# Uncertainties of GPM/DPR Rain Estimates Caused by DSD Parameterizations

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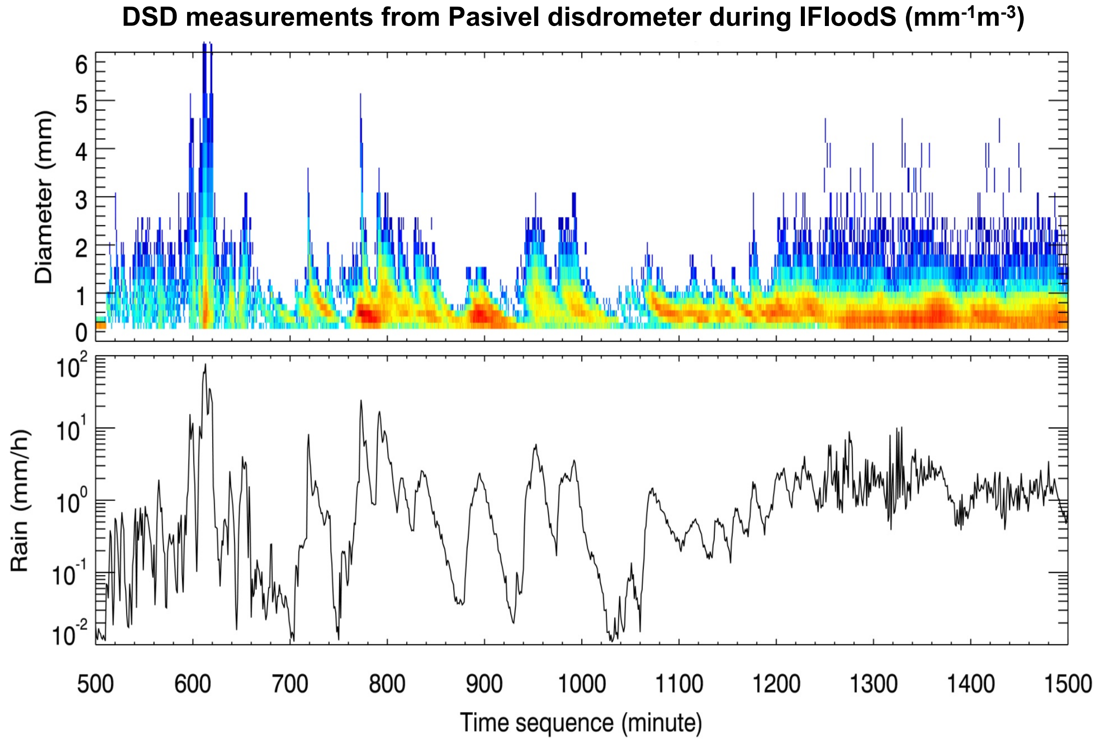


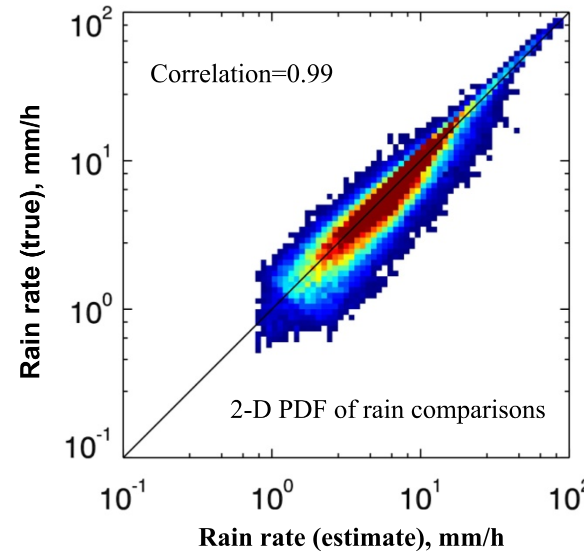


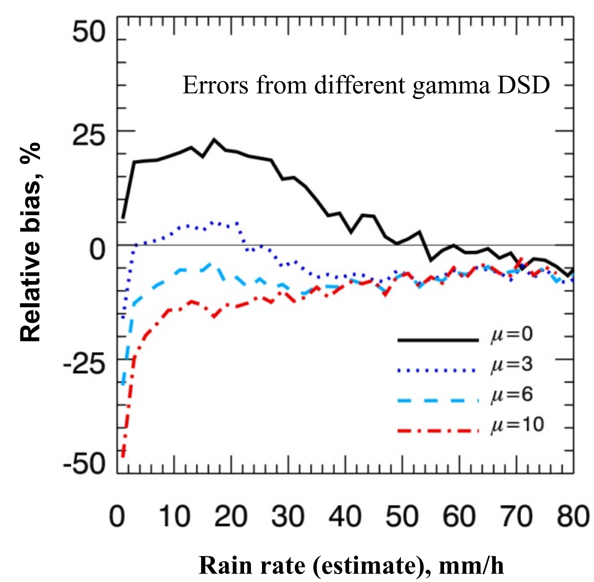


Rain rate from rain drop size distribution (DSD) derived by the Global Precipitation Measurement (GPM) Dual-wavelength Precipitation Radar (DPR) algorithms is compared with those directly obtained from measured DSD spectra to assess uncertainties in DSD models. Analysis of the comparisons of different DSD models reveals that the DPR retrievals using the fixed-μ ($\mu$=3) gamma distributions generally yield the smallest error, and therefore provide fairly accurate estimates of rain rate.

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**References:**

Liang Liao, Robert Meneghini, and Ali Tokay, 2014: Uncertainties of GPM DPR rain estimates caused by DSD parameterizations. *Journal of Applied Meteorology and Climatology*, 53, 2524–2537.
doi: http://dx.doi.org/10.1175/JAMC-D-14-0003.1

**Data Sources:** The DSD data used in this study are primarily from measurements made by Parsivel disdrometers during the Iowa Flood Studies (IFloodS) field experiment from May 1 to June 15, 2013. This work is supported by Dr. R. Kakar of NASA Headquarters under NASA's Precipitation Measurement Mission (PMM) Grant NNH12ZDA001N-PMM.

**Technical Description of Figures:**

***Measured DSD:*** Example of DSD measurements versus time taken from one of the Parsivel disdrometeors over approximately 1000 minutes of data. The image of the DSD spectra ($mm^{-1}m^{-1}$), given in the top panel with the color scale on the right, is displayed in terms of particle diameter (mm) along the ordinate and time (minute) along the abscissa. The rain rate (mm/h) from DSD is given in the bottom panel for the same time period. Measured DSD data are employed to generate the radar reflectivity factors at Ku- and Ka-band. These radar reflectivities are subsequently used to estimate the DSD parameters and then rain rate, under an assumed DSD model. The rain rates estimated from the radar-derived DSD are compared with those directly obtained from the measured DSD spectra. The difference between the rain rate retrieved by the radar and the directly measured rain rate can be interpreted as the uncertainty in the radar rain estimation arising from the DSD parameterization and the inherent errors in the radar retrieval method.

***Top-right panel:*** 2-dimensional probability density function (color-scale) that shows comparison of retrieved rain rates with true values that are computed directly from DSD data obtained from 11 Parsivel disdrometers during IFloodS. For reference, one-to-one line (red) is shown. ρ is correlation coefficient. For the radar retrieval, the shape parameter, μ, of the gamma distribution is fixed at 3.

***Bottom-right panel:*** Relative biases of the DPR-like dual-wavelength retrievals relative to their true values obtained directly from the DSD measurements. A fixed-μ gamma distribution is assumed for the DPR retrieval for μ values of 0, 3, 6 and 10. It is evident that the retrieved rain rates at μ=0 (exponential distribution) are significantly overestimated for rain rates up to 50 mm/h while the results at μ=6 show a small underestimation. The DPR-estimated rain rate is within ±10% bias if μ is chosen at 3 or 6.

**Scientific significance, societal relevance, and relationships to future missions:** The Ku- and Ka-band dual-frequency radar (DPR) is one of the instruments aboard the Global Precipitation Measurement (GPM) satellite. One of its primary goals is to derive rain rate by estimating DSD which is often modeled by an analytical function with two or three unknown parameters. The inability of the modeled DSD to represent actual DSD spectra as well as intrinsic variations of DSD in time and space lead to uncertainties in the estimates of rainfall rate obtained from the DPR. Understanding the uncertainties in rain estimation that depend on DSD parameterizations is important in evaluating the overall performance of DPR rain-retrieval algorithms. DSD parameterization models have an impact not only on the radar reflectivity-rain rate relationship but also on attenuation corrections that are needed to compensate for the loss of the radar signal caused by precipitation. Analysis of the uncertainties associated with the DSD model employed in the DPR rain estimation procedure also provides insight into the selection of DSD models adopted in the Ku- and Ka-band dual-wavelength radar rain-profiling algorithms. A large set of DSD measurement data (approximately 50,000 minutely-averaged spectra), taken from 11 Parsivel disdrometers during IFloodS field campaign, are employed in this study for assessment of retrieval uncertainties in connection with the choice of DSD model within the context of dual-frequency retrievals.

# A stable high-quality aerosol data record from MODIS Terra Deep Blue

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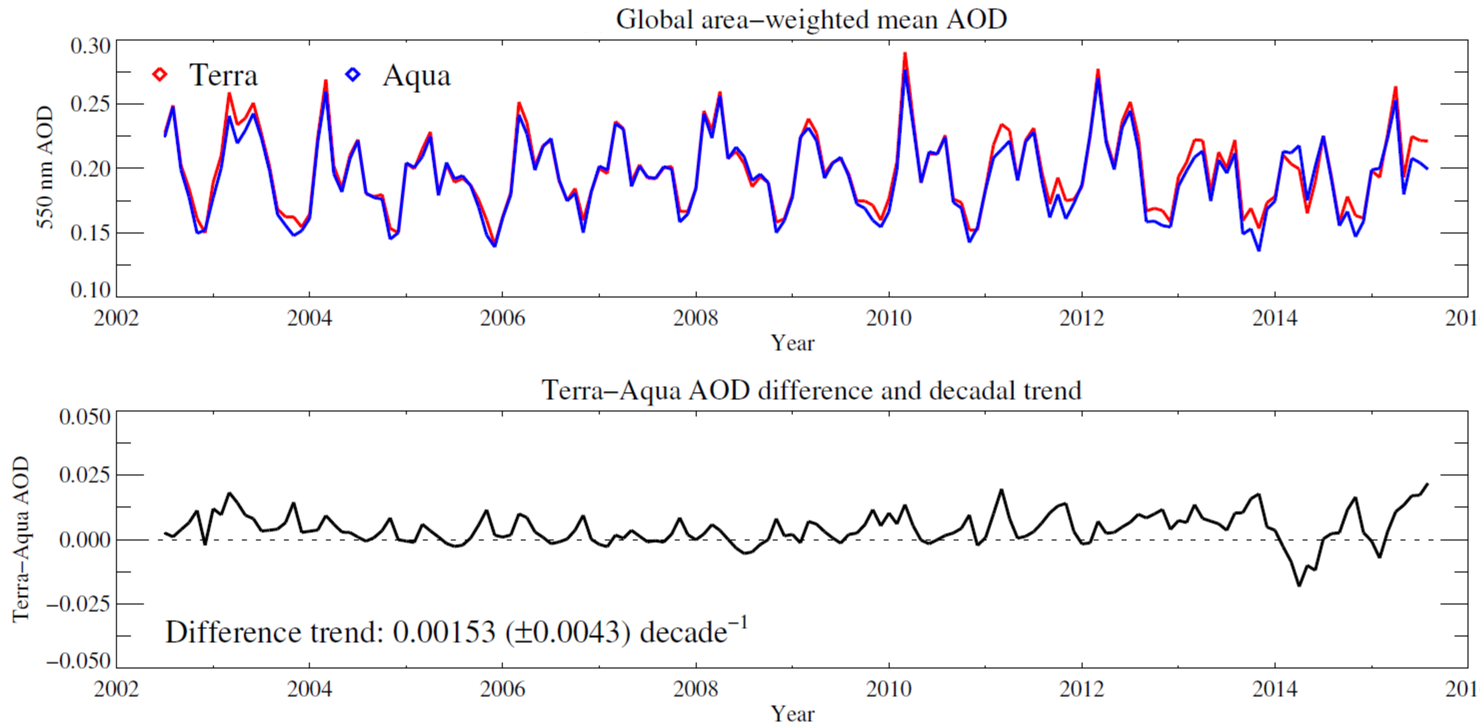
(a)

(b)




**The calibration efforts by the MODIS Characterization Support Team and Ocean Biology Processing Group have resulted in high quality measurements by the Terra MODIS instrument going back to its launch in 2000. As a result, the new Collection 6 MODIS Terra Deep Blue time series is highly consistent with its MODIS Aqua (launched 2002) counterpart, without the strong divergence exhibited in MODIS Collection 5.**

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**References:**

Sayer, A. M., N. C. Hsu, C. Bettenhausen, M.-J. Jeong, and G. Meister (2015), Effect of MODIS Terra radiometric calibration improvements on Collection 6 Deep Blue aerosol products: Validation and Terra/Aqua consistency, J. Geophys. Res. Atmos., 120, doi:10.1002/2015JD023878.

**Data Sources:**

NASA MODIS Terra data – Collection 6 Level 1B data, and Level 2 (orbit-level) and Level 3 (daily and monthly aggregates) of the 'Deep Blue' aerosol optical depth (AOD) data products. The MODIS Characterization Support Team (MCST) and Ocean Biology Processing Group (OBPG) are thanked for their extensive efforts monitoring and improving the calibration of the MODIS sensors. More information about Deep Blue can be found at http://deepblue.gsfc.nasa.gov.

**Technical Description of Figures:**

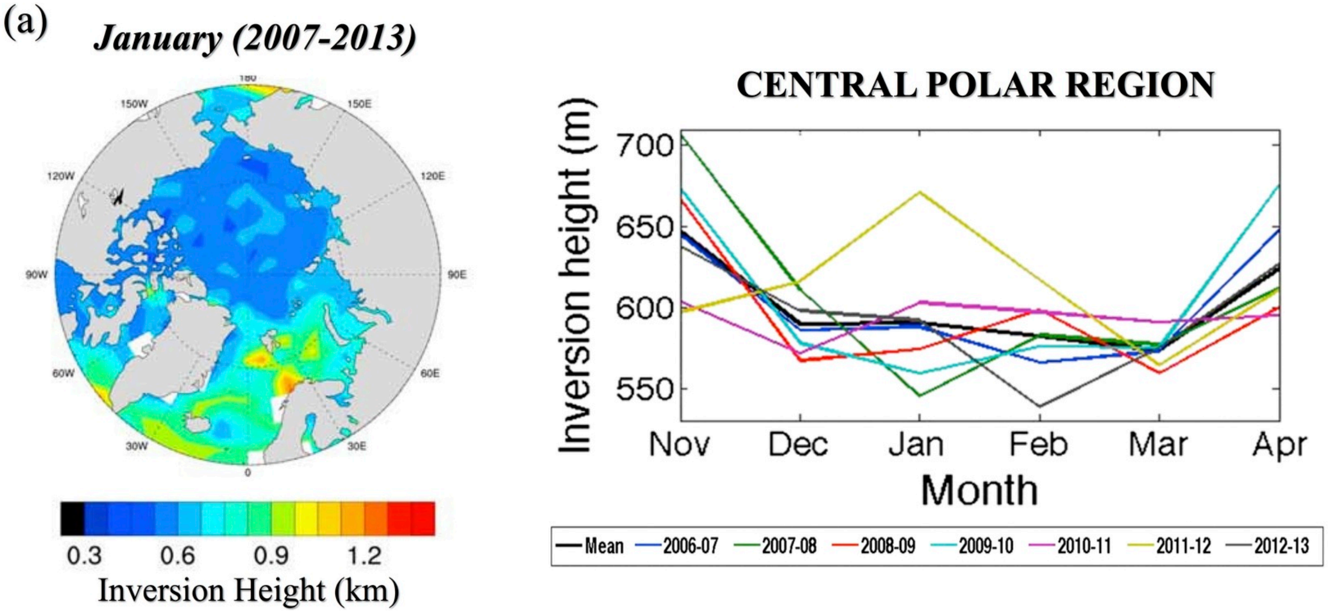
This figure shows the global over land area-weighted time series of DB (a) AOD from MODIS Terra (red) and Aqua (blue), and (b) the time series and decadal trend in the Terra-Aqua AOD difference. Uncertainties in calculated trends are presented as 90% confidence intervals. The correlation between the two time series is very high; the offset is small, and there is no discernable trend in the difference (with a precision of better than 0.01 over the mission to date). Additionally, there is no statistically-significant trend in global mean AOD in either data set, although regional trends have been established (not shown).
These results indicate that the two time series from different sensors have a high level of agreement, and are not diverging. Calibration issues in the previous Collection 5 limited the extent to which MODIS Terra data could be used for trend analyses and caused the data sets to diverge.

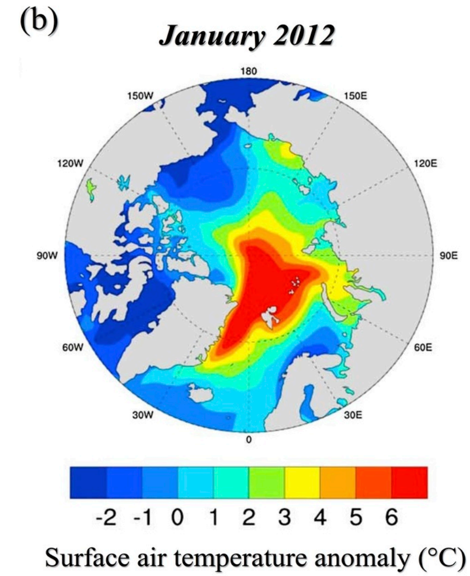
**Scientific significance, societal relevance, and relationships to future missions:**

Well-understood, accurate, and stable calibration of a satellite sensor is a requirement before attempting to detect trends in derived data sets such as aerosol loading or others. Sensors with calibration drift can falsely mask or magnify real changes in the Earth system. The present study illustrates and confirms the potential of MODIS Terra Collection 6 data for scientific analyses of trend studies. To understand the long-term behaviour of the Earth system, stable records from historical, current, and future space-based sensors must be obtained and stitched together to move towards a long-term climate data record. One of the goals of the Deep Blue aerosol project is to achieve this by applying the same basic approach to monitor aerosols from sensors including (at present) SeaWiFS (1997-2010), MODIS Terra (2000 onwards), MODIS Aqua (2002 onwards), and S-NPP VIIRS (2012 onwards).

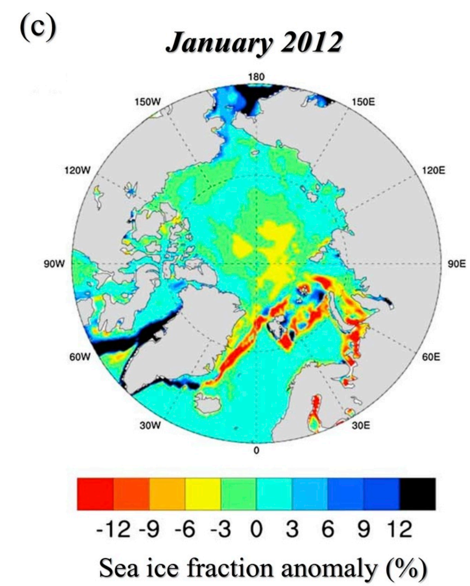
# GPS Radio Occultation (RO) valuable for polar boundary layer studies

Manisha Ganeshan[1] and Dong L. Wu[2], Code 613, NASA/GSFC and GESTAR/USRA.




With its high vertical resolution, GPS RO is a valuable technique for studying the polar atmospheric boundary layer (ABL). Over the frozen Arctic Ocean, the ABL inversion height from a refractivity-based RO retrieval method is found to be sensitive to the underlying surface temperature. Our results help model validation as well as monitoring ABL changes over the dynamic “new Arctic Ocean”.



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**References:**

Ganeshan, M., and D. L. Wu (2015), An investigation of the Arctic inversion using COSMIC RO observations, *Journal of Geophysical Research-Atmospheres*, 120, 9338–9351, doi:10.1002/2015JD023058.

**Data Sources:** GPS/COSMIC RO data were acquired from University Corporation for Atmospheric Research (http://www.cosmic.ucar.edu/). The NCEP/NCAR and ERA-Interim Reanalyses data were obtained from NOAA/OAR/ESRL Physical Sciences Division and the European Centre for Medium-Range Weather Forecasts (ECMWF), respectively. Radiosonde observations from SHEBA campaign, also used in this study, were obtained from NOAA's National Climatic Data Center (http://www.esrl.noaa.gov/ psd/arctic/sheba/).

**Technical Description of Figures:**

***Map (a):*** The January mean boundary layer inversion height (km) over the Arctic Ocean based on 7 years of COSMIC RO data (2007-2013).

***Map (b):*** The 1000 mb air temperature anomaly (°C) during January 2012 with respect to the multi-year monthly mean (2007-2013) based on ERA-Interim reanalyses data.

***Map (c):*** The sea ice fraction anomaly (%) during January 2012 with respect to the multi-year monthly mean (2007-2013) based on NCEP/NCAR reanalyses data.

***Graph:*** The interannual variability in the monthly mean RO-derived inversion height (m) over the central polar ice pack (region north of 80° N latitude).

**Scientific significance, societal relevance, and relationships to future missions:** This study describes a unique GPS RO refractivity based algorithm to derive boundary layer properties (viz. inversion height and surface-based inversion frequency) for the dry polar atmosphere (total precipitable water ≤ 3.6 mm). The retrieval method is applied to multi-year GPS/COSMIC RO data over the remote Arctic Ocean during the cold season (Nov-Apr). For the ice-covered Arctic Ocean, the retrieved inversion height is found to be sensitive to the surface air temperature. An irregular peak in the RO-derived inversion height reflects the anomalous warming in the central polar ice pack during January 2012 (evidenced by higher-than-average surface air temperatures and below average sea ice fraction). The refractivity-based retrieval method thus enables an independent evaluation of model and observations. It can also be used to investigate the boundary layer response to surface warming and to monitor the multi-year variability in polar climate. Changes to the Arctic Ocean and Greenland ice sheet have implications for the global population, and should be monitored closely for geopolitical and climatic reasons.
This work was supported by NASA's GNSS Remote Sensing and Interdisciplinary Research in Earth Science programs. Given the promise for polar climate monitoring, GPS RO should be considered as a measurement capability in the portfolio of future NASA missions.