Latest Development on the NOAA/NESDIS Snowfall Rate Product

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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
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)

\[
\begin{align*}
\Delta I_c & \quad | \quad \Delta D_e \quad | \quad \Delta \varepsilon_{23} \quad | \quad \Delta \varepsilon_{31} \\
\Delta \varepsilon_{89/88} & \quad | \quad \Delta \varepsilon_{157/165} \quad | \quad \Delta \varepsilon_{190/176} \quad | \quad (A^T A + E)^{-1} A^T \\
\end{align*}
\]

- $I_c$: ice water path
- $D_e$: ice particle effective diameter
- $\varepsilon_i$: 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 $\varepsilon_i$
- $E$: error matrix

- Iteration scheme with $\Delta T_{Bi}$ 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):

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

\[ A = \frac{\alpha I_c \delta_0^2 \eta}{24 \mathcal{H} \rho_w \rho_a D_e^4} \]

\[ B = \frac{8}{\delta_0^2 \eta} \sqrt{\frac{g \rho_a \rho_l}{3 c_0}} \]

- An adjusting factor, \( \alpha \), 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

![Graph showing satellite passes and years](Image)

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

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<th>RMS</th>
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<td>0.94</td>
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<tr>
<td>F17</td>
<td>0.56</td>
<td>-0.11</td>
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<td>F18</td>
<td>0.42</td>
<td>-0.06</td>
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SFR - GMI

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

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<tr>
<td>GMI</td>
<td>0.65</td>
<td>-0.14</td>
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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

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<th>Bias (mm/hr)</th>
<th>RMS (mm/hr)</th>
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<tr>
<td>ATMS</td>
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(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
  - 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!