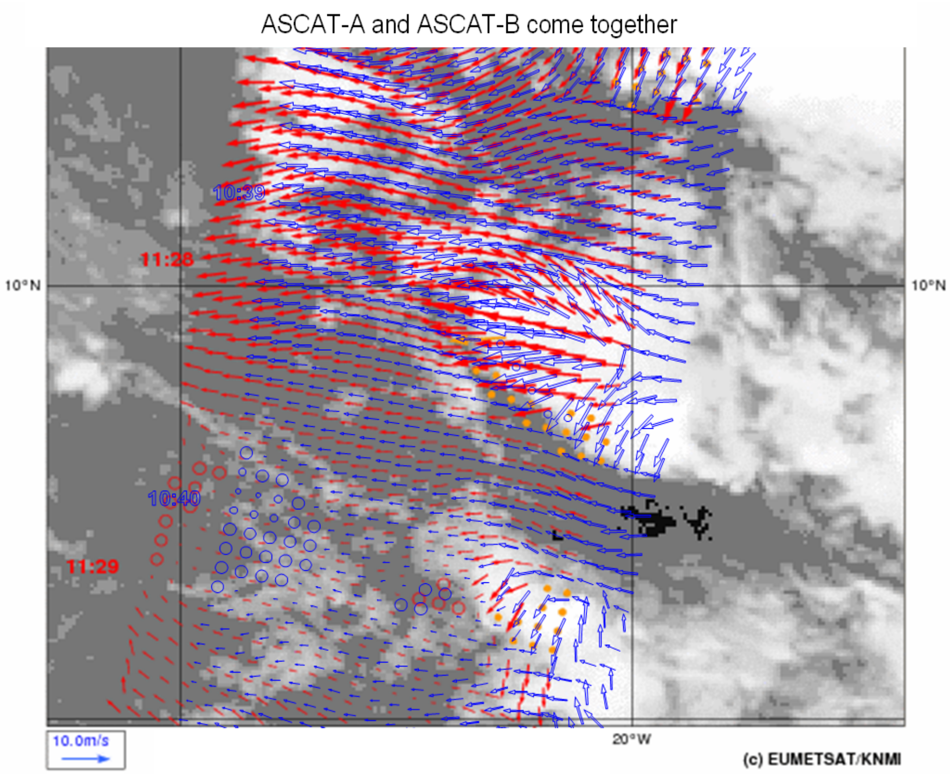


Metop-B: Validation in October 2012 (against COSMIC)

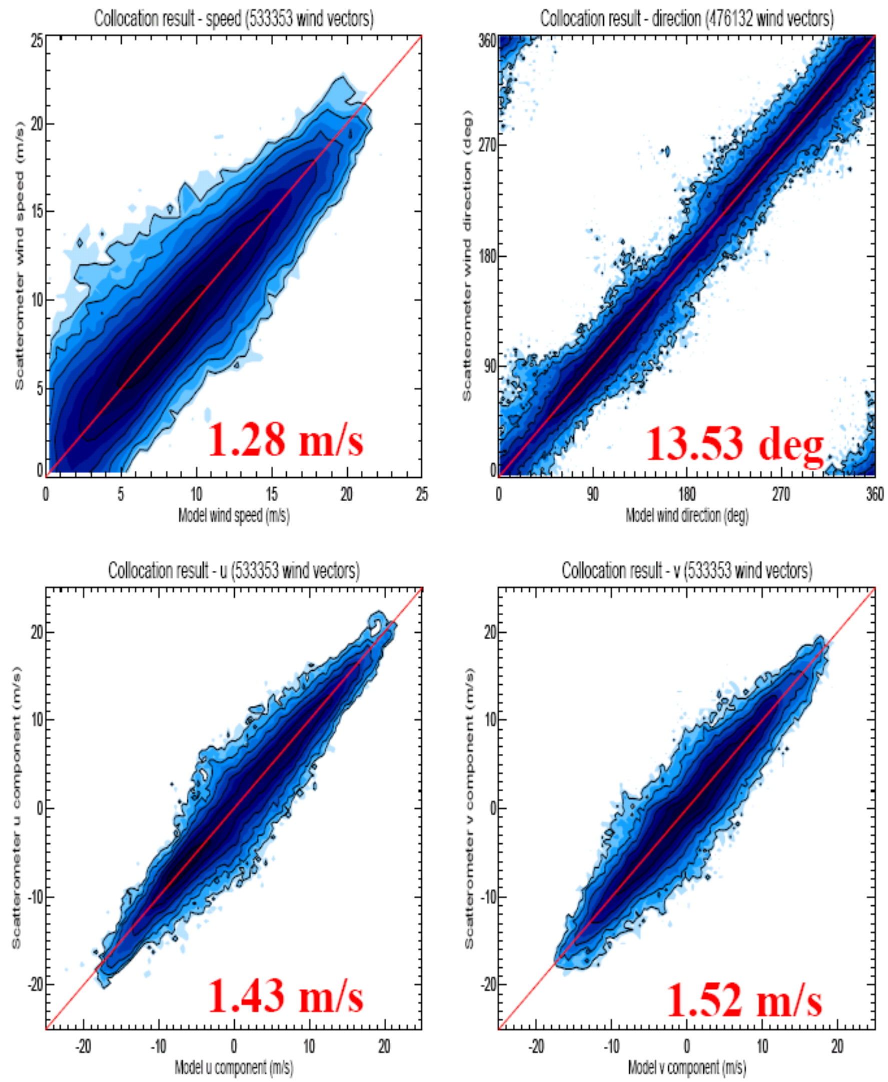


Radio occultation bending angle co-location statistics of GRAS on Metop-A, -B and COSMIC (within 300km, 3h). Otherwise as previous plot.

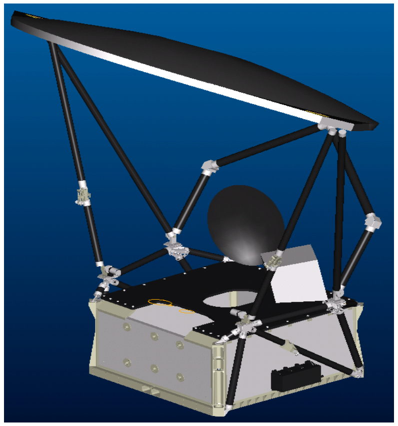
Surface Scatterometer Wind: METOP ASCAT L2 Winds

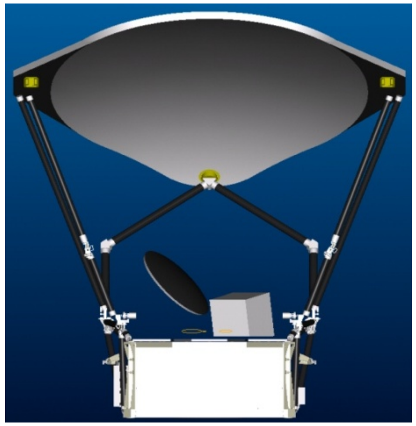


- ASCAT-A and –B winds very similar
- Top: ASCAT-B in blue
- Left: ASCAT-B statistics for wind speed, direction and u/v components, with respect to ECMWF winds: wind quality already well within requirements



Passive Microwave Imager: an example of GCOM-W1 AMSR-2 Instrument





Deploye
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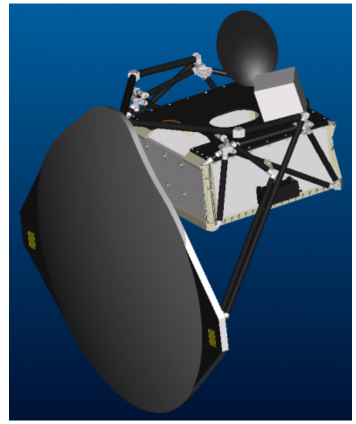


Stowe
d

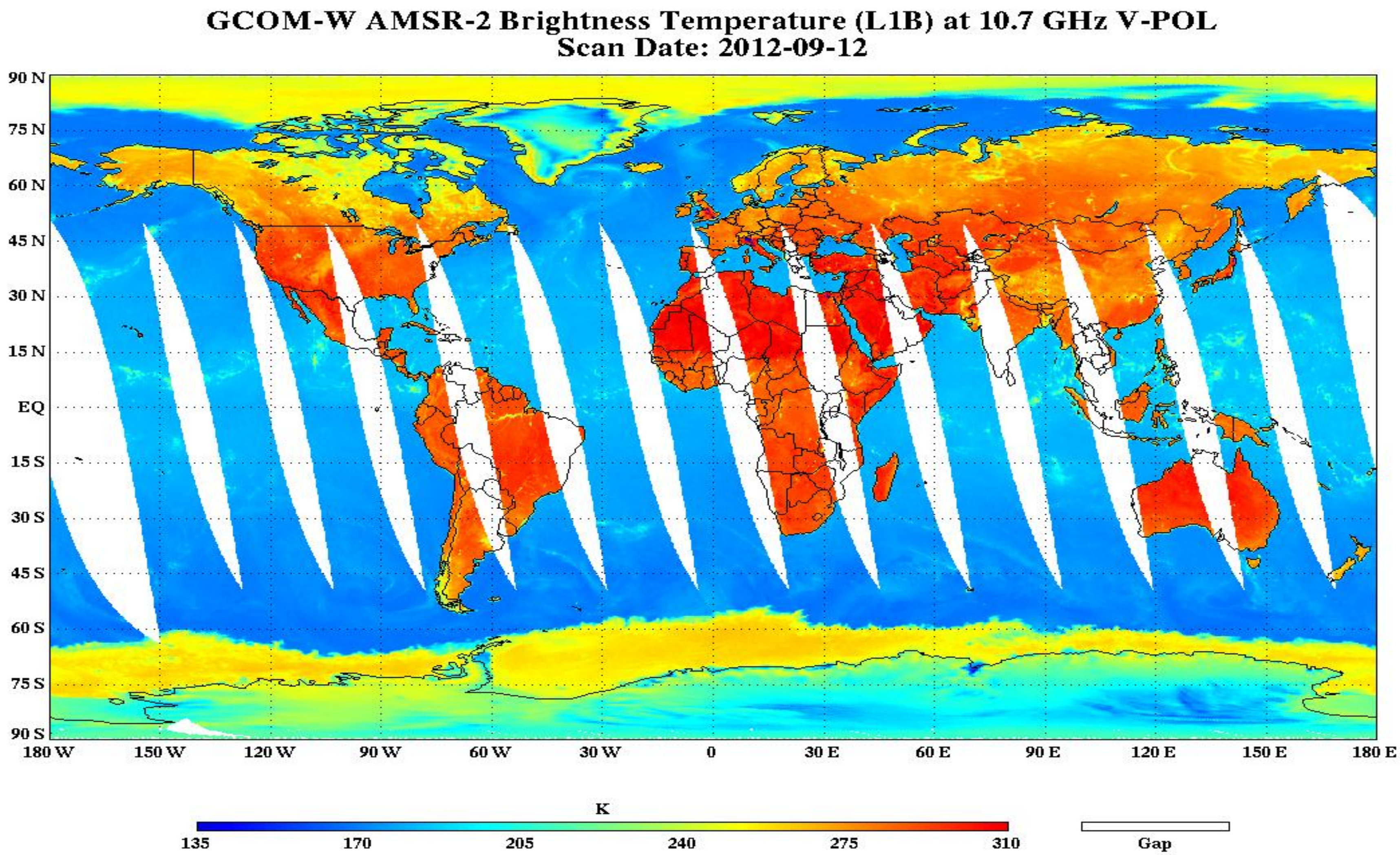
- Deployable main reflector system with 2.0m diameter.
- Frequency channel set is identical to that of AMSR-E except 7.3GHz channel for RFI mitigation.
- 2-point external calibration with the improved HTS (hot-load).

AMSR2 characteristics	
Scan	Conical scan
Swath width	1450km
Antenna	2.0m offset parabola
Digitalization	12bit
Incidence angle	nominal 55 degree
Polarization	Vertical and Horizontal
Dynamic range	2.7-340K

AMSR2 Channel Set				
Center Freq. [GHz]	Band width [MHz]	Polarization	Beam width [deg] (Ground res. [km])	Sampling interval [km]
6.925/ 7.3	350	V and H	1.8 (35 x 62)	10
			1.7 (34 x 58)	
10.65	100		1.2 (24 x 42)	
18.7	200		0.65 (14 x 22)	
23.8	400		0.75 (15 x 26)	
36.5	1000		0.35 (7 x 12)	
89.0	3000		0.15 (3 x 5)	5

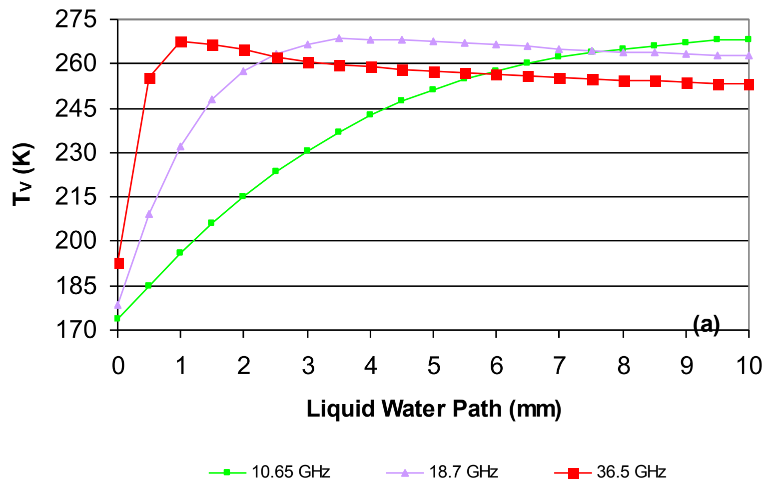
GCOM-W AMSR-2 provides higher space resolutions compared its precursor on EOS-Aqua (AMSR-E) and better design for mitigating radio frequency interference in land remote sensing application

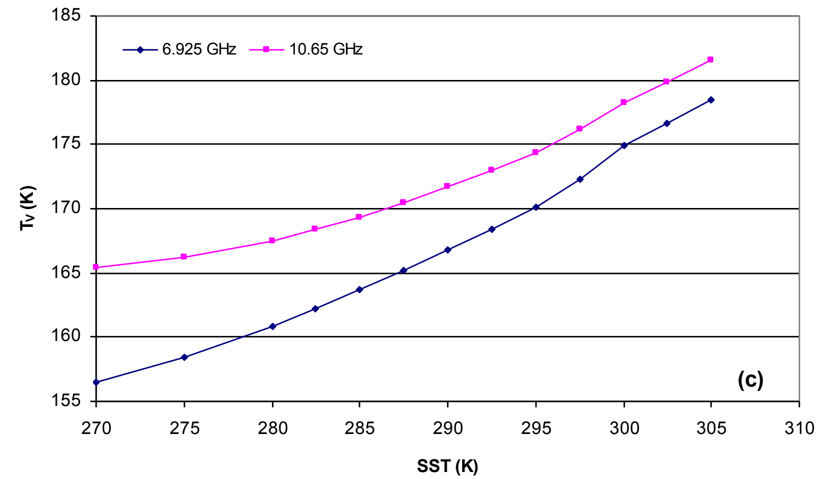
Information Content from GCOM-W1 AMSR2

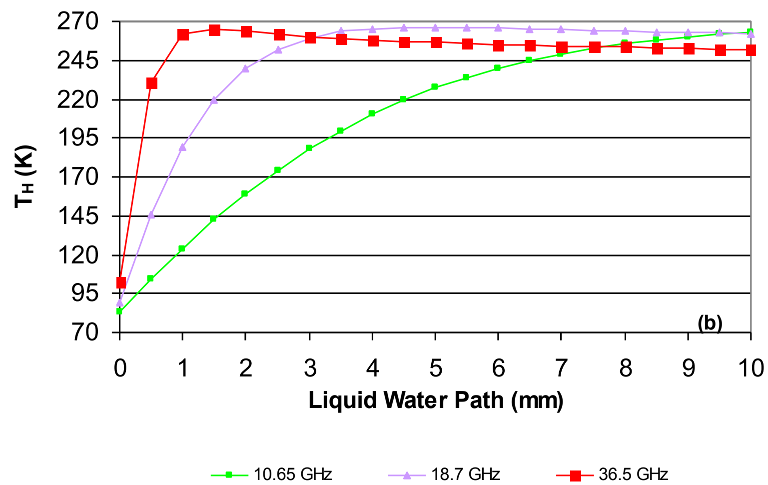


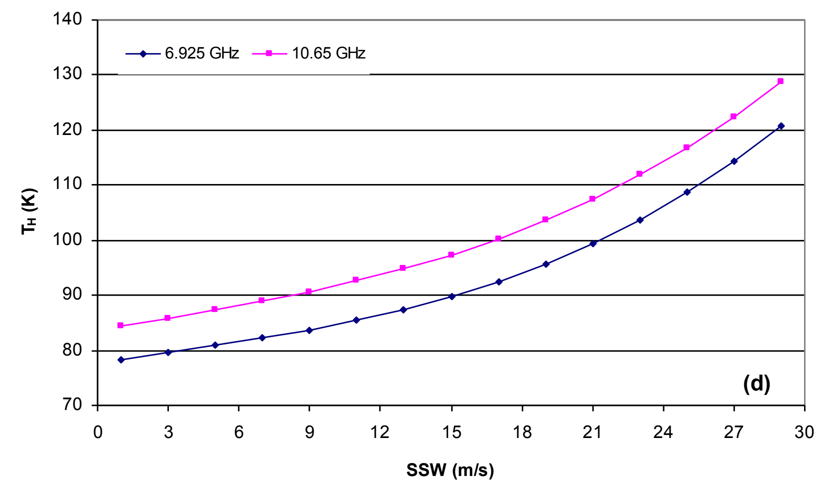
JAXA launched GCOM-W1 on Oct 18, 2011 with AMSR2 on board and NESDIS is developing NOAA unique AMSR2 products for user community.

AMSR-E Ocean Products: Theoretical Base

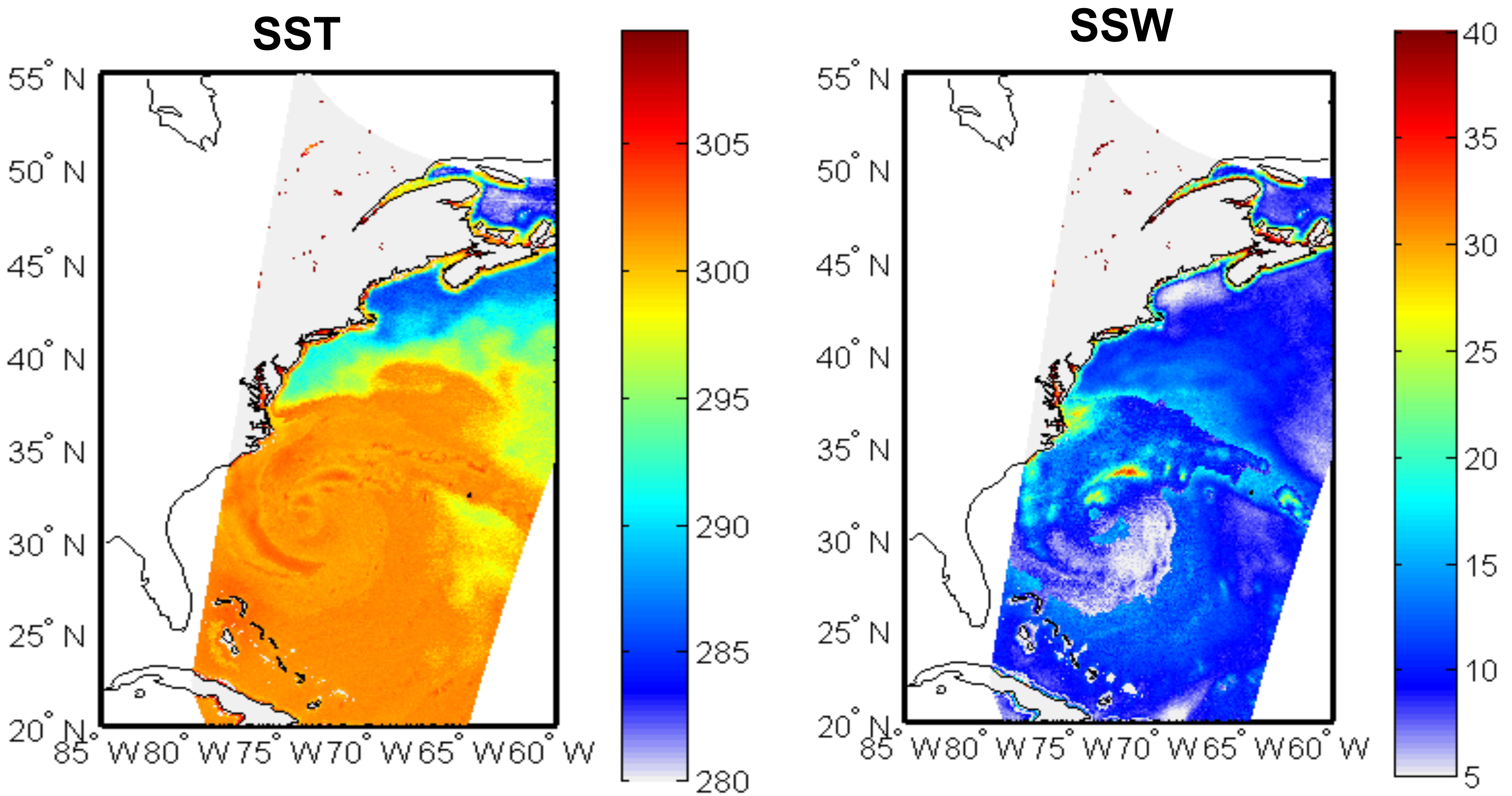








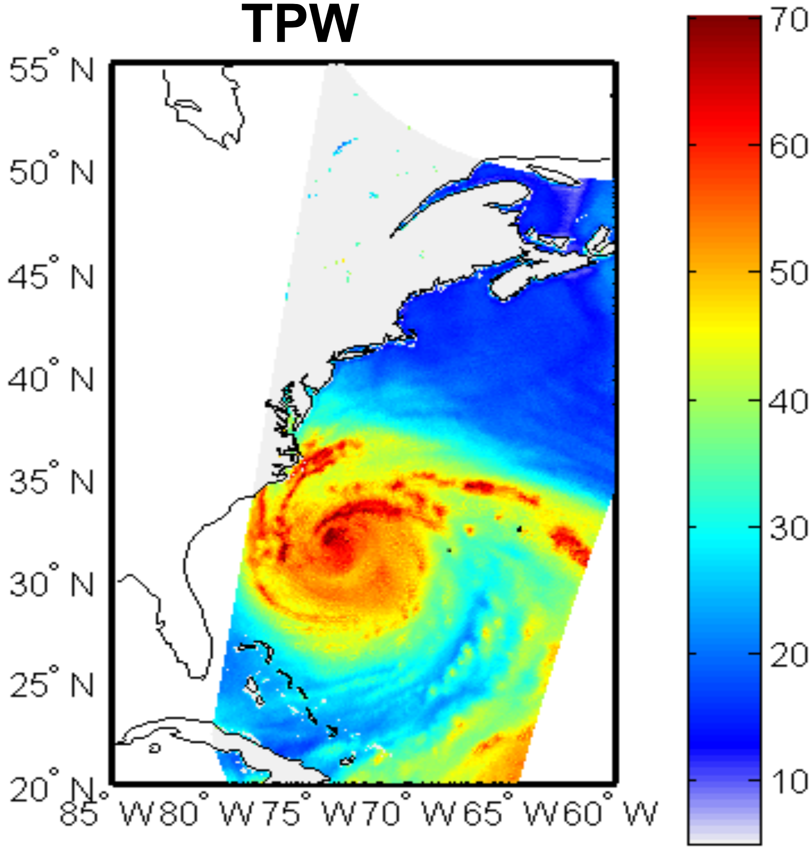
Information Content from GCOM-W1 AMSR2
Hurricane Sandy-10-28-2012 06 UTC



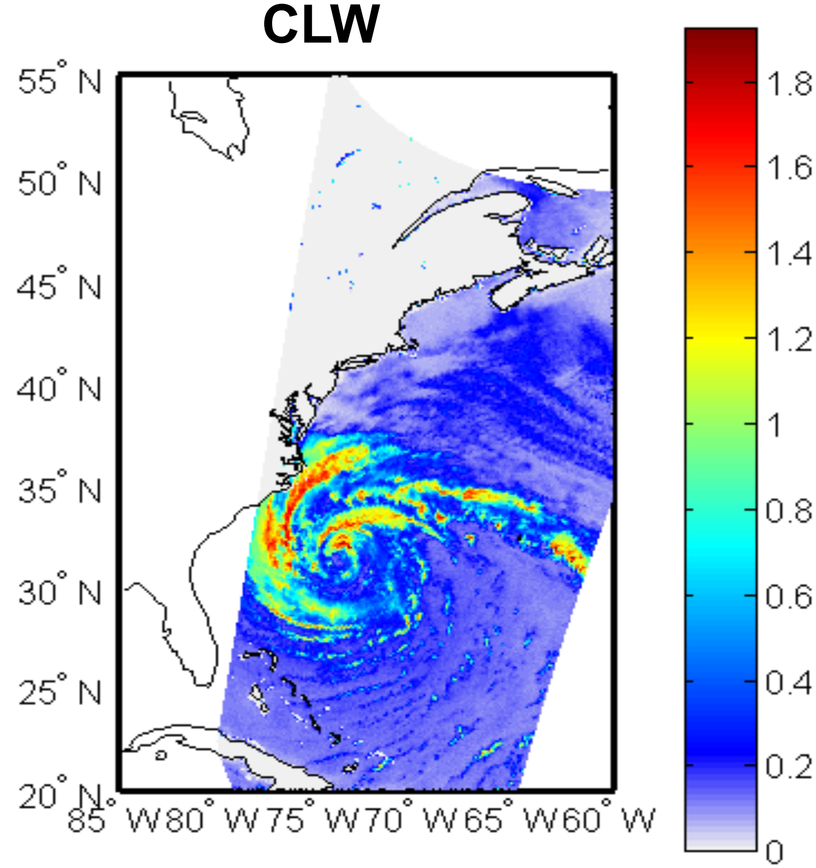
JAXA launched GCOM-W1 on Oct 18, 2011 with AMSR2 on board and NESDIS is developing NOAA unique AMSR2 products for user community.

Information Content from GCOM-W1 AMSR2
Hurricane Sandy-10-28-2012 06 UTC

TPW



CLW



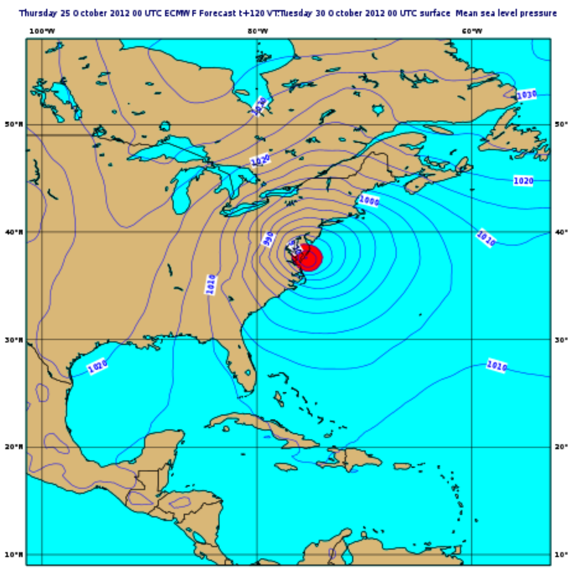
JAXA launched GCOM-W1 on Oct 18, 2011 with AMSR2 on board and NESDIS is developing NOAA unique AMSR2 products for user community.

Forecasts of Hurricane Sandy without Polar satellites

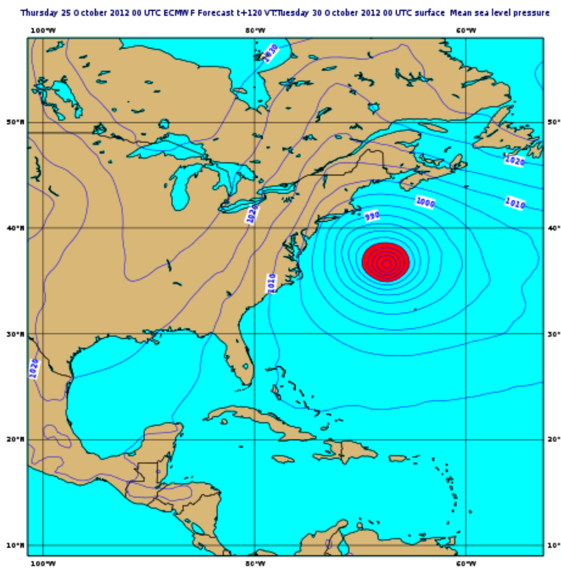
Tony McNally

ECMWF forecasts of Mean Sea Level Pressure, **5 days in advance** of the 30th October 2012 for the landfall of Hurricane Sandy. Forecasts from an assimilation system **with no polar satellites** fail to predict the landfall of the storm on the US east coast.

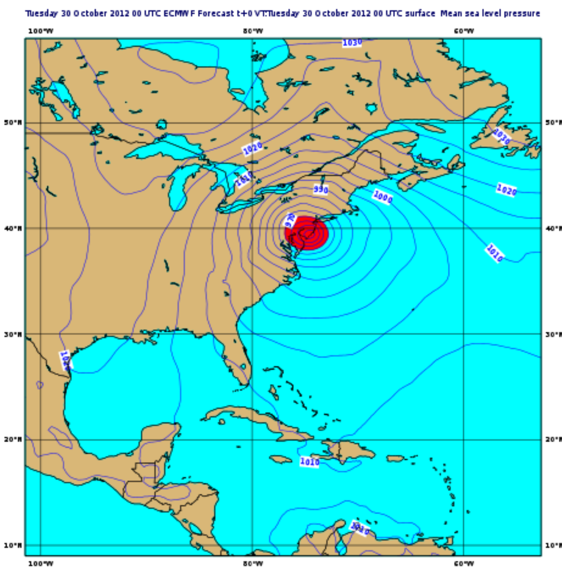
ECMWF OPS



NO POLAR SAT



VERIFICATION



5 day forecast: Base time 2012-10-25-00z **Valid Time: 2012-10-30-00z**

Satellite Data Critical for Improving Hurricane and Coastal Precipitation Forecasts

- Satellite microwave sounding data – provide hurricane thermal/moisture structure for improving intensity forecast (**SSMIS**/AMSU-A/MHS/**ATMS)**
- Satellite infrared sounding data – provide environmental thermal and moisture structure for track and precipitation forecast (HIRS/**CrIS**/AIRS/IASI)
- Ocean surface wind and temperature from satellite scatterometer and passive microwave imager – provide surface energy flux and surface vortex (ASCAT/ **AMSR2/GMI)**
- GPSRO refractivity and bending angle – provide tropical cyclonegenesis information (COSMIC/GRAS)
- Geostationary sounder and imager – provide real-time monitoring and tracking of all severe weather events with a high temporal and spatial resolutions (e.g. GOES etc).

Statement of Problems in GSI

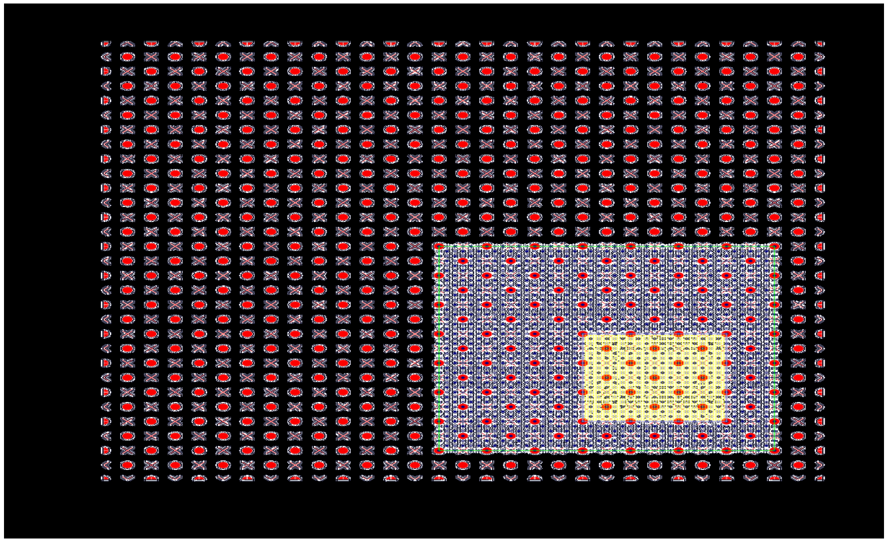
- NCEP GSI (3DVar data assimilation system) is being used by community for both global and regional model analysis but its interface is not designed well for different model configurations

- In 2011 and 2012 version of Hurricane Weather Research Forecast (HWRF) model, most of satellite data are not used in HWRF analysis process due to its model top setup

- Analyses show GSI quality controls for satellite water vapor sounding data are also problematic (lots of bad data sneak into the analysis process).

- Bias correction schemes for satellite data developed for the global model applications have not been fully vetted for regional model applications

STAR Baseline HWRF Model and Data Assimilation System



HWRF Model:

- 2012 NCEP-Trunk version 934
- Three telescoping domains:

Outer domain: 27km: 75x75^o;
Inner domain: 9km ~11x10^o
Inner-most domain: 3km inner-most nest ~6x6^o

Revised Model Level and Top:

- Vertical levels: 61
- Model top: 0.5 hPa

Data Assimilation System:

- GFS 6 hour forecasts
- GSI (3DVAR)

•The Hurricane Weather Research and Forecasting (HWRF) Model dynamical core is designed based on the WRF model using NCEP Non-Hydrostatic Mesoscale Model (NMM) core with a movable high-resolution nested grid (telescopic)
•Regional-Scale, Moving Nest, Ocean-Atmosphere Coupled Modeling System. Horizontal resolution: 27 km outer grid, 9 km inner grid, 42 vertical levels
•Non-Hydrostaticsystem of equations formulated on a rotated latitude-longitude, Arakawa E-grid and a vertical, pressure hybrid (sigma_p-P) coordinate.
•Advanced HWRF 3D Variational analysis that includes vortex relocation, correction to winds, MSLP, temperature and moisture in the hurricane region and adjustment to actual storm intensity.
•Uses SAS convection scheme, GFS/GFDL surface, boundary layer physics, GFDL/GFS radiation and Ferrier Microphysical Scheme.
•Ocean coupled modeling system (POM/HYCOM).

Data Sets Used for STAR HWRF Assimilation

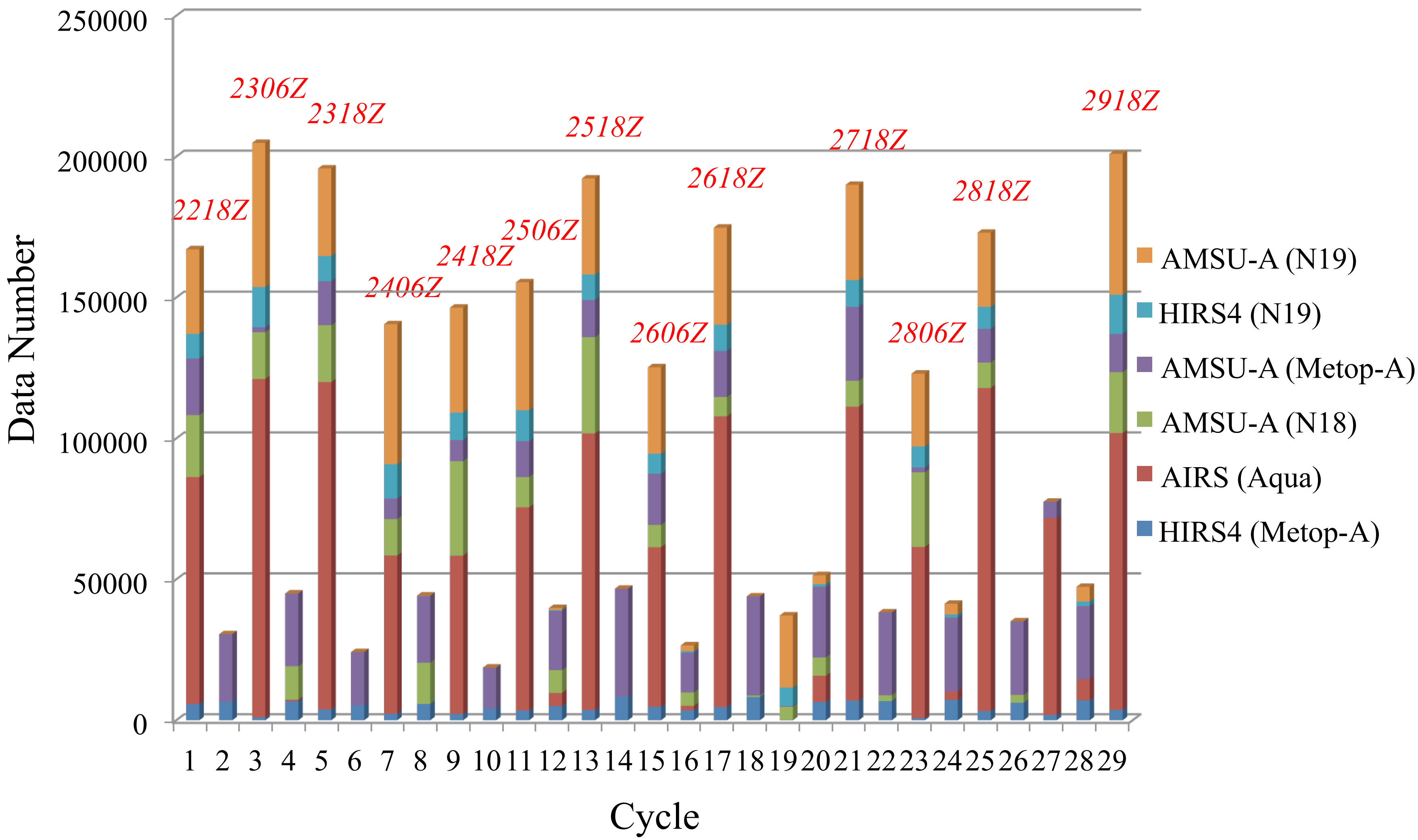
Conventional Data:

Radiosondes, aircraft reports (AIREP/PIREP, RECCO, MDCRS-ACARS, TAMDAR, AMDAR), Surface ship and buoy observations , Surface observations over land, Pibal winds,Wind profilers, VAD wind, Dropsondes

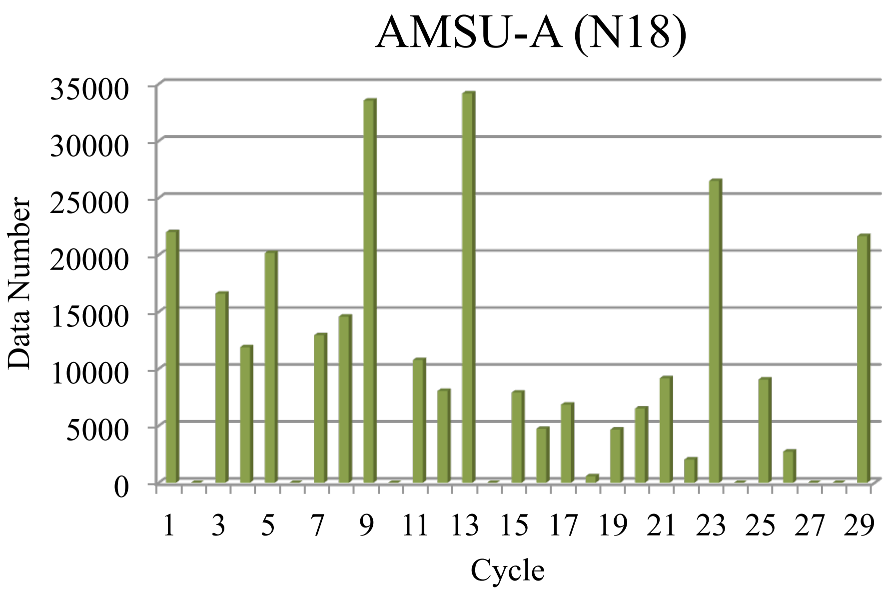
Baseline Satellite Instrument Data:

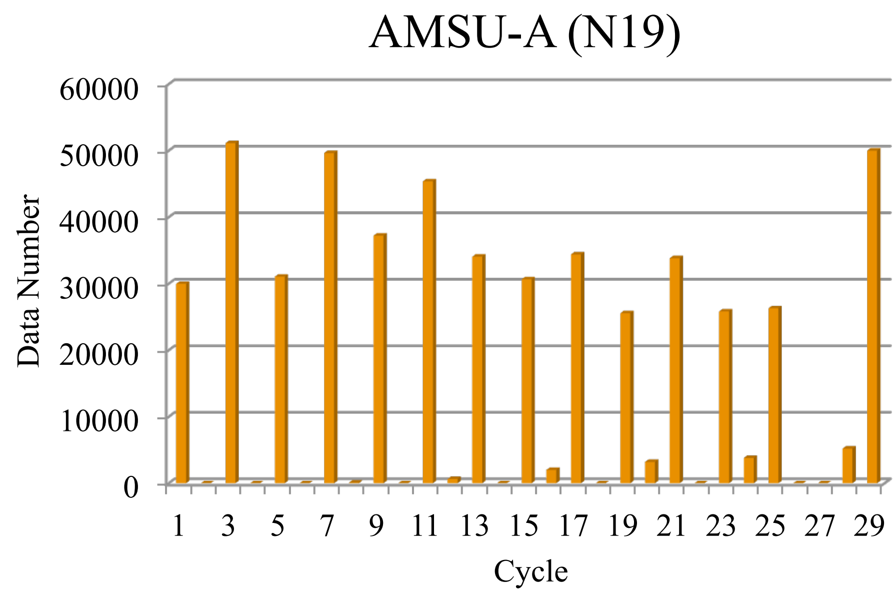
- AMSU-A (channel 5-14) from NOAA-18,19 and METOP-A, METOP-B
- HIRS from NOAA-19,METOP-A, METOP-B
- AIRS from EOS Aqua
- IASI from METOP-A and METOP-B
- ASCAT from METOP-A and METOP-B
- GPSRO from GRAS, COSMIC
- *CrIS/ATMS from Suomi NPP (to be added)*
- *SSMIS from F18 (to be added)*
- *AMSR2 from GCOM-W1 (to be added)*

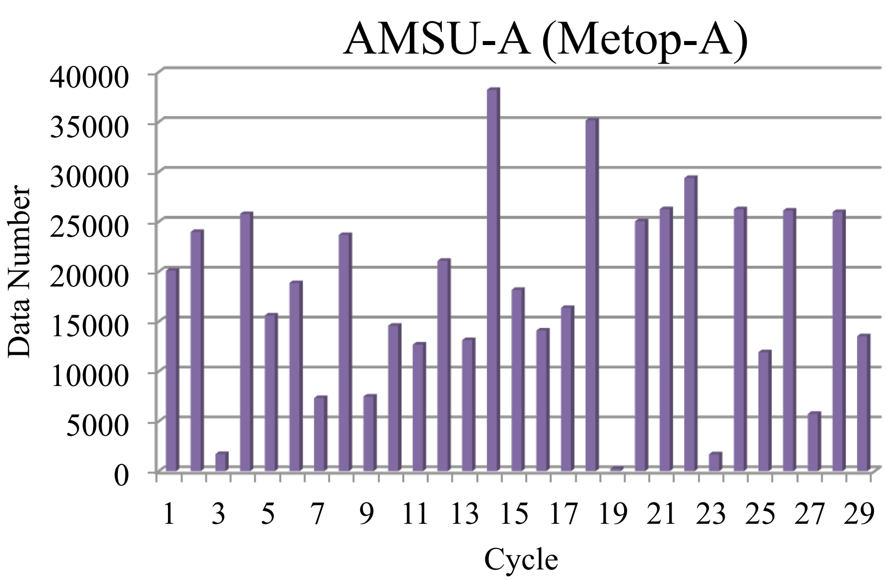
Number of Satellite Data Assimilated in HWRF-L61F



Number of Satellite Data Assimilated in HWRF-L61F







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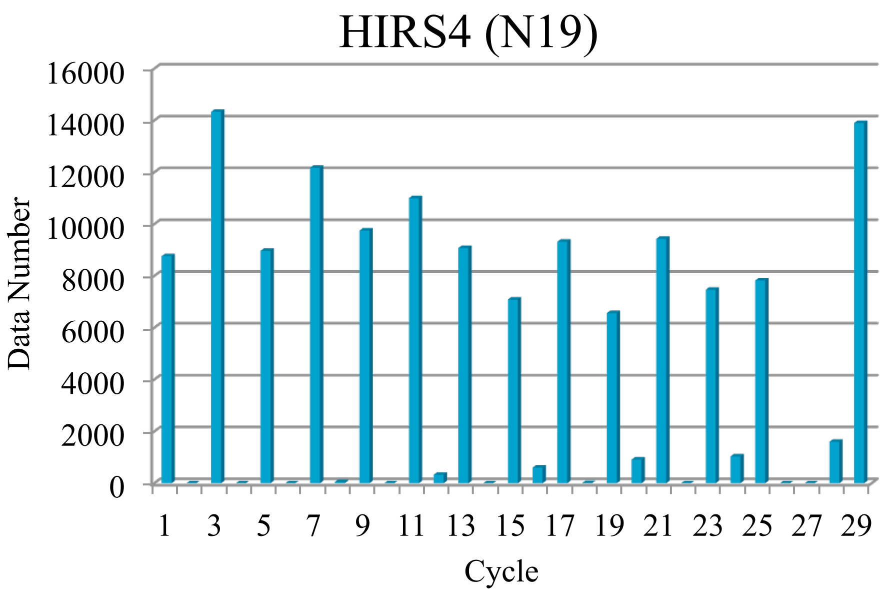
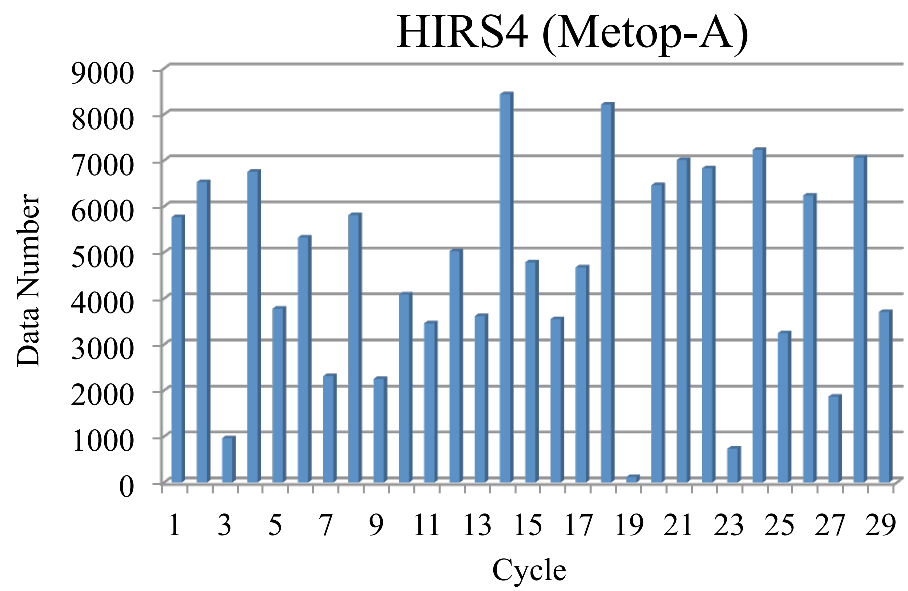
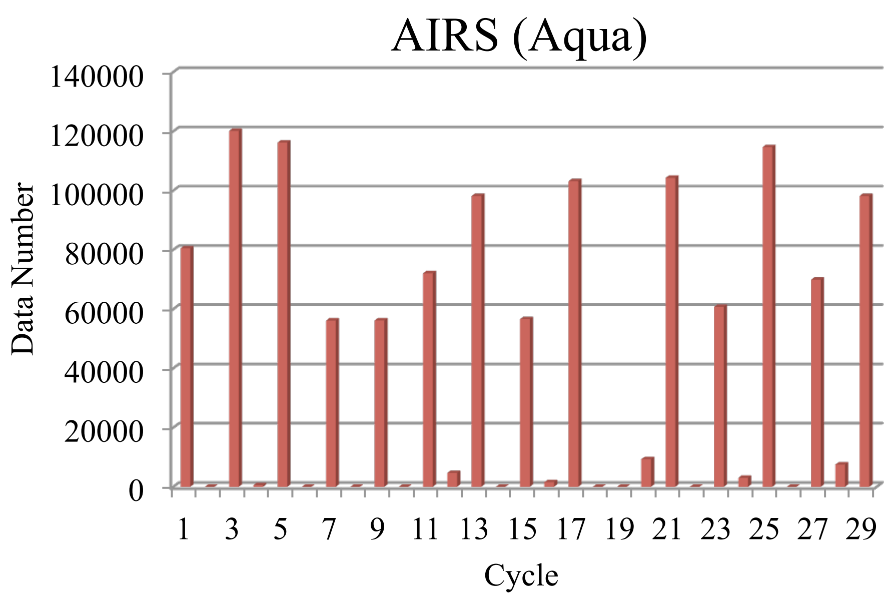
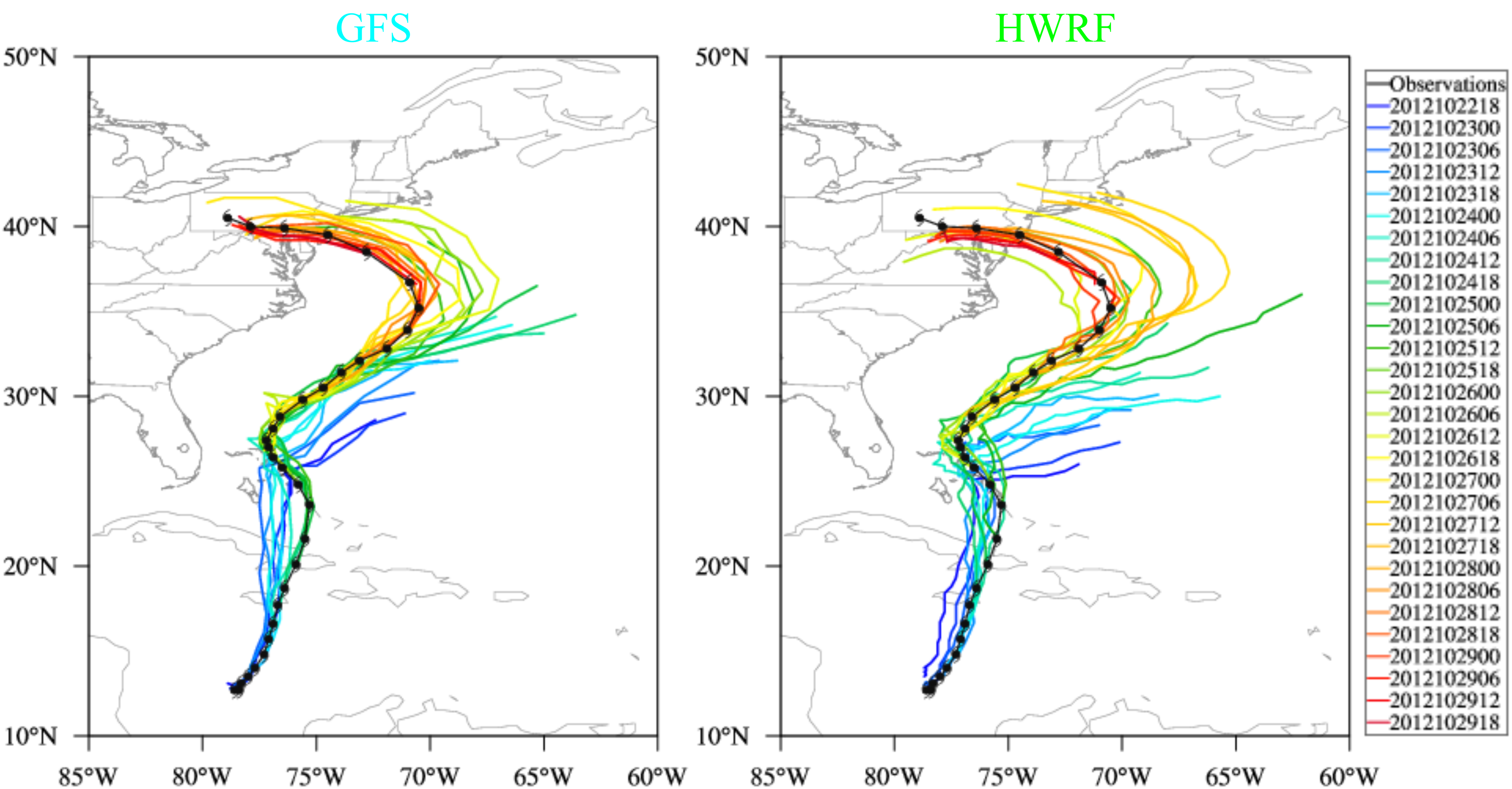


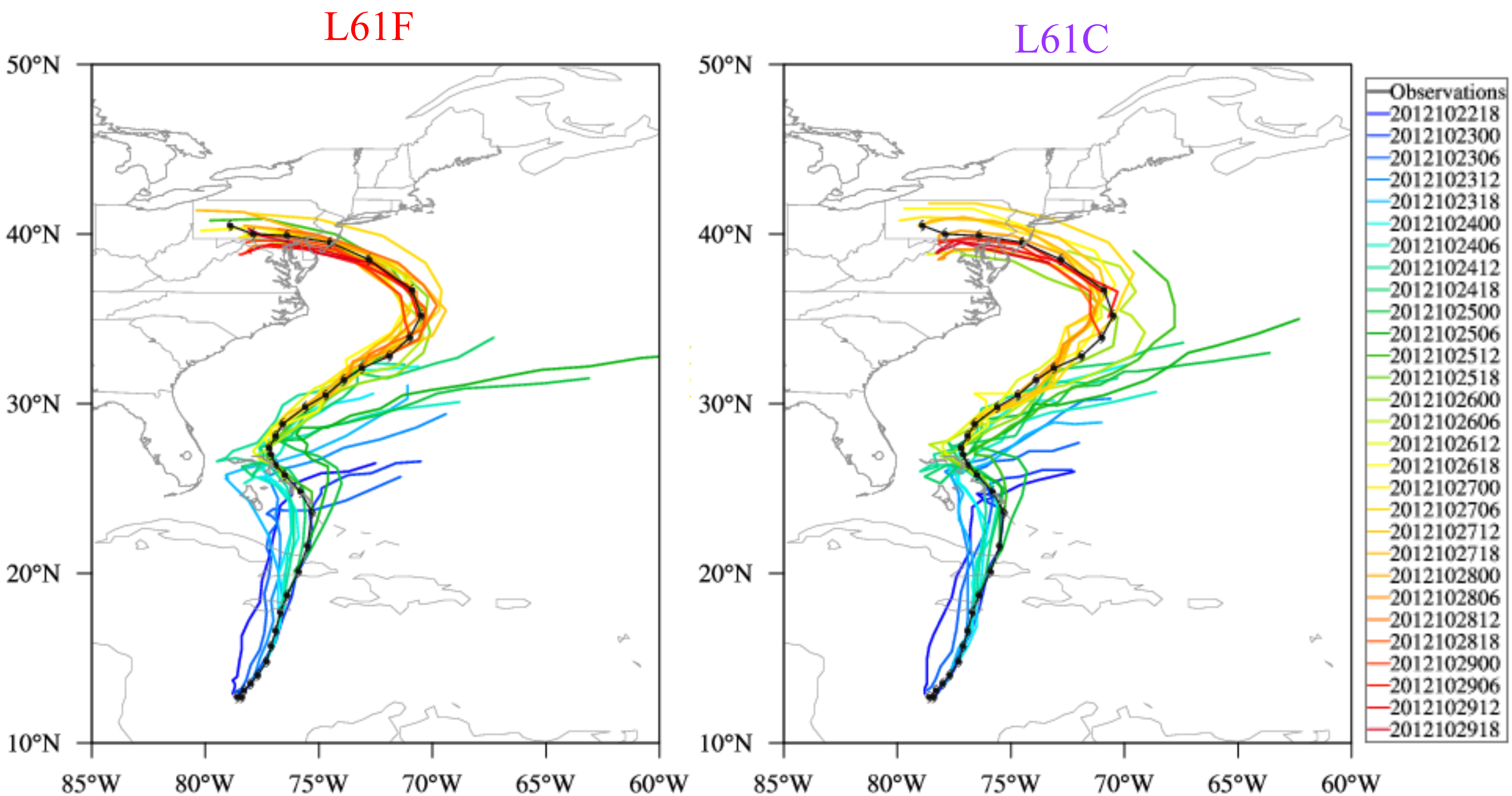




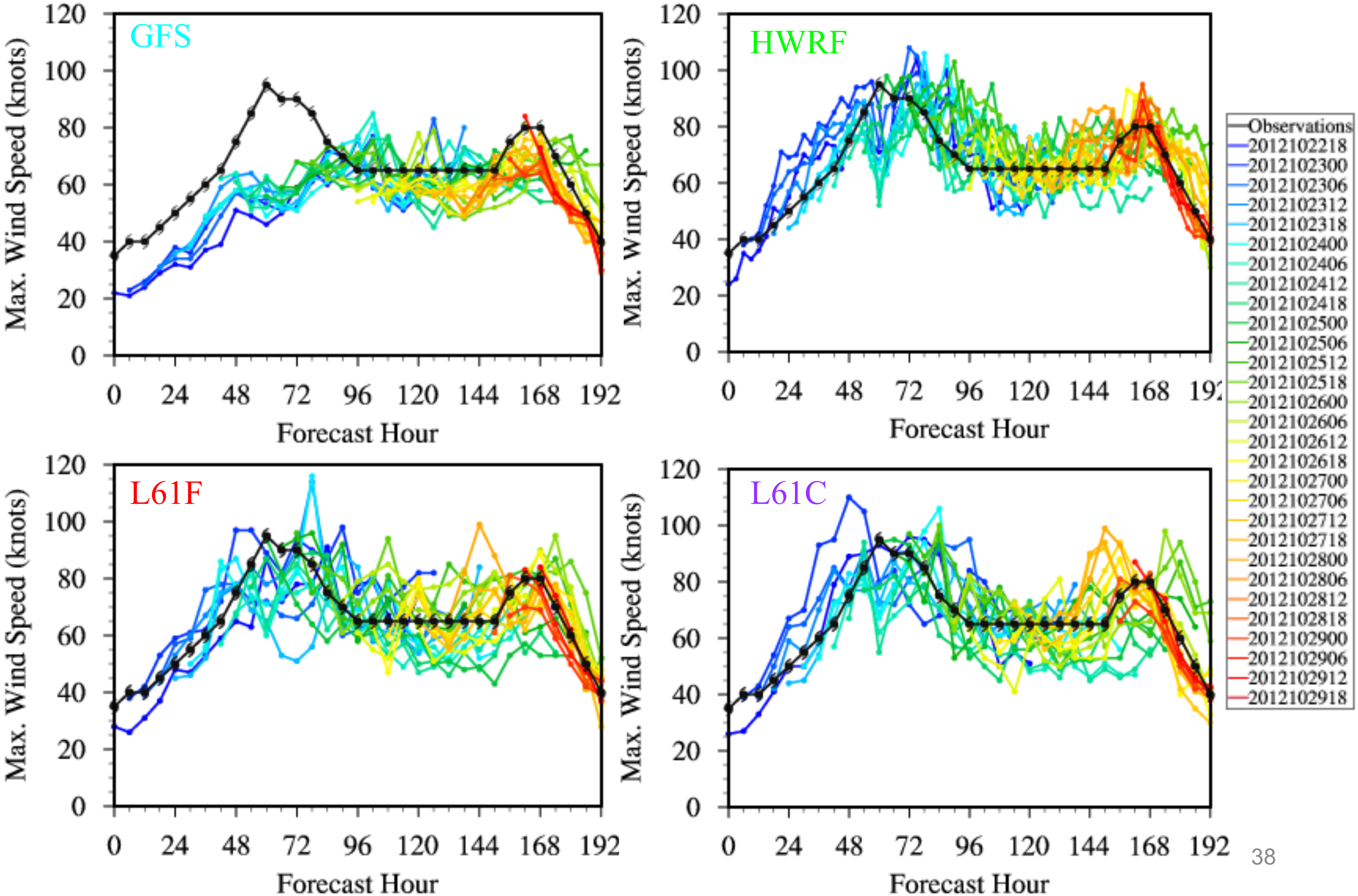
Multiple Forecasts of Tracks



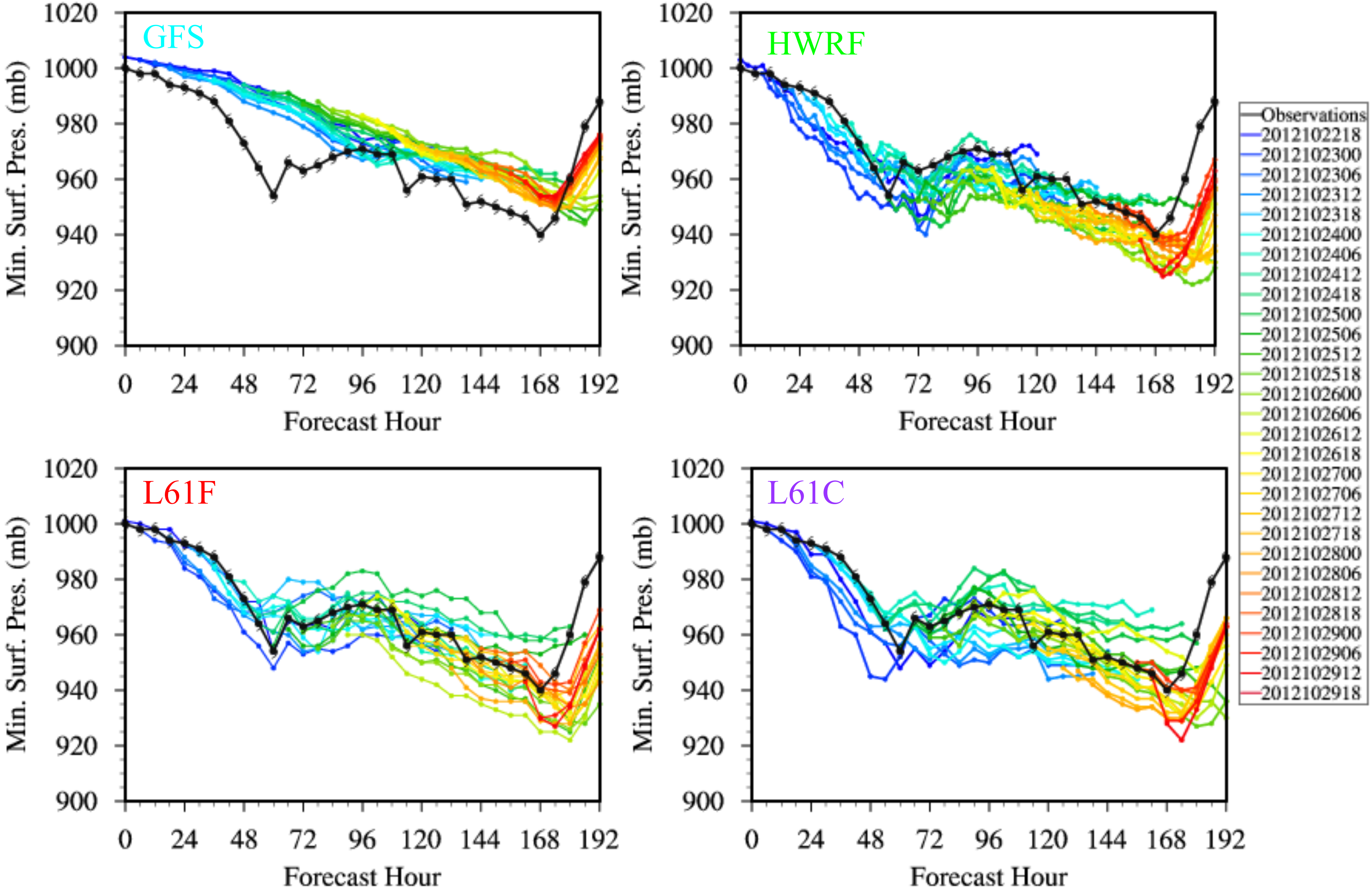
Multiple Forecasts of Tracks



Multiple Forecasts of Max. Wind Speed



Multiple Forecasts of Min. Surf. Pres.



Summary and Conclusions

- NOAA, METOP, DMSP polar satellites provide critical information on atmospheric vertical temperature structure for hurricane monitoring and forecasts

- Suomi NPP ATMS is very unique for resolving hurricane warm core features through spatial oversampling and additional channel

- GCOM-W1 AMSR2 are new instrument and can provide surface wind speed and SST for hurricane applications

- METOP and FY-3 unique instruments ((e.g. GPSRO, scattterometer, ozone) provide more information for NWP and other environmental applications

- A baseline version of HWRF and satellite instruments is defined for our hurricane and typhoon research and applications.

- In 2012 hurricane and typhoon season, Our baseline HWRF/DA system in general improves the intensity forecasts for most of study cases including Hurricane Sandy