Snowfall Rate Retrieval using S-NPP ATMS Measurements

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Introduction

S-NPP ATMS takes passive microwave (MW) measurements at certain high frequencies (88.2~183.31 GHz) that are sensitive to the scattering effect of snow particles and can be utilized to retrieve snowfall properties. An ATMS land snowfall rate (SFR) algorithm has been developed in a project supported by the JPSS Proving Ground and Risk Reduction (PGRR) Program. The ATMS SFR, combined with the operational AMSU/MHS (aboard NOAA-18/-19, and MetOp-A/-B) SFR product, can provide up to ten snowfall estimates at any location over global land at mid-latitudes. There are more estimates from overlapping orbits from ATMS and at higher latitudes from ATMS and AMSU/MHS.

Methodology

1. Detect snowfall using principal component analysis (PCA) and logistic regression model (Kongoli et al., 2014). Input includes temperature and water vapor sounding channels. Output is the probability of snowfall. In addition, a set of filters based on NWP model temperature and water vapor profiles are used for further screening. A cold snowfall extension was also developed which is a major advancement compared to the AMSU/MHS SFR.

2. Cloud properties are retrieved using an inversion method with an iteration algorithm and a two-stream Radiative Transfer Model (Yan et. al, 2008).

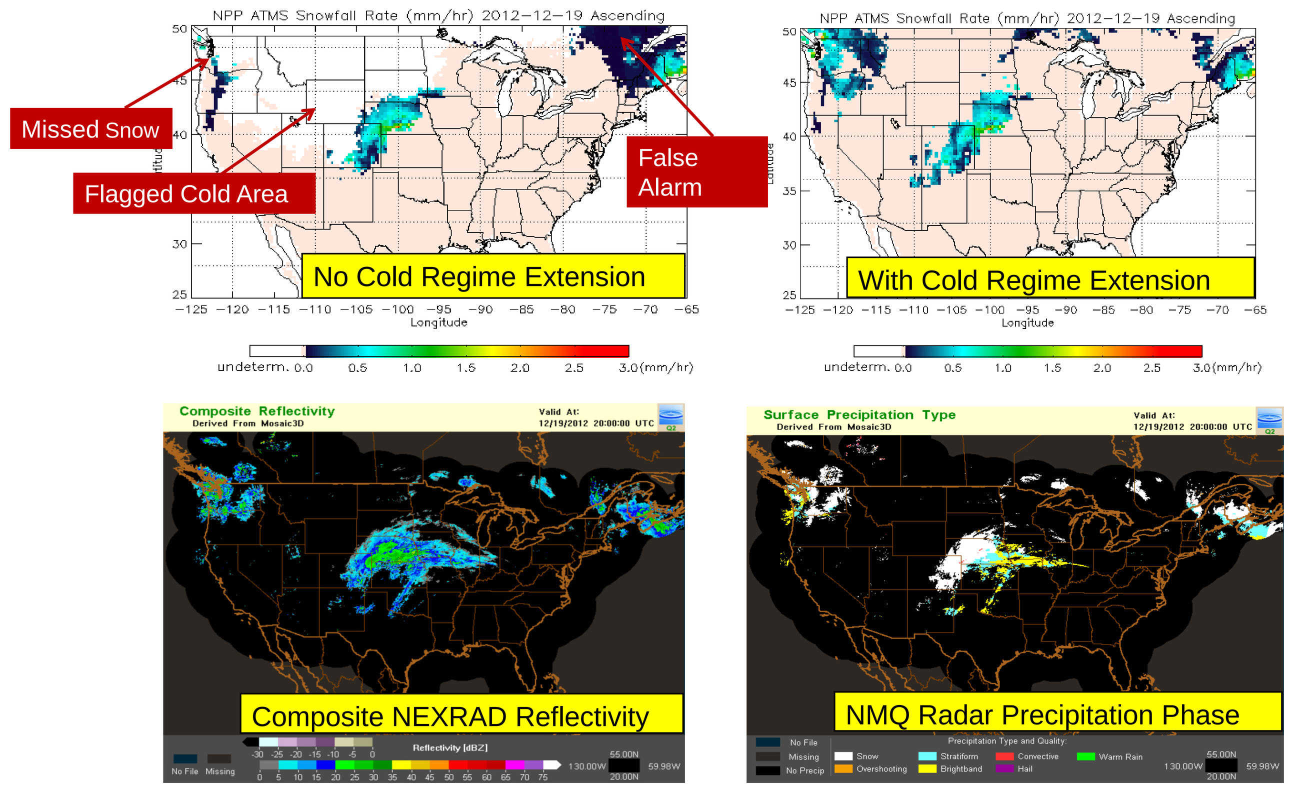
$$\begin{vmatrix}\Delta IWP\\ \Delta D_e\\ \Delta\varepsilon_{23}\\ \Delta\varepsilon_{31}\\ \Delta\varepsilon_{88}\\ \Delta\varepsilon_{165}\\ \Delta\varepsilon_{183\pm7}\end{vmatrix} = \left|(A^TA+E)^{-1}A^T\right| \begin{vmatrix}\Delta T_{B23}\\ \Delta T_{B31}\\ \Delta T_{B88}\\ \Delta T_{B165}\\ \Delta T_{B183\pm7}\end{vmatrix}$$

IWP: ice water path
D_e: ice particle effective diameter
ε: emissivity
A: Jacobian matrix
E: error matrix
T_B: brightness temperature

3. Compute snow particle terminal velocity (Heymsfield and Westbrook, 2010) and determine snowfall rate by numerically solving a complex integral.

- Heymsfield, A.J. and C.D. Westbrook, 2010, Advances in the Estimation of Ice Particle Fall Speeds Using Laboratory and Field Measurements. J. Atmos. Sci., 67, 2469-2482 doi: 10.1175/2010JAS3379.1
- Kongoli, C., H. Meng, J. Dong, R. Ferraro, N. Wang, 2014, A Snowfall Detection Algorithm over Land utilizing High-frequency Passive Microwave Measurements – Application to ATMS. To be submitted to Journal of Geophysical Research - Atmospheres.
- Yan, B., F. Weng, and H. Meng, 2008. Retrieval of snow surface microwave emissivity from the advanced microwave sounding unit, J. Geophys. Res., 113, D19206, doi:10.1029/2007JD009559.

ATMS Snowfall Detection With Cold Climate Extension



Statistics of Snowfall Detection Component

	Probability of Detection (%)	False Alarm Rate (%)	Heidke Skill Score
Warm Regime	73	9	0.63
Cold Regime	56	13	0.45

Product Applications

The SFR product can impact users mainly in two communities:

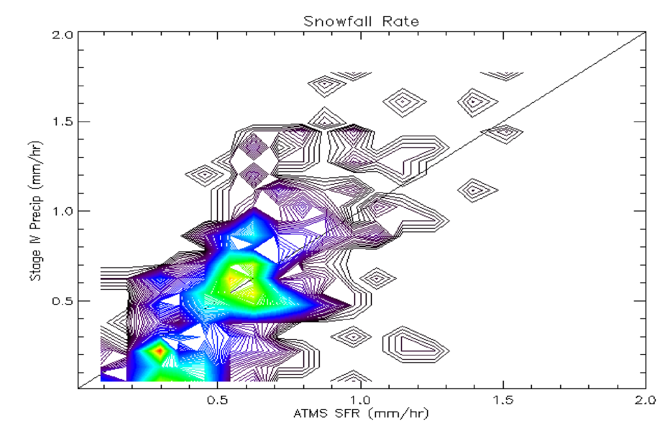
➢Global blended precipitation products traditionally do not include snowfall derived from satellites because such products were not available operationally in the past. The ATMS and AMSU/MHS SFR can provide the winter precipitation information for these blended precipitation products. NCEP/CPC CMORPH is the first such data set to include the SFR products.

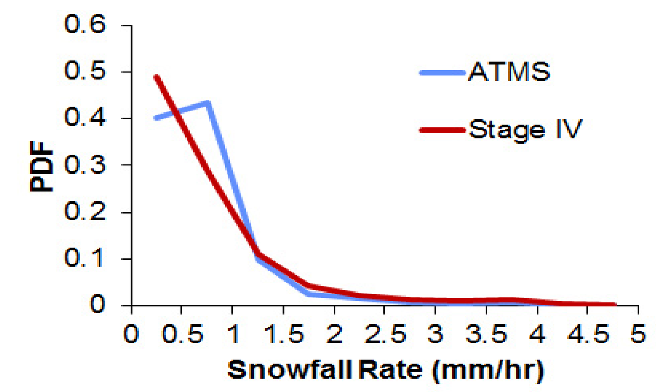
➢The SFR products can fill in the gaps where traditional snowfall data are not available to weather forecasters. The products can also be used to confirm radar and gauge snowfall data. NASA SPoRT led a project to evaluate the AMSU/MHS SFR at NWS Weather Forecast Offices and NESDIS/SAB in the past winter with very valuable feedback. The ATMS SFR will also be evaluated in the next winter in collaboration with SPoRT in a project supported by NASA.

Validation

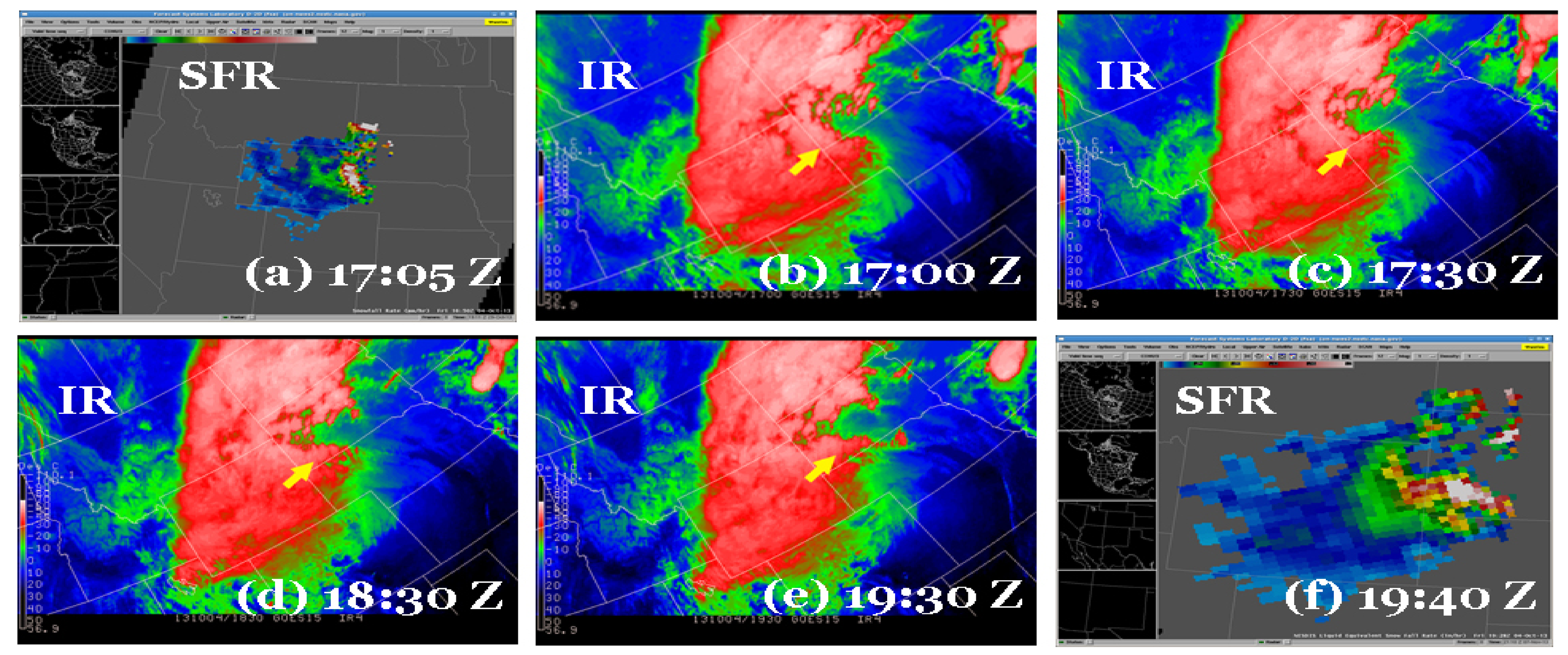
Limited validation has been conducted for the ATMS SFR product. Validation sources included StageIV radar and gauge combined hourly precipitation data, NMQ radar instantaneous precipitation data, and station hourly accumulated precipitation data. Snowfall product validation is especially challenging due to the spatial and temporal differences between satellite retrieval and validation data, and errors in the validation data etc.

	Correlation Coefficient	Bias (mm/hr)	RMSE (mm/hr)
Stage IV 02/21/2013	0.80	0.05	0.83
Stage IV 3/5/2013	0.65	0.02	0.26
Station	0.80	0.04	0.73





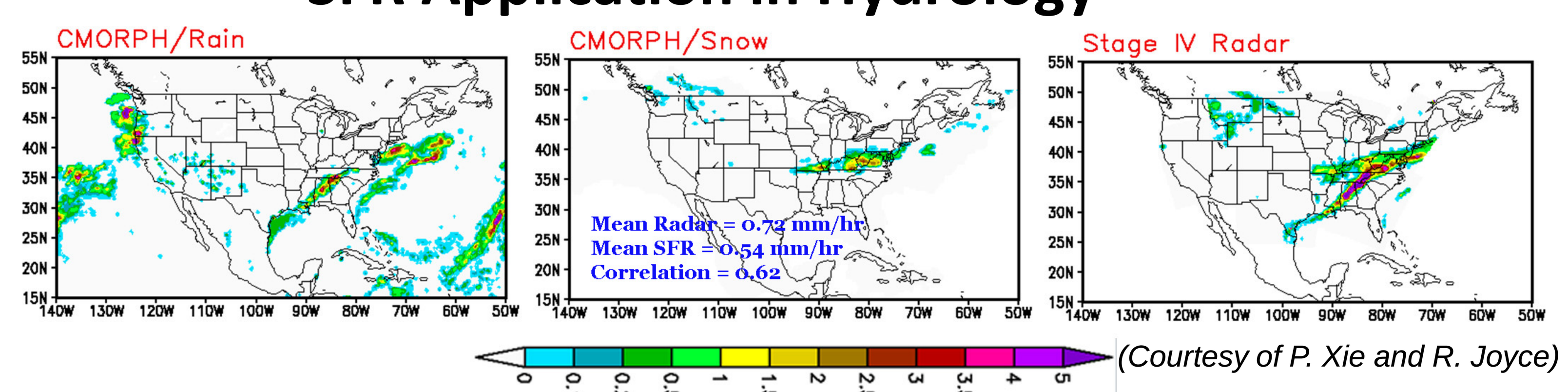
SFR Application in Weather Forecasting



(GOES images are courtesy of M. Folmer)

Time sequence of a snowstorm in the Northern Plains. (a) and (f): the AMSU/MHS SFR product at around 17:05Z and 19:40Z, respectively; (b)-(e) GOES-15 IR images at 17:00Z, 17:30Z, 18:30Z, and 19:30Z, respectively. The yellow arrow points to the most intense snow in the IR images. The IR sequence indicates that the snow max rotated counter-clockwise and moved north between the two SFR observations. This is confirmed by the second satellite pass at 19:40Z.

SFR Application in Hydrology



(Courtesy of P. Xie and R. Joyce)

NCEP/CPC CMORPH blended precipitation product uses both ATMS and AMSU/MHS SFR for its winter precipitation analysis. In this snowfall event, the correlation coefficient between the CMORPH 3-hour precipitation and Stage IV reaches 0.62.

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