Rapid Refresh Satellite Assimilation and Cloud Analysis Applications for Regional and Global Models

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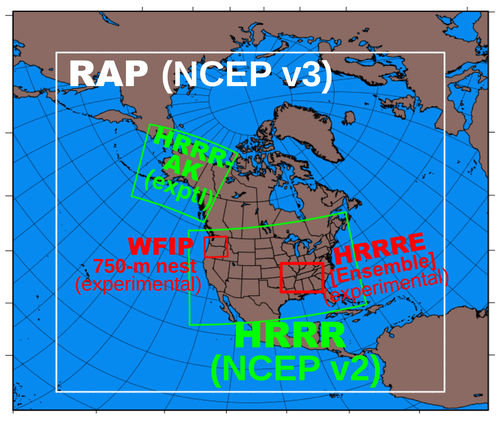
NOAA Rapid Refresh forecast applications



NCEP Operational

RAP -- Rapid Refresh
Version 3 implement expected July 2016
(improved radiance assimilation – see below)

HRRR -- High Resolution Rapid Refresh
V2 implement expected July 2016

GSD Experimental

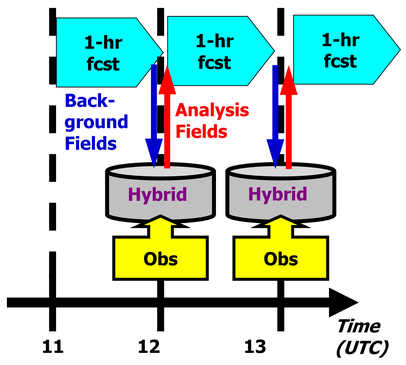
HRRR-AK – HRRR Alaska (3-km run to 36 hrs every 3 hours)

WFIP – Wind Forecast Improvement Project (750-m resolution, BL testing)

HRRRE -- High Resolution Rapid Refresh Ensemble (EnKF system provides Init. condit. for NEWS-E)

Assimilated Observations

Hourly Observation Type	Variables Observed	Observation Count
Rawinsonde	Temperature, humidity, wind, pressure	125
Profiler – NOAA/ 915 MHz	Wind, virtual temperature	2 / 20-30
Radar	VAD Wind, radial velocity	125 radars
Radar reflectivity – CONUS	3-d refl→Latent htg, rain,snow,graupel	~1,500,000
Lightning – NLDN / GOES-R	Flash density →Proxy reflectivity	10K
Aircraft	Wind, temperature	3,000 -25,000
Aircraft - WVSS	Humidity	0 - 800
Surface/METAR	Temperature, moisture, wind, press, clouds/ceiling, visibility, current weather	2200 - 2500
Surface/Mesonet	Temperature, moisture, wind	~5K-12K
Buoys/ships	Wind, pressure	200 - 400
GOES AMVs	Wind	10K
AMSU/HIRS/MHS (RARS)	Radiances (direct readout)	760K/200K/200K
ATMS/CrIS (direct readout)	Radiances	
GOES	Radiances (fire location/intensity-smoke)	~3,000K
Future GOES-R	Lightning, cloud-top cooling	>3,000K
GOES cloud-top press/temp	Brightness temp	~380K
GPS – Precipitable water	Humidity – integrated water vapor	300
METOP-B ASCAT	Winds	Monitor only



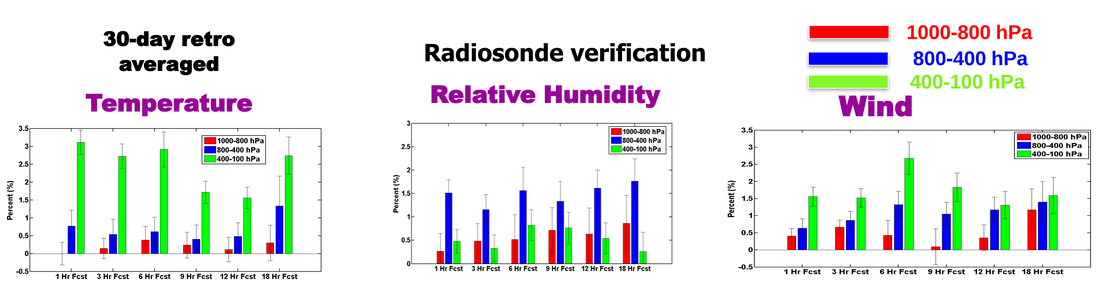
Hourly assimilation cycle used in RAP system (also includes cloud analysis). RAP partial cycled from GFS twice per day.

Operational RAP V3 Radiance Assimilation Upgrade

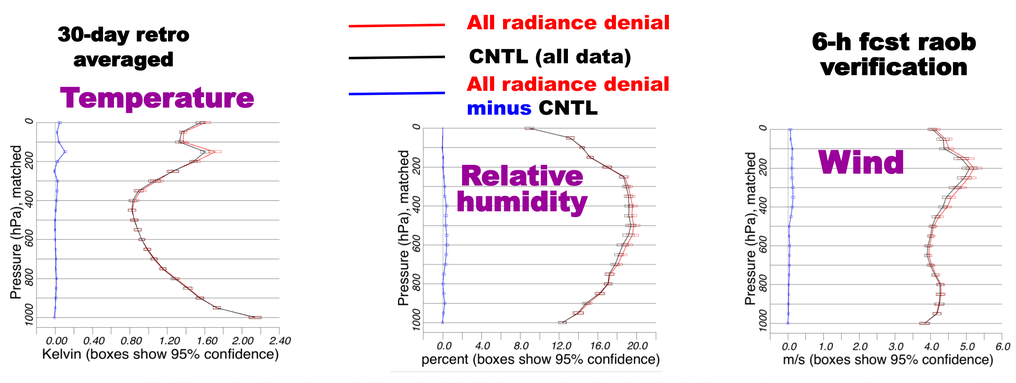
- Implement the enhanced variational bias correction scheme (developed by EMC/NCEP) with cycling
- Remove some high-peaking channels to fit the model top of the RAP and O_3 channels
- Include the direct readout (Regional ATOVS Retransmission Services (RARS)) data
- Include new sensors/data (GOES-15, AMSU-A/MHS from NOAA-19, METOP-B).

Satellite	Sensor	Channels assimilated
NOAA-15	AMSU-A	1-10, and 15
NOAA-18	AMSU-A	1-8, 10 and 15
	MHS	1-5
NOAA-19	AMSU-A	1-7, 9-10 and 15
METOP-A	AMSU-A	1-6, 8-10 and 15
	MHS	1-5
	HIRS-4	4-8 and 10-15
GOES-15	sndrD1/sndrD2/sndrD3/sndrD4	3-8 and 10-15

List of AMSU-A, MHS, HIRS4, and GOES radiance channels used in RAPv3 and the retro runs

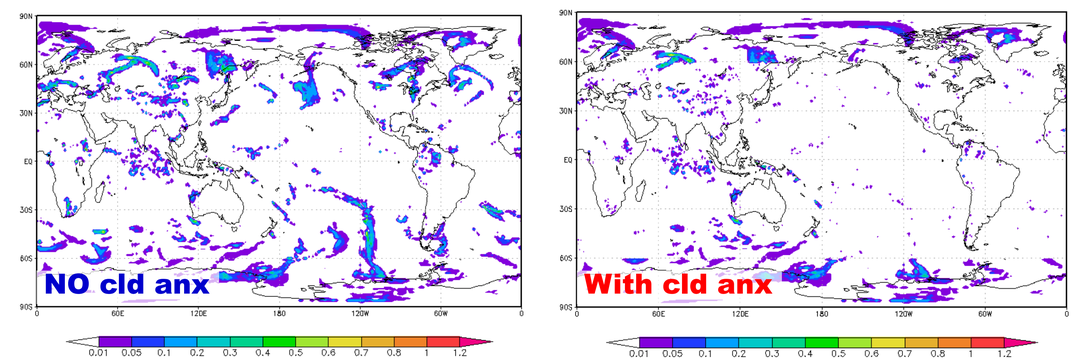


Normalized error reduction [(EXP – CNTL)/CNTL] (%) for 1000-800 hPa layer (red), 800-400 hPa (blue), and 400-100 hPa (green) from Exp. (radiance denial) for (a) temperature, (b) relative humidity, and (c) wind. The control run uses all data. Statistics are computed by layer over the RAP domain against radiosonde. The retrospective period is from May 01 to May 31, 2013. The error bar indicates the 1.96 standard error from the mean impact, representing the 95% confidence threshold for significance.



Temperature (left), relative humidity (middle), and wind (right) RMS errors for control run (black, with all data) and all radiance denial run (red) 6-h forecasts against radiosonde observations over the RAP domain at isobaric levels every 50 hPa for a one-month period (May 2013). The difference (all radiance denial minus control) is plotted in blue. Statistics are computed over the RAP domain against radiosonde. The error bar indicates the 1.96 standard error from the mean impact, representing the 95% confidence threshold for significance.

Application of GSD non-Variational Cloud Analysis to GFS/GDAS



Cloud liquid water (g/kg) at 500 hPa without GSD cloud analysis (left) and with GSD cloud analysis (right) from GDAS GSI analysis runs valid at 06Z 05/13/2016. Initial work is based on GFS/GDAS. Work ongoing on a global rapid refresh model system using Flow-following Icosahedral Model (FIM) as proxy model until NGGPS core selection made.

Work to develop variational cloud analysis, apply at all scales

- Initial test use non-var cloud analysis differences as innovations in variational cloud analysis. Using large assumed background error and very short correlation length scale, obtained close match to non-var cloud anx.
- Working to develop observation forward operators for METAR celiometers and satellite cloud-top observations
- METAR operator details:
  - Based on ceiling observation, make a observed cloud coverage column.
  - Use auto-conversion and temperature relationship to calculate, at cloudy point, cloud water or ice mixing ratio and calculate observations innovation in terms of cloud water/ice mixing ratio in station column.
  - Current effort: checking analysis results through case study to see if the forward model and var-cloud work correctly.

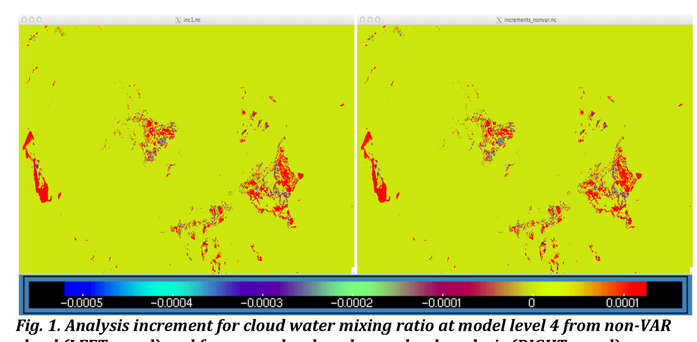
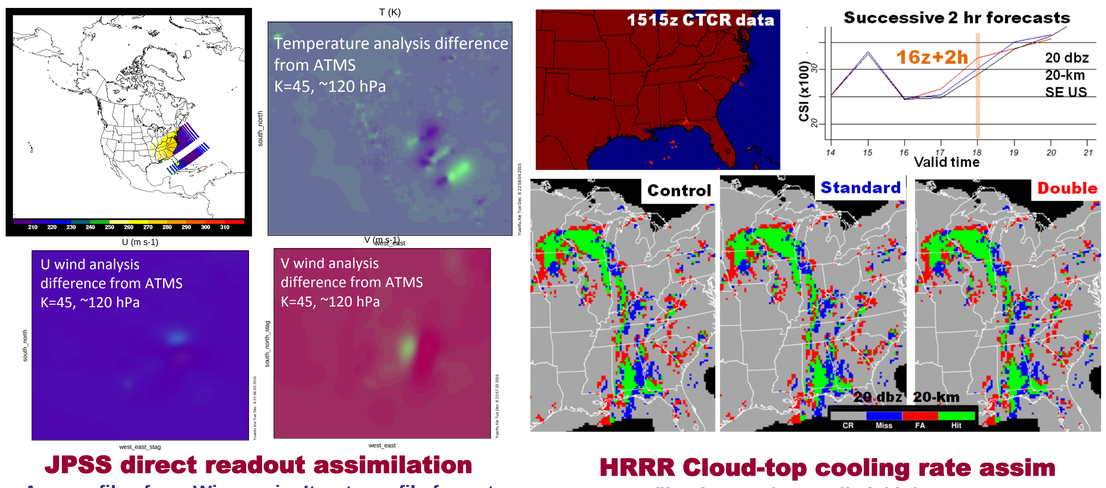


Fig. 1. Analysis increment for cloud water mixing ratio at model level 4 from non-VAR cloud (LEFT panel) and from new developed var –cloud analysis (RIGHT panel)

Different models / applications

Spatial resolution Forecast range Domain	3km 1-24h Regional	13km 1-24h Regional	10-15km 1h-16 day Global
Model development area	HRRR (High-Resolution Rapid Refresh)	RAP (Rapid Refresh)	FIM –atmos future - NGGPS
Data assimilation	Radar/cloud, ensemble DA	Sat radiance	Global Rapid Refresh
Dynamic core numerics	Use/refinement of WRF-ARW		Icos/isentropic coordinates
Physical parameterization	PBL/MYNN, cloud microphysics (Thompson), RUC land-surface,	Same as HRRR but with Grell-Freitas scale-aware cum.	GFS physics + Grell-Freitas cu. Testing of HRRR/RAP suite
Application of inline chemistry	2-aerosol – NCEP, testing of 18-aerosol	" + gas-phase chemistry	18-aerosol and gas-phase chem
Systematic error investigations	Clouds, precipitation	Clouds	Clouds, blocking, precipitation

JPSS Direct Readout Assim, HRRR cloud-top cooling rate assim



JPSS direct readout assimilation

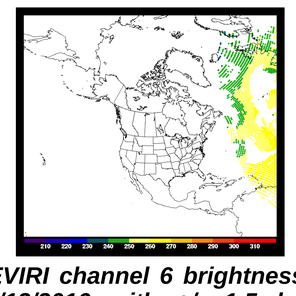
- Access files from Wisconsin, Iterate on file format
- Initial RAP benchmark test for ATMS assimilation
- Conduct regional retrospective test (Feb 1-7, 2016)
  - -- Very slight impact, assessing bias correction
  - -- Testing for other data sets
- Completing configuration for global rapid refresh

HRRR Cloud-top cooling rate assim

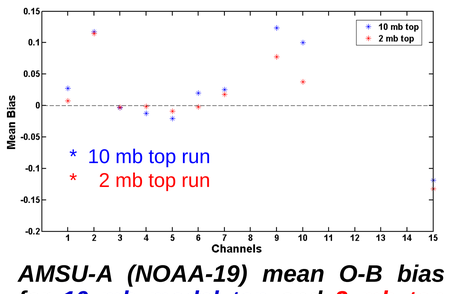
- Access files from John Mecikalski /UAH
- Apply latent heat for obs strong cloud-top cooling
- Four 15-min LH applications in HRRR pre-fcst hour
  - -- Slight positive impact, plan to test in real-time

➔ **Also testing rapid-scan AMV impact**

Initial SEVIRI Data assimilation, Raising model top



SEVIRI, as one proxy data to GOES-R ABI Ongoing work will expand to Himawari and GOES-R ABI when available both on global and regional models



SEVIRI channel 6 brightness temperature (K) at 12Z 01/12/2016 with +/- 1.5 hour time window. The expanded RAP v3 domain makes it possible to assimilate SEVIRI data into RAP. SEVIRI data has limited data coverage on the east oceans of the RAP domain. Two SEVIRI water vapor channels (channels 5 and 6) are assimilated into RAP. Initial RAP retro-runs with and without SEVIRI data show neutral impact based on radiosonde observation verification. Additional tests with global rapid refresh planned.

AMSU-A (NOAA-19) mean O-B bias for 10 mb model top and 2 mb top runs (same datasets used). Biases are calculated based on 7-day retro runs (05/01/2013-05/07/2013). Tests to assess impact from raising model top. Slight reduction in O-B mean bias for AMSU-A, especially for middle-high channels, but minimal forecast impact.