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.

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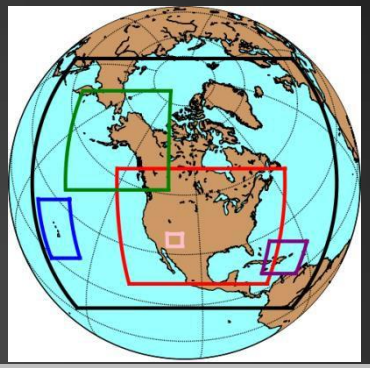
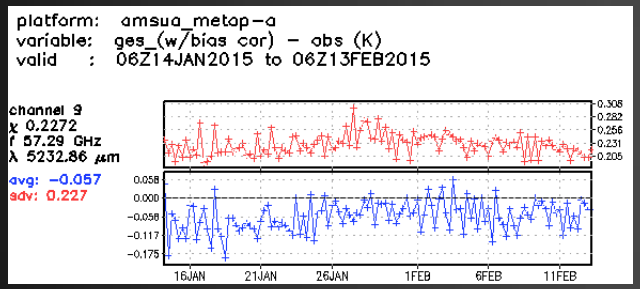
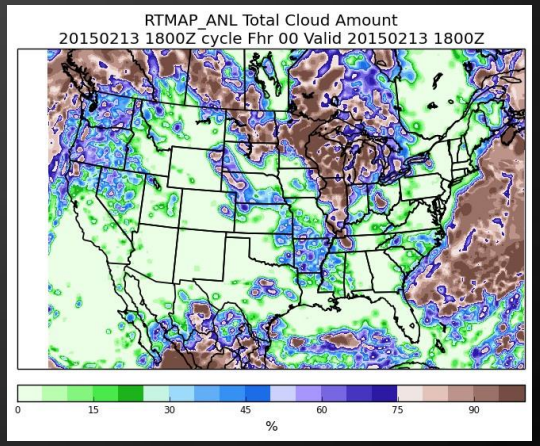


- Current uses
  - Real time assimilation of satellite radiances from a variety of instruments
  - Comprehensive satellite data monitoring



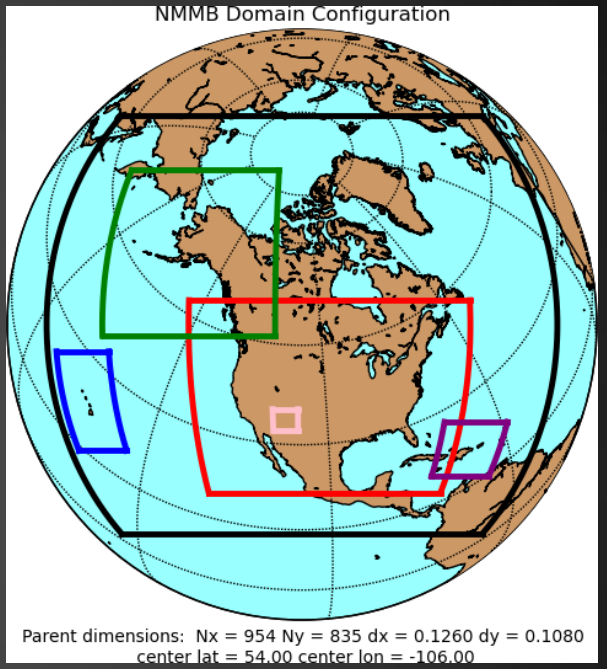
- Current testing and *some* next steps
  - Switching on new satellite data for assimilation in the NAM
  - Univ. Wisc./CIMSS GOES Imager data for sky cover analysis in RTMA/URMA
  - GOES-R testing using SEVIRI data with hourly-updated NAM placed over Africa



- 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)



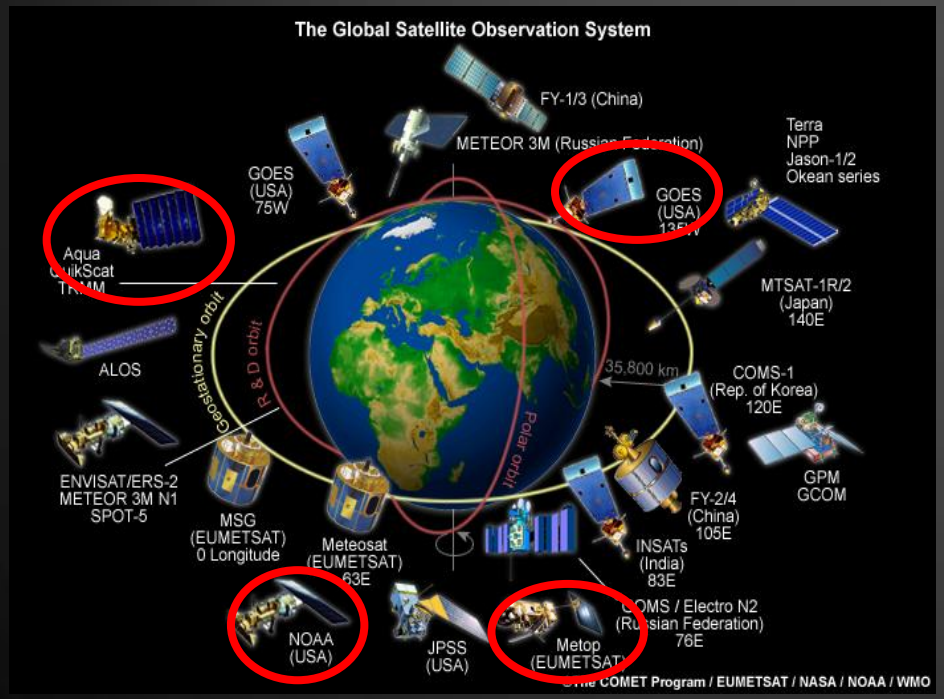
Heading toward NAMRR: NAM Rapid Refresh → Hourly updates

- 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.

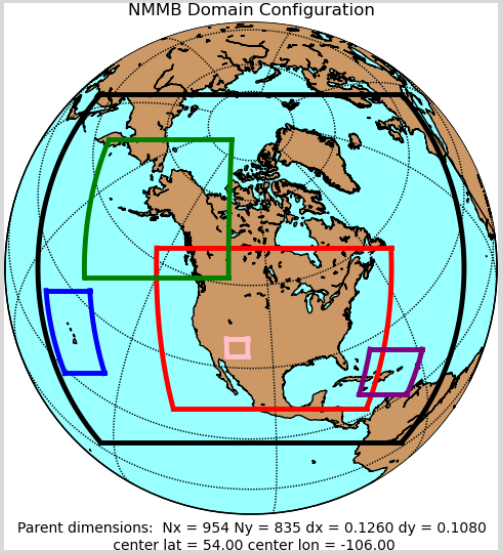


2015 02 20 00Z Analysis		
Obs Type	**Nobs**	**% of Total**
Surface Pressure	54296	5.2 %
Temperature	172676	16.6 %
Wind	284938	27.3 %
Moisture	79866	7.7 %
NEXRAD Radial Wind	9978	0.96 %
Precipitable Water	362	0.03 %
GPS	9436	0.91 %
Radiance	**430491**	**41.3 %**
Total Obs	**1042043**	**100.0 %**

Upcoming Changes for the NAM/NDAS

Not exhaustive!

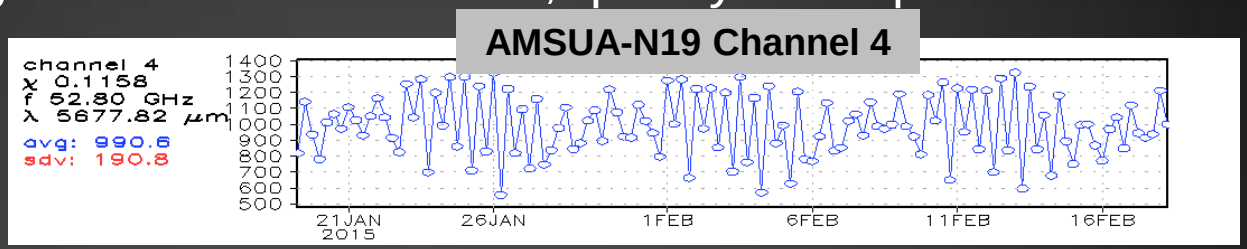
- Upgrades to NMMB prediction model
  - CONUS (4 km) and Alaska (6 km) nests → 3 km
  - Microphysics changes to address locally heavy QPF and increase stratiform QPF
  - Test shallow convection in NAM nests → improved convective initiation
  - Radiation changes → improve 2 m temperatures
- New observations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



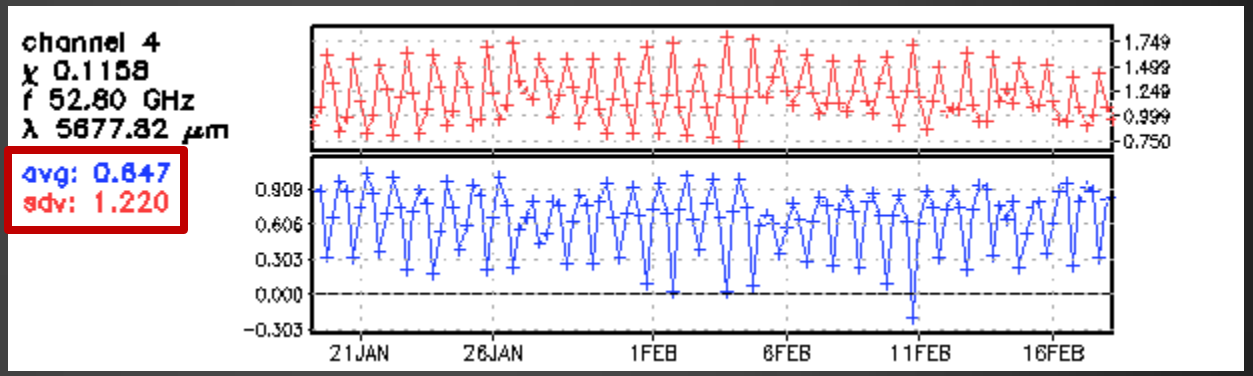
Keeping track of all the radiance data is vital

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

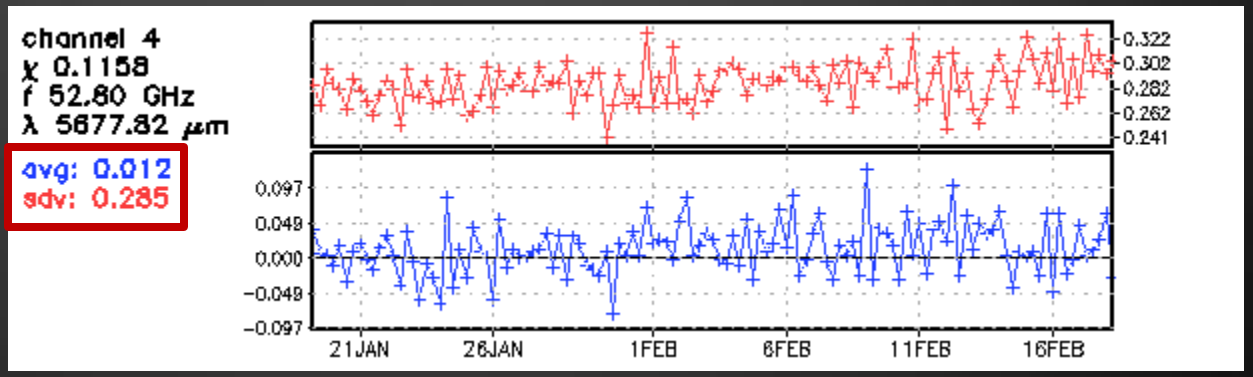
Number of observations



O-F (no bias correction)
Standard Deviation
Average



O-F (*with* bias correction)
Standard Deviation
Average



Thanks to Ed Safford for this slide

Improvements in use of radiances: Enhanced radiance bias correction scheme (Zhu et al. 2014)

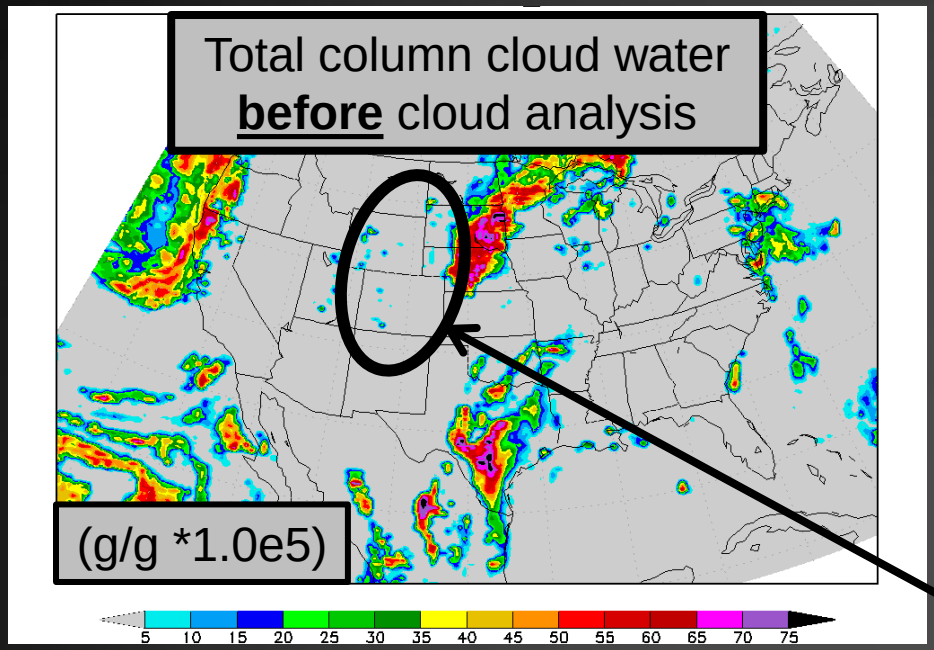
- Automatically detect any new/missing/recovery of radiance data and initialize new radiance data
- Quickly capture any changes in the data and the system

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

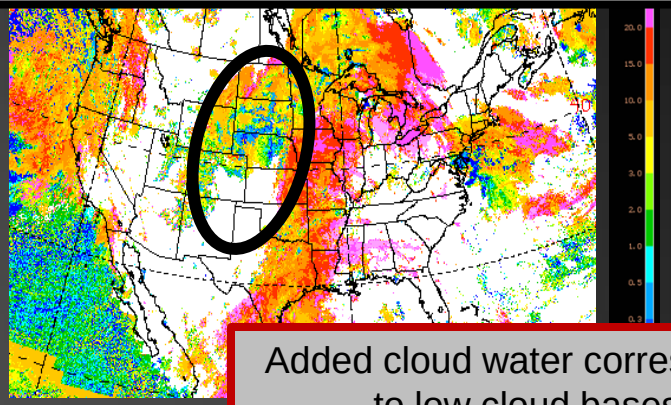
- Operational in the NAM/NDAS as of the August, 2014 upgrade
- Zhu, Y., Derber, J., Collard, A., Dee, D., Treadon, R., Gayno, G. and Jung, J. A. (2014), Enhanced radiance bias correction in the National Centers for Environmental Prediction's Gridpoint Statistical Interpolation data assimilation system. Q.J.R. Meteorol. Soc., 140: 1479–1492. doi: 10.1002/qj.2233

Thanks to Yanqiu Zhu for this slide

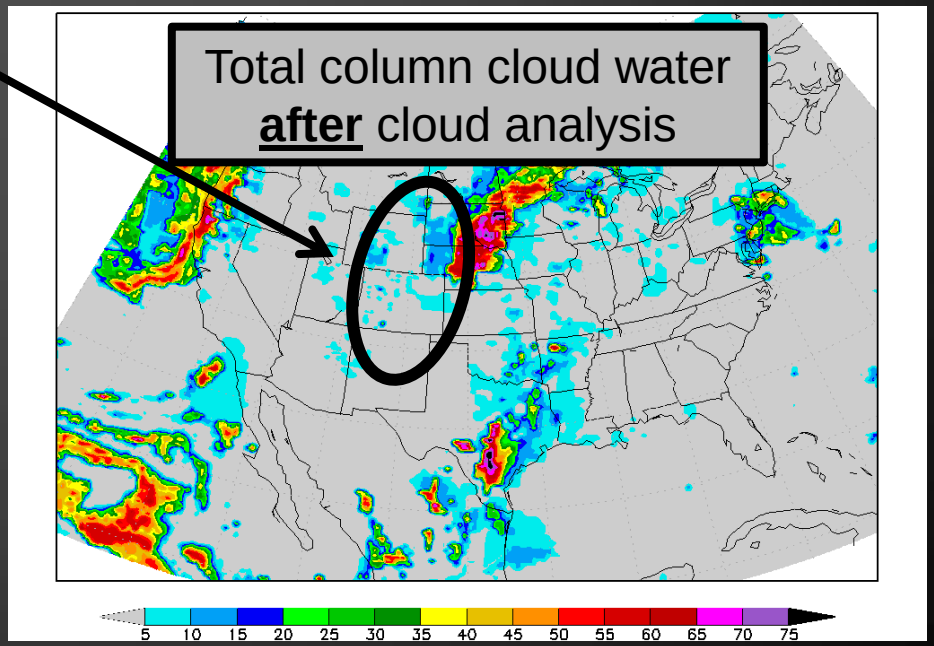
Applications of GSD's Cloud Analysis Package for the NAM (available in the GSI)



NASA Langley cloud base height



Added cloud water corresponds to low cloud bases

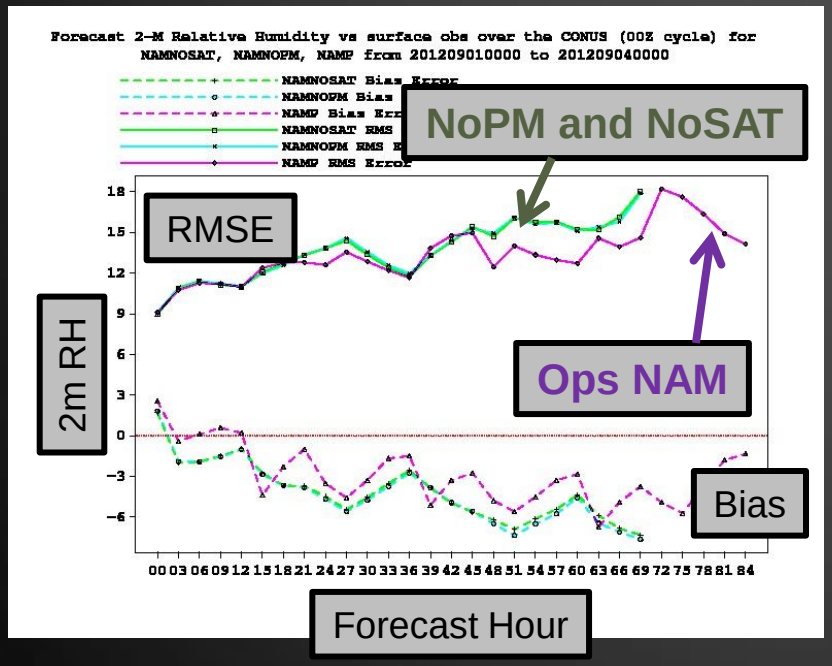


- Includes DDFI with radar derived temperature tendencies
- Cloud and hydrometeor modifications based upon satellite (e.g. NASA Langley data), surface observations, and radar observations
- Capability is in developmental NAMRR (hourly-update NAM)

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 migh this have on the NDAS/NAM? Study which covers ~60 days
- Results are very preliminary and work is ongoing



Observing System	Orbit	NAMP (Ops NAM)	NOPM	NOSAT
Conventional data	------	✔	✔	✔
AMVs (AQUA)	PM	✔	X	X
AQUA/AIRS	PM	✔	X	X
NOAA-19 AMSU-A, MHS	PM	✔	X	X
METOP ASCAT, IASI, AMSU-A, MHS	AM	✔	✔	X

* Results from only ~3 days of verification

Thanks to Ed Colon for this slide

Assimilation of SEVIRI data as GOES-R Proxy in NAMRR

March 1-31, 2012 → Covering Atlantic, portions of Europe, and Africa

Two Experiments:

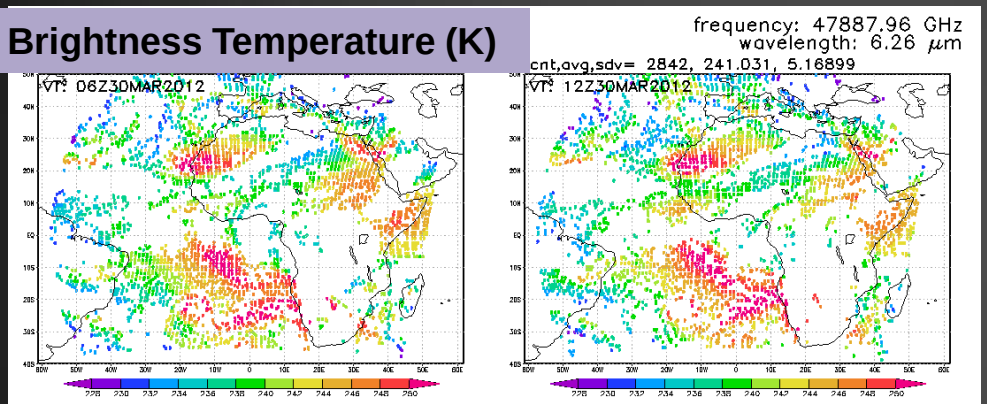
CTRL: Conventional data and radiance observations

Baseline: + SEVIRI clear-sky radiance

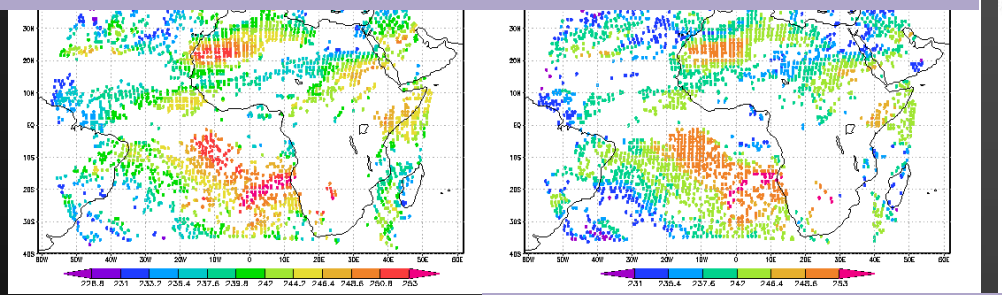
Satellite Radiances include:

- 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)**

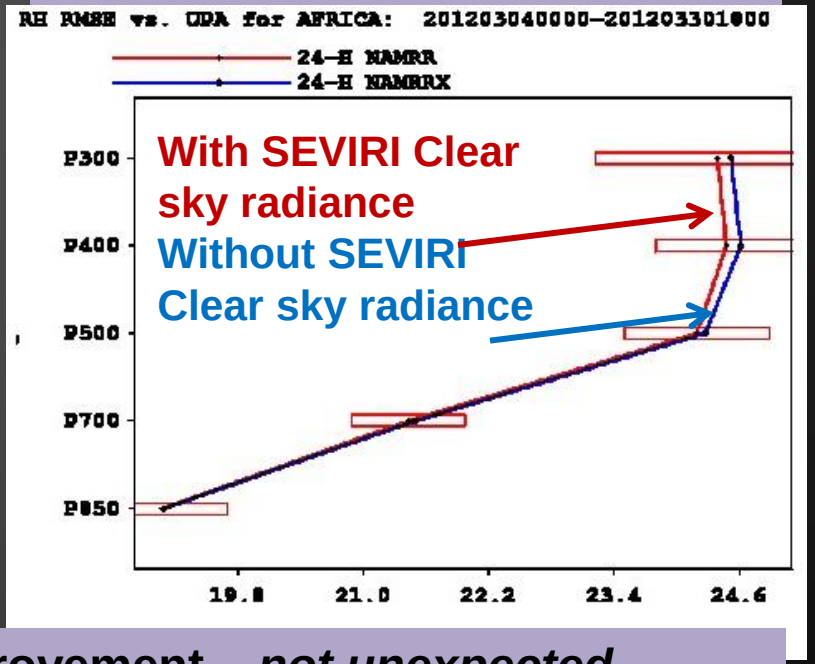
Brightness Temperature (K)



Before Assimilating: Thinning -> Bias Correction ->QC



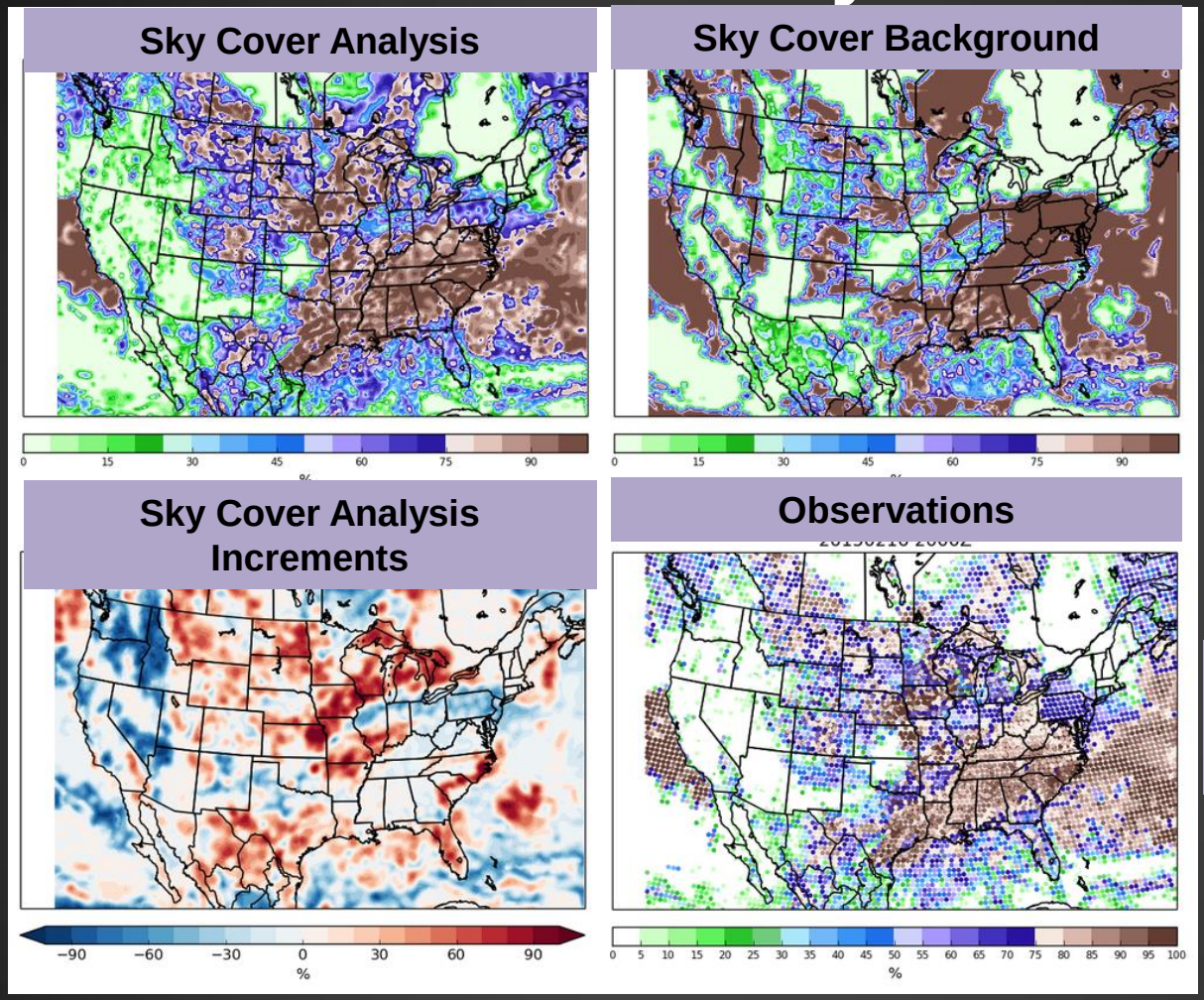
RMSE: Verification of 24-h RH



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

Thanks to Xiaoyan Zhang for this slide

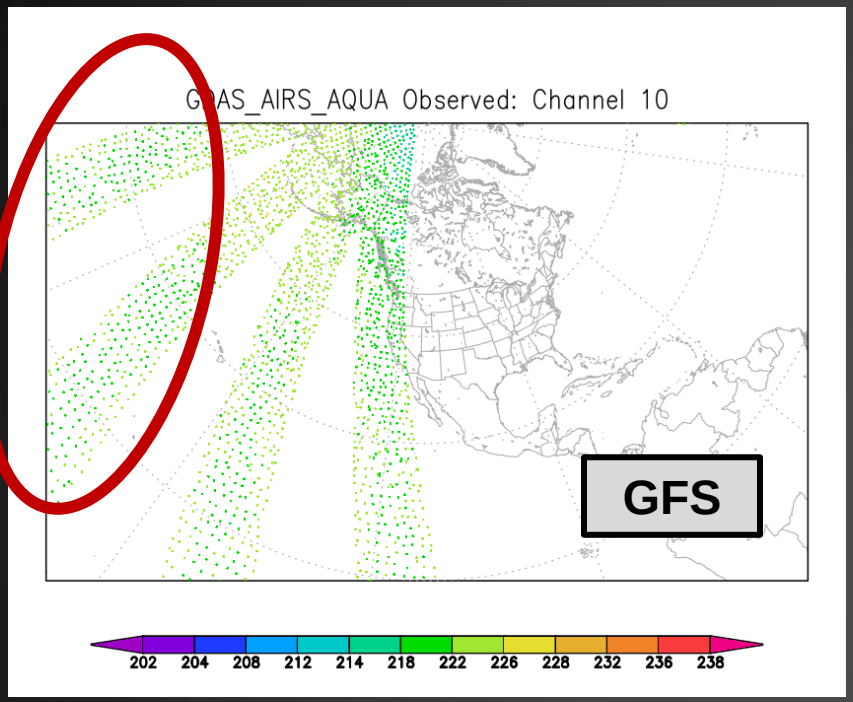
New RTMA/URMA - Sky Cover Analysis

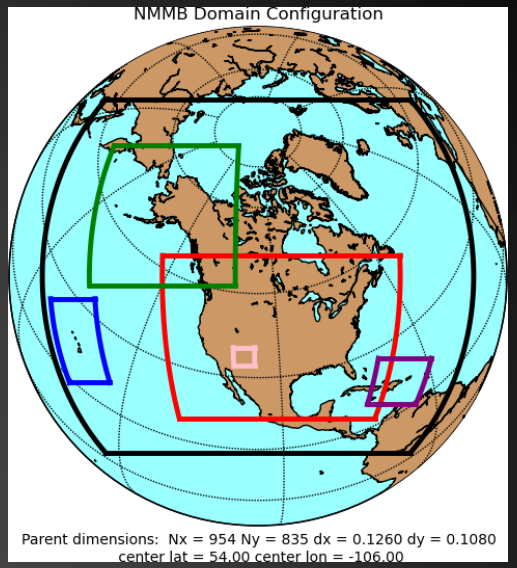


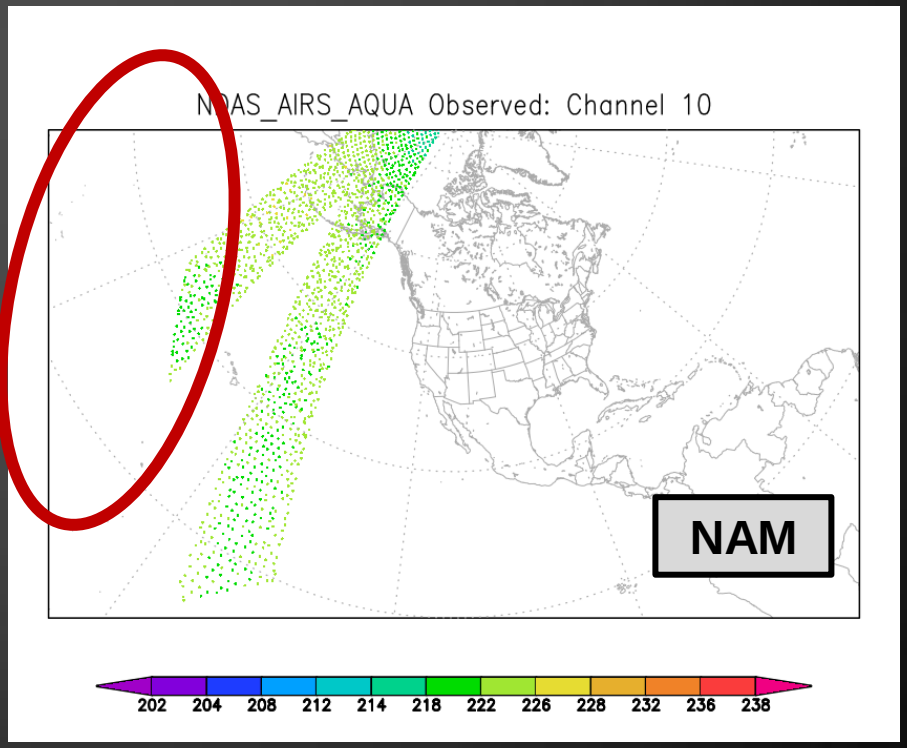
Includes surface and GOES13 + GOES15 data

- 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

Satellite DA Challenges for Regional

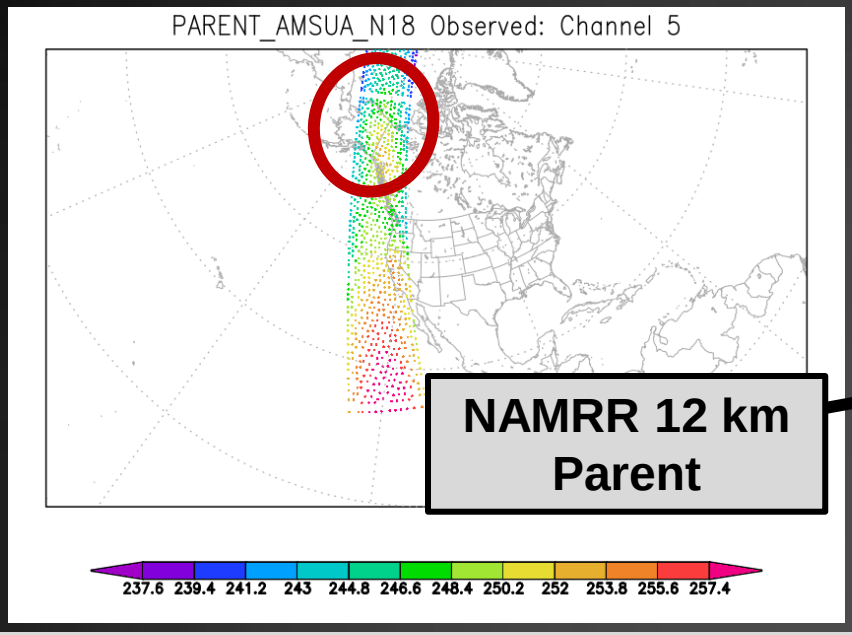




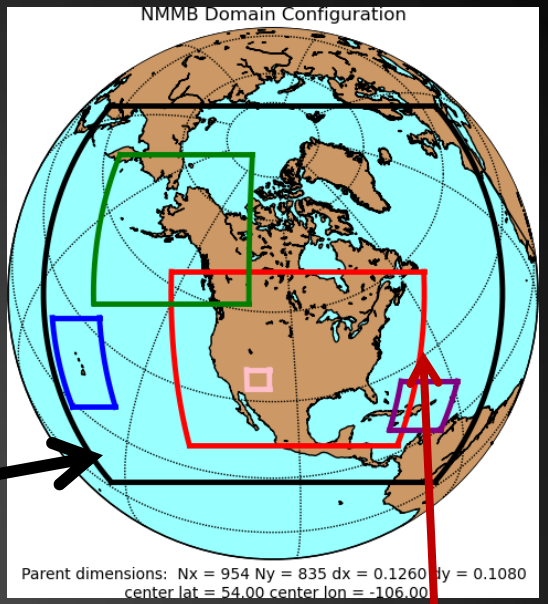


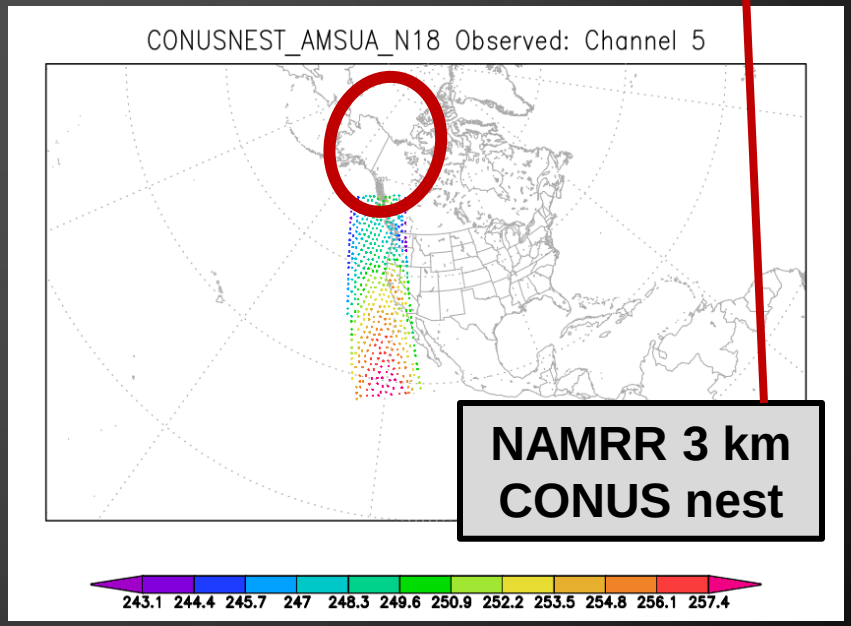
- Valuable satellite data is missed
  - Due to the nature of our limited domain
  - Earlier time cutoff for data (NAM runs before GFS)

Satellite DA Challenges for Regional



NAMRR 12 km Parent





NAMRR 3 km CONUS nest

- 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:

Jones et al. (2015, 2014, 2013, *MWR*) → Satellite + radar

Johnson et al. (2015, *MWR* – In press) → Multiscale: Conventional + radar

Thanks! Questions?

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