Passive Retrieval of Snowfall over Snow Cover: Lessens from GPM and Algorithms

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Goal and Motivation

- Improved understanding of the passive microwave signature of precipitation and its phase change over radiometrically complex snow-covered surfaces.
- Improved detection and estimation of snowfall with minimum amount of ancillary data.
- Moving toward physically-based snowfall and snow-cover retrievals using GPM data

Passive Microwave Precipitation Retrievals in TRMM Era

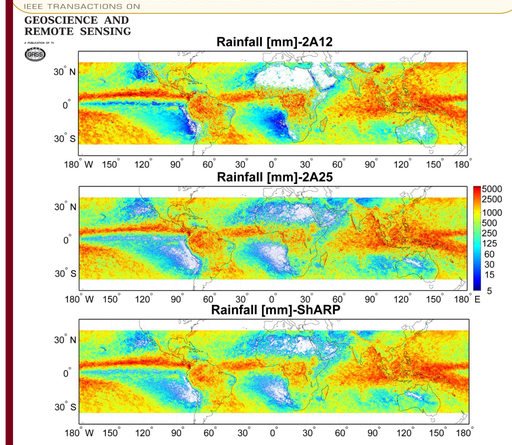


Fig.1: Annual estimates of the total rainfall [mm] in 2013 mapped onto a 0.1-degree regular grid.

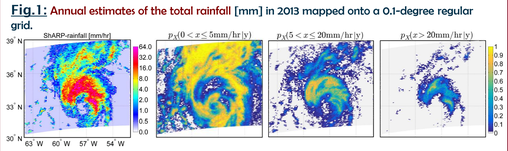


Fig.2 Probability maps showing different segments of the posterior probability density function for the ShARP retrieval of the hurricane Danielle (orbit No. 72840) at 09:48 UTC.

Snowfall signal over snow cover: a lesson from GPM

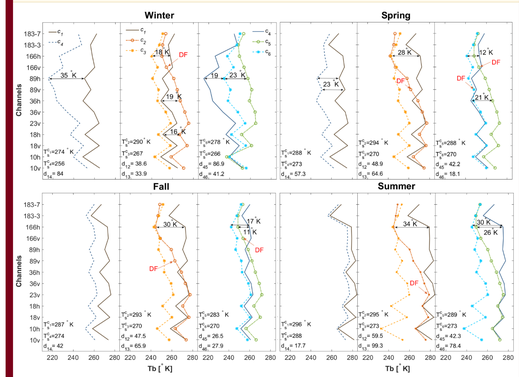


Fig.3 The seasonal class mean GMI brightness temperatures in 2015 for ground (c1), rain over ground (c2), snowfall over ground (c3), snow cover (c4), rainfall over snow cover (c5), and snowfall over snow cover (c6). At the lower left of each subplot, the mean values of surface skin temperatures ($T_s^{c_i}$) and the Euclidean distances between the class mean brightness temperatures ($d_{i,j}$) are shown. The classes are identified using the information from GPM precipitation radar, MODIS snow cover, and ancillary information of the 2 m air temperature from the MERRA-2 reanalysis.

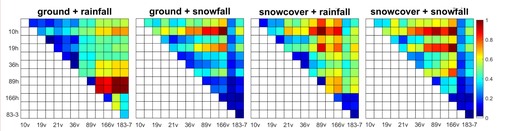
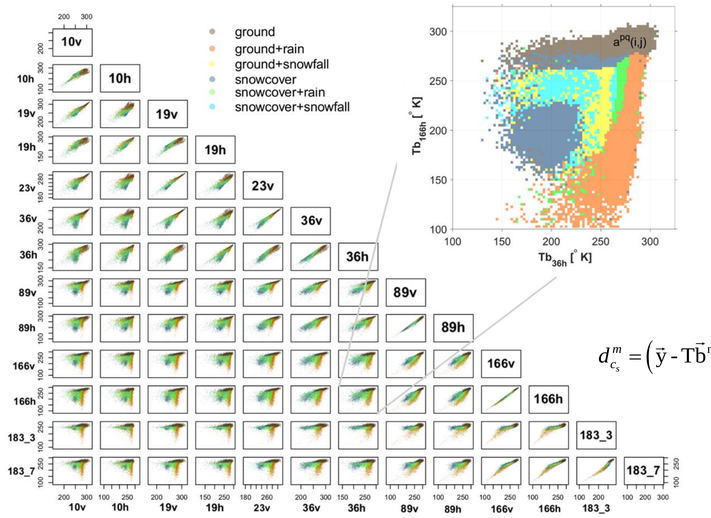


Fig.4 (first to fourth panels) Relative importance weights of the GMI channel pairs for passive separation of the land-atmosphere classes of interest with a precipitating atmosphere. The weights are proportional to the area of spectral regions over which a specific class exhibits the highest probability of occurrence.

GPM Channel weights – snowfall over snow cover



$$d^m_{c_s} = \left(\bar{y} - T\vec{b}^m\right)^T \mathbf{W}_{c_s} \left(\bar{y} - T\vec{b}^m\right)$$

Fig.5: Grouped scatterplots of the GMI brightness temperatures based on the defined land-atmosphere classes. The inset demonstrates the 2-D spectral regions, spanned by the horizontally polarized 36 and 166 GHz channels, over which the probability of a specific land-atmosphere class is maximum.

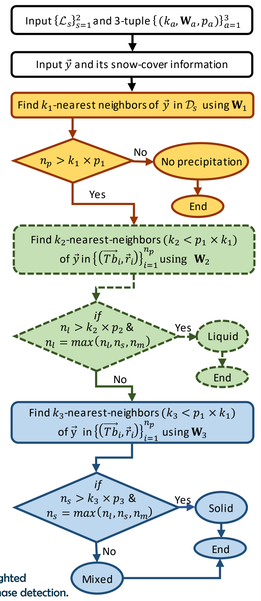


Fig.6: Algorithm flowchart of the proposed weighted k-nearest neighbor algorithm for precipitation phase detection.

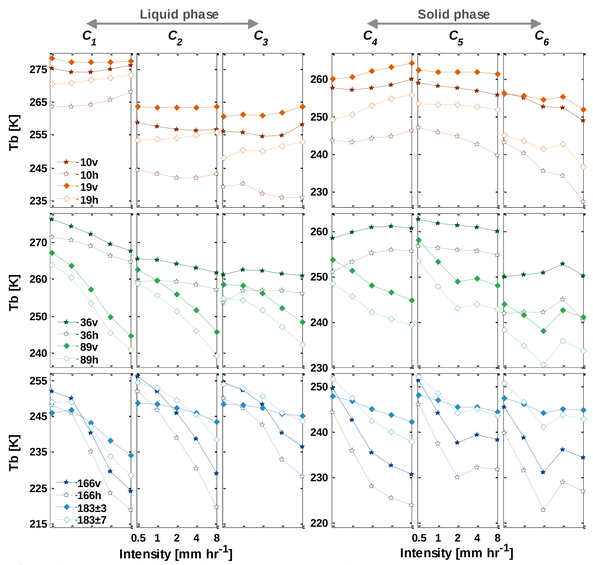


Fig.7: The variation of the mean brightness temperatures (June 2014 to May 2015) in response to changes in the precipitation intensity (top three rows) for different land-atmospheric classes including the liquid (solid) precipitation over the ground C1 (C4), wet C2 (C5), and dry C3 (C6) snow cover.

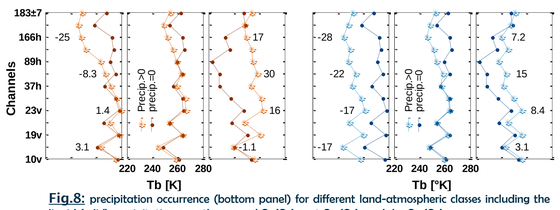


Fig.8: precipitation occurrence (bottom panel) for different land-atmospheric classes including the liquid (solid) precipitation over the ground C1 (C4), wet C2 (C5), and dry C3 (C6) snow cover.

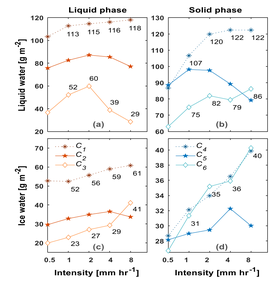


Fig.9: The annual mean variations of the cloud liquid and ice water path with respect to different precipitation intensities from GPM and MERRA-2 data.

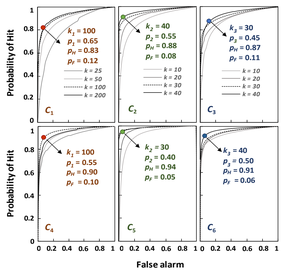


Fig.10: The receiver operating characteristic curves for optimal estimation of the algorithm parameters.

Summary of findings

- Snowfall and rainfall exhibit warmer signatures over dry snow cover--due to liquid water emission.
- Combination of low (10-19 GHz) and high (166-183 GHz) are critical for snowfall retrievals with reduced uncertainties.
- The ice water path increases 15% and 39% for rainfall and snowfall.
- the liquid water path increases about 14% and 41%.
- Over the dry snow cover: no evidence of any significant changes neither in ice nor in liquid water path at intensity values where we see the irregular behavior.
- The average probability of hit for precipitation detection reaches to 0.80 and the false alarm remains below 0.10.
- detection rate of solid precipitation is larger than the liquid phase by about 10%.
- The results suggest that this improved detection largely occurs over the dry snow cover, with improved detection rates for precipitation occurrence by 11% and the highest detection rate of 0.94 for snowfall.

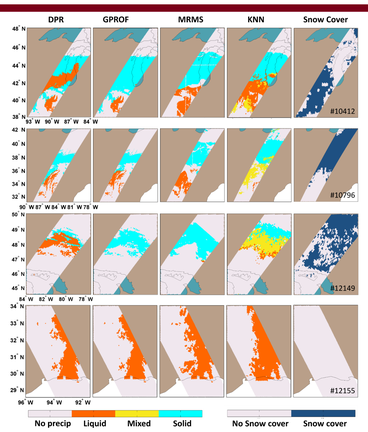


Fig.11: Orbital-level precipitation phase detection from KNN, DPR, GPROF, and MRMS for the following orbit numbers and dates: #010412 on 2015/12/28 (first row), #010796 on 2016/01/22 (second row), #012149 on 2016/04/18 (third row), and the #012155 on 2016/04/18 (fourth row).

Global Results

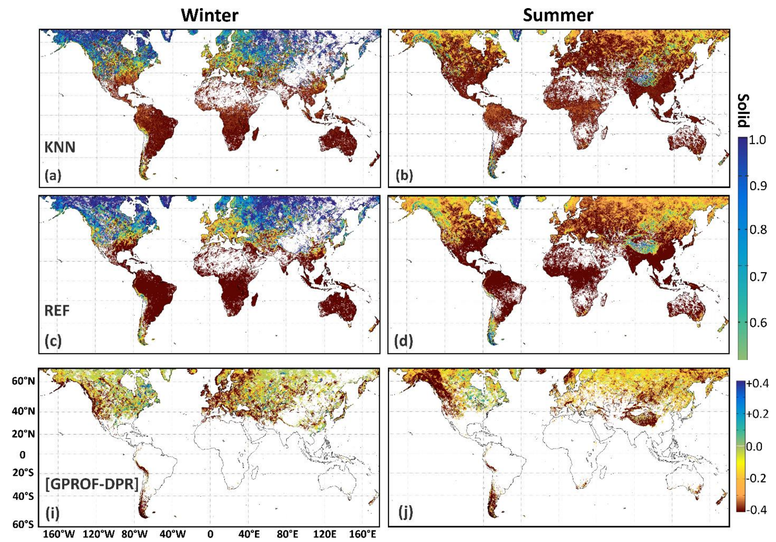


Fig.12: Seasonal probability maps of precipitation phase transitions with p=0 (liquid) to p=1 (solid)

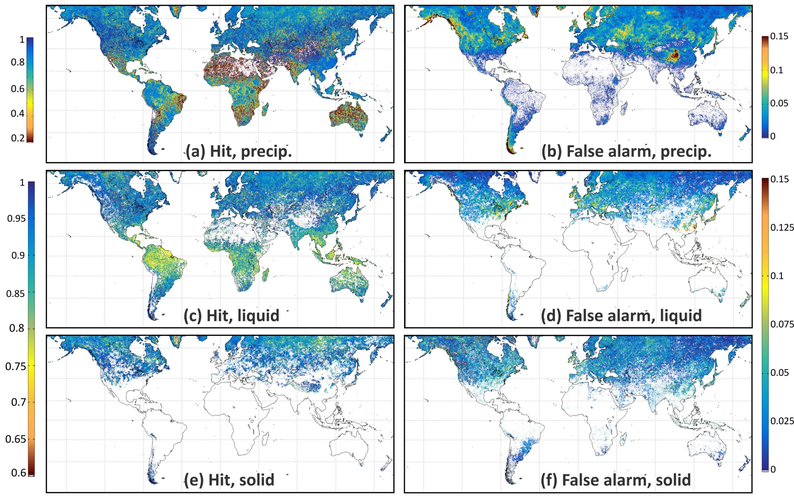
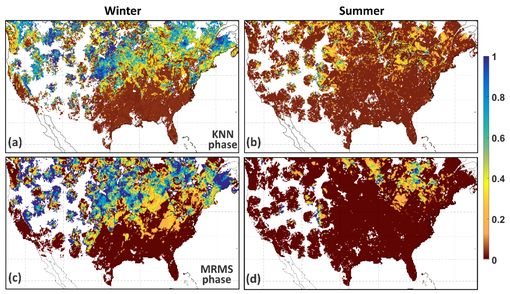


Fig.13: The annual maps of precipitation phase transitions with p=0 (liquid) to p=1 (solid).



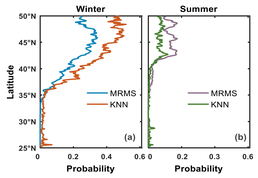


Fig. 15. The zonal mean comparison between the KNN and MRMS phases in winter (a) and summer (b)

Fig.14: Seasonal probability maps of precipitation phase transitions with p=0 (liquid) to p=1 (solid) for KNN and MRMS over the conterminous United States. All KNN results are presented only over the MRMS spatial coverage.

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3. Ebtehaj, A.M., R.L. Bras, E. Foufoula-Georgiou (2016), "Evaluation of ShARP passive rainfall retrievals over snow-covered land surfaces and coastal zones", *J. Hydrometeor*, 17, 1013–1029.doi: http://dx.doi.org/10.1175/JHM-D-15-0164.1.
4. Takbiri Z., A.M. Ebtehaj, and E. Foufoula-Georgiou (2017), "A Multi-sensor Data-driven methodology for all-sky Passive Microwave Inundation Retrieval", *Hydrol. Earth Syst. Sci.*, 21, 2685-2700, https://doi.org/10.5194/hess-21-2685-2017, 2017.
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