STAR GCOM-W1/AMSR2 PROJECT UPDATE AND STATUS

STAR GCOM-W1 Project Team
Presented by Paul Chang

Paul Chang, Ralph Ferraro, Zorana Jelenak, Suleiman Alsweiss, Patrick Meyers, Qi Zhu, Mark Romer, Xiwu Zhan, Jicheng Liu, Eileen Maturi, Fuzhong Weng, Andy Harris, Jeff Key, Cezar Kongoli, Walt Meier, Yong-Keun Lee, Walter Wolf, Tom King, Letitia Soullaird, Peter Keehn, Mike Wilson …

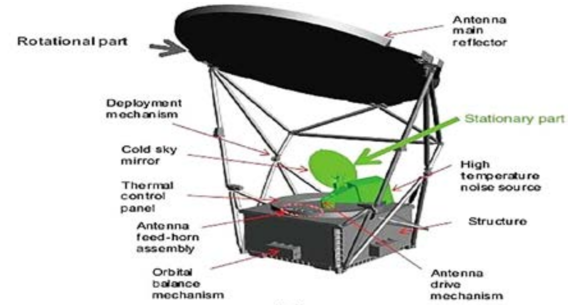
Outline

- Sensor Overview
- AMSR2 EDRs and Project Schedule
- Ongoing validation activities
- Long term monitoring and science maintenance
- Summary and Path Forward

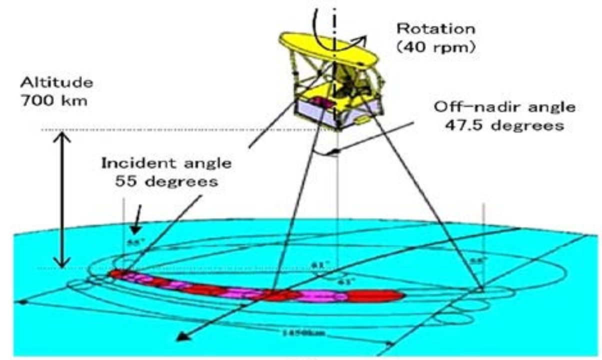
AMSR2 Instrument Overview

General Information

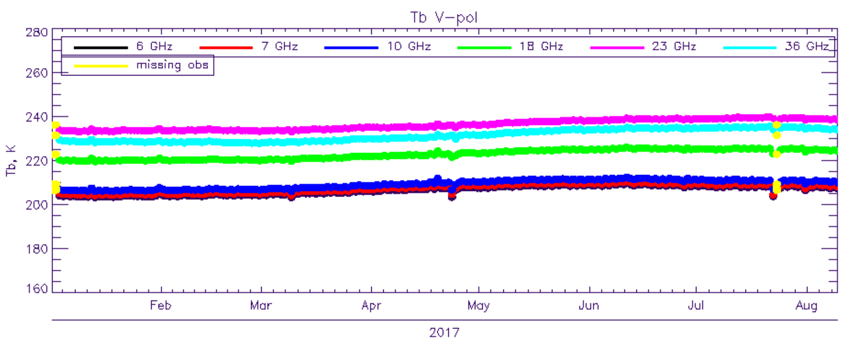
- Launched: JAXA, 05/2012
- Swath: 1450 km
- EIA: 55°
- Rate: 40 rpm
- Instrument is healthy and performing well
- Ample fuel reserves

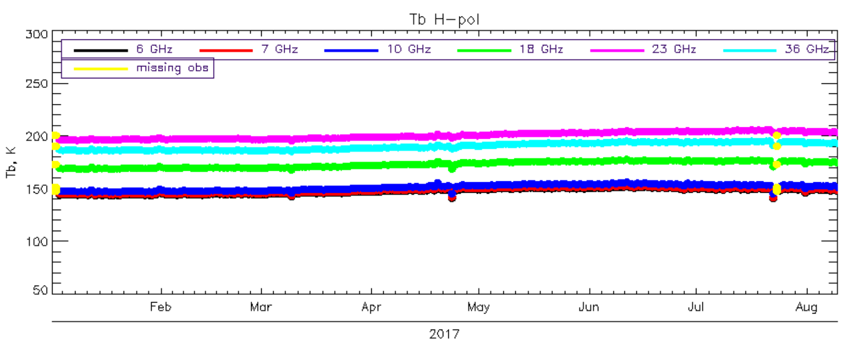


(a)



(b)





Center freq. (GHz)	Band width (MHz)	Beam width (3 dB, deg.)	Ground IFOV (km)	Sampling interval (km)
6.925/7.3	350	1.8	35 x 62	10
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

STAR GAASP Development

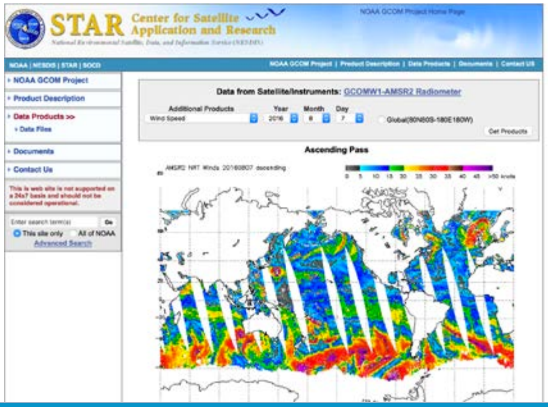
- GCOM-W1 AMSR2 Algorithm Software Processor (GAASP) development :
- Products
  - Microwave Brightness Temperature (MBT)
  - Total Precipitable Water (TPW)
  - Cloud Liquid Water (CLW)
  - Sea Surface Temperature (SST)
  - Sea Surface Wind Speed (SSW)
  - Precipitation Type/Rate (PT/R)
  - Snow Cover/Depth (SC/D)
  - Snow Water Equivalent (SWE)
  - Sea Ice Characterization (SIC)
  - Soil Moisture (SM)

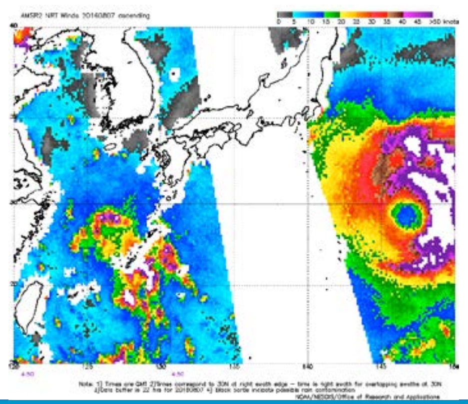
Project Schedule Overview

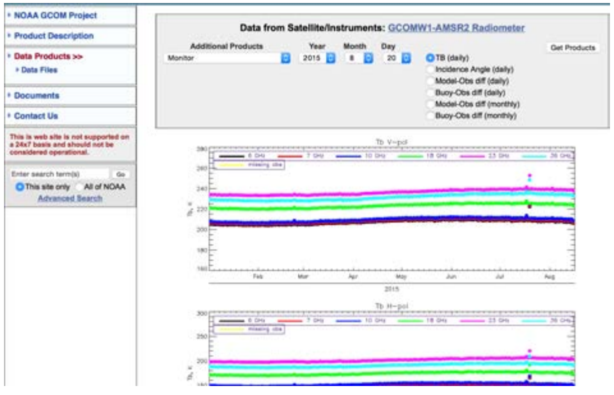
- As of September 27, 2016 all products were formally designated as operational
- Since June 2013: Products available in near real-time to users (NHC, JTWC, NRL, etc.) via the GAASP on the STAR GCOM-W1/AMSR2 product development and validation system
- Discontinuities were found the level 1 files that were introduced by the IDPS granules. This necessitated moving to full orbit contacts through IDPS which which was implemented in NDE 2.0 with IDPS B2.0.
  – Currently NDE is ingesting AMSR RDRs and processing to Level 1 locally utilizing JAXA provided software
- All NOAA GCOM-W1/AMSR2 products being distributed via PDA
- Updates delivered annually or as required in response to issues such as sensor aging, calibration updates, etc.:
  – Includes updates and enhancements to existing EDRs

Ongoing Validation Activiites

- Collocation of numerical model, objective analysis and satellite data with GCOM-W1/AMSR2 measurements
- Collocation of in-situ data from gauges and field experiments
- Statistical analysis of AMSR2 brightness temperature measurements (level 1 products) utilizing CRTM to characterize residual calibration errors that will impact higher level products
- Statistical analysis of NOAA AMSR2 level 2 products
- Responding to user feedback and questions
- STAR quality monitoring and product display for visual analysis of NOAA AMSR2 products
  - http://manati.star.nesdis.noaa.gov/gcom/
- STAR AMSR2 EDR quick look product page
- http://www.star.nesdis.noaa.gov/jpss/EDRs/products_gcom.php







Long Term Monitoring and Science Maintenance

- Extend validation datasets (spatially and temporally collocated numerical model and satellite data) to account for seasonal and annual trends.
- Collect in-situ data from relevant field experiments to support validation and quality assurance not possible by utilizing existing satellite or numerical model datasets. For example, characterization of product performance in extreme environmental conditions (tropical and winter storms) generally require specialized datasets.
- Algorithm sustainment, such as, updates to the algorithms when quality issues are identified in operation or when Level 1 processing updates are implemented by JAXA
- Other event-driven anomalies, such as, channel loss, sensor degradation, which will impact the measurements and thus the derived products

Summary & Path Forward

- Implement EDR improvements and enhancements resulting from ongoing validation activities and user feedback into GAASP updates
- Calibration updates, product updates and continued monitoring and quality control
  - Continue working with JAXA on Level 1 calibration improvements
    - NOAA-JAXA GCOM-W1/AMSR2 technical exchange meeting scheduled for Nov. 2017
  - Address JAXA updates to Level 1 processing software as needed
  - Continue validation and product monitoring and implement product updates as needed
  - User product training and outreach
- Provide support to JAXA as appropriate to help them realize a GCOM-W1 follow-on mission.
- Reprocessing of NOAA AMSR2 Level 2 products
  - Provide consistently processed products covering the entire mission dataset (5+ years) to support longer term product validation and utilization in seasonal/annual environmental monitoring and prediction.
- Evaluating change from Reynolds to CMC SST analyses for ancillary data input to GAASP
- Update wind speed product with an emphasis on improving high wind performance.

AMSR-2 HIGH WIND VALIDATION AND PRODUCT UPDATE STAGE I

Zorana Jelenak[1], Suleiman Alsweiss[2], Faozi Said[2], Joe Sapp[2], Seubson Soisuvarn[1]
and Paul S. Chang[3]
[1]NOAA/NESDIS/STAR-UCAR
[2]Global Science & Technology
[3]NOAA/NESDIS/STAR

Motivation

- There is tremendous interest in both the operational and research communities in high wind event observations
- However, there exist large disparities in wind intensity estimates between different sensor observations as well as between different wind products from the same sensor and there is a general lack of surface truth
- Disagreements stem from differences in:
  - Measurement resolution
  - Sensor sensitivity to high winds
  - Geophysical model functions
  - Retrieval algorithm approaches
  - Atmospheric and sea state impacts on measurements
- High wind algorithm and product developments led by NOAA STAR Winds Team, RSS, JPL, JAXA, Meteo France, ESA

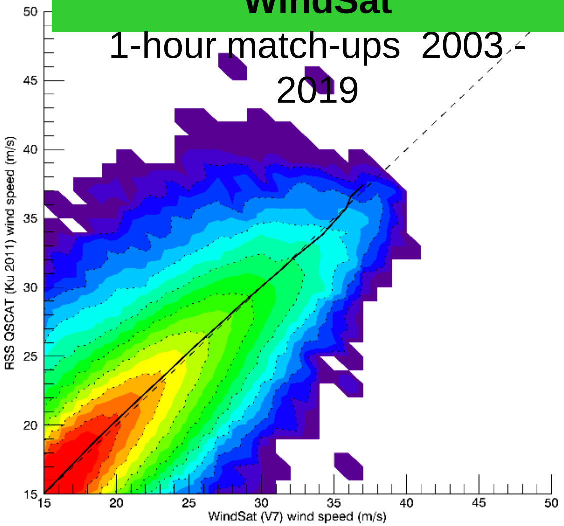
Remote Sensing Systems:

Bringing Consistency into High Wind Measurements with Spaceborne Microwave Radiometers and Scatterometers

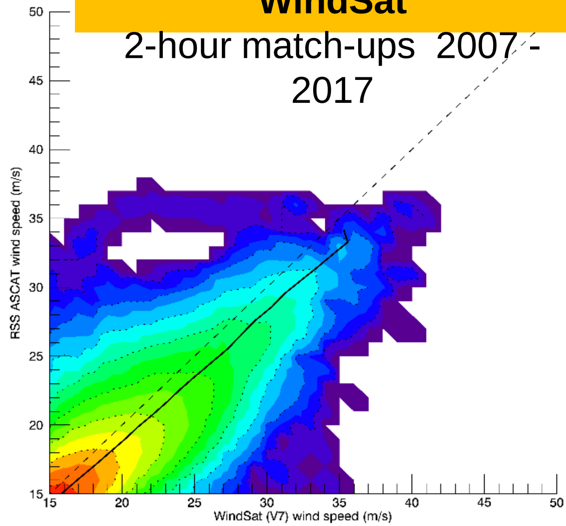
Product development based on H*Wind, SFMR, Dropsondes collocated with WindSat. All RSS Radiometer and Scatterometer retrievals calibrated to match WindSat

Remote Sensing Systems
www.remss.com

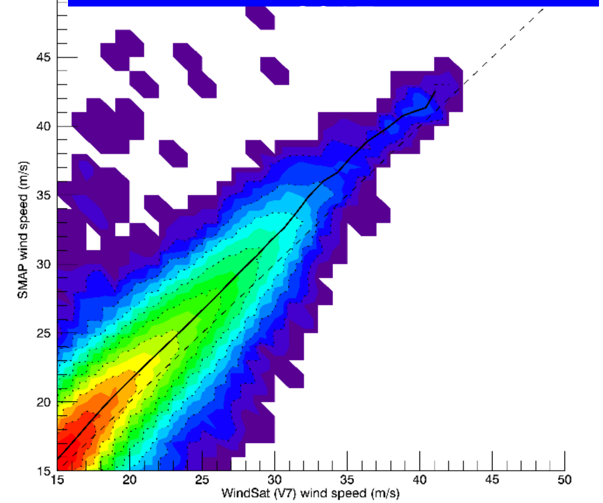
QuikScat (Ku 2011) vs WindSat
1-hour match-ups 2003 - 2019



RSS ASCAT (V2.1) vs WindSat
2-hour match-ups 2007 - 2017



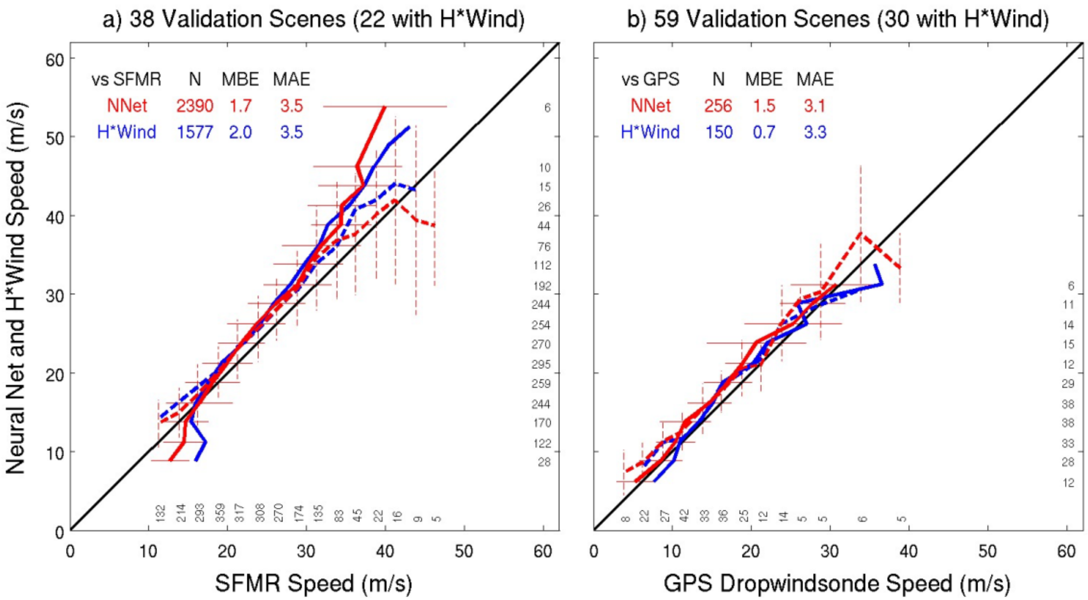
SMAP vs WindSat
1-hour match-ups 2015 -



Presented by Thomas Meissner IOWVST 2017

BAMS September 2017 issue
http://journals.ametsoc.org/doi/10.1175/BAMS-D-16-0052.1 in print

JPL High Wind Product Development



- Product development based on SFMR, Dropsondes, H*Wind model and best track

Presented by A. Fore (JPL)
High winds Workshop Nov 2016, Exeter

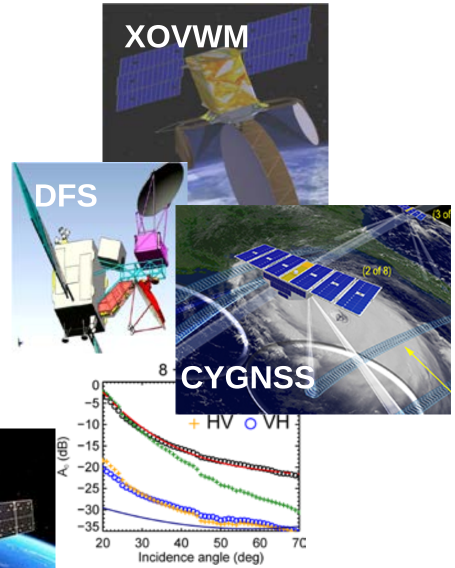
QuikSCAT All weather high wind speed
Presented by B. Stiles
IOVWST 2013

JAXA AMSR-2 High Wind Product

Presented at JAXA/EORC, RESTEC Nov 2015
Developed by Dr Akira Shibata

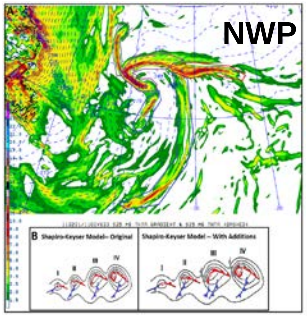
- The product contains wind speeds in the best track of typhoons announced by Japan Meteorological Agency and NOAA National Hurricane Center.
- The wind speeds above 17 m/s retrieved by this algorithm were compared with the maximum wind speeds within 200 km from the center position of the best track or the wind speeds observed by dropsondes.
- Utilizes 6.9- and 10.7- GHz H channels. This algorithm realizes to retrieve the sea surface wind speed more than 70 m/s.

NESDIS/STAR Ocean Winds Aircraft Experiment



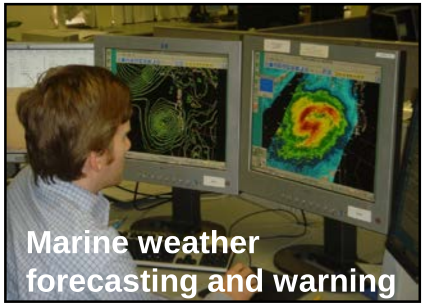
Calibration, validation and product improvements of current scatterometer and radiometer satellite measurements

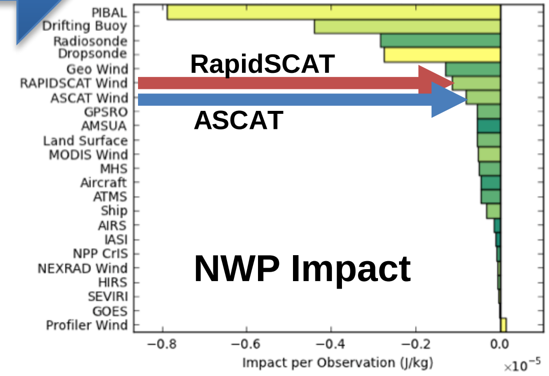
New instrument design and risk reduction for future satellite instruments



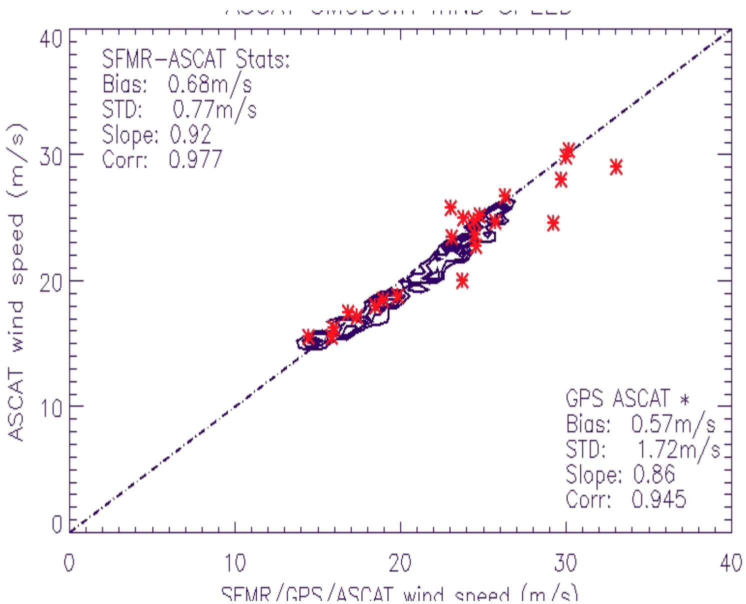
New insights into physics of hurricane force winds within extratropical storms

R2O

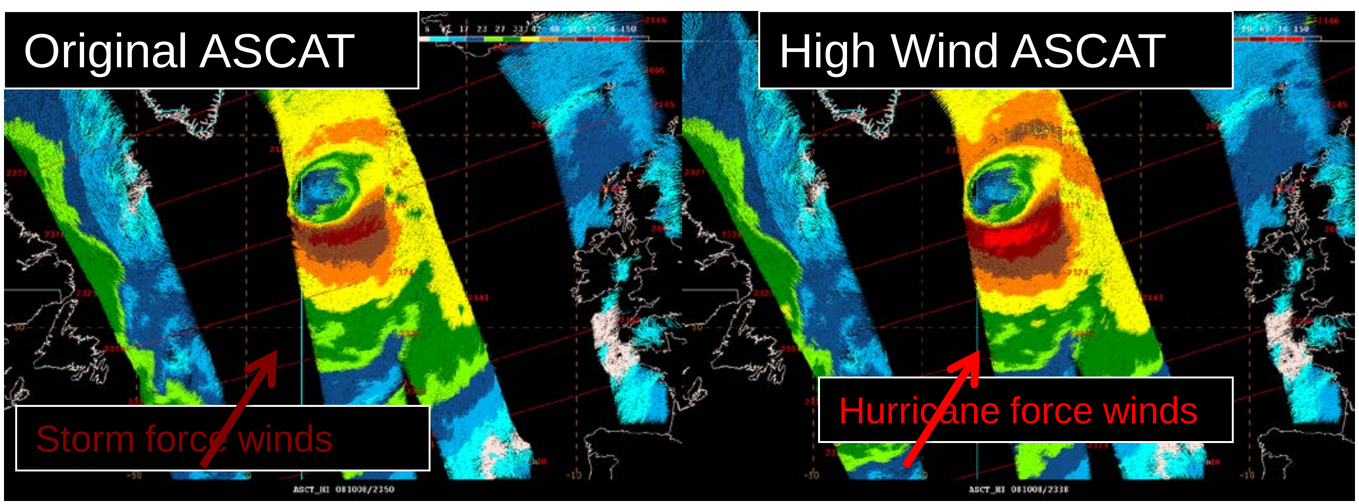




NOAA ASCAT Scatterometer High Wind Product



- Geophysical model function developed using airborne IWRAP scatterometers and SFMR radiometer measurements
- Satellite GMF tuned to match SFMR and dropsonde measurements in ETC
- Utilized in operations since 2011
  - Considered to have best high wind retrievals within ETC by operational community



S. Soisuvarn, Z. Jelenak, P. S. Chang, S. O. Al-sweiss, and Q. Zhu, “CMOD5.H—A High Wind Geophysical Model Function for C-Band Verti- cally Polarized Satellite Scatterometer Measure- ments,” IEEE Transactions on Geoscience and Remote Sensing, pp. 1–17, Nov. 22, 2012. doi: 10.1109/TGRS.2012.2219871.

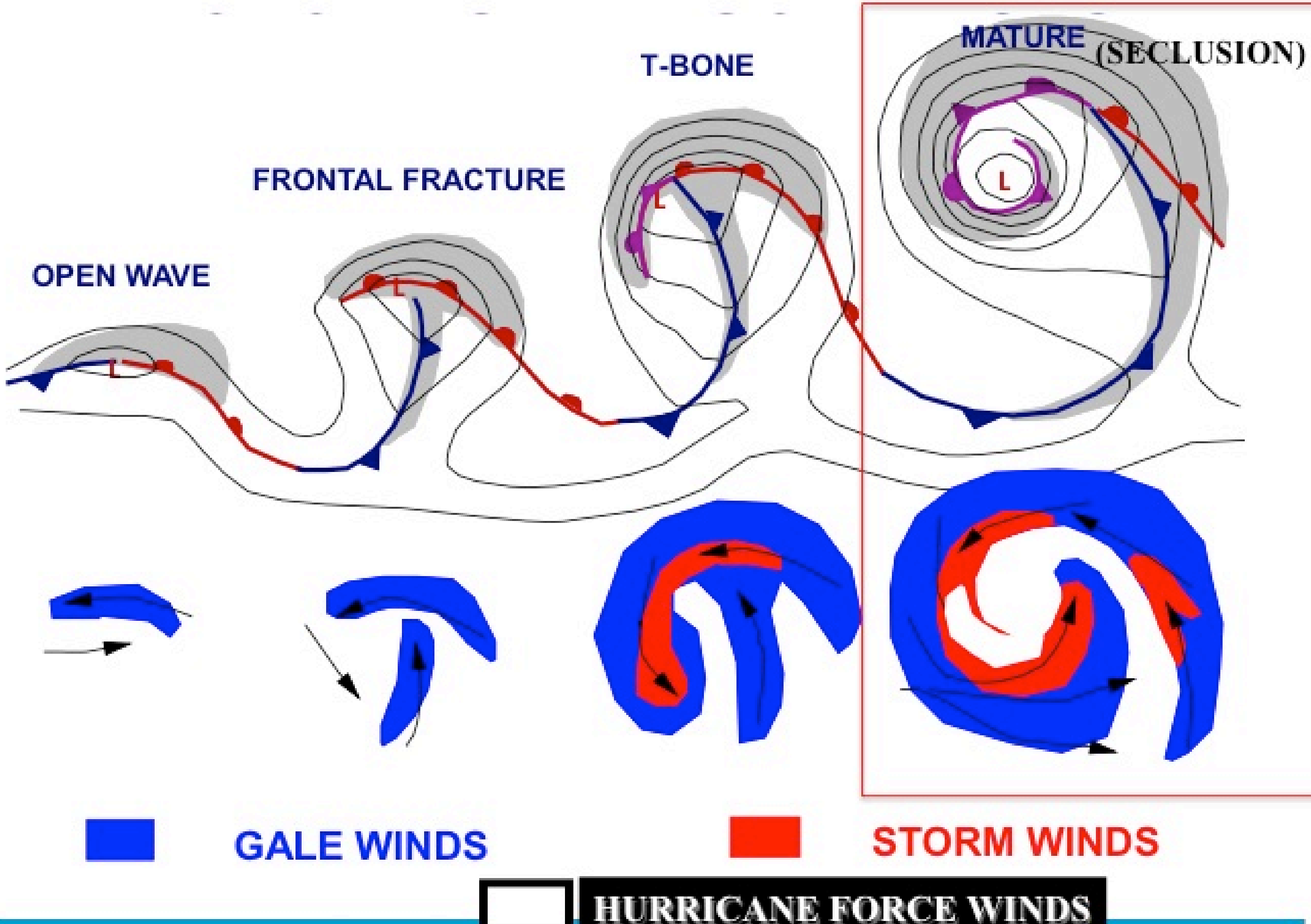
International Satellite High Wind Workshops Recommendations

- Two high wind validation workshops held in 2015 (Miami/NOAA) and 2016 (Exeter/ESA)
  - Agreed that dropsondes WL150 wind speeds will be our standard for truth.
  - SFMR winds will be the transfer mechanism from dropsondes winds to satellite winds
- Intercalibration of multiple-datasets by analyzing differences and similarities between the Passive and Active MW measurements.
  - Two wind regimes of strong interest:
    - overlap range between L-band, C- and Ku-band : 15-32 m/s
      - Extratropical cyclones ideally suited for ensuring consistency between scatterometer and radiometer observations
    - high wind regime > 33 m/s
- Recommendations:
  - Improve calibration by starting where products are similar and moving to
  - Higher wind speeds as sufficient comparison data exist.
  - Attempt to develop model function that also accounts for sea state and heavy rain (if found to be important)
  - Possible dependence on storm motion, SST, latitude, wave directions ? We suggest to use radii at 34Kts (18m/s), 50Kts (25.7) and 64Kts (33m/s) as this is relevant to the forecasters
  - We can also look at EKE, integrated power dissipation
    - look at other indices to help understand the tropical winds (quick ways to compare data sources)

Novel Approach for Satellite High Wind Validation: Comparison of ETC Wind Field Structures

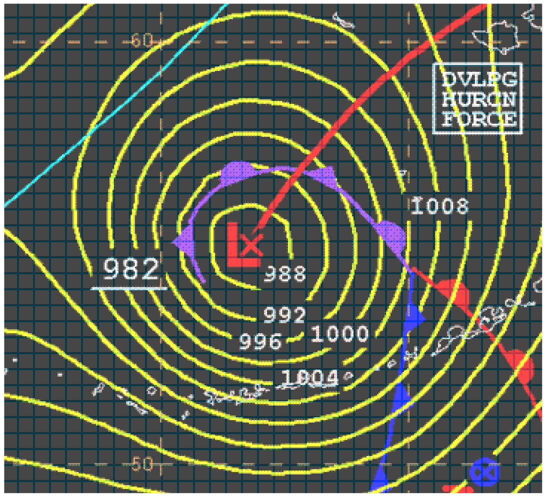
- All currently operational scatterometers and radiometers have adequate spatial resolution to observe high winds in extratropical cyclones
  - Winds in extratropical cyclones span up to 40m/s in most mature storms over the area of 100-1000km
- Satellite observations of extratropical cyclones
  - ASCAT-A: KNMI, NOAA and RSS
  - Microwave Radiometer wind products:
    - SSMIF16, SSMIf17,WindSat, AMSR-E, GMI (RSS)
    - AMSR-2 (NOAA, JAXA, RSS)
- RSS high wind products based on H*wind model and SFMR high wind measurements
- SMAP JPL based on SFMR TC measurements
- JAXA AMSR-2 dropsondes and best track max wind
- NOAA ASCAT high wind gmf based on SFMR/IWRAP observations of extratropical cyclones

Extratropical Storm Life Cycles
(adapted from Shapiro – Keyser Cyclone Model)

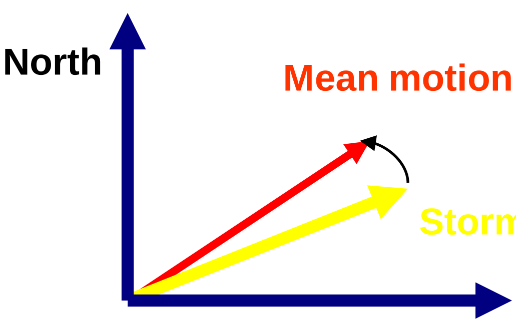


Storm track file

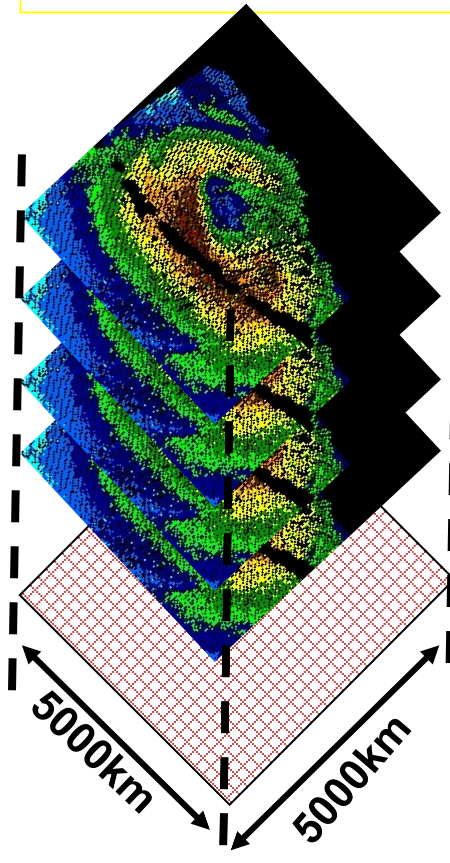
Read HF Cyclone Info.



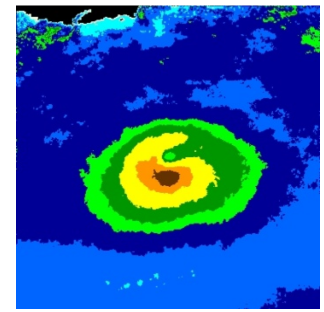
Estimate speed & Angle (Heading Vector)

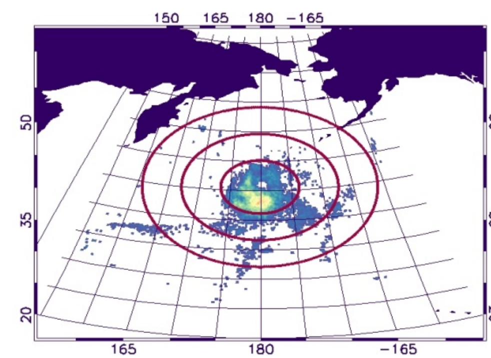


Extract Satellite 12.5km Data & Perform QC (land, ice, coast, rain) flags



Generate Mean Wind Fields

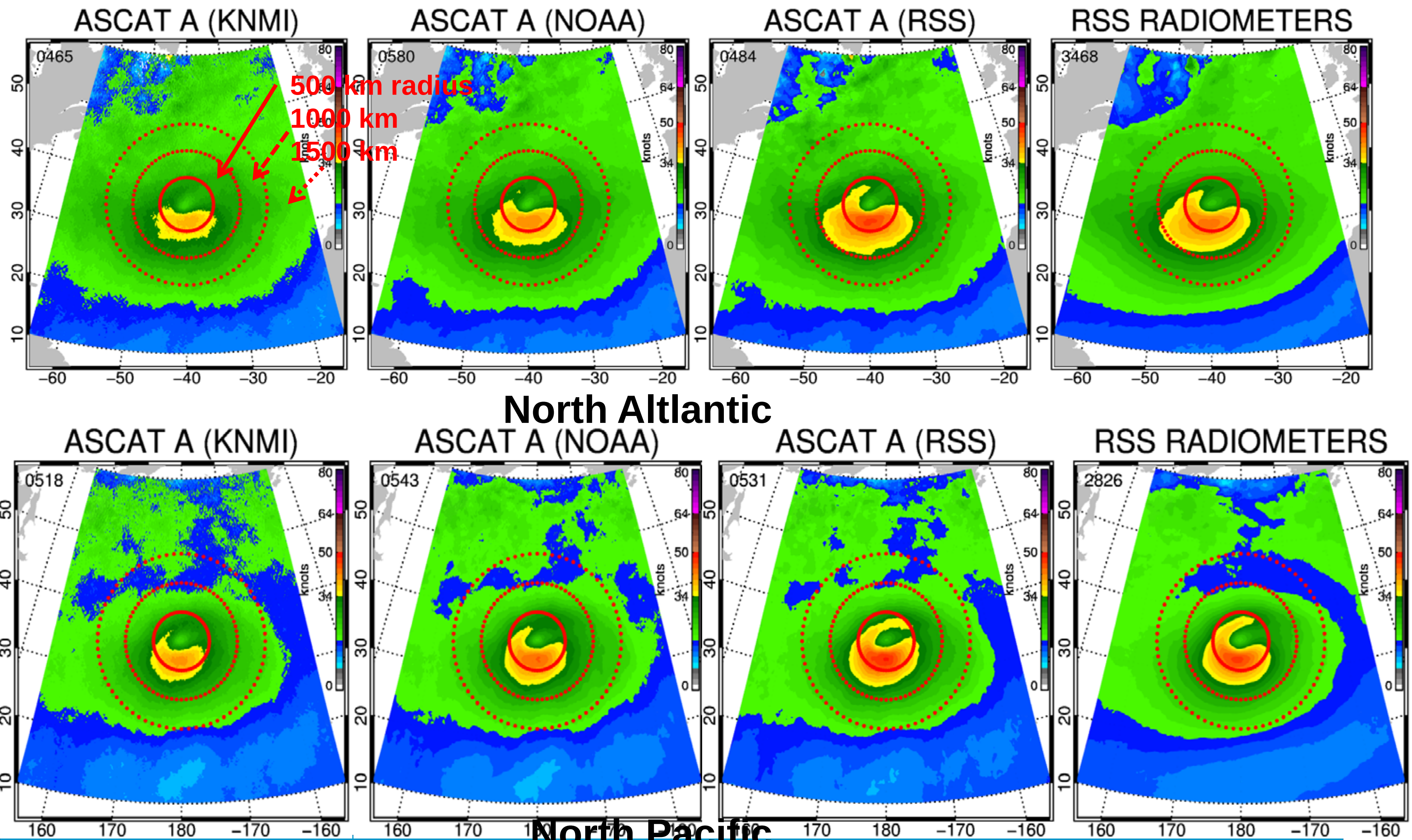


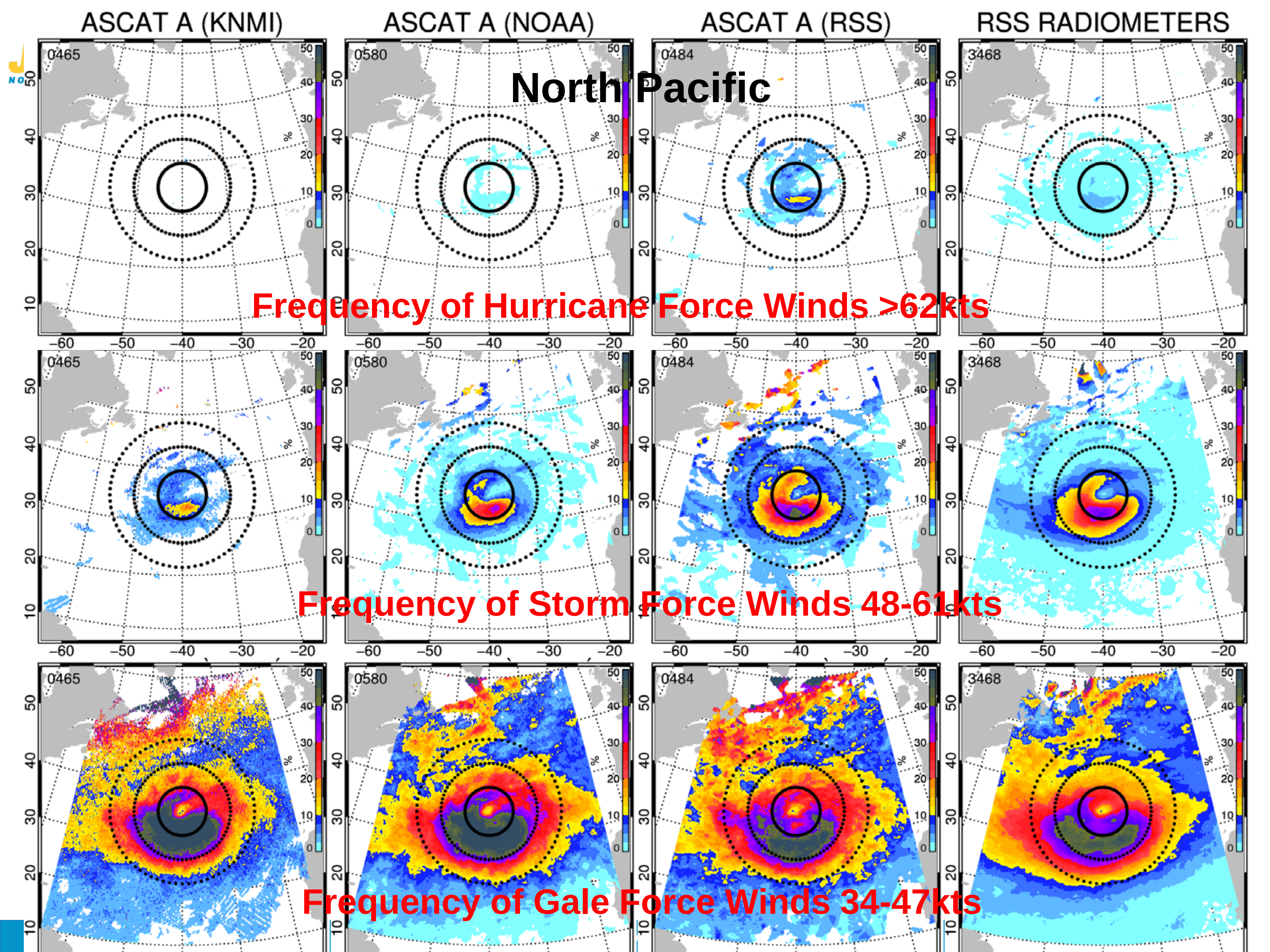


Generate Frequency of HF Occurrence per grid fields

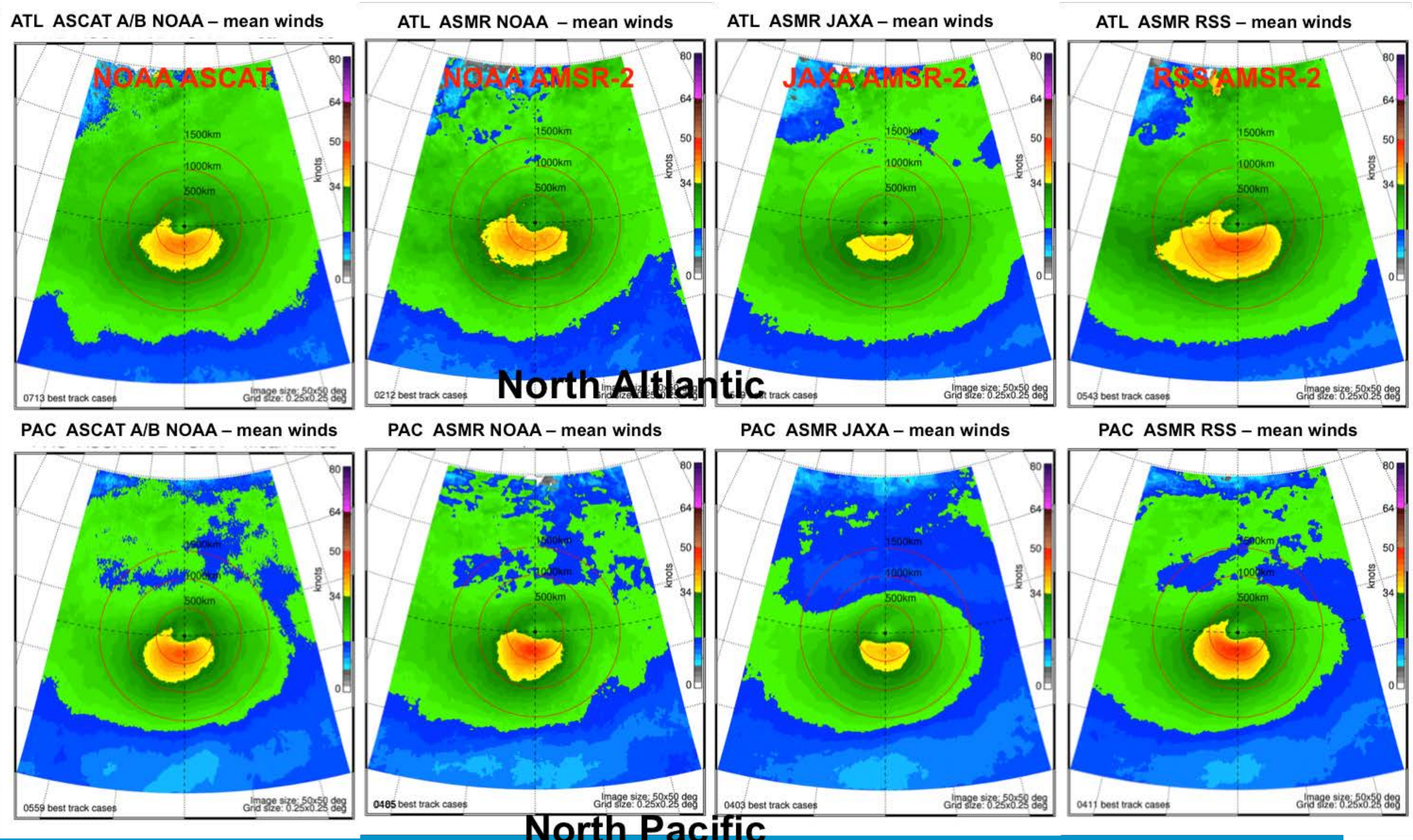
ASCAT-A Products Comparison 2007-2015

Spatial Resolution 35-60km

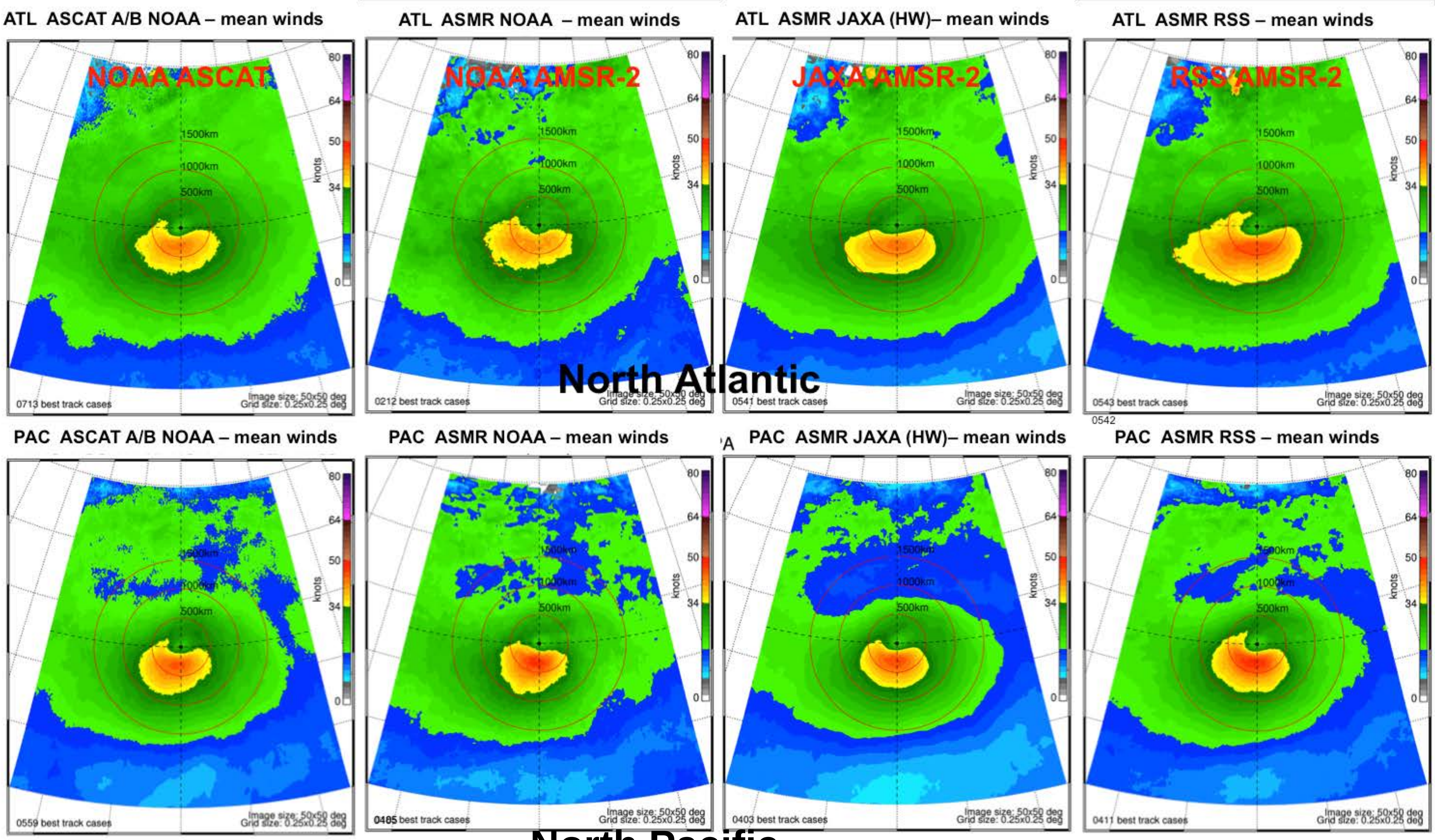


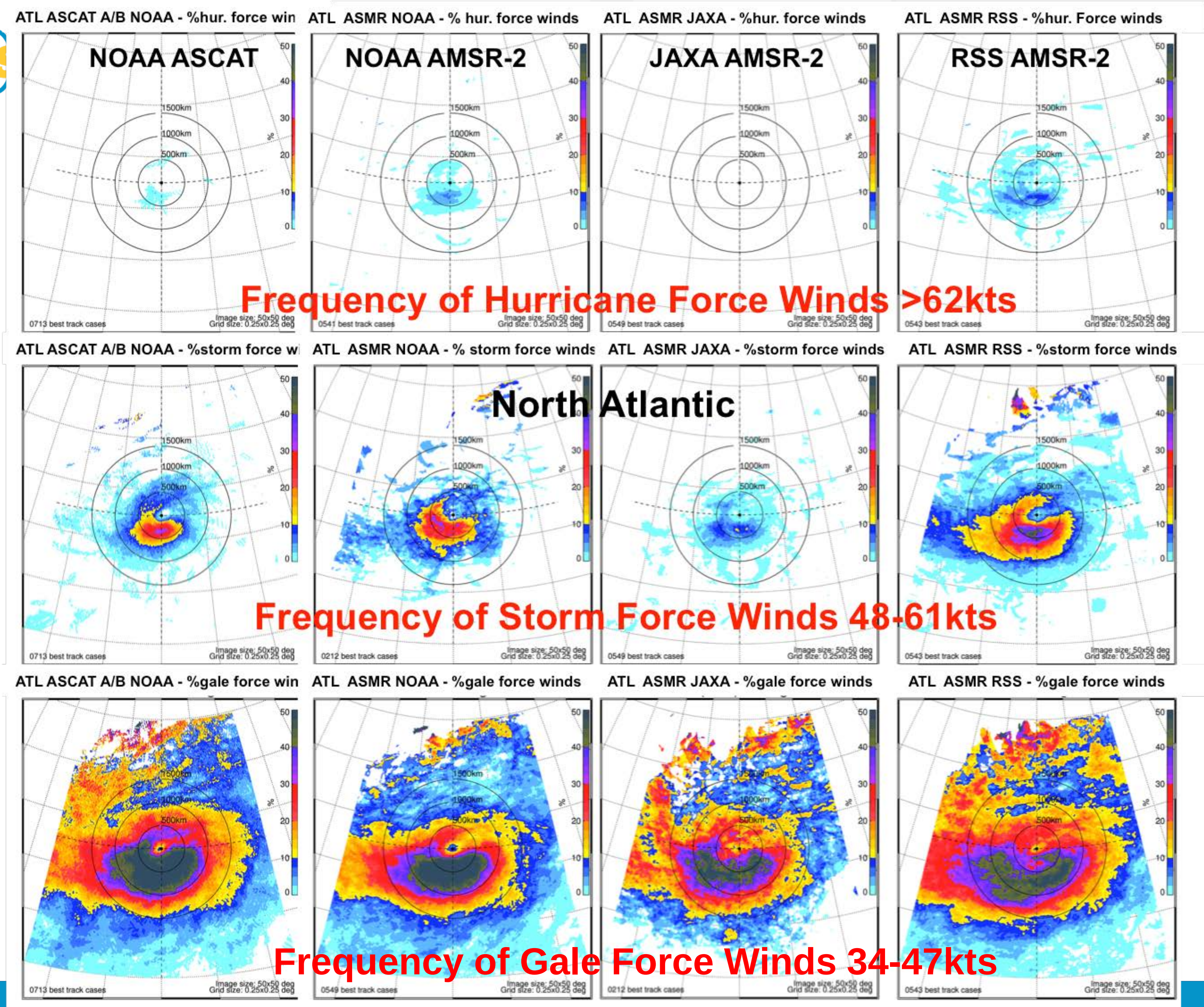

ASCAT A (KNMI)
ASCAT A (NOAA)
ASCAT A (RSS)
RSS RADIOMETERS
North Pacific
Frequency of Hurricane Force Winds >62kts
Frequency of Storm Force Winds 48-61kts
Frequency of Gale Force Winds 34-47kts
0465
0580
0484
3468
%

AMSR-2/ASCAT
Wind Products Comparison 2012-2017
Spatial Resolution ~10-60km



AMSR-2/ASCAT
Wind Products Comparison 2012-2017
Spatial Resolution ~10-60km




ATL ASCAT A/B NOAA - %hur. force win
ATL ASMR NOAA - % hur. force winds
ATL ASMR JAXA - %hur. force winds
ATL ASMR RSS - %hur. Force winds
NOAA ASCAT
NOAA AMSR-2
JAXA AMSR-2
RSS AMSR-2
Frequency of Hurricane Force Winds >62kts
0713 best track cases
0541 best track cases
0549 best track cases
0543 best track cases
ATL ASCAT A/B NOAA - %storm force wi
ATL ASMR NOAA - % storm force winds
ATL ASMR JAXA - %storm force winds
ATL ASMR RSS - %storm force winds
North Atlantic
Frequency of Storm Force Winds 48-61kts
0713 best track cases
0212 best track cases
0549 best track cases
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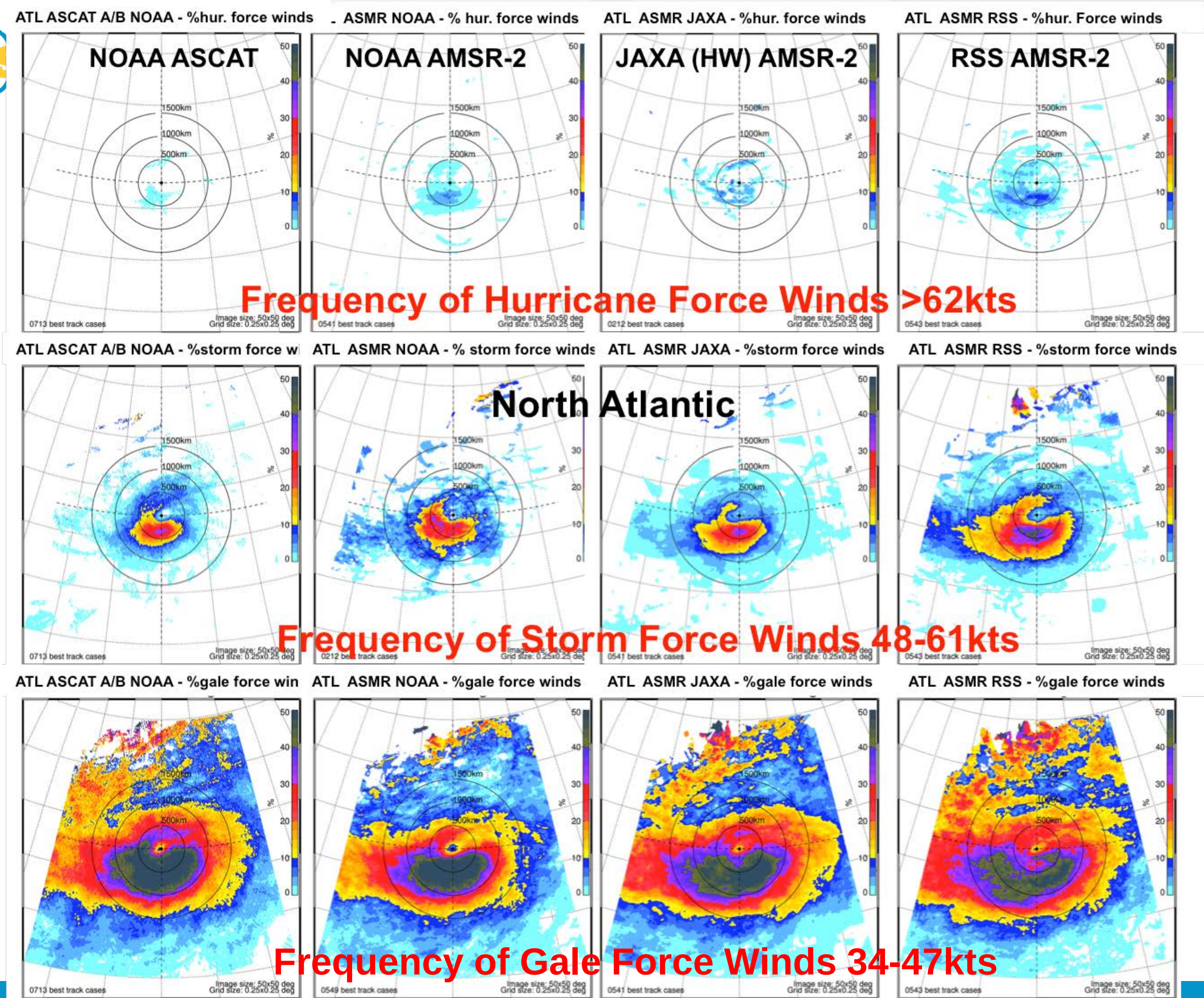
ATL ASCAT A/B NOAA - %gale force win
ATL ASMR NOAA - %gale force winds
ATL ASMR JAXA - %gale force winds
ATL ASMR RSS - %gale force winds
Frequency of Gale Force Winds 34-47kts
0713 best track cases
0549 best track cases
0212 best track cases
0543 best track cases
1500km
1000km
500km
Image size: 50x50 deg
Grid size: 0.25x0.25 deg


ATL ASCAT A/B NOAA - %hur. force winds
ASMR NOAA - % hur. force winds
ATL ASMR JAXA - %hur. force winds
ATL ASMR RSS - %hur. Force winds
NOAA ASCAT
NOAA AMSR-2
JAXA (HW) AMSR-2
RSS AMSR-2
Frequency of Hurricane Force Winds >62kts
ATL ASCAT A/B NOAA - %storm force wi
ATL ASMR NOAA - % storm force winds
ATL ASMR JAXA - %storm force winds
ATL ASMR RSS - %storm force winds
North Atlantic
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ATL ASMR NOAA - %gale force winds
ATL ASMR JAXA - %gale force winds
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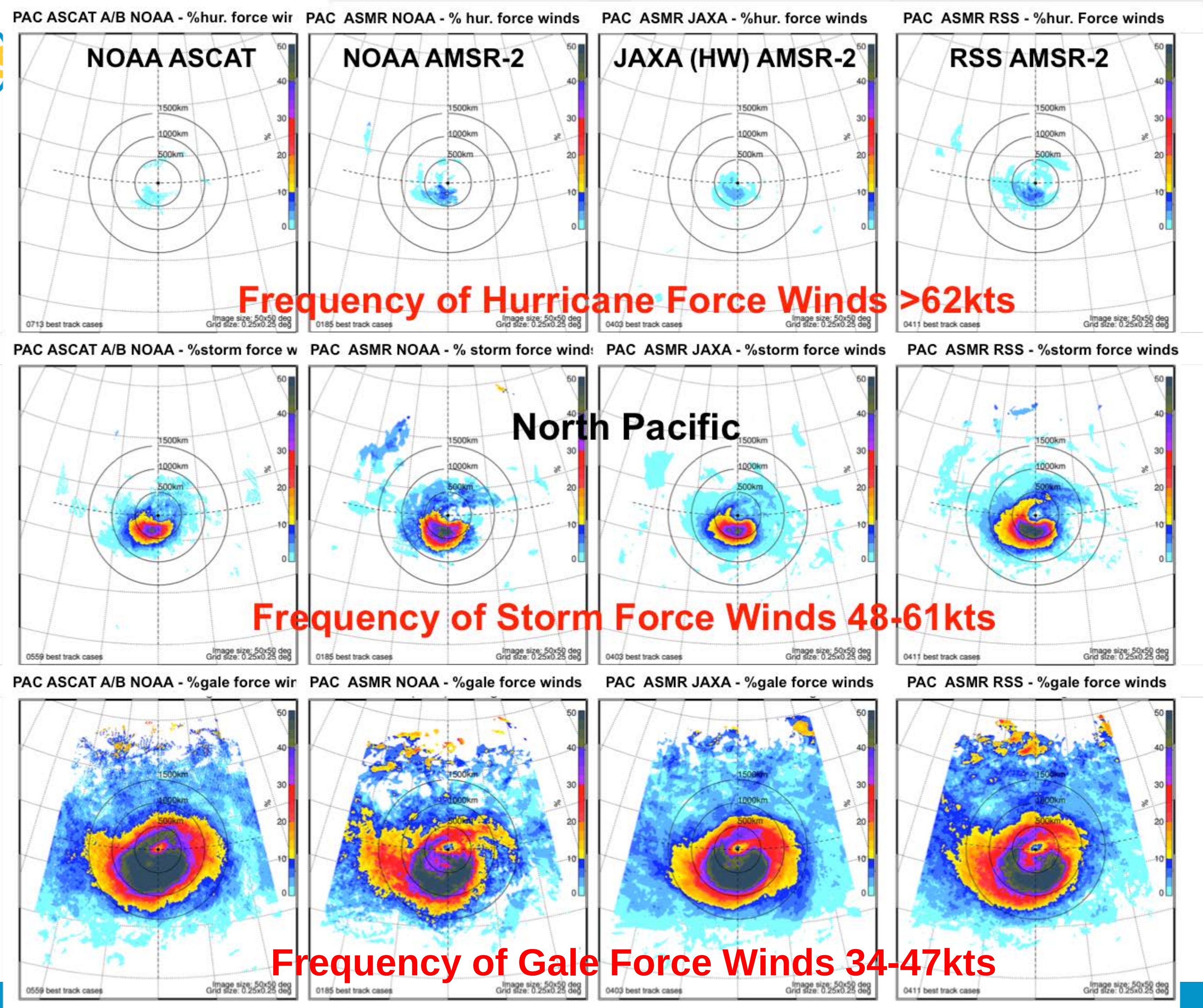
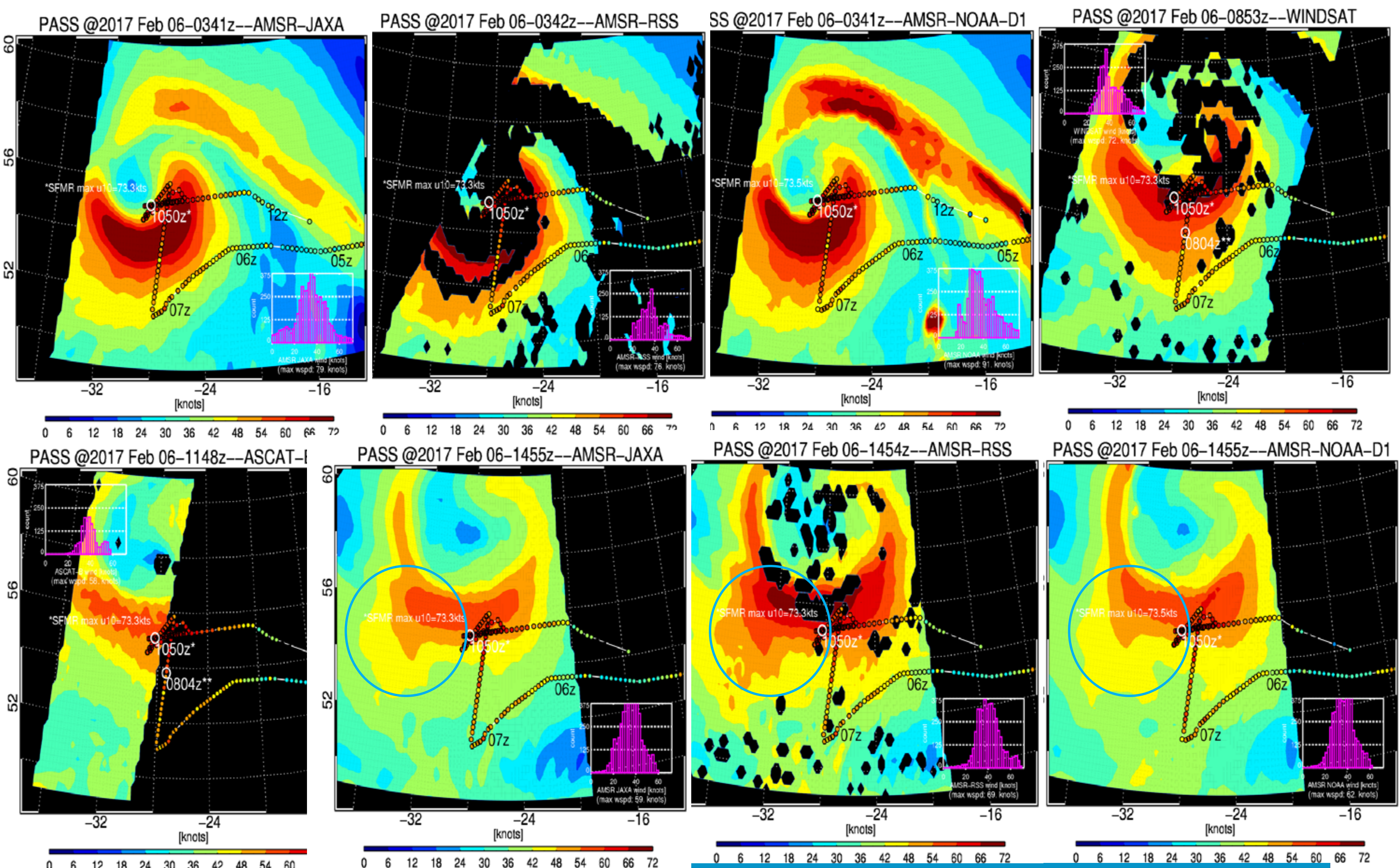
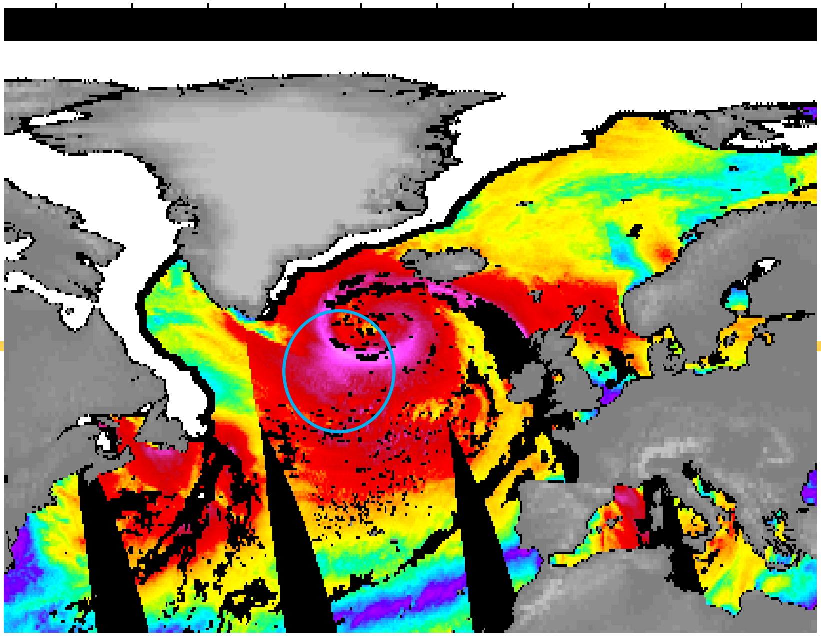

PAC ASCAT A/B NOAA - %hur. force wir
PAC ASMR NOAA - % hur. force winds
PAC ASMR JAXA - %hur. force winds
PAC ASMR RSS - %hur. Force winds
NOAA ASCAT
NOAA AMSR-2
JAXA (HW) AMSR-2
RSS AMSR-2
Frequency of Hurricane Force Winds >62kts
0713 best track cases
0185 best track cases
0403 best track cases
0411 best track cases
PAC ASCAT A/B NOAA - %storm force w
PAC ASMR NOAA - % storm force wind:
PAC ASMR JAXA - %storm force winds
PAC ASMR RSS - %storm force winds
North Pacific
Frequency of Storm Force Winds 48-61kts
0559 best track cases
PAC ASCAT A/B NOAA - %gale force wir
PAC ASMR NOAA - %gale force winds
PAC ASMR JAXA - %gale force winds
PAC ASMR RSS - %gale force winds
Frequency of Gale Force Winds 34-47kts
1500km
1000km
500km
Image size: 50x50 deg
Grid size: 0.25x0.25 deg

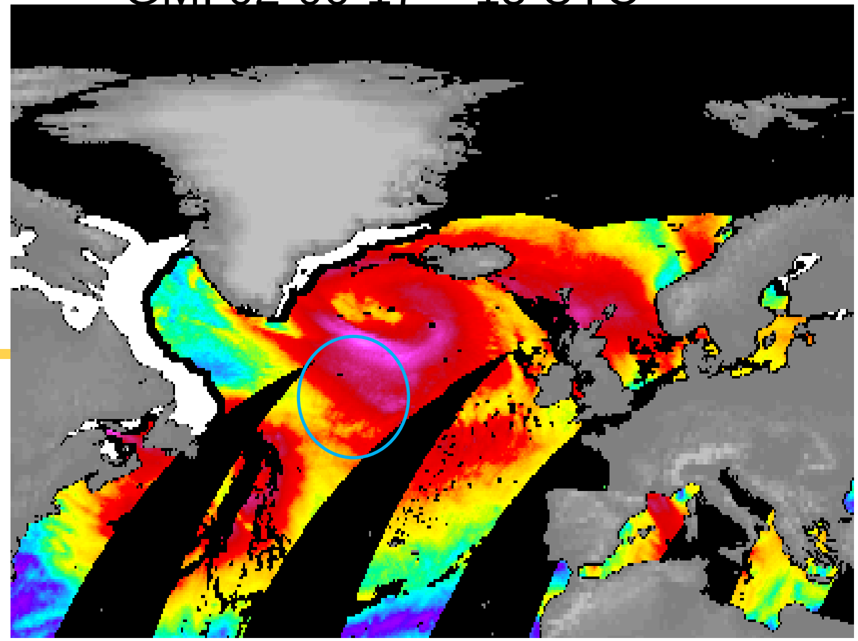
AMSR-2 February 6th,2017 Extratropical Storm Observations



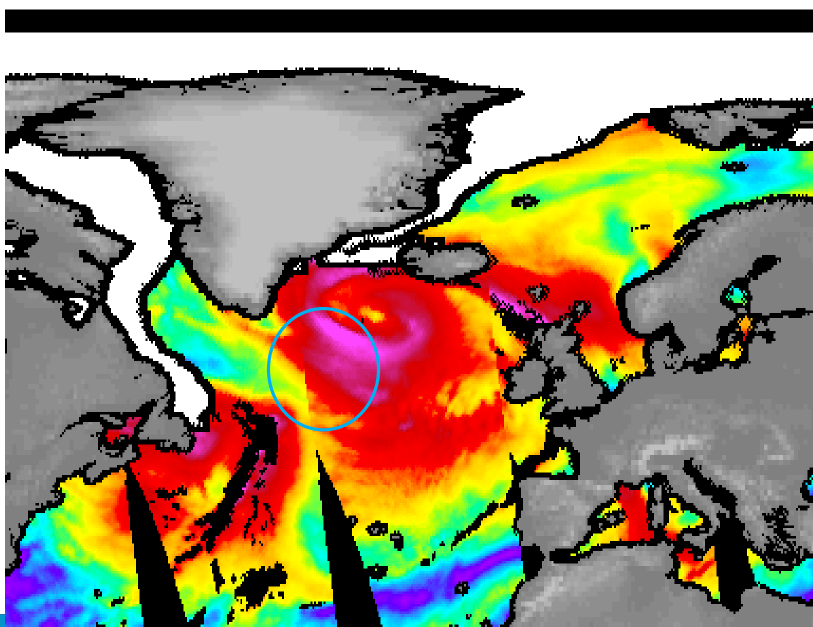
AMSR2 02-06-17 ~ 15 UTC



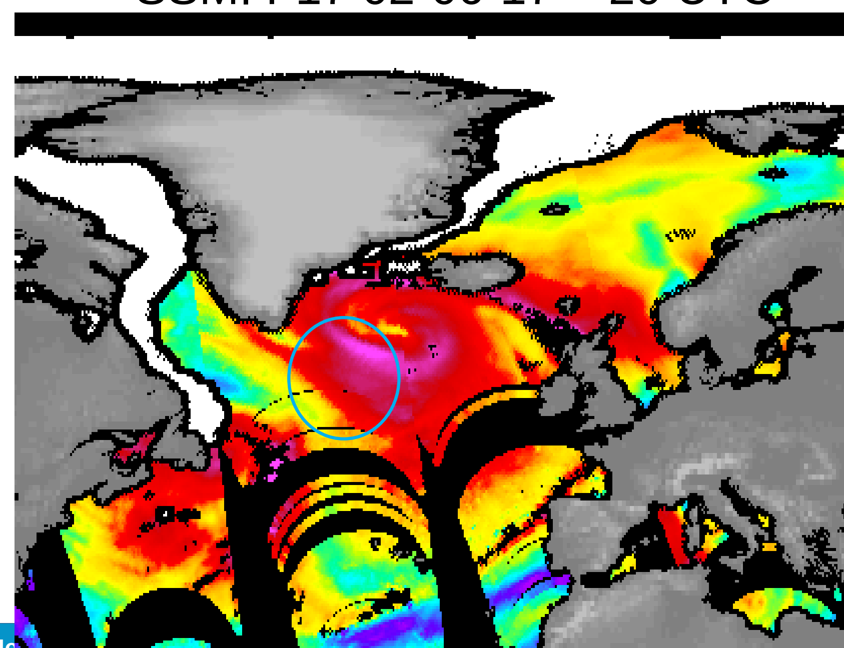
GMI 02-06-17 ~ 15 UTC



SSMI F18 02-06-17 ~ 20 UTC



SSMI F17 02-06-17 ~ 20 UTC



Evaluating Wind Speeds with Respect to Sea State Data Collection

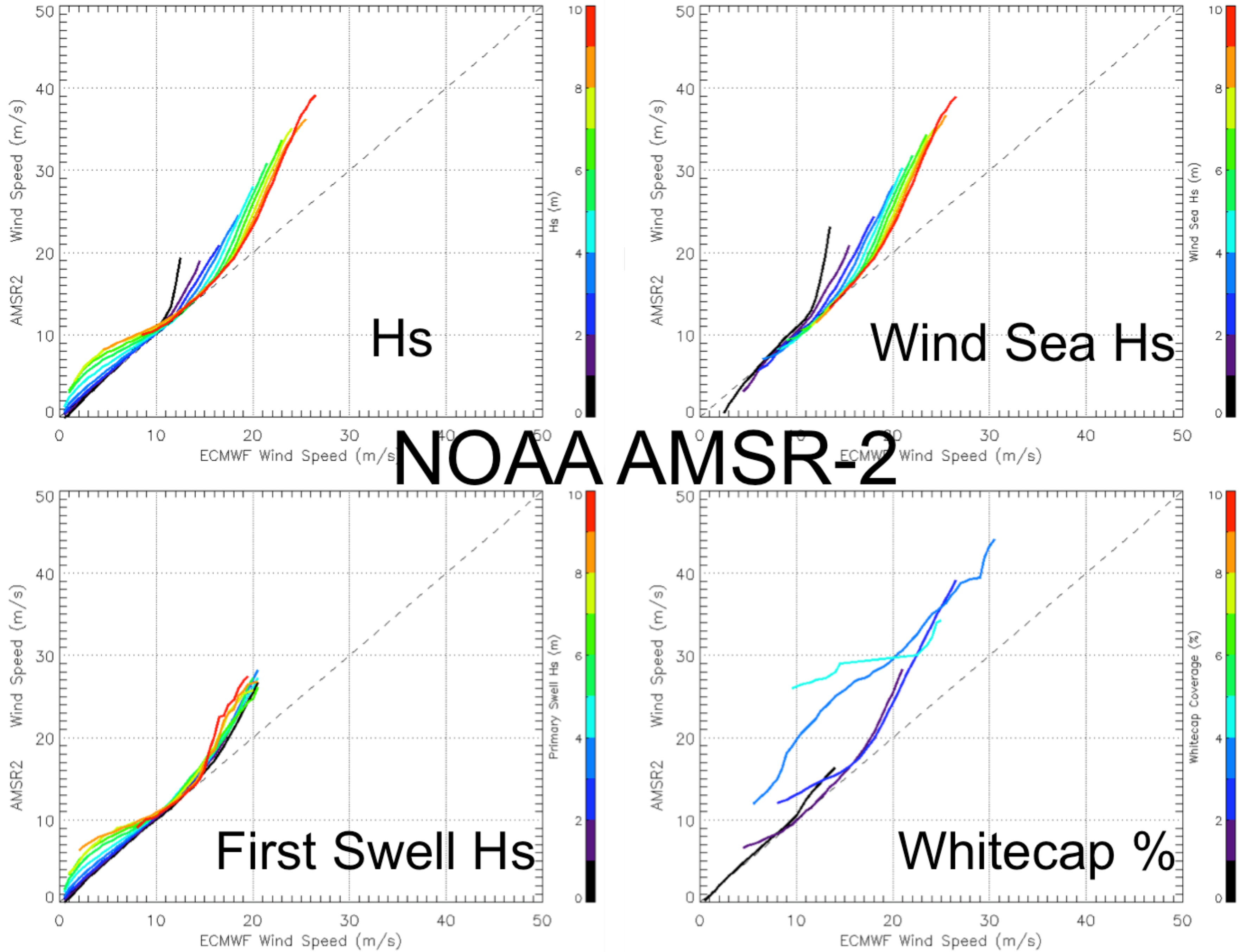
Products:
- 12.5km ASCAT A/B winds
- 12.5, 25km RapidScat winds, including NRCS
- Windsat, GMI, AMSR-2, SSMI-F16/17 from RSS
- AMSR-2 NOAA

each collocated (via bilinear interpolation) with

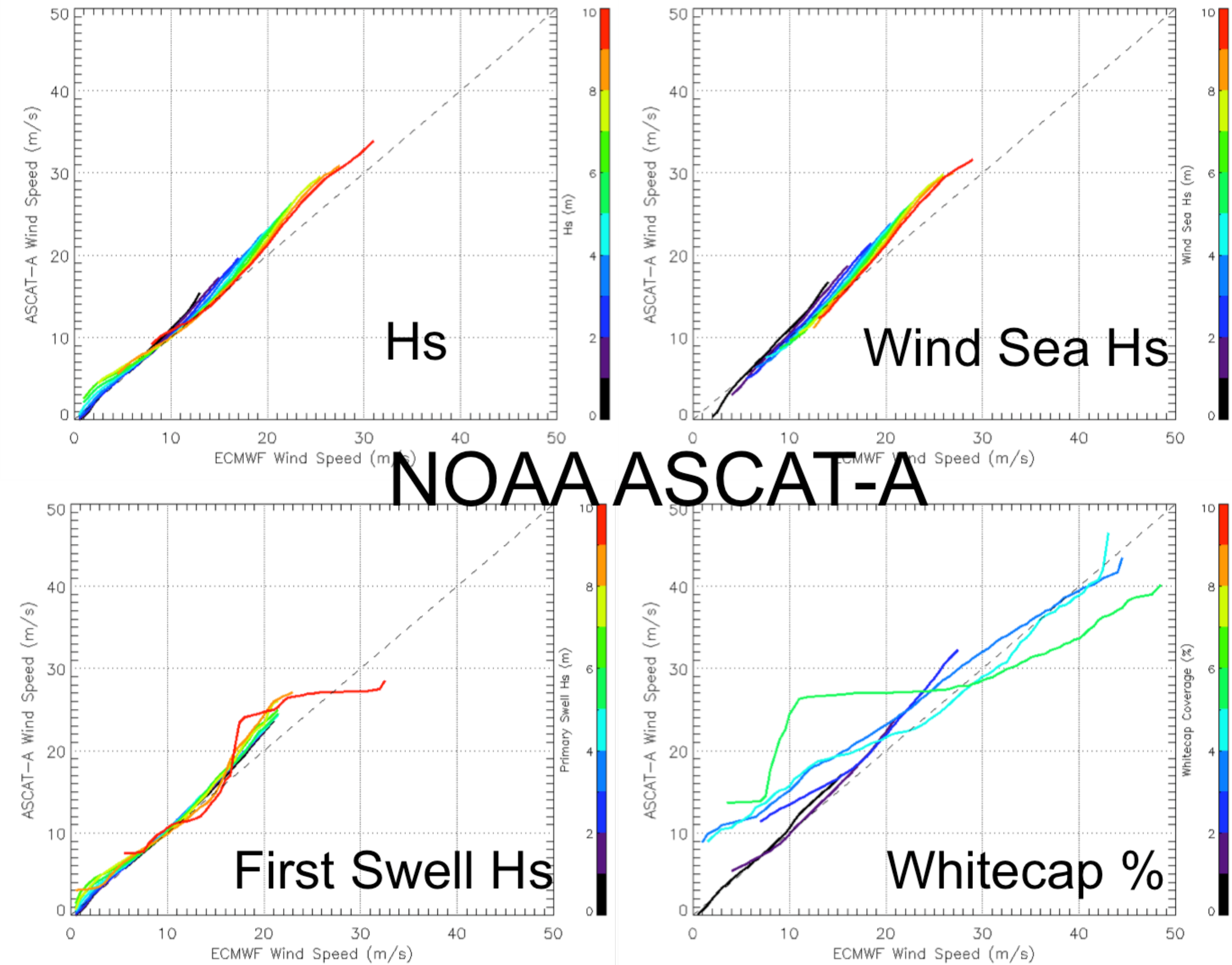
Models:
- ECMWF wind
- IFREMER wavewatch (hindcast)

Match up time period: July 1st 2014-Sep 30th 2015

NOAA AMSR-2


Hs
Wind Sea Hs
First Swell Hs
Whitecap %
AMSR2 Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Hs (m)
Wind Sea Hs (m)
Primary Swell Hs (m)
Whitecap Coverage (%)
0
10
20
30
40
50
0
2
4
6
8
10

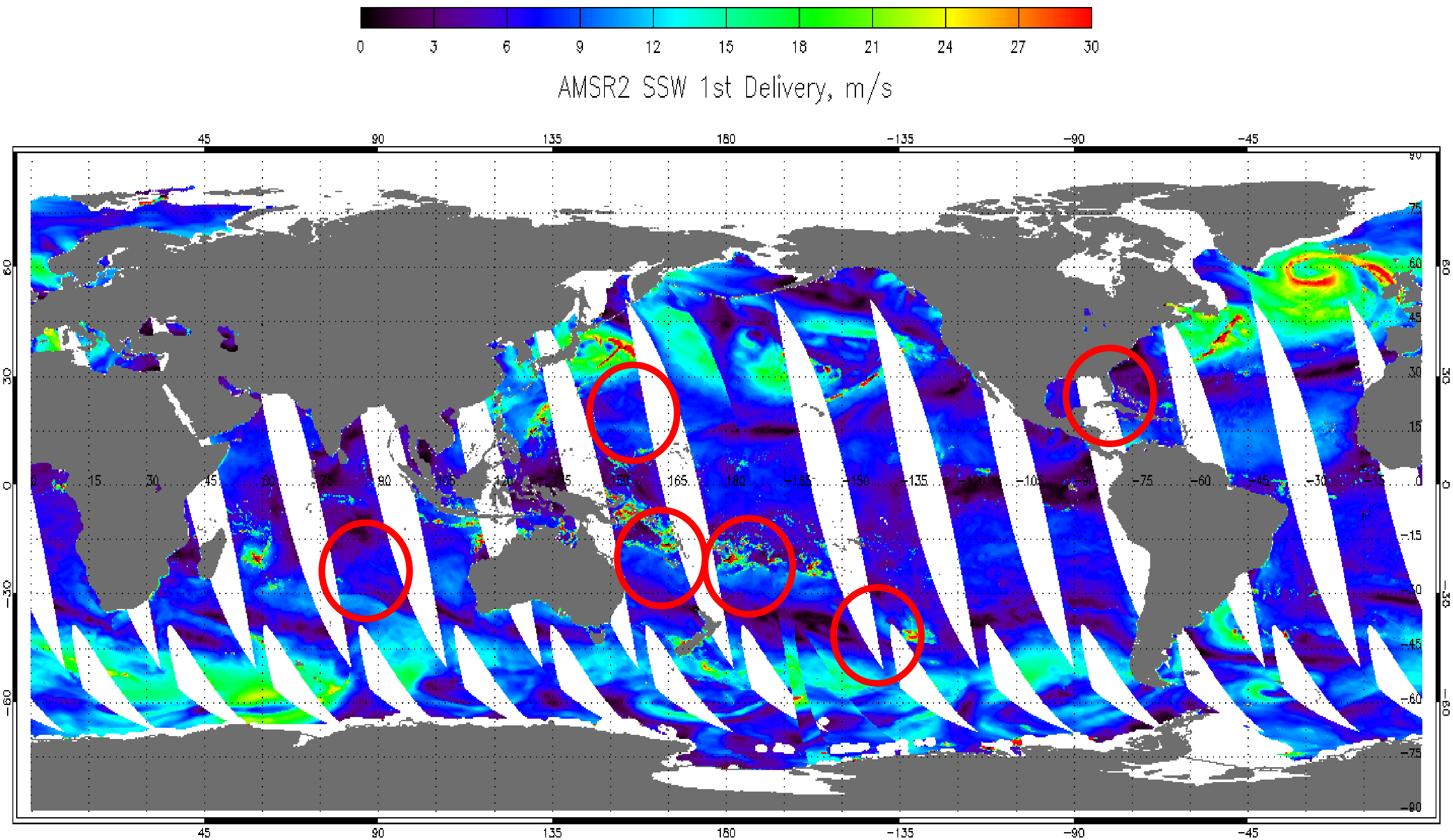
NOAA ASCAT-A


Hs
Wind Sea Hs
First Swell Hs
Whitecap %
ASCAT−A Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Hs (m)
Wind Sea Hs (m)
Primary Swell Hs (m)
Whitecap Coverage (%)
0
10
20
30
40
50
2
4
6
8

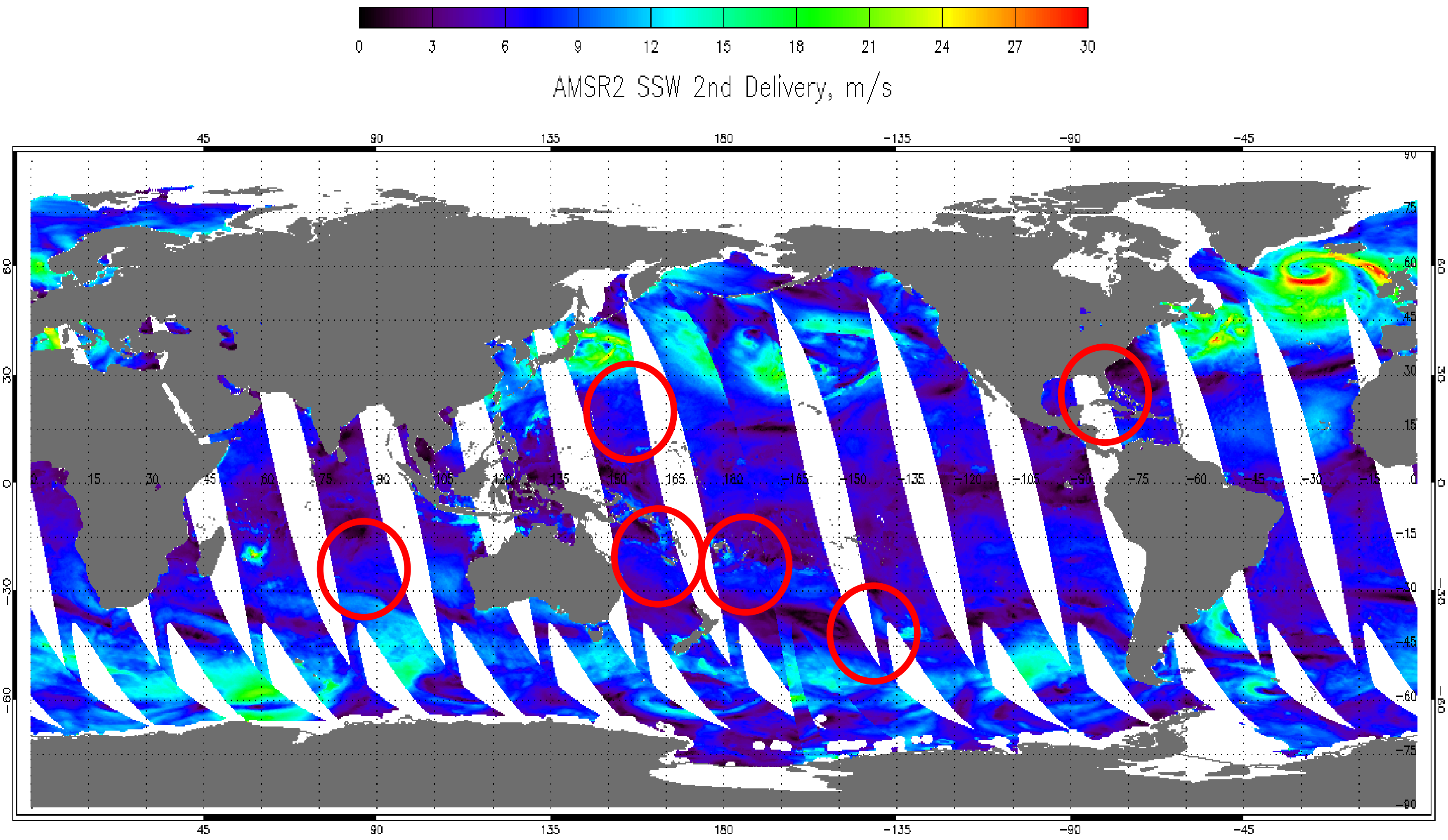
Second Generation
NOAA AMSR-2 Wind Speed Product

- 2nd Generation Wind Speed Algorithm
  - Uses all 6-36GHz channels
    - Proper channel weighing functions in different atmospheric regimes ensure that higher resolution features are preserved as much as possible
  - New product is all weather wind product
    - Significant improvement of winds in rain is achieved
    - Improved winds within ITCZ zone
    - Improved winds in Southern Hemisphere
  - Winds as close as 25km of the coast

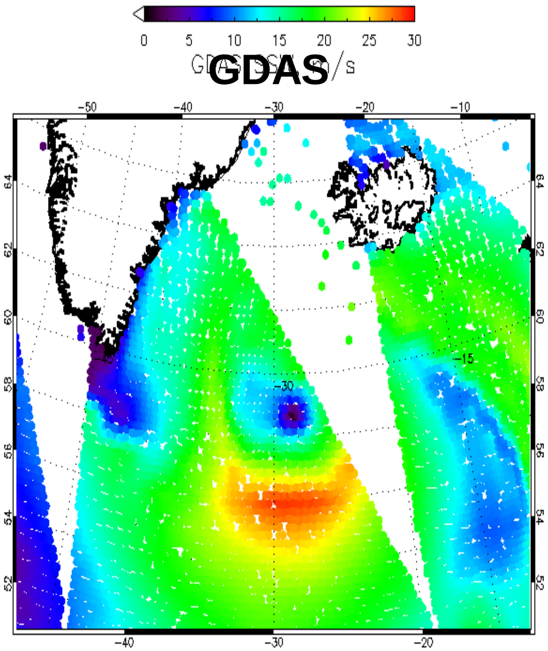
NOAA 1st Delivery



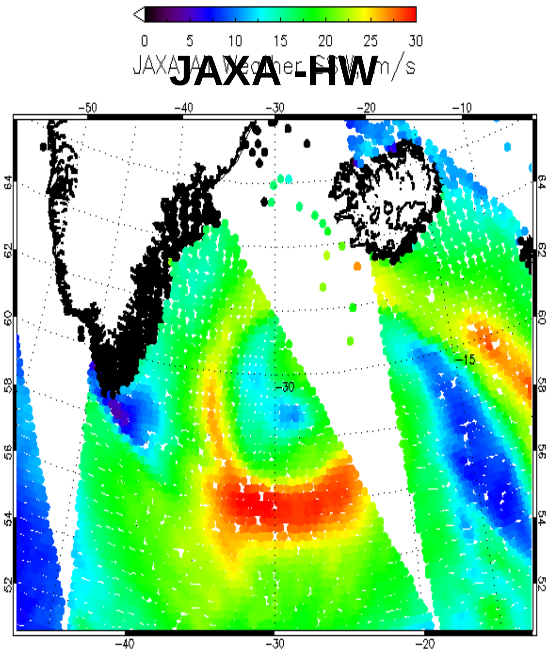
NOAA 2nd Delivery



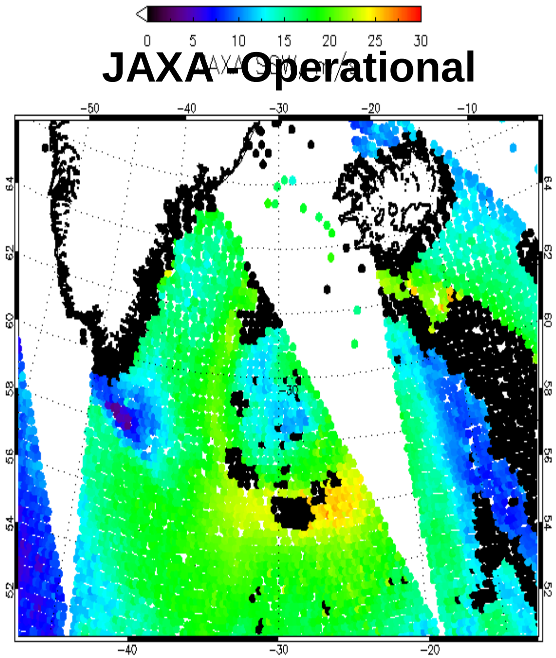
GDAS

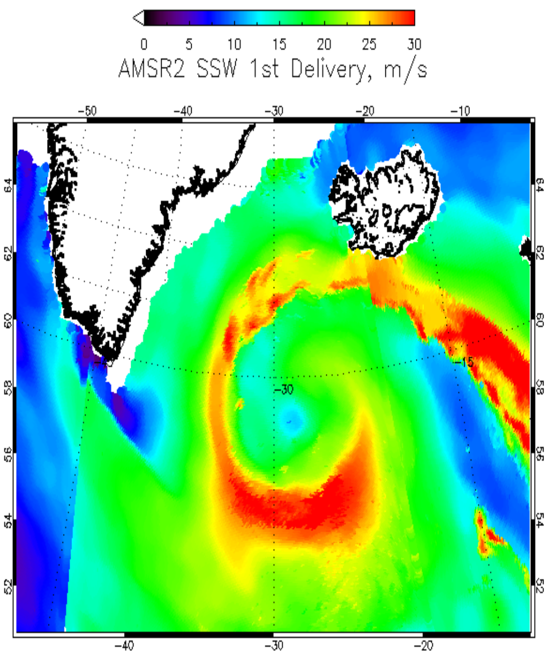


JAXA -HW

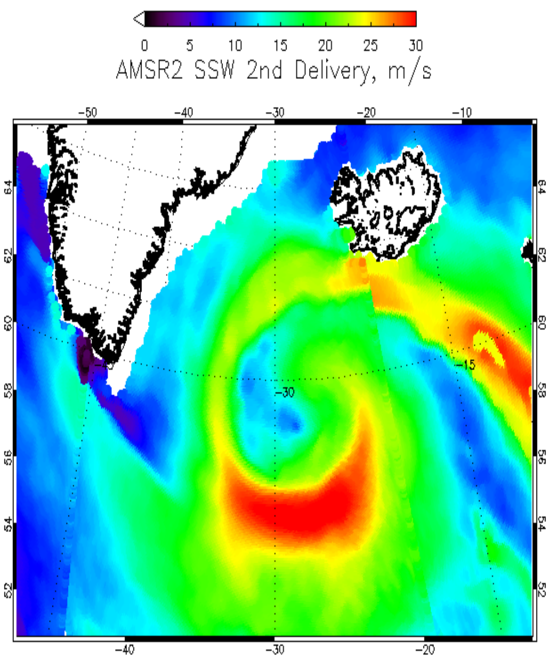


JAXA -Operational

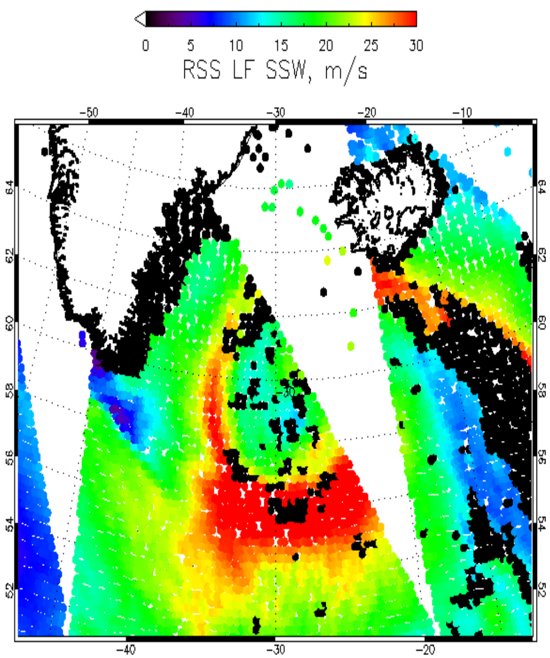




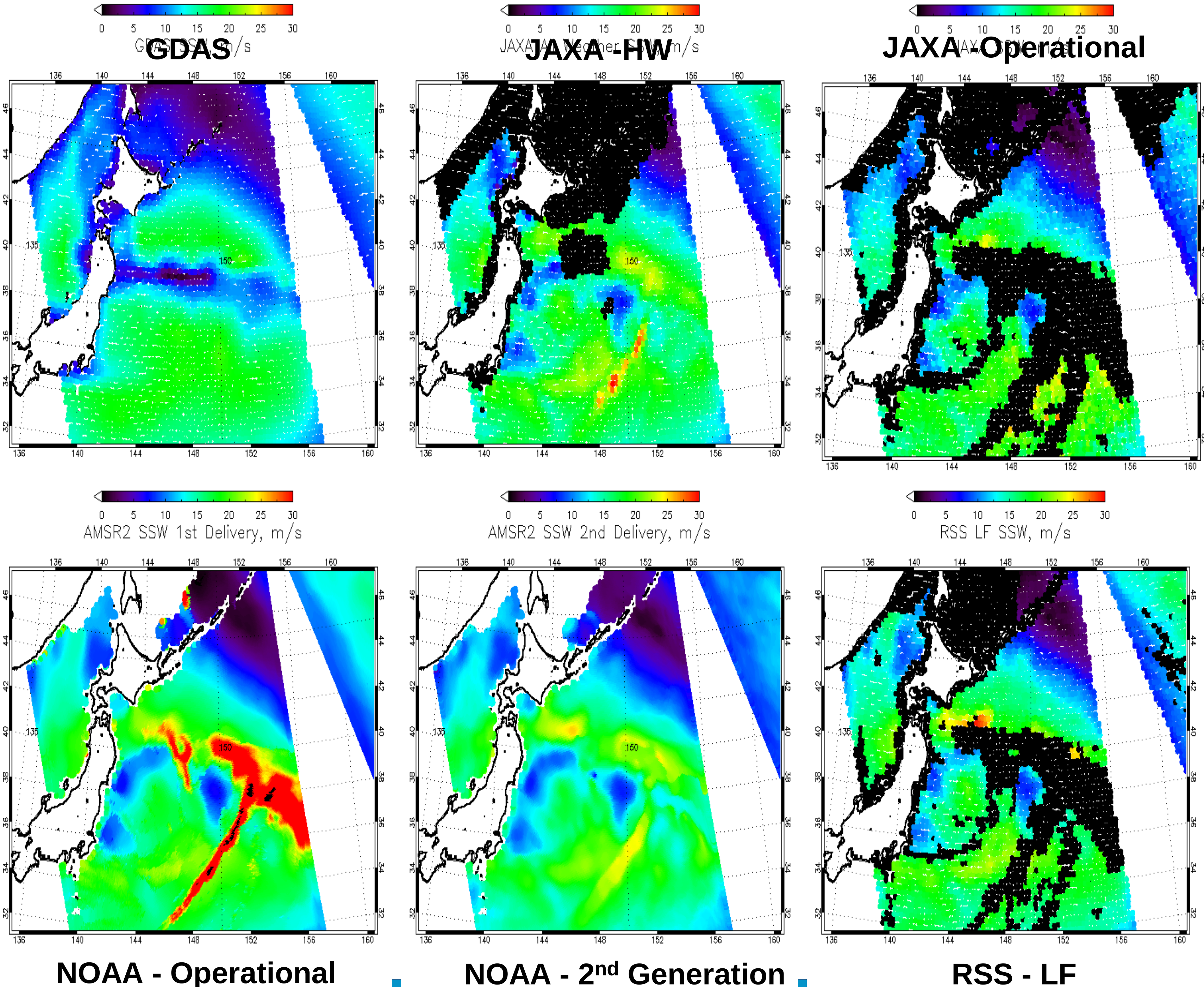
NOAA - Operational

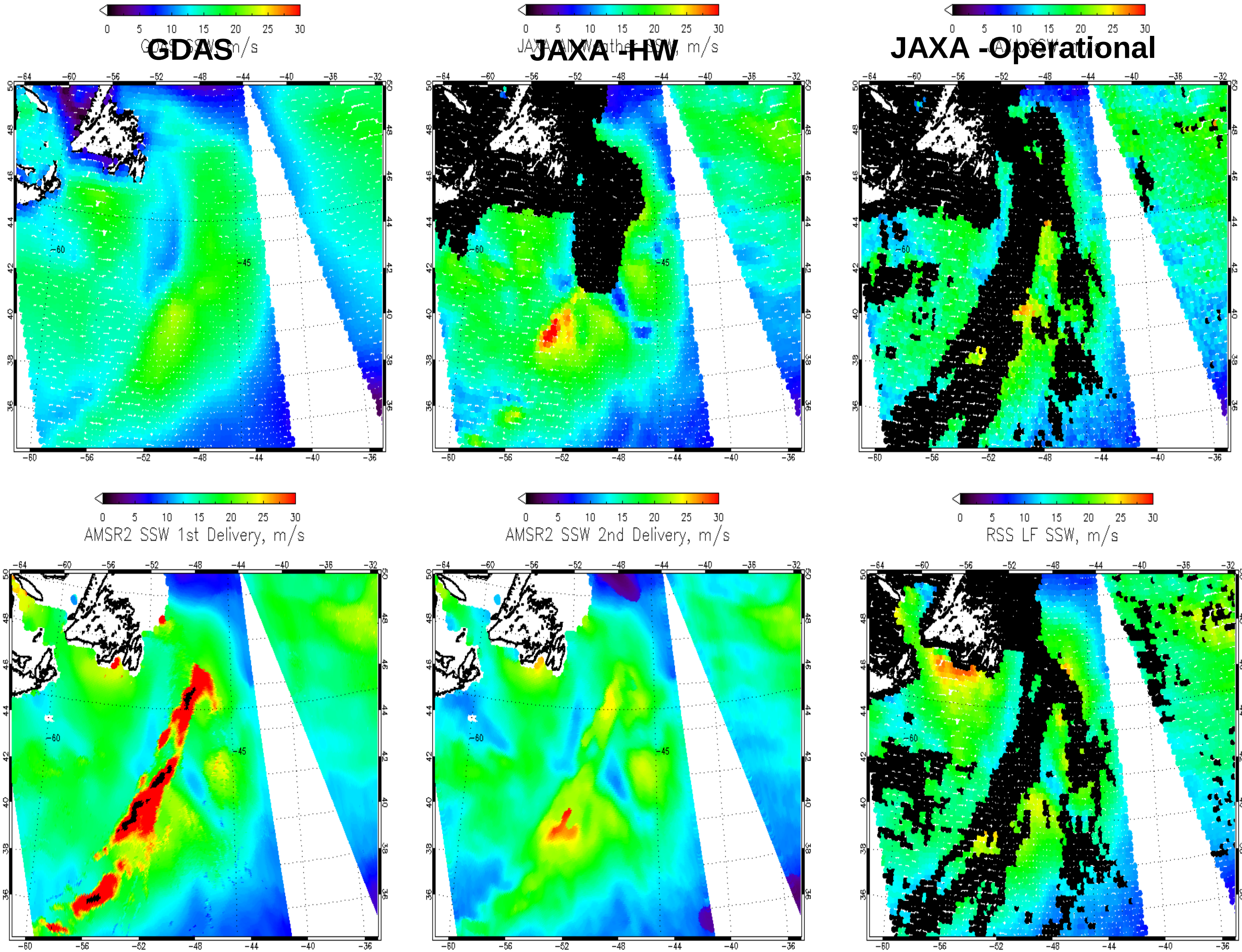


NOAA - 2nd Generation



RSS - LF

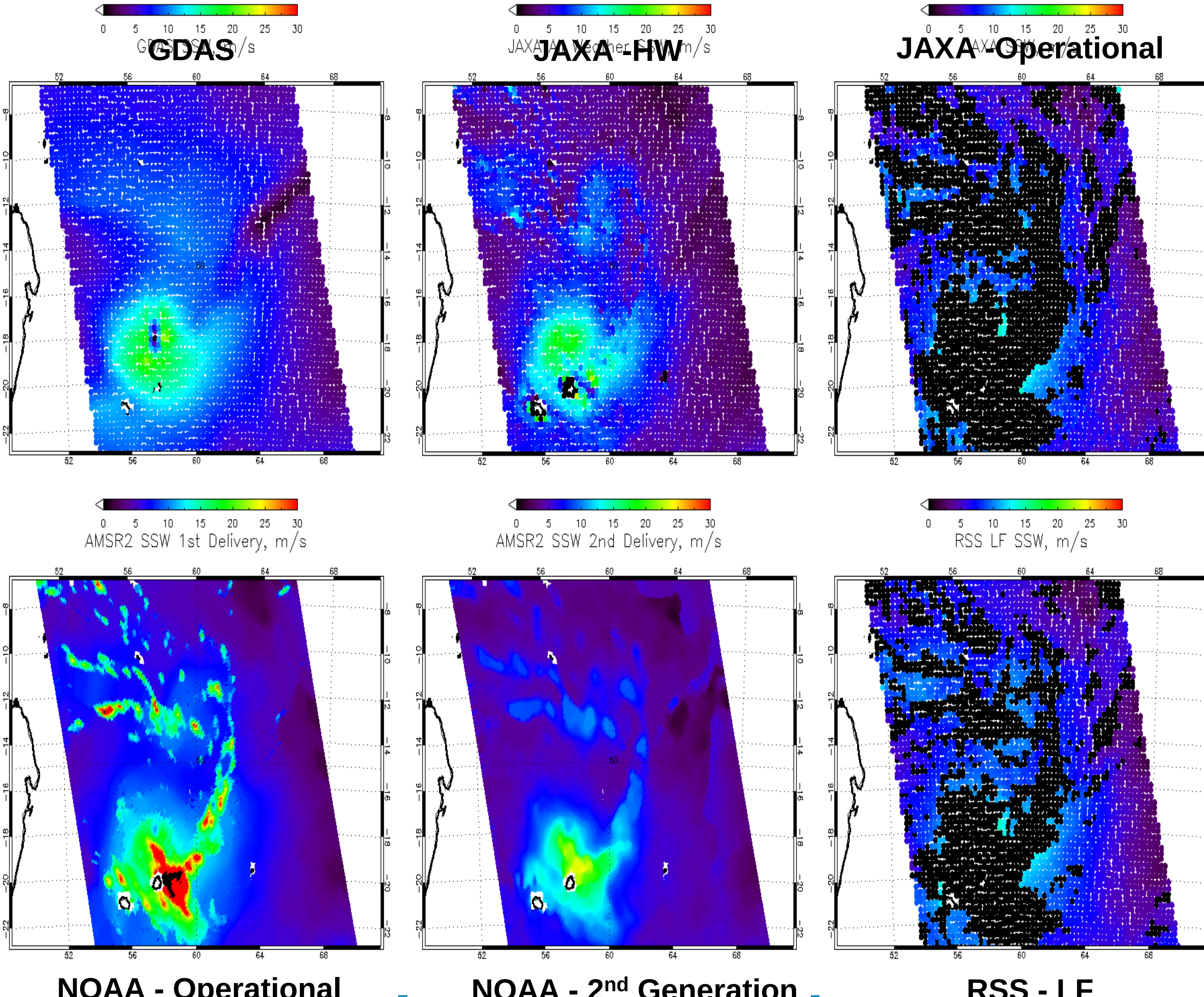

0 5 10 15 20 25 30
GDAS
JAXA -HW
JAXA -Operational
AMSR2 SSW 1st Delivery, m/s
AMSR2 SSW 2nd Delivery, m/s
RSS LF SSW, m/s
NOAA - Operational
NOAA - 2nd Generation
RSS - LF

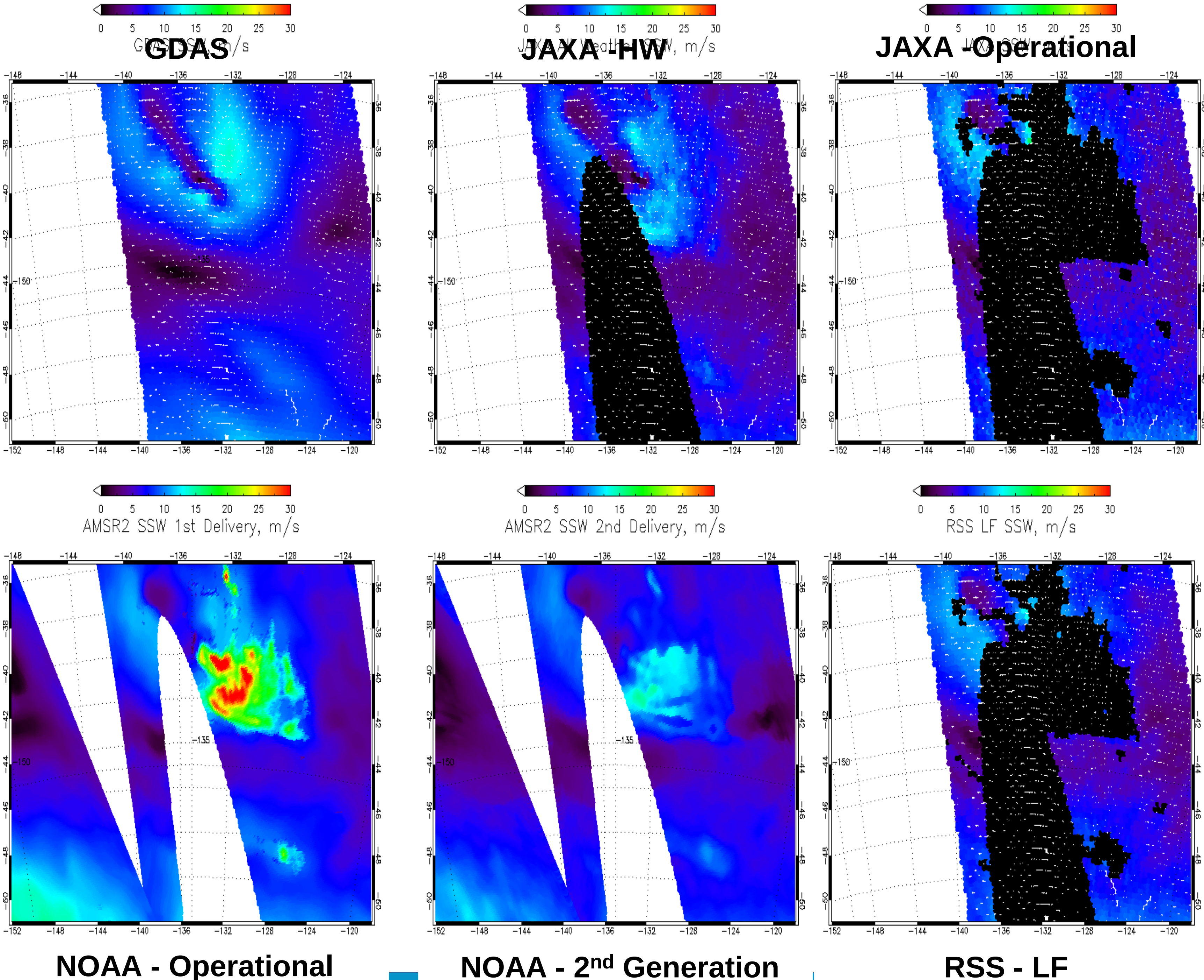


NOAA - Operational

NOAA - 2^{nd} Generation

RSS - LF


GDAS
JAXA -HW
JAXA -Operational
AMSR2 SSW 1st Delivery, m/s
AMSR2 SSW 2nd Delivery, m/s
RSS LF SSW, m/s
NOAA - Operational
NOAA - 2nd Generation
RSS - LF

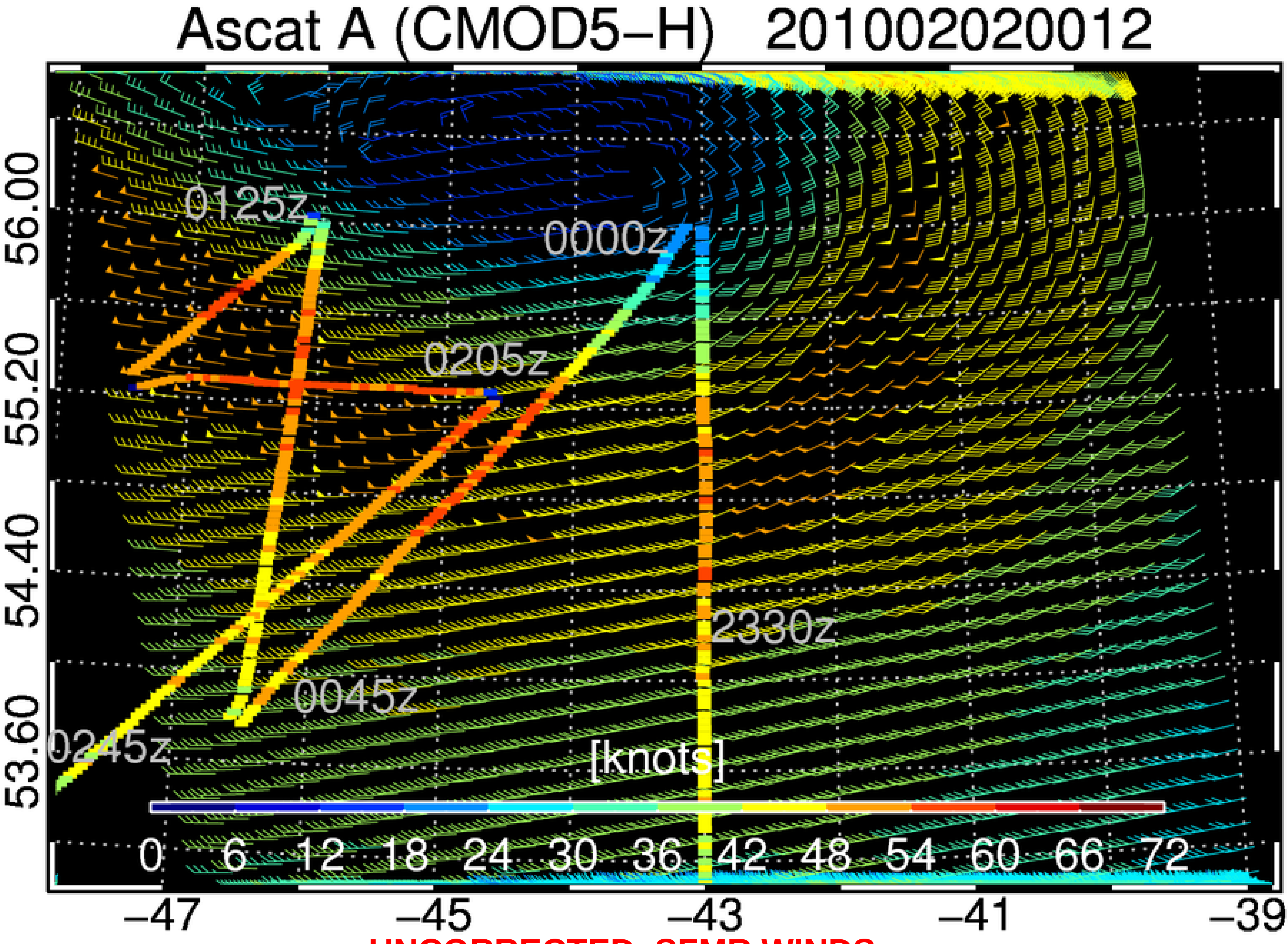

GDAS
JAXA -HW
JAXA -Operational
AMSR2 SSW 1st Delivery, m/s
AMSR2 SSW 2nd Delivery, m/s
RSS LF SSW, m/s
NOAA - Operational
NOAA - 2nd Generation
RSS - LF

Conclusions

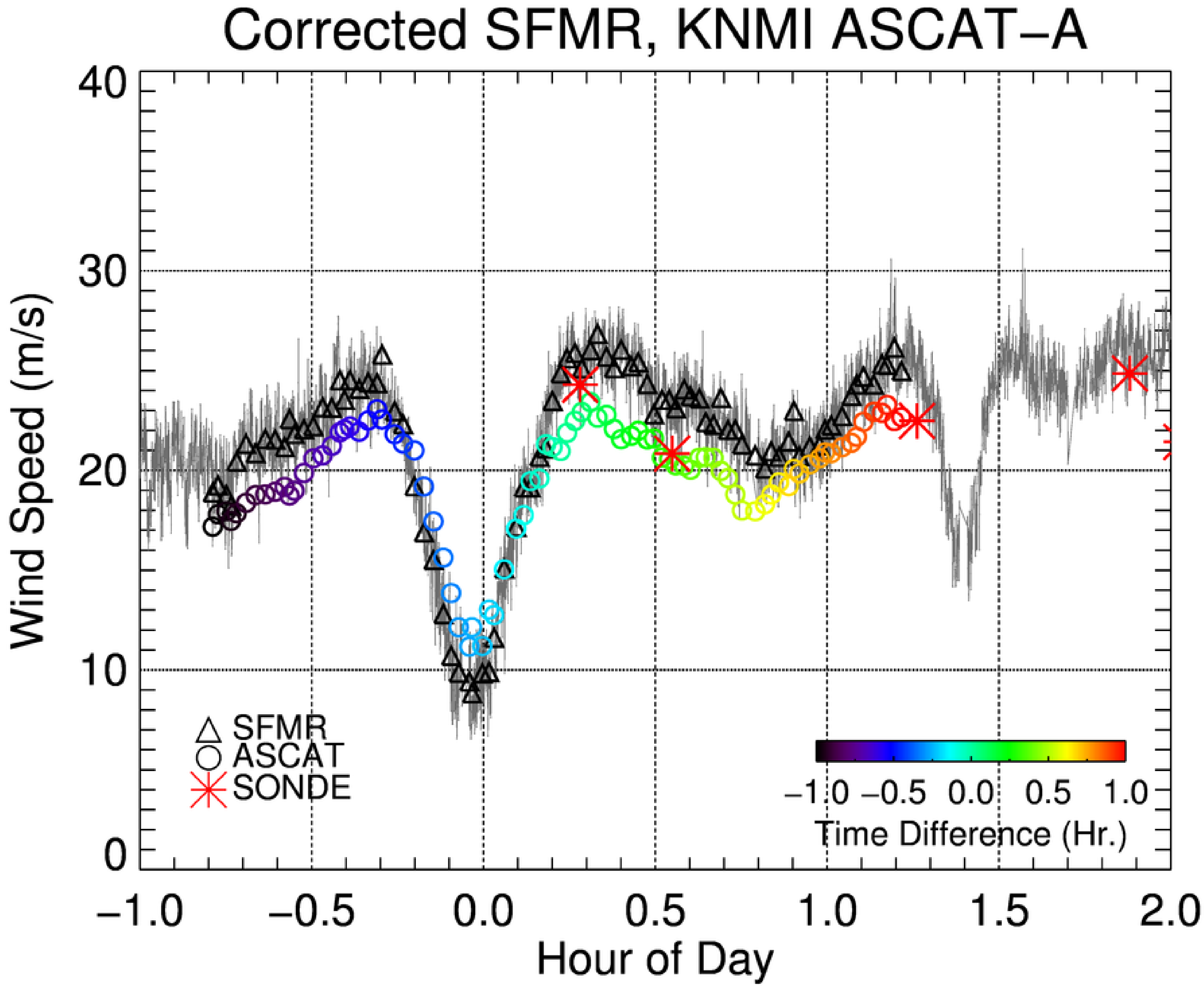
- 1st stage high wind validation performed. We have assessed performance of NOAA AMSR-2 Operational wind speed product performance within extratropical cyclones with respect to NOAA ASCAT, two JAXA wind products and all RSS radiometers
  - Wind field structure from NOAA Operational AMSR-2 product is:
    - On mean close to ASCAT and JAXA high wind product
    - Slightly overestimates storm force wind structure
    - Affected by rain
    - Affected by sea state
    - SFMR, IWRAP and dropsonde database developed and ready to be used for wind validation within tropical cyclones
- 2nd Generation product designed that addresses:
  - Wind retrieval performance in rain
  - High wind estimates overall intensity in rain and southern hemisphere

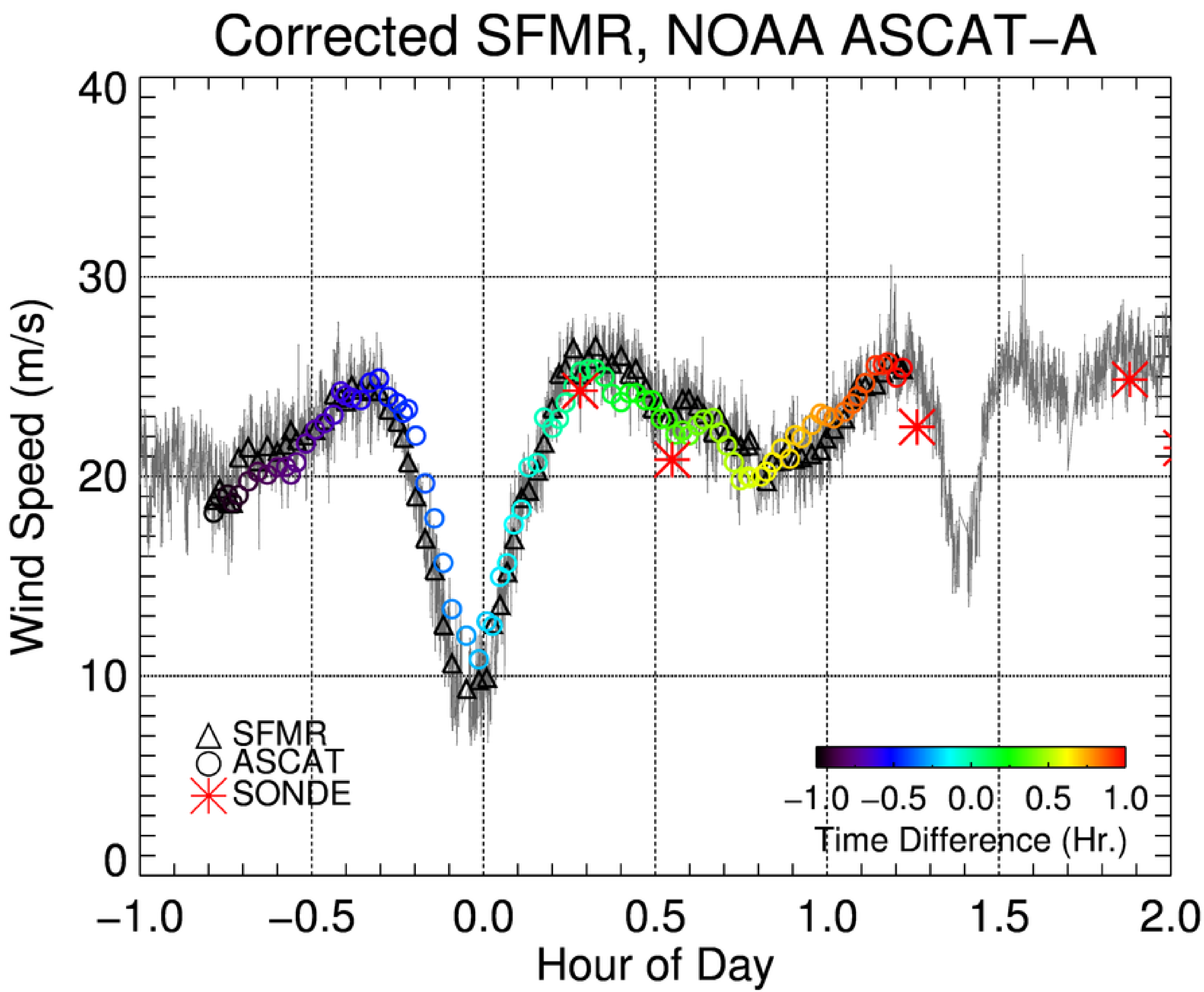
Backup Slides

KNMI, NOAA and RSS ASCAT High Winds Case Study Extratropical Storm Feb 1st, 2010 NOAA P3 Flight

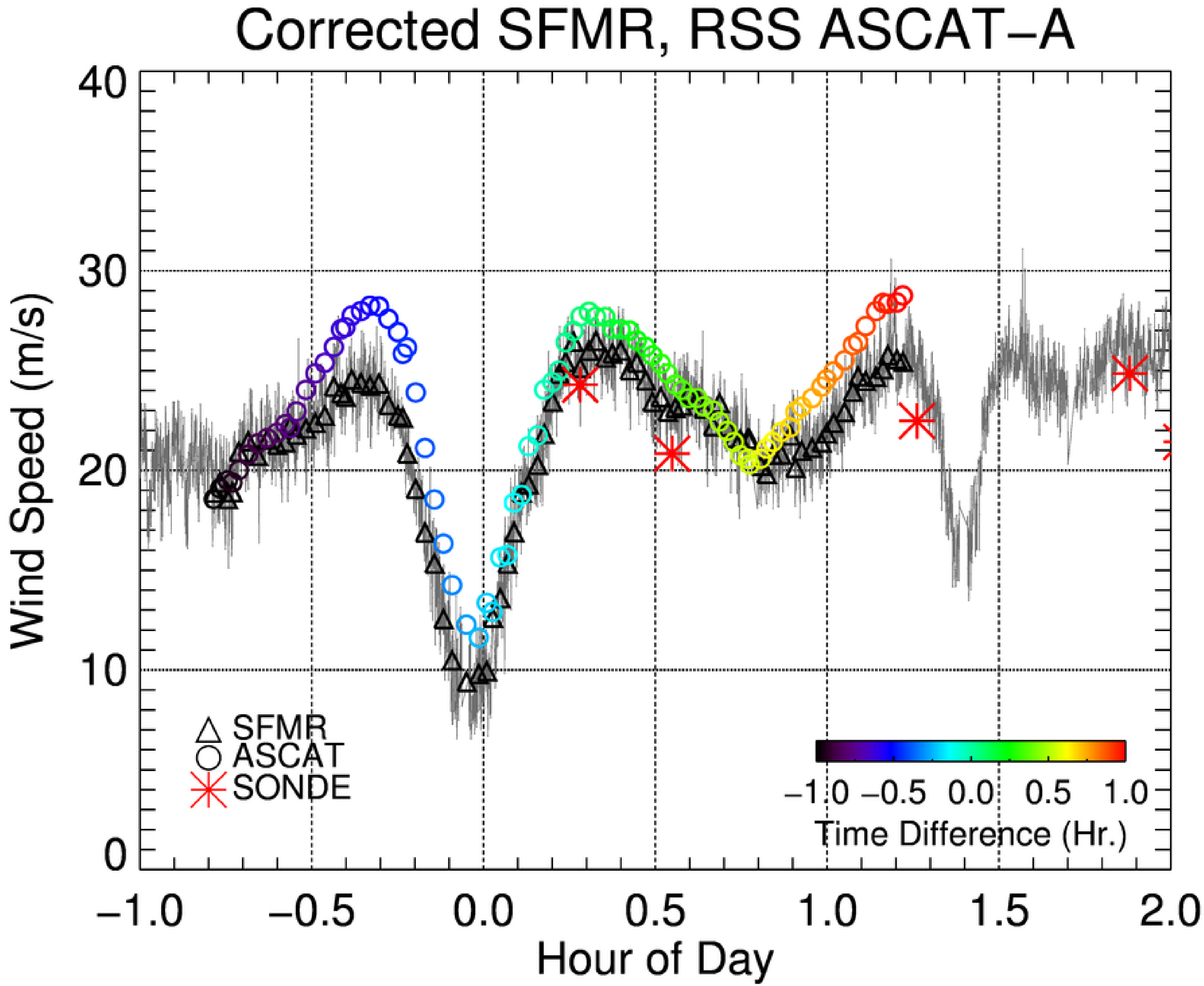


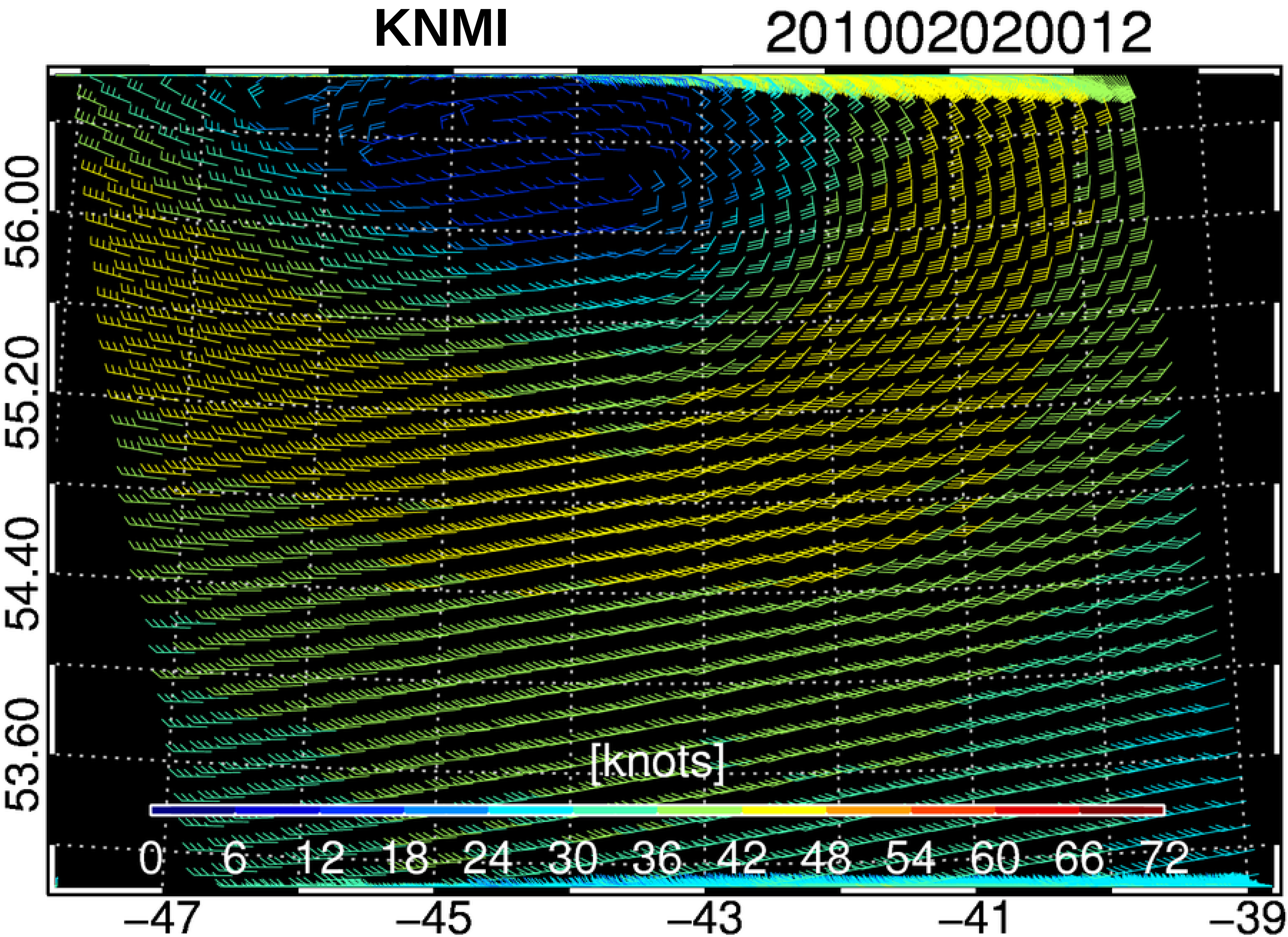
UNCORRECTED SFMR WINDS

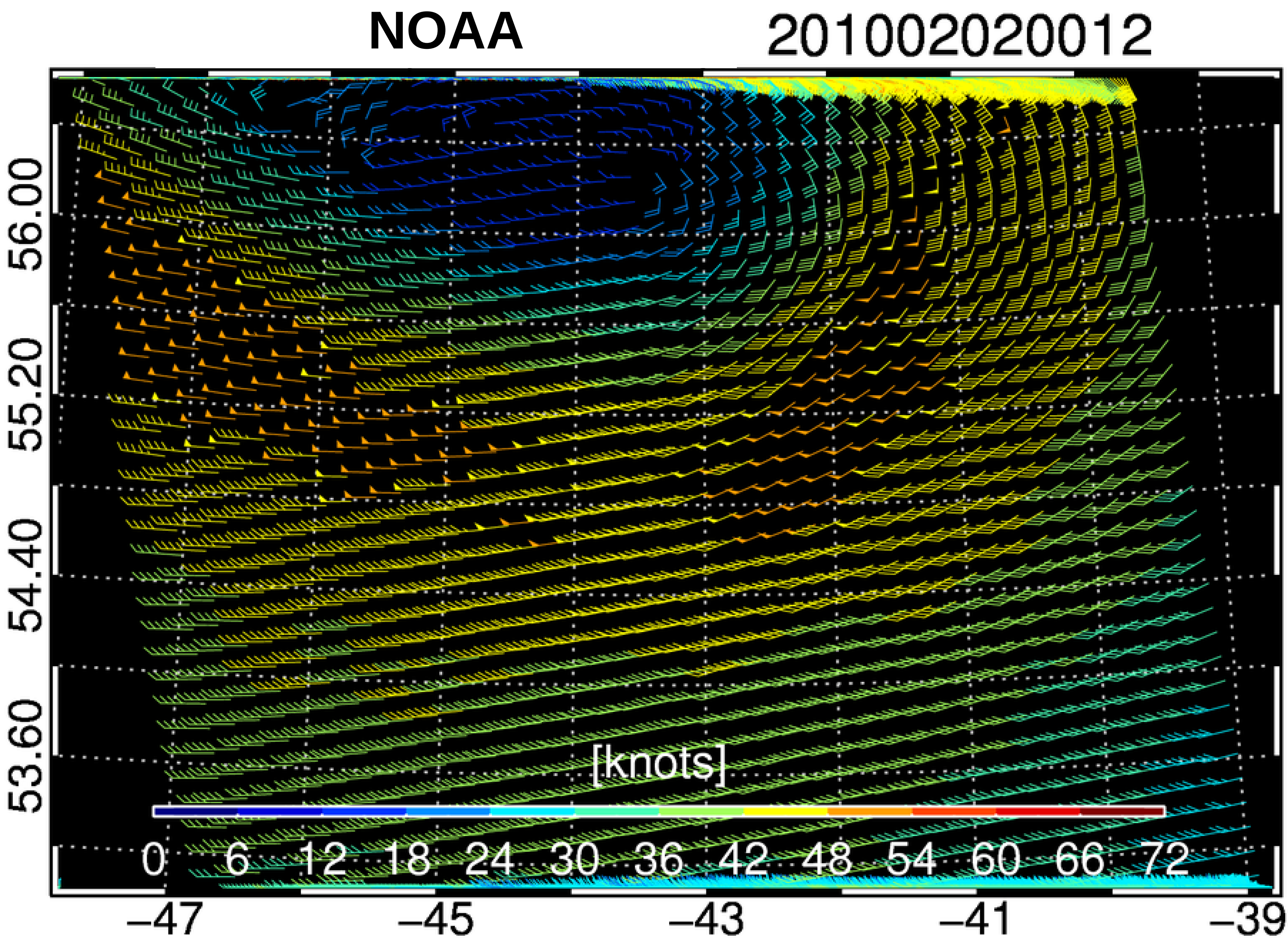

Corrected SFMR, KNMI ASCAT–A
Wind Speed (m/s)
40
30
20
10
0
–1.0
–0.5
0.0
0.5
1.0
1.5
2.0
Hour of Day
SFMR
ASCAT
SONDE
–1.0 –0.5 0.0 0.5 1.0
Time Difference (Hr.)

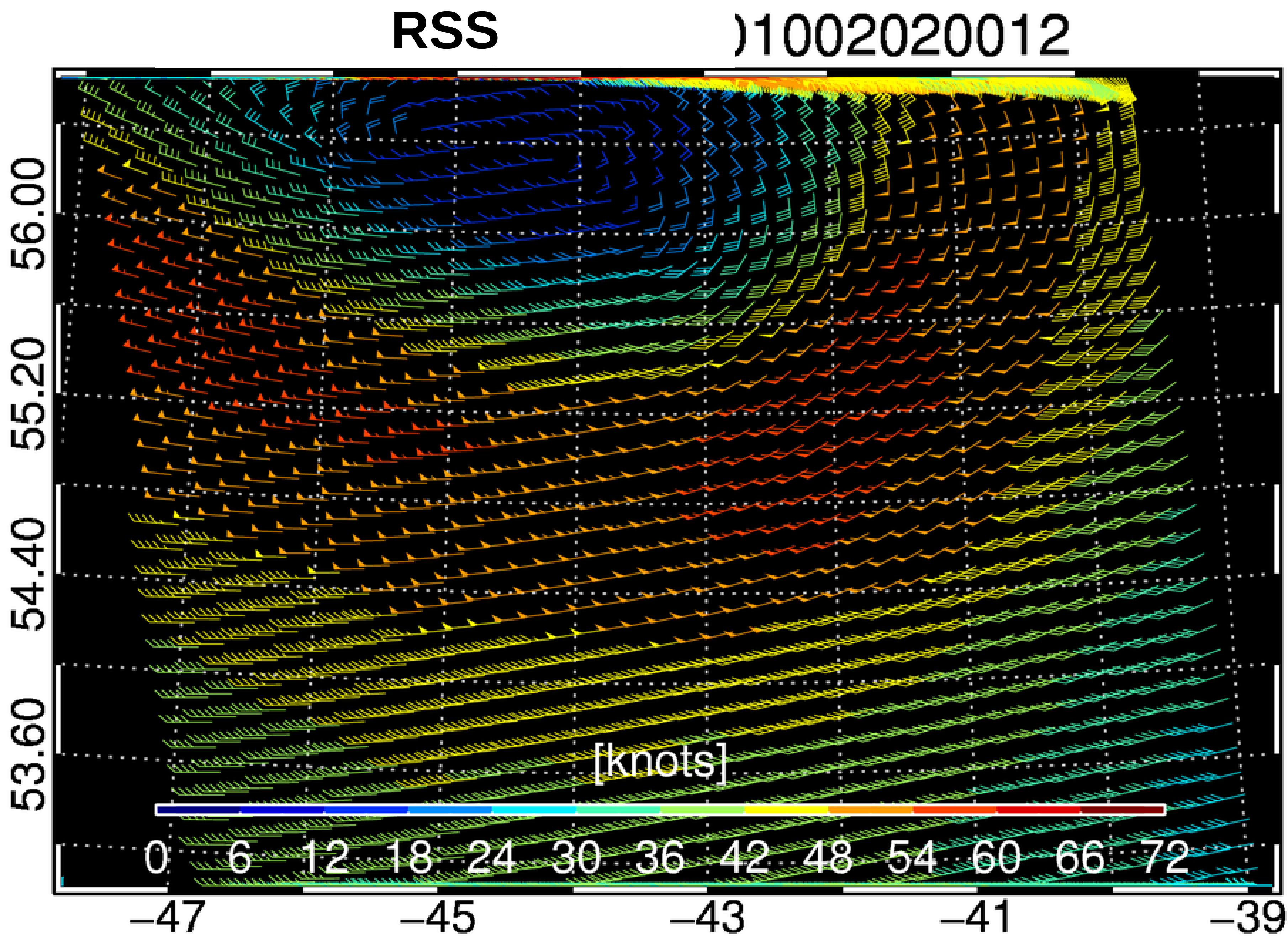


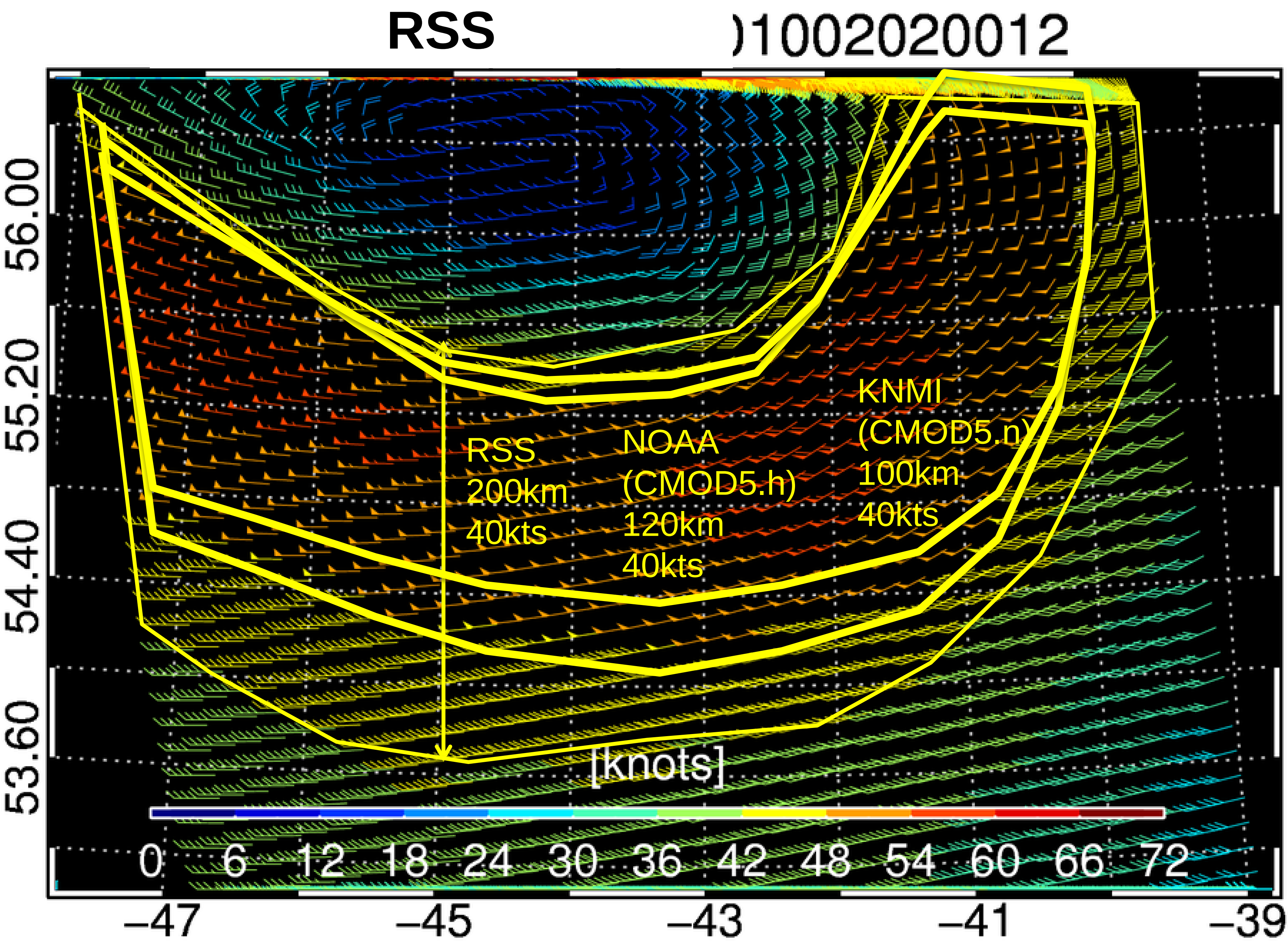
Corrected SFMR, NOAA ASCAT–A
Wind Speed (m/s)
40
30
20
10
0
–1.0
–0.5
0.0
0.5
1.0
1.5
2.0
Hour of Day
SFMR
ASCAT
SONDE
–1.0 –0.5 0.0 0.5 1.0
Time Difference (Hr.)

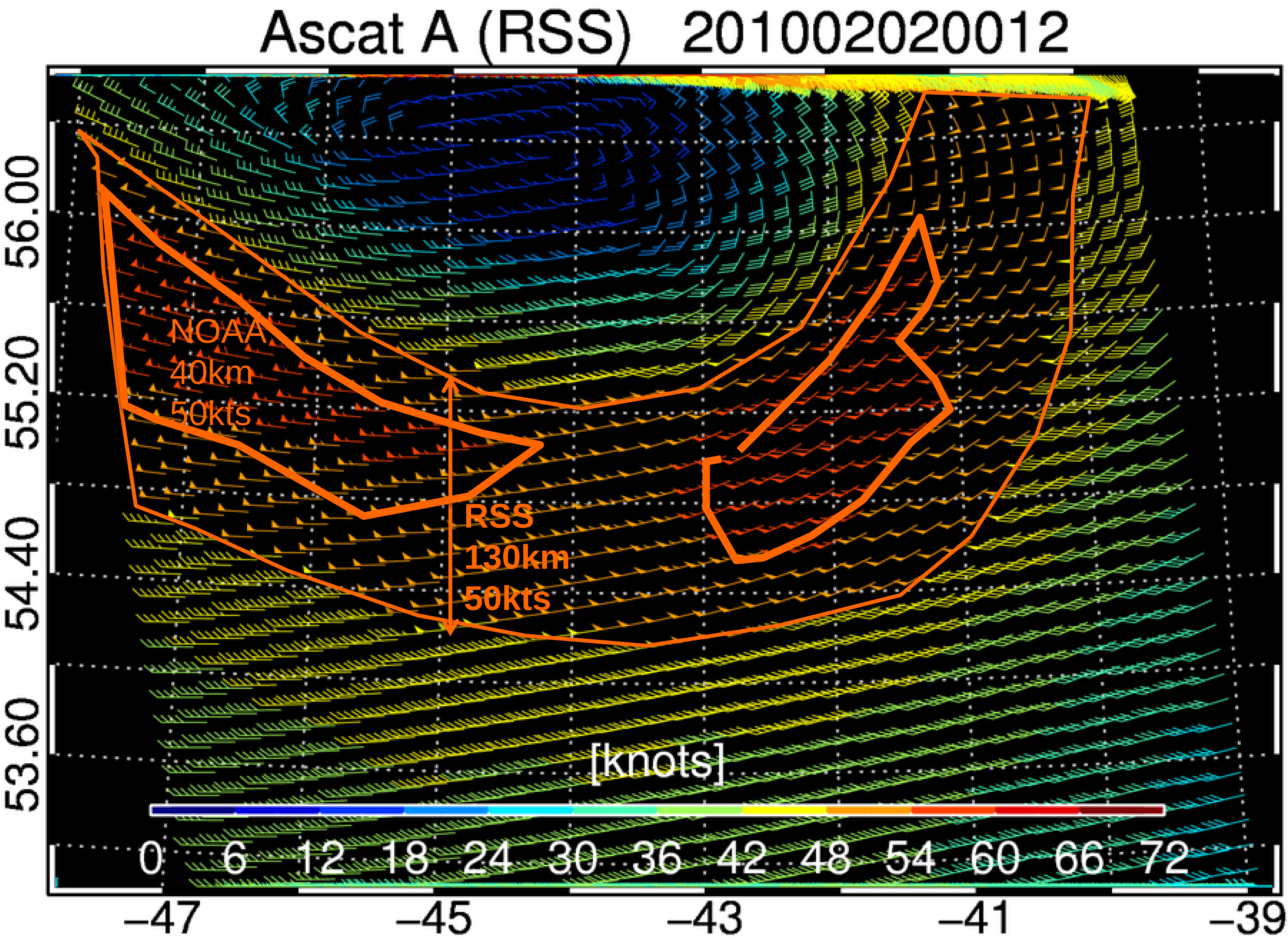

Corrected SFMR, RSS ASCAT–A
Wind Speed (m/s)
40
30
20
10
0
–1.0
–0.5
0.0
0.5
1.0
1.5
2.0
Hour of Day
SFMR
ASCAT
SONDE
–1.0 –0.5 0.0 0.5 1.0
Time Difference (Hr.)


KNMI
201002020012
56.00
55.20
54.40
53.60
[knots]
0 6 12 18 24 30 36 42 48 54 60 66 72
–47 –45 –43 –41 –39


NOAA
201002020012
56.00
55.20
54.40
53.60
[knots]
0 6 12 18 24 30 36 42 48 54 60 66 72
−47
−45
−43
−41
−39


RSS
)1002020012
56.00
55.20
54.40
53.60
[knots]
0 6 12 18 24 30 36 42 48 54 60 66 72
–47
–45
–43
–41
–39


RSS
)1002020012
56.00
55.20
54.40
53.60
–47
–45
–43
–41
–39
RSS
200km
40kts
NOAA
(CMOD5.h)
120km
40kts
KNMI
(CMOD5.n)
100km
40kts
[knots]
0 6 12 18 24 30 36 42 48 54 60 66 72


Ascat A (RSS) 201002020012
56.00
55.20
54.40
53.60
–47
–45
–43
–41
–39
NOAA
40km
50kts
RSS
130km
50kts
[knots]
0 6 12 18 24 30 36 42 48 54 60 66 72

GCOM-W1 AMSR2 Precipitation EDR Update

Patrick Meyers & Ralph Ferraro

August 16th, 2017

STAR JPSS Annual Meeting

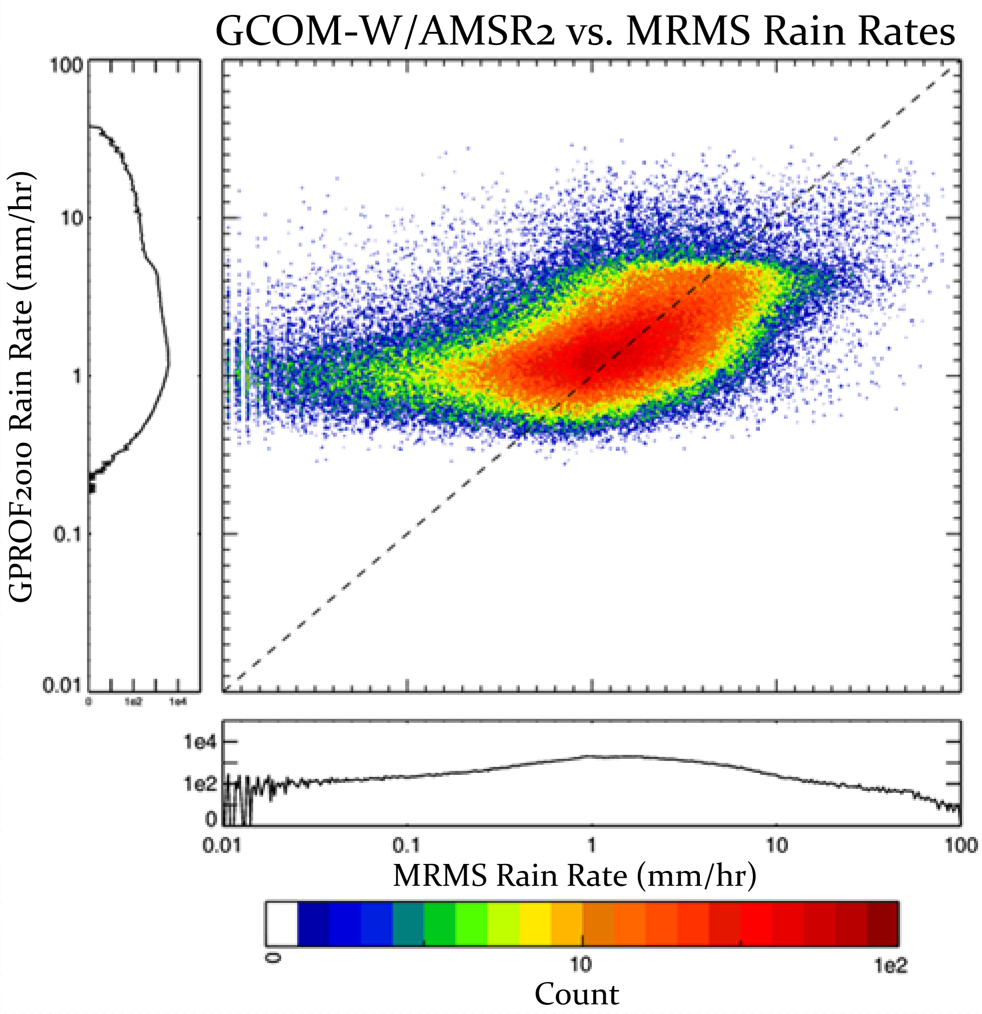
Overview

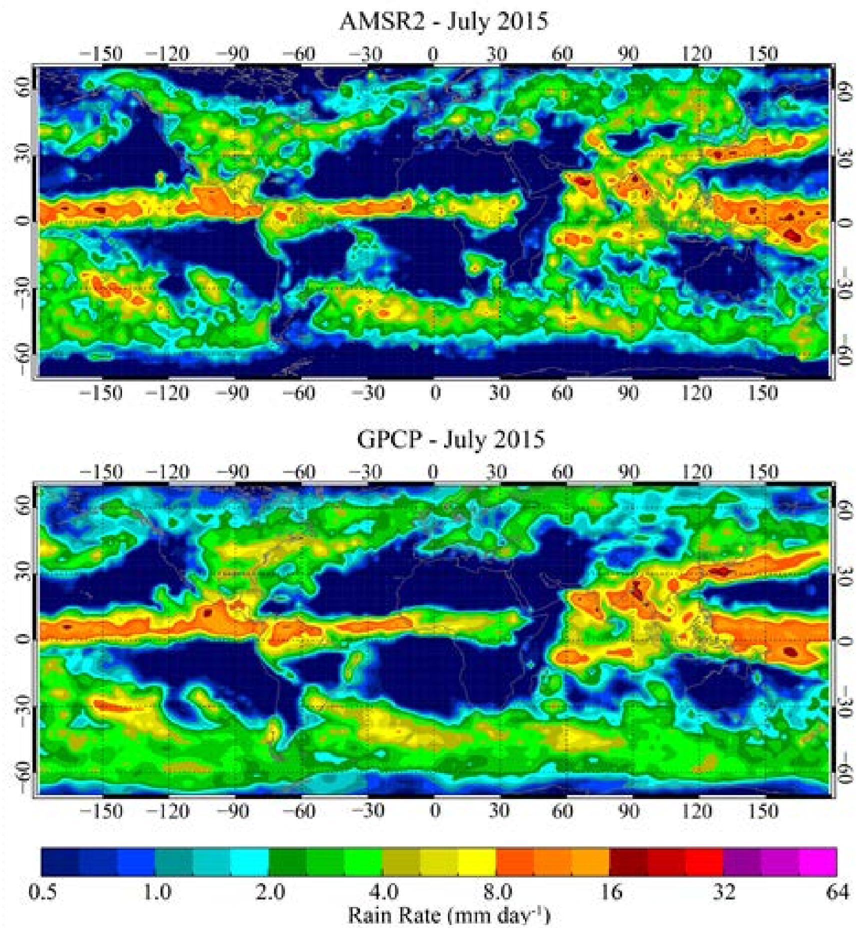
- Review of NOAA GCOM-W Precipitation EDR
  - GPROF2010V2
- Areas for Improvement
  - Precipitation detection over the Western US
  - SST Product Dependence
- Evaluation of GPROF2017

Program Requirements

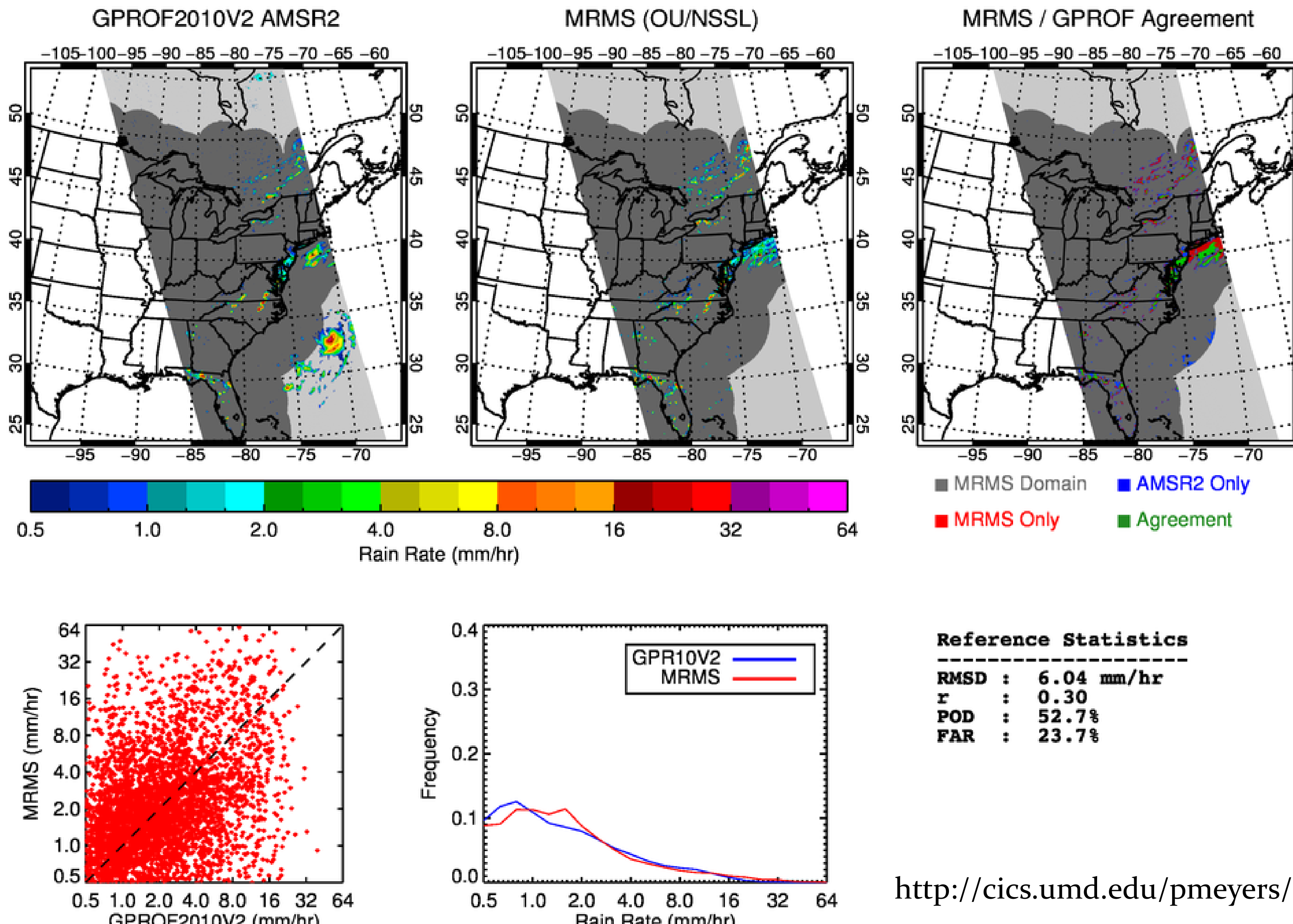
JPSS Requirements - GCOM Precipitation Type/Rate		
EDR Attribute	Threshold	AMSR2 EDR
Applicable conditions		Delivered under "all weather" conditions
Horizontal cell size	5 km land (89 GHz FOV); 10 km ocean (37 GHz FOV size); 5-10 km sampling	5.0 km (land); 10 km (ocean)
Mapping uncertainty, 3 sigma	< 5 km	~2.5 km
Measurement range	0 – 50 mm/hr	0 – 75 mm/hr
Measurement precision	0.05 mm/hr	0.01 mm/hr
Measurement uncertainty	2 mm/hr over ocean; 5 mm/hr over land	1.3 mm/hr (ocean) 3.6 mm/hr (land)
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)	91% every 20 h
Precipitation type	Stratiform or convective	Convective rain rate
Latency	25 minutes	8 min

Validation


GCOM-W/AMSR2 vs. MRMS Rain Rates
GPROF2010 Rain Rate (mm/hr)
MRMS Rain Rate (mm/hr)
100
10
1
0.1
0.01
1e4
1e2
0
0.01
0.1
1
10
100
0
10
1e2
Count


AMSR2 - July 2015
GPCP - July 2015
−150 −120 −90 −60 −30 0 30 60 90 120 150
60 30 0 −30 −60
0.5 1.0 2.0 4.0 8.0 16 32 64
Rain Rate (mm day⁻¹)

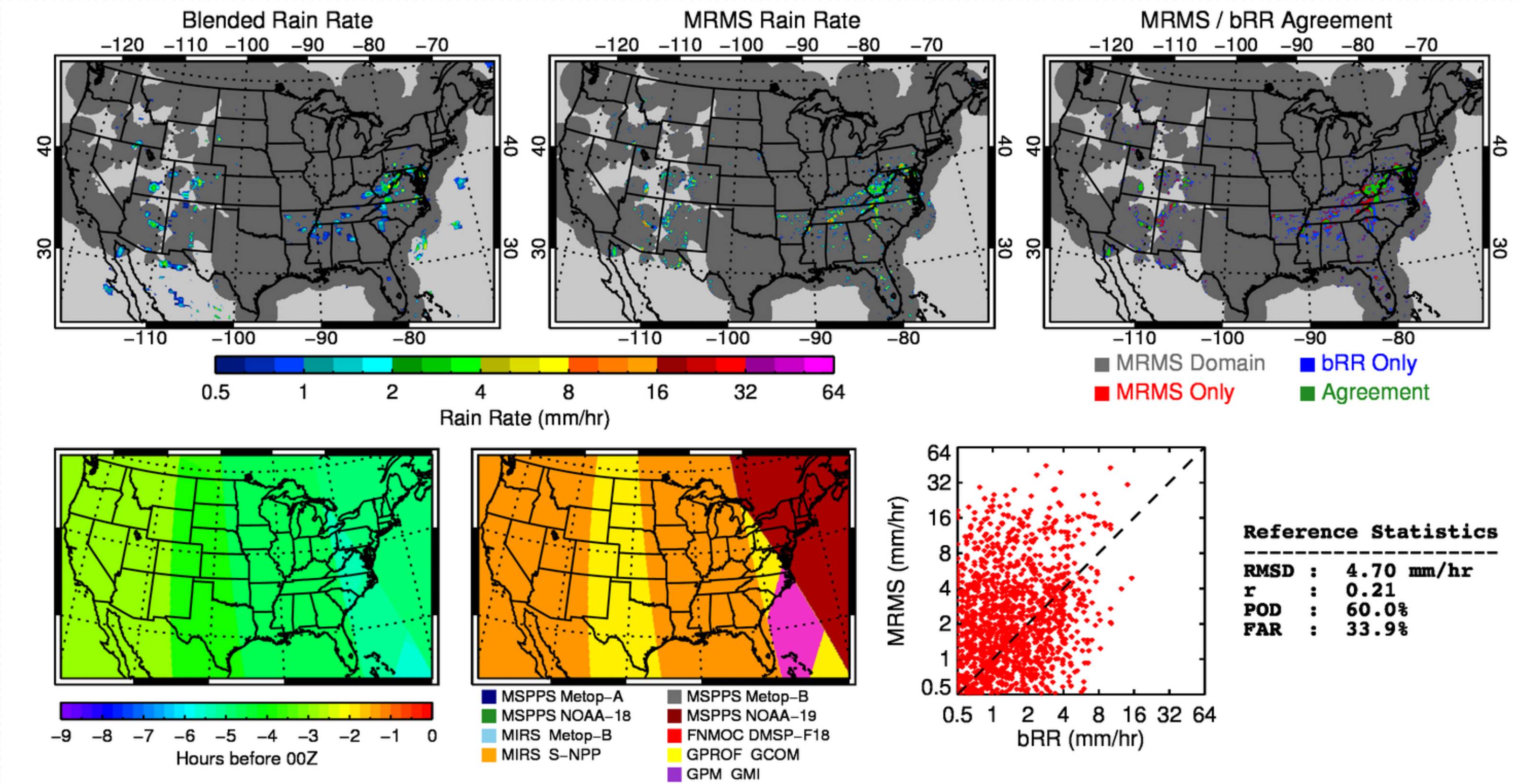
Routine Monitoring



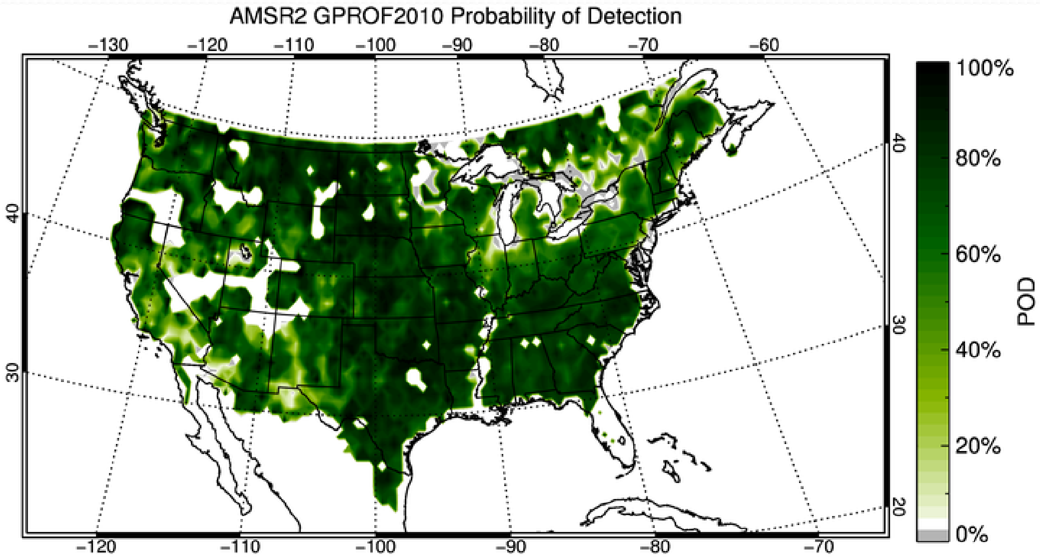
http://cics.umd.edu/pmeyers/amsr2/

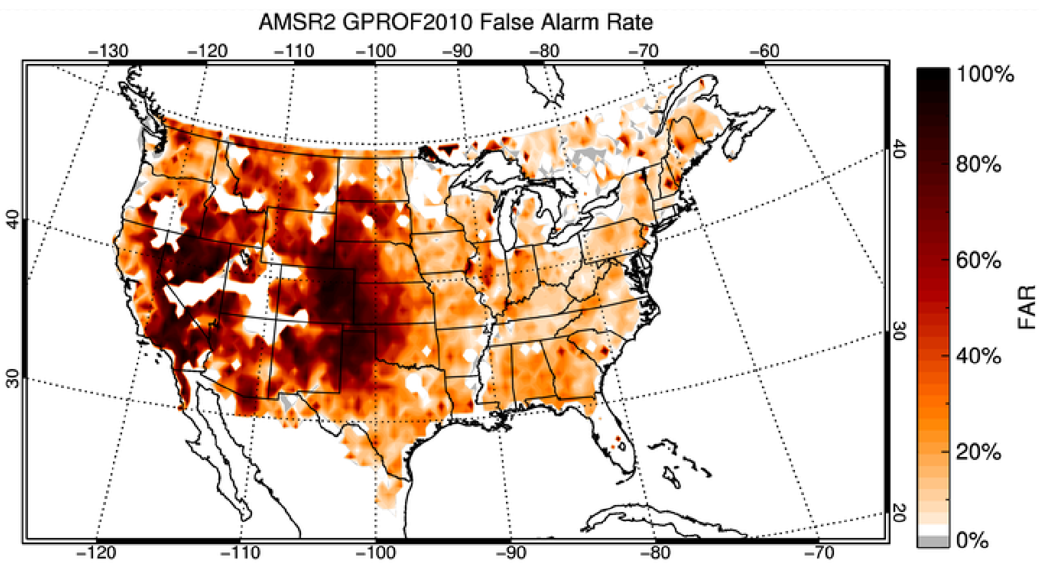
Applications

- bRR (Blended Rain Rate; below)
- eTRaP [Ensemble Tropical Rainfall Potential]
- Direct Broadcast



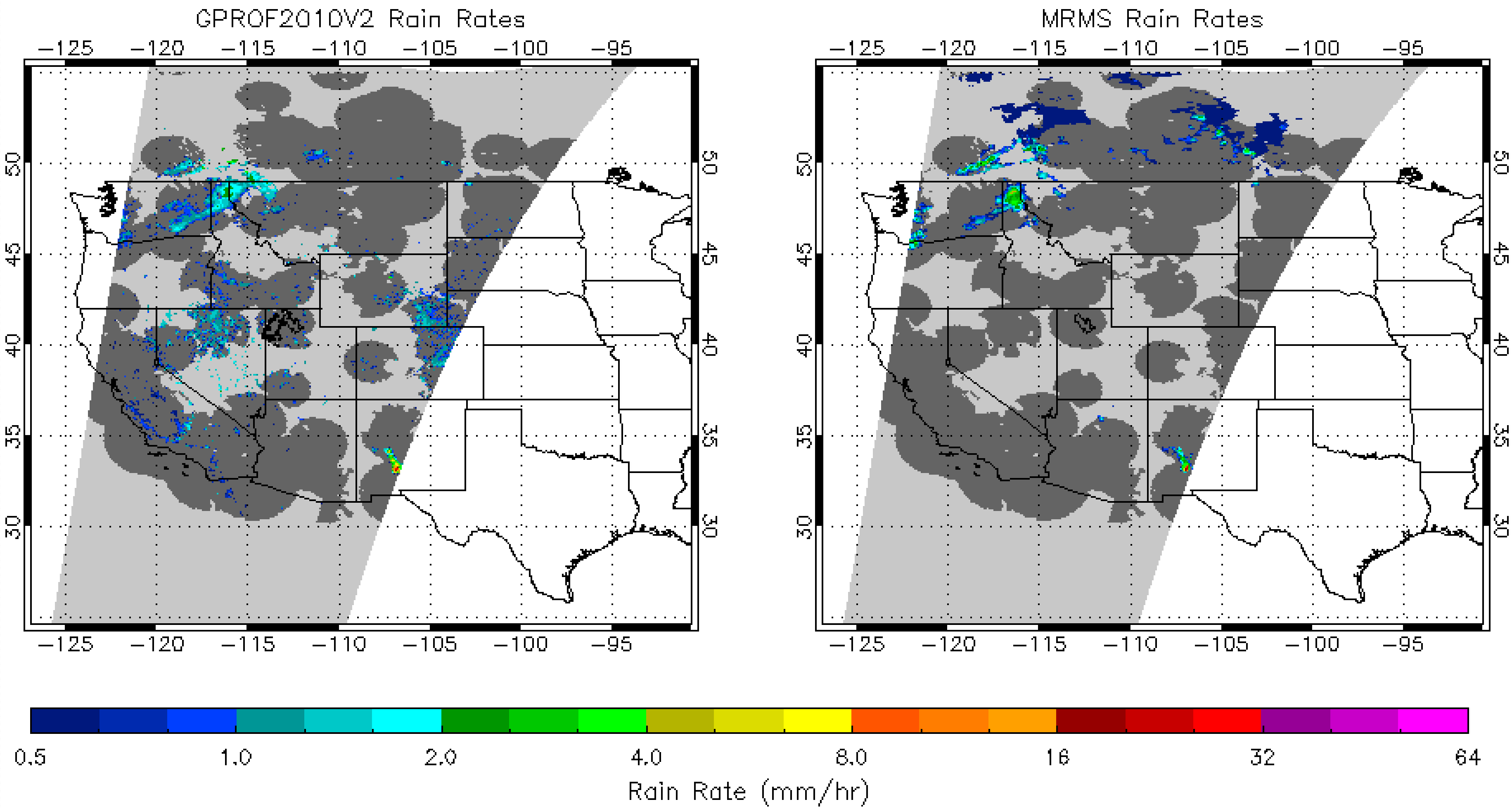
Detection Limitations



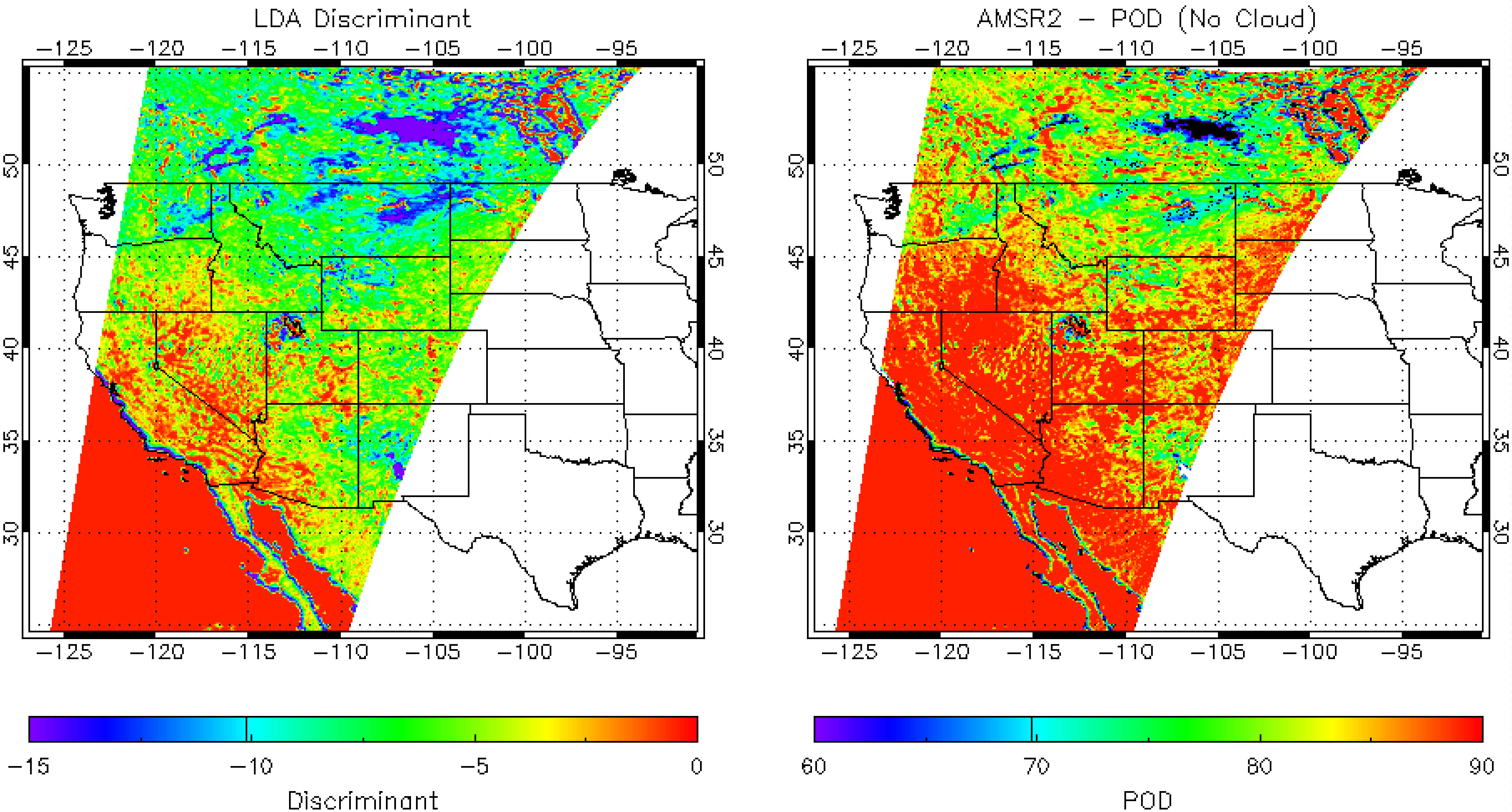


- False detection of precipitation based on Scattering Index and Tb thresholds
- Apply Turk (2016) cloud-free detection algorithm
- Use last IMS snow analysis for screening

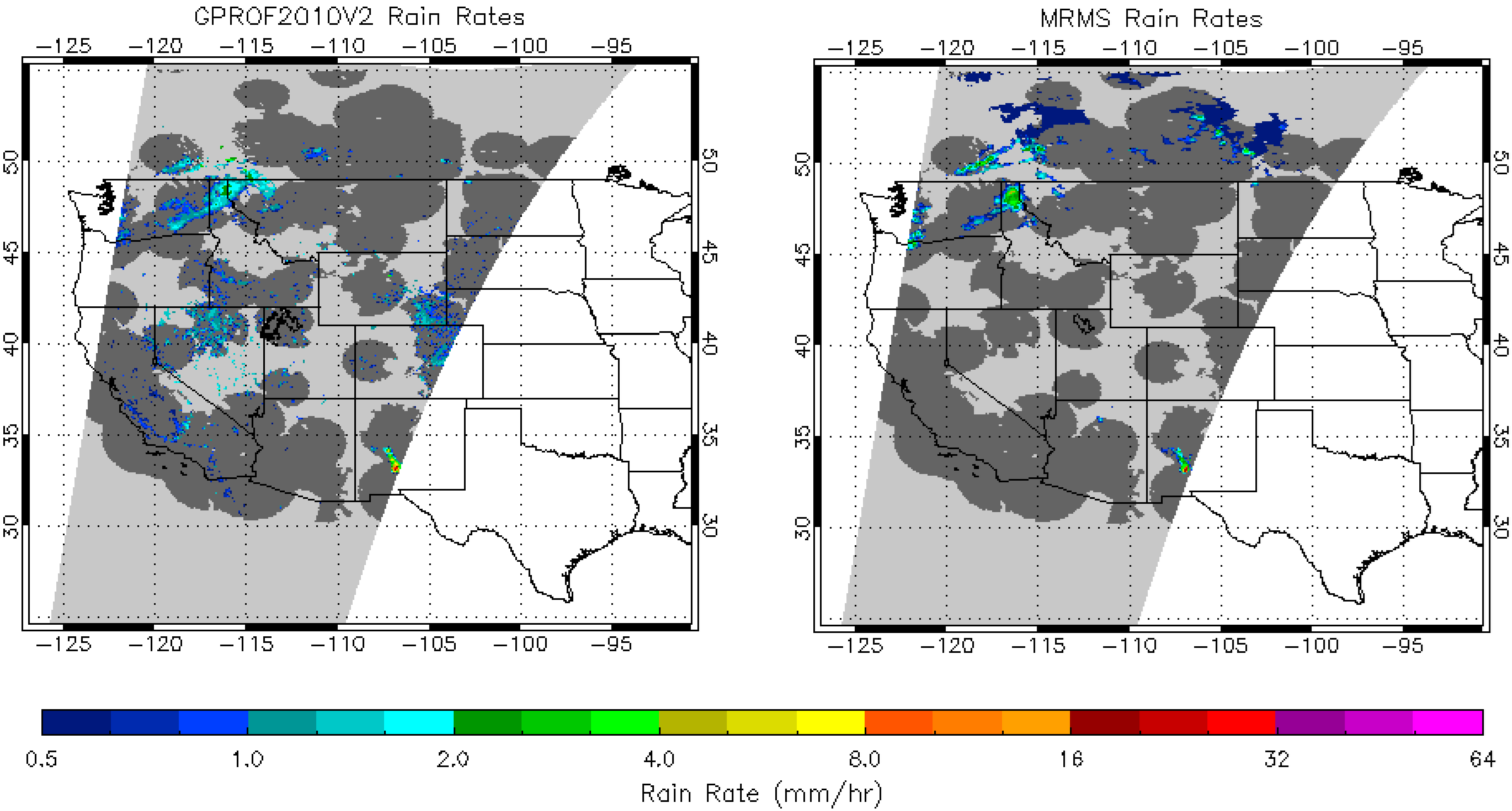
Nighttime False Alarms



Linear Discriminant Analysis for Cloud-Free Scenes



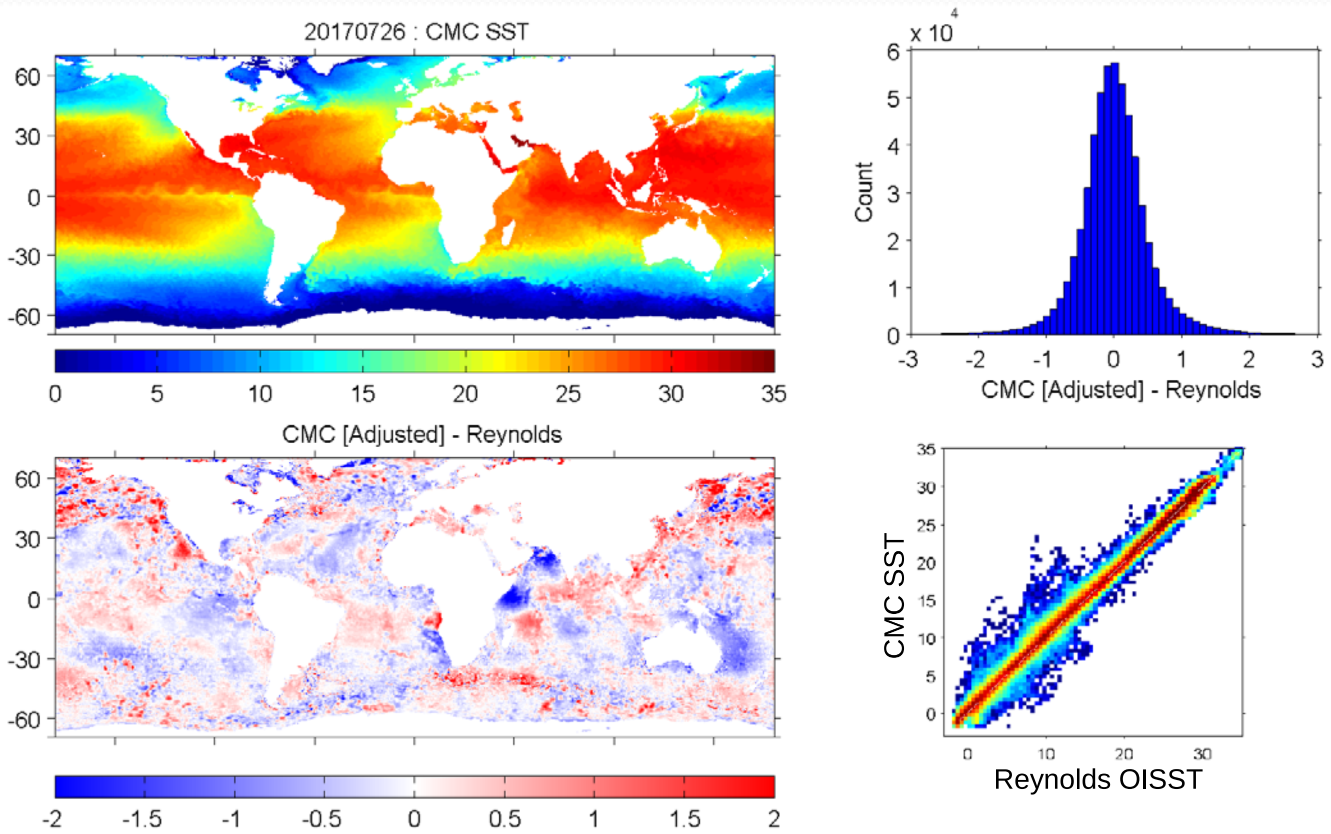
FAR Reduction



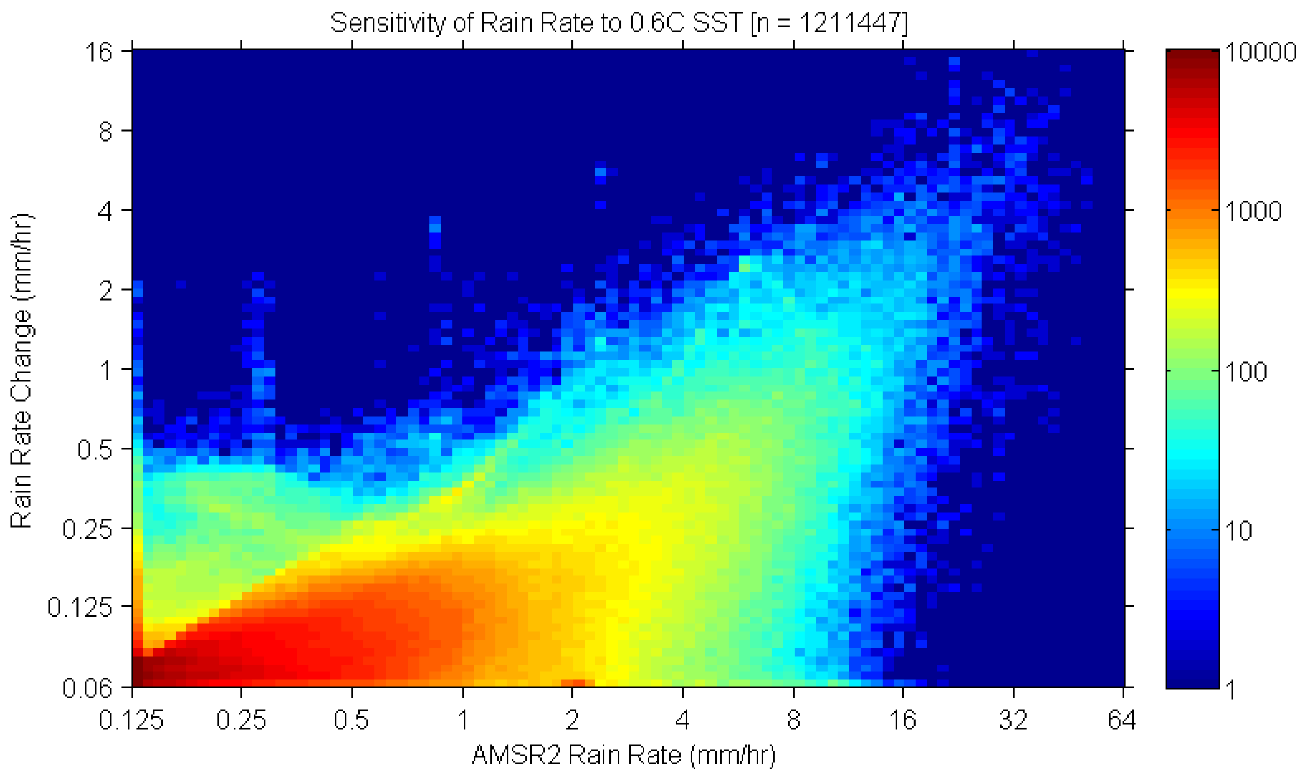
Fall-Spring:	POD	FAR	CSI	HSS
Original :	0.644735	0.535026	0.370140	0.515073
Filtered :	0.593108	0.318920	0.464190	0.618437

SST Product Reliability

- Currently using non-operational Reynolds ¼° OISST
  - JPSS-RR suggests evaluating CMC SST



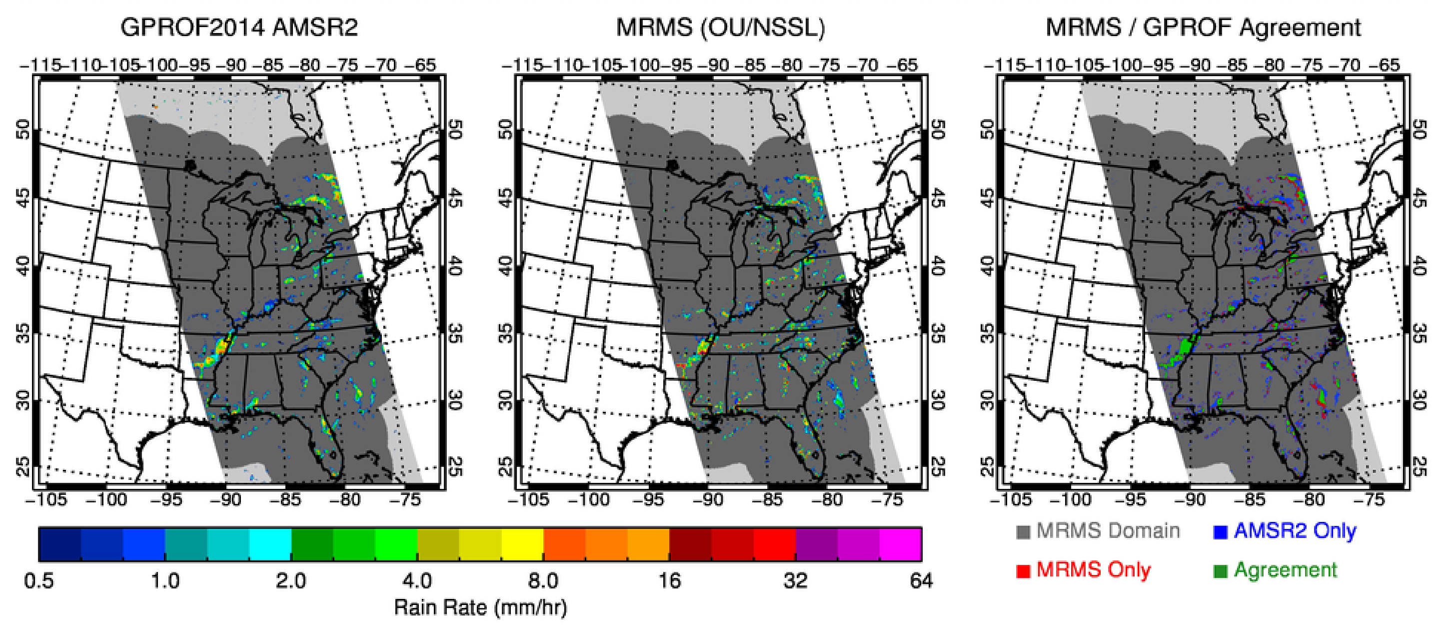
SST Product Sensitivity



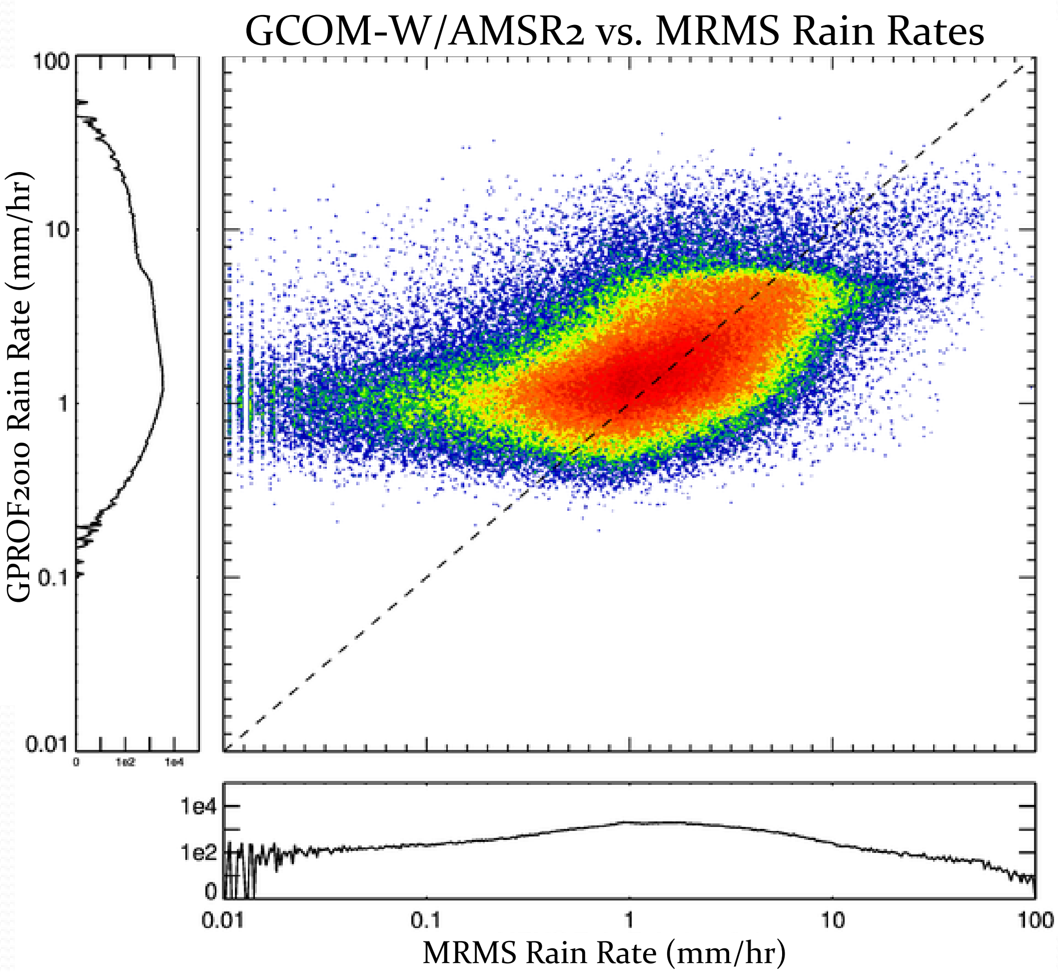
- Would require validation with respect to requirements
- May require recalculation of a priori database

Evaluation of GPROF2017

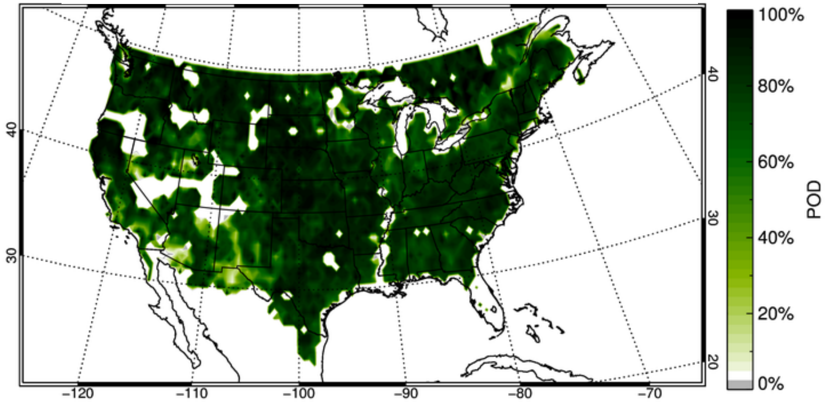
- Collaboration with NASA/GPM
- Fully Bayesian retrieval
  - Separated by surface type, TPW, and near surface temp
- Trained with Dual-frequency Precipitation Radar



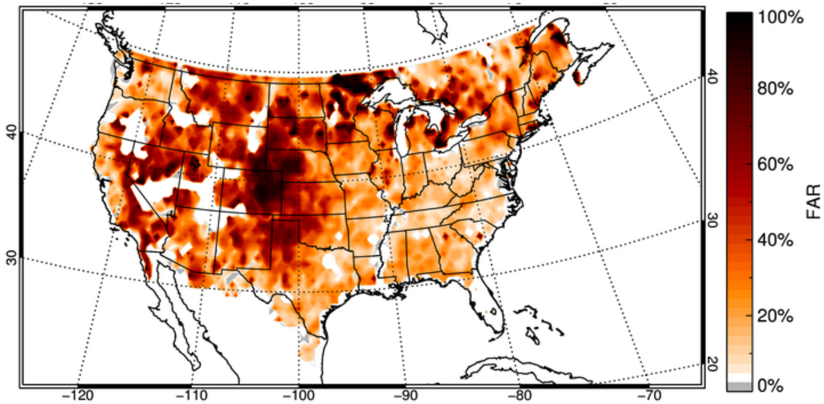
GPROF2010v3



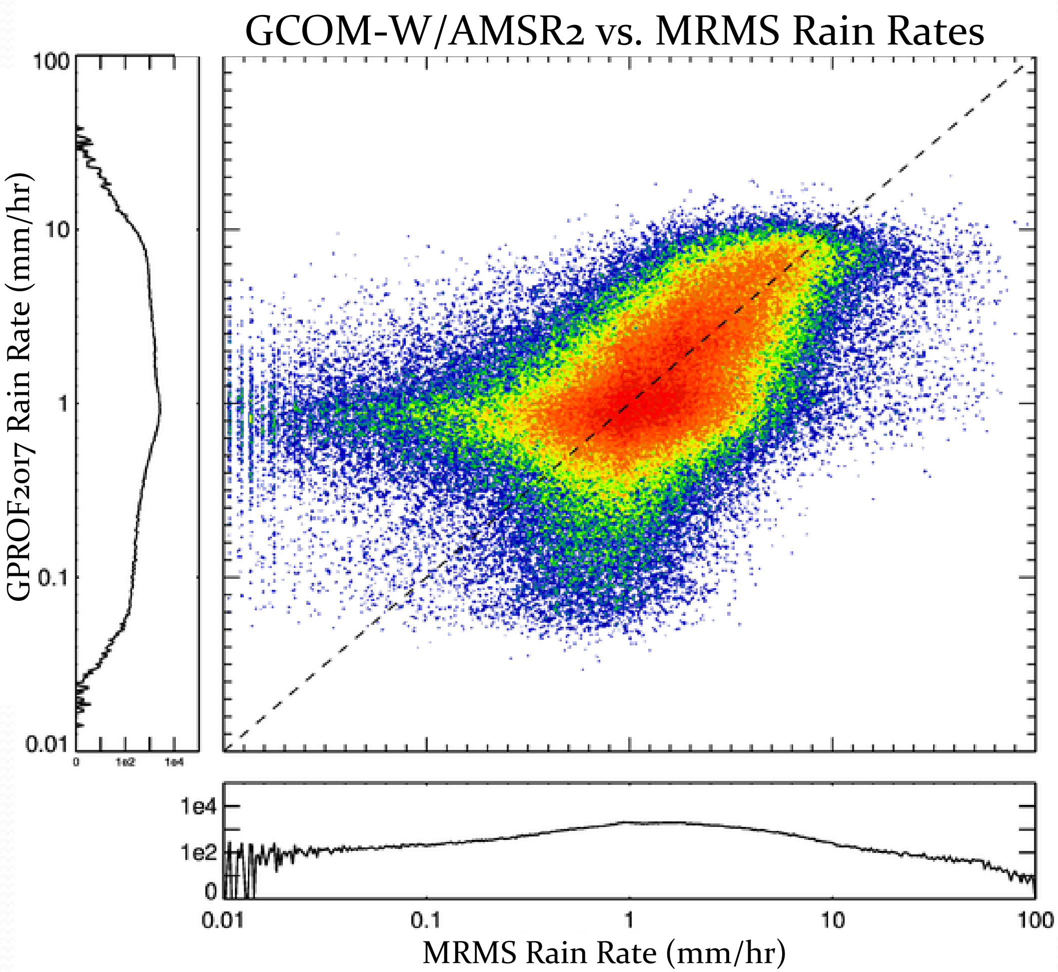
POD



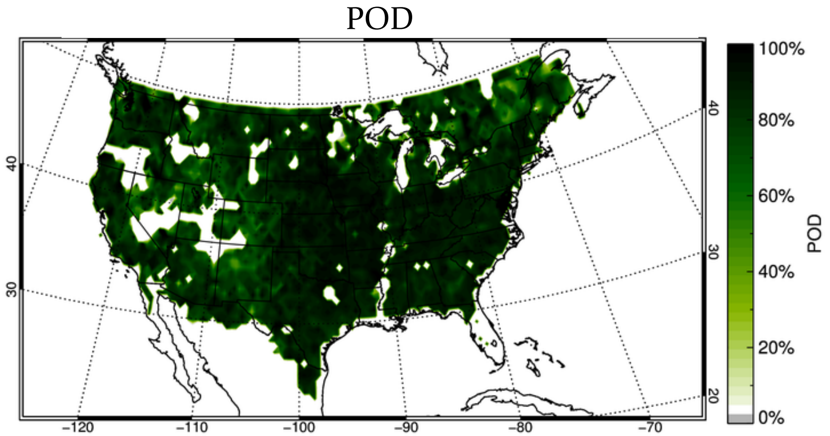
FAR



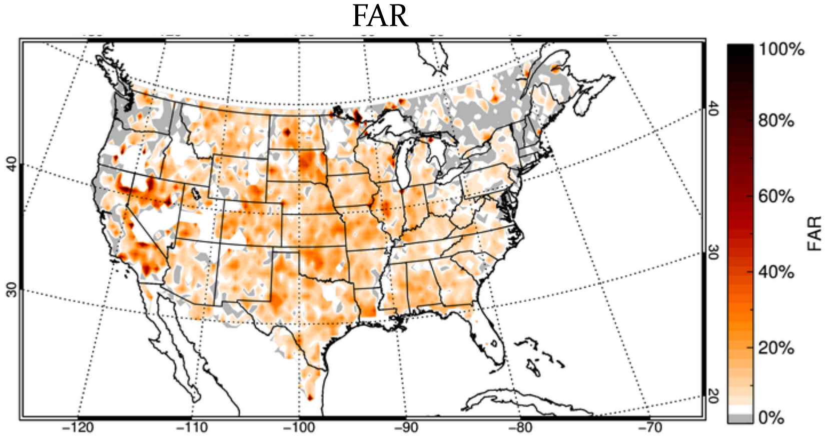
GPROF2017



GCOM-W/AMSR2 vs. MRMS Rain Rates
GPROF2017 Rain Rate (mm/hr)
MRMS Rain Rate (mm/hr)
100
10
1
0.1
0.01
1e4
1e2
0
0.01
0.1
1
10
100



POD
100%
80%
60%
40%
20%
0%
POD



FAR
100%
80%
60%
40%
20%
0%
FAR

Notes on GPROF2017

- Ongoing work to improve Conv/Strat using environmental conditions [Veljko Petkovic]
- Need to evaluate ancillary products for potential transition into STAR operational framework

Algorithm	POD	FAR	CSI
GPROF2010V3	0.83	0.37	0.55
GPROF2017	0.86	0.10	0.78

Summary & Paths Forward

- Modifications of AMSR2 precipitation algorithm reduce false alarms and improve performance metrics
- Implementation and reprocessing of updated GPROF2010 algorithm
- Suitability testing of GPROF2017 for NOAA operations
- Leveraging more ancillary data
  - GOES-16 ABI & GLM
  - Environmental information

GCOM-W1/AMSR2 SOIL MOISTURE

NOAA NESDIS STAR

301-683-3599; Xiwu.Zhan@noaa.gov

X. Zhan, J. Liu, T. King, R. Ferraro, P. Chang

Outline

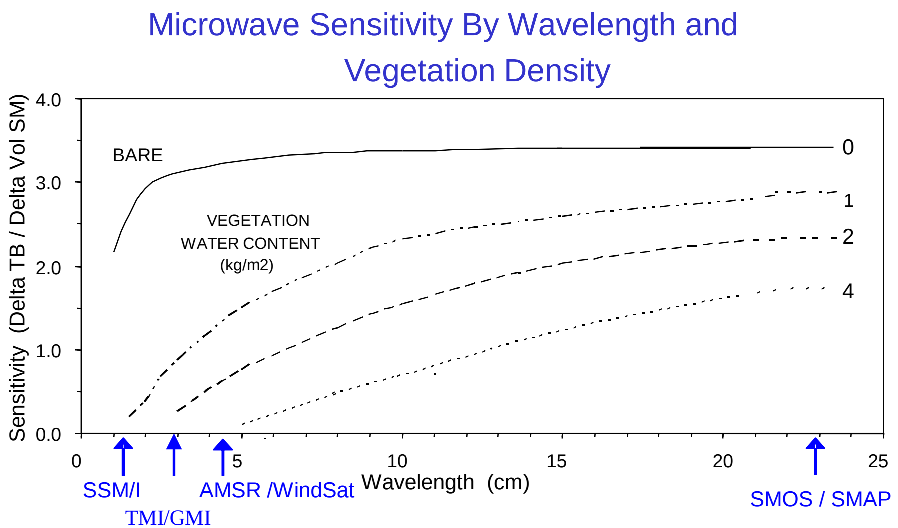
- AMSR2 Soil Moisture EDR Team Members
- Soil Moisture Sensor Overview
- AMSR2 Soil Moisture Algorithm
- AMSR2 Soil Moisture Data Product
- Summary and Path Forward

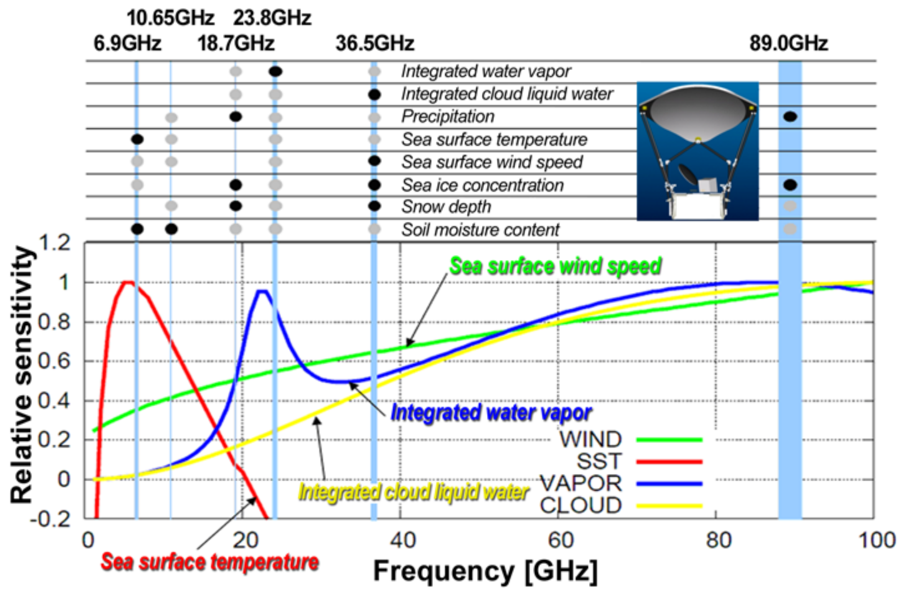
AMSR2 Soil Moisture Team Members

Team Member	Organization	Roles and Responsibilities
Xiwu Zhan	NESDIS-STAR	AMSR2 Soil Moisture Team Lead
Jicheng Liu	UMD-CICS/ NESDIS-STAR	SM Algorithm and Validation Lead
Tom King	IMSG/ NESDIS-STAR	GAASP Development Lead
Zorana Jelenak	UCAR/ NESDIS-STAR	JPSS GCOM-W1 EDR Lead
Ralph Ferraro	NESDIS-STAR	JPSS GCOM-W1 Project Deputy
Paul Chang	NESDIS-STAR	JPSS GCOM-W1 Project Lead

Soil Moisture Sensor Overview

- Soil Moisture remote sensing is based on the sensitivity of L/C/X band microwave emission to soil dielectric constant
- Soil moisture capable passive microwave satellite sensors include: SMMR, SSM/I and SSMIS, AMSR/AMSR-E, WindSat, **SMOS**, **AMSR2**, **GMI** and **SMAP**
- AMSR2 on board of JAXA's GCOM-W1 satellite is currently the only **operational passive microwave soil moisture** sensor in NASA-NOAA JPSS program





JPSS Requirements for AMSR-2 Soil Moisture EDR

Table 6.1.10 - GCOM-W Soil Moisture		
EDR Attribute	Threshold	Objective
Applicable conditions	Delivered under “all weather” conditions	Delivered under “all weather” conditions
Sensing depth	Surface to -0.1 cm (skin layer)	Surface to -80 cm
Horizontal cell size	25 km (1)	3 km
Mapping uncertainty, 3 sigma	5 km	1 km
Measurement Uncertainty	6% volumetric RMSE (goal) with VWC < 1.5 kg/m^2 or GVF < 0.5 and < 2 mm/hr precip rate	Surface: 5% 80 cm column: 5%
Measurement range	0 – 50%(2)	0 – 50%
Refresh	At least 90% coverage of the globe about every 20 hours (monthly average)(3)	n/s

Note:
(1) Per AMSR-E legacy and user convenience, 25km can be obtained with resampling AMSR-2 footprints to 25km. 3km could be obtained by interpolation with VIIRS optical observations
(2) Absolute soil moisture unit (m^3/m^3 volume %) is preferred by most users of NWP community
(3) This Refresh requirement is consistent with the AMSR-2 Cross-track Swath Width design of 1450 km for a single orbit plane

Soil Moisture Algorithm Overview

Land Parameter Retrieval Model (LPRM) :

(Owe, de Jeu & Holmes, 2008)

$$\min\{delta = T_{Bh}{}^{obs} - T_{Bh}{}^{cmp}\}$$

$$T_{Bh}{}^{cmp} = T_s \{e_{h,r} \exp(-\tau/\cos\theta) + (1 - \omega)[1 - \exp(-\tau/\cos\theta)][1 + (1 - e_{h,r})\exp(-\tau/\cos\theta)]\}$$

$\tau = f(MPDI)$, $MPDI = (T_{Bv} - T_{Bh})/(T_{Bv} + T_{Bh})$

$e_h = f(e_s, h, Q)$

$e_s = f(\varepsilon)$ -- Fresnel Equation

$\varepsilon = f(SM)$ -- Mixing model (Wang & Schmugge)

$T_s = f(T_{B37v})$ or $T_s{}^{LSM}$

$T_{Bh}{}^{obs} = T_{B06h}$, T_{B07h} or T_{B10h}

Soil Moisture Algorithm Overview

Single Channel Algorithm (SCA) :

(Jackson, 1993)

$$T_{B10h} = T_s [1 - (1-e_r) \exp(-2\tau / \cos\theta)]$$

$$\tau = b * VWC, \quad VWC = f(NDVI)$$

$$e_h = f(e_v, h, Q)$$

$$e_s = f(\varepsilon) \quad \text{-- Fresnel Equation}$$

$$\varepsilon = f(SM) \quad \text{-- Mixing model}$$

$$T_s = f(T_{B37v}) \text{ or } T_s^{LSM}$$

AMSR2 Soil Moisture Algorithm

SCA: Inverse tau-omega equation of a TB_h (C/X-band) for *SM* with *tau* from *NDVI* and T_s from TB_{36v}. Used in SMOPS

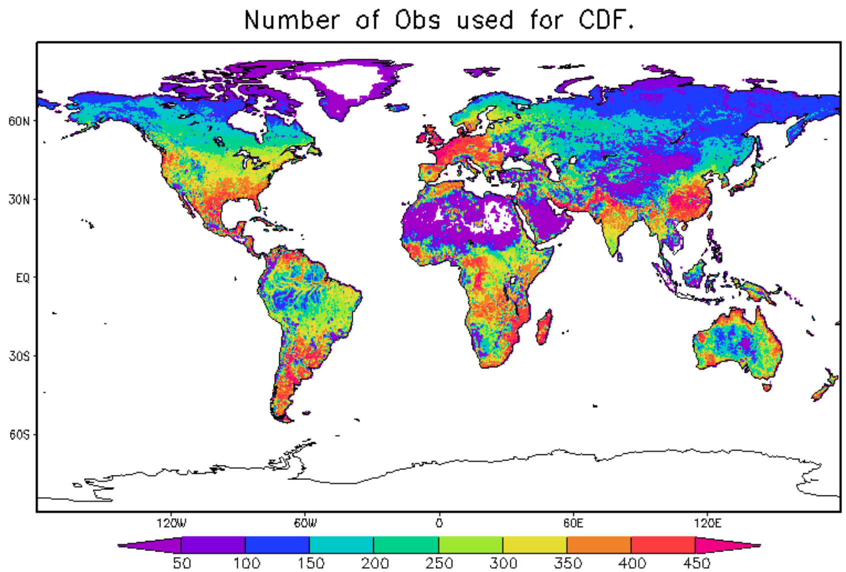
LPRM: Inverse tau-omega equations of TB_h and TB_v (C/X-band) for *tau* and *SM* with T_s from TB_{36v}

Hybrid: Use LPRM inversed *tau* in SCR for AMSR2 soil moisture EDR

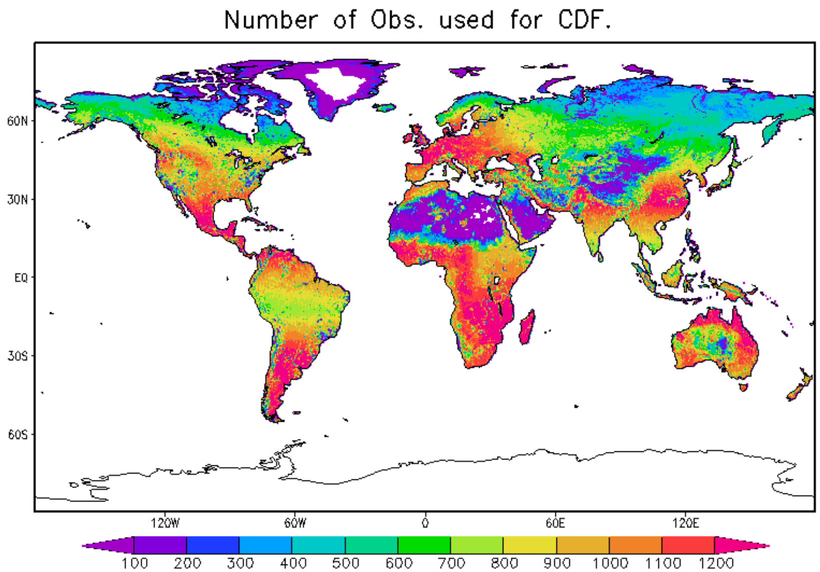
AMSR2 Soil Moisture Algorithm Update

1. **Fine-tuning of LPRM model parameters for better spatial coverage of valid retrievals.**
2. **Updating static data base with longer data period.**

CDF Version 1.0 (2013-2014)



CDF Version 2.0 (2013-2016)

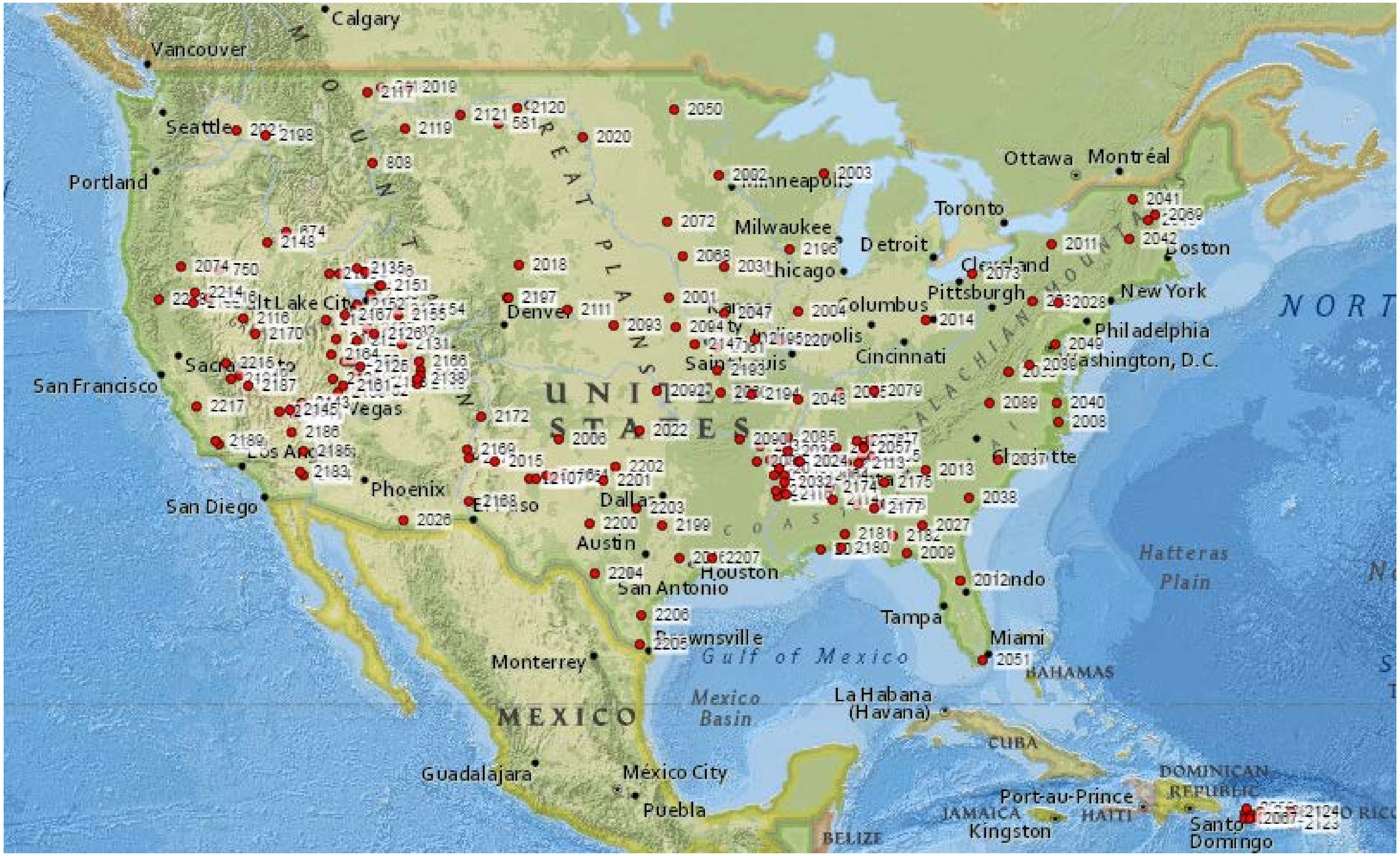


AMSR2 Soil Moisture Products

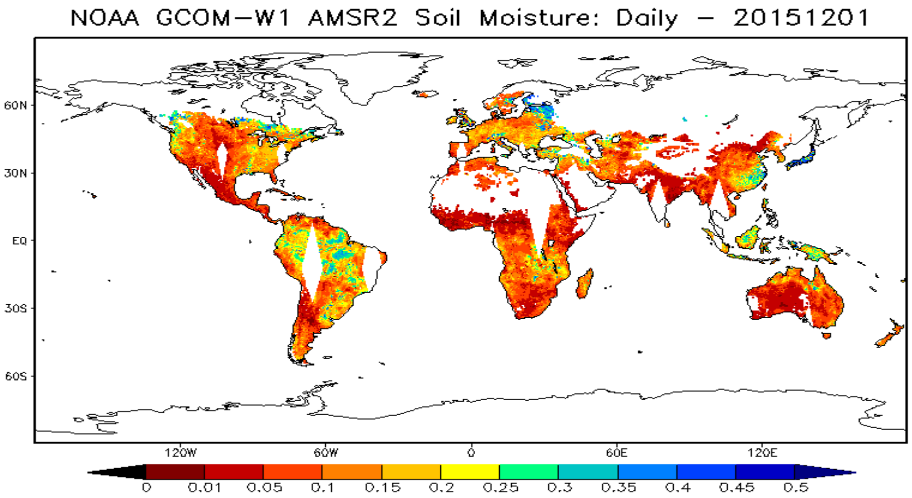
- AMSR2 soil moisture EDR is generated with the hybrid algorithm implemented in NESDIS GCOM-W1 AMSR2 Algorithm Software Processor (GAASP) using AMSR2 6.9/7.3GHz H-pol TB data, available as Level 2 swath product
- Global 0.25 degree (Level 3) gridded AMSR2 soil moisture data product are made available through NESDIS Global Soil Moisture Operational Product System (SMOPS) in 6 hour or daily NetCDF and GRIB2 files
- Algorithm Readiness Review for the Day 2 EDR of GCOM-W1 products was held in May 2016
- SMOPS update for AMSR2 to provide Level 3 global soil moisture product for users has been operational since September 2016

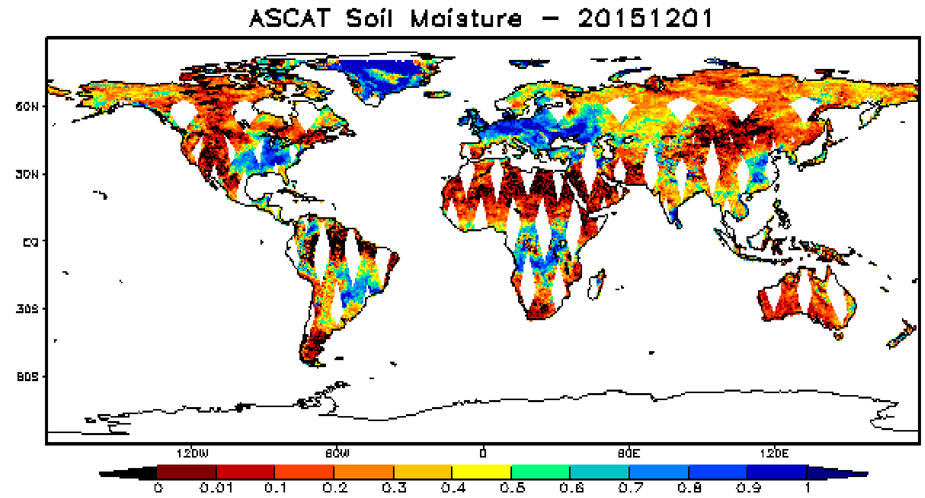
AMSR2 Soil Moisture Performance

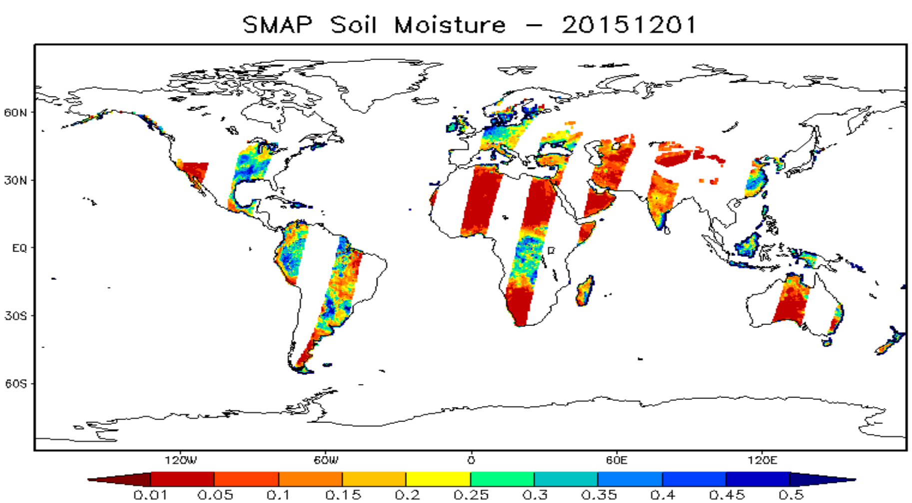
Comparison with in situ Measurements of SCAN Sites

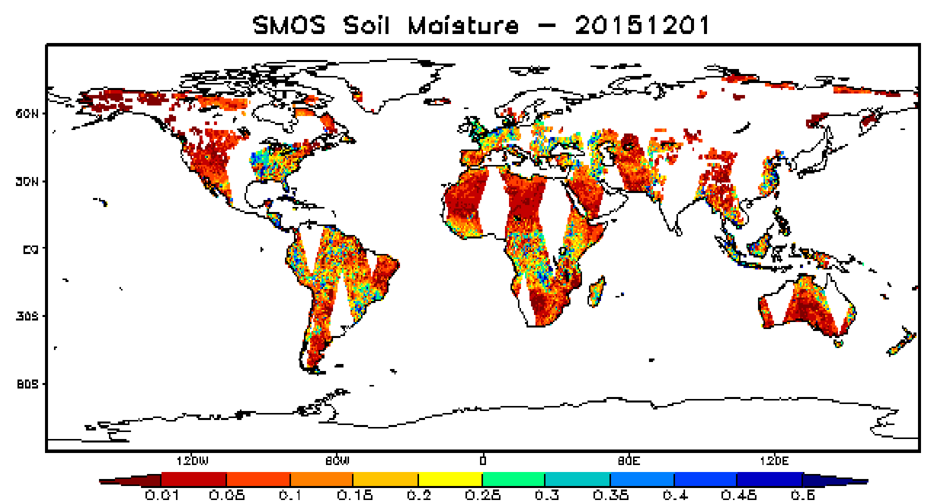


AMSR2 SM vs Other SM Products



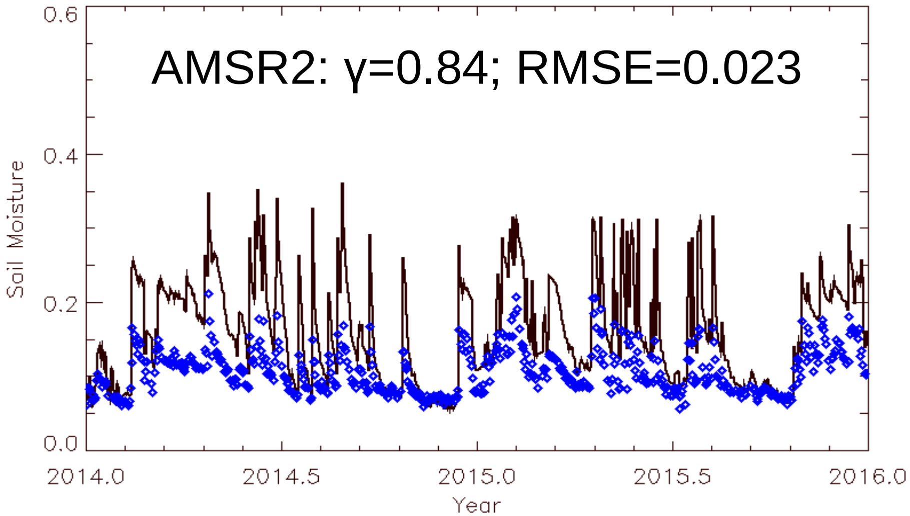


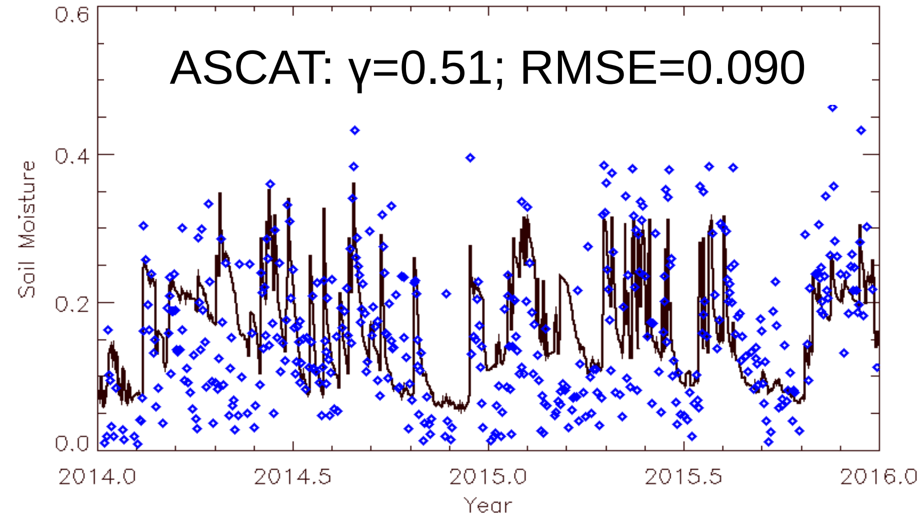


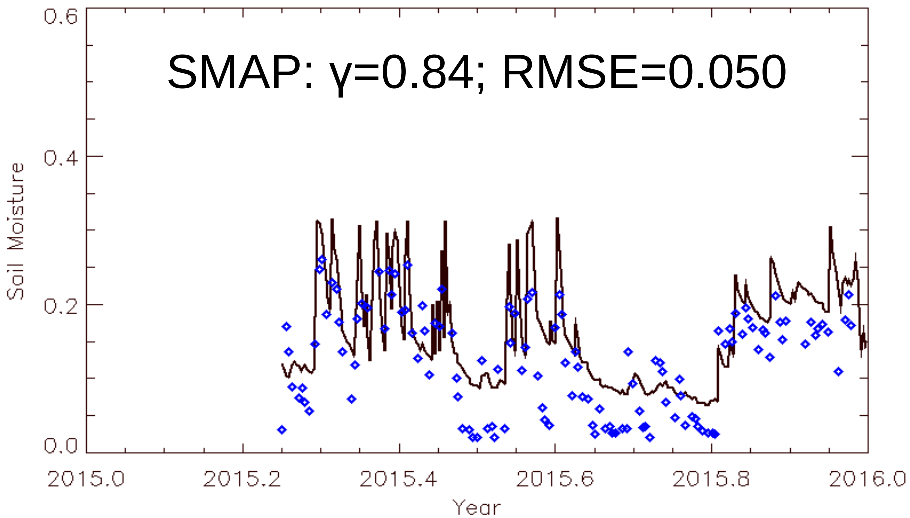


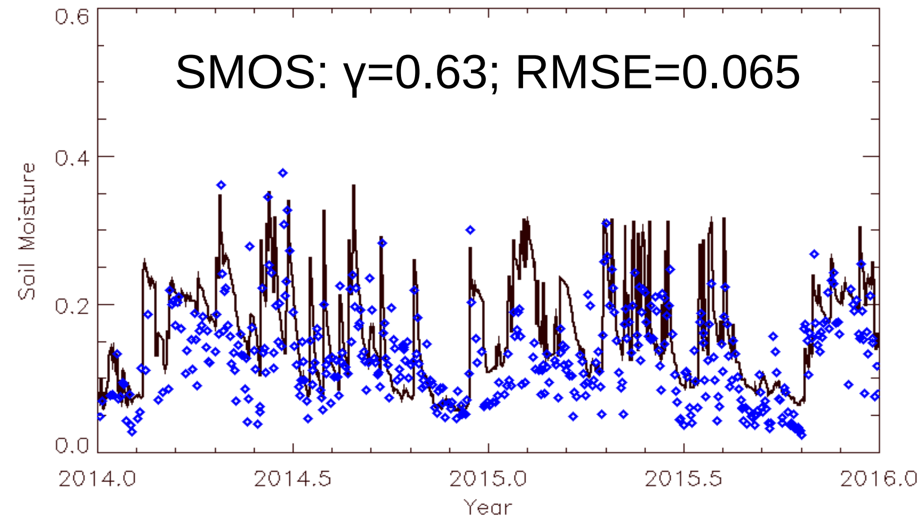
AMSR2 SM vs Other SM Products: Phillipsburg, KS

(γ: correlation coefficient; RMSE: Root Mean Square Error)



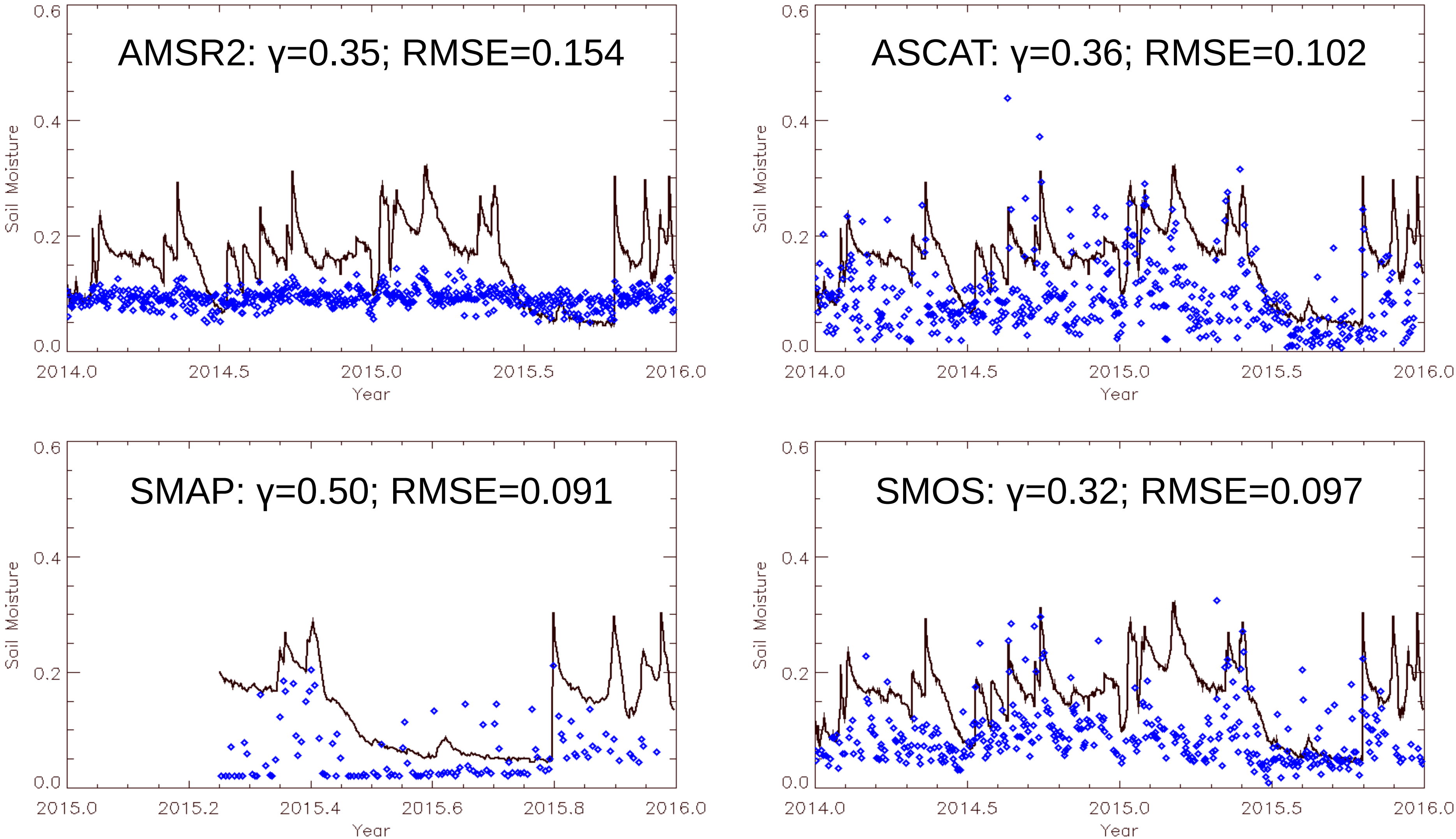




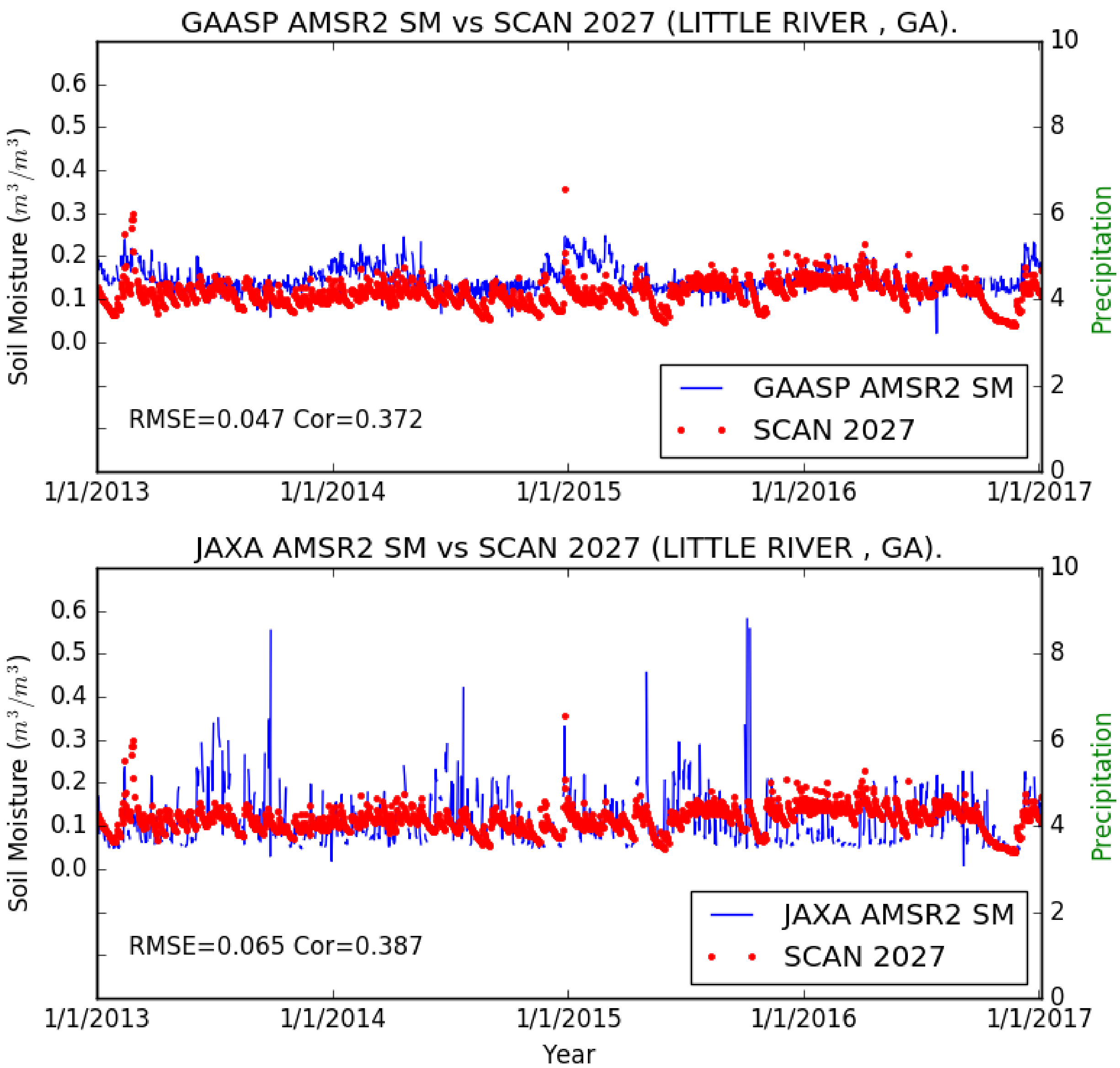


AMSR2 SM vs Other SM Products: Milford, UT

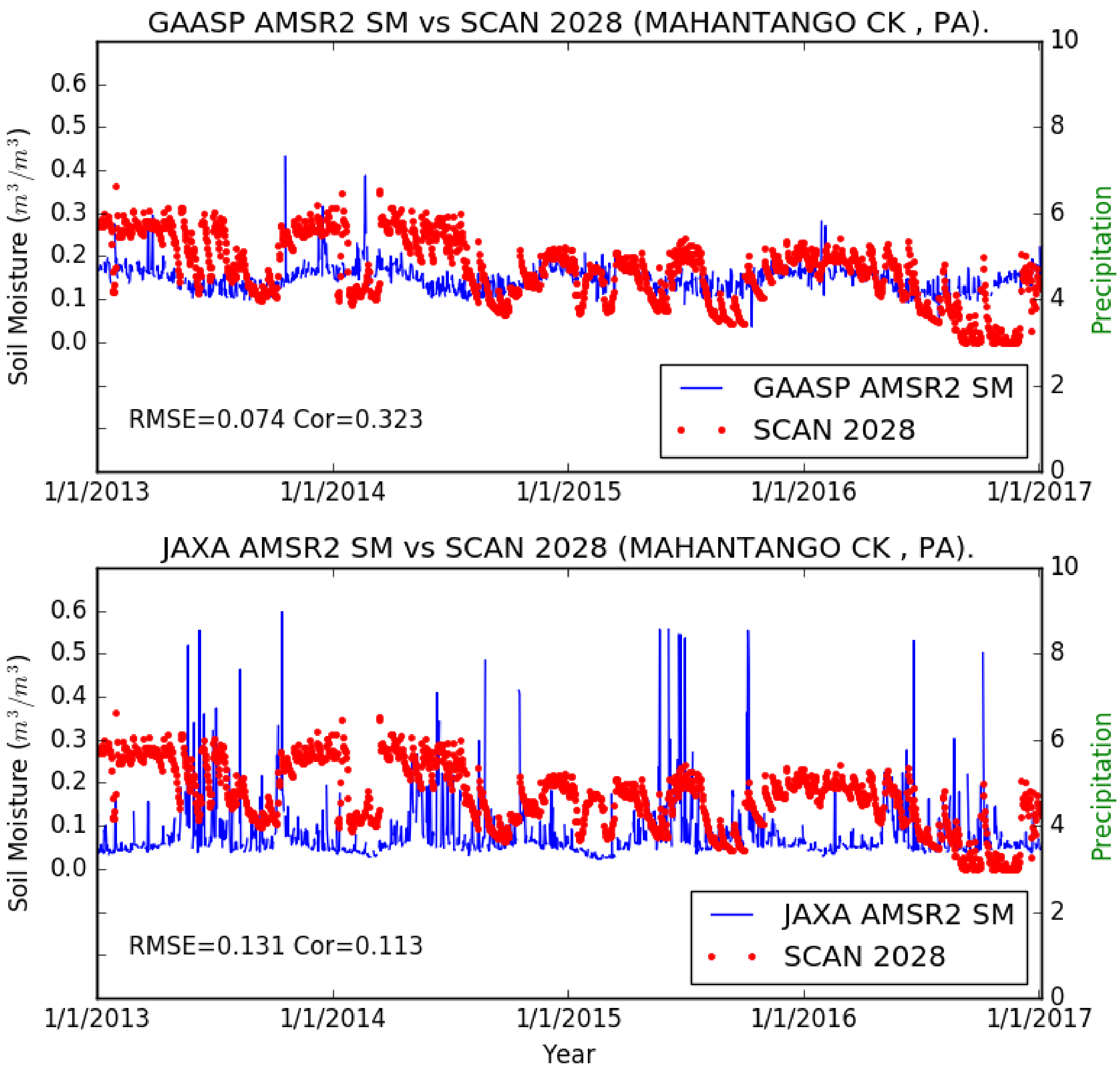
(γ: correlation coefficient; RMSE: Root Mean Square Error)



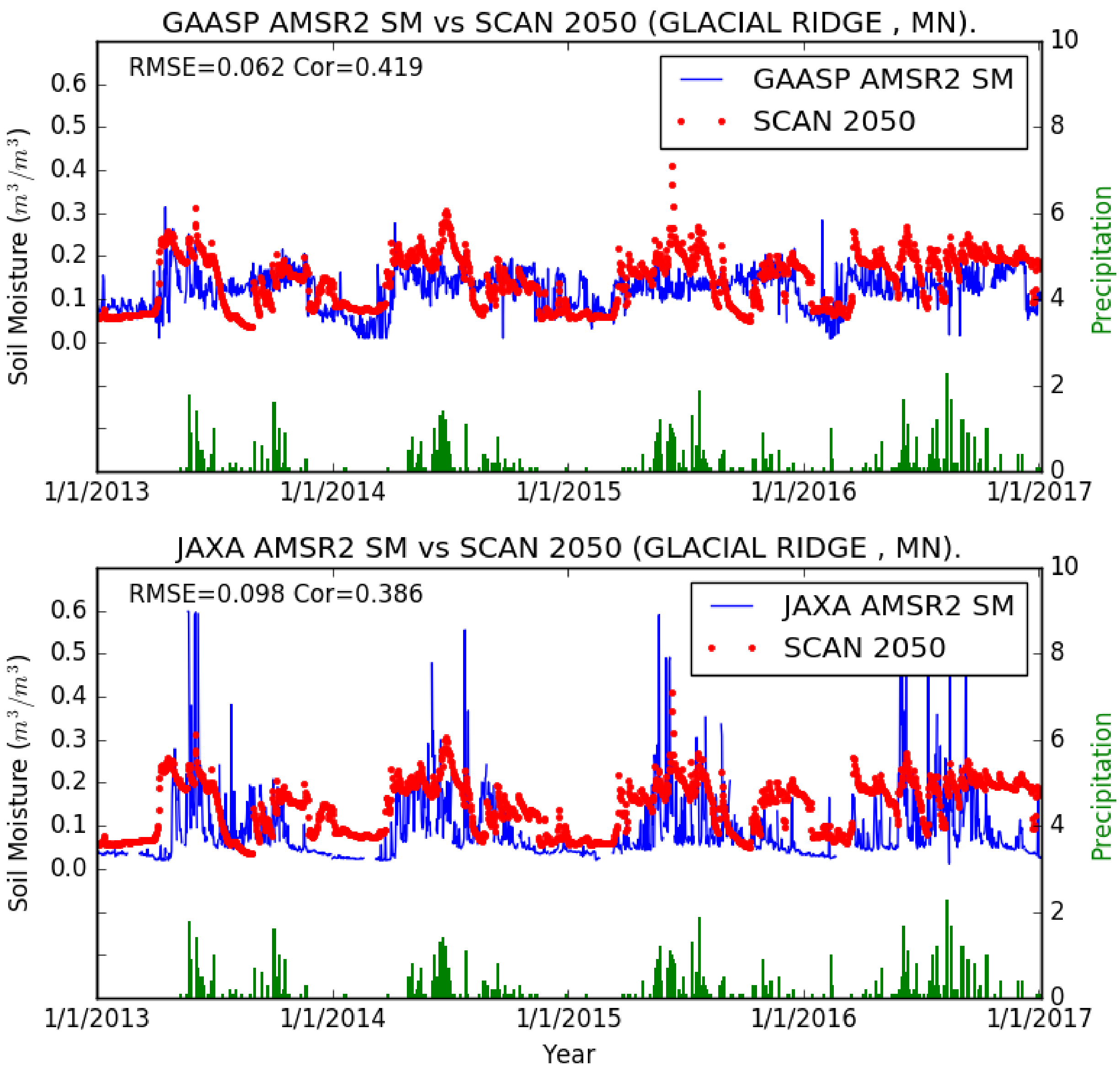
AMSR2 SM Performance: NOAA vs JAXA



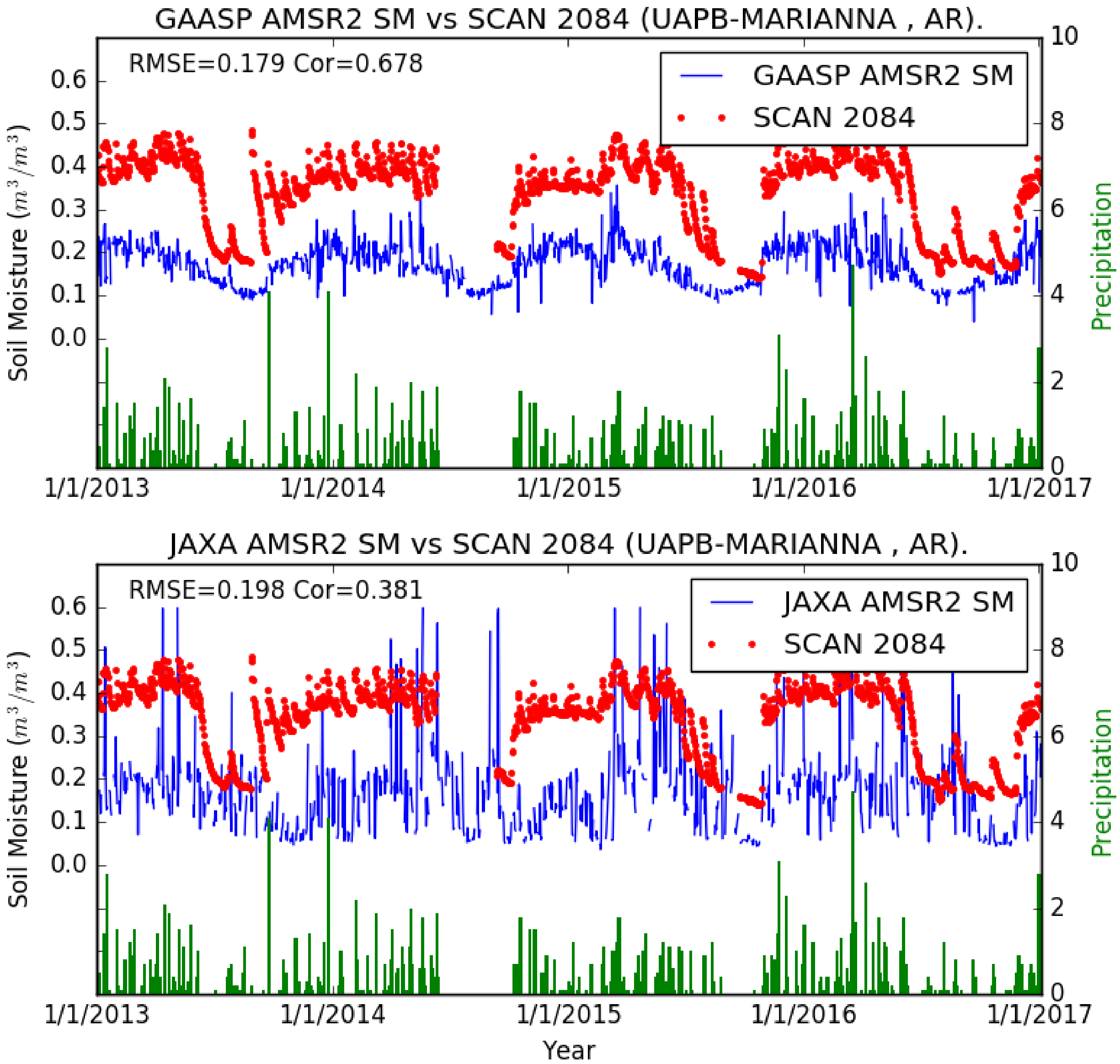
AMSR2 SM Performance: NOAA vs JAXA



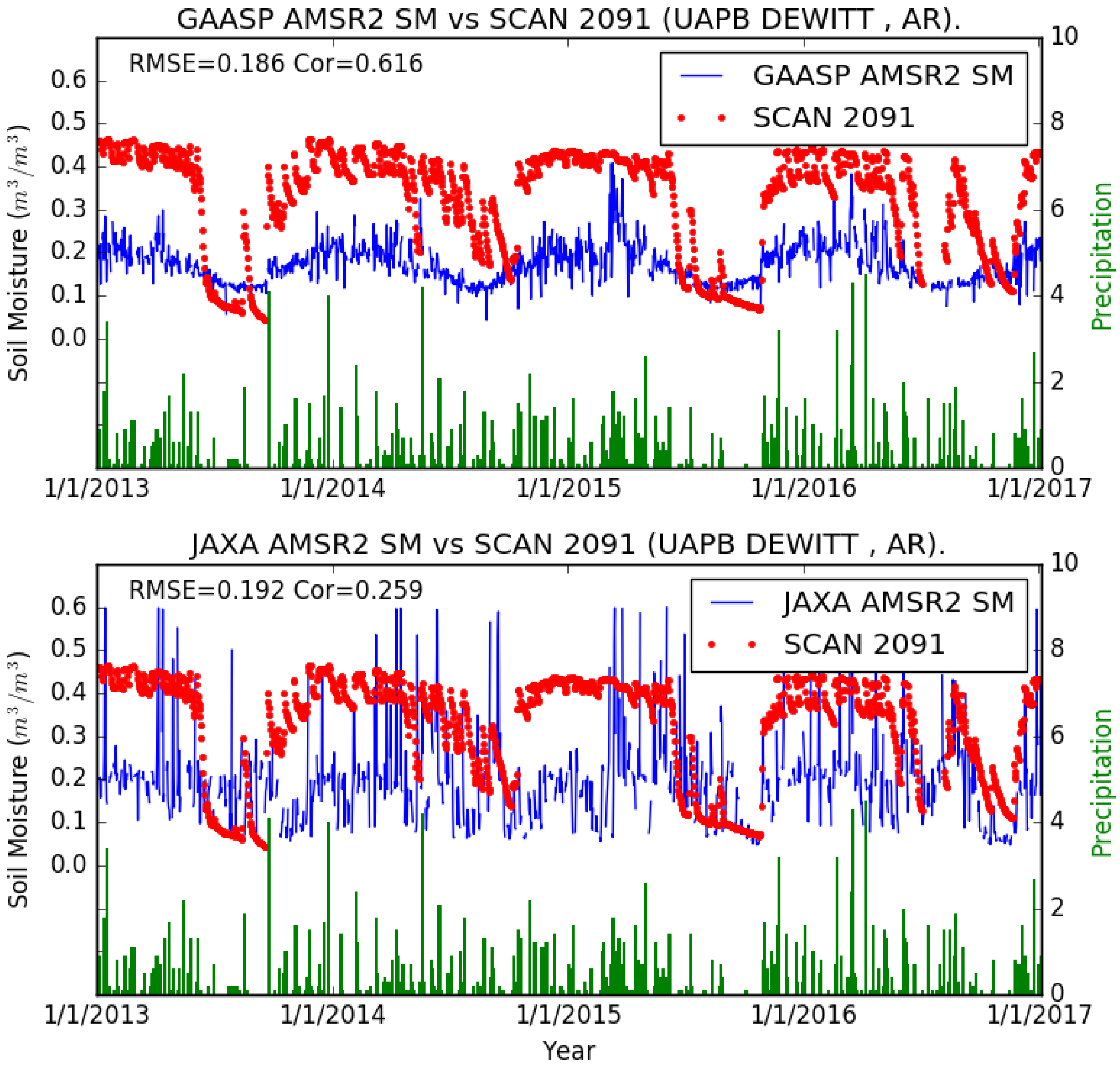
AMSR2 SM Performance: NOAA vs JAXA



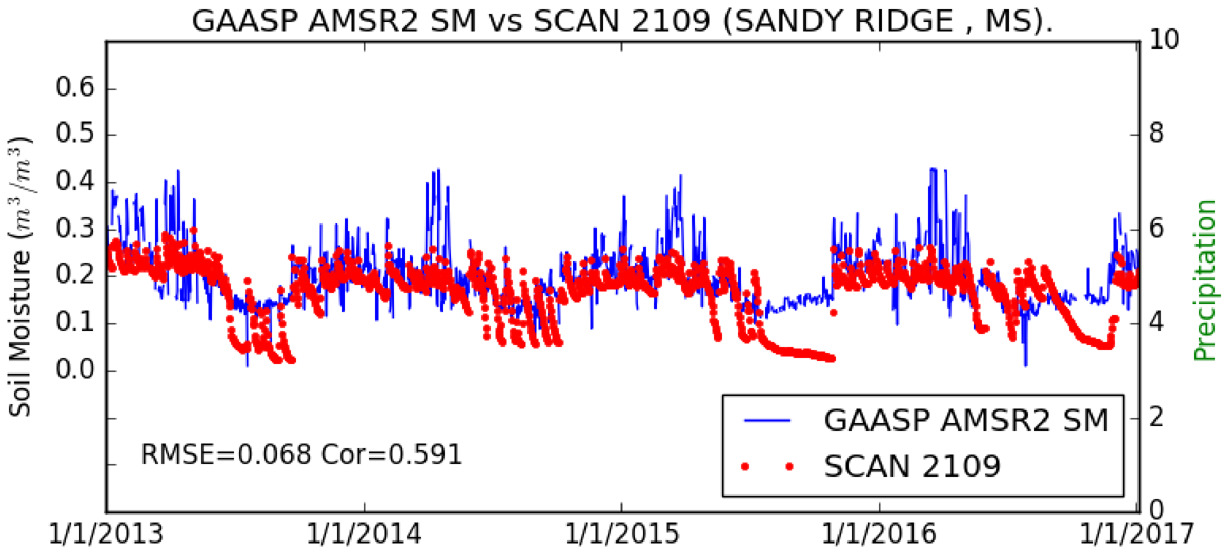
AMSR2 SM Performance: NOAA vs JAXA

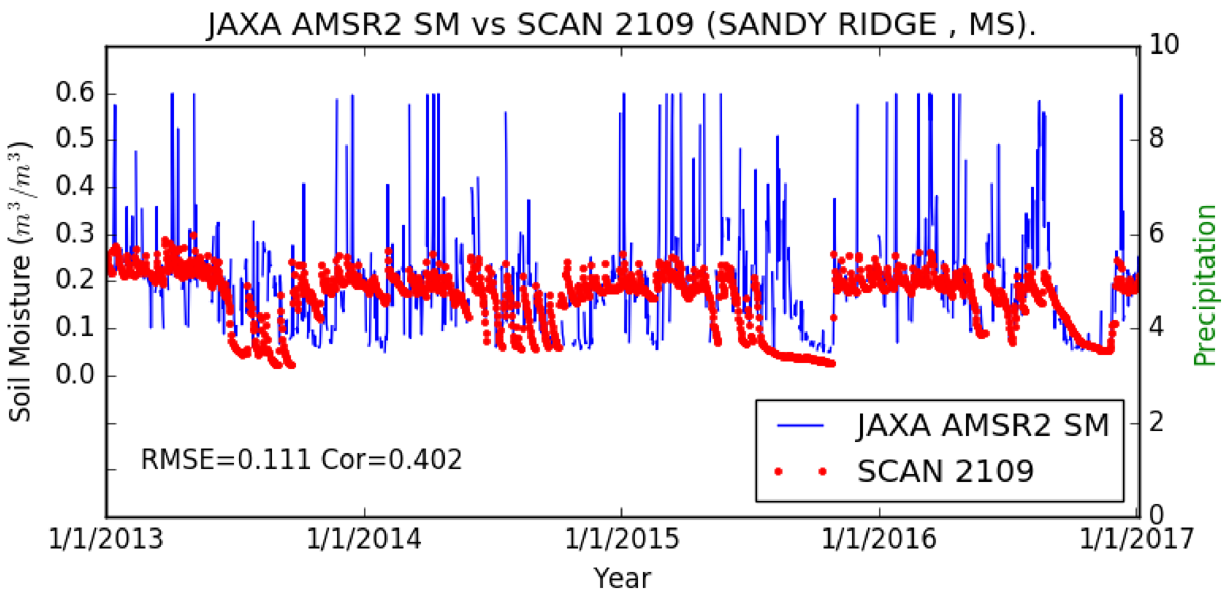


AMSR2 SM Performance: NOAA vs JAXA

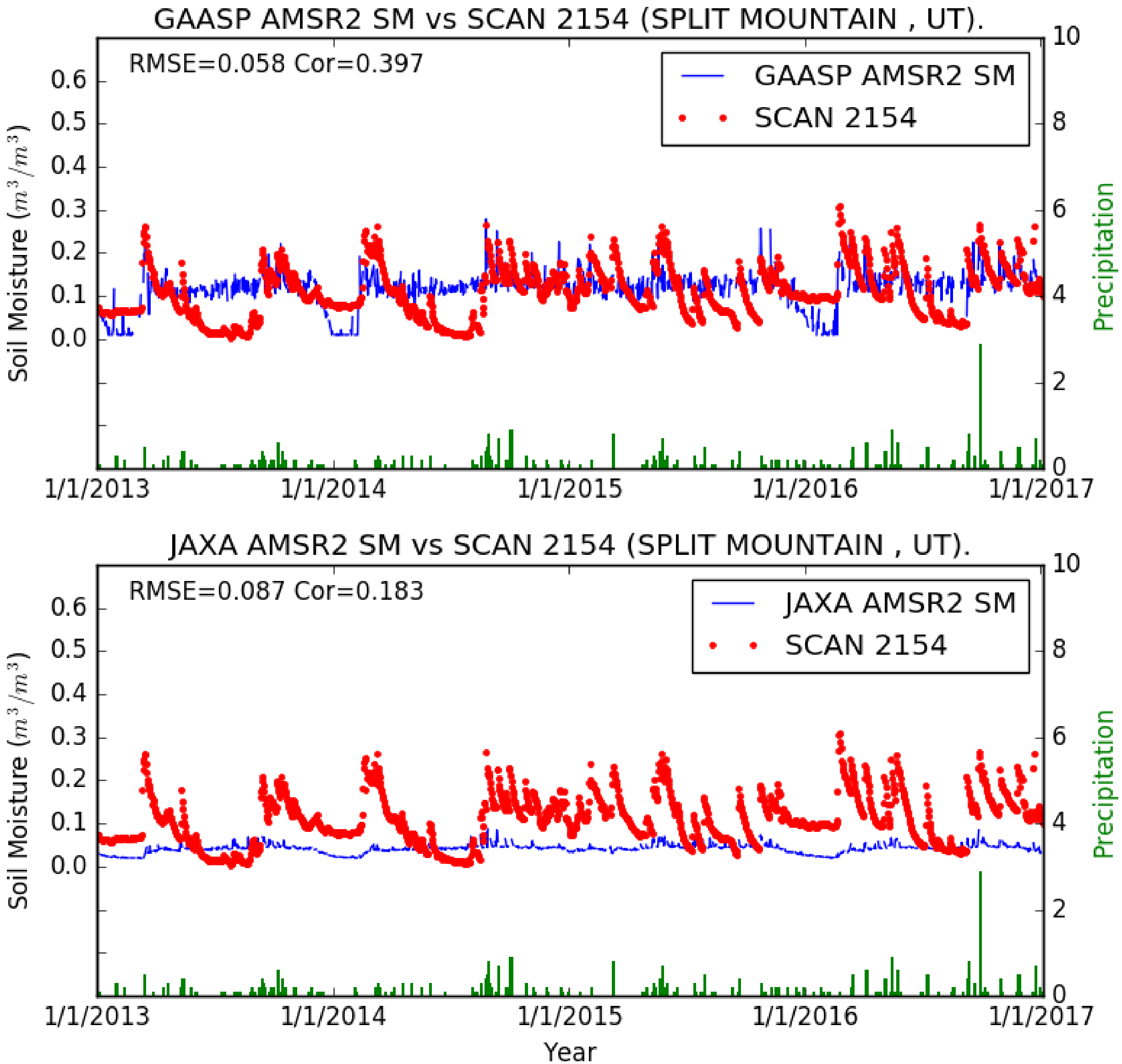


AMSR2 SM Performance: NOAA vs JAXA





AMSR2 SM Performance: NOAA vs JAXA



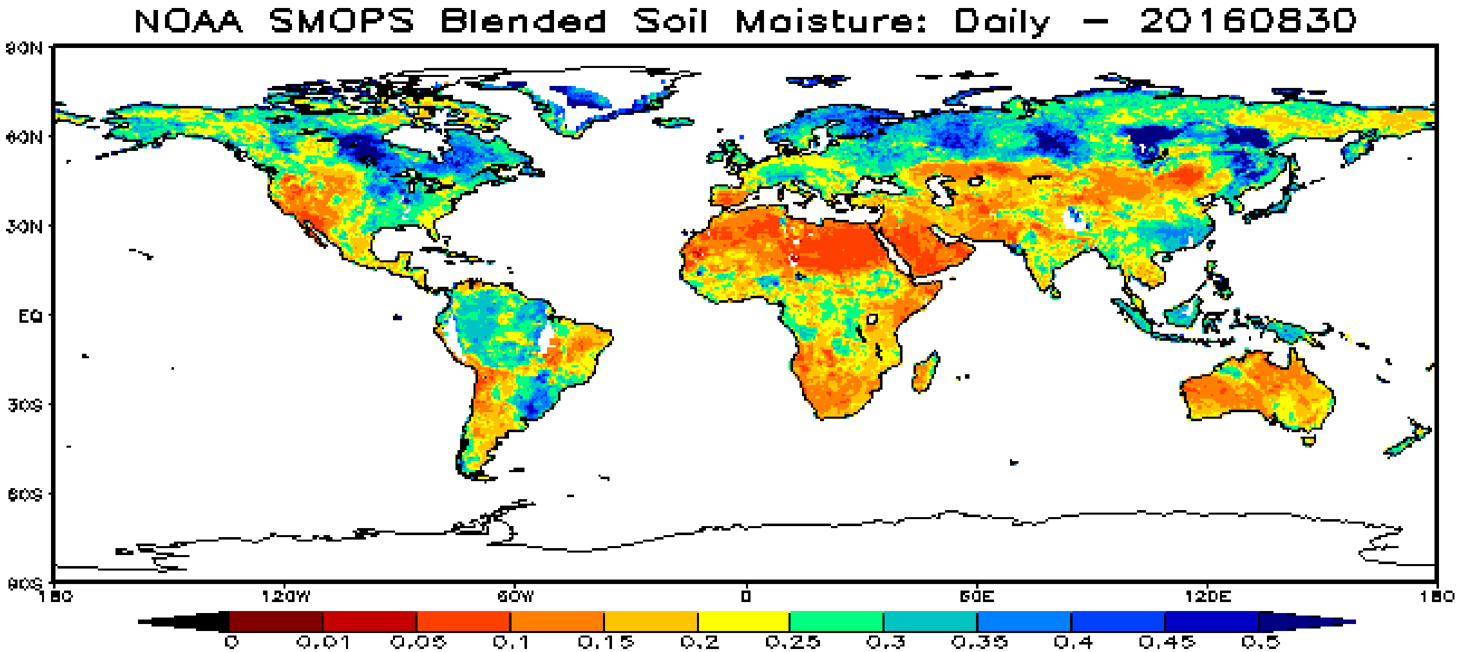
AMSR2 EDR integrated SMOPS

NOAA Soil Moisture Operational Product System (SMOPS) data layers

Soil Moisture Product	SMOPS Version 1.3	SMOPS Version 2.0 (current operational version)	SMOPS Version 3.0
SMOPS Blended	√ (1)	√ (1)	√ (1)
NOAA AMSR-E	√ (2)	×	×
NRT SMOS	×	√ (2)	√ (2)
ESA SMOS	√ (3)	√ (3)	√ (3)
EUMETSAT ASCAT-A	√ (4)	√ (4)	√ (4)
EUMETSAT ASCAT-B	√ (5)	√ (5)	√ (5)
NOAA WindSat	√ (6)	×	×
NOAA AMSR2	×	√ (6)	√ (6)
GMI	×	×	√ (7)
NRT SMAP	×	×	√ (8)
NASA SMAP	×	×	√ (9)

AMSR2 EDR integrated SMOPS

AMSR2 SM Contributes to SMOPS Blended Product



Product	NRT SMOS	ASCAT-A	ASCAT-B	AMSR2	GMI	NRT SMAP
Percentage in Blended Product	43	26	26	**30**	39	42

AMSR2 Soil Moisture EDR Overview

- Validated Maturity Review (Oct 2016) Panel Suggestions:
  - ✓ Improvement over dense vegetation areas: Using VIIRS VI
  - ✓ Development of combined product: Blended into SMOPS
- Performance generally meets requirements
- Reprocessing Plan/Status: in development
- Long Term Monitoring/Website Links:
  - SMOPS website at STAR is in development
    - https://www.star.nesdis.noaa.gov/smcd/emb/soilmoisture/SMOPSMaps.php
  - SMOPS update for AMSR2 at OSPO is ready for review later this month
    - http://www.ospo.noaa.gov/Products/land/smops/smops_loops.html?Imap=6H
- Enterprise Algorithm Status: SMOPS
- Users Feedback:
  - NCEP use of SMOPS and AMSR2 data are in research mode
  - SMOPS products are used in DoD AFWA and USDA FAS operationally
  - SMOPS products are tested for Blended Drought Index

Readiness for Follow-on Satellites

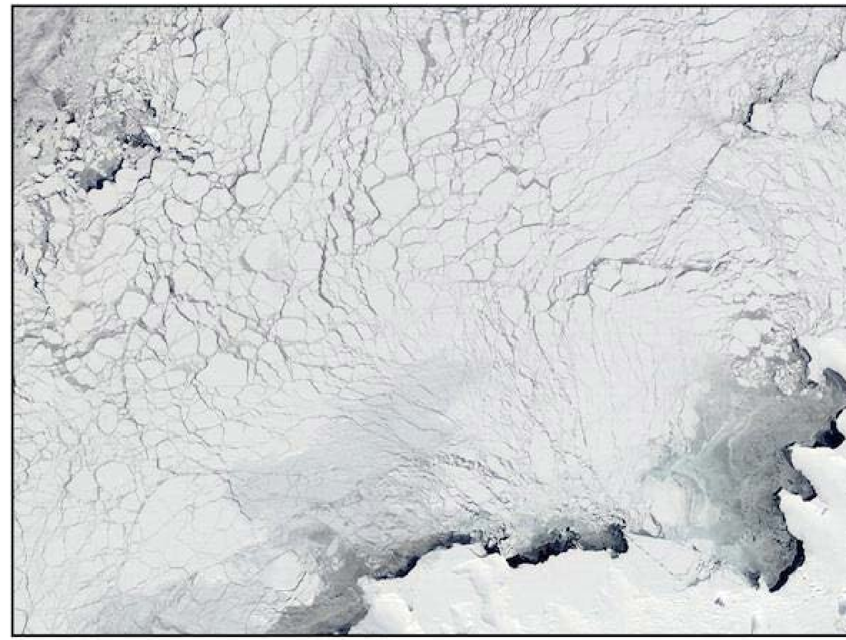
- Significant algorithm change may be implemented for follow-on satellite, GAAPS update, and/or AMSR2 reprocessing
- Accomplishments and Highlights Moving forward
  - A NASA funded project may leverage an effort of downscaling AMSR2/3 soil moisture data product for high resolution data need
- Major Risks/Issues/Challenges/ and Mitigation
  - No GCOM-W1 follow-on satellite is approved yet
- Collaboration with Stake Holders/User Agencies
  - Interaction with user community has been frequent, including NCEP, DoD 557, USDA, etc.

Summary

- Validated maturity review for GCOM-W1/AMSR2 soil moisture EDR (NESDIS GAASP as Day 2 product) has been passed in Oct 2016
- AMSR2 soil moisture EDR quality is compatible with other available satellite products and meets JPSS accuracy requirements generally
- NESDIS SMOPS has been operationally ingesting GAAPS SM EDR since September 2016
- Algorithm enhancement and reprocessing are planned for FY18 if support will be available

Thanks!

NOAA AMSR2 SNOW AND ICE PRODUCTS



Jeff Key

NOAA/NESDIS

Madison, Wisconsin USA

AMSR-2 Snow and Ice Products

- **Snow Cover** (SC) – Presence/absence of snow
- **Snow Depth** (SD) – The depth of snow on land
- **Snow Water Equivalent** (SWE) – The amount of water in the snowpack
- Sea Ice Characterization (SIC) –
  - **Ice concentration** (area fraction in a pixel)
  - **Ice type** or Age class (first-year or multiyear ice)

Snow and ice algorithms are built around heritage products with important, but low-risk, improvements.

All products are now operational (September 2016 for snow; March 2017 for ice).

Team Members

EDR	Name	Organization
Lead; Snow, ice	Jeff Key	NESDIS/STAR
Wisconsin:		
Snow products	Yong-Keun Lee	CIMSS/U. Wisconsin
Maryland:		
Snow	Cezar Kongoli	CICS
Colorado:		
Sea ice	Walt Meier	NSIDC (formerly NASA GSFC)
Sea ice	Scott Stewart	CU Contractor
Sea ice	Florence Fetterer	NSIDC

NOAA AMSR2 SNOW PRODUCTS

Yong-Keun Lee[1], Cezar Kongoli[2], Jeff Key[3]

[1]Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin-Madison

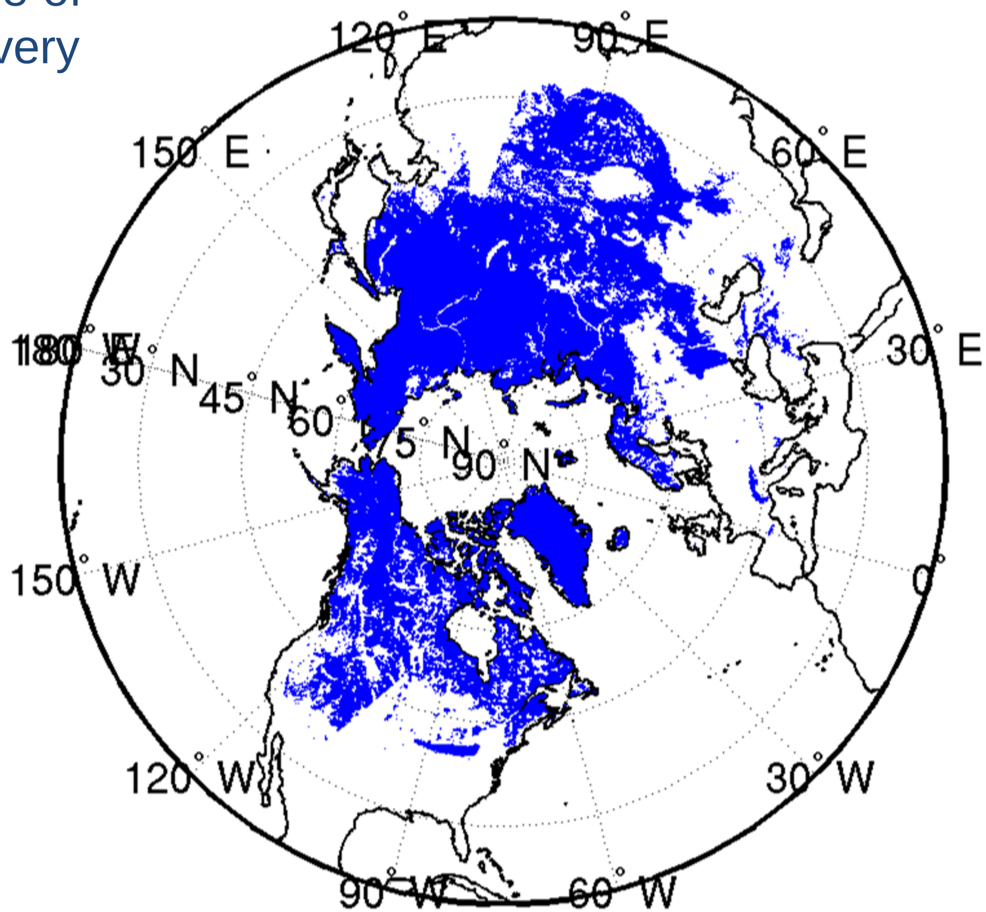
[2]Cooperative Institute for Climate Studies (CICS), University of Maryland

[3]NOAA/NESDIS

Product Examples: Snow Cover

The **Snow Cover** product provides the presence/absence of snow cover for every pixel.

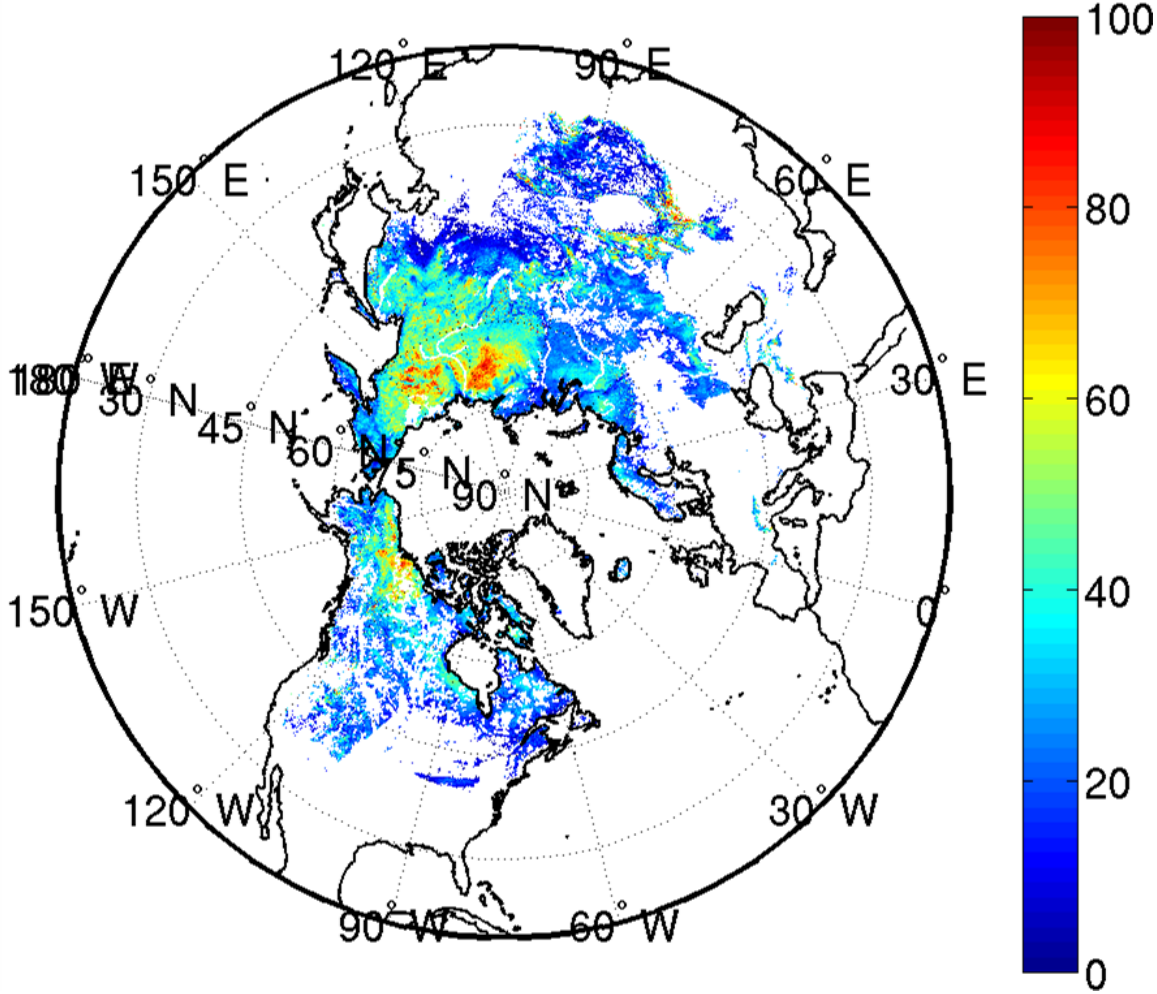
Snow cover on January 15, 2015



Product Examples: Snow Depth

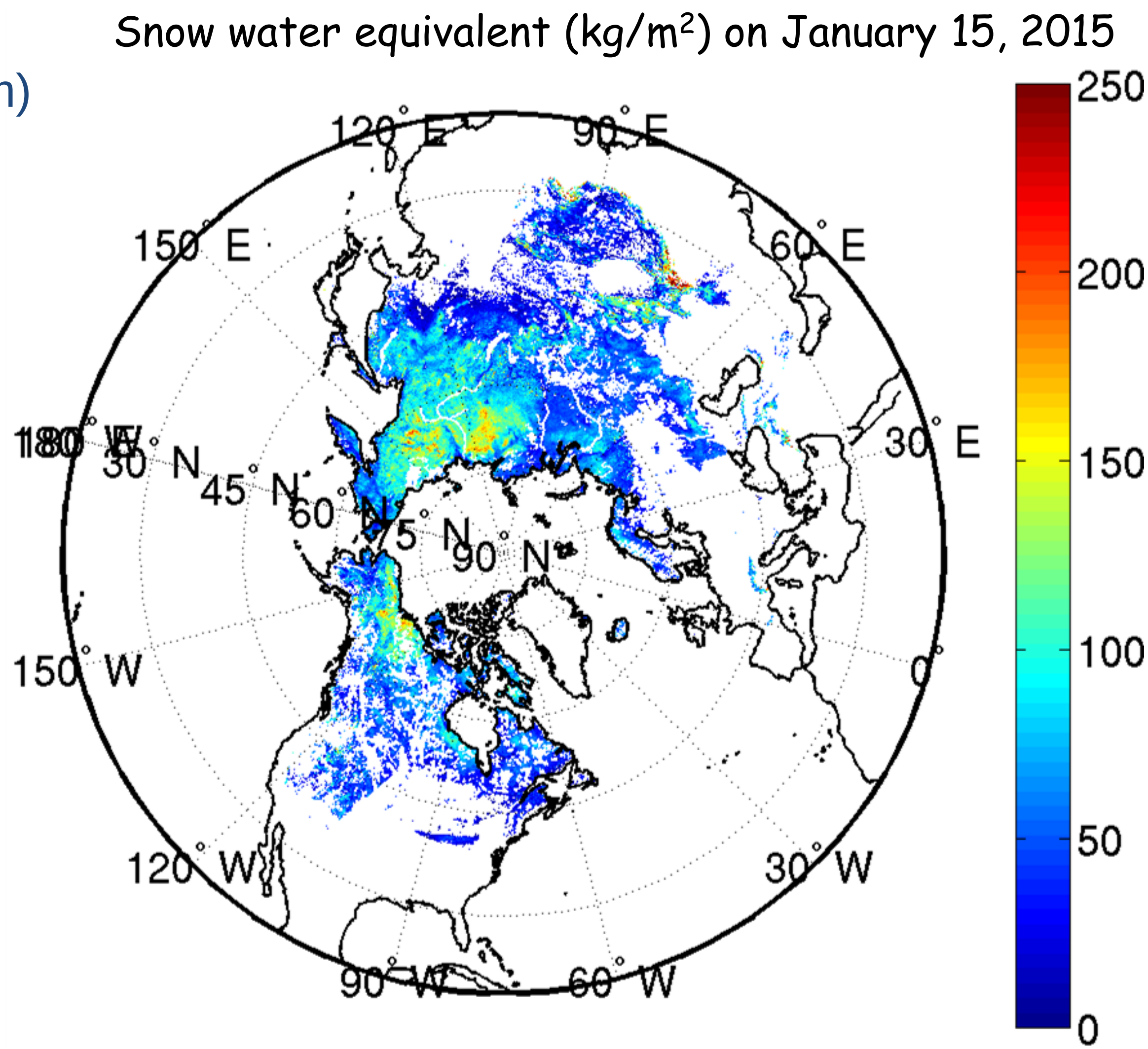
The **Snow Depth** product provides the depth of the snow cover (cm).

Snow depth (cm) on January 15, 2015

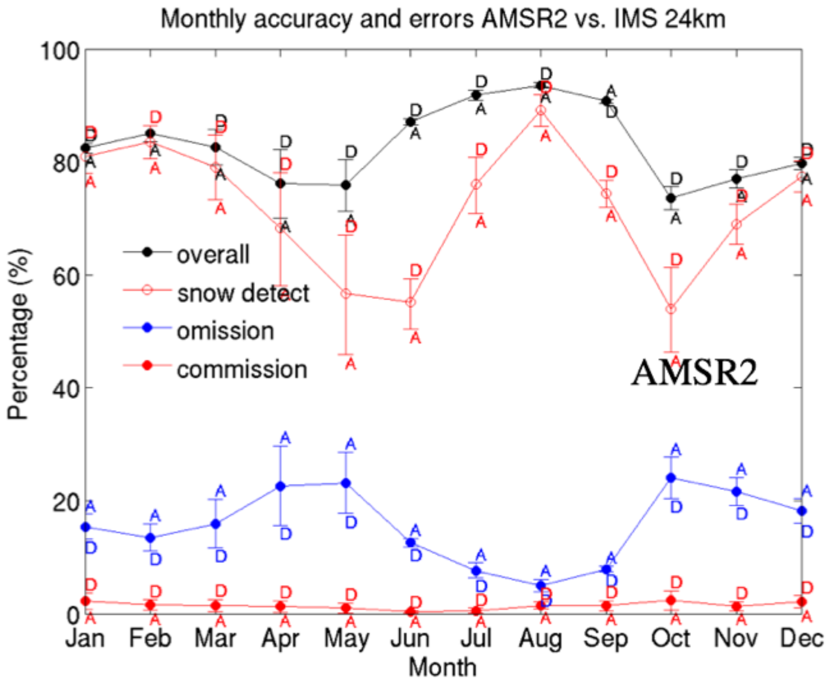


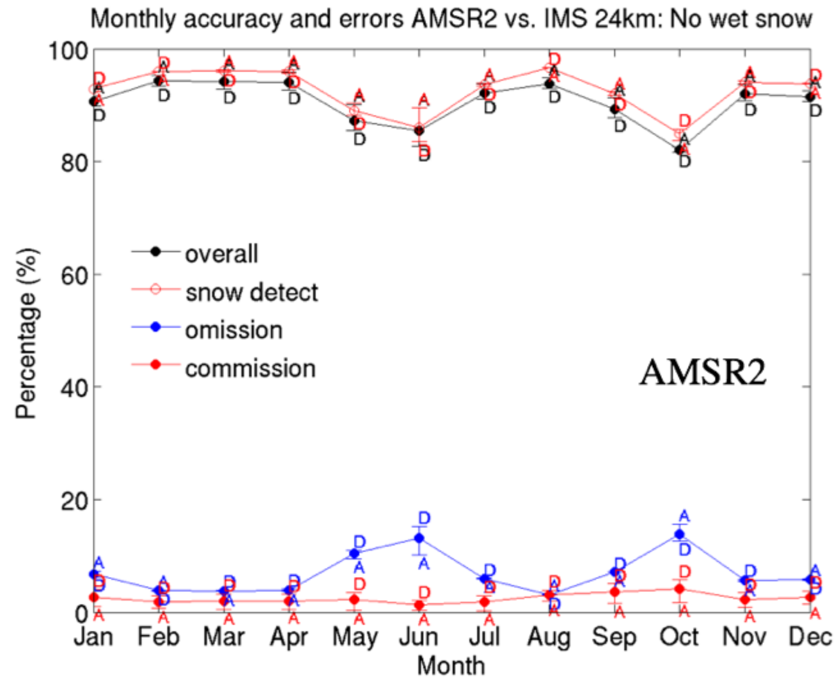
Product Examples: SWE

The **Snow Water Equivalent** (SWE) product provides the water equivalent (mm) of the snow cover.



Snow Cover Validation

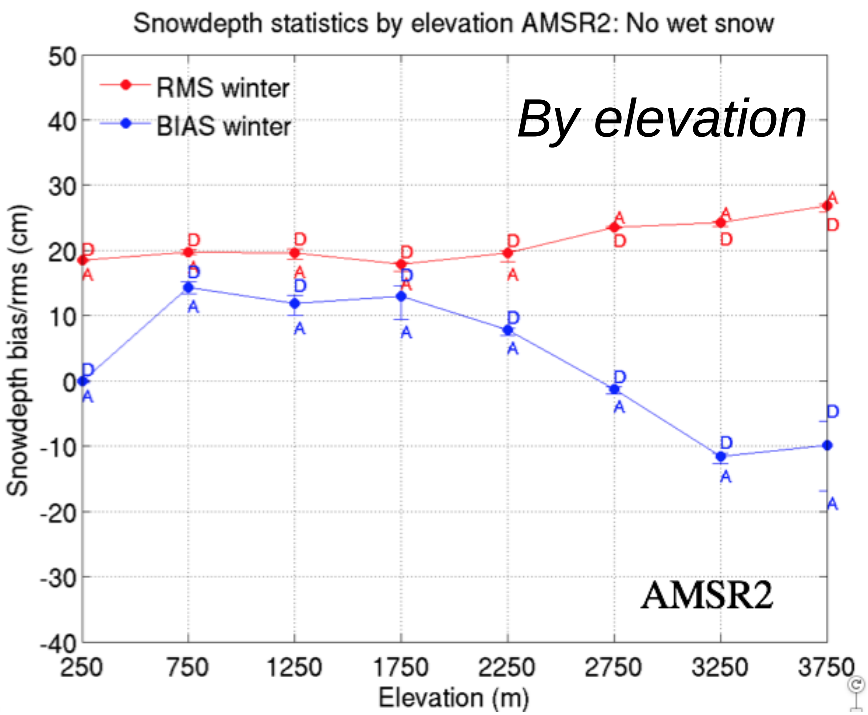


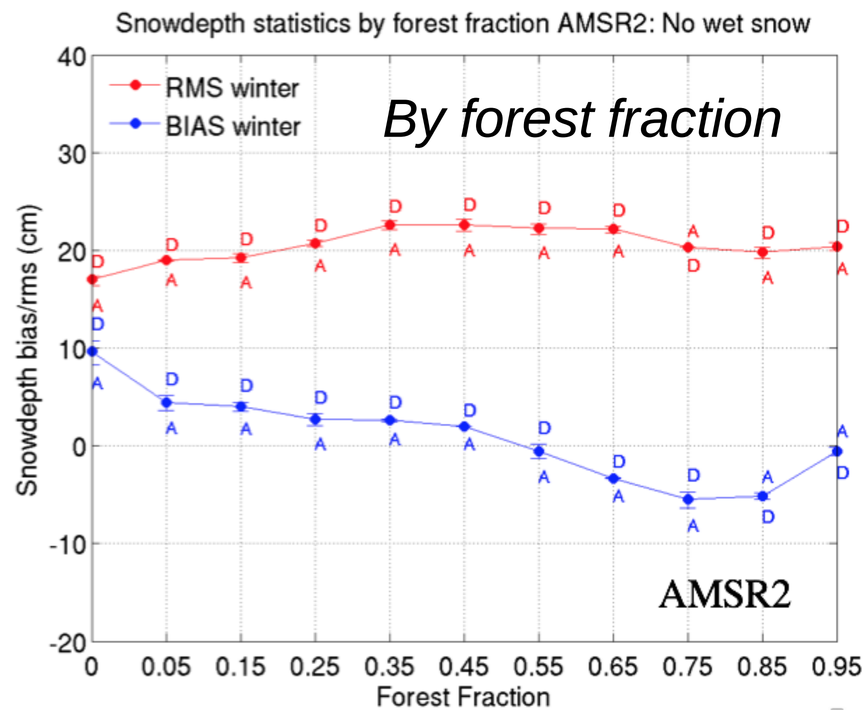


If wet snow is not included, detection accuracy is higher.

	Tundra	Taiga	Maritime	Ephemeral	Prairie	Alpine
Overall Accuracy	94.6%	97.4%	80.9%	71.7%	74.0%	86.9%

Snow Depth Validation





	Tundra	Taiga	Maritime	Ephemeral	Prairie	Alpine
RMSE (cm)	18.77	20.96	19.37	14.95	18.93	21.97
Bias (cm)	4.51	3.77	-5.34	6.05	2.75	-4.45
Mean (cm) of in-situ obs	25.10	19.18	20.20	8.40	18.49	25.14

Snow Water Equivalent Validation

SWE comparison between AMSR2 retrievals and **GHCN**

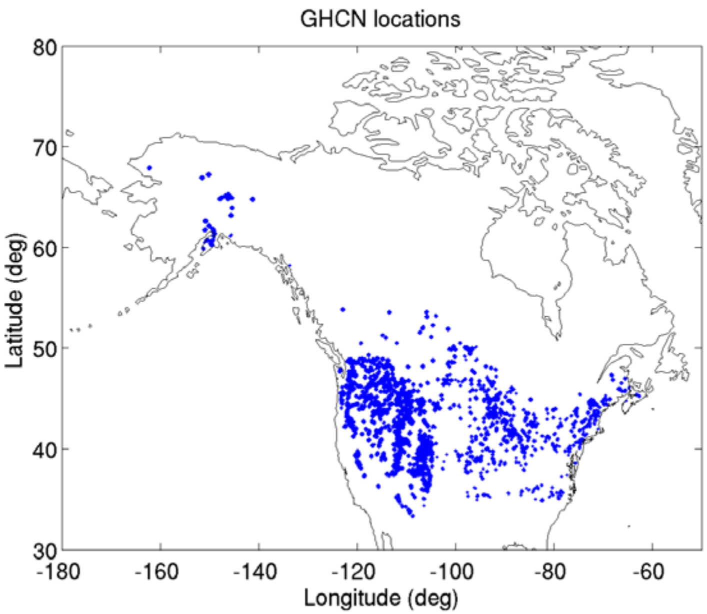
When 10 < AMSR2 SWE < 100 and 10 < GHCN SWE < 100 and the location altitude < 3000m:

bias	std	rmse	mean1	mean2	number of pixels
-7.97	30.77	31.79	46.54	54.52	45033

When 100 < AMSR2 SWE and 100 < GHCN SWE and the location altitude < 3000m:

bias	std	rmse	mean1	mean2	number of pixels
-29.91	50.91	59.05	115.56	145.47	657

mean1: average of AMSR2 SWE
mean2: average of GHCN SWE
bias: mean of AMSR2 SWE - GHCN SWE
GHCN: Global Historical Climatology Network



Error Budget

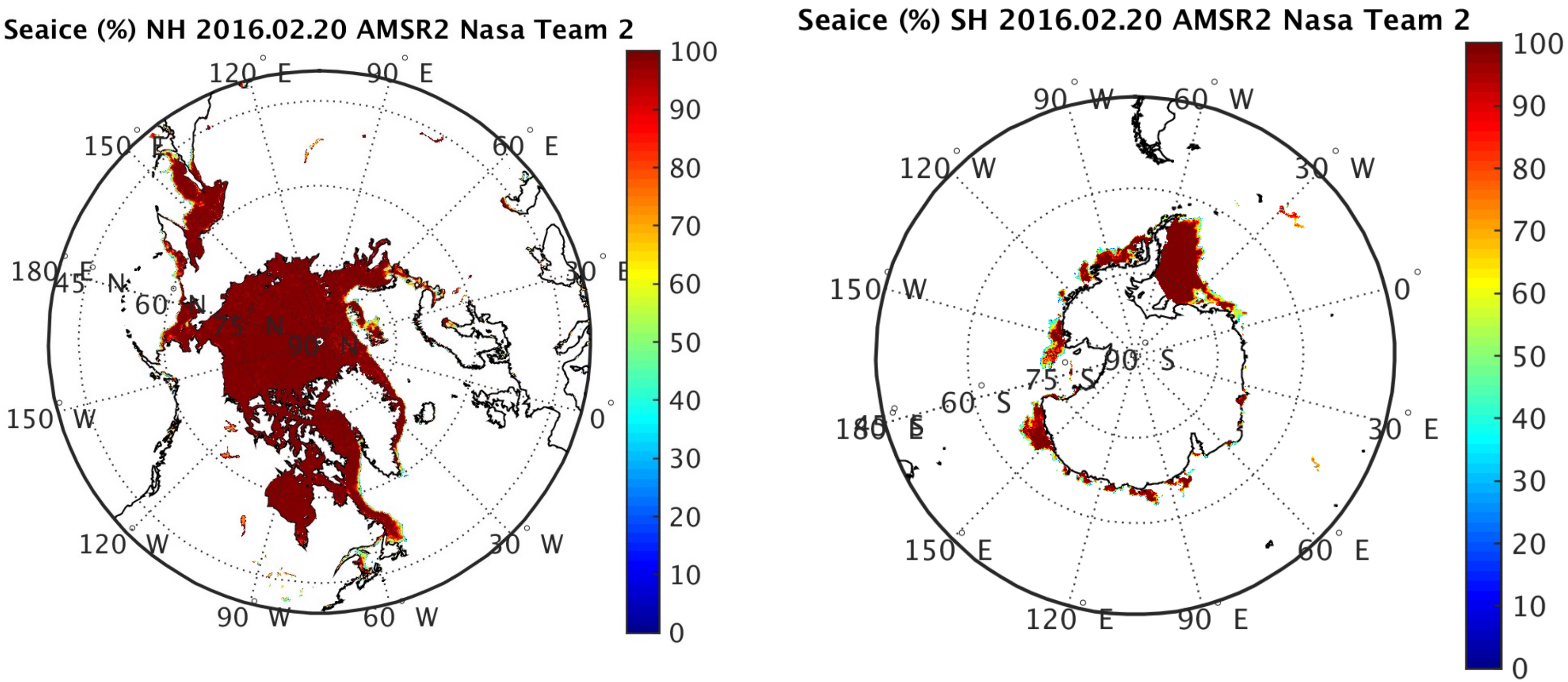
Attribute Analyzed	L1RD Threshold	Validation Result	Error Summary	Meets Requirement?
Snow cover	80% prob of correct snow/no-snow classification	72-97% correct classification	If wet snow is excluded, 90+% correct	**Y**
Snow depth	20 cm snow depth uncertainty	15-22 cm depth uncertainty	If alpine excluded, depth uncertainty < 20 cm	**Y**
SWE	50-70% uncertainty (shallow to thick snowpacks)	20-60%	Larger validation dataset would improve reliability of results. More thin snowpack cases needed.	**Y** (marginally)

AMSR2 SEA ICE CHARACTERIZATION

Walt Meier[1] and Scott Stewart[2]

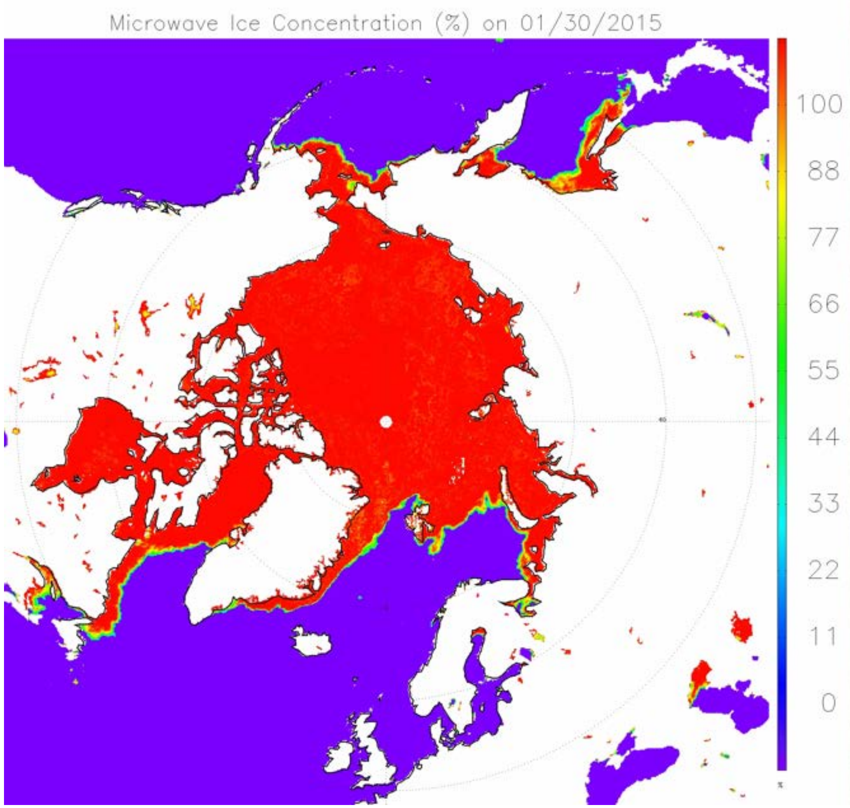
[1]National Snow and Ice Data Center (NSIDC; formerly NASA GSFC)
Cooperative Institute for Research in the Environmental Sciences
University of Colorado, Boulder
[2]NSIDC contractor

AMSR2 Sea Ice Concentration Examples

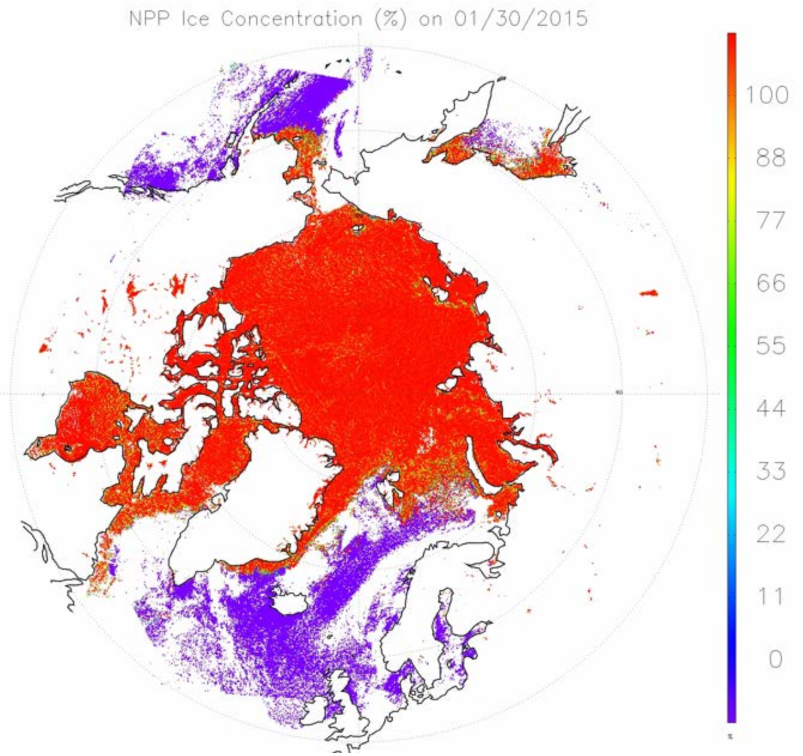


Examples of AMSR2 sea ice concentration over the Arctic (above) and Antarctic (right) on 20 February 2016.

Validation



Comparison of AMSR2 (left) and VIIRS (below) sea ice concentration over the Arctic on 31 January 2015.

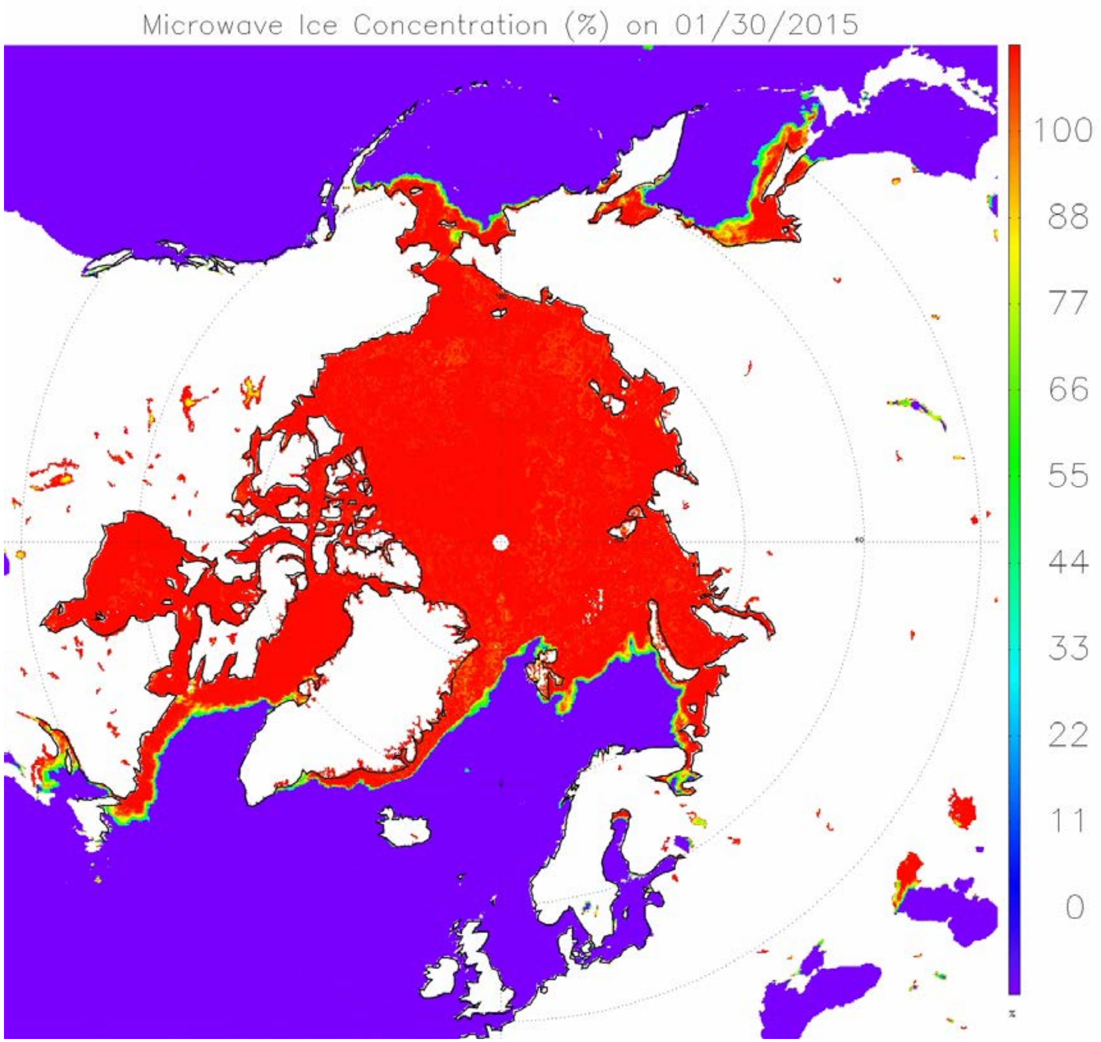


Additional information on validation is in the notes section of this slide

Sea Ice Concentration Validation

Comparison of AMSR2 and VIIRS sea ice concentration over the Arctic on 31 January 2015.

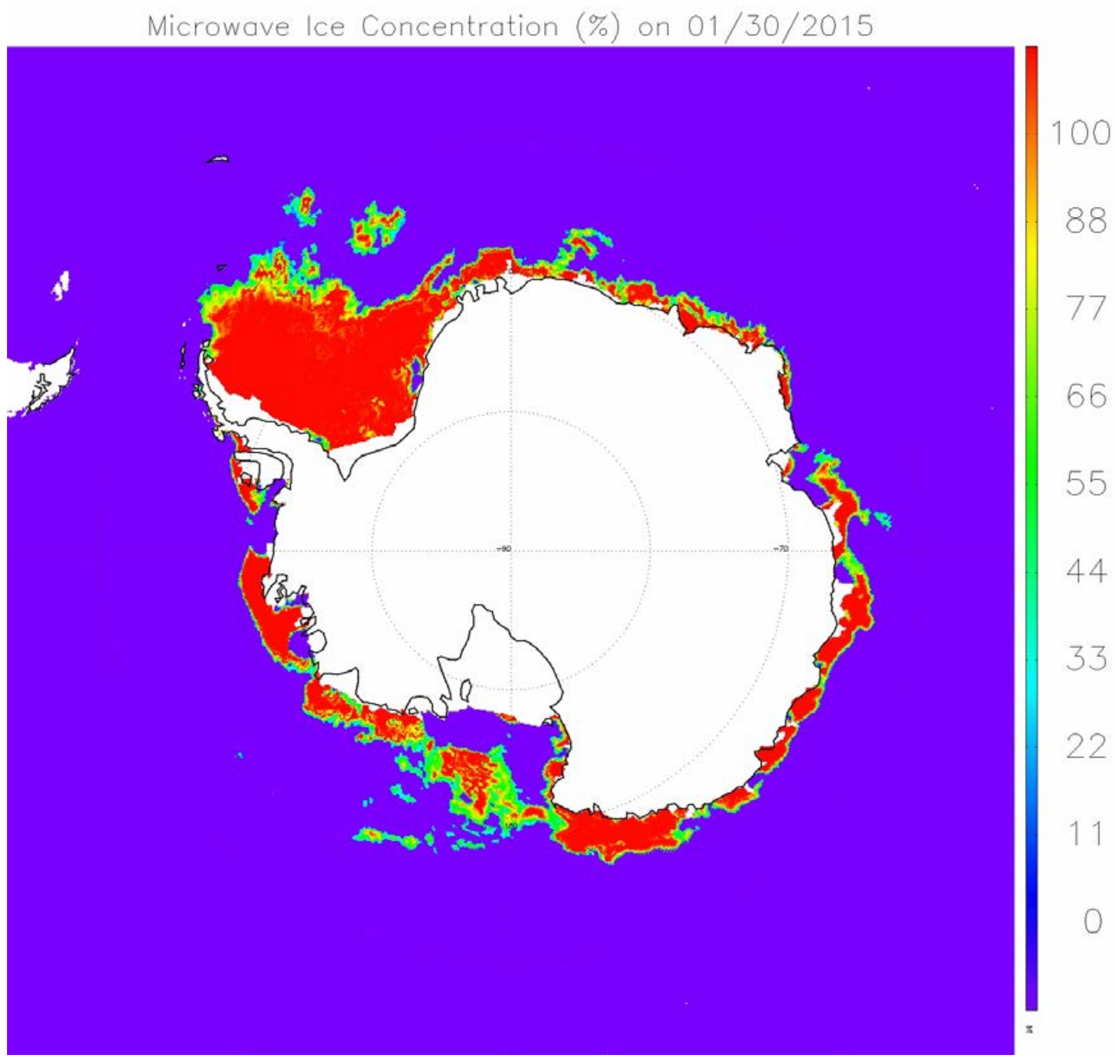
(animation)



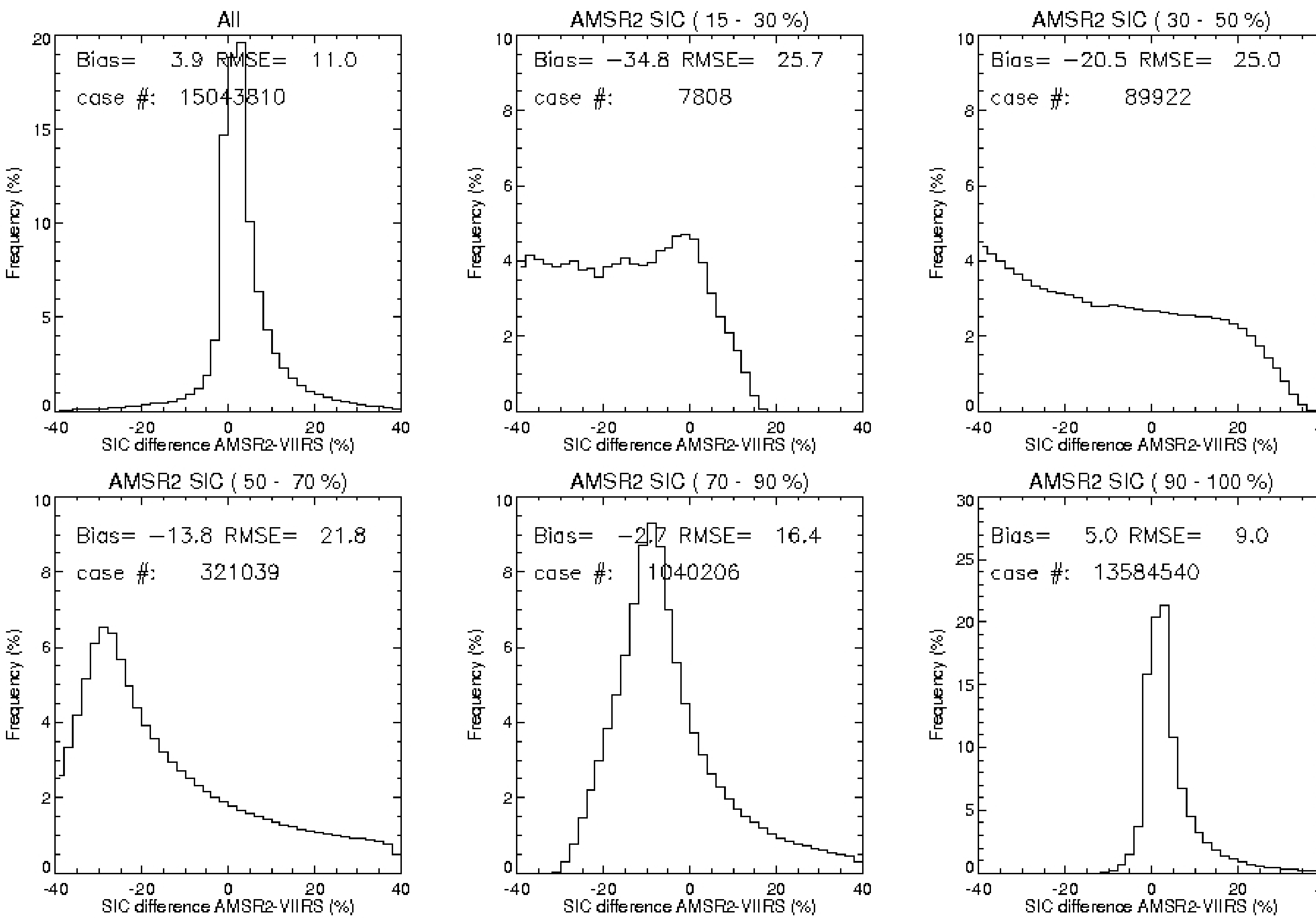
Sea Ice Concentration Validation

Comparison of AMSR2 and VIIRS sea ice concentration over the Antarctic on 31 January 2015.

(animation)

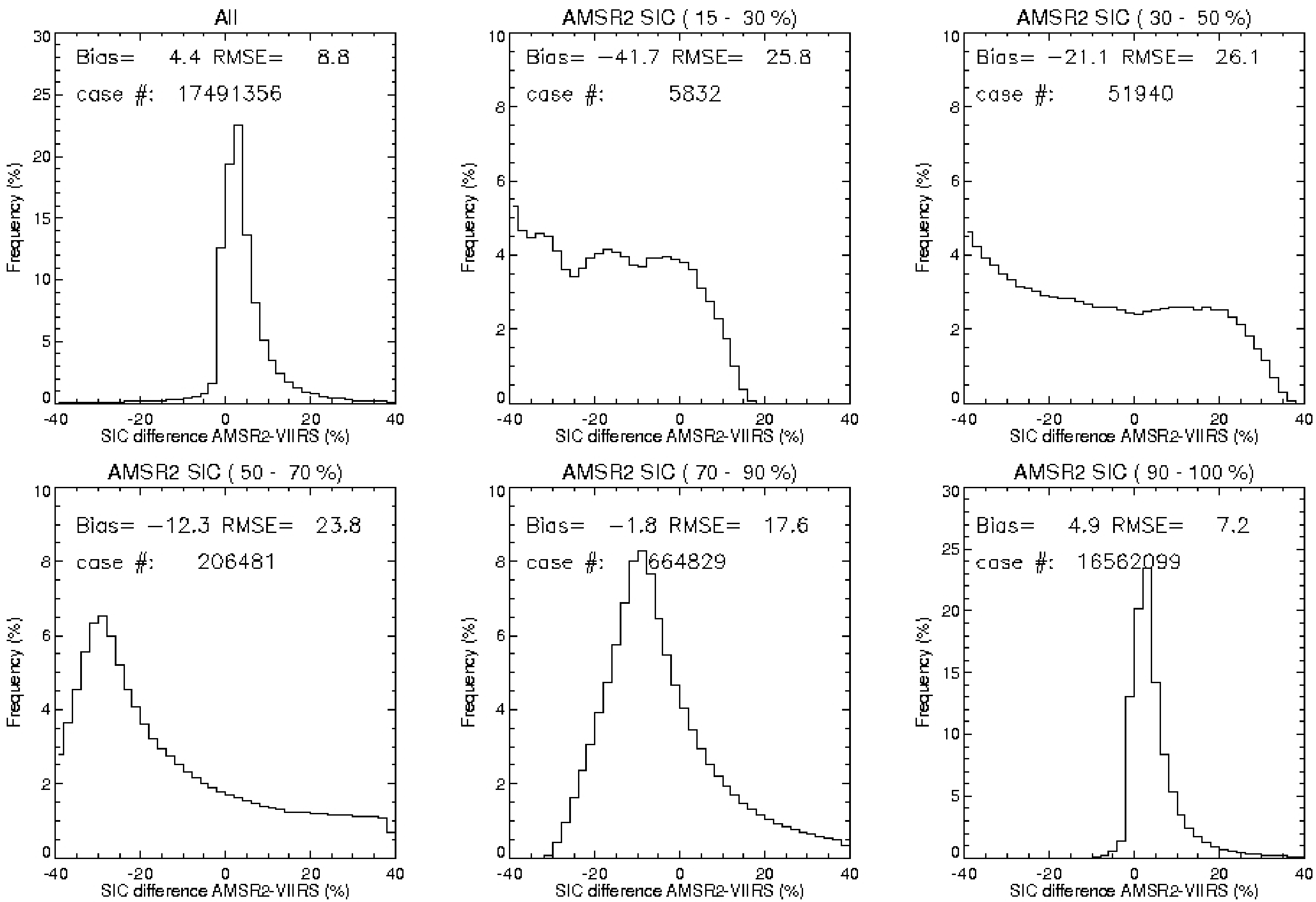


Sea Ice Concentration Validation



Comparison of AMSR2 minus VIIRS ice concentrations for different AMSR2 ice concentration ranges/bins in the Arctic. Note that the y-axis range is different for "All", "90-100%", and the other plots. Data are from January to October 2016.

Sea Ice Concentration Validation



Same as previous slide except for the Antarctic.

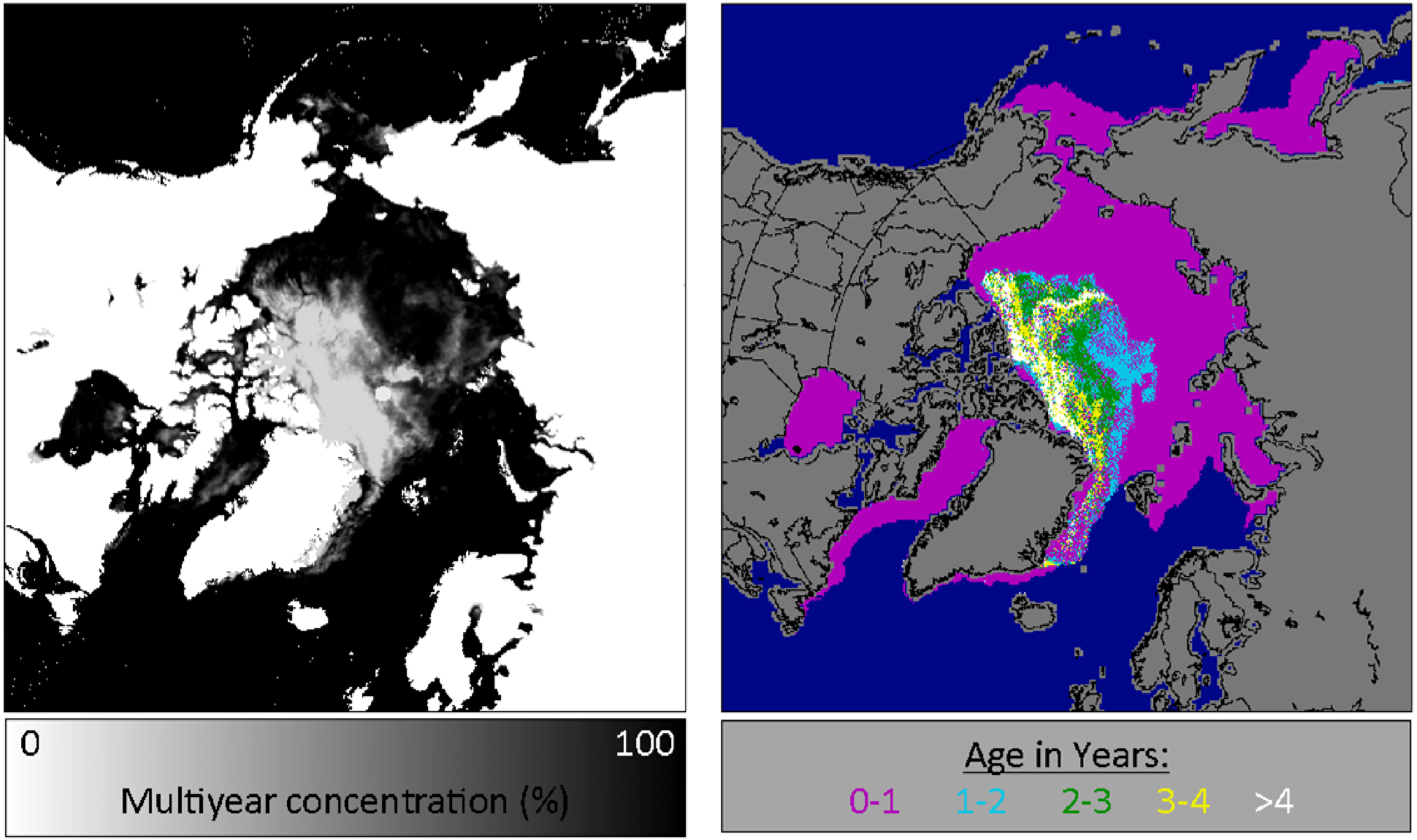
Sea Ice Concentration Validation

Statistical results of the comparison in sea ice concentration between AMSR2 and VIIRS.

Maximum (red) and minimum (blue) values in each column are highlighted.

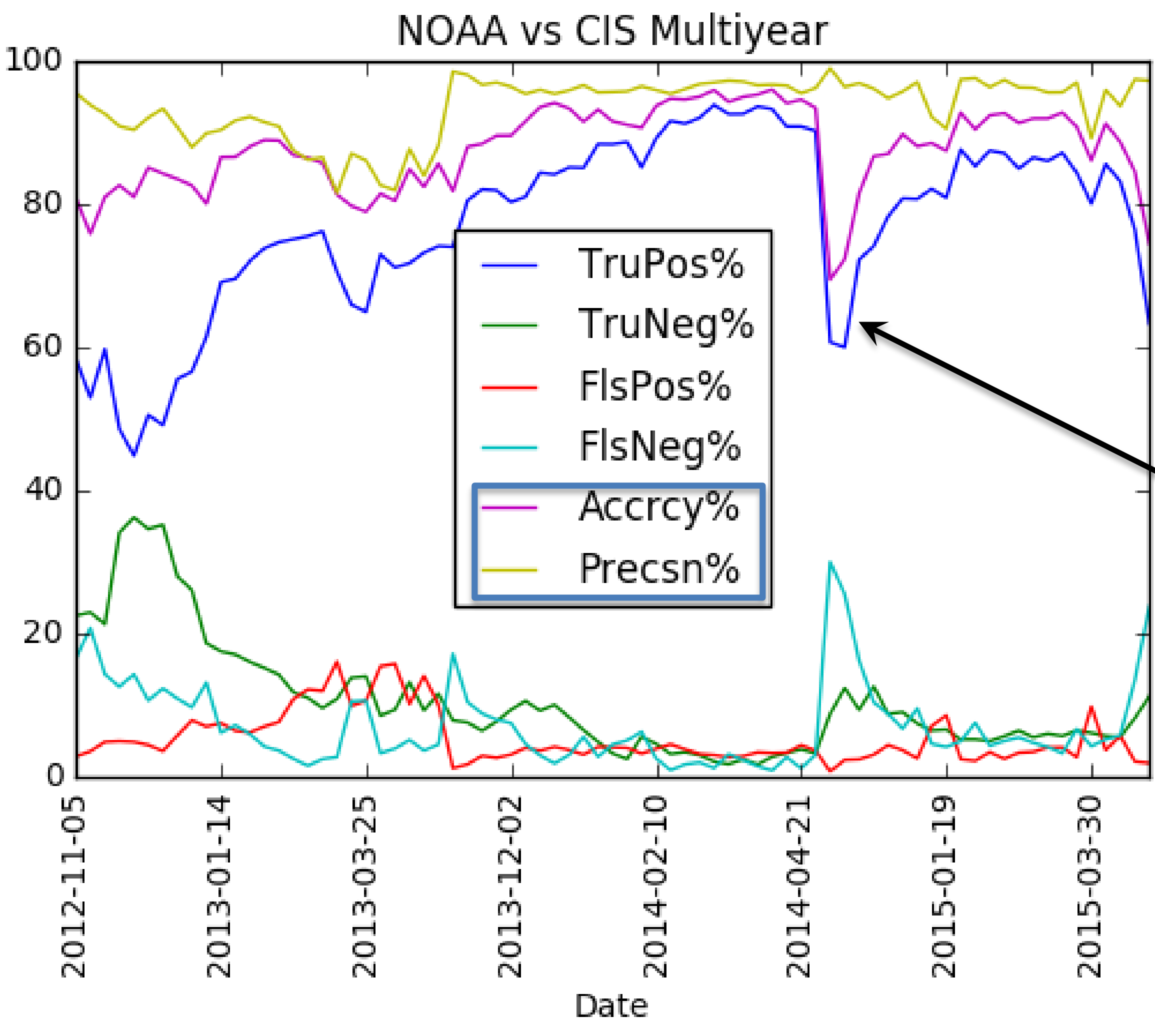
	Arctic			Antarctic		
	Accu	Prec	Cases	Accu	Prec	Cases
01/30	1.61	***8.76***	123747	0.50	21.45	22776
01/31	1.62	9.10	***124514***	1.53	***22.03***	***19556***
02/27	2.05	9.91	122376	1.04	20.19	20101
02/28	2.03	9.35	120343	***0.21***	20.88	22256
03/30	2.45	10.01	122108	1.52	14.90	48343
03/31	2.12	9.39	118841	2.48	15.24	43737
04/30	3.02	11.98	88959	1.85	12.64	79228
04/31	3.01	11.87	79756	2.24	12.62	82094
05/30	3.20	11.46	65418	2.19	13.03	99093
05/31	***3.22***	11.92	70990	1.80	12.97	104142
06/30	2.19	14.05	56864	1.55	***11.08***	121964
06/31	1.89	14.41	55580	1.56	11.78	123805
07/30	1.89	18.33	35577	2.43	12.62	***142350***
07/31	2.53	18.20	38069	2.58	12.34	138524
08/30	***0.25***	***18.48***	28727	2.79	11.87	133027
08/31	0.61	17.19	***27315***	***2.95***	12.71	142208

Multiyear Ice Validation



Initial comparison with independent ice age fields (Lagrangian tracking of ice parcels) indicates good agreement in terms of spatial distribution of multi-year ice cover.

Ice Type Validation: Ice Charts

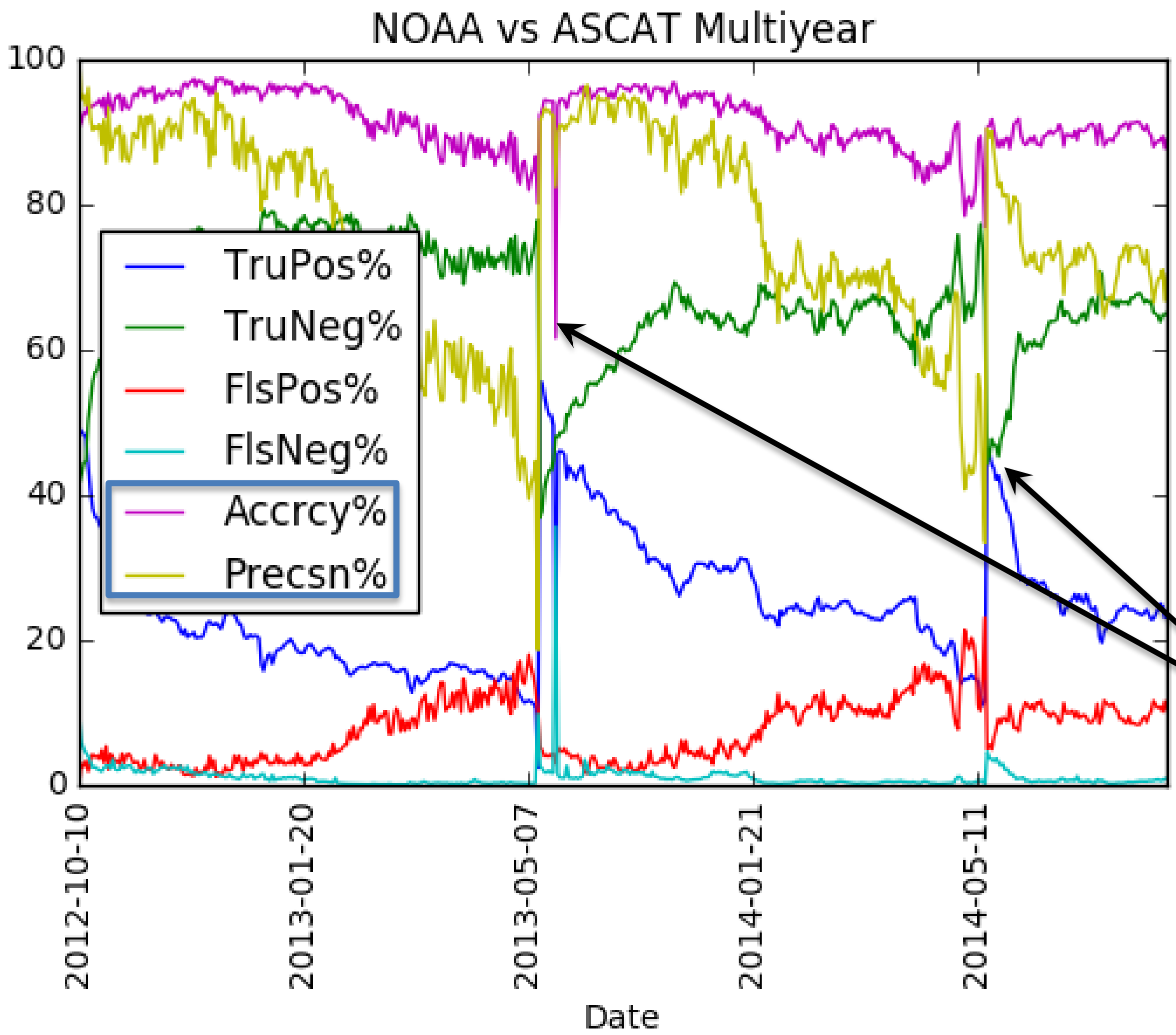


Comparison of NOAA vs. Canadian Ice Service (CIS) charts in high Arctic

Performance drops in May (melt onset)

NOTE: Summer months are not included in plot.

Ice Type Validation: ASCAT



Comparison of NOAA vs. ASCAT scatterometer

Lower performance expected from ASCAT as well

Performance drops in May

NOTE: Summer months are not included in plot.

Ice Type Validation: OSI-SAF

Confusion Matrix results, 2012-2015

- Average over all 3.5 years (Oct. 2012 – Dec. 2015)
- Mid-October through mid-April each year

	OSISAF MYI	OSISAF no-MYI
NOAA MYI	28.1%	2.1%
NOAA no-MYI	4.8%	65.1%

Accuracy: 93.2 ± 2.3%
Precision: 84.5 ± 8.5%

NOAA agrees with OSISAF (i.e., "correct" retrieval)

Error Budget

Attribute Analyzed	L1RD Threshold	Analysis/Validation Result	Error Summary	Meets Requirement?
Concentration	10% uncertainty (see note)	1-4% accuracy 9-15% precision	Most errors well below 10% threshold, higher errors near ice edge	**Y**
Ice type (MYI)	70% correct typing	80-90% (preliminary) during Arctic winter	Multiyear ice (MYI) detection only	**Y** (preliminary)

Note: Measurement uncertainty should be changed to measurement accuracy (absolute value of the mean bias). The term "accuracy" and the specified value (10%) are consistent with ice concentration requirements for GOES-R ABI and JPSS VIIRS. It's likely that accuracy is what was intended.

Future Plans

Snow:

- Regional assessment of biases in AMSR2 snow products and adjustment of algorithm parameters to improve retrievals;
- Explore and develop a data assimilation-based AMSR2 SWE product similar to ESA's GlobSnow.

Sea ice:

- Further development and validation of ice type and publication of ice type methodology.

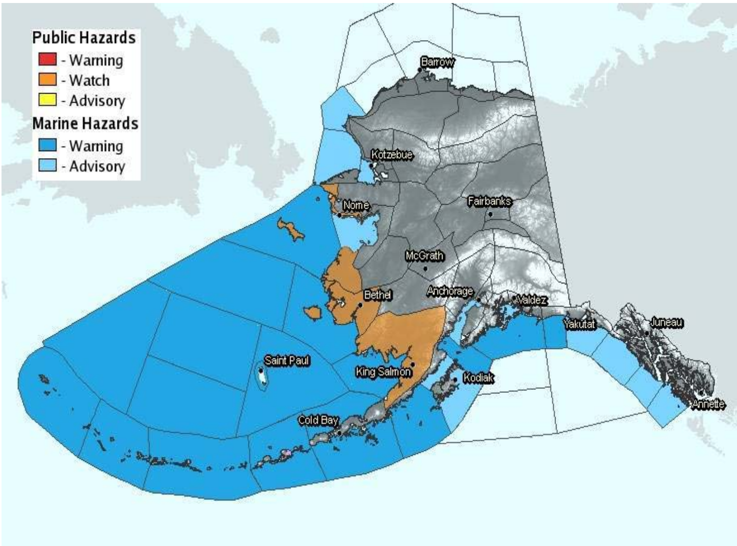
Snow and Ice Product Users (planned)

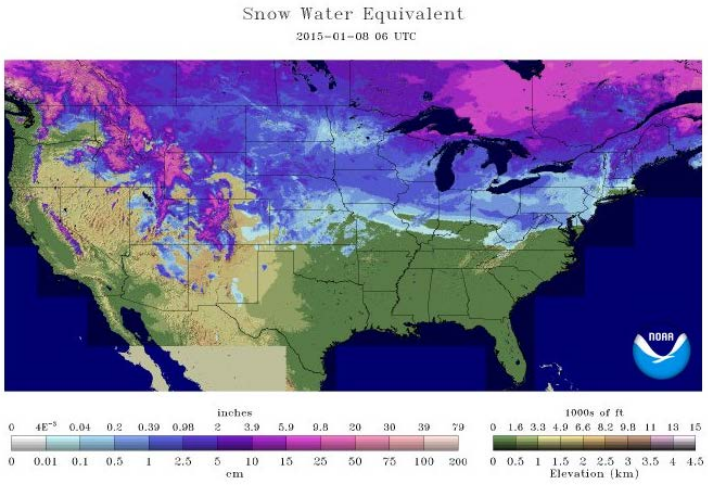
Operational Ice Services

- U.S. National Ice Service
- North American Ice Service
- Anchorage Ice Desk

Modeling

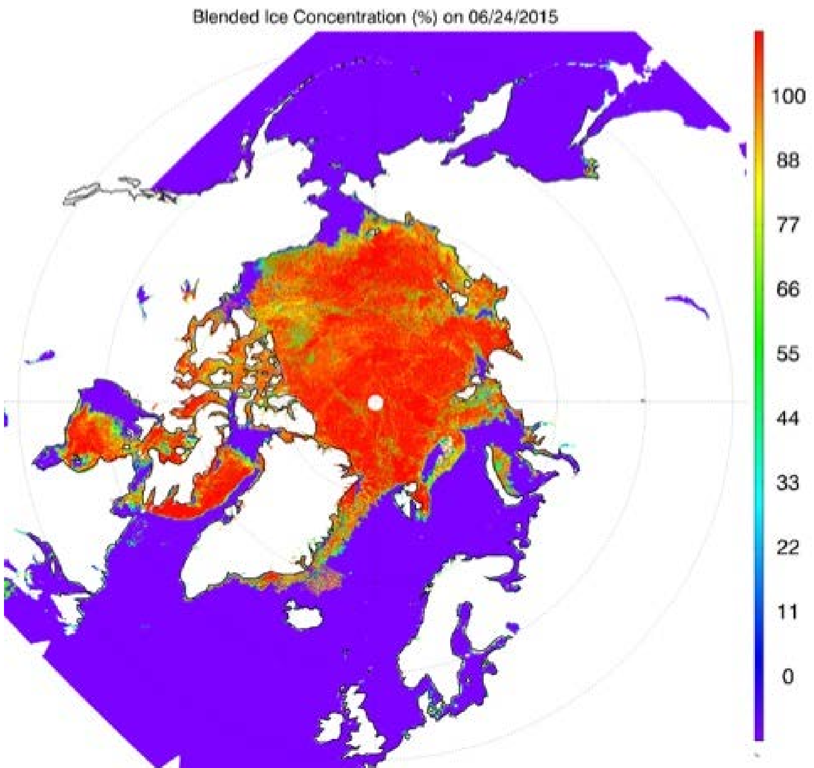
- Snow: National Operational Hydrologic Remote Sensing Center Snow Data Assimilation System (SNODAS)
- Snow: Weather forecasting, e.g., NCEP
- Ice: Naval Research Lab, Arctic Cap Nowcast/Forecast System (ACNFS)

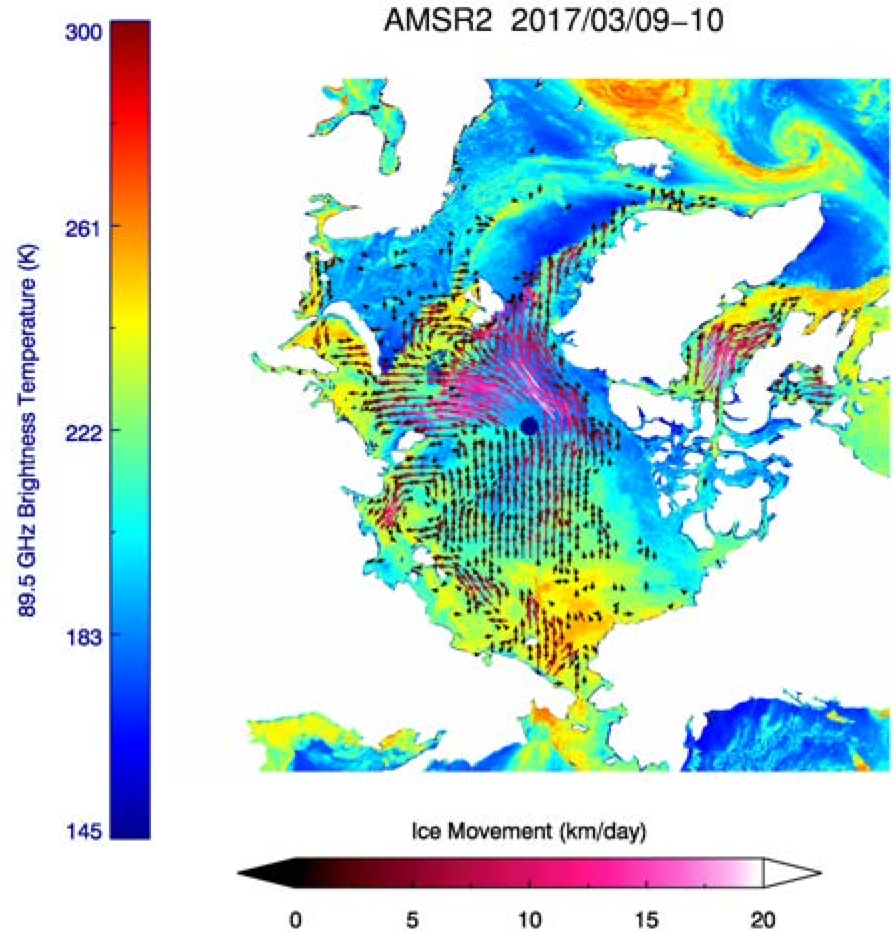




Experimental Products

Blended Ice Concentration (AMSR2 + VIIRS)

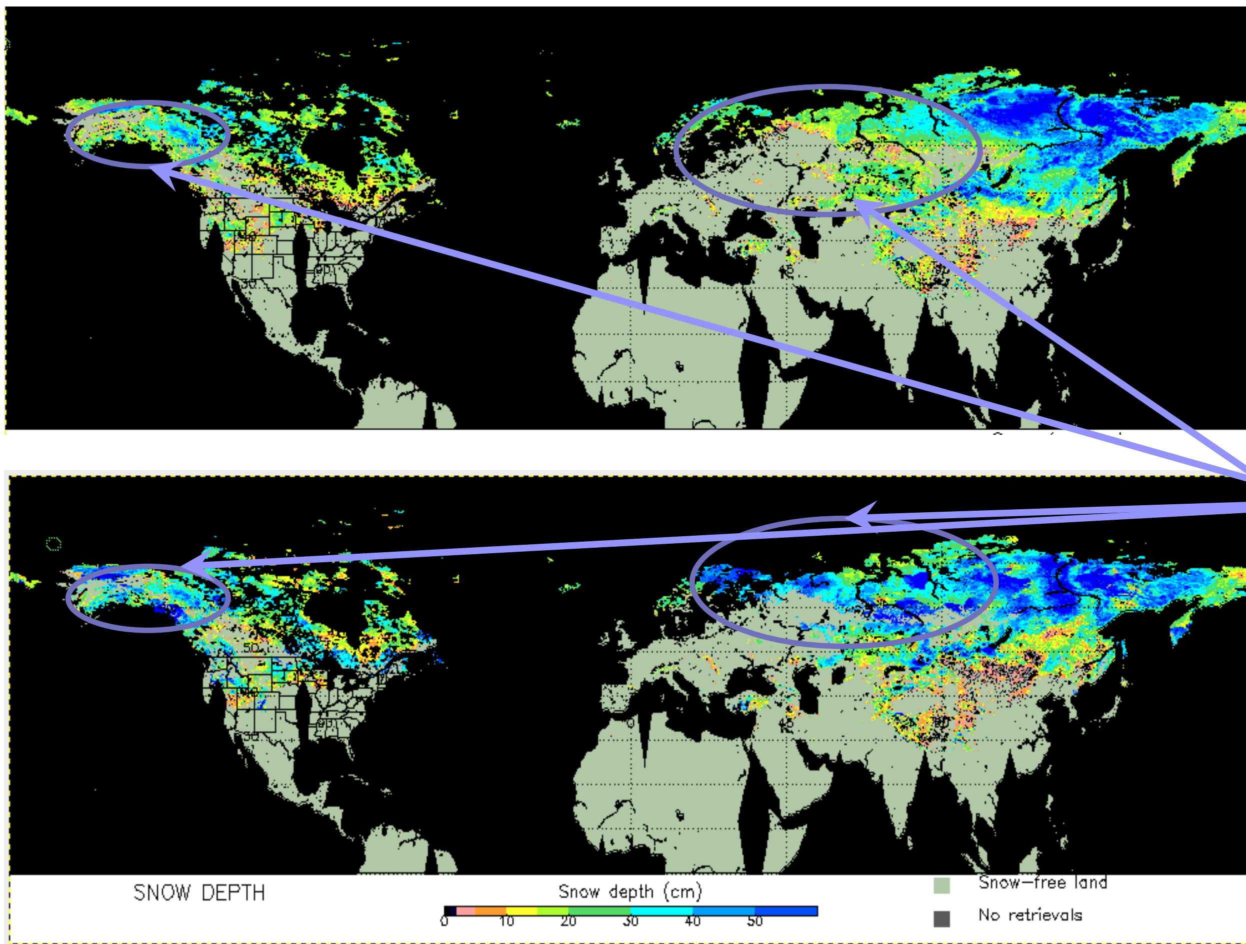




Ice Motion (AMSR2 + VIIRS)

Experimental Products, cont.

AMSR2 Snow Depth (top) and blended AMSR2 + in situ (bottom)



Improved SD areas