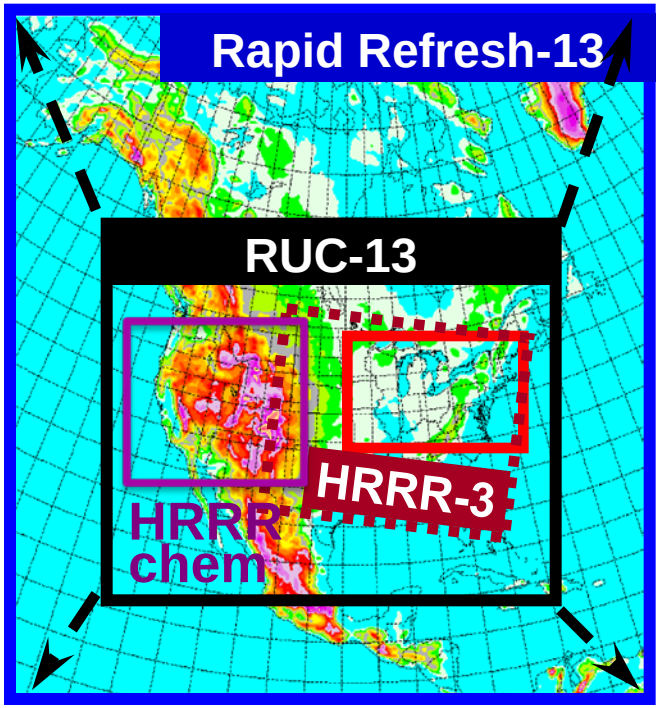
Initial Rapid Refresh assessment and case study analysis (and some details on the High Resolution Rapid Refresh -- HRRR)

Steve Weygandt - NOAA Earth System Research Lab
Stan Benjamin

Other key colleagues at ESRL

Joe Olson	Ming Hu
Tanya Smirnova	Dezso Devenyi
John M. Brown	Georg Grell
Bill Moninger	Kevin Brundage
Brian Jamison	Susan Sahm
Curtis Alexander	Barry Schwartz



Thurs 12 March 2009

http://ruc.noaa.gov
http://rapidrefresh.noaa.gov

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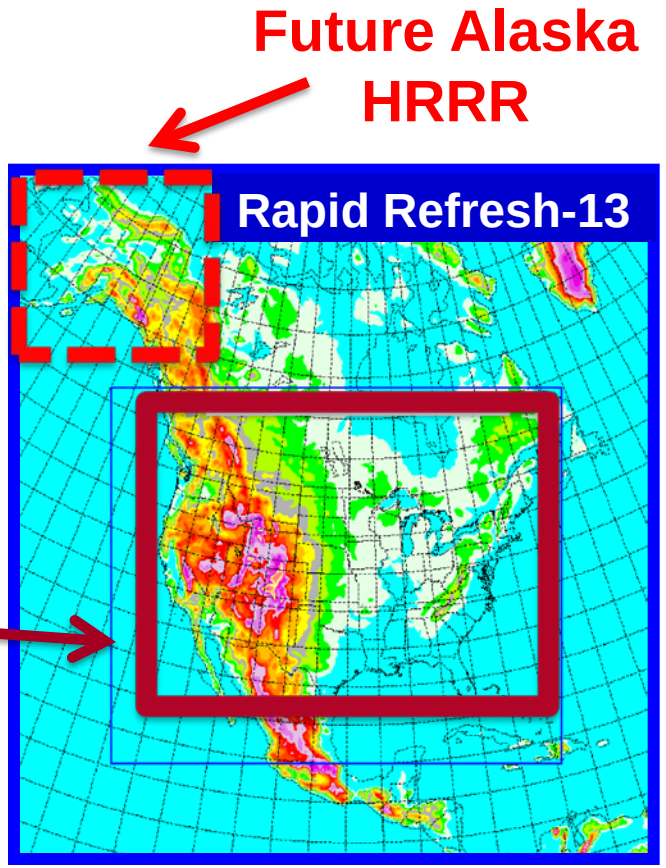

Outline

Rapid Refresh challenges

- Consistent hourly updated grids for all of North America
- Match/exceed RUC skill over CONUS, other model skill elsewhere (upper-level winds, surface fields, clouds, storms)

Rapid Refresh data assimilation features

- Switch from RUC 3DVAR to Gridpoint Statistical Interpolation (GSI)
- Special observation treatments (surface, clouds, radar, lightning)

Preliminary RUC / Rapid Refresh comparison

- Upper level statistics and sounding structures
- Surface field statistics and case study examples
- Precipitation statistics and case study examples

Details on High Resolution Rapid Refresh

- Summer 2008 convective forecasts
- Real-time Western U.S. HRRR-chem runs

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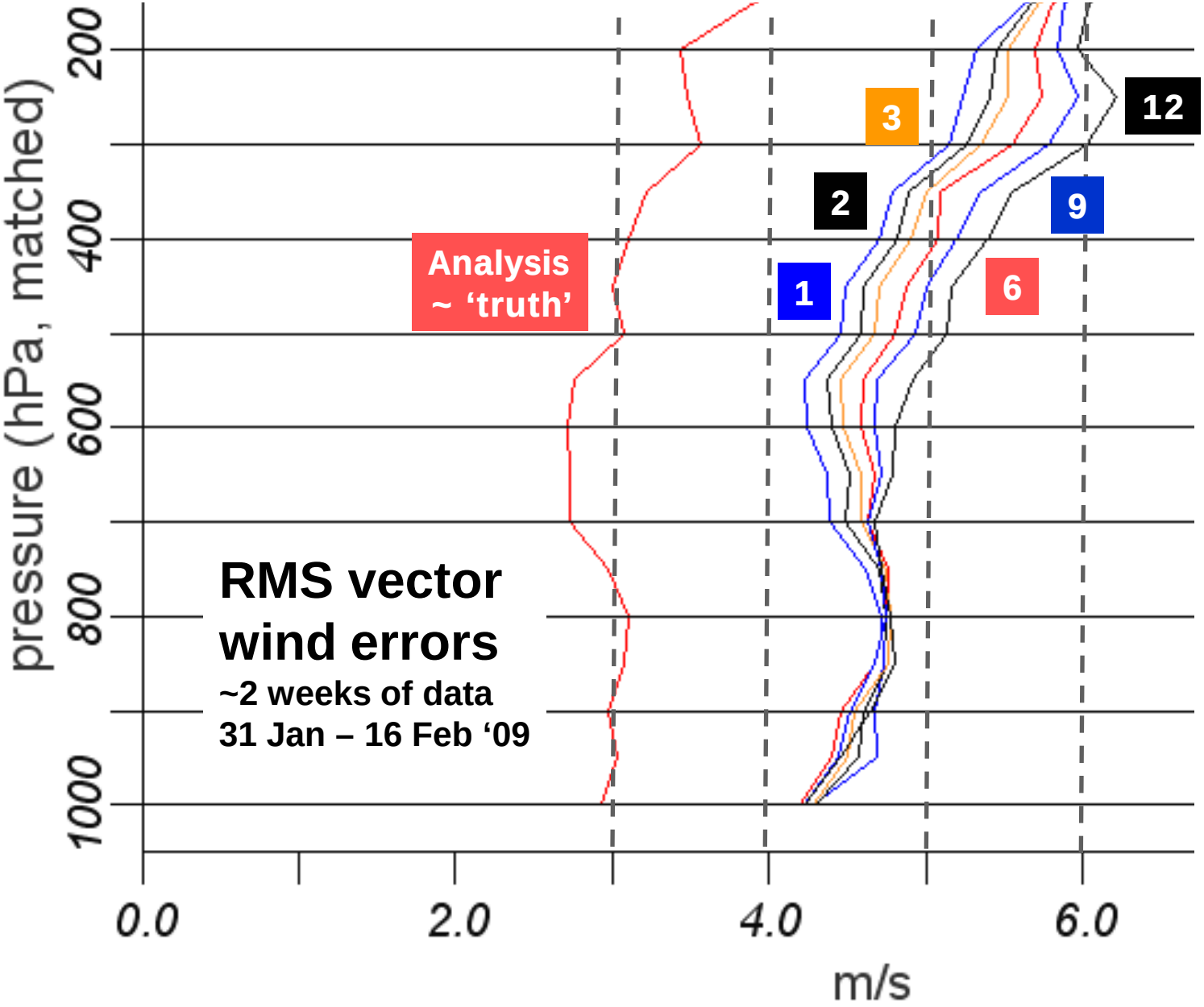
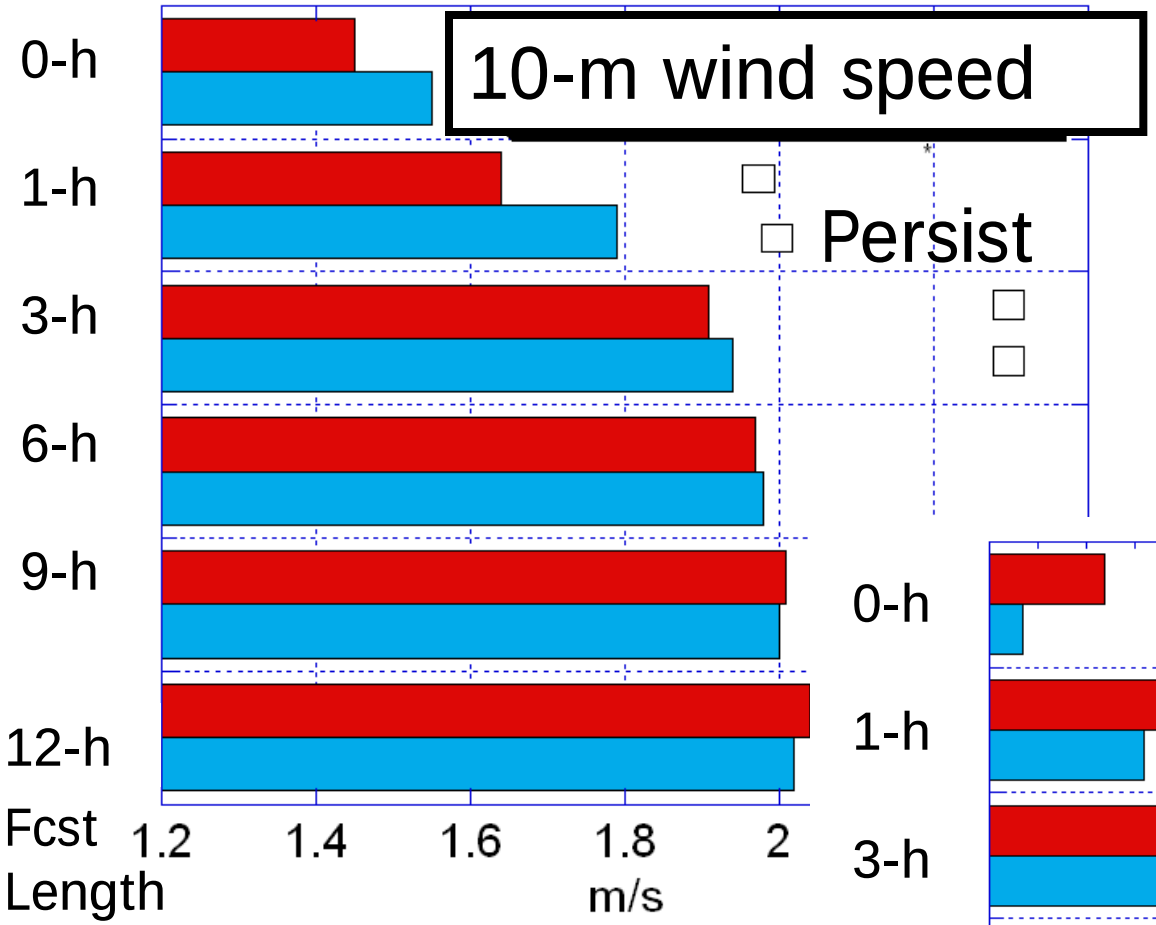
Rapid Refresh Summary

Rapid Update Cycle (RUC)

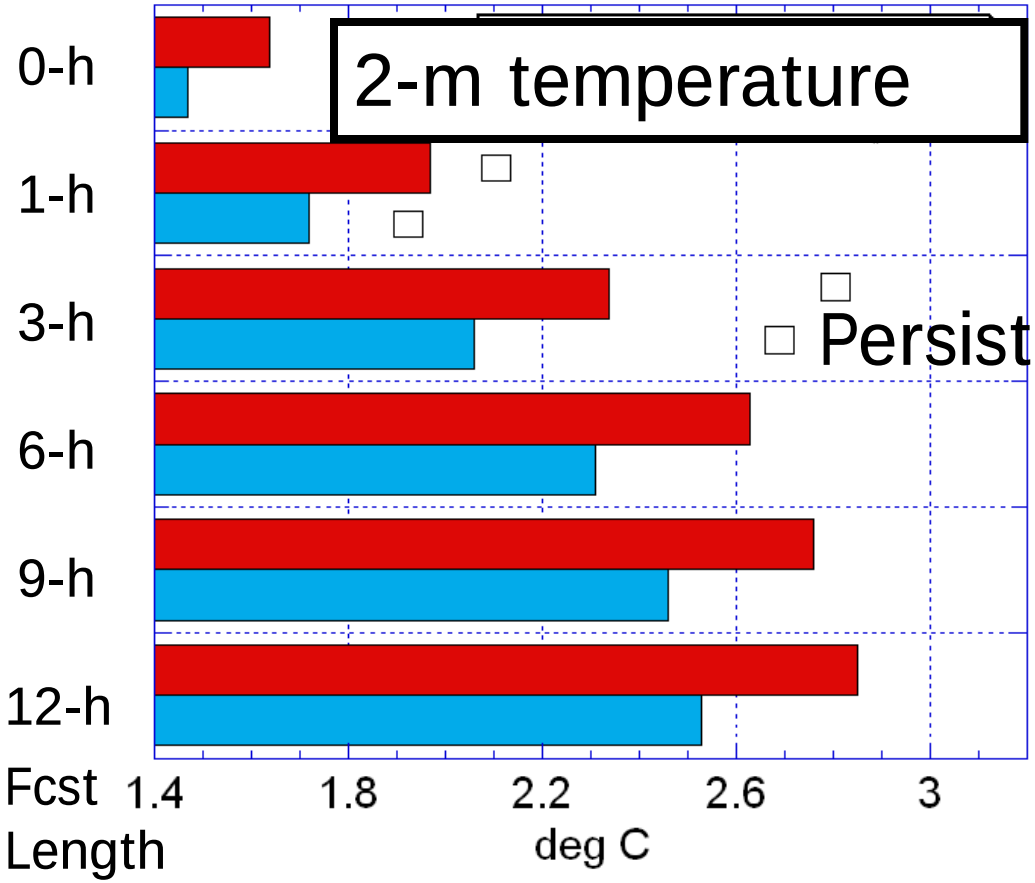




Verify RUC sfc fcst against all U.S. sfc obs

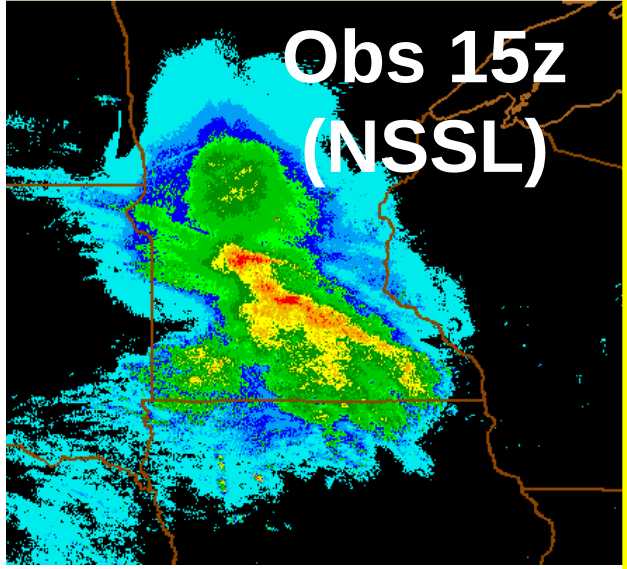
SUM (Apr–Sep)

WIN (Oct–Dec)



RUC improves *surface* wind, temp skill down to 1-h fcst

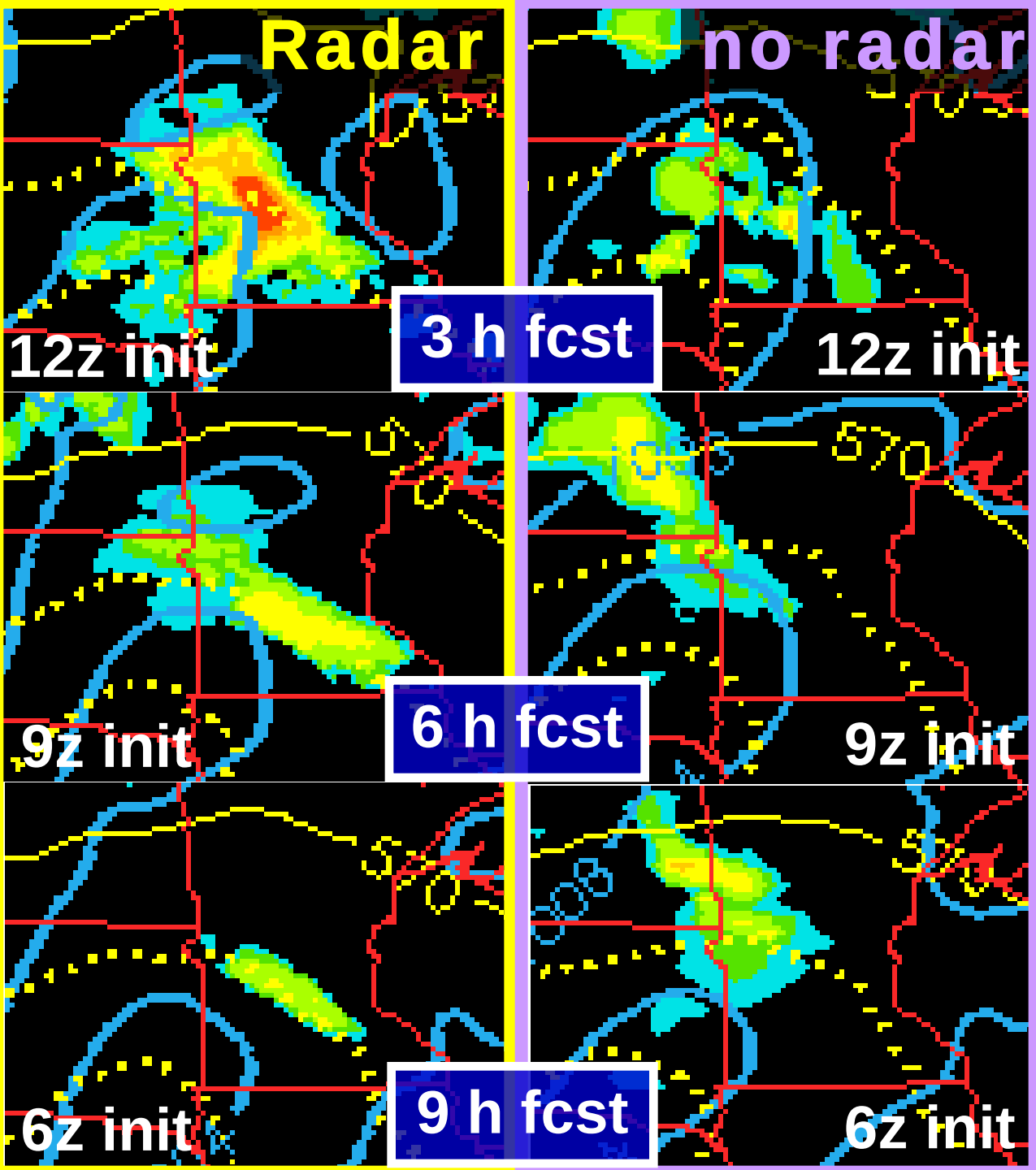
Much better than 1-h, 3-h persistence forecasts



3-h acc. precip.

Valid 15z
31 July 2008

RUC radar assimilation improves forecasts



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Rapid Refresh Summary

Rapid Refresh Data Assimilation

Switch to Gridpoint Statistical Interpolation (GSI)

- Developed at NCEP for GFS, also used in NAM, RTMA
- Mature satellite radiance assim. with bias correction
- **Does not fit observations as closely as RUC 3DVAR**

Features being added for Rapid Refresh

- Cloud analysis, radar and lightning assimilation
- Use of satellite products over northern latitudes
- Closer fit to observations

Surface observation assimilation -- ongoing

- **Account for model vs. terrain height difference**
- **Apply surface obs. innovations through PBL**
- **Select best background for coastal observations**

RUC surface obs assimilation

If abs[Psfc(obs-model)] < 70 mb.

Extrapolate obs T,Td,Z from $Psfc_{obs}$ to $Psfc_{model}$

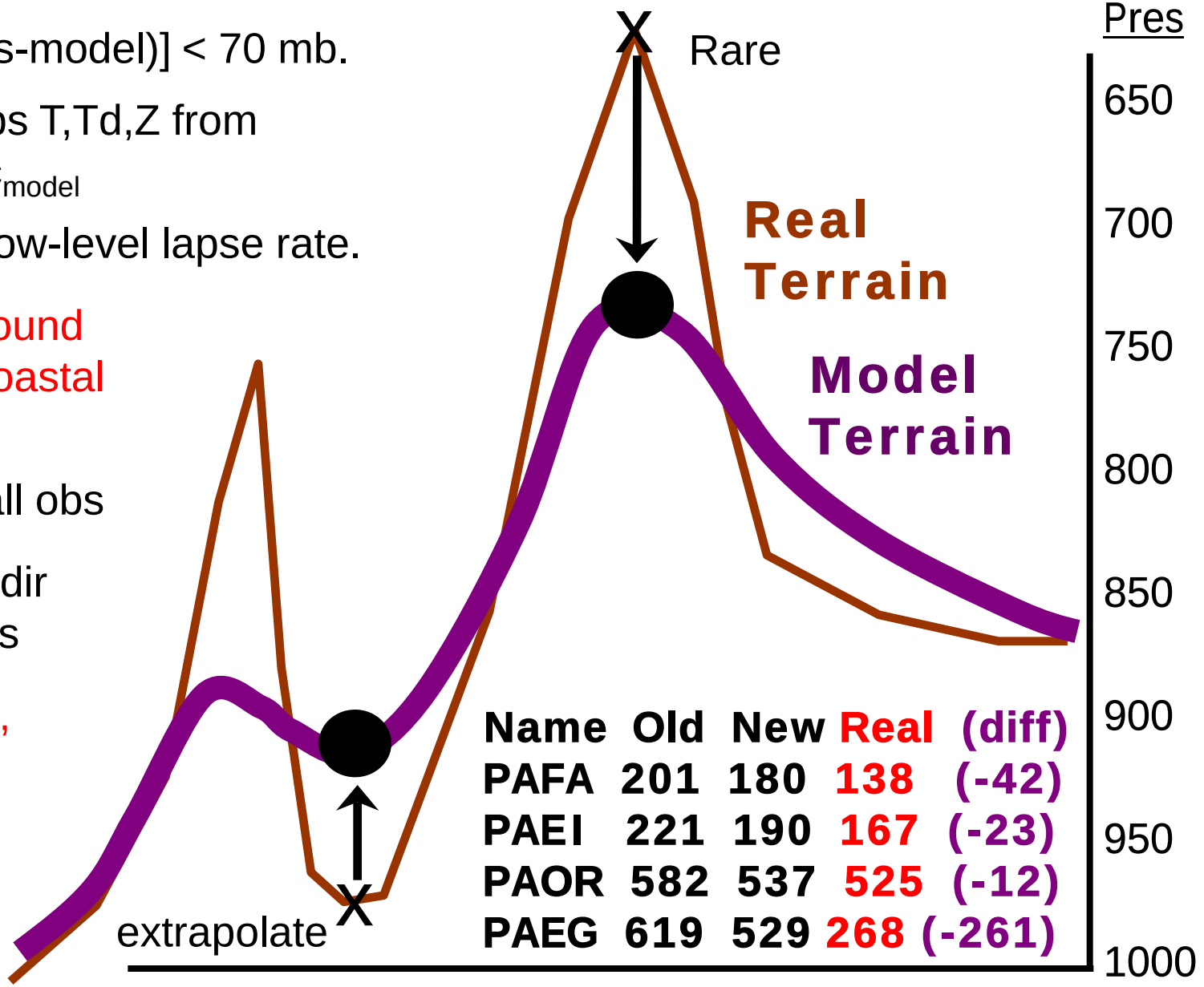
Use bckgrnd low-level lapse rate.

Match background land-use for coastal stations

Use wind for all obs

Bckgrnd wind dir for wind < 5 kts

Derive 2m T/q, 10m winds

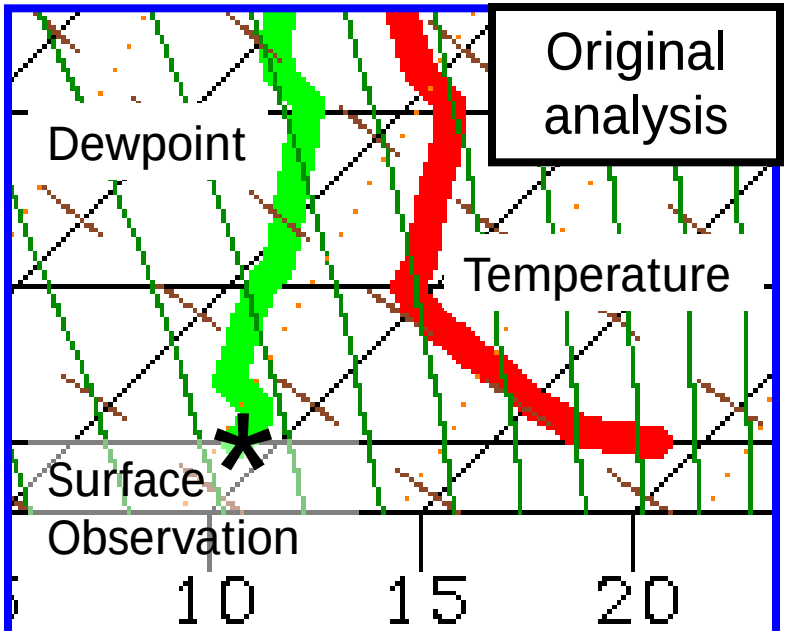


Name	Old	New	Real	(diff)
PAFA	201	180	138	(-42)
PAEI	221	190	167	(-23)
PAOR	582	537	525	(-12)
PAEG	619	529	268	(-261)

Use of surface obs information throughout boundary layer in the RUC analysis

Problem

- Information from surface observation not used through depth of PBL by RUC analysis
- Surface observation not retained in model forecast



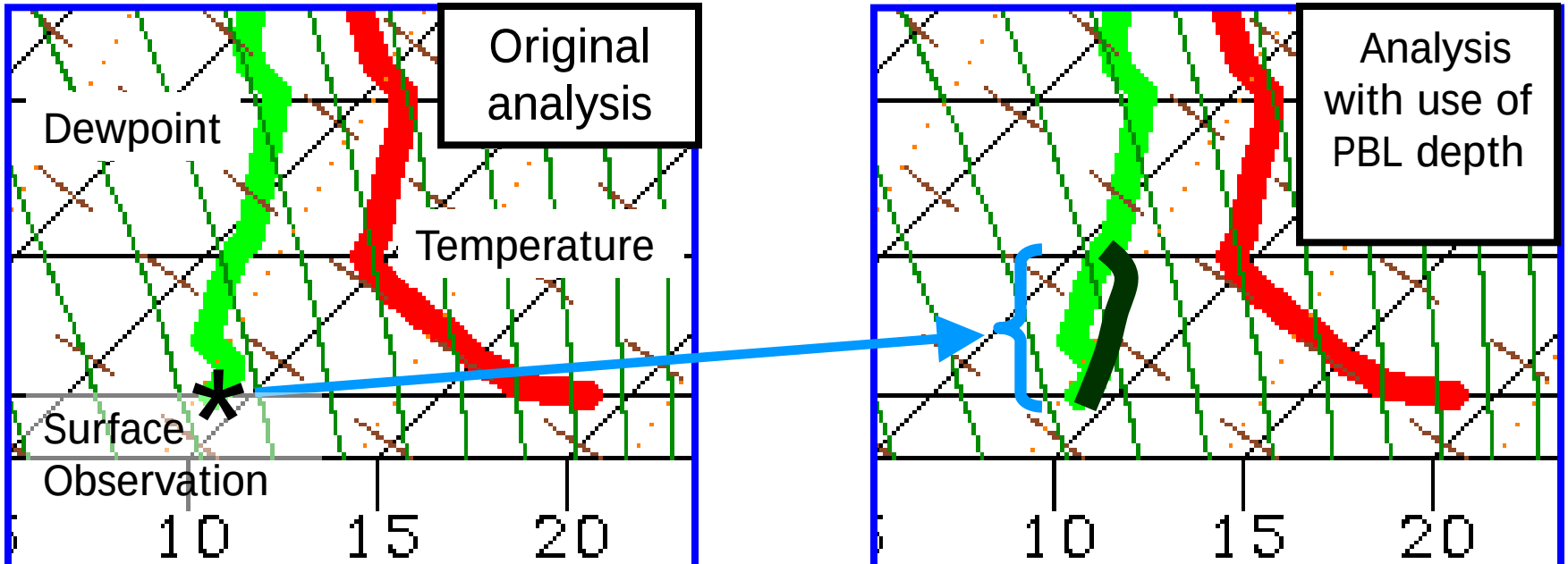
Use of surface obs information throughout boundary layer in the RUC analysis

Problem

- Information from surface observation not used through depth of PBL by RUC analysis
- Surface observation not retained in model forecast

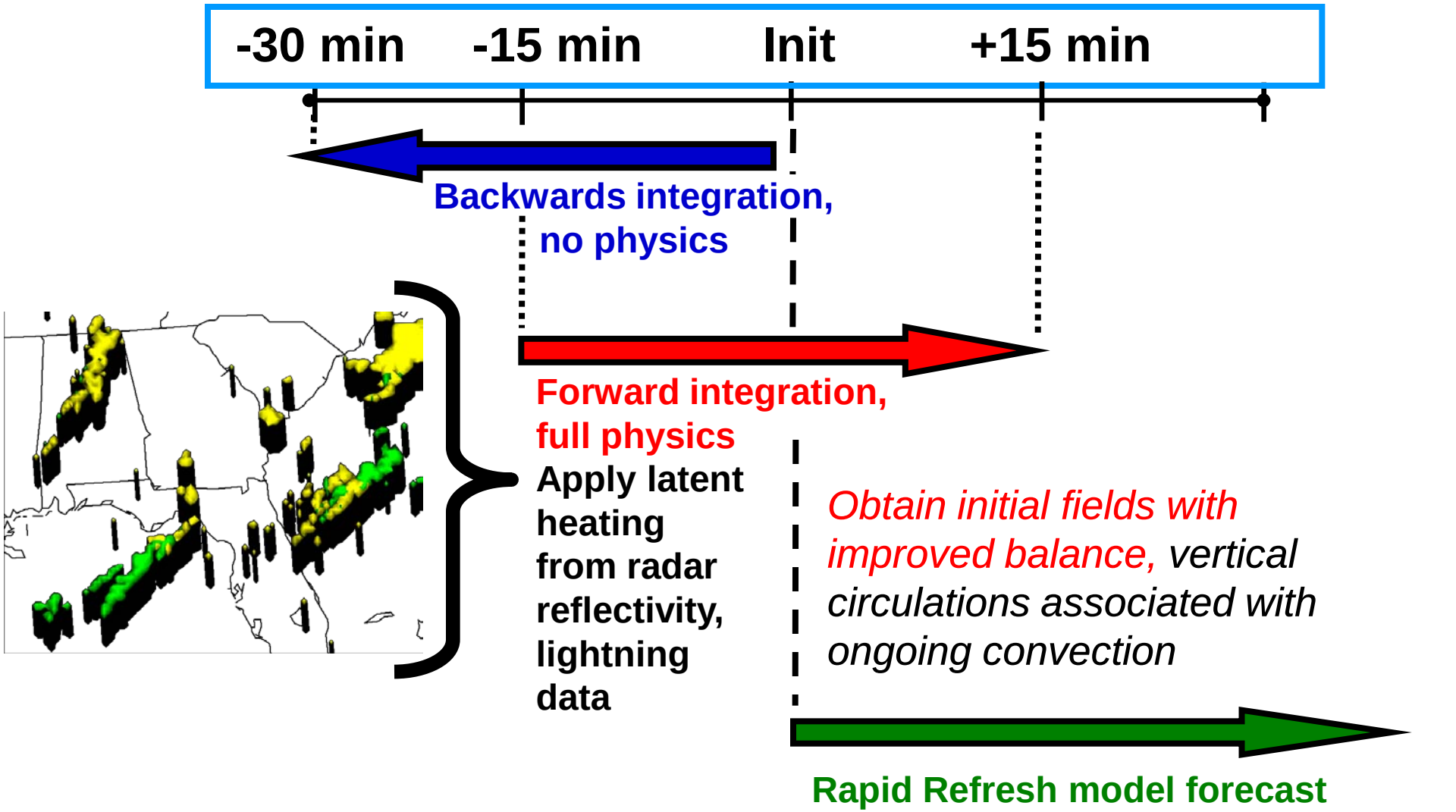
Solution

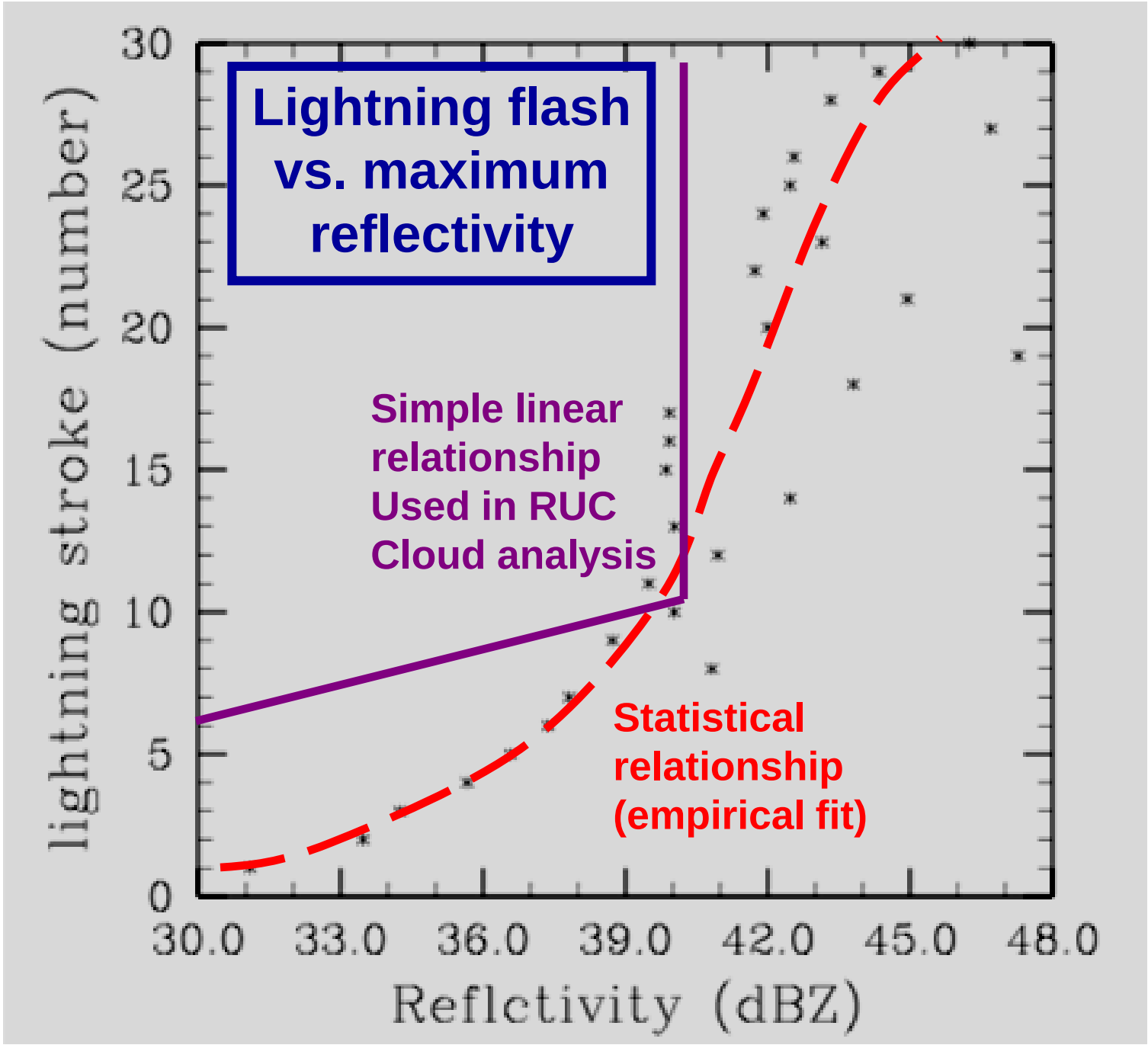
- Use METAR observation throughout PBL depth (from background field)
- Better model retention of surface observations

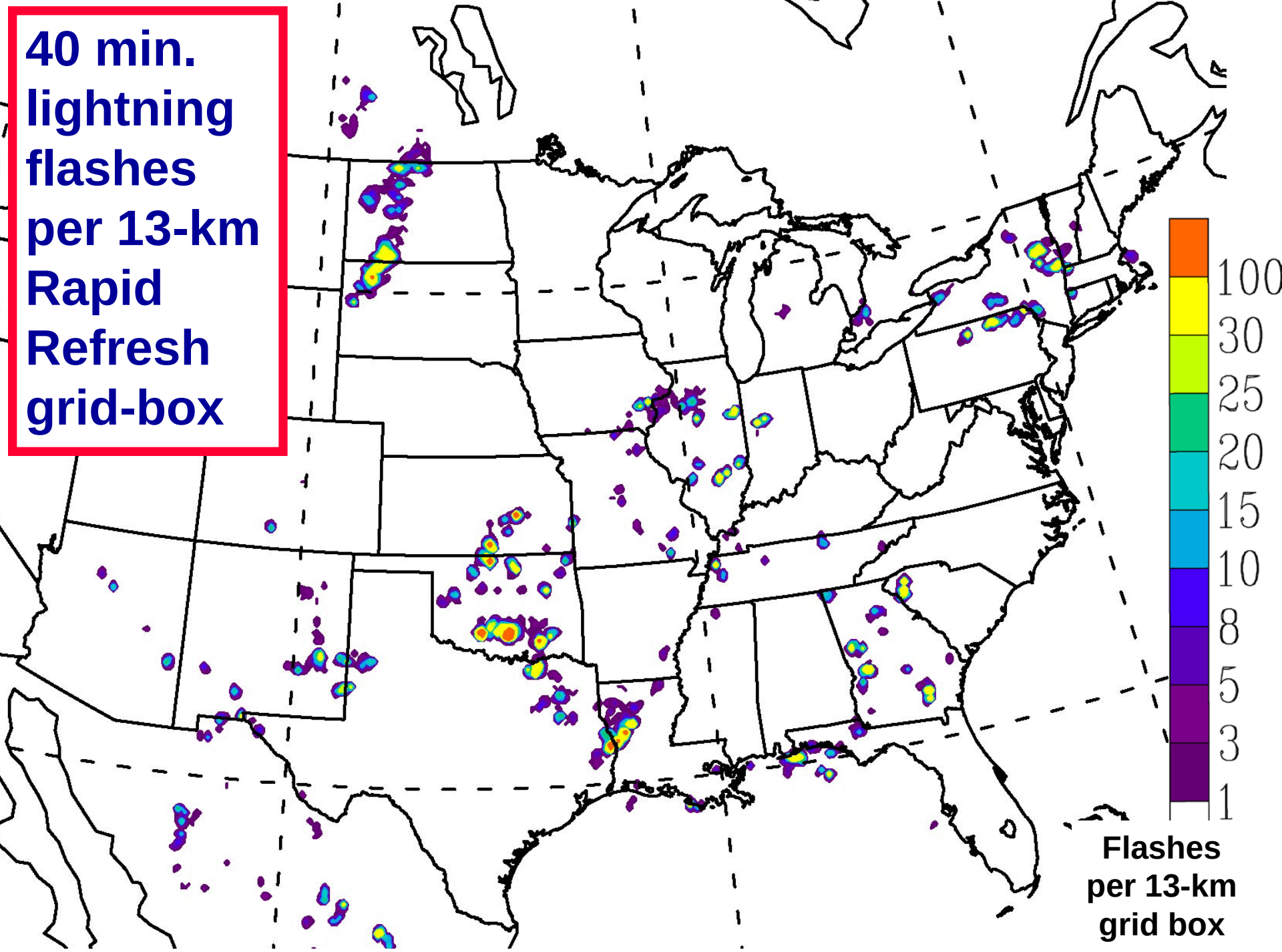


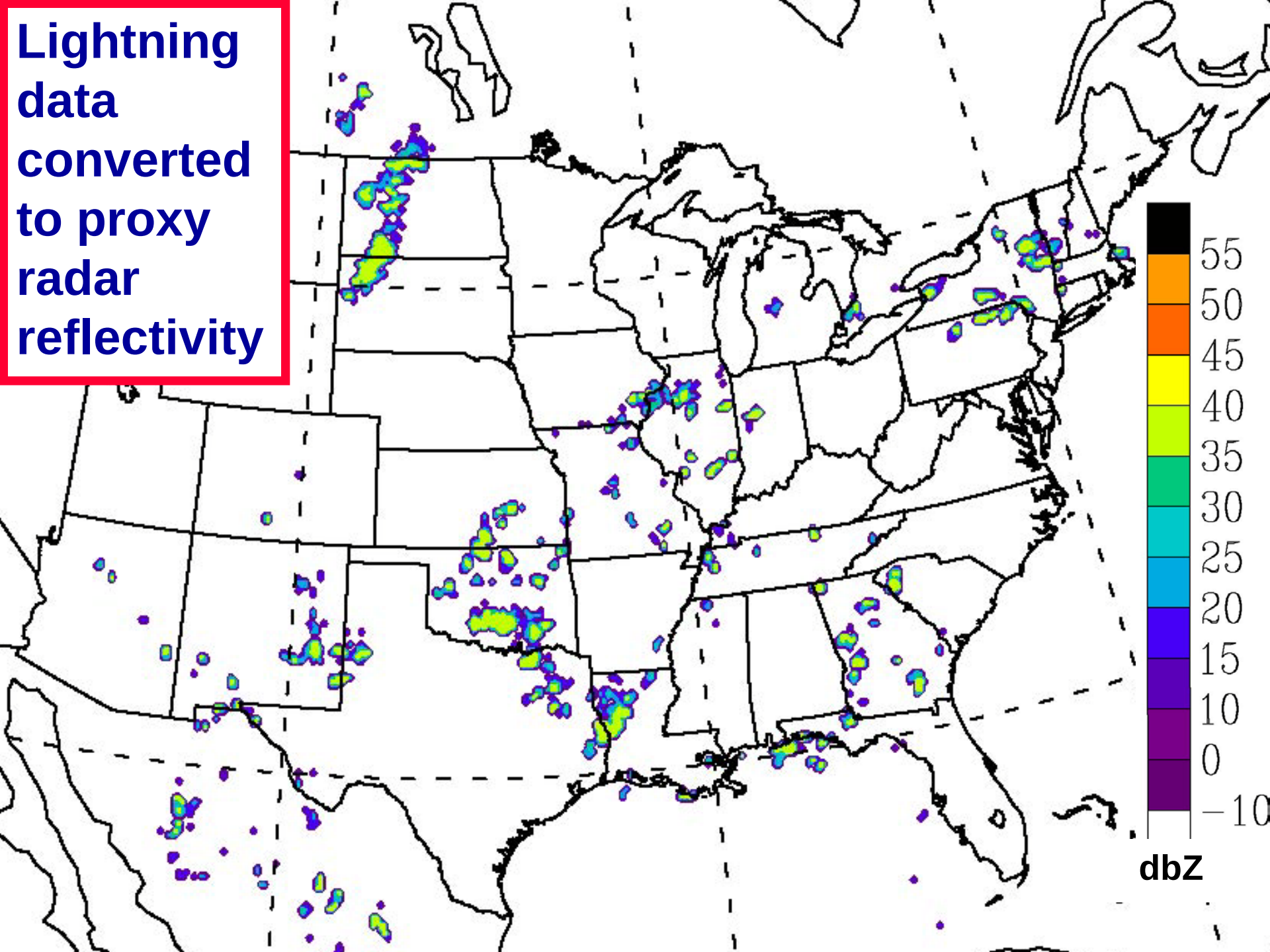
Radar data assimilation using Diabatic Digital Filter Initialization (DDFI)

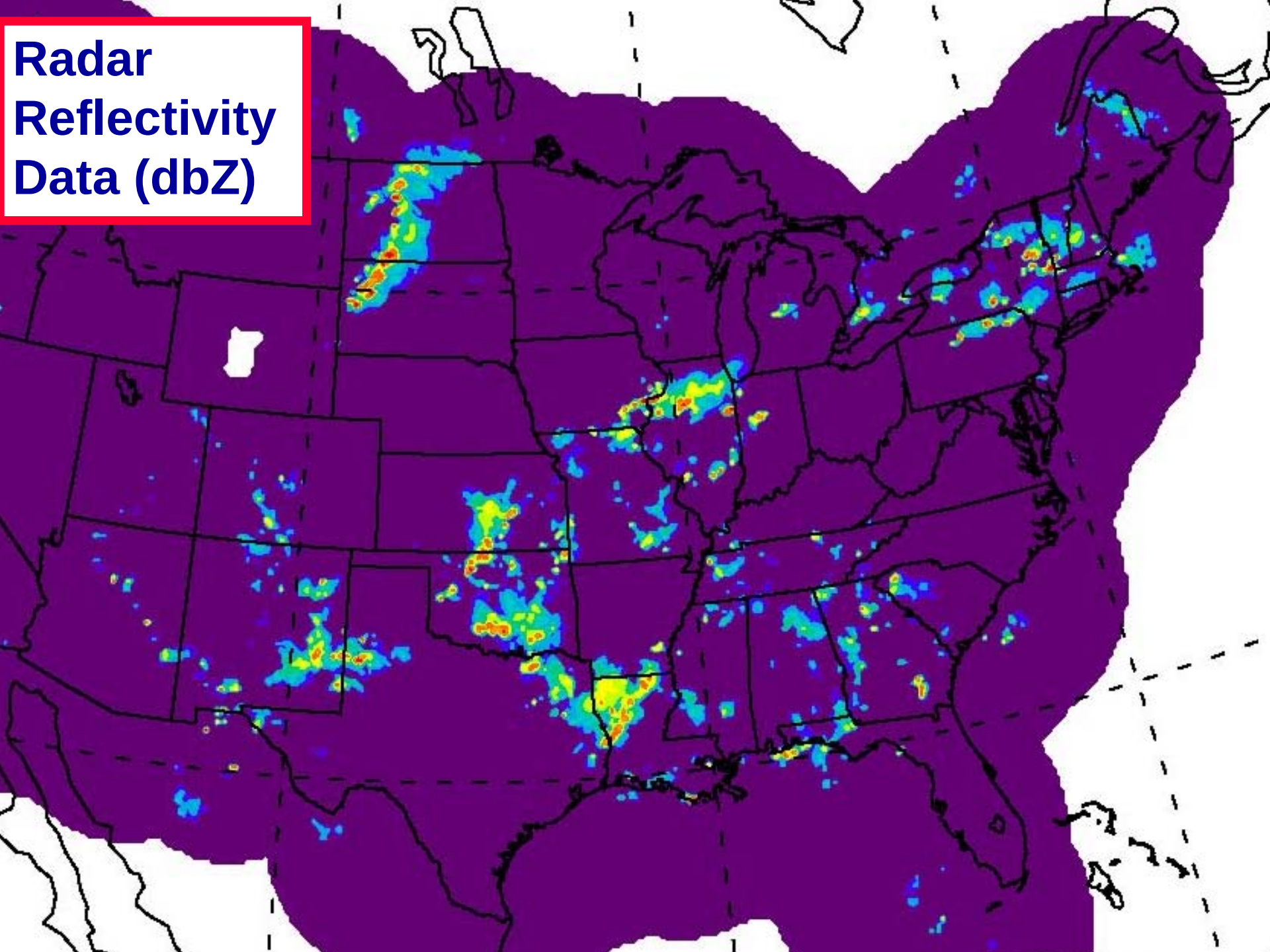
RR coding complete, evaluation ongoing

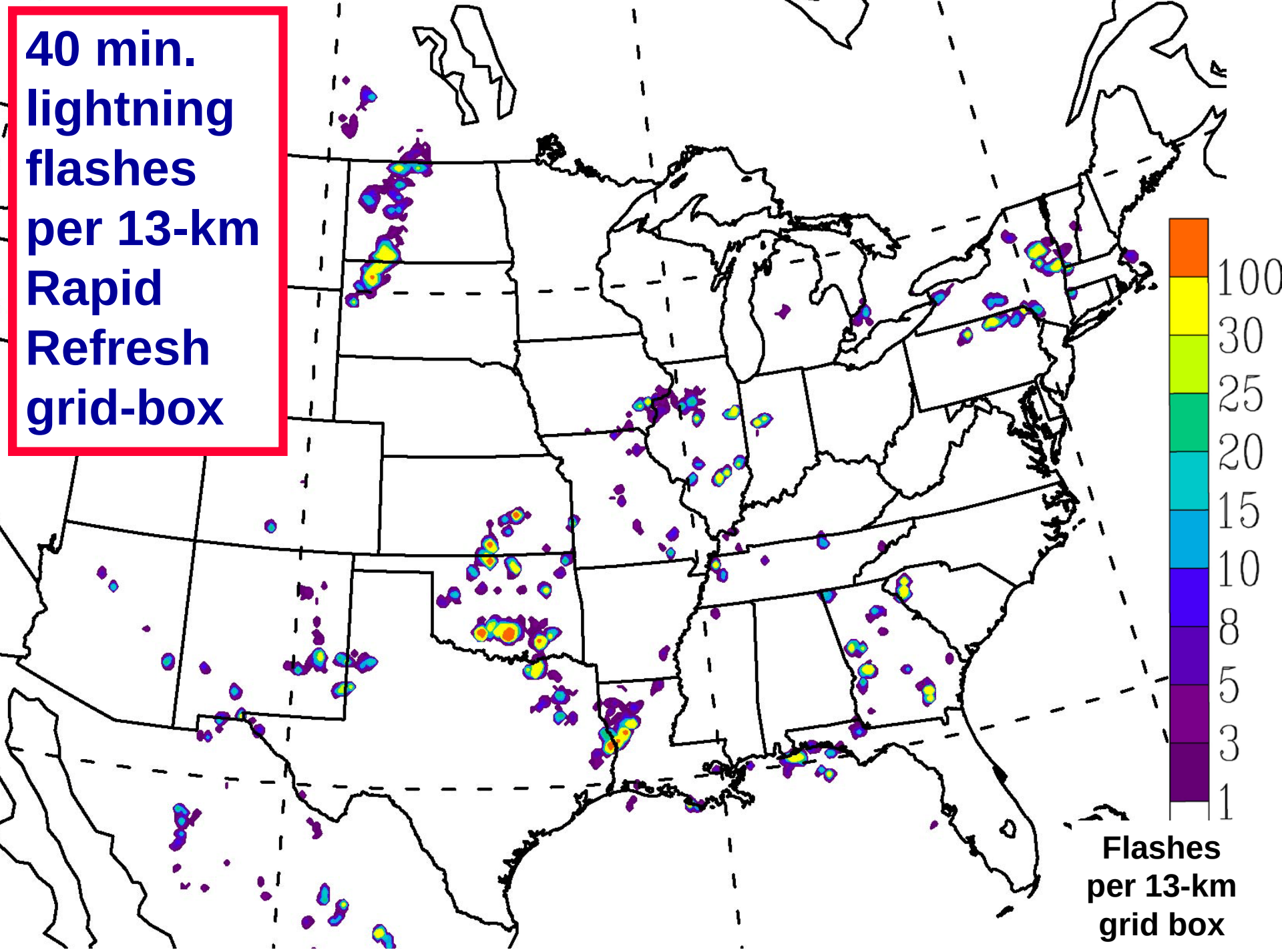



Lightning flash vs. maximum reflectivity
Simple linear relationship Used in RUC Cloud analysis
Statistical relationship (empirical fit)
lightning stroke (number)
Reflctivity (dBZ)
0
5
10
15
20
25
30
30.0
33.0
36.0
39.0
42.0
45.0
48.0

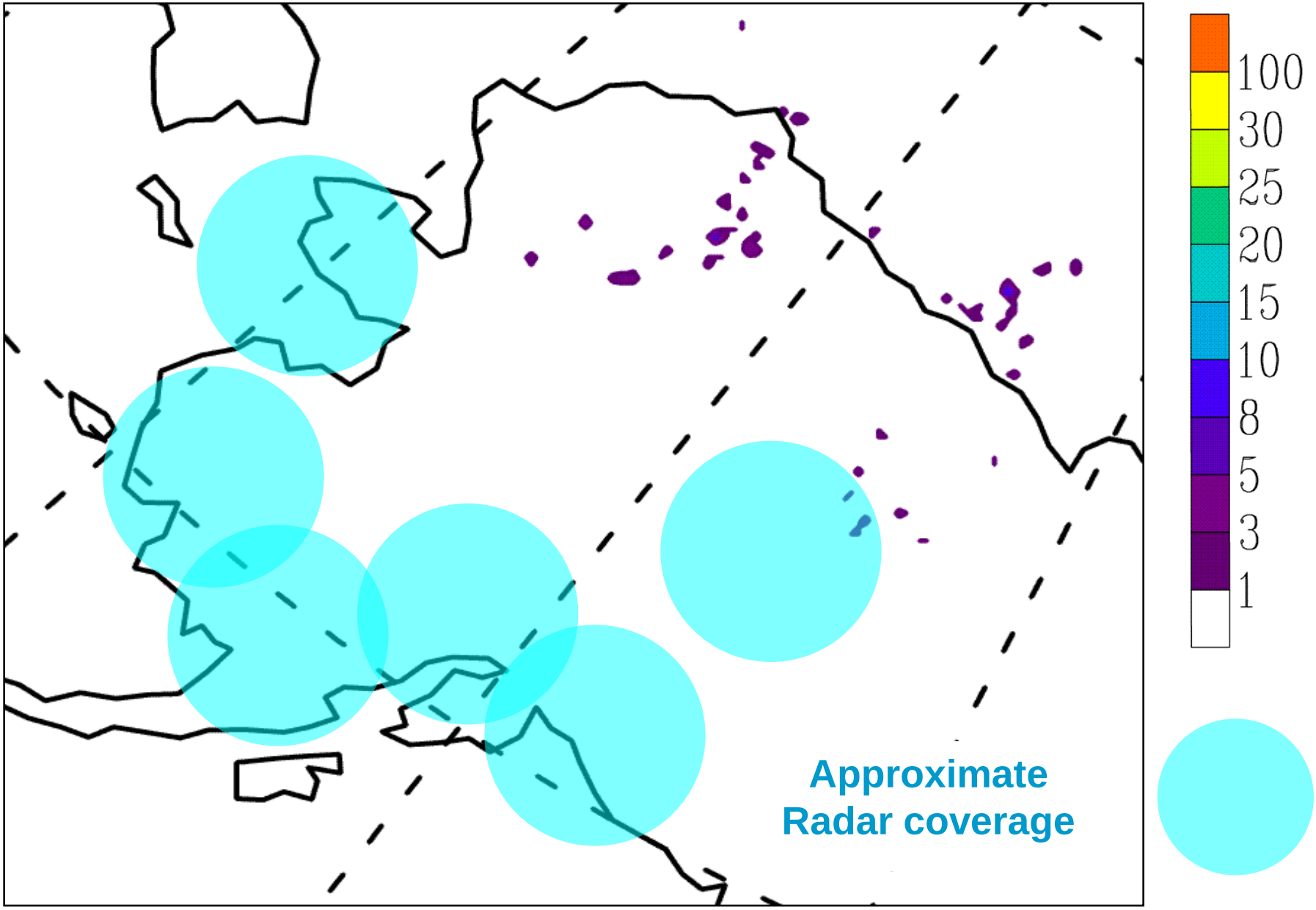

40 min. lightning flashes per 13-km Rapid Refresh grid-box
100
30
25
20
15
10
8
5
3
1
Flashes per 13-km grid box


Lightning data converted to proxy radar reflectivity
55
50
45
40
35
30
25
20
15
10
0
−10
dbZ


Radar
Reflectivity
Data (dbZ)


40 min. lightning flashes per 13-km Rapid Refresh grid-box
100
30
25
20
15
10
8
5
3
1
Flashes per 13-km grid box

LTG flash density 00z 10 July 2007



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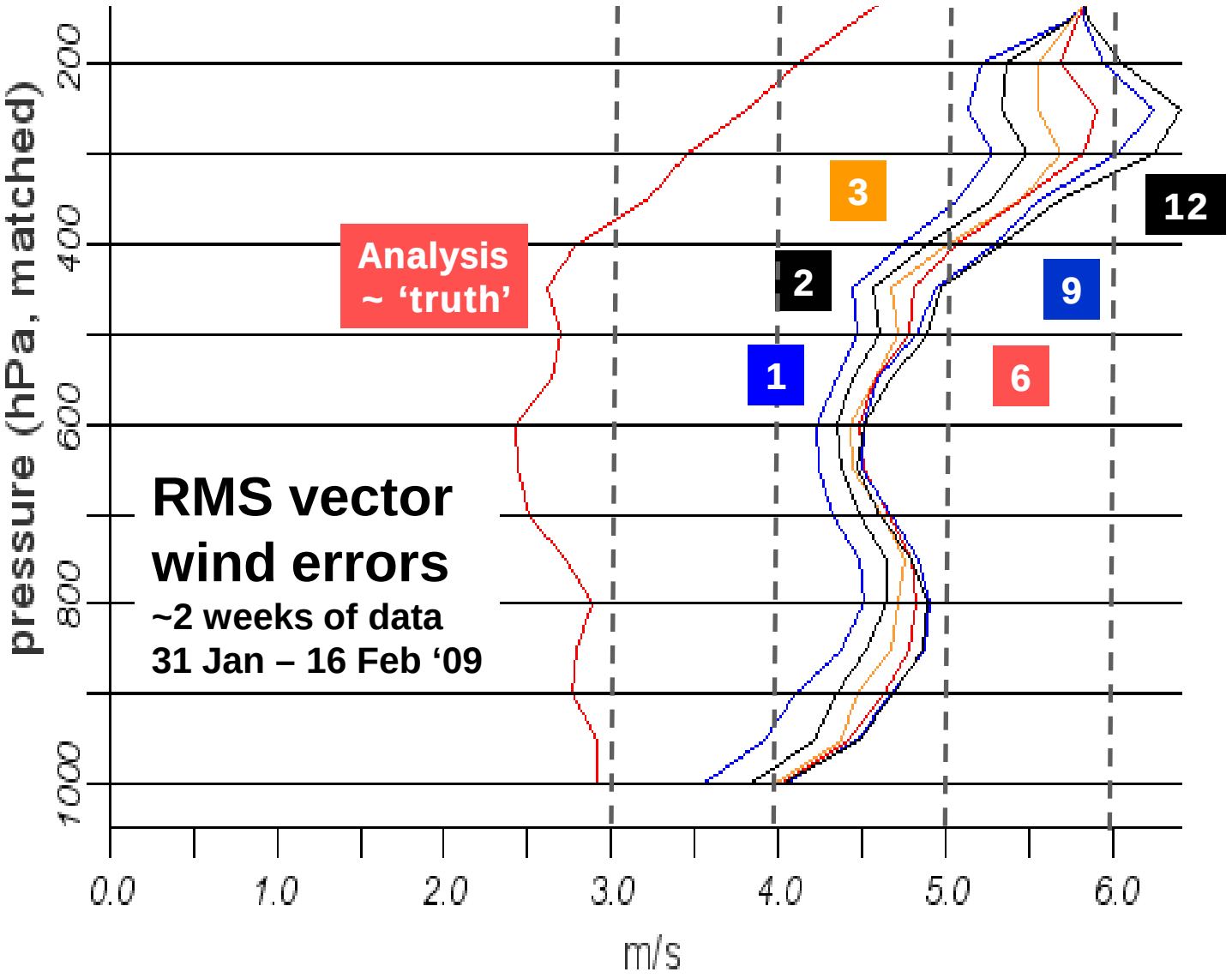
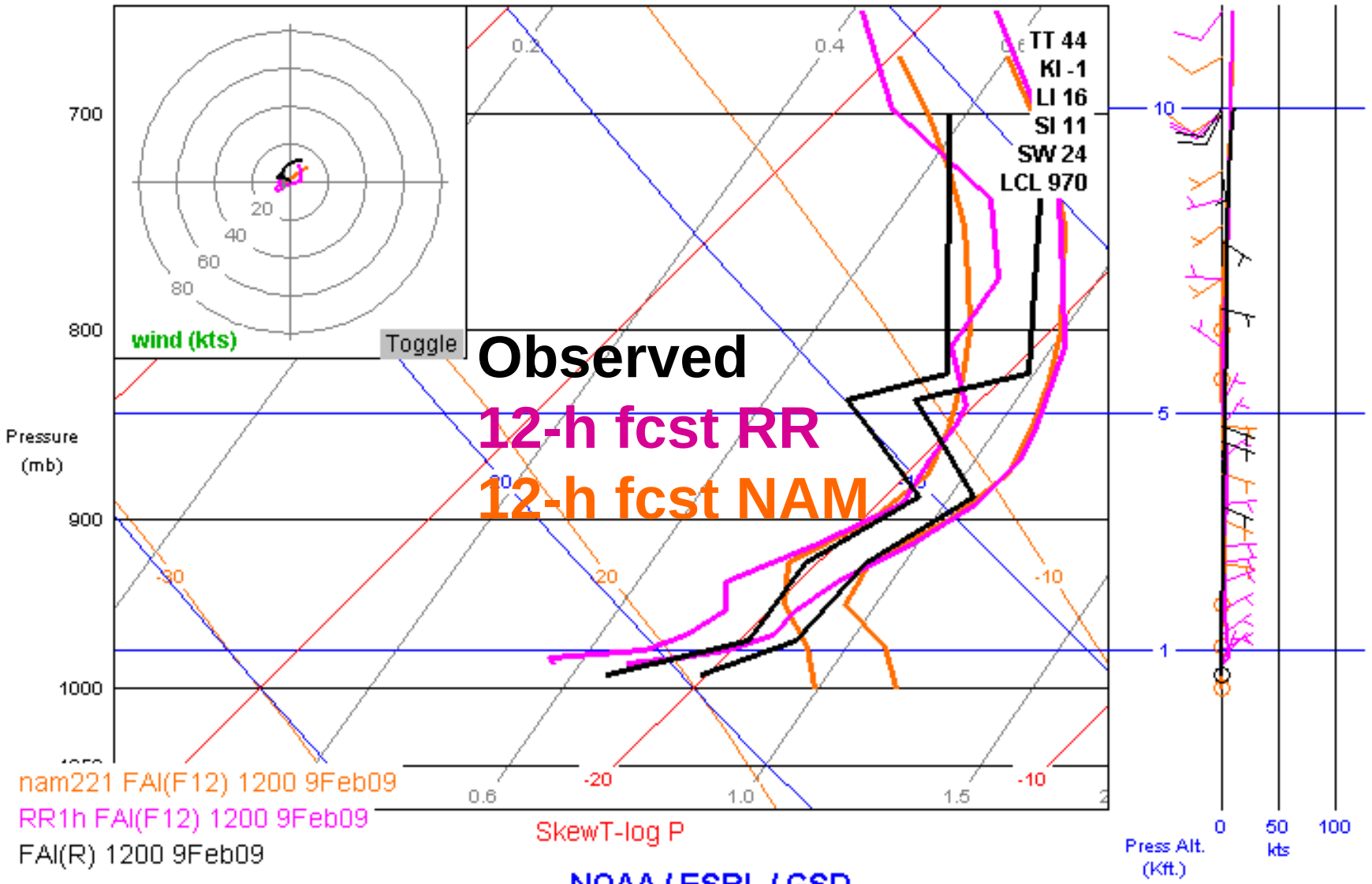
Rapid Refresh Summary

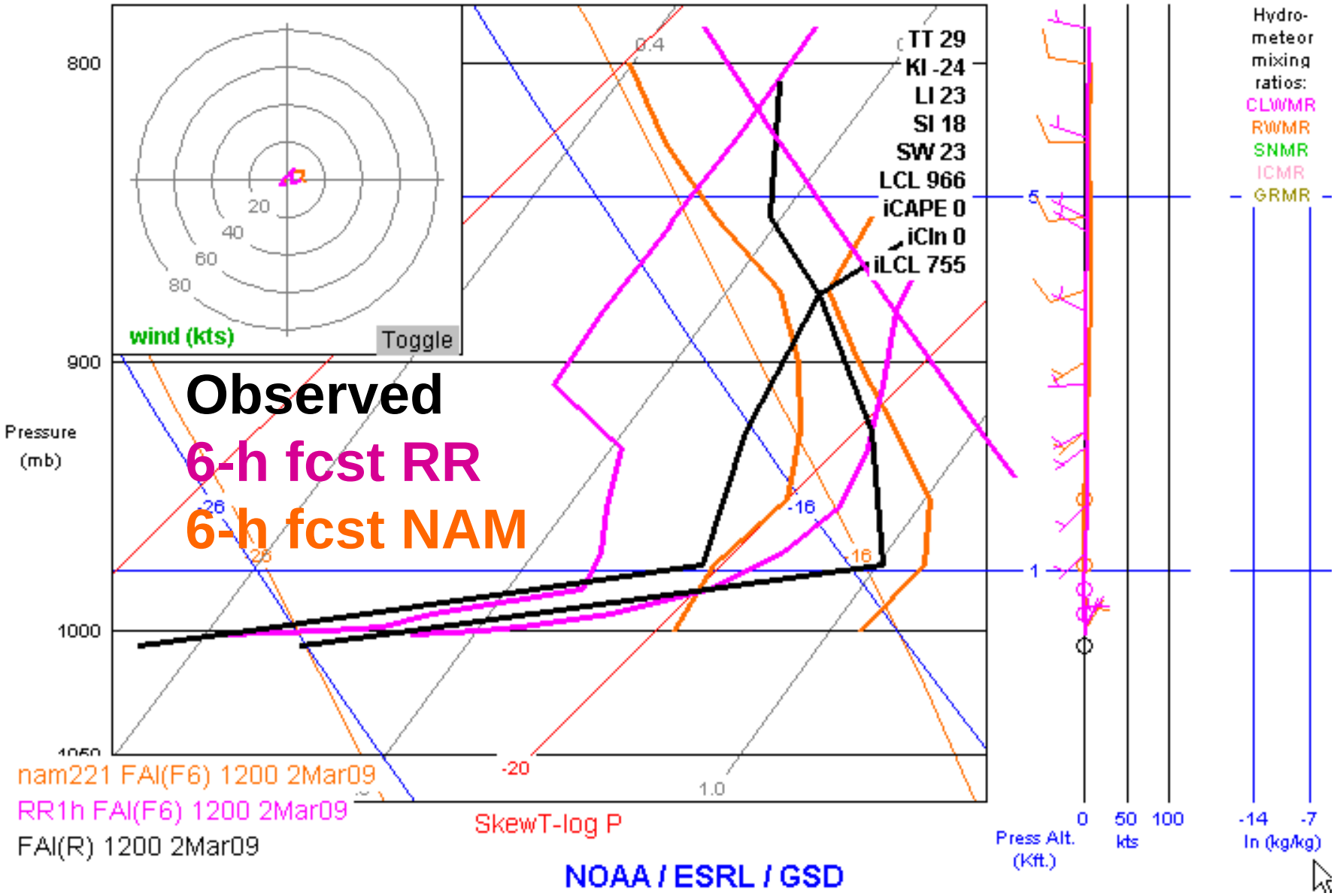
Rapid Refresh (RR)



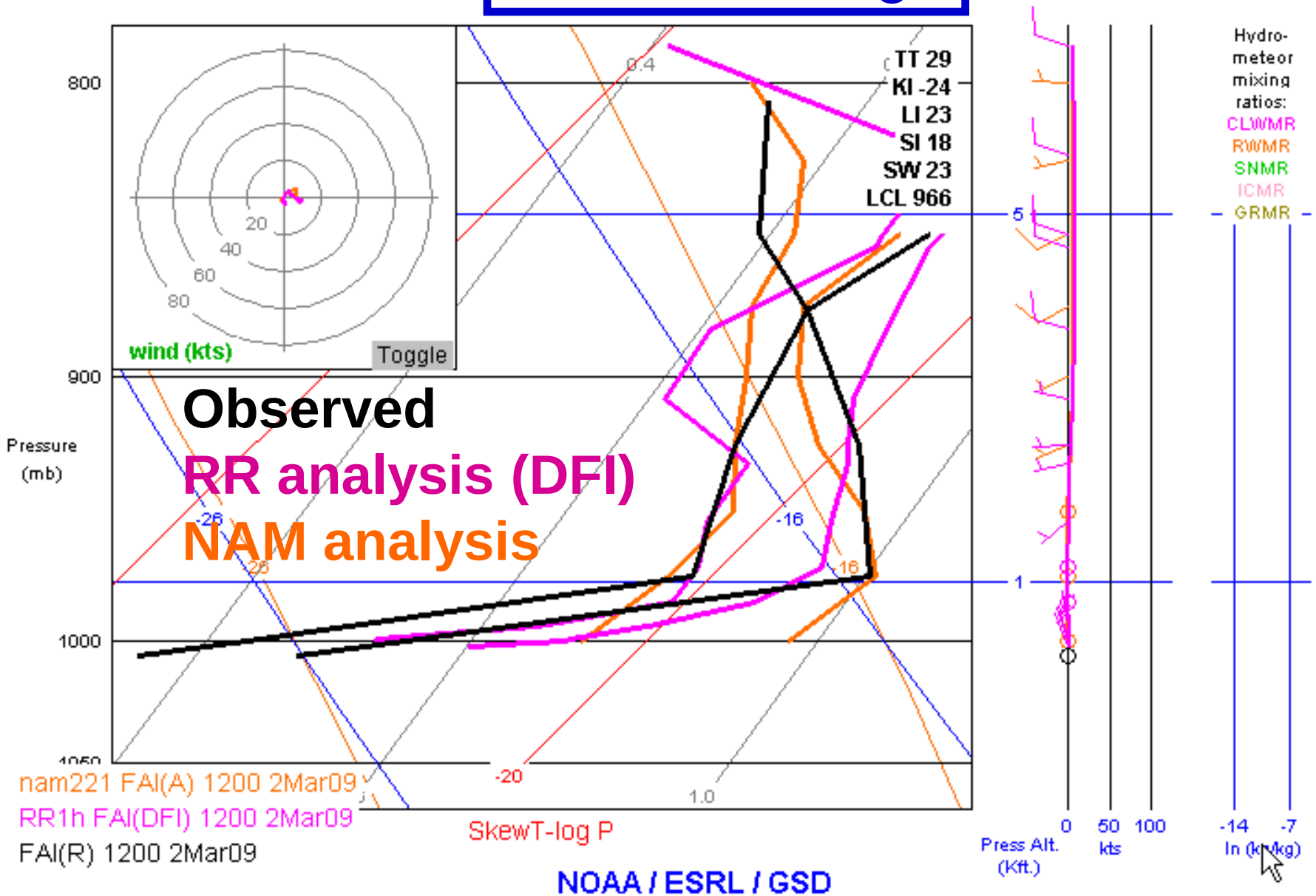
12z 9 Feb 2009
FAI sounding



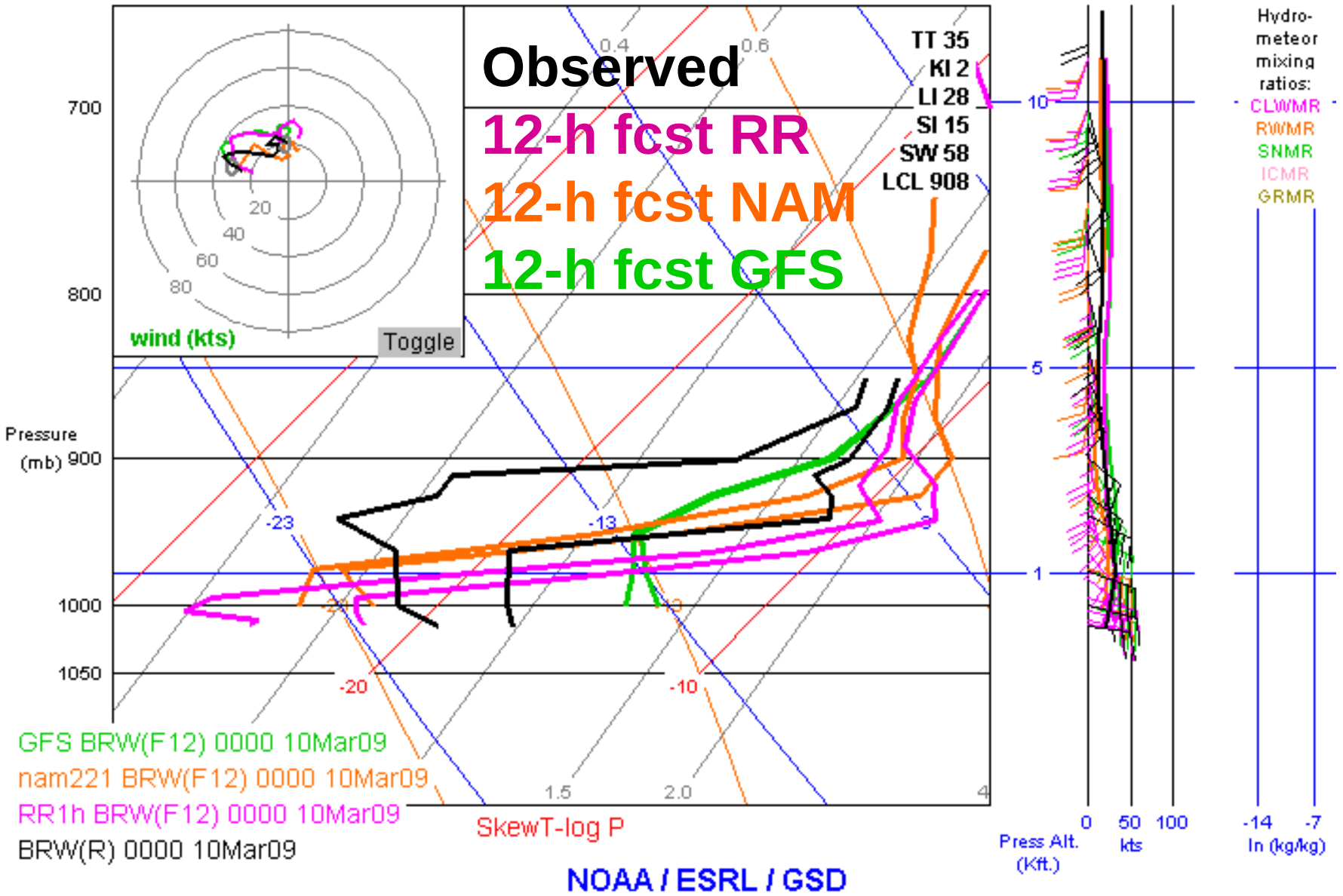
12z 2 Mar 2009
FAI sounding



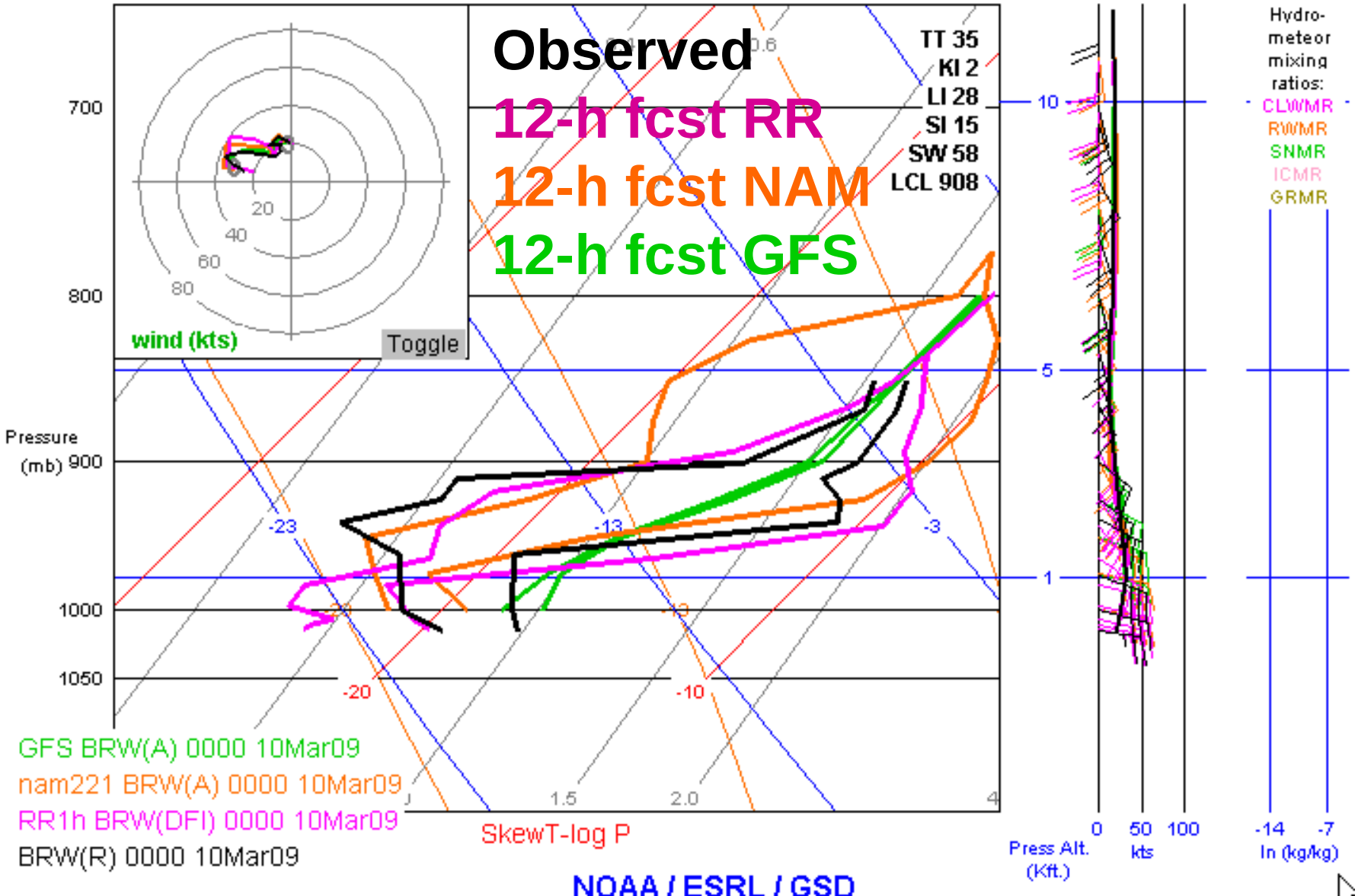
12z 2 Mar 2009
FAI sounding



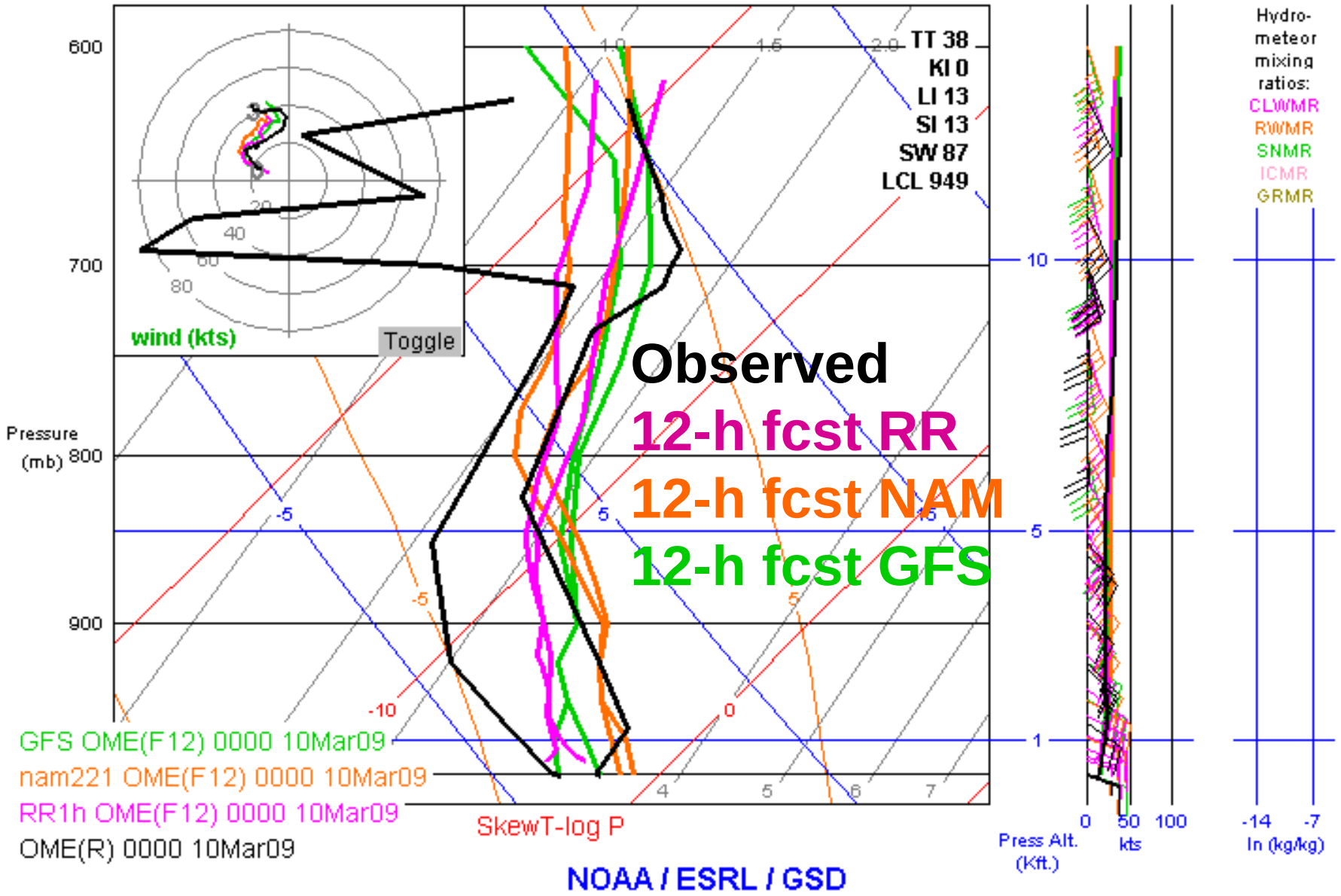
00z 10 Mar 2009
BWR sounding



00z 10 Mar 2009
BWR sounding

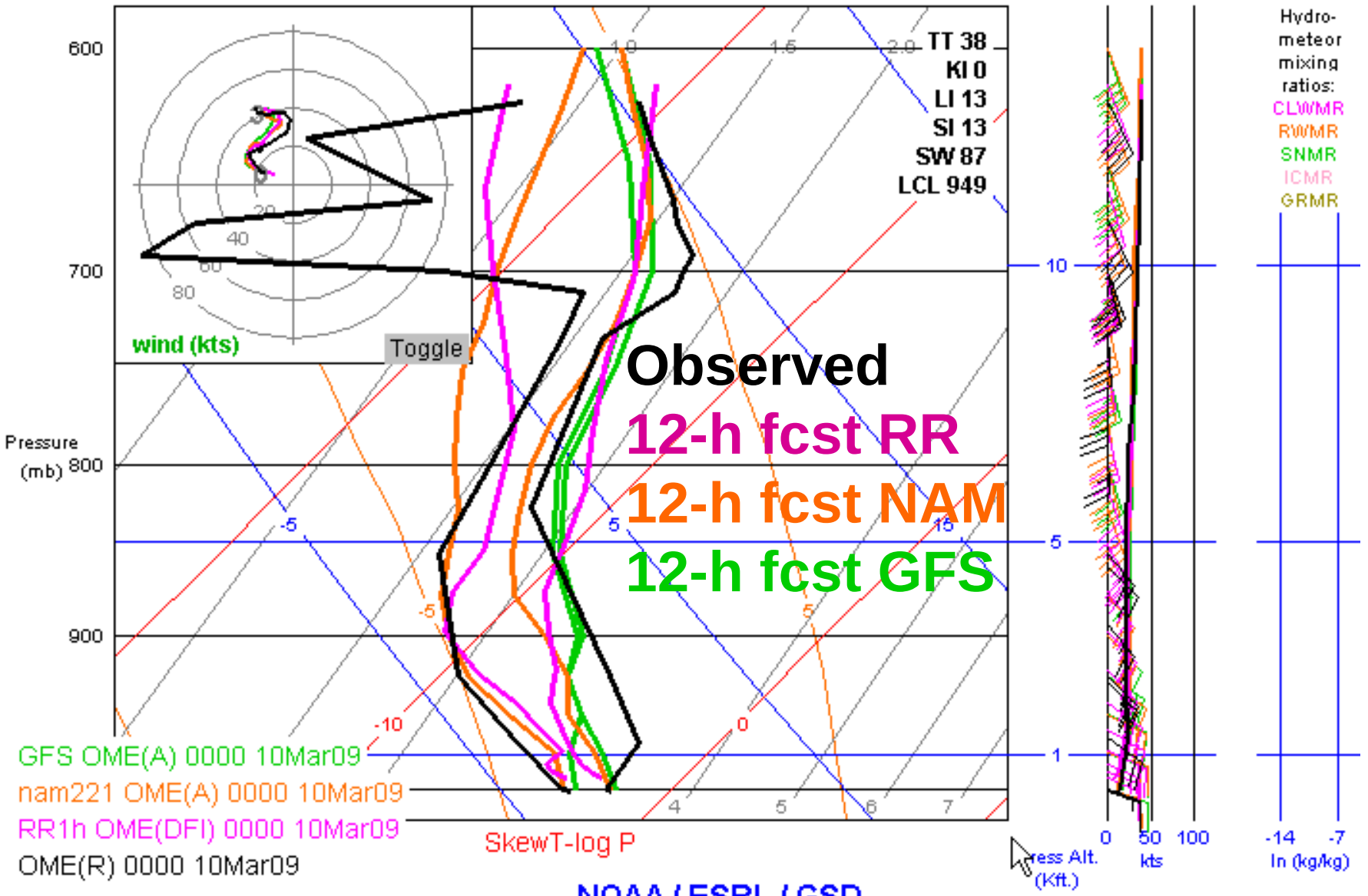


00z 10 Mar 2009
OME sounding



NOAA / ESRL / GSD

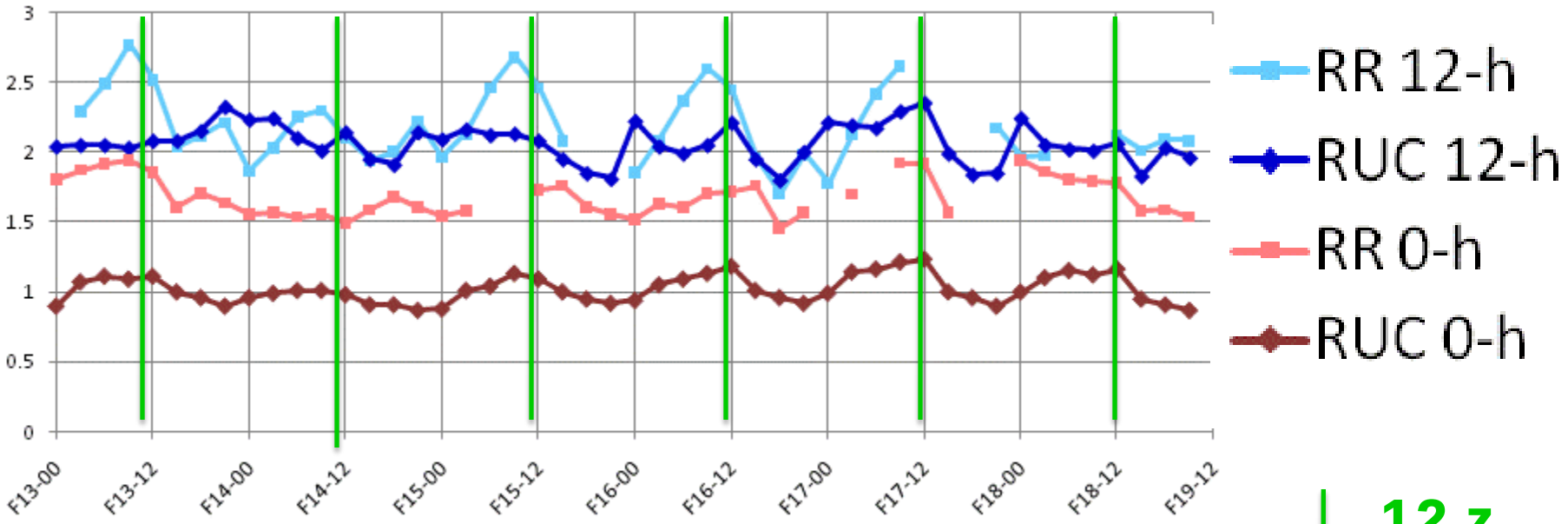
00z 10 Mar 2009
OME sounding



RR vs. RUC sfc. T verification

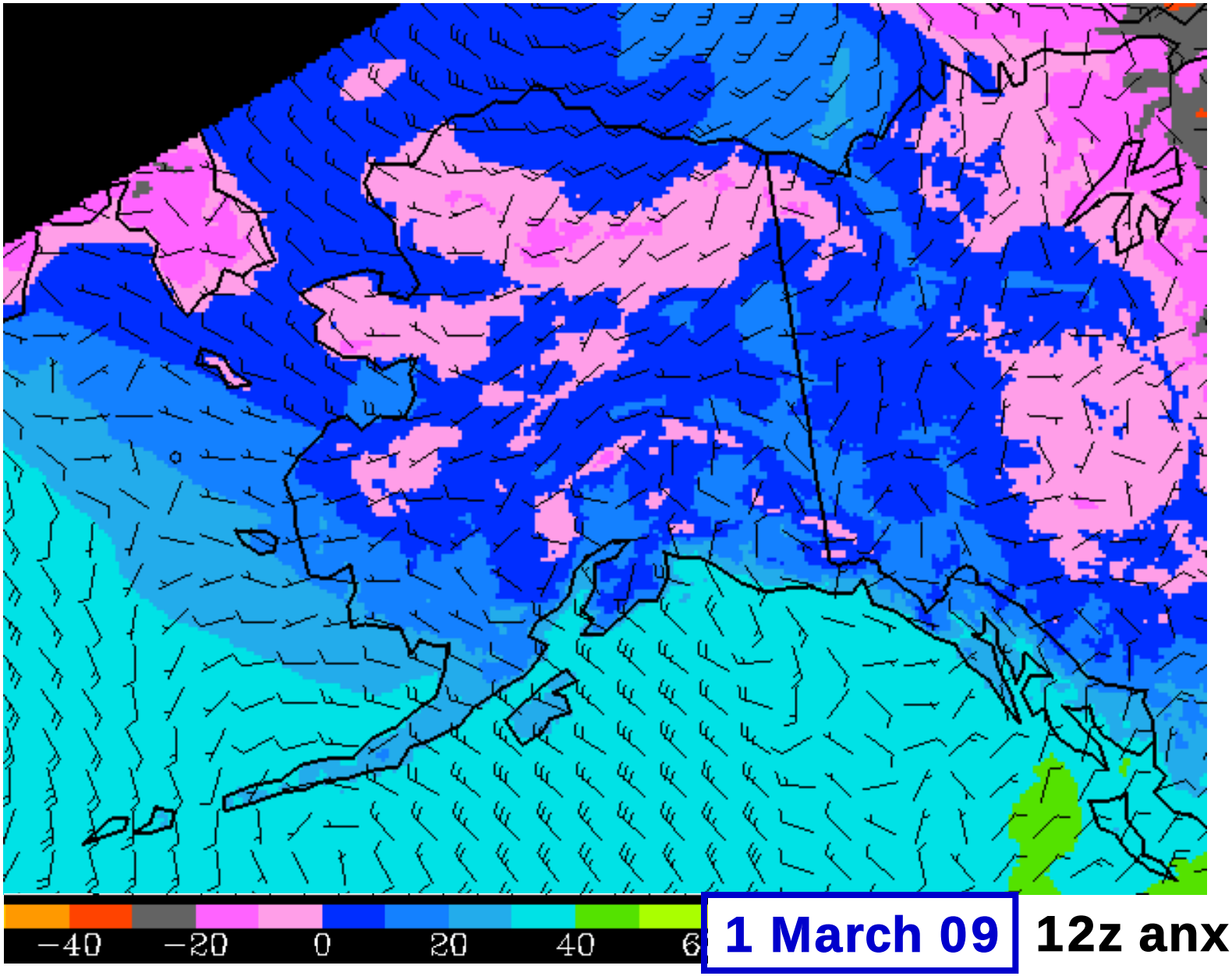
6-d time series for analyses and 12-h forecasts

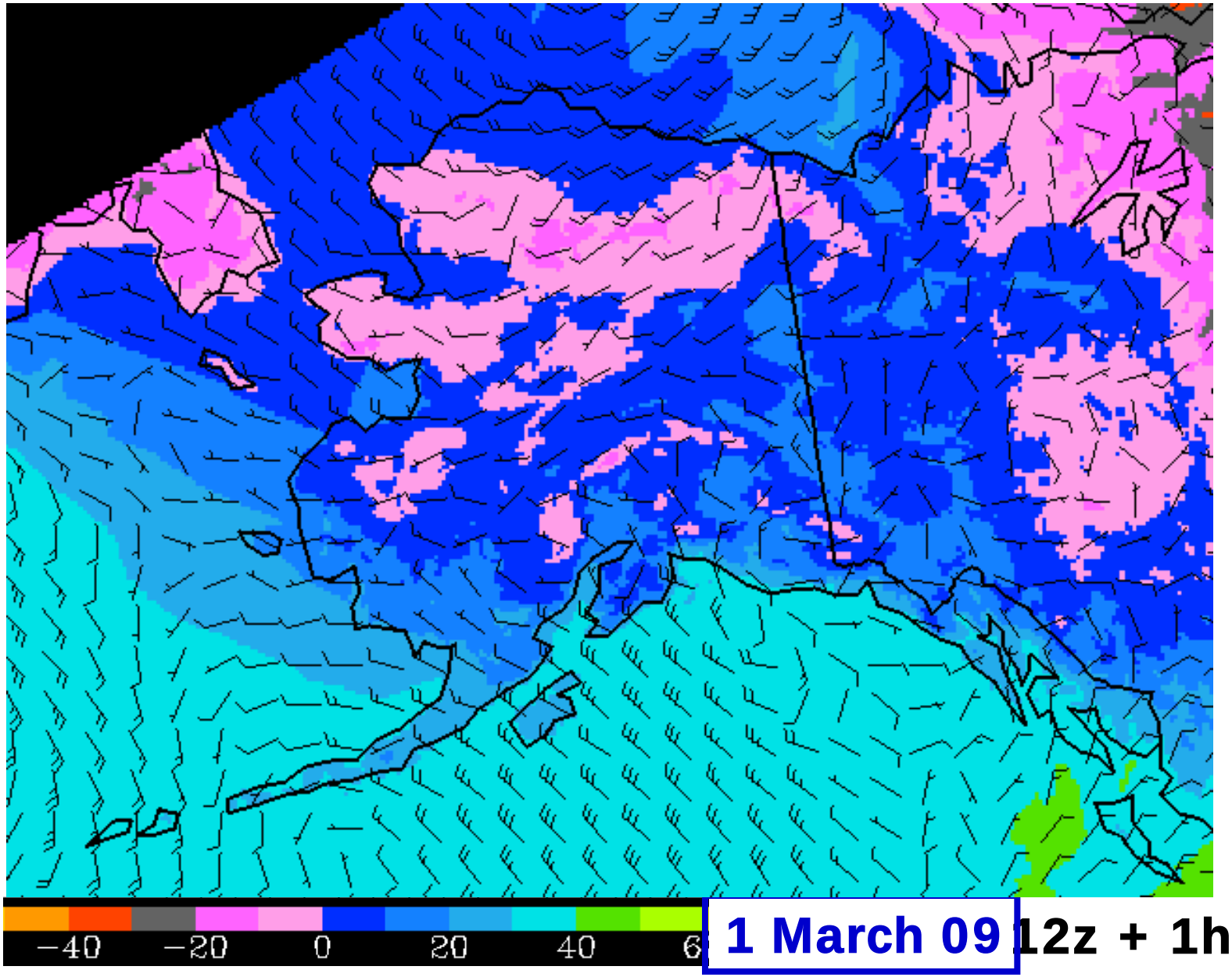
Sfc. T MAE (K)

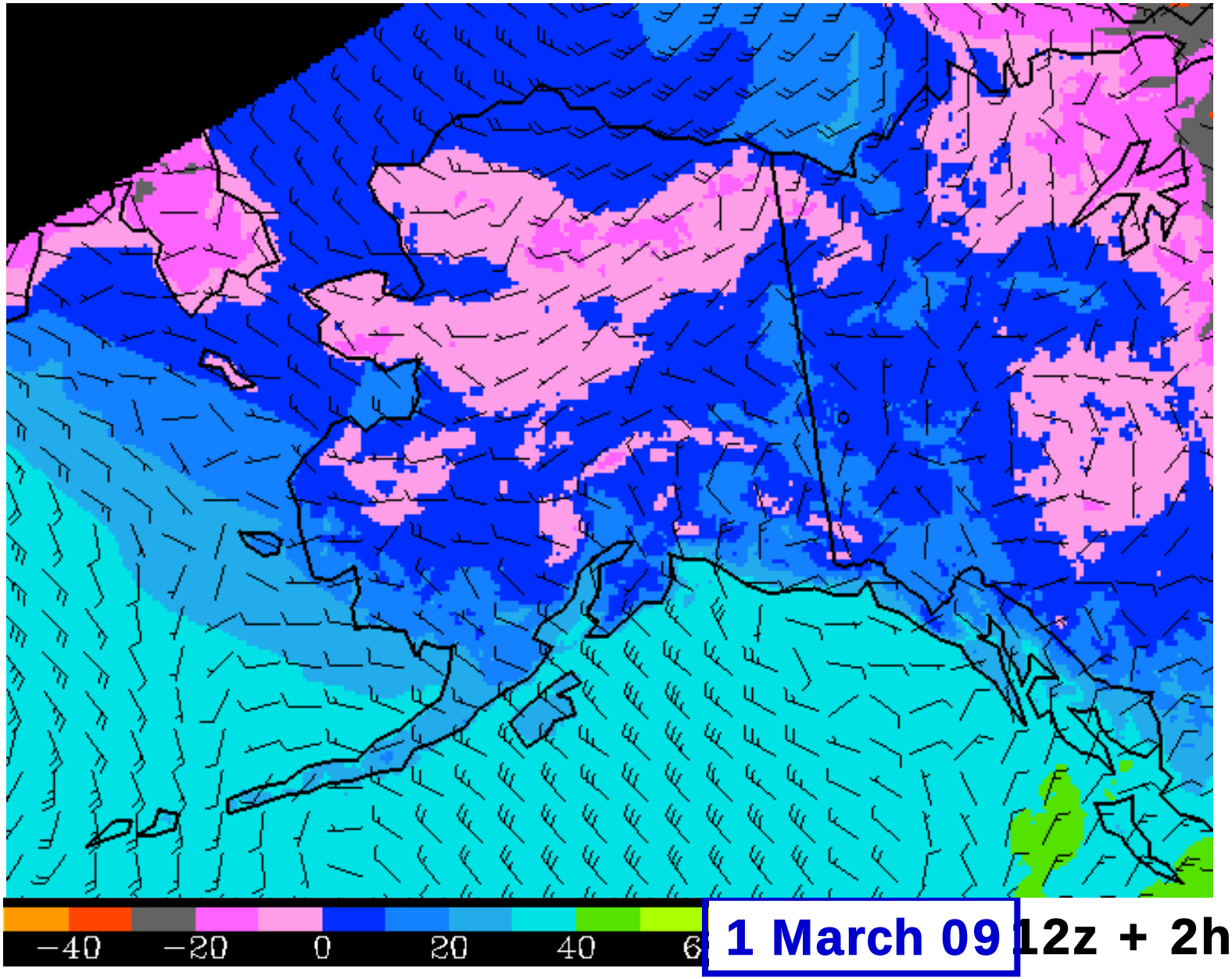


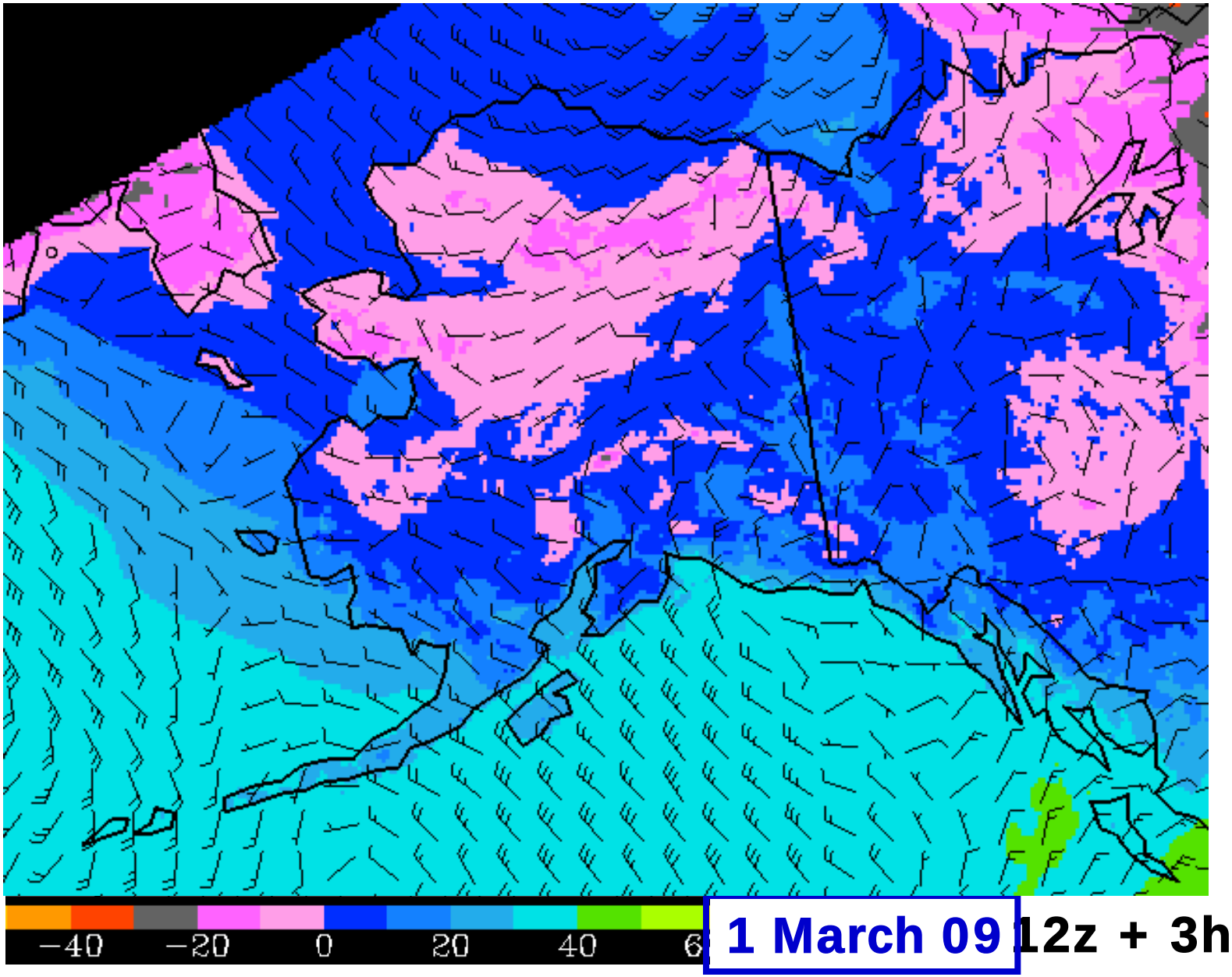
Valid time

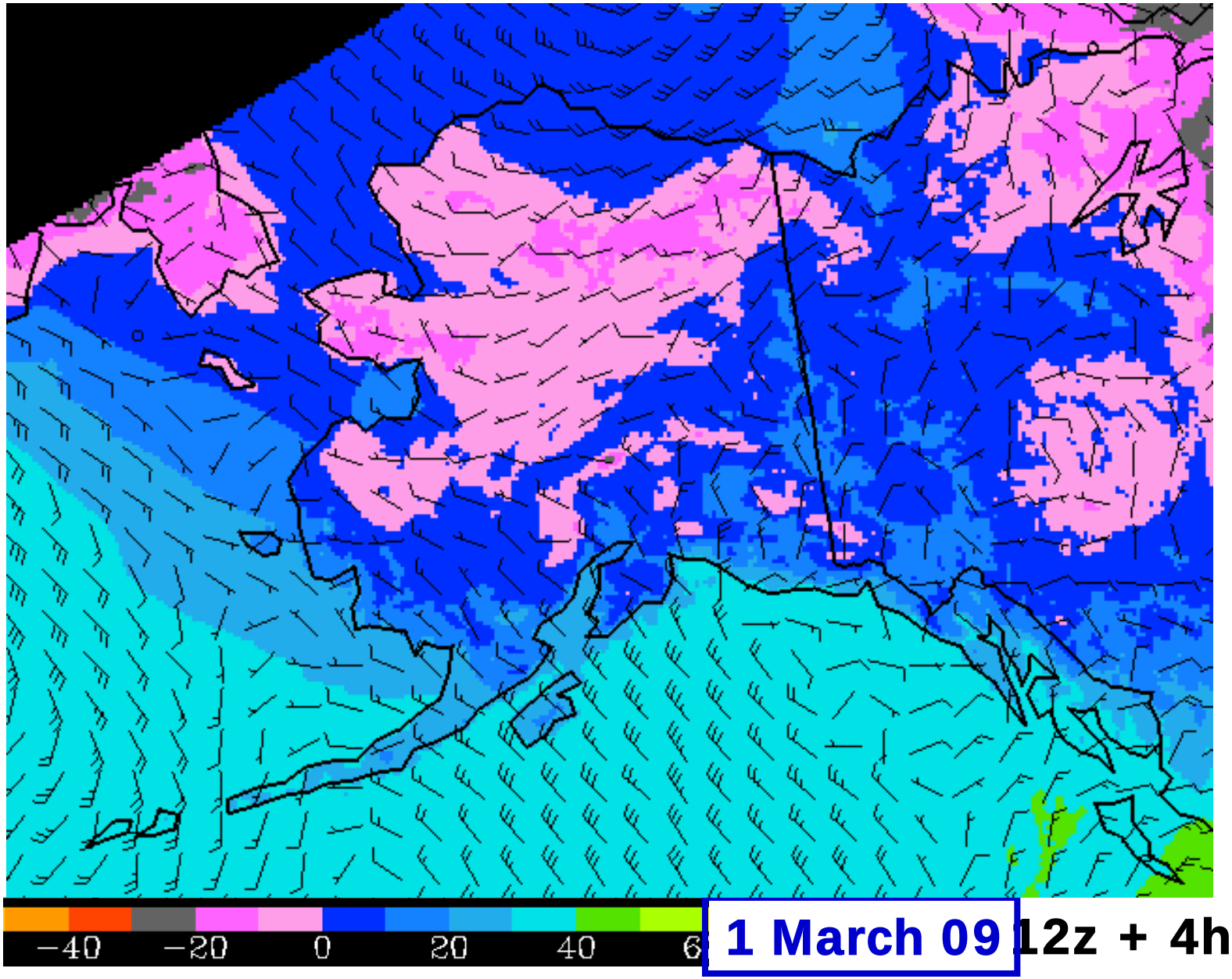
12 z valid times

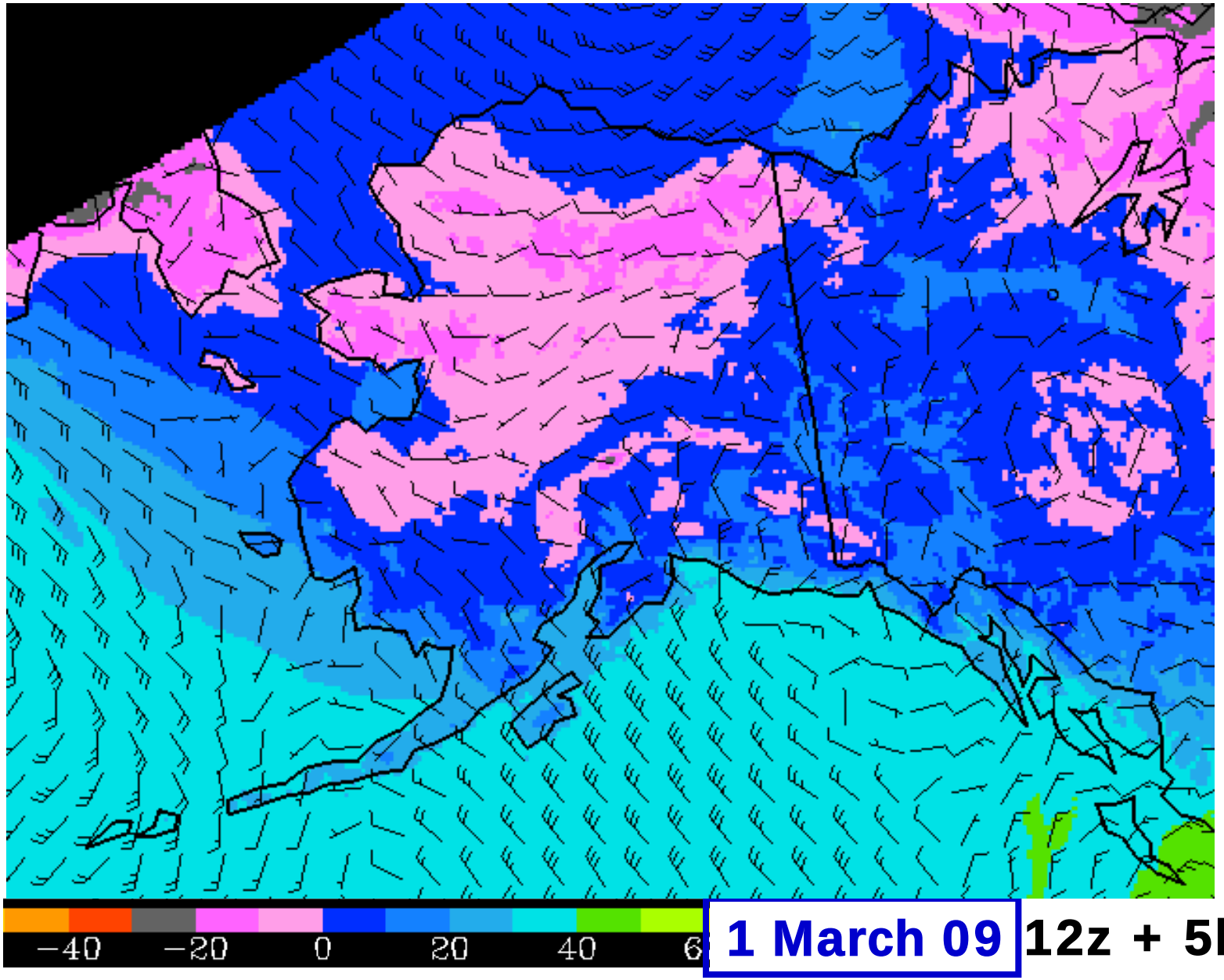

−40
−20
0
20
40
6
1 March 09
12z anx

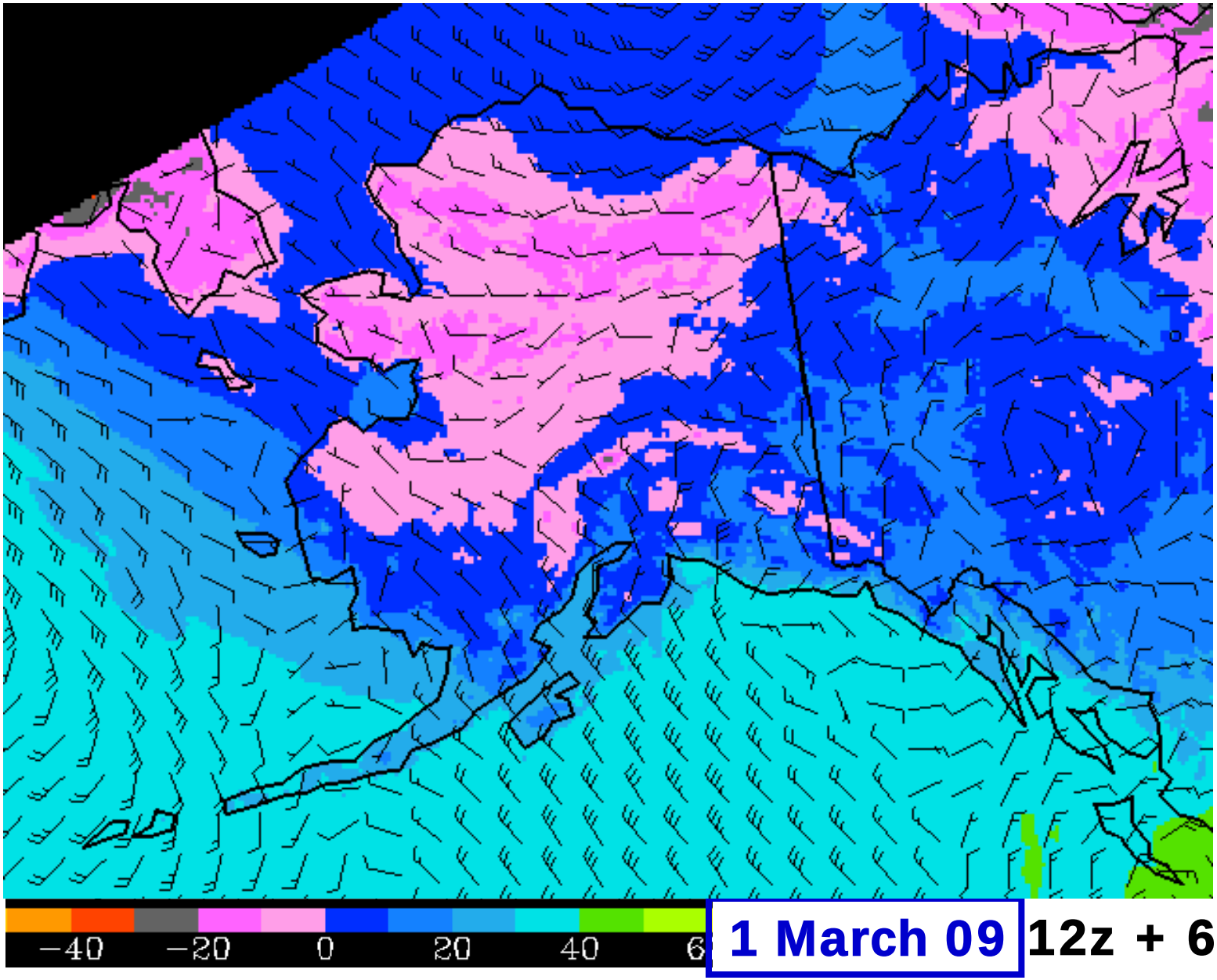

−40
−20
0
20
40
6
1 March 09
12z + 1h


−40
−20
0
20
40
6
1 March 09
12z + 2h

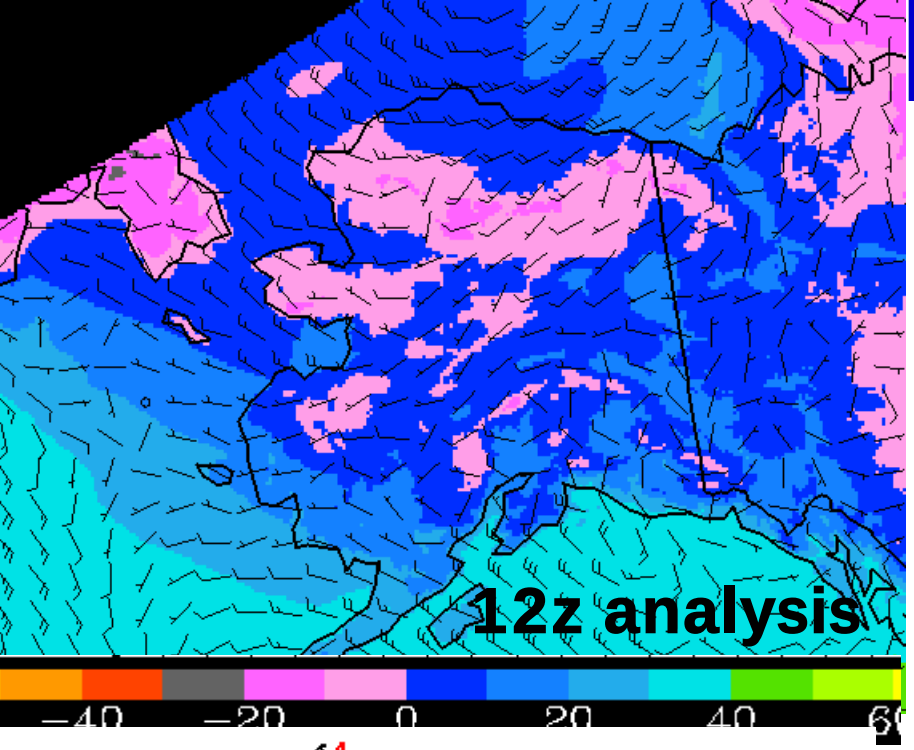

−40
−20
0
20
40
6
1 March 09
12z + 3h

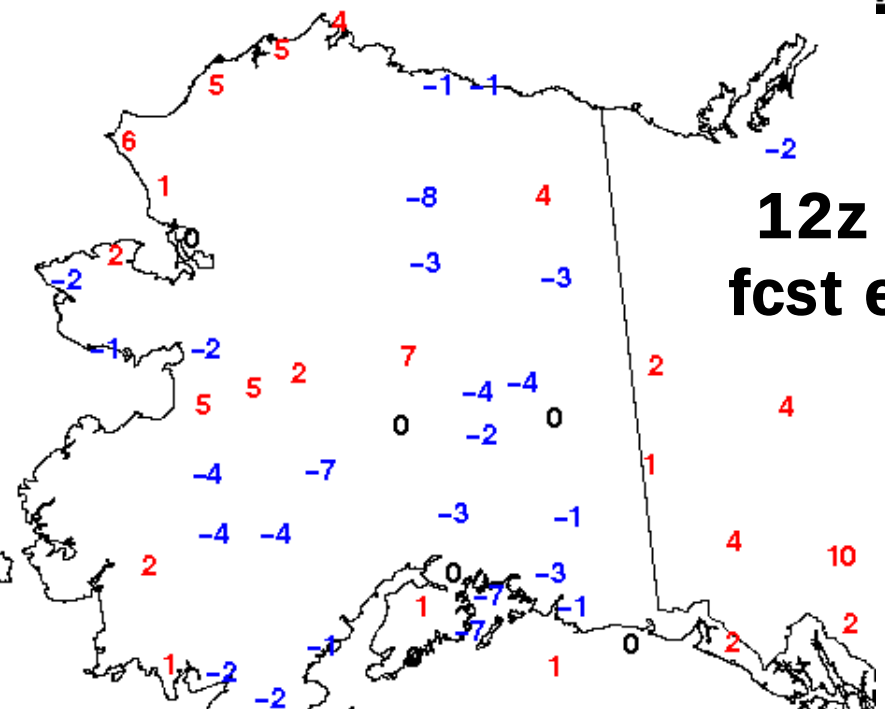

−40
−20
0
20
40
1 March 09 12z + 4h


−40
−20
0
20
40
1 March 09
12z + 5h

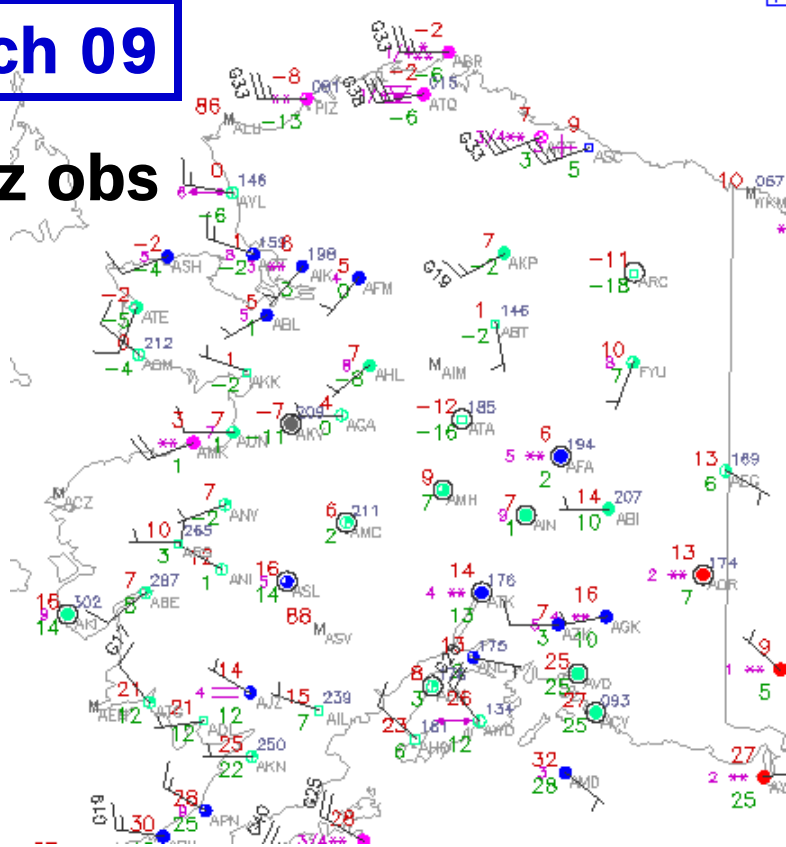

−40
−20
0
20
40
6
1 March 09
12z + 6h

1 March 09

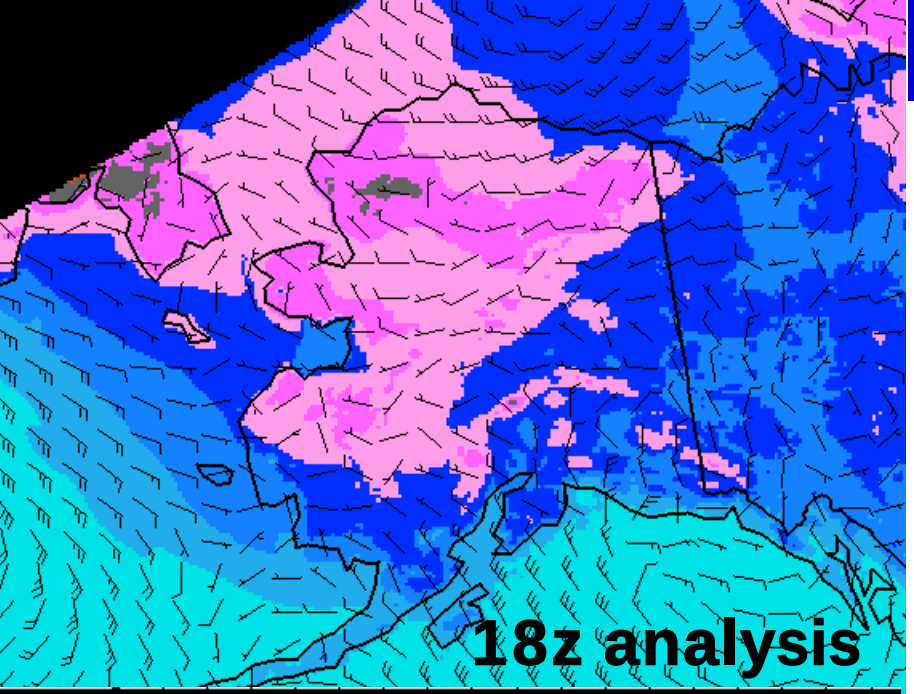


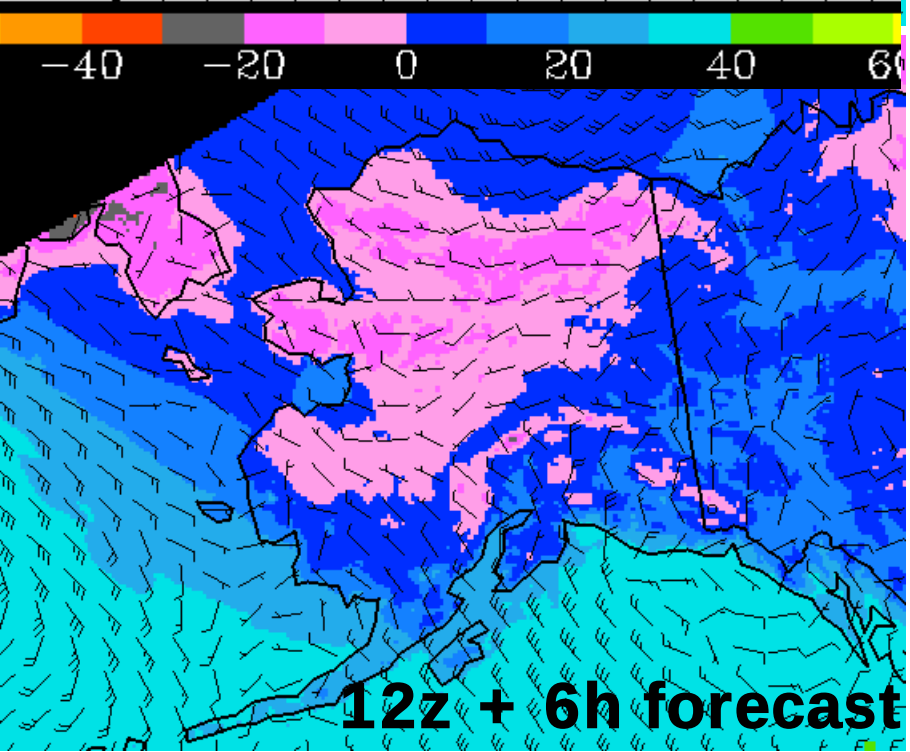


12z anx
fcst error



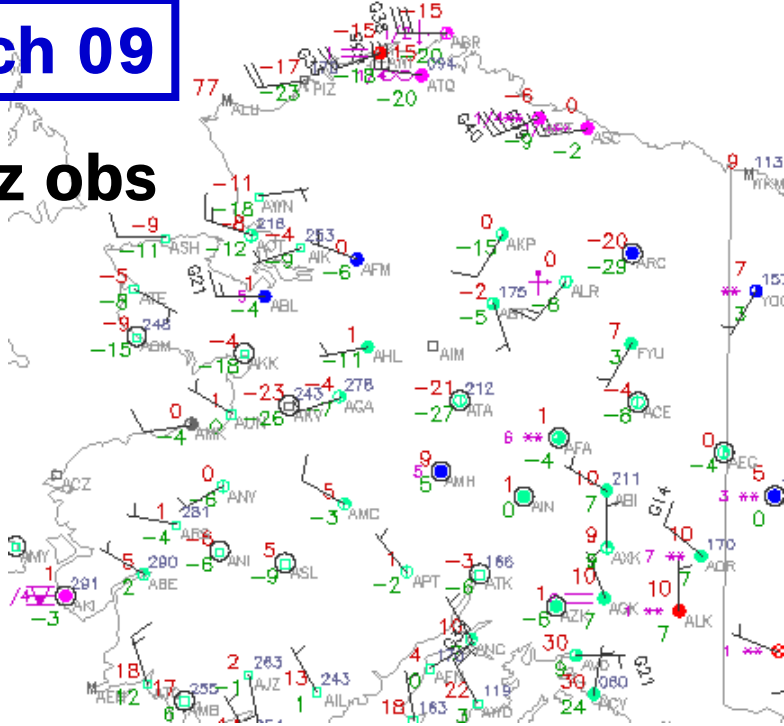
12z obs



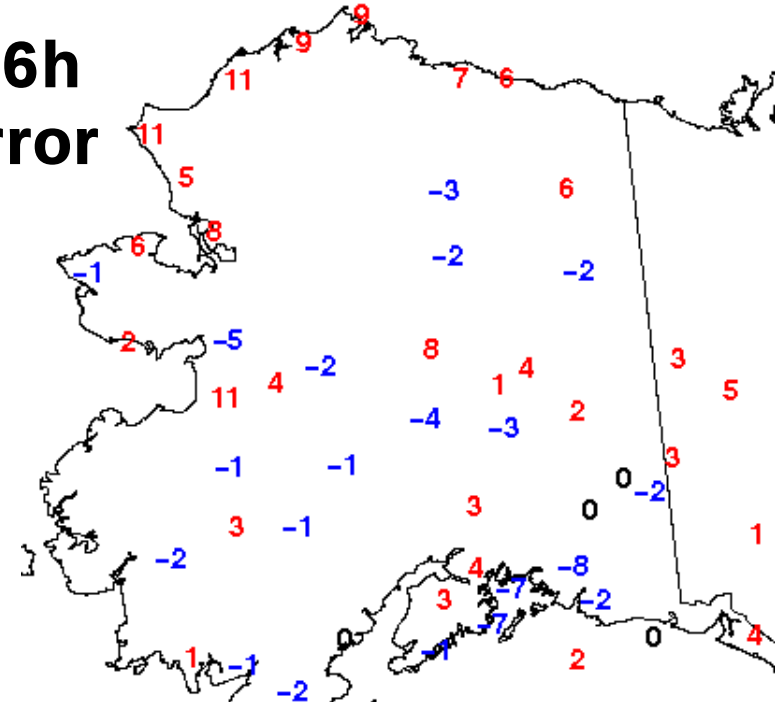


1 March 09

18z obs

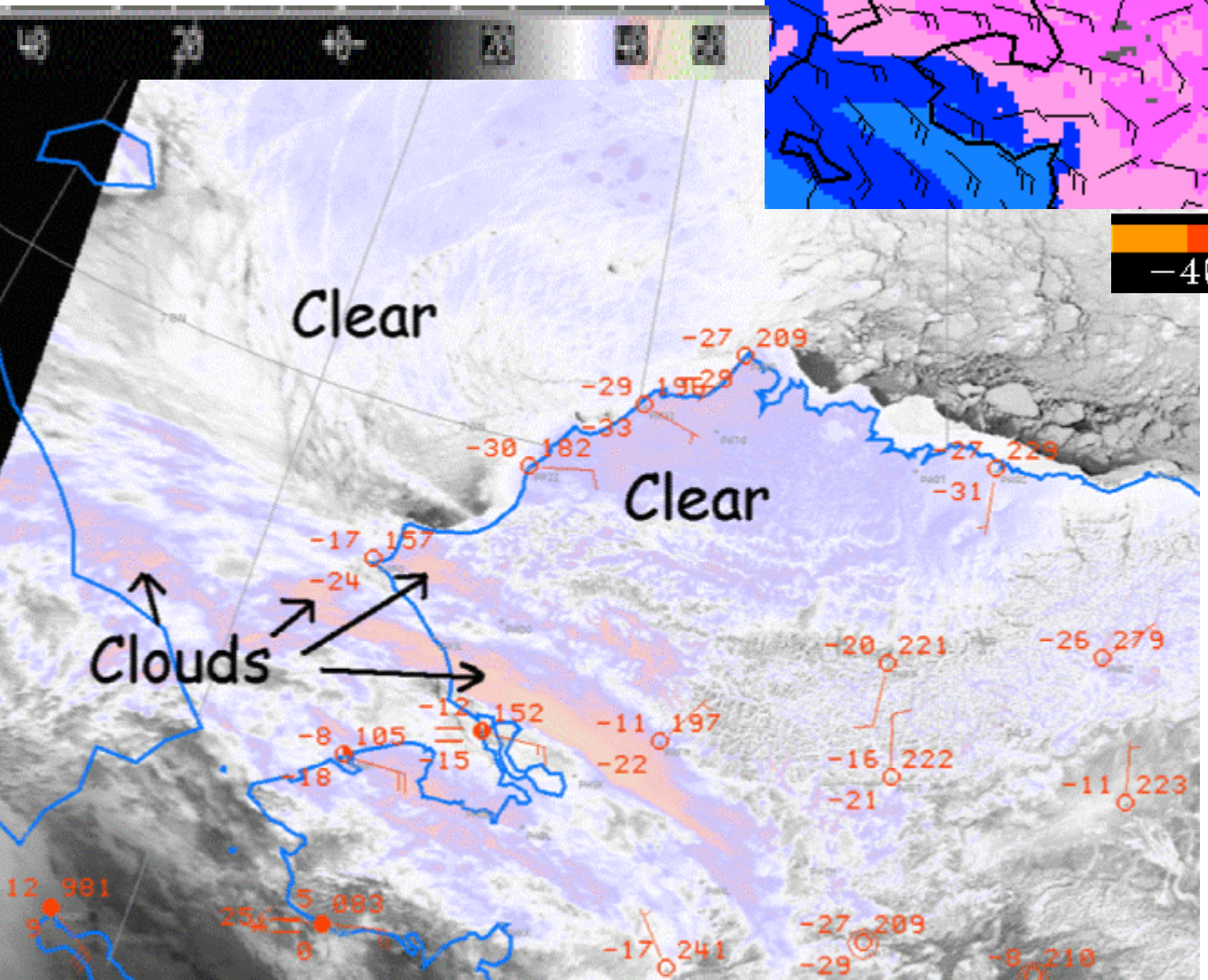


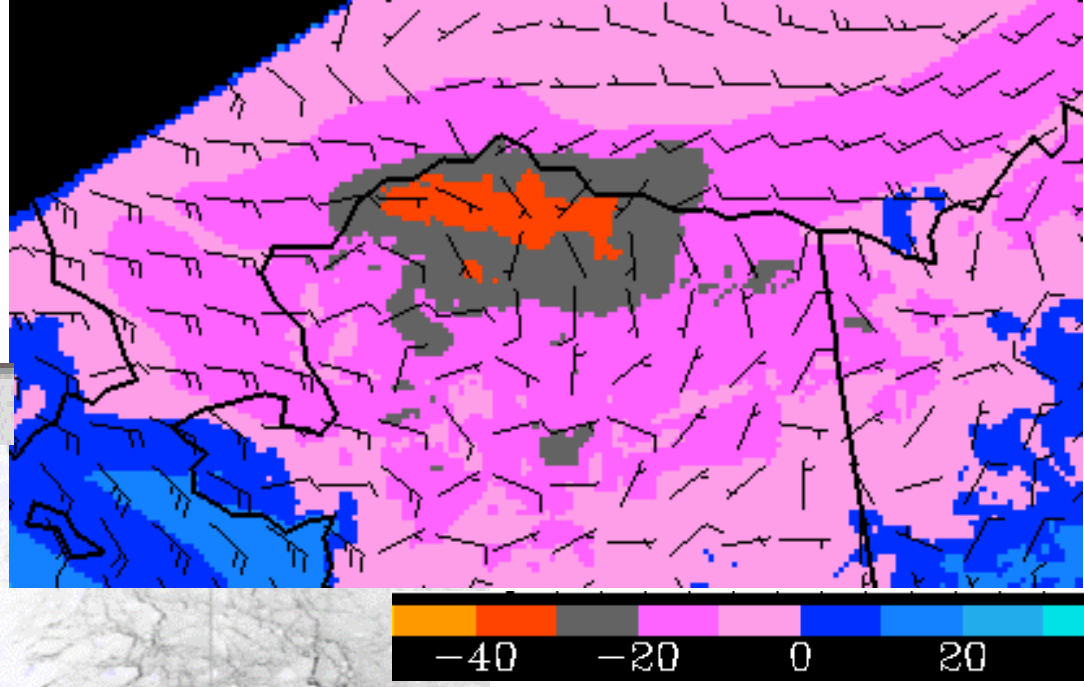
12z+6h Fcst error



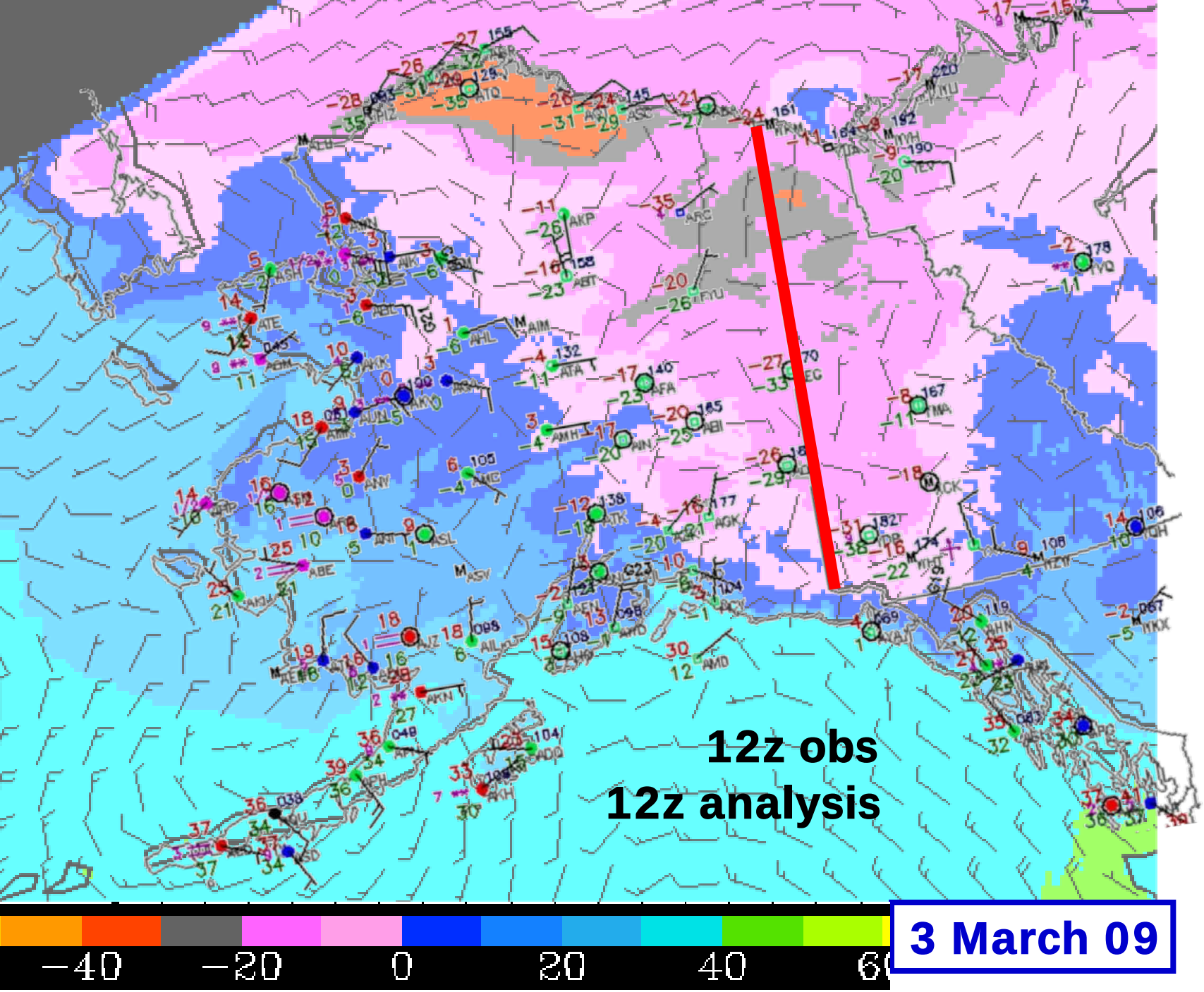
2 March 09

12z satellite image

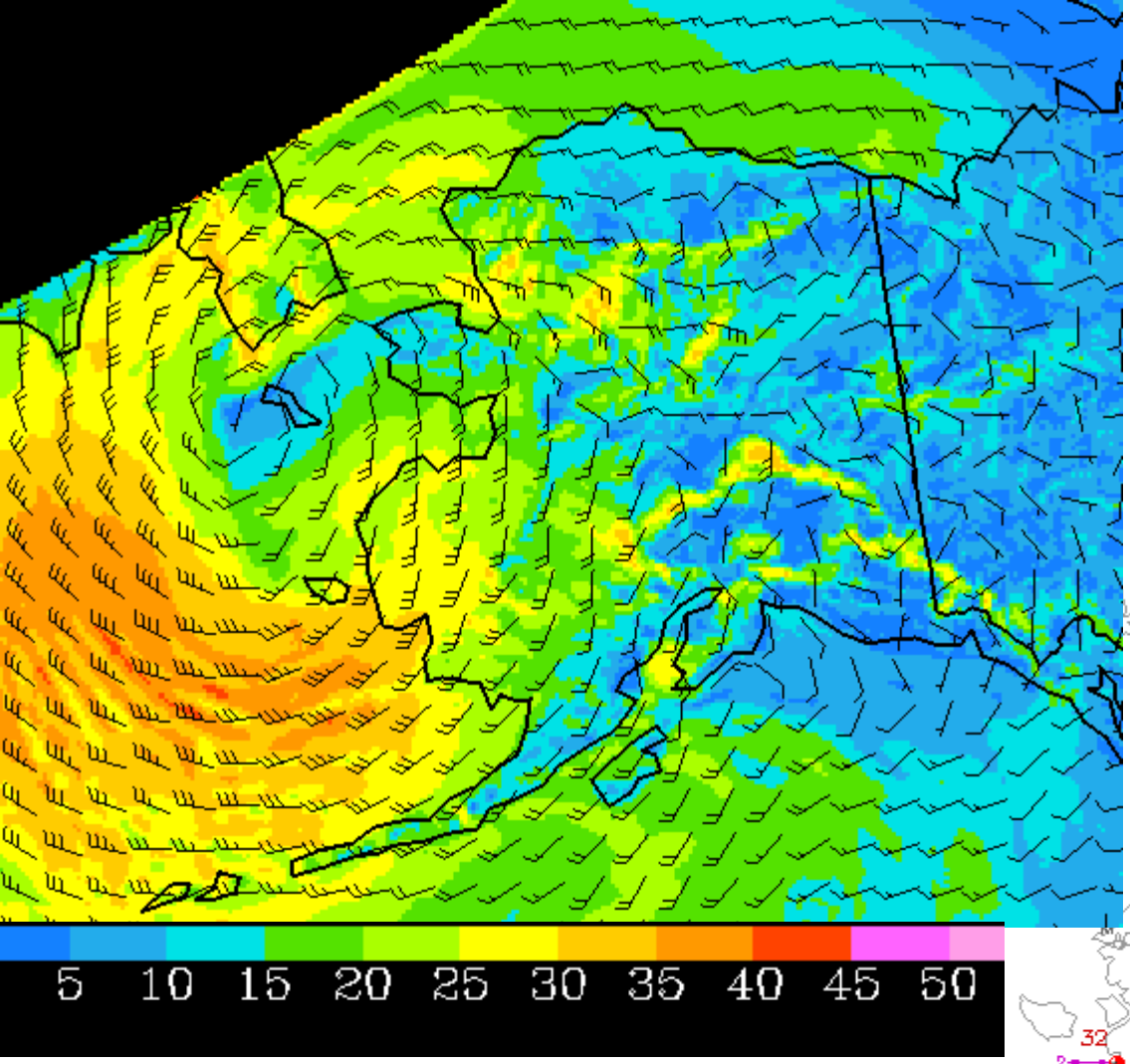




12z + 8h fcst

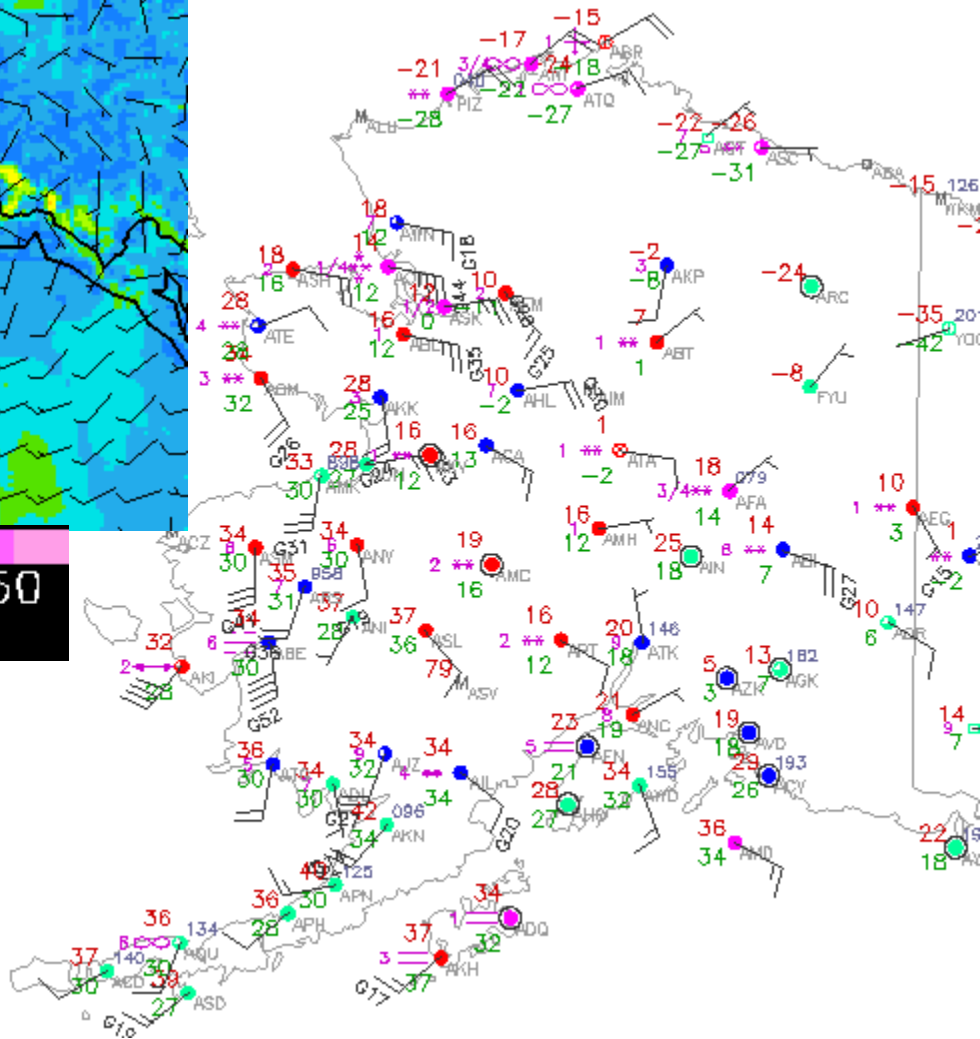

12z obs
12z analysis
−40
−20
0
20
40
3 March 09

5 Mar 2009



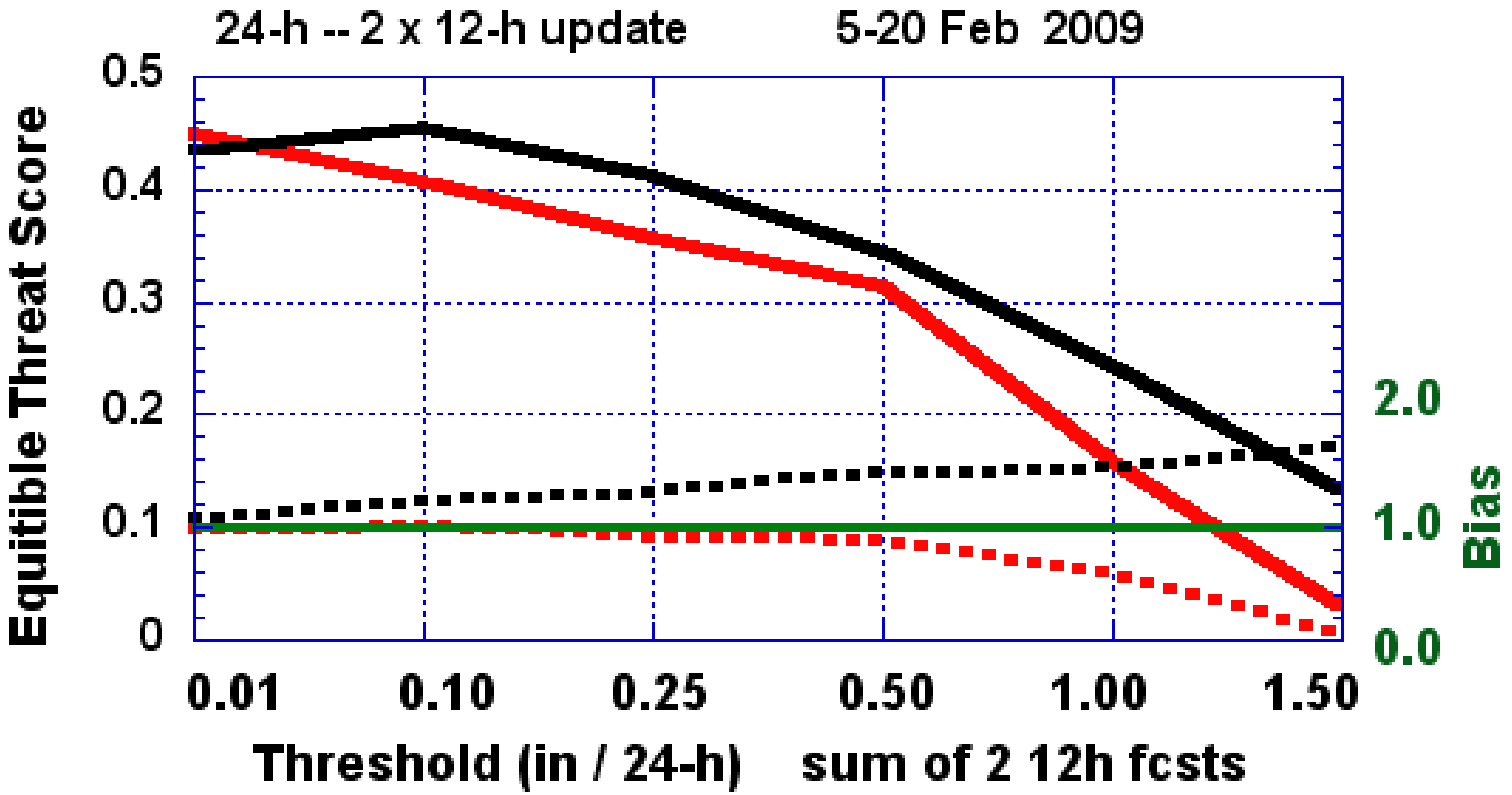
03z + 12h fcst sfc. wind

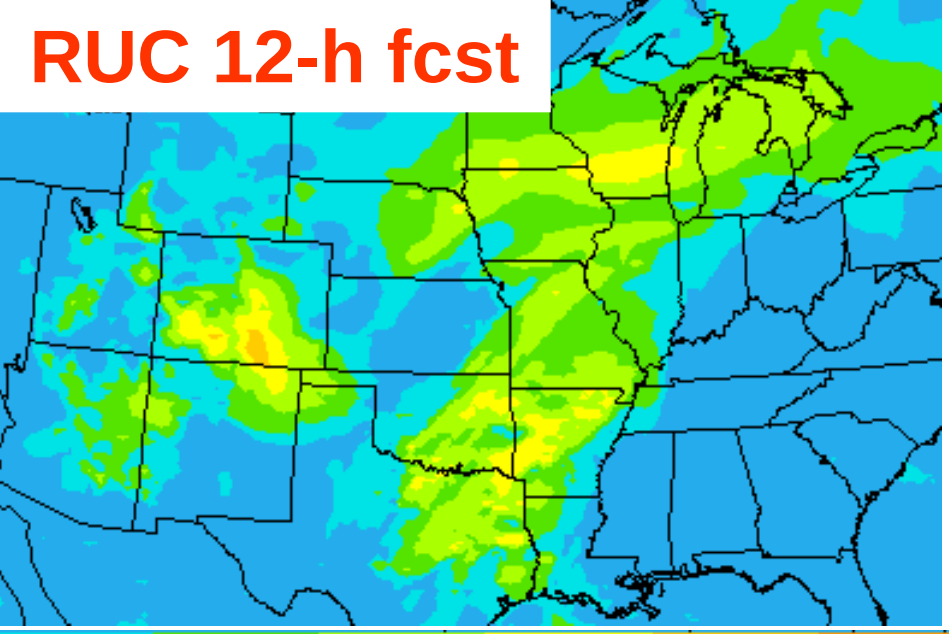
15z obs

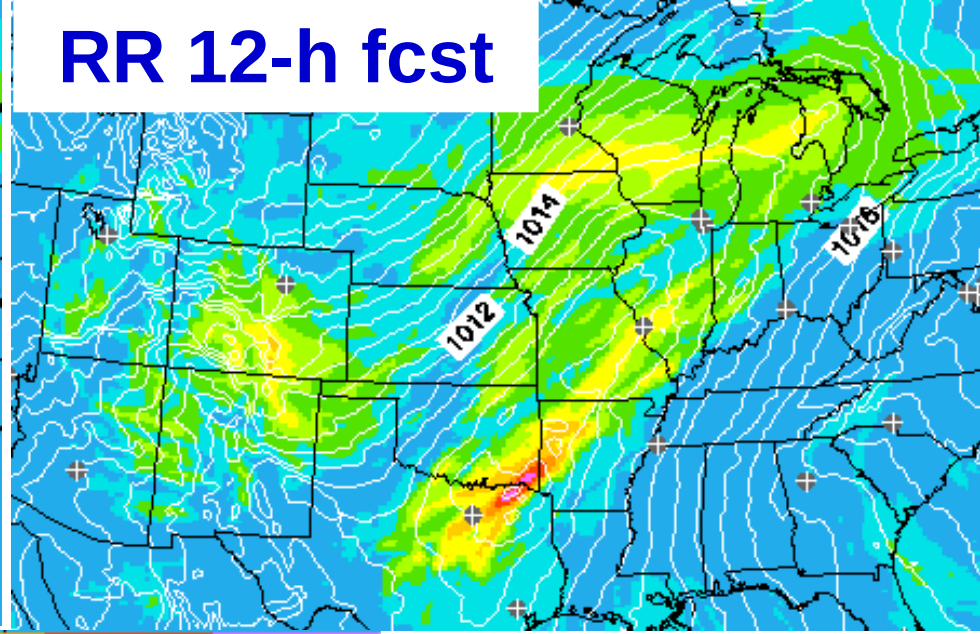


Comparison of Rapid Refresh and RUC precipitation skill scores

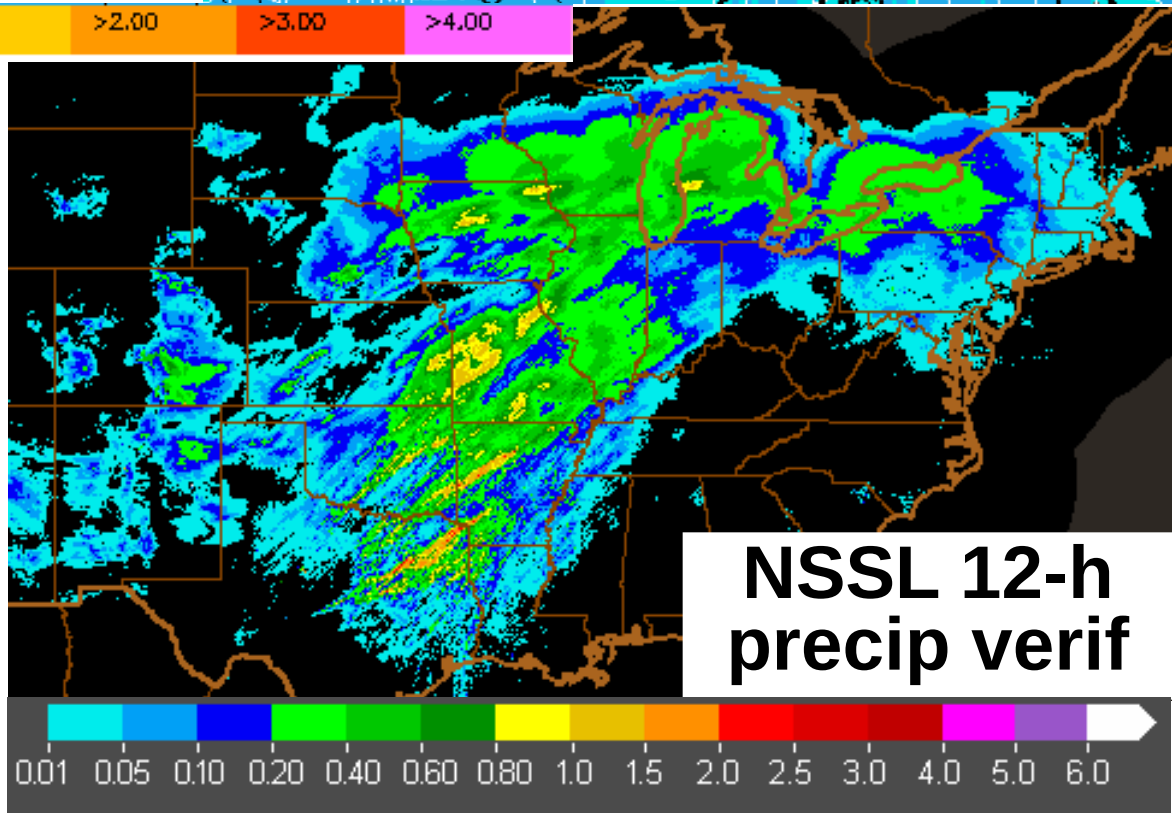
- RR has improved ETS for nearly all threshold
- RR bias higher, especially for higher thresholds





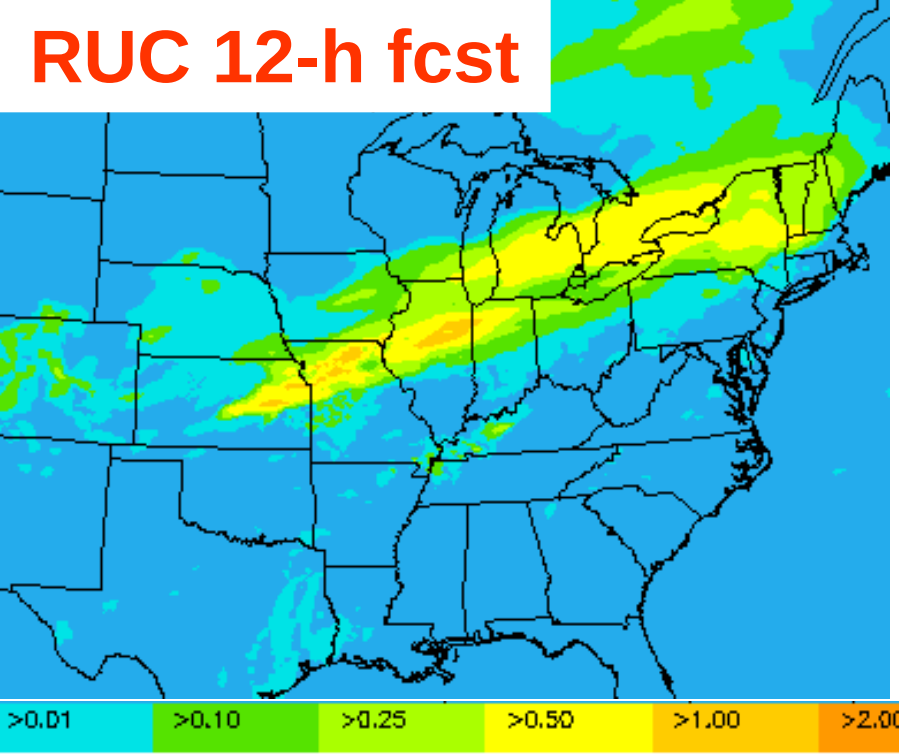


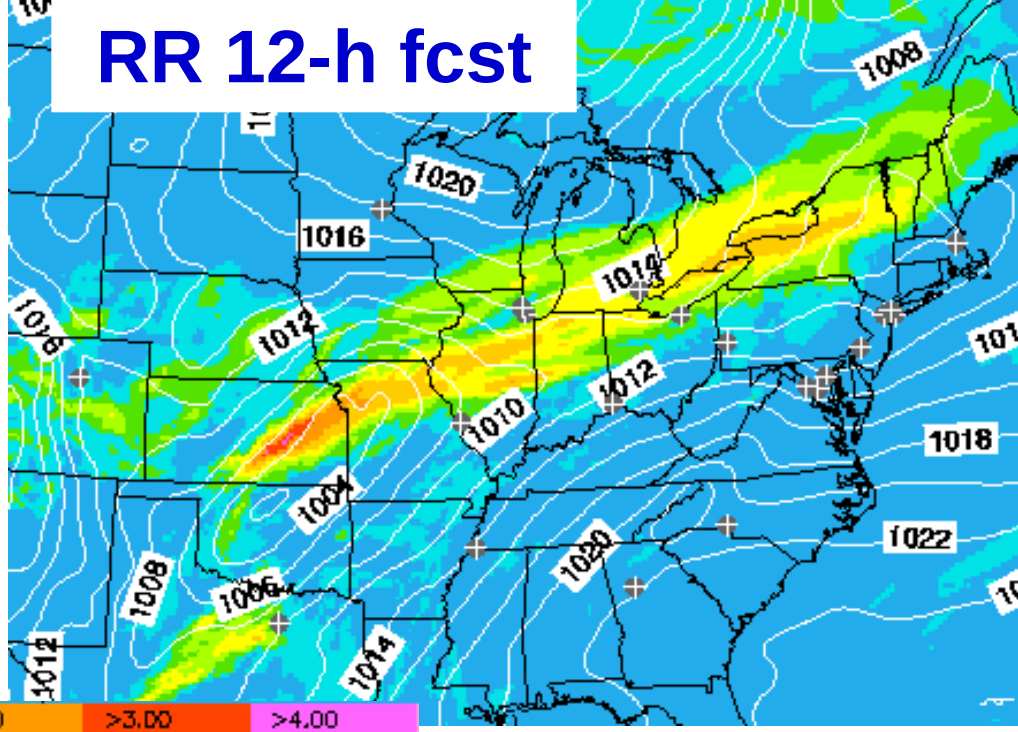
12-h accum. precipitation 12z Dec 9, 2008



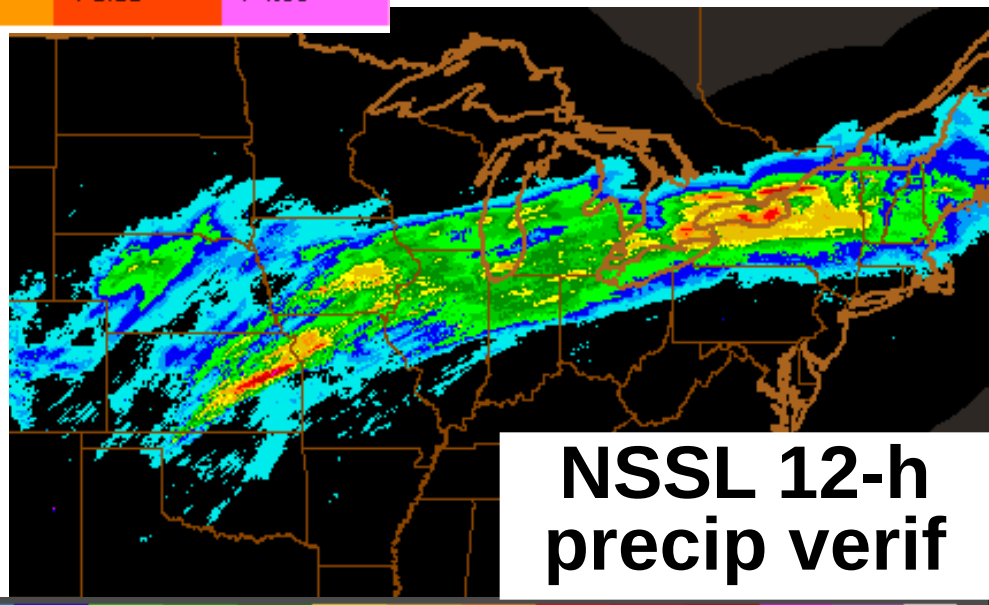
RUC 12-h fcst

RR 12-h fcst





12-h accum. precipitation 06z Mar 8, 2009



NSSL 12-h precip verif

Outline

Rapid Refresh challenges

- Consistent hourly updated grids for all of North America
- Match/exceed RUC skill over CONUS, other model skill elsewhere (upper-level winds, surface fields, clouds, storms)

Rapid Refresh data assimilation features

- Switch from RUC 3DVAR to Gridpoint Statistical Interpolation (GSI)
- Special observation treatments (surface, clouds, radar, lightning)

Preliminary RUC / Rapid Refresh comparison

- Upper level statistics and sounding structures
- Surface field statistics and case study examples
- Precipitation statistics and case study examples

Details on High Resolution Rapid Refresh

- Summer 2008 convective forecasts
- Real-time Western U.S. HRRR-chem runs

Rapid Refresh Summary

Relationship of HRRR to RR

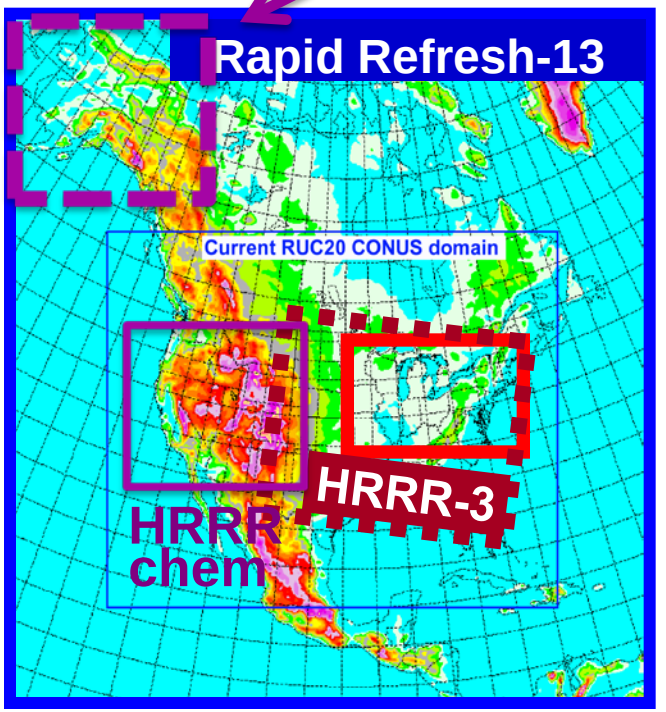
- **HRRR runs as a nest within RUC, transition to run HRRR as nest within Rapid Refresh**
- **Data assimilation for HRRR is within RUC, similar data assimilation exists for RR**
- **Key HRRR features for success:**

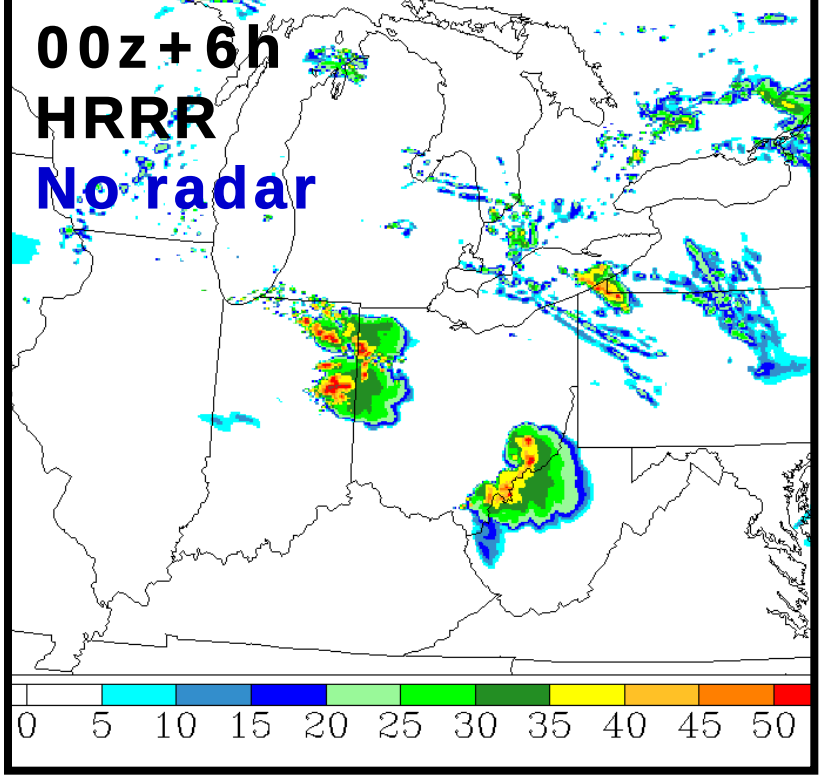
3-km resolution (realistic thunderstorm structures, improved terrain-related features)

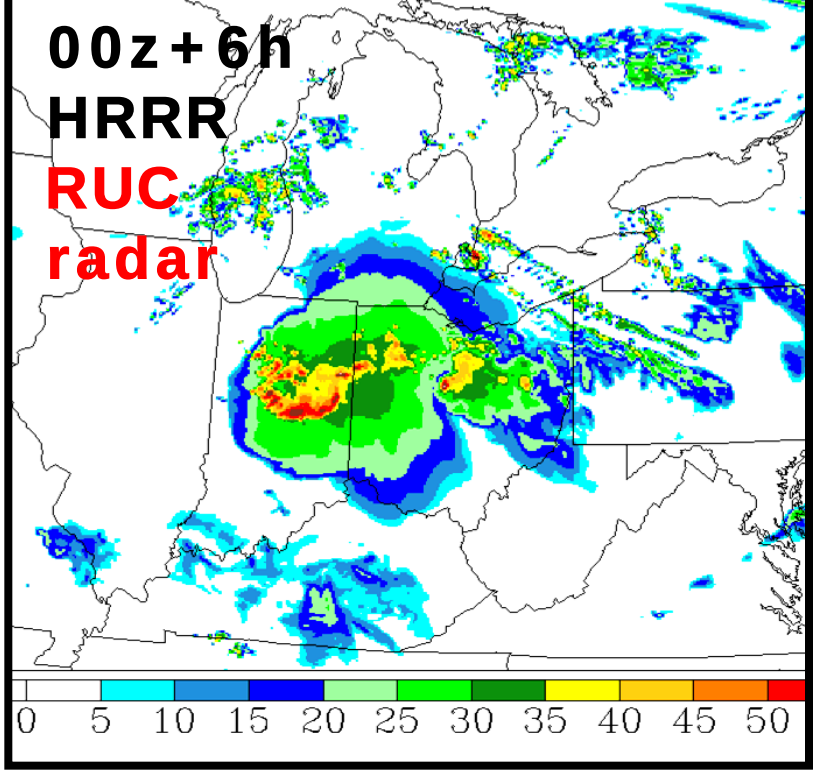
RUC/RR reflectivity assimilation (improved location of thunderstorms)

  – Supplemental radar assimilation planned for HRRR 3-km grid

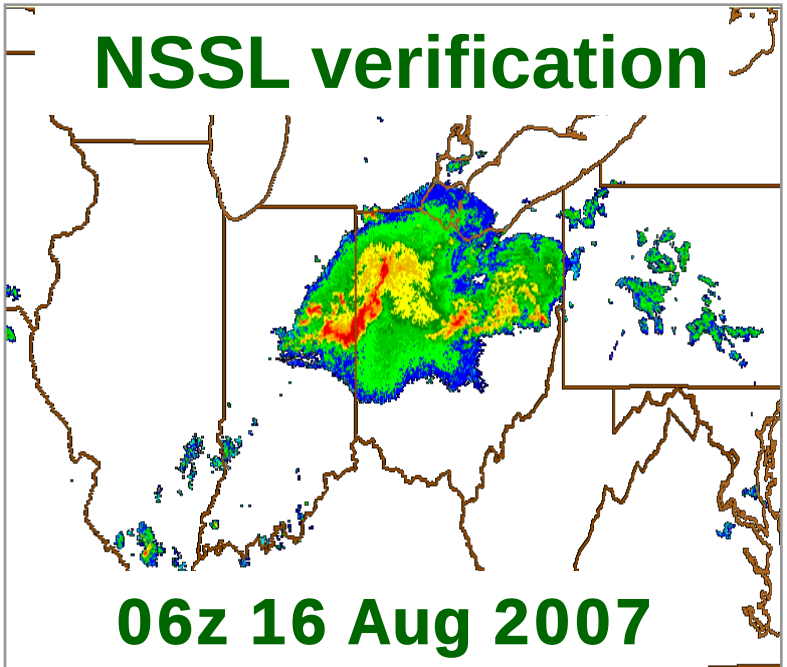
  – Assimilation of other observations will likely remain on 13-km grid



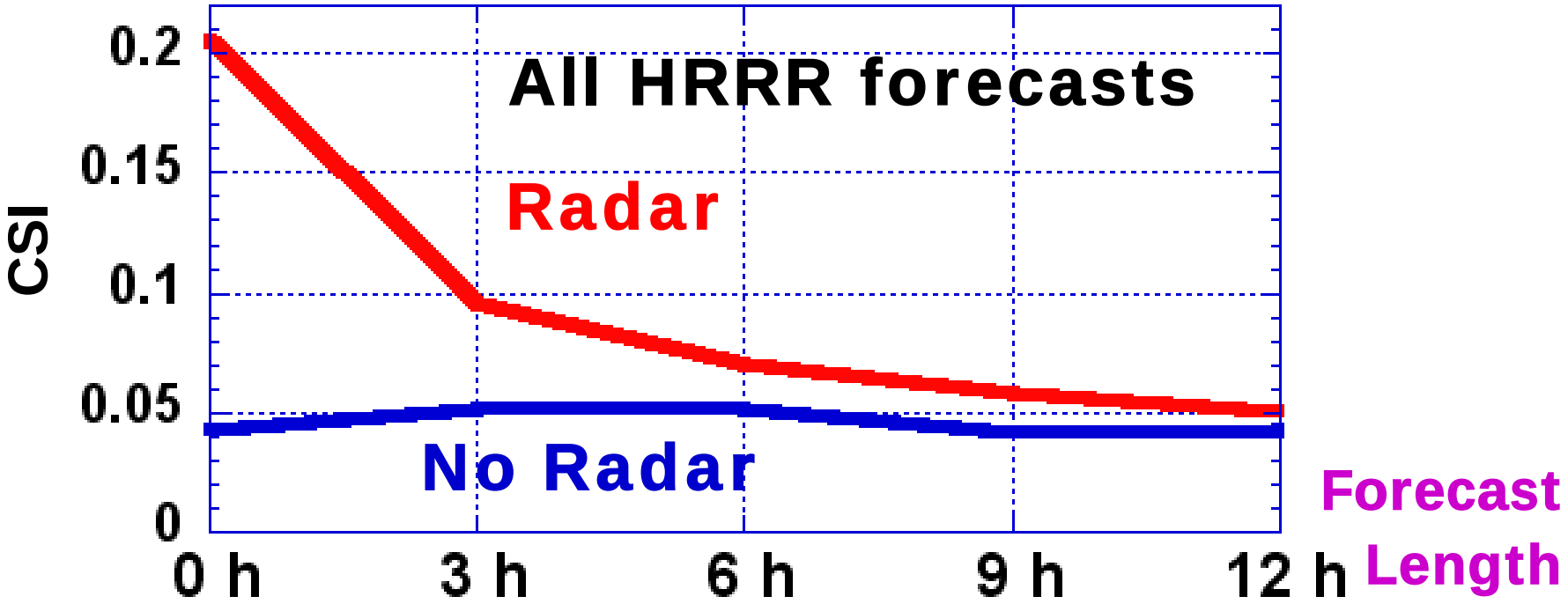




RUC radar assimilation on 13-km grid improves HRRR 3-km forecast



HRRR reflectivity verification
Skill vs. forecast length



30 dBZ reflectivity
on HRRR 3-km grid

Verification period
23 June – 25 Aug 2008

Real-time HRRR-Chem

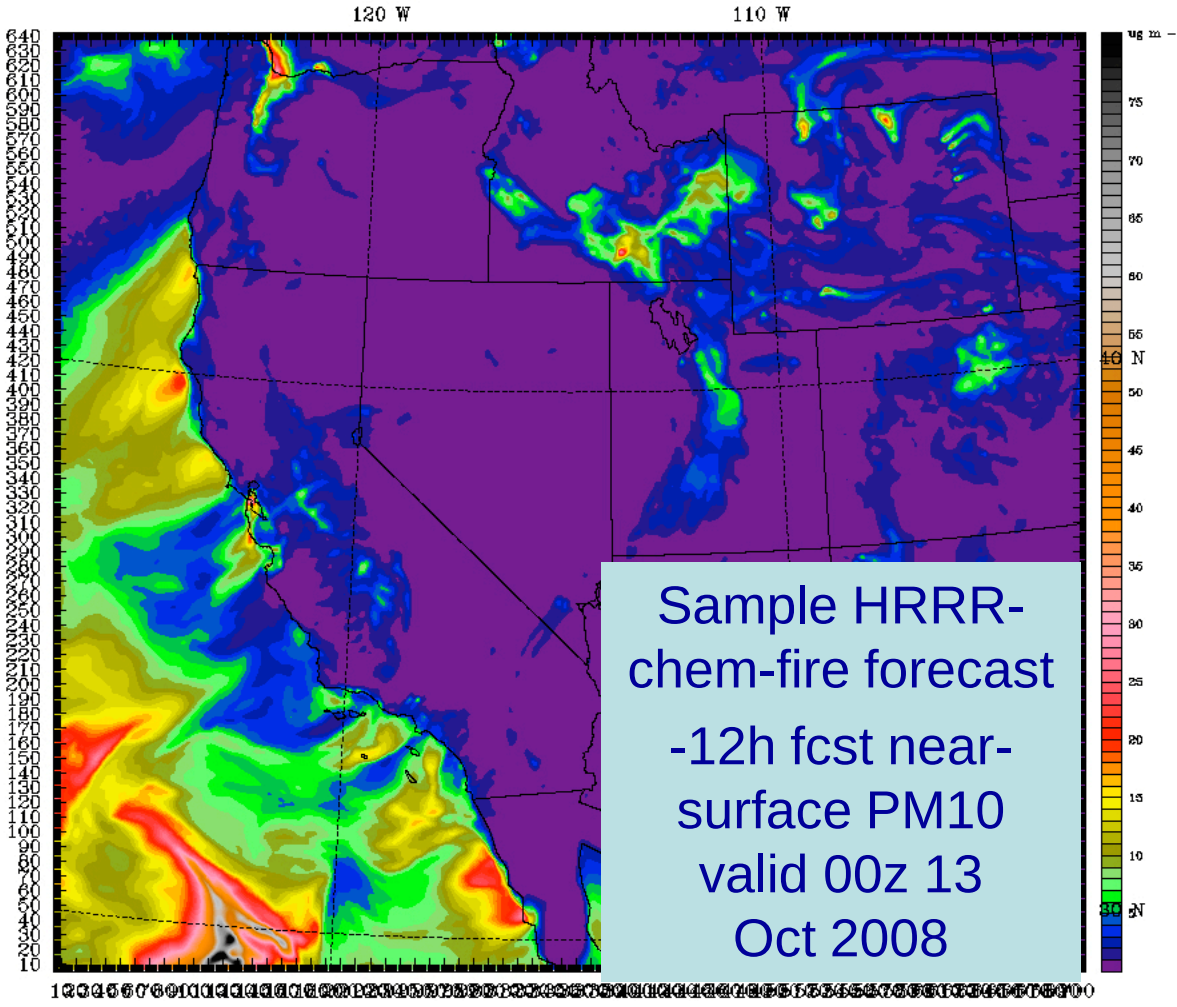
Georg Grell, Tanya Smirnova, Steven Peckham,
Brian Jamison, John Brown, Stan Benjamin

HRRR-chem domain

3 km horizontal grid
711 x 647 grid points
51 Vertical levels
Vertical stretched

Physics options:
Thompson microphysics
Goddard SW
RRTM LW scheme
RUC land surface
MYJ TKE PBL scheme

Chemistry options:
RADM2/SORGAM
Aerosol-Radiation feedback (direct effect)



Real Time AQ Forecasts

http://ruc.noaa.gov/hrrr

http://www-frd.fsl.noaa.gov/mab/hrrr3wchem/

Every 6 h over the western US (as of Aug08)

Real-time fire information (GOES ABBA) to provide air quality guidance

Uses radar-enhanced RUC-DFI (Digital Filter Initialization) grids

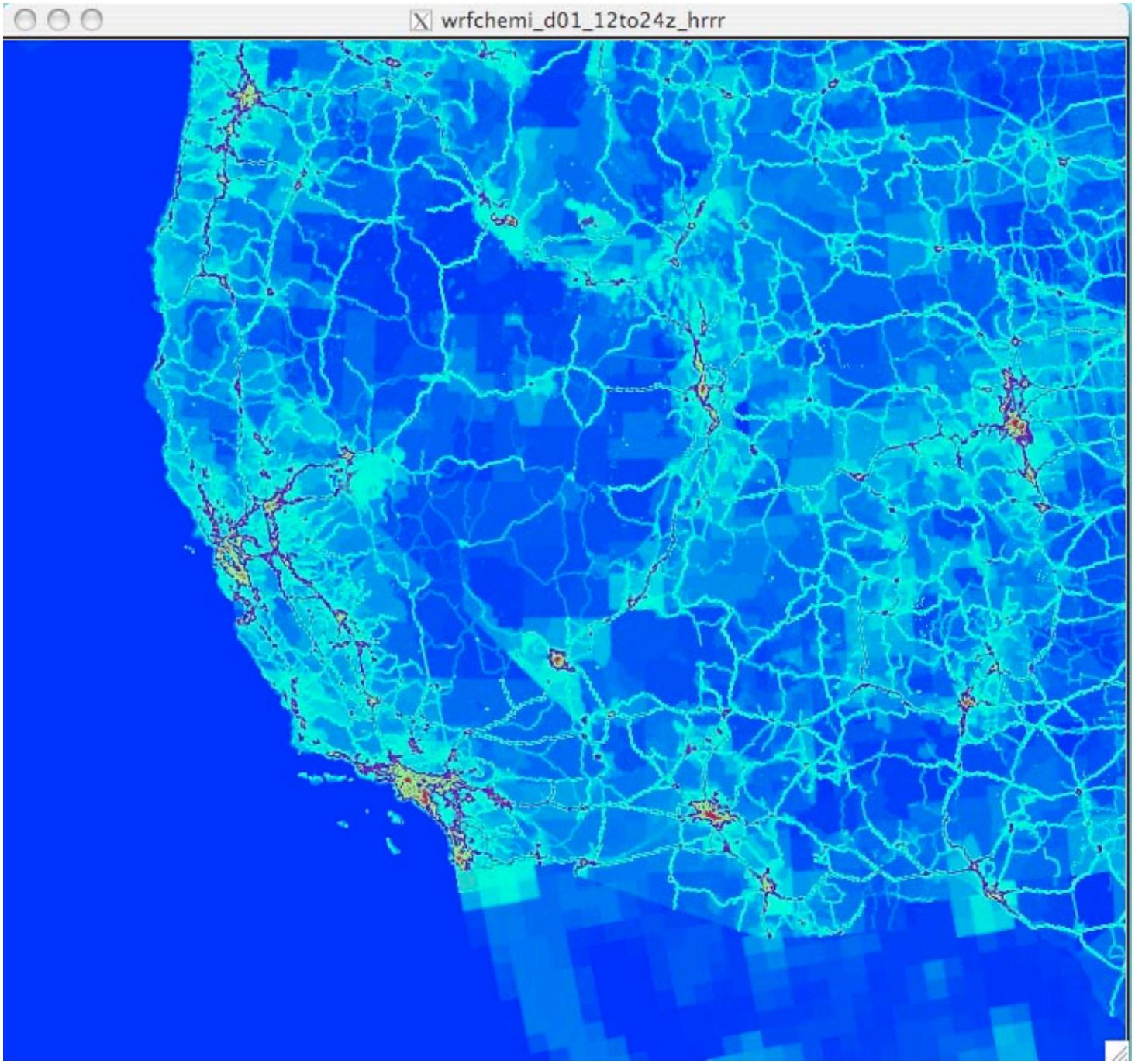
- atmospheric initial conditions, same as hourly NE Corridor HRRR.

Cycled chemistry variables, including:

- Ozone,
- PM 10 aerosol,
- PM 2.5 aerosol.

Includes direct effect feedback from atmospheric aerosols

CO emissions file (daytime) used in HRRR-chem-fire runs



Possible configurations and applications for HRRR-chem

- Full coupled atmos-chem model with hourly updated
  - Fire forecasting
  - Application a few hours out
- Emergency trajectories
  - Hazardous emission
  - Use pre-calculated trajectories,
  - Will benefit from hourly updating, even chemistry effects on PBL mixing

Rapid Refresh Assessment Summary

skill evaluation

- Upper level winds, temperatures better than RUC
- Precipitation similar to RUC (better ETS, higher bias)
- **Issues with surface fields, especially inversions**

Surface observation assimilation -- ongoing

- **Account for model vs. terrain height difference**
- **Apply surface obs. innovations through PBL**
- **Select best background for coastal observations**

Other remaining RR tasks

- Resolve periodic lateral BC crashes
- Add satellite cloud products for high latitudes
- LSM, snow cycling issues