# GLOBAL ENSEMBLE FORECASTING AT NCEP

**Zoltan Toth**[1]

Environmental Modeling Center, NCEP

*Acknowledgements:*

**Yuejian Zhu**[1] EMC

***http://sgi62.wwb.noaa.gov:8080/ens/enshome.html***

1. General Sciences Corporation (Laurel, MD) at NCEP, Zoltan.Toth@noaa.gov; (301) 763–8000/ext. 7268

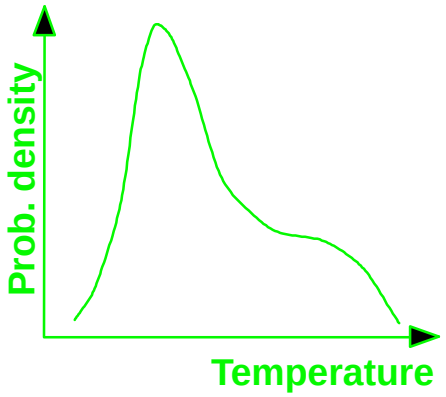
# VISION 2005 – NWS STRATEGIC GOAL:

## *"PROVIDE WEATHER ... FORECASTS IN PROBABILISTIC TERMS"*

END TO END PARADIGM: REQUIREMENT OF INTELLIGENT USER

*Old user attitude: Give me a (point) forecast – 60 degree, light rain*

*New user attitude: Give me a probability distribution*




**SCIENCE**

**ENSEMBLE FCST OPERATIONS**

**PUBLIC OUTREACH**

**FCST PRODUCTS** ⟷ **TRAINING**

*LEADING EDGE SCIENCE,*

*DOWN–TO–EARTH MULTIDISCIPLINERY APPLICATIONS MERGE*

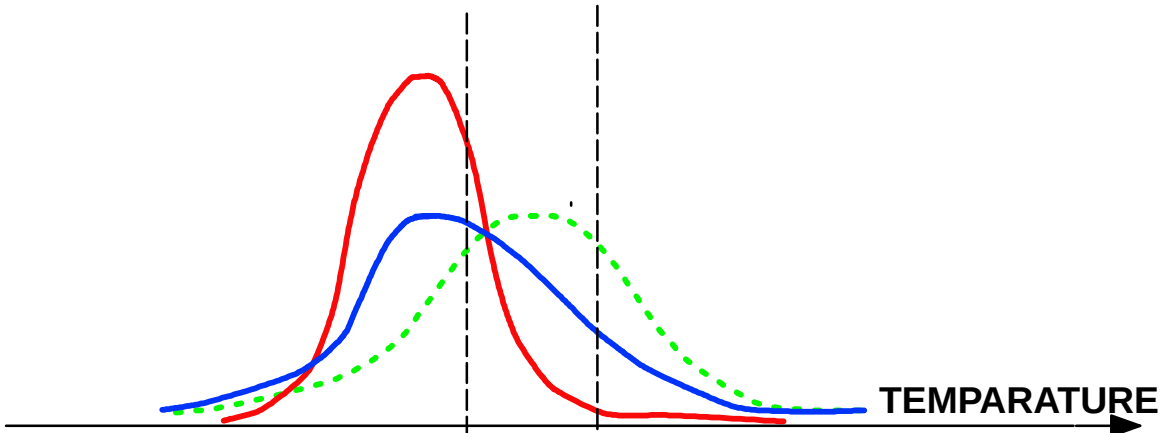
# VISION 2005 – NWS STRATEGIC GOAL:

## *"PROVIDE WEATHER ... FORECASTS IN PROBABILISTIC TERMS"*

*Have to prepare – Process started many years ago*

| *CONTRIBUTORS* | **STAGE** | RESULTS |
|---|---|---|
| | *MOTIVATION* | |
| *EMC–Collaborators* | **SCIENCE** | Predictability depends on initial value and model |
| | ⇩ *Technique Devel.* | |
| *NCO* | **OPERATIONS** | Multiple model runs |
| | ⇩ *Fcster needs* | |
| *AWIPS, Service Cntrs* | **PRODUCTS** | Probabilistic fcst displays |
| | ⇩ *Use and interpretation* | |
| *COMET, Univs.* | **TRAINING** | Case studies, modules |
| | ⇩ *Forecast distribution* | |
| *Fcsters* | **PUBLIC OUTREACH** | Feedback from profes-sional/lay end users |

# WHY USERS NEED PROBABILISTIC FORECASTS?




| | | | |
|---|---|---|---|
| CLIMATE PROB | 33% | 33% | 33% |
| FCST WITH LARGE UNCERTAINTY | 48% | 29% | 23% |
| MORE RELIABLE FCST | 85% | 12% | 3% |

**BOTH FCSTS CALL FOR BELOW AVERAGE TEMPERATURES**

**ECONOMIC EXAMPLE: COMPANY SELLING "WEATHER DERIVATIVES" (INSURANCE THAT FCST IS CORRECT)**

**FOR UNCERTAIN FCST, INSURANCE PREMIUM MUST BE HIGHER**

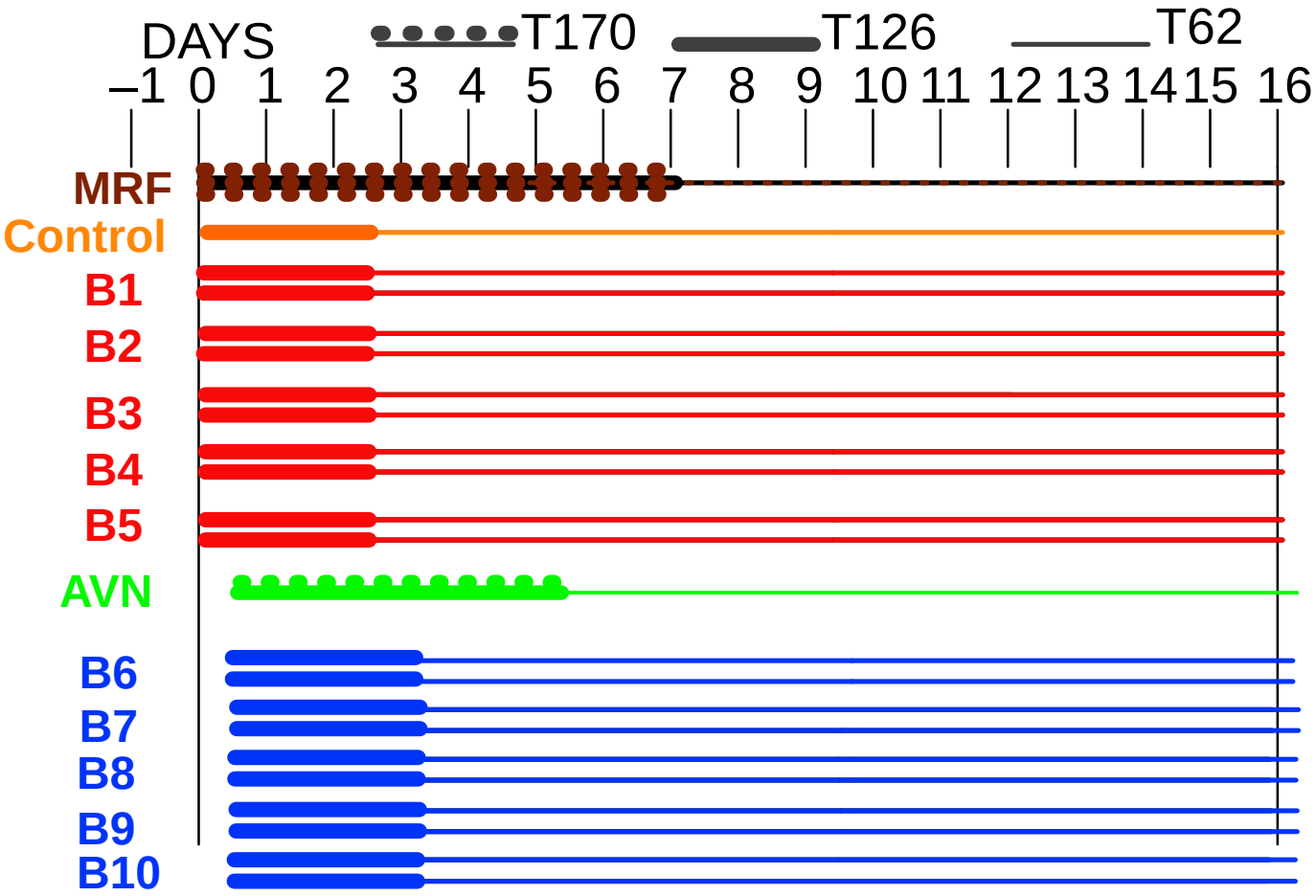
***IT IS ESSENTIAL THAT THE USERS KNOW ABOUT THE UNCERTAINTIES ASSOCIATED WITH WEATHER FCSTS***

Unless it is in terms of a probability distribution –
forecast is NOT complete

From probability distribution one can deduce all fcst info

*We must condense all our knowledge into prob. distrb.*

# CONFIGURATION SINCE 28 JUNE 2000




**INCREASED MEMBERSHIP:**

Add 6 perturbed forecasts at 1200 UTC

**INCREASED HORIZONTAL RESOLUTION:**

From T62 to T126 for first 84 hrs for all members

**3 times CPU increase well within 5–fold increase in capabilities –**

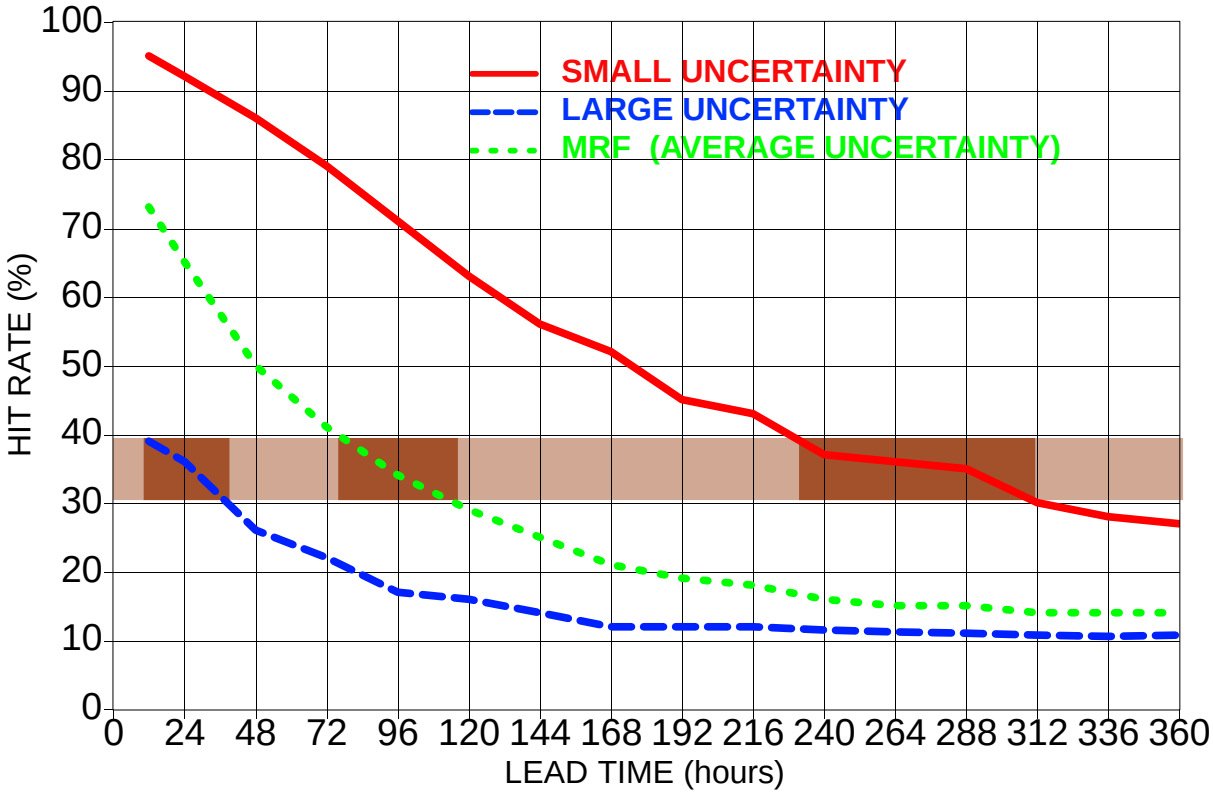
***Ensembles are ideal for parallel computing!***

**Acknowledgements to: M. Brown, D. Michaud, J. Irwin, others**

***Need more CPU resources to remain competitive***

| | NCEP | ECMWF |
|---|---|---|
| 1994 | 14 members, T62 | 32 members, T62 |
| 2000 | 20 members, T126 for 60 hrs | 50 members, T159 |
| 2002, plan | 40 members, T126 for 180 hrs | 50 members, T255 |

# SEPARATING HIGH VS. LOW UNCERTAINTY FCSTS




*THE **UNCERTAINTY OF FCSTS** CAN BE **QUANTIFIED IN ADVANCE***

***HIT RATES FOR 1–DAY FCSTS***

*CAN BE **AS LOW AS 36%**, OR **AS HIGH AS 92%***

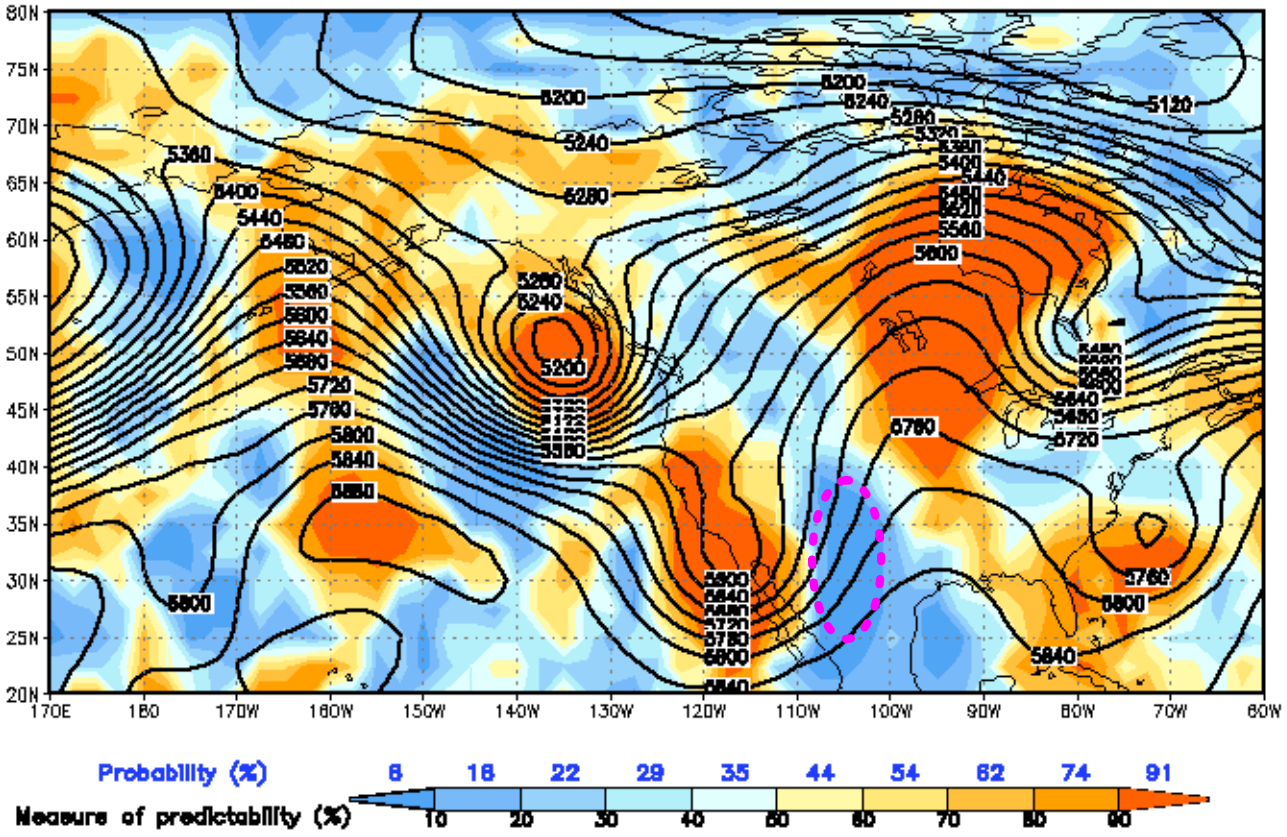
*10–15% OF THE TIME A 12–DAY FCST CAN BE AS GOOD, OR A 1–DAY FCST CAN BE AS POOR AS AN AVERAGE 4–DAY FCAST*

*1–2% OF ALL DAYS THE 12–DAY FCST CAN BE MADE WITH MORE CONFIDENCE THAN THE 1–DAY FCST*

*AVERAGE HIT RATE FOR EXTENDED–RANGE FCSTS IS LOW –*
***VALUE IS IN KNOWING WHEN FCST IS RELIABLE***

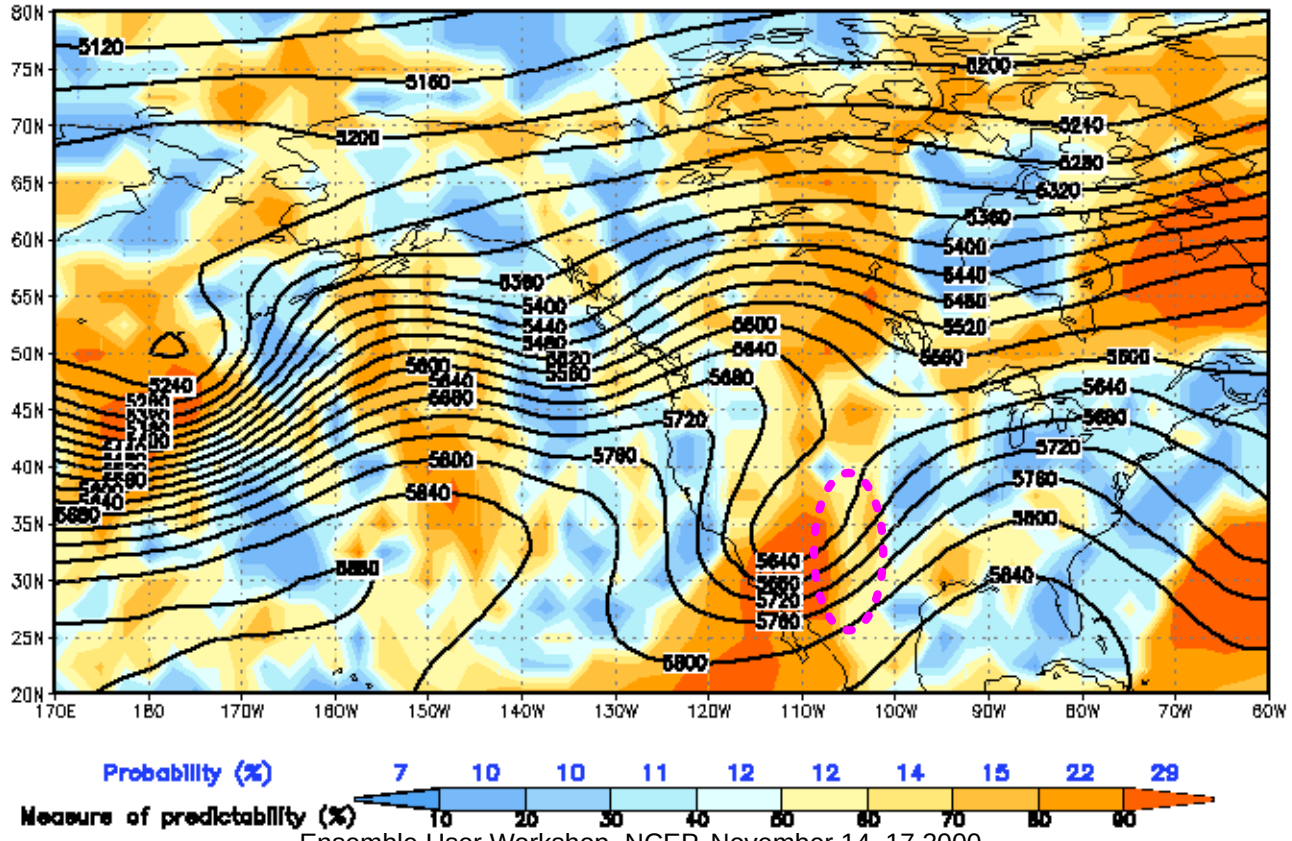
Relative measure of predictability (colors)
for ensemble mean forecast (contours) of 500 hPa height

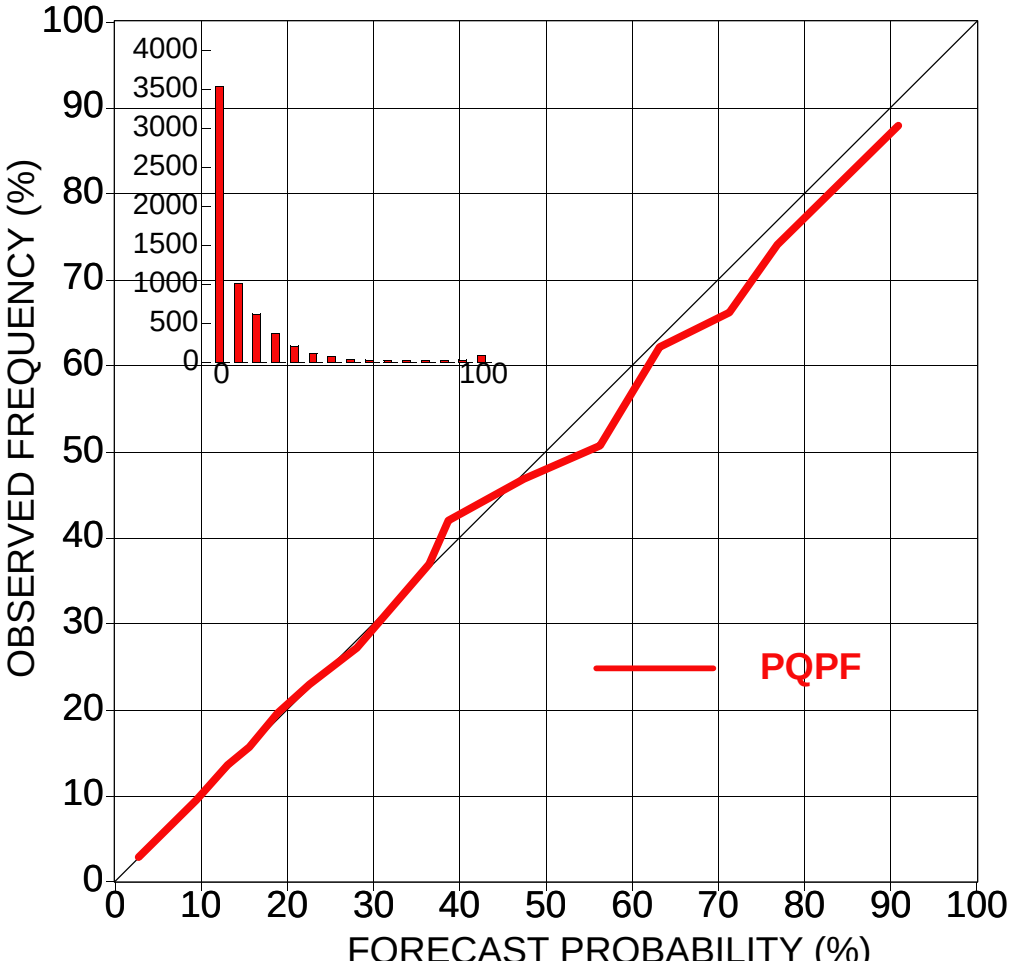
ini: 2000102700 valid: 2000102800 fcst: 24 hours



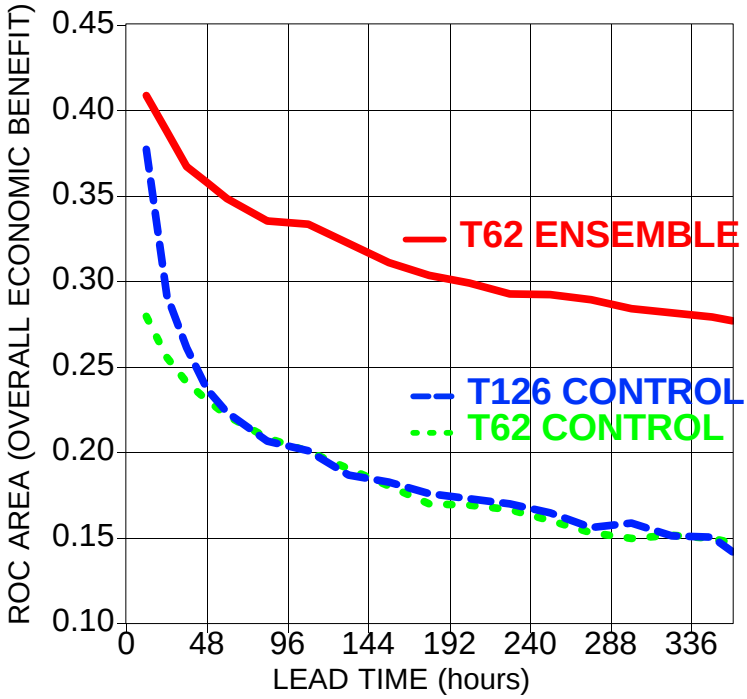

Relative measure of predictability (colors)
for ensemble mean forecast (contours) of 500 hPa height

ini: 2000102700 valid: 2000110400 fcst: 192 hours

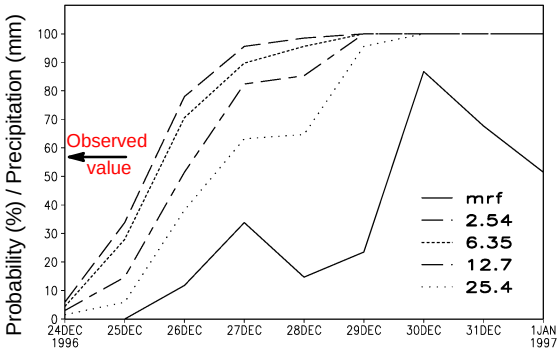





*Reliability diagram for 120–144 hour calibrated Probabilistic Quantitative Precipitation Forecasts for North America, June 1999. 0–12 hour MRF and AVN QPF forecasts are used as verification. Calibrated forecast probabilities are based on observed frequencies associated with the same number of ensemble members falling in a particular bin during April 1999. PQPF forecasts are evaluated for 11 forecast events, associated with increasing amount of precipitation. The diagram in the upper left corner indicates the number of cases the different forecast probabilities are used.*




*Relative Operating Characteristic Area, representative of overall economic benefits that users distributed equally with respect to their cost/loss ratio can attain from using different PQPF forecast systems. An ROC area of 0.5 corresponds to perfect forecasts while 0 indicates no skill above sample climatology. 0–12 hour MRF and AVN forecasts are used for verification. Results for the North American region for June 1999 indicate that a 132–hour ensemble–based probabilistic forecast may have as much benefit as a 24–hour single value forecast based on a higher resolution control forecast.*




*24–hr accumulated precipitation forecasts for 5 by 5 degree box centered at 38.75N, 121.75W by the MRF model with different initial dates, for the period ending 1997 January 2 1200 UTC, along with associated PQPF exceedance probabilities from the global ensemble for 0.1, 0.25, 0.5, and 1.0 inch thresholds.*

# PLAN: TURN VISION INTO REALITY –

## *PROVIDE ALL WEATHER FORECASTS IN PROBABILISTIC TERMS*

*Reach maturity in weather forecasting –*

Show example to other physical sciences (Following Lorenz' tradition)

**SCIENCE**
Model related uncertainty
Feedback to model devel.

⇨

**OPERATIONS**
40–members per day
T126 out to 7.5 days
30–day fcsts
Targeting
Use in analysis

⇦

**NEW PRODUCTS**
Bias correction
Multicenter ensemble
Anomaly probabilities
Joint probabilities

⇨

**MANAGEMENT**
New requirement –
describe fcst uncertainty

⇩

**FORECASTING**
New conceptual framework –
Single => multiple threads
Training module critical

⇩

**END USERS**
Serve decision making
Private sector critical
(energy, insurance, etc)

⇨

**PUBLIC**
Educate (TV)
Build trust
(More funds?)

***Continue and expand collaboration with NWS, NOAA & Univers.***

# WHAT MAKES FCSTS BETTER / MORE USEFUL?

1) **More / better quality data** – within 25 years:
10% 2D error reduction, 6–hr gain

2) **Improved analysis schemes**

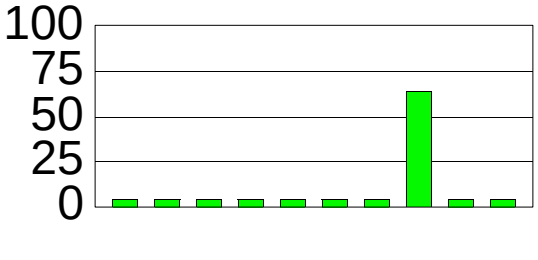
– within 6 years:
10% 5D AC improvement, 12–hr gain

3) **Better fcst models**

4) **Use of ensembles:** 25–30% 5D Brier score imprvm.,24–hour gain

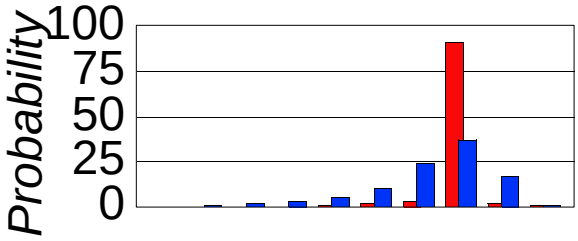
CONTROL

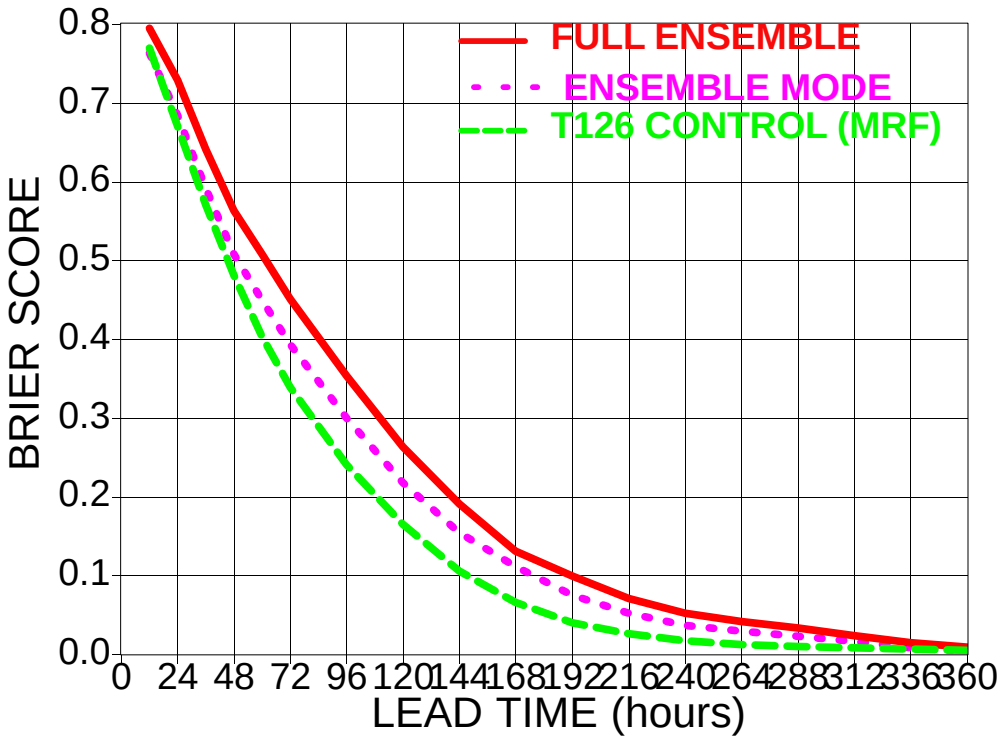
Yes or No fcst for an event



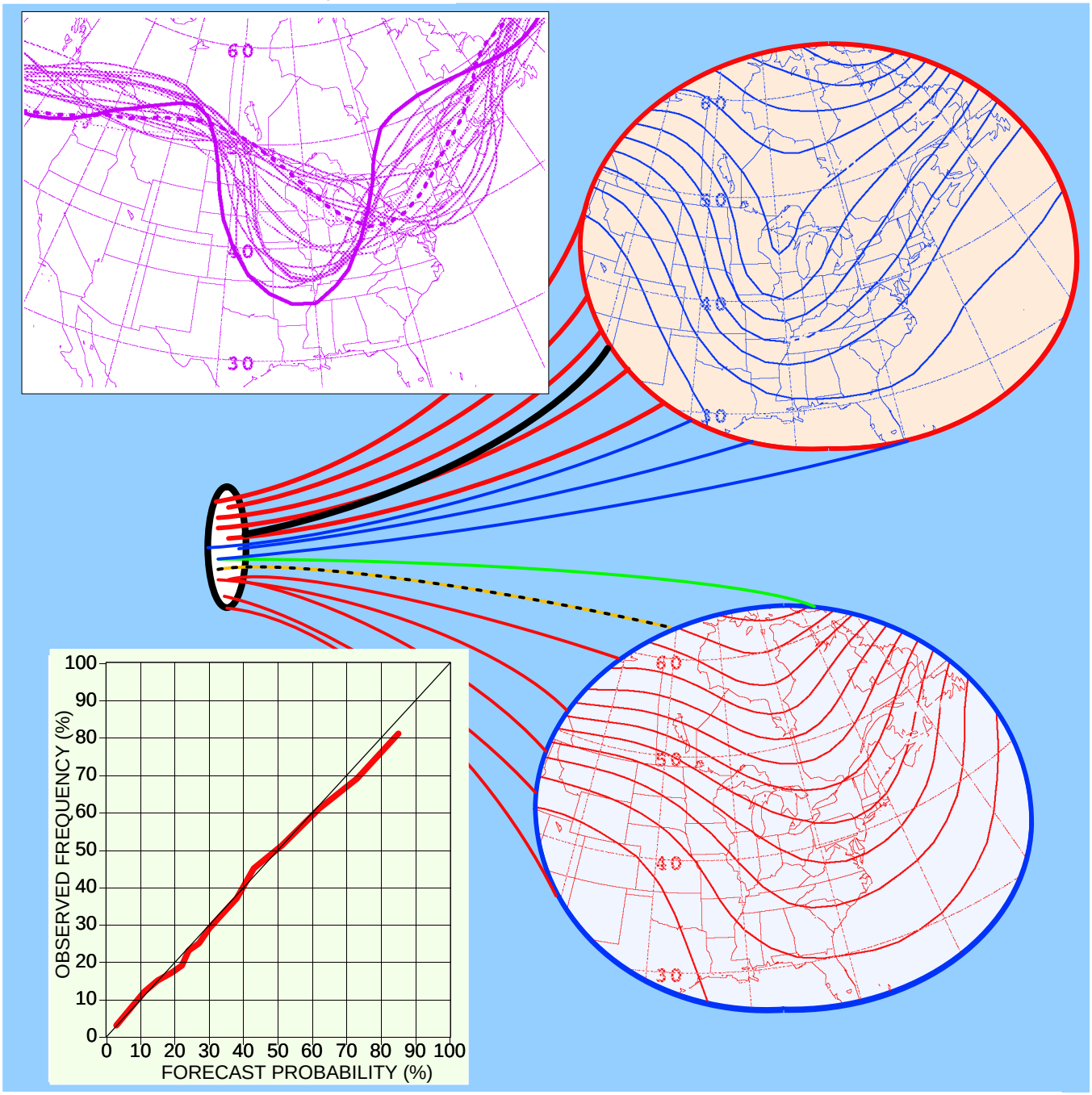

ENSEMBLE

Full probability distribution




Control forecast always predicts same level of reliability whereas ensemble indicates flow dependent level of reliability




***Eleventh AMS Conference on Numerical Weather Prediction (August 19–23, 1996, Norfolk, VA) Preprint Volume Front Cover:*** Over the past few years ensemble forecating has become an important component of numerical weather prediction and operational forecasting (Tracton et al., this volume). As an illustration, the 5640 m single contour ("Spaghetti") diagram of the 500 hPa height is shown at 4.5 days lead time (valid at 1200 UTC on October 20, 1995, top left), displaying all the 17 members of the NCEP global ensemble (Kalnay and Toth, this volume). The yellow dotted and solid green lines represent the high resolution (T126) control forecasts (started on the 16th and 15th at 0000 UTC and 1200 UTC, respectively), while the red and blue lines, respectively, are the perturbed forecasts about the two controls. The verifying analysis is shown as a heavy black line.

The central schematic illustrates the divergence of solutions as a result of analysis uncertainties. Out of the 17 members, two dominant clusters of 8 (top right) and 7 (bottom right, including the two controls) forecasts were formed in this case, indicating the possibility of two distinctly different flow patterns at day 4.5. The verification (heavy black line) falls within the first cluster, which indicated a deeper and slower developing trough than the controls alone would suggest. For additional synoptic examples and other products derived from the ensemble, see Wobus et al. (this volume).

Probabilistic forecasts from the NCEP ensemble have demonstrated useful resolution and sharpness, and are very reliable, as displayed for the 4.5 days 500 hPa NH extratropical height forecasts (bottom left). Probabilistic forecasts (abscissa) are made for 10 climatologically equally likely bins and then the relative occurrence of the verifying analysis in all bins are accumulated as a condition of forecast probabilities (ordinate). The ensemble based probabilistic forecasts for February 1996 were calibrated using independent verification data from January 1996 (Zhu et al., this volume).