Assimilation of GOES-16 ABI, N20 CrIS-FSR/ATMS (including Direct Broadcast) in RAP Version 5

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BACKGROUND

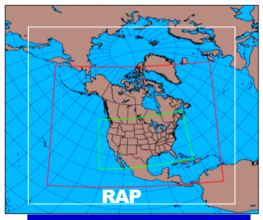
- Challenges for regional, rapid updating radiance assimilation
  - Bias correction (difficulty due to non-uniform data coverage and small domain)
  - Lower model top (10-hPa for the RAP; channel selection)
  - Data availability issues for real-time use
    - Large data latency especially for polar-orbital satellites
    - Short data cut-off time of hourly system (~30 min)
- Goal: Evaluate the impact of real-time radiance data on the hourly Rapid Refresh (RAP) mesoscale prediction system; examine ways to maximize the very short-term forecast using the satellite radiance data; provide upgrades (including new data, e.g., GOES-16 ABI and CrIS/ATMS from JPSS) to the operational RAP/HRRR.

RAP and HRRR

Hourly updated assimilation / forecast using GSI analysis, WRF ARW model

RAP NCEP implementation:
- version 1-- May 2012
- Version 2 (EnKF hybrid) -- Feb 2014
- Version 3 -- Aug 2016
- Version 4 --July 2018
- Version 5 – June 2020 (planned)

HRRR NCEP implementation
- Version 1 -- Sept 2014
- Version 2 -- August 2016
- Version 3 -- July 2018
- Version 4 – June 2020 (planned)



RAPv5 Radiance Updates (Planned June 2020)

- Include GOES-16 ABI infrared radiance data;
- Include CrIS Full-Spectral-Resolution (FSR) data both from NOAA-20 and S-NPP;
- Include ATMS from NOAA-20;
- Include the Direct Broadcast (DB) data from NOAA-20;

Radiance Channels for RAPv5

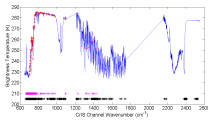
- **AMSU-A**
  - NOAA_n15: channels 1-5, 7-10, 15;
  - NOAA_n18: channels 1-10,15; (removed channels 5, 8)
  - NOAA_n19: channels 1-9,10, 15; (removed channel 7)
  - METOP-a: channels 1-6, 9,10,15;
  - METOP-b: channels 1-10,15; (removed channels 1-7, 15)
  - AQUA: channels 6, 8-10; (remove channel 6)
- **MHS**
  - NOAA_n18, METOP-A, and METOP-B:1-5
  - NOAA-19: 1-5 (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 S-NPP
- **CrIS-NSR**: 66 channels from S-NPP (replaced by CrIS-FSR)
- **SSMIS** : channels 1-2, 5-7 from DMSP-17 (removed channel 2)
- **AIRS**: 66 channels from AQUA
- **IASI**: 98 channels (longwave) from METOP-A and METOP-B
- **CrIS-FSR**: 72 channels from S-NPP and NOAA-20
- **ATMS**: channels 1-11, 16-22 from NOAA-20
- **ABI** : three water vapor channels (channels 8-10) from GOES-16

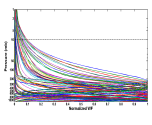
RAPv3 / earlier
RAPv4 (2018)
RAPv5 (2020)

DB/RARS for:
AMSU-A
MHS
IASI
ATMS
CrIS

Also adding radiance assimilation into 3-km HRRRv4-Alaska

CrIS-FSR Channel Selection

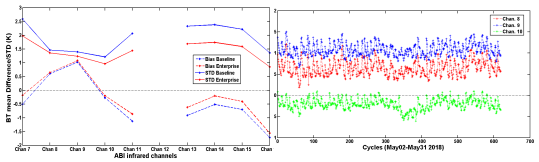




Left: Simulated BT for CrIS FSR 2211 channels with RAP selected 72 channels (red), GDAS selected 100 channels (magenta), and NESDIS selected 431 channels (black). Right: weighting functions for selected 72 RAP channels

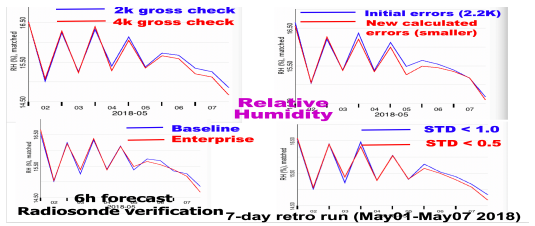
GOES-16 ABI Radiance Data Assimilation

One-Month ABI O-B Evaluation



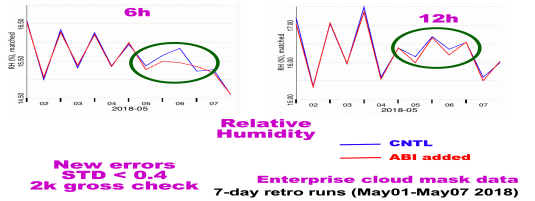
One-month (May02-May31 2018) (a) O-B mean bias and standard deviation for baseline cloud mask radiance data (blue) and enterprise cloud mask radiance data (red) for 9 infrared ABI channels, (b) time series mean bias for three water vapor channels for enterprise cloud mask radiances.

ABI Experiments with QC/Error Tuning



Time series of 6h RH forecast radiosonde verification for different ABI experiments (05/01/2018-05/08/2018) with QC/error tuning.

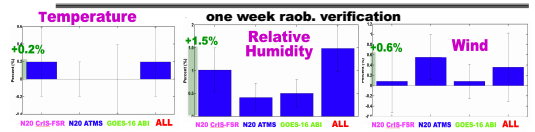
ABI Assimilation vs. CNTL



Time series of 6h and 12h RH forecast radiosonde verification for GOES-16 ABI experiments (05/01/2018-05/08/2018) compared with the control run (RAPv4 setting without ABI).

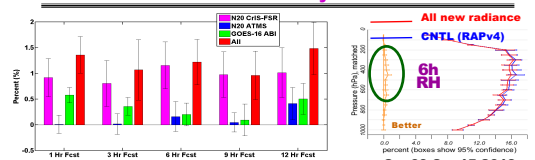
Forecast Impact from New Data sets in RAPv5

12-h fcst. Normalized Errors from New Data Sets



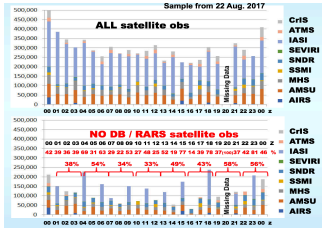
12h forecast normalized error reduction (against radiosonde) from new data sets (individually and combined together) against the control run (09/09/2018-09/15/2018, using all operational data).

1-12 fcst. Relative Humidity Verification



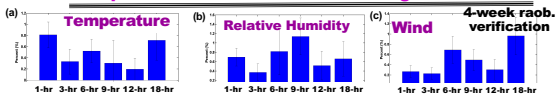
Forecast Impact from Direct Broadcast (DB) Data

Radiance Observation Counts w/ and w/o DB Data

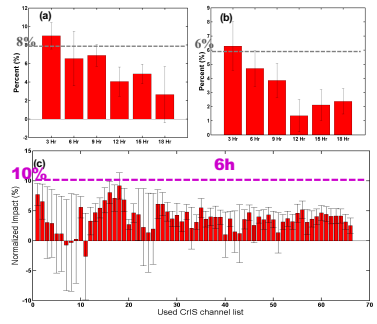


Stacked bar charts indicating the number of observations for the various satellite radiance data types for all the hours of a sample day. The top chart shows the counts for the experiment with all the data, while the bottom chart shows the counts when the DB and RARS data are removed. The red numbers associated with the brackets give the % of observations retained for averages of 3 1-h cycles and the smaller red numbers (with % sign omitted) give the hourly % of observations retained.

% Improvement from DB Data Verified against Raob.

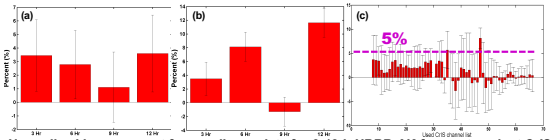


% Improvement from DB Data Verified against CrIS BT



Normalized improvement from DB/RARS data for 3-18 h forecast against CrIS observed BT for (a) chan. 83 (with peak weighting function at 218 hPa) and (b) chan. 165 (with peak weighting function at 814 hPa), and (c) 6-h normalized improvement from DB/RARS data for 6-h forecast against all used CrIS channels. Forecast verification was calculated on a 3-week (09/01/2017-09/21/2017) retro period. CRTM was used to calculate the simulated BT from model forecast and the simulated BT was compared with the time (<30 min.) and spatial co-located observed CrIS BT.

HRRR-AK Radiance DA



Normalized improvement from radiance data for 3-12 h HRRR-AK forecast against CrIS observed BT for (a) chan. 148 (with peak weighting function at 450 hPa) and (b) chan. 168 (with peak weighting function at 742 hPa), and (c) 6-h normalized improvement from radiance data against all used CrIS channels. with the time (<30 min.) and spatial co-located observed CrIS BT. The control HRRR-AK run (May01-May07 2018) used all operational data.

SUMMARY AND FUTURE WORK

Summary:
- GOES-16 ABI RAP retro results: small positive impact with additional QC/error tuning;
- RAPv5 radiance upgrade package (GOES-16 ABI, N20 CrIS-FSR/ATMS) with overall up to 1.5% normalized improvement (against raob.) for RH;
- Positive forecast impact from direct broadcast data seen in verification against radiosondes and against CrIS observed brightness temperature (larger impact);
- Radiance data have positive impact in HRRR-AK for verification against CrIS BT;
- RAPv5 and HRRRv4-AK radiance upgrade package complete.

Ongoing and Future work :
- Assimilate GOES-17 ABI infrared radiance;
- Migrate satellite radiance DA capability to FV3-based Rapid Refresh Forecast System (RRFS) and FV3-based global rapid refresh.