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4A.6 THE RTMA BACKGROUND – HOURLY DOWNSCALING OF RUC DATA TO 5-KM DETAIL

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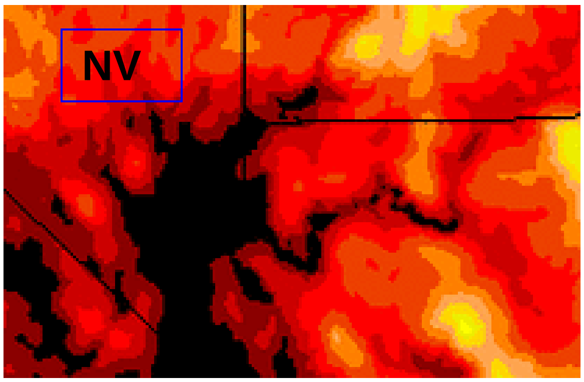

Figure 1. Example of RUC-RTMA 5-km downscaled 2-m temperature (Units - deg F, 21z 7 Aug 2006) over NV, UT, and AZ (including Grand Canyon). (See Figs. 7-9 for more details).

1. INTRODUCTION

In spring 2006, an initial version of the 5-km downscaling of RUC data for the CONUS Real-Time Mesoscale Analysis (RTMA) was implemented at the National Centers for Environmental Prediction. Since that time, the RUC downscaling techniques within the RUC post-processing have been refined several times, based on daily reviews by forecasters within the National Weather Service (NWS). Upgrades have been made to the RUC-RTMA downscaling as recently as in April 2007, and here we summarize its current status.

The Real-Time Mesoscale Analysis is designed to provide the best 5-km gridded estimate of current surface and near-surface conditions on an hourly basis in support of National Weather Service operational activities and the NWS National Digital Forecast Database (NDFD). Even with availability of increasingly dense mesonet observations, the RTMA must incorporate a 3-d atmospheric/land-surface model to ensure some measure of physical consistency with land-surface conditions, land-water contrasts, terrain elevation, and even includes 3-d effects with realistic thermal stability, boundary-layer structure, and local circulations. Therefore, the RTMA relies on a background field fully consistent

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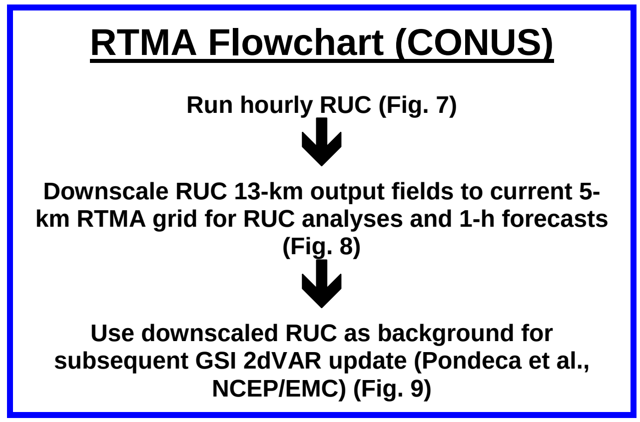

Figure 2. Flowchart for RTMA processing.

with these 3-d model-based effects by using the previous 1-h forecast from the Rapid Update Cycle (RUC). The RUC, with its detailed hourly assimilation of 3-d atmospheric observations and special emphasis on 3-d variational assimilation of METAR and mesonet data, is appropriate for providing the RTMA background field for a subsequent GSI-2dVAR enhancement (see Pondeca et al. 2007 at this same conference).

As part of the hourly postprocessing in the NCEP-operational 13-km RUC, a downscaling technique was developed to produce 5-km gridded fields from the full-resolution native (hybrid sigma-isentropic) RUC coordinate data to calculate values consistent with the higher-resolution 5-km RTMA terrain elevation field (e.g., Fig. 1). The RUC-RTMA downscaling technique includes both *horizontal* and *vertical* components. The vertical component uses near-surface stability from the RUC native data to adjust to the RTMA 5-km terrain with variable-dependent treatment for vertical extrapolation vs. interpolation. In the horizontal, for example, coastline definition is enhanced as part of this RUC-RTMA downscaling using a 5-km land/water mask to sharpen land-water boundaries on the 5-km RTMA grid. The fields downscaled to the 5-km grid include

- 2-m temperature
- 2-m dewpoint
- surface pressure
- 10-m wind components
- 2-m specific humidity
- gust wind speed
- cloud base height (ceiling)
- visibility

Ceiling and visibility (not yet required for RTMA) are defined with some accuracy due to RUC hourly assimilation of METAR cloud and visibility observations.

RTMA downscaling for temperature uses virtual potential temperature (θ_v), the related prognostic/analysis variable in the RUC model/assimilation systems. This is advantageous for interpolation in irregular terrain in mixed layer conditions. Different techniques were developed for these different variables, including special approaches for vertical extrapolation vs. interpolation dependent on whether RTMA terrain elevation is higher or lower than RUC terrain. The accuracy of the RTMA fields is dependent on this RUC-RTMA downscaling, and therefore, of considerable interest to NWS RTMA users.

2. Characteristics of RUC analysis appropriate for Real-Time Mesoscale Analysis

Use of the RUC analyses or 1-h forecasts as the background for the RTMA brings unique advantages for accuracy of the RTMA. Benjamin et al. (2004a) have demonstrated clearly that assimilation of the latest observations using the RUC analysis / 1-h forecast cycle adds value in forecast accuracy. In particular, improved accuracy has been shown specifically for 2-m temperature, 2-m dewpoint, and ceiling/visibility down to the 1-h duration for RUC forecasts. In other words, RUC 1-h forecasts are generally more accurate than 3-h, 6-h, or 12-h forecasts valid at the same time.

We summarize below the key aspects of the RUC below that make it suitable for the RTMA background. These are discussed in more detail in the analysis/1-h cycle and model descriptions in Benjamin et al. (2004a,b):

- Hourly mesoscale analysis (DFI - Digital Filter Initialization essential for non-noisy 1h forecasts)
- Designed to fit observations (within expected error)
(including surface 2-m temperature (via θ_v), dewpoint (via water vapor mixing ratio), altimeter, wind)
- Full-physics 1-h forecast (most important aspects of physics – boundary layer, land-surface contrasts involving vegetation type, satellite-derived vegetation fraction, roughness length, soil type, land/water contrasts, albedo, snow cover, ice cover. (Benjamin et al. 2004b)
- Accounting for local mixed-layer depth in assimilation of surface data (implemented in RUC analysis in June 2005, Benjamin et al. 2004d)
- Accounting of land-water contrast in assimilation of coastal surface observations and buoys (improved in June 2006)
- Assimilation of METAR cloud, visibility, current weather (to infer cloud depth) (Benjamin et al. 2004c)
- Assimilation of mesonet observations (T, Td, sfc pressure)
- Assimilation of GPS precipitable water, boundary-layer profiler observations
- QC criteria for mesonet different than those for METAR observations (to account for different siting standards)
- Assimilation of GOES cloud-top data into initial fields of 3-d hydrometeor fields cycled in the RUC (mixing ratios for cloud water, ice, rain, snow, and graupel).

Two new mesonet quality control (QC) monitoring capabilities have been developed to improve assimilation of mesonet observations, both of which will benefit the RTMA-RUC downscaling. First, a mesonet provider uselist has been defined for providers (e.g., OK Mesonet) that shows consistency with RUC 1-h forecasts for daytime wind speed, and are, therefore, evidence for good mesonet station sitings. This uselist will be introduced to the operational RUC later in 2007, allowing an extra 600 wind observations hourly near the surface.

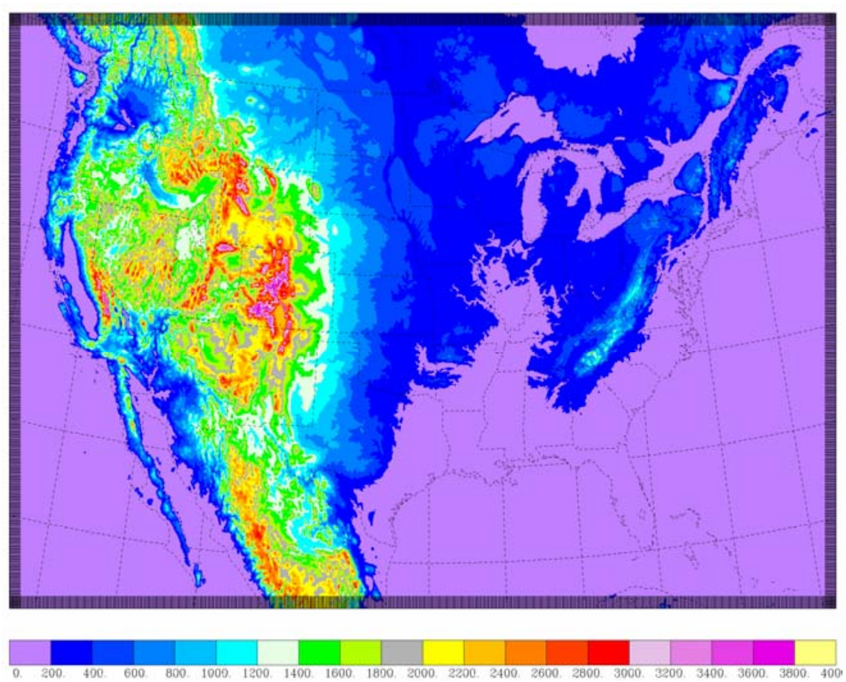

Figure 3. 5-km RTMA-CONUS terrain elevation (no smoothing)

Second, a station-by-station QC monitoring capability for mesonet observation differences with RUC 1-h forecasts, is separately discussed in Benjamin et al. 2007. This will allow daily updates of mesonet station uselists (and reject lists) for each variable.

3. RTMA-RUC downscaling

Currently, the RTMA-RUC downscaling runs at NCEP on an hourly basis at the end of the RUC postprocessing from each RUC hourly cycle. The RTMA-RUC downscaling is currently run only for the analysis (00h) and the 1-h forecast.

Two fixed fields for the 5-km RTMA grids are used, all extracted from the WRF Standard Initialization (WRF-SI) (or WRF Pre-processing System – WPS) program:

- 5-km topography (no smoothing)
- 5-km land-water mask.

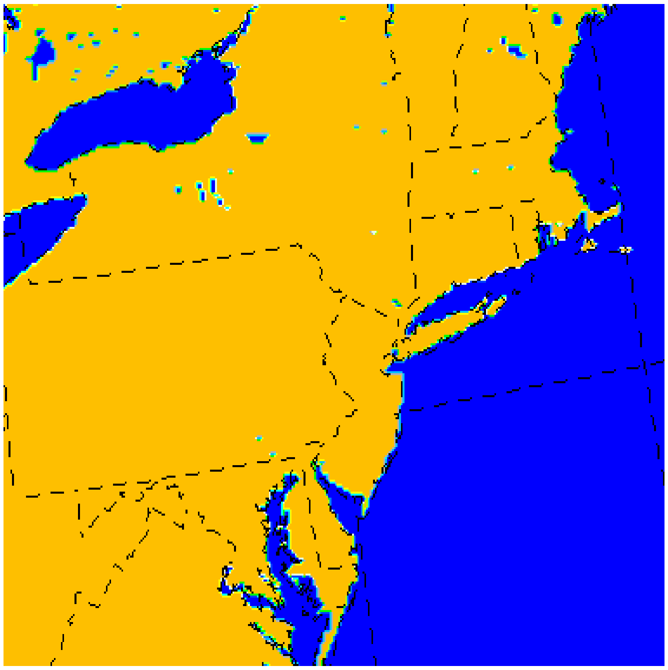

Figure 4. RTMA 5-km land-water mask subset over northeastern United States.

The RTMA-RUC downscaling has three primary components:

- horizontal component
- vertical component
    - o separate techniques dependent on relative terrain elevations of RTMA and RUC data
- coastline sharpening via horizontal adjustment.

We discuss these three steps below:

3.1 Horizontal interpolation

The first step is to simply bilinearly interpolate the appropriate RUC 13-km fields to the RTMA 5-km grid, initially without any adjustment or variable transformation. The RUC postprocessing diagnoses all of these variables on the RUC 13-km grid, so these are horizontally interpolated – p, z, 2-m T/Td/q, u/v, wind gust, ceiling, visibility. In the following discussion, we refer to these RUC fields straightaway interpolated to the RTMA 5km grid as *RUC-5km fields*.

In preparation for Step 3, an additional field, land/water (0.0-1.0), is also interpolated from the 13-km RUC grid to the 5-km RTMA grid to be used for the coastline sharpening in Step 3.

3.2 Vertical component

Determination of the **2-m temperature** is the most critical part of RTMA downscaling. We consider this under two conditions:

- If z-RUC > z-RTMA (RTMA terrain lower than RUC)

In this condition, the procedure uses the local lapse rate from native RUC lowest 25 hPa, constrained between dry adiabatic and isothermal to extrapolate down to RTMA terrain.

- If z-RUC < z-RTMA

In this condition, the procedure *interpolates* from native RUC vertical levels, but maintains surface-based inversions in the RUC, such that 2mT-RTMA cannot exceed 2mT-RUC in this condition. This last constraint was found to be critical for the accurate estimate over irregular terrain at nighttime, especially when snow cover is present and producing very sharp thermal inversions near the surface.

Dewpoint –

- z-RUC > z-RTMA

  Maintain original dewpoint depression with new RTMA temperature.
- z-RUC ≤ z-RTMA

Recalculate Td using RTMA surface pressure and RUC-5km water vapor mixing ratio. Vertical interpolation was found to be problematic, especially when the RUC profile showed much drier air just above a sharp inversion (usually nocturnal or snow-induced), as shown in Fig. 6a (vertical interpolation) vs. Fig. 6b (revised technique using RUC-5km water vapor mixing ratio).

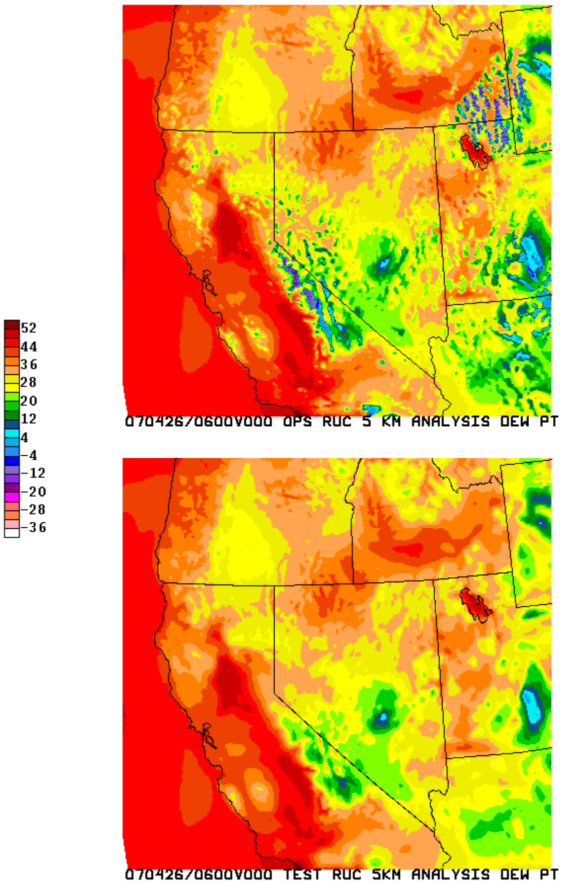

Figure 5. Downscaled RUC 2m dewpoint (deg F) using two different techniques for z-RUC<z-NDFD condition. a) vertical interpolation, b) Td calculation using p-NDFD and q-RUC-5km.

Wind components, wind gust

- z-RUC > z-RTMA

Use RUC-5km winds and wind gust as is (http://ruc.noaa.gov/vartxt.html#gust) .

- z-RUC ≤ z-RTMA

Use maximum of either a) RUC-5km 10-m wind or b) vertically interpolated wind multiplied by 0.7 to crudely mimic surface frictional effects. For wind gust, use maximum of RUC-5km value or b) free atmosphere value from vertically interpolated wind speed.

Surface pressure

Surface pressure at the 5-km RTMA terrain elevation is taken by a local reduction (e.g., Eq. 1 – Benjamin and Miller, 1990) with mean temperature in the layer between z-RUC and z-RTMA as the mean of the RUC 2-m temperature and the reduced RTMA 2-m temperature as shown at the beginning of section 3.2.

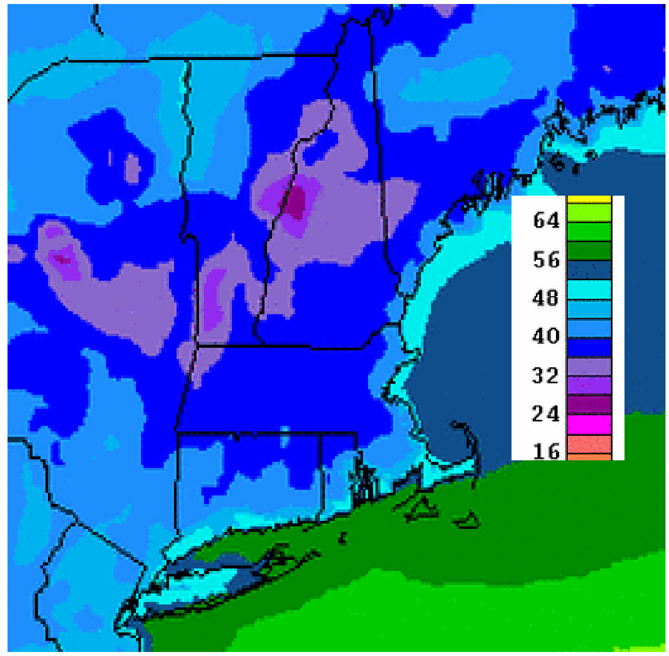

Figure 6. 2-m temperature (deg F) after coastline sharpening.

Ceiling (cloud base)

The ceiling cloud base uses horizontal interpolation of RUC 13-km values of ceiling above sea level (height - ASL). The ceiling for the downscaled 5-km RTMA grid is set to ensure that it is at least 5 m greater than the 5-km RTMA terrain height. This assumption of locally stratiform cloud can result in more detailed low/zero downscaled ceiling values using the detailed RTMA 5-km terrain field.

3.3 Coastline sharpening

An effective procedure has been developed to sharpening expected coastline gradients consistent with the 5-km RTMA land-water fields but only under conditions of **contiguity** with 13km land-water features. This procedure is used for temperature, dewpoint, and wind fields.

The coastline sharpening procedure is followed:

- Compare land-water masks for each RTMA grid point from a) 13-km land-water mask from RUC (0-water, 1-land) interpolated to the 5km RTMA grid and then rounded to 0 or 1, and b) 5-km-RTMA mask (Fig. 4).
- When these mask values at a given RTMA grid point differ, set RTMA-5km value from nearest neighbor RUC values with the same land/water mask value but ONLY if contiguous bodies of water are present both in 13km to 5km interpolated RUC and 5-km-RTMA land-water mask files.
- Search for potential land-water contiguity by recursively expanding frames around non-

matching mask fields. This coastline sharpening procedure is required only once and then can be applied to all variables.

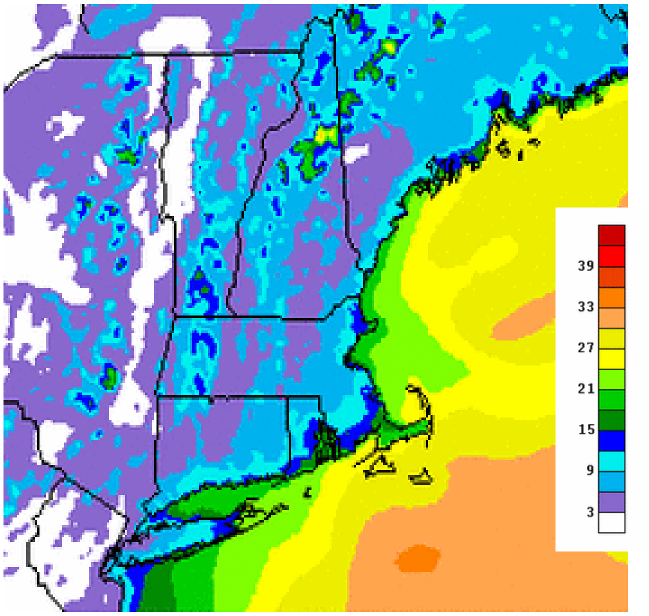

Figure 7. 10-m wind speed (kts) after coastline sharpening.

Examples of coastline sharpening are shown in Figs. 5 and 6. Note, for instance, that Martha's Vineyard and Nantucket Island off the Massachusetts coast do not meet the contiguity requirement since neither is resolved as land points in the 13-km RUC model, but the extensions of Cape Cod and Long Island are both treated successfully by the coastline sharpening procedure via contiguity.

4. Conclusions

The RUC-RTMA downscaling has been successful in providing background fields for the CONUS RTMA. On the last page of this paper, we review fields from the process shown in Fig. 2, starting with the RUC 13-km grids (Fig. 7) to the 5-km downscaled RUC data (Fig. 8) to the final RTMA analysis (Fig. 9) for 2-m temperature for 21z 6 August 2006. In this case and many others, most of the detail in the RTMA fields are provided by the RUC-RTMA downscaling itself.

These same techniques described in this paper are being applied to downscaling for the North American Mesoscale (NAM) data as described by Manikin (2007, same conference).

GSD is currently working in collaboration with NCEP toward a new 1-h cycle assimilation/model system to replace the current RUC, retaining the unique aspects developed for the RUC including assimilation of surface data and cloud observations from GOES and METARs. The RUC replacement, to be called the Rapid Refresh (Benjamin et al. 2006), will use a version of the WRF model and a version of the Gridpoint Statistical Interpolation (GSI) assimilation. The Rapid Refresh 1-h forecasts will also provide a downscaled background field for the RTMA over a larger North American domain. Again, we credit the ongoing discussions between RTMA users and GSD developers at NOAA's ESRL as critical in this effort toward improved RTMA quality via RTMA-RUC downscaling refinements.

5. References

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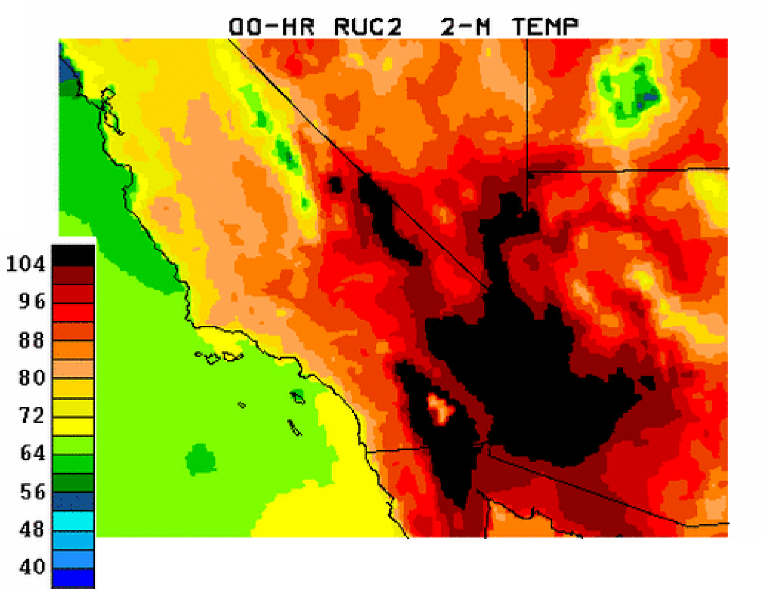
Figure 8. 2-m temperature (deg F) from 13-km RUC using 13-km RUC terrain. For analysis at 2100 UTC 7 August 2006.



<u>RTMA Flowchart (CONUS)</u>

Run hourly RUC (Fig. 7)

↓

Downscale RUC 13-km output fields to current 5-km RTMA grid for RUC analyses and 1-h forecasts (Fig. 8)

↓

Use downscaled RUC as background for subsequent GSI 2dVAR update (Pondeca et al., NCEP/EMC) (Fig. 9)

Figure 9. RUC data from 1-h forecast initialized at 2000 UTC valid at 2100 UTC downscaled from 13-km RUC grid/terrain to 5-km RTMA grid/terrain.

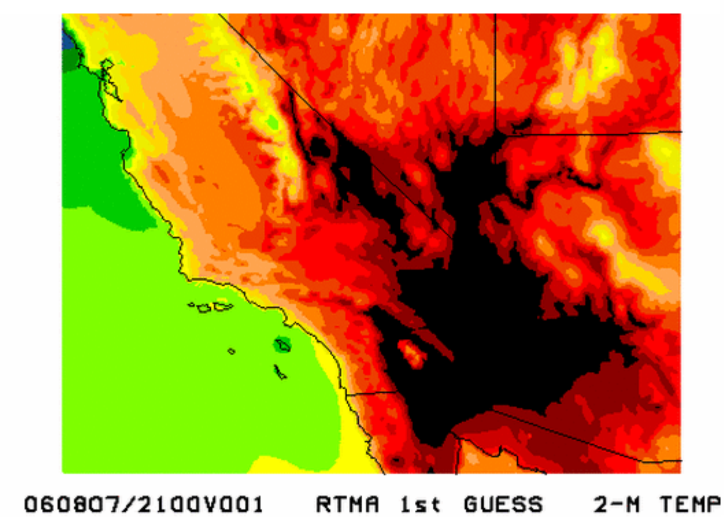


Figure 10. Final RTMA 2-m temperature analysis valid at 2100 UTC using RTMA background (Fig. 3) as its preliminary field.