NESDIS Operational Blended Products

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NOAA/NESDIS OSPO and STAR

August 18, 2017

Outline

- Attributes of Blended Products
- Current Operational Capability
- Data Access
- Looking Forward

Attributes of Blended Products (1/2)

- **Unified products**
  - From multiple resources, satellites/sensors/algorithms
    - Could also include in-situ data
  - Much better spatial and temporal resolution than any individual L2 product
  - Best analysis from available individual L2 products

- **Value added L3 product**
  - With quality dependency on the L2 products used

- **Highly desirable by NESDIS operations and end users**
  - Optimizes computer resources for both producer and user
  - Puts quality burden of L2 products on producer not user

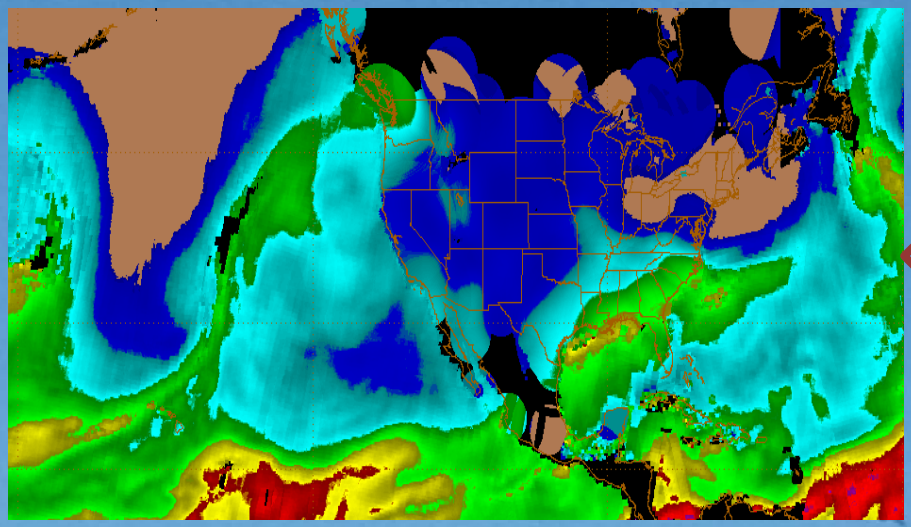
Attributes of Blended Products (2/2)

- **Common Features**
  - Normalization Process
    - Each L2 could have different attributes
      - » Native spatial resolution; Latency; Observation frequency; Scan geometry/biases, etc
    - Generally, each L2 is “adjusted” to a reference
      - » Highest quality L2, independent data, human eye (IMS), etc.
    - End usage also dictates how the normalization is done
      - » AWIPS/image products; Input to NWP or Hydrological Models; Global vs. Regional
  - Merging Algorithm
    - Overlay
      - » Latest; closest; most accurate
    - Average
    - Weighting Function
      - » Error attributes; Time latency, etc.

Current NESDIS Operational Capability - Overview

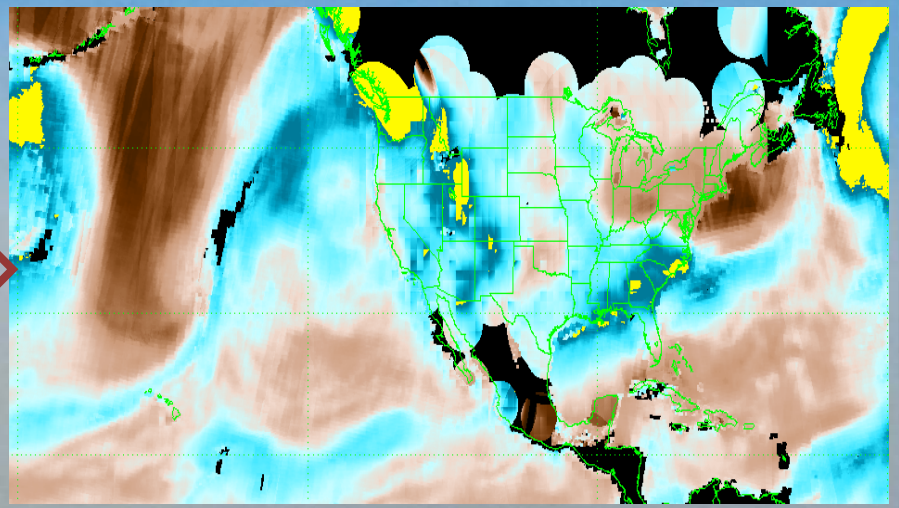
Applications	Satellites/Sensors	Products
bTPW - Blended Total Precipitable Water	NOAA-18, NOAA-19, Metop-A and Metop-B, GOES-W/-E, GPS-Met, DMSP F18	Global TPW map
bRR - – Blended Rain Rate	NOAA-18, NOAA-19, Metop-A and Metop-B, DMSP F17	Global Rain Rate map
eTRaP - Ensemble Tropical Rainfall Potential (eTRaP)	NOAA-18, NOAA-19, Metop-B, DMSP 17&18, GOES-W/-E, Meteosat-8, Meteosat-10, Himawari-8	Ensemble forecast of 6~24-hour rainfall potential for tropical systems
SMOPS - Soil Moisture Operational Products System	Metop-A/-B, SMOS, SMAP, GPM	Global soil moisture map
GHE - Global Hydro-Estimator	GOES-W/-E, Meteosat-8, Meteosat-10, Himawari-8	Global rainfall estimate with different temporal scale
Blended SST – Blended Sea Surface Temperature	Metop-B/AVHRR, S-NPP/VIIRS, GOES-E&-W/Imager, Meteosat-10/SEVIRI and Himawari-8/AHI	Global Sea Surface Temperature
GBBEPx - Blended Global Biomass Burning Emissions Product from MODIS and Geostationary Satellites	GOES-E&-W/Imager, EOS-Terra/MODIS, EOS-Aqua/MODIS	Daily global biomass burning emissions
MTCSWA - Multiplatform Tropical Cyclone Surface Wind Analysis	NOAA-15, NOAA-18, NOAA-19, Metop-A, S-NPP	Six-hourly estimates of tropical cyclone wind fields
TOAST – Total Ozone Analysis	NOAA-19/SBUV-2 and Metop-B/TOVS	Global ozone map
Enhanced TOAST – Enhanced Total Ozone Analysis	NOAA-19/SBUV/2 and S-NPP/CrIS	Global Ozone map
IMS – Interactive Multi-sensor Snow and Ice Mapping System	NOAA-18&-19, Metop-A, S-NPP, Aqua/TERRA, Radarsat-2, Meteosat-10, Himawari-8, DMSP, GOES-E&-W	Snow and Ice cover maps for the Northern Hemisphere

Blended TPW Products Suite



Blended TPW – Merges TPW from AMSU, SSMIS, ATMS, AMSR2, GMI, GOES Sounders and GPS-Met into a unified resource to provide forecasters no-gap TPW coverage over globe and serves as a very helpful tool for forecasters to identify conditions that could result in heavy precipitation and subsequent flooding.

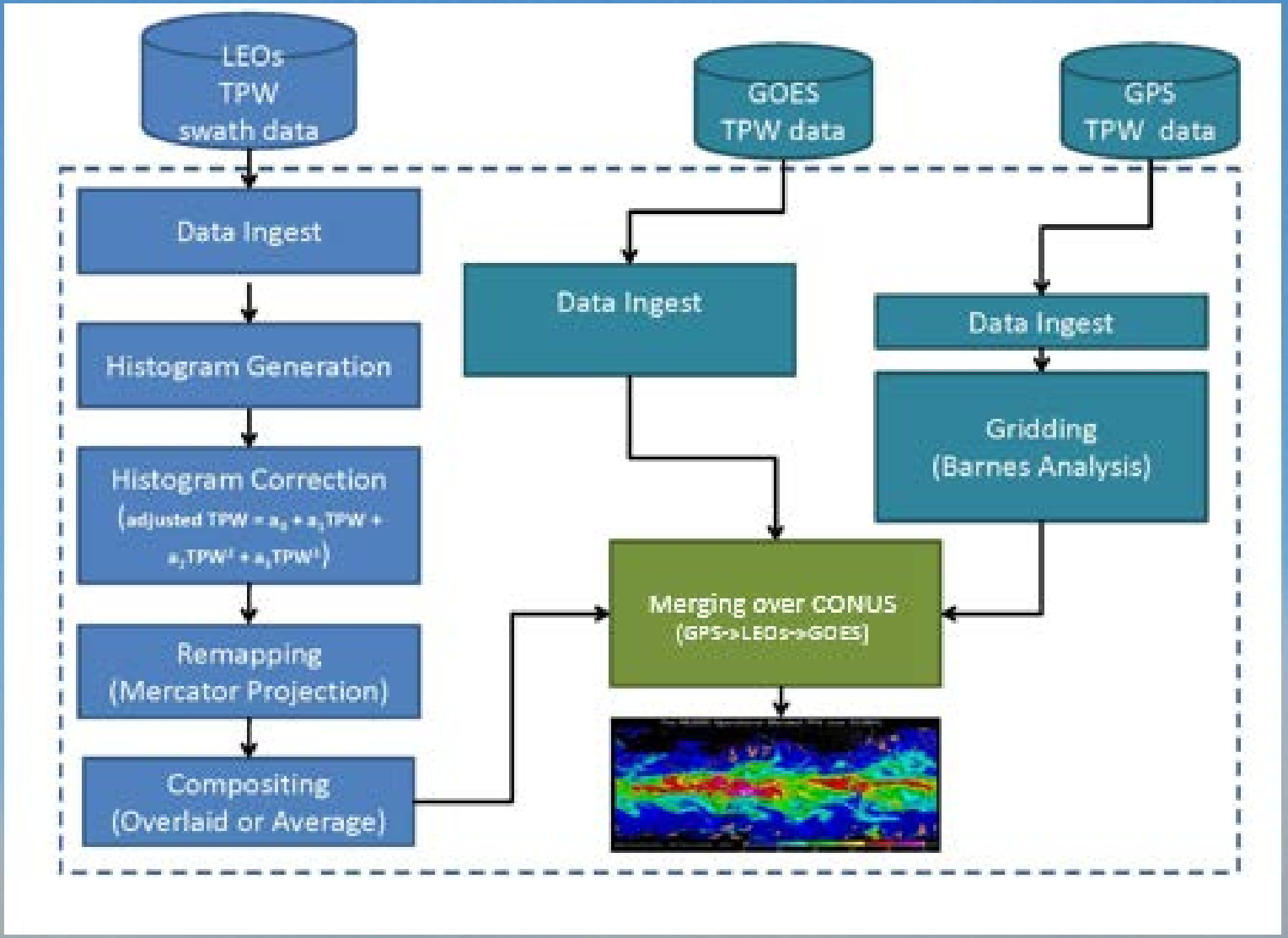
Percent of Normal TPW – Compares the blended TPW with the NVAP (NASA Water Vapor Project) weekly mean. It helps forecasters quickly see areas where active weather is occurring and assess the severity of the situation. For instance, the "Yellow" areas indicate TPW > 200% of the weekly mean, and usually are potential threat areas



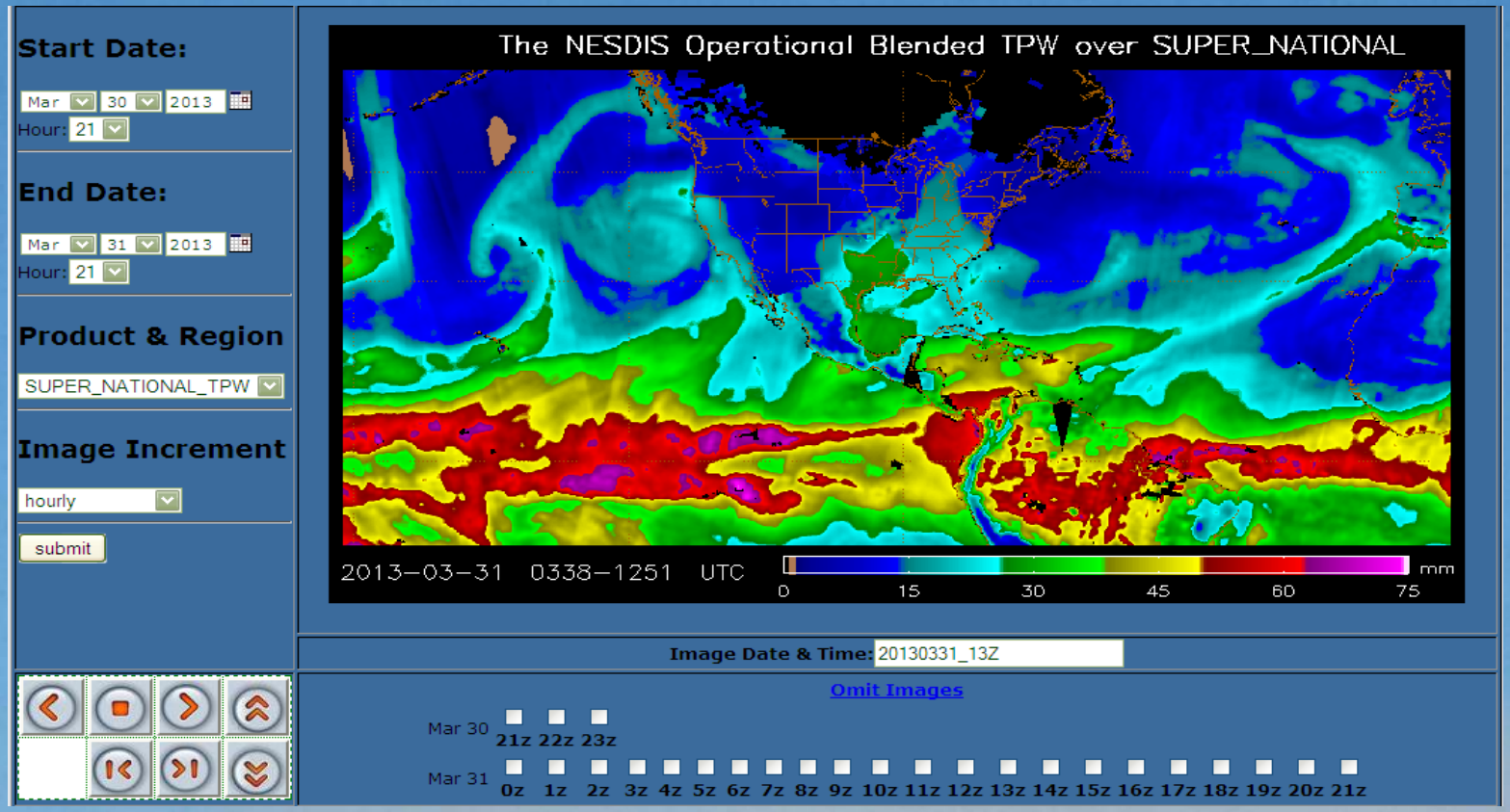
Blended TPW Products

- **Product**
  - Unified, meteorologically significant TPW maps, which merges the TPW retrievals from various satellites/algorithms to provide a global coverage.
- **Current Status**
  - **Operational:** since March 09, 2009
  - **Over Ocean**
    - TPW from NOAA-15, -18, -19 and Metop-A/-B, F17, F18, S-NPP, GCOM-W1, GPM
  - **Over Land**
    - GPS-Met over CONUS, Alaska and Hawaii – primary data source over CONUS
    - MIRS TPW from N18, N19 and Metop-A/-B, F17, F18, S-NPP, GPM over CONUS when GPS is not available, and also over other Landmasks
    - GOES over CONUS, and part of east pacific ocean – used to fill the hole when no GPS and MIRS TPW are available
  - **Products:** *TPW, Percentage of Normal TPW; 16x16km*
  - **Formats:** HDF-EOS, McIDAS area and AWIPS; netCDF4 in near future
  - **Data Access:** DDS/PDA, ADDE and AWIPS
  - **The imagery products are also available on the Internet through:** http://www.ospo.noaa.gov/Products/bTPW/index.html
  - **POCs**: Limin Zhao and Ralph Ferraro

Blended TPW Products - Algorithm



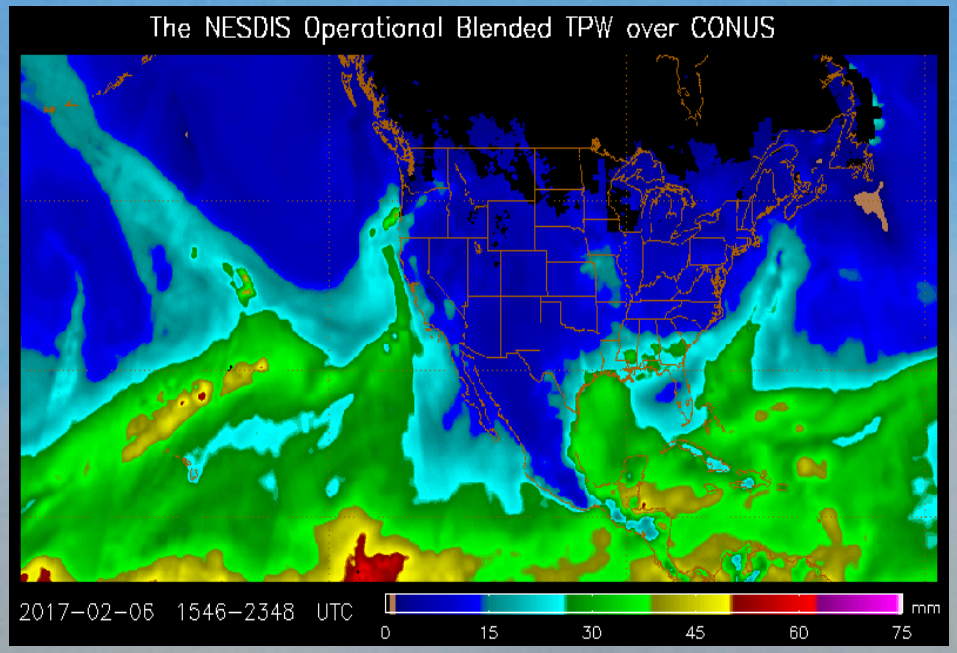
Blended TPWs – Animation Tool

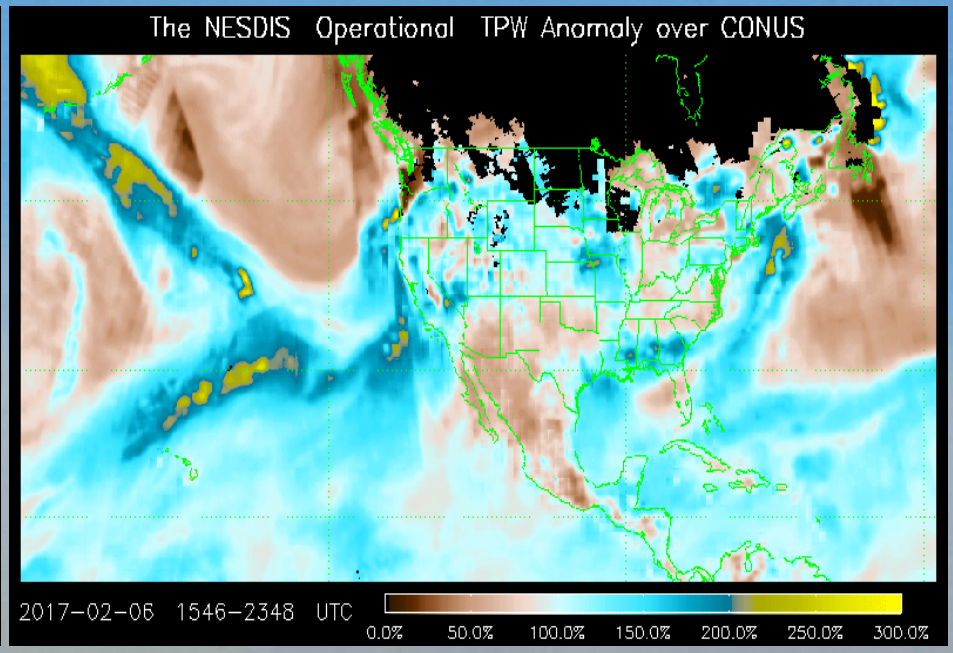


Animation – Near-real time loops of blended TPW and PCT available at: http://www.ospo.noaa.gov/bTPW
Regions – 16 area of interest regions for zooming in details
Image Interval – 1 hour, 3, 6, 12 and 24 hours
Historical Data – up to three months

Example of Blended TPWs

The blended TPW has been used, together with the percentage of normal TPW, by satellite analysts and forecasters to improve analysis and prediction of heavy precipitation and flash flood, and also monitoring the “atmospheric rivers” (ARs). Here shows the animation of bTPW and PCT for a heavy rain event during Feb 6~9, 2017, when an atmospheric river event brought a prolonged period of moderate to heavy rain to portions of northern California on Feb 6. That rain, combined with snowmelt in some areas, brought flooding and several mudslides to parts of California and Nevada.





(Animations credited to Nancy Merckle)

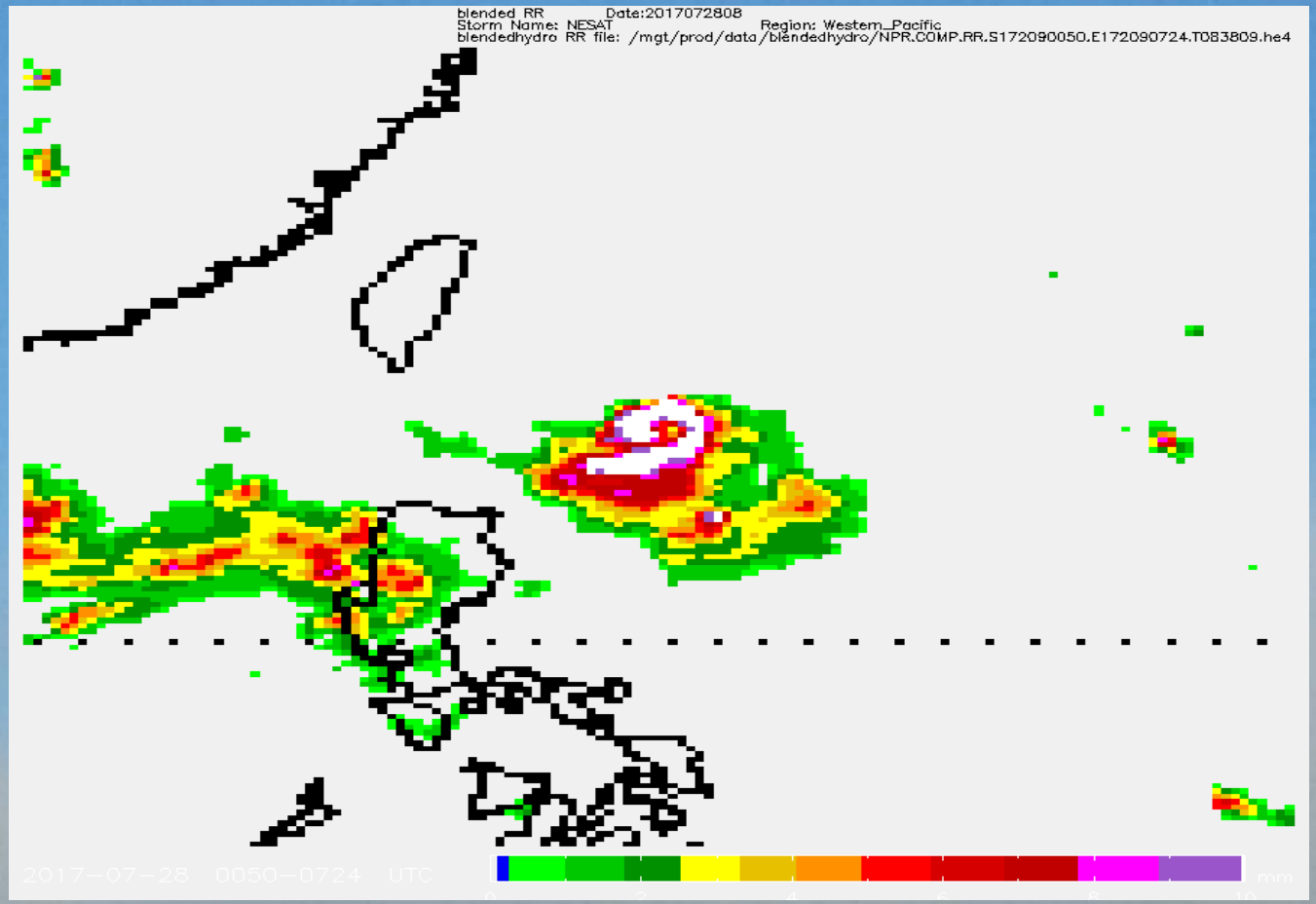
Blended RR

- **Product**
  - **Unified global rainfall rate map generated from multi-satellites and multi–algorithms**
  - **With the same approach as that of blended TPW**

- **Current Status**
  - **Operational:** since September 18, 2012
  - **Data Sources:**
    - AMSU RR from N18, N19 and Metop-A/-B
    - SSMIS RR from FNMOC F17 and F18
    - ATMS RR and GMI RR from MiRS
    - GCOM-W1 RR from GAASP/GPROF
  - **Products:** Rain Rate; 16x16km
  - **Formats:** HDF-EOS, McIDAS and AWIPS; netCDF4 in near future
  - **Data Access:** DDS/PDA, ADDE and AWIPS
  - The imagery products are also available on the Internet through: http://www.osdpd.noaa.gov/Products/atmosphere/brr
  - **POCs**: Limin Zhao and Ralph Ferraro

Blended Rain Rate

Here shows the animation of blended RR for Typhoon NESAT, which swept across Taiwan on 2017 July 29, injuring more than 80 people, forcing the capital to shut down essential services and knocking out power to hundreds of thousands of homes. The blended RR provided a more timely and frequently update on the rainfall dumped by NESAT.



Data Access

- **Real-time data access to ESPC DDS/PDA through Data Access Request(DAR):**
  http://www.ospo.noaa.gov/Organization/About/access.html

- **Historical data access through NOAA/CLASS/NCDC:**
  http://www.class.ngdc.noaa.gov/saa/products/welcome

- **Imagery Products through Internet:**

  bRR - *http://www.ospo.noaa.gov/Products/atmosphere/brr*
  bTPW - *http://www.ospo.noaa.gov/bTPW*
  GHE - *http:// ://www.ospo.noaa.gov/Products/atmosphere/ghe*
  eTRaP - *http://www.ssd.noaa.gov/PS/TROP/etrap.html*
  SMOPS - *http://www.ospo.noaa.gov/Products/land/smops*
  Blended SST – http://www.ospo.noaa.gov/Products/ocean/sst/contour/index.html
  GBBEPx – http://www.ospo.noaa.gov/Products/land/gbbepx/
  MTCSWA – *http://www.ssd.noaa.gov/PS/TROP/mtcswa.html*
  TOAST – *http://www.ospo.noaa.gov/Products/atmosphere/toast/index.html*
  Enhanced TOAST – *http://www.ospo.noaa.gov/Products/atmosphere/etoast/index.html*
  IMS - *http://www.natice.noaa.gov/ims/ims_1.html*

- **Questions/Comments:** *Limin.Zhao@noaa.gov*

Looking Forward (next year or so)

- Integrate the data from S-NPP (for some products that haven't done so yet) and JPSS-1
- Integrate the data from GOES-R as they become operational
- Update the merging algorithm to implement more quality controls and to count the error statistics from each retrievals
- Newest product for operational consideration - Layered Blended TPW

Discussion Topics/Ideas….

- Should there be a ‘recipe’ we develop that
  - Defines approaches to be considered when developing new blended products
  - The recipe needs to account for latency requirements
    - There will not be a ‘one size fits all’ because of this
  - Consider the final end user
    - NWP, forecaster, global monitoring, etc.
- How do we incorporate blended products within the evolving Enterprise Approaches?
- How does reprocessing of L2 factor in?

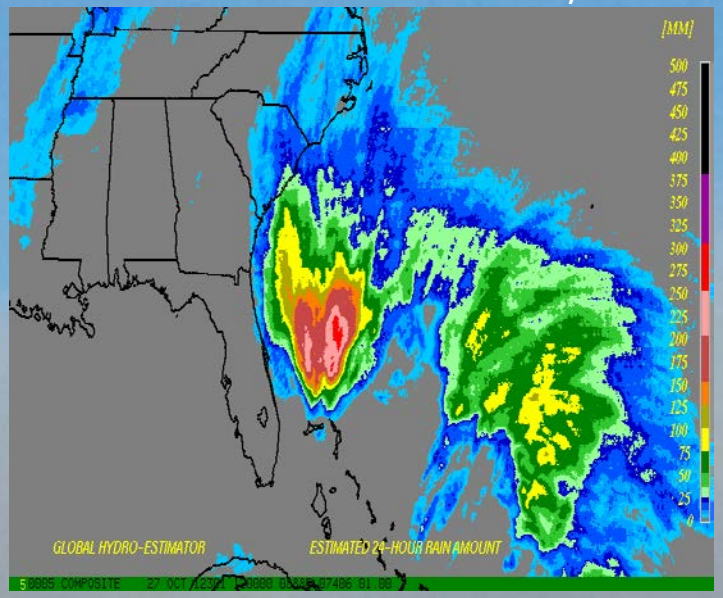
Backup Slides

Additional examples of blended products

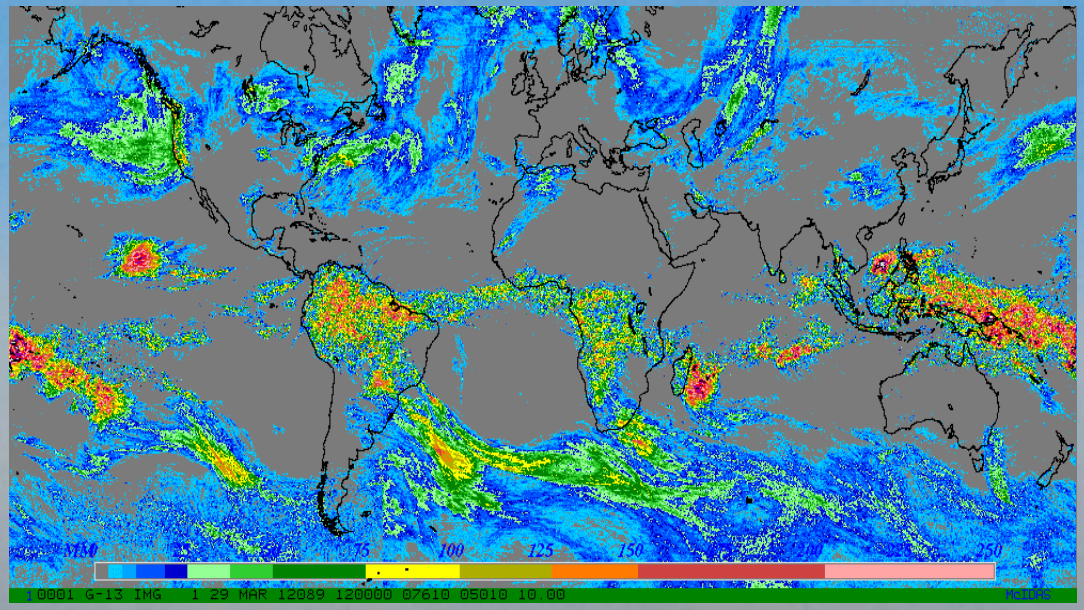
GHE

- **Products:**
  - Global rainfall maps generated from multi-geo-satellites
- **Data Source:** GOES-W/-E, Meteosat-8, Meteosat-10, Himawari-8
- **Products:** *Instantaneous rain rate, 1 hour, 3 hour, 6 hour, 24 hour and also multi-day rainfall accumulation; 4x4 km*
- **Format:** GRIB1, McIDAS area and netCDF4
- **Web Link:** http://www.ospo.noaa.gov/Products/atmosphere/ghe
- **Data Access POCs:** Limin Zhao and Bob kuligowski

24-hour Rainfall Total - Sandy

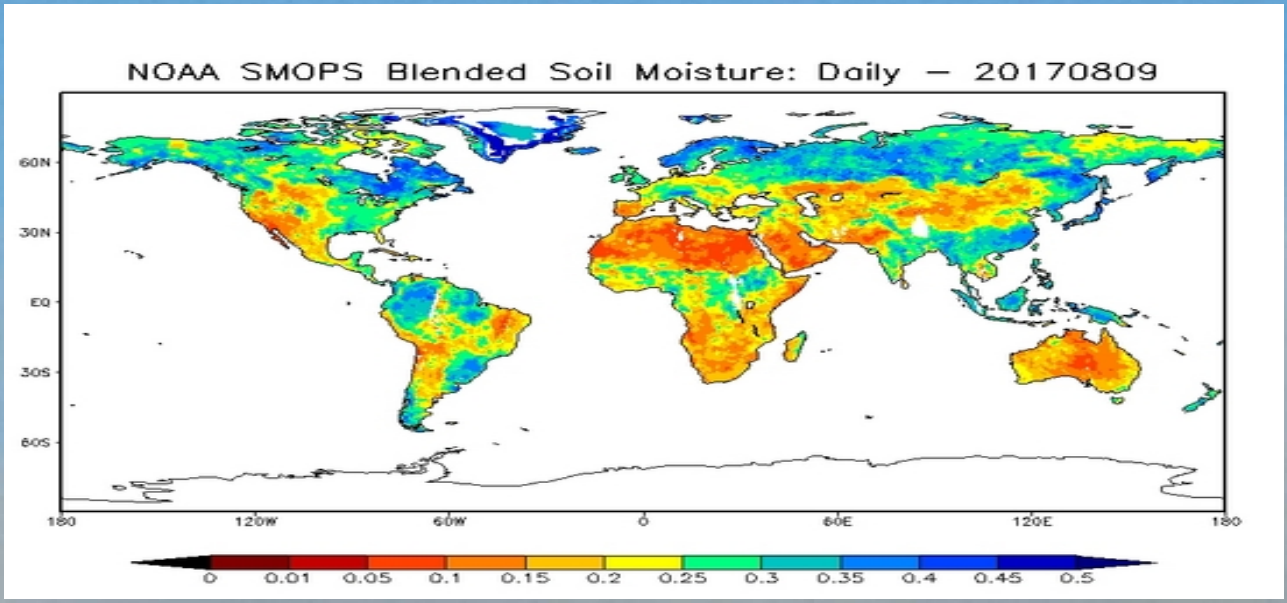


5-Day Rainfall Total



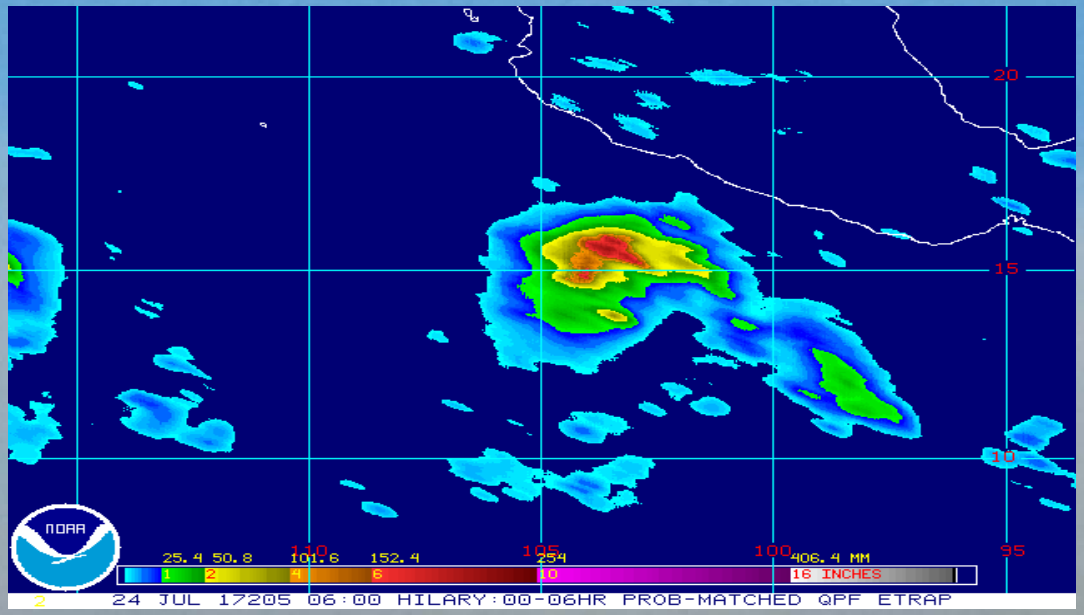
SMOPS

- **Products:**
  - Global soil moisture map generated from multi-satellites and/or –algorithms
- **Data Resource**
  - Metop-A/-B, SMOS, SMAP, GPM
- **Products:** 0.25x0.25 degree; 6 hourly, Daily
- **Format:** GRIB2 and netCDF4
- **Web Link**
  - http://www.ospo.noaa.gov/Products/land/smops
- **Data Access POCs:** Limin Zhao and Xiwu Zhan



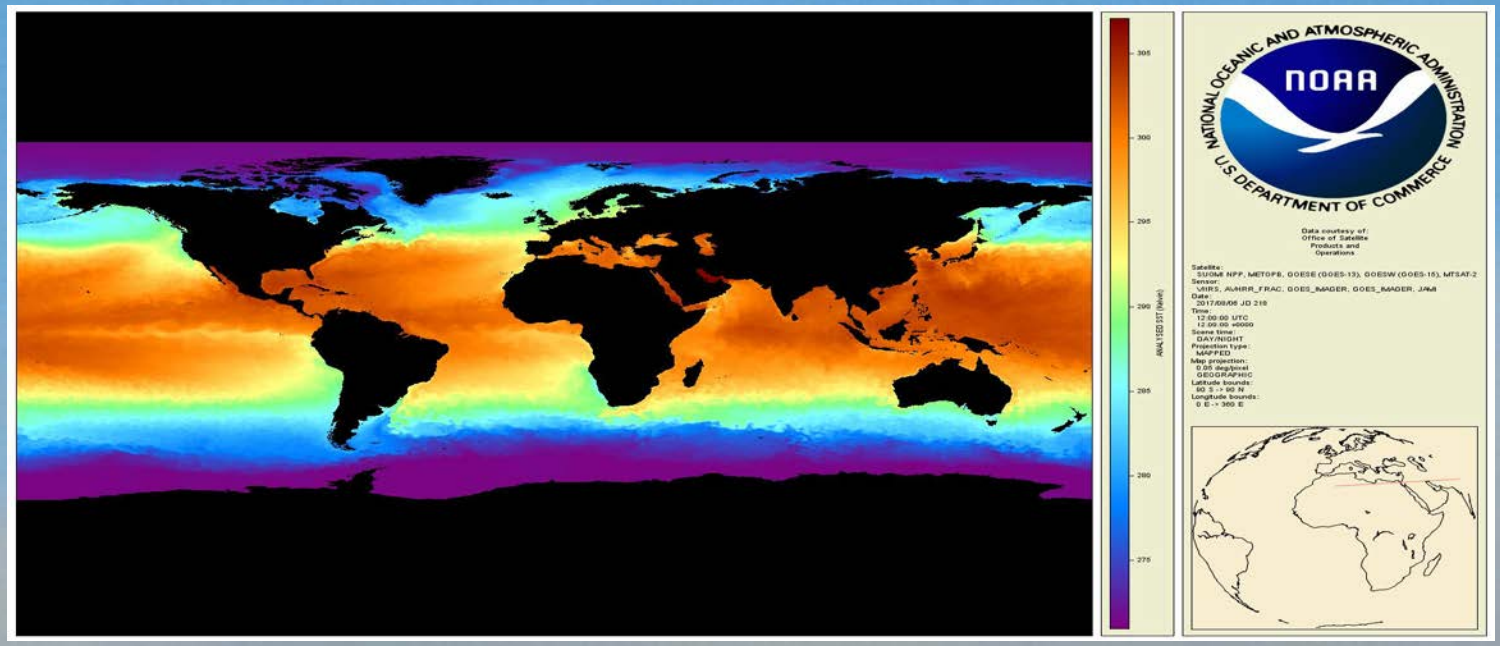
eTRaP

- **Products:**
  - **Ensemble forecast of 6~24-hour rainfall potential for tropical systems based on extrapolation of satellite-derived rainfall rates along predicted storm track**
- **Data Resource**
  - Rainfall Rate from N18, N19 and Metop-A/-B, F17, F18, GOES-W/GOES-E, Meteosat-8, Meteosat-10, Himawari-8
- **Products:** *Probability (PoP), Prob-Matched QPF (PMQPF)*
- **Format:** ASCII, McIDAS and gifs
- **Web Link:** http://www.ssd.noaa.gov/PS/TROP/etrap.html
- **Data Access POCs:** Liqun Ma and Bob kuligowski



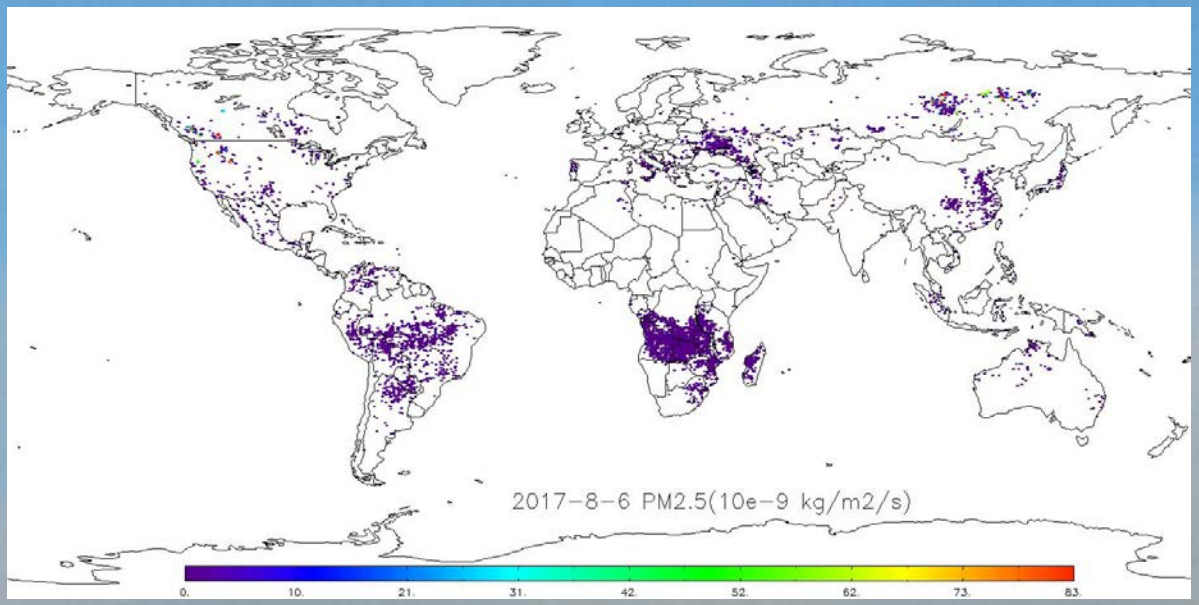
Blended SST

- **Products**
  - Blended SST combines polar-orbiting and geostationary data to provide daily global fields of sea surface temperature on a 0.05° (~5 km) grid for a range of applications in climate, ecosystems, weather, and mesoscale oceanography.
- **Data Resource**
  - Metop-B/AVHRR, S-NPP/VIIRS, GOES-E&-W/Imager, Meteosat-10/SEVIRI and Himawari-8/AHI
- **Format:** netCDF4, hdf4 (will be terminated soon)
- **Web Link:** http://www.ospo.noaa.gov/Products/ocean/sst/contour/index.html
- **Data Access POCs:** John Sapper and Eileen Maturi



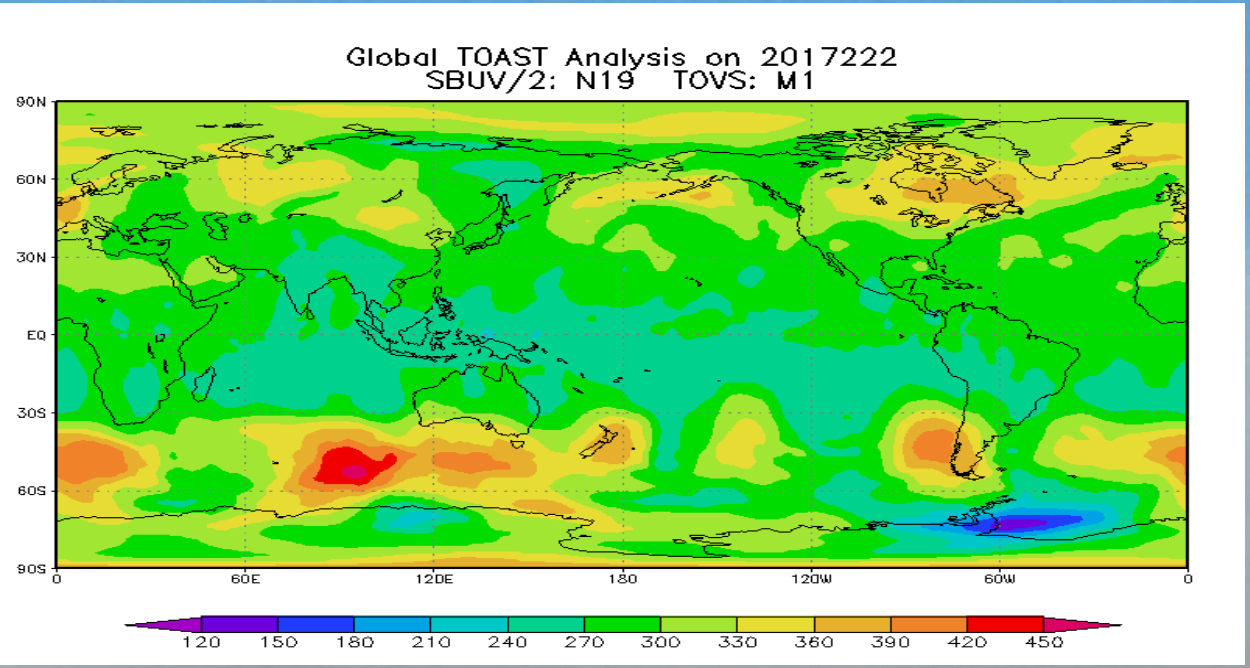
Blended Global Biomass Burning Emissions Product

- **Products:**
  - The GBBEPx produces daily global biomass burning emissions (PM2.5, BC, CO, CO2, OC, and SO2) released from wildfires using fire wildfires power retrieved from MODIS and Geostationary Satellites.
- **Data Resource**
  - GOES-E&-W/Imager, EOS-Terra/MODIS, EOS-Aqua/MODIS
- **Format:** netCDF4, PNG
- **Web Link:** http://www.ospo.noaa.gov/Products/land/gbbepx/
- **Data Access POCs:** Hanjun Ding and Shobha Kondragunta



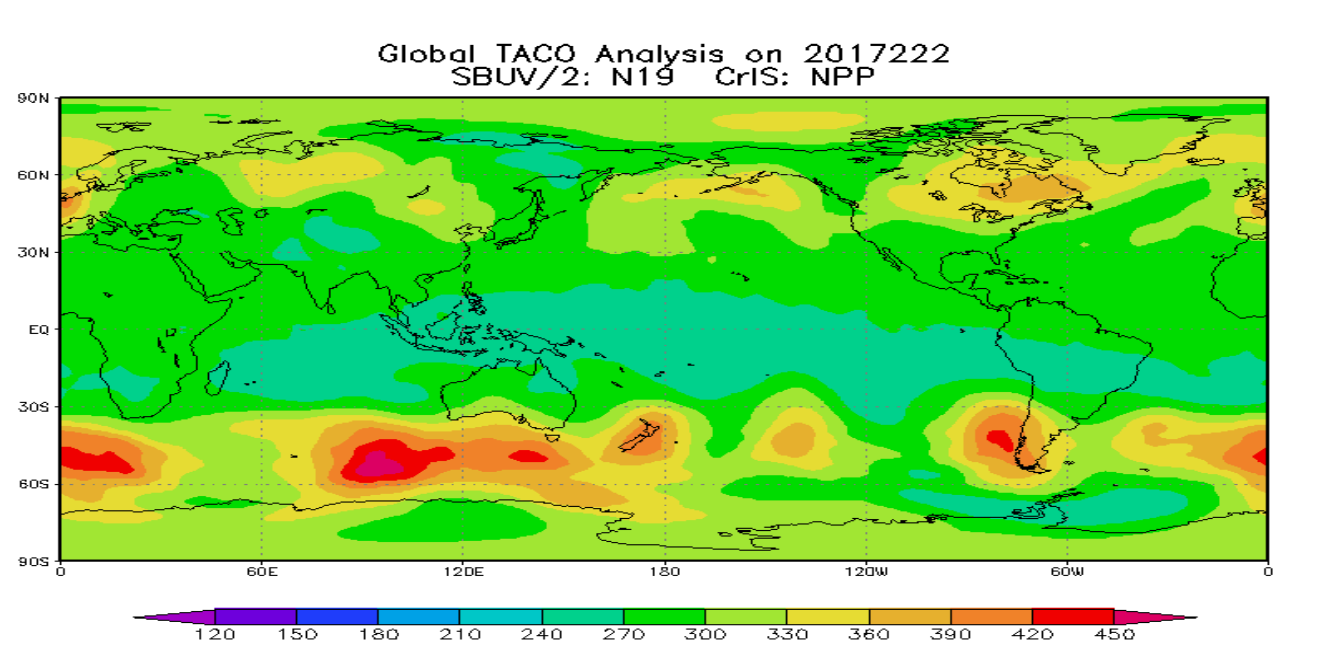
TOAST

- **Products:**
  - Near real-time operational ozone maps generated by combining TOVS (MetOp-B) tropospheric and lower stratospheric (4 to 23 km) ozone retrievals with SBUV/2 (N19) spatially smoothed mid-to-upper stratospheric (24 to 54 km) layer ozone retrievals.
- **Data Resource**
  - NOAA-19/SBUV-2 and Metop-B/TOVS
- **Format:** GRIB, PNG
- **Web Link:** http://www.ospo.noaa.gov/Products/atmosphere/toast/index.html
- **Data Access POCs**: Vaishali Kapoor and Larry Flynn



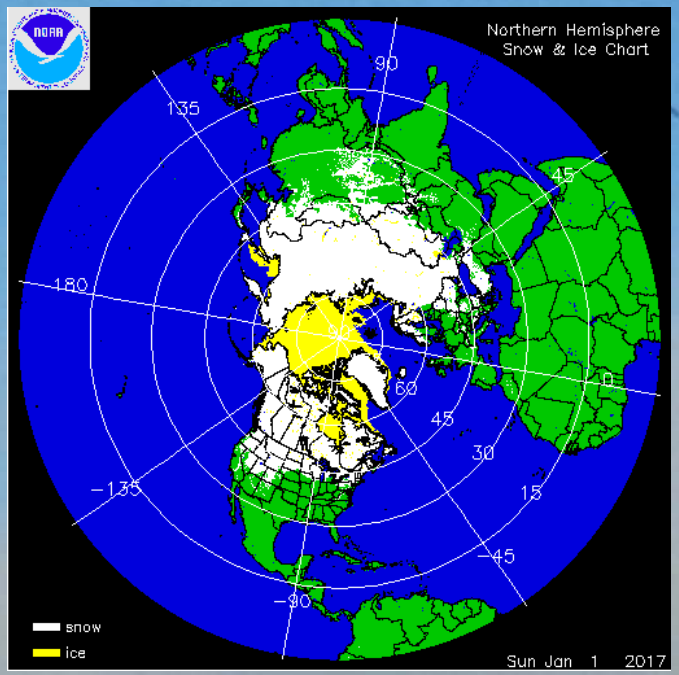
ETOAST

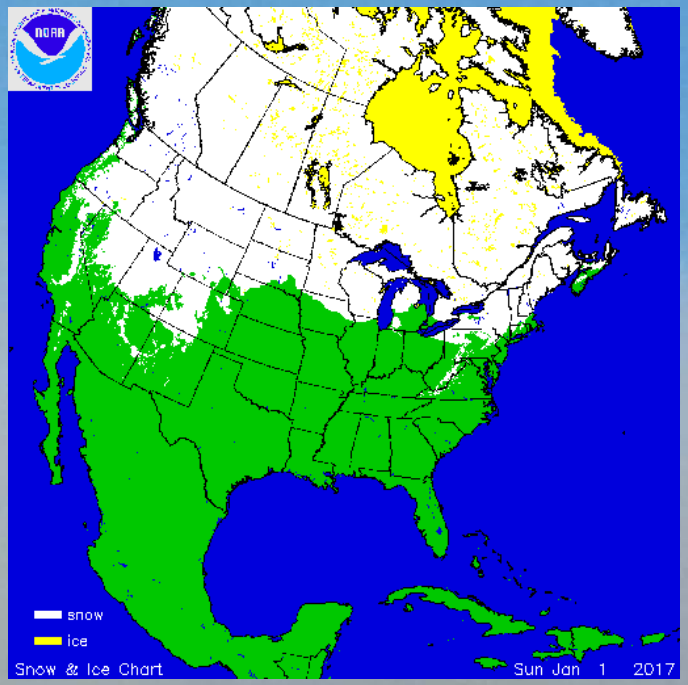
- **Products:**
  - Near real-time operational ozone maps generated by combining UV and IR ozone retrievals generated using Total Ozone Analysis of Cross-track Infrared Sounder- CrIS (NPP) and Solar Backscatter UltraViolet Version 2 - SBUV/2 (N19), which is an enhancement to TOAST with a new algorithm.
- **Data Resource**
  - NOAA-19/SBUV/2 and S-NPP/CrIS
- **Format:** GRIB, PNG
- **Web Link:** http://www.ospo.noaa.gov/Products/atmosphere/etoast/index.html
- **Data Access POCs**: Vaishali Kapoor and Larry Flynn



IMS

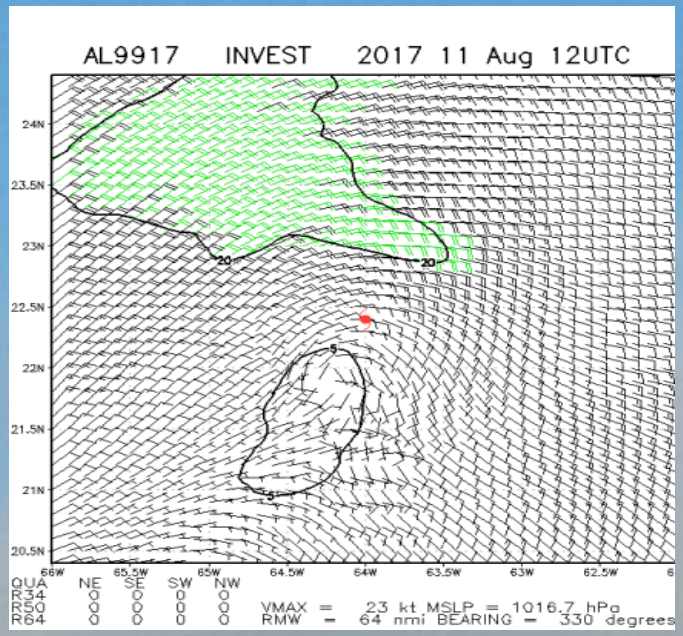
- **Products:**
  - Snow and Ice cover maps for the Northern Hemisphere derived from a variety of data products including satellite imagery and in situ data.
- **Data Resource**
  - NOAA-18&-19, Metop-A, S-NPP, Aqua/TERRA, Radarsat-2, Meteosat-10, Himawari-8, DMSP 15, GOES-E&-W
- **Format:** ASCII and PNG
- **Web Link:** http://www.natice.noaa.gov/ims/ims_1.html
- **Data Access POC:** Sean Helfrich

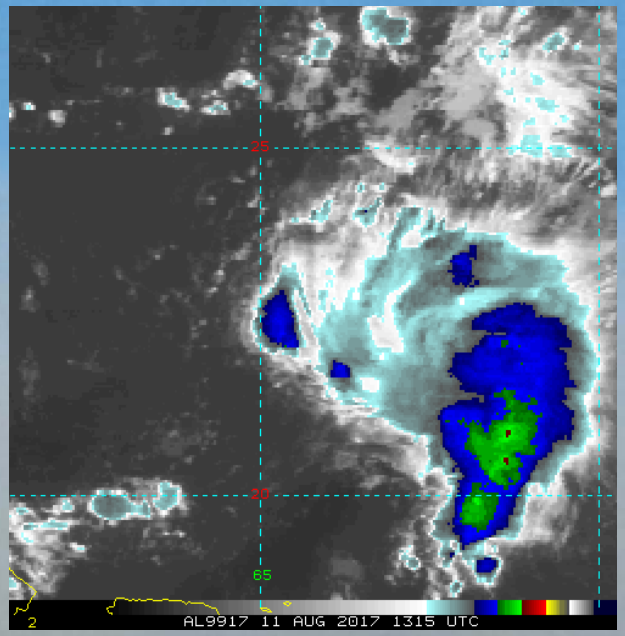




MTCSWA

- **Products:**
  - Six-hourly estimates of tropical cyclone wind fields based on a variety of satellite based winds and wind proxies.
- **Data Resource**
  - NOAA-15, NOAA-18, NOAA-19, Metop-A, S-NPP
- **Format:** ASCII and PNG
- **Web Link:** http://www.ssd.noaa.gov/PS/TROP/mtcswa.html
- **Data Access POCs:** Liqun Ma and John Knaff





Thank You

Soil Moisture Operational Product System (SMOPS)

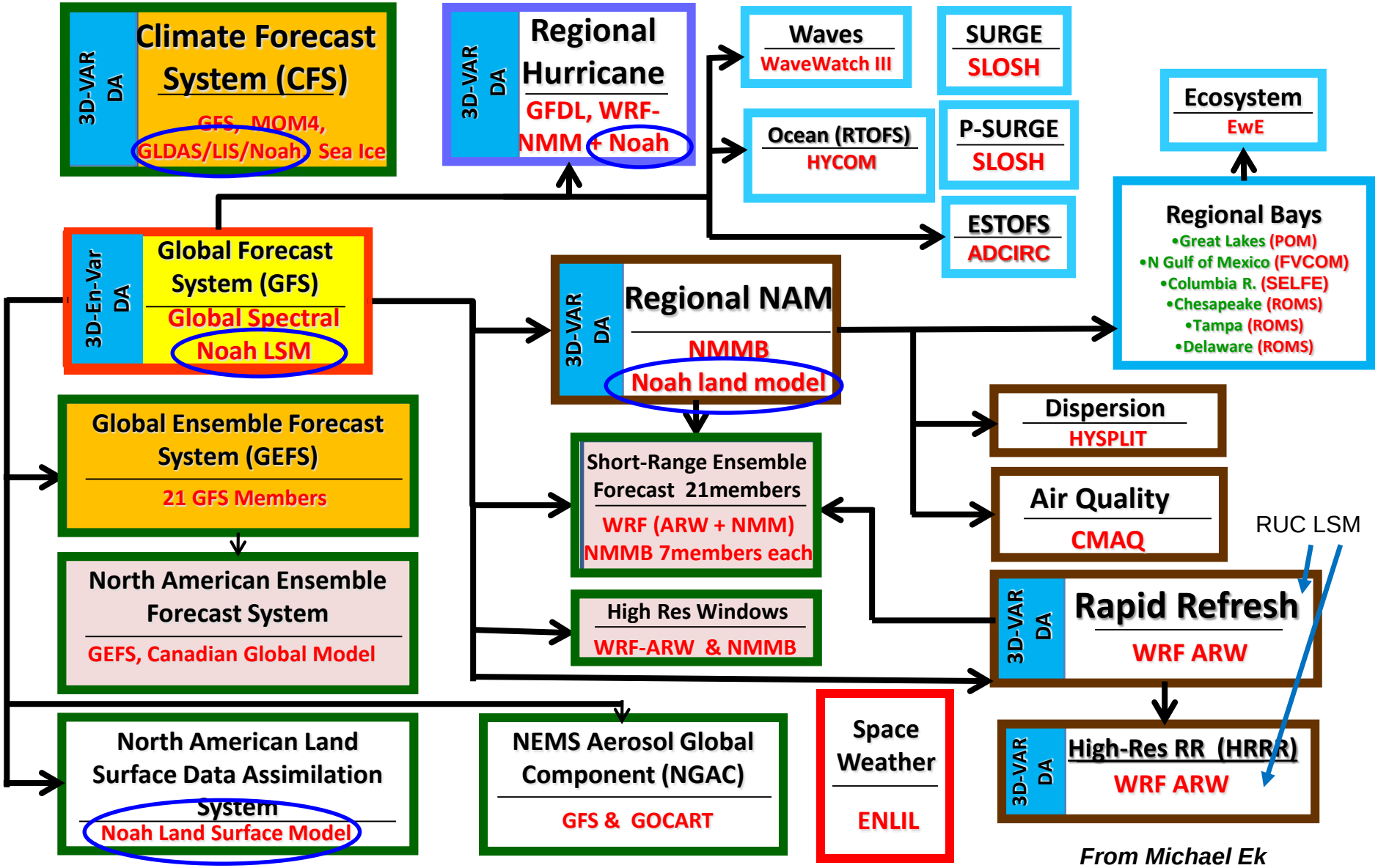
X. Zhan[1], J. Liu[1, 2], L. Zhao[3], L. Fang[1, 2], J. Yin[1, 2], C. Hain[4], W. Zheng[5], M. Ek[5], I. Csiszar[1] , F. Weng[1]

[1] NESDIS-STAR, [2] UMD-CICS, [3] NESDIS-OSPO, [4] NASA-MSFC, [4] NWS-NCEP

Outline

- Why SMOPS
- System Structure
- Product Validation
- Product Applications

Land Prediction in Weather & Climate Models: NOAA's Operational Numerical Guidance Suite



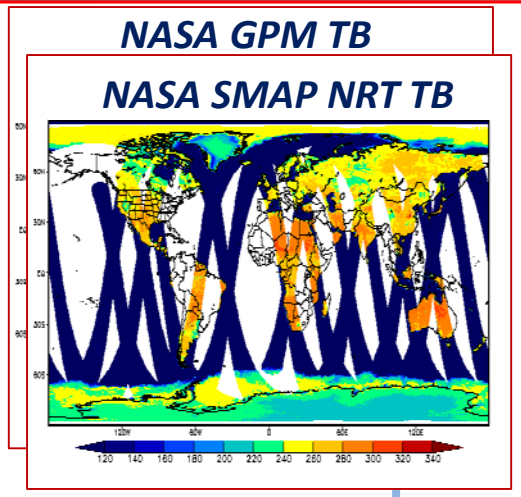
From Michael Ek

Soil Moisture Operational Product System

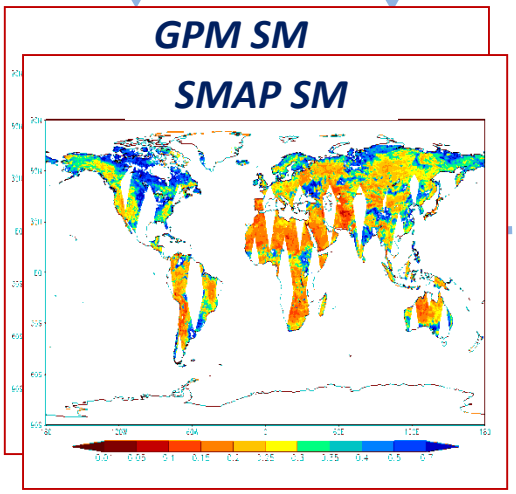
- **Requirements**
  - SPSRB requirement #0707-17, “Soil Moisture Products System”: NCEP GFS requires global soil moisture data products from “NASA's TMI on TRMM and AMSR-E on Aqua, NRL's WindSat, ESA's SMOS, and future soil moisture related missions by NASA and NPOESS ” submitted by Ken Mitchell (Michael Ek’s predecessor) , NCEP/EMC
    - TMI replaced by GMI, AMSR-E replaced by AMSR2
  - JPSS Supplement requirement L1RDS-2260, “The JPSS shall support modifications to ESPC blended products.”
  - JPSS Environmental Satellite Processing Center Requirements Document (JERD) Vol 2 identifies requirement to add GCOM-W1 AMSR2 data to blended soil moisture product
  - Others: USDA FAS needs global soil moisture for world crop forecasts and soil moisture is one of the top three critical EDRs of NPOESS; SMOPS Letter of Support (LoS) from the interagency LIS collaboration, including EMC, 557th www, NASA, UK Met Office, etc.
- **User community**
  - NWS (NCEP, OCWWS, CR), the 557th www, JCSDA, USDA, Universities
- **Benefit to user**
  - More accurate and complete soil moisture data/information as input to prediction models or decision making processes
    - Better land surface fluxes result in better weather, climate and hydrologic forecasts
    - Societal benefits include agricultural crop forecasts, flash flood forecasts, and military mobility
- **NOAA Mission Goal supported:**
  - Weather & Water, Climate, Commerce & Transportation
- **Mission priority:**
  - Critical

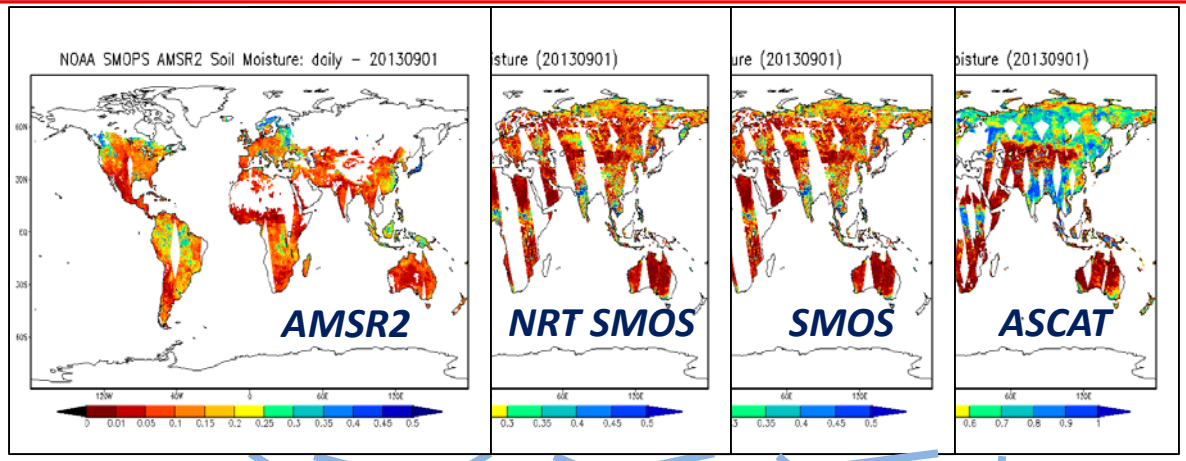
Soil Moisture Operational Product System

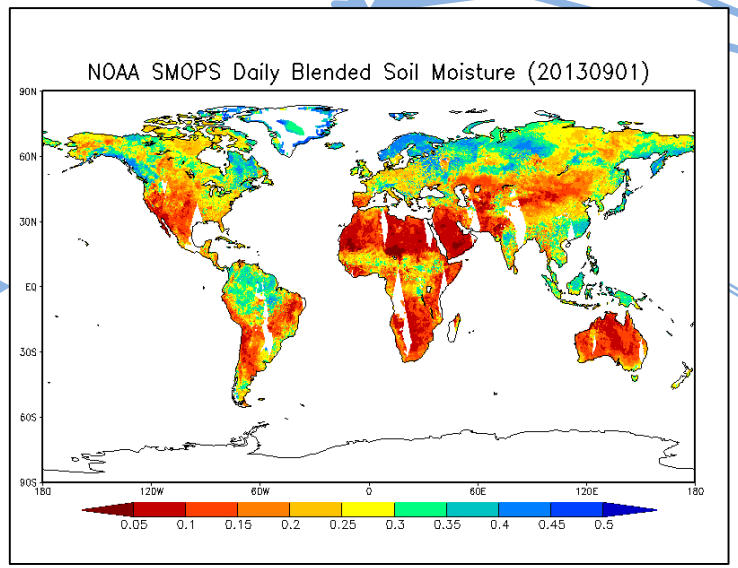
SMOPS 2.0/3.0



NOAA Ancillary Data



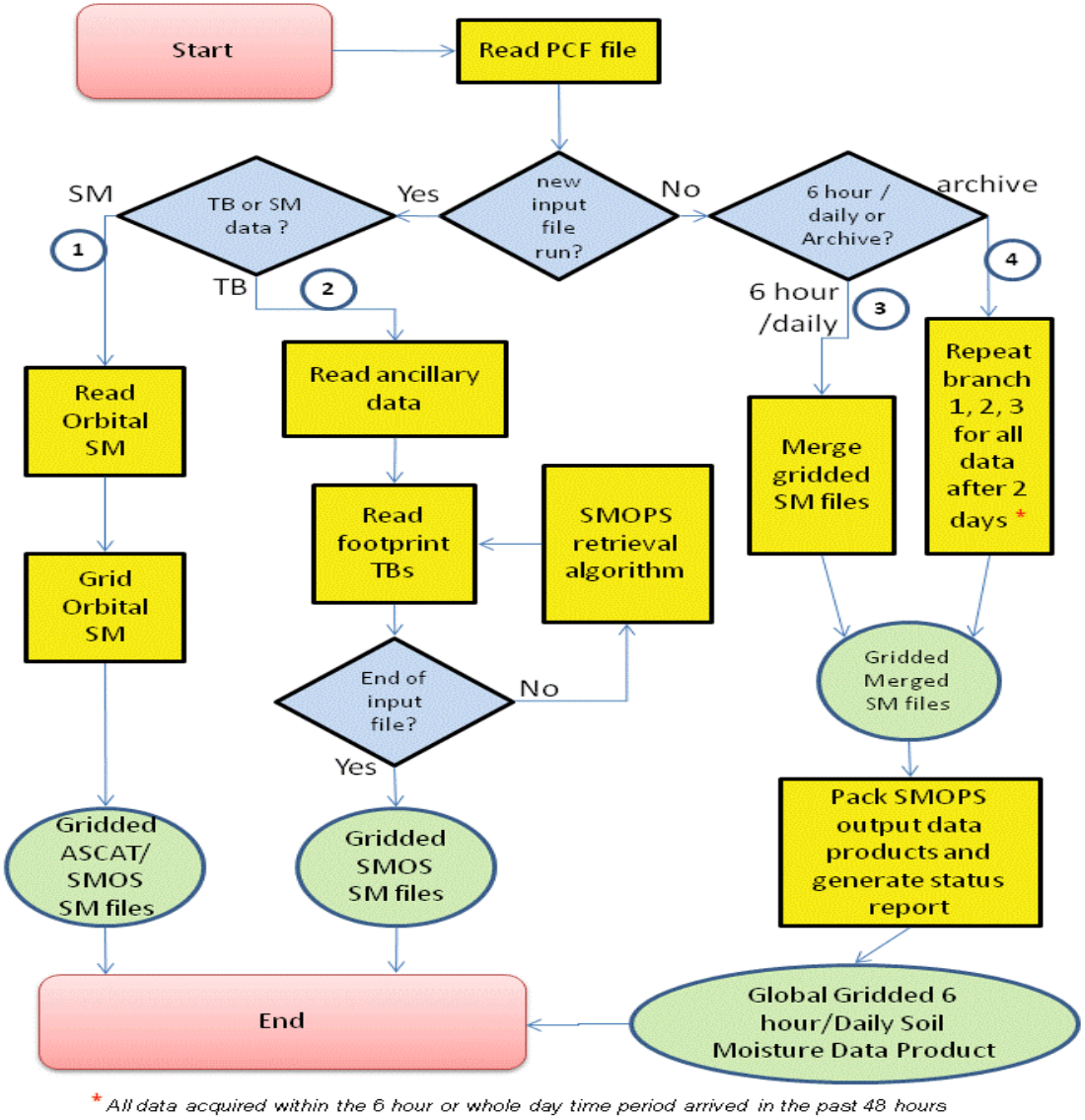




NWP models
NCEP
GFS/NAM
NLDAS/GLDAS
AFWA, etc

NESDIS SMOPS 3.0 upgraded over the current SMOPS 3.0 Ingest NASA SMAP NRT and GPM TB data to retrieve global soil moisture with NOAA ancillary Data

Soil Moisture Operational Product System Data Processing Functions



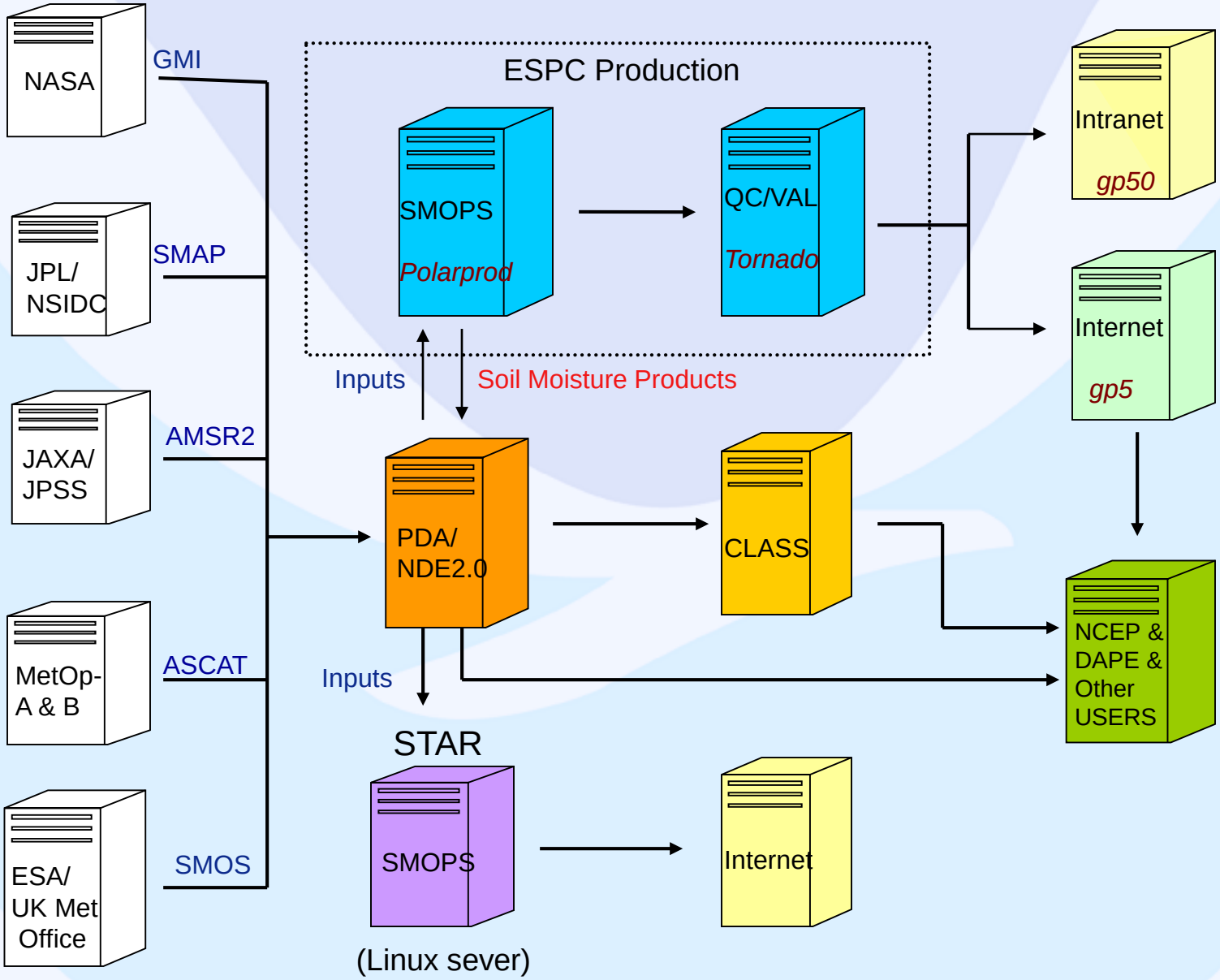
* *All data acquired within the 6 hour or whole day time period arrived in the past 48 hours*

1. **SM ingesting**
2. **SM retrieving**
3. **SM merging**
4. **Reprocessing for the archive product**

SMOPS Algorithm

- A single-channel algorithm is used to retrieve soil moisture from x-band brightness temperature observations (Jackson, 1993);
- An regression equation is used to estimate land surface temperature from 37GHz brightness temperature (de Jeu, 2008);
- An empirical equation is used to estimate vegetation optical depth from optical observations of vegetation index (Jackson & Schmugge, 1991);
- A CDF-matching approach is used to merge soil moisture retrievals from difference satellite sensors.

SMOPS Production IT Infrastructure



Input Data: MetOp-A & B ASCAT soil moisture data, and SMOS Level 1B & L2 soil moisture data, AMSR2 L1B & soil moisture, GMI L1C, SMAP SM and VIIRS EVI

SMOPS Output File Data layers

Soil Moisture Product	SMOPS Version 1.3	SMOPS Version 2.0	SMOPS Version 3.0
SMOPS Blended	√ (1)	√ (1)	√ (1)
NOAA AMSR-E	√ (2)	×	×
NOAA 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)
NOAA GMI	×	×	√ (7)
NOAA NRT SMAP	×	×	√ (8)
NASA SMAP	×	×	√ (9)

SMOPS Product Suite

Products	Description	Format	Projection	Spatial Coverage	Spatial Resolution	Main Purpose
SMOPS 6-Hour Product	SMOPS 6-hour Gridded Soil Moisture	GRIB2	Lat/Long	Global	0.25 degree (720x1440)	For operational use
SMOPS Daily Product	SMOPS Daily Gridded Soil Moisture	GRIB2	Lat/Long	Global	0.25 degree (720x1440)	For operational/ research use
SMOPS Archive Product	SMOPS Daily Gridded Soil Moisture	netCDF4	Lat/Long	Global	0.25 degree (720x1440)	For research use

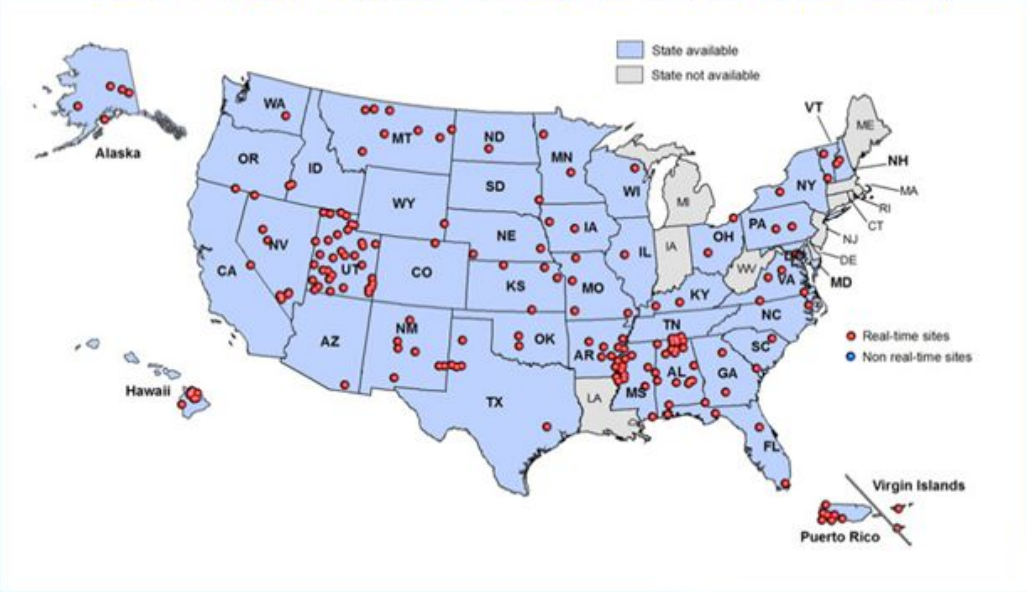
SMOPS Product Validation (1/11)

Comparison with in situ measurements:

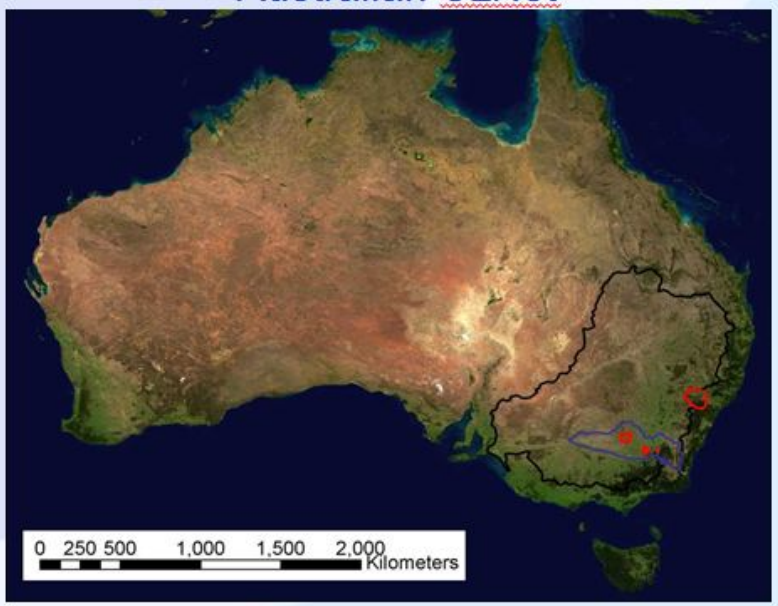
- Field Data Used
  - SCAN (Soil Climate Analysis Network, USDA)
  - USDA-ARS MicroNet
  - Australian OzNet
  - China SMNet
- Data Quality Verified against User Requirements
  - Soil moisture time series for the observation site.
  - Statistical metrics, including mean, standard deviation, RMSE, mean bias, etc.

SMOPS SM Product Validation Data Sets (2/11)

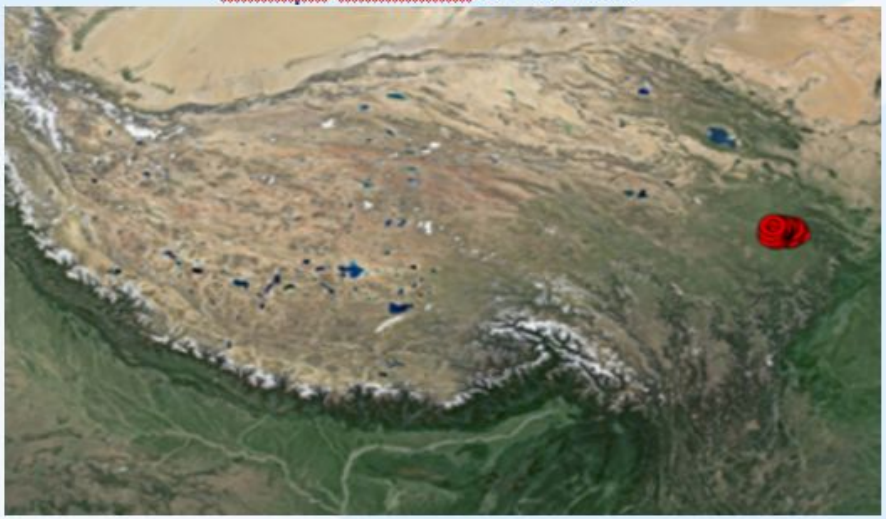
SCAN (Soil Climate Analysis Network, USDA)



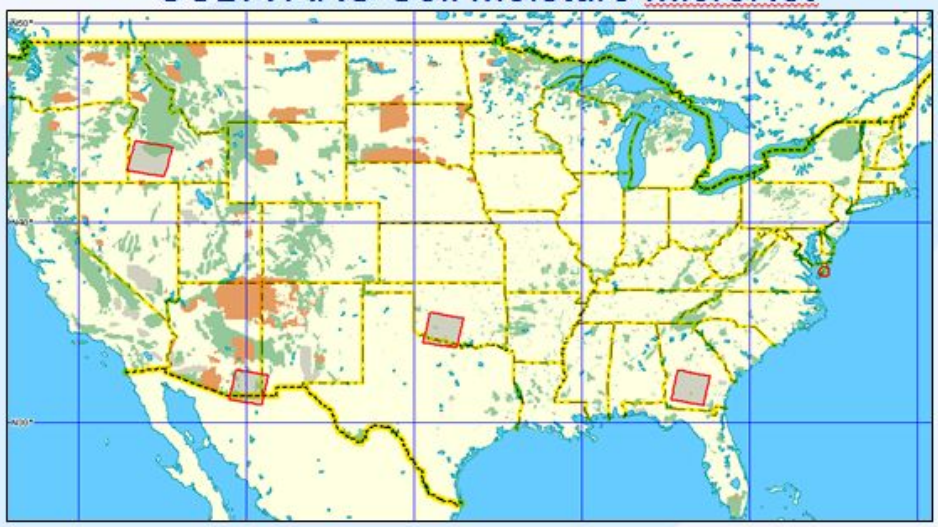
Australian OzNet



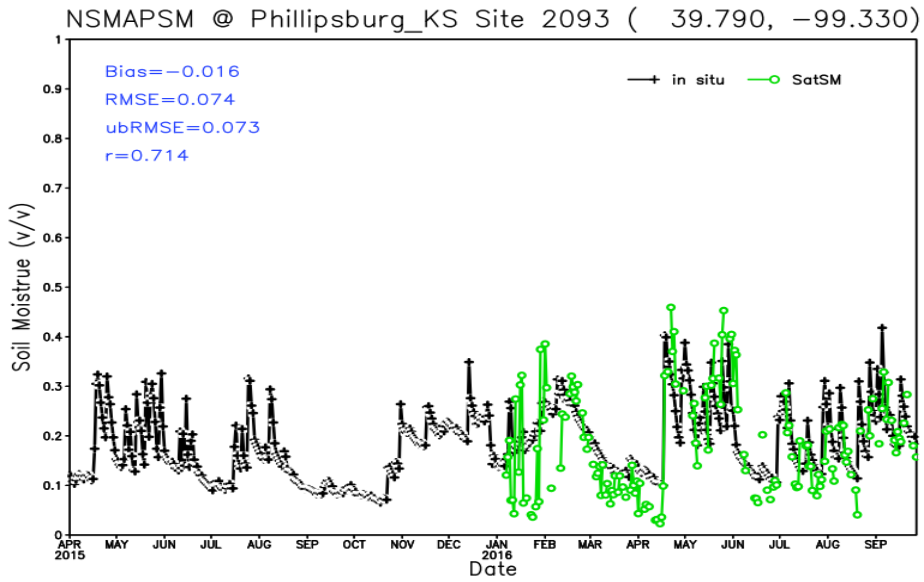
Maqu SMNet of China

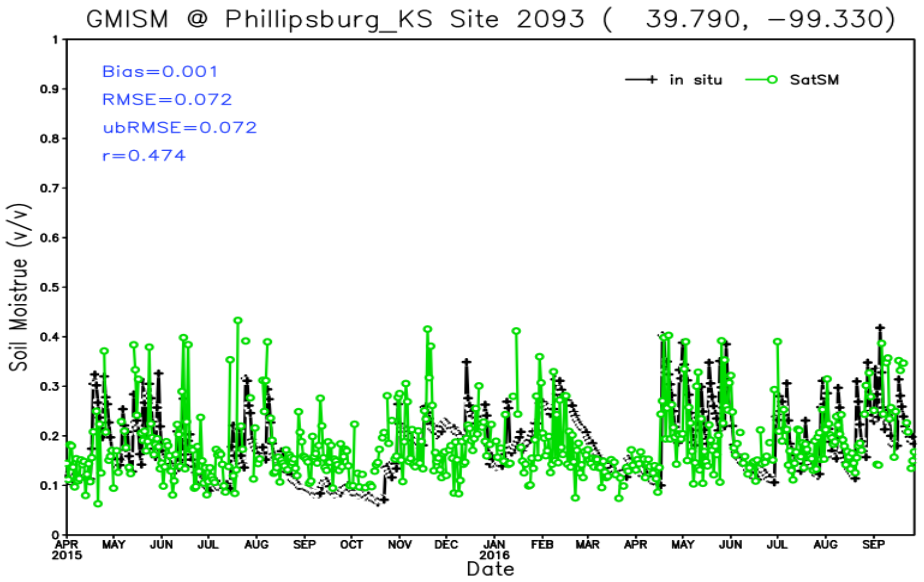


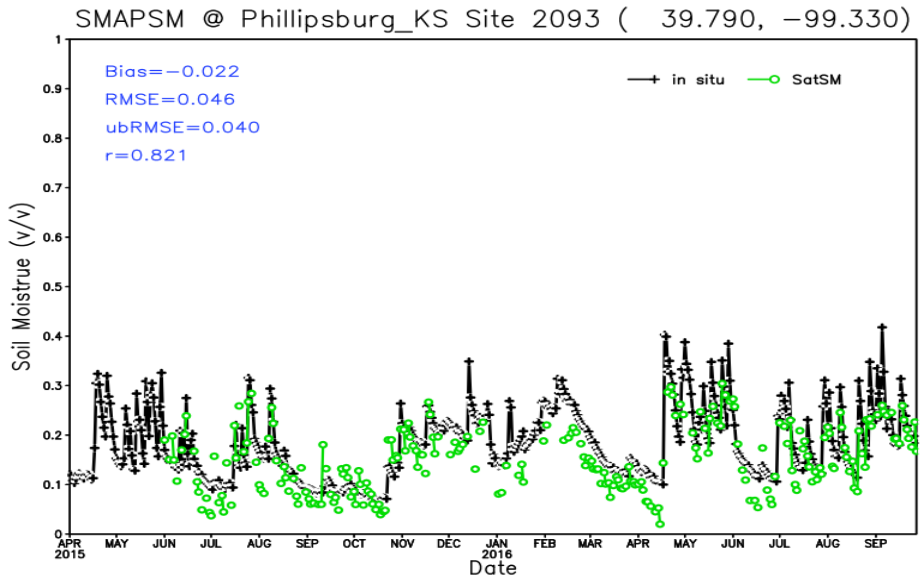
USDA-ARS Soil Moisture MicroNet

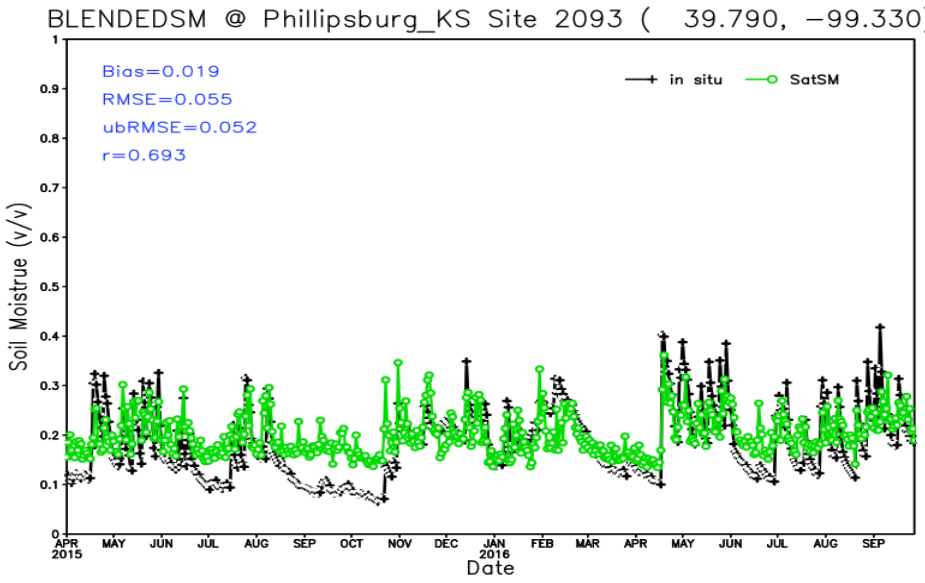


CASE 1: SMOPS SM vs Phillipsburg_KS (3/11)

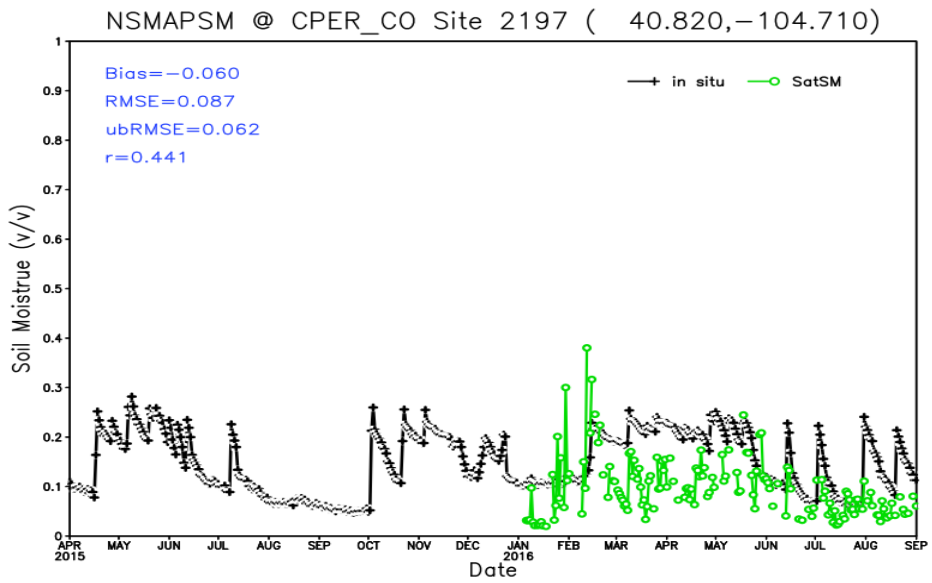


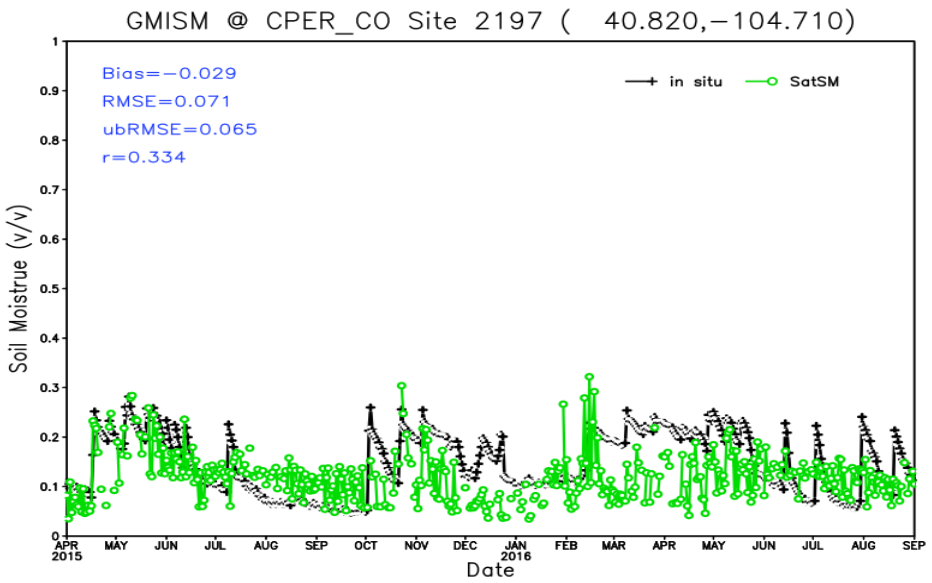


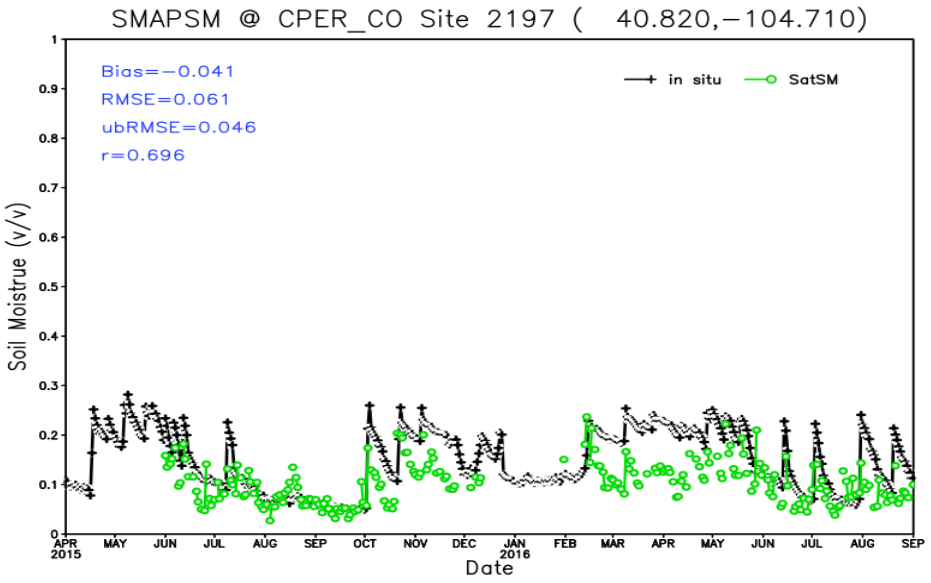


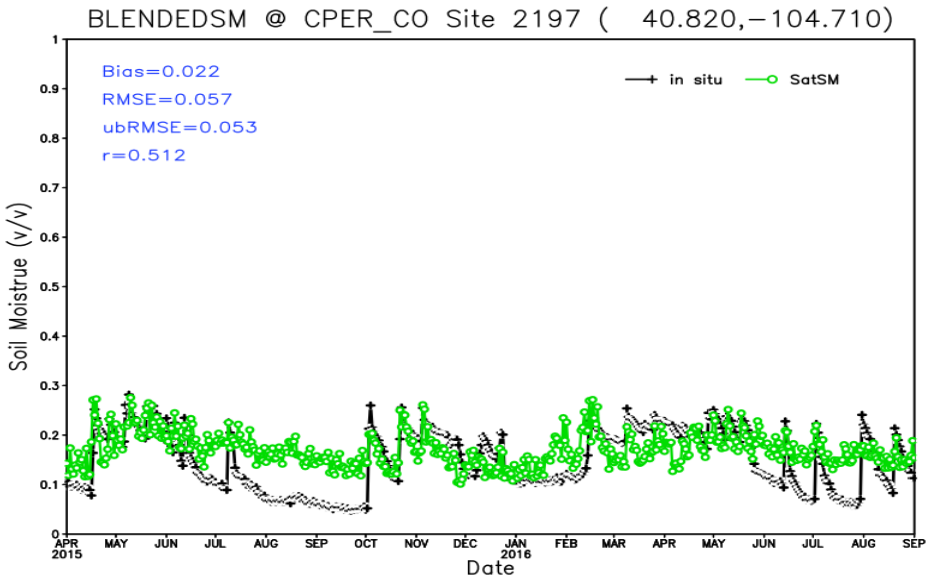


CASE 2: SMOPS SM vs CPER_CO (4/11)

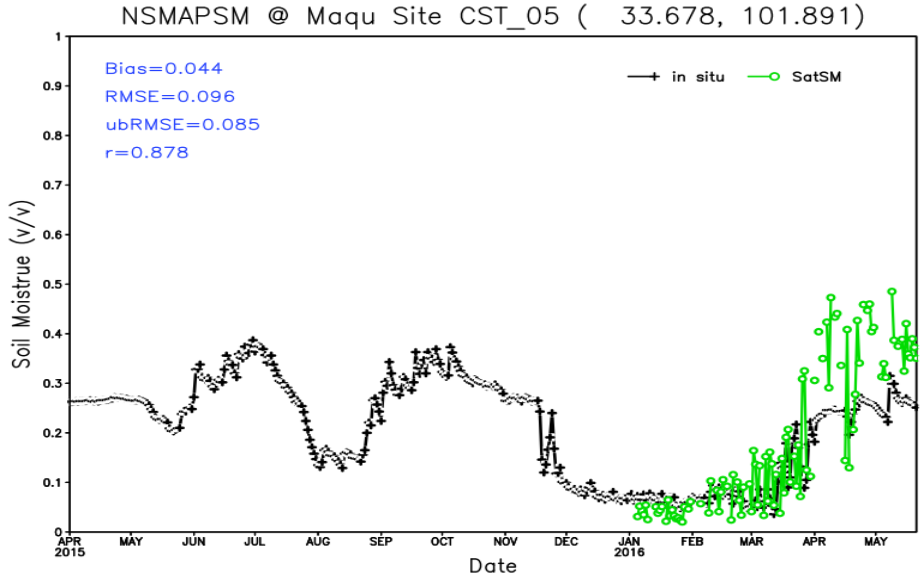


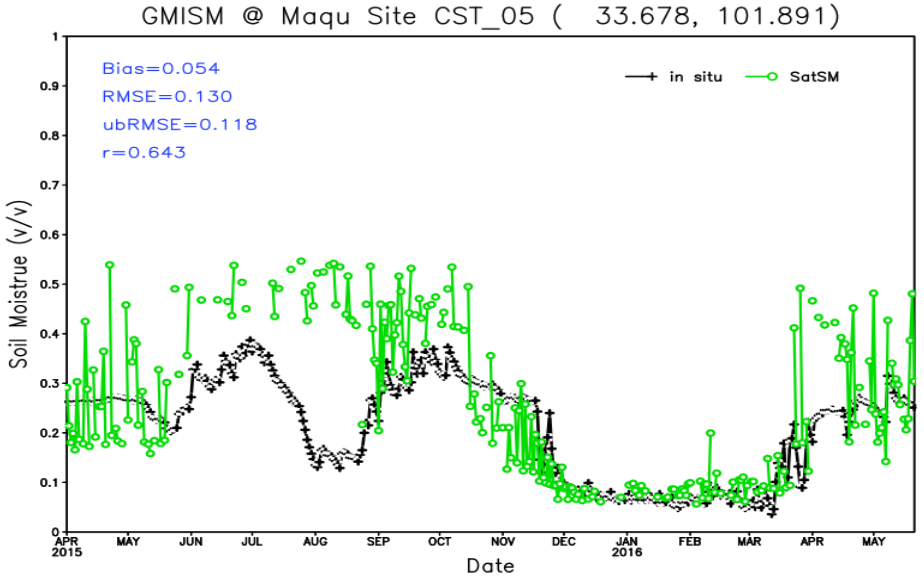


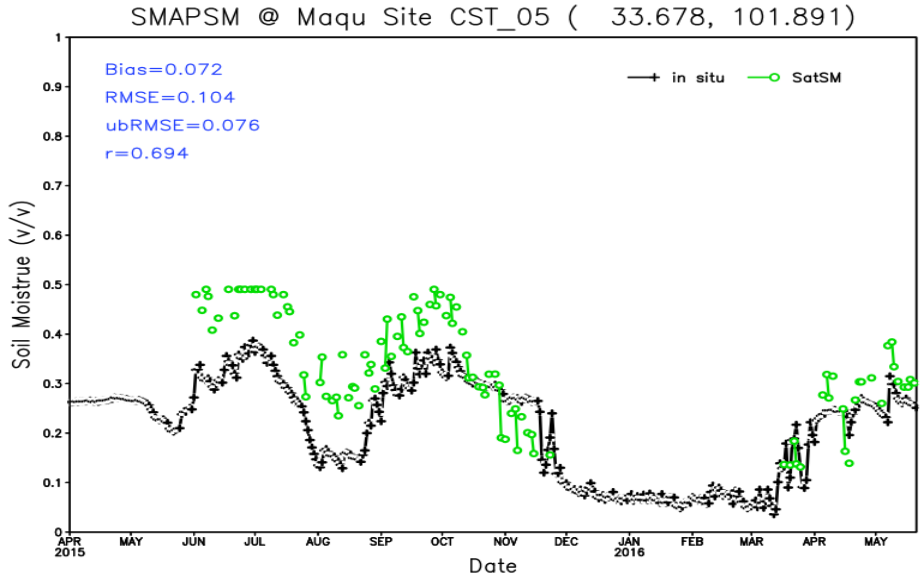


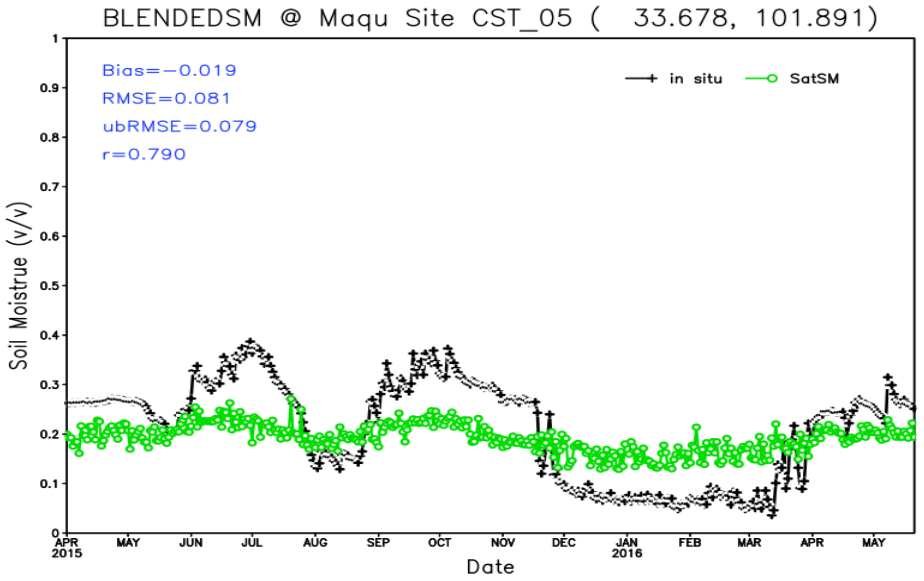


CASE 3: SMOPS SM vs Maqu_CN (5/11)

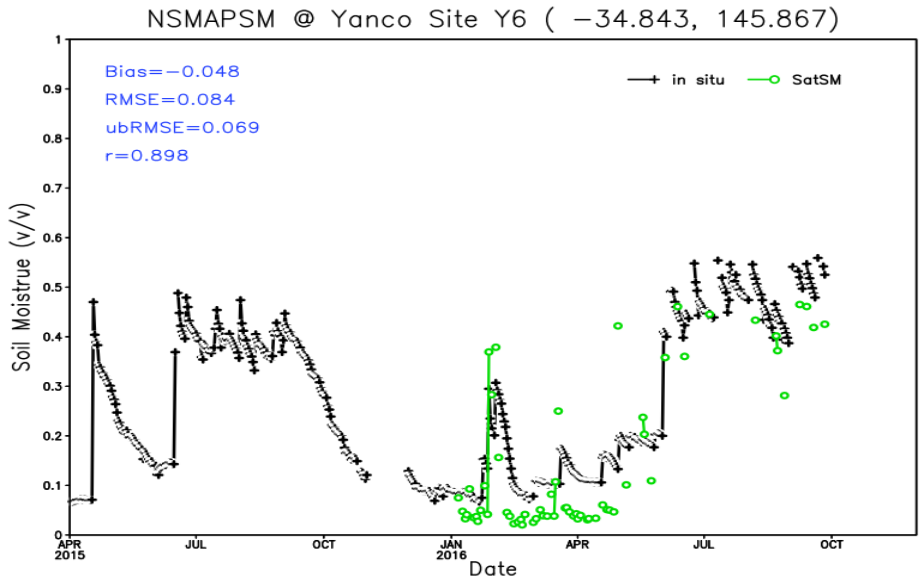


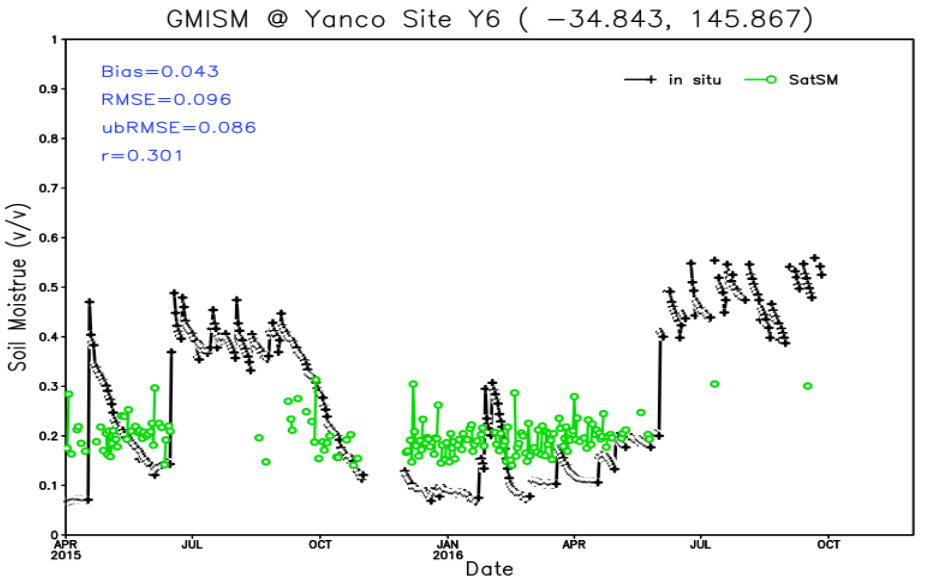


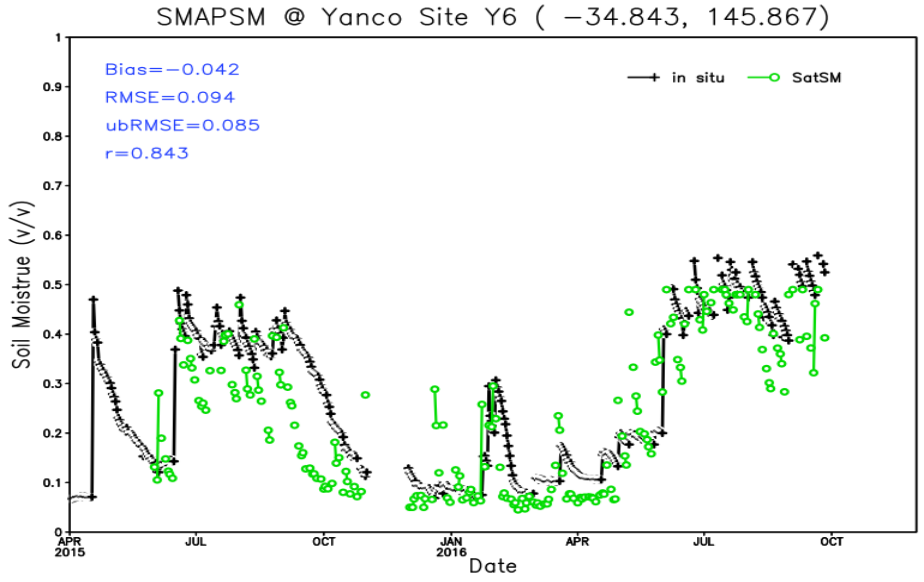


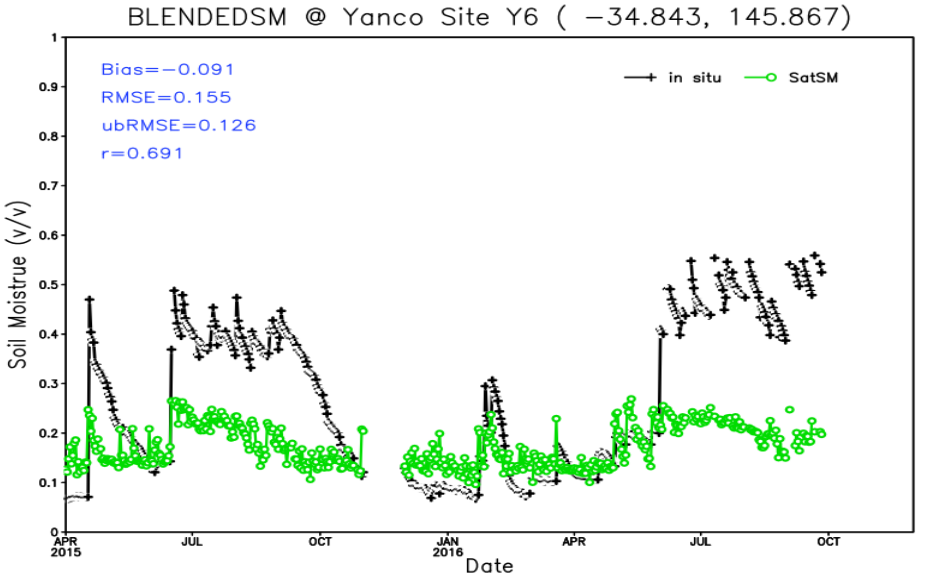


CASE 4: SMOPS SM vs Yanco_OZ (6/11)

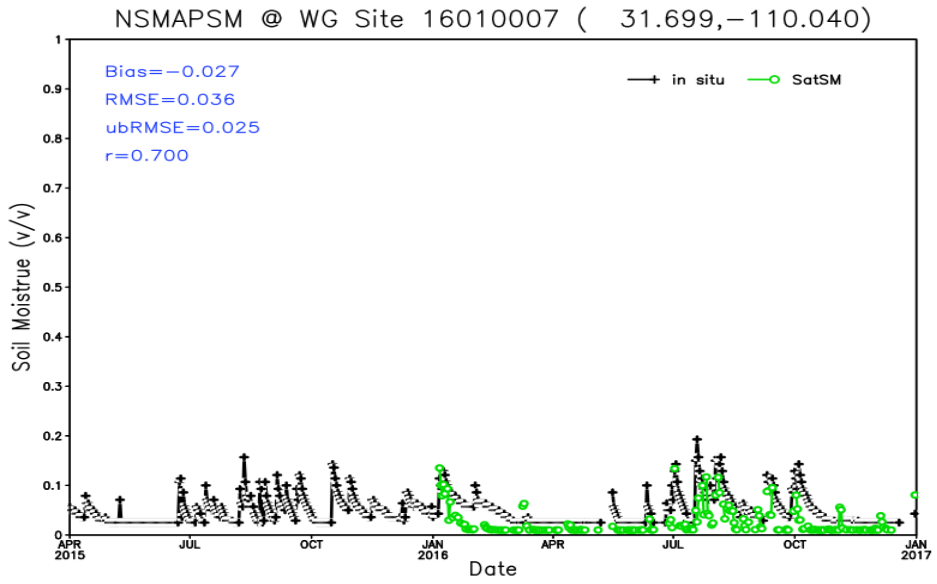


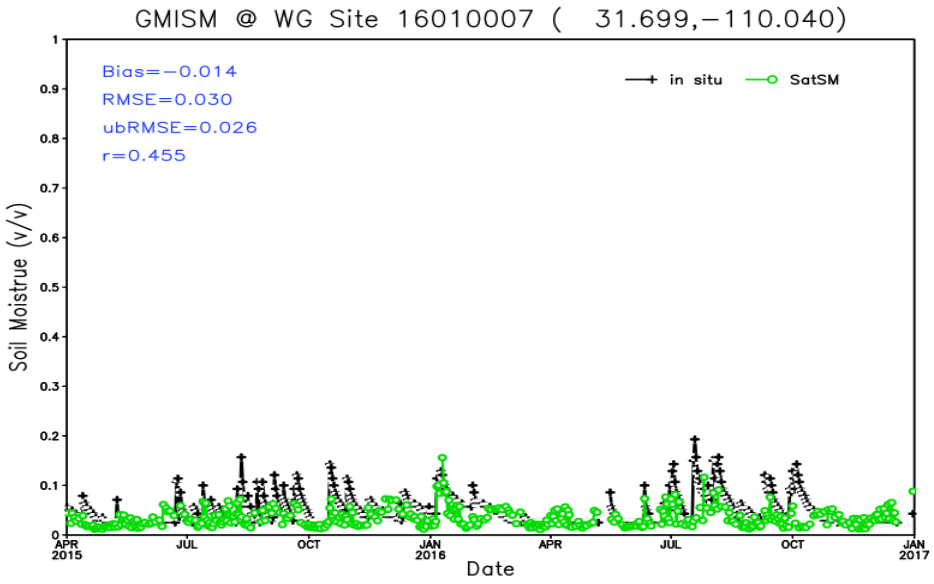


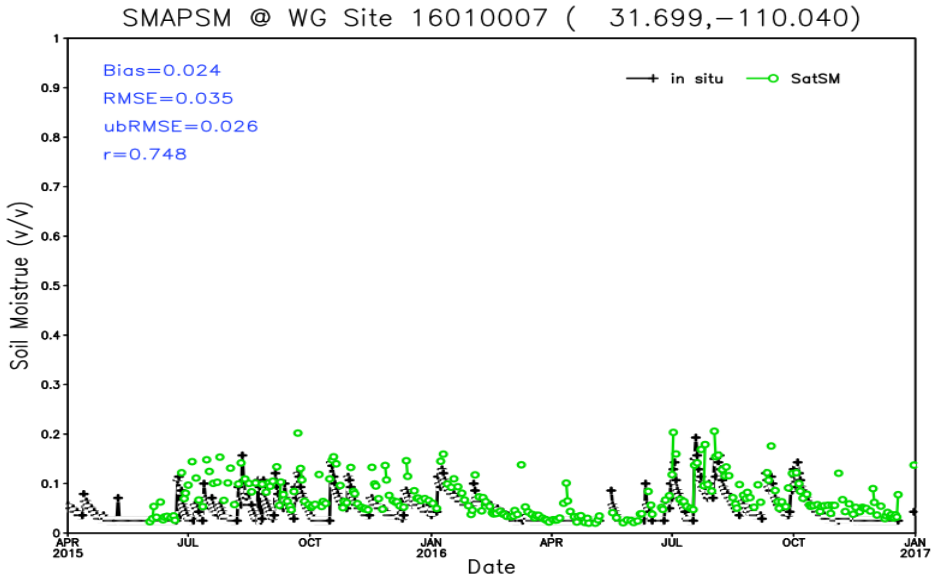


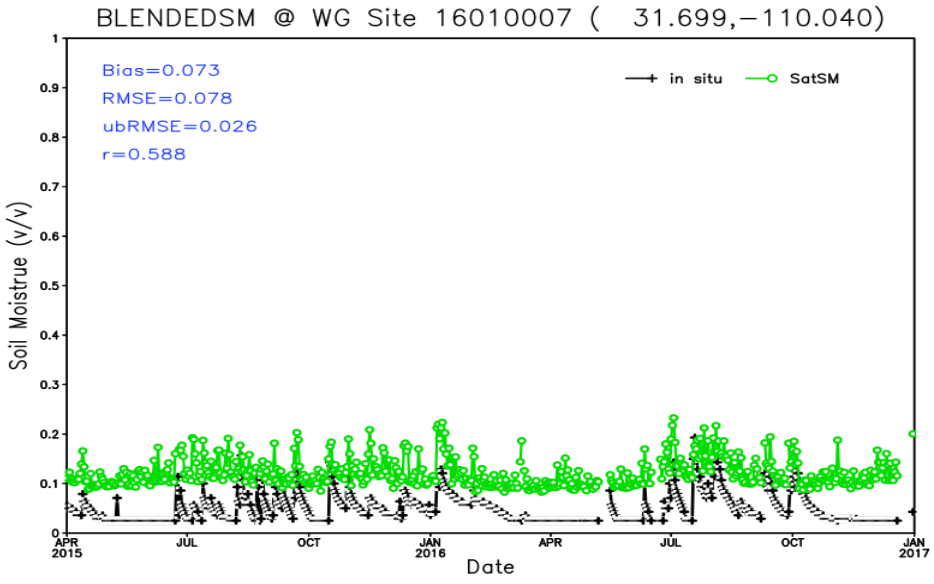


CASE 5: SMOPS SM vs WG_AZ (7/11)

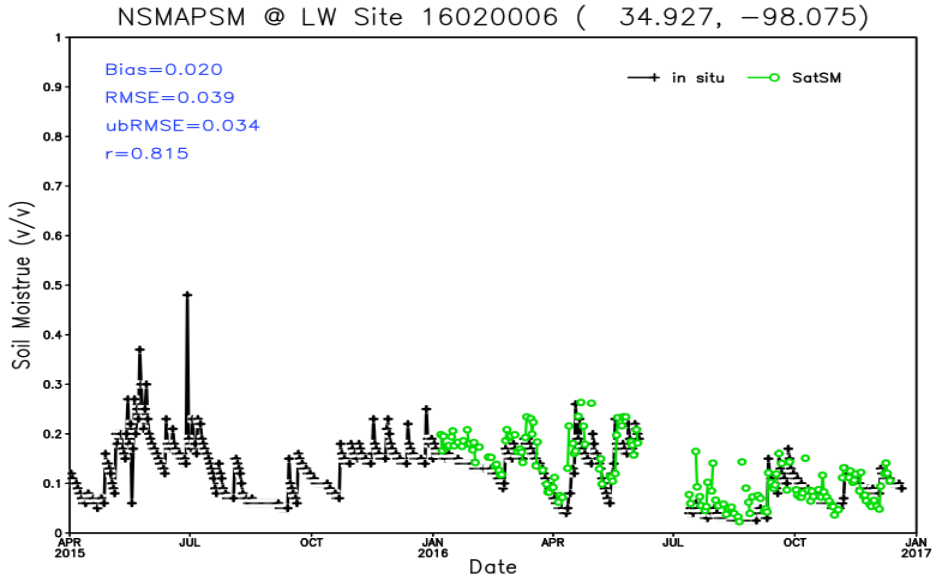


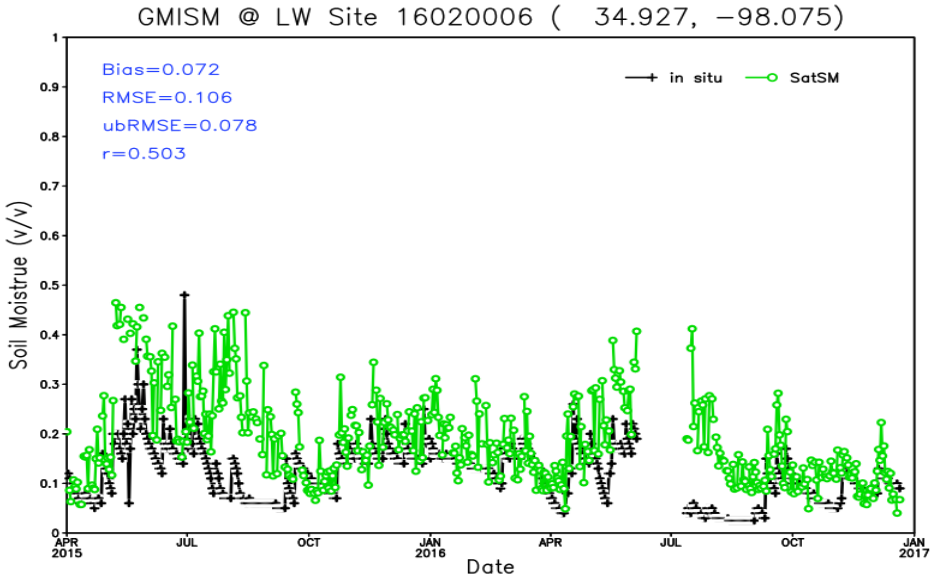


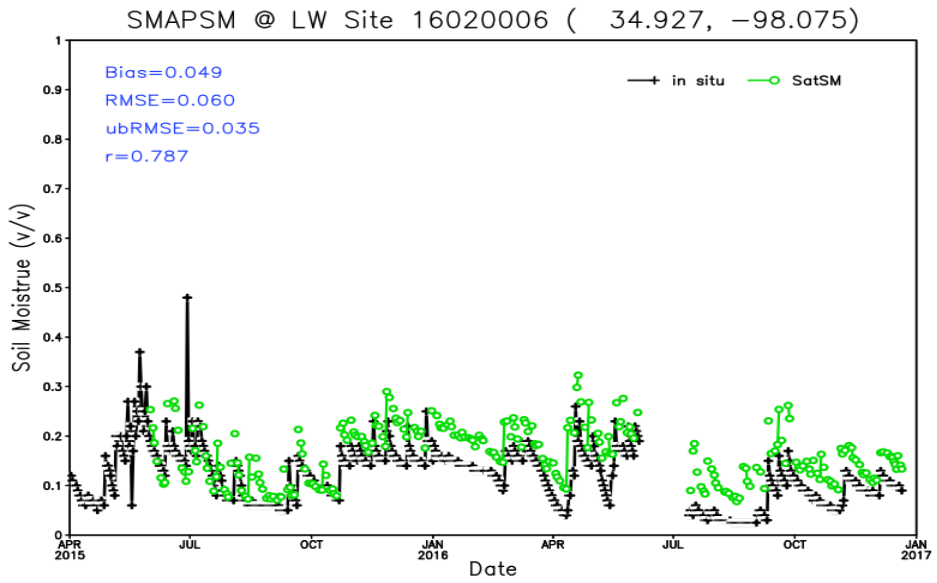


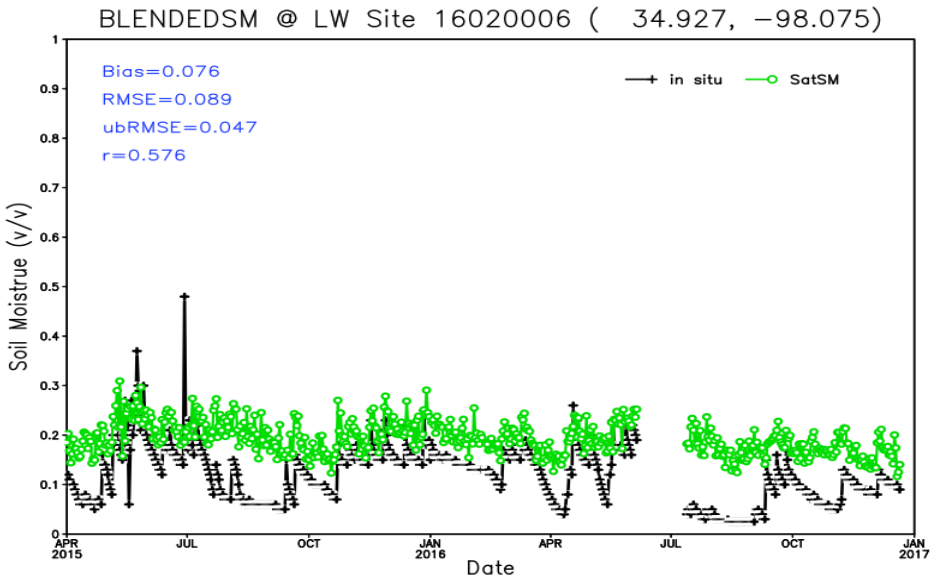


CASE 6: SMOPS SM vs LW_OK (8/11)









SMOPS SM Product Validation (9/11)

In situ Sites	*Correlation Coefficient (r)*			
	GMI	*NSMAP*	*SMAP*	*Blended*
Phillipsburg, KS	0.474	0.714	0.821	0.693
CPER, CO	0.334	0.441	0.696	0.512
Torrington, WY	0.437	0.684	0.711	0.577
Geneva, NY	0.355	0.501	0.779	0.486
Maqu, China	0.643	0.878	0.694	0.790
Yanco, Australia	0.301	0.898	0.843	0.691
WG, AZ	0.455	0.700	0.748	0.588
LW, OK	0.503	0.815	0.787	0.576
Average	**0.438**	**0.704**	**0.760**	**0.614**

- *Different products have different performance, which could be caused by the different heterogeneity feature of in situ site and product accuracy*

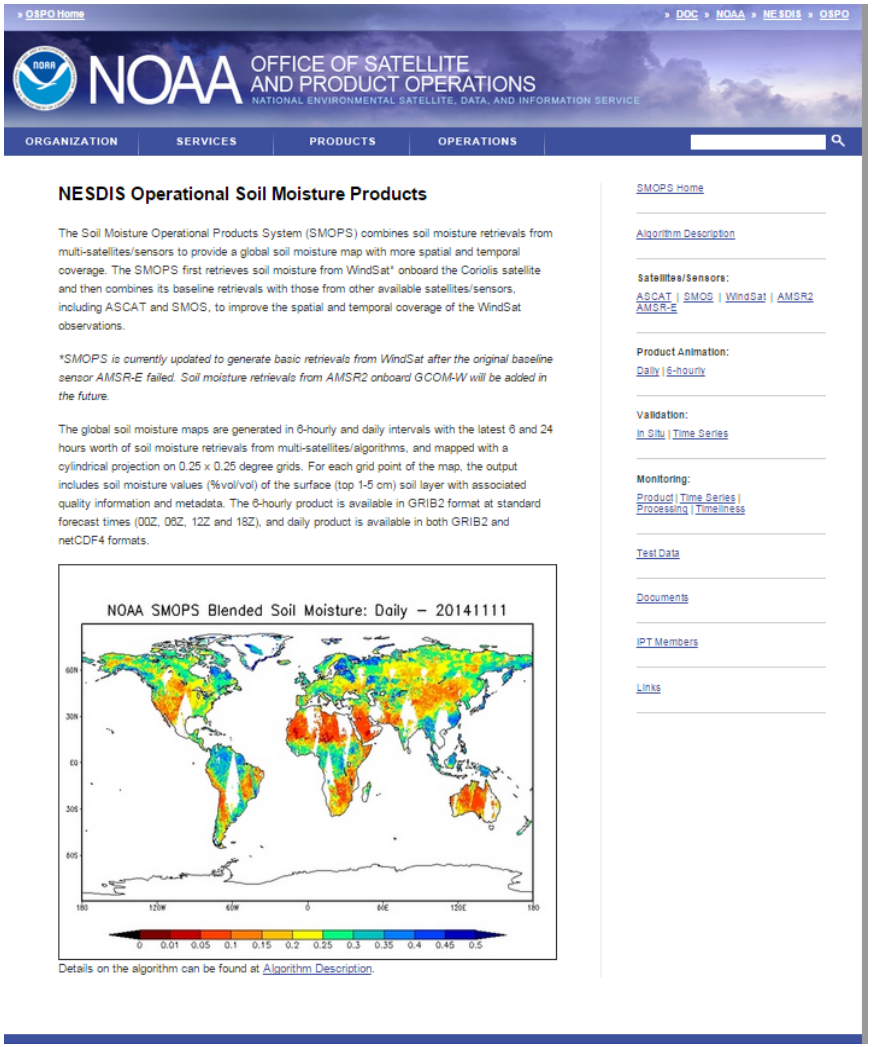
SMOPS SM Product Validation (10/11)

In situ Sites	*Unbiased Root-mean-square-error(ubRMSE)*			
	GMI	*NSMAP*	*SMAP*	*Blended*
Phillipsburg, KS	0.072	0.073	0.040	0.052
CPER, CO	0.065	0.062	0.046	0.053
Torrington, WY	0.047	0.034	0.035	0.040
Geneva, NY	0.064	0.094	0.047	0.066
Maqu, China	0.118	0.085	0.076	0.079
Yanco, Australia	0.086	0.069	0.085	0.126
WG, AZ	0.026	0.025	0.026	0.026
LW, OK	0.078	0.034	0.035	0.047
Average	**0.070**	**0.060**	**0.049**	**0.061**

- *The ubRMSE average **6.1%** [v/v] meets the **4-10%** [v/v] requirement specified in the NCEP user request (SPSRB requirement **#0707-17**).*

Soil Moisture Operational Product System

http://www.ospo.noaa.gov/Products/land/smops/index.html



- **Developed by NOAA/NESDIS/STAR**
- **Operationally running at NOAA/NESDIS/OSPO**

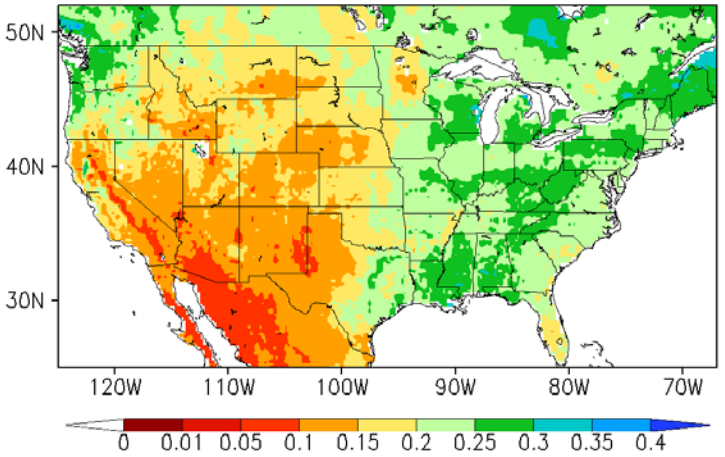
Operational data access contact:
Limin.Zhao@noaa.gov

Science and historical data contact:
Xiwu.Zhan@noaa.gov,
Jicheng.Liu@noaa.gov,

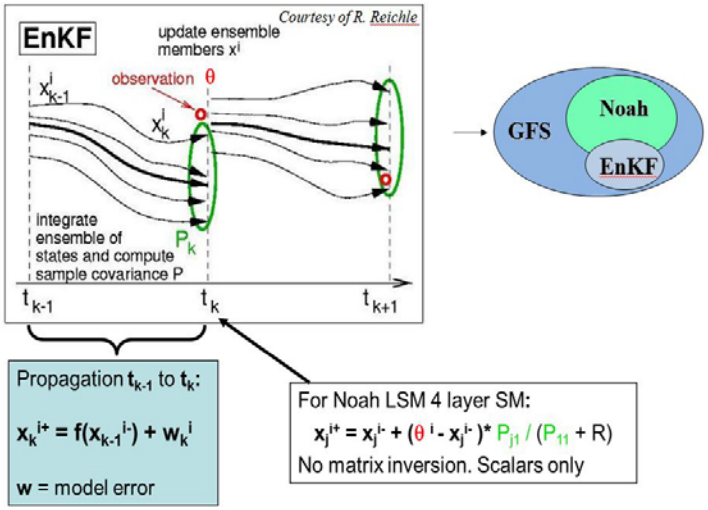
Assimilation of SM in NCEP GFS

- SMOPS combines soil moisture retrievals from multiple satellites sensors to provide a global climatologically consistent soil moisture map with more spatial and temporal coverage.

- Positive impact has been shown on the model performance, particularly for precipitation forecasts by assimilating SMOPS blended product into GFS using a simplified EnKF

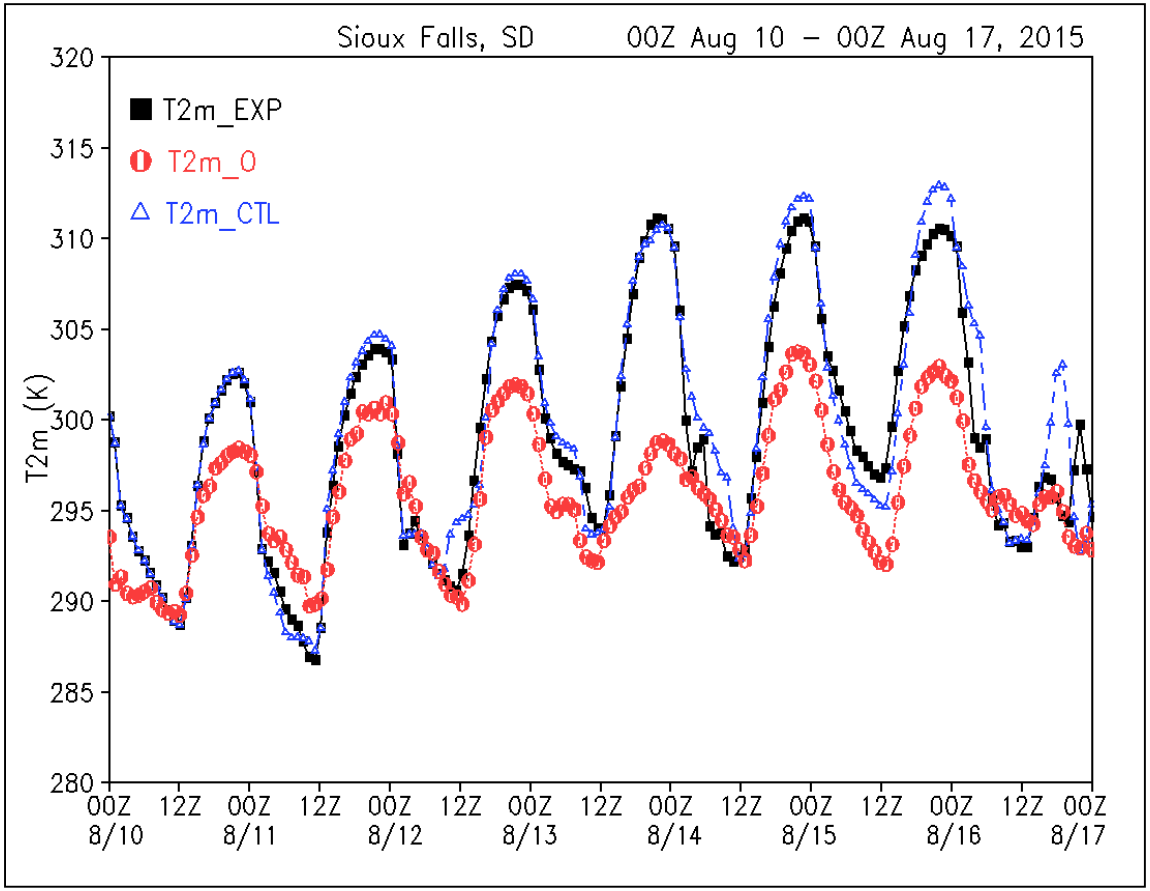


SMOPS blended product over CONUS in Apr 2012



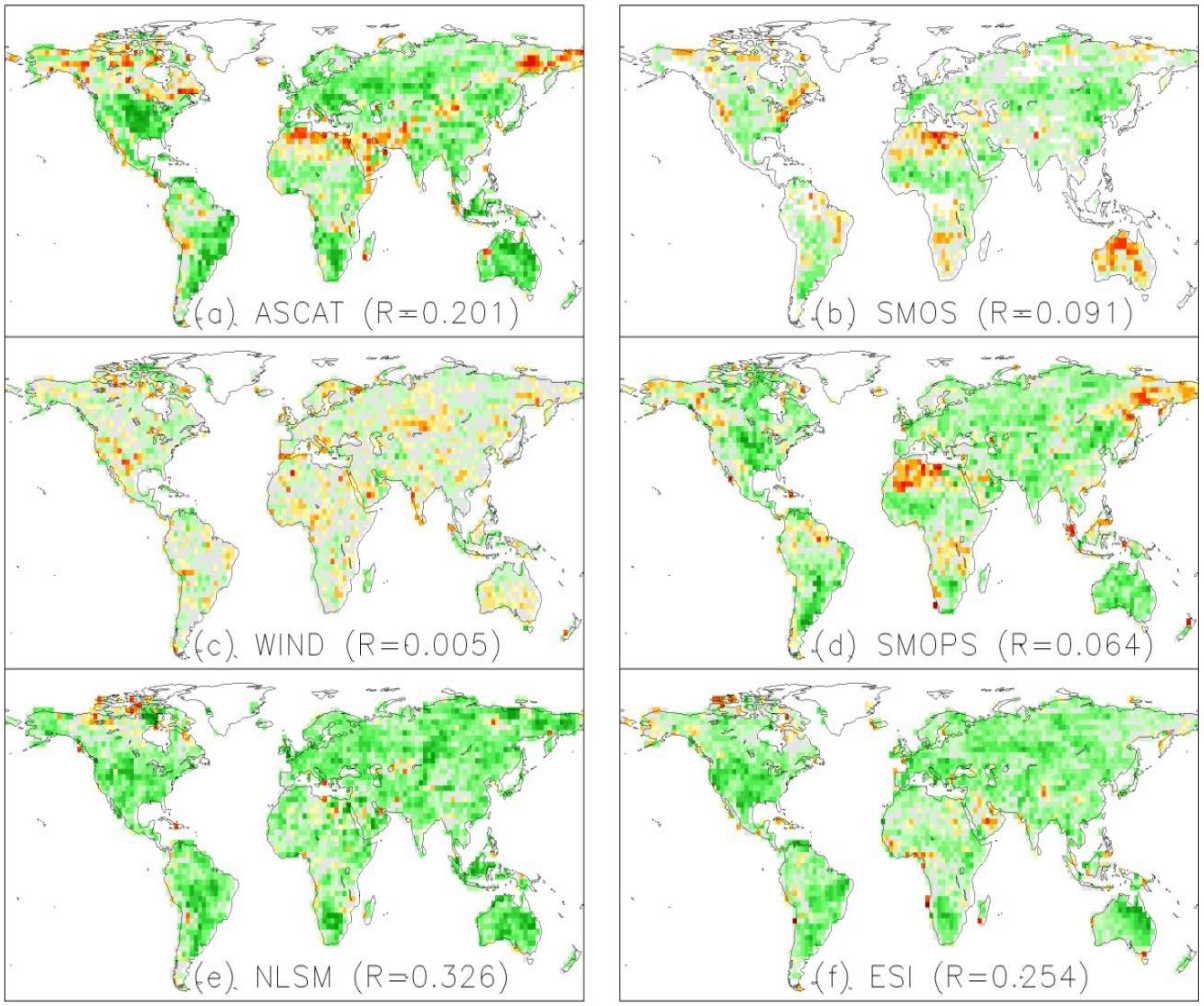
A Simplified EnKF data assimilation utility implemented in NCEP GFS

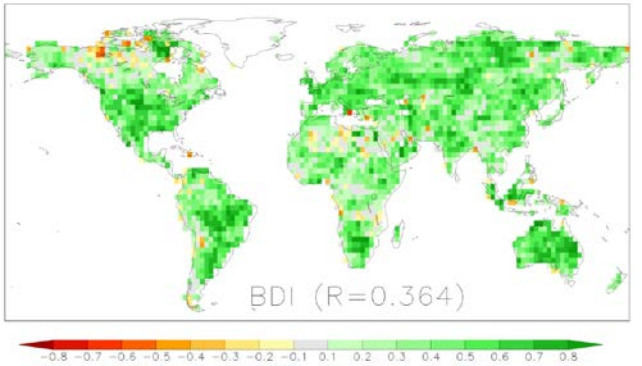
Assimilation of SM in NCEP GFS



Assimilating SMAP SM from 8/1 – 8/10/2015 Reduces the daytime warm biases of NCEP GFS four (4) day forecasts of 2 meter air temperature

Blending Sat SM for Drought Monitoring





Correlation coefficients (R) between PDSI standard anomalies (against 1985-2014 averages) and drought estimations for (a) ASCAT, (b) SMOS, (c) WindSat, (d) SMOPS, (e) NLSM and (f) ESI cases. Grey color indicates insignificant correlation. The Blended Drought Index (BDI) has better correlation than all other data sources

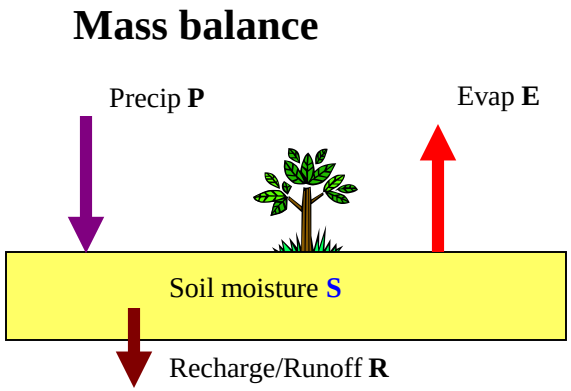
SUMMARY

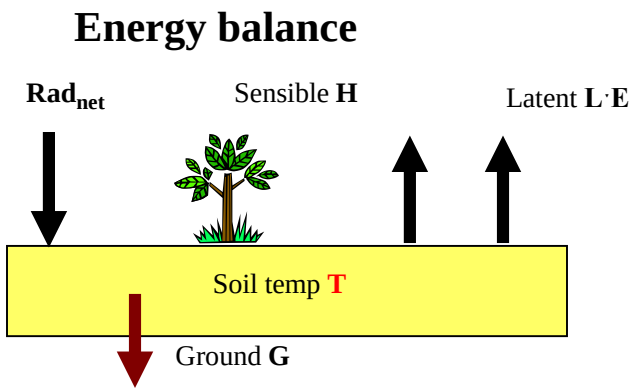
- *Soil moisture is required for NWP model initialization*
- *A soil moisture operational product system (SMOPS) has been developed for providing users with near real time satellite soil moisture products and their blend*
- *Current SMOPS blends soil moisture observations from ASCATs (MetOp-A & MetOp-B), SMOS (ESA & NRT), AMSR2, SMAP (NASA & NRT), GMI*
- *Application of these products in drought monitoring operations and NCEP models are explored*

Thanks for your attention!

Why Soil Moisture for NOAA

Soil moisture controls land surface **mass** and **energy** partitioning through impacting **evapotranspiration**





$$V\frac{dS}{dt} = P - E(T, S) - R(S) \quad \Longleftrightarrow \quad c\frac{dT}{dt} = Rad_{net}(T) - H(T) - L \cdot E(T, S)$$

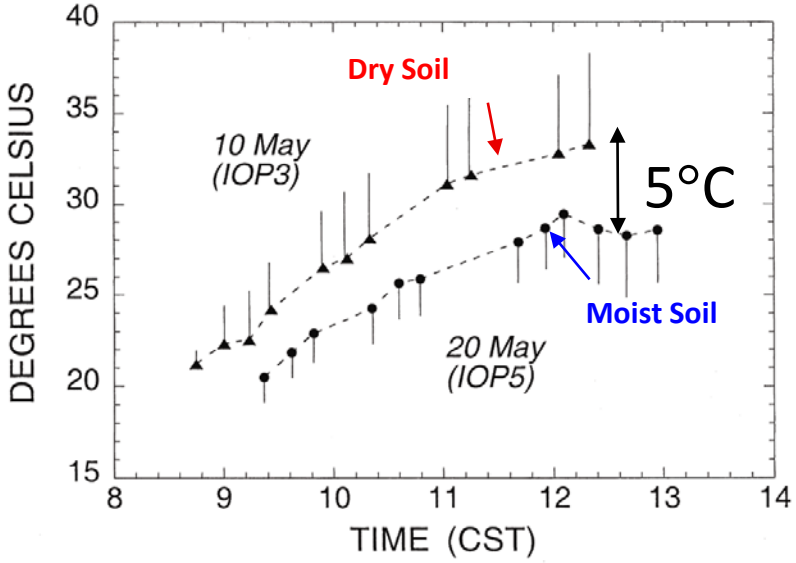
Evaporation & soil moisture **couple mass & energy balances** at land surface

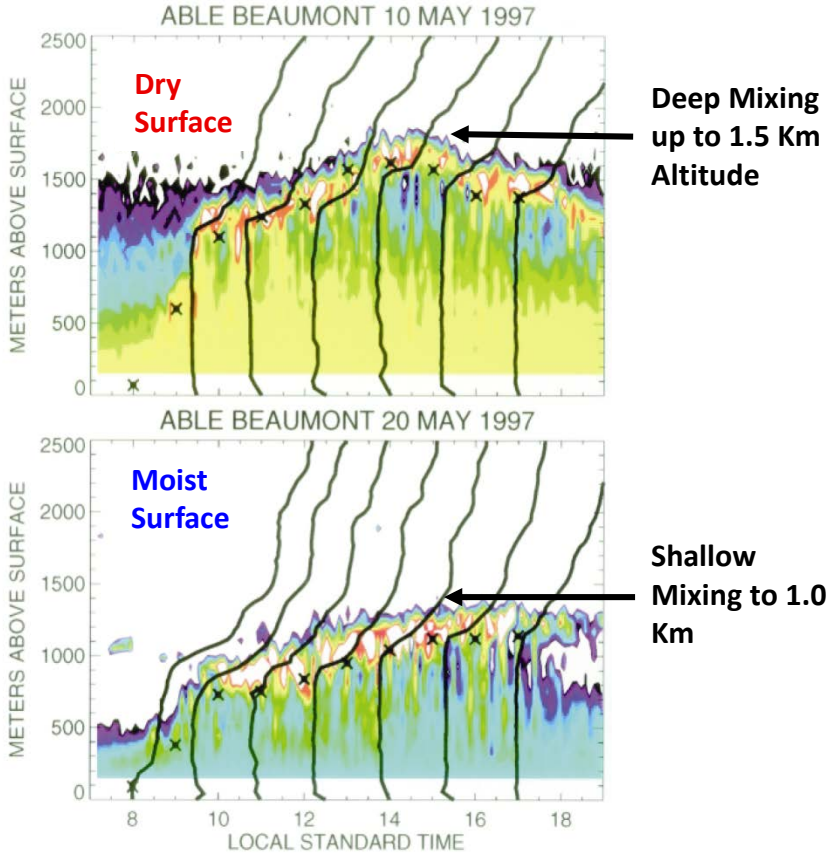
L is the latent heat of vaporization: 2.5×10^6 [J/kg]

Why Soil Moisture for NOAA

Over land actual evapotranspiration depends on both **incident energy** and **soil moisture**.

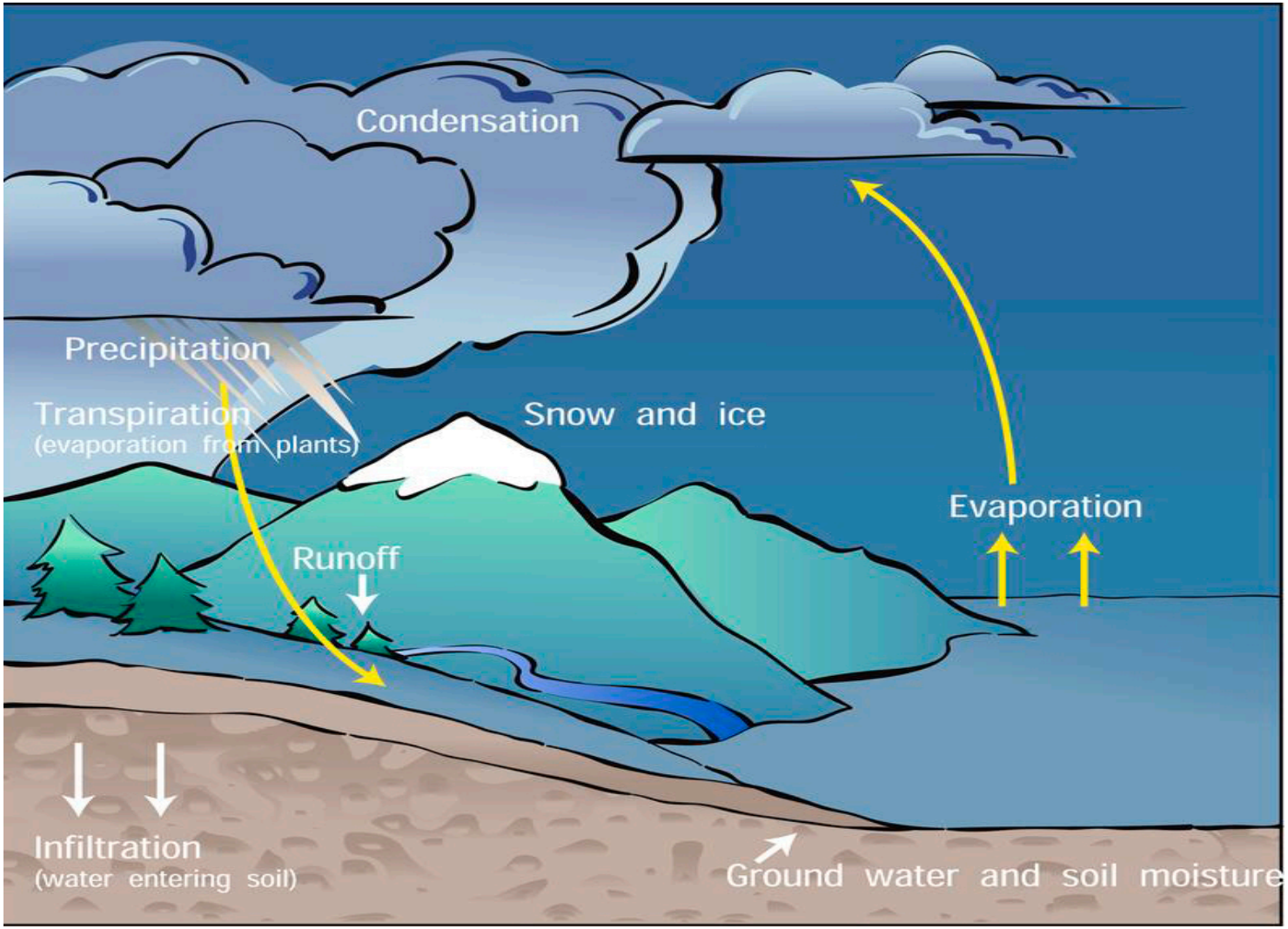
May 10	Dry soil, clear, mild winds. (**LE≈H**)
May 18	90 mm Rain
May 20	Moist soil, clear, mild winds. (**LE>H**)





CASES'97 Field Experiment, *BAMS*, 81(4), 2000.

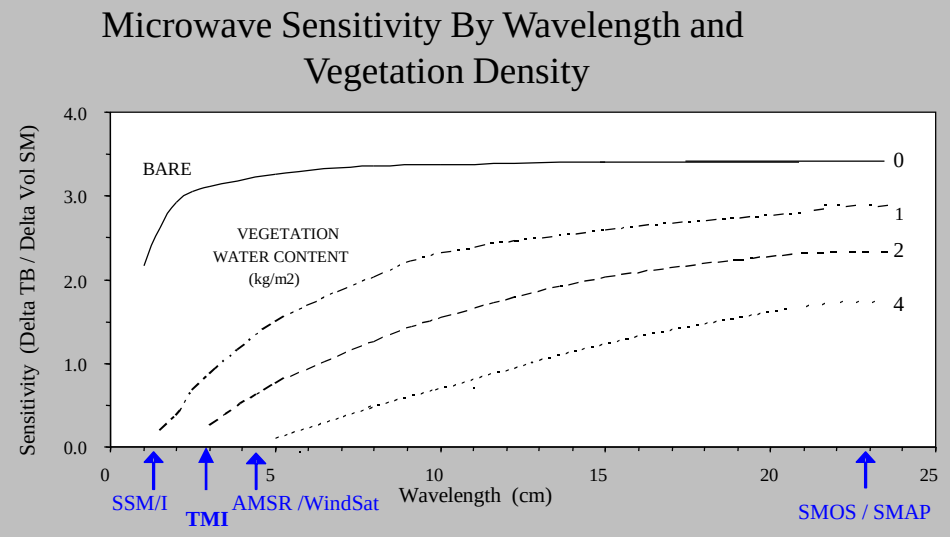
Soil Moisture for Water Cycle Studies

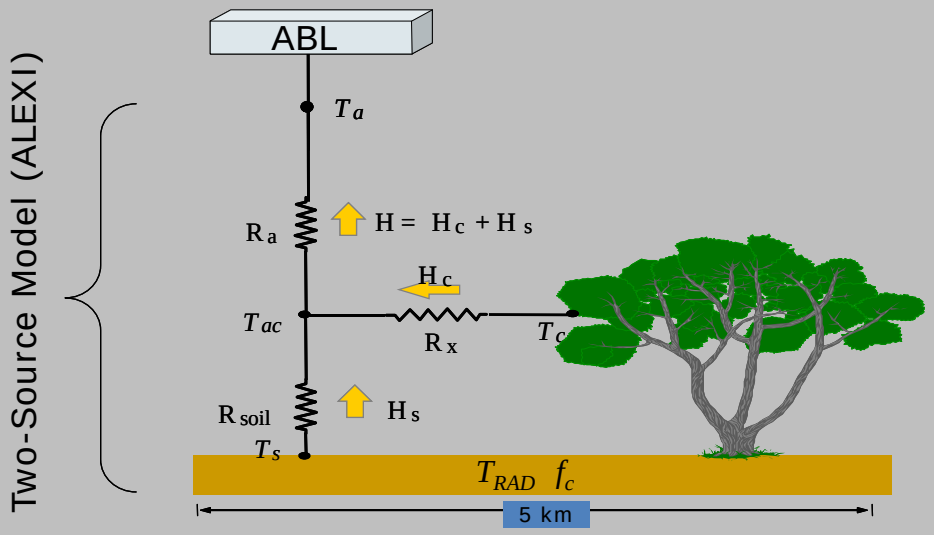


Soil Moisture Remote Sensing Science

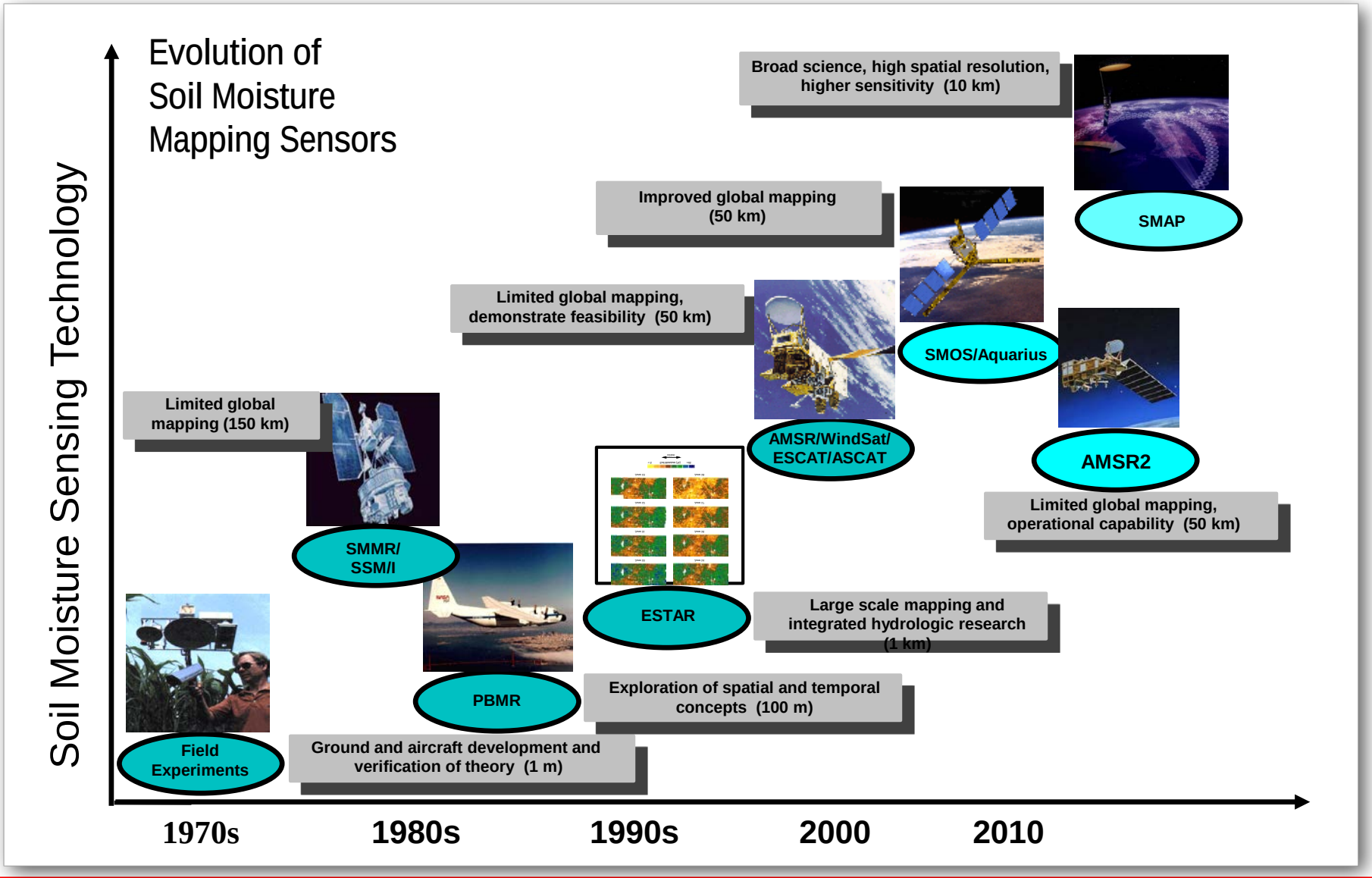
Two ways to retrieve soil moisture from satellites:

- Microwave (MW): Observed MW brightness temperature depends on soil dielectric constant that is related to soil moisture:
  - **Strength:** higher reliability based on direct physical relationships
  - **Weakness:** antenna technology limits spatial resolution
- Thermal Infrared (TIR): Observed surface temperature changes result from surface energy balance that is dependent on soil moisture:
  - **Strength:** TIR sensor could have higher spatial resolution
  - **Weakness:** relies on land surface energy balance model that is prone to input data errors.





MW Soil Moisture Remote Sensing Technology



Ensemble Tropical Rainfall Potential (eTRaP)

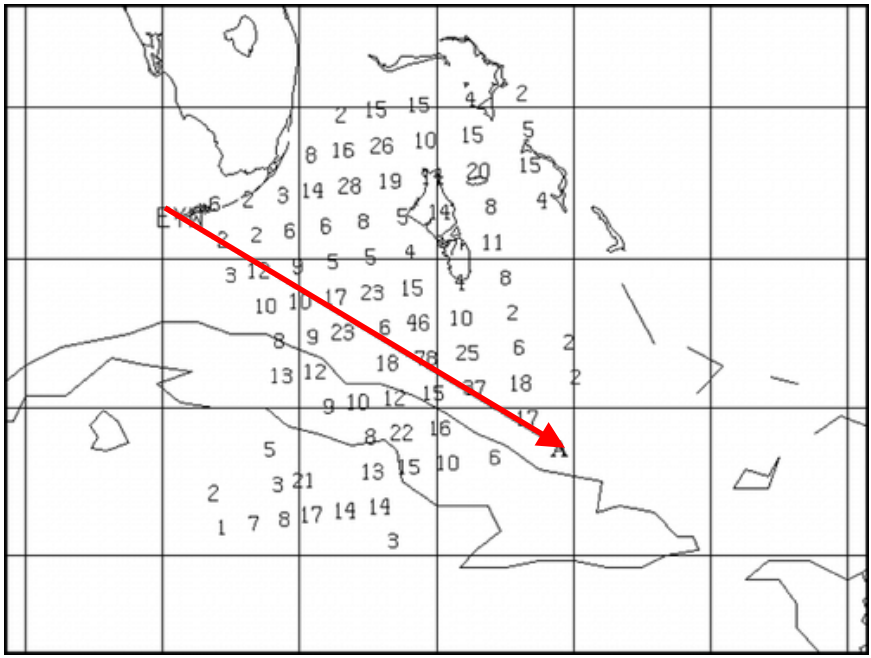
Bob Kuligowski

NOAA / NESDIS / Center for Satellite Applications and Research (STAR)

…and many others!

eTRaP Background

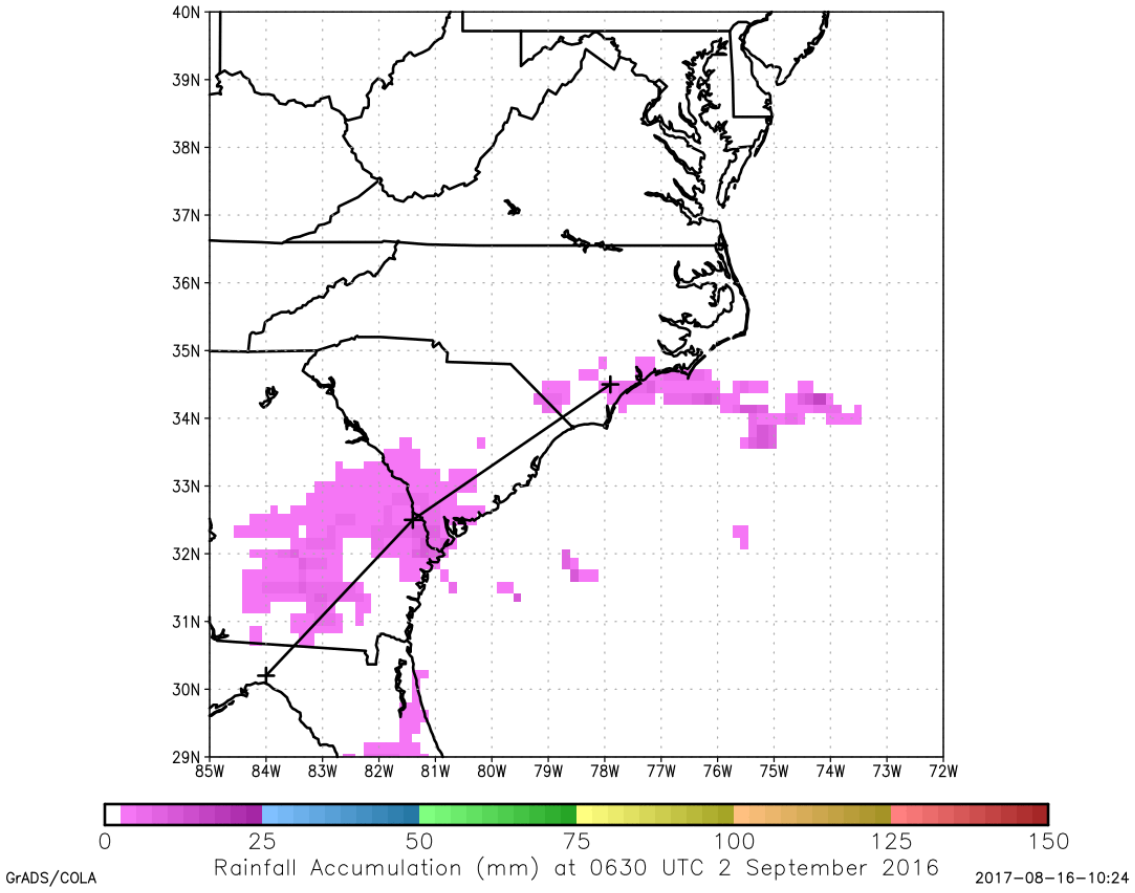
- eTRaP began in the 1980s with Tropical Rainfall Potential (TRaP), which was initially a manually-produced, point forecast of total rainfall from a tropical system
  - Initially based on its satellite-estimated diameter, speed, and average rain rate
  - Later based on gridded rain rates from microwave retrievals



NOAA-15 AMSU-A rain rates (0.01”/h) for Hurricane Georges at 0023 UTC 25 September 1998

eTRaP Background

- This eventually evolved into an automated, gridded forecast of 24-h rainfall from a tropical system by advecting the (gridded) satellite estimates of instantaneous rain rate forward along the operational forecast track



eTRaP Background

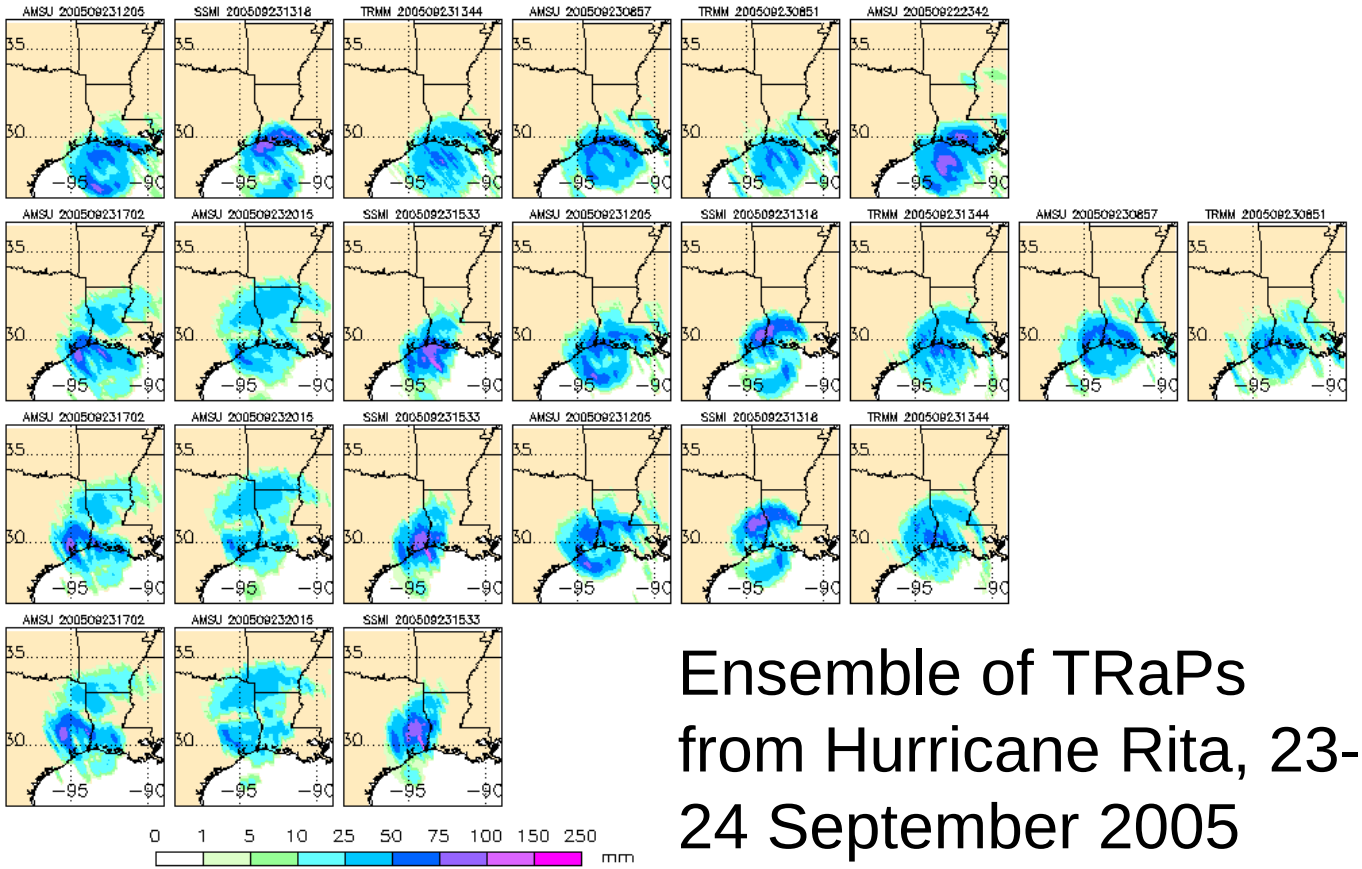
- The next step was to create an ensemble of TRaPs from different sensors, forecast initialization times, and operational forecast tracks to get deterministic and probabilistic (threshold exceedance) rainfall forecasts

18-00 UTC

00-06 UTC

06-12 UTC

12-18 UTC



Ensemble of TRaPs from Hurricane Rita, 23-24 September 2005

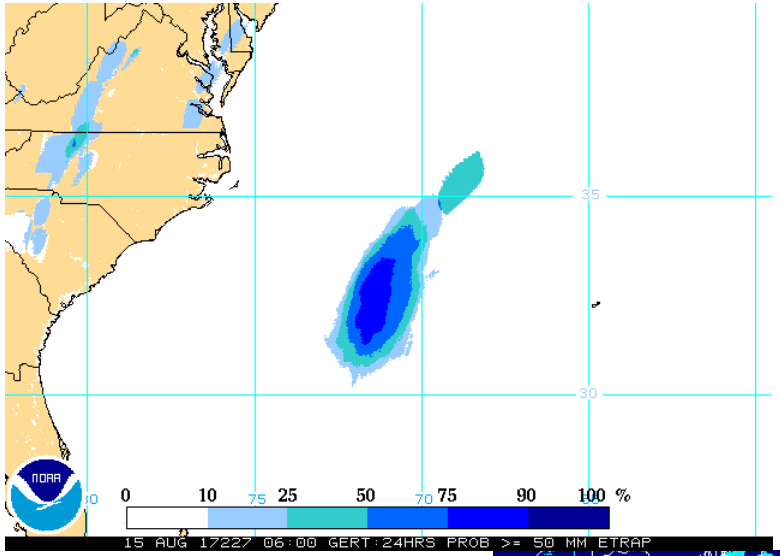
eTRaP Inputs

- eTRaP is produced every 6 h (initialization times 00, 06, 12, 18 UTC, data cutoff +3 h, latency 1 h) for tropical systems worldwide using TRaPs from
  - AMSU (NOAA-18/19, METOP-A/B)
  - SSMIS (DMSP F16/17/18)
  - 11 μm IR (Hydro-Estimator) (GOES-E/W, METEOSAT-8/10, Himawari-8)
  - **ATMS (S-NPP)**
  - **AMSR2 (GCOM-W)**
  - GMI (GPM)
- Rainfall CLImatology-PERsistence (R-CLIPER), which uses rain rates from conditional climatology in place of satellite estimtates, will be added at the end of August.

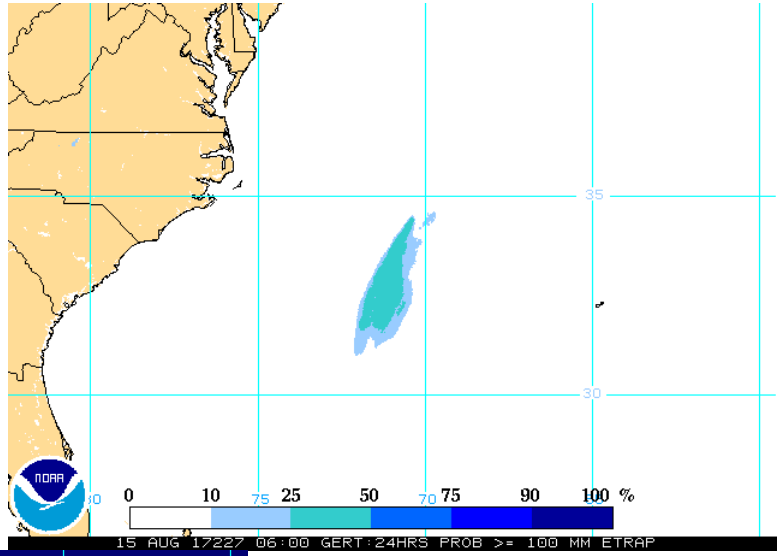
eTRaP Example: Hurricane Gert

0-24 h forecasts initialized 1200 UTC 15 August 2017

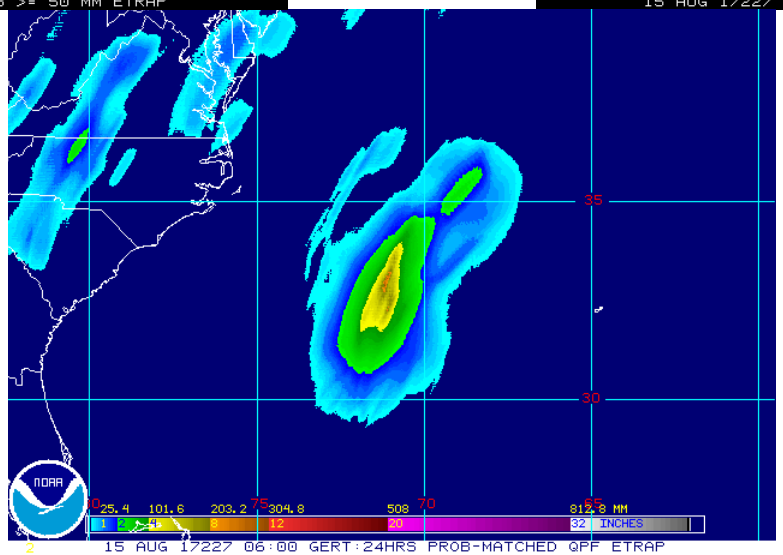
Probability of ≥50 mm



Probability of ≥100 mm

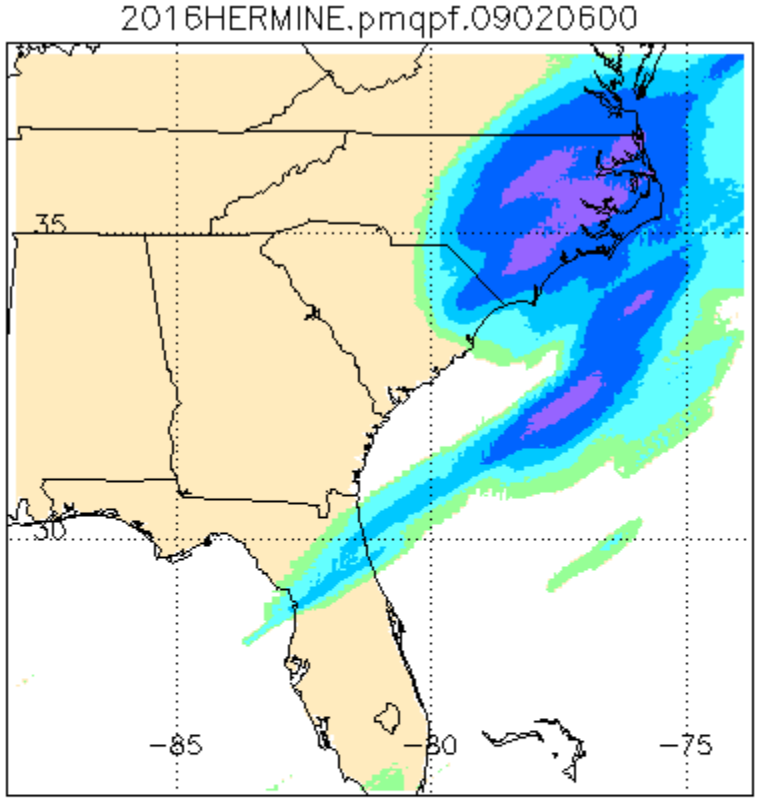


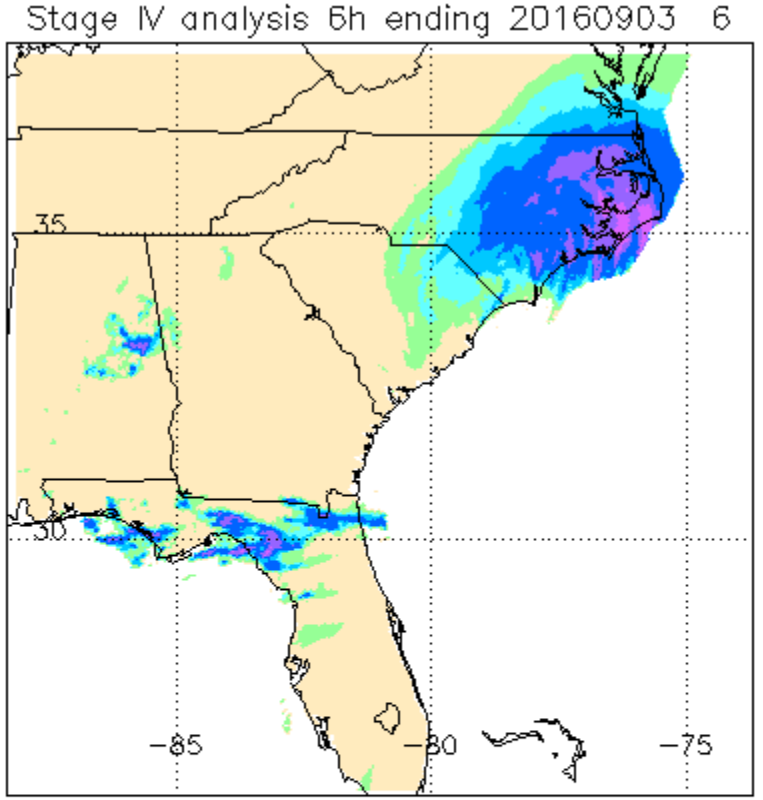
Probability-Matched QPF



eTRaP Example: Hurricane Hermine

18-24 h forecast initialized 06 UTC 2 September 2017





No data
<1 mm
1–5 mm
5–10 mm
10–20 mm
20–50 mm
50–100 mm
100–200 mm
200–400 mm
400–600 mm

		Observed ≥12.7	Observed <12.7
Forecast	≥12.7	8469	3835
Forecast	<12.7	1794	76671

Total number(≧0)=90769, grid=0.030°

Statistics for rain ≧12.7 mm	Obs	Fcst
# gridpoints	10263	12304
Average rainrate (mm)	40.41	36.01
Rain volume (km^3)	42.09	37.51
Maximum rain (mm)	202.11	81.68

Mean abs error = 19.44 mm
RMS error = 28.45 mm
Correlation coeff = 0.131
Bias score = 1.199
Probability of detection = 0.825
False alarm ratio = 0.312
Hanssen & Kuipers score = 0.778
Equitable threat score= 0.557

Questions?

CMORPH:

A Multi-Sensor, Multi-Platform Blended Product of Global High-Resolution Precipitation

Pingping Xie
NOAA Climate Prediction Center

September 18, 2017

Overview

- CMORPH: CPC Morphing Technique
- Basic Notion

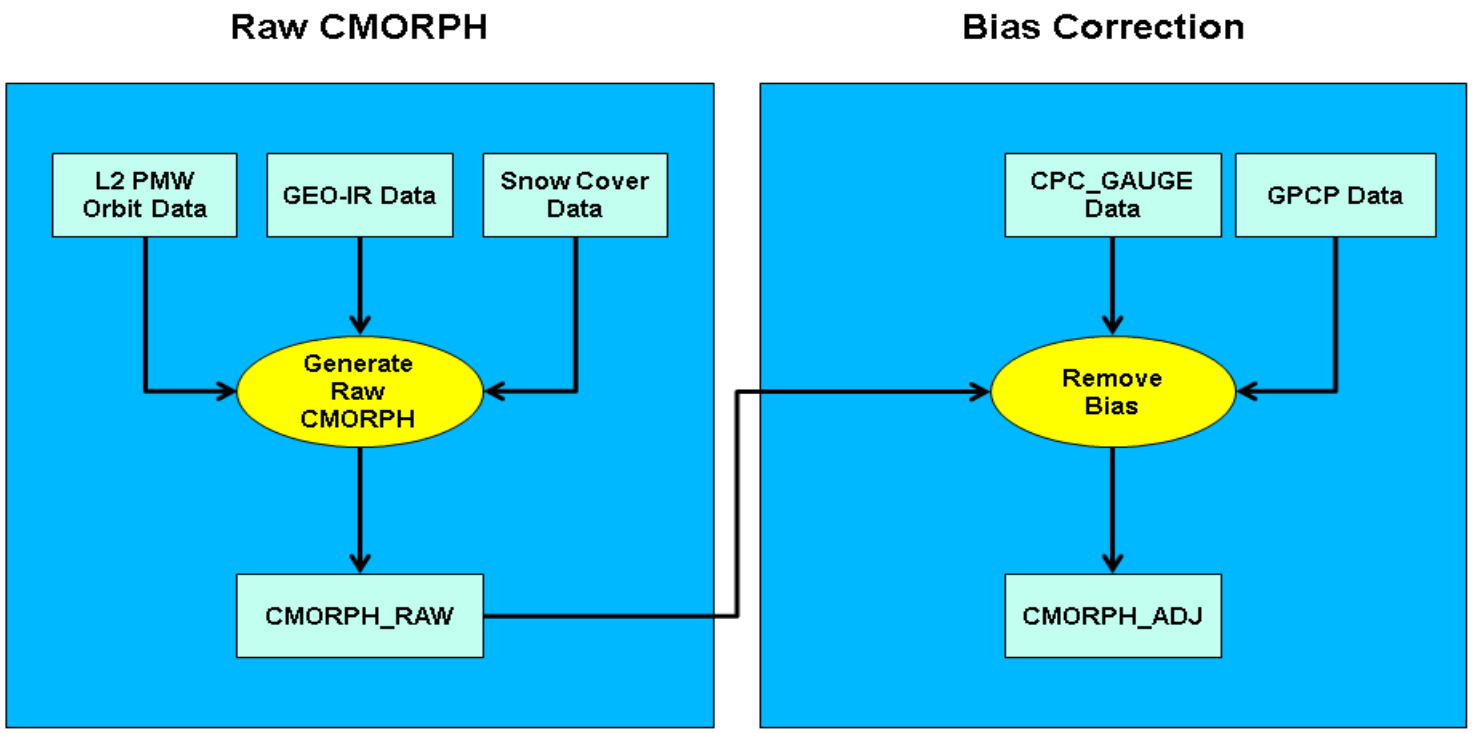
  To construct high-quality, high-resolution global precipitation estimates through integrating information from ALL available sources:
  - *Level 2 PMW precipitation retrievals from all relevant LEO satellites*
  - *IR precipitation estimates from GEO & LEO platforms*
  - *Precipitation fields generated by numerical models*
  - *Measurements from gauges and other in situ instruments (e.g. buoys)*
  - *…..*
- Timeline
  - *2002: Version 0 started real-time operation*
  - *2009: Version 1 algorithm and system finalized*
  - *2014: Version 1 reprocessing completed for 1998 ~ present*
  - *2015: Version 2 prototype algorithm developed*
  - *2017: Version 2 test real-time production started*

1st Generation CMORPH

[1] Overall System Structure

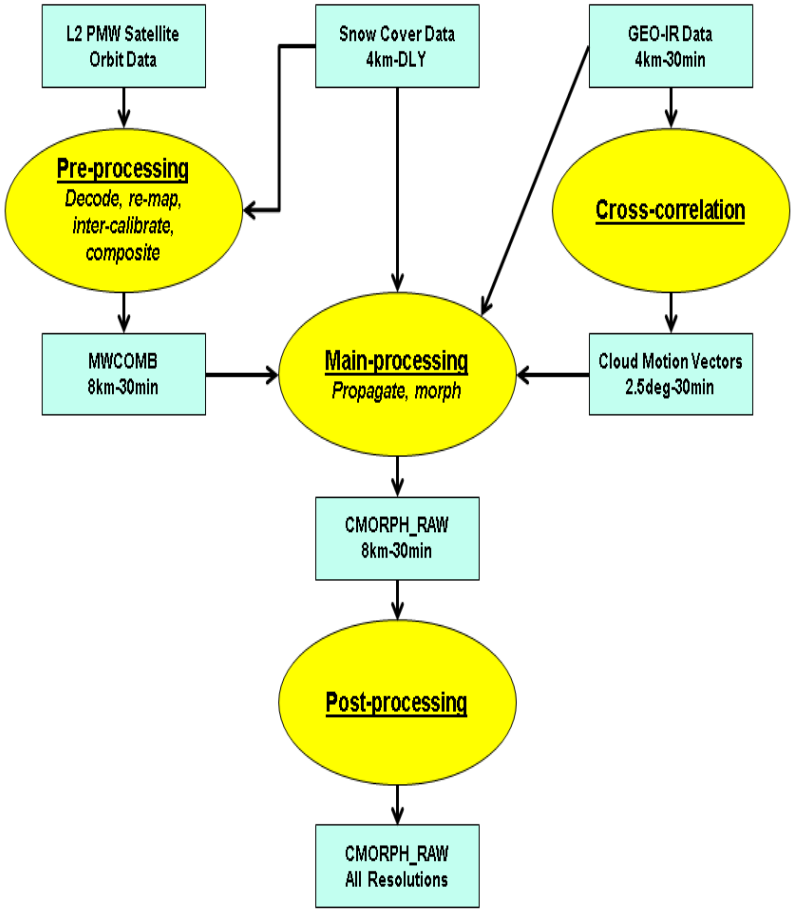
- A Two-step approach
  - *Integrating information from all satellites (LEO PMW + GEO IR)*
  - *Removing bias in satellite estimates through calibration against gauge data*

- Joyce et al. (2004); Xie and Joyce (2017)



1st Generation CMORPH

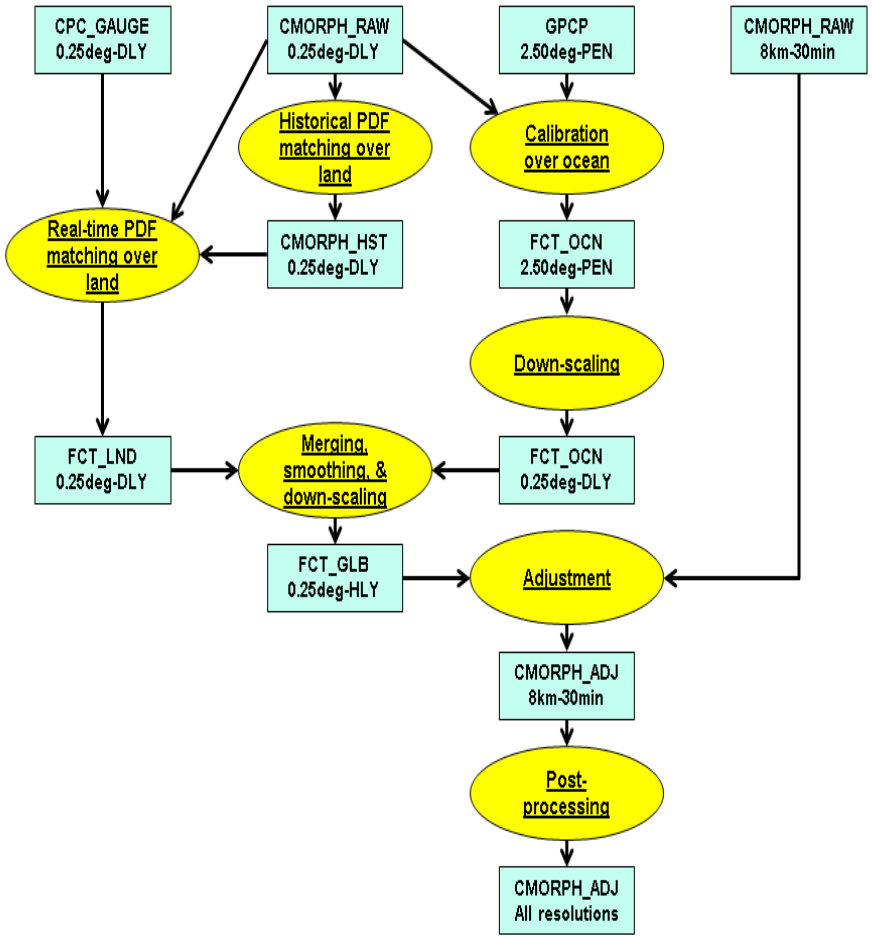
[2] Purely Satellite-Based Estimates



- PDF inter-calibration against a common reference (TMI)
- Propagation of L2 PMW retrievals from respective observation times to target analysis time along cloud motion vectors
- Cloud motion vectors computed from two consecutive GEO IR images 30-min apart using maximum cross correlation (MCC) technique
- Propagation performed in both forward & backward directions and the purely satellite-based raw CMORPH is defined as weighted mean of the two propagated PMW.

1st Generation CMORPH

[3] Bias Correction



- Over land:
  PDF matching against CPC gauge analysis

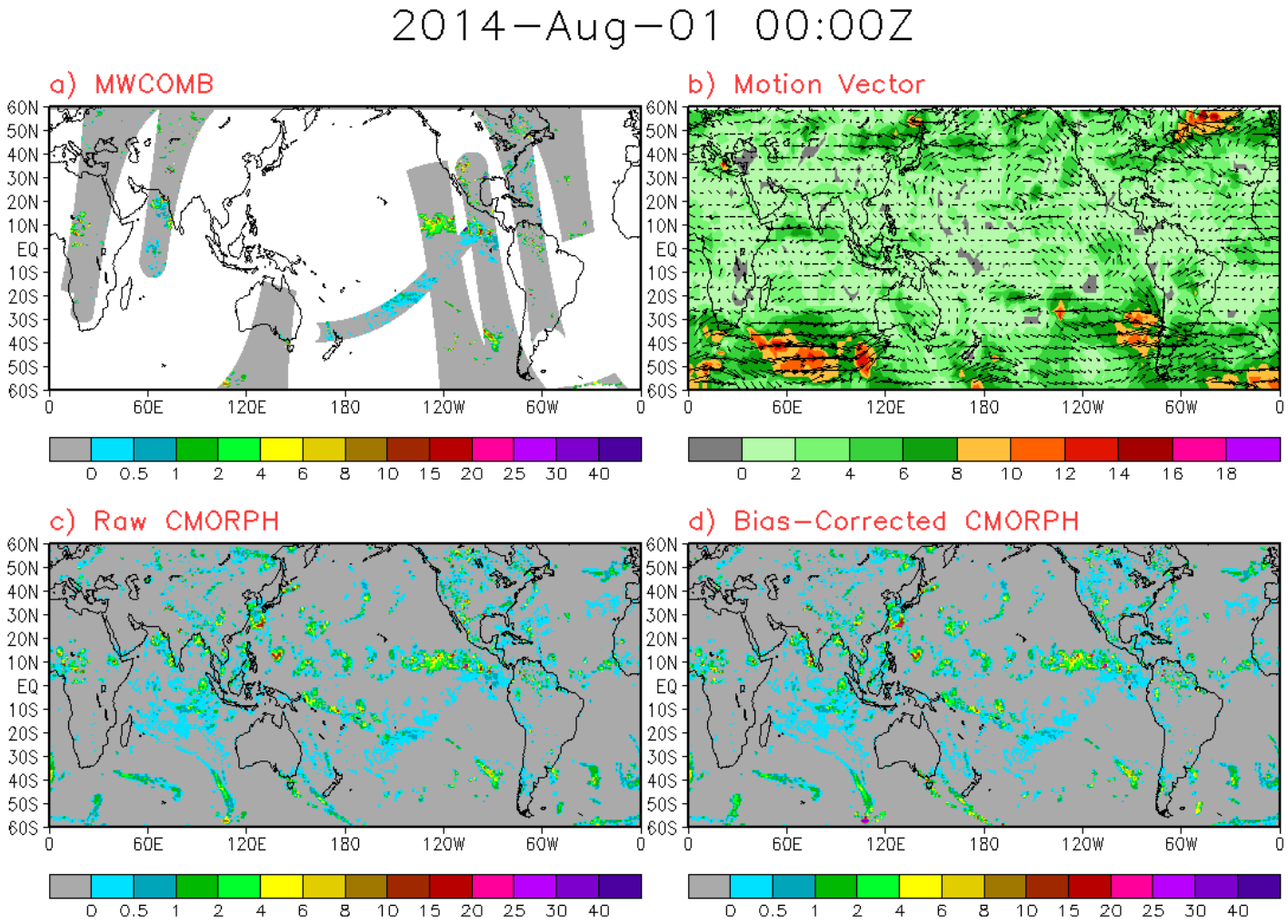
- Over ocean:
  Adjustment against pentad GPCP

Final Outputs:

- 8kmx8km over the globe (60^oS-60^oN)
- 30-min interval from 1998 to the present
- Real-time operation at a latency of 2 hours

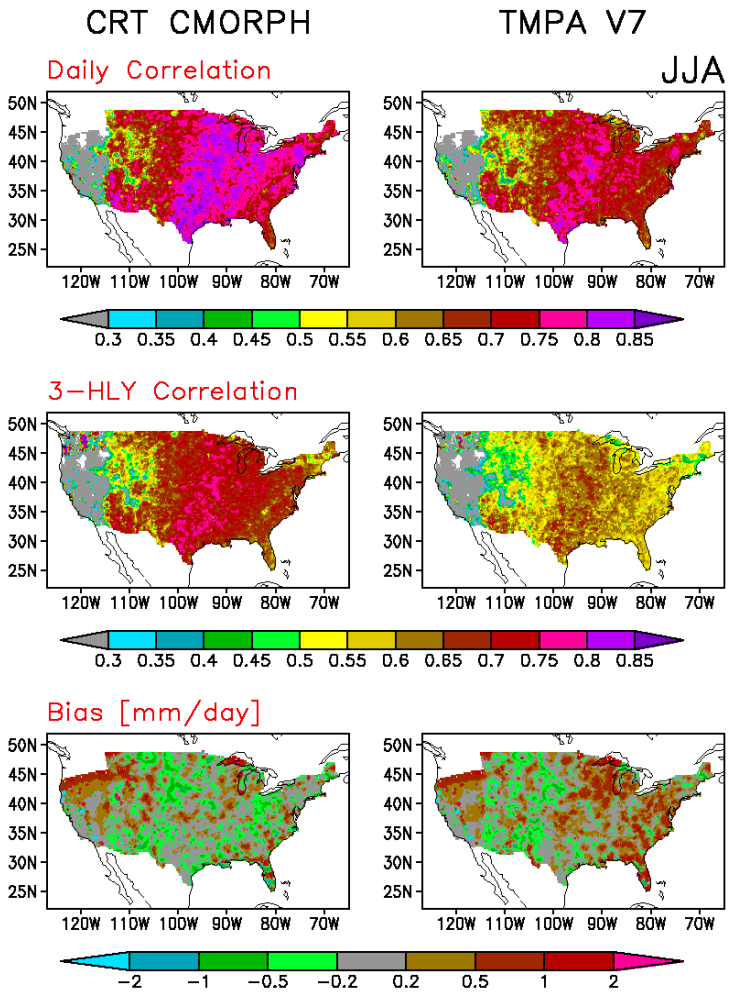
1st Generation CMORPH

[4] Sample



1st Generation CMORPH

[5] CMORPH V 1 Outperforms TRMM/TMPA V7

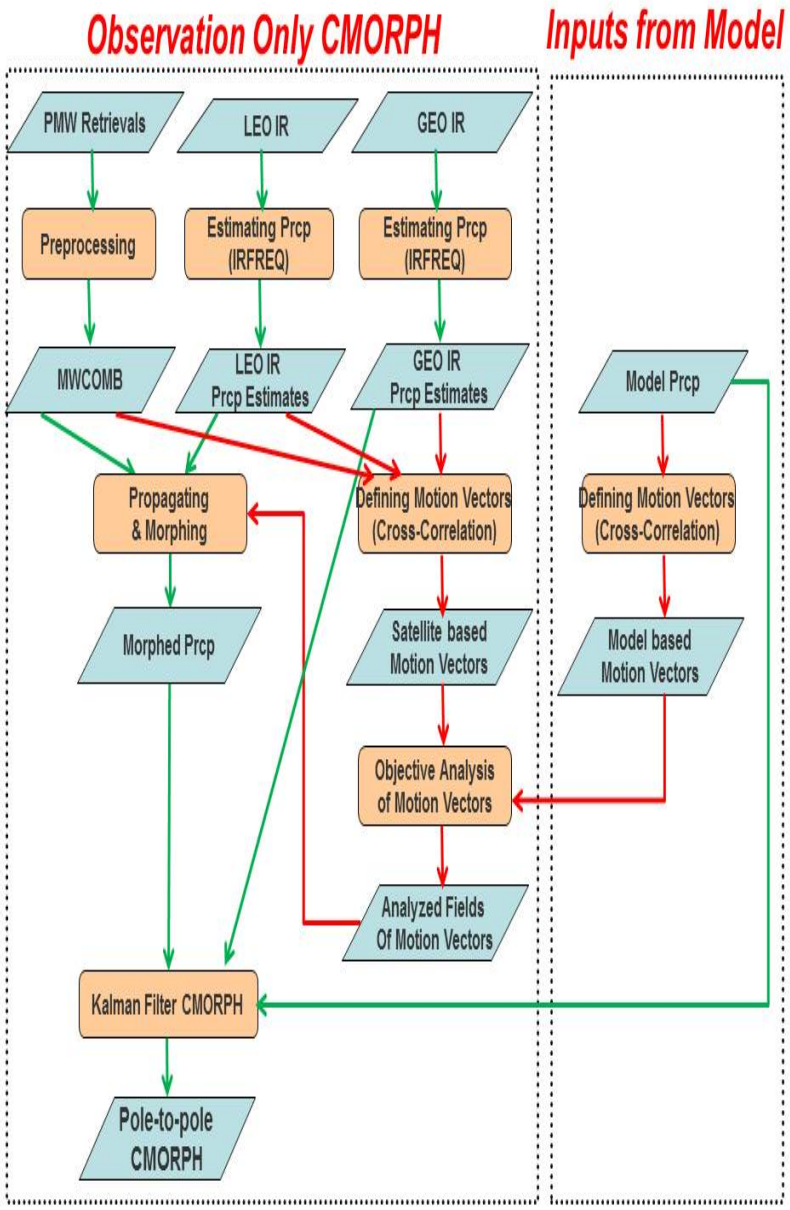


- Comparison of CMORPH V1 / TMPA against Stage IV radar over CONUS

2nd Generation CMORPH

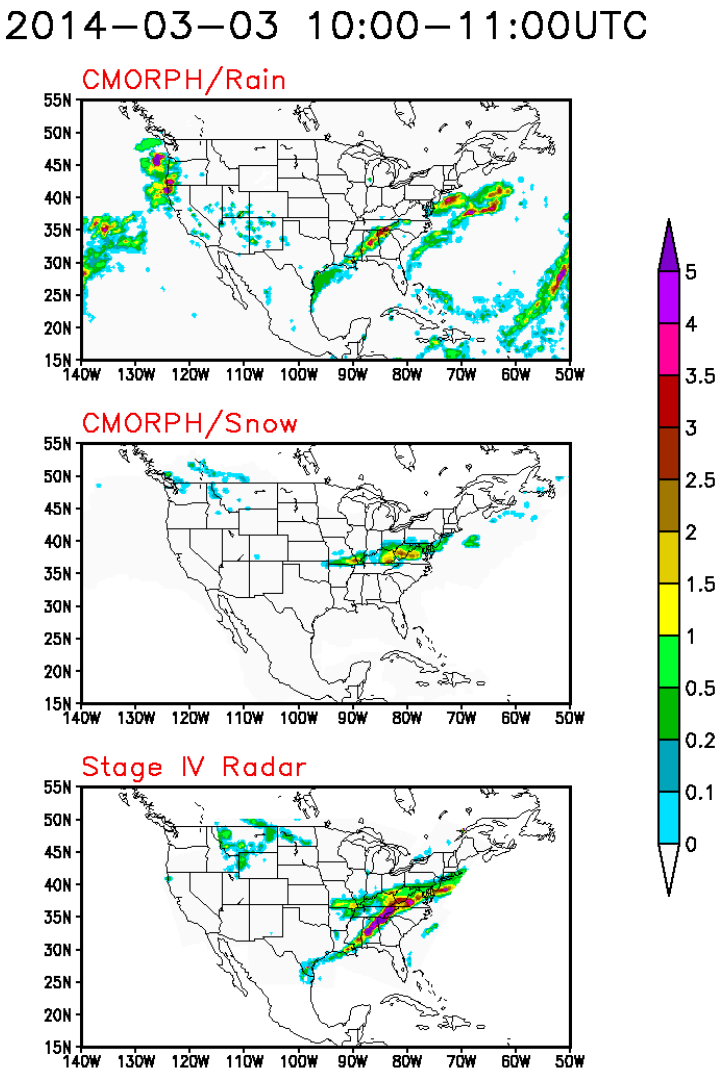
[1] Overall System Structure

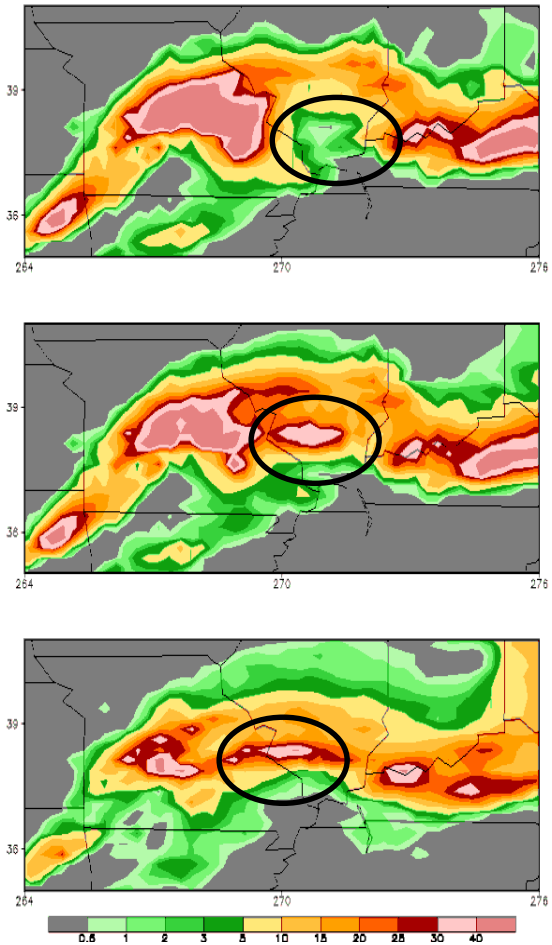
- Developed with support from JPSS
- Upgrades upon CMORPH1
  - *Pole to pole global coverage*
  - *0.05°lat/lon grid*
  - *Improved snowfall rate*
  - *Better accuracy*
  - *Reduced latency (<1 hour)*
- Strategy
  - *Inputs from more sources*
    - *PMW SFR retrievals*
    - *GEO/LEO IR precip estimates*
    - *Model precipitation fields*
  - *Vectors*
    - *2DVAR combining vectors from model and satellite estimates*
  - *Integration framework*
    - *Kalman Filter*



2nd Generation CMORPH

[3] Improved SFR and Strong Convection Representation





CMORPH w/o SNPP

CMORPH with SNPP

Stage IV Radar Est

Summary

- We appreciate it very much JPSS support to our CMORPH development work!

- Synthesizing information from different sources is demonstrated an effective mean to construct high-quality, high resolution precipitation estimates

- CMORPH has a track record of leading the world in the technology development and operational production
  - *The NASA/GPM IMERG core algorithm (integration part) is adopted from CMORPH through code migration*
  - *The Japanese GSMaP is a variation of the CMORPH algorithm*
  - *The full-resolution IR created at CPC and used as input to the CMORPH is also used by IMERG and other global satellite precip products;*
  - *The MWCOMB, inter-calibrated PMW maps, is also used by several other precip products*

  - **WE ARE THE FIRST TO PRODUCE BLENDED PRECIP ESTIMATES POLE TO POLE!**