Advanced Snow Water Path Retrieval Algorithm for the GPM Microwave Imager Provides Wide-Swath Snowfall Detection over All Surfaces

Lisa Milani (Code 612, NASA/GSFC and UMD); Jean-François Rysman, Giulia Panegrossi, Paolo Sanò, Anna Cinzia Marra, Stefano Dietrich (CNR-ISAC); Mark S. Kulie (MTU)

Snowfall Occurrence

Snow retrieval ALgorithm fOr gMi (SLALOM) is a snowfall retrieval algorithm for GMI based on Cloudsat/CALIPSO products. Based on a random forest classification method, it provides snowfall and supercooled liquid water cloud detection and using a segmented multi-linear regression approach it also provides snow water path (SWP) estimates in good agreement with CloudSat CPR with the advantage of wide swath coverage versus the nadir-only view of CloudSat.
References:

Data Sources: The Global Precipitation Measurement (GPM) Microwave Imager (GMI) brightness temperatures, in particular the 2B-CSATGPM product merging CloudSat Cloud Profiling Radar (CPR) reflectivities and GMI brightness temperatures. Water Phase Mask provided by the DADAR (liDAR+raDAR) product combining CPR and CALIPSO lidar data. This research is carried out through a no-cost scientific collaboration proposal between the EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H SAF) and the NASA GPM mission.

Technical Description of Figures:
**Graphic 1:** (Left) Snowfall percentage of occurrence as given by CPR, from May 2014 to May 2016 on a 1ºx1º grid. The Antarctic coast is the region with the highest occurrence of snowfall, with values reaching 40% in some areas, followed by Greenland and the Labrador Sea. Note that even at the grid spacing at which the data is presented, there are significant striping artifacts due to the sparse sampling resulting from the nadir-only view of CPR.

**Graphic 2:** (Right) Snowfall percentage of occurrence as given by the snow detection module of SLALOM, from May 2014 to May 2016 on a 0.1ºx0.1º grid. The results agree quite well with CPR. SLALOM exhibits an 83% probability of detection (POD), including light snow, and the false alarm rate (FAR) is 12%. The improved sampling due to the wide GMI swath offers more consistent sampling than CPR, even at fine grid spacing. Snow water path estimates (not shown) also agree well with CPR: root mean squared error is 0.04 kg m⁻² with a bias of ~20% and a correlation coefficient of 0.86.

Scientific significance, societal relevance, and relationships to future missions: Snow plays a central role in the Earth climate system (water cycle, Earth radiative budget) and global snowfall can only be monitored by spaceborne instruments. Spaceborne cloud radars, e.g., CPR, have the sensitivity to detect and quantify snowfall profiles but on a narrow swath, while spaceborne radiometers, e.g., GMI, available on a large swath, are sensitive to snowfall but are subject to background surface contamination and are indirectly linked to surface snowfall. In particular, radiometer snowfall detection capabilities strongly depend on the interconnection between background surface characteristics, atmospheric water vapor content, and occurrence and vertical distribution of supercooled liquid water clouds, which tend to mask the scattering signal related to snowfall. The Snow retrieval ALgorithm fo rGMI (SLALOM) leverages strengths of both CPR and GMI instruments to detect snowfall and retrieve associated snow water path on the GMI swath. The SLALOM algorithm is also able to detect supercooled liquid water clouds, which play important roles in the radiative budget and in cloud microphysics. For detecting the occurrence of these clouds, POD is 97% and FAR is 5%. Through the exploitation of all 13 GMI channels, and the optimal use of ancillary variables describing atmospheric conditions (with no ancillary information on the background surface), SLALOM is able to predict snowfall occurrence and snow water path in very good agreement with the CloudSat CPR, with the advantage of ensuring a much larger spatial coverage corresponding to the GMI swath. The SLALOM approach is being extended to other radiometers, e.g., the Advanced Technology Microwave Sounder (ATMS) on board the Suomi National Polar-orbiting Partnership (NPP) and the Joint Polar-orbiting Satellite System (JPSS) 1, to be able to fully cover the polar regions and to contribute to global snowfall monitoring.
A new MODIS Collection 6 MAIAC product (MCD19) was released in May 2018. The MCD19 suite includes 1km cloud mask, column water vapor, aerosol optical depth and type (smoke/dust), smoke plume height, as well as spectral surface reflectance (BRF) at 1km and 500m resolution and BRDF model parameters. A subpixel snow fraction and snow grain size are reported for the detected snow.
References:


Technical Description of Figures:

Image: The MODIS Adaptive Processing System (MODAPS) global browse images showing MAIAC aerosol optical depth (AOD) and RGB BRF (surface reflectance) for March 1 (left column) and August 18 (right column) of 2005. The AOD images illustrate regional and seasonal variability of major aerosol sources over global land. The RGB images of cloud-free land surface reflectance show a contrasting seasonality of snow cover and vegetation dynamics between the northern and southern hemispheres from the start of boreal spring to the peak of summer. Gridded MAIAC data are provided at 1km resolution on Sinusoidal projection.

Scientific significance, societal relevance, and relationships to future missions: MAIAC MODIS MCD19 product is an important contribution to the Earth System data record. Due to its advanced cloud and snow detection, MAIAC improves the quality of atmospheric correction, in particular over tropics and at northern latitudes, regions significantly affected by climate change. Since 2014, majority of studies of Amazon tropical forests, which used MODIS data, relied on MAIAC processing. Presently, MAIAC is the only algorithm providing high 1km resolution reliable aerosol retrievals over land including urban regions. This has drawn an unparalleled interest in the air quality and health studies. Finally, MCD19 data are important for data assimilation and climate models due to high accuracy of MAIAC water vapor, aerosol and land surface BRDF products.
Estimation of Terrestrial Global Gross Primary Production (GPP) with Satellite Data-Driven Models and Eddy Covariance Flux Data

Joanna Joiner (GSFC 614), Yasuko Yoshida (GSFC 614), Yao Zhang (Columbia Univ.), Gregory Duveiller (European Commission), Martin Jung (Max Planck Institute), Alexei Lyapustin (GSFC 613), Yujie Wang (GSFC 613), Compton Tucker (GSFC 610.9)

GPP is the amount of CO$_2$ taken up by plants and is one of the most variable and uncertain components of the global carbon cycle.

- We estimate global GPP using MODIS (on right) reflectances and chlorophyll fluorescence from an instrument on European weather satellites.
- Our GPP is higher than previous satellite-based estimates because it more accurately accounts for cloud effects (plants are more efficient in cloudy conditions because scattered sunlight can reach more of the canopy).

Total estimated amount of carbon taken up by plants in 2007 is 140.8 peta grams ($10^{15}$ grams) of carbon per year

Annual Average Terrestrial Gross Primary Production (GPP) 2007
Name: Joanna Joiner, NASA/GSFC, Code 614
E-mail: Joanna.joiner@nasa.gov
Phone: 301-614-6247


Data Sources:
Measurements and data products are from the NASA Aqua and Terra MODerate-resolution Imaging Spectroradiometer (MODIS). The products included in the paper are MCD43 (NBAR reflectance), MOD09 (reflectance), MOD13 (NDVI), MOD15 (FPAR), MOD17 (GPP), and MOD19 (MAIAC reflectance). We acknowledge greatly the MODIS instrument and algorithm teams. We also used solar-induced fluorescence from the Global Ozone Monitoring Experiment 2 (GOME-2) flying on the European Meteorological Satellite (EUMETSAT) MetOp-A. This product is produced by the lead authors (Joiner and Yoshida). This work used eddy covariance data acquired and shared by the FLUXNET community (Tier 1), including these networks: AmeriFlux, AfriFlux, AsiaFlux, CarboAfrica, CarboEuropeIP, CarboItaly, CarboMont, ChinaFlux, Fluxnet-Canada, GreenGrass, ICOS, KoFlux, LBA, NECC, OzFlux-TERN, TCOS-Siberia and USCCC. We also used the FLUXCOM-RS GPP product and the Vegetation Photosynthesis Model (VPM) GPP product. Finally, we used short-wave radiation fluxes from the Clouds and Earth’s Radiant Energy System (CERES) and the NASA Global Modeling and Assimilation Office’s (GMAO) Modern-Era Retrospective Analysis for Research and Applications (MERRA-2).

Technical Description of Figure: Maps of annual averaged GPP estimated with remote sensing data for the year 2007. Global map was generated by training a fairly simple regression model to predict GPP using MODIS (MCD43 NBAR) angle adjusted reflectances and solar-induced fluorescence from the Global Ozone Monitoring Experiment – 2 (GOME-2) on EUMETSAT MetOp 2. The training was “calibrated” using eddy covariance flux measurements from the FLUXNET 2015 data set. We account for the fact that photosynthesis is more efficient (per unit incoming light) in cloudy conditions. Our GPP estimates out-performed other popular satellite-based estimates such as FLUXCOM, MODIS GPP (MOD17), and the Vegetation Photosynthesis Model (VPM) as compared with independent FLUXNET data. Our GPP estimates are higher than previous estimates, particularly in the cloudy tropics and agree well with the single FLUXNET Tier 1 EC tropical flux tower as well as with process models. We have made our global 15 year data set available on the Aura Validation Data Center https://avdc.gsfc.nasa.gov.

Scientific significance, societal relevance, and relationships to future missions: It is of importance for carbon cycle science, in particular for evaluating terrestrial biochemical models (TBM)s to have estimates of global GPP on weekly to monthly time scales. The carbon cycle in general is of interest for missions where XCO2 is measured, such as OCO-2 and in the future GEO-Carb.