



# The Analysis of Forecasting Skill in a Mesoscale Model and the Possible Determination of Modeling Error



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## Objectives

4-dimensional variational data assimilation treats modeling errors as either non-existent or on an ad hoc basis in the absence of information for more realistic treatment. Vukicevic et al. 2005 demonstrates that using current knowledge of modeling errors in 4-dimensional variation analysis does not improve assimilation. Our goal is to better understand modeling errors in a mesoscale model based on comparisons of simulations and observations of different weather events. This will ultimately enable us to address and treat modeling errors in our 4-dimensional variational assimilation experiments (e.g. Vukicevic et al. 2005). We also specifically want to address errors in cloud forecasting using information from satellite measurements in the presence of clouds (Koyama et al. 2005).

## Assumptions

Errors in initial conditions have minimal to no impact on numerical weather prediction runs as our time of interest is sufficiently temporally removed from model initialization. Errors are primarily a result of deficiencies in model physics and model vertical and horizontal resolution.

## Relevance to DOD

Assessment of the capabilities of a numerical weather prediction (NWP) model is required for improvements in data assimilation. Deficiencies in a poor model will limit the gains from data assimilation. Also for a good NWP model a quantitative estimate of modeling errors and their inclusion in the minimization of the cost function will result in faster convergence and provide more accurate results. This will result in both cost saving and increased accuracy. Also identification of deficiencies will help modelers in targeting specific model areas for improvement. Also cloud forecasting skill improvements will greatly help the DOD.

## Requirements

- (a) Model outputs for weather events from the relevant NWP model model.
- (b) High temporal and spatial resolution satellite observations for comparison.
- (c) Radiative transfer models to compute radiances and reflectance for comparison with satellite observations.

## Modeling specifics

Mesoscale model used is CSU-RAMS as it has two moment microphysics with two way nested gridding capabilities. Gaseous absorption is computed using OPTRAN (McMillin et al. 1995). Condensate optical properties is computed using Anomalous Diffraction theory (Greenwald et al. 2002). Radiance computations are made using a delta-eddington scheme (infrared) and a plane parallel version of the Spherical Harmonics Discrete Ordinate Method (SHDOMPP) (Evans 1998).

## Methodology

RAMS was run at 2 km resolution with initialization using ETA reanalysis data for a severe thunderstorm outbreak in Oklahoma for May 8, 2003.

Output used to compute cloud brightness temperature for 10.35  $\mu\text{m}$  (Channel 13 of GOES-R) after averaging model output to 4km resolution.

Region of interest extracted for comparison with GOES-12 data for 10.7  $\mu\text{m}$ . Only brightness temperatures below 243 K are considered while screening for thunderstorm cloud tops.

## Results

The band of observed thunderstorms in Figure 1(c) are considered for comparison with the modeled thunderstorm shown in Figure 2(b). The comparisons are made using consolidated dataset that cover a period of around an hour.

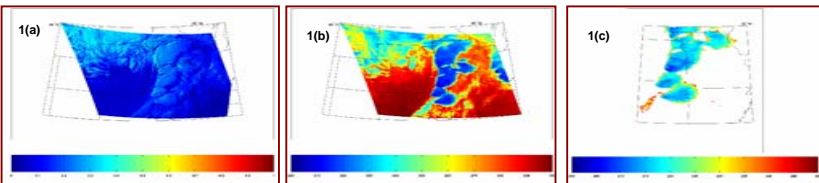
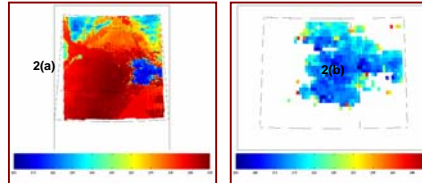
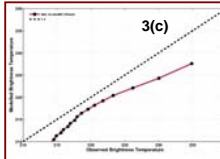
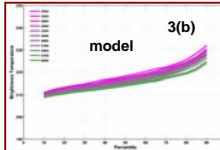
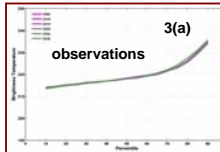


Figure 1: (a) visible reflectance (0.65  $\mu\text{m}$ ) (b) infrared brightness temperature (10.7  $\mu\text{m}$ ) and (c) the infrared brightness temperature screened for temperatures lower than 243 K for observations from GOES 12 at 23:45 UTC on May 8, 2003.



A 6000 seconds window (approximately 2 hours) was selected from RAMS output to generate the brightness temperature for 10.35  $\mu\text{m}$  corresponding to channel 13 of GOES-R. The brightness temperatures were computed at every 5 minutes during that period. Figure 2(a) shows one snapshot (timestamp 5700 second) while figure 2(b) shows the snapshot screened to show thunderstorm cloud top ( $T_b < 243 \text{ K}$ ).



For comparing observations to models we selected approximately 1 hour of data from each set. For observations we chose hour 23 while we chose 3000-6000 seconds to represent the model. Our goal was to construct a sample encompassing multiple snapshots that are statistically similar. Figure 3(a) shows that percentiles of brightness temperatures from the thunderstorm cloud top observations for selected the 1 hour period. Figure 3(b) is similar to Figure 3(a) but for model output. It should be noted that in both the observations and model the distribution for each individual time is similar to the other times considered. Therefore the larger samples that are constructed by including data from the times shown in Figures 3(a) and 3(b) are statistically similar to each individual time.

Figure 3(c) shows a plot of observed to modeled brightness temperatures in percentile for all the data shown in Figure 3(a) and 3(b). It is seen that the observations are slightly warmer than the model. The increase in cloud top brightness temperature in the observations corresponding to the thunderstorm anvils are not perfectly replicated in the model. This is primarily a result of the vertical resolution used in the model. It is to be expected that thinner layers (less than 500 m) should be considered in order to better replicate the observations.

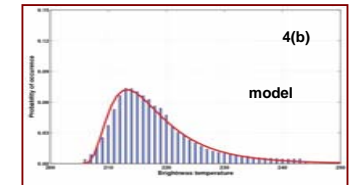
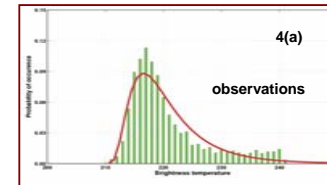


Table 1

Statistics	Observations	Model
Mean	220.9 K	218.3 K
Median	218.8 K	216.6 K
Std. Deviation	6.7 K	7.4 K
No. of data points	46514	111153
Offset for lognormal fitting	210	205
Lognormal mean	2.22	2.43
Lognormal width	0.581	0.570
95% CI for lognormal mean	2.21-2.23	2.43-2.44
95% CI for lognormal width	0.577-0.585	0.568-0.572

The datasets considered for comparison in Figure 3(c) are shown as histograms in Figure 4(a) for observations and Figure 4(b) for the model output. The red curve shows that the cloud top brightness temperature follow a lognormal distribution with parameters shown in Table 1.

## Conclusions and future work

Mesoscale models with two moment microphysics are capable of generating realistic thunderstorm simulations. While CSU-RAMS has this capability other models like WRF do not. The distribution of the model output follows the distribution of the observations.

Clouds brightness temperatures for thunderstorms are lognormally distributed. Therefore cloud data assimilation using satellite information should account for lognormal distributions.

Statistically speaking modeling errors are low for this comparison. Other cases and weather events need to be considered so that we can get an idea about the skill of this NWP model. That will in turn provide us with a better idea regarding the handling of modeling errors in data assimilation.

Future work involves using more cases (e.g. a hurricane simulation, a lake effect snow event) to investigate model performance. Information from these studies will feed into the 4D-Variational data assimilation effort in CG/AR.

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