# IS WRF REALLY IMPROVING?

## A COMPREHENSIVE VERIFICATION OVER THE PACIFIC NORTHWEST
## and

## An Editorial

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# A lot of effort has been expended…

- We have all worked hard over the past ten years transitioning from MM5 to WRF.
- In addition, a great deal of effort has gone into improving physics parameterizations, numerics, and adding additional modeling options.

# But …

- Does WRF with all its improvements verify better than MM5 for key case studies and over extended verification periods?
- Do we have the tools and capabilities to monitor adequately the evolving quality of our modeling systems?
- Is it possible that some recent “enhancements” and new options have actually detracted from modeling system skill when used with other components?

# In general, we don't have satisfactory answers for these questions.

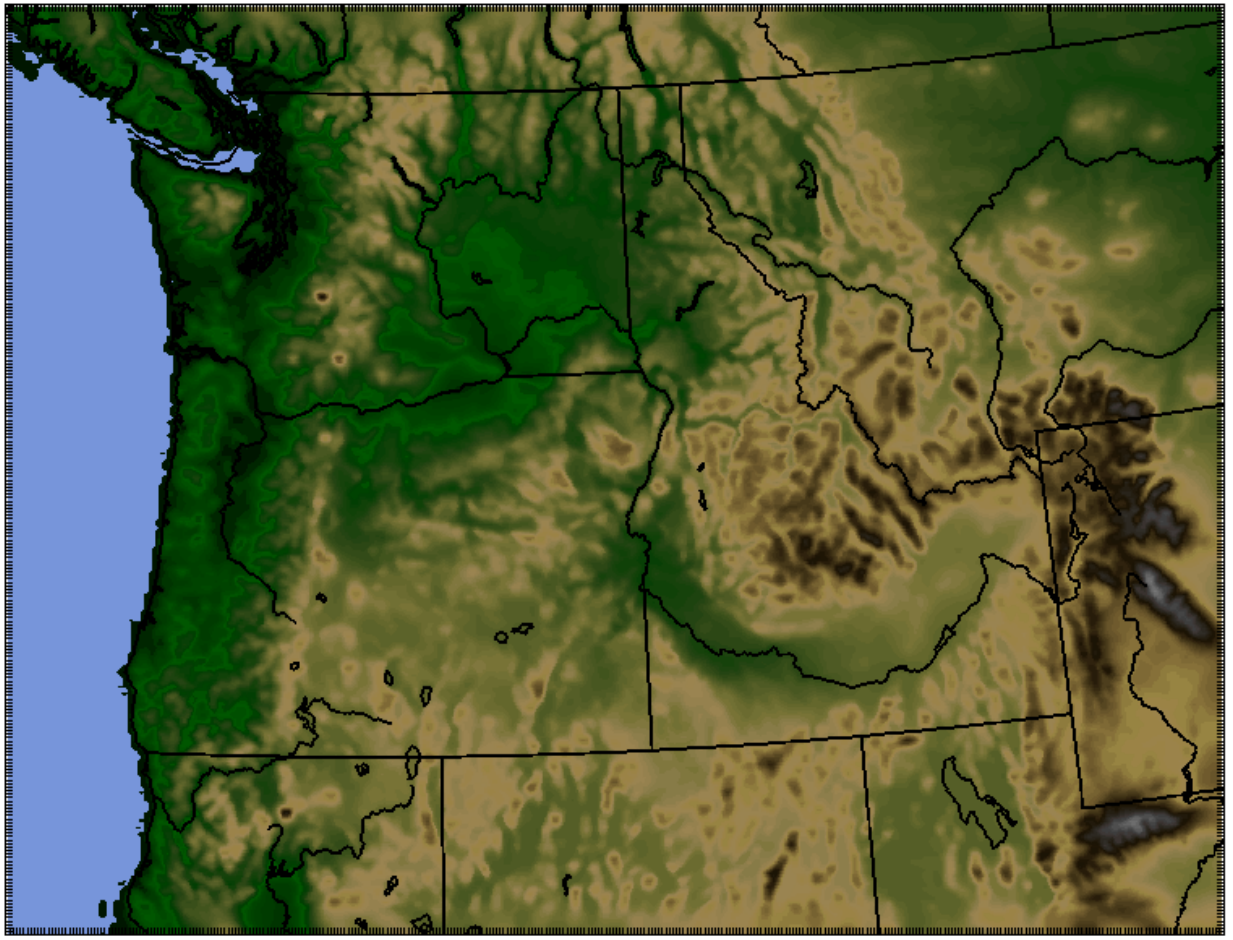
- Neither NWS NCEP EMC, nor the Developmental Test Center (DTC), nor any national entity appears to have such information.
- Or it seems impossible to find it.
- We need evaluation mechanisms and capabilities in place to evaluate and guide our model development.

# Objective Guidance

- We need to use objective guidance to decide which models and options are really useful to keep around.
- And we need to follow such guidance even when it is not politically or institutionally favored.

# Our community is flying blind

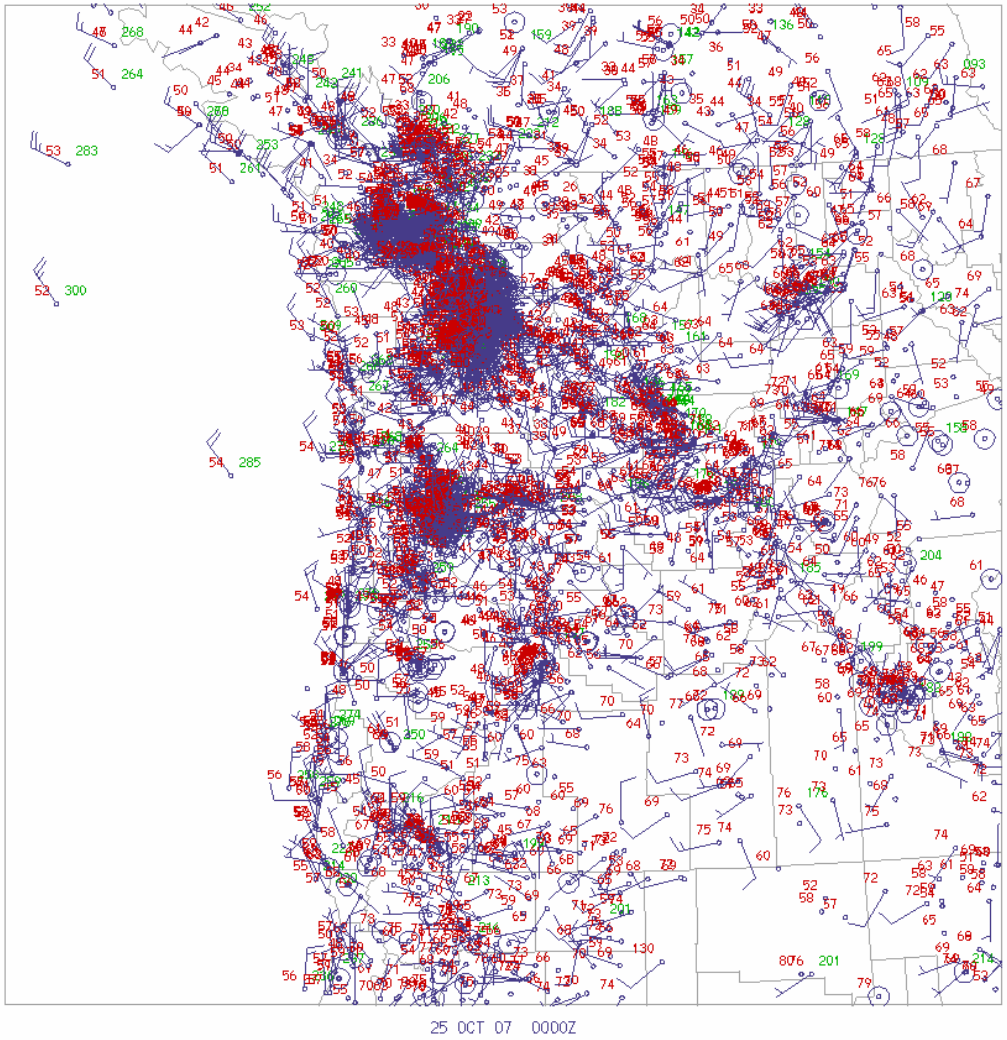
A limited amount of such information is available for one portion of the country-The Pacific Northwest



# Northwest U.S. MM5 and WRF

- Real-time since 1995 at 00 and 12 UTC
- Now running:
  - MM5 (36-12 km) nested in NWS NAM
  - WRF ARW 3.0 (36-12-4 km) nested in NWS GFS
  - WRF currently uses Thompson microphysics, YSU PBL, NOAH LSM, RRTM LW, Dudhia SW, K-F PBL
  - MM5 uses MRF PBL, K-F.
- Extensive multi-year verification on QC data.
- Have run extensive tests of WRF V3.1, MM5 driven by GFS, and a collection of varying physics, including with and without LSM

# Verification Data Source: NW Net Over 70 QC Networks



http://www.atmos.washington.edu/~qcreport/verification_index.psp

BARNES Powell's Third Elliott Thesaurus Traffic Google CNN.com AMS SPU MyUW SnowMap NSF NWS-SAT NCEP Model

Sno-Isle Libraries: H... | Index of /~cliff/MW... | Sno-Isle Libraries: H... | Sno-Isle Libraries: H... | Sno-Isle Libraries: H...

# Verification Page

**University of Washington Dept. of Atmospheric Sciences**

Plots | Documentation | Observations Quality Control | History / Change Log | Contact

## Verification Plots

| | |  Temperature |  Dewpoint Temperature |  Wind Speed |  Wind Direction |  Sea Level Pressure |  6-hour Precipitation |  Relative Humidity |
|---|---|---|---|---|---|---|---|---|
| **MM5 vs WRF Verification Plots** | Time Series Plots | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | n/a |
| | Maps | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | n/a |
| | Upper Air | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | n/a | n/a | 00Z \| 12Z |
| **MM5 & WRF vs. Synoptic Models Verification Plots** | Synoptic Time Series Plots | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z | 00Z \| 12Z |
| **MM5 Bias Correction Verification Plots** | Bias Correction | 00Z \| 12Z | 00Z \| 12Z | n/a | n/a | n/a | n/a | n/a |

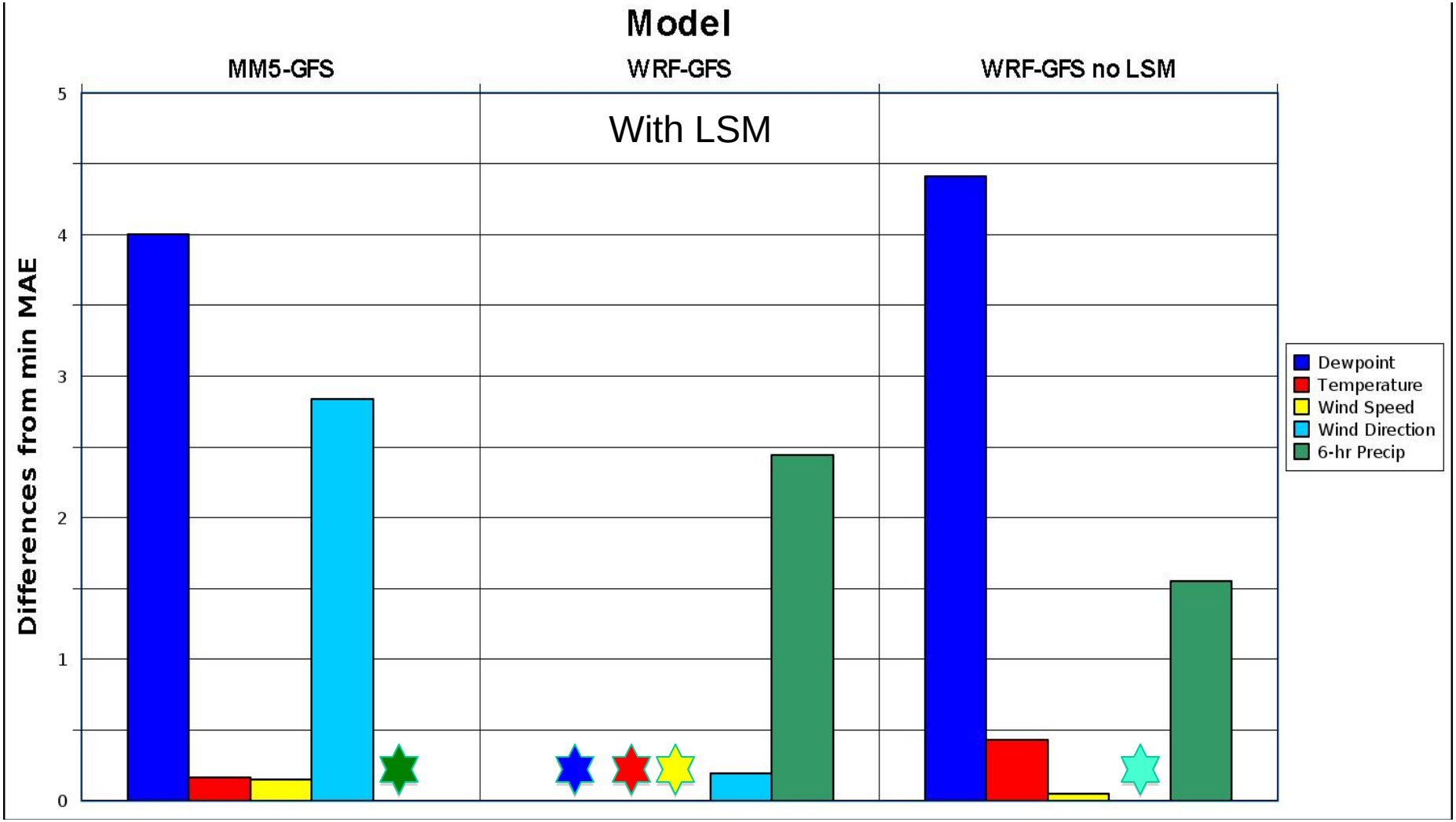
# The Analysis

- Based on multi-month, twice daily runs, let us try to answer (for the NW) some of the following questions:
  - What have we gained by moving to WRF?
  - What have we lost?
  - Is the NOAH LSM a plus or minus for the key parameters?
  - Are we making progress?

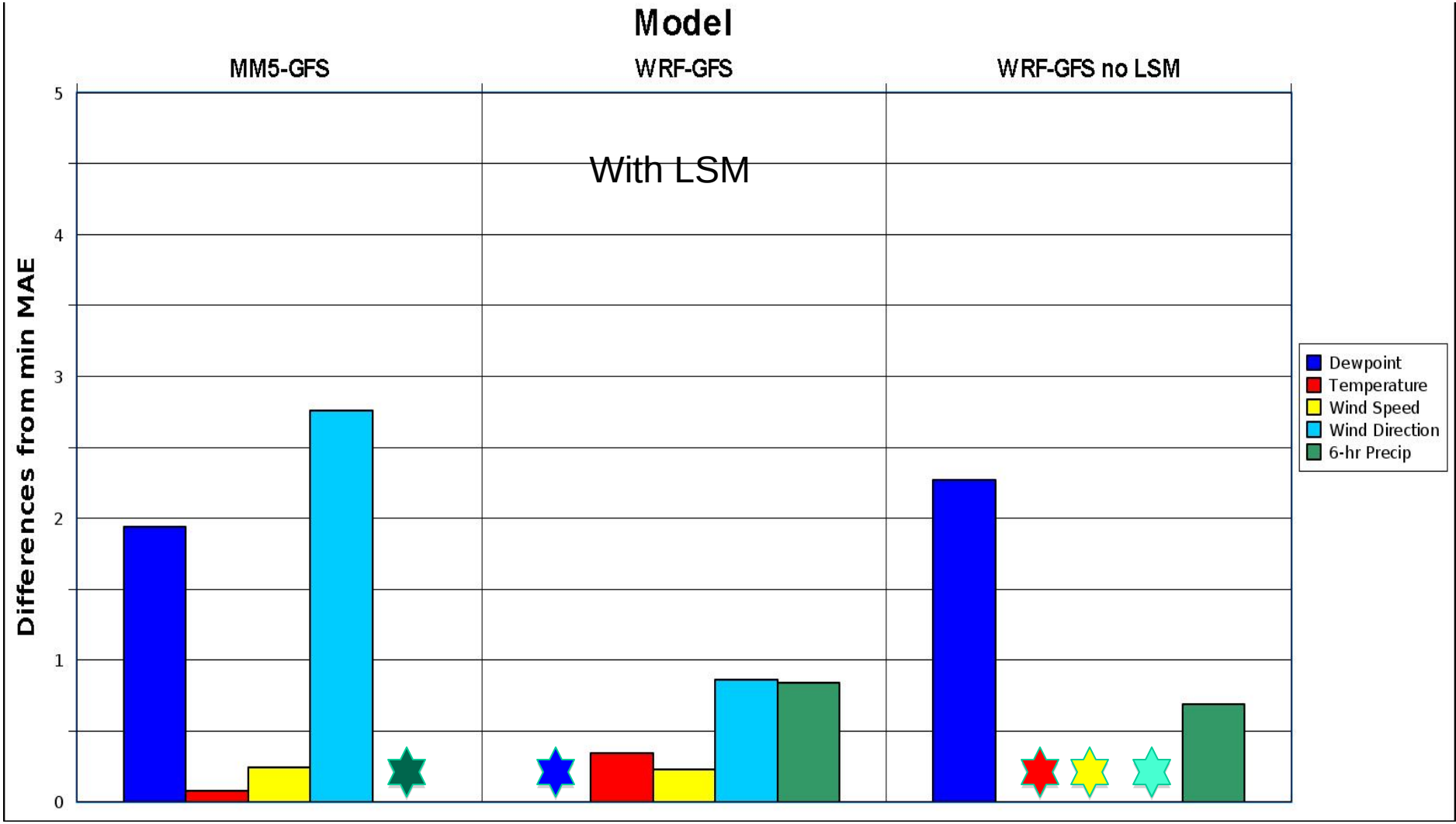
# A Three-Way Match

- MM5
- WRF 3.0 with LSM
- WRF 3.0 without LSM
- All nested in GFS
- Verified over surface stations in the 4-km domain (Washington, Oregon, Idaho, southern BC)

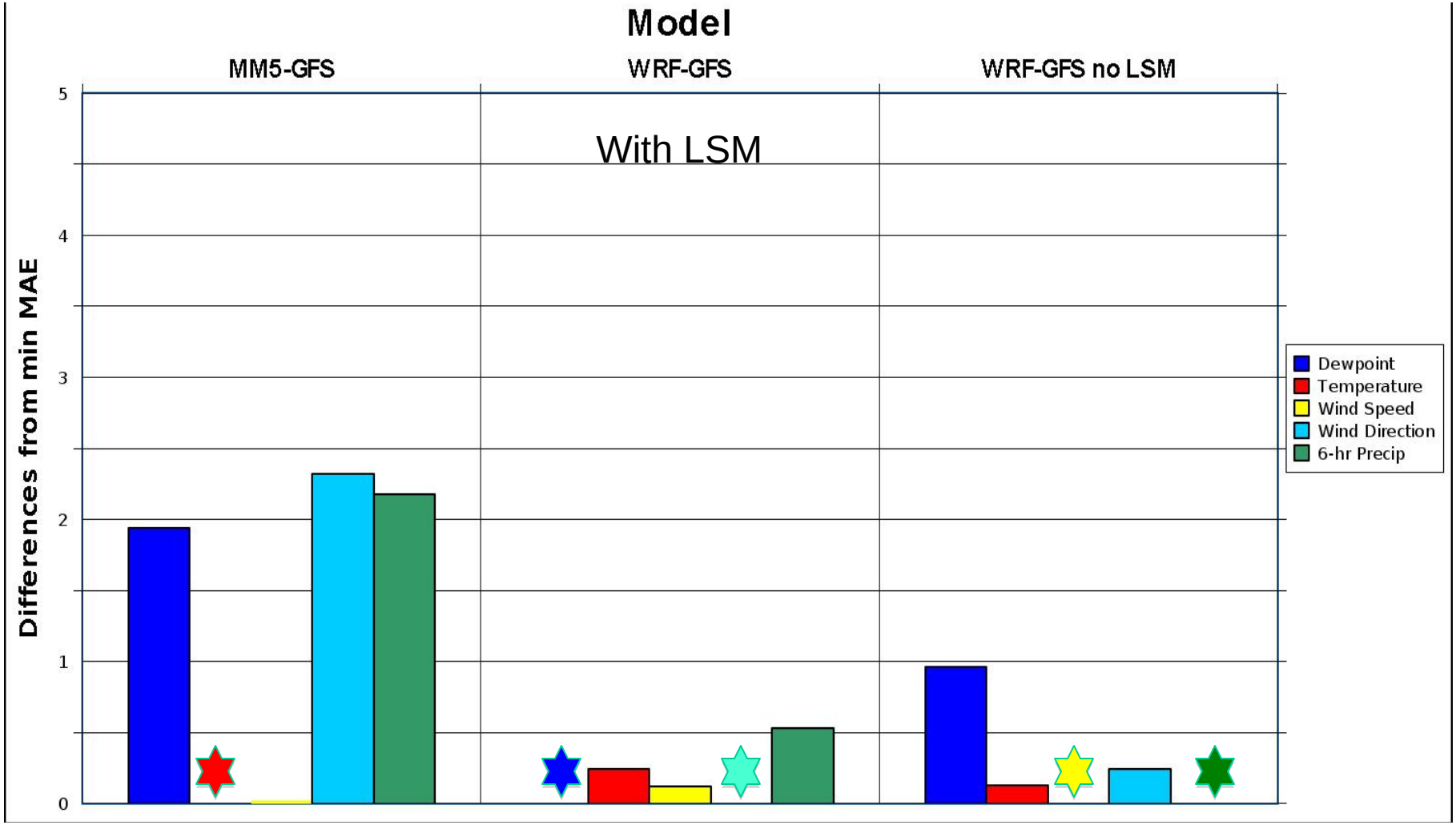
# 0000 UTC (5 PM) MAE, July-August 2008



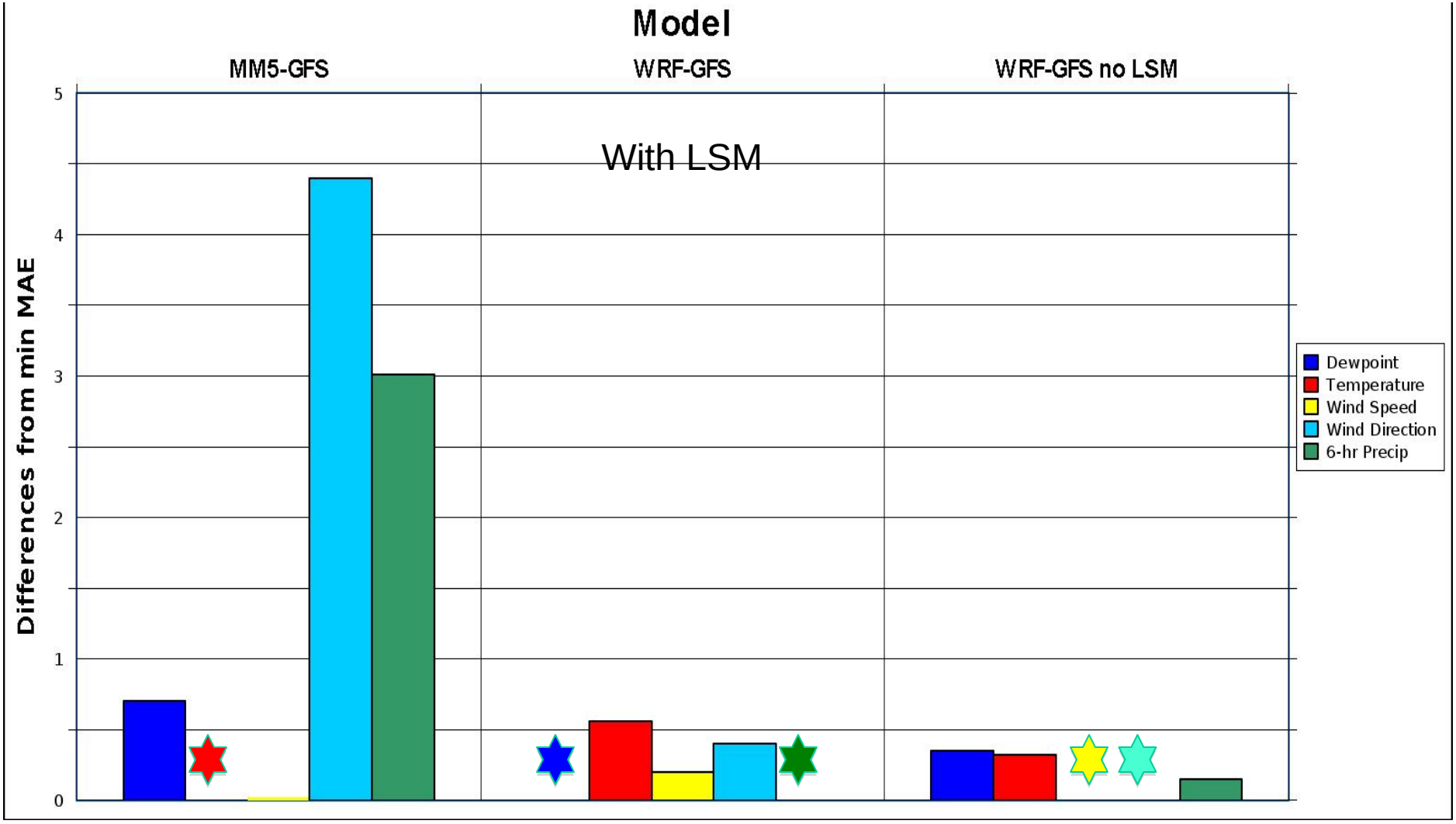
# 1200 UTC (5 AM) MAE, July-August 2008

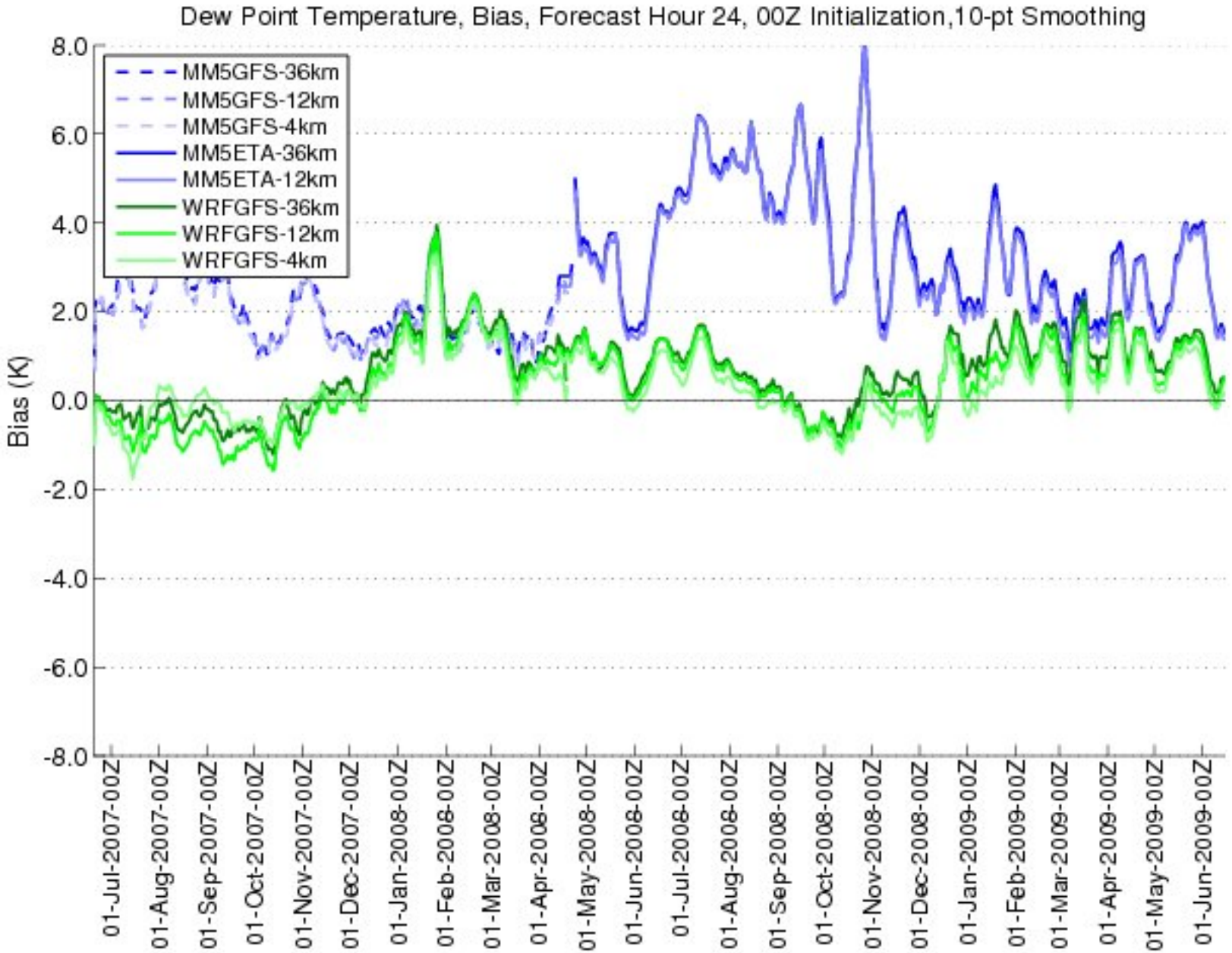


# 0000 UTC (5 PM) MAE, Jan-Feb 2009



# 1200 UTC (5 AM) MAE, Jan-Feb 2009




Dew Point Temperature, Bias, Forecast Hour 24, 00Z Initialization,10-pt Smoothing
MM5GFS-36km
MM5GFS-12km
MM5GFS-4km
MM5ETA-36km
MM5ETA-12km
WRFGFS-36km
WRFGFS-12km
WRFGFS-4km
Bias (K)
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
01-Jul-2007-00Z
01-Aug-2007-00Z
01-Sep-2007-00Z
01-Oct-2007-00Z
01-Nov-2007-00Z
01-Dec-2007-00Z
01-Jan-2008-00Z
01-Feb-2008-00Z
01-Mar-2008-00Z
01-Apr-2008-00Z
01-May-2008-00Z
01-Jun-2008-00Z
01-Jul-2008-00Z
01-Aug-2008-00Z
01-Sep-2008-00Z
01-Oct-2008-00Z
01-Nov-2008-00Z
01-Dec-2008-00Z
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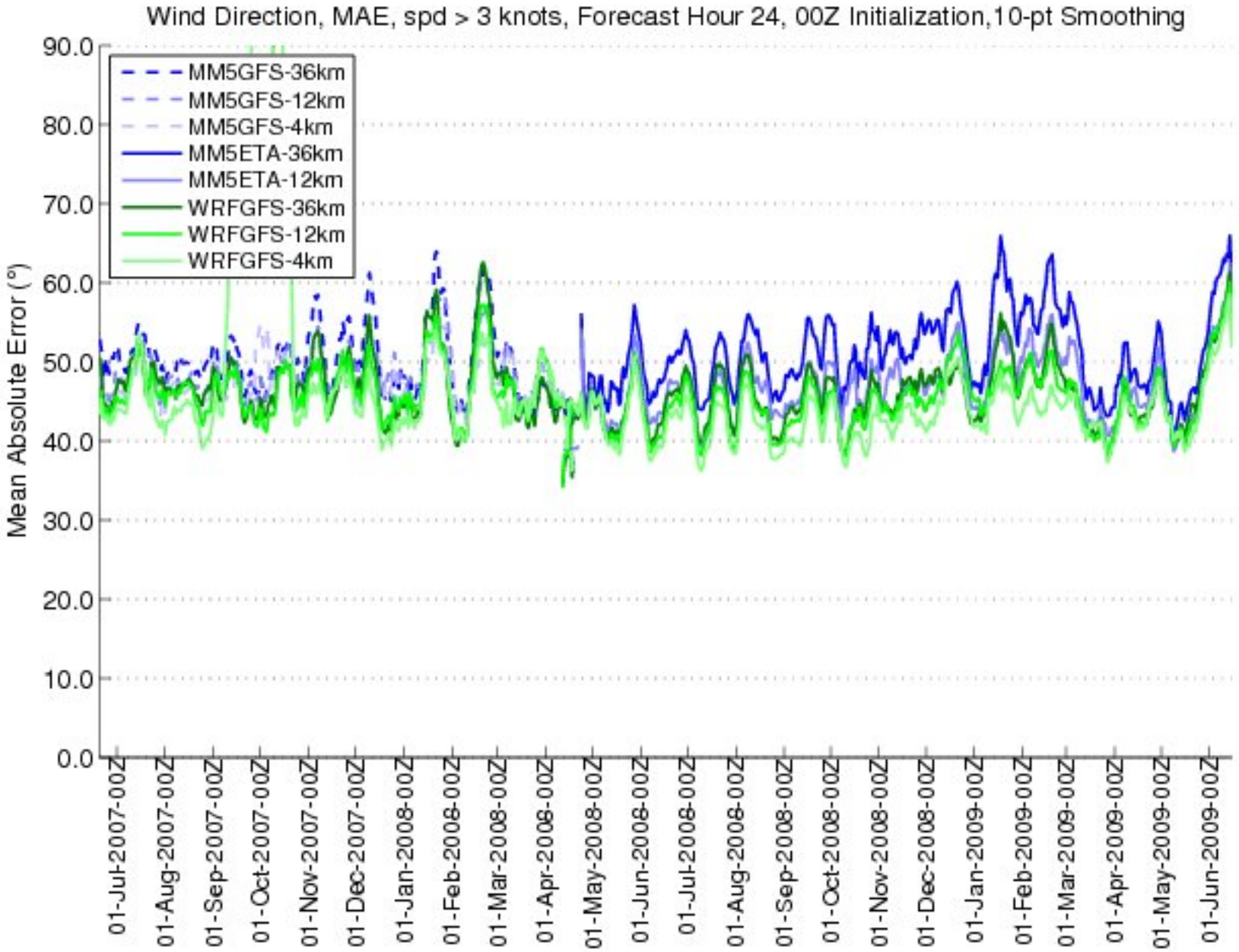
01-Mar-2009-00Z
01-Apr-2009-00Z
01-May-2009-00Z
01-Jun-2009-00Z


Wind Direction, MAE, spd > 3 knots, Forecast Hour 24, 00Z Initialization,10-pt Smoothing
Mean Absolute Error (°)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
MM5GFS-36km
MM5GFS-12km
MM5GFS-4km
MM5ETA-36km
MM5ETA-12km
WRFGFS-36km
WRFGFS-12km
WRFGFS-4km
01-Jul-2007-00Z
01-Aug-2007-00Z
01-Sep-2007-00Z
01-Oct-2007-00Z
01-Nov-2007-00Z
01-Dec-2007-00Z
01-Jan-2008-00Z
01-Feb-2008-00Z
01-Mar-2008-00Z
01-Apr-2008-00Z
01-May-2008-00Z
01-Jun-2008-00Z
01-Jul-2008-00Z
01-Aug-2008-00Z
01-Sep-2008-00Z
01-Oct-2008-00Z
01-Nov-2008-00Z
01-Dec-2008-00Z
01-Jan-2009-00Z
01-Feb-2009-00Z
01-Mar-2009-00Z
01-Apr-2009-00Z
01-May-2009-00Z
01-Jun-2009-00Z

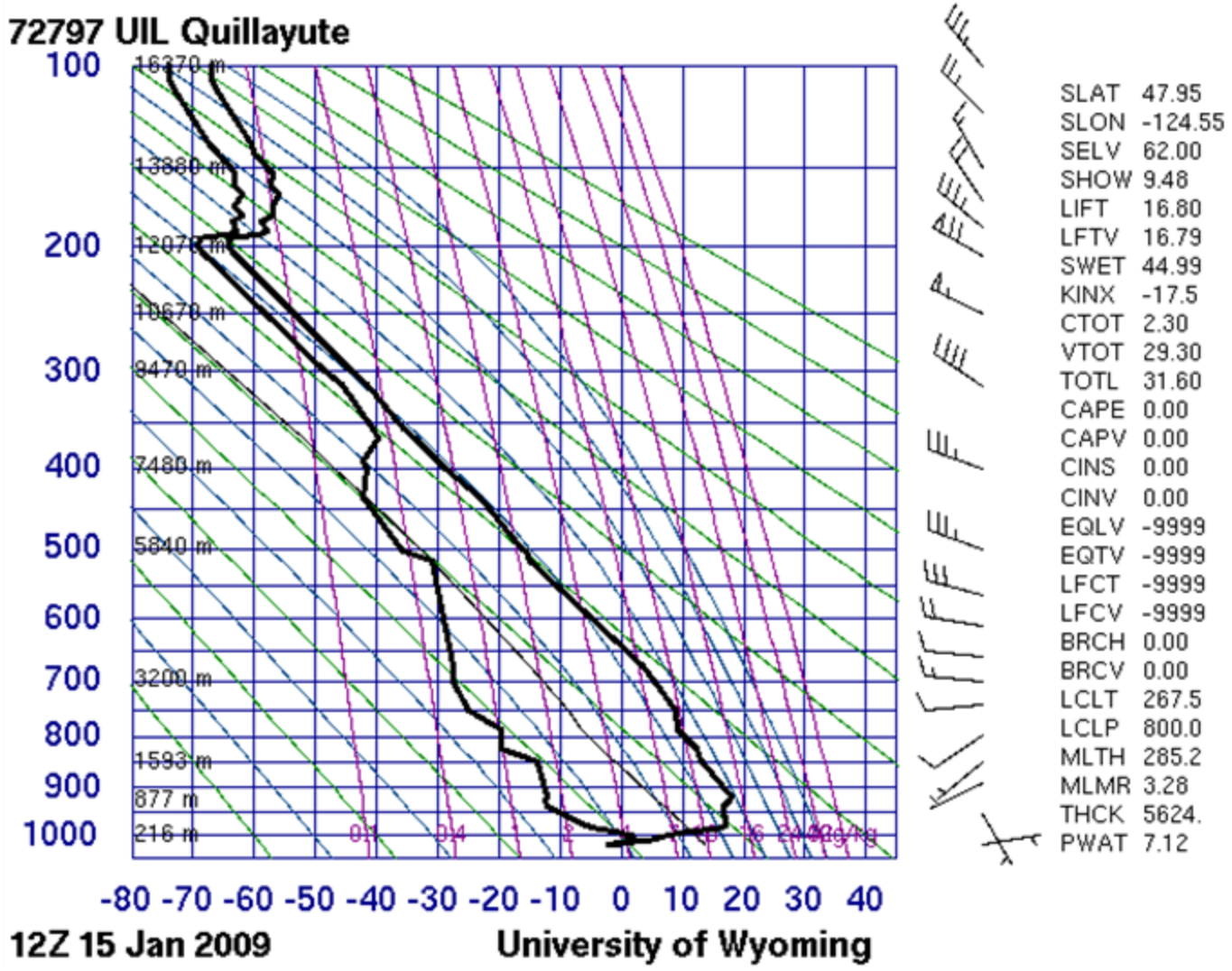
# What do verification scores tell us about MM5 and WRF and LSM?

- The LSM greatly improves the dewpoint temperature forecast. So WRF with LSM is much better for dewpoint than MM5 or WRF without.
- For temperature, the LSM helps in the afternoon, but hurts in the morning.
- WRF is better than MM5 for wind direction. But the errors are still large.
- For precipitation, MM5 is better in summer, WRF in winter.
- Very little difference in wind speed.

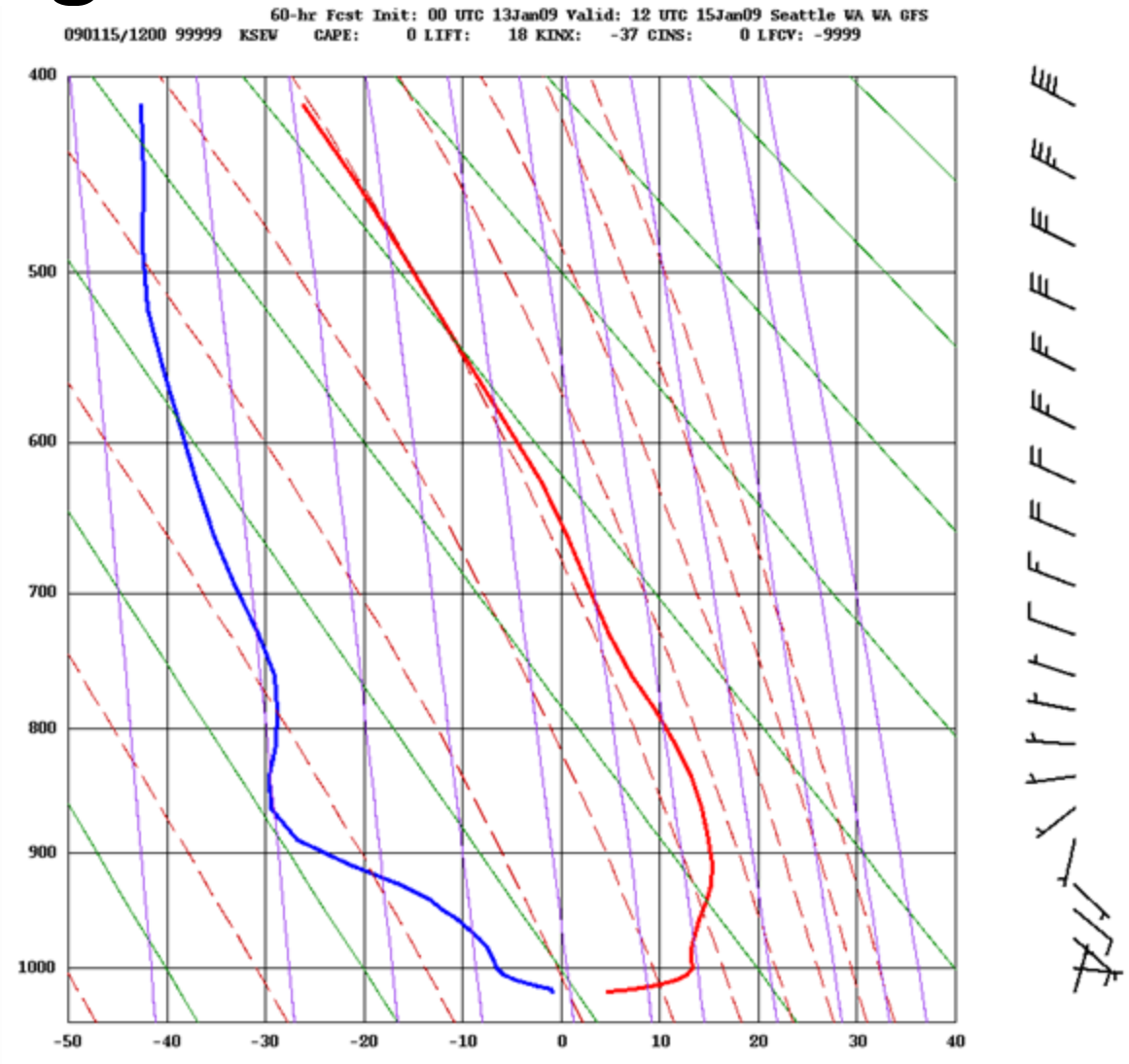
# A Reoccurring Problem in Both MM5 and WRF

## Inability to Maintain a Shallow Fog/Cloud Layer

# January Inversion Period



# Mixing out of shallow moist layer



One of the big advances in WRF was the addition of positive definite numerics

# Dec 13-14,2001 IMPROVE case

TABLE 2. Model bias scores in Fig. 12 calculated from PDA and NOPDA runs at 4- and 1.33-km resolutions and binned according to the regions defined in Fig. 3. "Domain total" precipitation represents an average of each region of interest, whereas the "weighted total" is normalized by precipitation in each subdomain.

| | 4 km | | 1.33 km | |
|---|---|---|---|---|
| Domain | NOPDA | PDA | NOPDA | PDA |
| Coast water | 112 | 107 | 113 | 109 |
| Coast mountains | 101 | 94 | 105 | 89 |
| Willamette Valley | 161 | 141 | 159 | 137 |
| Cascade windward | 135 | 120 | 138 | 115 |
| Cascade leeward | 223 | 178 | 216 | 182 |
| Domain total | 153 | 132 | 153 | 130 |
| Weighed total | 140 | 123 | 142 | 120 |

# Model Biases in Incoming Flow at Salem, Oregon

TABLE 3. Vertically averaged (0–3 km) biases in water vap
of the 13–14 Dec eve

| | 2100 UTC 13 Dec | |
|---|---|---|
| | NOPDA | PDA |
| Water vapor | 9.1% | 9.4% |
| Wind | 18.0% | 17.9% |
| QV flux | 31.0% | 31.3% |

# Excessive Water Vapor Flux Approaching the Mountains Is Apparent over Longer Periods

TABLE 4. Biases in water vapor, wind, and moisture flux for GFS F00 and F24 , WRF (12 km), and MM5 (12 km) as compared to soundings at Salem and Quillayute from 2 Sep 2007 through 14 Apr 2008. Average values over 0–3 (WRF and MM5) and 0.5–3 km (GFS).

| | Salem | | | | Quillayute | | | |
|---|---|---|---|---|---|---|---|---|
| | WRF | MMS | GFS F00 | GFS F24 | WRF | MMS | GFS F00 | GFS F24 |
| Water vapor | 4.6% | 1.5% | 3.4% | 4.1% | 5.2% | 4.6% | 4.0% | 4.1% |
| Wind | 3.6% | 5.1% | −0.4% | 5.3% | 2.7% | 3.2% | −0.8% | 0.8% |
| QV flux | 12.7% | 12.1% | 4.4% | 11.7% | 12.2% | 12.4% | 6.4% | 8.9% |

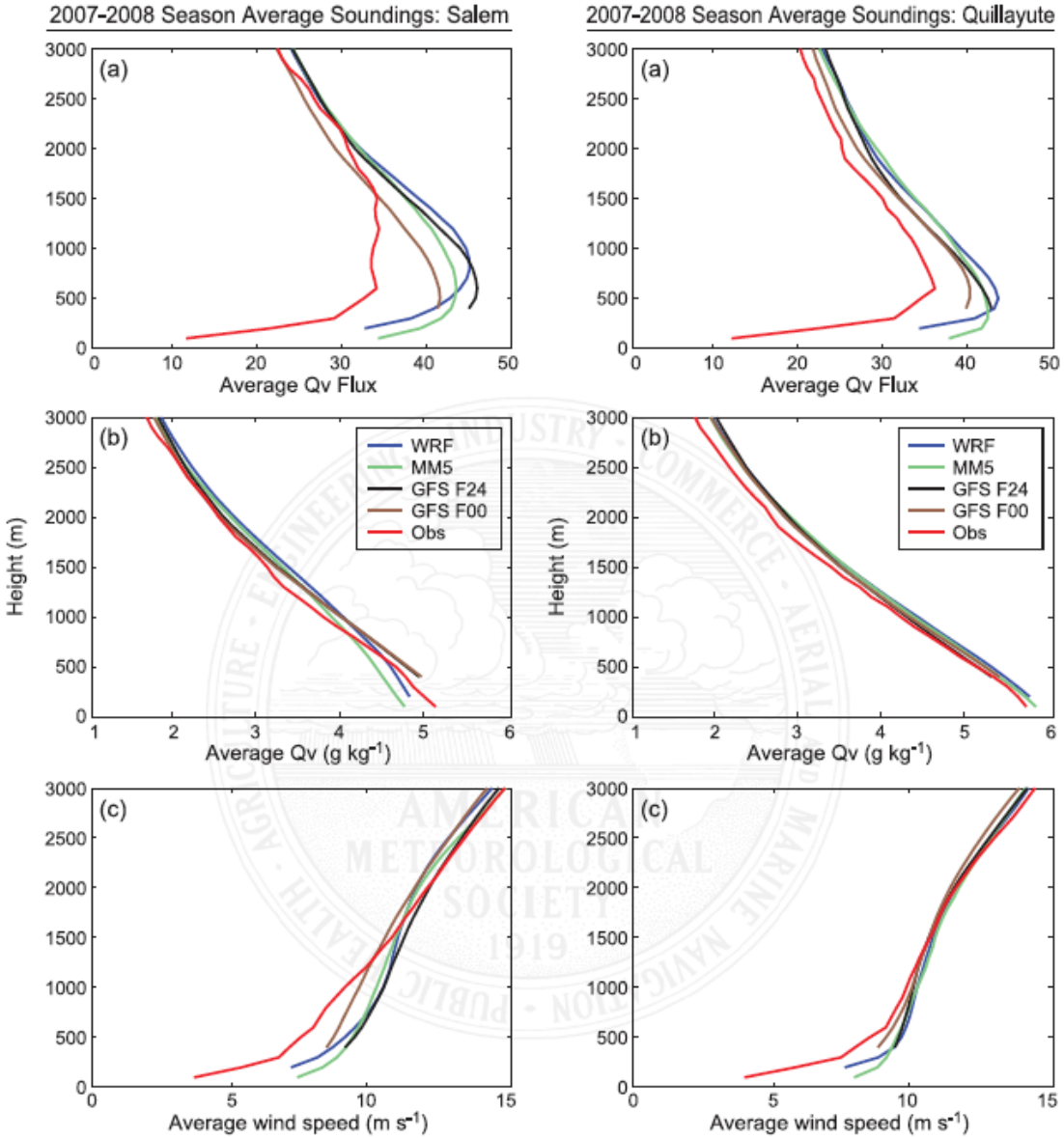



FIG. 14. Salem sounding comparison of WRF (PDA), MM5, GFS (initialization and FH 24), and a VIZ-B2 rawinsonde launched twice daily at 0000 and 1200 UTC throughout the 2007/08 cool season (2 Oct–12 Apr). Out of 388 potential sounding times,

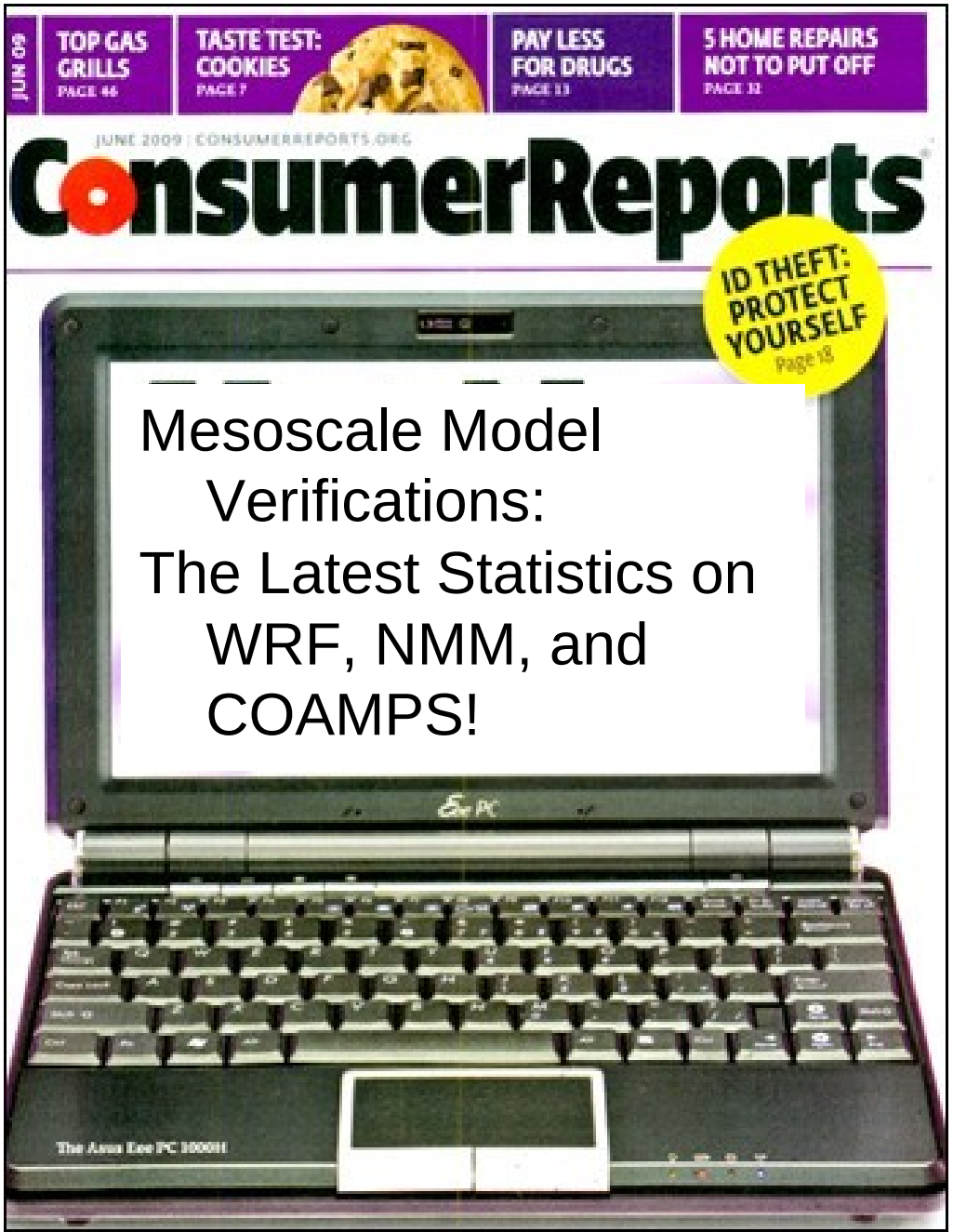



FIG. 15. As in Fig. 14, but for Quillayute and out of 388 potential sounding times, 337 had complete observational profiles and were used in this analysis.

So how much of the precipitation bias is from boundary layer scheme problems, not microphysics?

# An Organized National Effort for Model and Parameterization Verification/evaluation is Required to Guide Our Work

- A community “consumer’s report” for modeling systems and parameterizations.
- Can help guide research and development.
- Can promote the effective use of limited resources.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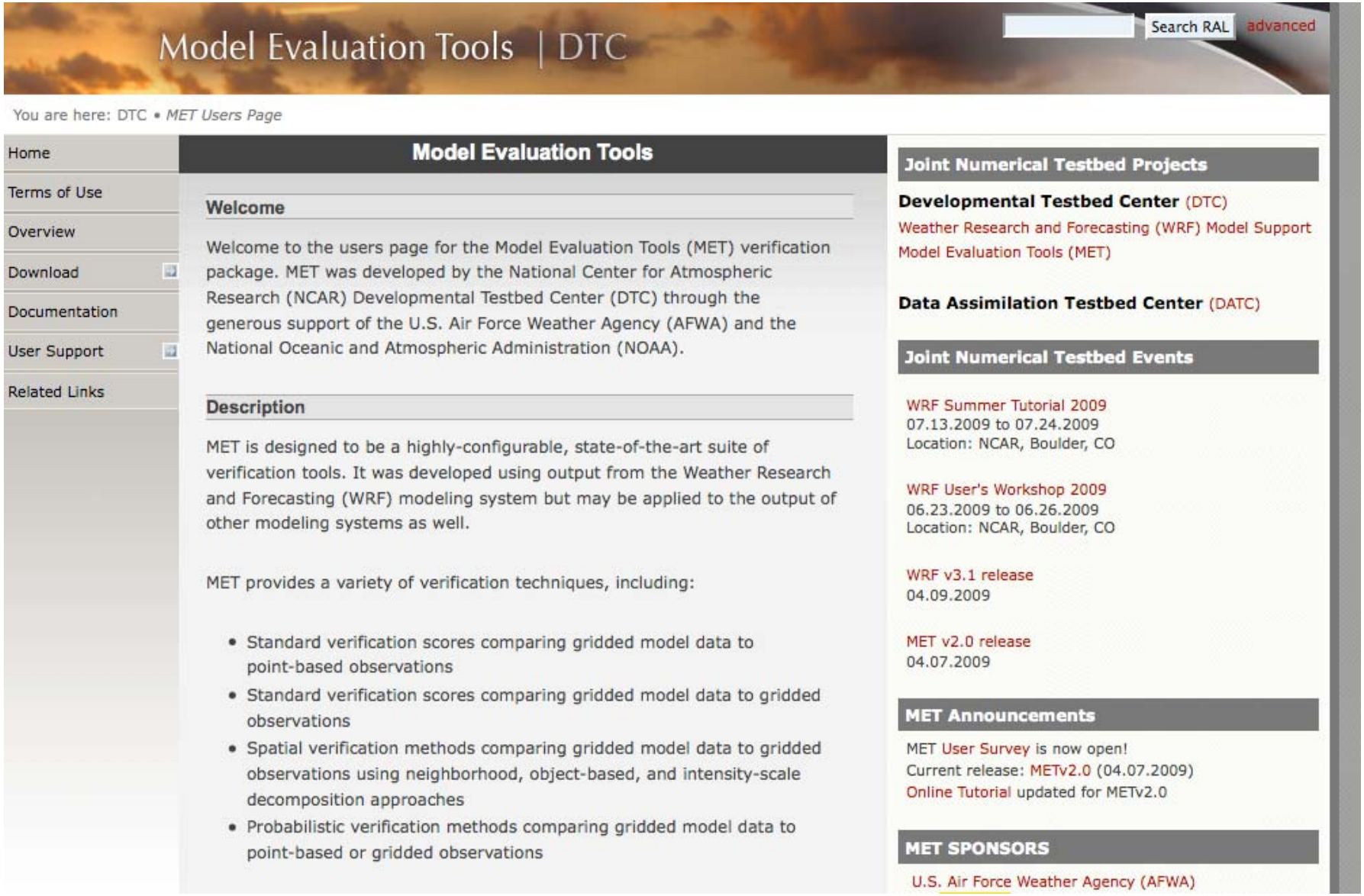
# An Honest Broker

- We have pieces of the puzzle:
  - The Developmental Testbed Center (DTC) is a natural center for such activities.
  - Powerful verification capabilities have been developed (Model Evaluation Tools, MET)
  - Regional verification effots
- DTC should take on this key responsibility as an unbiased evaluator of model and parameterization performance.


Model Evaluation Tools | DTC
Search RAL
advanced
You are here: DTC • MET Users Page
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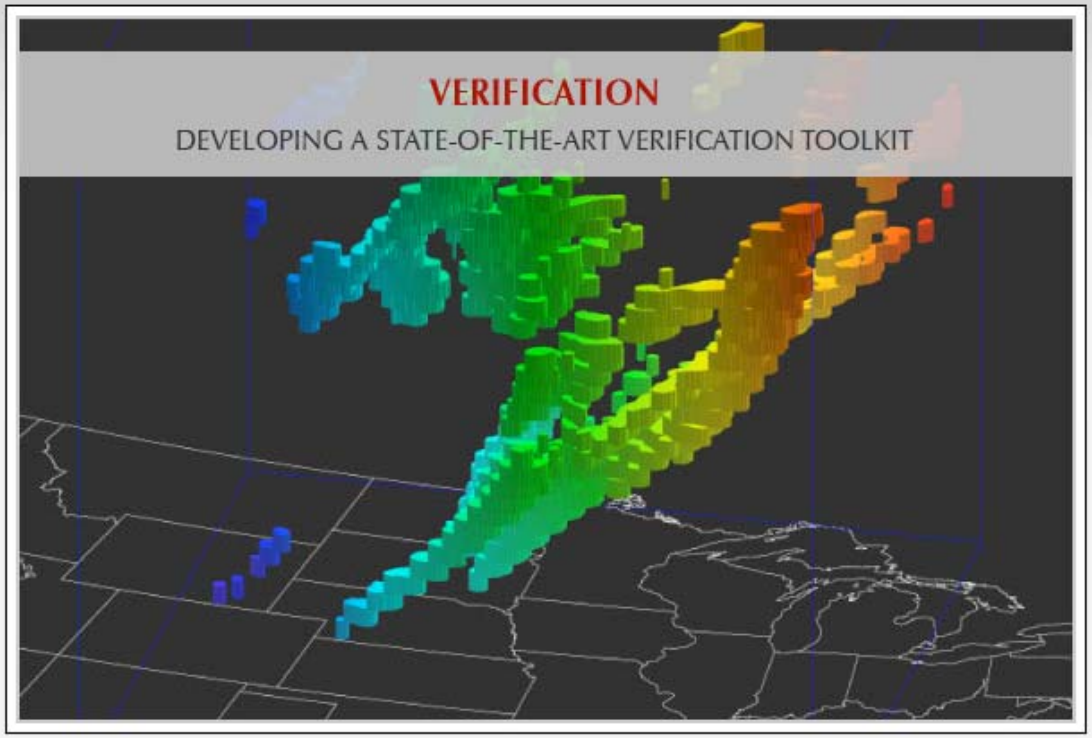
Model Evaluation Tools
Welcome
Welcome to the users page for the Model Evaluation Tools (MET) verification package. MET was developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center (DTC) through the generous support of the U.S. Air Force Weather Agency (AFWA) and the National Oceanic and Atmospheric Administration (NOAA).
Description
MET is designed to be a highly-configurable, state-of-the-art suite of verification tools. It was developed using output from the Weather Research and Forecasting (WRF) modeling system but may be applied to the output of other modeling systems as well.
MET provides a variety of verification techniques, including:
Standard verification scores comparing gridded model data to point-based observations
Standard verification scores comparing gridded model data to gridded observations
Spatial verification methods comparing gridded model data to gridded observations using neighborhood, object-based, and intensity-scale decomposition approaches
Probabilistic verification methods comparing gridded model data to point-based or gridded observations
Joint Numerical Testbed Projects
Developmental Testbed Center (DTC)
Weather Research and Forecasting (WRF) Model Support
Model Evaluation Tools (MET)
Data Assimilation Testbed Center (DATC)
Joint Numerical Testbed Events
WRF Summer Tutorial 2009
07.13.2009 to 07.24.2009
Location: NCAR, Boulder, CO
WRF User's Workshop 2009
06.23.2009 to 06.26.2009
Location: NCAR, Boulder, CO
WRF v3.1 release
04.09.2009
MET v2.0 release
04.07.2009
MET Announcements
MET User Survey is now open!
Current release: METv2.0 (04.07.2009)
Online Tutorial updated for METv2.0
MET SPONSORS
U.S. Air Force Weather Agency (AFWA)

# Verification

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## State of the Art Verification

Coming Soon

**Community Connections**

DTC Verification Workshops
Verification Advisory Group

**Tools**

Model Evaluation Tools (MET) (includes current release info.)

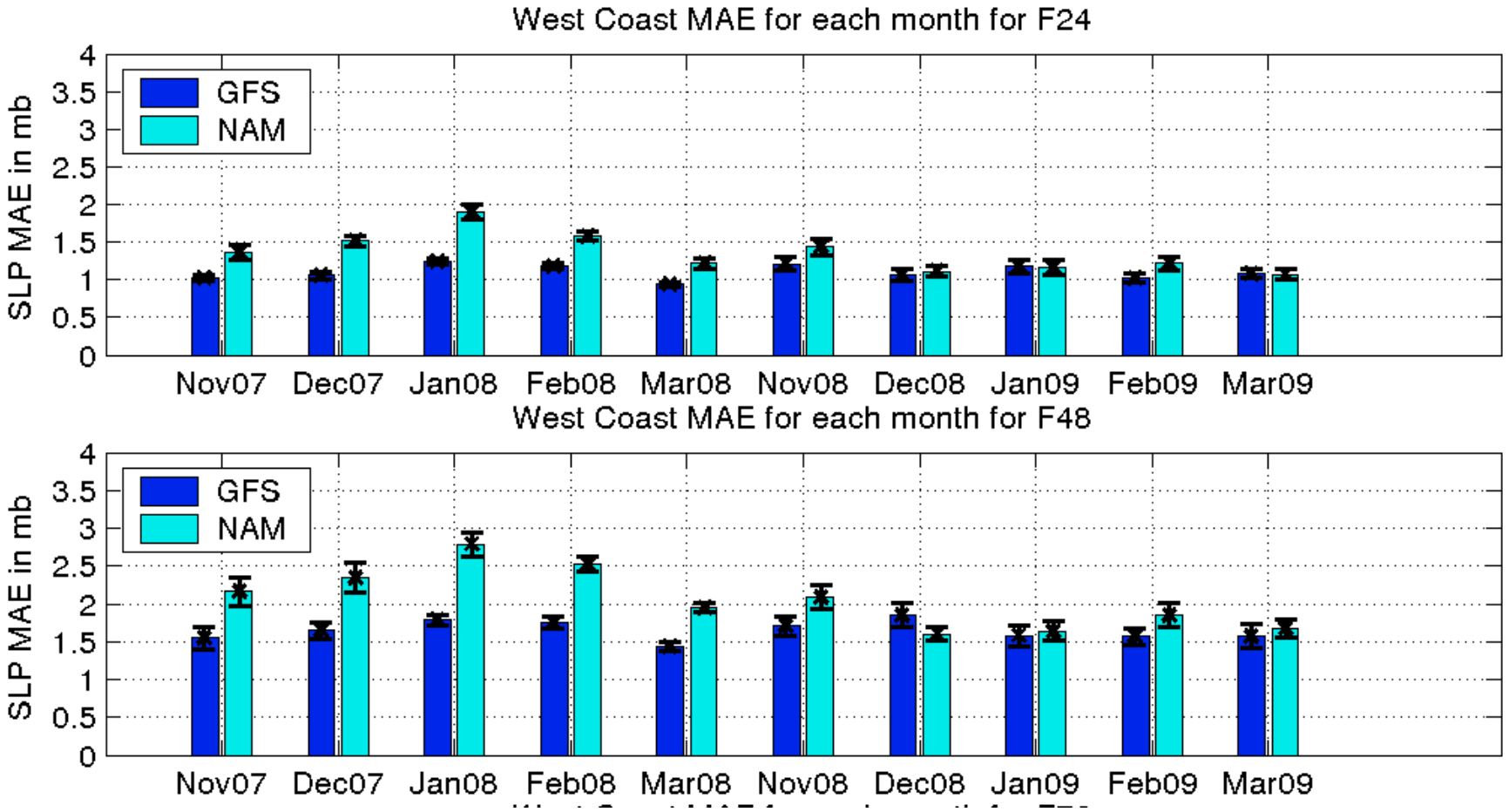
**Demonstration Projects**

Hazardous Weather Testbed Spring Experiment

# National Verification Effort

- We need a long-term baseline of model performance including “best combinations” of model physics options and promising options.
- Would have the ability to evaluate/run models and parameterizations for extended periods.
- Would have a collection of “interesting” and important cases of societal importance.
- Needs to separate out data assimilation from core modeling systems.

# Big Improvements for NAM



# National Model Evaluation

- Would expand to verification of probabilistic prediction.
- Requires sufficient scientific/technical competency to insure rigorous evaluation.

Without more organized evaluation of our models, the U.S. will waste resources and provide inferior products

To know your future, you must
know your past,
each stepping stone that has been
cast.