Impact of Satellite Atmospheric Motion Vectors in the GMAO GEOS-5 Global Data Assimilation System

Ron Gelaro, Dagmar Merkova, King-Sheng Tai
*Global Modeling and Assimilation Office, NASA GSFC, USA*

with special thanks to Pat Pauley, Nancy Baker
*Naval Research Laboratory, USA*
FNMOC and GMAO Observation Impact Monitoring

Current Operations

Much larger relative impact of AMVs in Navy system
Why does FNMOC get such large impact from satellite winds?

- Use of more satellite winds from more sources?
- More effective treatment of satellite winds ...superothing?
- Assimilation of fewer satellite radiances?
- All of the above?

### Notable observing system differences:

<table>
<thead>
<tr>
<th></th>
<th>Satwind</th>
<th>AMSU-A</th>
<th>Hyps IR</th>
<th>AllObs</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMAO</td>
<td>90</td>
<td>520</td>
<td>1220</td>
<td>2500</td>
</tr>
<tr>
<td>FNMOC</td>
<td>350</td>
<td>350</td>
<td>800</td>
<td>2200</td>
</tr>
</tbody>
</table>

Approximate average values for the year ending 15 May 2012

A simple first experiment:

*Assimilate NRL/FNMOC-prepared satellite winds in the GMAO forecast system...*
GEOS-5 Observing System Experiments

GEOS-5 Forecast System (reduced resolution)
- GEOS-5 AGCM + GSI analysis (~½° L72)
- 6-h assimilation cycle, 3DVar
- 5-day forecasts, adjoint-based 24h obs impacts at 00z
  (dry energy norm, sfc-150 hPa)

Experiments for Winter (Dec-Jan 2010/11), Summer (Aug-Sep 2010)
- Control – GMAO/NCEP operational data set

- NRLAMV – substitute NRL Geo, MODIS, LeoGeo winds
  (NRL obs error & QC, no other retuning)

- NoAMV – withhold all geo winds
- NoRAOBB – withhold all radiosonde
- NoACRFT – withhold all aircraft
- NoGPS – withhold all GPSRO
- NoAMSUA – withhold all AMSU-A (5)
- NoHYPS – withhold all AIRS and IASI
Sources of Satellite Wind Observations
10 Jan 2011  00z

- FNMOC assimilates far more WV winds, and Vis, IR and WV winds from additional sources…most notably U.Wisc/CIMSS
- FNMOC uses superobs; GMAO uses observation thinning
Satellite Wind Data Coverage and Density

10 Jan 2011  00z
OSE Satellite Wind Observation Counts (used) – Global

10 Dec 2010 – 31 Jan 2011 00z

Control

NRLAMV

65-80K obs/anal

160-200K obs/anal

(No satwinds received on 18 Jan)
Data Assimilation Statistics for Satellite Winds
10 Dec 2010 – 31 Jan 2011 00z

Data Counts

Departures

Normalized Cost
GEOS-5 OSE Forecast Skill and Significance
10 Dec 2010 – 31 Jan 2011 00z

Northern Hemisphere

ACC 500 hPa Height

Forecast Day

Control
NoRAOB
NoACRFT
NoAMV
NRLAMV

ACC 500 hPa Height

Forecast Day

Control
NoGPS
NoAMSUA
NoHYPS
GEOS-5 OSE Forecast Skill and Significance

10 Dec 2010 – 31 Jan 2011 00z

Southern Hemisphere

ACC 500 hPa Height

Forecast Day

Forecast Day
Time Series of Satellite Wind Total Impact – Global

10 Dec 2010 – 31 Jan 2011 00z

- Total impact of NLR satwinds is roughly 2x that of control satwinds
- Dates with large satwind impact tend to coincide in both experiments
Time Series of Satellite Wind Impact Per Observation – Global

10 Dec 2010 – 31 Jan 2011 00z

- Impact per observation comparable in both experiments, though slightly larger in the control
Summary of Total Observation Impact – Global
10 Dec 2010 – 31 Jan 2011 00z

- NRL satwinds (in all locations) have roughly *double* the total impact of GMAO satwinds

... “inconsistency” with OSE result?
Summary of Total Observation Impact – Tropics

10 Dec 2010 – 31 Jan 2011 00z

Control

NRLAMV
Summary of Total Observation Impact – Tropics
10 Dec 2010 – 31 Jan 2011 00z

- Contributions from CIMSS and non-CIMSS winds are comparable to each other, and to that from GMAO control winds.

...NRLAMV data volume drives the larger impact
Area-Averaged Vertical Profiles of Satellite Wind Impact

10 Dec 2010 – 31 Jan 2011 00z

Global

N.Hem

S.Hem

Tropics

- Discounting contribution from CIMSS winds, impacts of NRL and GMAO satwinds have virtually identical magnitude and vertical distribution
Gridded Vertically Summed Impact of Satellite Winds
10 Dec 2010 – 31 Jan 2011 00z
A Previous Intercomparison Study...

January 2007

Satwind impacts 700-300 hPa

...more uniformly beneficial impact of satwinds in NOGAPS compared with Canadian and GMO systems

Gelaro et al. 2010
Relative Impacts of Selected Observing Systems
10 Dec 2010 – 31 Jan 2011 00z

- NRL satwinds have *double* the fractional impact of GMAO satwinds, and slightly reduce the fractional impacts of several other observing systems (e.g. aircraft)
Relative Impacts of Selected AMV Types
10 Dec 2010 – 31 Jan 2011 00z

• Relative impacts of most AMV types correlate well with data counts

• Beneficial impact of MODIS winds in NRLAMV (versus non-beneficial impact in control) requires other explanation….superobs?
Compensating effects of removing conventional observing systems are largest in the NH

Removal of raobs increases fractional impact of aircraft and AMSU-A (>60%); removal of aircraft increases fractional impact of raobs (>30%)
Compensating effects of removing satellite radiances are largest in the SH
• Removal of AMSU-A doubles the fractional impact of hyperspectral IR; removal of hyperspectral IR increases the fractional impact of AMSU-A (>35%)
A Previous Comparison of OSE- and ADJ-Based Obs Impacts

July 2005

...generally consistent, but not in all cases.  (Gelaro and Zhu 2009)
Conclusions

• NRL AMVs were crudely but “successfully” assimilated into the GMAO GEOS-5 data assimilation system

• Compared to the control run with GMAO (NCEP) AMVs, the assimilation of NRL AMVs provides substantially increased beneficial impact (ADJ), and also appears to improve forecast skill overall (OSE)

• All results indicate that the greater volume (versus superobing) of the NRL AMVs is primarily responsible for their larger impact, but there is evidence that superobing is also beneficial

• Observation mix plays a significant role in modulating the impact of any one data type: the smaller impact of the NRL AMVs in the GMAO system (compared with their impact in the NRL system) is likely due to the larger number of satellite radiances in the GMAO system

• Additional experiments might include assimilating NRL AMVs while reducing the number of radiances

• Richness of (not inconsistency between) OSE and ADJ results argues for the continued use of both approaches where possible