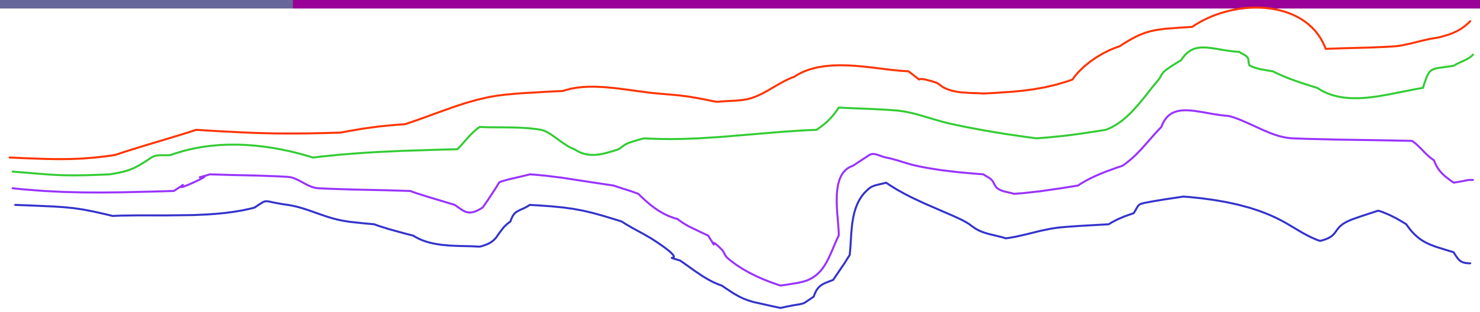

Review of UWME Forecast Performance and Post-Processing

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Multi-Analysis Collection

Abbreviation/Model/Source	Type	Resolution (~ @ 45 °N) Computational	Distributed	Objective Analysis
gfs, Global Forecast System (GFS), National Centers for Environmental Prediction	Spectral	T254 / L64 ~55 km	1.0° / L14 ~80 km	SSI 3D Var
cmcg, Global Environmental Multi-scale (GEM), Canadian Meteorological Centre	Finite Diff	0.9°×0.9°/L28 ~70 km	1.25° / L11 ~100 km	3D Var
eta, limited-area mesoscale model, National Centers for Environmental Prediction	Finite Diff.	12 km / L45	90 km / L37	SSI 3D Var
gasp, Global AnalysiS and Prediction model, Australian Bureau of Meteorology	Spectral	T239 / L29 ~60 km	1.0° / L11 ~80 km	3D Var
jma, Global Spectral Model (GSM), Japan Meteorological Agency	Spectral	T106 / L21 ~135 km	1.25° / L13 ~100 km	OI
ngps, Navy Operational Global Atmos. Pred. System, Fleet Numerical Meteorological & Oceanographic Cntr.	Spectral	T239 / L30 ~60 km	1.0° / L14 ~80 km	OI
tcwb, Global Forecast System, Taiwan Central Weather Bureau	Spectral	T79 / L18 ~180 km	1.0° / L11 ~80 km	OI
ukmo, Unified Model, United Kingdom Meteorological Office	Finite Diff.	5/6°×5/9°/L30 ~60 km	*same* / L12	3D Var

Old UWME and UWME+ Physics Configuration

(October 2002 – January 2005)

IC	ID#	PBL	PBL Soil	PBL vertical diffusion	Cloud Microphysics	Cumulus 36-km Domain	Cumulus 12-km Domain	Cumulus shlw. cumls.	Radiation	SST Perturbation	Land Use Table
UWME		MRF	5-Layer	Y	Simple Ice	Kain-Fritsch	Kain-Fritsch	N	cloud	*standard*	*standard*
UWME+											
avn	**plus01**	MRF	LSM	Y	Simple Ice	Kain-Fritsch	Kain-Fritsch	Y	RRTM	SST_pert01	LANDUSE.plus1
cmcg	**plus02**	MRF	5-Layer	Y	Reisner II	Grell	Grell	N	cloud	SST_pert02	LANDUSE.plus2
eta	**plus03**	Eta	5-Layer	N	Goddard	Betts-Miller	Grell	Y	RRTM	SST_pert03	LANDUSE.plus3
gasp	**plus04**	MRF	LSM	Y	Shultz	Betts-Miller	Kain-Fritsch	N	RRTM	SST_pert04	LANDUSE.plus4
jma	**plus05**	Eta	LSM	N	Reisner II	Kain-Fritsch	Kain-Fritsch	Y	cloud	SST_pert05	LANDUSE.plus5
ngps	**plus06**	Blackadar	5-Layer	Y	Shultz	Grell	Grell	N	RRTM	SST_pert06	LANDUSE.plus6
tcwb	**plus07**	Blackadar	5-Layer	Y	Goddard	Betts-Miller	Grell	Y	cloud	SST_pert07	LANDUSE.plus7
ukmo	**plus08**	Eta	LSM	N	Reisner I	Kain-Fritsch	Kain-Fritsch	N	cloud	SST_pert08	LANDUSE.plus8

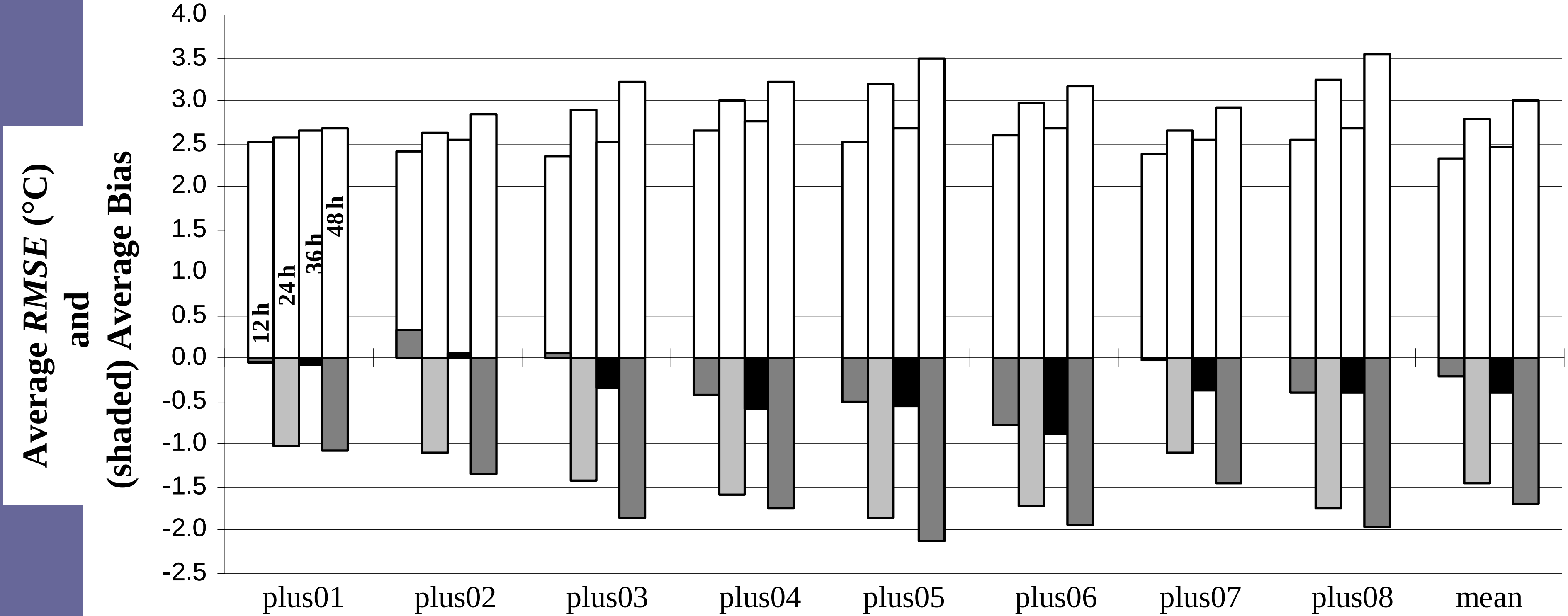
1) Albedo
2) Roughness Length
3) Moisture Availability

- **Assumed differences between model physics options approximate model error coming from sub-grid scales**

- **Perturbed surface boundary parameters according to their suspected uncertainty**

Member-Wise Forecast Bias Correction

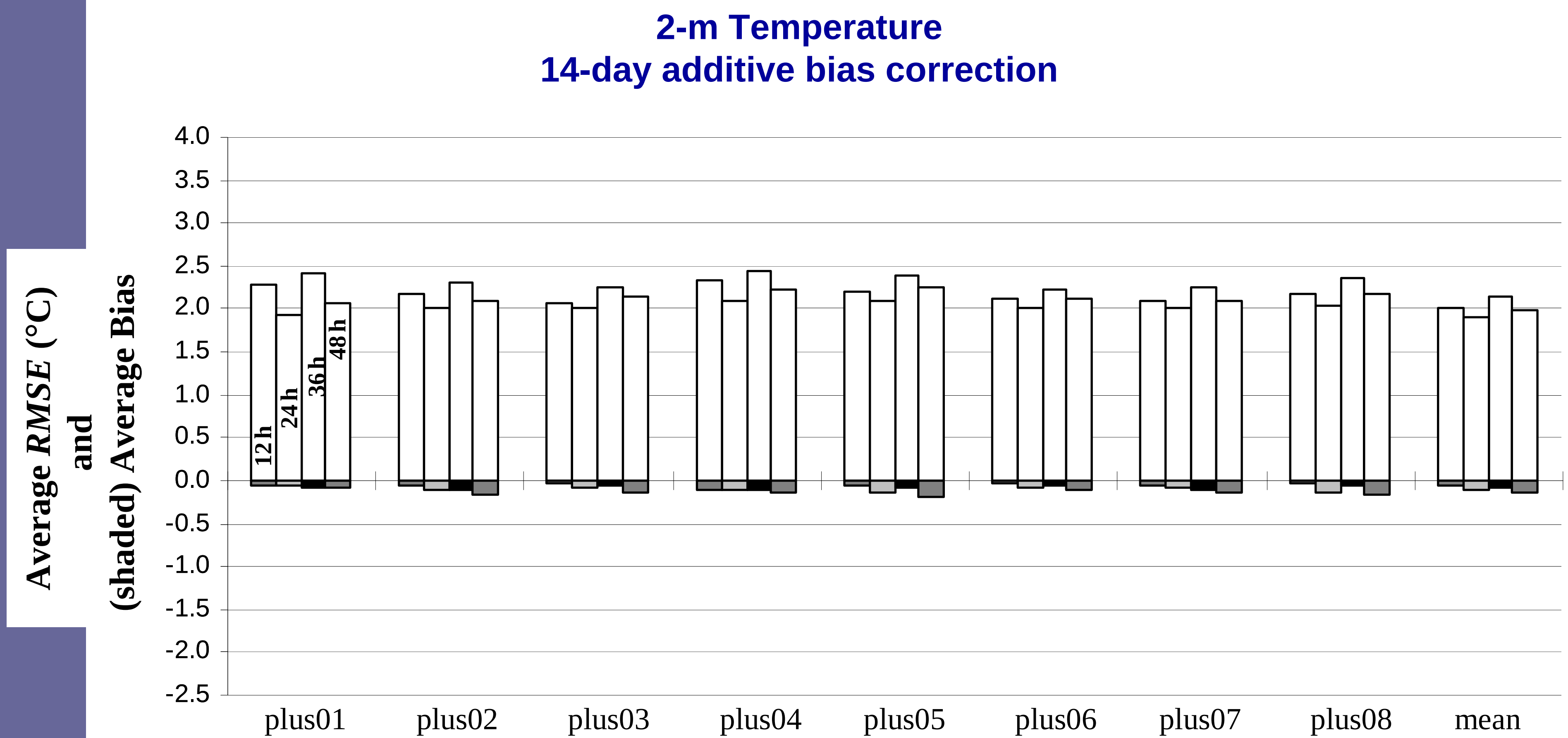
2-m Temperature



(0000 UTC Cycle; October 2002 – March 2003)

Eckel and Mass 2005

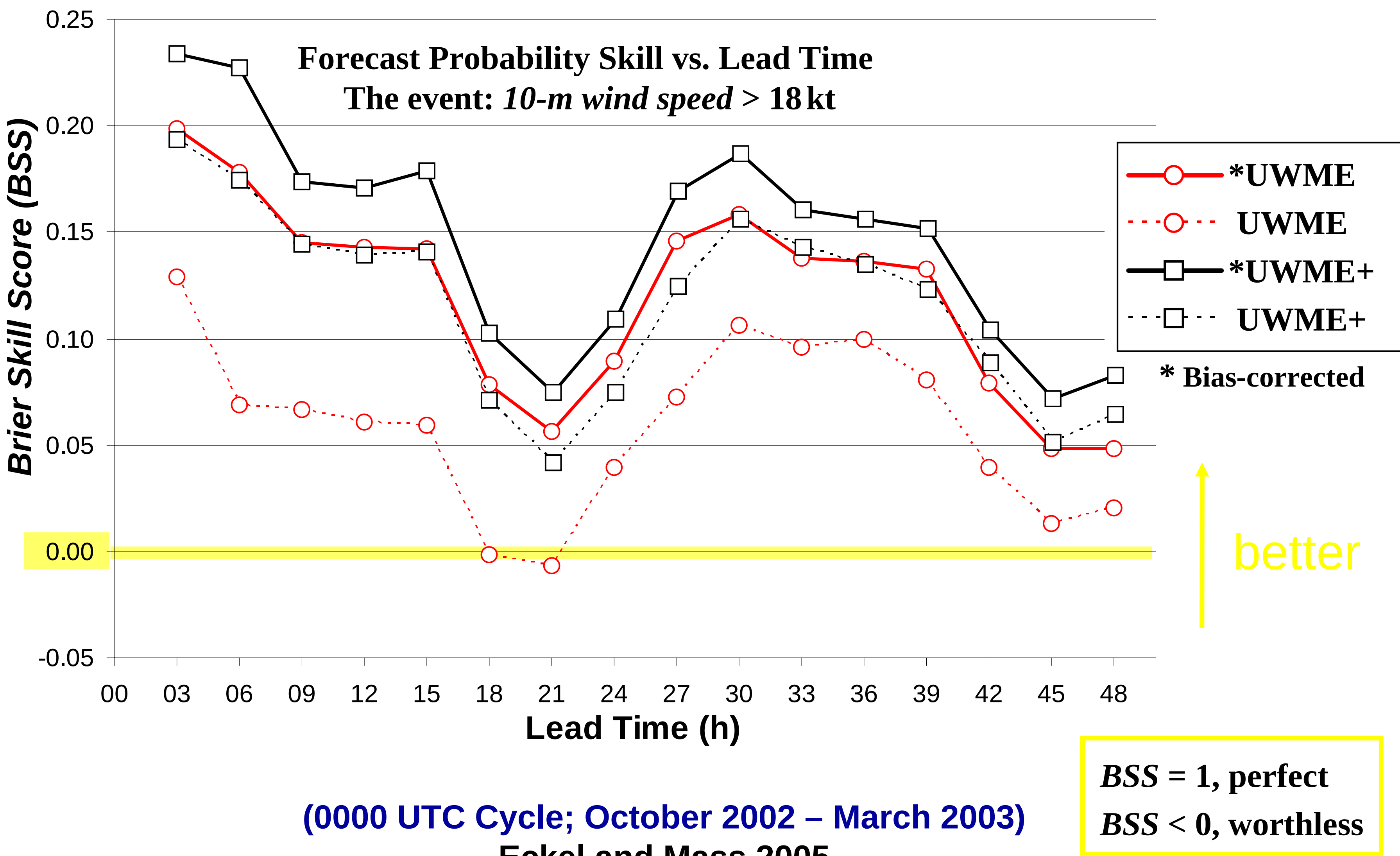
Member-Wise Forecast Bias Correction



(0000 UTC Cycle; October 2002 – March 2003)

Eckel and Mass 2005

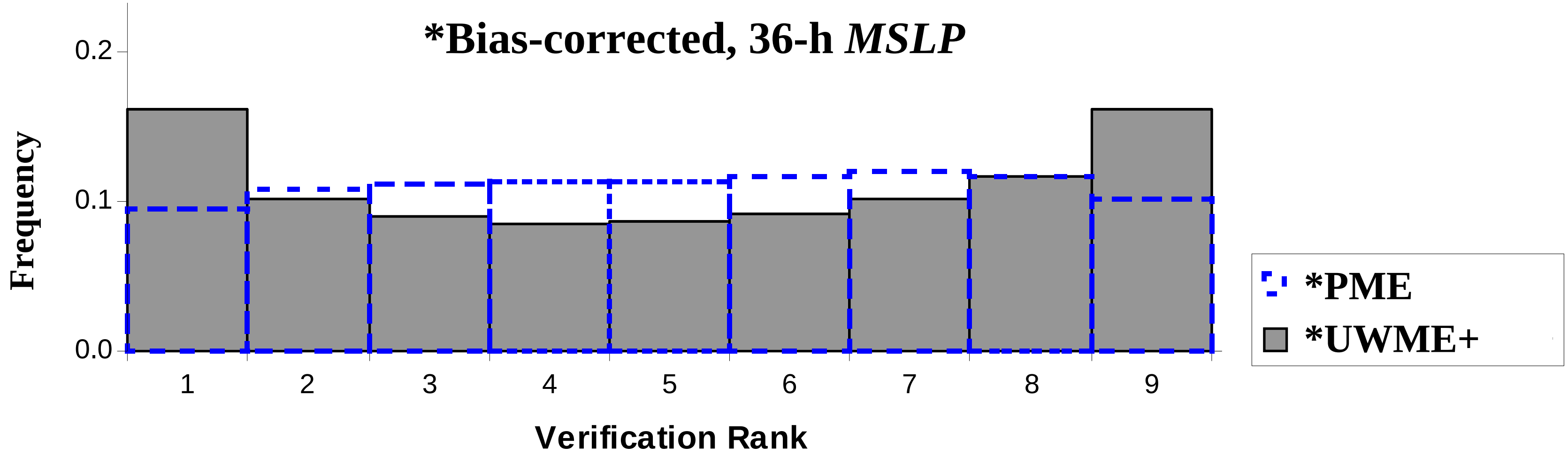
Forecast Probability Skill Example



(0000 UTC Cycle; October 2002 – March 2003)

Eckel and Mass 2005

Under-Dispersion Example



(0000 UTC Cycle; October 2002 – March 2003)
Eckel and Mass 2005

- **Poor Man's Ensemble (PME) exhibits more dispersion than *UWME+**
  - ***PME (a multi-model system) has more model diversity**
  - ***PME is better at capturing growth of synoptic-scale errors**

"Nudging" MM5 outer domain may improve dispersion

Verification Rank Histogram

Record of where verification fell (i.e., its rank) among the ordered ensemble members:

Flat  **Well-calibrated** (truth is indistinguishable from ensemble members)

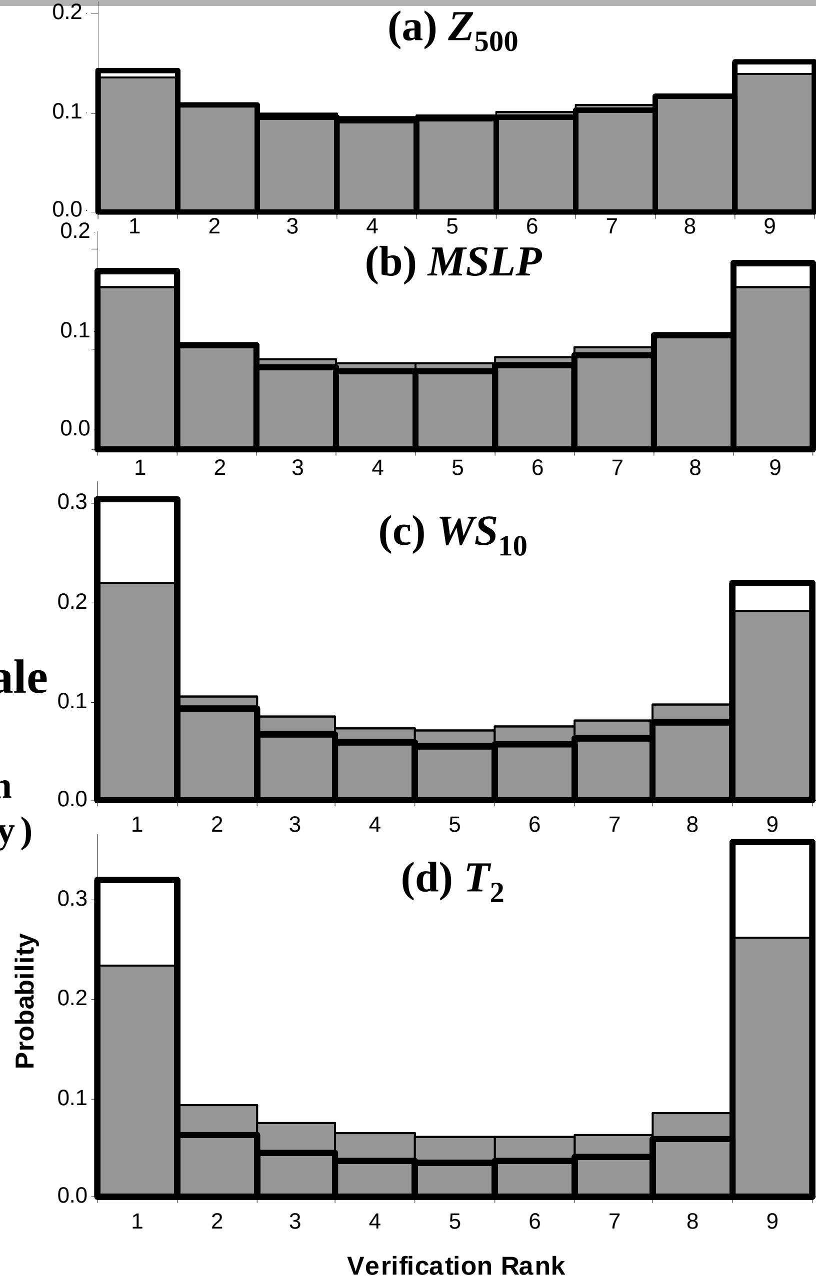
U-shaped  **Under-dispersive** (truth falls outside the ensemble range too often)

Humped  **Over-dispersive**

Under-Dispersion by Variable

Synoptic Variable
(Errors Depend on Analysis Uncertainty)

Surface/Mesoscale Variable
(Errors Depend on Model Uncertainty)



	VOP
(a) *UWME	5.0 %
(a) *UWME+	4.2 %
(b) *UWME	9.0 %
(b) *UWME+	6.7 %
(c) *UWME	25.6 %
(c) *UWME+	13.3 %
(d) *UWME	43.7 %
(d) *UWME+	21.0 %

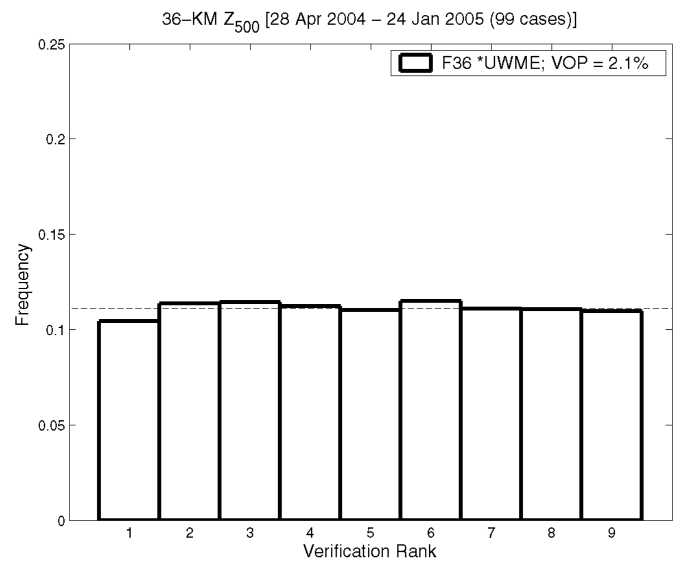
Effect of Nudging

- FDDA ("nudging") was applied to the 36-km domain on all UWME forecasts beginning 27 April 2004 with the 1200 UTC run.

  Has this helped?

- Apparently, the answer is YES for synoptic variables.
  - Although, there is some evidence for over-dispersion now (T_{850}, not shown).
  - Note that, comparisons with the non-nudged UWME are *not completely fair* due to different time periods of study.

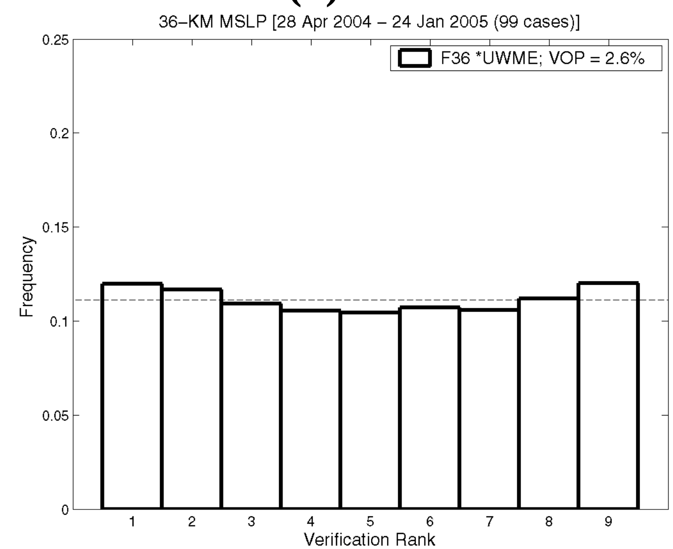
(a) Z_{500}



VOP

2.1%

(b) *MSLP*



2.6%

(0000 UTC Cycle; April 2004 – January 2005)

Post-Processing: Forecast Bias Correction

- Under-dispersion is NOT corrected.

- In fact, because this bias correction is applied to each member individually:
  - The ensemble spread is reduced.
  - The ensemble spread-skill relationship is degraded.

    (please visit my poster for more information on this topic!)

- One alternative is to estimate forecast bias from the ensemble mean and apply it to all members.
  - This is the usual approach.
  - This would preserve ensemble spread, which appears to be valuable in an under-dispersive system, even if it is "bad spread".
  - The original spread-skill relationship, if one exists, would be maintained.
  - Probability forecast skill might be lower.

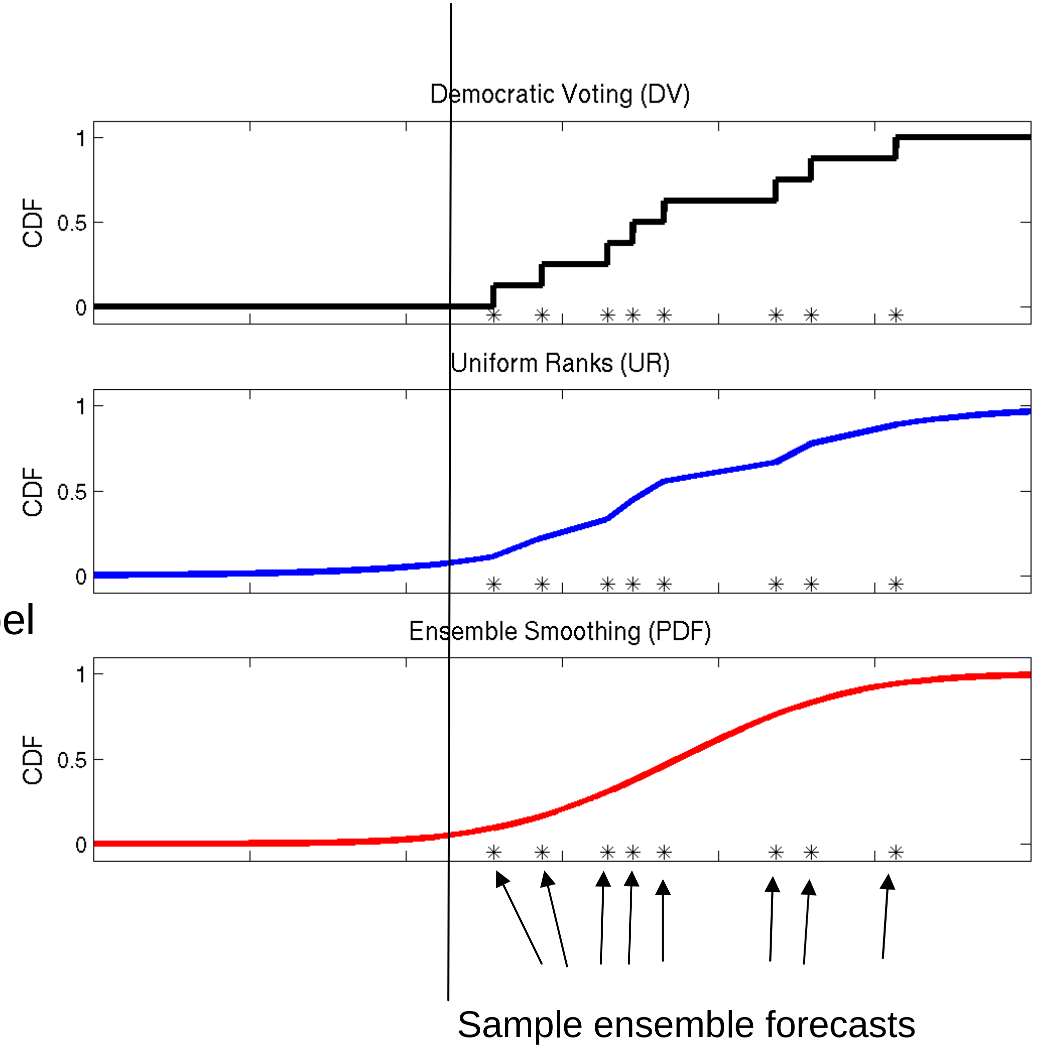
Post-Processing: Probability Densities

Q: How should we infer forecast probability density functions from a finite ensemble of forecasts?

A: Some options are…

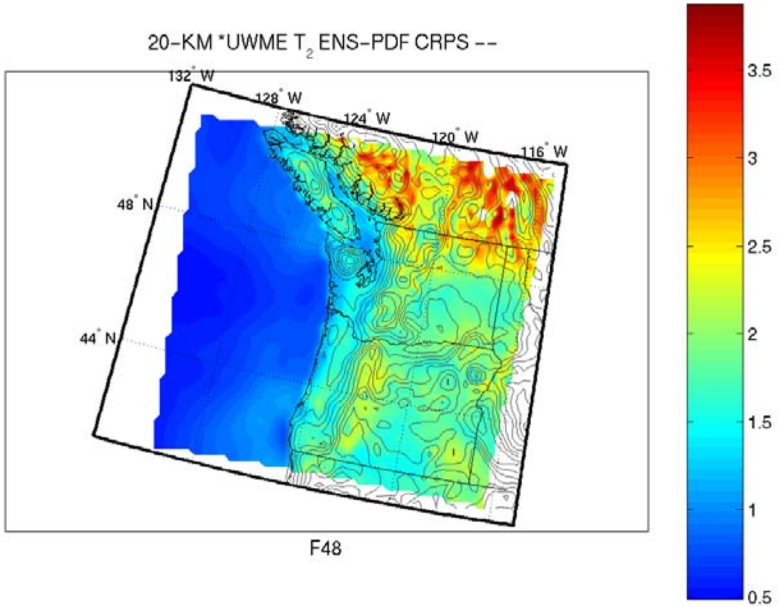
- Democratic Voting (DV)
  - P = x / M
    x = # members > or < threshold
    M = # total members
- Uniform Ranks (UR)***
  - Assume flat rank histograms
  - Linear interpolation of the DV probabilities between adjacent member forecasts
  - Extrapolation using a fitted Gumbel (extreme-value) distribution
- Ensemble Smoothing (PDF)
  - Fit a statistical distribution (e.g., normal) to the member forecasts

***currently operational scheme



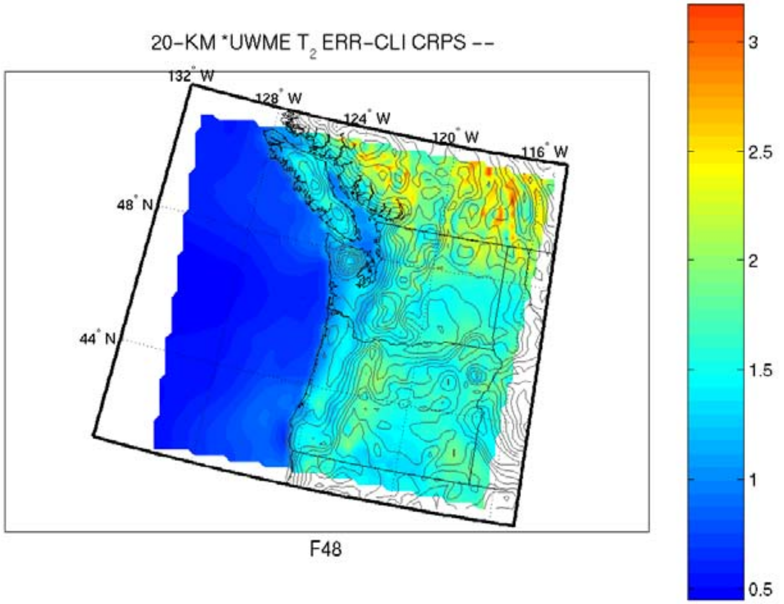
Post-Processing: Calibration

- One can convert a deterministic forecast into a probabilistic forecast by "dressing" it with its historical forecast error statistics.
  - Such a probability forecast is time-invariant (a static forecast of uncertainty; a climatology).
  - Such a probability forecast is calibrated for large samples, but not very sharp.



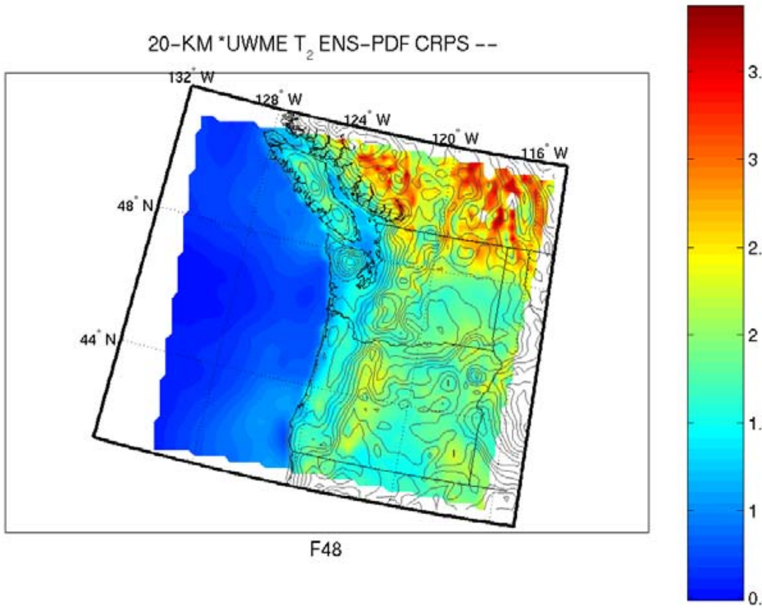
- For the ensemble mean, we shall call this forecast mean error climatology (MEC).

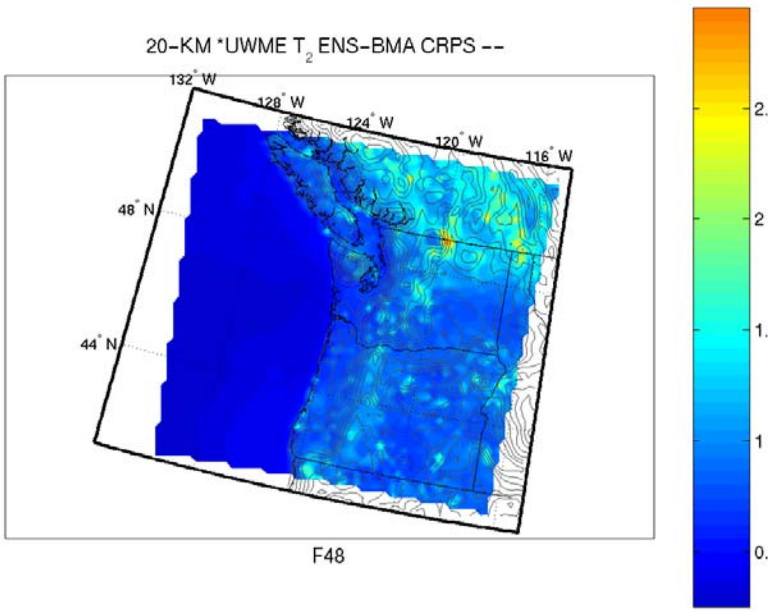
- We have found that MEC performs extremely well (e.g., 48-h 2-m temperature forecasts at right).
  - MEC consistently outperforms the ensemble PDF.



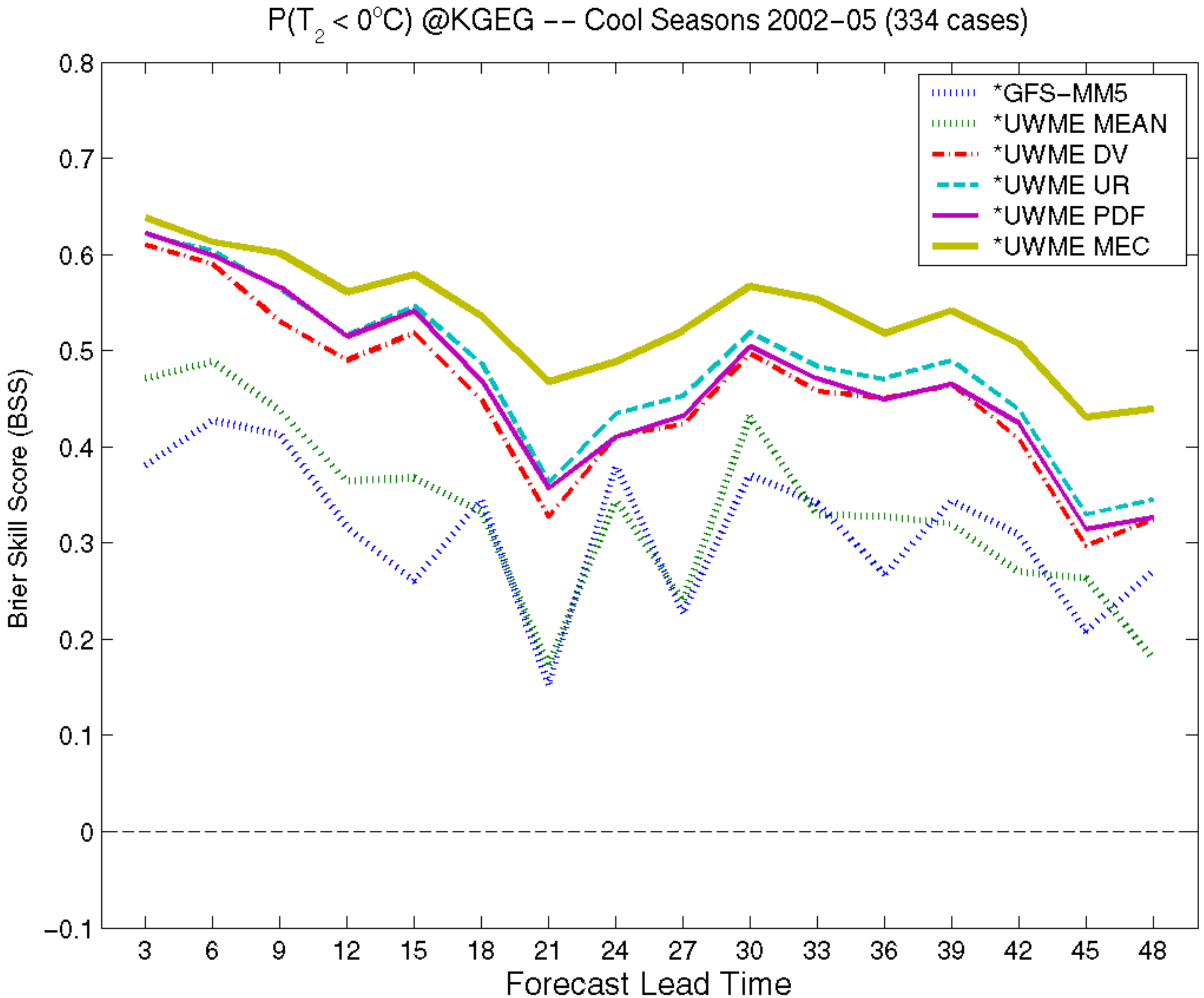
Post-Processing: Calibration

- Bayesian Model Averaging (BMA) has several advantages:
  - Time-varying uncertainty forecast
  - A way to keep multi-modality, if it is warranted
  - Can use short training periods with good results
- After several different attempts and configurations, we found that:
  - An adaptation of BMA where the training data is selected from a neighborhood of grid points with similar land-use type and elevation produced EXCELLENT results!
  - Example at right uses only 14 training days.

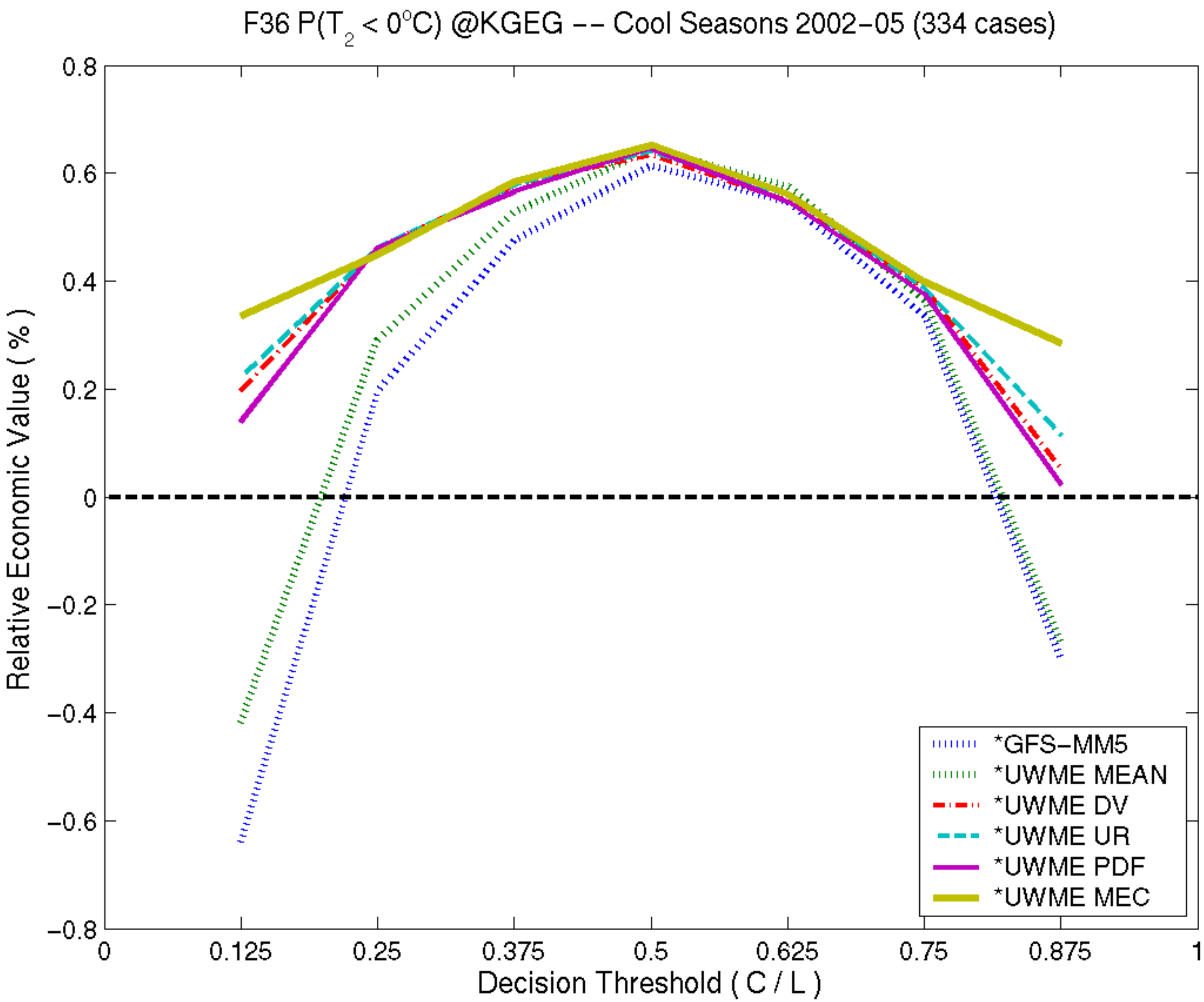




A Concrete Example



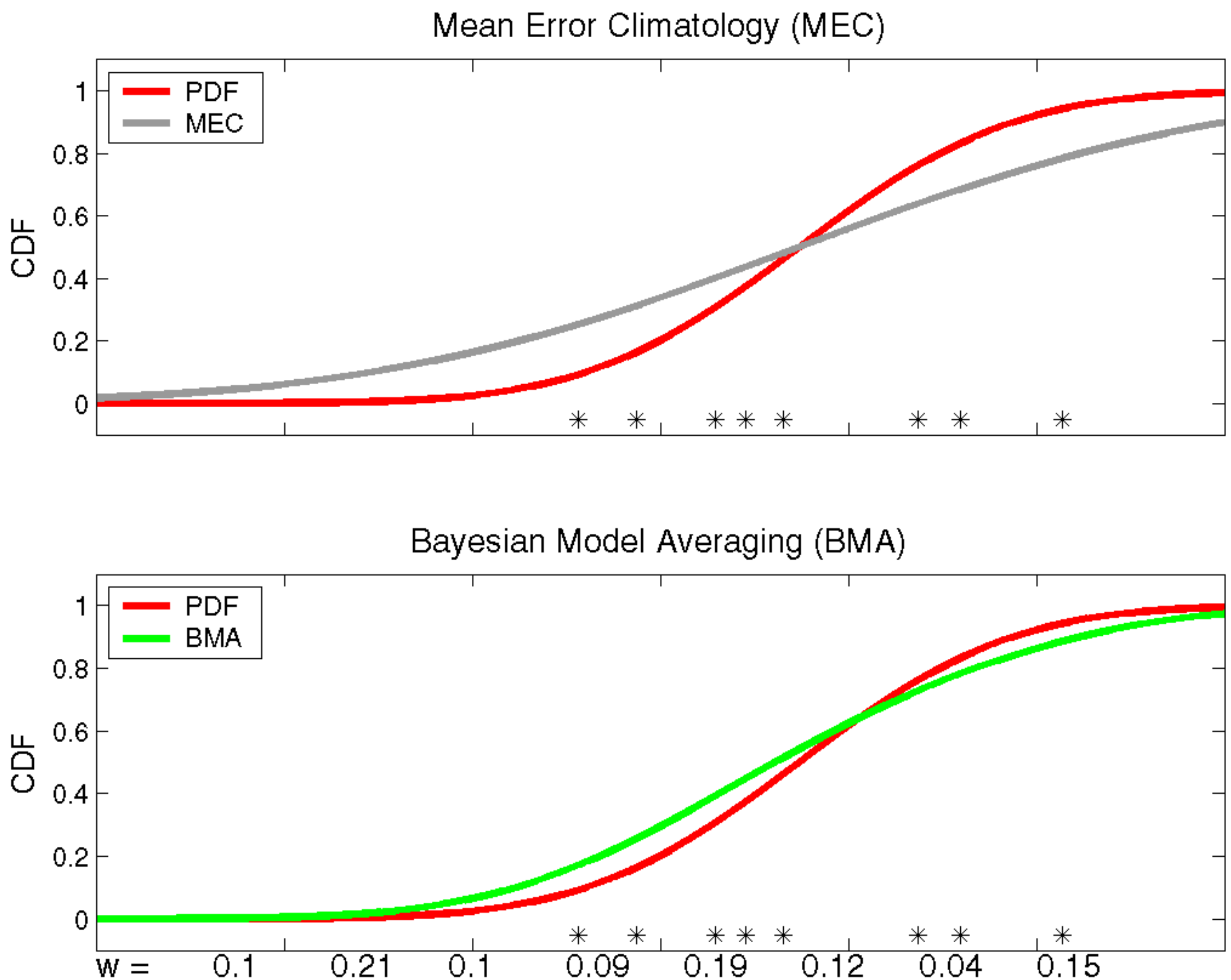
A Concrete Example



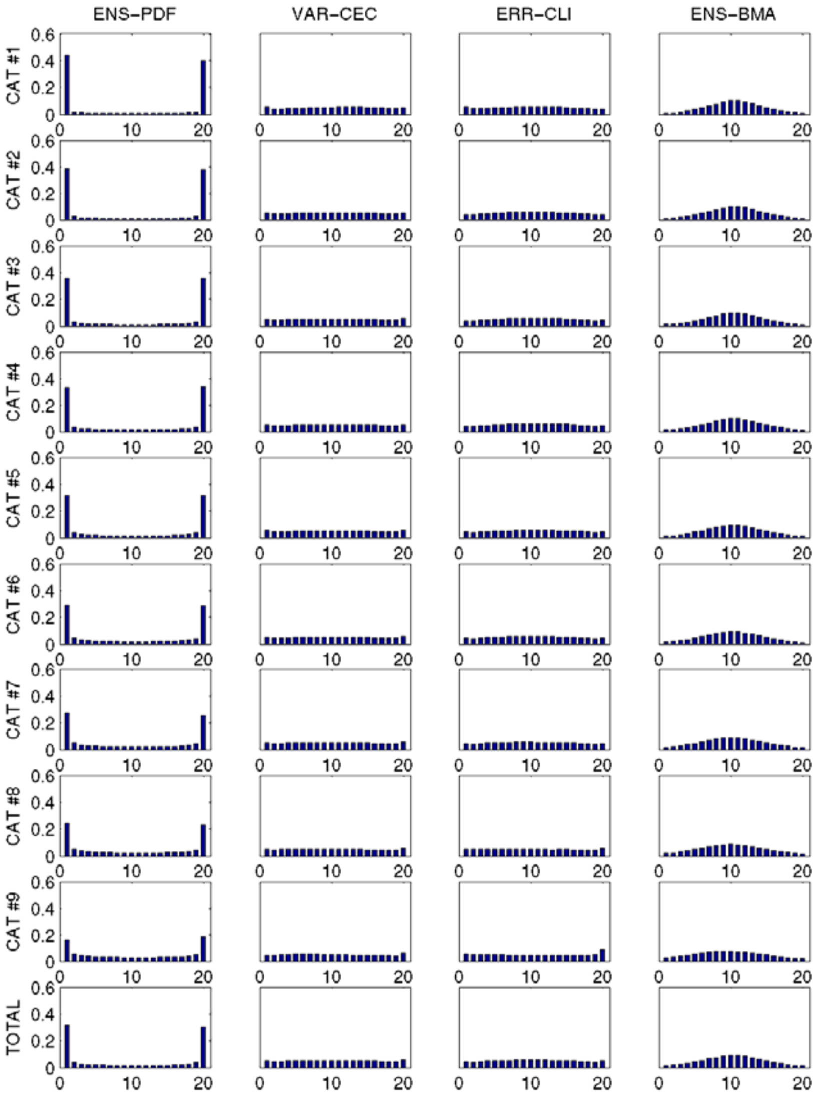
Minimize Misses **Minimize False Alarms**

Extra Slides

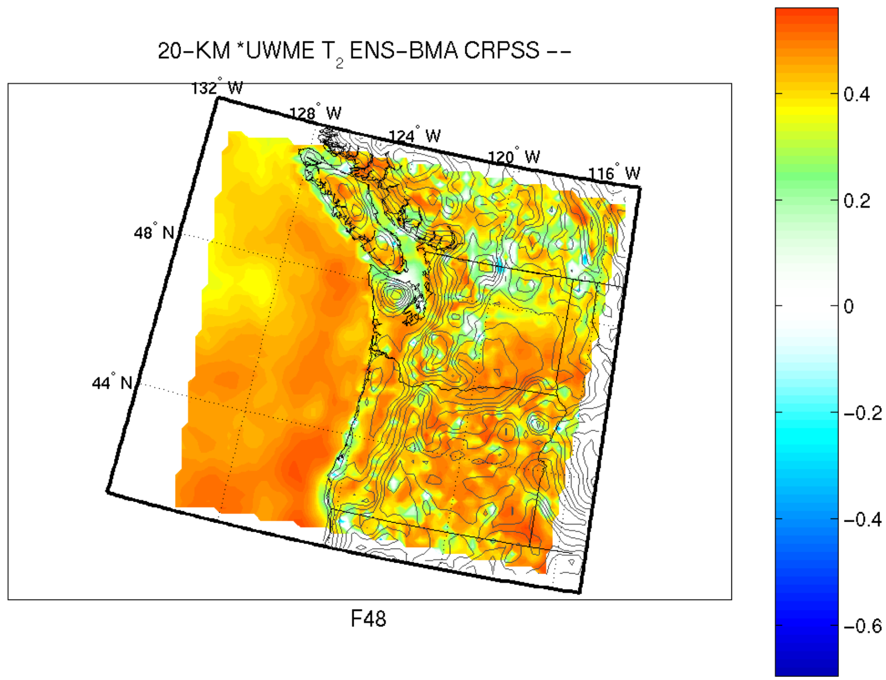
Post-Processing: Probability Densities



BMA – Neighbor* Weights/Variance



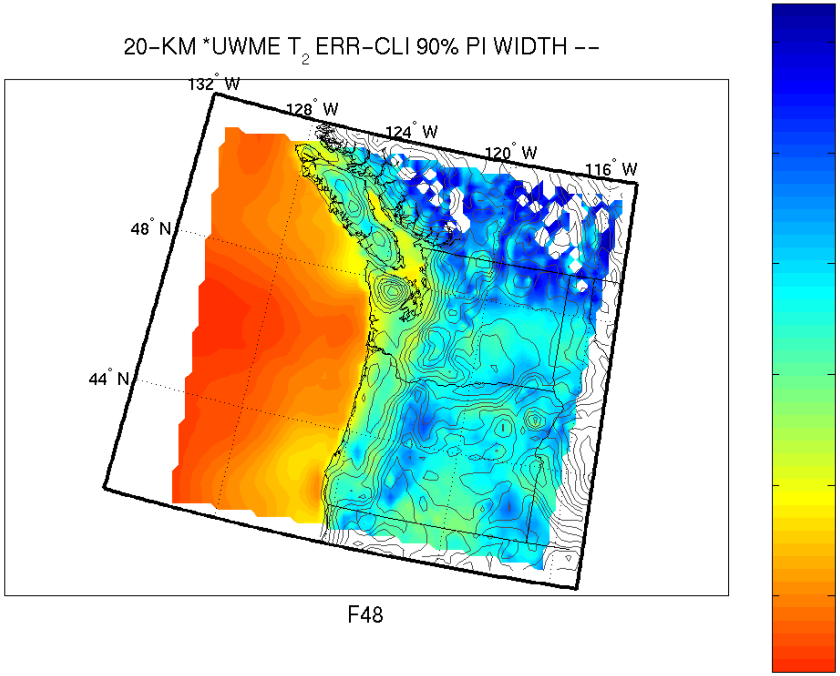
BMA improvement over MEC



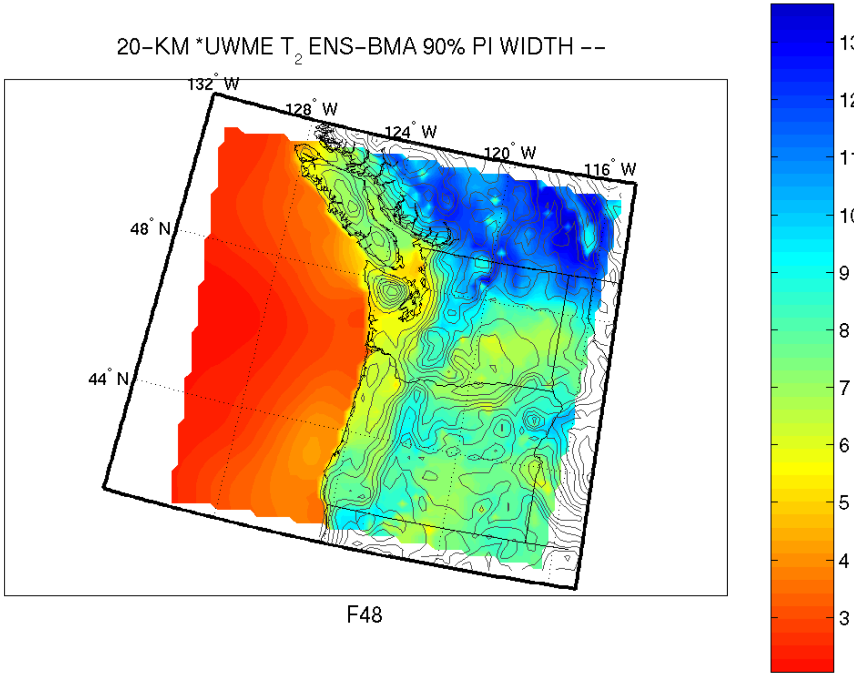
*neighbors have same land use type and elevation difference < 200 m within a search radius of 3 grid points (60 km)

90% Prediction Interval Widths (Sharpness)

ERR-CLI



BMA – Neighbor Weights/Variance



Panel Discussion:

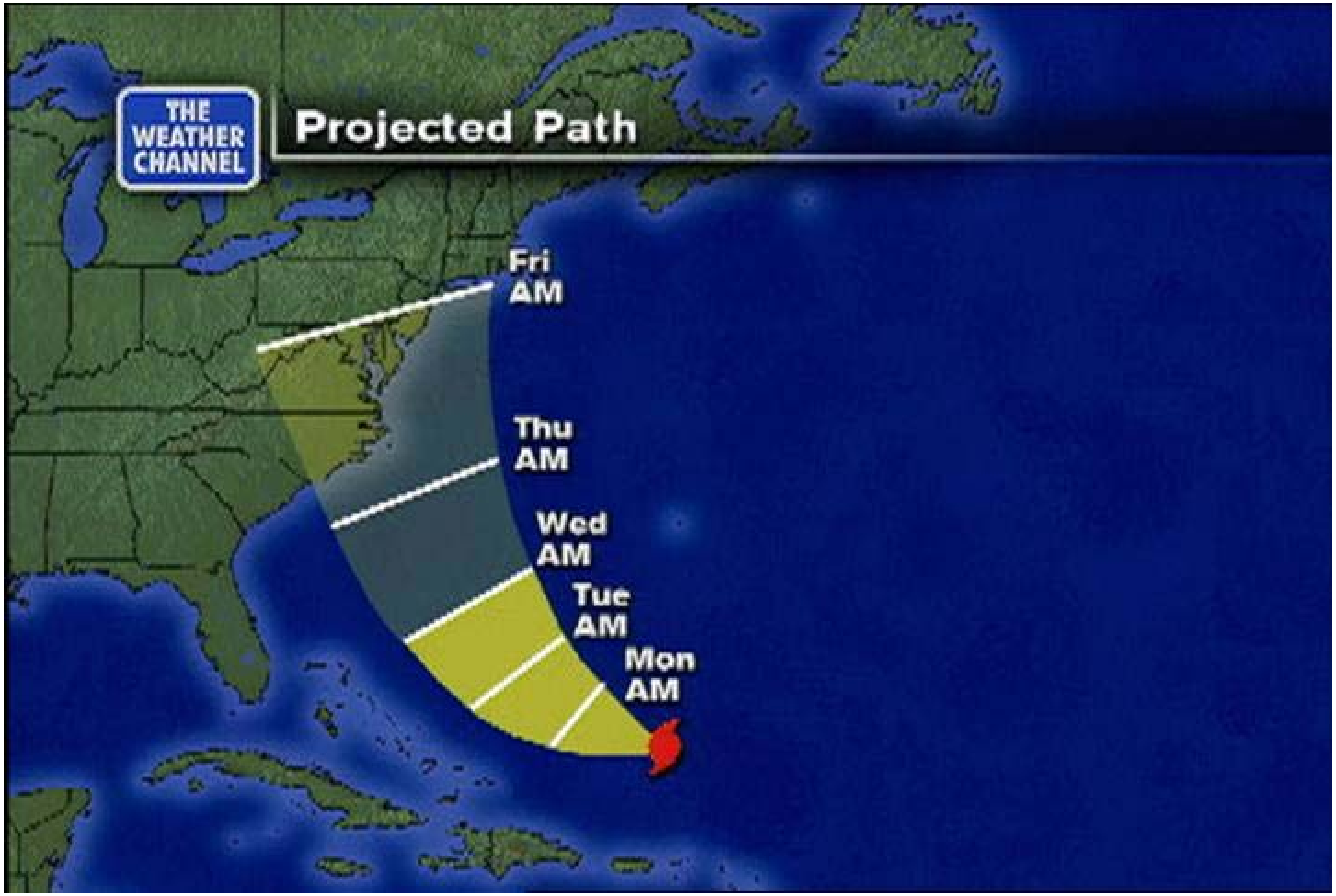
How do we effectively communicate probabilistic weather information to the public and users?

The "Academic" Perspective

- **#1: Know the limitations of the probabilistic forecasts you are communicating!**
  - Is it a "calibrated" probabilistic product? (can it be taken at face value?)
  - What is the size of the ensemble from which this product is generated? (what implications does that have for rare/extreme events?)
  - At what forecast lead time does this product cease to have value? (when should you switch to using a climatology-based product?)

- **#2: Know your users!**
  - What is the relative cost of false alarms vs. missed events???

- **#3: Presentation, presentation, presentation!**
  - TV, internet, newspaper, radio


THE WEATHER CHANNEL
Projected Path
Fri AM
Thu AM
Wed AM
Tue AM
Mon AM