MEDIUM RANGE FORECASTING
AN HPC METHODOLOGY

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HYDROMETEOROLOGICAL PREDICTION CENTER

Hydrometeorological Prediction Center

OUR MAIN JOB:

INTERPRET THE MODELS/VARIED DATA AND PROVIDE QUALITY FORECAST GUIDANCE

WE ARE OPERATIONAL FORECASTERS CO-LOCATED WITH COMPUTER MODELERS

HPC'S MEDIUM RANGE DESK

EXTENDED FORECAST DISCUSSION

3-5 DAY FRONTS/PRESSURES

3-7 DAY TEMPERATURES/PoPS

5-DAY ACCUMULATED QPF

5-DAY HAWAII DISCUSSION

12 STEP METHODOLOGY OUTLINE

1- WHICH MEDIUM RANGE MODELS ARE AVAILABLE?

2- LATEST MODEL SOFTWARE CHANGES AND UPDATED MODEL CHARACTERISTICS AND BIASES

3- MEAN HEIGHT MAPS AND CLIMATE PATTERN TO ESTABLISH STORM TRACK

4- COMPARE INITIAL AND MODEL FORECAST FIELDS TO OBSERVED DATA

5- CONTRAST MEDIUM RANGE MODEL RUNS..ASSESS PLAUSIBILITY..AND CONSIDER THE FORECAST PROBLEMS OF THE DAY

6- MODEL RUN-RUN CONTINUITY AND TRENDS

7- ENSEMBLE FORECASTING TECHNIQUES

8- VERTICAL AND SPACIAL CONSISTENCY

9- SHORT RANGE GUIDANCE UPDATE

10- CHOOSE A MODEL(S) OR AN ADJUSTED SOLUTION

11- EXPERIENCE TO APPLY SENSIBLE WEATHER FORECASTING TECHNIQUES AFTER ASSESSMENT OF FORECAST CONFIDENCE AND UNCERTAINTY

12- VERIFICATION MAKES YOU SMARTER!!

HOW DO COMPUTER MODELS WORK?

WEATHER IS GOVERNED BY PHYSICAL LAWS WHICH CAN BE EXPRESSED AS MATHEMATICAL EQUATIONS

DATA IS COLLECTED TO ESTIMATE THE CURRENT STATE OF THE ATMOSPHERE

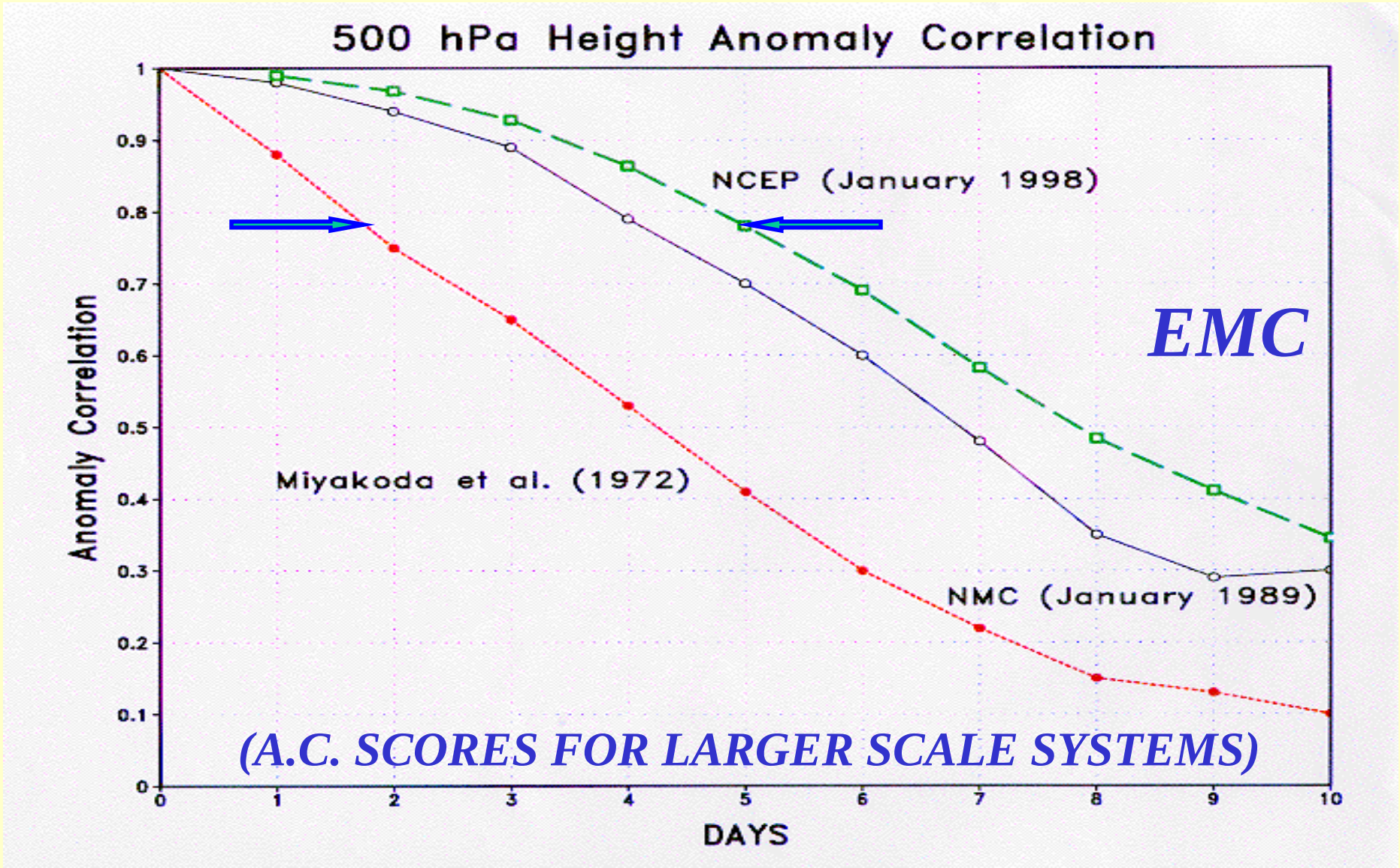
COMPUTER MODELS USE THE DATA IN THE EQUATIONS TO APPROXIMATE HOW THE ATMOSPHERE WILL CHANGE OVER TIME

MEDIUM RANGE MODELS

GLOBAL MODEL	RUN TIME (UTC)	MAX HORIZONAL RESOLUTION (KM)	VERTICAL LEVELS
ECMWF	12	42	60
UKMET	00&12	60	30
MRF (NEW)	00	79	42
NOGAPS	00&12	84	24
CANADIAN	00	100	28
MRF (OLD)	00	104	28
AVN-EXT	12	208	28

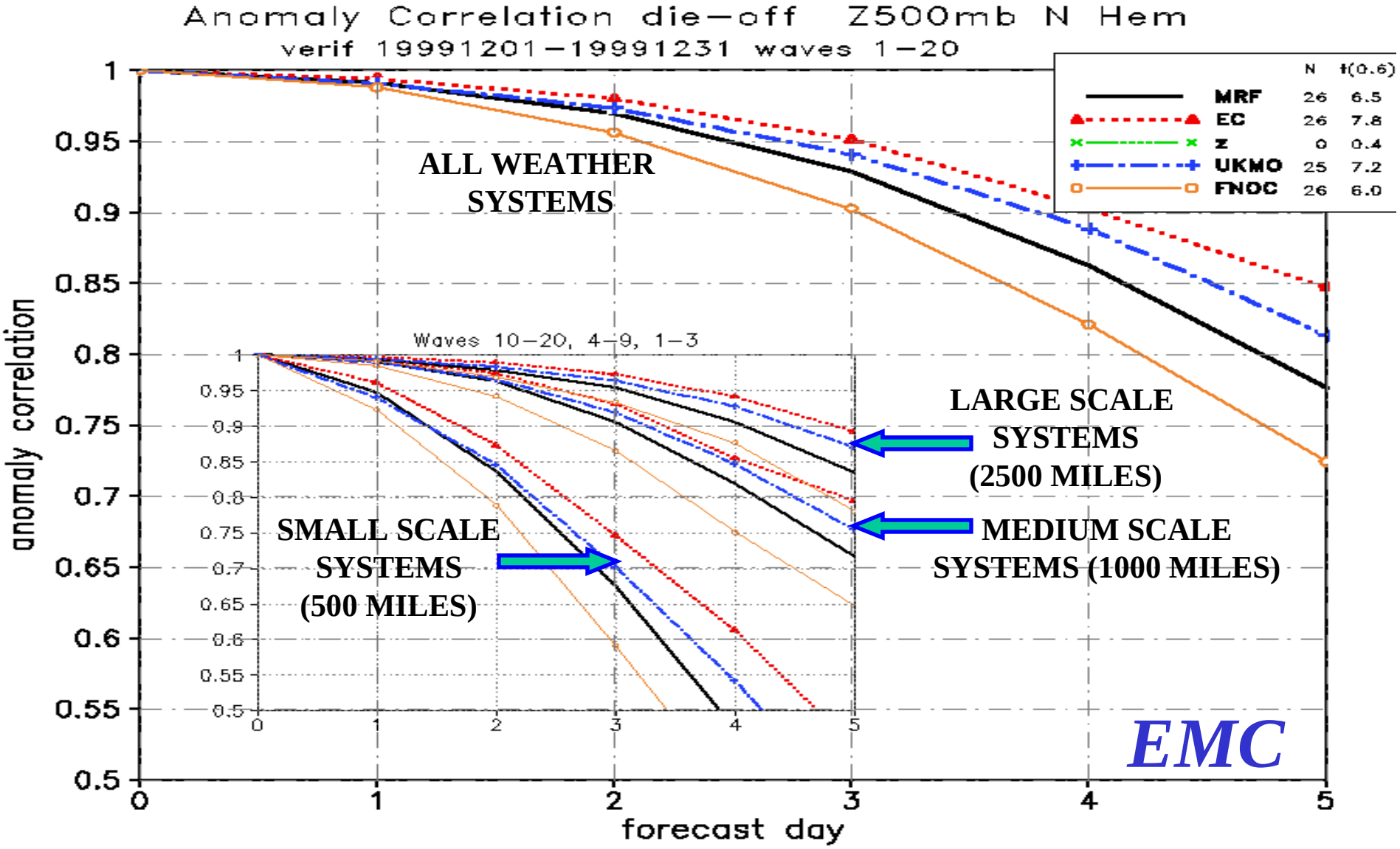
THE NEW MRF BECAME OPERATIONAL JAN 24, 2000

TODAY'S MRF DAY5 500 MB FORECAST IS AS GOOD AS A 1972 MRF 36-HOUR FORECAST!

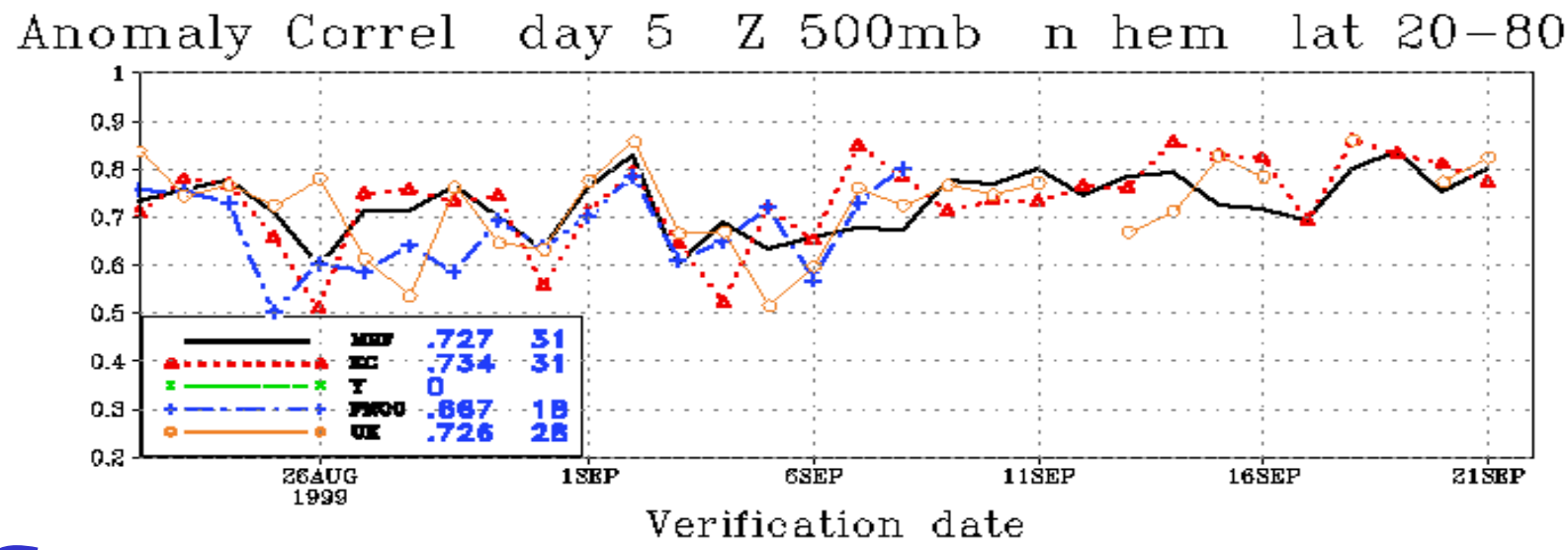


THE MRF HAS GOOD SKILL TO DAY5 AND MARGINAL SKILL DAY6/7

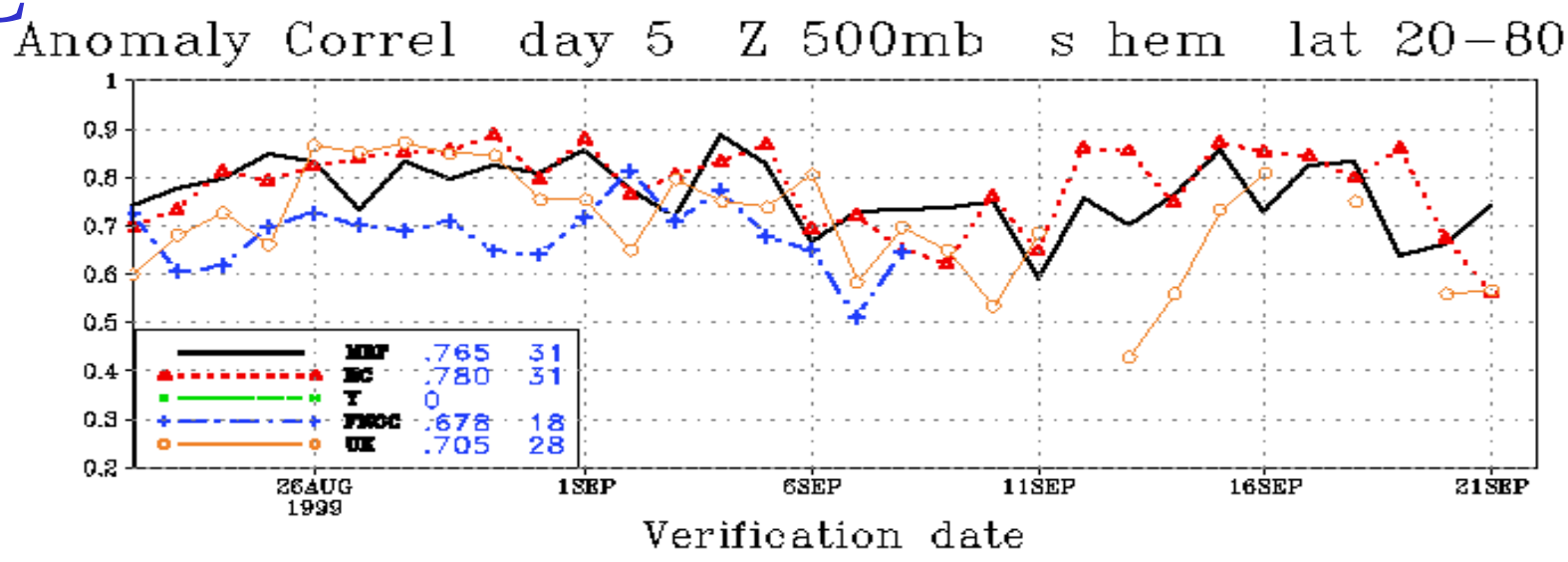
THE MODELS HAD DECENT SKILL (A.C. > .7) FOR DECEMBER INTO DAYS 5-7 FOR LARGER SYSTEMS BUT ONLY TO DAY3 FOR SMALLER SYSTEMS



DAILY 500 MB SKILL SCORES SPIKES

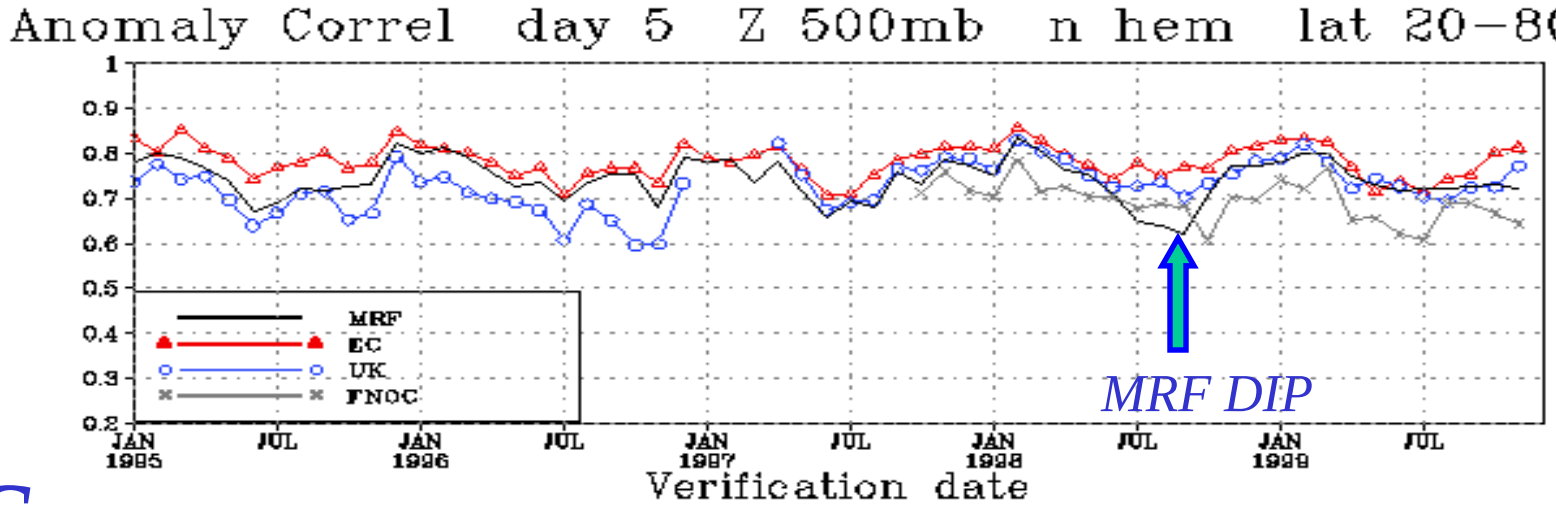


EMC

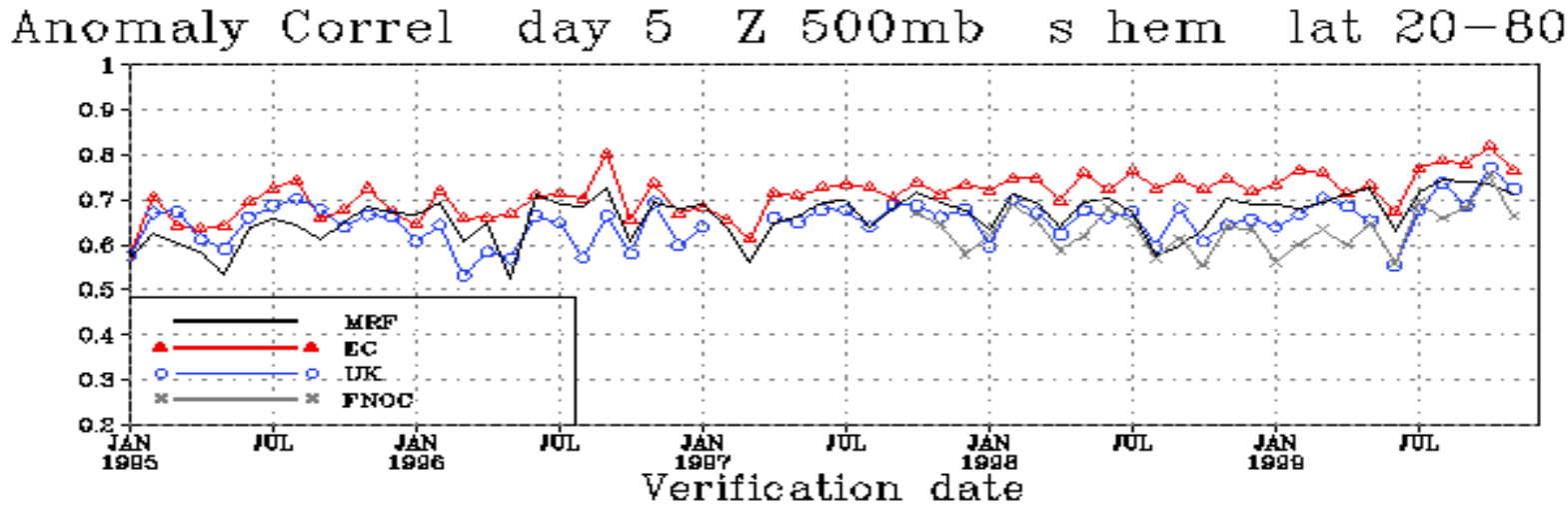


ANY MODEL CAN BE THE MOST SKILLFUL ON A GIVEN DAY

MRF VS ECMWF VS UKMET VS NOGAPS (MONTHLY SCORES 1994-PRESENT)



EMC

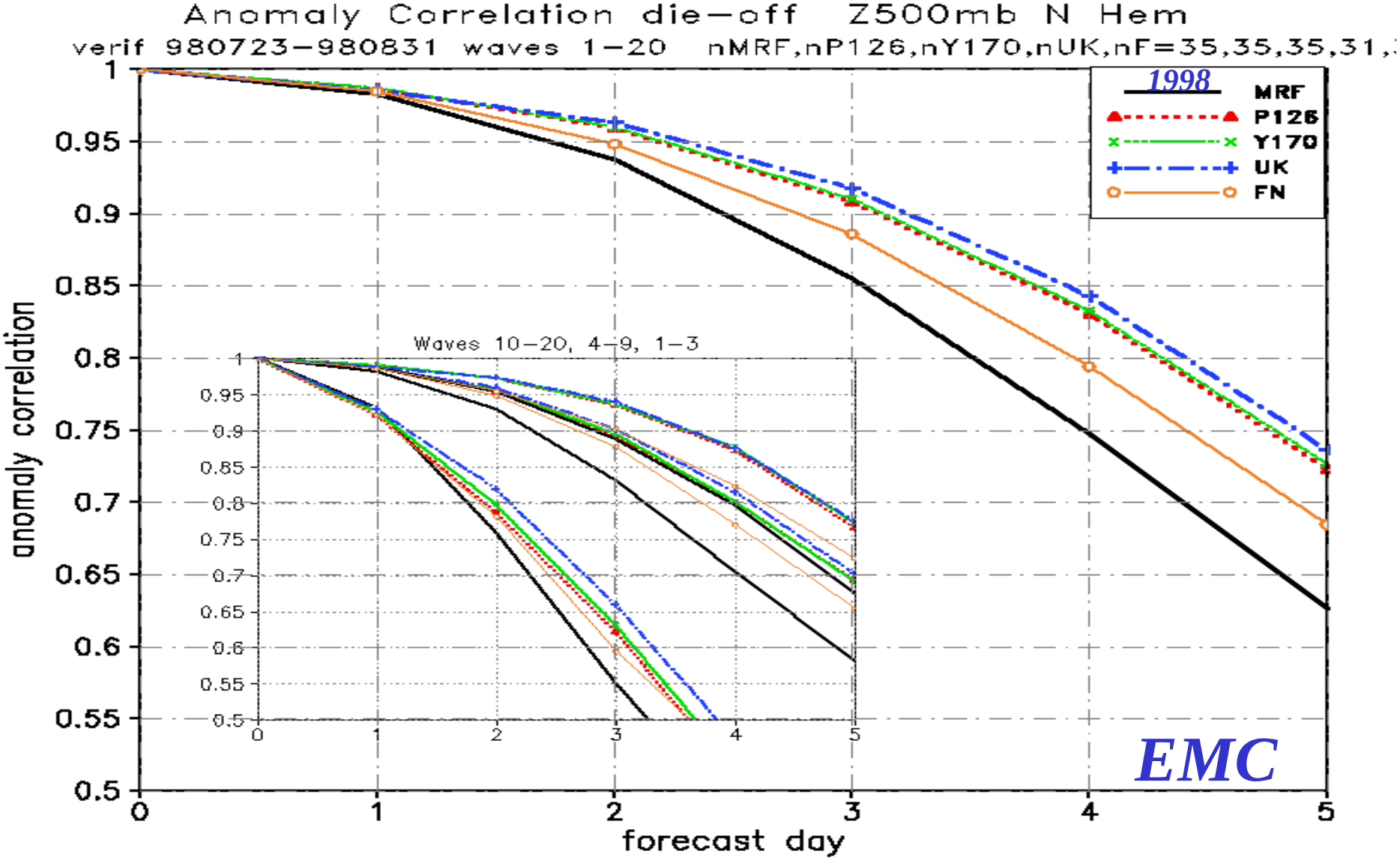


ECMWF HAS MORE SKILL THAN THE MRF/UKMET/NOGAPS

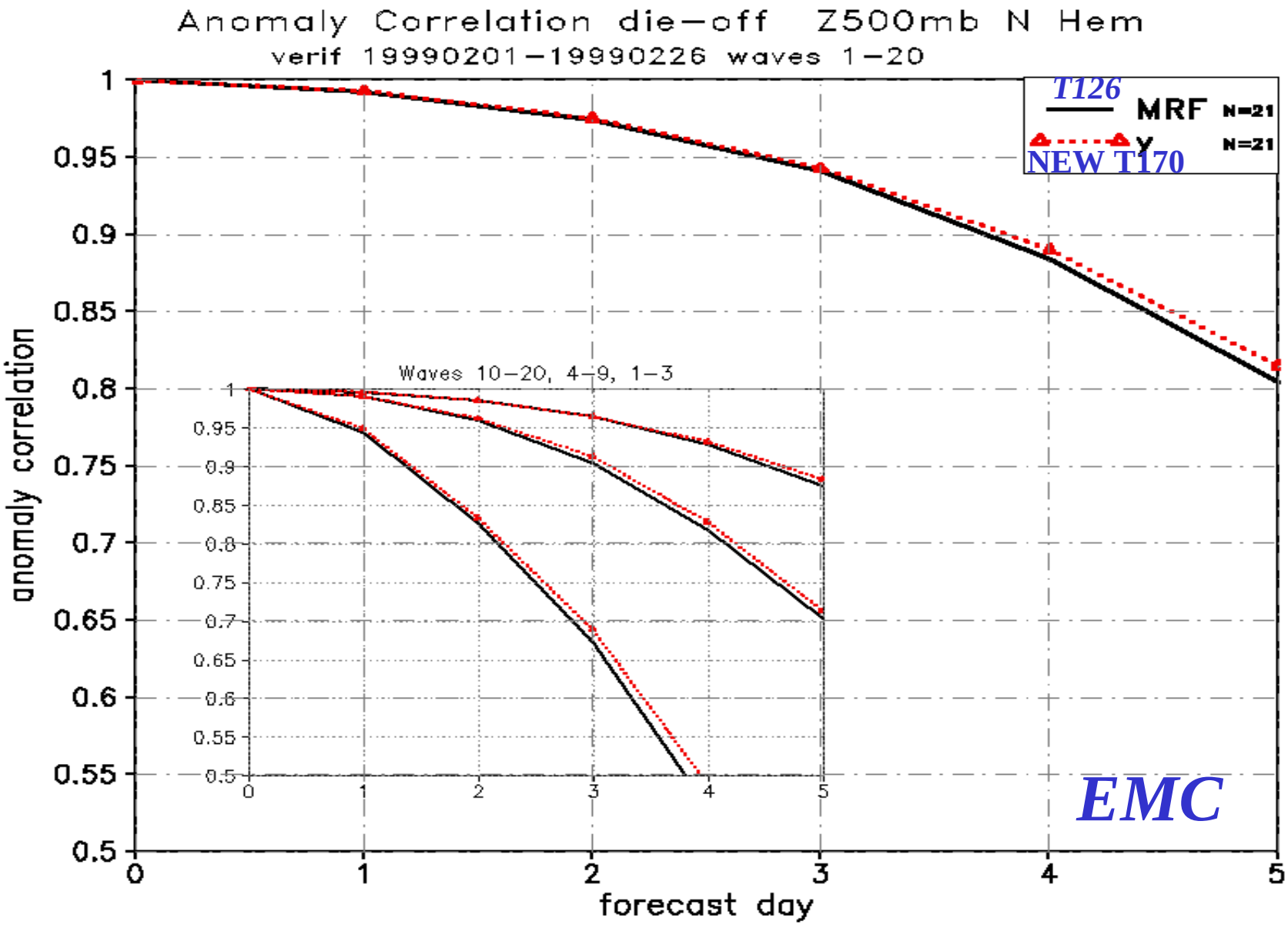
MAJOR 1998-2000 MRF CHANGES

- **6/98: INCREASED HORIZONTAL RESOLUTION FROM 104 TO 79 KM..VERTICAL LAYERS FROM 28-42..AND ADDED NEW PHYSICS**
- **LED TO TEMPERATURE BIASES..INITIALIZATION PROBLEMS.. SPURIOUS TROPICAL DEVELOPMENT..& QPF BULLSEYES**
- **7/98: EMERGENCY MODEL IMPLEMENTATION**
- **ADDRESSED TEMPERATURE BIASES & QPF BULLSEYES BUT NOT INITIALIZATION AND TROPICAL DEVELOPMENT PROBLEMS**
- **10/98: DECREASED HORIZONTAL RESOLUTION BACK TO 104 KM & VERTICAL LEVELS TO 28.. BUT KEPT NEW PHYSICS**
- **LED TO THE BETTER INITIALIZATION OF SYSTEMS AND LESS SPURIOUS TROPICAL DEVELOPMENT**
- **1/00: INCREASED HORIZONTAL RESOLUTION BACK TO 79 KM AND VERTICAL LEVELS TO 42.**

A RERUN FOR THE SUMMER OF 1998 SHOWS THAT THE NEW 79 KM (T170) MRF WON'T HAVE THE ERRORS OF THE 1998 (T170) VERSION OF THE MRF



MRF 104 KM (T126) VS NEW MRF 79 KM (T170) SCORES



EXPECT MARGINAL T170 SKILL IMPROVEMENT

THE MAIN REASONS WHY MODELS HAVE FORECAST PROBLEMS

- **THE CURRENT STATE OF THE ATMOSPHERE MAY NOT BE DEPICTED ACCURATELY ENOUGH. BAD QUALITY CONTROL OR LOST DETAIL MAY BE IMPORTANT.**

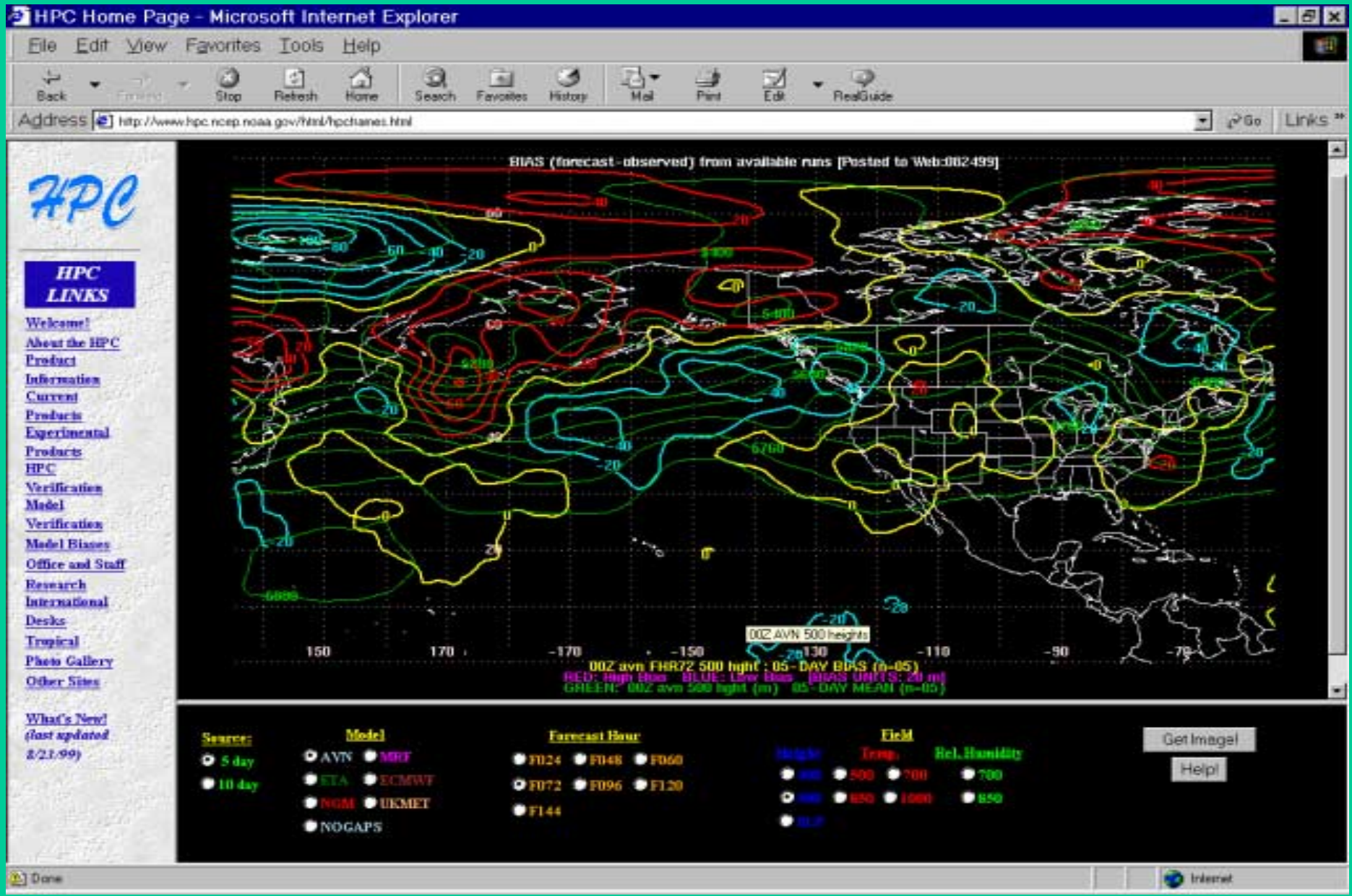
- **SMALL ERRORS IN THESE INITIAL CONDITIONS WILL LEAD TO LARGE FORECAST ERRORS OVER TIME.**

- **THE MODELS MAY NOT HAVE SUFFICIENT HORIZONTAL OR VERTICAL RESOLUTION TO DEPICT TERRAIN AND WEATHER SYSTEM INTERACTIONS (OR TOO MUCH RESOLUTION!).**

- **THE MATHEMATICAL CALCULATIONS IN THE MODEL ARE APPROXIMATIONS**

***THE MODELS HAVE STRENGTHS, WEAKNESSES & BIASES**

HTTP://WWW.HPC.NCEP.NOAA.GOV



MODEL SOFTWARE CHANGE=BIAS CHANGE

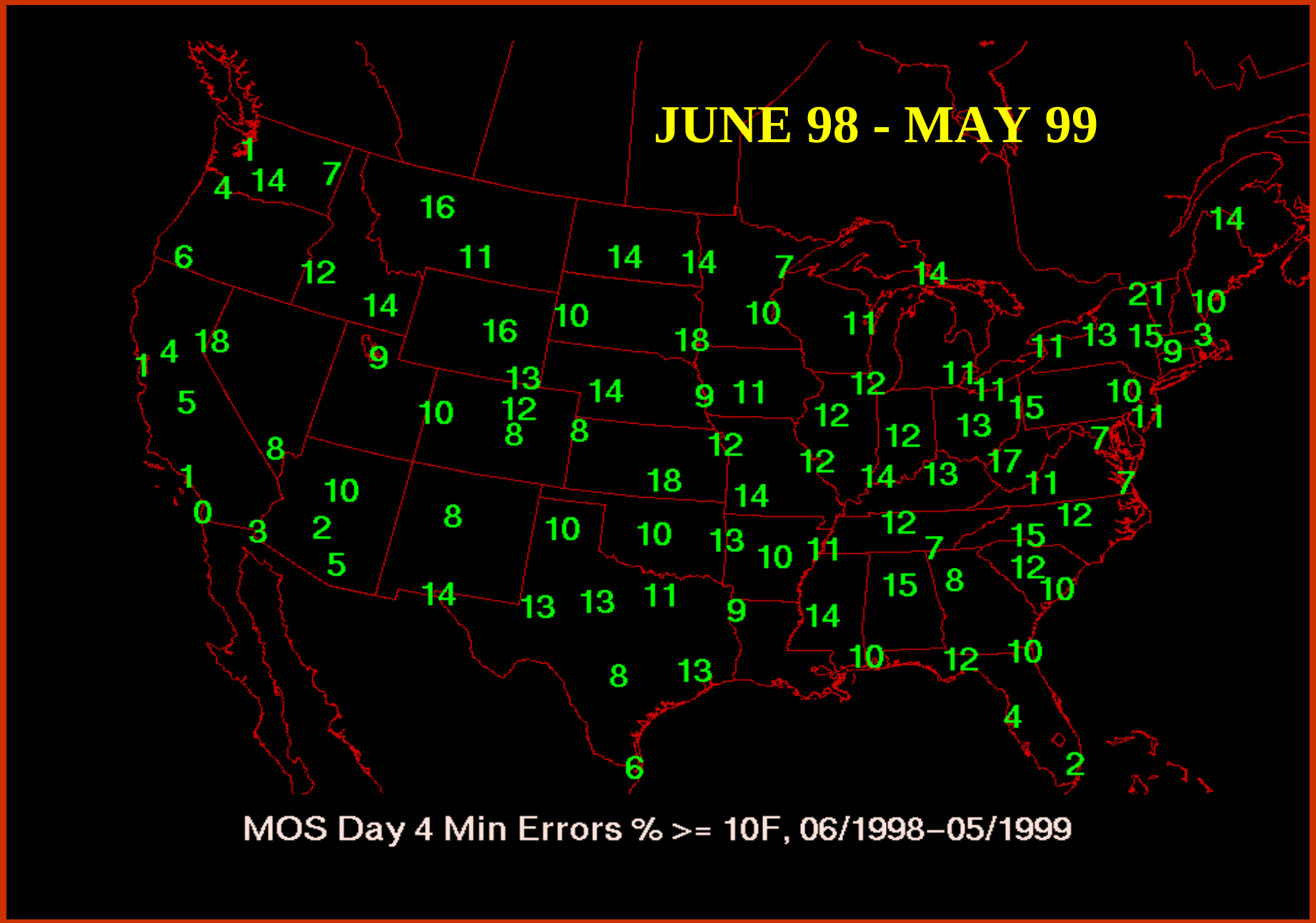
STATISTICAL MODEL GUIDANCE

MRF MOS

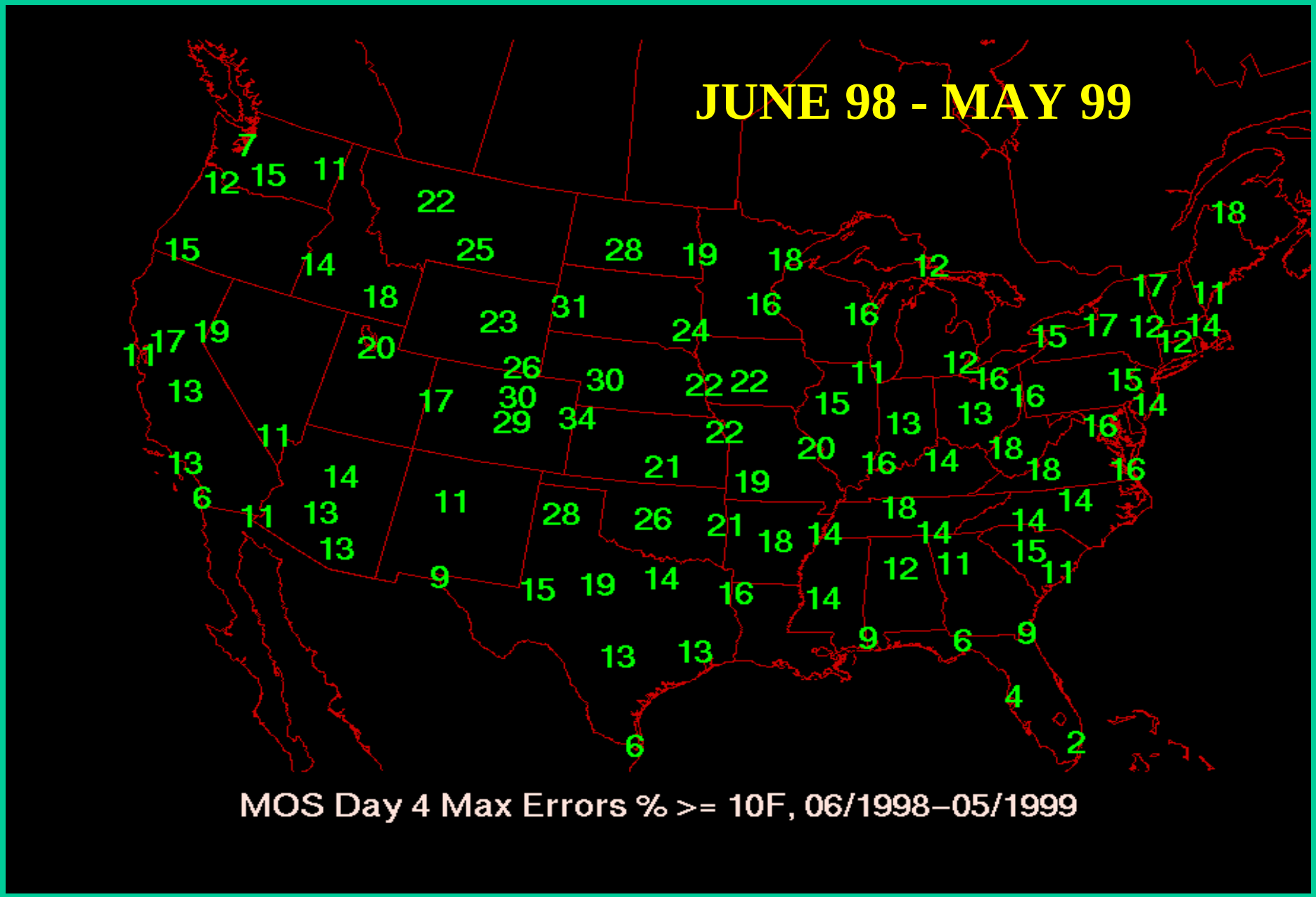
ACCOUNTS FOR CLIMATOLOGY AND MRF BIASES AND PROVIDES A GOOD FIRST GUESS FOR MEDIUM RANGE FORECASTS WHEN THE MRF PROVIDES REASONABLE GUIDANCE (UPDATED MRF MOS 2000 COMING SOON)

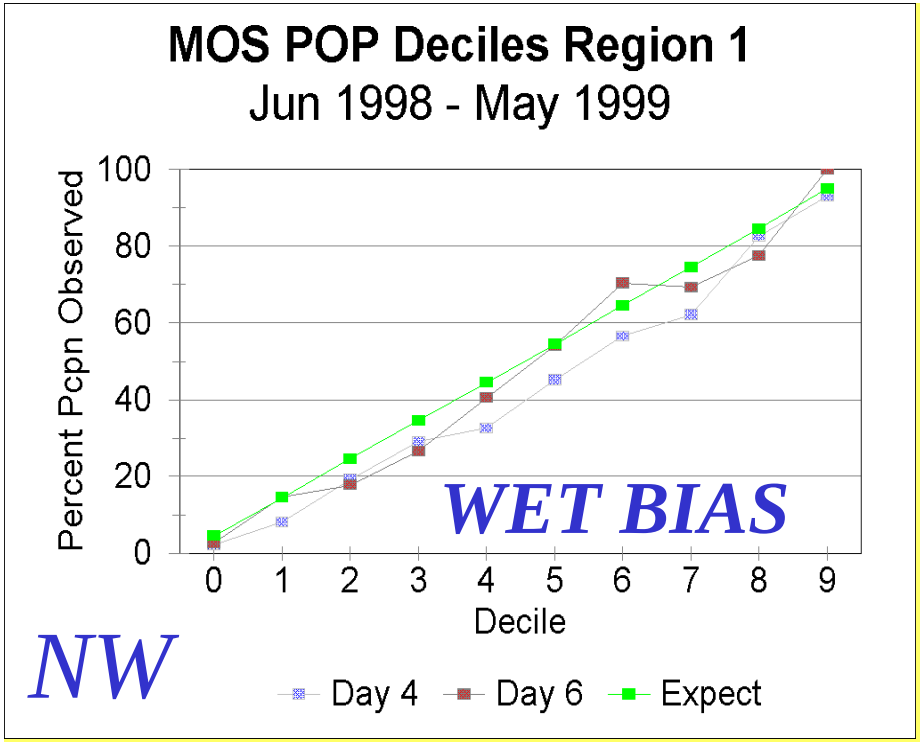
OTHERWISE..THERE IS PLENTY OF ROOM FOR MANUAL FORECAST ADJUSTMENTS

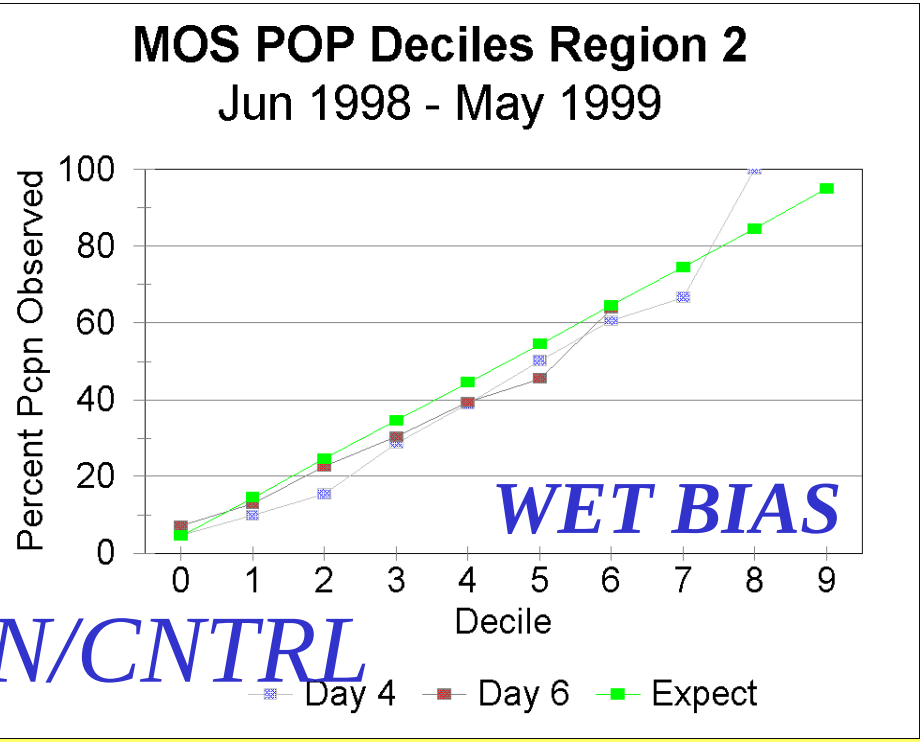
% OF MOS DAY 4 MIN TEMP ERRORS 10F+

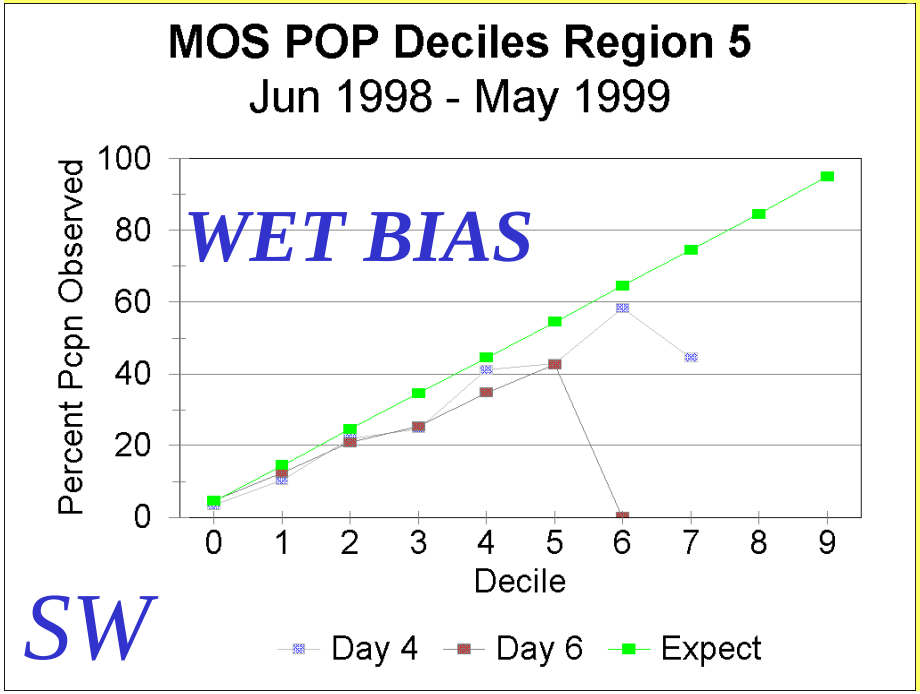


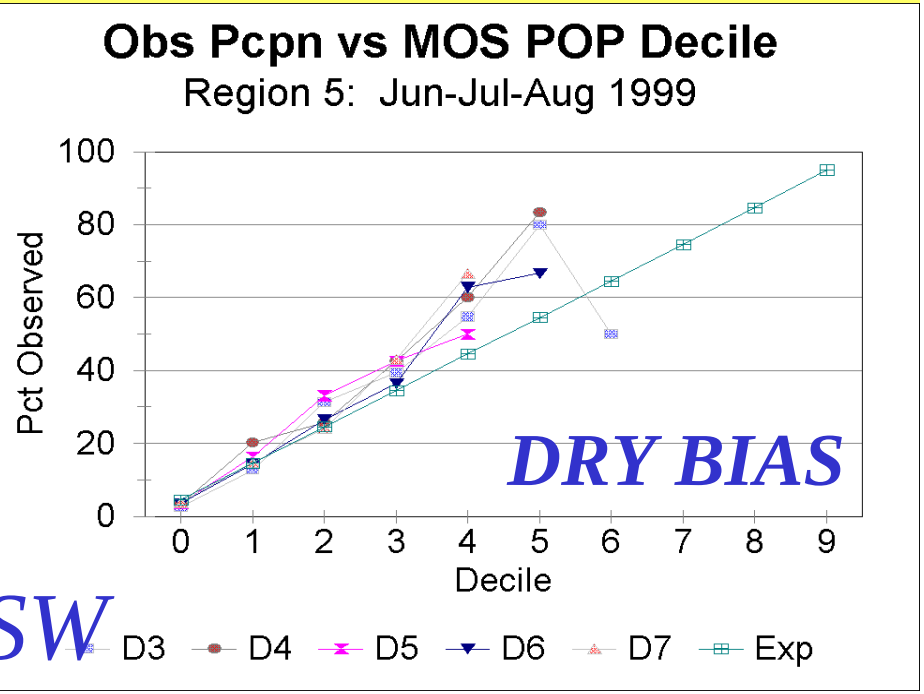
% OF MOS DAY 4 MAX TEMP ERRORS 10F+




MOS POP Deciles Region 1
Jun 1998 - May 1999
Percent Pcpn Observed
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9
Decile
WET BIAS
NW
Day 4
Day 6
Expect


MOS POP Deciles Region 2
Jun 1998 - May 1999
Percent Pcpn Observed
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9
Decile
WET BIAS
N/CNTRL
Day 4
Day 6
Expect


MOS POP Deciles Region 5
Jun 1998 - May 1999
Percent Pcpn Observed
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9
Decile
WET BIAS
SW
Day 4
Day 6
Expect


Obs Pcpn vs MOS POP Decile
Region 5: Jun-Jul-Aug 1999
Pct Observed
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9
Decile
DRY BIAS
SW
D3
D4
D5
D6
D7
Exp

DISCLAIMER!!!

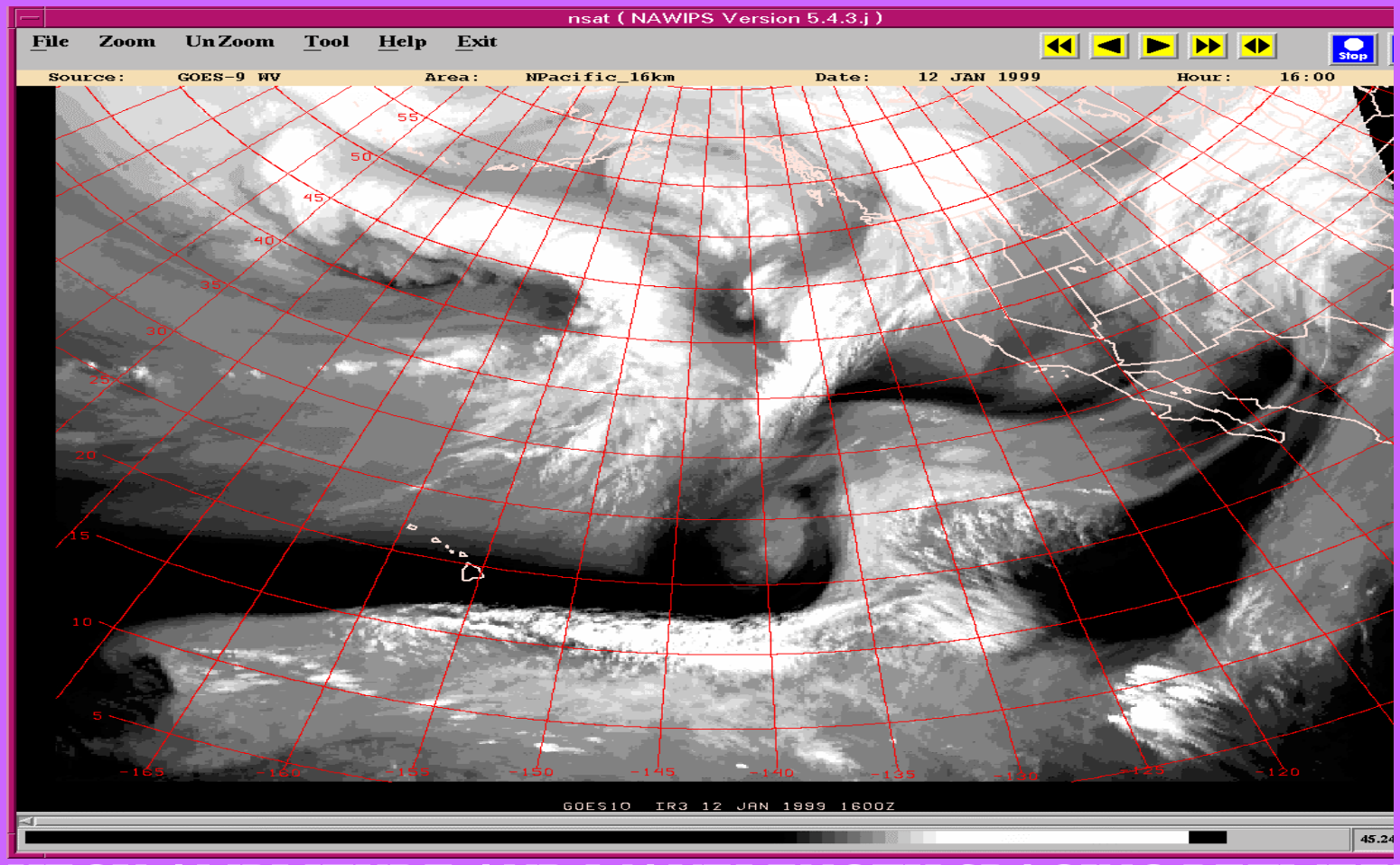
THE PAST SLIDES HAVE DEPICTED BACKGROUND INFORMATION NEEDED FOR MEDIUM RANGE FORECASTING.

YOU MUST DO YOUR HOMEWORK BEFORE TRYING TO MAKE A FORECAST.

A 3-5 DAY FORECAST CASE STUDY (SLIDES 24-39) STARTS HERE

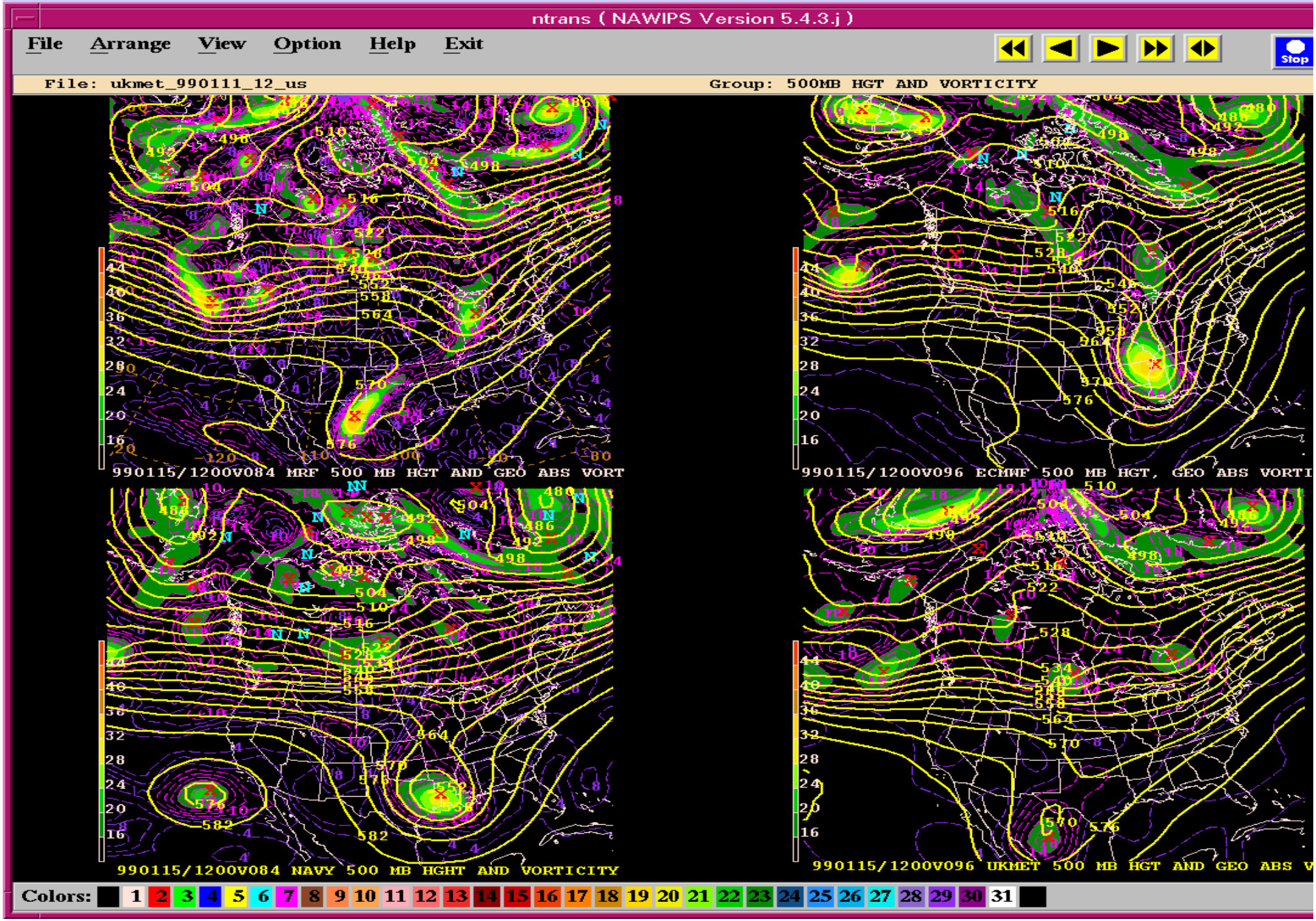
MEDIUM RANGE SATELLITE IMAGERY?

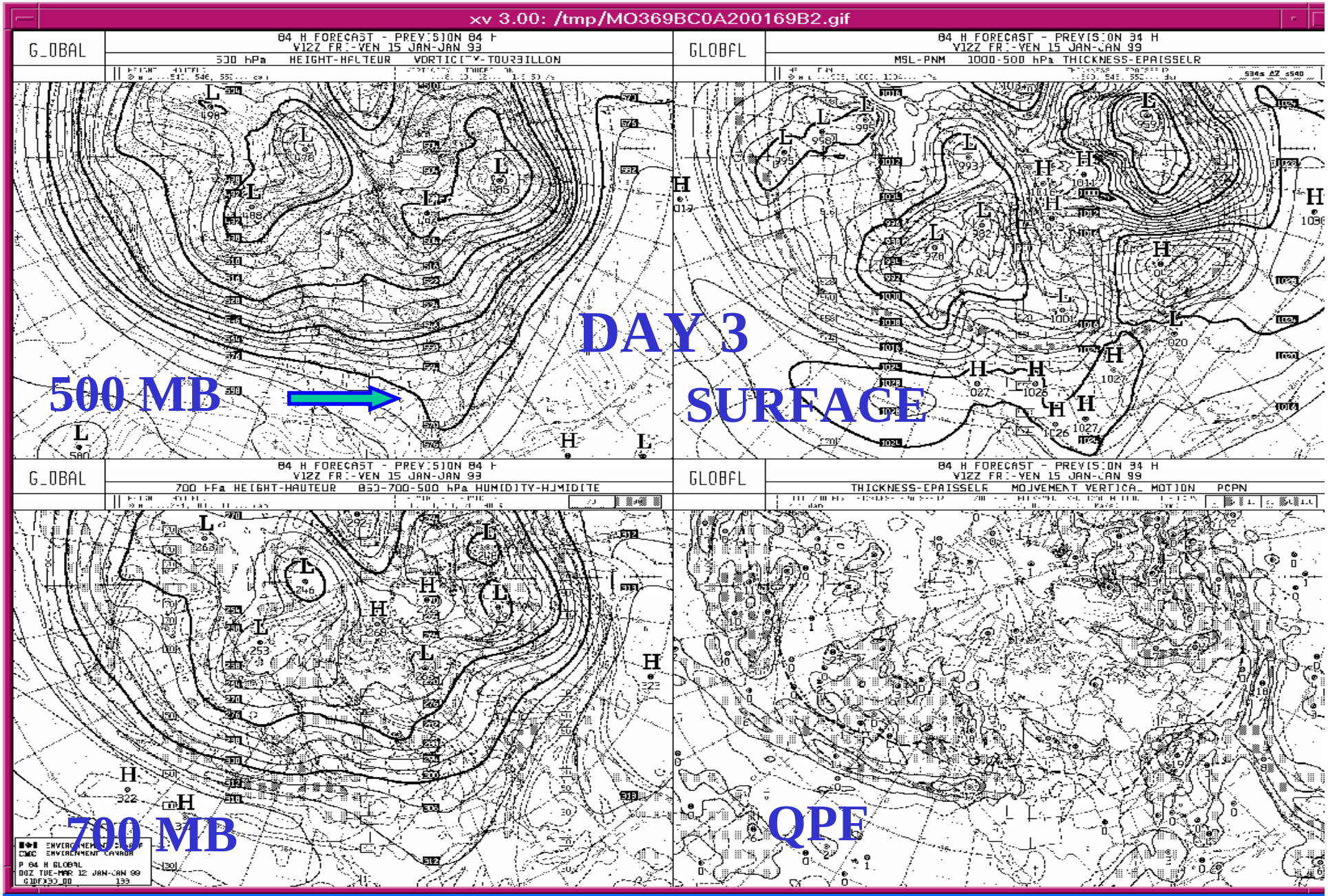
ARE THE MODELS INITIALIZED CORRECTLY? HOW ABOUT THEIR 12/24 HOUR FORECAST FIELDS?



CHECK AMPLITUDE AND WAVELENGTH SPACING BETWEEN SHORTWAVES AND ACCESS MODEL UNCERTAINTY

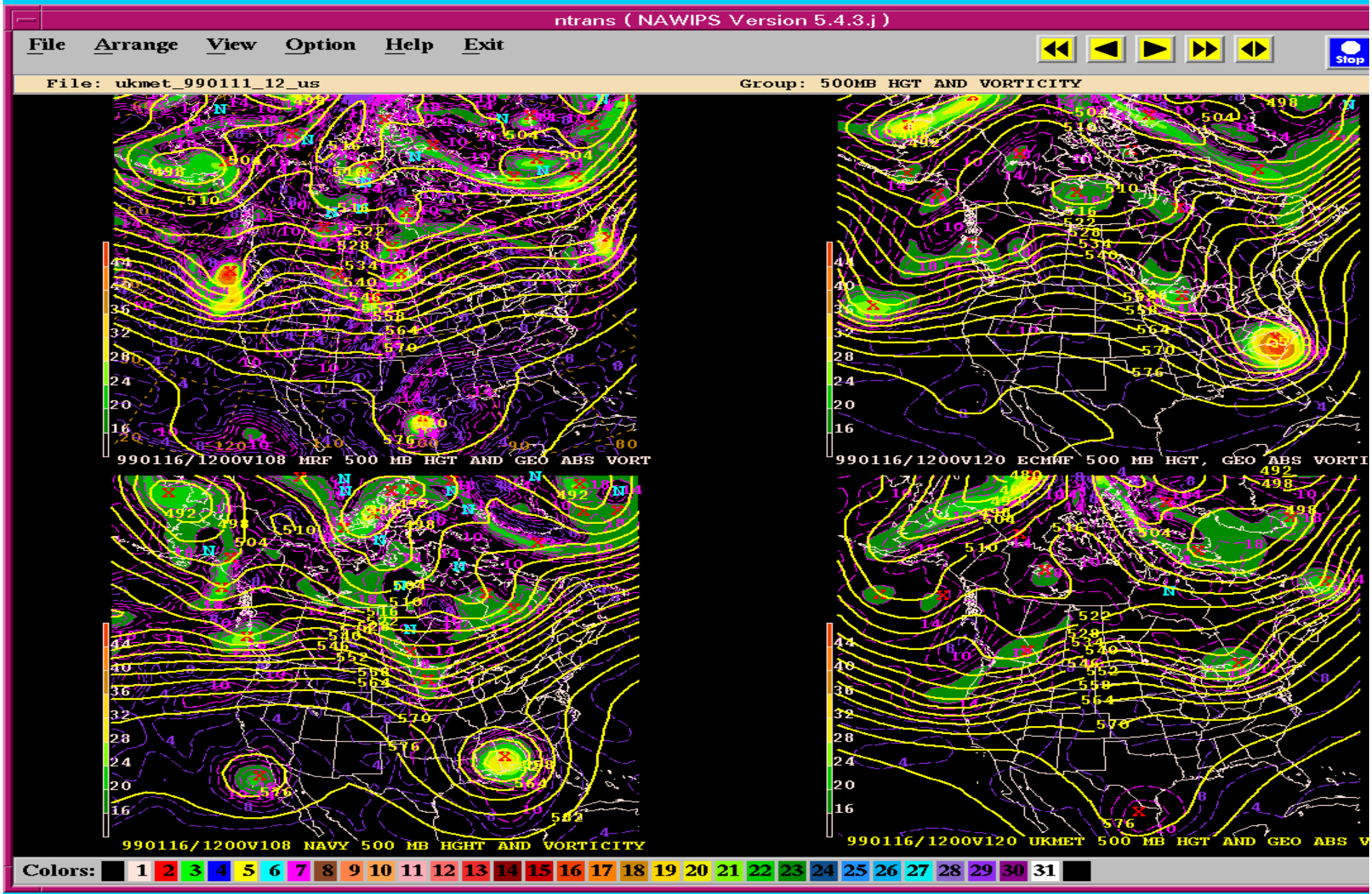
DAY 3 MRF/UKMET VS ECMWF/NOGAPS





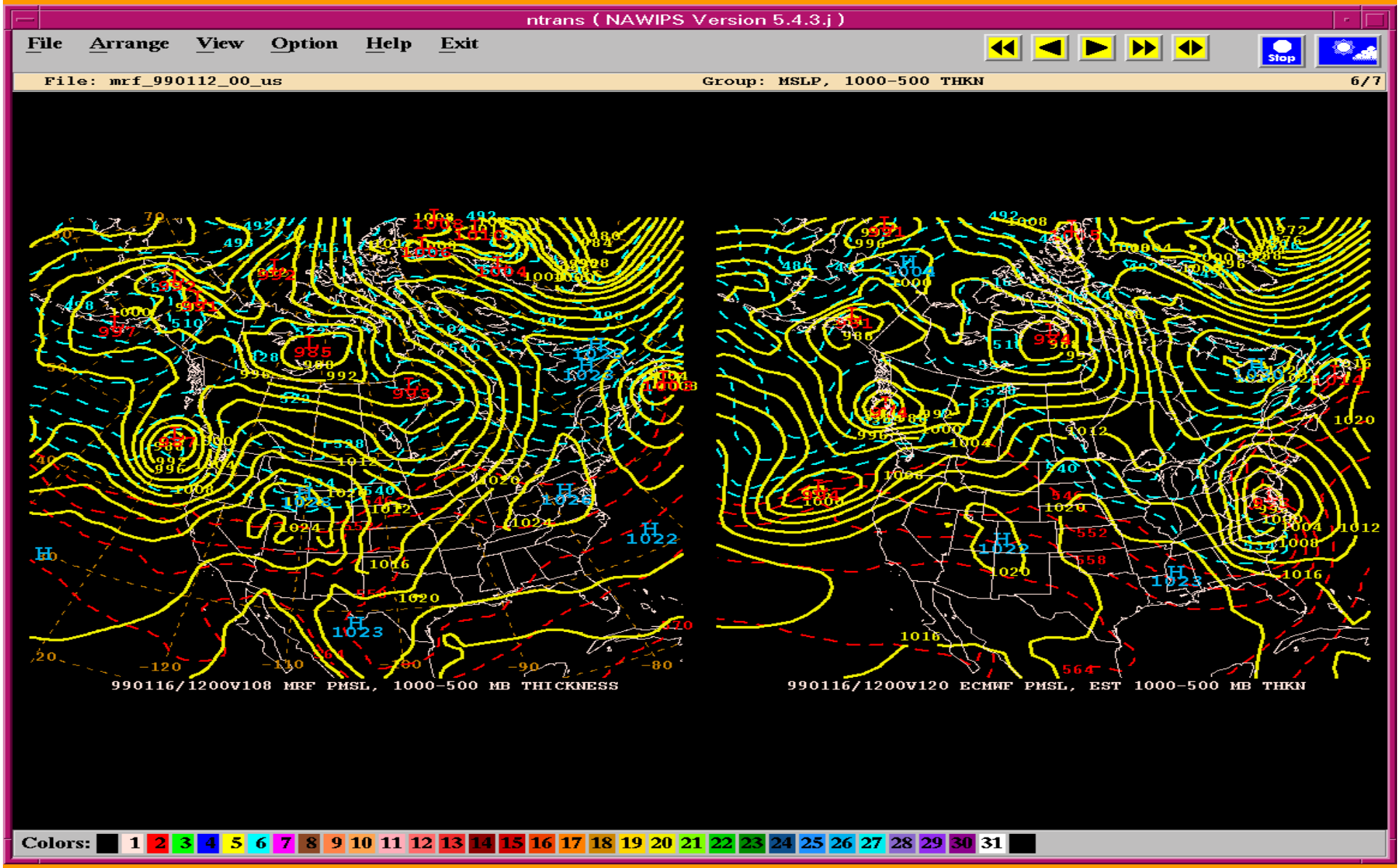
THE CANADIAN MODEL AT WWW.CMC.EC.GC.CA

MRF/ECMWF/UKMET/NOGAPS 500 MB DAY 4



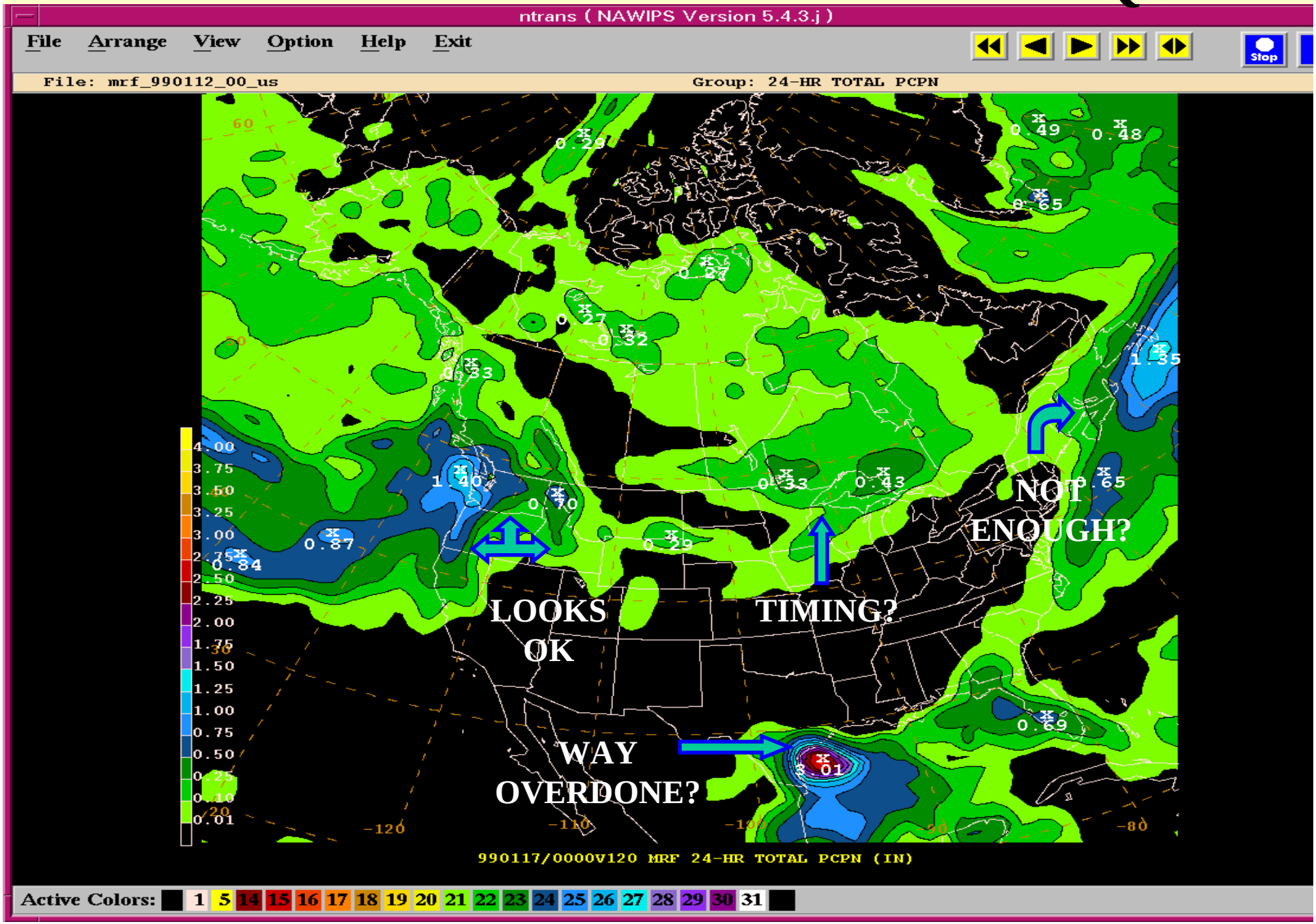
WHICH SOLUTION IS PREFERRED..IF ANY?

MRF VS ECMWF DAY 4 PMSL FORECASTS

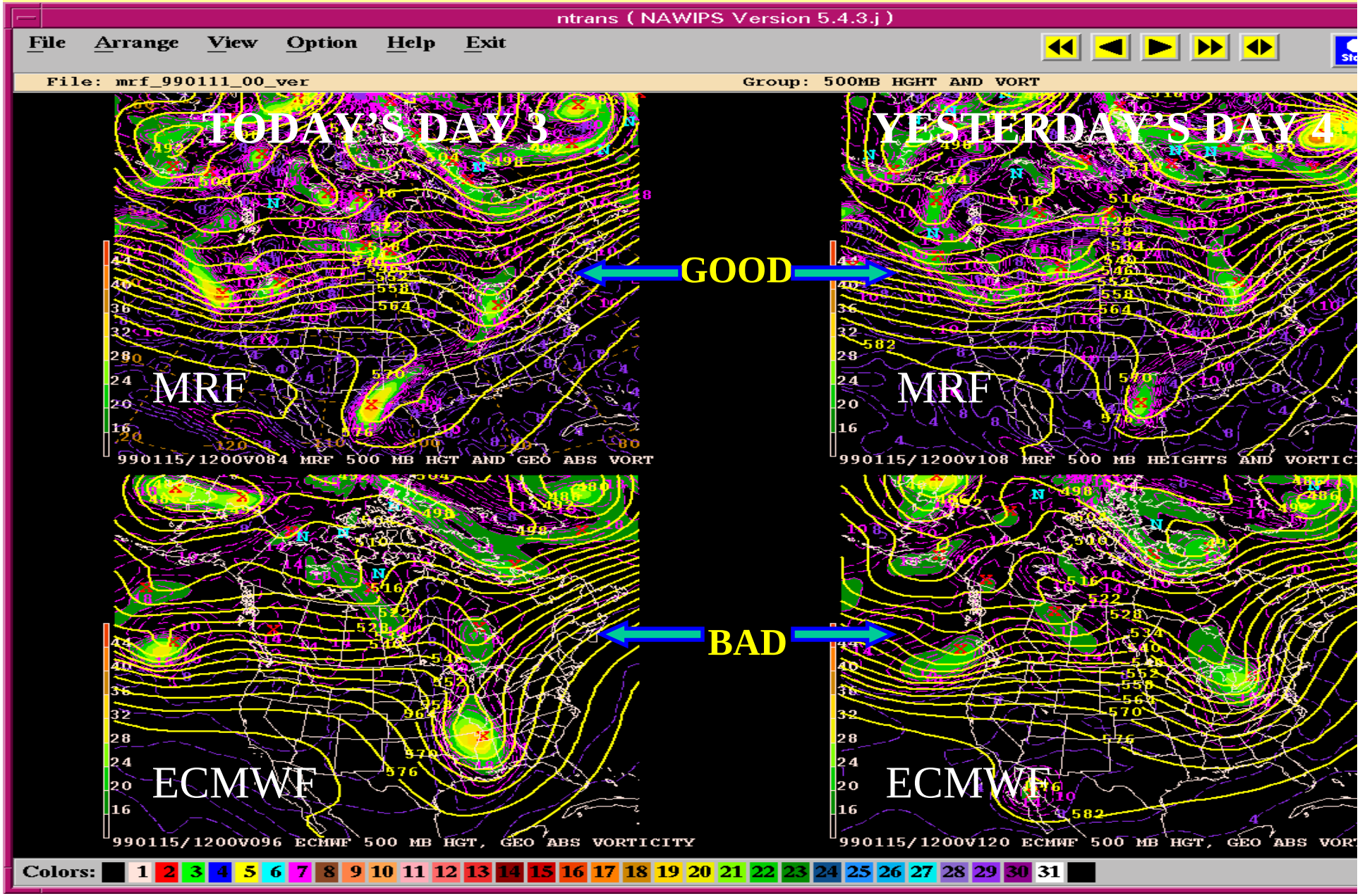


FORECAST UNCERTAINTY IS USUALLY HIGHER WHEN A MODEL COMPARISON SHOWS SIGNIFICANTLY DIFFERENT SOLUTIONS

OPERATIONAL MRF 108-132 HOUR QPF



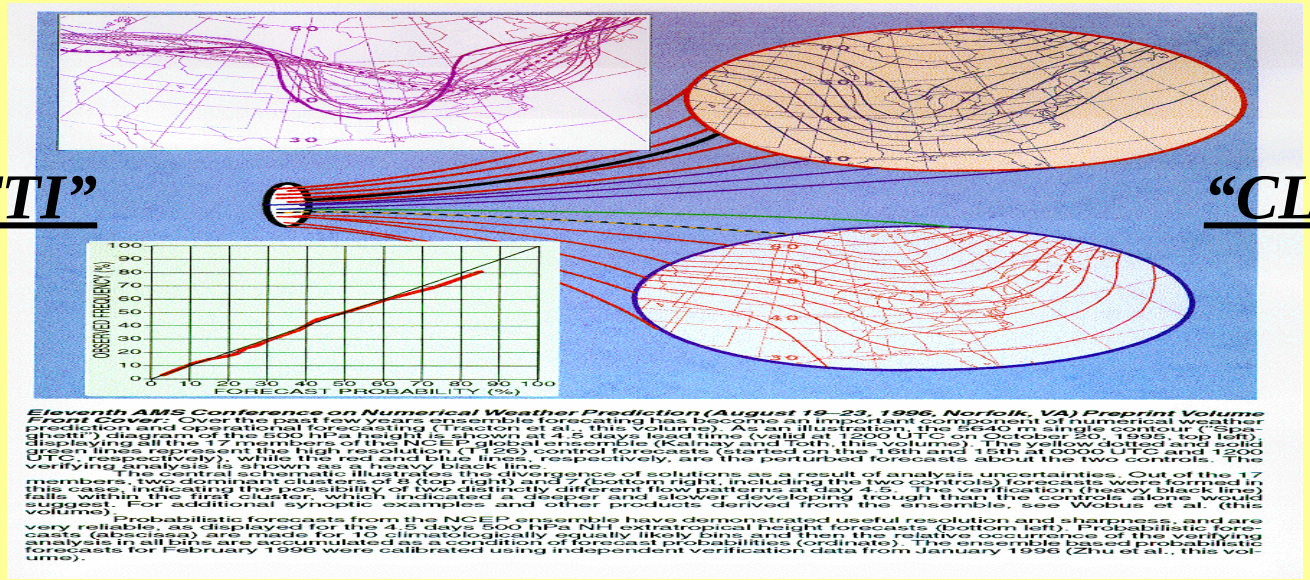
DO TODAY'S MODEL FORECASTS HAVE GOOD RUN TO RUN CONTINUITY?



ENSEMBLE FORECASTING

- **SLIGHTLY DIFFERENT INITIAL CONDITIONS PRODUCE A NUMBER OF POSSIBLE FORECASTS**

"SPAGHETTI" ***"CLUSTER"***



Eleventh AMS Conference on Numerical Weather Prediction (August 19–23, 1996, Norfolk, VA) Preprint Volume

Front Cover: Over the past few years ensemble forecasting has become an important component of numerical weather prediction and operational forecasting (Tracton et al., this volume). As an illustration, this 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 30, 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 9 (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 illustrated for the 4.5 day 500 hPa NH extratropical height forecasts (bottom left). Probabilistic forecasts (reliability) are made for 10 climatologically equally likely bins and then the relative occurrence of the verifying analysis in all bins are accumulated as a correct forecast probabilities (ordinate). The reliability curve based on probabilistic forecasts for February 1996 were calibrated using independent verification data from January 1996 (Zhu et al., this volume).

- **ASSUMES MEDIUM RANGE FORECASTS AND BEYOND ARE NON-DETERMINISTIC (~DAY4+)**
- **QUANTIFIES UNCERTAINTY (SPREAD)**
- **ENSEMBLE MEANS SHOW THE MORE PREDICTABLE FORECAST COMPONENTS. (INCREASED SKILL IS EQUAL TO SEVERAL YEARS OF MODEL DEVELOPMENT)**

ENSEMBLE FORECAST MODELS

MODEL	# OF ENSEMBLE MEMBERS	MAX HORIZONTAL RESOLUTION (KM)
ECMWF	51	85
MRF	17	104*
CANADIAN	17	205

** TO BE IMPLEMENTED SPRING 2000?*

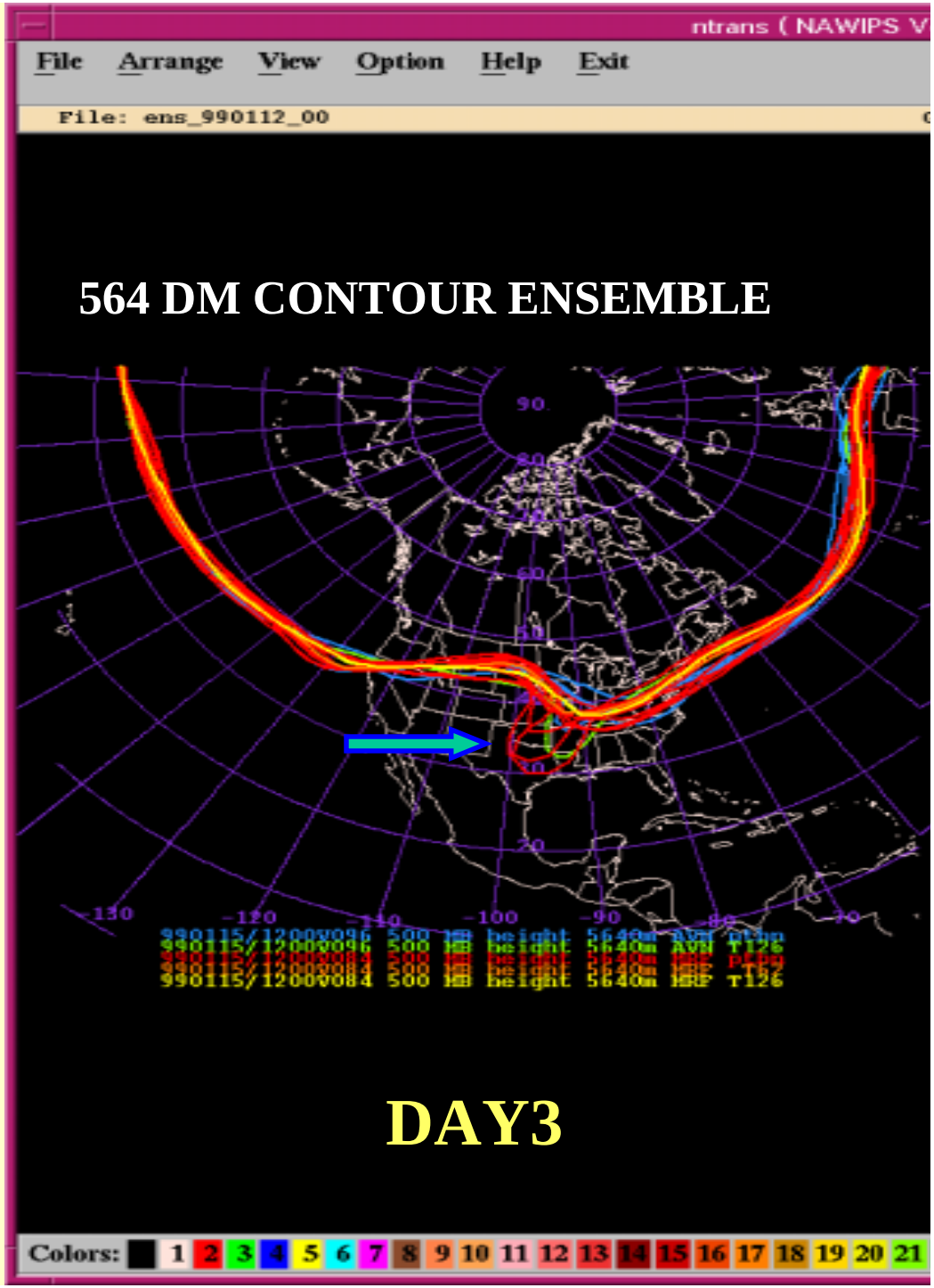
MRF ENSEMBLE PRODUCTS

VARIABLE	HEIGHT in hPa (or m)
Geopotential height (Gph)	1000
Gph	700
Gph	500
Gph	250
Winds (U,V)	10 m
U,V	850
U,V	500
U,V	250
Temperature (T)	2 m
T	850
Relative humidity	700
Mean sea level pressure	
Total accumulated precipitation	

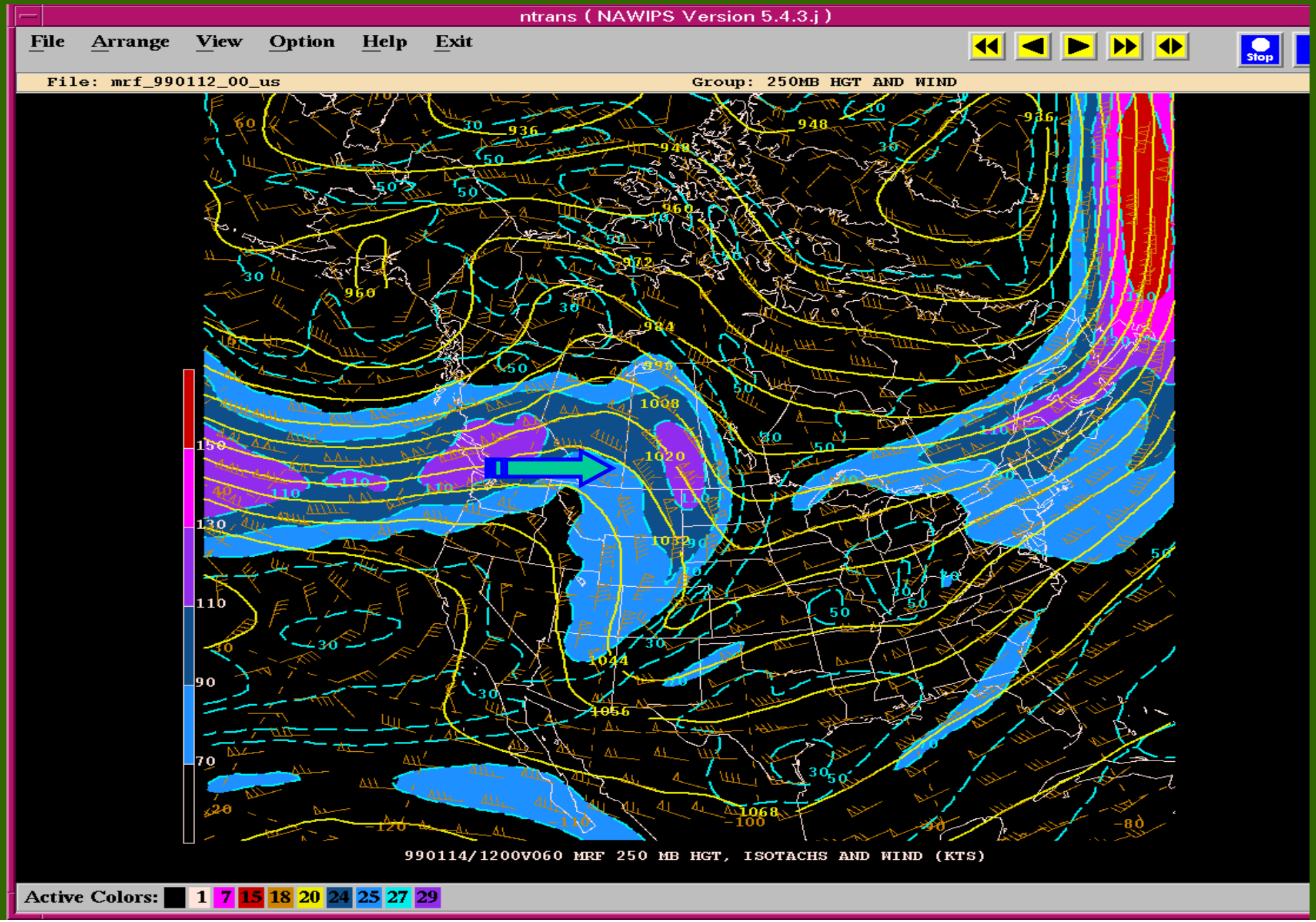
TABLE 1. The list of variables that are available for the global ensemble from NCEP through anonymous ftp (nic.fb4.noaa.gov, /pub/ens).

“SPAGHETTI” DIAGRAM

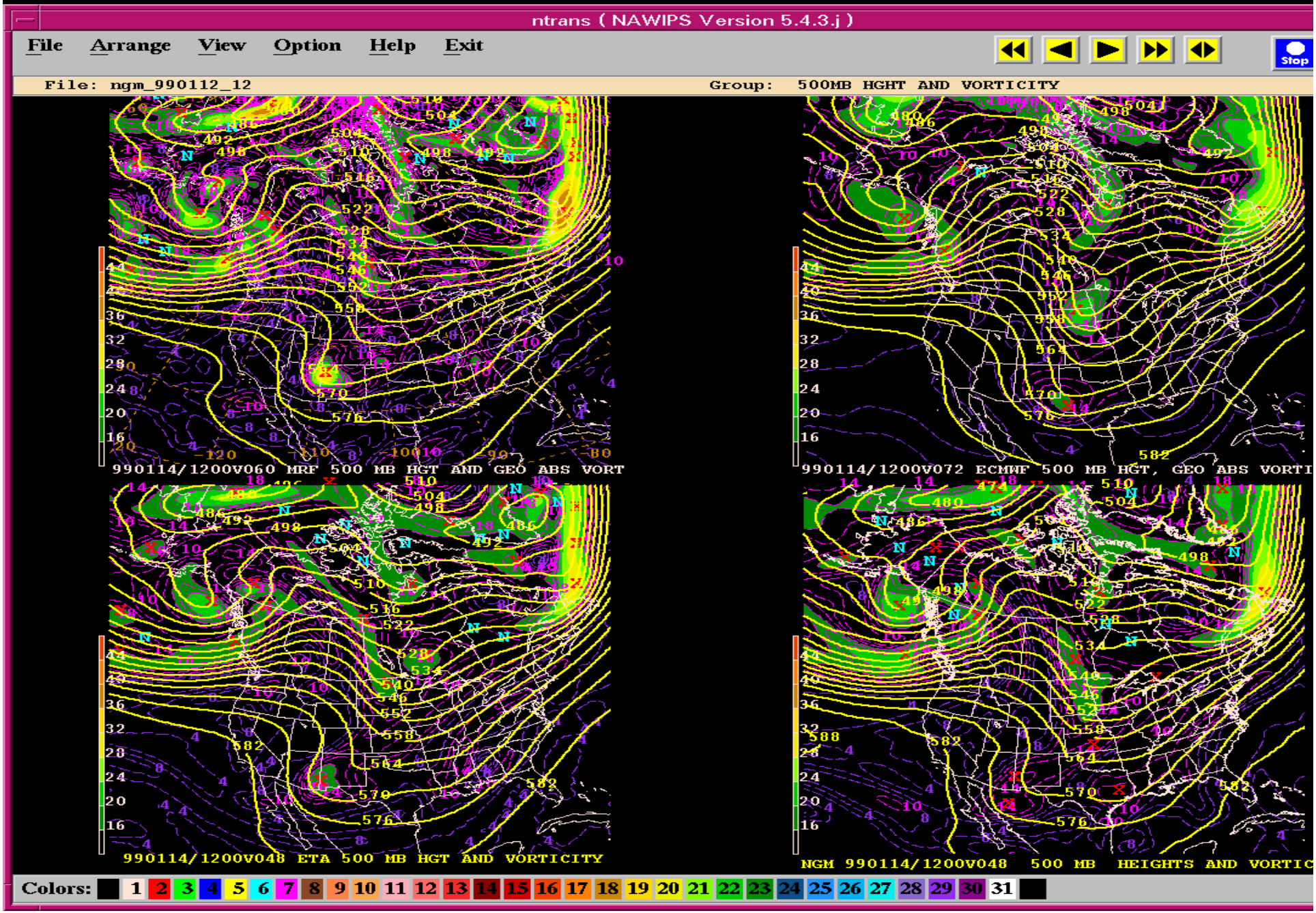
MRF ENSEMBLE MEMBERS SHOW A PROGRESSIVE PATTERN ALBEIT WITH SOME MEMBERS DEPICTING A MORE “DIGGY” NORTHERN STREAM TROUGH OVER THE CENTRAL U.S. THAN THE OPERATIONAL MRF



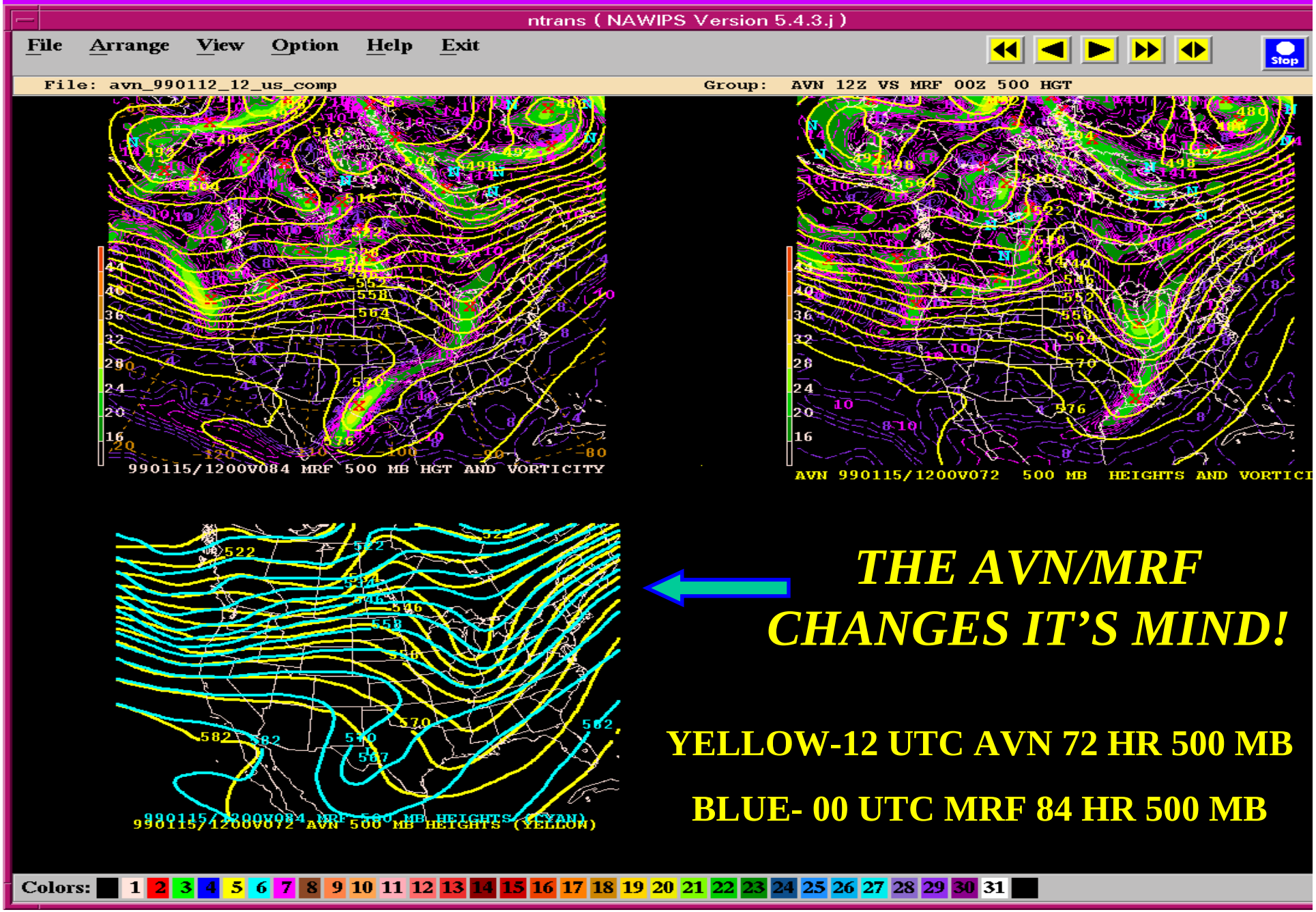
THE MRF 250MB 60HR JET FORECAST SUGGESTS MRF 500MB PLAINS SHORTWAVE DIGGING IS UNDERDONE



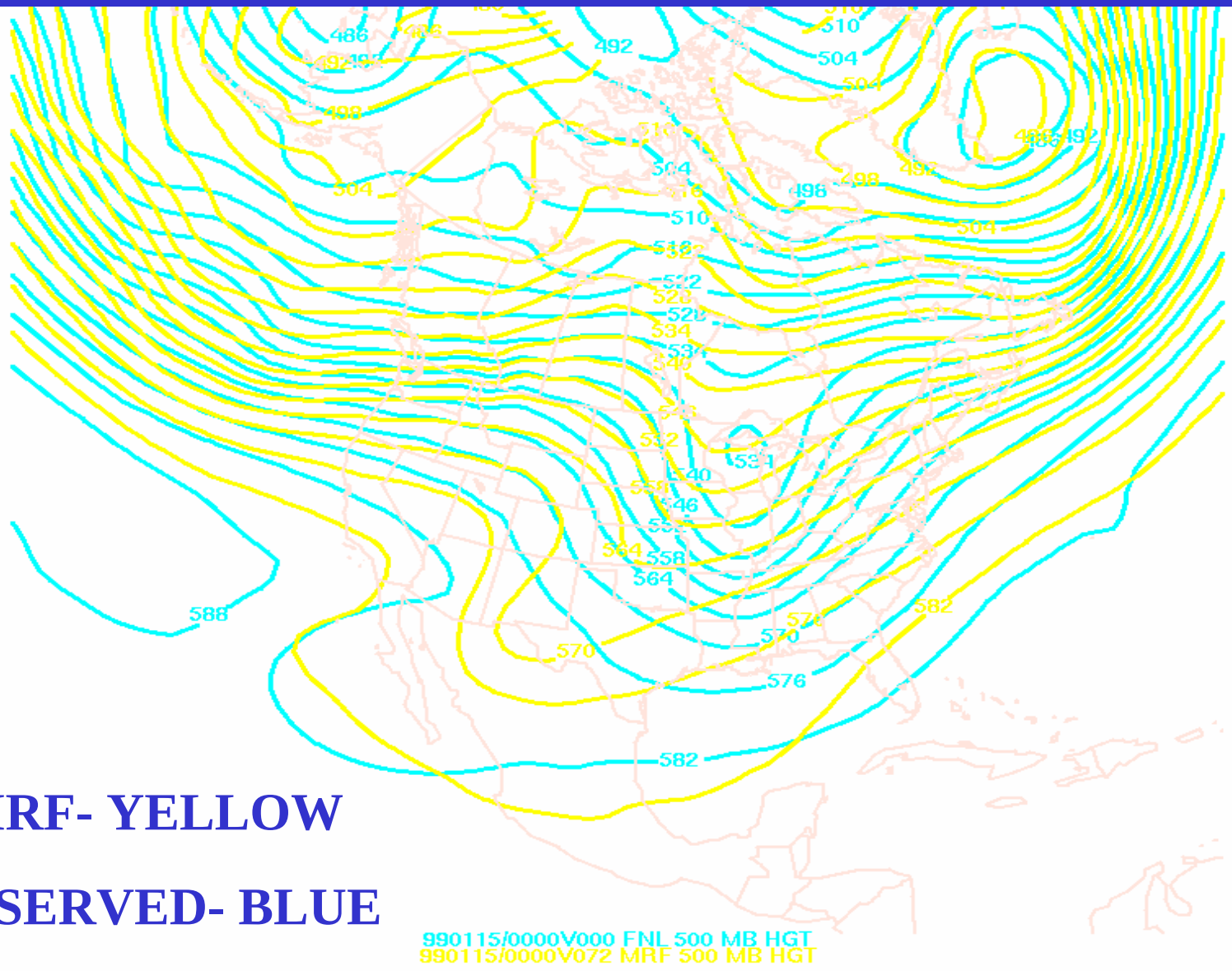
MRF AND ECMWF 500 MB VS ETA AND NGM 500 MB



BIG CHANGES: 00 UTC MRF VS 12 UTC AVN



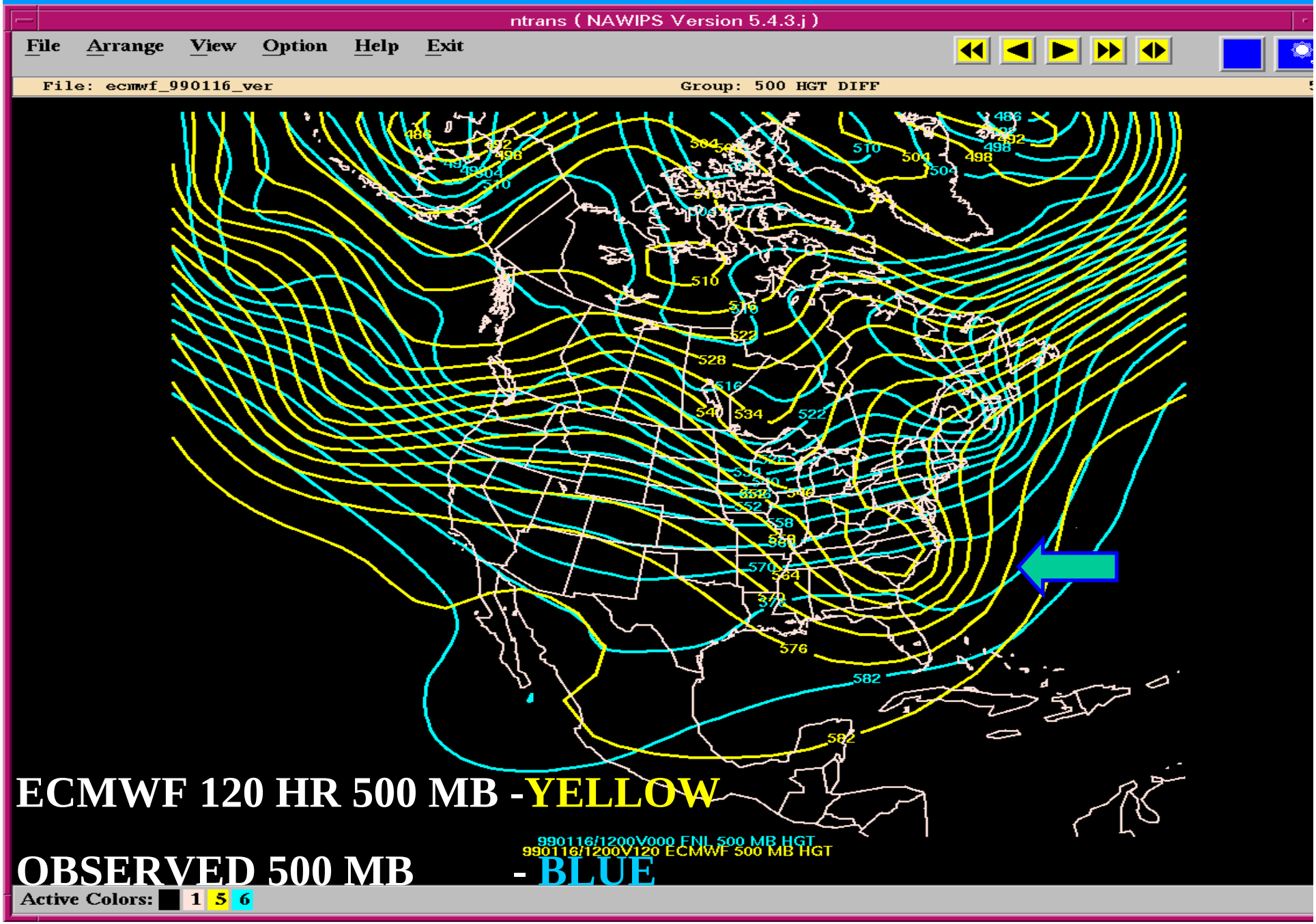
VERIFICATION SECTION:
72 HR MRF 500 MB FORECAST VS OBSERVED



MRF- YELLOW

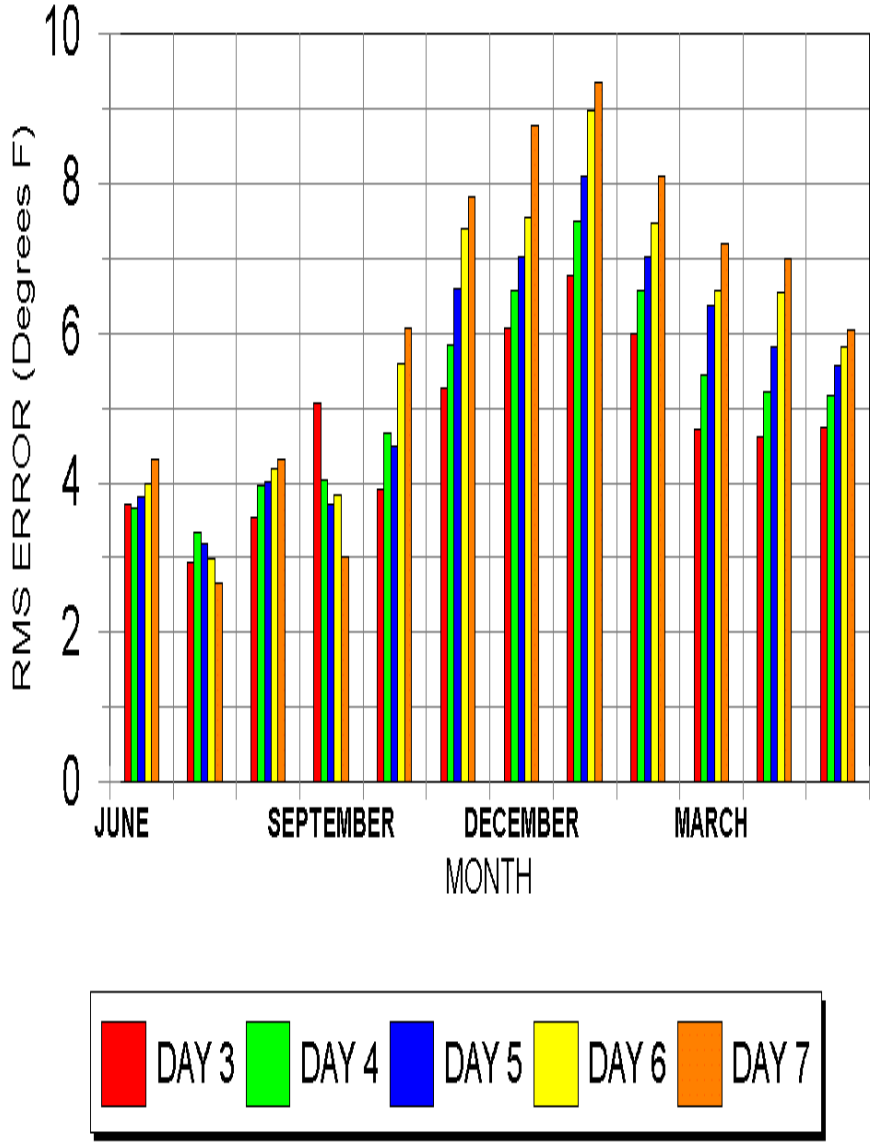
OBSERVED- BLUE

120HR ECMWF 500MB HEIGHTS VS OBS



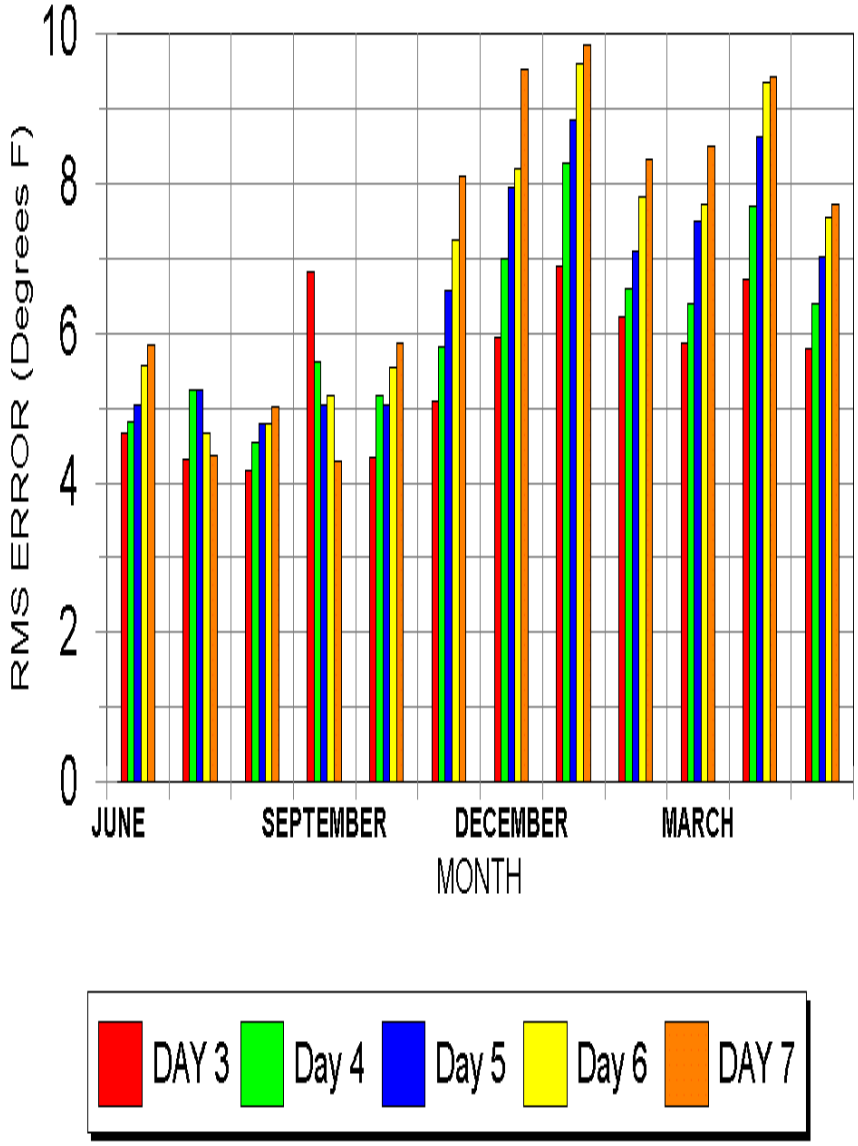
HPC MEDIUM RANGE RMS ERRORS

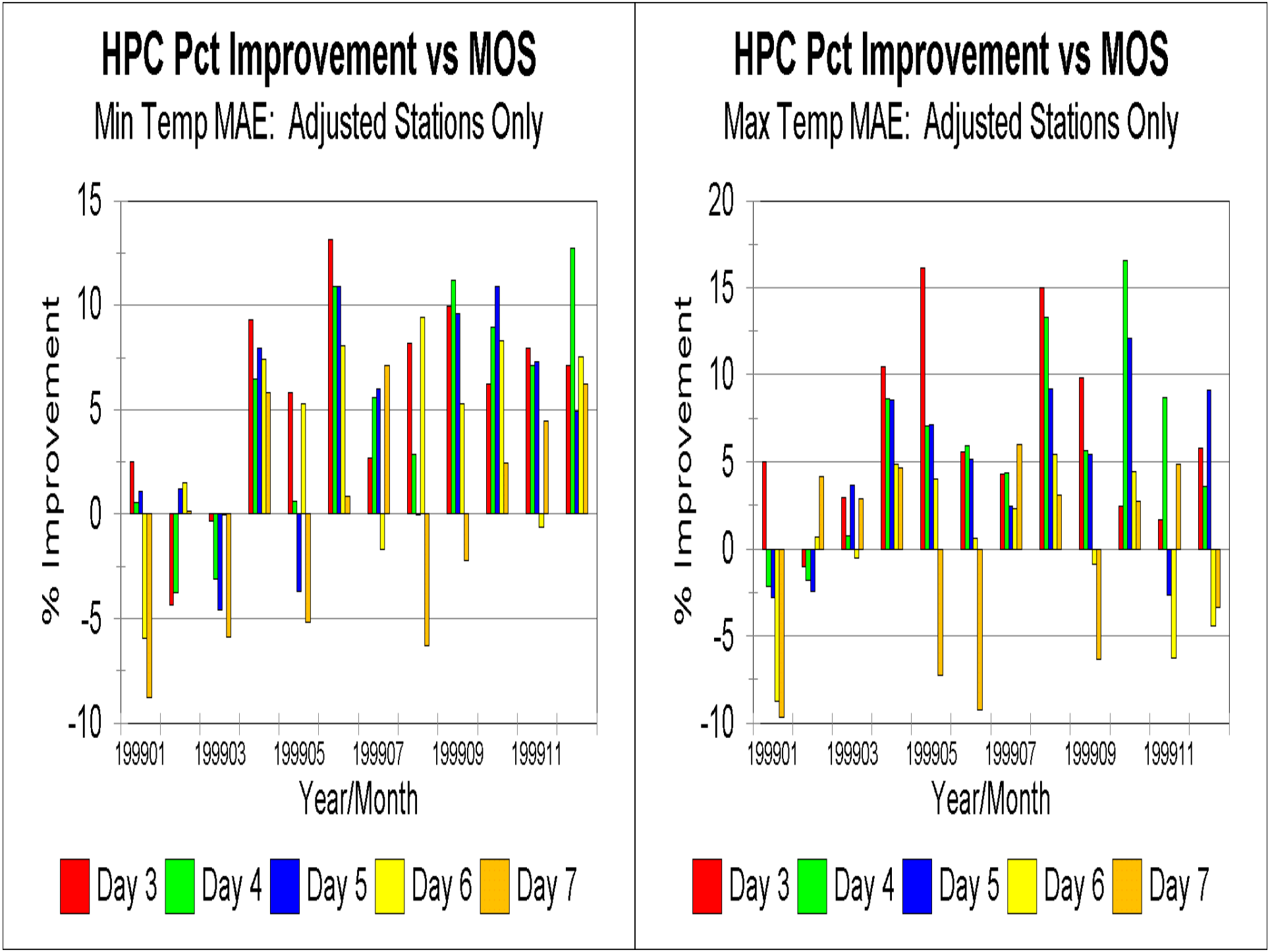
MINIMUM TEMPERATURES



HPC MEDIUM RANGE RMS ERRORS

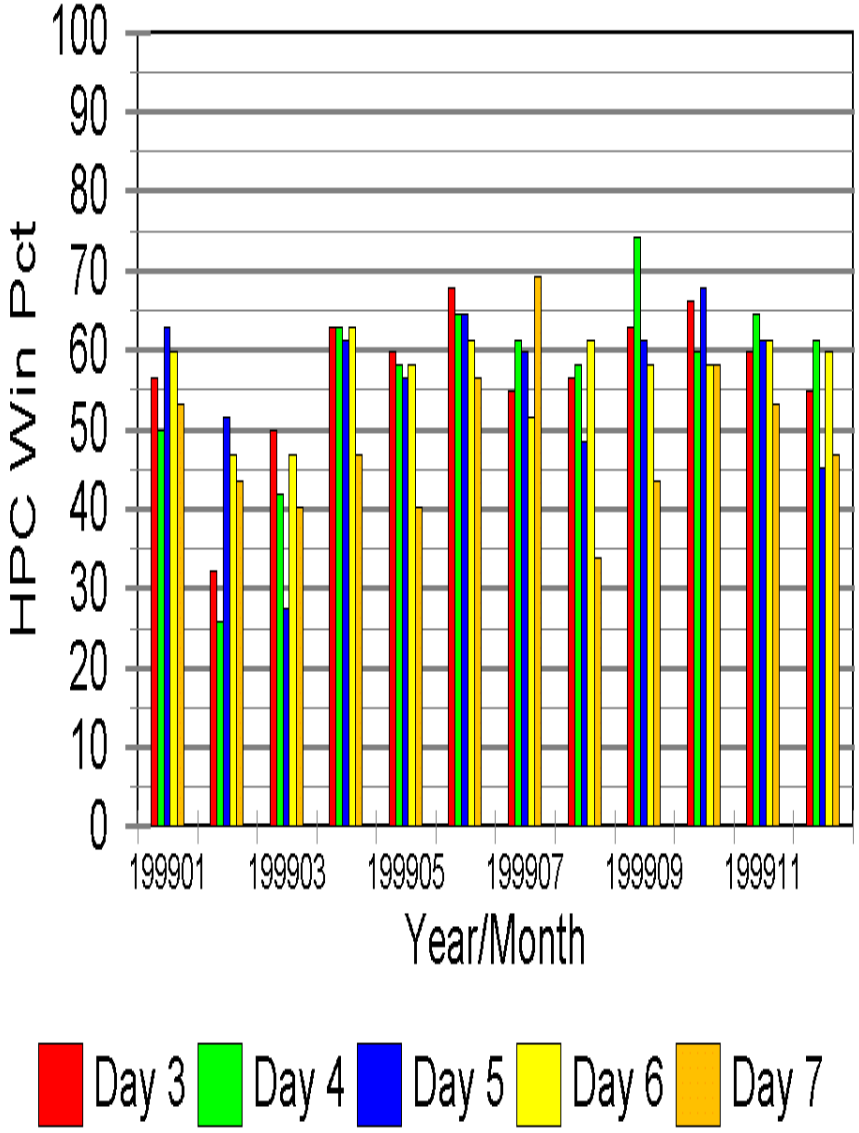
MAXIMUM TEMPERATURES




HPC Pct Improvement vs MOS
Min Temp MAE: Adjusted Stations Only
% Improvement
15
10
5
0
-5
-10
199901
199903
199905
199907
199909
199911
Year/Month
Day 3
Day 4
Day 5
Day 6
Day 7
HPC Pct Improvement vs MOS
Max Temp MAE: Adjusted Stations Only
% Improvement
20
15
10
5
0
-5
-10
199901
199903
199905
199907
199909
199911
Year/Month
Day 3
Day 4
Day 5
Day 6
Day 7

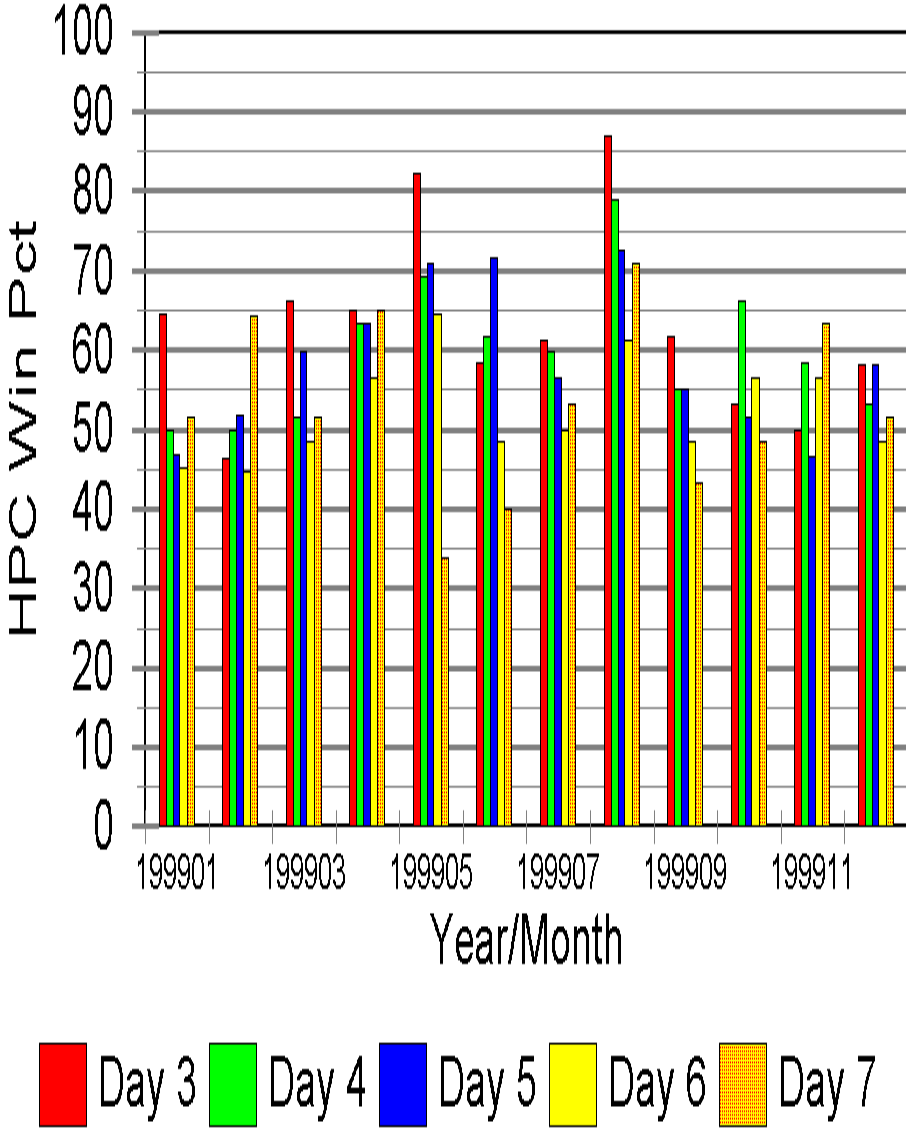
Daily HPC Win Pct vs MOS

Min Temp MAE



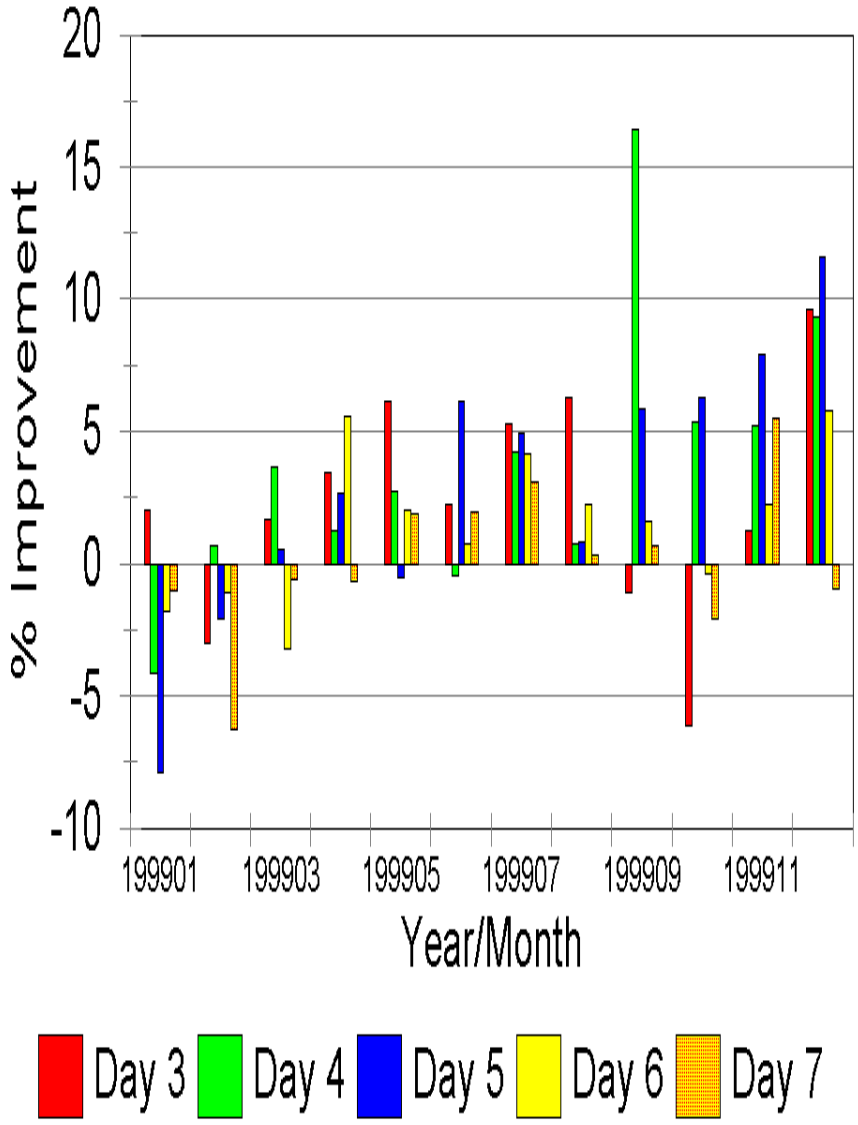
Daily HPC Win Pct vs MOS

Max Temp MAE



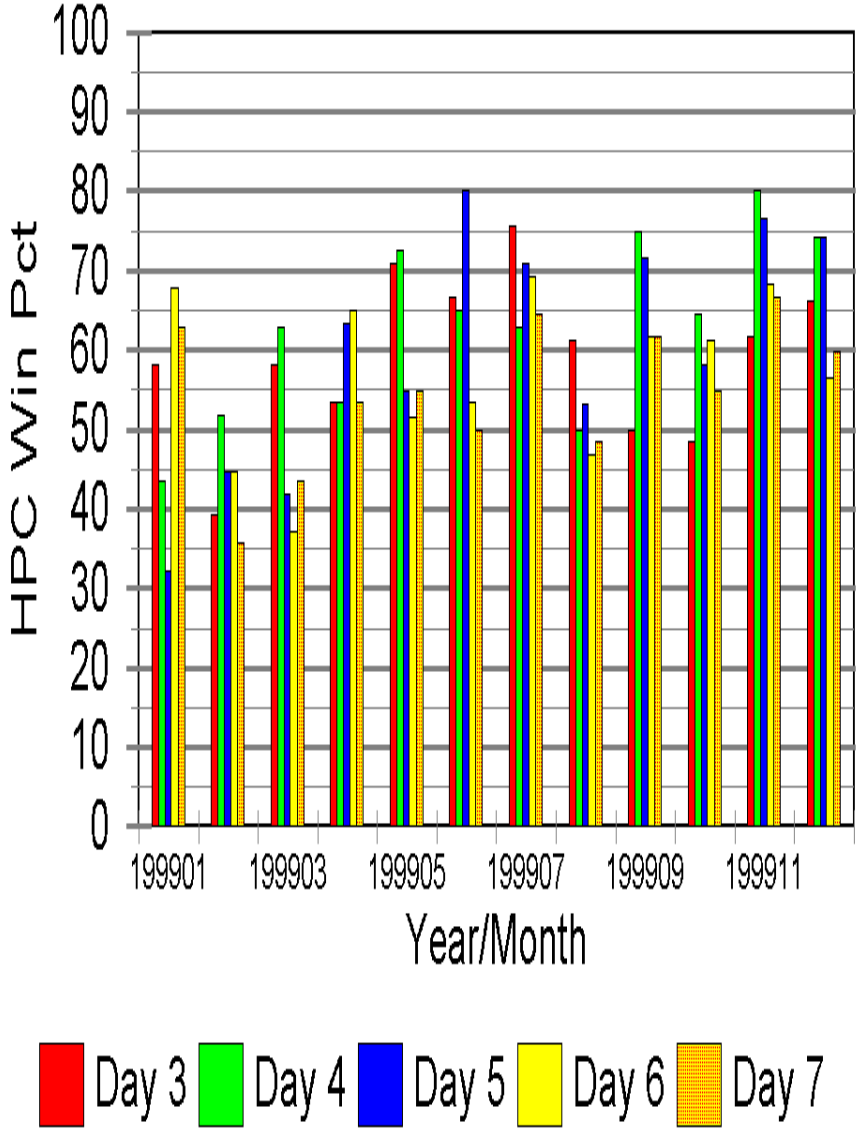
HPC Pct Improvement vs MOS

Brier Score: Adjusted Stations Only

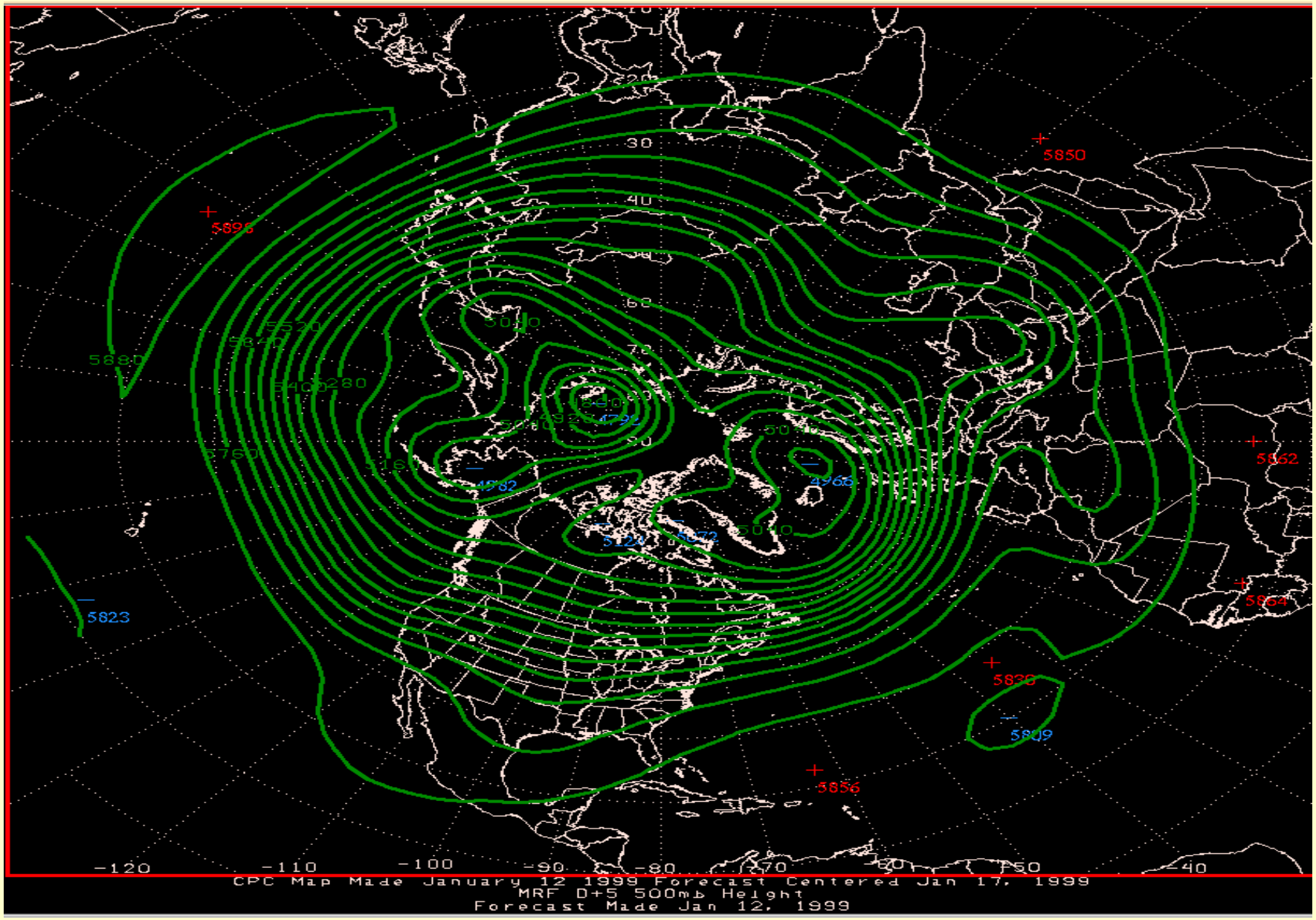


Daily HPC Win Pct vs MOS

POP Brier Score

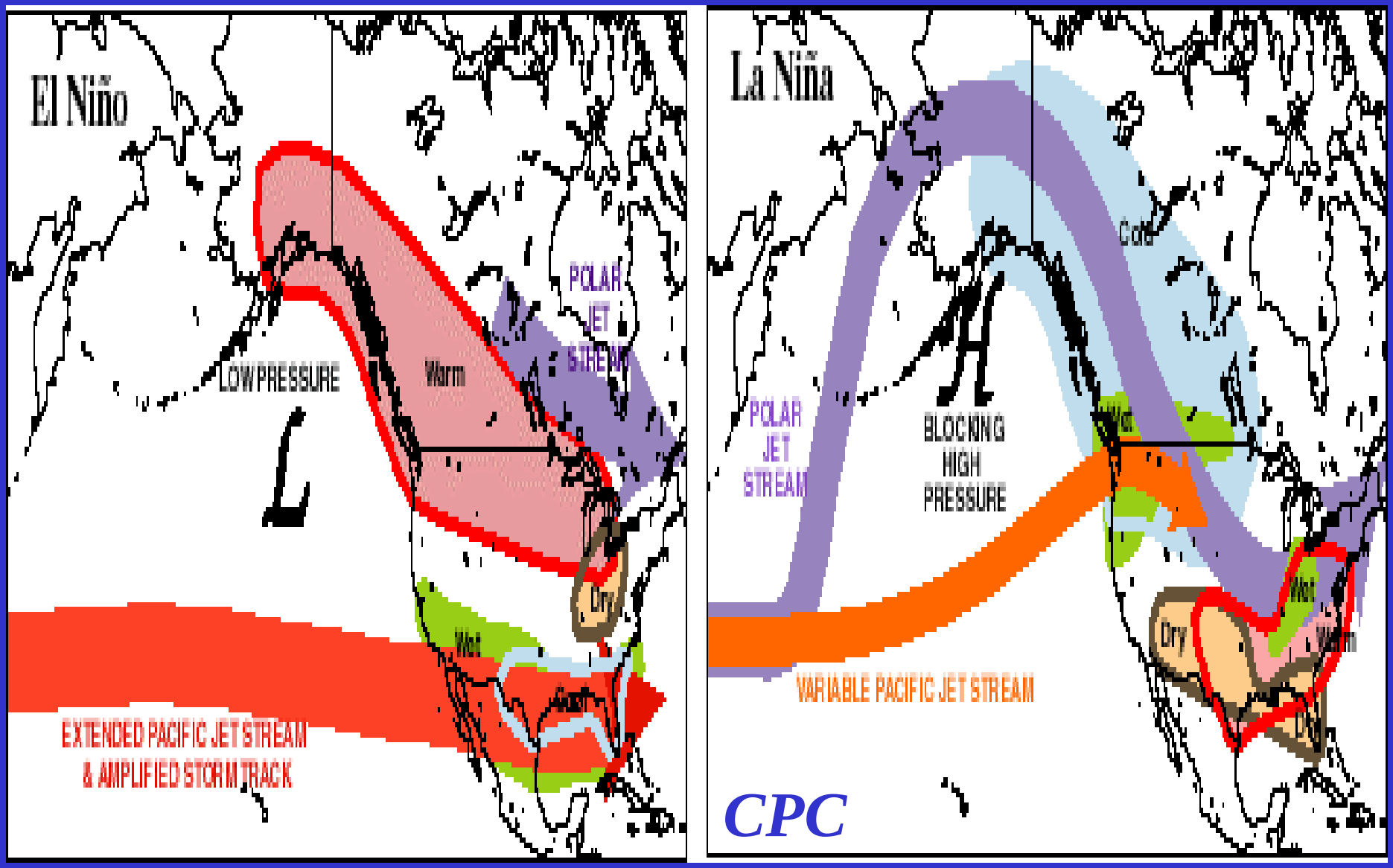


5-7 DAY FORECASTS

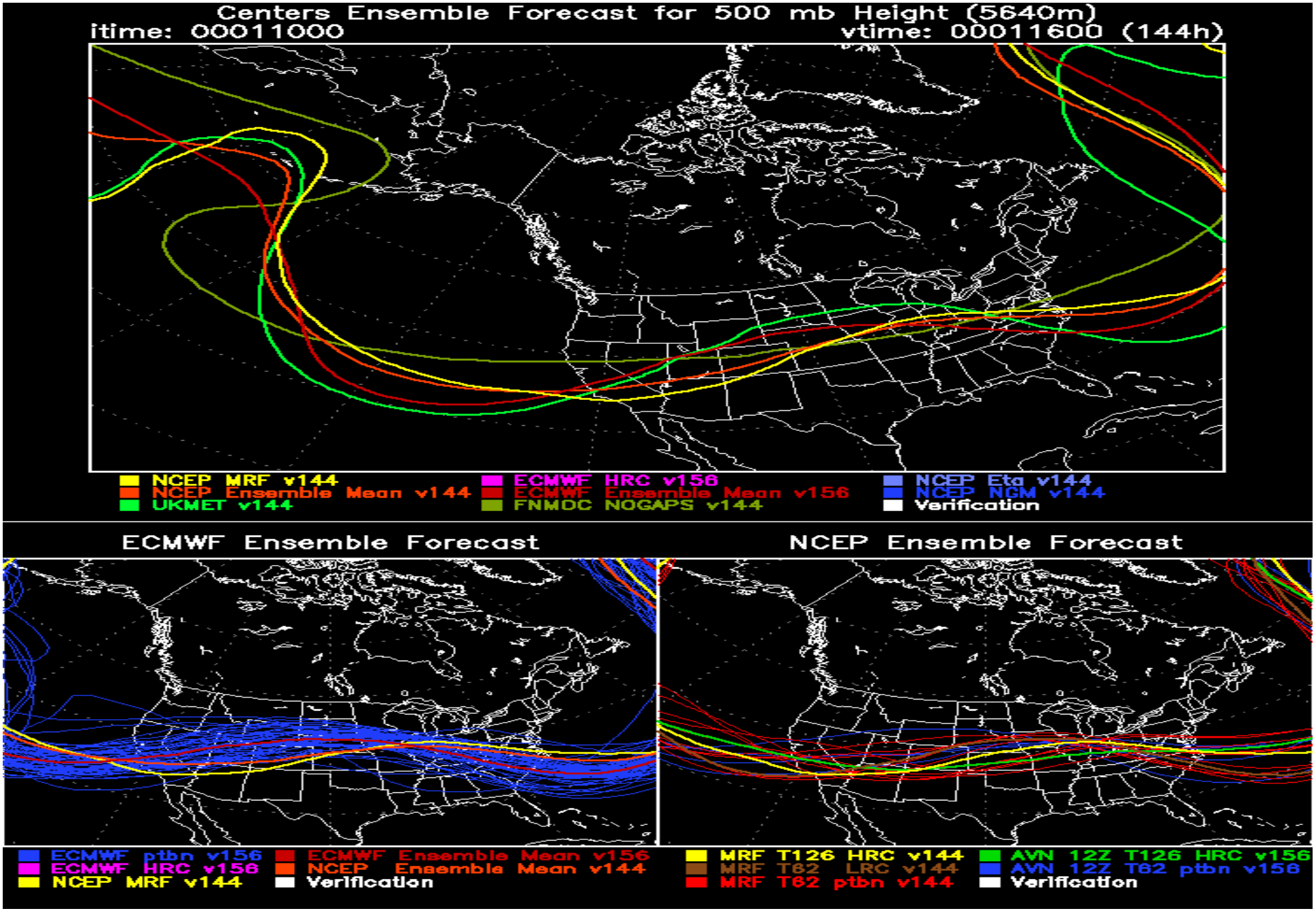


EXAMPLE OF MRF 5-DAY MEAN 500 MB HEIGHT FORECAST

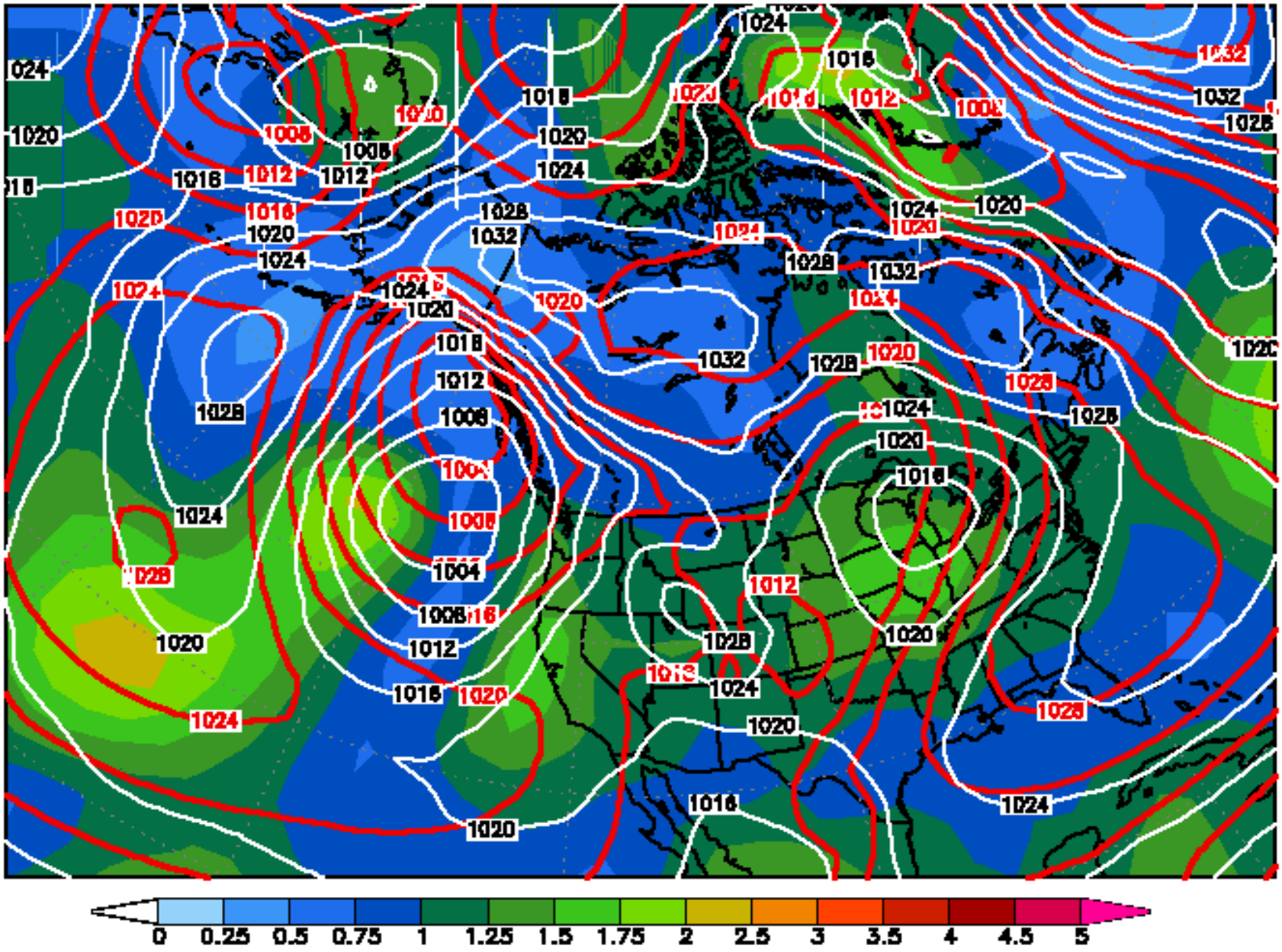
CONSIDER THE CLIMATIC PATTERN TO IDENTIFY PREFERRED STORM TRACKS



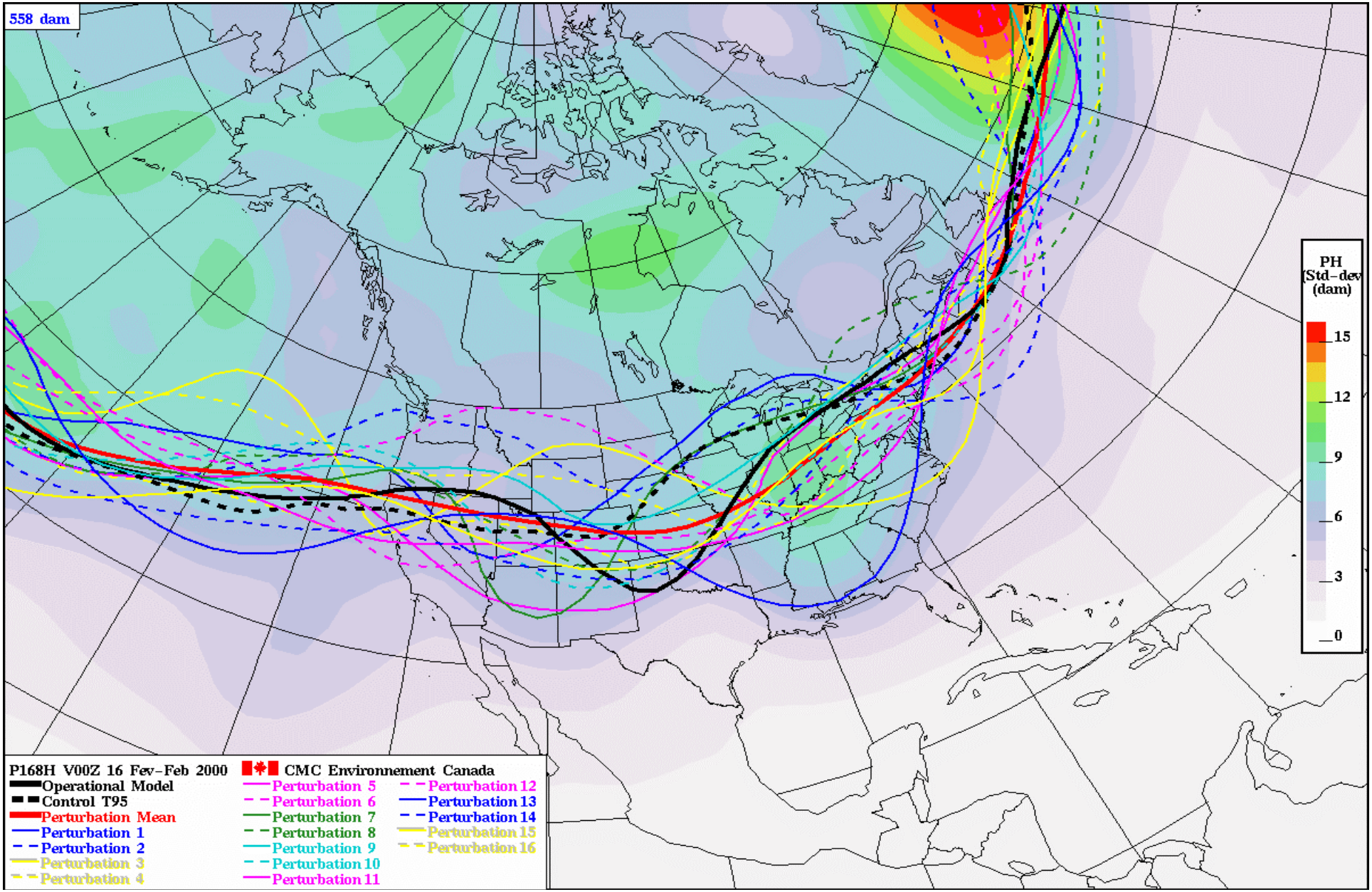
EXAMPLES OF ENSEMBLES



Ensemble Mean MSLP Forecasts: NCEP(white) ECMWF(red)
NCEP Ensemble Normalized MSLP Spread (shaded)
itime: 00011000 vtime: 00011700 (168h) *(EXAMPLE)*

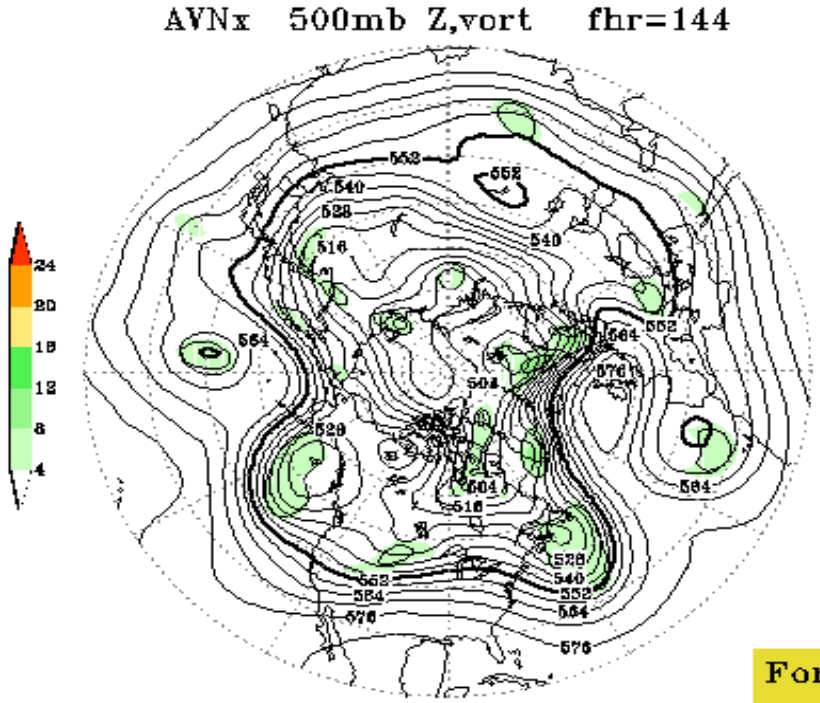


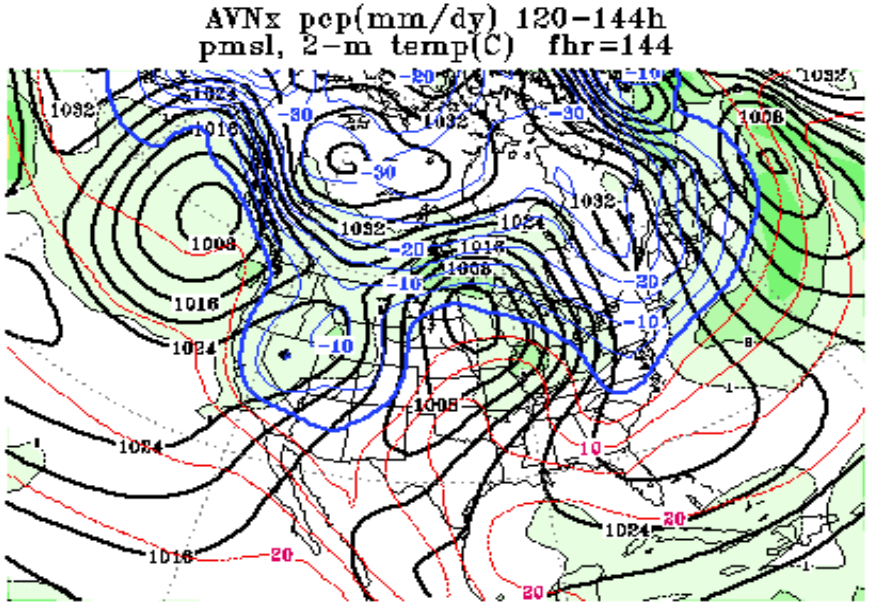
EXAMPLE OF CANADIAN ENSEMBLES



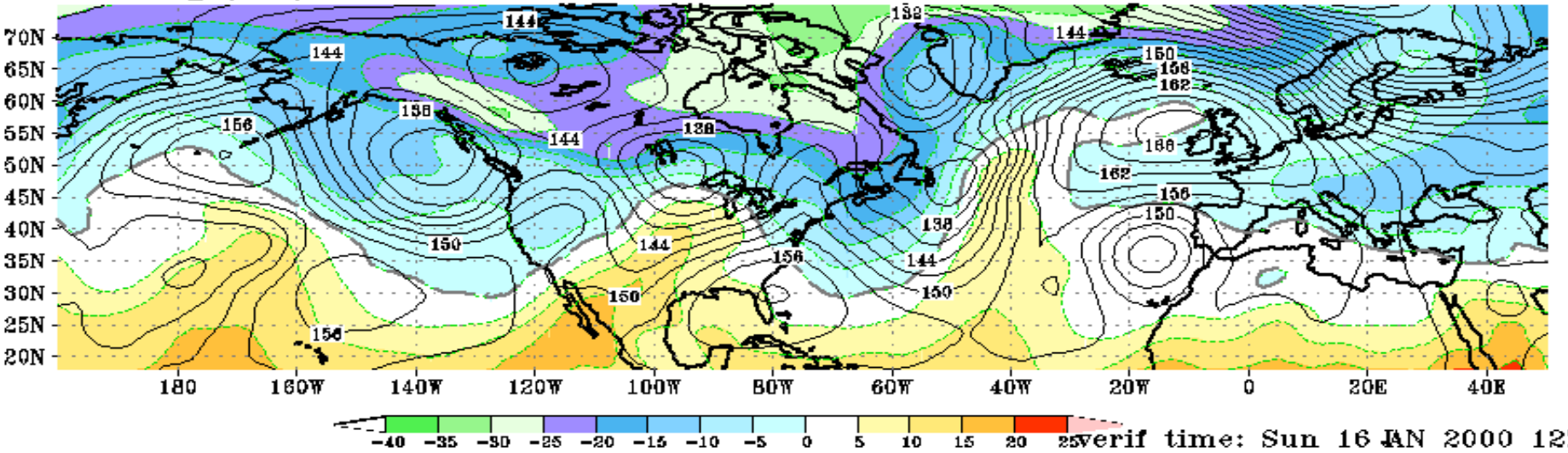
http://www.cmc.ec.gc.ca/rpn/ensemble_products/index.html

EXAMPLE OF THE 12 UTC AVN-EXT

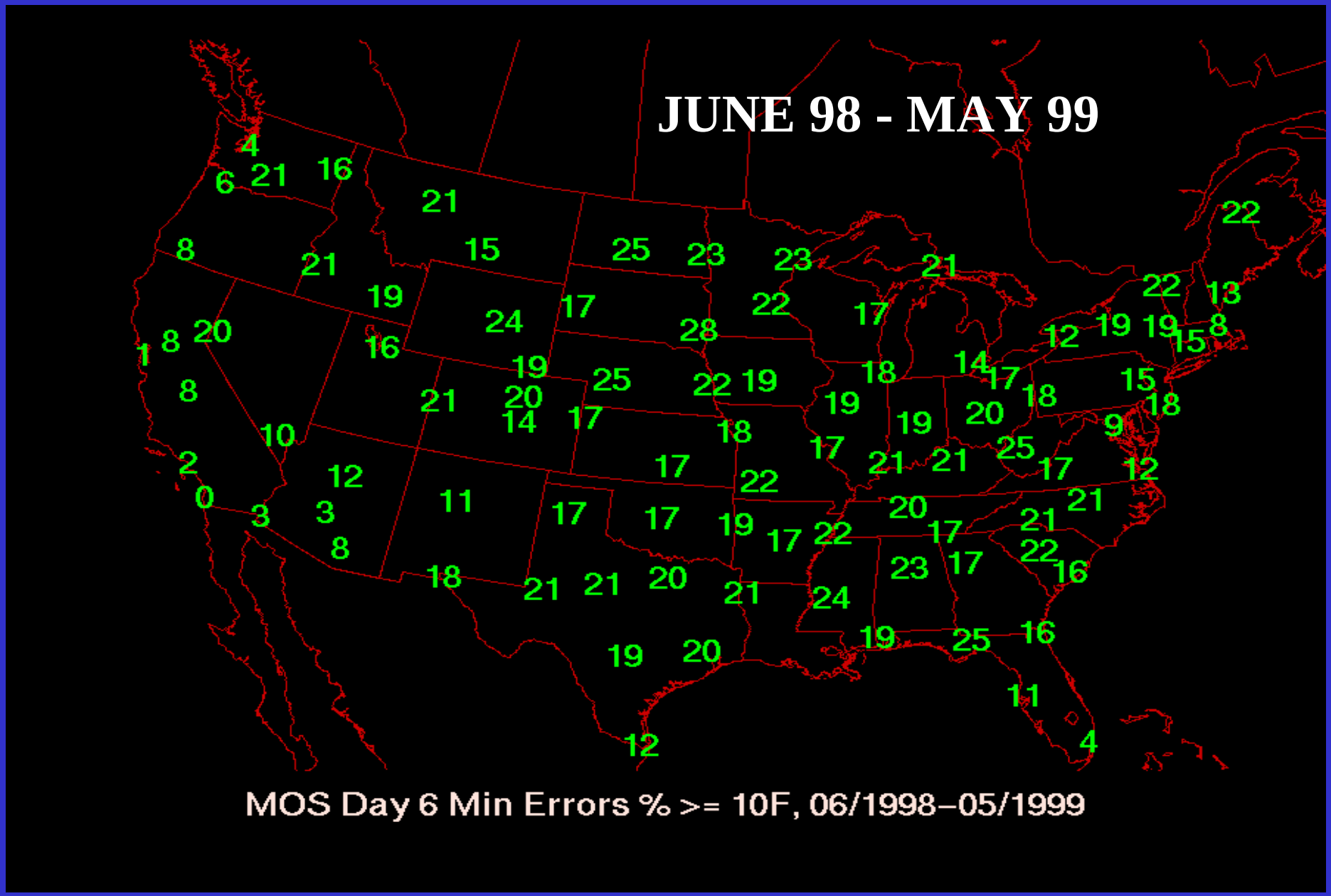




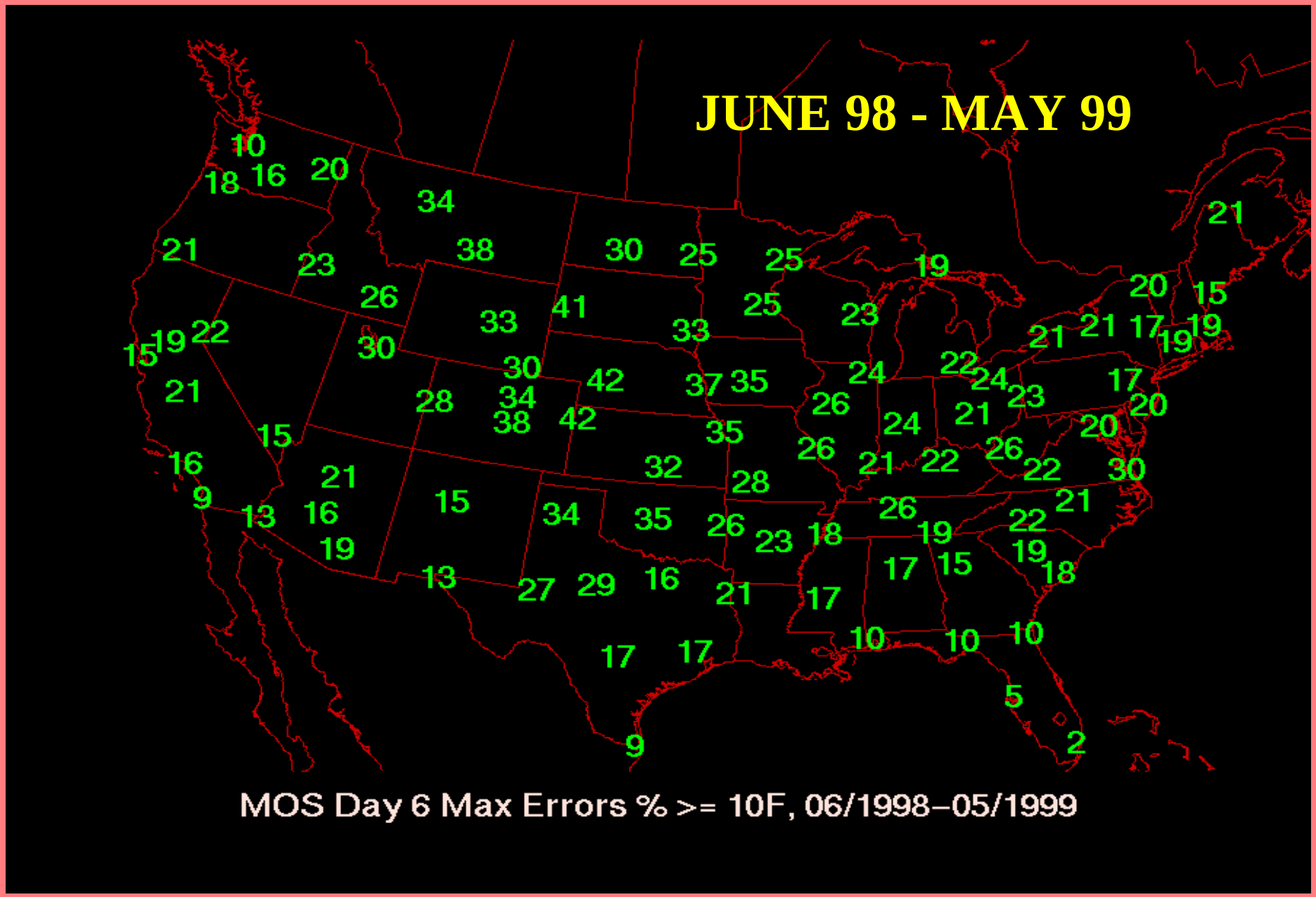
Forecasts from
12Z 10 JAN 2000



% OF MOS DAY 6 MIN TEMP ERRORS 10F+



% OF MOS DAY 6 MAX TEMP ERRORS 10F+



CONCLUSIONS

MEDIUM RANGE FORECASTING REQUIRES:

1- EXPERIENCE

2- BACKGROUND KNOWLEDGE

3- EASY/TIMELY ACCESS TO VARIED GUIDANCE AND OBSERVATIONAL DATA

4- PROPER FORECASTING METHODOLOGIES

5- AMPLE PREPARATION TIME

6- ABILITY TO TEST NEW FORECAST TOOLS

7- VERIFICATION MAKES YOU SMARTER

8- LUCK