ATMS Snowfall Rate Product to Support NWS

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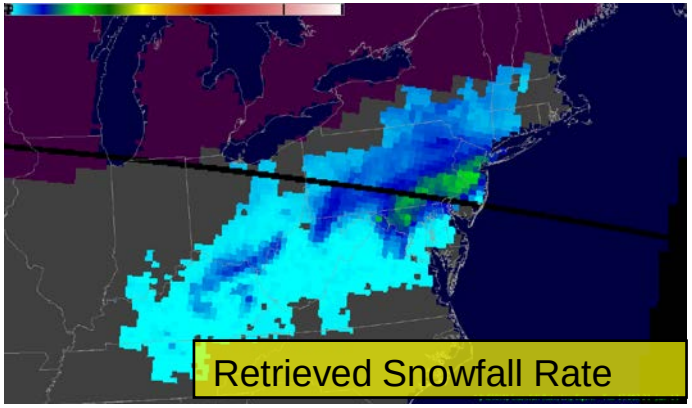
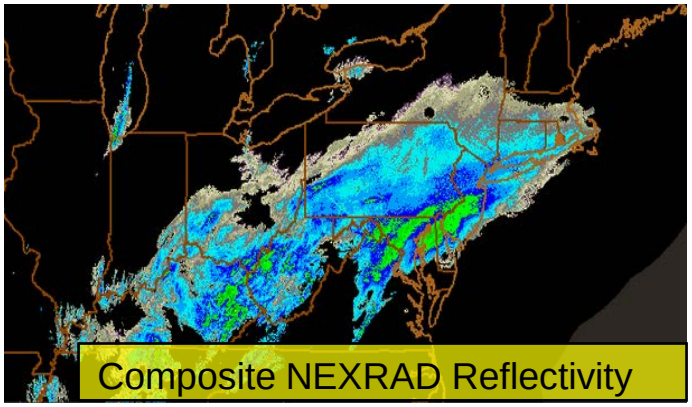
Introduction

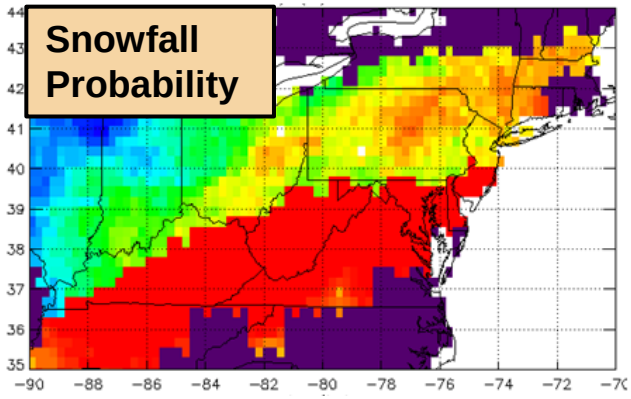
- The ATMS Snowfall Rate (SFR) product was developed with the support of JPSS Proving Ground and Risk Reduction program
- SFR is water equivalent snowfall rate estimate over global land
- The algorithm partially inherits the operational AMSU/MHS SFR, but with many new developments that lead to superior performance
- Currently, SFR is generated from five satellites (S-NPP and four POES and Metop satellites) with about ten estimates per day in mid-latitudes and more in high latitudes
- The AMSU/MHS SFR product has been integrated in MiRS as an operational product

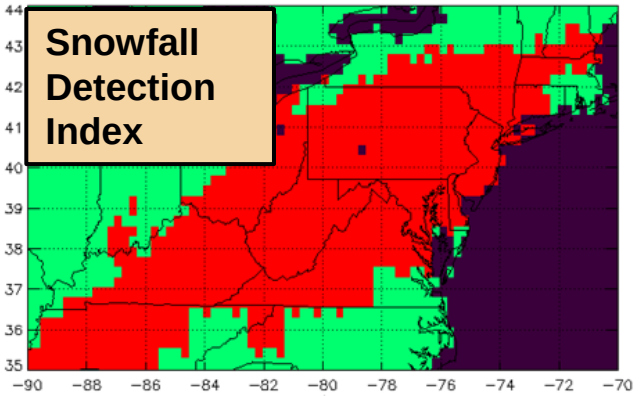


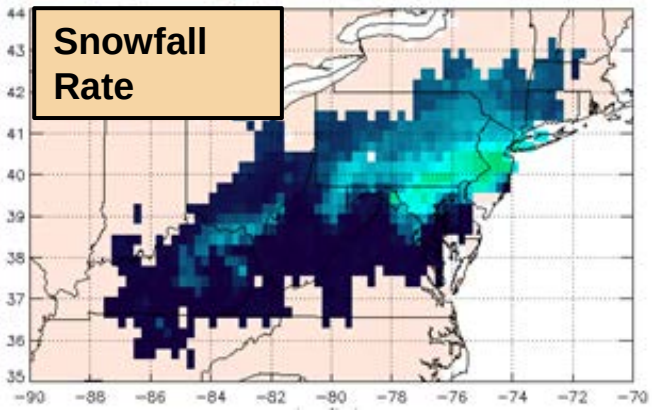


Algorithm

- SFR is composed of a Snowfall Detection algorithm and a Snowfall Rate algorithm
- Snowfall Detection
  - ✓ Statistical algorithm
  - ✓ Coupled principal component and logistic regression model
  - ✓ Use all seven high-frequency channels at and above 88.2 GHz and the temperature sounding channel at 53.6 GHz
  - ✓ Trained with gauge observations
  - ✓ Output is probability of snowfall; use preset thresholds to determine snowfall
  - ✓ Additional NWP model-based filters and screenings to improve the accuracy of snowfall detection







Algorithm (2)

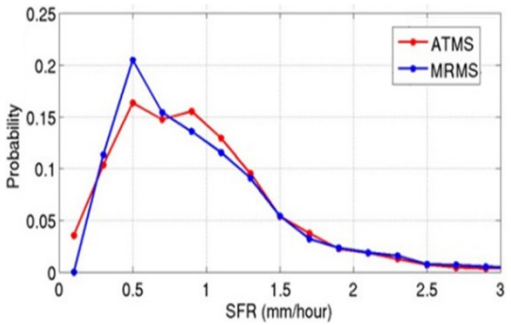
- Snowfall Rate
  - ✓ Physically based algorithm
  - ✓ Retrieve cloud properties using 1D VAR – coupled radiative transfer simulations and an iteration scheme
  - ✓ Derive snowfall rate from cloud properties and an existing snow particle terminal velocity model
  - ✓ Calibration through histogram matching with Multi-Radar Multi-Sensor (MRMS) radar precipitation data

$$SFR = A\int_{D_{min}}^{D_{max}} D^2 e^{-D/D_e}\left[\left(1+BD^{3/2}\right)^{1/2}-1\right]^2 dD$$

$$A = \frac{\alpha I_c \delta_0^2 \eta}{24 H \rho_w \rho_a D_e^4} \qquad B = \frac{8}{\delta_0^2 \eta}\sqrt{\frac{g\rho_a \rho_I}{3C_0}}$$

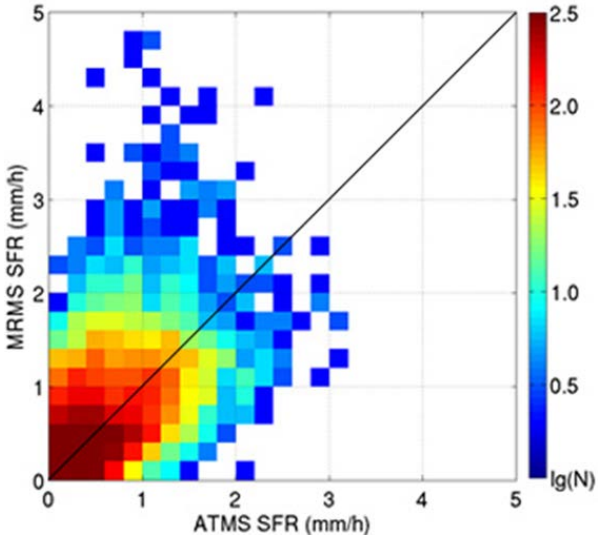
Validation - Statistics

- Snowfall Detection validation
  - ✓ Validation against CONUS gauge data
  - ✓ About 50% of in-situ data is 'trace' snow - challenging to detect for satellite product



	POD	FAR
Warm Regime	0.45	0.09
Cold Regime	0.43	0.09

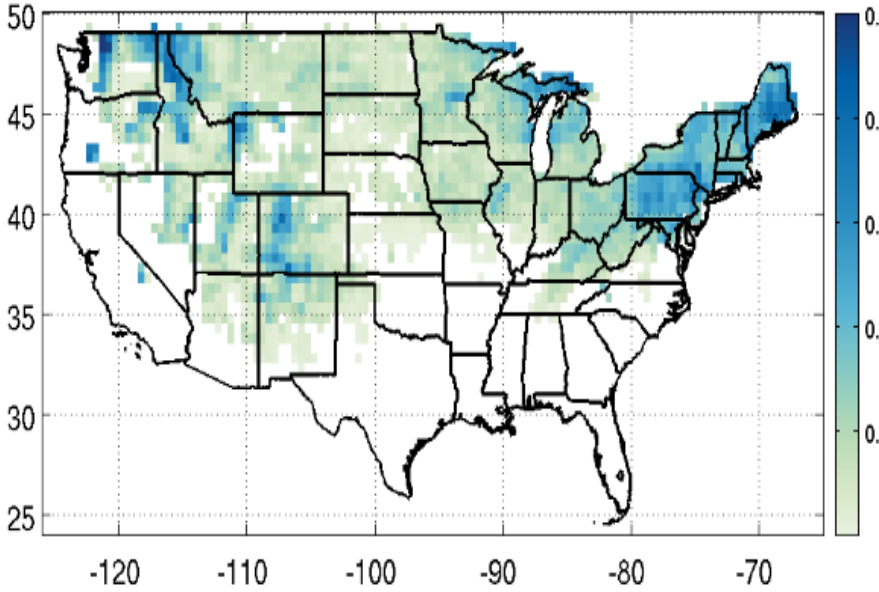
- Snowfall Rate validation
  - ✓ Validation against MRMS radar snowfall rate data



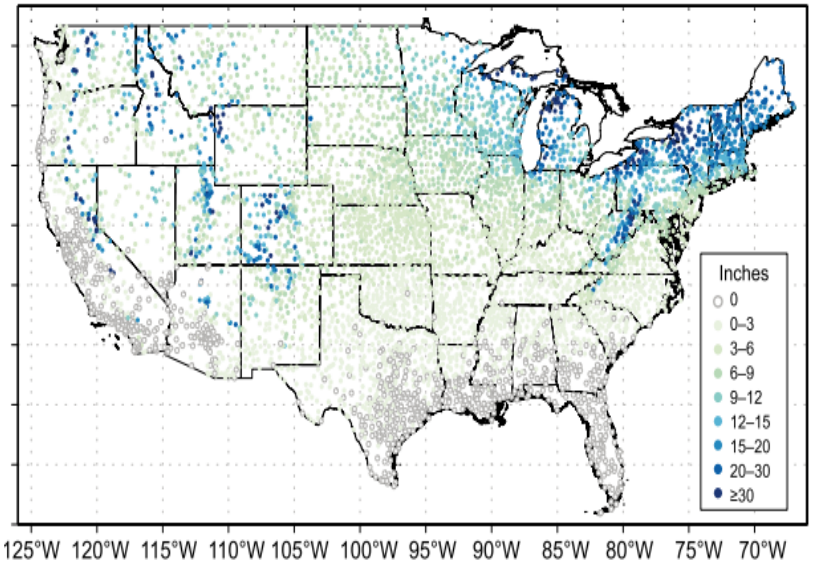
Correlation Coefficient	Bias (mm/hr)	RMSE (mm/hr)
0.52	-0.07	0.55

Validation - Climatology

ATMS Snowfall Rate
January Average, 2015-2016



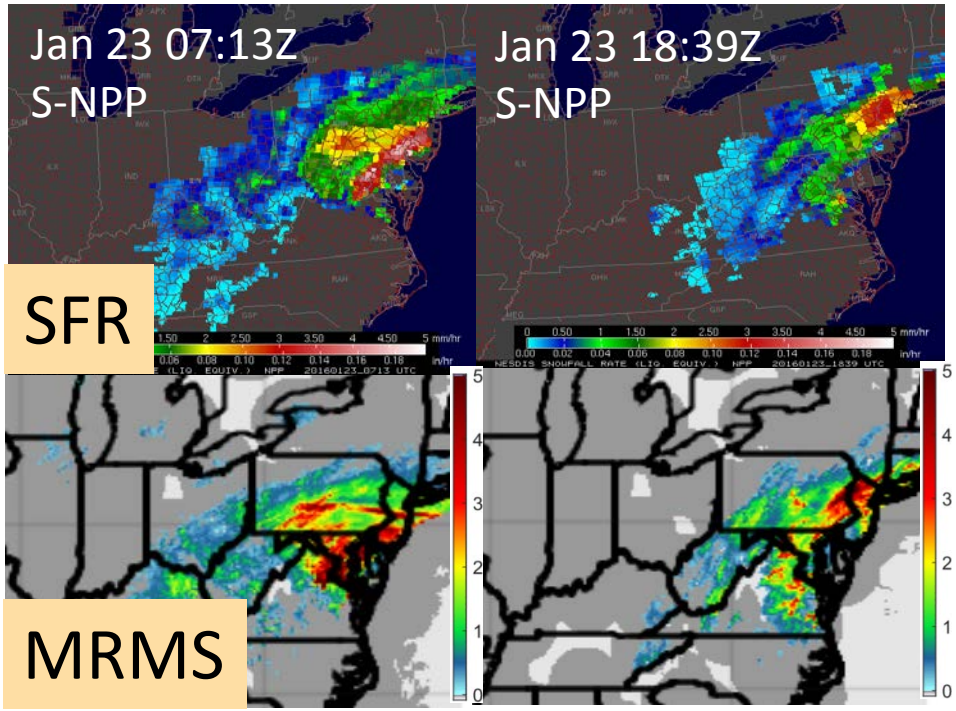
Gauge Accumulated Snowfall
January Average, 1981-2010



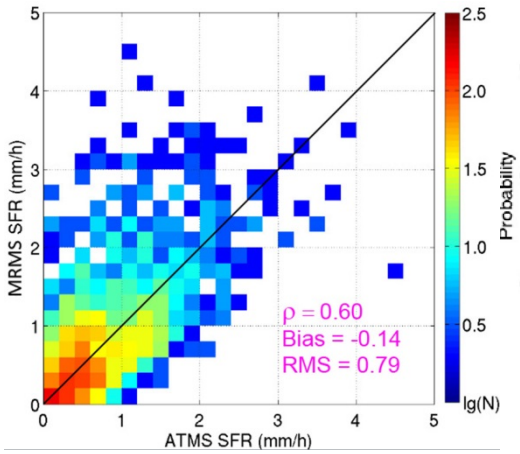
(Durre, 2013)

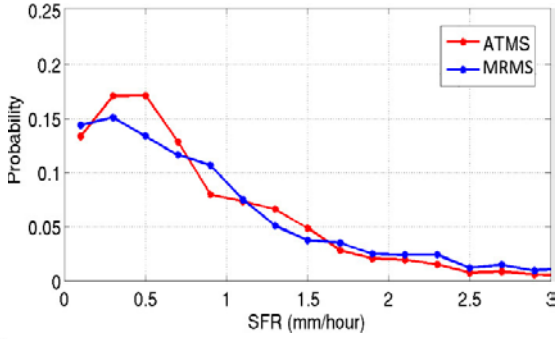
Validation – Case Study

- The 2016 Blizzard hit the Mid-Atlantic region on January 22-24, 2016 and produced record snowfall in many local areas
- The ATMS and MHS SFR products captured the evolution of the blizzard with five satellites including S-NPP, POES and Metop.



	Correl. Coeff.	Bias (mm/hr)	RMS (mm/hr)
ATMS	0.60	-0.14	0.79
MHS	0.54	-0.53	0.88

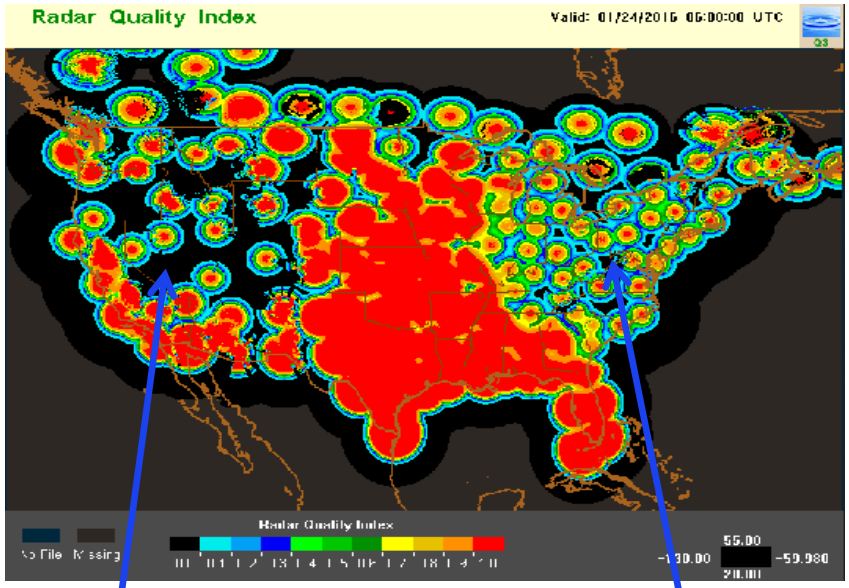




Application in Weather Forecasting

- ATMS and AMSU/MHS SFR was evaluated at several NWS Weather Forecast Offices (WFOs) in a project supported by NASA through collaboration with SPoRT. User feedback indicates that SFR is a useful product for weather forecasting operations
- SFR is especially useful for filling observational gaps in mountains and remote regions where radar and weather stations are sparse or radar blockage and overshooting are common
- SFR also provides quantitative snowfall information to complement snowfall observations or estimations from other sources (stations, radar, GOES imagery data etc.)
- Use CIMSS direct broadcast data to meet latency requirement for weather forecasting

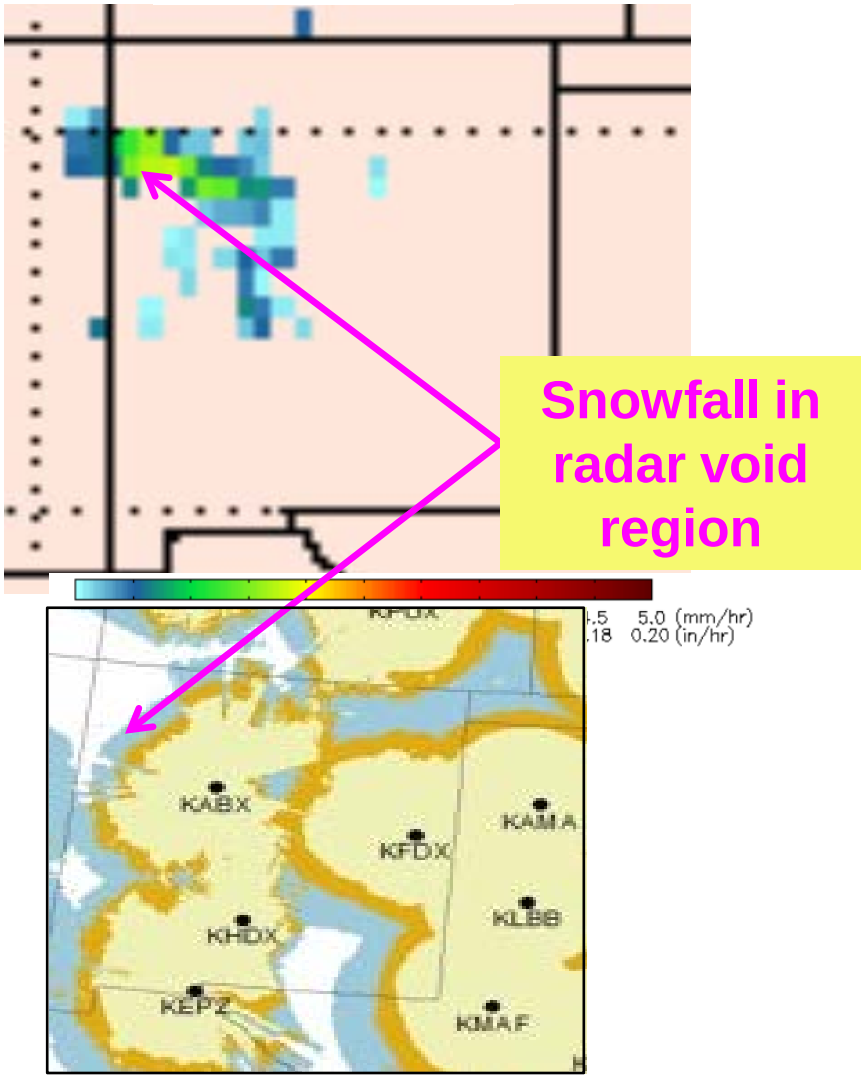
MRMS Radar Precip Quality Index during 2016 East Coast Blizzard



Use Case 1: Jan 14, 2015

Albuquerque, NM WFO (ABQ) : The 919UTC image matched the NAM12 QPF forecast very well within a data void region. From this information I was able to determine the NAM forecast was too slow with the evolution of the precip…The radar values dropped off away from the KABX radar which is expected, whereas the SFR product increased in the area of heaviest snowfall. Rates were close to the observed value at KGUP. The NM DOT web page indicated difficult driving conditions within this region.

ATMS SFR



Radar Coverage Map

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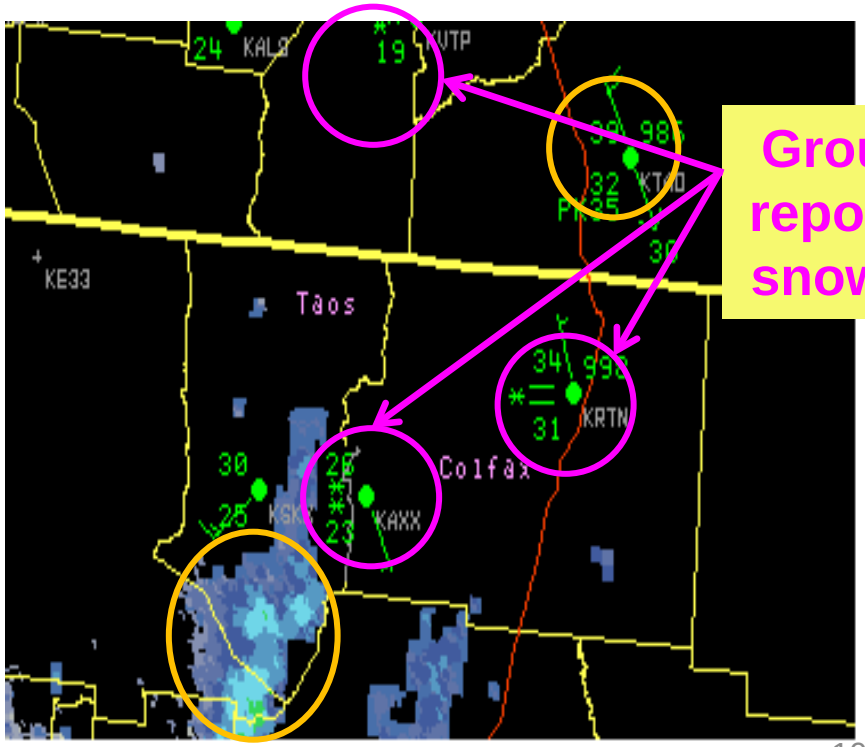
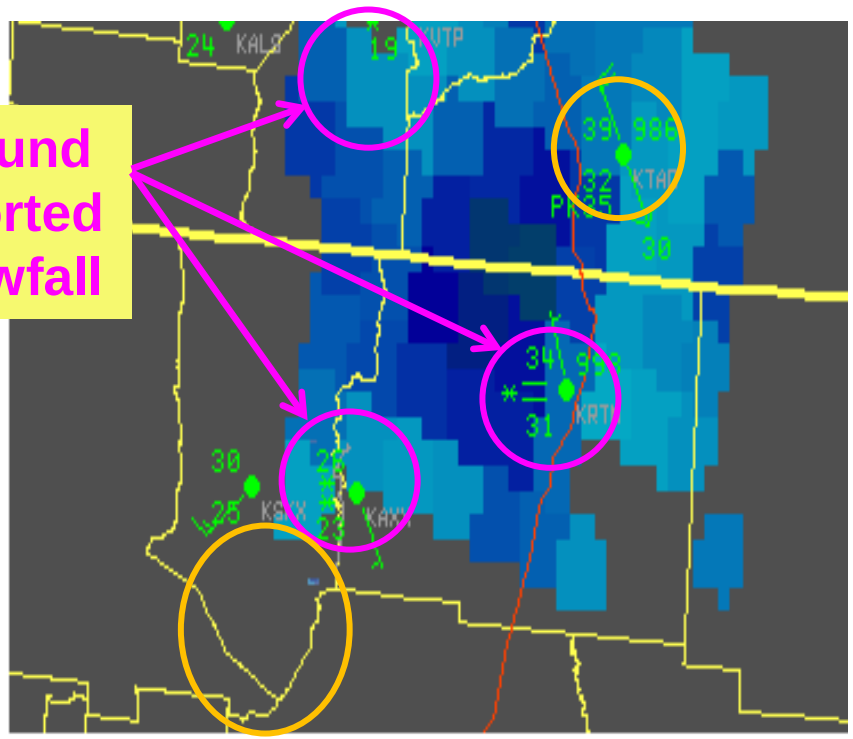
Use Case 2, December 14, 2014

Albuquerque, NM WFO (ABQ): The product (SFR) did validate that we will indeed be able to complement radar void coverage areas in an operational forecast environment using polar-orbiting satellite imagery.



Composite Reflectivity 14-Dec-14 1642Z



Snow Fall Rate Product 14-Dec-14 at 1645Z

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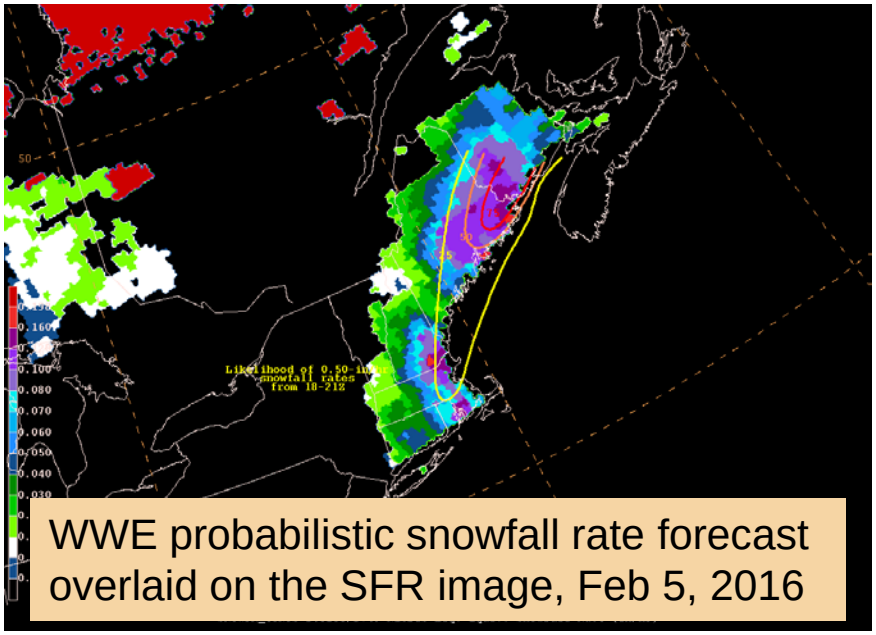
Application at WPC

- NWS/Weather Prediction Center (WPC) Hydrometeorological Testbed regularly conducts Winter Weather Experiment (WWE)
- 2016 WWE
  - ✓ Created a probabilistic winter hazards impacts-based product
- Verification challenges
  - ✓ Gauge and radar data all have various issues as verification data source: reliability, latency, precip type only, etc.

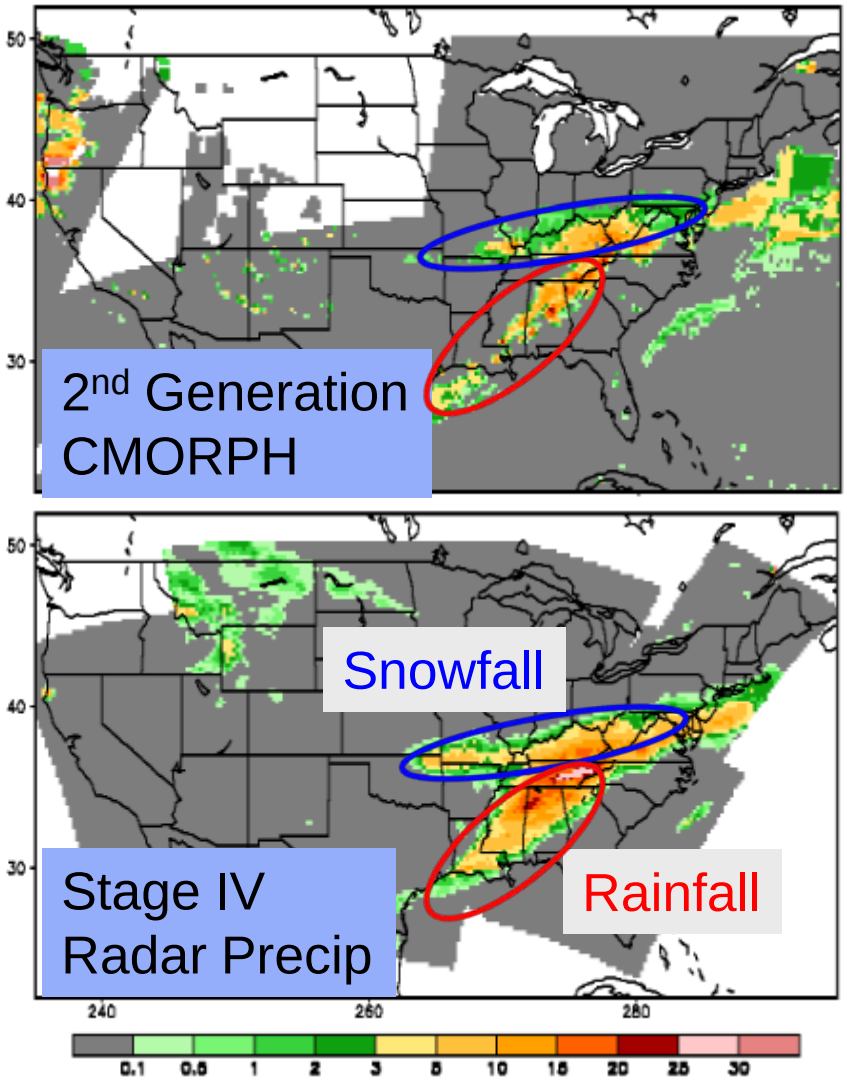


WWE probabilistic snowfall rate forecast overlaid on the SFR image, Feb 5, 2016

- SFR as a verification tool
  - ✓ Case studies show SFR and WWE probabilistic winter hazards product agree well in most cases both in location and intensity
  - ✓ 2017 WWE will utilize SFR to verify probabilistic snowfall rate forecasts
- SFR will be utilized operationally at WPC and SAB
  - ✓ Training will start soon for winter 2016-2017 assessment

Application in Hydrology
Blended Satellite Precipitation Product - CMORPH

- CMORPH is a NWS/NCEP global blended precipitation analysis product with wide-ranging applications (EMC, NWC, etc.)
- The first generation CMORPH only has rain rate. The ATMS and AMSU/MHS SFR is integrated in the second generation CMORPH with the support of JPSS PGRR
- A sample for a major snowstorm over the east coast of US in March 2014 (right)
  - ✓ Stage IV radar precipitation image (bottom) shows a warm band (rainfall) and a cold band (snowfall) of precipitation from a frontal system
  - ✓ The second generation CMORPH (top) captures both bands after integrating SFR



(Xie and Joyce, NCEP/CPC)

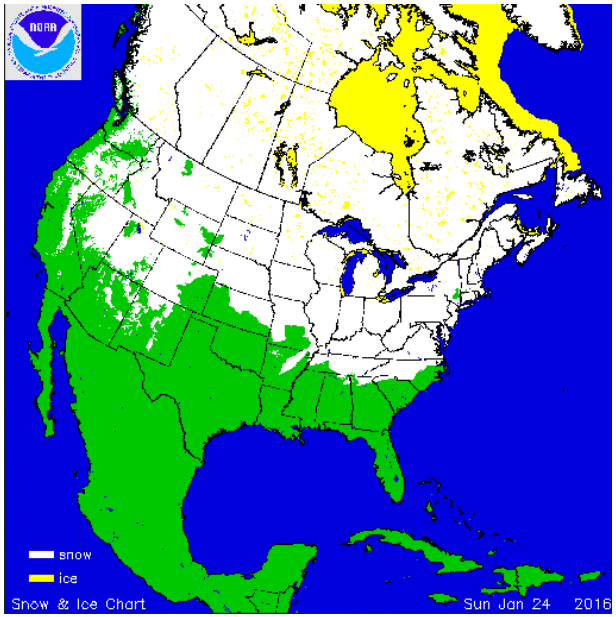
Future Application at National Water Center

- David Kitzmiller (NWC): National Water Center will use the 2nd Generation CMORPH (with SFR) in the precipitation Analysis of Record for Calibration (AORC)
  - ✓ CMORPH is used to disaggregate daily gauge-based precipitation analyses to hourly, over areas without radar coverage
  - ✓ CMORPH's capability to detect snow precipitation is important to the accuracy of the AORC products
  - ✓ CMORPH (hence SFR) will be used on a daily basis
  - ✓ AORC has numerous beneficiaries in the NWC and the general user community
- Ed Clark, Director, Geo Intelligence Division, NWC
  - ✓ NWC staff eagerly anticipate improved precipitation estimates from the SCSB/CICS-MD team, particularly enhanced rainfall and snowfall rate retrievals, achieved through synergistic use of the ABI, GLM and JPSS microwave sensors (ATMS, AMSR2). Such products are vital to improving precipitation monitoring over areas that are beyond effective radar and rain gauge network coverage, particularly large portions of Alaska and Canada, and the products will be used to improve inputs for the National Water Model and for NWC situational awareness.

Future Applications at National Ice Center

- Sean Helfrich (NIC, Science Department Head): NIC's monitoring of snow is mission critical to supporting numerical weather prediction modeling and climate monitoring for NOAA and many other agencies worldwide
  - ✓ NIC can use SFR to determine snow line globally, including Alaska, where surface radar is unavailable and clouds obscure the direct observation from IR and VIS instruments
  - ✓ NIC can use the SFR product to greatly enhance their ability to monitor active and important snow storms worldwide
  - ✓ SFR could also be used to enhance other snow characterization required by NIC such as snow depth and snow water equivalent

NIC's Snow and Ice Product, MIS After 2016 East Coast Blizzard



Summary and Future Plan

- An ATMS Snowfall Rate product has been developed with support from JPSS PGRR
- Extensive validation studies have demonstrated the quality of the product
- ATMS SFR has current and future applications to support NWS
  - ✓Hydrology: CMORPH (CPC), NWC
  - ✓Weather Forecasting: WFOs, WPC
  - ✓NWP Models: CPC and EMC (through NIC MIS and CMORPH)

Future Plan

(Supported by JPSS PGRR)

- Algorithm enhancement
- Development of SSMIS SFR algorithm
- Development of GMI SFR algorithm
- Development of prototype ocean SFR algorithms

Thank You!