Latest Development on the NOAA/NESDIS Snowfall Rate Product

Jun Dong[1], Cezar Kongoli[1], Huan Meng[2], Ralph Ferraro[2], Banghua Yan[2], Nai-Yu Wang[1], Bradley Zavodsky[3]

[1]University of Maryland/ESSIC/Cooperative Institute for Climate and Satellites
[2]NOAA/NESDIS/Center for Satellite Applications and Research
[3]NASA/Short-term Prediction Research and Transition Center

Outline

- Background of Snowfall Rate (SFR) product
- SFR algorithm and new development
- SSMIS and GMI SFR
  - ✓ F16, F17, F18 and GPM
- Development of Near Real Time (NRT) SFR System (on-going)
  - ✓ All available passive microwave sensors with high frequencies
  - ✓ Unified SFR retrieval system

Background

- The NESDIS Snowfall Rate (SFR) product is water equivalent snowfall estimate and has been in NOAA operation since 2012
- Passive microwave sensors: MHS
- Satellites: NOAA-18, NOAA-19, Metop-A, and Metop-B
- The SFR for ATMS aboard S-NPP has also been developed with the support of JPSS-PGRR; the product has been added to the JPSS Baseline Requirement (L1RD) and will be transitioned to operation in the near future
- The five satellites provide ~10 SFR estimates daily in mid-latitudes
- Direct Broadcast (DB) data: provide SFR for CONUS and AK in less than 30 minutes

SFR Algorithm

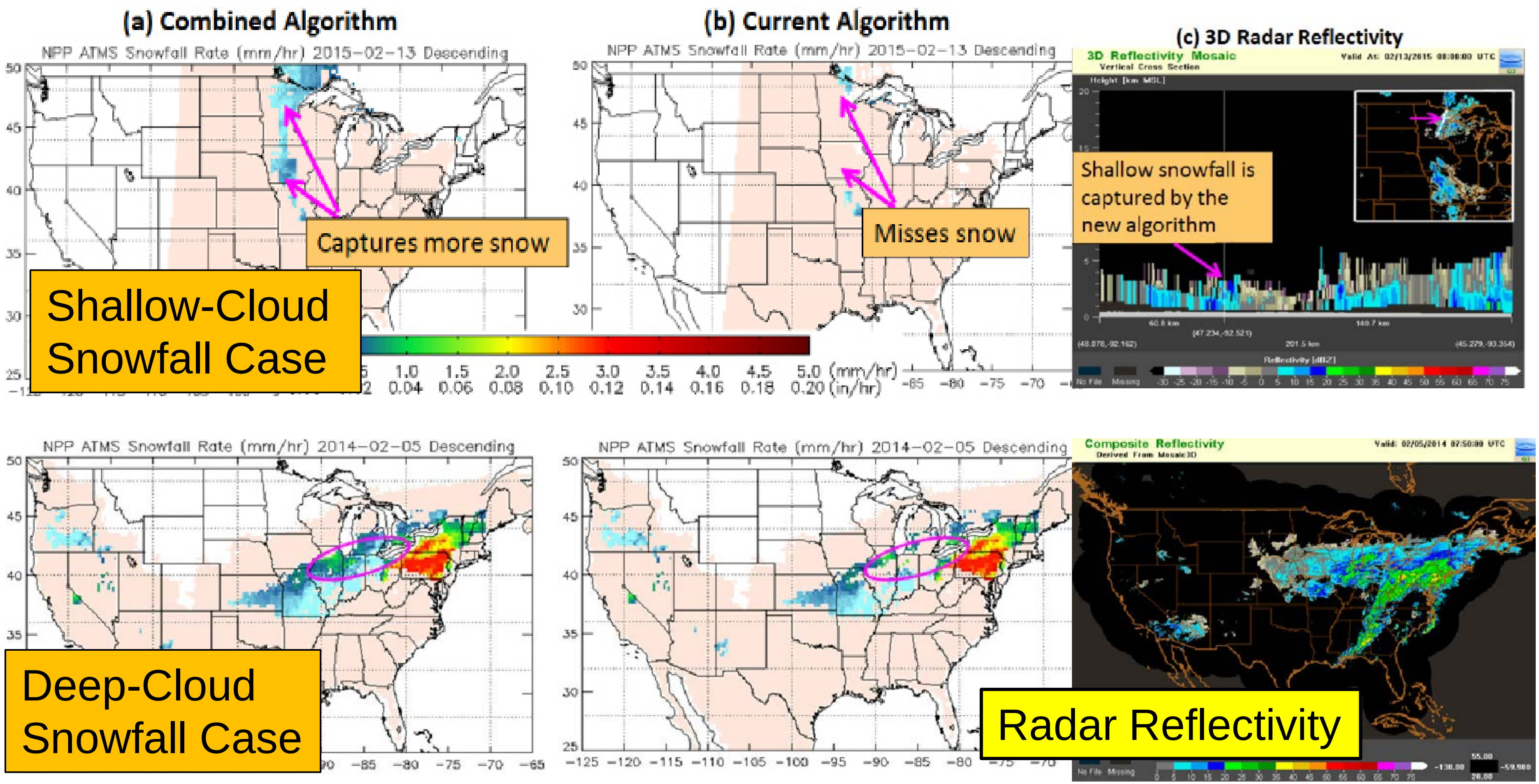
- First Step: Snowfall Detection (SD)
  - ✓ Logistic regression model
  - ✓ New development: combined SD method
- Second Step: Snowfall Rate retrieval
  - ✓ 1DVAR-based retrieval
  - ✓ New development: extended to SSMIS and GMI

Snowfall Detection

- Satellite-based module
  - ✓ Coupled principal components and logistic regression model (Kongoli et al., 2015)
  - ✓ Model output is snowfall probability
  - ✓ Training dataset are composed of matching satellite and ground snowfall observation data
- NWP model-based module
  - ✓ Logistic regression model
- Final SD is the optimal combination of the two modules

SD Improvement

- The combined SD improves detection for both shallow and thick-cloud snowfall



SFR - Retrieval of Cloud Properties

- 1D variational method
  - ✓ Forward simulation of Tb's with a radiative transfer model (RTM) (Yan *et al.*, 2008)

$$\begin{vmatrix} \Delta I_c \\ \Delta D_e \\ \Delta \varepsilon_{23} \\ \Delta \varepsilon_{31} \\ \Delta \varepsilon_{89/88} \\ \Delta \varepsilon_{157/165} \\ \Delta \varepsilon_{190/176} \end{vmatrix} = \left| (A^T A + E)^{-1} A^T \right| \begin{vmatrix} \Delta T_{B23} \\ \Delta T_{B31} \\ \Delta T_{B89/88} \\ \Delta T_{B157/165} \\ \Delta T_{B190/176} \end{vmatrix}$$

I_c: ice water path

D_e: ice particle effective diameter

ε_i: emissivity at 23.8, 31.4, 89(MHS)/88.2(ATMS), 157/165.5, and 190.31/183±7 GHz

T_{Bi}: brightness temperature at 23.8, 31.4, 89/88.2, 157/165.5, and 190.31/183±7 GHz

A: Jacobian matrix, derivatives of T_{Bi} *over IWP,* D_e*, and* ε_i

E: error matrix

- ✓ Iteration scheme with ΔT_{Bi} thresholds
- ✓ IWP and De are retrieved when iteration stops

Snowfall Rate

- Terminal velocity is a function of atmospheric conditions and ice particle properties, Heymsfield and Westbrook (2010):

$$v(D) = \frac{\eta R_e}{\rho_a D}$$

- Snowfall rate model (Meng et al., 2016):

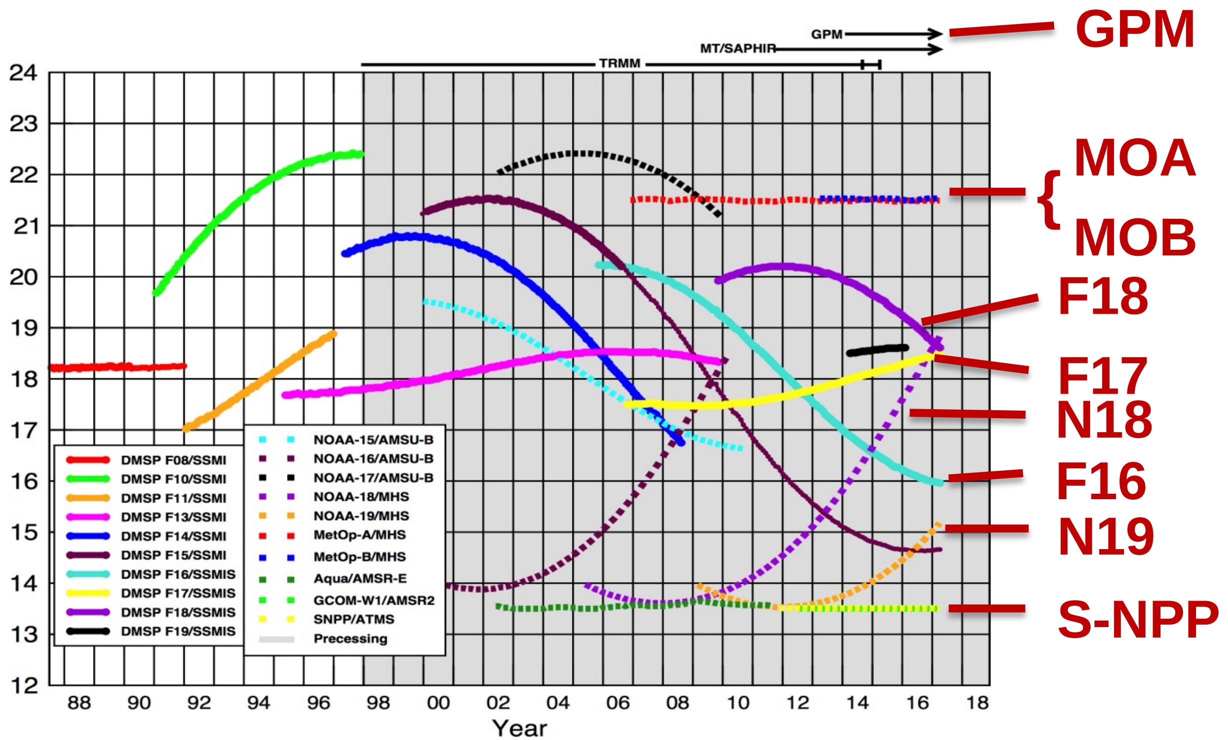
$$SR = A \int_{D_{min}}^{D_{max}} D^2 e^{-D/D_e} \left[\left(1 + BD^{3/2}\right)^{1/2} - 1 \right]^2 dD$$

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

- An adjusting factor, α, to compensate for non-uniform ice water content distribution in cloud column; derived from collocated satellite and radar data

SFR Expansion

- Expand SFR to using DMSP SSMIS and NASA GMI sensors
  - ✓ Snowfall is highly dynamic
  - ✓ It is essential to utilize all available passive microwave sensors with high frequencies to improve temporal resolution

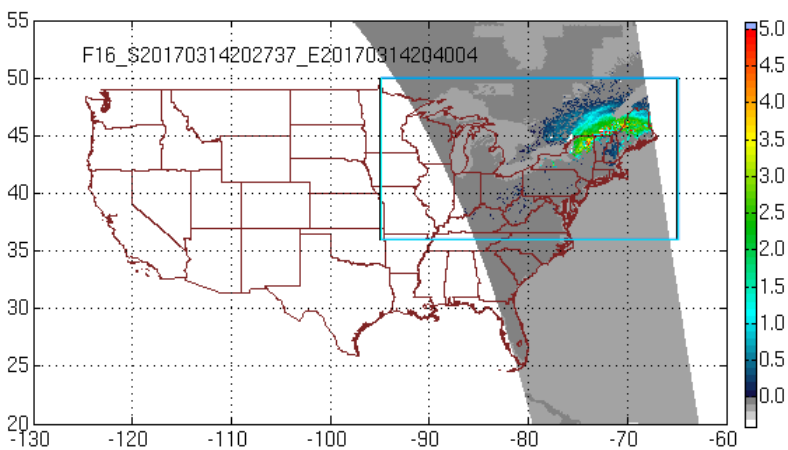


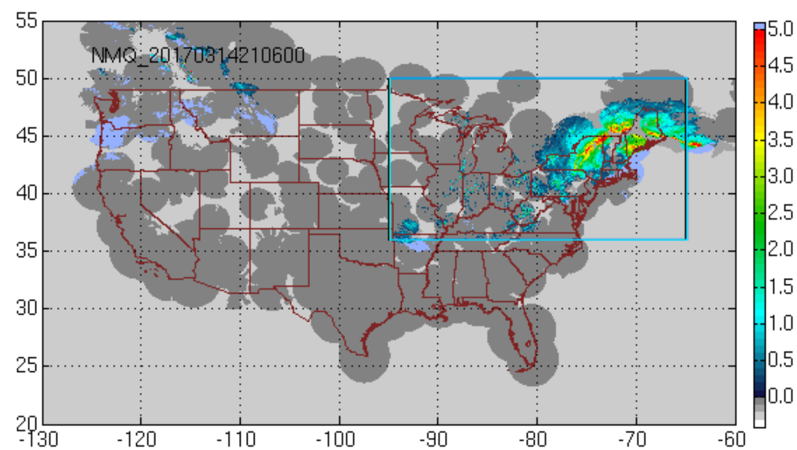
Ascending passes (F08 descending); satellites depicted above graph precess throughout the day.
Image by Eric Nelkin (SSAI), 28 April 2017, NASA/Goddard Space Flight Center, Greenbelt, MD.

SFR - SSMIS

- SSMIS is aboard three DMSP satellites: F16, F17, F18
- Conical scanning radiometers; different from ATMS and MHS which are cross scanning sensors
- Similar algorithm framework as for ATMS SFR

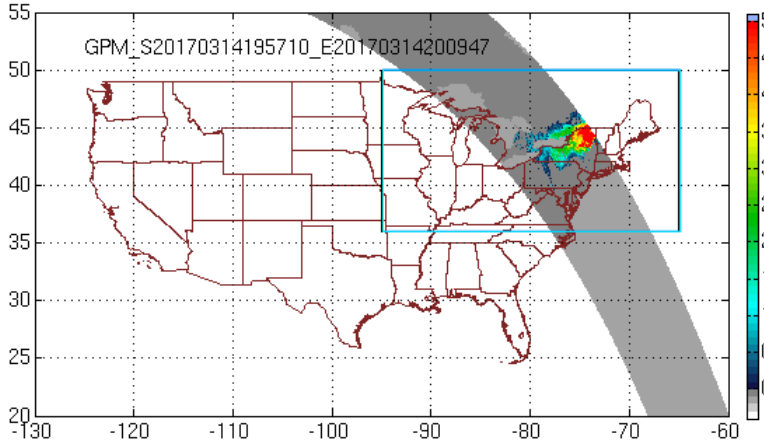
	COR	BIAS	RMS
F16	0.44	0.01	0.94
F17	0.56	-0.11	0.88
F18	0.42	-0.06	0.91

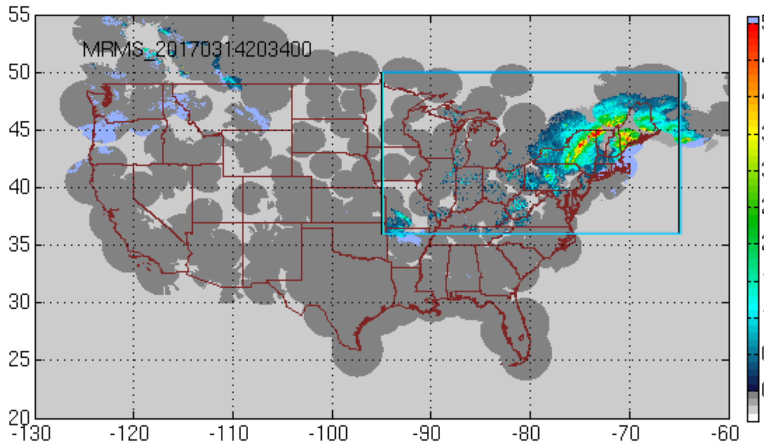




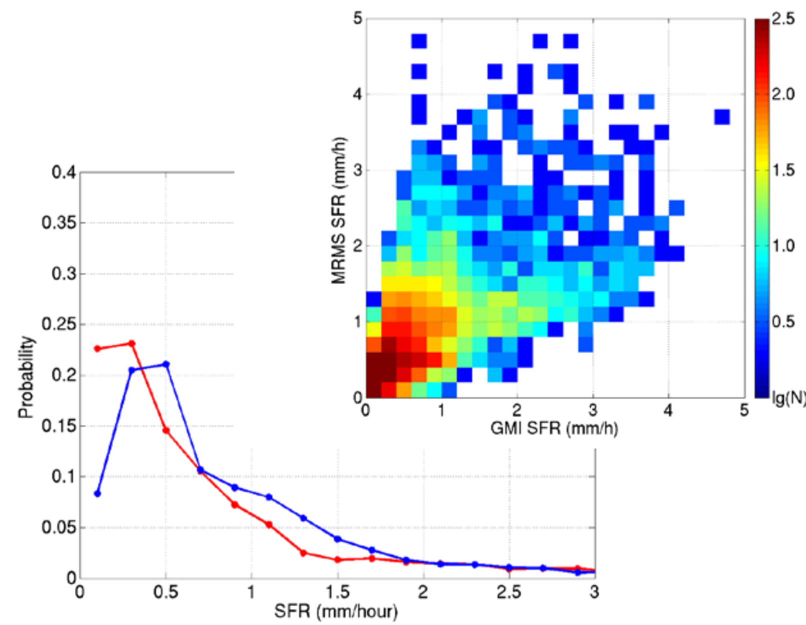
SFR - GMI

- GMI is aboard NASA GPM core satellite
- Conical scanning radiometer with high spatial resolution
- Similar algorithm framework as for ATMS SFR





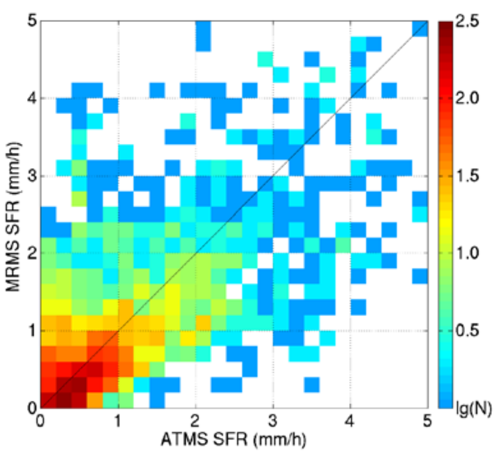
	COR	BIAS	RMS
GMI	0.65	-0.14	0.67

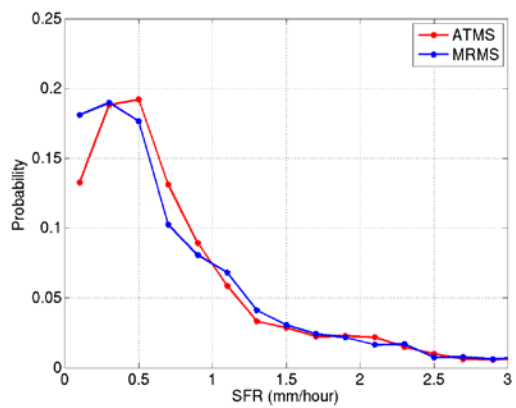


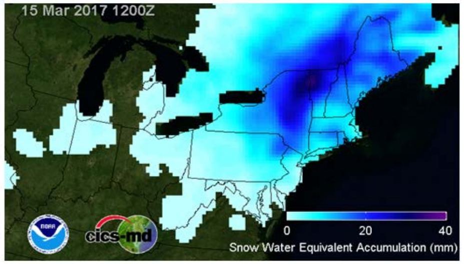
2017 Nor'easter Blizzard

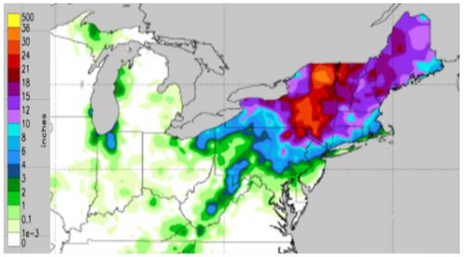
- A Blizzard hit the Mid-Atlantic region on March 14-15, 2017 and produced record snowfall
- SFR products captured the evolution of the blizzard with five satellites including S-NPP, POES and Metop

	Correl. Coeff.	Bias (mm/hr)	RMS (mm/hr)
ATMS	0.67	0.06	0.67









(Top image is the courtesy of Patrick Meyers)

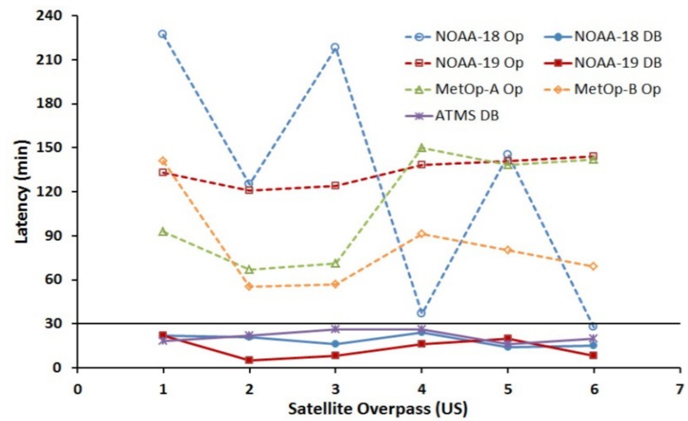
SFR using DB data

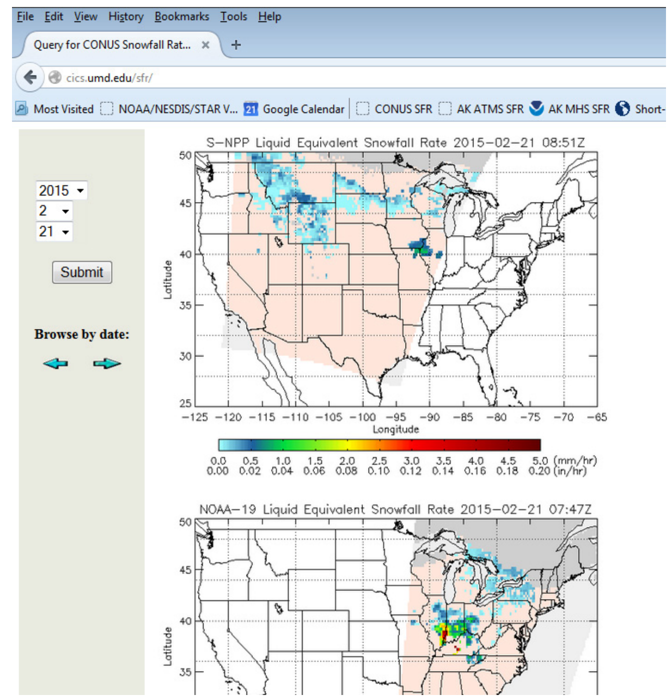
- Reduce latency to meet requirement for weather forecasting – forecasters' feedback
- Retrieve DB CONUS and Alaska L1B data from Univ. of Wisconsin, Madison/CIMSS
- Generate SFR within 30 min of observation; SFR with operational L1B data has 30 min ~ 3 hr delay
- Output:
  - ✓ Data made available to NASA/SPoRT, reformat to AWIPS, and disseminate to WFOs and WPC
  - ✓ Images posted on SFR webpage at near real-time
- Webpage:
  - ✓ CICS and NESDIS:

    http://cics.umd.edu/sfr

    http://www.star.nesdis.noaa.gov/corp/scsb/mspps_backup/sfr_realtime.html
  - ✓ SPoRT:

    http://weather.msfc.nasa.gov/cgi-bin/sportPublishData.pl?dataset=snowfallrateconus&product=conus_snowrate





SFR Near Real Time System

- Ongoing development of a unified SFR retrieval system
  - ✓ All 9 satellites
  - ✓ NRT data to reduce latency to within 30 min
  - ✓ Similar Cal/Val for all satellites

Assessment – this winter

Conduct SFR assessment at NWS Weather Forecast Offices through a collaboration with NASA SPoRT in winter 2017-2018.

Summary

- Building on the MHS and ATMS SFR product, the SFR algorithm has been developed for SSMIS and GMI
- A unified SFR system is being developed to retrieve SFR using all available passive microwave radiometers that have high frequencies suitable for retrieving snowfall rate
- Using NRT data, SFR from most of satellites can be generated within 30 min
- The SFR product has applications in hydrology and weather forecasting

Acknowledgement

- JPSS Proving Ground and Risk Reduction Program
- NASA SPoRT
- NOAA/NESDIS

Thank you!