Impact of GMI all-sky radiance assimilation in the NASA GEOS forecast system

Ron Gelaro, Min-Jeong Kim, Will McCarty, Jianjun Jin
NASA Global Modeling and Assimilation Office

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GMI all-sky radiance assimilation in GEOS

All-sky assimilation of GPM Microwave Imager (GMI) radiances implemented in GEOS real-time production system on 11 July 2018

- GMI data selection
  - Six (of 13) GMI channels assimilated
  - Low-frequency: 5(23.8 GHz V), 6(36.5 GHz V), 7(36.5 GHz H)
  - High-frequency: 10(166 GHz V), 12(183.3 ±3 GHz V), 13(183.3 ±7 GHz V)
  - Observations over ocean surfaces only

- Upgrades to assimilation infrastructure
  - New control variables for hydrometeors: cloud liquid, cloud ice, rain, snow
  - Improved radiative transfer (3-bullet DDA, CRTM)
  - New background error (hybrid) and observation error (symmetric, Geer and Bauer 2011) models
  - Modified QC and bias correction

Details in Kim et al. (2019)
Hybrid background errors for hydrometeors

Longitudinal slice along 150°E

Climatological error standard deviation

Ensemble-based error standard deviation 12 Dec 2015 12UTC
Dynamic adjustments in precipitating regions

Hurricane Gaston case study

Dynamic impact of GMI all-sky radiances on GEOS analyses is demonstrated in a case study of Hurricane Gaston in which GMI data only (right) are assimilated
Dynamic adjustments in precipitating regions

Assimilation of GMI all-sky radiances in **hybrid 4D-EnVar** adjusts not only hydrometeors but also dynamic variables such as wind and pressure.
Pre-production experimentation

• Science testing
  • GEOS hybrid 4D-EnVar
  • 25-km GCM, 25-km GSI, 32 x 100-km EnKF
  • Control with full observing system
  • Experiments add GMI all-sky (or clear-sky) radiances only
  • Winter and summer 2016

• High-resolution parallel production
  • GEOS hybrid 4D-EnVar
  • 12.5-km GCM, 25-km GSI, 32 x 50-km EnKF
  • Full observing system plus GMI all-sky radiances
  • Model physics updates
  • Winter-Spring 2017/18
Science testing data assimilation feedback

GMI Data Counts

Observation Count per Analysis

GMI Channel

<table>
<thead>
<tr>
<th>GMI Channel</th>
<th>Total GMI (thinned)</th>
<th>All-Sky GMI</th>
<th>Clear-Sky GMI</th>
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Background Fit to Satwinds 60N-60S

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<td>All Levels</td>
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<td>Low Levels (below 600hPa)</td>
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<td>Mid Levels (400-600hPa)</td>
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### Science testing forecast scorecard

**Control v. GMI all-sky**

**Dec 2016**

#### Legend

- ▲ far better, significant (95% confidence)
- △ better, significant (90% confidence)
- ■ slightly better, significant (68% confidence)
- □ not really any difference
- △△ slightly worse, significant (68% confidence)
- ▼ worse, significant (90% confidence)
- ▼▼ far worse, significant (95% confidence)

#### Northern Hemisphere

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Science testing
Adding GMI all-sky radiances improves the initial state and leads to reduced error, especially in the Tropics. Largest impact is at day-1, with diminishing impact thereafter.

High-resolution parallel production
Combining GMI assimilation with retuned model physics extends the beneficial impacts into the medium range. The retuning modifies the effective radii and fall-rate of ice crystals.
Current GEOS production observation impacts

Global Moist Energy Norm  Aug – Nov 2018 00UTC

Observation Count

Total Impact
Current GEOS production observation impacts

Global Moist Energy Norm  Aug – Nov 2018 00UTC

Impact Per Observation

Fraction of Beneficial Obs

GPM GMI

NOAA-15 AMSUA
SNPP ATMS
NOAA-19 AMSUA
NOAA-18 AMSUA
NOAA-18 MHS
METOP-B MHS
METOP-B AMSUA
NOAA-18 AVHRR
METOP-A MHS
METOP-A AMSUA
METOP-A AVHRR
SNPP CrIS
GOES-15
AIRS
F17-SSMIS
METOP-A IASI
METOP-B IASI

GPM GMI

NOAA-18 MHS
SNPP ATMS
METOP-B MHS
METOP-A MHS
SNPP CrIS
METOP-A AVHRR
NOAA-18 AVHRR
GOES-15
NOAA-15 AMSUA
NOAA-19 AMSUA
NOAA-18 AMSUA
AIRS
METOP-A AMSUA
METOP-B IASI
F17-SSMIS
METOP-A IASI
METOP-B AMSUA

Observation Impact (J/kg) ×10^6

Observation Count Per Analysis

Fraction of Beneficial Obs (%)

Observation Count Per Analysis

×10^4

×10^5

×10^6
Current GEOS production observation impacts

Low Frequency

High Frequency
All-sky assimilation of GPM Microwave Imager (GMI) radiances was successfully implemented in the GEOS real-time production system on 11 July 2018.

All-sky GMI radiances have a significant positive impact on GEOS forecasts of tropospheric water vapor, temperature and winds especially in the tropics.

Assimilation of GMI all-sky radiances in hybrid 4D-EnVar adjusts not only hydrometeors but also dynamic variables such as wind and pressure.

GMI all-sky radiances over land surfaces will be included in a near-future implementation of the GEOS production system, as will all-sky radiances for MHS, ATMS, AMSU-A and AMSR-2.

All-sky techniques are being applied to historical microwave instruments such as TRMM/TMI for future GMAO reanalyses.