

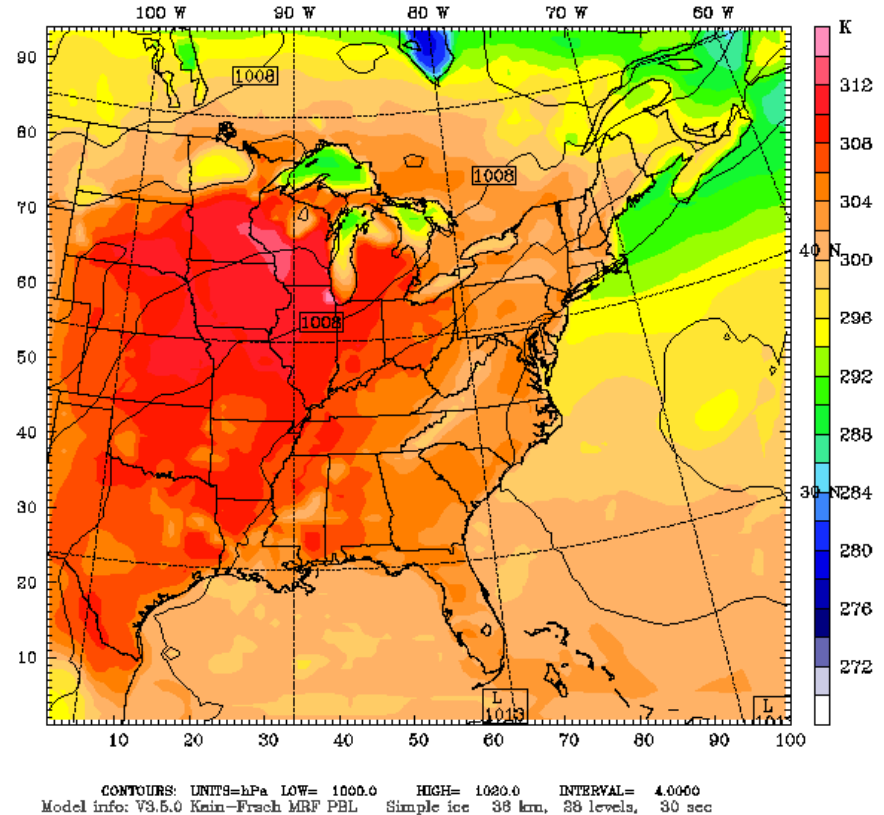
# Meteorological Modeling: Model Performance Evaluation

3<sup>rd</sup> PM/RH/O3 Modeling Workshop  
May 20, 2005

Pat Dolwick  
USEPA: OAQPS/EMAD/AQMG  
NOAA: ARL/ASMD/AMB

Atlanta A (Terrain v3.5)  
Fcst: 48.00  
2-meter Temperature  
Sea-level pressure

Init: 0000 UTC Wed 12 Jul 95  
Valid: 2200 UTC Thu 13 Jul 95 (1800 EDT Thu 13 Jul 95)



# Outline

- Importance of meteorological modeling
- Evaluating meteorological modeling input data
  - Operational evaluation
  - Phenomenological evaluation
  - Blending the meteorological evaluation results w/ the AQM results

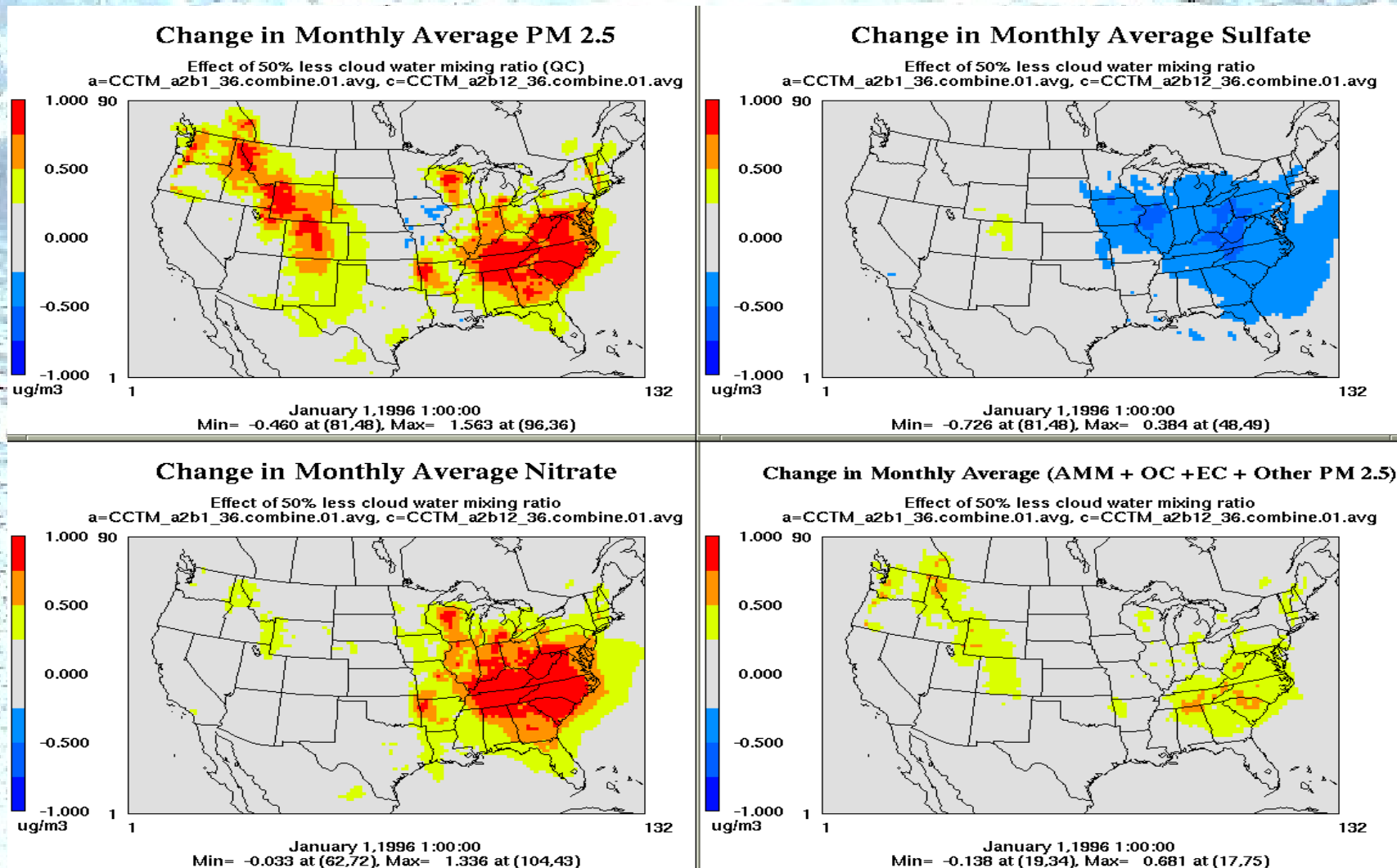
# Importance of Meteorological Modeling

- Generally less energy goes into meteorological modeling, relative to emissions & the model itself
  - Three-legged stool analogy
- Meteorological effects are increasingly important in PM/RH applications
- Example: Recent EPA 12km CMAQ modeling



# Importance of Meteorological Modeling

## 1996: Simple sensitivity testing



# Evaluation of Meteorological Modeling

- Guidance rewritten to incorporate many of the latest findings re: evaluation of meteorological modeling. Influenced by several documents:
  - **Tesche et al (2002): “Operational evaluation of the MM5 meteorological model over the continental United States: Protocol for annual and episodic evaluation.”**
  - **Emery and Tai (2001): “Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes.”**
  - **Numerous MM5 evaluations: (e.g., Olerud et al., 2000; Doty et al., 2001; Johnson, 2003; Baker, 2004; Gilliam, 2004).**
- AQMs used in attainment demonstrations have consistently been subjected to a rigorous performance assessment, but in many cases the meteorological inputs to these models are accepted as is, even though this component of the modeling arguably contains a higher quantity of potential errors that could affect the results of the analysis (Tesche, 2002).

# Evaluation of Meteorological Modeling

- Evaluation goal is to move away from “as is” acceptance of meteorological inputs and move toward an understanding of how the bias & error of the meteorological data affect the resultant AQM simulations.
- Two specific evaluation objectives:
  - **1) Determine if the meteorological model output fields represent a reasonable approximation of the actual meteorology that occurred during the modeling period. (Operational evaluation)**
  - **2) Identify and quantify the existing biases and errors in the meteorological predictions in order to allow for an downstream assessment of how the air quality modeling results are affected by issues associated with the meteorological data. (Phenomenological evaluation)**

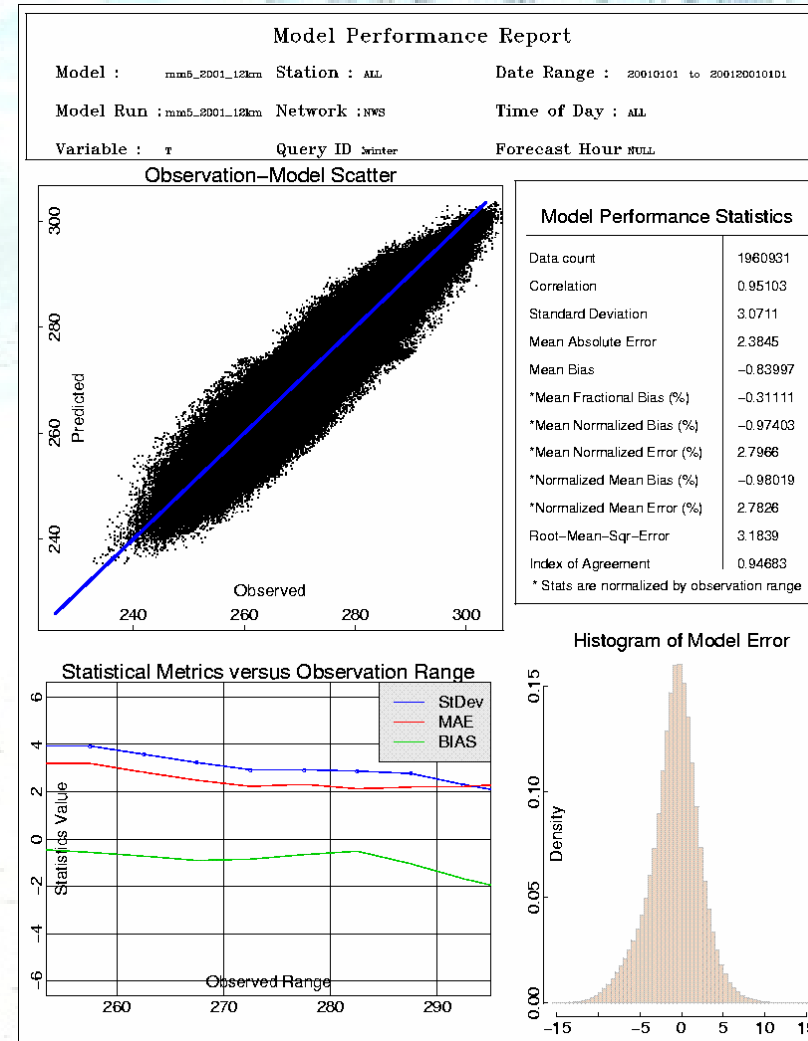
# Operational Evaluation:

- **Statistical Measures:**

- comparisons of the means,
- mean bias, mean normalized bias,
- mean absolute error, mean absolute normalized error, RMSE (s & u), and
- index of agreement.

- **Met Parameters:**

- temperature
- water vapor mixing ratios / humidity
- wind speed / wind direction
- clouds / radiation
- Precipitation
- PBL (max, time series evolution)

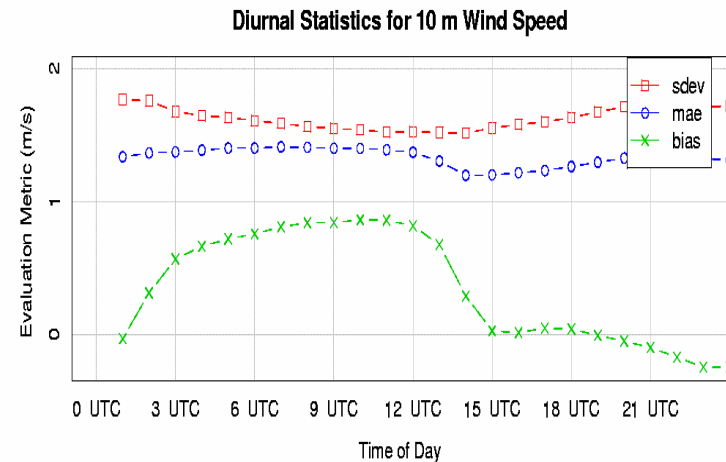
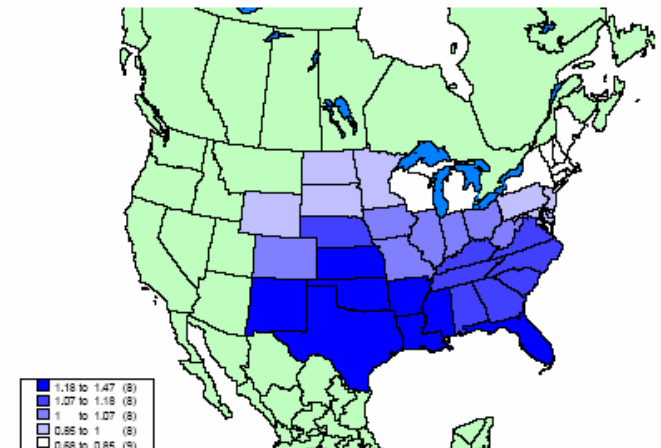


Results courtesy of Rob Gilliam (ORD)

# Operational Evaluation

- For large modeling exercises, it is recommended that the operational evaluation be broken down into individual segments to allow for a more comprehensive assessment of the meteorological strengths and weaknesses.
  - Geographic subregions
  - Individual episodes
  - Aloft vs. surface
  - Diurnal cycle
  - As a function of synoptic regimes

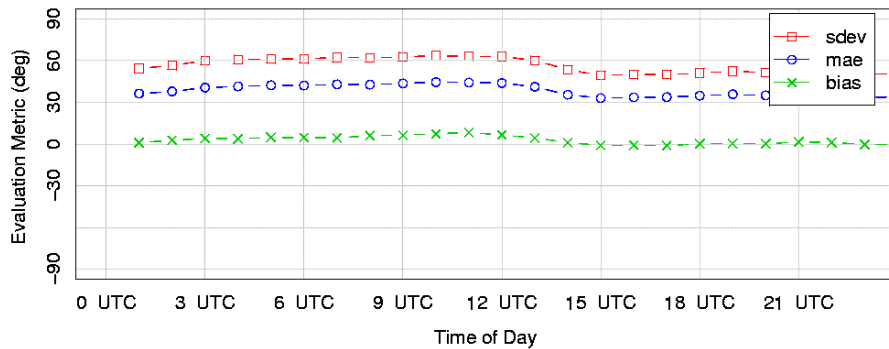
Figure 3-151: Episode Average Mixing Ratio Error (g/kg).



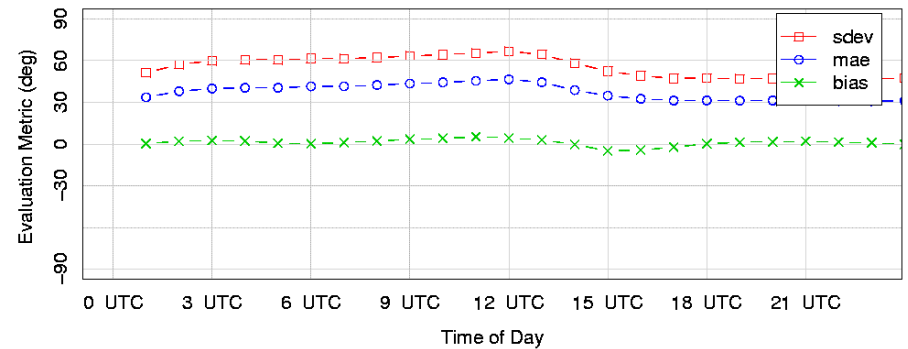
Results courtesy of Dennis McNally (Alpine G.), and Rob Gilliam (ORD)

# Operational Evaluation

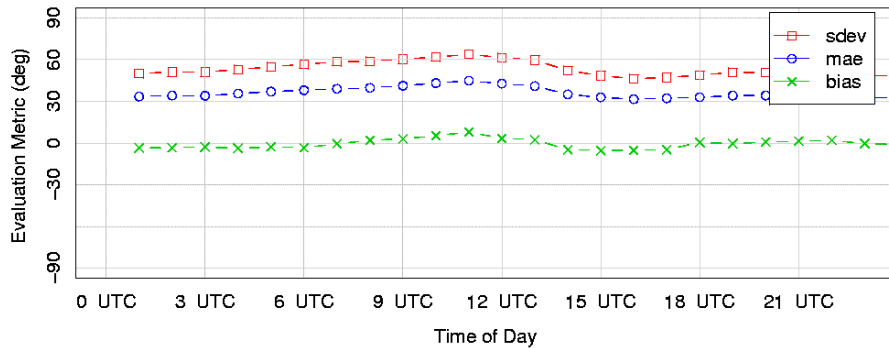
Diurnal Statistics for 10 m Wind Direction **Water**



Diurnal Statistics for 10 m Wind Direction **Agriculture**



Diurnal Statistics for 10 m Wind Direction **Urban**



## Model Evaluation Metrics Comparison Table

### Root-Mean-Square Error

	<b>T</b>	<b>Q</b>	<b>WS</b>	<b>WD</b>
coastal	2.34	6.72	1.70	59.39
inland	2.47	7.58	1.38	60.91
mountains	2.95	7.43	1.74	57.35

Results courtesy of Rob Gilliam (ORD)

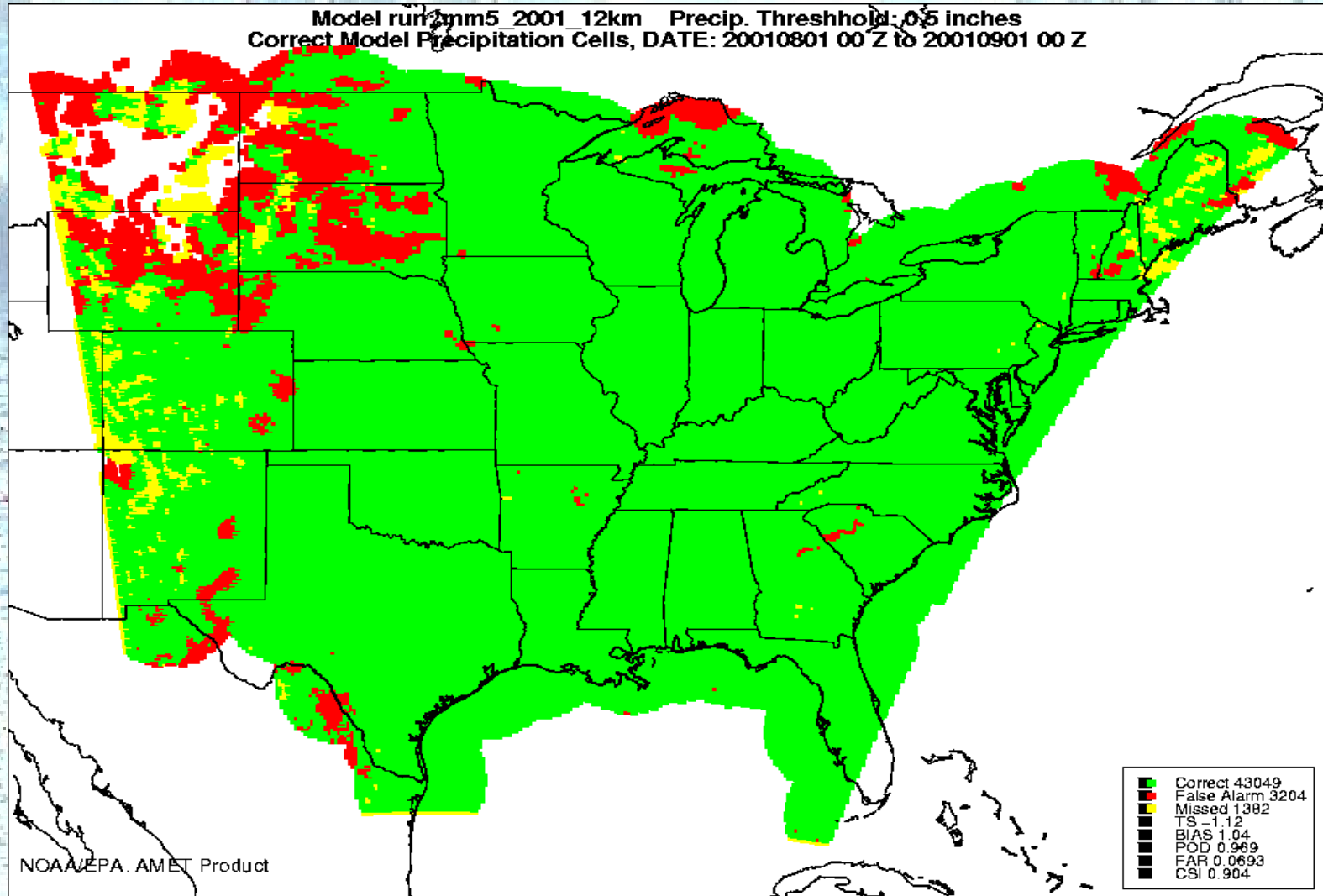
# Operational Evaluation

- Whenever possible, met modelers should try to set aside a portion of the ambient data strictly for evaluation purposes (i.e., data not used in the FDDA).
- Evaluation should take place not only on the raw meteorological outputs, but on the post-processed meteorology as well
  - May be possible to show w/ limited analysis
- What about the use of performance benchmarks?
  - Can help with the initial objective of assessing general confidence in the meteorological model data, however ...
  - EPA has concerns about potentially misleading comparisons of model performance findings across different analyses w/ differing model configurations and FDDA strengths, therefore ...
  - while we plan to compare the statistical evaluation outputs back against a set of performance benchmarks, we do not recommend the results of these comparisons be used in a pass/fail mode.

# Phenomenological Evaluation

- Components of the evaluation should be tied to the conceptual model of the AQ issue being considered:
  - For example, if a sea breeze is an important regulator of where and when ozone is formed, then the phenomenological evaluation should assess the ability of the meteorological model to reproduce this feature in space/time
- Other possible elements of a phenomenological evaluation include:
  - Comparison of model trajectories vs. “actual” trajectories (transport)
  - Existence of a low-level jet in model / ambient
  - Ability of the model to capture frontal passages, airmass residence time
- Because of the event-oriented nature of the phenomenological evaluation, one will need to summarize model performance in terms of a different suite of statistical metrics: e.g., probability of detection and false alarm rate.

# Phenomenological Evaluation



Results courtesy of Rob Gilliam (ORD)

# Blending the Meteorological Evaluation Results w/ the AQM results

- Armed with the results of the operational and phenomenological evaluation results, one should have an idea of the strengths and weakness of the model.
- At this stage, a decision should be made as to whether to proceed with the meteorological inputs, or whether it is necessary to rerun the met model.
  - Generally, manipulation of existing MM5/RAMS/WRF datasets is not recommended, due to interdependencies of data
- The evaluation results can be used to guide AQ modelers as to those regions/periods/regimes where model performance is optimized, yielding more certain AQM projections.