Satellite Radiance Assimilation upgrades for RAP version 4

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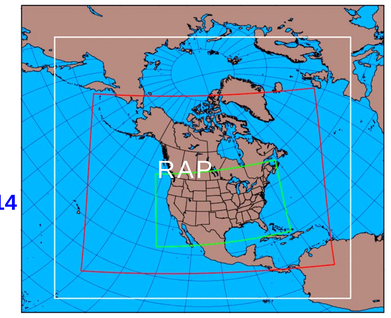
BACKGROUND

- Challenges for regional, rapid updating radiance assimilation
  - Bias correction (difficulty due to non-uniform data coverage and smaller domain)
  - Lower model top (10-hPa for the RAP; channel selection)
  - Data availability issues for real-time use
    - Large data latency especially for polar-orbital satellites
    - Short data cut-off time of hourly system (~35 min)
    - Complicates bias correction
    - Direct readout data
- Goal: Evaluate the impact of real-time radiance data on the hourly Rapid Refresh (RAP) mesoscale prediction systems; examine ways to maximize the very short-term forecast using the satellite radiance data; give upgrades to the operational RAP based on these tests.

RAP and HRRR

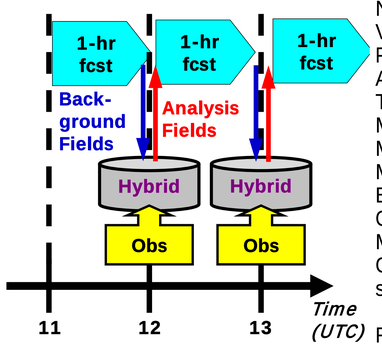
Hourly updated assimilation/model system using GSI analysis and WRF ARW model

RAP NCEP implementation:
- version 1-- May 2012
- Version 2 (EnKF hybrid) -- Feb 2014
- Version 3 -- Aug 2016
  - Larger Domain (red → white)
  - Longer Forecasts
  - Radiance updates (see below)
- Version 4 --Feb. 2018 (planned)
  - Radiance updates (see below)



Rapid Refresh

HRRR NCEP implementation
- Version 1 -- Sept 2014
- Version 2 -- August 2016
- Version 3 -- Feb. 2018 (planned)



Data types – counts/hr

Rawinsonde (12h)	150
NOAA profilers	35
VAD winds	~130
PBL profilers / RASS	~25
Aircraft (V,T)	3500–10,000
TAMDAR	200 – 3000
METAR surface	2000 -2500
Mesonet (T,Td)	~8000
Mesonet (V)	~4000
Buoy / ship	200-400
GOES cloud winds	4000-8000
METAR cloud/vis/wx	~1800
GOES cloud-top P,T	10 km res.
satellite radiance	AMSUA/MHS/HIRS/ GOES/ATMS etc....
Radar reflectivity	1 km res.

RAPv3 radiance updates (August 2016)

- 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).

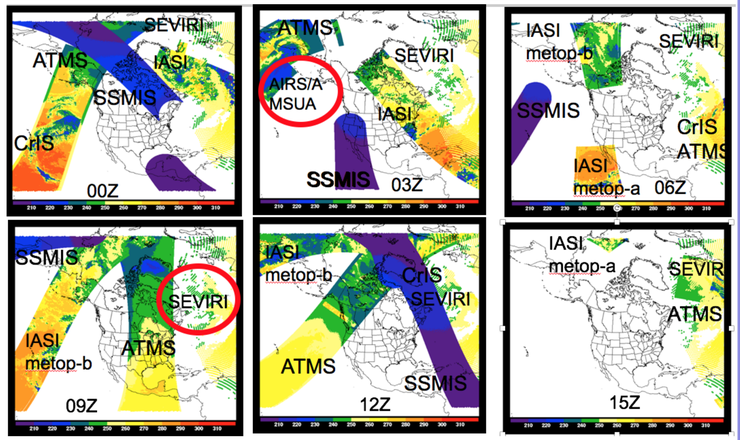
RAPv4 radiance updates (Planned Feb. 2018)

- Include new sensors/data (ATMS, CrIS, SEVIRI, AIRS, SSMIS, IASI);
- Remove some known bad channels;
- Start the partial cycles late, so partial cycles can have longer cut-off time to include more data;
- Use more RARS data and direct broadcast data for improved real-time coverage.

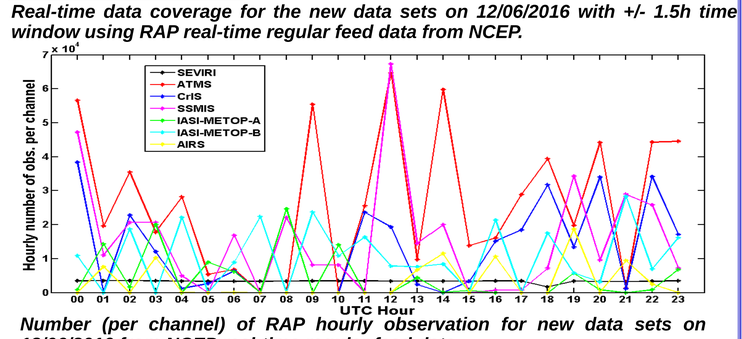
Planned Radiance Channels for RAPv4

- AMSU-A
  - NOAA_n15: channels 1-5, 7-10, 15;
  - NOAA_n18: channels 1-4, 6-7,10,15 (removed channels 5, 8);
  - NOAA_n19: channels 1-6, 9,10, 15 (removed channel 7);
  - METOP-a: channels 1-6, 9,10,15;
  - METOP-b: channels 8-10 (removed 1-7, and 15 per NCEP recommendation)
  - AQUA: channels 6, 8-10;
- HIRS4 (METOP-A) (all turned off per NCEP recommendation)
- MHS
  - NOAA_n18, METOP-A, and METOP-B:1-5
  - NOAA-19: 1, 2, 4, 5 (removed channel 3)
- GOES
  - GOES-15 (sndrD1,sndrD2,sndrD3,sndrD4): channels 3-8, 10-15
- SEVIRI: channels 5,6 from M10
- ATMS: channels 1-11, 16-22 from NPP
- CrIS: 66 channels from NPP
- SSMIS : channels 1-2, 5-7 from DMSP-17
- AIRS: 66 channels from AQUA
- IASI: 98 channels (longwave) from METOP-A and METOP-B

RAP Real Time Data Coverage for New Data Sets in RAPv4

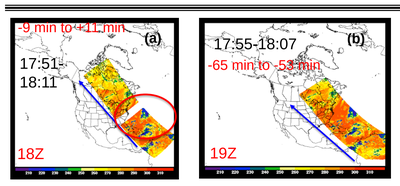


Real-time data coverage for the new data sets on 12/06/2016 with +/- 1.5h time window using RAP real-time regular feed data from NCEP.



Number (per channel) of RAP hourly observation for new data sets on 12/06/2016 from NCEP real-time regular feed data.

Direct broadcast vs. regular feed data

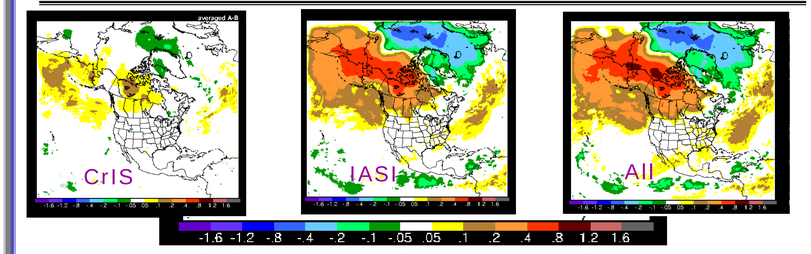


CrIS real-time data coverage from (a) regular feed data on 18Z; (b) direct broadcast feed on 19Z 08/25/2016.

Experiment design

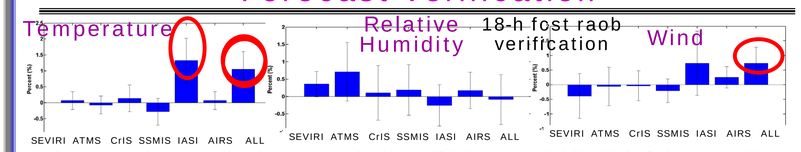
- Control run (CNTL) – (All data in RAPv3)
  - 1-h cycling run, 7-day retro run (December 01 –07 2016) using an ESRL experiment version towards RAPv4
- Experiment runs (use real-time hourly data from NCEP)
  - CNTL + SEVIRI (2 channels from m10)
  - CNTL + ATMS (18 channels from NPP)
  - CNTL + CrIS (66 channels from S-NPP)
  - CNTL + SSMIS (6 channels from SDMP-17)
  - CNTL + IASI (113 channels from METOP-A/B)
  - CNTL + AIRS (68 channels) + AMSU-A (4 channels) from Aqua
  - CNTL + All above new data sets
  - CNTL - radiance data (conventional data only experiment)

mean analysis 500 hPa temperature difference (expt.- cntl)

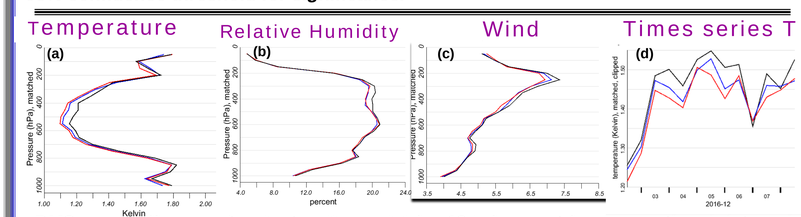


Mean analysis 500 hPa temperature difference (expt. – cntl) averaged over 159 analysis cycles for (left) CrIS experiment; (middle) IASI experiment; (right) All experiment.

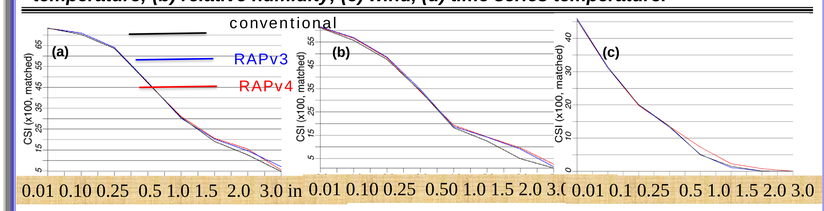
Forecast Verification



18-h forecast normalized error reduction [(EXP – CNTL)/CNTL] (%) from different experiments against the control run for (left) temperature, (middle) relative humidity, and (right) wind. Statistics are computed for 1000-100-hPa layer over the RAP domain. The error bar indicates the ±1.96 standard error from the mean impact, representing the 95% confidence threshold for significance.

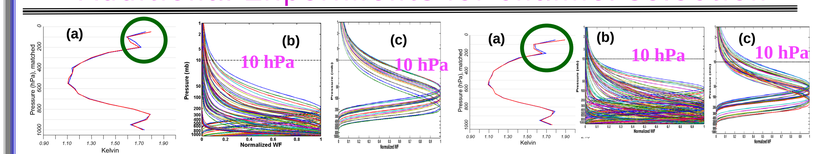


RMS error difference (against radiosonde) for 18-h forecast for conventional data only (black), RAPv3 radiance updates (blue), and RAPv4 radiance updates (red) for (a) temperature; (b) relative humidity; (c) wind, (d) time series temperature.



Critical Success Index (CSI) for (a) 24-h accumulated precipitation, (b) 12-h accumulated precipitation, and (c) 6-h accumulated precipitation for conventional data only run (black), RAPv3 radiance updates run (blue), and RAPv4 updates run (red).

Additional Experiments for channel selection



(a) RMS error difference (against radiosonde) for 18-h forecast from 82 CrIS channel run (red) and 66 CrIS channel run (blue), (b) Weighting function (WF) for 66 CrIS channel set, (c) WF for additional 16 channels in the 82 channel set.

(a) RMS error difference (against radiosonde) for 18-h forecast from 144 CrIS channel run (red) and 113 IASI channel run (blue), (b) Weighting function (WF) for 113 IASI channel set, (c) WF for additional 31 channels in the 144 channel set.

SUMMARY AND FUTURE WORK

Summary:
- A series of radiance updates have been tested at ESRL/GSD and will be implemented on operational RAPv4 (planned in February 2018);
- Adding new data sets in RAPv4 shows 0.5-1.2% normalized positive impact (against operational RAPv3) with statistical significance for temperature and wind especially for 18-h forecast from preliminary 7-day retro runs.
- Among the new data sets added to RAP4, IASI has the largest positive impact;
- Radiance data have slightly positive impact for high threshold precipitation;
- Direct broadcast data provide improved real-time data coverage for hourly RAP.

Future work:
- Assimilate data (ABI radiance, AMV, GLM lighting) from GOES-16 into RAP/HRRR;
- Assimilate data from GOES-16 into sub-hourly HRRR;
- More retrospective runs with longer period for radiance data impact within RAPv4.