Development and Transition of ATMS Snowfall Rate Product

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Project Overview

- JPSS Proving Ground/Risk Reduction Program and NESDIS/Center for Satellite Application and Research (STAR) support the development of the ATMS snowfall rate (SFR) product
    - Project period: July 2012 – June 2015
- NASA supports the transition of the ATMS SFR product through collaborations between the algorithm developers and NASA Short-term Prediction Research and Transition Center (SPoRT)
    - Project period: July 2014 – June 2016
    - The project also includes the development and transition of an ATMS SFR and radar precipitation (NMQ) merged product

ATMS and Comparison with AMSU/MHS

- ATMS: Advanced Technology Microwave Sounder
  AMSU: Advanced Microwave Sounding Unit
  MHS: Microwave Humidity Sounder
  ATMS is the successor to AMSU/MHS
- ATMS onboard SNPP and future JPSS satellites; AMSU/MHS onboard four NOAA POES and EUMETSAT Metop satellites
- Cross track scanning passive microwave radiometers
- Include a collection of window and temperature/water vapor sounding channels
- ATMS has improved sampling with more channels, especially more water vapor channels for precipitation retrieval

AMSU/MHS			ATMS		
Ch	GHz	Pol	Ch	GHz	Pol
1	23.8	QV	1	23.8	QV
2	31.399	QV	2	31.4	QV
3	50.299	QV	3	50.3	QH
			4	51.76	QH
4	52.8	QV	5	52.8	QH
5	53.595 ± 0.115	QH	6	53.596 ± 0.115	QH
6	54.4	QH	7	54.4	QH
7	54.94	QV	8	54.94	QH
8	55.5	QH	9	55.5	QH
9	fo = 57.29	QH	10	fo = 57.29	QH
10	fo ± 0.217	QH	11	fo±0.3222±0.217	QH
11	fo±0.3222±0.048	QH	12	fo± 0.3222±0.048	QH
12	fo ±0.3222±0.022	QH	13	fo±0.3222±0.022	QH
13	fo± 0.3222±0.010	QH	14	fo±0.3222 ±0.010	QH
14	fo±0.3222±0.004 5	QH	15	fo± 0.3222±0.0045	QH
15	89.0	QV			
16	89.0	QV	16	88.2	QV
17	157.0	QV	17	165.5	QH
18	183.31 ± 1	QH	18	183.31 ± 7	QH
19	183.31 ± 3	QH	19	183.31 ± 4.5	QH
20	191.31	QV	20	183.31 ± 3	QH
			21	183.31 ± 1.8	QH
			22	183.31 ± 1	QH

Product Overview

- Product: satellite retrieved water equivalent snowfall rate (SFR) estimate over global land
- ATMS SFR mostly inherits the operational AMSU/MHS SFR algorithm with the exception of the snowfall detection component
- Algorithm uses a combination of window and temperature/water vapor sounding channels
- Up to two ATMS SFR estimates per day at any location over global land; up to ten estimates per day in combination with AMSU/MHS SFR grouped into five estimates in the morning (0Z-12Z) and five in the afternoon (12Z-0Z)
- Resolution: 16 km at nadir

Methodology

1. Detect snowfall
2. Retrieve cloud properties with an inversion method
3. Compute snow particle terminal velocity and derive snowfall rate

Snowfall Detection (SD)

- SD algorithm employs a statistical logistic regression model
  - Use water vapor absorption channels
  - Training data set is composed of 4-month of matching data between ATMS and station hourly snow accumulation
  - Model output is the probability of snowfall
- Model performance

Probability of Detection (%)	False Alarm Rate (%)	Heidke Skill Score
62	7	0.58

Retrieval of Cloud Properties

- Inversion method
  - Simulation of Tb's with a two-stream, one-layer RTM (Yan *et al.*, 2008)

$$\begin{vmatrix}\Delta I_c \\ \Delta D_e \\ \Delta\varepsilon_{23} \\ \Delta\varepsilon_{31} \\ \Delta\varepsilon_{88} \\ \Delta\varepsilon_{165} \\ \Delta\varepsilon_{176}\end{vmatrix} = \left|(A^T A + E)^{-1} A^T\right| \begin{vmatrix}\Delta T_{B23} \\ \Delta T_{B31} \\ \Delta T_{B88} \\ \Delta T_{B165} \\ \Delta T_{B176}\end{vmatrix}$$

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, 88.2, 165.5, and 183±7 GHz

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

E: error matrix

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

Snowfall Rate

- Terminal velocity: Heymsfield and Westbrook (2010):

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

- Snowfall rate
  - Assume spherical habit
  - An adjusting factor to compensate for non-uniform ice water content distribution in cloud column
  - SFR model:

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

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

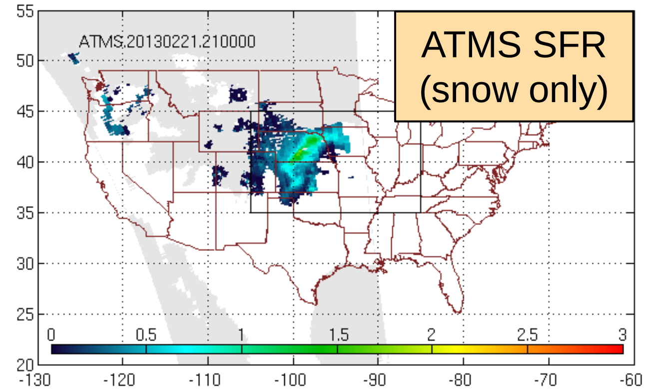
Integration is solved numerically

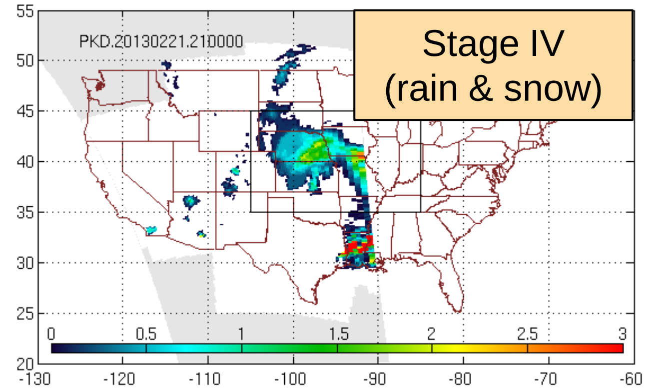
Limited Validation

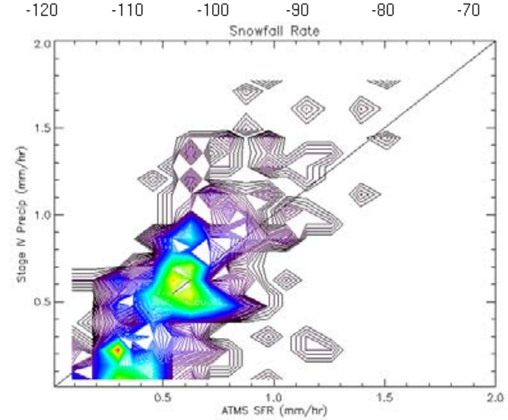
- Validation data
  - ❖ Stage IV radar and gauge combined hourly precipitation data
  - ❖ Station hourly accumulated precipitation data
- Algorithm Performance

	Time Offset (min)	Correlation Coeff	Bias (mm/hr)	RMSE (mm/hr)
Stage IV 12/21/2012	30-60	0.80	0.05	0.83
Stage IV 3/5/2013	30-60	0.65	0.02	0.26
Station	60-90	0.80	0.04	0.73

- ❖ AMSU/MHS SFR: correlation coefficient around 0.3-0.4 and bias around 0.1-0.2 mm/hr







Product Transition (1/2)

- SPoRT will lead the effort to transition the ATMS SFR product to select NWS Weather Forecast Offices (WFOs) and NESDIS/Satellite Analysis Branch (SAB) for assessment
- Following the on-going transition and assessment of the AMSU/MHS SFR product
  - SPoRT formats AMSU/MHS SFR product to AWIPS compatible form
  - The formatted data are disseminated to participating WFOs: Albuquerque, NM; Burlington, VT; Sterling, VA; and Charleston, WV
  - Training was conducted
    - ✓ Teletraining session
    - ✓ Distribution of both electronic and paper training materials to each participating office
  - Product assessment (next slide)

Product Transition (2/2)

- SPoRT protocol for product assessment
  - Forecasters evaluate product performance in their operations by
    - ✓ filling out online assessment forms
    - ✓ making posts on SPoRT's blog
    - ✓ or sending group emails
  - Product developers receive forecasters feedback and interact with users quickly and effectively
- Preliminary feedback from the current assessment helps to shape future development
  - Extension to colder regime is essential
  - More observations or extension over time is highly desired
  - Decreased latency will improve the utility of the product

Summary

- An ATMS Snowfall Rate (SFR) product has been developed based on an operational AMSU/MHS SFR algorithm in a project supported by the JPSS PGRR Program.
- The Snowfall Detection (SD) component of the ATMS SFR is an advanced algorithm compared to the original AMSU/MHS model.
- Preliminary validation results demonstrate that the ATMS SFR outperforms the AMSU/MHS SFR.
- SPoRT will lead the effort to transition the ATMS SFR product to selected WFOs for assessment in a project supported by NASA.
- The transition will follow the on-going effort to transition and assess the AMSU/MHS SFR. Preliminary feedback from the latter is helping to shape how the new JPSS-era product will be configured and used.