Satellite Data and Regional NWP at the Environmental Modeling Center

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Thanks to colleagues at NCEP/EMC for providing much of the material and information in this talk.
Satellite Data and Regional NWP at the Environmental Modeling Center

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- Current uses
  - Real time assimilation of satellite radiances from a variety of instruments
  - Comprehensive satellite data monitoring

- Current testing and *some* next steps
  - Switching on new satellite data for assimilation in the NAM
  - Univ. Wisc./CIMSS GOES Imager data for sky cover analysis in RTMA/URMA
  - GOES-R testing using SEVIRI data with hourly-updated NAM placed over Africa

- What’s next? *Some* long(er) term thoughts
  - Satellite data assimilation and high impact weather
  - Use of GOES-R GLM lightning observations in NWP
Data Assimilation in the current NAM/NDAS

- **NAM** – North American Mesoscale forecast system
  - Runs 4x daily at 00, 06, 12, 18Z
  - Short-range mesoscale NWP system for the U.S. which provides guidance to day 3.5

- **Cycled DA is currently only done on the parent, 12 km domain**
  - Each cycle has a 12hr pre-forecast DA period with a 3 hr update frequency

- **Uses the Gridpoint Statistical Interpolation system (GSI)**

- **Hybrid ensemble-3DVar approach with passive use of the 80 EnKF members from the GDAS to provide multivariate flow dependence**

- **Assimilates full range of conventional (e.g. surface, ship, profiler, mesonests, etc.), Doppler radar radial velocities & VAD, and suite of satellite observations (radiances, AMVs, and cloud products)**

**Heading toward NAMRR: NAM Rapid Refresh → Hourly updates**
- Important step toward High Resolution Ensemble Forecast System with Rapid Refresh
- NAMRR + RAP/HRRR Foundation
Satellite Radiance Data Currently Used in the NAM/NDAS

- **Satellites and instruments**
  - NOAA15: AMSUA
  - NOAA18: AMSUA, MHS
  - NOAA19: AMSUA, MHS
  - METOP-A: HIRS4, AMSUA, MHS, IASI
  - GOES15: SNDR1-4
  - AQUA: AIRS, AMSUA

After thinning and QC – satellite radiances make up about 40% of all observations used in a single NDAS/NAM analysis.

<table>
<thead>
<tr>
<th>Obs Type</th>
<th>Nobs</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Pressure</td>
<td>54296</td>
<td>5.2 %</td>
</tr>
<tr>
<td>Temperature</td>
<td>172676</td>
<td>16.6 %</td>
</tr>
<tr>
<td>Wind</td>
<td>284938</td>
<td>27.3 %</td>
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<tr>
<td>Moisture</td>
<td>79866</td>
<td>7.7 %</td>
</tr>
<tr>
<td>NEXRAD Radial Wind</td>
<td>9978</td>
<td>0.96 %</td>
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<tr>
<td>Precipitable Water</td>
<td>362</td>
<td>0.03 %</td>
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<tr>
<td>GPS</td>
<td>9436</td>
<td>0.91 %</td>
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<tr>
<td>Radiance</td>
<td>430491</td>
<td>41.3 %</td>
</tr>
<tr>
<td><strong>Total Obs</strong></td>
<td>1042043</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>
Upcoming Changes for the NAM/NDAS
Not exhaustive!

- Upgrades to NMMB prediction model
  - CONUS (4 km) and Alaska (6 km) nests → 3 km
  - Microphysics changes to address locally heavy QPF and increase stratiform QPF
  - Test shallow convection in NAM nests → improved convective initiation
  - Radiation changes → improve 2 m temperatures

- New observations
  - SEVIRI, NOAA17-18, SSMIS (F16-F18)
  - Metop_B (IASI, HIRS4, AMSUA, MHS)
  - NPP (ATMS, CRIS)
  - Tall tower + wind turbine nacelles (result of WFIP project)

- Data assimilation
  - Move to an hourly cycle (+ cycle for 3 km CONUS nest)
    - NAM-RR (NAM Rapid Refresh)
  - Tropical cyclone relocation
  - 4DEnVar (tentative)
  - Direct analysis of hydrometeors (tentative)
  - Improve use of Doppler radial wind observations for 3 km domains
  - Digital filter with radar-derived temperature tendencies

\[ \text{Parent dimensions: } N_x = 954, N_y = 835, dx = 0.1260, dy = 0.1080 \]
\[ \text{center lat = 54.00, center lon = -106.00} \]
Keeping track of all the radiance data is vital

- Use a comprehensive monitoring package
- Monitor usage and stats in real time, quickly catch problems

Thanks to Ed Safford for this slide
Improvements in use of radiances: Enhanced radiance bias correction scheme (Zhu et al. 2014)

- Automatically detect any new/missing/recovery of radiance data and initialize new radiance data
- Quickly capture any changes in the data and the system

Any new radiance data can be used now with initial radiance bias correction set to be zero

- Operational in the NAM/NDAS as of the August, 2014 upgrade

Thanks to Yanqiu Zhu for this slide
Applications of GSD’s Cloud Analysis Package for the NAM (available in the GSI)

- Includes DDFI with radar derived temperature tendencies
- Cloud and hydrometeor modifications based upon satellite (e.g. NASA Langley data), surface observations, and radar observations
- Capability is in developmental NAMRR (hourly-update NAM)

Thanks to Shun Liu for this slide
Gap mitigation study with NDAS/NAM (ongoing)

- Risk of a gap in polar satellite data in the afternoon orbit
  - Between the time that the current polar satellite is expected to reach the end of its life and when the next satellite is expected to be in orbit and operational
- What kind of impact might this have on the NDAS/NAM? Study which covers ~60 days
- Results are very preliminary and work is ongoing

```
<table>
<thead>
<tr>
<th>Observing System</th>
<th>Orbit</th>
<th>NAMP (Ops NAM)</th>
<th>NOPM</th>
<th>NOSAT</th>
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<tbody>
<tr>
<td>Conventional data</td>
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<td>✅</td>
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<tr>
<td>AMVs (AQUA)</td>
<td>PM</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>AQUA/AIRS</td>
<td>PM</td>
<td>✅</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>NOAA-19 AMSU-A, MHS</td>
<td>PM</td>
<td>✅</td>
<td>X</td>
<td>X</td>
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<tr>
<td>METOP ASCAT, IASI, AMSU-A, MHS</td>
<td>AM</td>
<td>✅</td>
<td>✅</td>
<td>X</td>
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</tbody>
</table>
```

* Results from only ~3 days of verification

Thanks to Ed Colon for this slide
Two Experiments:

**CTRL:** Conventional data and radiance observations

**Baseline:** + SEVIRI clear-sky radiance

Satellite Radiances include:

- AMSUA (METOP-a; NOAA-15; NOAA-18; NOAA-19)
- AMSUB (NOAA-17)
- HIRS4 (METOP-a, NOAA-19)
- IASI (METOP-a); AIRS (AQUA)
- MHS (METOP-a; NOAA-19)
- Clear-sky SEVIRI (MSG-9)

Brightness Temperature (K)

Before Assimilating: Thinning -> Bias Correction -> QC

RMSE: Verification of 24-h RH

With SEVIRI Clear sky radiance
Without SEVIRI Clear sky radiance

Very small improvement – **not unexpected.**
Next step is to focus on cloudy radiances.

Thanks to Xiaoyan Zhang for this slide
New RTMA/URMA - Sky Cover Analysis

- Collaboration with J. Gerth of Univ. Wisconsin/CIMSS
  - Established NCEP data feed for GOES Imager Sky Cover data produced via GOESR algorithms for use in RTMA/URMA
  - Becoming operational in RTMA/URMA ~ Early April, 2015

Includes surface and GOES13 + GOES15 data
• Valuable satellite data is missed
  • Due to the nature of our limited domain
  • Earlier time cutoff for data (NAM runs before GFS)
Satellite DA Challenges for Regional

- This problem gets **more challenging** as we focus on our CONUS-sized, convection allowing grids!
- Use of data over land will become more important → very difficult
- Limited domain makes use of satellite data difficult WRT to bias correction (smaller sample size)
- Hourly updates require earlier data-cutoff
  - Somewhat mitigated through regular catch-up cycles
What’s next?

• Improved use of satellite radiances over land
  • Increasingly important challenge as we focus on convection-allowing domains that feature little coverage over water bodies
  • e.g.; Zheng et al. (2012, *JGR*)

• Use of lightning data
  • GOES-R GLM: Will provide coverage over a very large area and, unlike WSR-88D radar, there will be no have coverage limitations in complex terrain or ocean areas
  • e.g.; Mansell et al. (2014, *MWR*),

• Cloudy radiance assimilation
  • A challenging, yet promising task being actively pursued at EMC (talk by A. Collard during Session 1)
  • Especially challenging for finer resolution grids and high-impact weather (e.g. convection)
    • Microphysics
    • e.g.; Errico (2007, *JAS*), Otkin (2012, *JGR*)
What’s next? → The fusion of all of these valuable data

A. Storm-scale DA of radar observations
B. Storm-scale DA of lightning observations (e.g. GOES-R GLM)
C. Storm-scale DA of satellite observations
D. All of the above (including conventional observations)

A big challenge and will certainly take time!
Already some encouraging work being done for this at convection-allowing scales, examples:


Thanks! Questions?

See talk by A. Collard from Session 1 for information on cloudy radiance DA at NCEP with the GFS