



Predicting GPM Signals with the GPM Satellite Simulator

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The Global Precipitation Measurement (GPM) Core satellite plays a central role in the GPM mission by calibrating the precipitation algorithms of the GPM Constellation satellites. Before its launch (Feb 2014), first generation GPM Core precipitation algorithms must be established, particularly for areas outside the current TRMM range.

- To support Core precipitation algorithm development, the Synthetic GPM Satellite Simulator integrates GPM Ground Validation (GV) observations, regional high-resolution storm simulations from cloud-resolving models, and GPM instrument simulators (forward modeling).
- GV in-situ observations are used to constrain the storm simulations, which are used to predict GPM-observable signals through the unified GPM simulator.
- The simulated GPM orbital testbeds are used to diagnose the performance of pre-launch precipitation algorithms for the upcoming launch of the GPM Core Observatory.

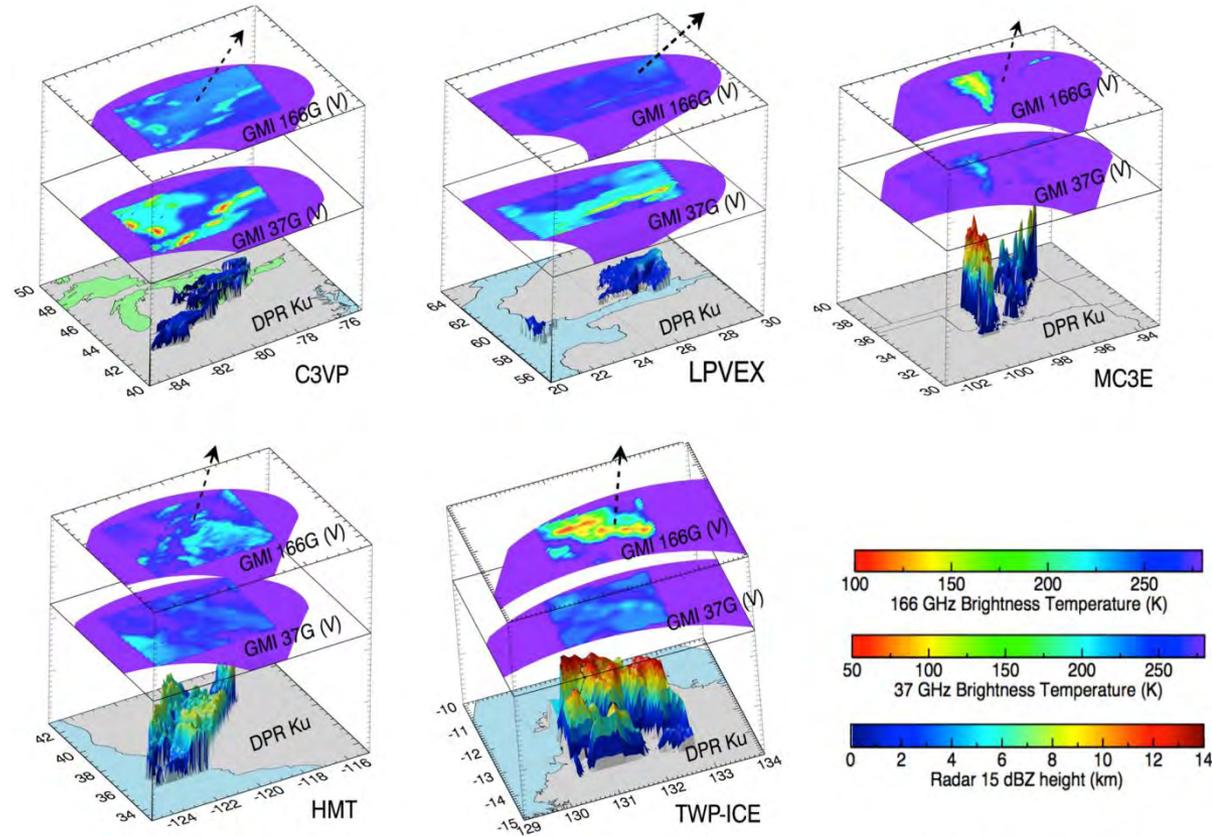


Figure 1: Three-dimensional view of the simulated GPM orbital data over selected simulation scenes from field campaigns C3VP, LPVEX, MC3E, HMT, and TWP-ICE. Color-shaded terrain (bottom layer) represents the 15-dBZ echo-top height of the DPR Ku band, and the horizontal contour plots (layers 2 and 3) represent microwave brightness temperatures of the GMI 37-GHz (V) and 166-GHz (V) channels.



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Data Sources: *The GPM Ground Validation (GV) program* recently conducted a series of field campaigns in mid- and high-latitude regions over Ontario, Canada [Canadian CloudSat/CALIPSO Validation Project (C3VP) and the GPM Cold-season Precipitation Experiment (GCPEX)]; Helsinki, Finland [Light Precipitation Validation Experiment (LPVEX), L'Ecuyer et al. (2010)]; and Oklahoma [Midlatitude Continental Convective Clouds Experiment (MC3E)] to study a variety of precipitation processes. Observations from ground- and aircraft-based in-situ and remote sensing data are used to evaluate macro- and micro-structure of cloud-precipitation processes in model simulations of these weather systems/storms. The high-resolution simulations were conducted using the Weather Research and Forecasting (WRF) model with spectral bin microphysics (WRF-SBM, Iguchi et al. 2012, 2013) and the forward modeling from the Goddard Satellite Data Simulator Unit (G-SDSU, Matsui et al 2009).

Technical Description of Figures:

Figure 1: Figures displays simulated GMI Tb and Dual Polarization Radar (DPR) reflectivity from a selected scene of each GV site. The simulated GPM satellite signals associated with the different precipitating systems depicted have broad spectra. However, the signal database is limited to the WRF-SBM domain instead of an entire orbit. The simulated orbital data include detailed, retrieval-like geophysical parameters, such as rainfall rate, column water vapor, surface skin temperature, and moments of precipitation PSDs derived from the WRF-SBM. These geophysical parameters are then processed in the forward modeling with the same antenna convolution method in the GMI and DPR modules. Thus, the satellite sensor-observable signals and algorithm-retrievable geophysical parameters are sampled in identical footprints within the same dataset, allowing algorithm scientists to quickly assess their retrieval algorithm products.

Scientific significance: The Synthetic GPM Simulator utilizes a comprehensive regional storm model with detailed microphysics, constrained by the best possible in-situ and aircraft measurements from the GPM GV field campaigns. Both precipitation process studies and the first generation of GPM Core Satellite precipitation algorithms are resulting from this unique combination of data and models.

Relevance for Future Missions: Global Precipitation Measurement (GPM) mission will detect rainfall rate globally approximately every three hours using an international constellation of satellites. The Synthetic GPM Simulator can be initially utilized for constructing virtual algorithm testbeds. After the launch of the GPM core satellite, this software can be also used for data assimilation or radiance-based evaluation in cloud-precipitation process of mesoscale atmospheric models.



New MODIS 3 km product provides insight about urban aerosol retrieval biases

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The MODIS instruments aboard the Terra and Aqua satellites have provided a rich dataset of aerosol information at a 10 km spatial scale. Although originally intended for climate applications, the air quality community is also using the MODIS aerosol data. However, 10 km resolution is not sufficient to resolve local scale aerosol features. With this in mind, MODIS Collection 6 (Levy et al., 2013) is including a global aerosol product with a 3 km resolution (Remer et al., 2013). Here, we evaluate the 3 km product over the Baltimore/Washington D.C., USA corridor during the summer of 2011 by comparing with a temporary network of 44 AERONET sun photometers spaced ~10 km apart, as part of NASA's DISCOVER-AQ field campaign (www.nasa.gov/mission_pages/discover-aq/). Figure 1 (left) shows excellent agreement between MODIS and AERONET AOD at sites outside the urban areas, but Figure 1 (right) shows an overestimation of AOD in urban areas. In order to study this further, we separate the 3 km MODIS/AERONET collocations by AERONET station, and compute agreement statistics for each station. Figure 2 (left) shows remarkable variability in the percent of collocations within expected error (EE, $\pm 0.05 \pm 1.5AOD$) for each station, ranging between 16% to 95%. The stations with the smallest percent within EE are clustered around the Baltimore urban center, and the more urbanized I-95 corridor between Washington D.C. and Baltimore. Figure 2 (right) shows that there is a strong relationship between the overestimation of AOD at an AERONET site and how much urban surface is near the AERONET site location.

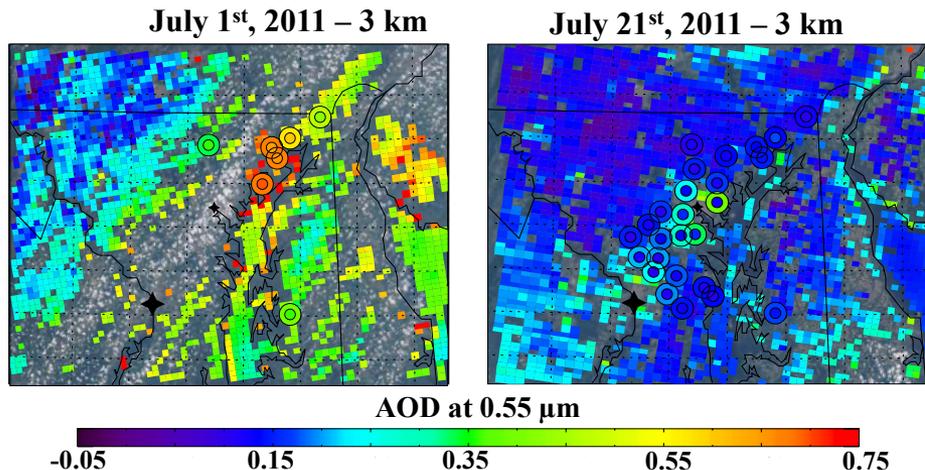


Figure 1: MODIS AOD at 3 km resolution for two days, 7/21/2011 (left) and 7/01/2011 (right). Circles represent MODIS/AERONET collocation statistics, the inner circle being the temporal average (± 30 minutes) from AERONET, and the outside circle being the spatial average (5×5 pixel box) from MODIS. The cities of Washington and Baltimore are plotted as black stars.

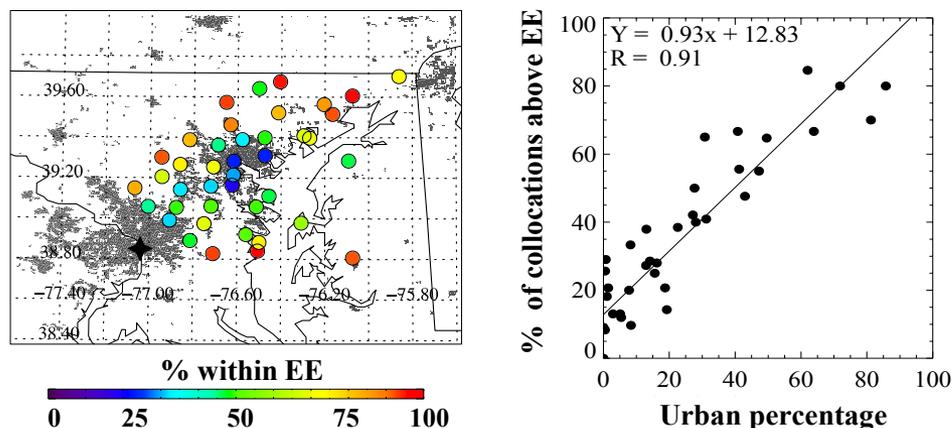


Figure 2: (Left) Percent of 3 km MODIS/AERONET 0.55 μm AOD collocations that MODIS retrieves AOD within expected error ($\pm 0.05 \pm 1.5AOD$). Urban landcover, identified by the MODIS land product, is shown in grey. (Right) Percent of the collocations where the MODIS AOD exceeds the expected error, compared to the percentage of the 5×5 box which is urban.



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Levy et al., (2013), The Collection 6 MODIS aerosol products over land and ocean, *Atmos. Meas. Tech. Discuss.*, 6, 159-259, doi:10.5194/amtd-6-159-2013.

Data Sources: MODIS Level 1B data, MODIS Collection 6 aerosol products (MxD04_L2 and MxD04_3K), MODIS land cover product (MCD12Q1), AERONET data

Technical Description of Figures:

Figure 1: MODIS AOD at 3 km resolution for two days, 7/21/2011 (left) and 7/01/2011 (right). MODIS/AERONET collocations are plotted in the circles, the inner circle being the AERONET temporally averaged AOD, and the outside circle being the spatial average of the MODIS AOD in a 5x5 pixel box around the AERONET station. Only land pixels with a QA = 3 are used in the collocations. Washington D.C. is shown with the large black star and Baltimore, MD is shown with the small black star. The true color image, created from the MODIS red, green and blue bands, is shown in the background.

Figure 2: (Left) Percent of 3 km MODIS/AERONET collocations of 0.55 μm AOD within expected error ($\pm 0.05 \pm 1.5\text{AOD}$) at each AERONET station. Land identified as urban/built up by the MODIS land cover product (MCD12Q1) is plotted in grey. (Right) Percent of 3 km MODIS/AERONET 0.55 μm AOD collocations above expected error ($+0.05 + 1.5\text{AOD}$) at each AERONET station, plotted against the percentage of pixels within the 15 km by 15 km collocation box identified as urban by the MODIS land cover product.

Scientific significance: Routinely monitoring urban air quality remains a challenge, particularly in the developing world where in-situ measurements are sparse or non-existent. Satellite measurements of aerosols have shown promise to supplement monitoring networks; however, the relatively coarse scale of AOD measurements does not adequately resolve small scale sources of pollution. The MODIS 3 km product is a large step forward towards matching the scale of observations to the scale needed to measure aerosols for air quality applications. However, there is evidence that a significant source of bias observed in the 3 km product results from improper characterization of urban surfaces. The poor performance of the 3 km product over urban surfaces is clearly a limitation in terms of air quality applications. How to best address this problem in an operational environment remains an open question.

Relevance for future science: Better characterizing surface reflectance would improve aerosol retrievals over much of the world, including in urban areas and over moderately vegetated brighter surfaces. Although the MODIS sensor is an aging instrument, the VIIRS instrument aboard NPP and slated for launch on JPSS1 and JPSS2 can employ an algorithm that is very similar to MODIS to retrieve aerosols. This provides an excellent opportunity for creating long term data records, and monitoring change in aerosol over urban regions.



A Long-Term Data Set of Ozone Measurements from Space

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Total column ozone and ozone profile data from the Nimbus-4 Backscatter UltraViolet (BUV) instrument, Nimbus-7 Solar Backscatter Ultraviolet (SBUV) instrument, as well as from seven NOAA SBUV/2 instruments have been newly reprocessed with the Version 8.6 ozone retrieval algorithm. This yields a coherent data set with no data gaps or time periods with large uncertainties due to calibration issues from 1979 to the present. The data from 1970-1975 are included to give an unprecedented time series of over 40 years of ozone measurements from space.

Comparisons to ground-based ozone measurements (Figure 1) show that the satellite retrievals are of high quality. The annual mean time series comparisons to an ensemble of ground stations show an agreement within ~1% over for almost the whole time period with the bias approaching zero over the last decade. The aerosols associated with Mt Pinatubo caused an underestimation of ozone in 1992 from the NOAA-9 SBUV/2 instrument.

Figure 2 shows that ozone has decreased by about 5% over the past 40 years, with most of the decrease occurring in the 1980's. This time series provides the best existing data for trend analysis and model validation. A careful multivariate analysis is being carried out to accurately determine long-term ozone trends and to separate the processes impacting the trends.

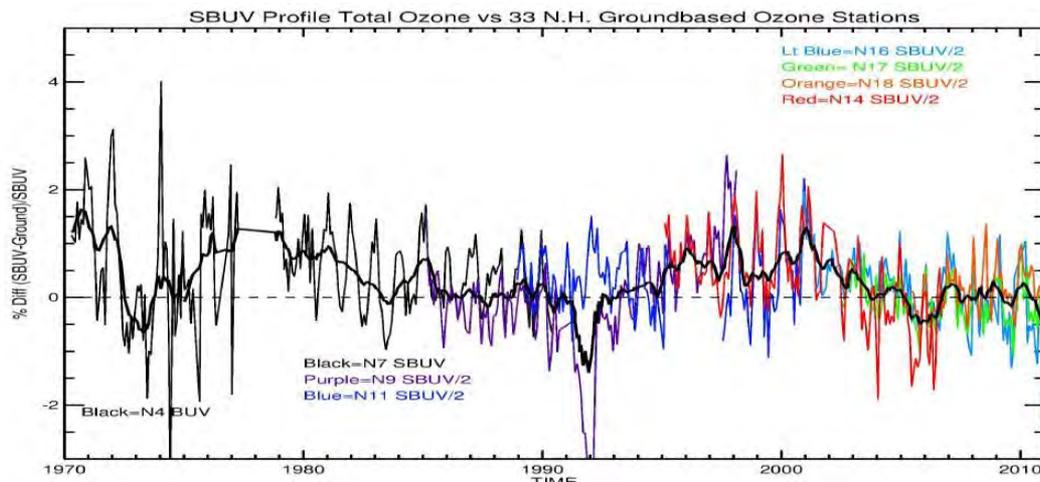


Figure 1: A comparison of all the BUV & SBUV instruments (processed with Version 8.6 algorithm) to an ensemble of 33 Northern Hemisphere Ground Stations. The agreement is within +/- 1% for almost the entire data record.

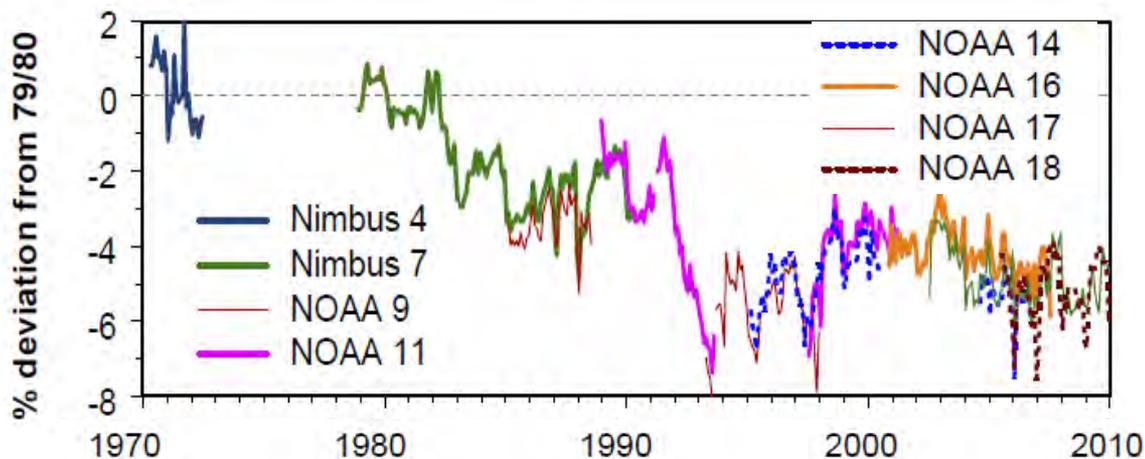


Figure 2: Global ozone trends (65N to 65S). % difference from 1979/1980 showing the long-term decrease in total column ozone.



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Data Sources: The BUUV, SBUV and SBUV/2 overpass ozone data are publicly available at <ftp://jwocky.gsfc.nasa.gov/pub/sbuuv> All ground-based ozone data were taken (and are currently available) from the WOUDC in Downsview, Canada.

Technical Description of Figures:

Figure 1: 33 Different Northern Hemisphere Dobson and/or Brewer stations were used in this comparison. The Nimbus-4 BUUV data (1970-1976) has more uncertainty associated with it and the satellite calibration is not known as well as the later instruments. The ground-based data is also not of the same quality as the post 1980 data. The aerosols associated with Mt Pinatubo caused a slight underestimation of ozone from the NOAA-9 instrument because it was in an early morning equator crossing time orbit. NOAA-11's orbit was much closer to noon and did not have the same problem because its view geometry was much better. The small trend in the differences seen from 1993-2003 is not currently understood.

Figure 2: The average monthly ozone percent difference in total column ozone from the 1979/1980 average. The percent difference plot removes the large annual variation to reveal small long term changes. Most of the ozone decrease occurred in the 1980's and early 1990's and has leveled off since. As this data set is continued into the future, the recovery of the ozone layer should become evident.

Scientific significance: The ozone time series derived from satellites can now be used as far back as 1970. These data can now be used for model testing and for global long-term ozone trend analysis. It can also be used to assess the quality of individual ground instruments. Ozone depleting substances (ODS) have been banned from production by the Montreal Protocol (1989) and the ozone layer is predicted to recover to pre-industrial levels by 2050. A long term, highly accurate series of measurements from space is important in order to establish a baseline to detect the recovery of the ozone layer and confirm model predictions.

Relevance for Future Missions: Data from the operational SBUV/2 instruments will be added to the existing ozone data record which will allow continued monitoring of the state of the ozone layer. Ozone recovery due to decreasing ODS emissions is predicted to take decades and monitoring the this recovery is critical to our understanding of the atmosphere. The recently launched Suomi National Polar-orbiting Partnership (NPP) mission is continuing NASA's 40+ year monitoring of the ozone layer. NPP is the result of a partnership between NASA, the National Oceanic and Atmospheric Administration, and the Department of Defense. Future missions such as the Joint Polar Satellite System (JPSS) is the next generation polar-orbiting operational environmental satellite system which will carry ozone measurements well into the future.