RAPID REFRESH (RAP)
Upgrade V2.0.4

Briefing to the NCEP Director

February 10, 2014

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Charter Overview

- **This project is an NWS and NCEP Annual Operating Plan (AOP) milestone for Q2 FY2014**

- **Upgrade scheduled for February 25, 2014**
- **Rapid Refresh description**
  - **Used by SPC, AWC, WPC, FAA and various private sector companies (wind energy, aviation….) for hourly analyses and updated short-range forecasts**
  - **24 cycles/day – each run out to 18 hours**
  - **6-hour catch-up "partial" cycle run twice per day and initialized by the GFS**

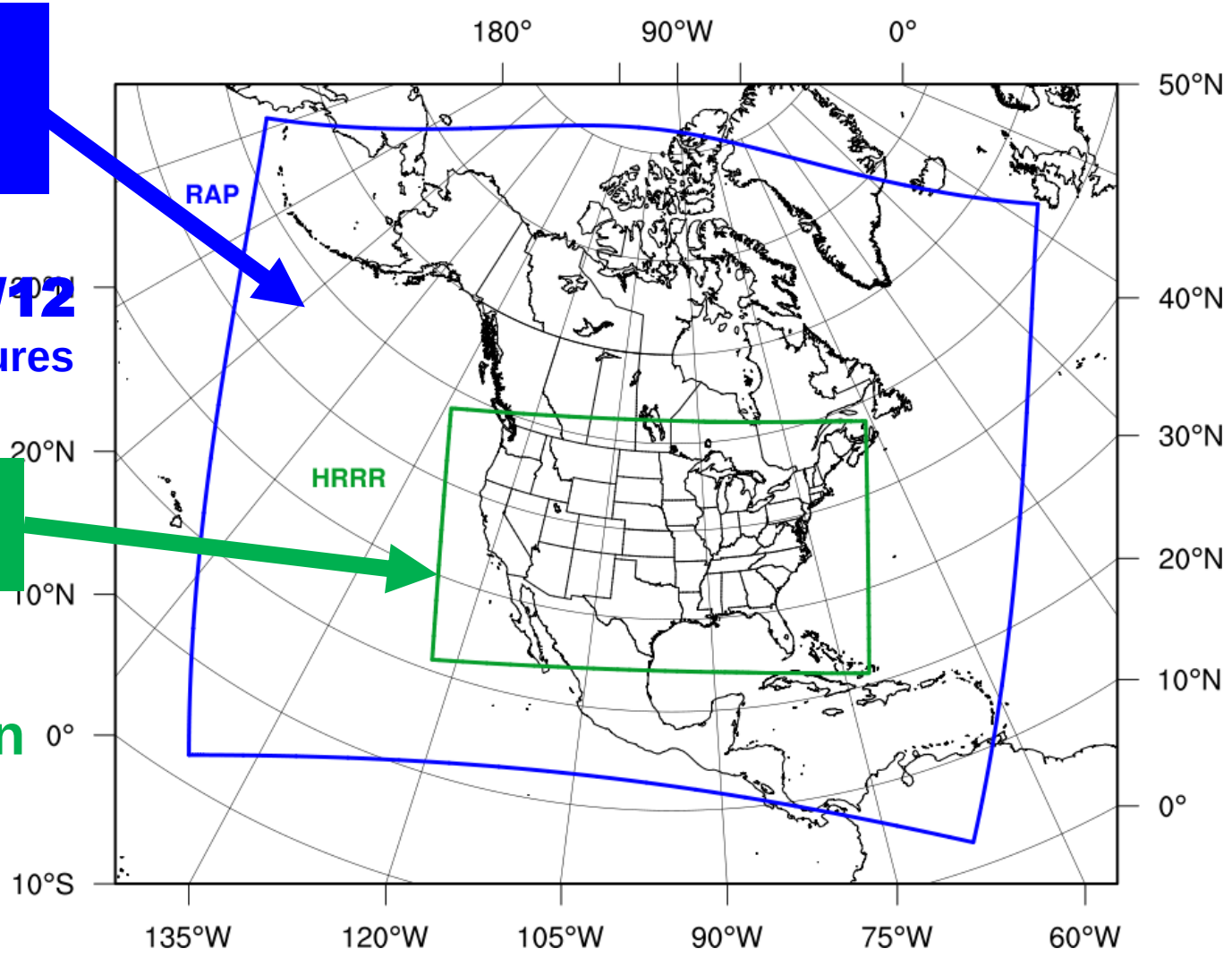
- **What's being changed**
  - **Updates to most recent trunk versions of WRF, GSI, and post processing codes**
  - **Significant upgrades to GSI (analysis) code**
  - **Significant upgrades to model code**
  - **Additional parameters in output files**

13km Rapid Refresh (RAP) (mesoscale)

Replaced RUC at NCEP 05/01/12

WRF, GSI, RUC features

3km HRRR (storm-scale)



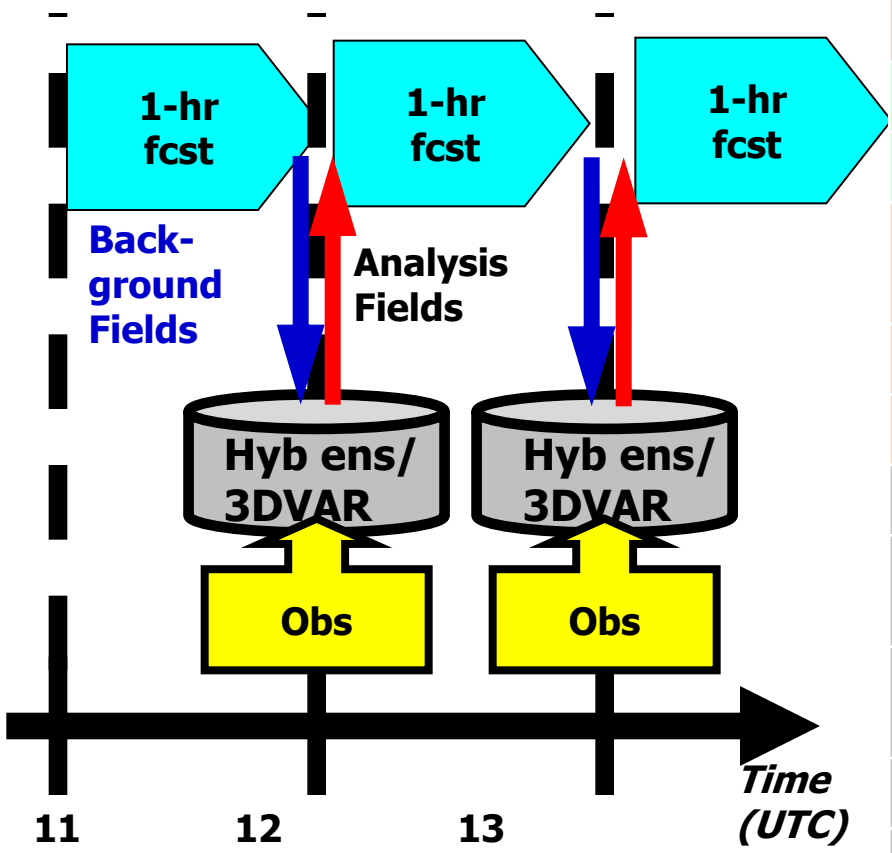
High-Resolution Rapid Refresh

Experimental 3km nest inside RAP, hourly 15-h fcst

Rapid Refresh
Hourly Update Cycle

Partial cycle atmospheric fields – introduce GFS information 2x/day

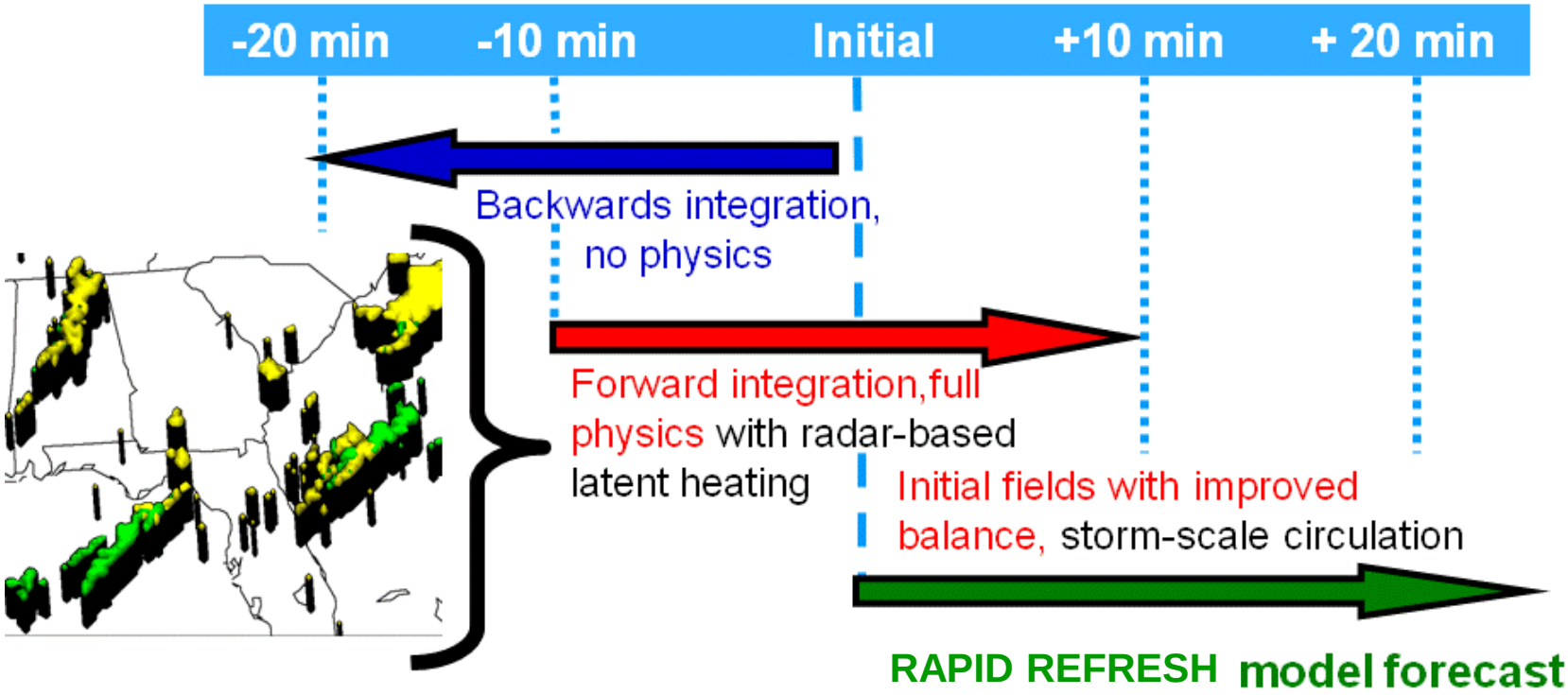
Fully cycle all land-sfc fields



Hourly Observations	RAP 2012 N. Amer
Rawinsonde (T,V,RH)	120
Profiler – NOAA Network (V)	21
Profiler – 915 MHz (V, Tv)	25
Radar – VAD (V)	125
Radar reflectivity - CONUS	2km
Lightning (proxy reflectivity)	NLDN, GLD360
Aircraft (V,T)	2-15K
Aircraft - WVSS (RH)	0-800
Surface/METAR (T,Td,V,ps,cloud, vis, wx)	2200- 2500
Buoys/ships (V, ps)	200-400
Mesonet (T, Td, V, ps)	flagged
GOES AMVs (V)	2000- 4000
AMSU/HIRS/MHS radiances	Used
GOES cloud-top pressure/temp	13km
GPS – Precipitable water	
WindSat scatterometer	2-10K

Rapid Refresh – specific analysis features

DFI-radar reflectivity assimilation



RAP v2 improvement:

(1) Temperature-dependent hydrometeor specification from 3D radar reflectivity (much smaller 1h precip bias)

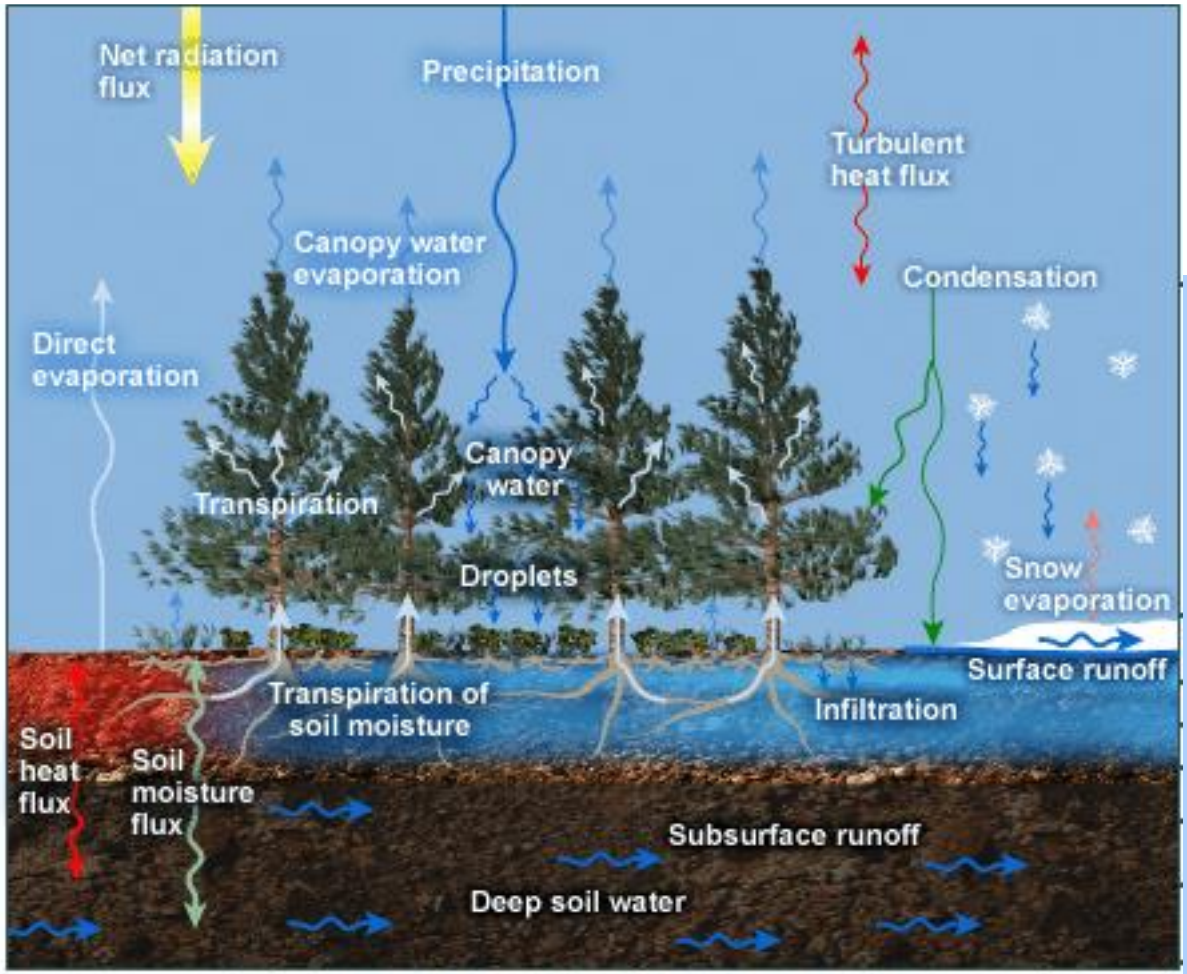
(2) Add lightning data to complement radar reflectivity

– Overview of Changes in Version 2

- Updated versions of WRF model and GSI
- Using GFS ensemble background error covariances in GSI
- 9-layer soil model (V1 has 6 layers) and modified roughness length specification for some land-use classes
- Update to Thompson microphysics
- Adjustment of soil temperature/moisture inside GSI based on atmospheric low-level temperature and moisture increments
- Modification to radar hydrometeor specification and adding a sfc-temperature dependency
- Addition of PBL-based pseudo-innovations for sfc moisture observations in GSI
- Adding snow-building capability and improving snow trimming
- Retaining cloud fraction from METAR and satellite cloud data and other cloud assimilation improvements
- Assimilation of lightning data as proxy for radar reflectivity
- Correction in radiation code to attenuation due to falling snow
- Improvement in assimilation of GPS precipitable water data
- Switch PBL scheme from MYJ to MYNN

RAP/HRRR 2013 Model Update

RUC Land Surface Model (LSM) increased from 6 to 9 levels
Changed PBL scheme from MYJ (Mellor-Yamada-Janjic) to MYNN (Mellor-Yamada-Nakanishi-Niino)
Increased surface roughness lengths



OLD ~ 8 m	NEW ~ 8 m
0 (cm)	0 (cm)
	1
	4
5	
	10
20	
	30
40	
	60
	100
160	160
300	300

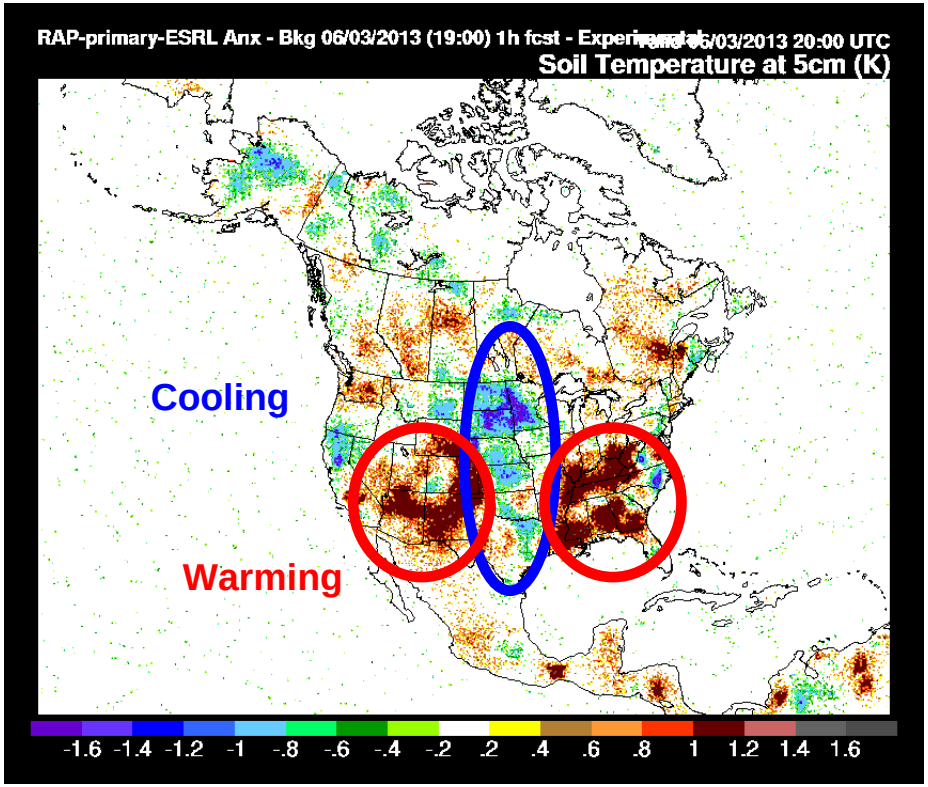
Thinner soil layer in the energy and moisture budgets – potential for increased diurnal cycle near surface: reduced warm bias at night and cold bias during the day

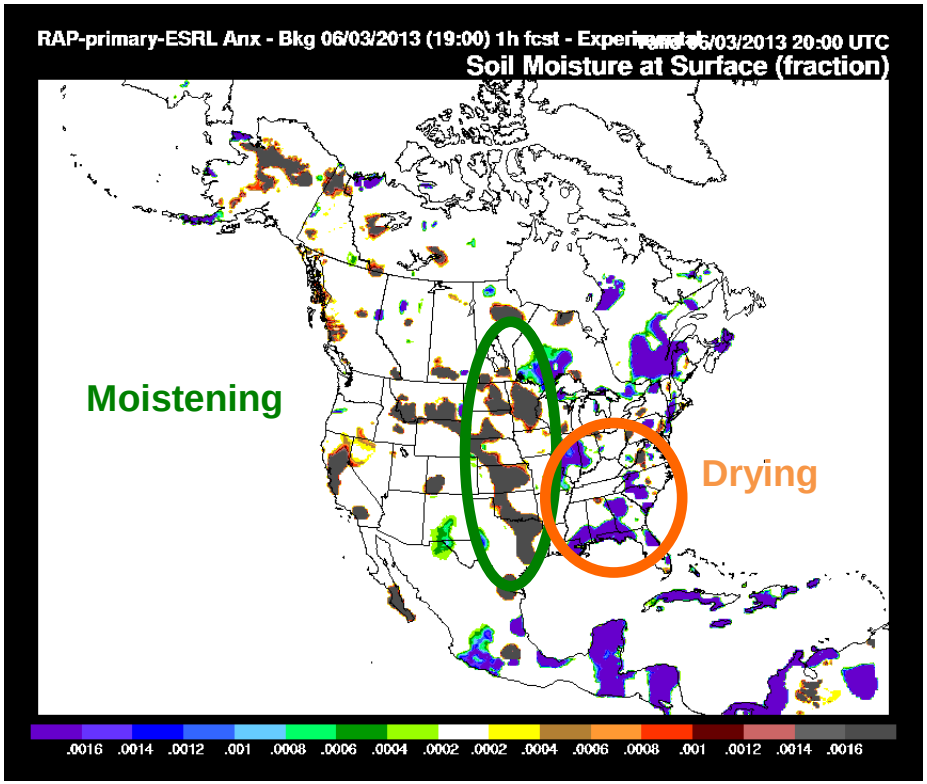
Soil Adjustment (GSI)

Soil Temperature

Valid
20 UTC
03 June 2013

Soil Moisture





Based upon surface temperature and dewpoint innovations

– Expected Benefits to End Users Associated with Upgrade

- Significant improvement in 2-m temperature bias, particularly the warm late afternoon bias
- Overall improvements to 2-m dew points
- Improvements to 2-m temperature analyses/forecasts in spring near edges of snowpack – significant impact to RTMA
- Improvements to 2-m temperature in falling snow
- All of the above feed back into improved instability and precip forecasts too
- Overall improved synoptics
- Improvements to 10-m winds
- Improved precip forecasts near coastline in convective events and possible feedback into sea level pressure in coastal storms

DEVELOPMENTAL TESTING

- RAP V2 run at GSD for 2+ years; code frozen March 2013
- Built at EMC in spring 2013
- Land-sfc bug corrected August 2013
- NCO parallel built in October to run on prod machine
- Boundary/Terrain modified November/December 2013
- Hypsometric Option changed early January 2014

ADDITIONAL TESTING

- EMC summer stats rendered questionable by August change, although significant impact from change not expected
- GSD therefore also ran summer retrospective to verify that August change did not have major impact on stats

DEVELOPMENT TESTING

- Statistics reveal overall improvement in all seasons
- Overall synoptic improvement but biggest gains in 2-m temperatures/moisture
- 10-m winds are better too
- HRRR testing shows improvement to that model using V2
- NARRE-TL looks better in tests using V2 as well

PARALLEL EVALUATION

- SPC has been downloading RAP V2 files from ESRL for 2+ years
- SPC mesoanalysis graphics available on web, generated from both V1 and V2
- EMC and ESRL web sites
- Official NCO evaluation period completed: SPC, AWC, WPC, FAA, NWS Regions

JOB / RESOURCE CHANGES

- RAPV1 already in vertical structure, so no major code overhaul was required
- GSI now takes ~2 minutes longer to run
- 5 extra nodes being used to run the full cycle forecast job; 2 extra nodes being used to run the partial cycle forecast job (full and partial cycle forecast jobs will now use same number of total nodes - should have been the same previously)
- most of the 2 minutes lost in the analysis job is made up during the full cycle forecast

PRODUCT CHANGES

RAP currently generates:

- 13, 20, and 40 km hourly output on pressure levels
- 13, 20 km hourly output on native levels
- 11 km hourly Alaska output
- 32 km hourly full domain output
- 16 km hourly Puerto Rico output
- smartinit output for CONUS, AK, PR, Juneau zoom
- bufr sounding files

- no partial cycle output is generated

PRODUCT CHANGES

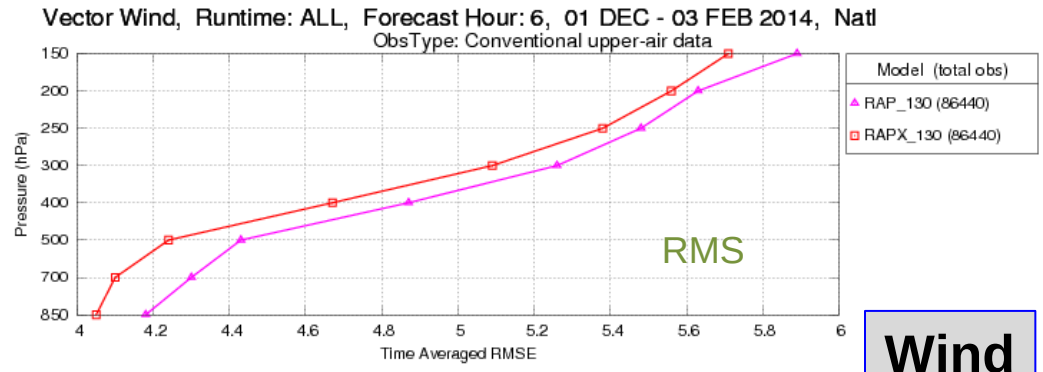
-
- **Changes:**
  - 24 new records in all pressure level files (extra 2.6 GB/day)
  - 56 new records in all native level files (extra 0.75 GB/day)
  - 29 new records in all full domain files (extra 0.75 GB/day)
  - 27 new records in all Alaska files (extra 0.15 GB/day)
  - 22 new records in all PR files (extra 0.1 GB/day)
  - 28 new stations in bufr output and 4 stations relocated (extra 30 MB/day)
  - 1 additional parameter in smartinit files
- **Addition:**
  - 2 new internal post-digital filter analysis file being generated extra (2.4 GB/day)

November/December Issues

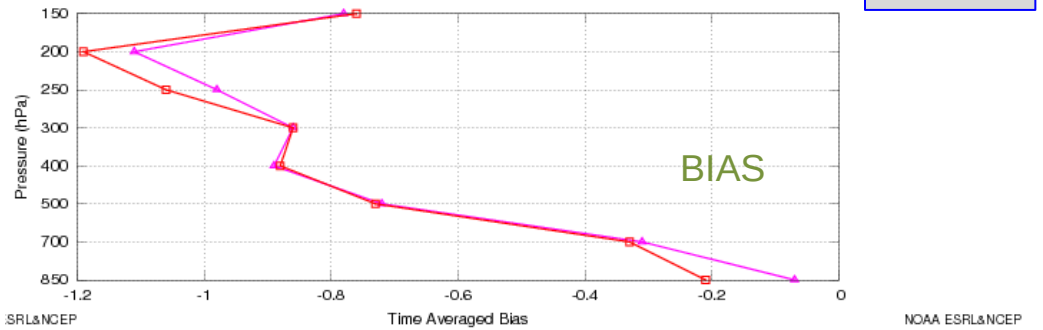
- RAP parallels had multiple crashes in November due to strong flow over very sharp terrain along the southern boundary in South America
- A few crashes also occurred due to strong flow over very sharp terrain in Greenland
- Solution was to adjust the boundary terrain (set outer row height to value at 2nd row) all around and also to smooth the terrain over Greenland
- Corrected radar processing bug in early December (did not affect model stability)
- More crashes in late December; finally attributed to WRF code bug in boundary height tendencies in logP hypsometric option – this likely caused the November crashes too
- Reverted to previous method of solving hypsometric option – NCO code frozen 1/15/14
- None of these recent changes have compromised earlier results – evaluation period ended as scheduled in early February

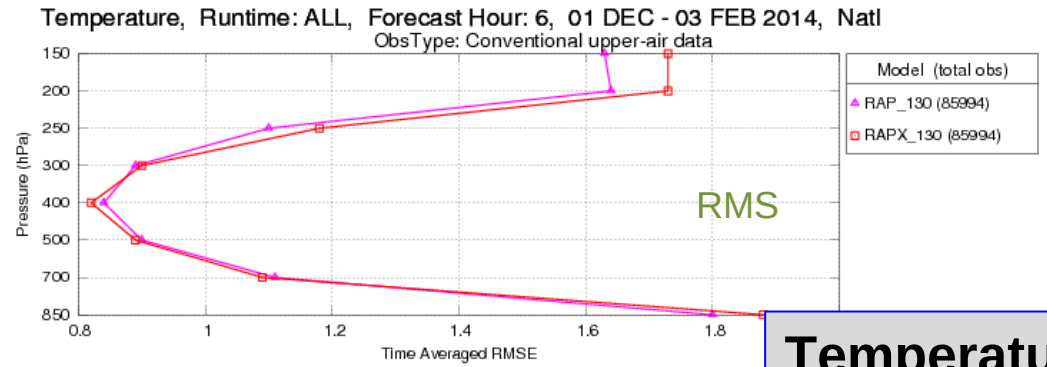
REAL-TIME PARALLEL STATS

December 2013 - Current

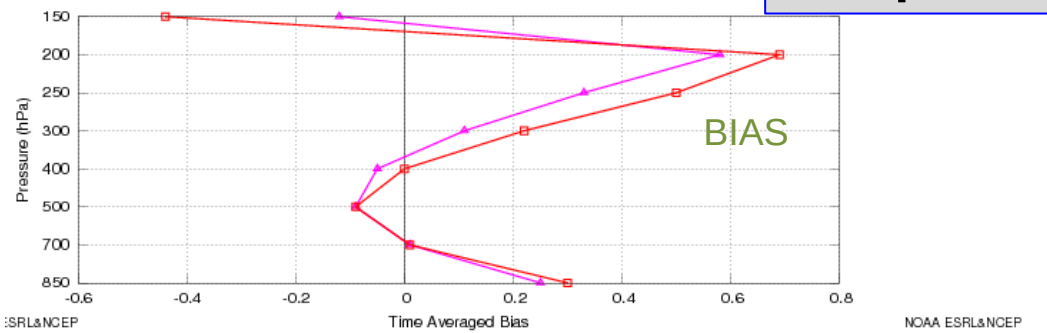


Wind





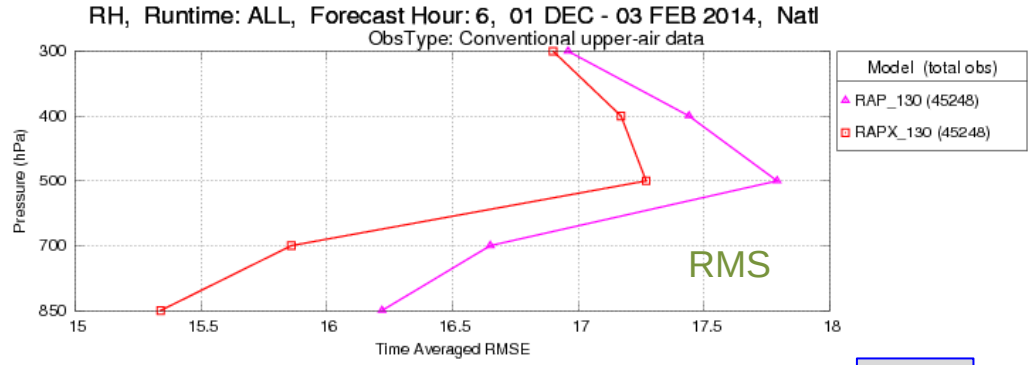
Temperature

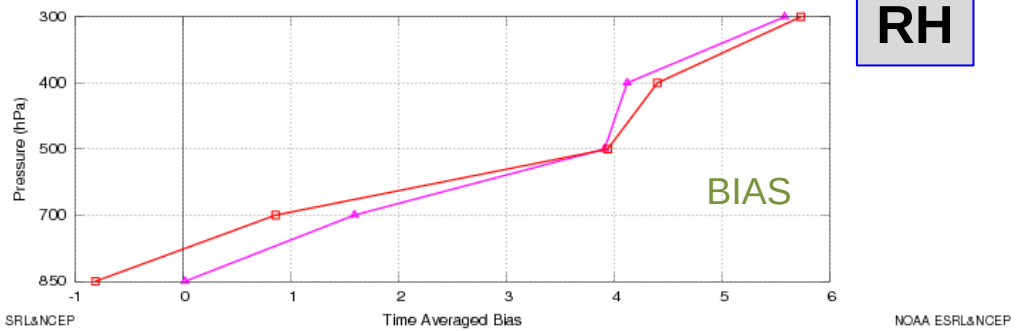


6h forecast – RMS/BIAS
1 Dec 2013 – 3 Feb 2014
(current)
RAPv1 vs. **RAPv2**

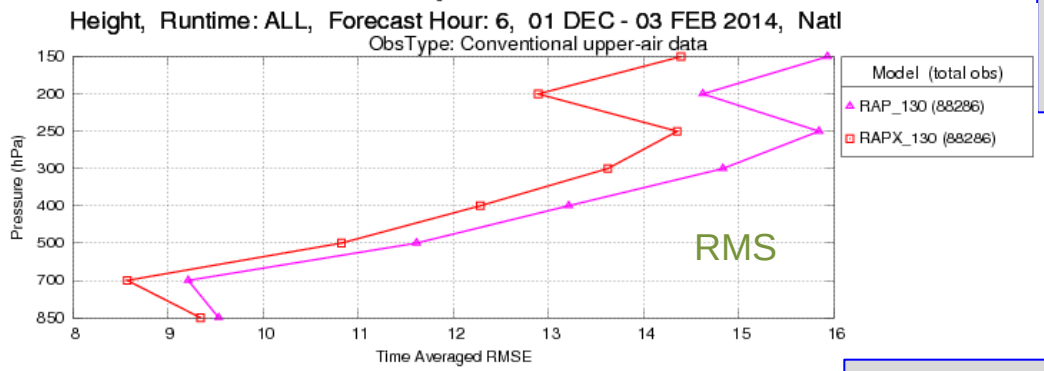
Wind
- Improvement at all levels

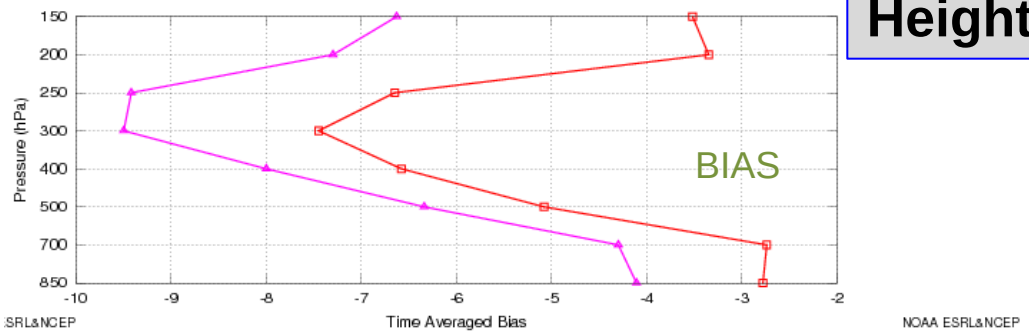
Temp
- RMS Similar for RAPv1 and RAPv2, improved bias in upper levels





RH





Height

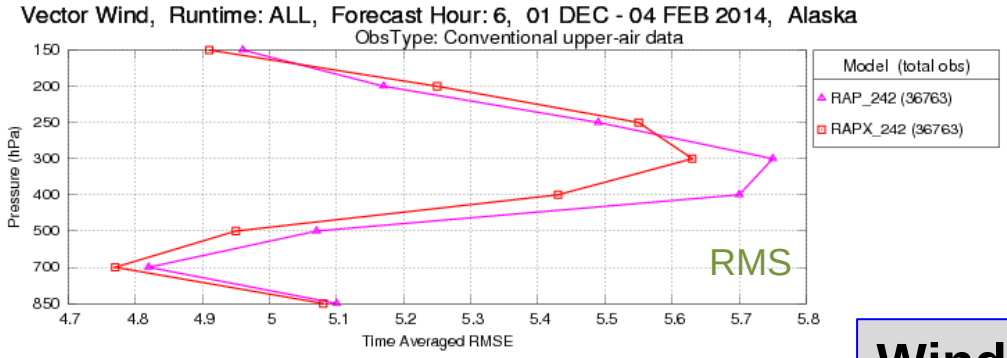
6h forecast – RMS/BIAS
1 Dec 2013 – 3 Feb 2014
(current)
RAPv1 vs. **RAPv2**

RH (850-300)

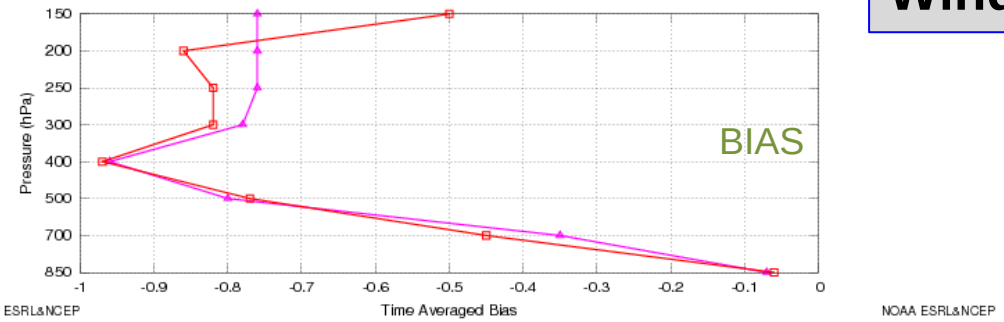
- V2 improvement at all levels except very slight dry bias at sfc

Heights

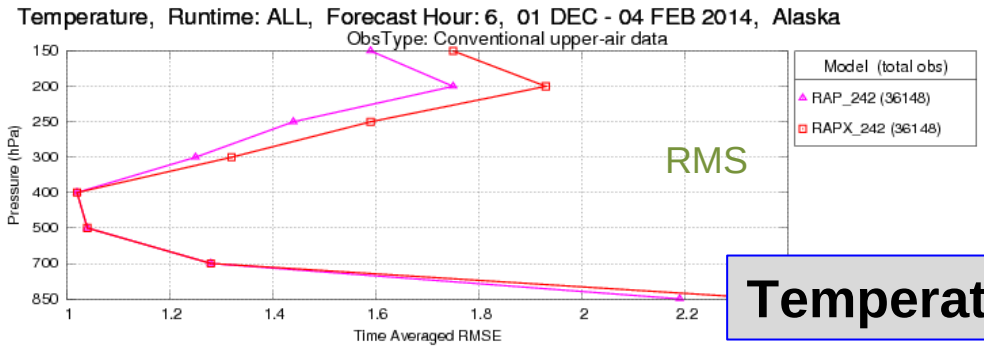
- V2 Improvement at all levels



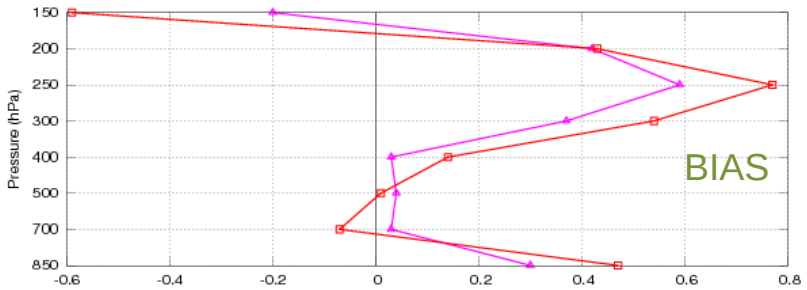
Wind



6h forecast – RMS/BIAS
1 Dec 2013 – 3 Feb 2014
(current) ALASKA
RAPv1 vs. **RAPv2**

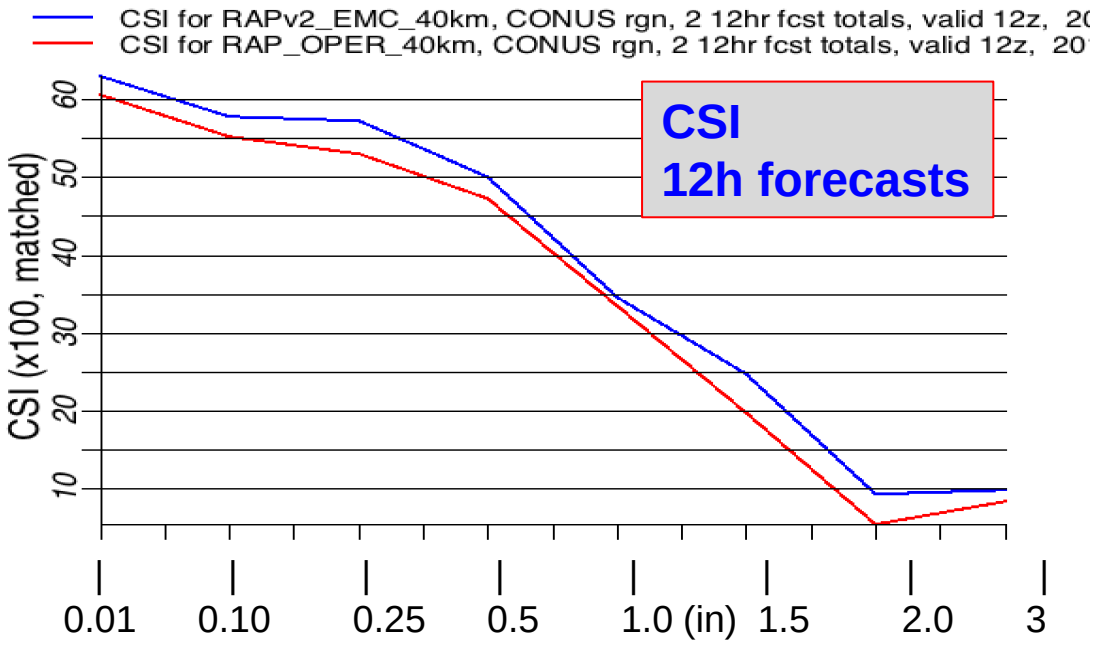


Temperature

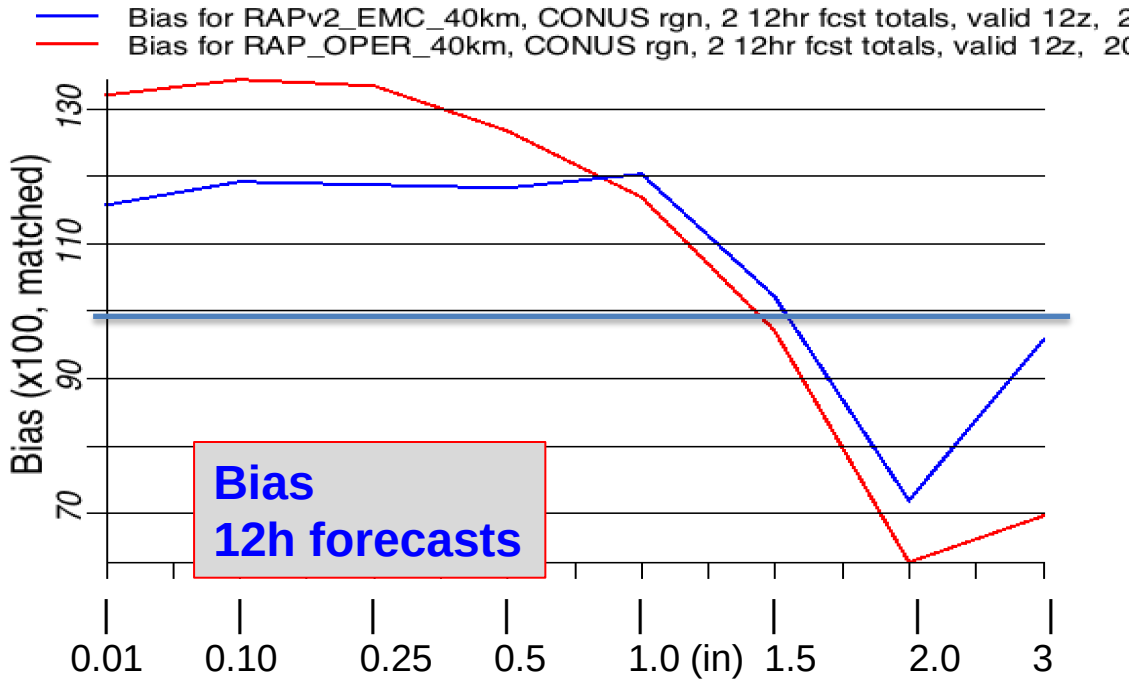


Wind
- Slight improvement in mid levels

Temp
- RMS Similar for RAPv1 and RAPv2, slightly worse v2 bias



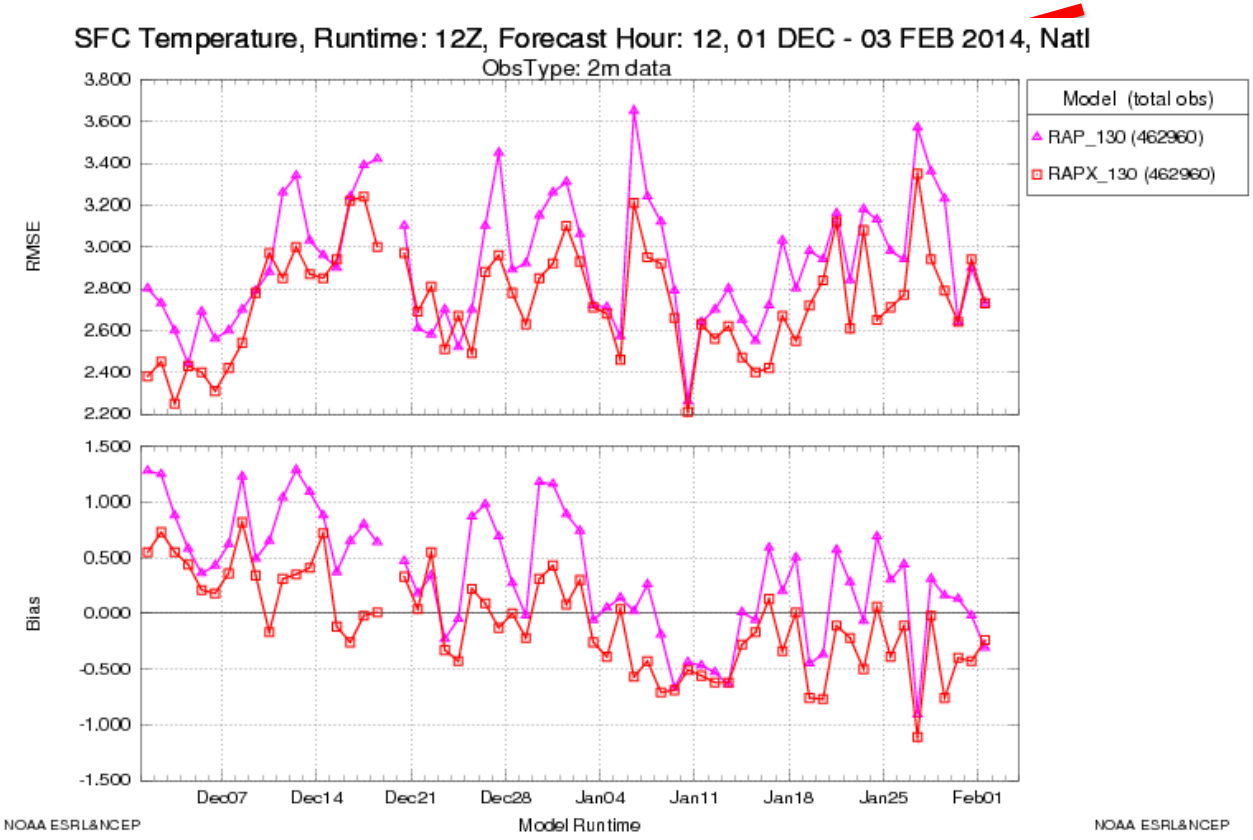
Precip – CONUS
28 Dec 13–6 Feb 2014
RAPv1 vs. **RAPv2**



Precipitation forecasts –

- RAPv2 better CSI than RAPv1
- RAPv2 bias closer to 1.0 at almost every threshold

RAPv2 has lower **RMS** 2m temp errors than RAPv1



12z Cycles

12-hr <u>2m Temp</u>

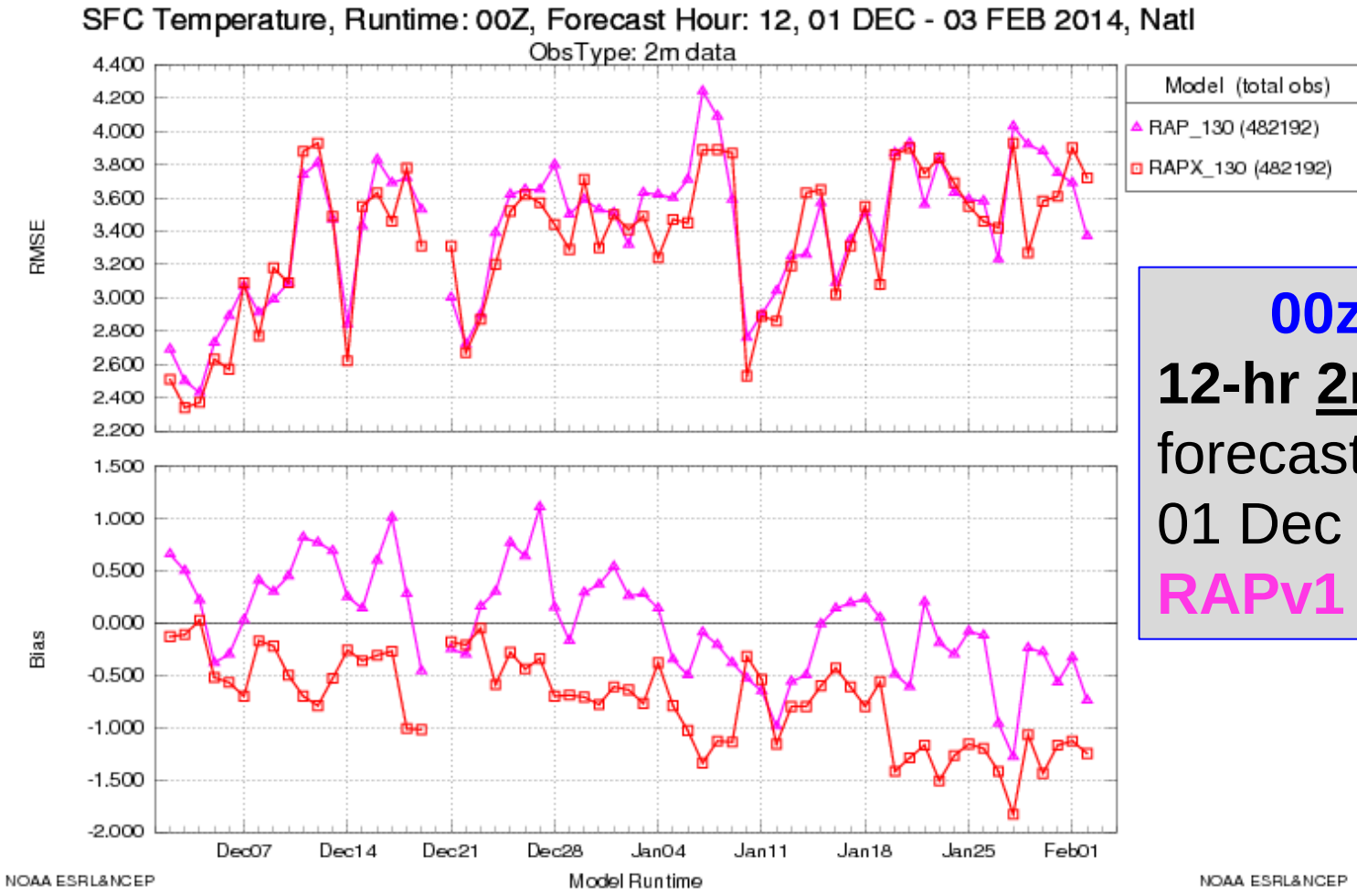
forecasts Valid 00z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

RAPv2 has lower warm 2mT **bias (F-O)** than RAPv1

RAPv2 has slightly lower nighttime **RMS** 2m temp errors than RAPv1



00z Cycles

12-hr <u>2m Temp</u>

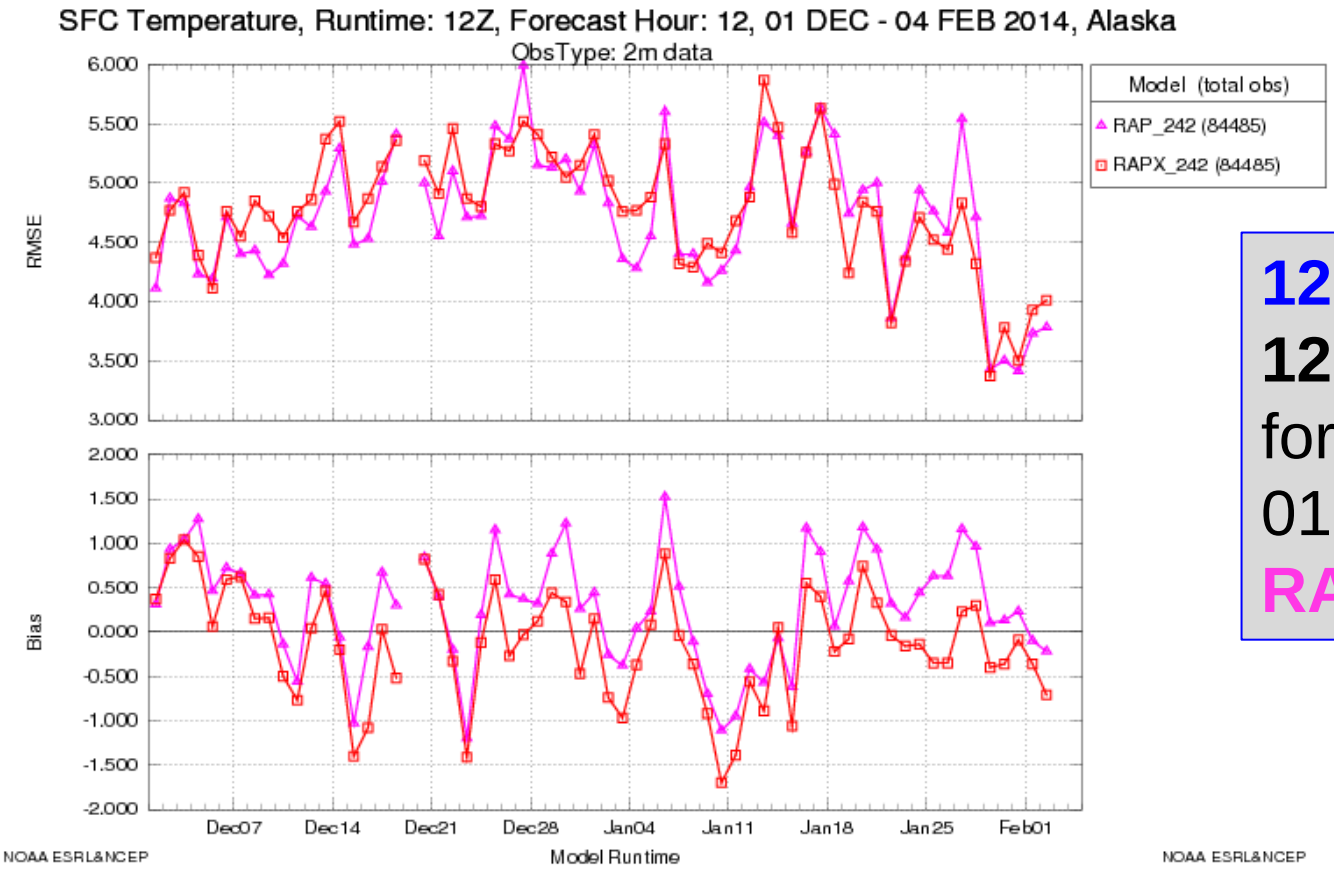
forecasts Valid 12z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

RAPv2 introduces a slight cold bias at night

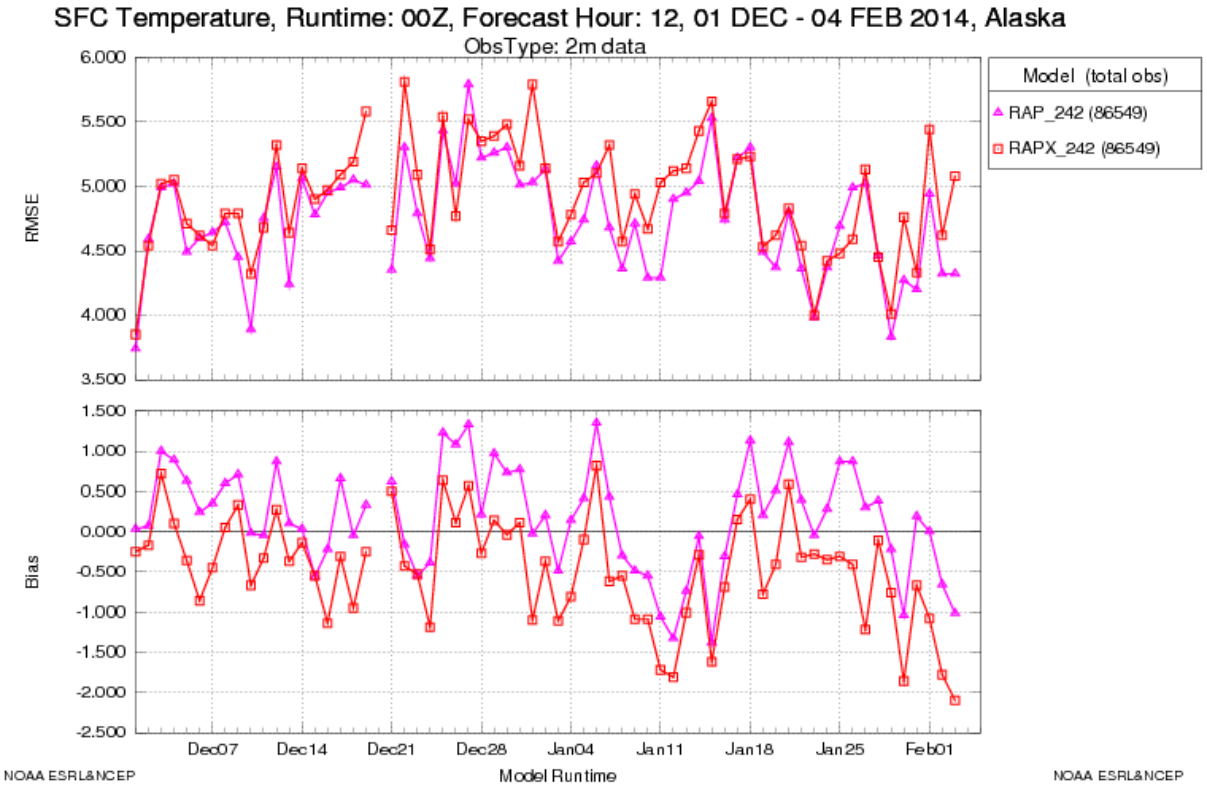
RAPv2 overall fairly even with RAPv1 in daytime RMS errors



12z Cycles - Alaska
12-hr 2m Temp
forecasts Valid 00z
01 Dec – 03 Feb
RAPv1 vs. **RAPv2**

RAPv2 reduces a slight warm bias during day

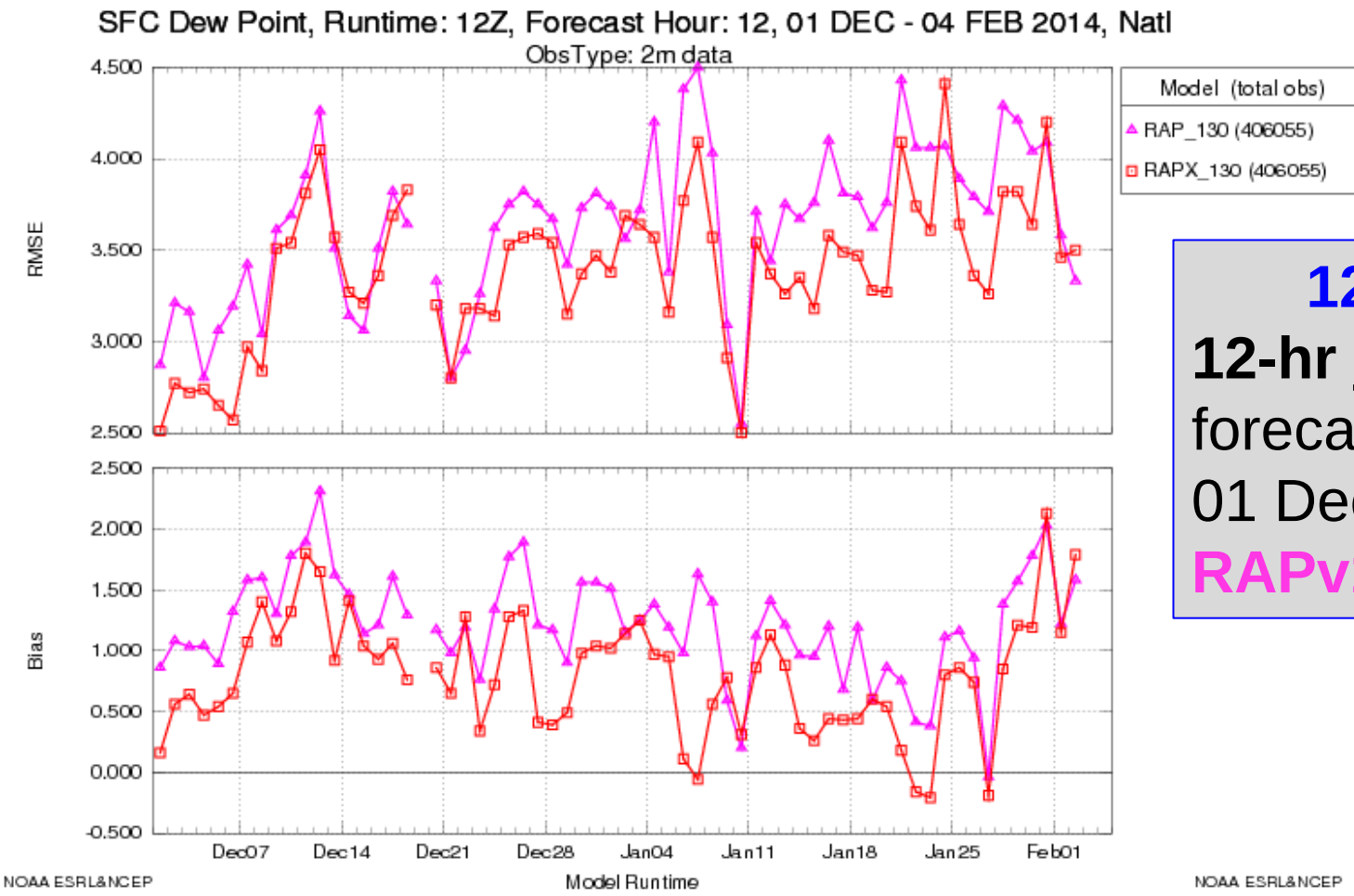
RAPv2 overall fairly even with RAPv1 in nighttime RMS errors



00z Cycles - Alaska
12-hr 2m Temp
forecasts Valid 12z
01 Dec – 03 Feb
RAPv1 vs. **RAPv2**

RAPv2 introduces a slight cold bias at night

RAPv2 has slightly lower daytime **RMS** 2m Dew Pt errors than RAPv1



12z Cycles

12-hr 2m Dew Pt

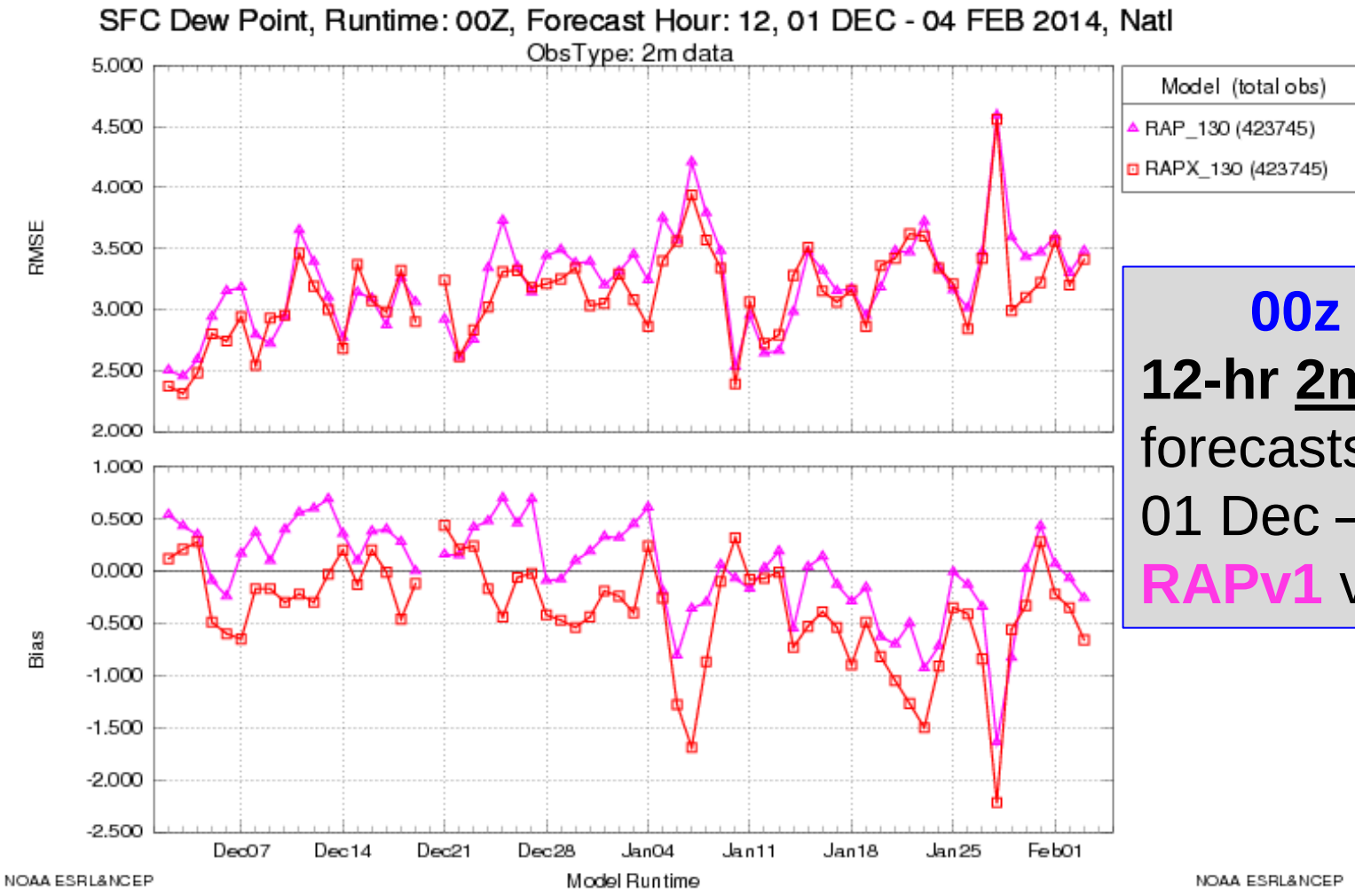
forecasts Valid 00z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

RAPv2 improves a moist bias in late afternoon

RAPv2 has slightly lower nighttime **RMS** 2m Dew Pt errors than RAPv1



00z Cycles

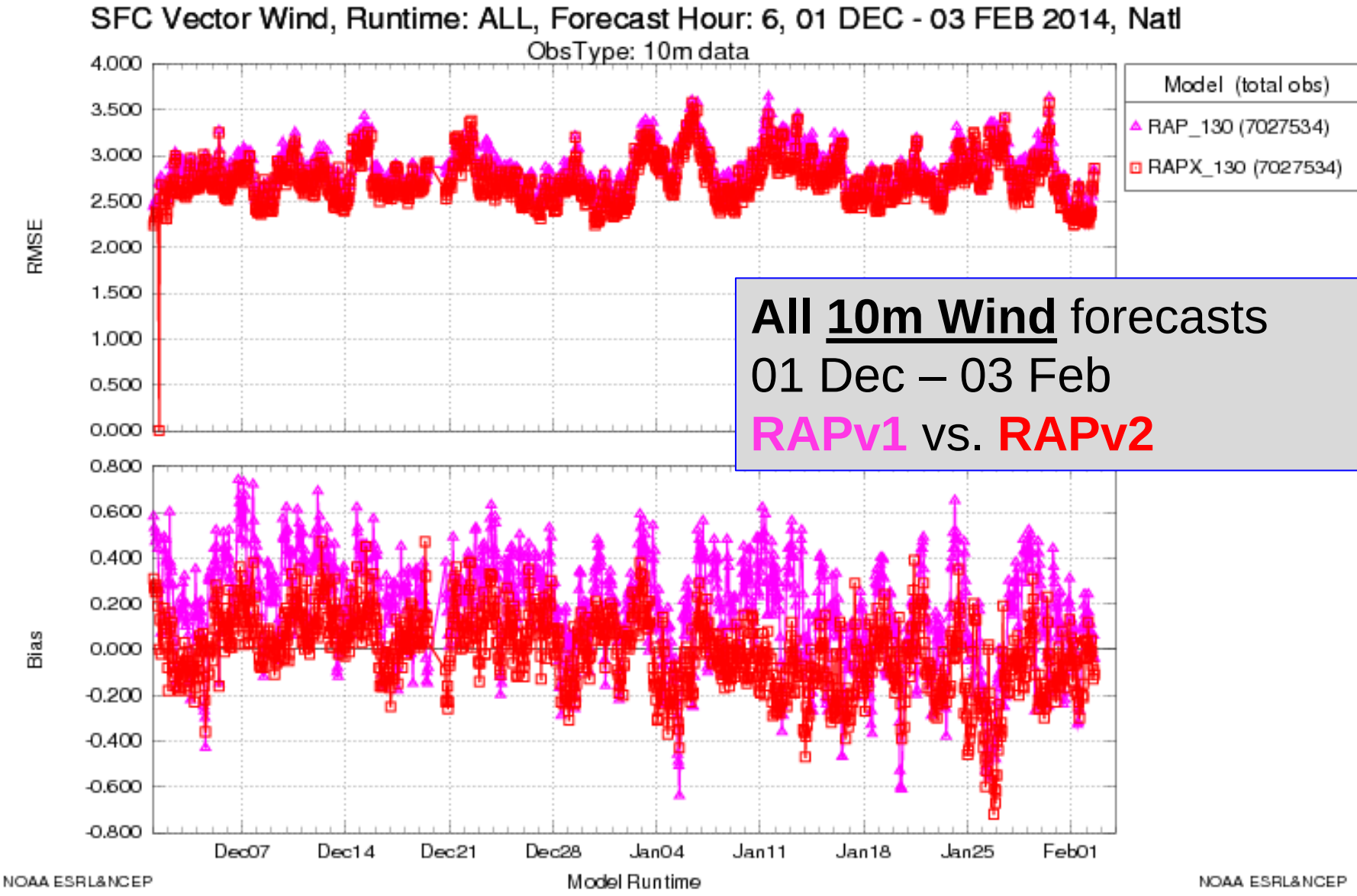
12-hr 2m Dew Pt

forecasts Valid 12z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

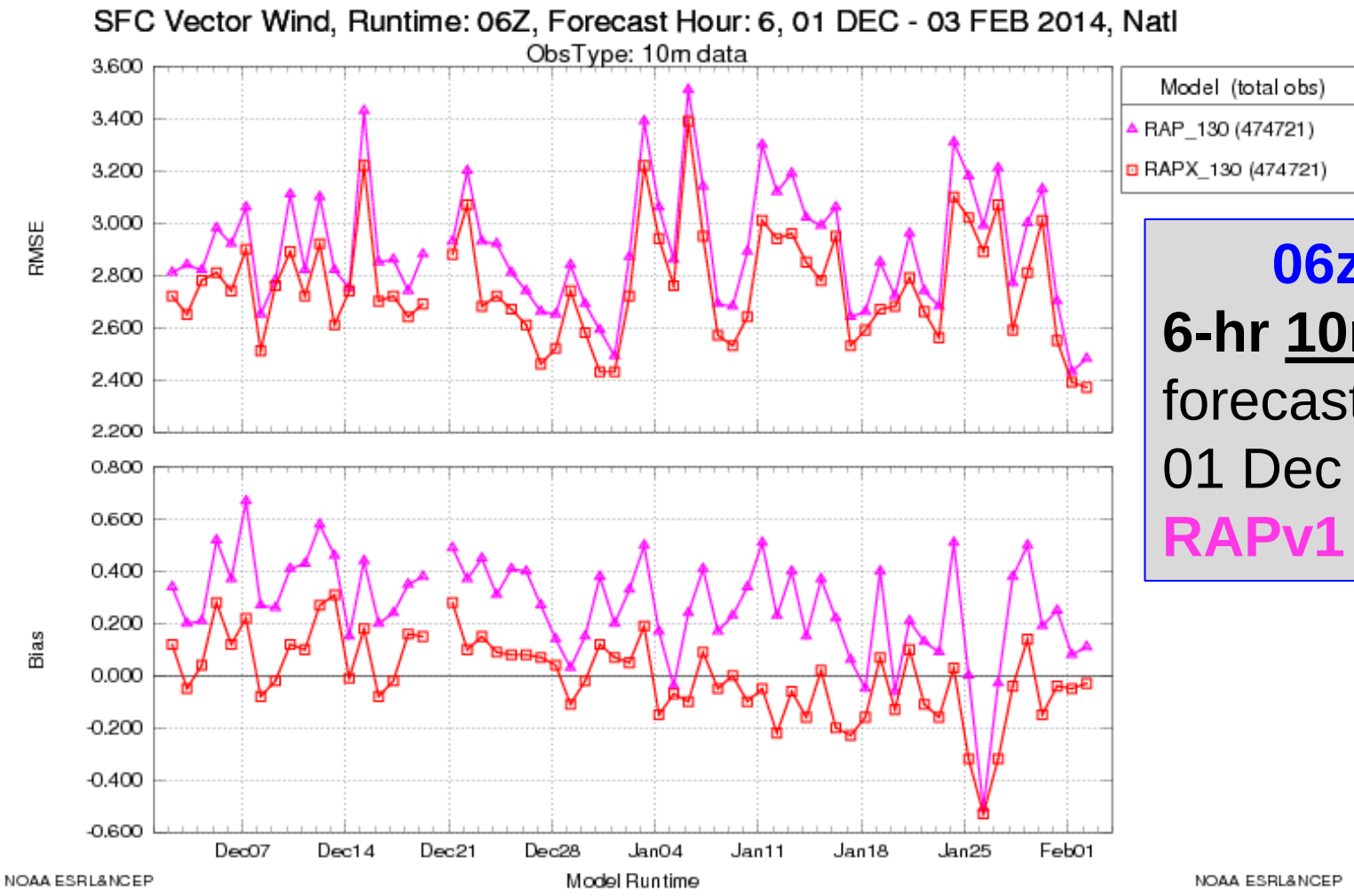
RAPv2 introduces a slight dry bias at night



All <u>10m Wind</u> forecasts
01 Dec – 03 Feb
RAPv1 vs. **RAPv2**

RAPv2 has a clear lower speed **bias (F-O)** than RAPv1

RAPv2 has slightly lower nighttime **RMS** 10m wind errors than RAPv1



06z Cycles

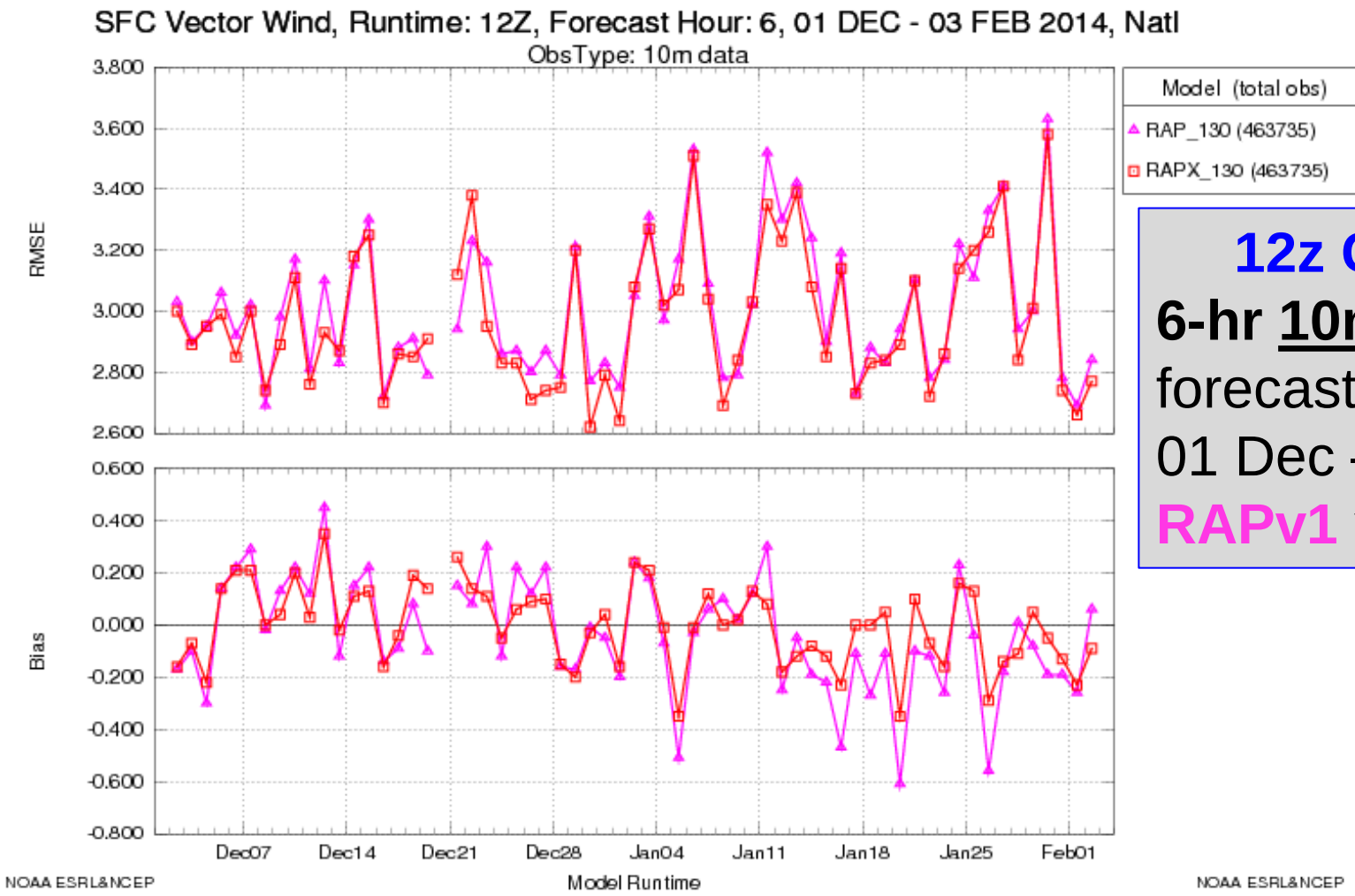
6-hr 10m Wind

forecasts Valid 12z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

RAPv2 nicely reduces a slight positive bias



12z Cycles

6-hr 10m Wind

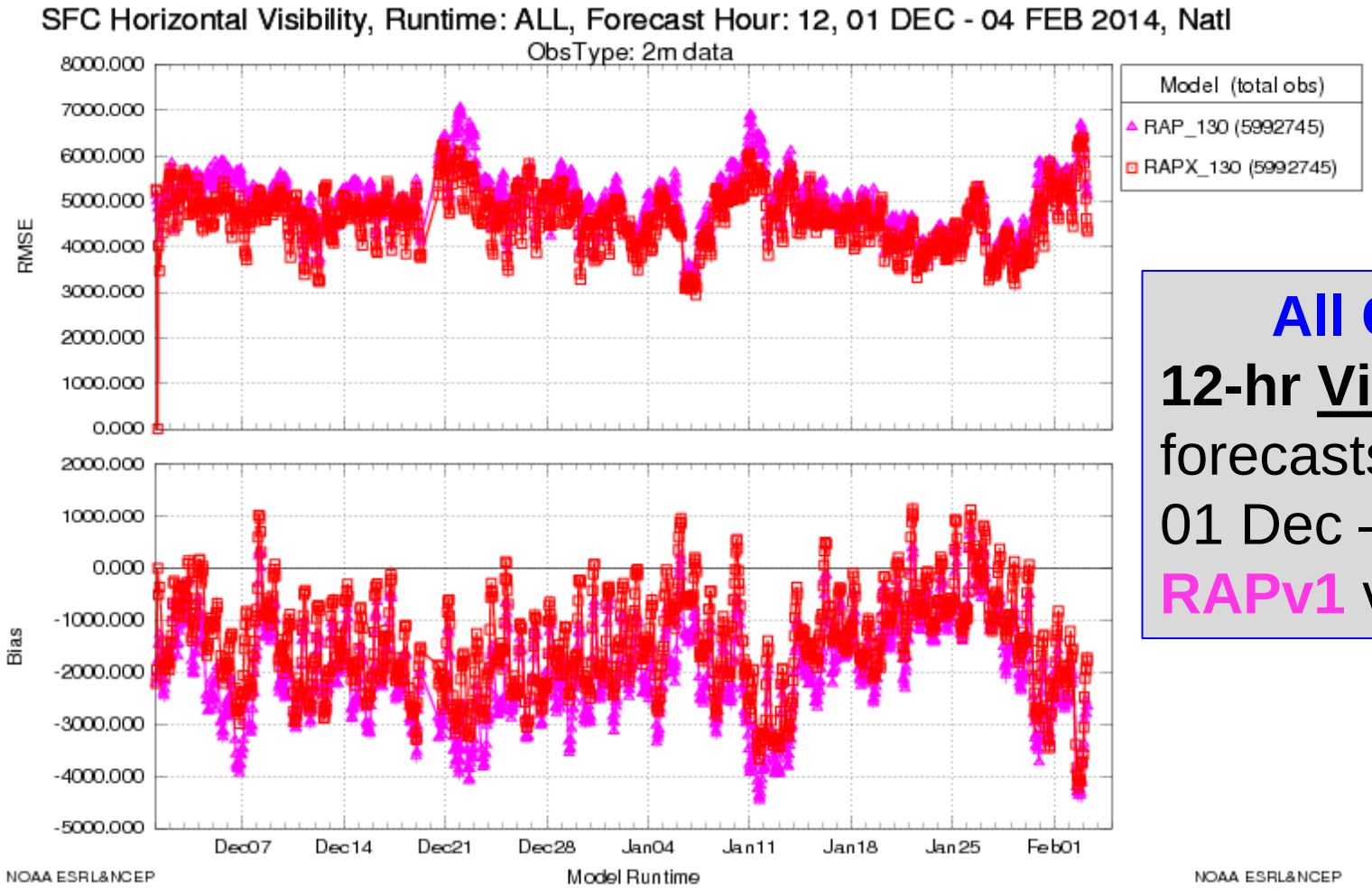
forecasts Valid 18z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

Minimal RAP V2 impact during afternoon

RAPv2 has improved RMS/Bias for visibility



All Cycles

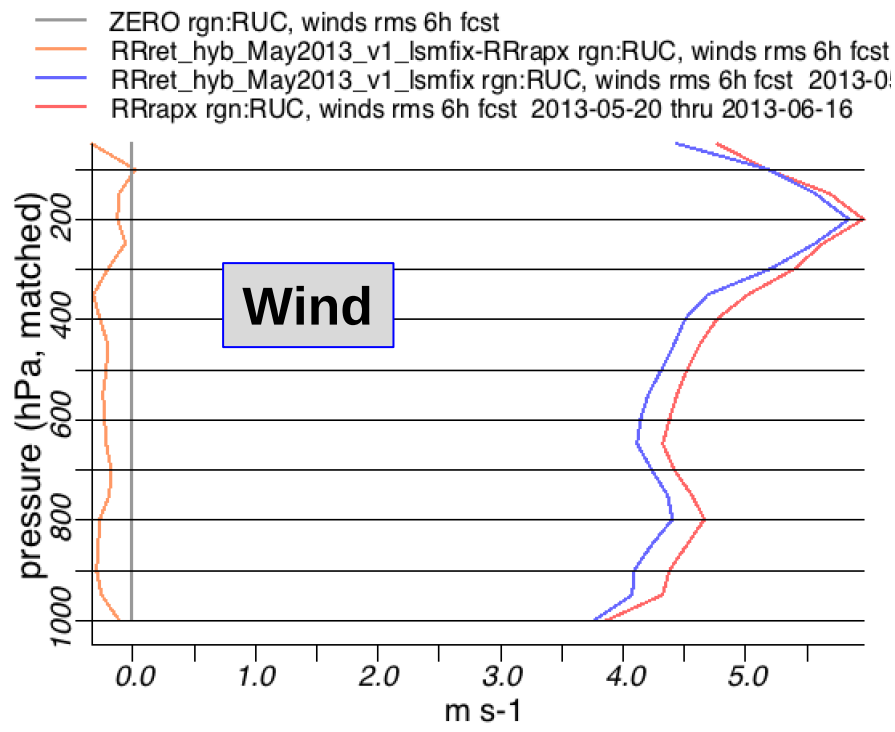
12-hr <u>Visibility</u>

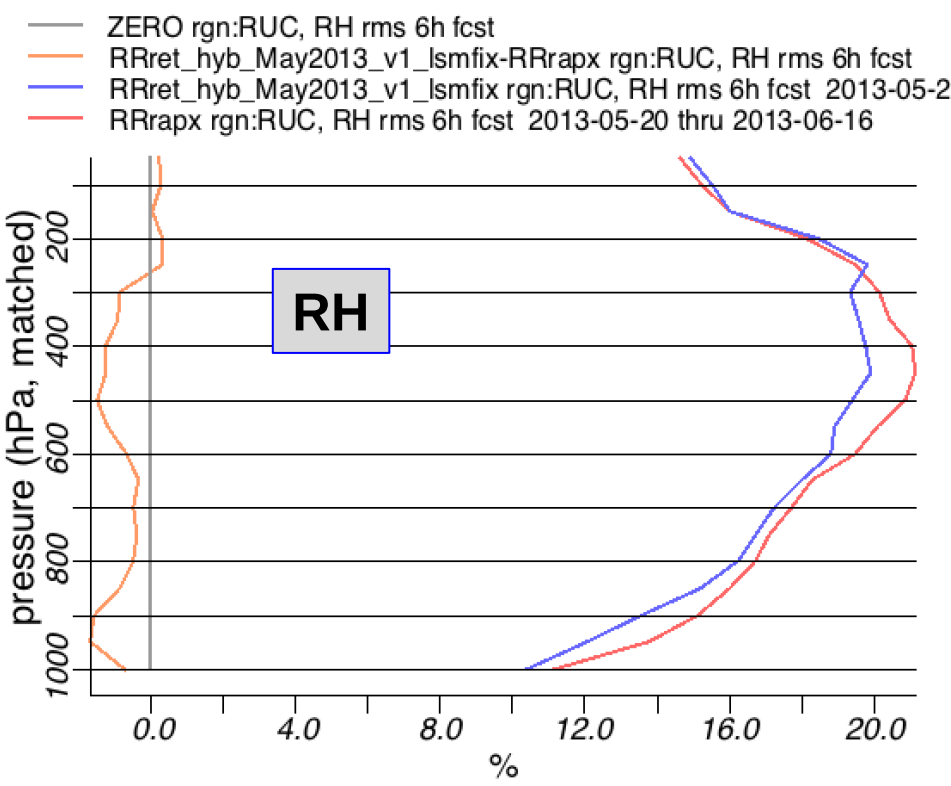
forecasts Valid 12z

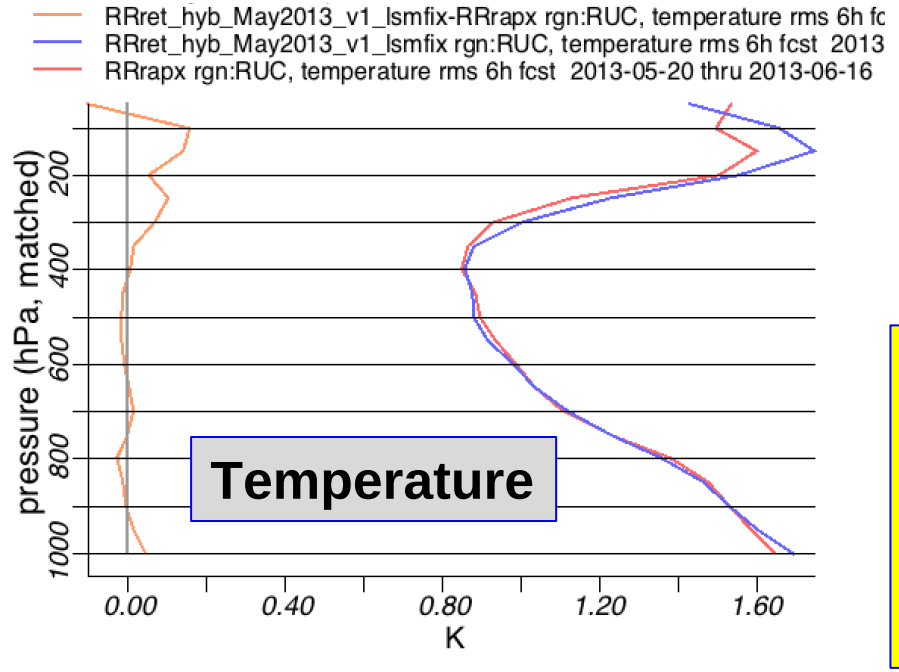
01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

Switch to summer retro period
15 May – 15 June 2013
RAPv2 vs. RAPv1 comparison







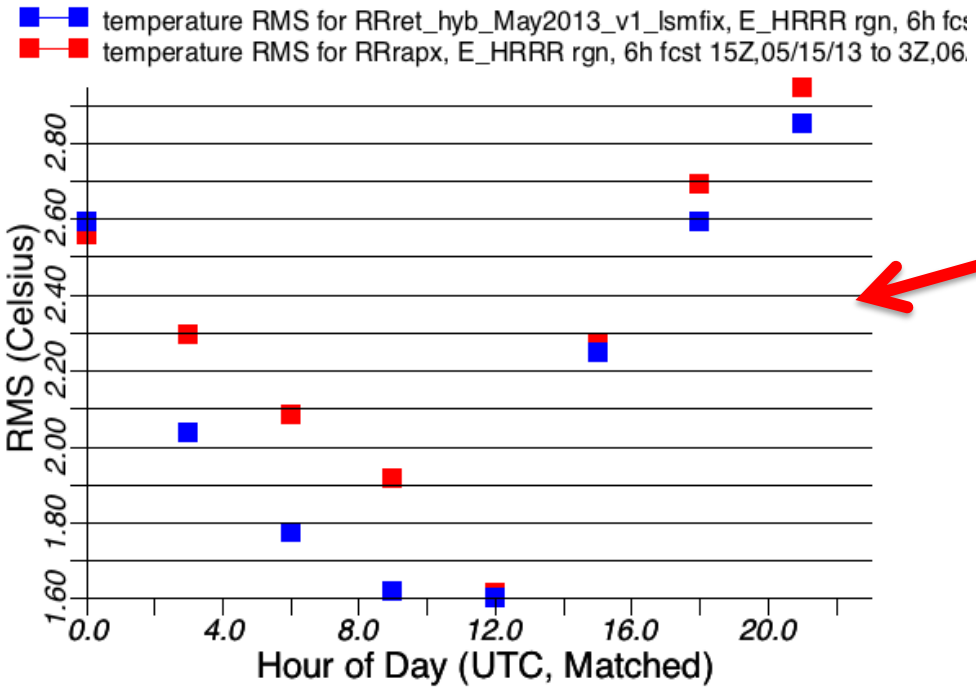
6h forecasts – upper-air
15 May - 15 June 2013
RAPv1 vs. **RAPv2**

Wind, RH

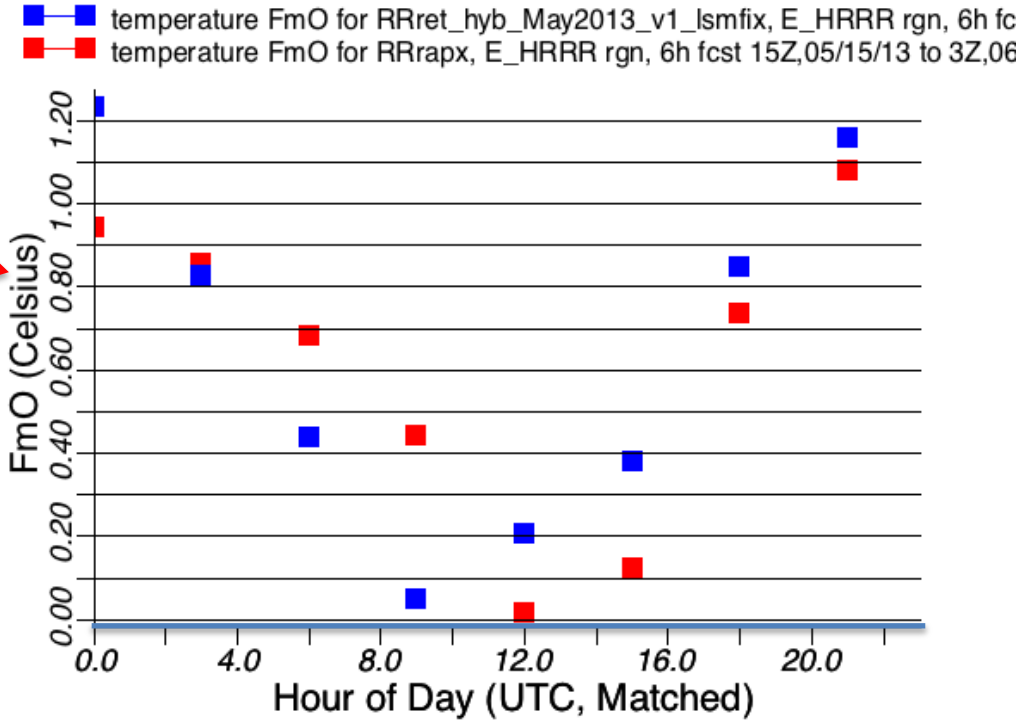
- Somewhat lower error with RAPv2

Temp

- Similar error, RAPv2 worse for 100-250 hPa

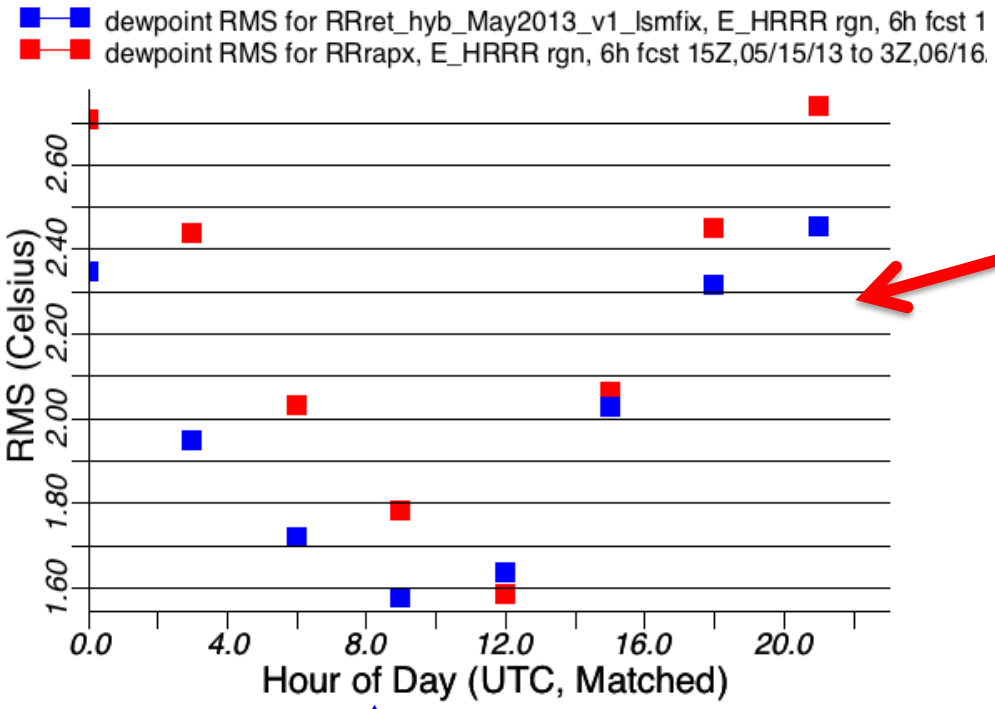


RAPv2 has lower **RMS** 2m temp errors than RAPv1 all times of day, esp. at night



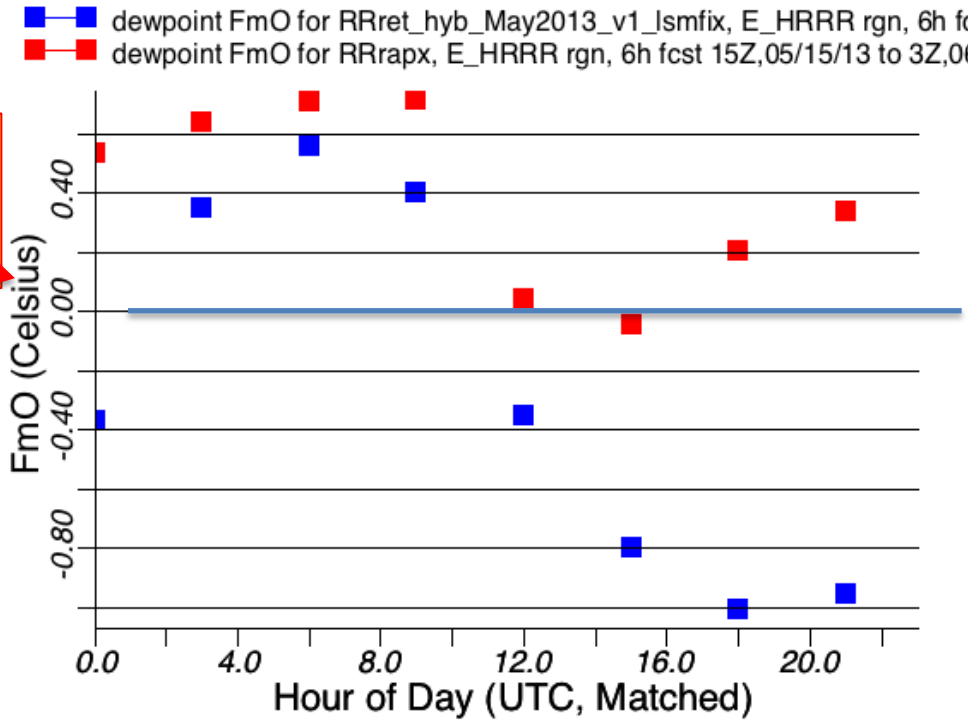
RAPv2 has less warm nighttime 2mT **bias (F-O)** than RAPv1, similar in day (but more at 00z)

6h <u>2m Temp</u> forecasts
Eastern/Central US
15 May – 15 June 2013
RAPv1 vs. **RAPv2**

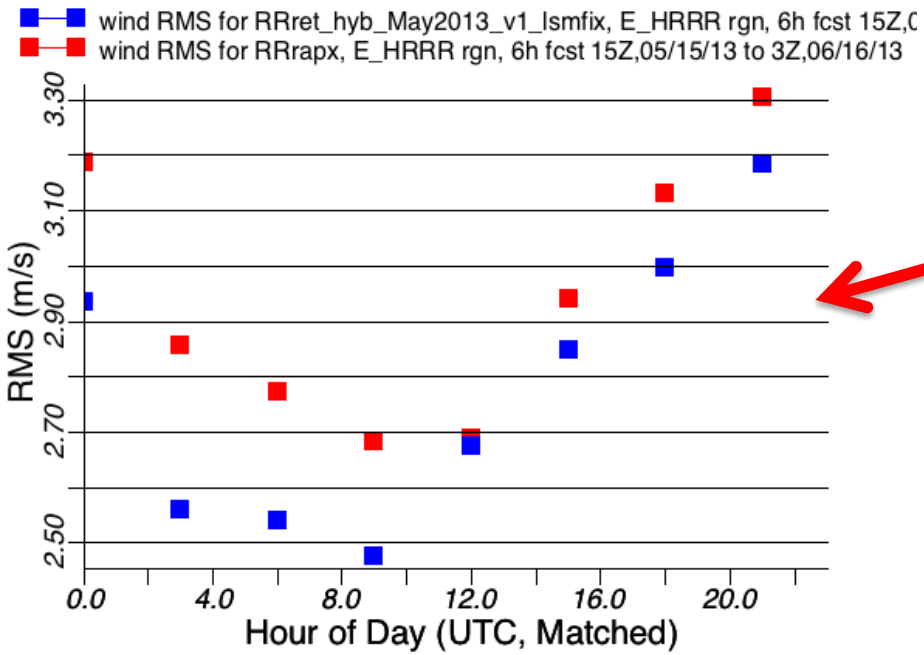


RAPv2 has lower **RMS** 2m dewpoint errors than RAPv1 all times of day

RAPv2 has drier 2m Td **bias (F-O)** than RAPv1. Better RMS Td in moist regions, less cancellation results in overall drier bias

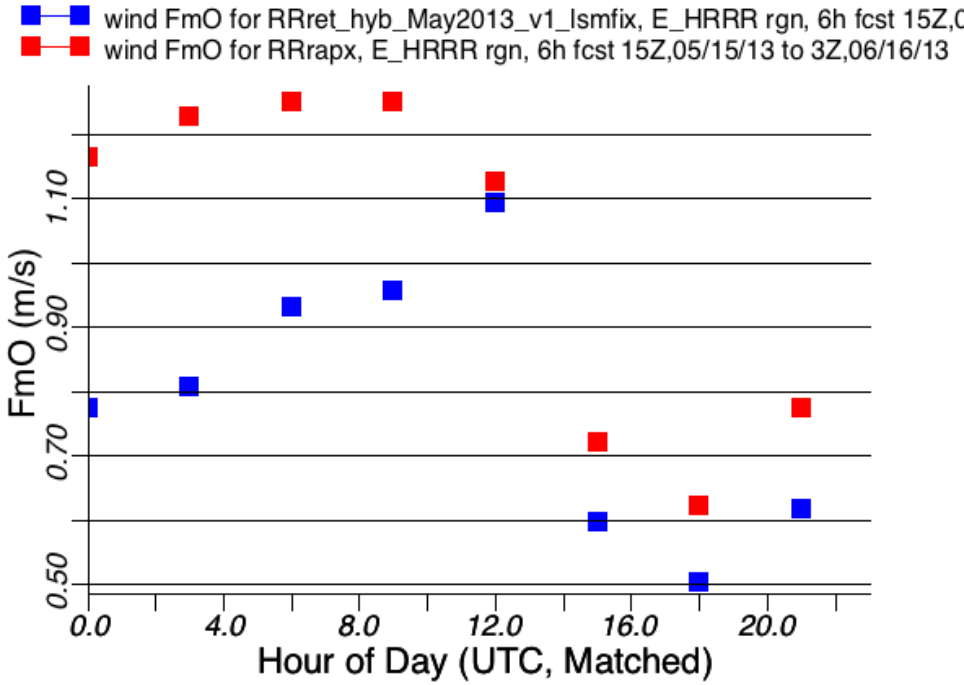


6h <u>2m Dewpoint</u> forecasts
Eastern/Central US
15 May – 15 June 2013
RAPv1 vs. **RAPv2**



RAPv2 has lower **RMS** 10m wind vector errors than RAPv1 all times of day

RAPv2 has less 10m wind speed **bias (F-O)** than RAPv1 at all times of day, especially at night.

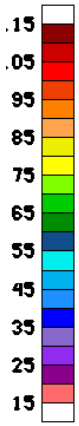


6h <u>10m wind</u> forecasts
Eastern/Central US
15 May – 15 June 2013
RAPv1 vs. **RAPv2**

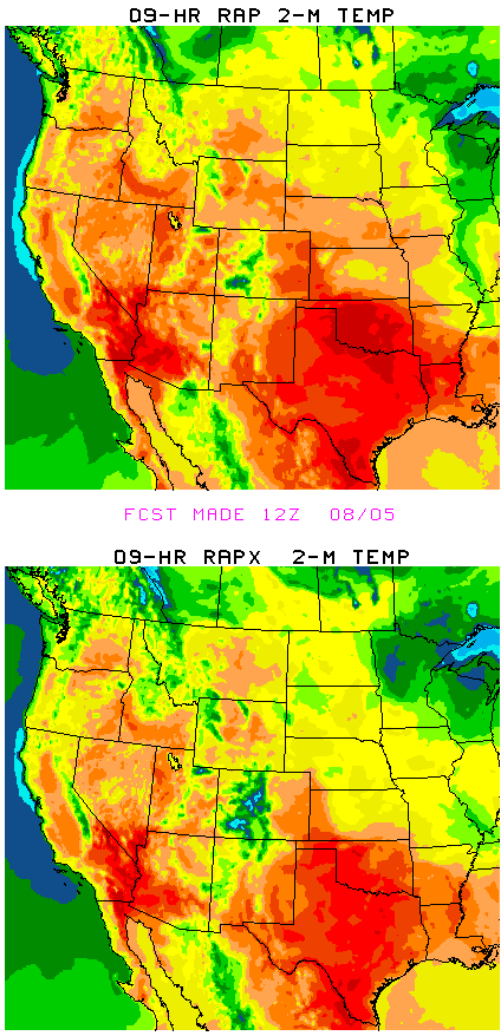
Case Examples

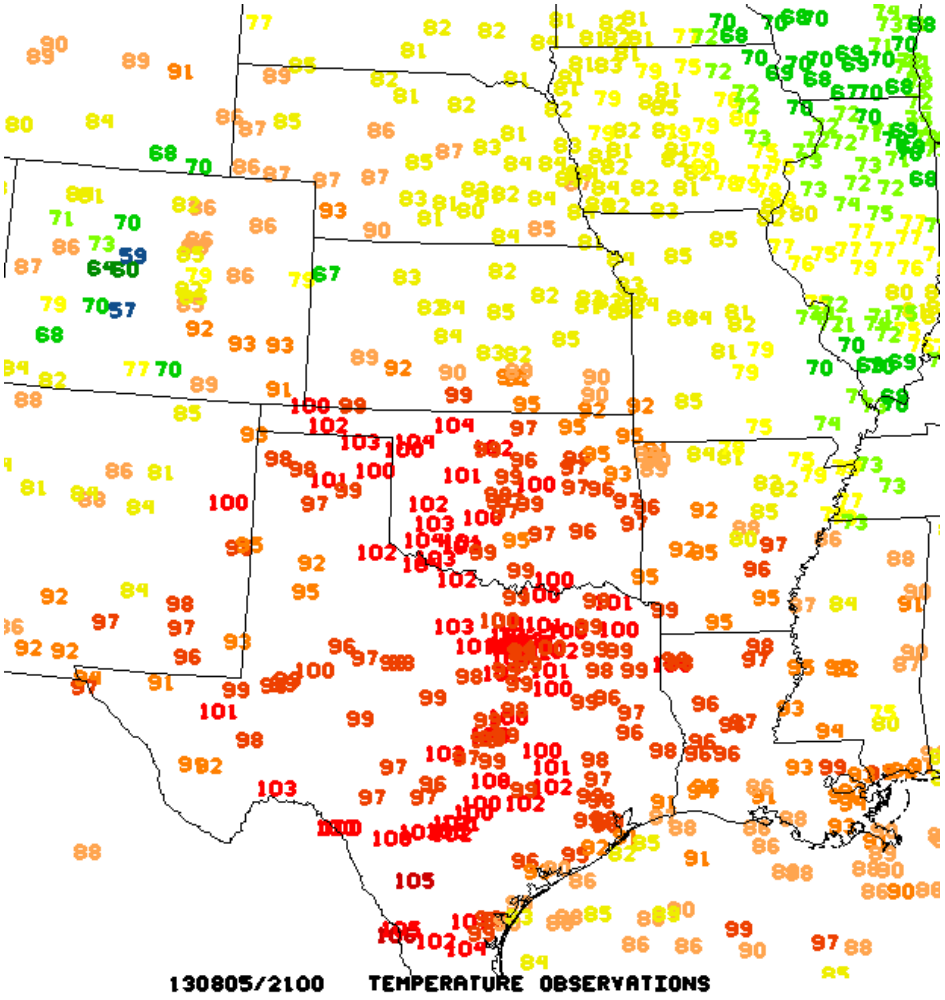
9-hr 2m Temp Forecasts 12z 5 August 2013

OPS



PARA

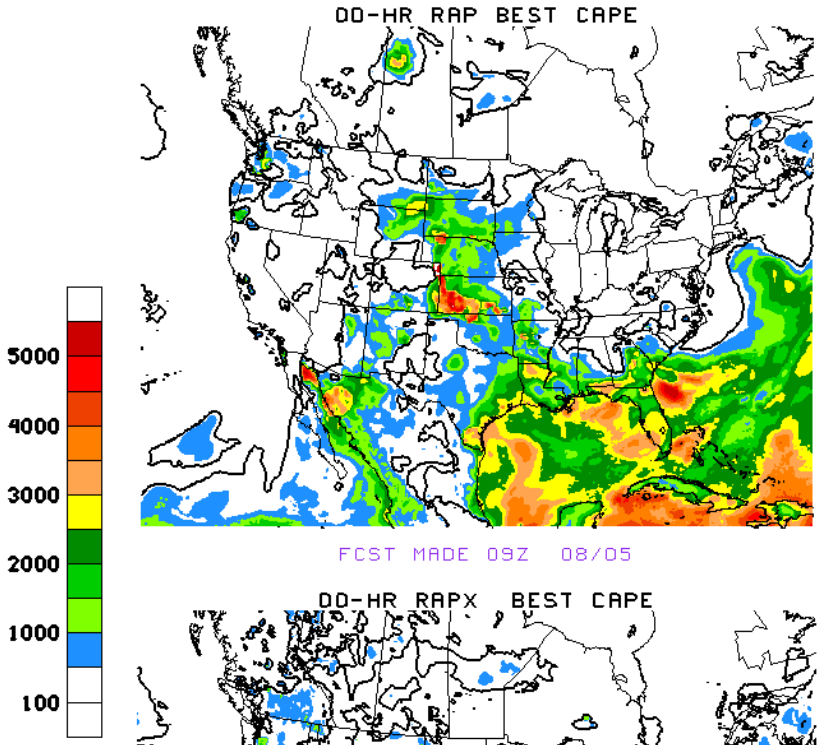




RAPv1 too warm across OK

00-hr Best CAPE Forecasts 9z 5 August 2013

OPS



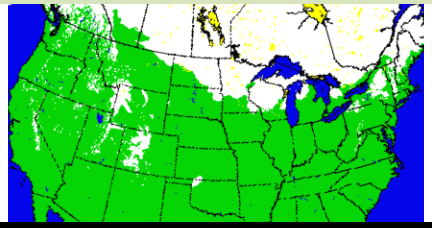
PARA

RAPv1 showing unlikely analysis cape values over midwest exceeding 5000 j/kg at 09z

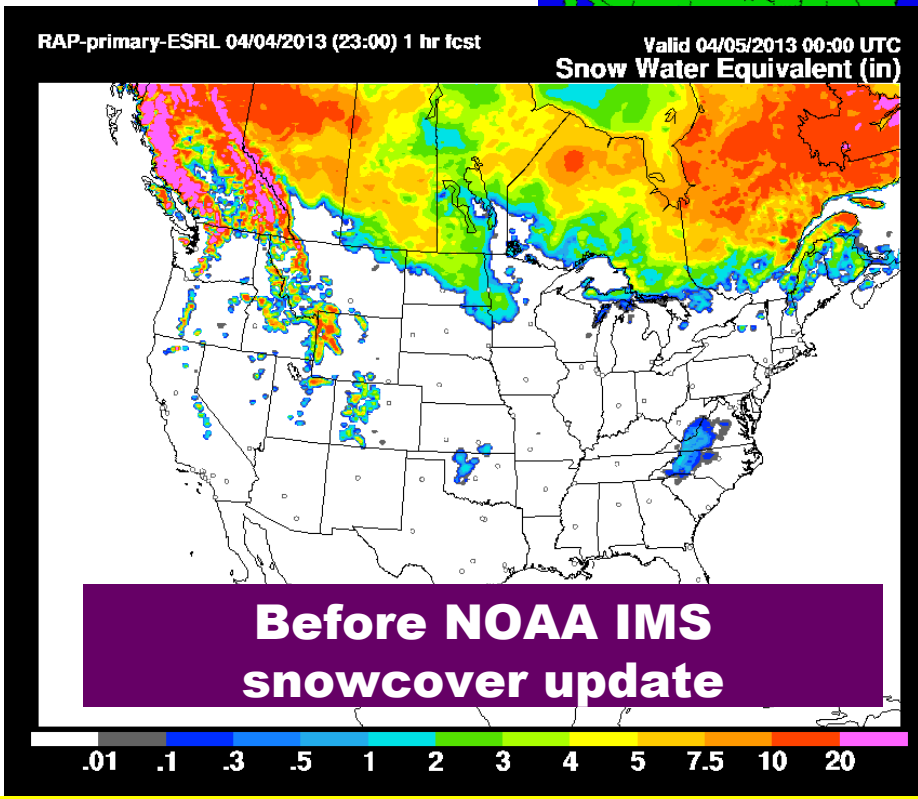
ESRL RAP 2013 Data Assimilation

Surface Snow Water Equivalent
Valid 00z 05 April 2013

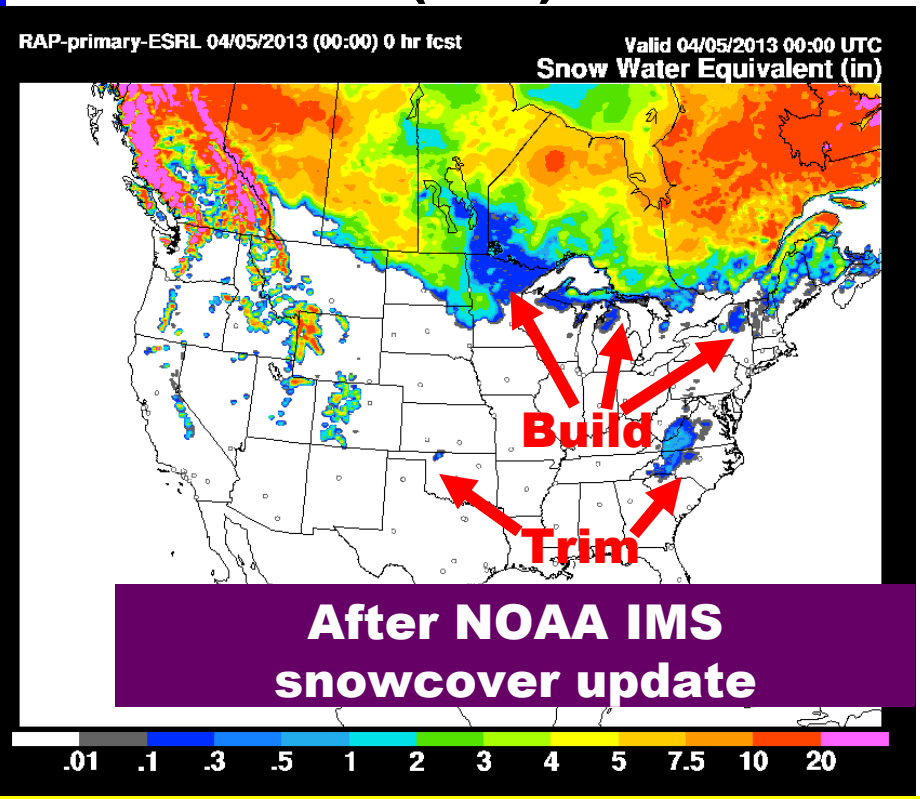
GSI Snow Cover Analysis (Run 00z Daily)



Using Interactive Multisensor Snow/Ice Mapping System (IMS)



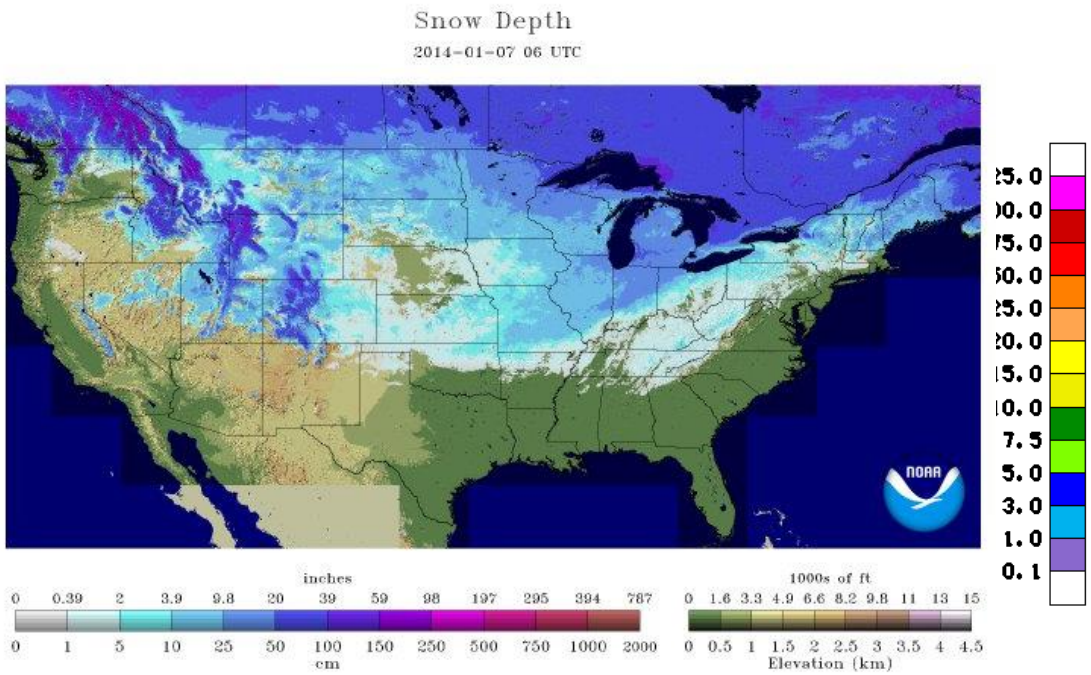
Before NOAA IMS snowcover update

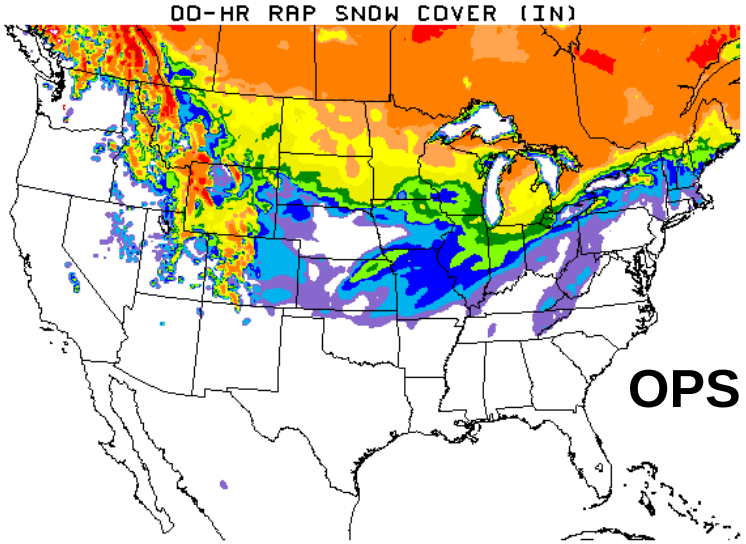


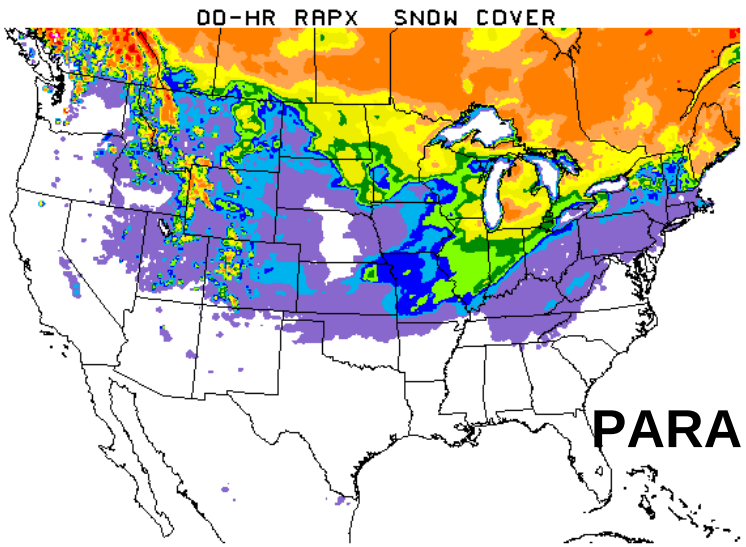
After NOAA IMS snowcover update

Improved snowcover

Snow Depth Analyses
00z 7 January 2014



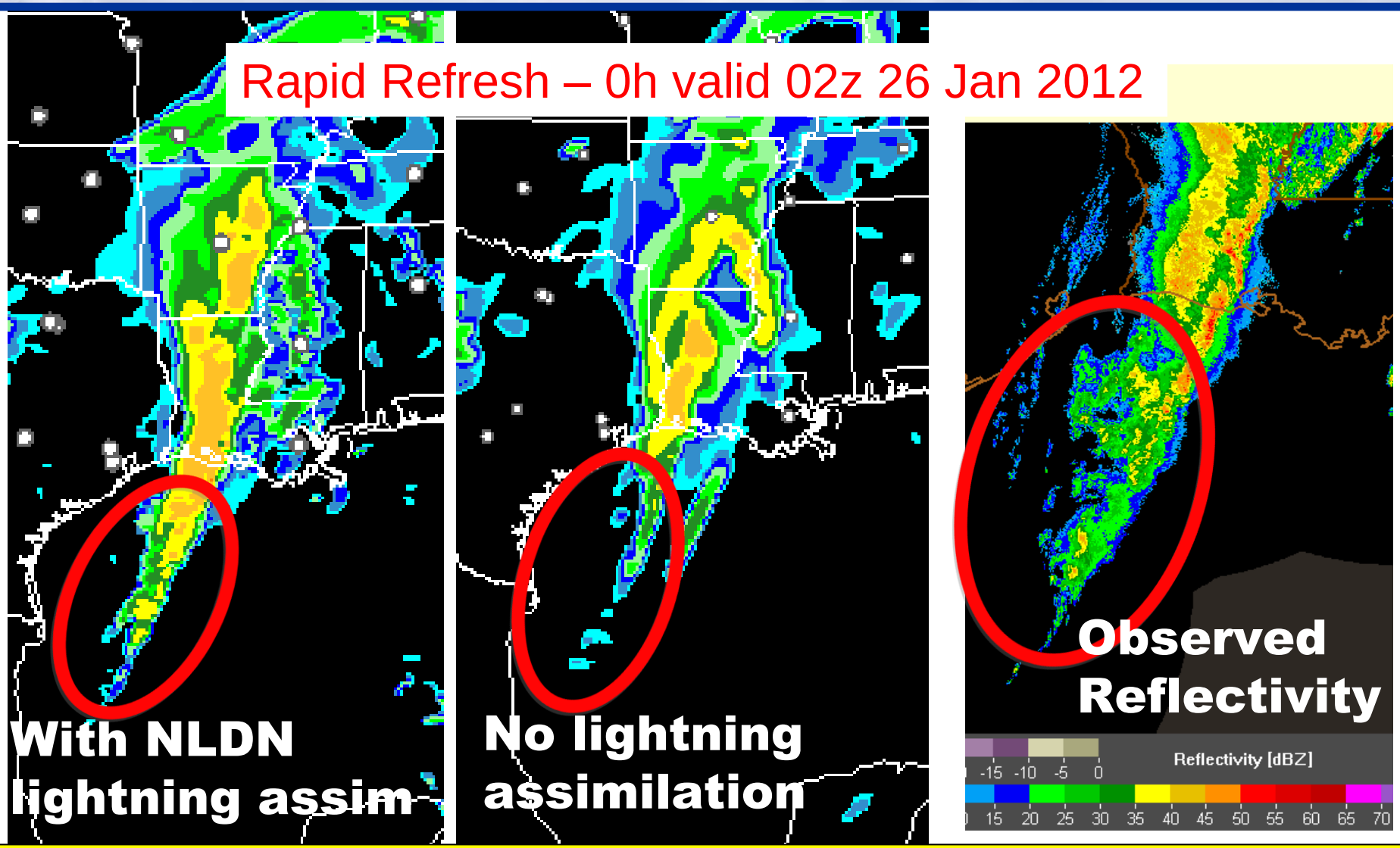




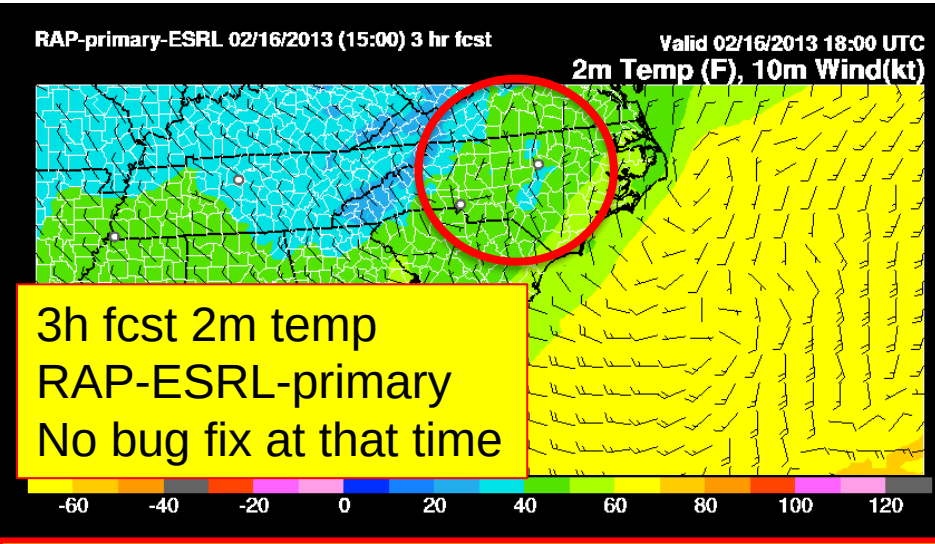
RAPv2 much better with snow depth initialization across KY/TN/OK/IL

RAP Lightning Assimilation

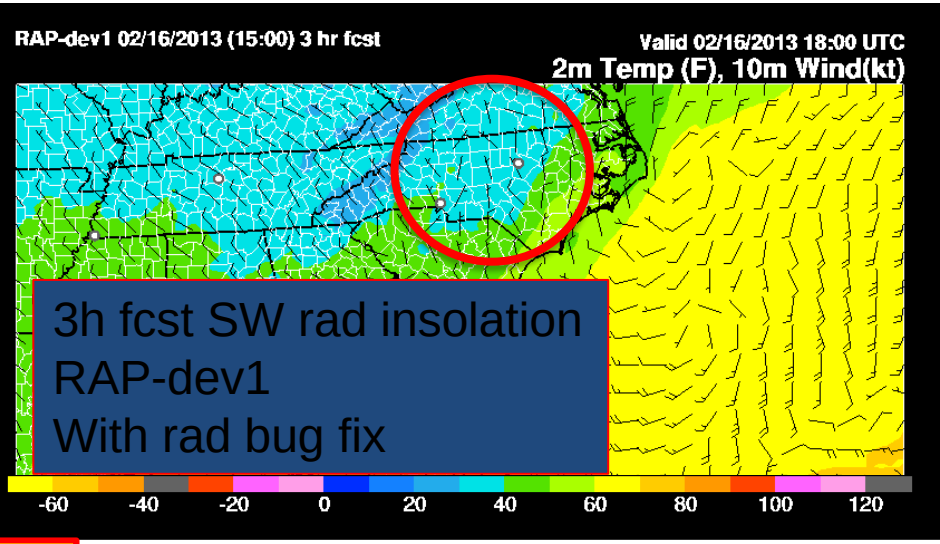
Rapid Refresh – 0h valid 02z 26 Jan 2012



Improved convective coverage off the coast with lightning assimilation



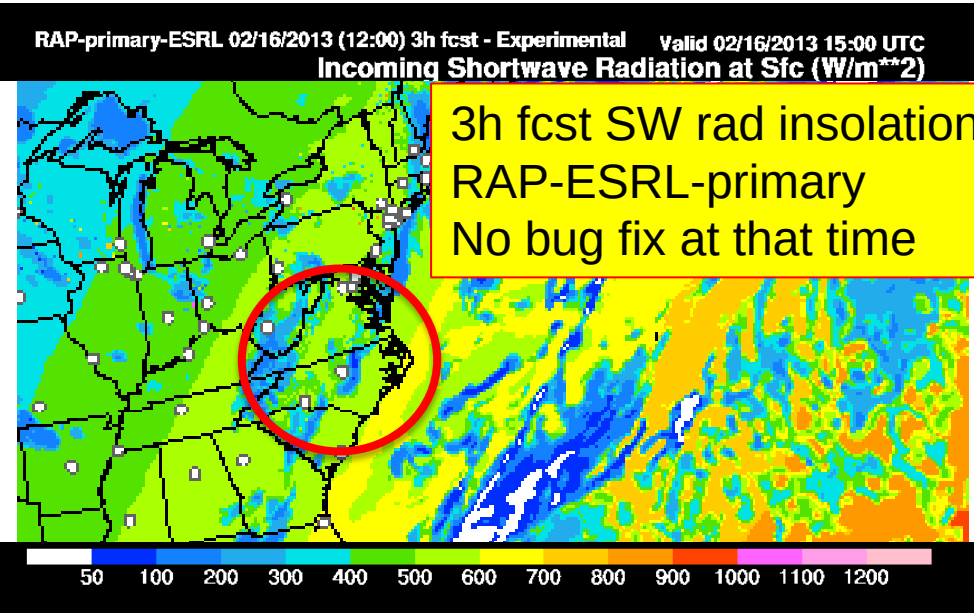
3h fcst 2m temp
RAP-ESRL-primary
No bug fix at that time



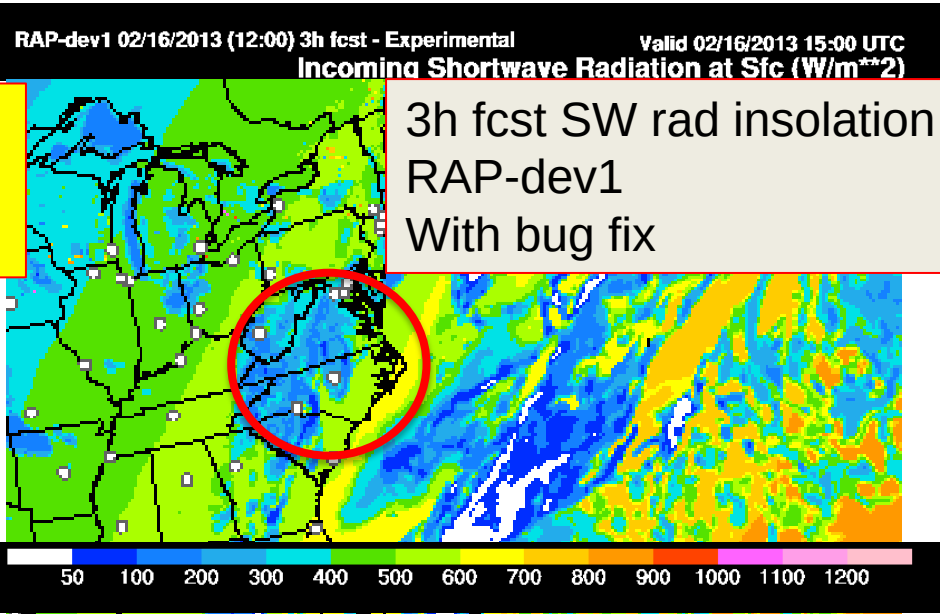
3h fcst SW rad insolation
RAP-dev1
With rad bug fix

RAP-NCEP 2m temp/ptype bust
Sat 16 February 2013
Courtesy - Jonathan Blaes – NWS Raleigh

Traced to WRF radiation bug – no attenuation for snow mixing ratio



3h fcst SW rad insolation
RAP-ESRL-primary
No bug fix at that time



3h fcst SW rad insolation
RAP-dev1
With bug fix

Similar situation in recent Atlanta snow event 1/28/14

06z RAP

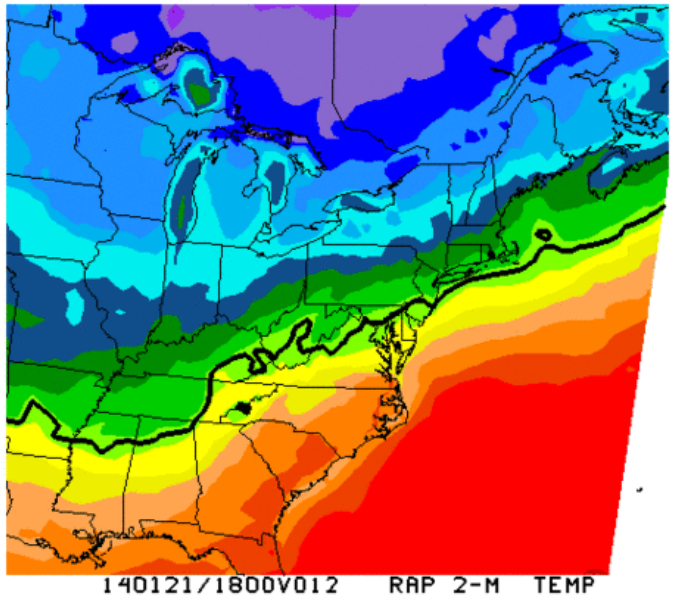
STN	YYMMDD/HHMM	2-m T T2MS	1-hr pcp P01I
722190	140128/1200	-1.90	0.00
722190	140128/1300	-1.30	0.00
722190	140128/1400	0.60	0.00
722190	140128/1500	3.10	0.00
722190	140128/1600	3.80	0.00
722190	140128/1700	2.40	0.01
722190	140128/1800	**2.40**	0.03
722190	140128/1900	**3.40**	0.07
722190	140128/2000	**3.90**	0.06
722190	140128/2100	**4.00**	0.04
722190	140128/2200	**2.60**	0.03
722190	140128/2300	0.20	0.04
722190	140129/0000	-0.90	0.02

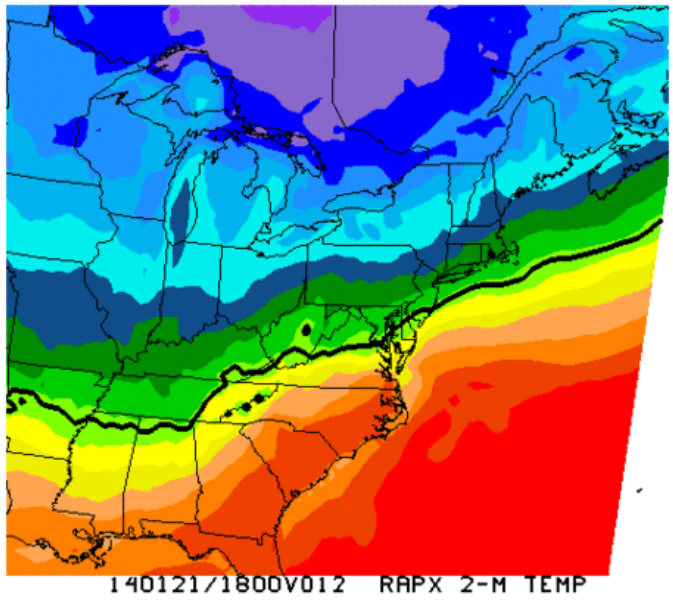
06z RAPX

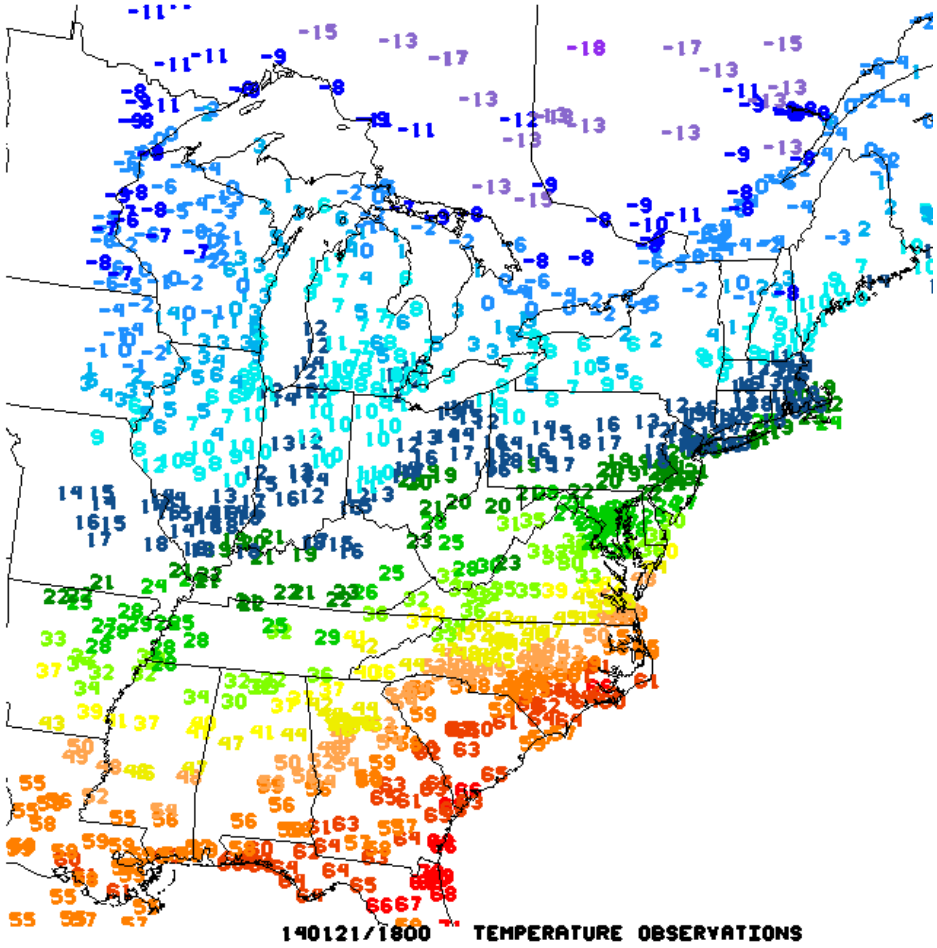
STN	YYMMDD/HHMM	2-m T T2MS	1-hr pcp P01I
722190	140128/1200	-2.70	0.00
722190	140128/1300	-2.10	0.00
722190	140128/1400	-0.20	0.00
722190	140128/1500	1.10	0.00
722190	140128/1600	1.70	0.00
722190	140128/1700	2.00	0.00
722190	140128/1800	1.10	0.00
722190	140128/1900	-1.60	0.02
722190	140128/2000	-2.00	0.05
722190	140128/2100	-1.90	0.04
722190	140128/2200	-1.30	0.04
722190	140128/2300	-1.60	0.01
722190	140129/0000	-2.40	0.01

Ops RAP showing temperatures well above freezing during snow; colder in RAPX

21 January 2014 DC area snowstorm







RAPv1 too slow to bring colder air into DCA/PHL/NYC/BOS; v2 shows improvement

28 January 2014 Birmingham, AL snow

06z RAP

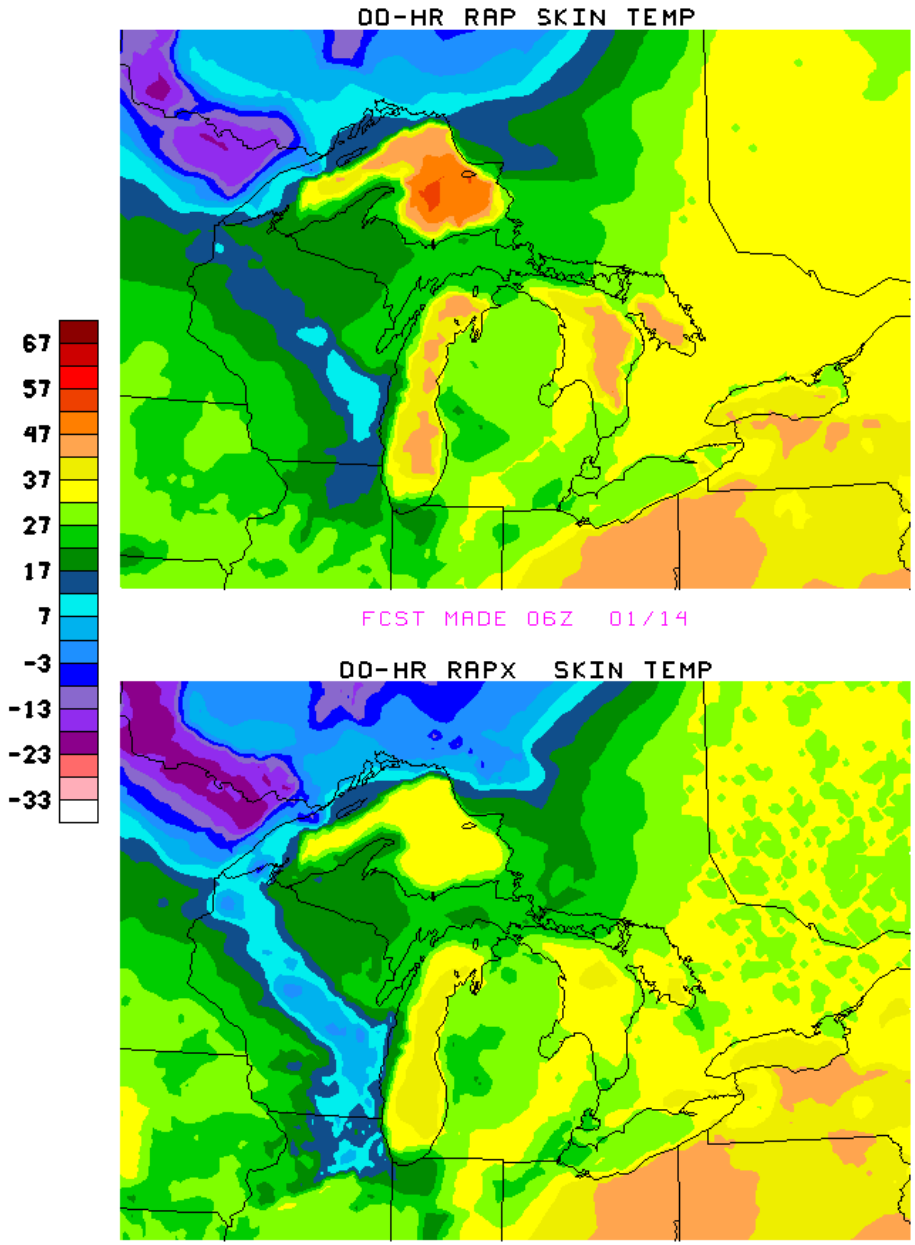
STN	YYMMDD/HHMM	2-m T T2MS	1-hr pcp P01I
722280	140128/1200	-4.80	0.00
722280	140128/1300	-4.80	0.00
722280	140128/1400	-3.90	0.00
722280	140128/1500	-3.30	0.00
722280	140128/1600	-3.70	0.03
722280	140128/1700	**-2.50**	0.05
722280	140128/1800	**-2.00**	0.06
722280	140128/1900	-2.10	0.04
722280	140128/2000	-2.10	0.03
722280	140128/2100	-2.30	0.02
722280	140128/2200	-3.60	0.00
722280	140128/2300	-4.20	0.00

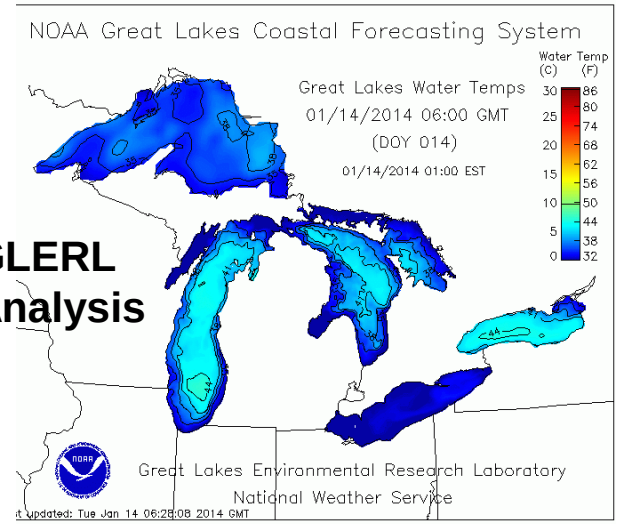
06z RAPX

STN	YYMMDD/HHMM	2-m T T2MS	1-hr pcp P03I
722280	140128/1200	-5.70	0.00
722280	140128/1300	-5.60	0.00
722280	140128/1400	-5.50	0.00
722280	140128/1500	-5.10	0.00
722280	140128/1600	-5.70	0.00
722280	140128/1700	**-6.80**	0.02
722280	140128/1800	**-6.40**	0.04
722280	140128/1900	-4.50	0.04
722280	140128/2000	-3.30	0.01
722280	140128/2100	-3.30	0.00
722280	140128/2200	-2.70	0.00
722280	140128/2300	-3.20	0.00

RAPv1 too warm with sfc temperatures which were in the -7C range during the snow

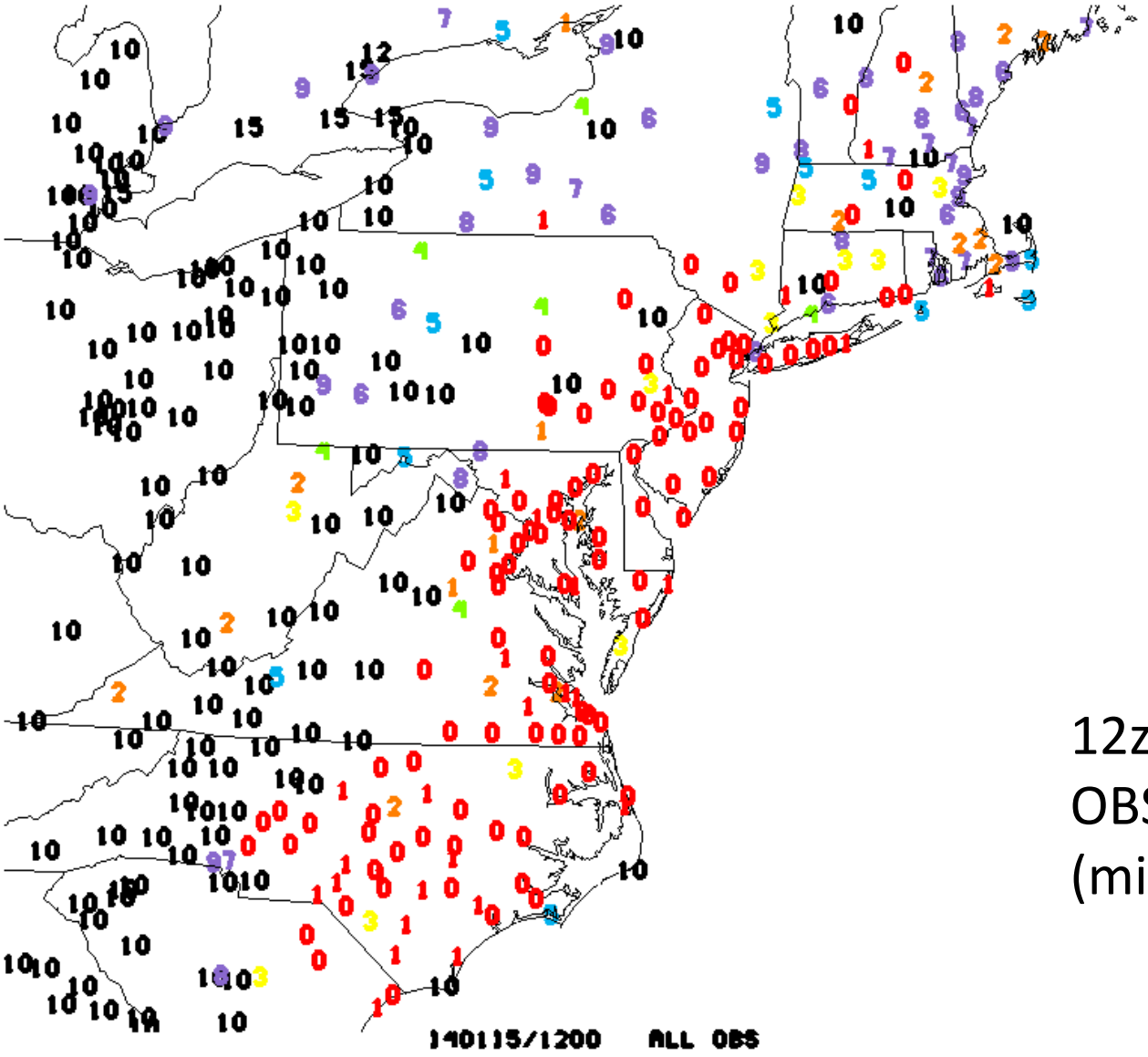
06z 14 January 2014 Skin Temps (SST)





Para RAP has moved to alternate handling of Great Lake temps; major improvement shown

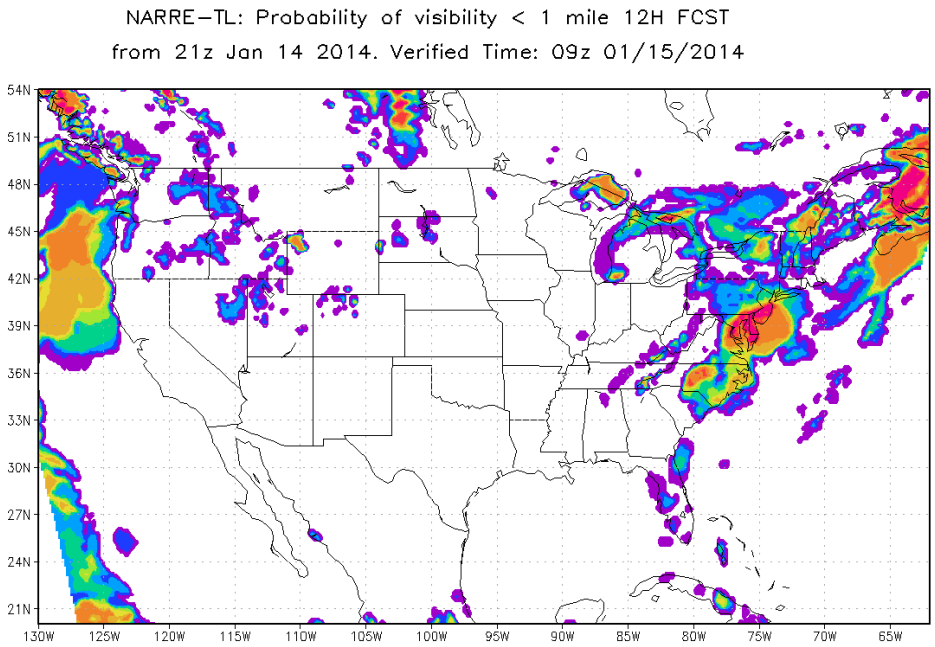
DENSE FOG 1/15/14



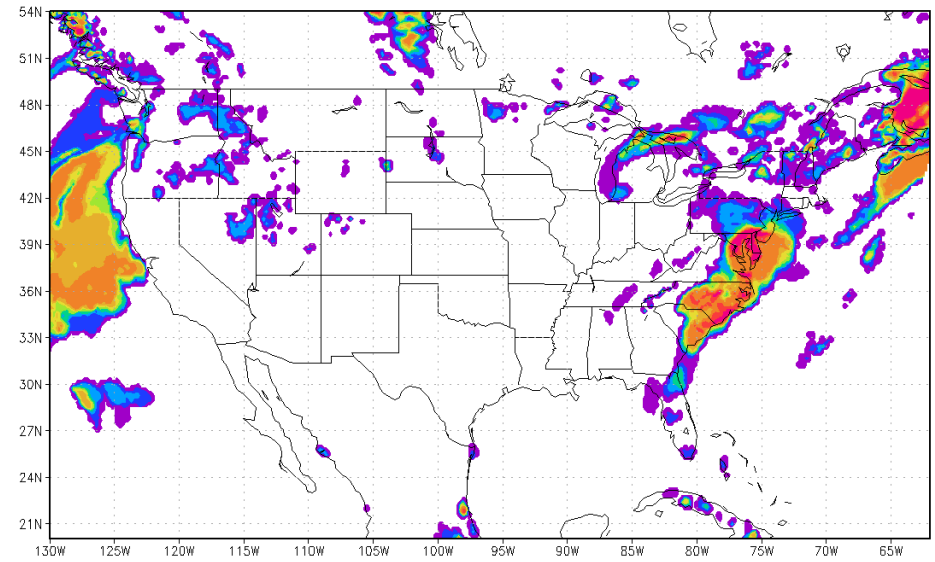
12z
OBS VIS
(miles)

21z 1/14 12-hr Fcst of Prob of Vis < 1 mile

21z NARRE-TL

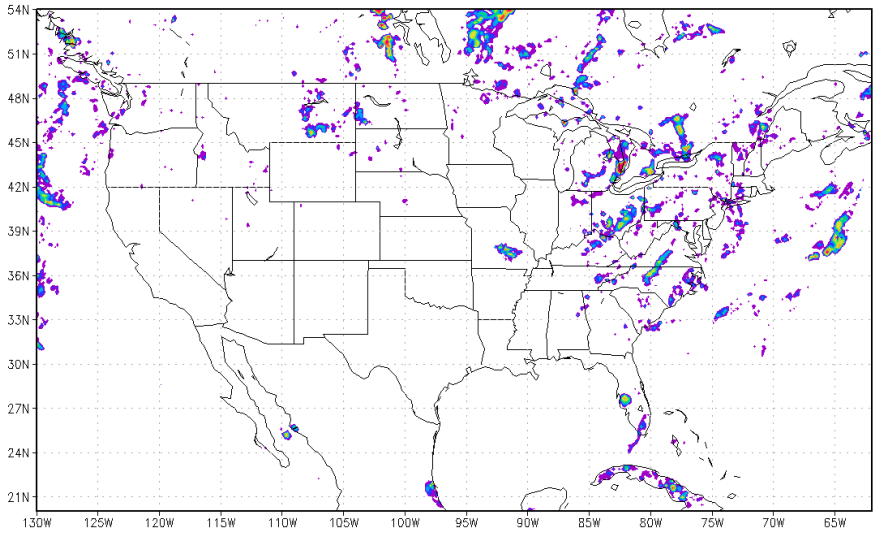


PARA 21z NARRE-TL
w RAPV2

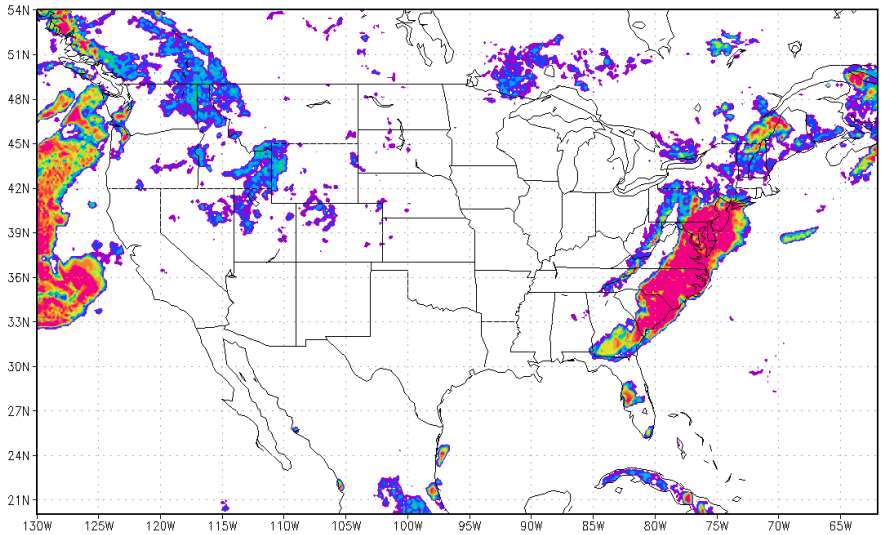


Probability of Fog

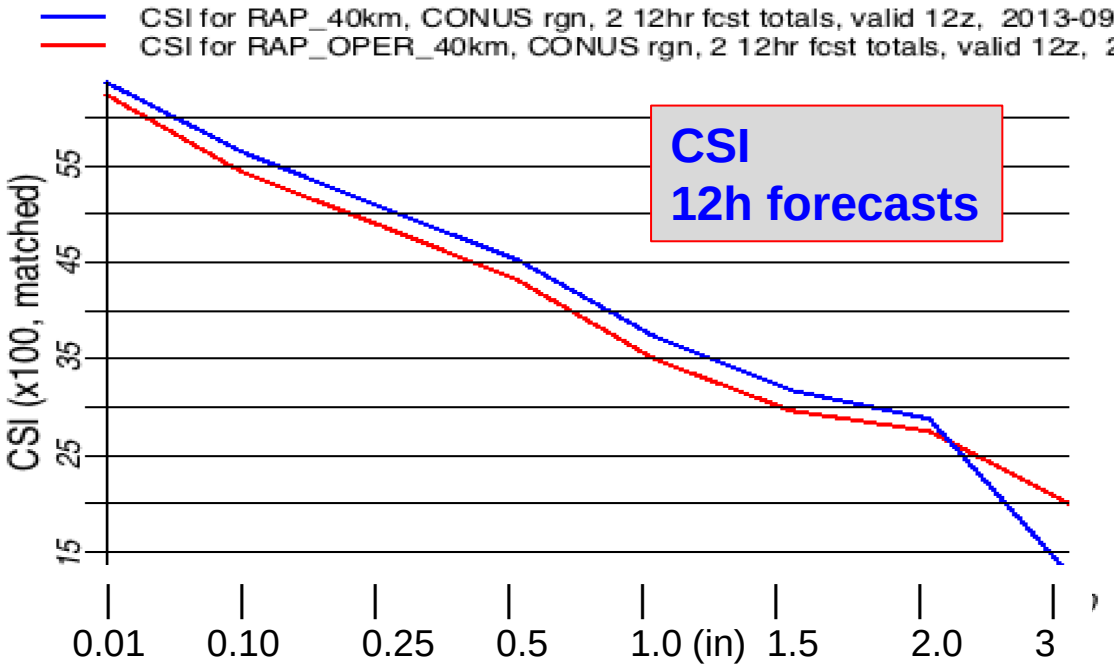
6z NARRE-TL



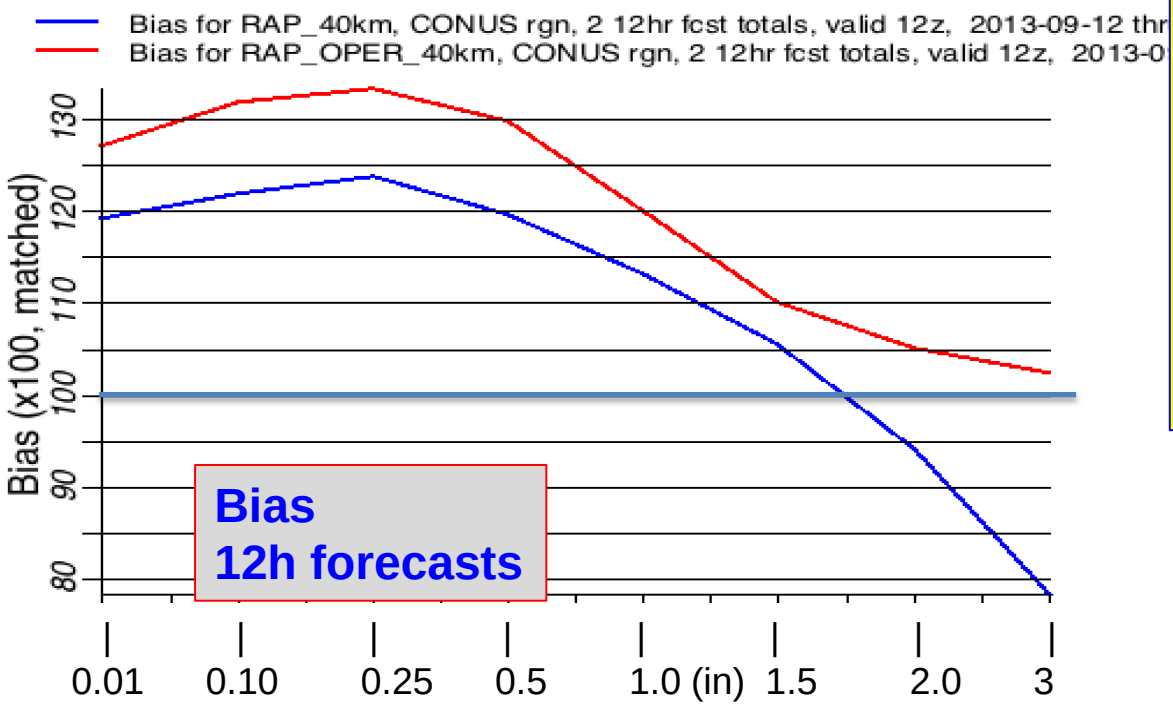
6z NARRE-TL w RAPV2



Extra Slides



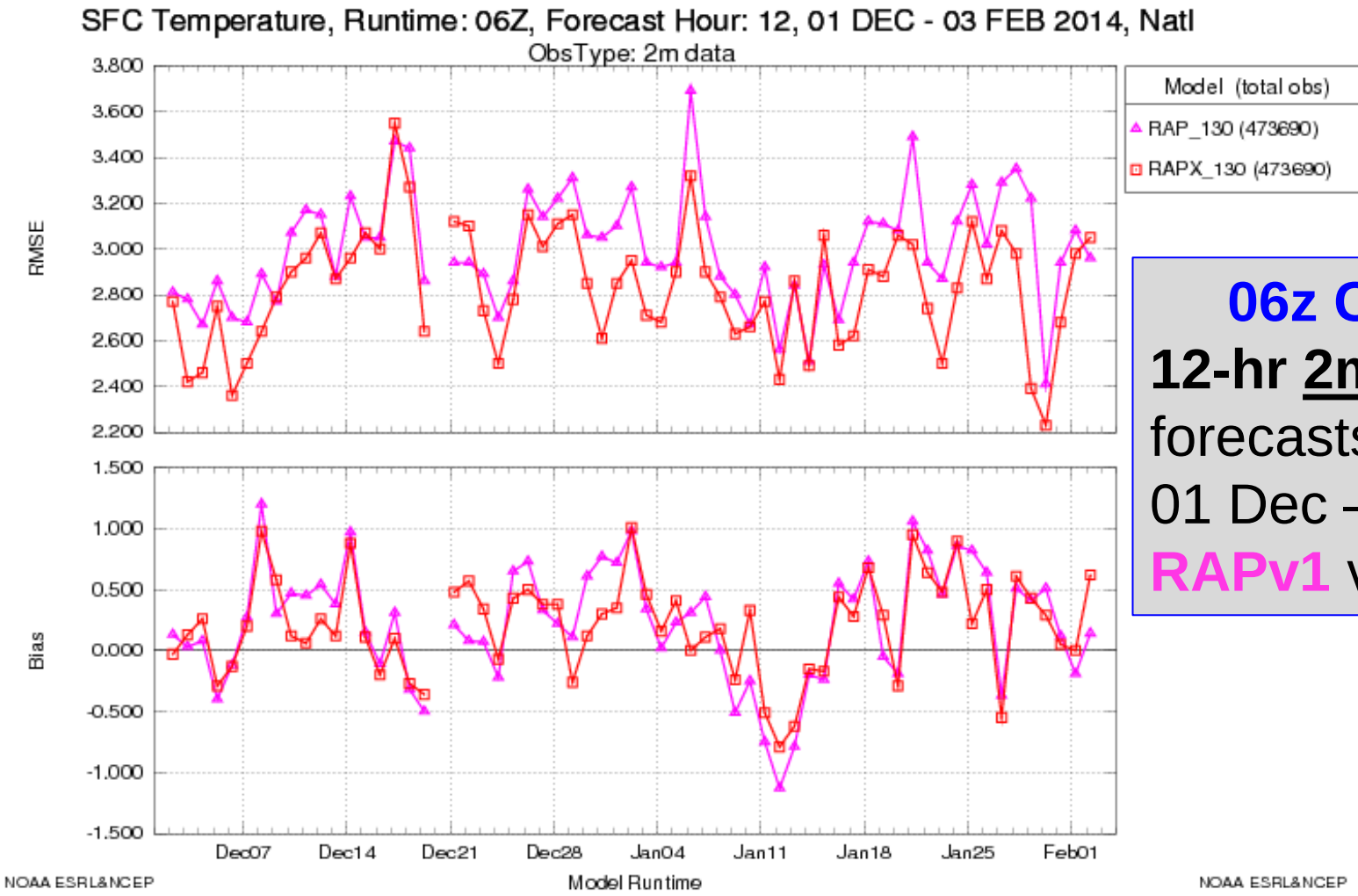
Precip – CONUS
13 Oct–14 Dec 2013
RAPv1 vs. **RAPv2**



Precipitation forecasts –

- RAPv2 better CSI than RAPv1
- RAPv2 lower (better) bias for 0.01 through 1.5” (less bias for light to moderate precipitation)

RAPv2 has lower **RMS** 2m temp errors than RAPv1



06z Cycles

12-hr 2m Temp

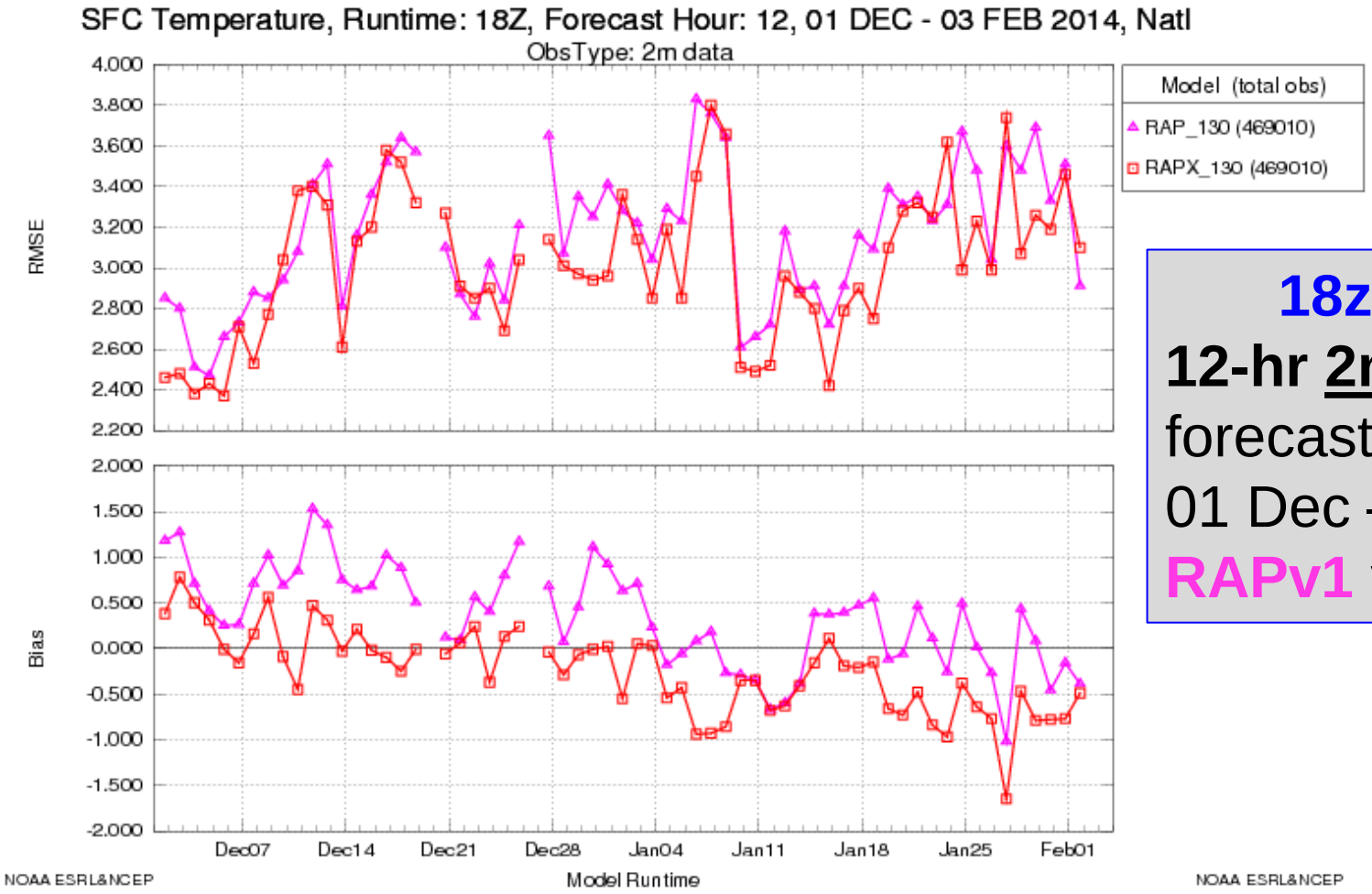
forecasts Valid 18z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

RAPv2 has lower warm 2mT **bias (F-O)** than RAPv1

RAPv2 has lower **RMS** 2m temp errors than RAPv1



18z Cycles

12-hr <u>2m Temp</u>

forecasts Valid 06z

01 Dec – 03 Feb

RAPv1 vs. **RAPv2**

RAPv2 has lower warm daytime 2mT **bias (F-O)** than RAPv1