Hourly assimilation including radar, cloud, and surface observations in the NOAA 3km HRRR and 13km RAP models, also with land-atmospheric coupled assimilation

Stan Benjamin, Ming Hu, Curtis Alexander, David Dowell, Haidao Lin, Terra Ladwig, Eric James, Stephen Weygandt, Tatiana Smirnova, Jaymes Kenyon

NOAA Earth System Research Laboratory, Boulder, Colorado USA. Stan.Benjamin@noaa.gov

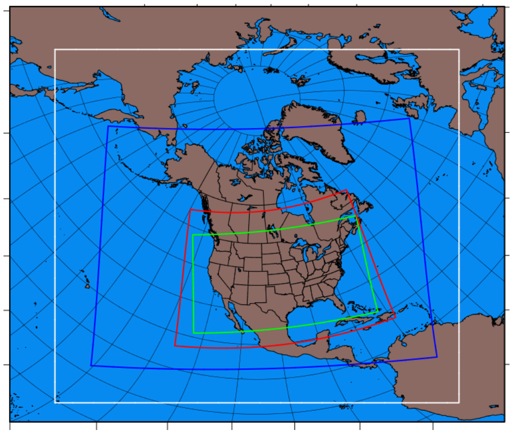

Fig 1. Domains for 3km HRRR model (green) and current RAP (RAPv3, white), Benjamin et al 2016. Also shown for the previous RAP (blue) and previous Rapid Update Cycle models (red).

The 13km Rapid Refresh (**RAP**) analysis and forecast system and 3km High-Resolution Rapid Refresh (**HRRR**) provides *hourly updated* shorter-range forecasts over North America (Fig. 1) for severe weather, aviation/transportation, and other situational awareness decision making. The HRRR runs out to 21 h, with a new data assimilation forecast cycle using latest hourly observations to run new forecasts every hour.

The HRRR and RAP models were recently updated (**HRRRv2/ RAPv3**) at NOAA/NCEP in August 2016. An overall description of the RAP/HRRR configuration for model and assimilation details are provided in Benjamin et al 2016 (B16). The RAPv3/HRRRv2 versions featured a largely removed warm/dry bias (Fig. 2, also B16 - section 6) through improved assimilation and model physics.

The HRRR and RAP data assimilation uses a GSI (NOAA's Gridpoint Statistical Interpolation) version enhanced by advanced capabilities for:

1. Hybrid (ensemble/variational) assimilation (B16, Hu et al 2017).

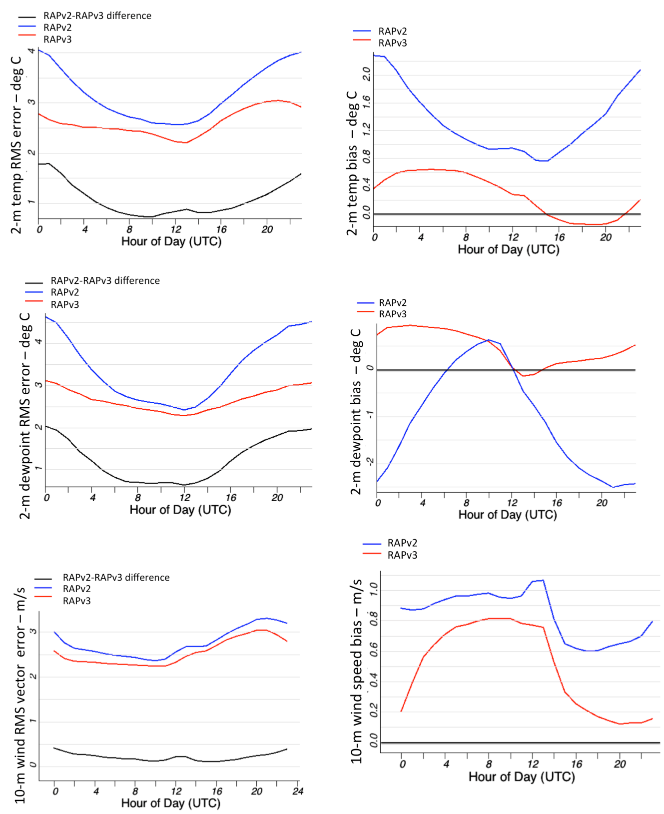

Fig 2. Surface verification over the 4-month period from 1 May – 31 Aug 2015 for 12-h forecasts from RAPv2 and RAPv3 in eastern CONUS region for (left column) RMS error and (right column) bias over period. Both RMS errors and bias are calculated for forecasts versus METAR observations. Statistics in each column are for (top) 2-m temperature, (middle) 2-m dewpoint, and (bottom) 10-m wind. (Benjamin et al 2016, Fig 11)

2. Radar reflectivity assimilation via latent heating. Latent heating is applied via a digital filter initialization in RAP (Reference B16) and directly at 3km at 15min intervals in HRRR (B16).
3. Cloud and precipitation hydrometeor assimilation (B16), using satellite cloud-top and METAR ceiling observations.
4. PBL-based pseudo innovations from surface observations (B16, 2f).
5. Full radiance assimilation in hourly RAP cycle (Lin et al 2017).
6. Soil temperature adjustment via coupled atmospheric-soil assimilation using near-surface atmospheric analysis increments (B16, Smirnova et al 2016).

A more recent observation system (impact) set of experiments for 10 different observation types revealed that short-range RAP forecast skill is most highly dependent on aircraft observations (Fig 3 below, from James and Benjamin 2017).
Further improvements in radar, cloud, and surface assimilation are included in the HRRRv3/RAPv4 update currently planned at NCEP in February 2018.

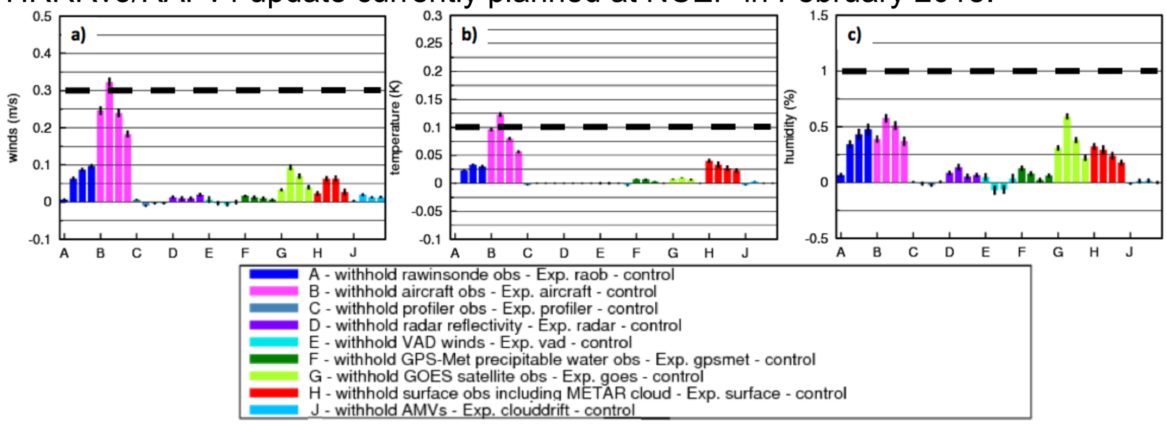

Fig 3. Observation impact results for RAP (increase in 1000-100 hPa 3/6/9/12h forecast vs. raobs when 9 different observation types are withheld. Integrated over 10-day experiments from all three seasons (JB17, Fig. 7) showing results for (a) wind, (b) temperature, and (c) relative humidity. Dashed lines indicate the level of 25% forecast error reduction. Statistical uncertainties are indicated for each experiment by narrow black lines showing ±1 standard error from the mean impact.

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