A Real-Time Forecast Uncertainty and Verification System for the UW Mesoscale Ensemble Using BMA

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http://isis.apl.washington.edu/bma/

Work under the MURI Project

The MURI is a multi-disciplinary project that brings together University of Washington Statistics, Atmospheric Sciences, Psychology, and Applied Physics to pursue new methods in weather forecasting, forecast uncertainty and verification.

The APL's work on the MURI brings new methods of visualizing forecast uncertainty and verification to the user through web-enabled applications. In the process a ground work for automated data access has been created.

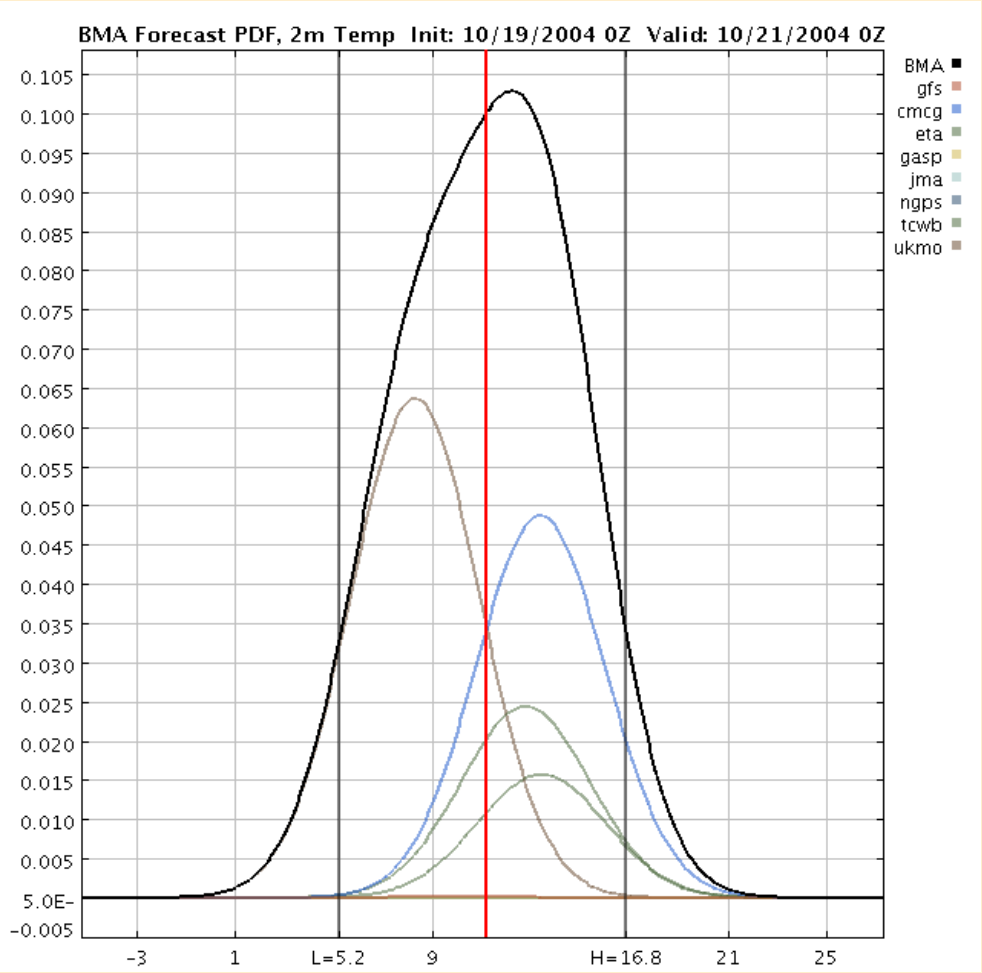
We are currently over four years into the project, with a couple of years to go. For several months APL has been operating the Bayesian Model Averaging web application with the help of the MURI partners.

Bayesian Model Averaging

Bayesian Model Averaging (BMA) describes a method of combining multiple deterministic model predictions (such as the MM5 ensemble members producing forecasts for the Northwest) to produce a single probabilistic forecast.

Based on a given training period, a predictive distribution is assigned to each individual model. These distributions are combined by way of a weighted average to produce a single forecast predictive distribution. The BMA forecast produces a full forecast PDF at every model grid point.

Uncertainty information is then based on the sharpness of the BMA predictive interval. Other metrics of interest are also produced from the PDF.



The Bayesian Model Averaging Web Site

The UW BMA web site (http://isis.apl.washington.edu/bma/) is a real-time implementation of the BMA process for the MM5 ensemble operated by UW Atmospheric Sciences. Though a functional forecast tool, it also serves a test bed for exploring visualizations of uncertainty and probabilistic forecasts.

New ensemble and observation data is collected on a daily basis.

Integrated into archived data to gather a training data set.

Training data is used to generate the BMA parameters (bias correction, weights, variances) on a daily basis. The BMA algorithm itself is run from the package submitted to the CRAN project by UW statistics.

At each grid point, five parameters (based on the predictive distribution) are provided . . . .

The Bayesian Model Averaging Parameters

Forecast parameters:

1) Deterministic forecast

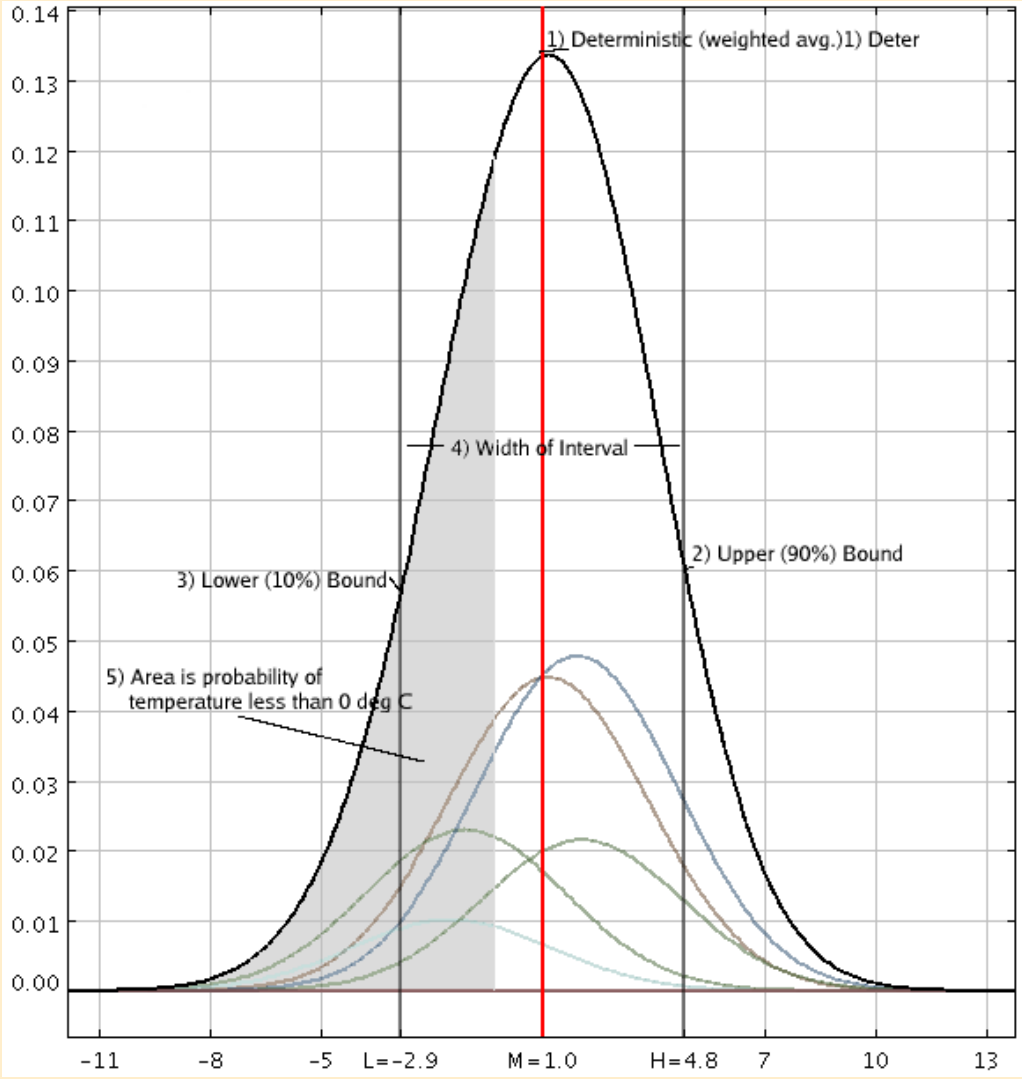
2) Upper bound of interval

3) Lower Bound of interval

4) Width of interval
(Uncertainty / sharpness)

5) Probability a threshold
is exceeded

Shown here is a PDF with parameters for a 80% interval (bounded by the 10% and 90% bounds) and a threshold of “below 0 deg C” shaded. These parameters are all defined by the user in the web application. Distributions from contributing ensemble members can also be seen (the colored curves).



The Bayesian Model Averaging Web Site

How to display (or visualize) the BMA parameters we want to present?

As a first step, we simply plot each of the five the scalar values across the model domain, on a map. The first three parameters show a temperature forecast, while the width field is in units of temperature but not an absolute forecast, and the threshold plot is in percent likelihood.

Each set of BMA parameters only applies to a single forecast, so we allow users to navigate init date, parameter, etc.

We also make the display interactive by generating visualizations “on-the-fly”, and allow the user to adjust certain parameters (interval width / bounds, thresholds) and select a geographic location on the map to display the underlying PDF.

The Bayesian Model Averaging Web Site

http://isis.apl.washington.edu/bma/

UW Ensemble Bayesian Model Averaging - Mozilla

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http://isis/bma/index.jsp?initYear=2004&initMonth=10&initDay=4&param=T2&init=00&tau=48&

Search

UW Ensemble Bayesian Model Averaging

BMA Parameters

Init Date: 2004 October 4

Param: 2m Temperature

Init Time: 0Z

Forecast Hour: 48 Hour

Toggle Contour Lines OFF

Grid Forecast:

- Deterministic
- Upper Bound of CI
- Lower Bound of CI
- Half-width of CI
- Prob. param exceeds threshold

Point Forecast:

Latitude: 4

Longitude: -121.51

Upper Bound: .95

Lower Bound: .05

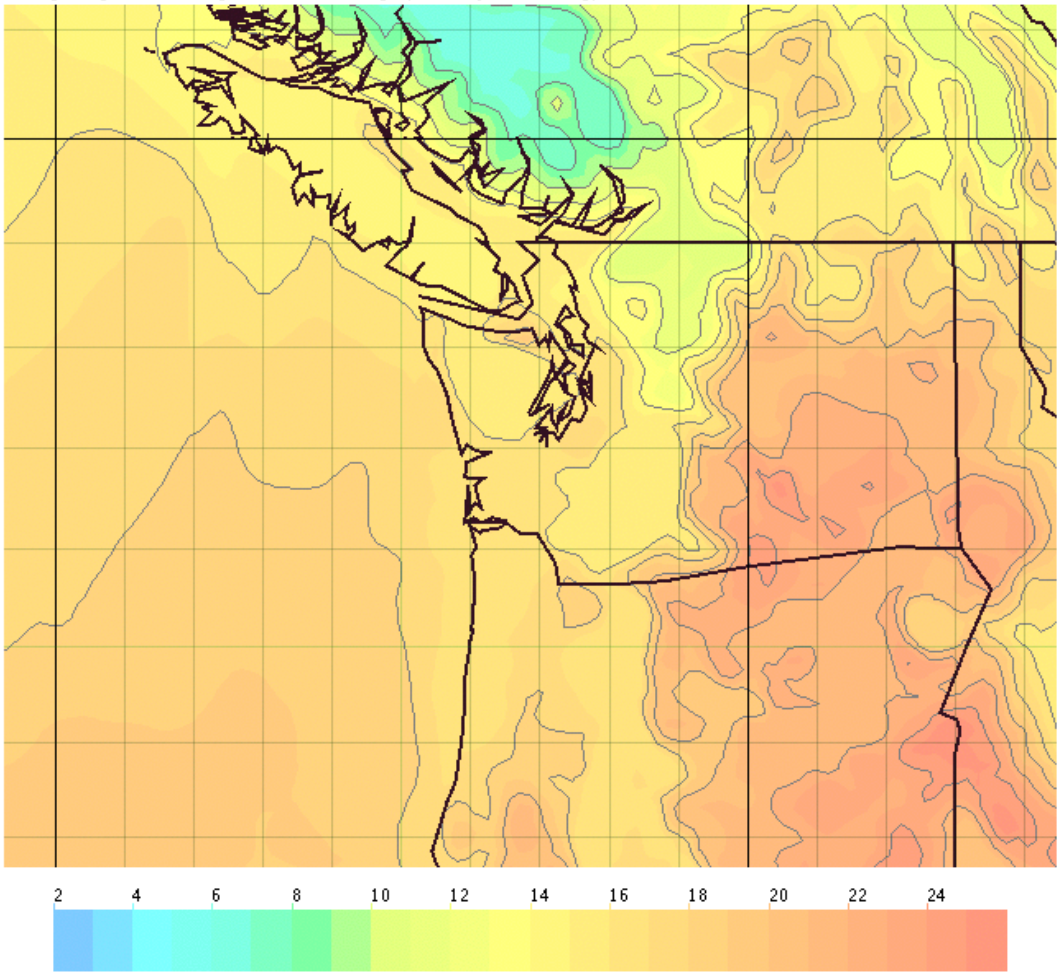
Threshold: 0

Greater than Less than

Retrieve Data

Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.

BMA Deterministic Forecast Param: 2m Temp Initialized: 10/4/2004 0Z Valid: 10/6/2004 0Z
Weights: gfs=0.000 cmcg=0.489 eta=0.088 gasp=0.027 jma=0.005 ngps=0.001 tcwb=0.000 ukmo=0.390



Done

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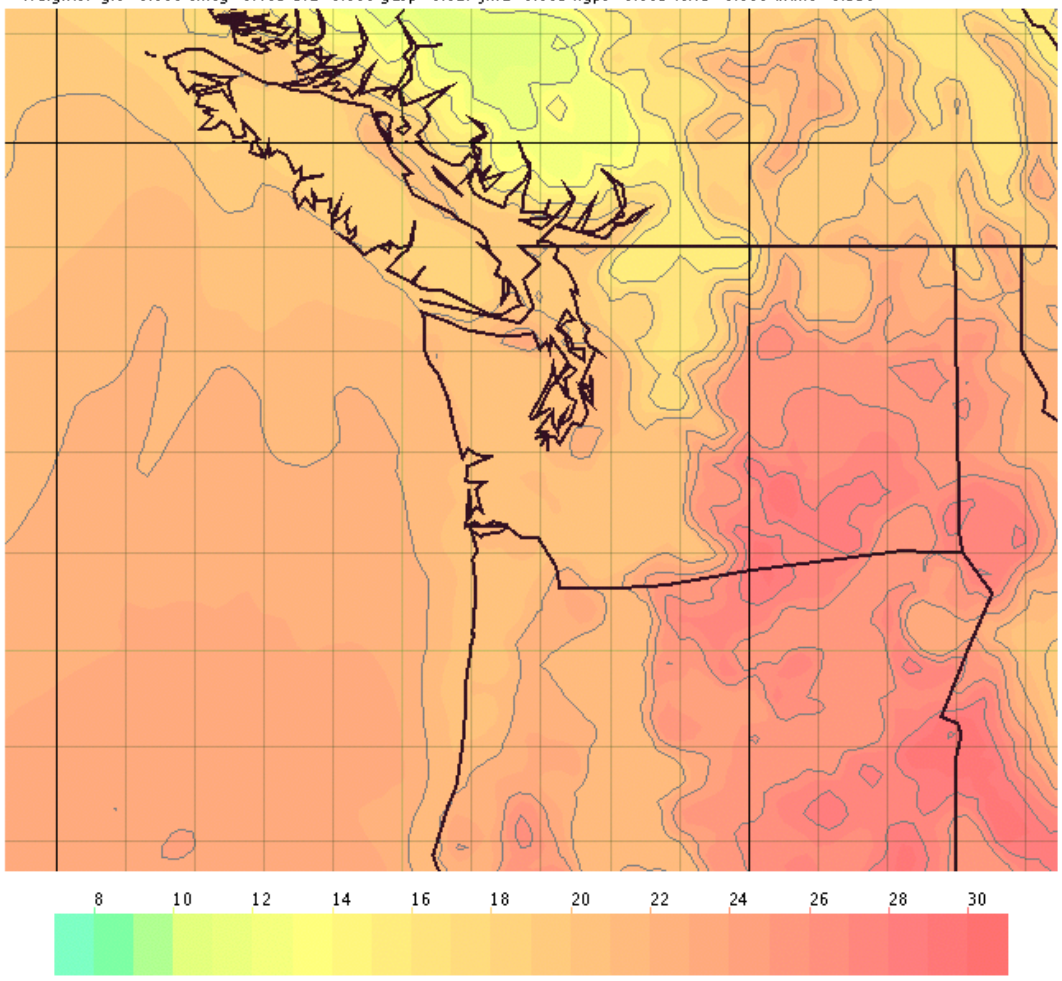
Greater than Less than

Retrieve Data

Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.

BMA 95.0% prob. less than given value; Param: 2m Temp Initialized: 10/4/2004 0Z Valid: 10/6/2004 0Z
Weights: gfs=0.000 cmcg=0.489 eta=0.088 gasp=0.027 jma=0.005 ngps=0.001 tcwb=0.000 ukmo=0.390



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Lower Bound: .05

Threshold: 0

Greater than Less than

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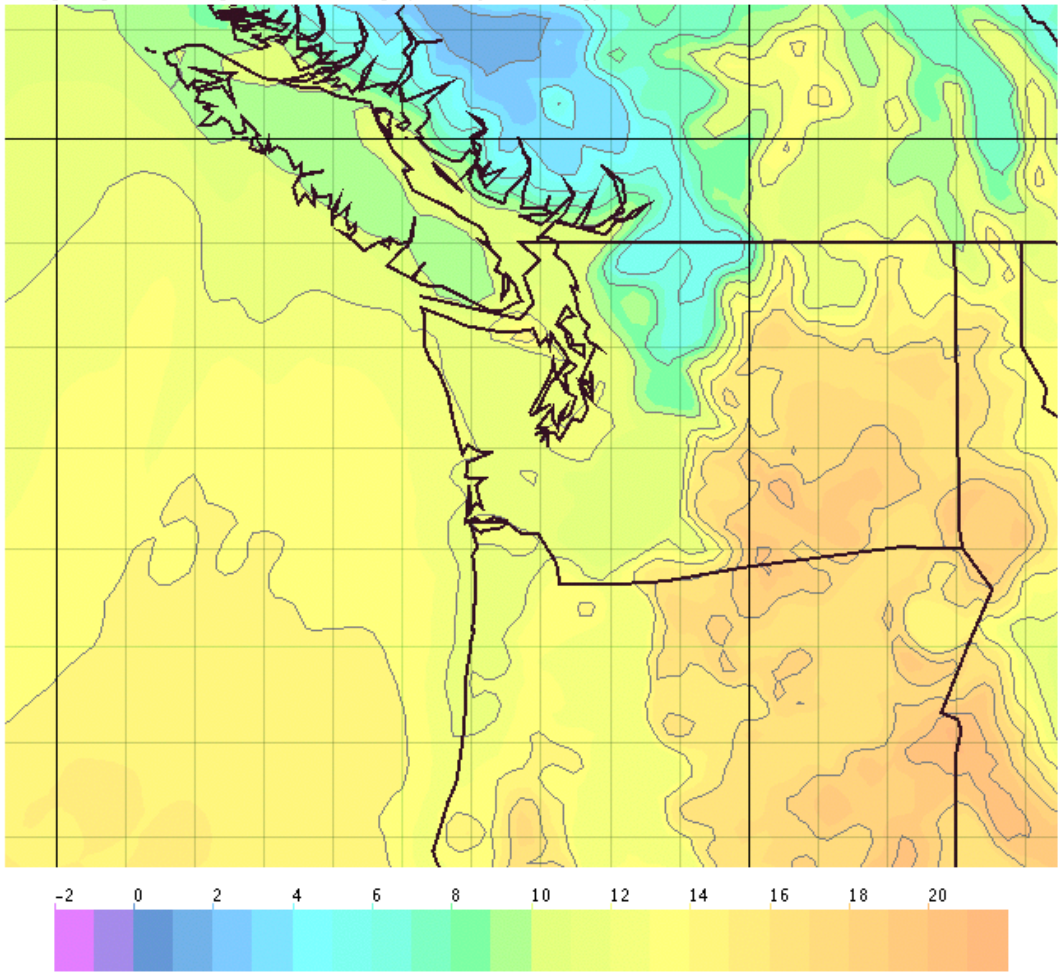
Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.

BMA 95.0% prob. greater than given value; Param: 2m Temp Initialized: 10/4/2004 0Z Valid: 10/6/2004 0Z
Weights: gfs=0.000 cmcg=0.489 eta=0.088 gasp=0.027 jma=0.005 ngps=0.001 tcwb=0.000 ukmo=0.390



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Lower Bound: .05

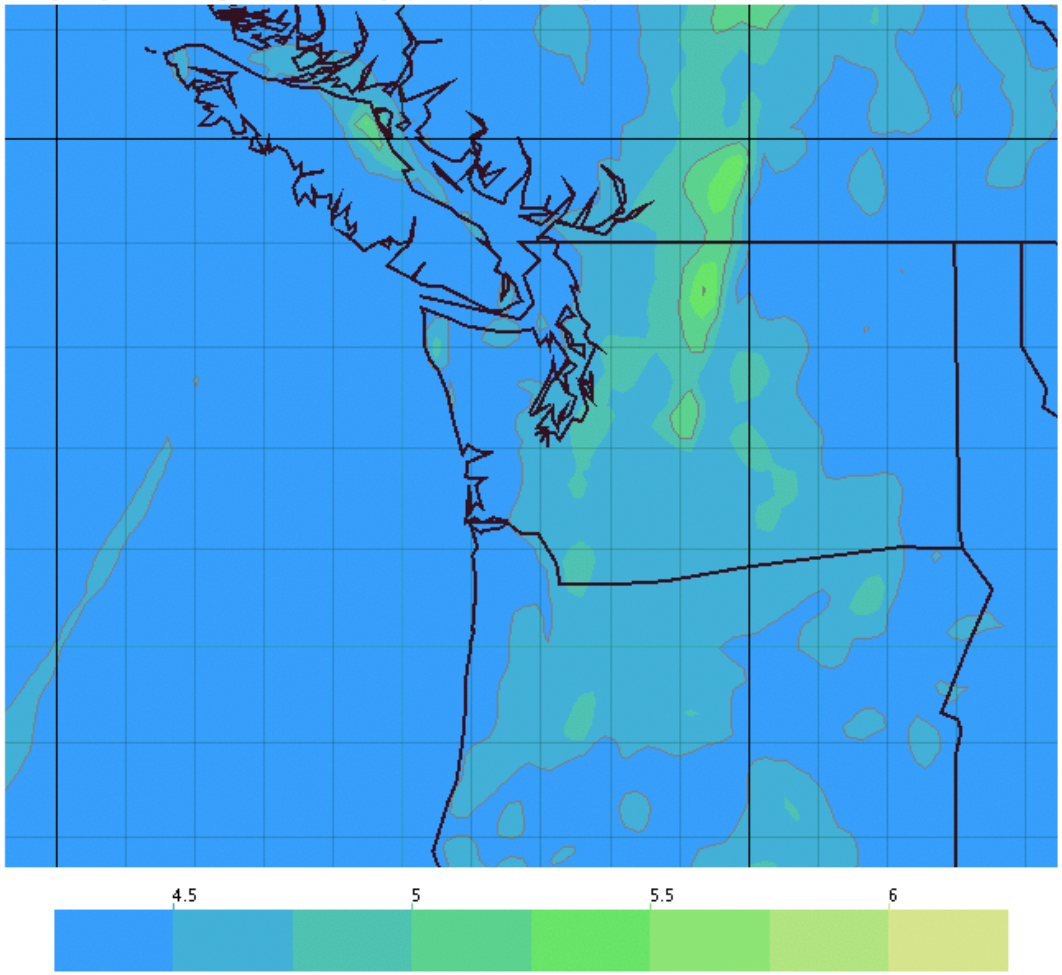
Threshold: 0

Greater than Less than

Retrieve Data

Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.

BMA 90.0% predictive interval half-width, from 5.0 to 95.0%; Param: 2m Temp Initialized: 10/4/2004 0Z Valid: 10/6/2004 0Z
Weights: gfs=0.000 cmcg=0.489 eta=0.088 gasp=0.027 jma=0.005 ngps=0.001 tcwb=0.000 ukmo=0.390



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Point Forecast:

Latitude: 4

Longitude: -121.51

Upper Bound: .95

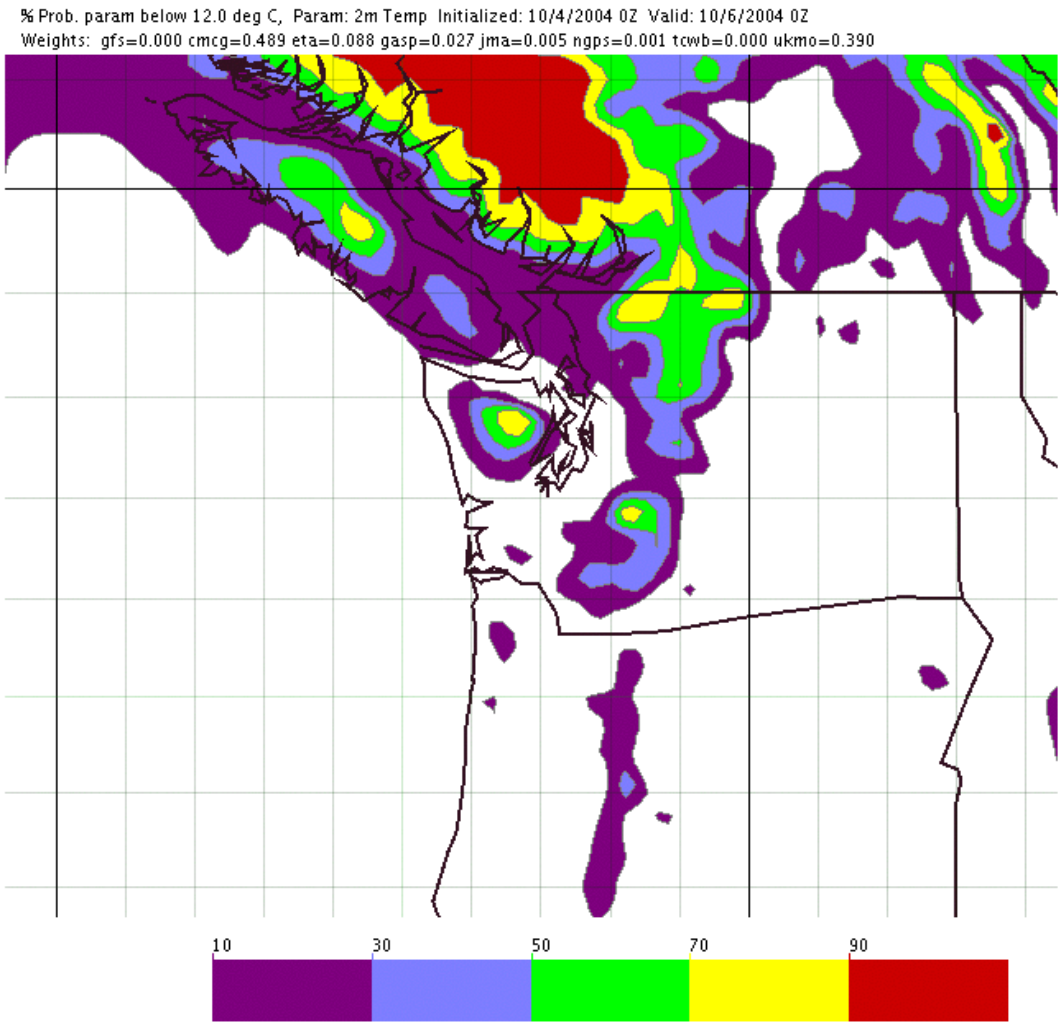
Lower Bound: .05

Threshold: 12

Greater than Less than

Retrieve Data

Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.



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Point Forecast:

Latitude: 4

Longitude: -121.51

Upper Bound: .95

Lower Bound: .05

Threshold: 12

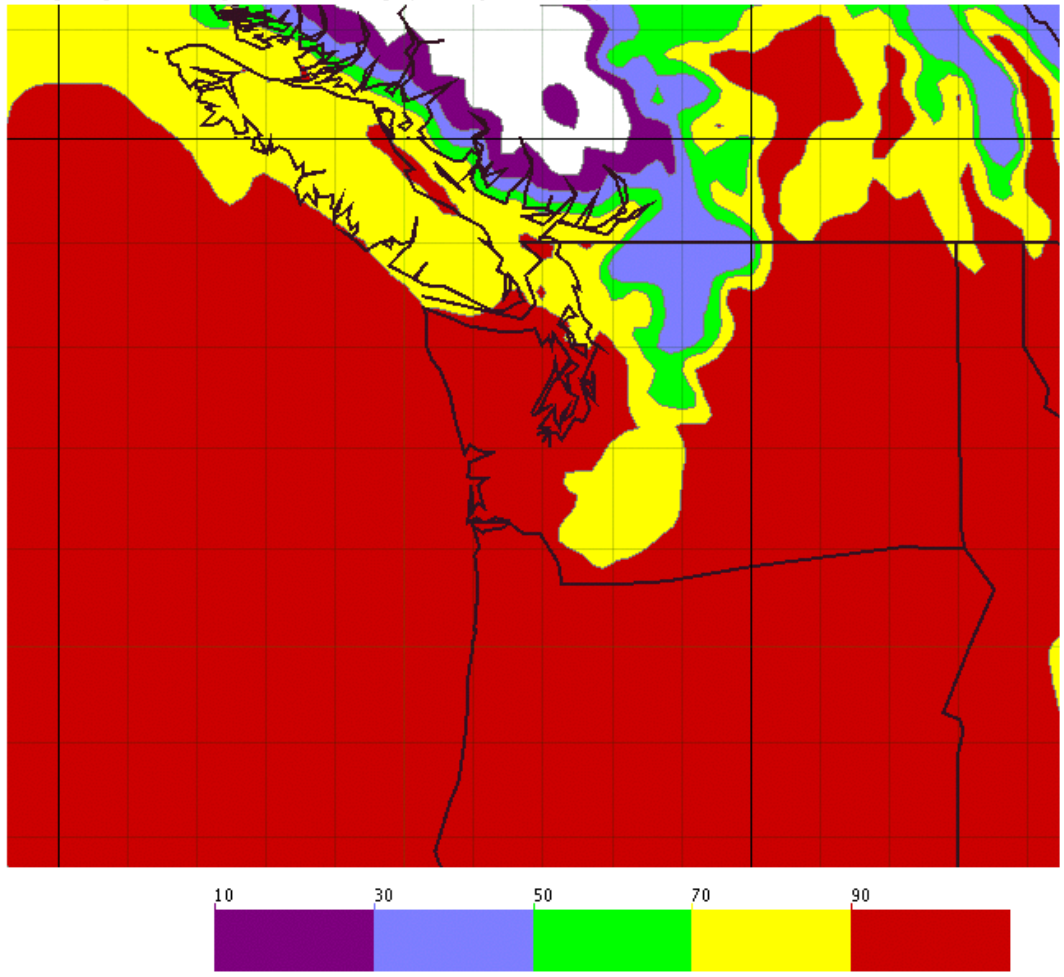
Greater than Less than

Retrieve Data

Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.

% Prob. param above 12.0 deg C, Param: 2m Temp Initialized: 10/4/2004 0Z Valid: 10/6/2004 0Z

Weights: gfs=0.000 cmcg=0.489 eta=0.088 gasp=0.027 jma=0.005 ngps=0.001 tcwb=0.000 ukmo=0.390



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Toggle Contour Lines ON

Grid Forecast:

- Deterministic
- Upper Bound of CI
- Lower Bound of CI
- Half-width of CI
- Prob. param exceeds threshold

Point Forecast:

Latitude: 49.4721

Longitude: -120.42

Upper Bound: .95

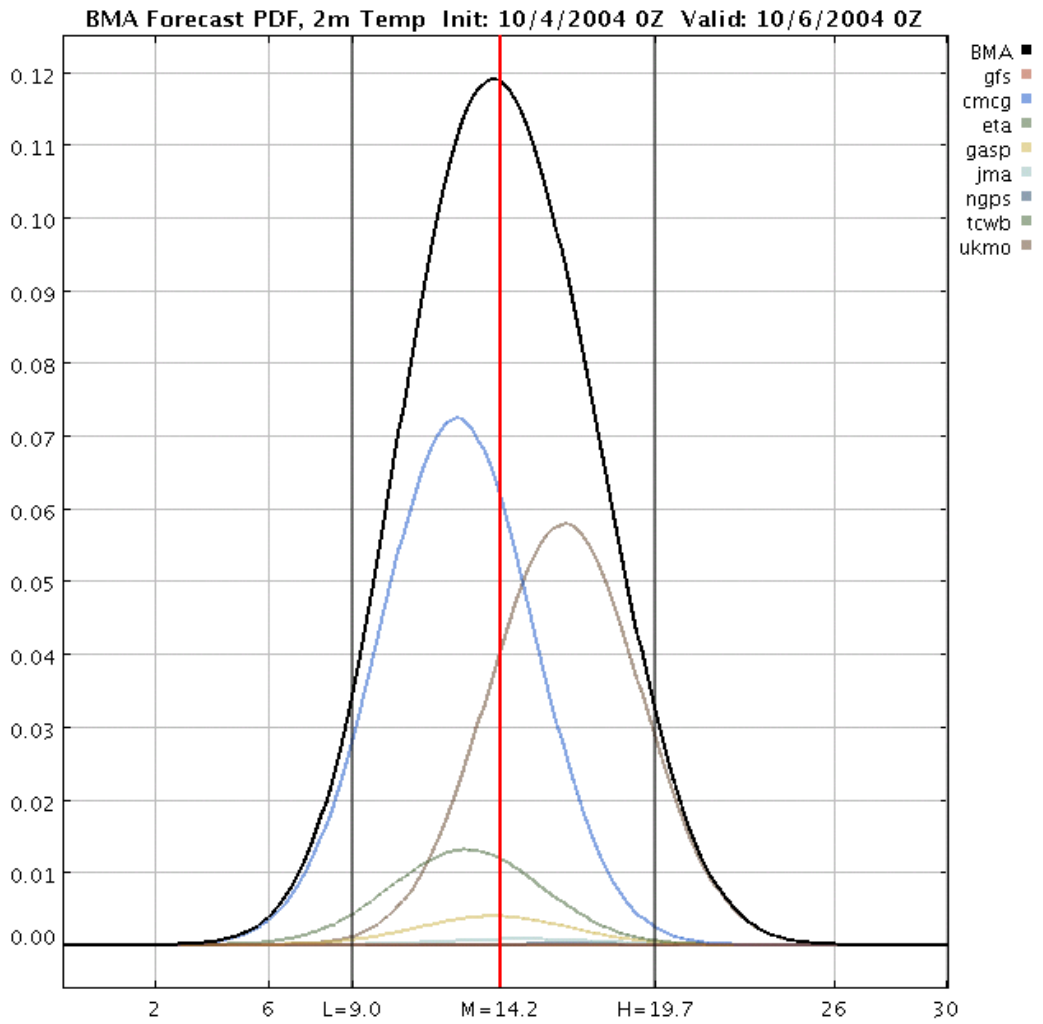
Lower Bound: .05

Threshold: 12

Greater than Less than

Retrieve Data

Click a location on the map presented below to view the probability distribution for the given parameter at that point, or choose a new plot from the menu on the left and click the 'Retrieve Data' button.



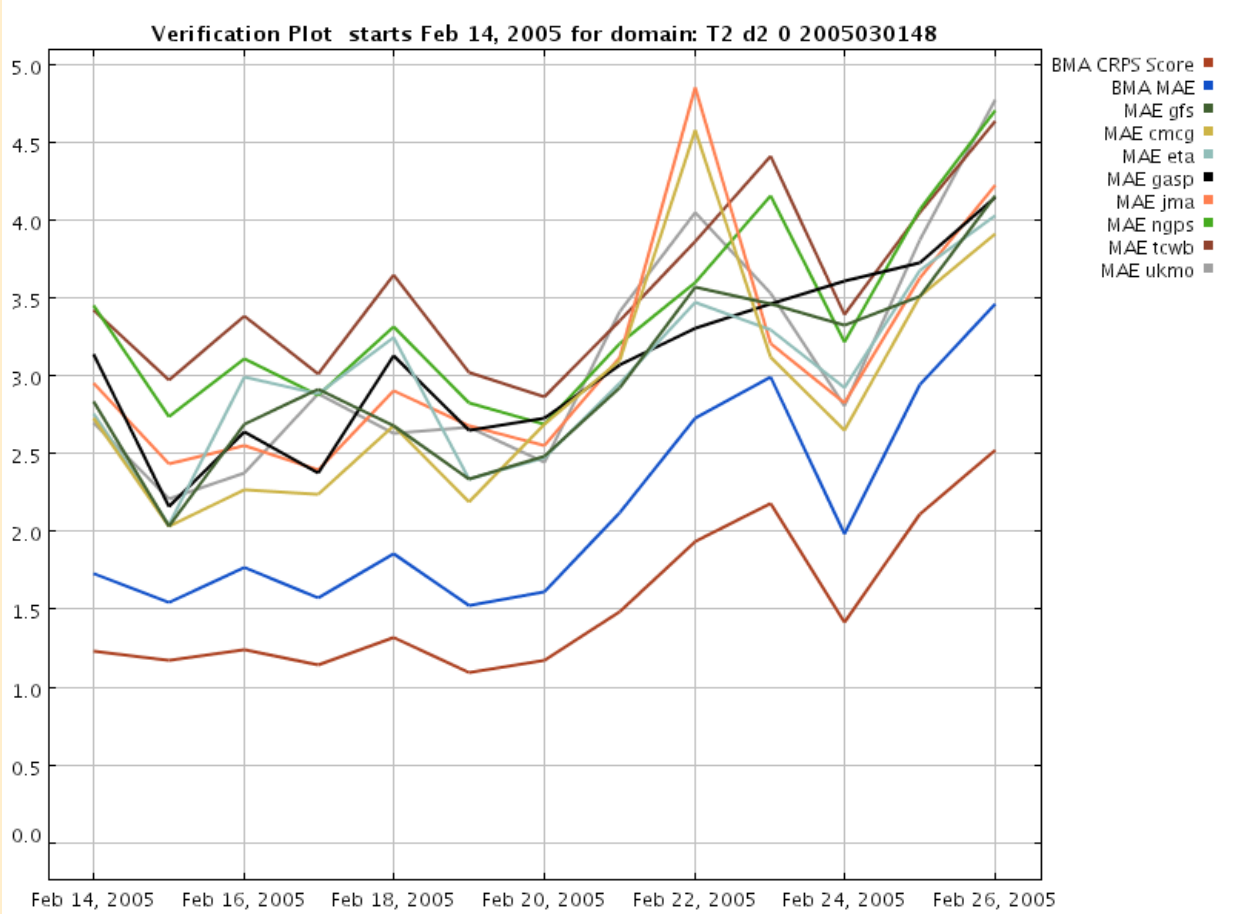
Done

BMA Results

Results:

1) BMA MAE (blue line) tracks below ensemble (cluster of multicolored lines).

2) BMA CRPS (red line, probabilistic skill score, units in deg C) tracks below both.



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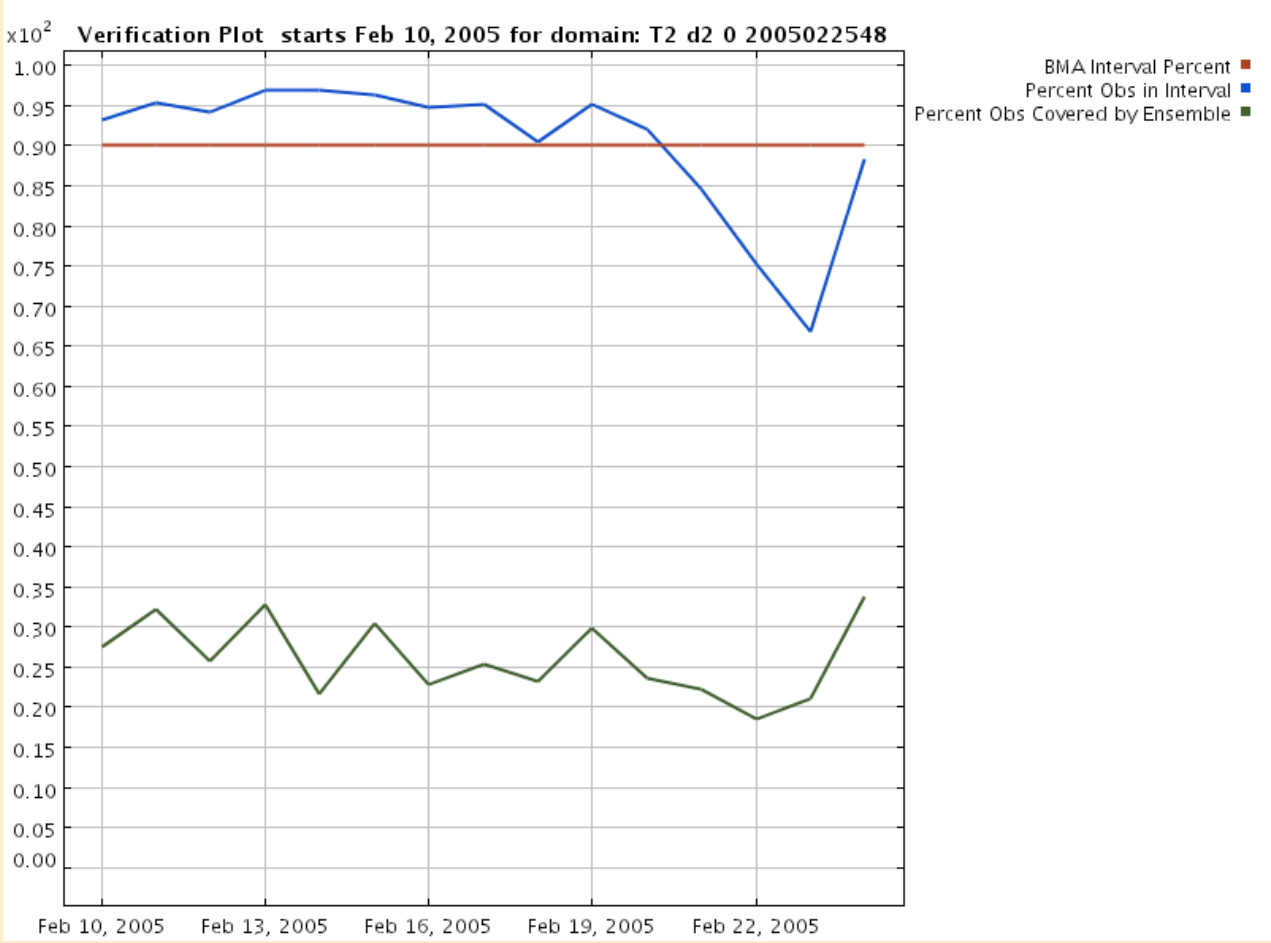

Future Work in Forecast Uncertainty

Currently working on a verification counterpart for the BMA page, that provides real-time statistics for BMA and the MM5 ensemble: CRPS, RMSE, MAE, coverage, interval width, bias, and weights.

We plan on adding new parameters to the BMA system, such as precipitation and wind.

In the near future, we would like to apply lessons learned from BMA and more advanced visualizations to create a unified forecast verification and uncertainty tool known as the MURI Uncertainty Monitor (version 2). This work would focus on providing logical and intuitive visualizations such as stoplight graphics to communicate the forecast quality and sharpness in a quick to understand fashion, while also providing access to the more complex forecast situation (individual model verification, contributions, etc).

In Conclusion

In the BMA web site we have developed a real-time forecast tool that provides straightforward visualizations of forecast uncertainty and probabilistic parameters.

The real question: how to best apply these techniques? The generalized forecast maps may not be the best way, when compared to more specific applications such as transportation weather or other situations where a “probability-of-event-occuring” is needed.

End

Questions? Comments?