NORTH AMERICAN ENSEMBLE FORECAST SYSTEM

JOINT CANADIAN-US
RESEARCH, DEVELOPMENT, AND IMPLEMENTATION PROJECT

Can provide example for THORPEX multi-center ensemble work

June 3 2004

NORTH AMERICAN ENSEMBLE FORECAST SYSTEM PROJECT

All NAEFS activities are important to NCEP

Genuine interest in sharing work and ideas
Very good collaboration on personal level
NAEFS activities integrated into/with our routine daily work =>
Recipe for success?

Plan for the morning:

1) General overview of NAEFS Plan *8:45-9:00*
2) Activities and plans related to Initial Operational Capability (IOC) *9-10*
    a) Data exchange
        Communication
        Variable list
    b) Products
    c) Status report
    BREAK *10:00-10:15*
3) Beyond IOC – OPEN ISSUES: *10:15-10:30*
    a) Next workshop to coordinate work on bias correction, products, verification
    b) Future of telecommunication
    c) Products – Intermediate vs. Final?
    b) Future ensemble configuration
4) Detailed discussions *10:30-11:15*
    Bias correction
    Products
    Verification
5) Possible areas of expansion – links with THORPEX *11:15-11:45*
6) IOC “ceremony”, wrap-up *11:45-12:00*

NORTH AMERICAN ENSEMBLE FORECAST SYSTEM PROJECT

GOALS: **Accelerate improvements in operational weather forecasting**
through Canadian-US collaboration
Seamless (across boundary and in time) suite of products
through joint Canadian-US operational ensemble forecast system

PARTICIPANTS: Meteorological Service of Canada (CMC, MRB)
US National Weather Service (NCEP)

PLANNED ACTIVITIES: Ensemble data exchange (June 2004)
Research and Development (2003-2007) -*Statistical post-processing*
-*Product development*
-*Verification/Evaluation*
Operational implementation (2004-2008)

POTENTIAL PROJECT EXPANSION / LINKS:
Shared interest with THORPEX goals of
Improvements in operational forecasts
International collaboration
Expand bilateral NAEFS in future
Entrain broader research community
Multi-center / multi-national ensemble system:
Currently available in house: NCEP, MSC, ECMWF, JMA
Aquire in future: FNMOC, UKMET?

NAEFS ORGANIZATION

Meteorological Service of Canada MSC	***National Weather Service, USA NWS***
PROJECT OVERSIGHT	
Michel Beland, Director, ACSD	Louis Uccellini (Director, NCEP/NWS)
Pierre Dubreil, Director, AEPD	Jack Hayes (Director, OST/NWS)
PROJECT CO-LEADERS	
J.-G. Desmarais (Implementation)	Zoltan Toth (Science)
Peter Houtekamer (Science)	D. Michaud/B. Gordon (Implementatn)
JOINT TEAM MEMBERS	
Meteorological Research Branch MRB	*Environmental Modeling Center EMC*
Gilbert Brunet Herschel Mitchell	Richard Wobus, Yuejian Zhu
Laurence Wilson	
	NCEP Central Operations NCO
Canadian Meteorological Center CMC	TBD
Richard Hogue Louis Lefaivre	*Hydrometeor. Prediction Center HPC*
Richard Verret	Peter Manousos
	Climate Prediction Center CPC
	Ed O'Lenic, Mike Halpert, David Unger

NAEFS OVERVIEW

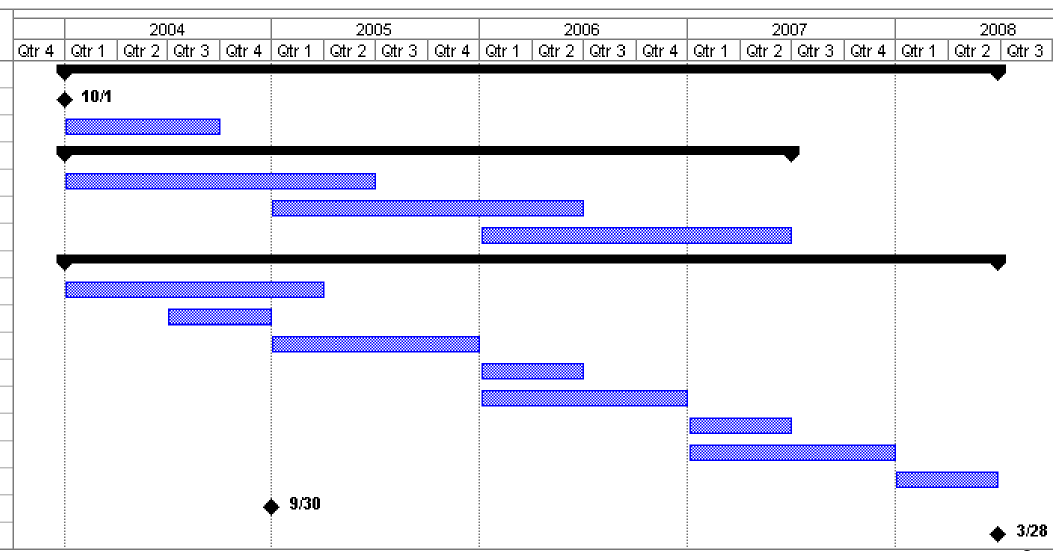
Feb 2003	MSC – NOAA / NWS high level agreement (Long Beach)
May 2003	Planning workshop (Montreal)
Oct 2003	Research, Development, and Implementation Plan complete
Sept 2004	Initial Operational Capability
Fall 2004	2nd Workshop (NCEP)?
July 04 – March 08	3 overlapping18-month R/D & implementation cycles with Jan 06, Mar 07, Mar 08 implementation dates *Successively enhanced bias correction, products, verification*
March 2008	Last operational implementation

NAEFS
RESEARCH, DEVELOPMENT, & IMPLEMENTATION PLAN

STEP-WISE APPROACH

0) Initial Oper. Capability – Existing products based on other ensemble
1) First Implementation – Basic joint forecast system (not comprehens.)
2) Second Implementation - Refinement (Full system)
3) Final Implementation - High impact weather enhancements

ID	Task Name
1	**Development and Implementation of the North American Ensemble Forecast System**
2	Establish Agreement with Canada
3	Coordinate & Implement Exchange of Ensemble Forecast Data
4	**Scientific Research and Development**
5	Joint Verification Development
6	Bias Correction
7	Downscaling
8	**Product Development**
9	Establish List
10	Implement Baseline Product Suite
11	Develop Joint Ensemble Product Suite
12	Implement Joint Ensemble Product Suite
13	Develop 2nd Joint Ensemble Product Suite
14	Implement 2nd Joint Ensemble Product Suite
15	High Impact WX Product Suite
16	Implement High Impact WX Product Suite
17	Initial Operational Capability
18	Final Operational Capability



NAEFS
RESEARCH, DEVELOPMENT, & IMPLEMENTATION PLAN

MAJOR TASKS

- Exchange ensemble data between 2 centers
- Statistically bias-correct each set of ensemble
- Develop products based on joint ensemble
- Verify joint product suite, Evaluate added value

COORDINATED EFFORT

Between Research / development and operational implementation

Between MSC and NWS

Area of strong common interest between 2 centers, on all levels

Broaden research scope - Enhanced quality

Share developmental tasks - Increased efficiency

Seamless operational suite- Enhanced product utility

ROBUST OPERATIONAL SETUP

Two mirror sites, running same routines provide backup coverage

Single ensemble used in case of communication or computer failures

NAEFS MAJOR TASKS

DATA EXCHANGE

- Identify common set of variables/levels for exchange ~50 fields
- For NCEP data, use GRIB1 with NCEP ensemble PDS extension
- Use native resolution for transfer, convert to common 1x1 (2.5x2.5) grid
- Every 12 hrs, out to 16 days (MSC out to 10 days until later in 2004)

  Subset already available on a non-operational basis

NAEFS MAJOR TASKS – BIAS CORRECTION

ISSUES

Exchange raw or bias-corrected forecasts?

To ensure 100% backup capabilities =>

Exchange raw data, use same bias-correction at both centers

Bias-correct before or after merging different ensembles?

Sub-components have different biases etc => Calibrate before merging

Correct univar. prob. distribution functions (pdf) or individual members?

Users need both – eg, joint probability products (prob hi winds and lo temp)

Correct individual members => pdf falls out free

Correct for expected value enough?

No, need to correct for bias in spread => multi-step approach:

a) Shift all members

b) Adjust spread around mean

c) Reduce temporal variations in spread (if too confident, *Unger*)

How much training data (forecast – verifying analysis pairs) enough?

Open research question =>

Need flexible algorithm that can be used either with

Small amount of data – Smooth adjustments to eliminate gross error

Large amount of data – Finer adjustments possible

NAEFS MAJOR TASKS – PRODUCT DEVELOPMENT

TYPES OF PRODUCTS

A) **Joint ensemble** (bias-corrected ensembles merged on model grid)

B) **Anomaly joint ensemble**

Express forecast anomalies from reanalysis climatology –
(model grid, easy to ship)

C) **Local joint ensemble forecast** (local, bias-corrected, downscaled)

Add forecast anomaly to observed climatology at
- Observational locations or
- NDFD high resolution (2.5x2.5 km) grid

D) **Host of products** based on any of 3 choices above

Gridded, graphical, worded, week 2, etc for
- Intermediate users (forecasters at NCEP, etc)
- End users (automated products at MSC)
  - Specialized users
  - General public

E) **High impact weather products**

Assess if general procedures above are adequate or can be enhanced for forecasting rare/extreme events

NAEFS MAJOR TASKS – VERIFICATION

ISSUES

1) Data sets/archiving – Center specific

2) Software to compute common set of statistics – Shared by 2 centers
   Modular subroutines - common
   - Input
   - Output
   - Options/parameters

3) Verifying against both analysis fields and observations

4) Forecast events based on climate or ensemble distribution, or user input

5) Benchmarks: climatological, persistence, or alternative forecast systems

6) Special product / high impact weather forecast evaluation

NAEFS - BENEFITS

Two independently developed systems combined, using different:

- Analysis techniques
- Initial perturbations
- Models

Joint ensemble may capture new aspects of forecast uncertainty

Procedures / software can be readily applied on other ensembles:

- Possible Multinational expansion linked with THORPEX
  - ECMWF
  - JMA
  - FNMOC
  - UKMET, etc

Basis for future multi-center ensemble

Collaborative effort

Broaden research scope -	Enhanced quality
Share developmental tasks -	Increased efficiency
Seamless operational suite -	Enhanced product utility

Framework for future technology infusion (MDL, NOAA Labs, Univs.)

IOC

NAEFS ISSUES – IOC IMPLEMENTATION

IOC Requirements (by Sept. 2004):

1) Operationally exchange selected ensemble forecast data between two centers
2) Generate separate sets of products based on two ensembles at both centers

Issues at NCEP:

a) Coordination of variable list with MSC – ***completed***

53 number of fields selected:

Temp, Winds (2), Humidity, Geop. Height at 8 levels

(2/10m except for Z, 1000, 925, 850, 700, 500, 250, 200 hPa)

SP, MSLP, Top., Precip amount, Pr. types (4), Total cloud cover, PW, Cape, Tmin/Tmax

Number of variables	*Current*	*IOC*	*"Final"*
NCEP –	*26*	*52*	*53*
MSC -	*17*	*45*	*53*

Wave products – MSC - 2005? NCEP – Research phase

Precip type, Tmin,max, CAPE - MSC 2005? UNIFY ALGORITHMS

b) Provide required NCEP ensemble data on NWS ftp server – ***by June 22***

NCEP provides "enspost" type file format (MSC to convert to pgrib at their end)

MSC provides pgrib type file format (NCEP to convert to enspost at their end)

Future – switch to GRIB2 in 1-2 year timeframe

c) Pre-process MSC ensemble data after it is received – ***by June 22***

Convert pgrib into enspost file format

d) Generate basic products:

mean, spread – ***by June 22***

PQPF for MSC ensemble – ***under testing***

Communication issues in Ensemble Data Exchange

Brent Gordon

NCEP Central Operations

NAEFS IOC Presentation

June 3rd 2004

NAEFS Data Exchange

- CMC to NCEP
  - Using Internet to access data from CMC
  - 16 members – 1 cycle per day
  - ~ 1 Gb of data per cycle
- NCEP to CMC
  - NCEP delivering data to NWS FTP server
  - Full data set available 22 June 2004
  - 11 members – 2 cycles per day
  - ~ 2 Gb of data per cycle

Data Exchange Challenges

- NCEP use of internet to acquire CMC ensembles not optimal
- Operational reliability issues need to be addressed
  - Are occasional internet outages acceptable?
- Future data exchange will most certainly require additional bandwidth
- Funding for NWS/CMC operational network upgrade may be required
  - Currently only T-1 access

Data Exchange Specifications

Richard Wobus

Environmental Modeling Center / SAIC

NAEFS IOC Presentation

June 3rd 2004

IOC LIST OF EXCHANGED VARIABLES

COORDINATION OF VARIABLE LIST WITH MSC – ***completed***

53 number of fields selected:

Temp, Winds (2), Humidity, Geop. Height at 8 levels

(2/10m except for Z, 1000, 925, 850, 700, 500, 250, 200 hPa)

SP, MSLP, Top., Precip amount, Pr. types (4), Total cloud cover, PW, Cape, Tmin/Tmax

Number of variables	***Current***	***IOC***	*"Final"*
NCEP –	***26***	***52***	*53*
MSC -	***17***	***45***	*53*

MISSING VARIABLES:

Wave products – MSC - 2005? NCEP – Research phase

Precip type, Tmin,max, CAPE - MSC 2005?

UNIFY ALGORITHMS FOR PRECIP TYPE, CAPE

LIST OF VARIABLES FOR ENSEMBLE EXCHANGE BETWEEN CMC - NCEP

Height
Temperature
Humidity
Wind
Other

Summary "Appendix 5"

Enspost and Ensstat data exchange - height

Variable	Present from NCEP	June 2004 from NCEP	June 2004 from CMC	Future from NCEP and CMC
z200		X	X	X
z250	X	X	X	X
z500	X	X	X	X
z700	X	X	X	X
z850		X	X	X
z925	X	X	X	X
z1000	X	X	X	X
zsfc		X	X	X

Enspost and Ensstat data exchange - Temperature

Variable	Present from NCEP	June 2004 from NCEP	June 2004 from CMC	Future from NCEP and CMC
t200		X	X	X
t250	X	X	X	X
t500	X	X	X	X
t700	X	X	X	X
t850	X	X	X	X
t925		X	X	X
t1000	X	X	X	X
t2m	X	X	X	X
tmin 2m	X	X	X	X
tmax 2m	X	X	X	X

Enspost and Ensstat data exchange – humidity

Variable	Present from NCEP	June 2004 from NCEP	June 2004 from CMC	Future from NCEP and CMC
rh200		X	X	X
rh250		X	X	X
rh500		X	X	X
rh700	X	X	X	X
rh850		X	X	X
rh925		X	X	X
rh1000		X	X	X
rh2m		X	X	X

Enspost and Ensstat data exchange - winds

Variable	Present from NCEP	June 2004 from NCEP	June 2004 from CMC	Future from NCEP and CMC
u,v 200		X	X	X
u,v 250	X	X	X	X
u,v 500	X	X	X	X
u,v 700		X	X	X
u,v 850	X	X	X	X
u,v 925		X	X	X
u,v 1000		X	X	X
u,v 2m	X	X	X	X

Enspost and Ensstat data exchange – other variables

Variable	Present from NCEP	June 2004 from NCEP	June 2004 from CMC	Future from NCEP and CMC
pmsl	X	X	X	X
psfc		X	X	X
prcp	X	X	X	X
prcp type	X	X		X
pwat		X	X	X
cape		X		X
tot cld cov		X	X	X
wave ht				X

LIST OF VARIABLES IDENTIFIED FOR ENSEMBLE EXCHANGE BETWEEN CMC - NCEP

Parameter	CMC	NCEP
Ensemble	8 SEF, 8 GEM	
GRID	2.5x2.5 deg, (144x73 lat-lon) [1.2 X 1.2 (300X151 lat-lon)]	1x1 deg (360x180 lat-lon) for day 1-7 2.5x2.5 deg (144x73 lat-lon) day 8-15
DOMAIN	Global	Global
FORMAT	WMO Grib Format	WMO Grib Format
HOURS	0, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, 168, 180, 192, 204, 216, 228, 240	0, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, 168, 180, 192, 204, 216, 228, 240, 252, … 384
GZ	**[200]*, 250, 500, 700, 850,[925,1000]**	**[200], 250, 500, 700, 850 ,[925], 1000**
TT	**[200]*, 250, 500,700, 850 ,[925,1000]**	**[200], 250, 500, 700, 850 ,[925], 1000**
U,V	**[200]*, 250, 500,700, 850 ,[925,1000]**	**[200], 250, 500, 700, 850 ,[925], 1000**
TT	**12000 Now redefined in grib file to be 2m AGL**	**2m**
U,V	**Now redefined in grib file to be 10m AGL**	**10m**
ES	**12000 Now redefined in grib file to be 2m AGL**	**RH at 2m**
MSLP	**(PN) level 0, i.e. at surface**	***PRMSL, i.e. at surface***
PR	**level 0, i.e. at surface**	**level 0, i.e. at surface**
NT	**level 0**	**Total Cloud Cover**
IH	**level 0**	**Total Precipitable Water**
Sfc Pres	**(SEF) (P0) level 0 at surface**	**Sfc Pressure**
Model Topography	**Model* Topography**	**Model Topography**
CAPE	**1st quarter 2004**	**Sometime in 2004**
Precip type	**1st quarter 2004**	**Precip type**
T_{max}	**1st quarter 2004**	**2m**
T_{min}	**1st quarter 2004**	**2m**
WAM	**Sometime in 2004**	**may not be available for a while**

Black : data presently exchanged
Blue : items have been added in prototype script for expanded CMC dataset.
Red : items can be easily added to the expanded dataset via an autoreq for CMC; next implementation period for NCEP
* these will be added within 1 month for CMC
** these will be added within 2 months for CMC
Green: items that require further consideration and resources

List of variables identified for ensemble exchange between CMC - NCEP

Parameter	CMC	NCEP
Ensemble	8 SEF, 8 GEM	10 paired
Grid	2.5x2.5 deg (144x73) & 1.2x1.2 deg (300x151)	2.5x2.5 deg (144x73) & 1.0x1.0 deg (360x181)
Domain	Global	Global
Format	WMO GRIB Format	WMO GRIB Format
Hours	0, 12, 24, 36, 48, . . . ,216, 228, 240	0, 6, 12, 18, 24, ……., 360, 366, 372, 378, 384
GZ	200, 250, 500, 700, 850, 925, 1000	200, 250, 500, 700, 850, 925, 1000
TT	200, 250, 500, 700, 850, 925, 1000	200, 250, 500, 700, 850, 925, 1000
E	Tdd at 200, 250, 500, 700, 850, 925, 1000	RH at 200, 250, 500, 700, 850, 925, 1000
U, V	200, 250, 500, 700, 850, 925, 1000	200, 250, 500, 700, 850, 925, 1000
TT Sfc	12000, redefinied in GRIB file as 2m AGL	2m
U, V Sfc	Redefined in GRIB file as 10m AGL	10m
ES	Tdd at 12000, redefined in GRIB file as 2m AGL	RH at 2M
MSLP	(PN) level 0	PRMSL
PR (total precip)	Level 0 , I.e. at surface	Level 0, I.e.at surface
NT (total cloud cover)	Level 0	Column
IH (total precipitable cover)	Level 0	Column
Sfc Pres	(SEF) (P0) level 0 at surface	Sfc Pressure
Model Topography	Model Topography	Model Topography at t=0
CAPE	Later 2004	Most unstable layer
Precip Type	Later 2004	4 bitmap variables for 4 types
Tmax	Later 2004	2m
Tmin	Later 2004	2m
WAM	Later	Later

Black: data presently exchanged
Blue: data to be exchanged & processed by NCEP June 2004

Red: data to be added by CMC later in 2004
Green: data to be exchanged later

Derived Products

Yuejian Zhu
Environmental Modeling Center

NAEFS IOC Presentation
June 3rd 2004

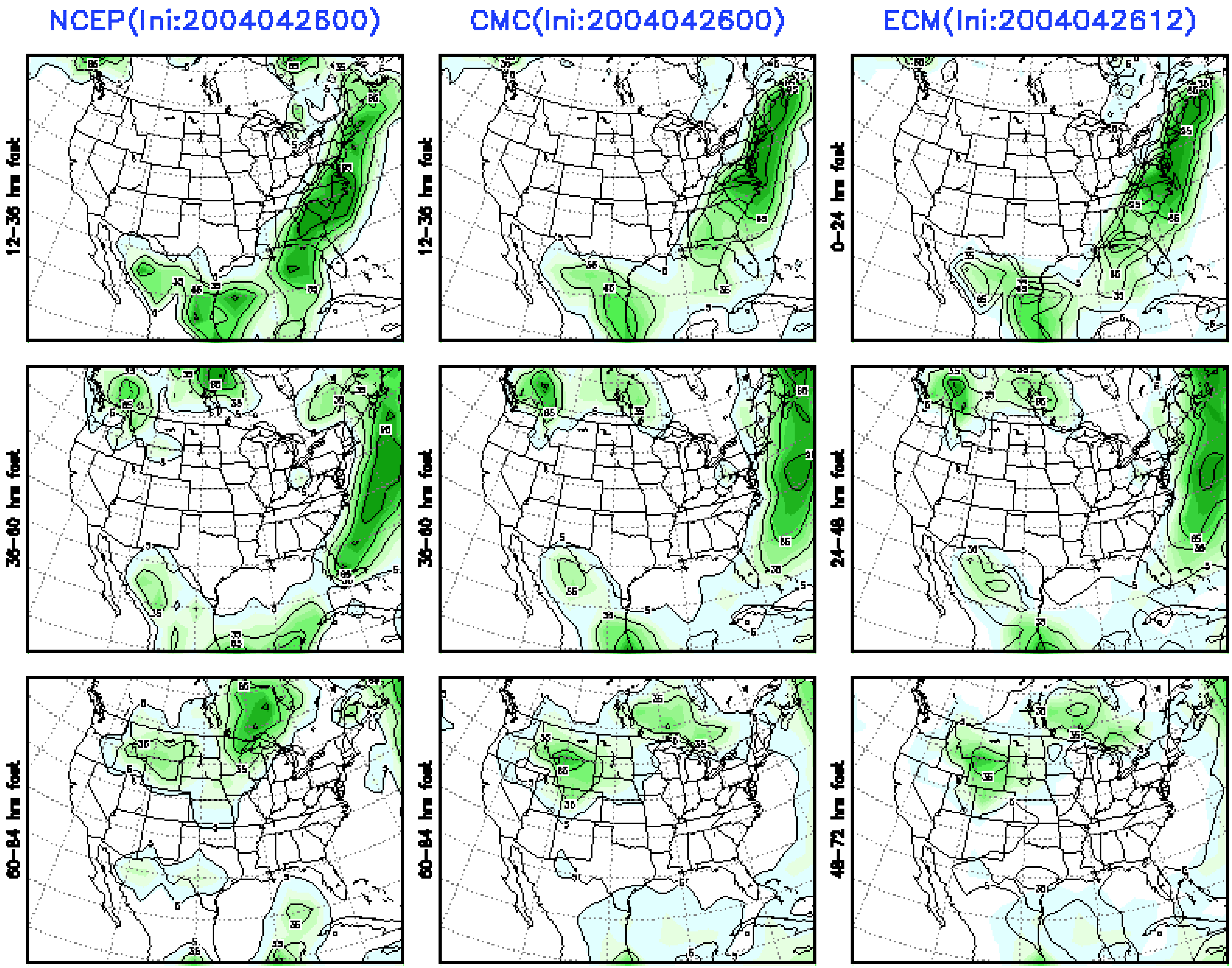
Derived Products - grids

- Ensemble Mean and Spread (**NAEFS-IOC**)
- Probabilistic Forecasts
  - Probabilistic Quantitative Precipitation Forecast (PQPF) (**NAEFS-IOC**)
  - Precipitation type forecast (PQRF,PQSF,PQFF & PQIF) (**NCEP-OPR**, future NAEFS)
- Calibrated PQPF (NCEP-OPR, future NAEFS)
- Relative Measure of Predictability (**EMC-EXP**)
- Verifications (deterministic and probabilistic)
  - Against global analysis (**EMC-EXP**)
  - Against observation (Work started)
- Special products generated locally by NCEP Service Centers (to be discussed later)

Derived Products
- Graphics (NCEP-para)

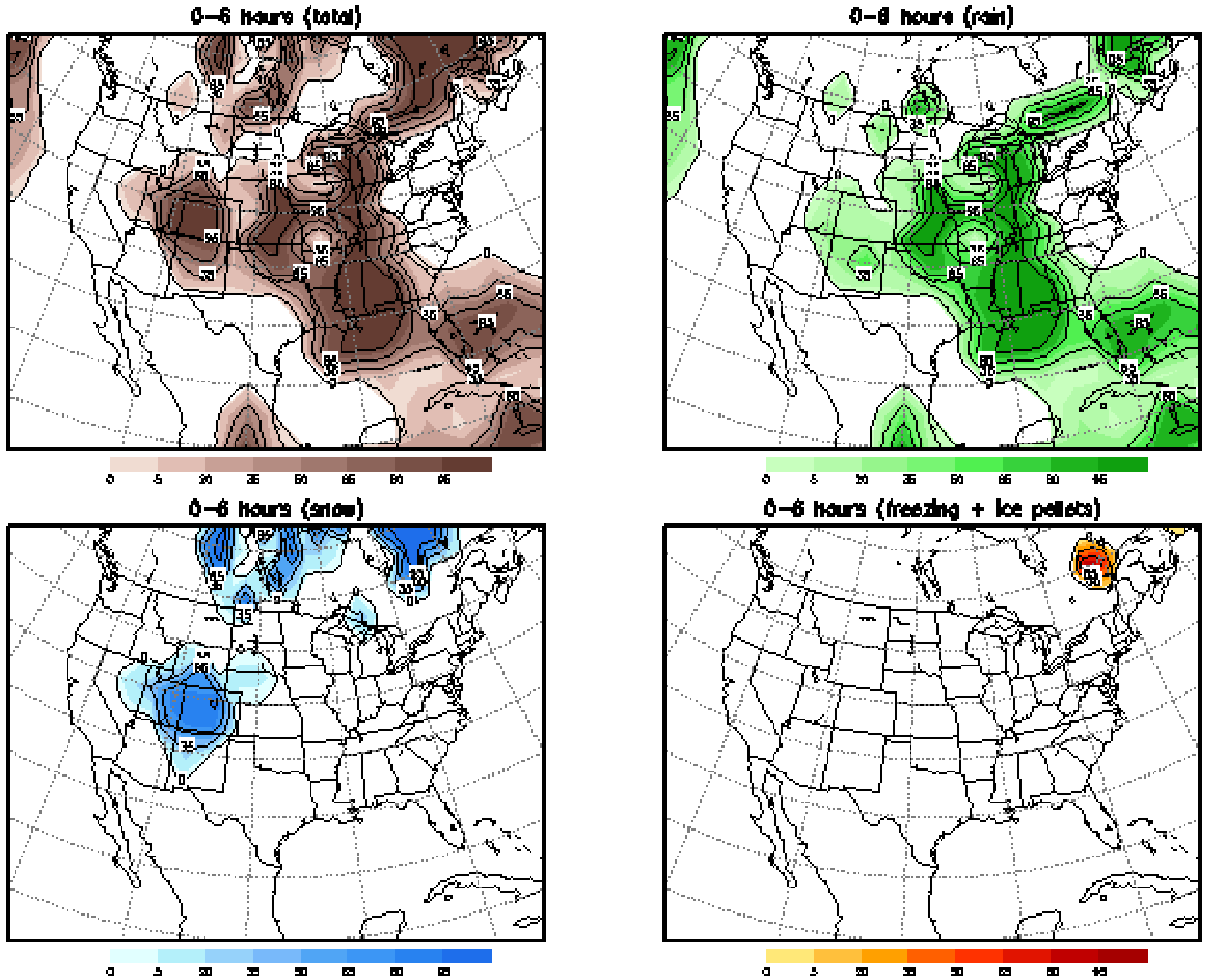
- Ensemble Mean and Spread (Tim Marchok)
- Probabilistic Forecasts
  - Probabilistic Quantitative Precipitation Forecast (PQPF)
  - Precipitation type (PQPF, PQRF,PQSF & PQF+IF)
- Calibrated QPF and PQPF
- Relative Measure of Predictability (RMOP)
- Spaghetti diagrams (Bill Bua)
- Cyclone tracks (Tim Marchok)
- Verifications (against analysis and observation)

PQPF example for NCEP, CMC and ECMWF

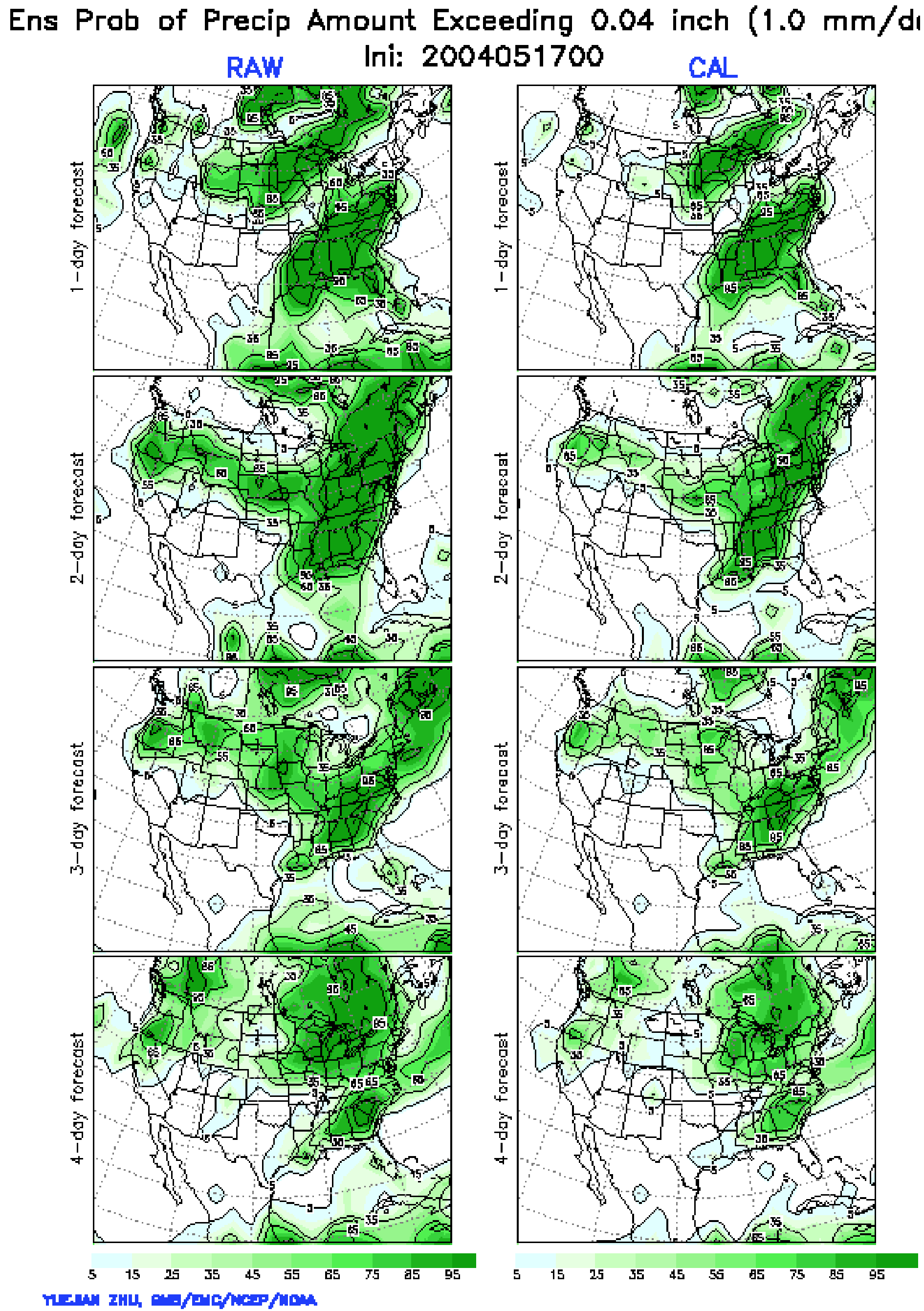


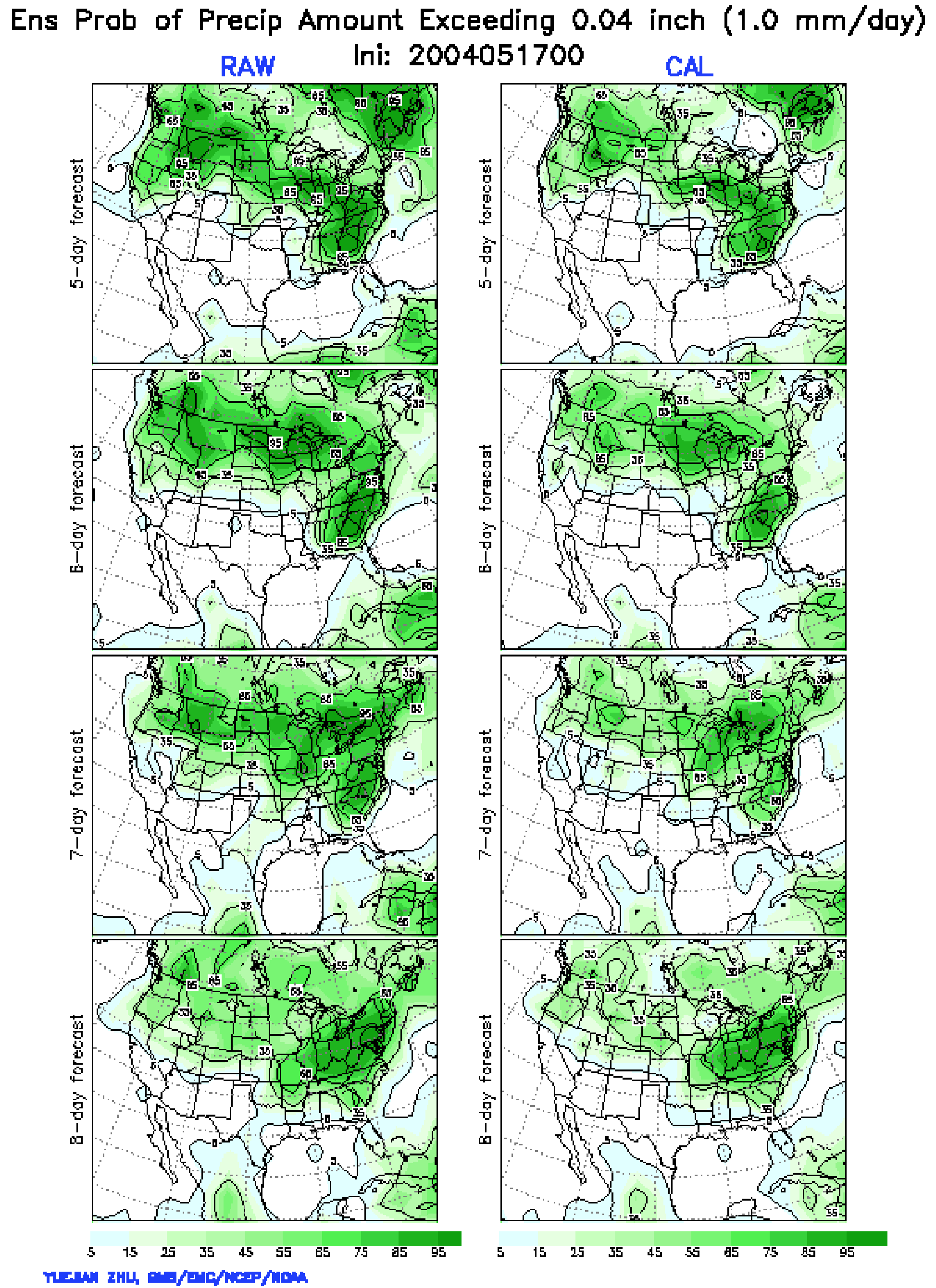
NCEP PQPTF example

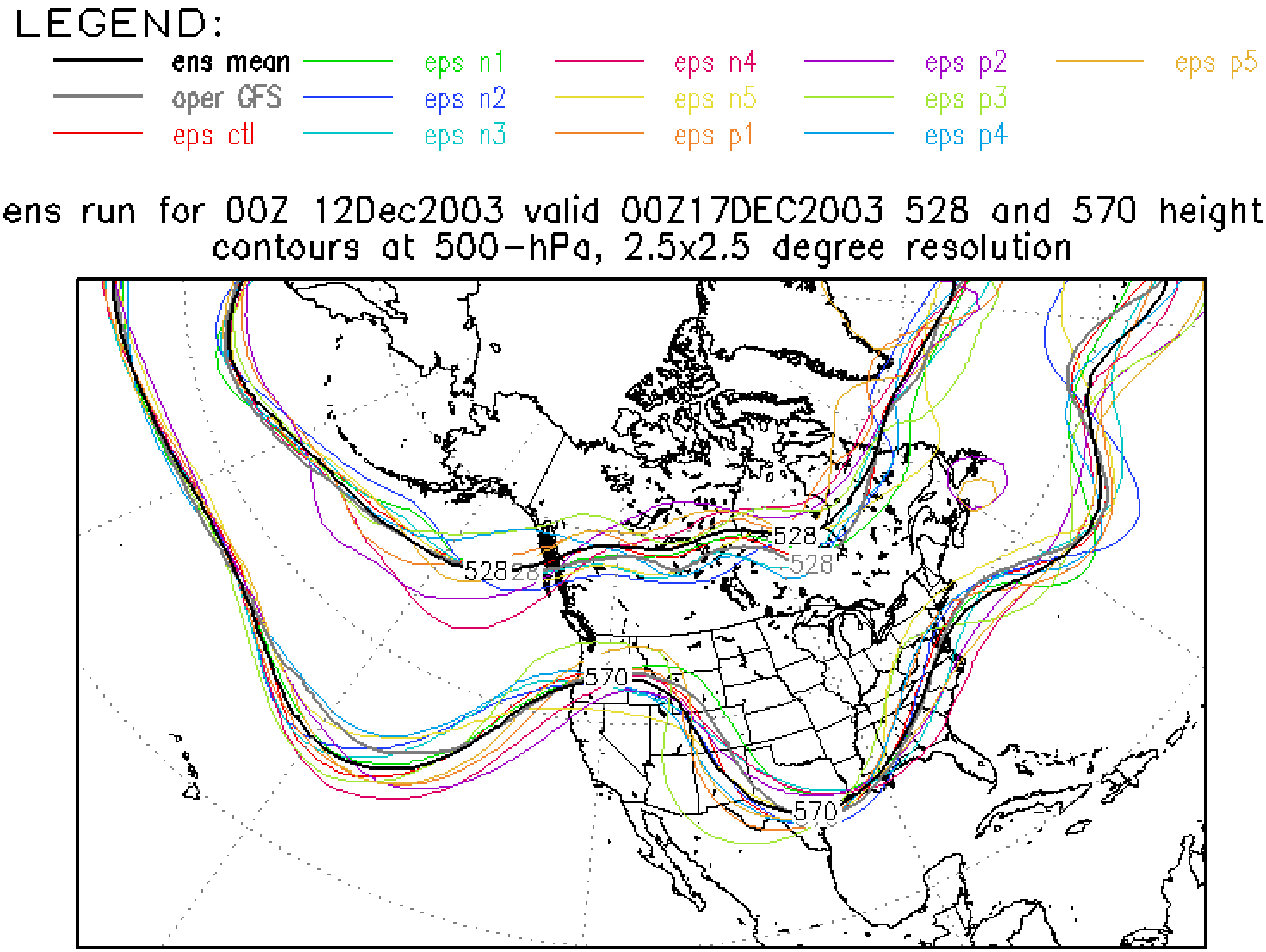
Ensemble Based Probabilistic Quantitative Precipitation Type Forecast
Ini:2004043000 Valid:2004043000-2004043006 Amount>=0.254mm/6hrs



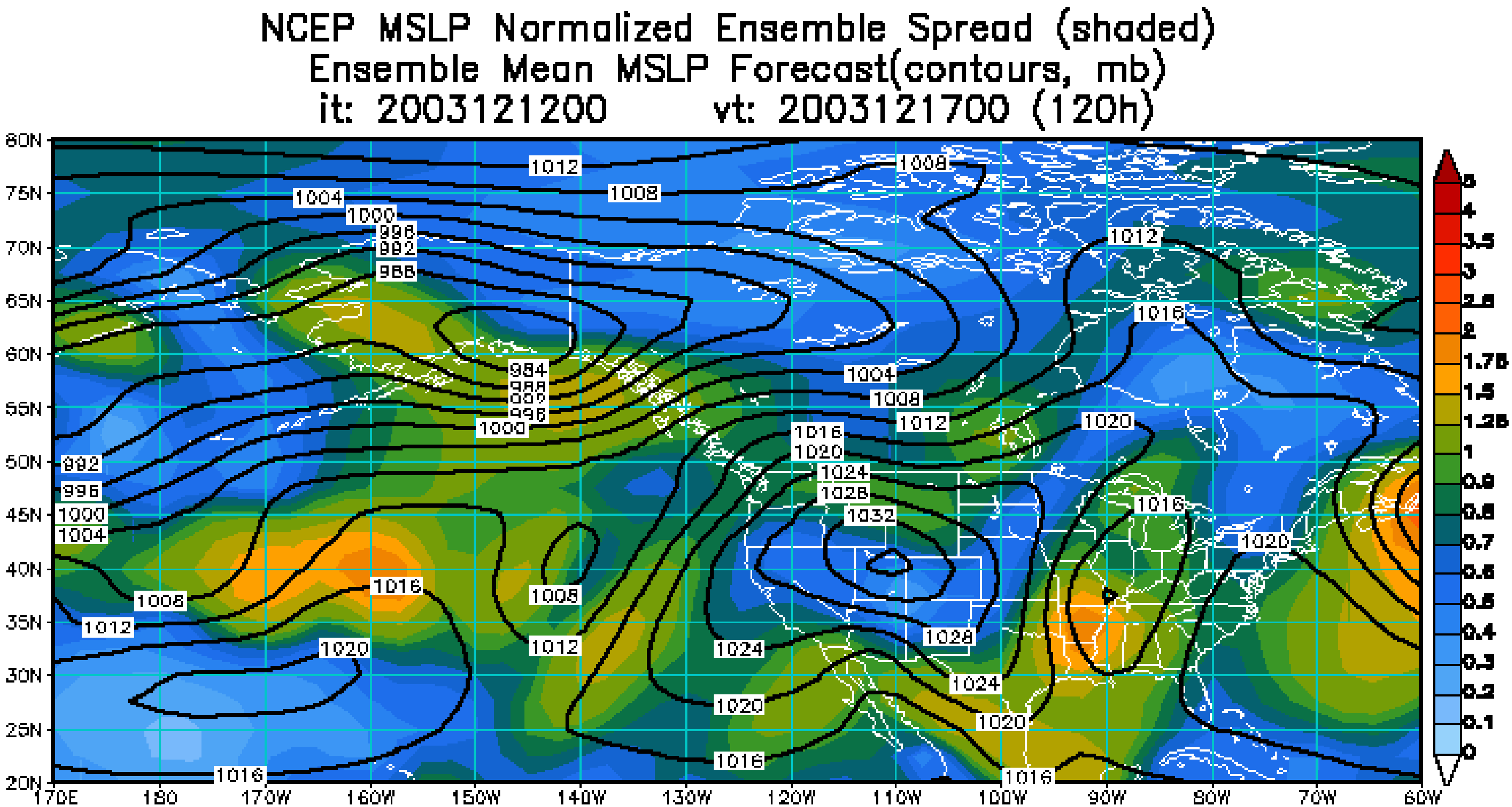
NCEP Calibrated PQPF example






LEGEND:
ens mean
oper GFS
eps ctl
eps n1
eps n2
eps n3
eps n4
eps n5
eps p1
eps p2
eps p3
eps p4
eps p5
ens run for 00Z 12Dec2003 valid 00Z17DEC2003 528 and 570 height
contours at 500-hPa, 2.5x2.5 degree resolution
528
528
570
570

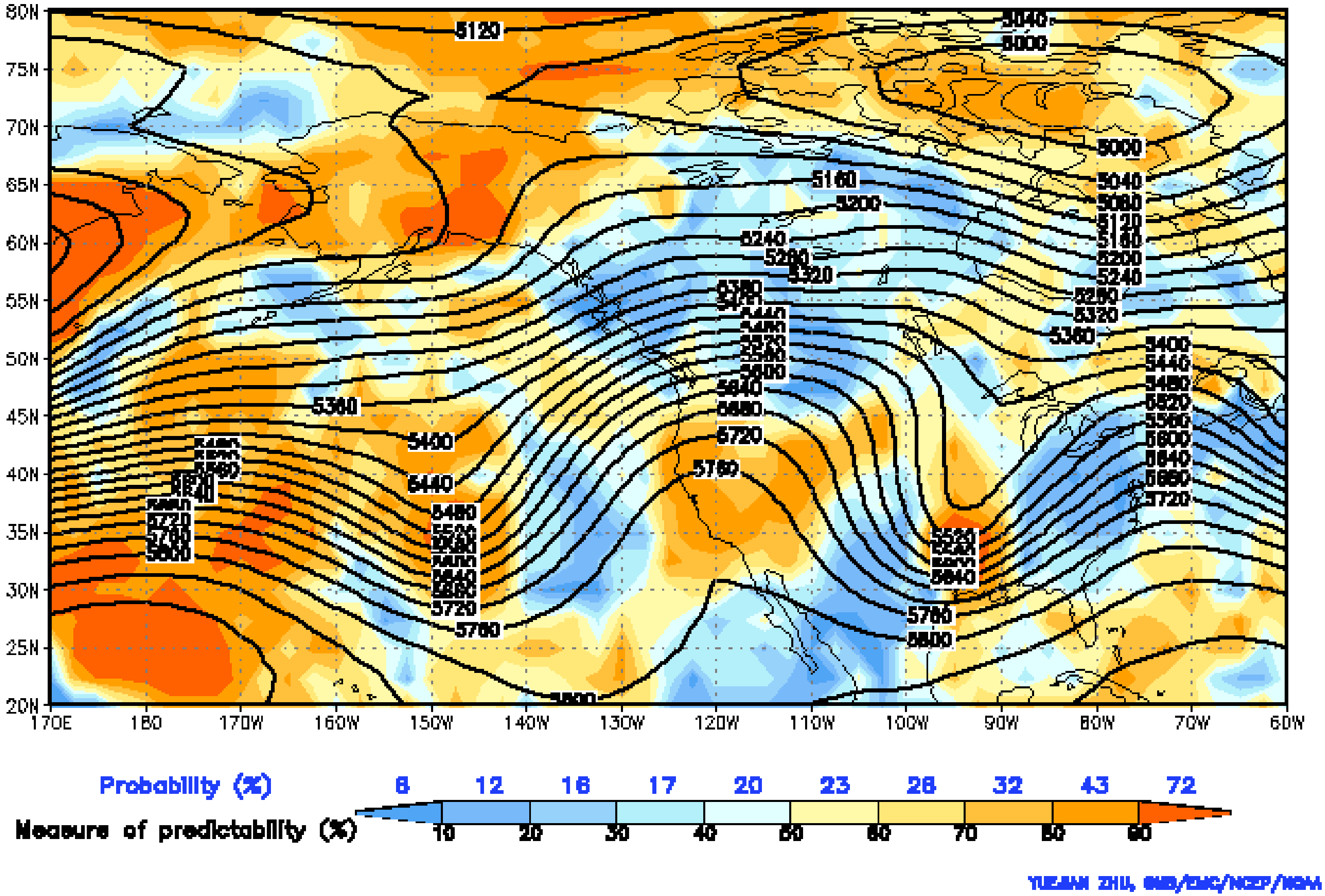
By Bill Bua

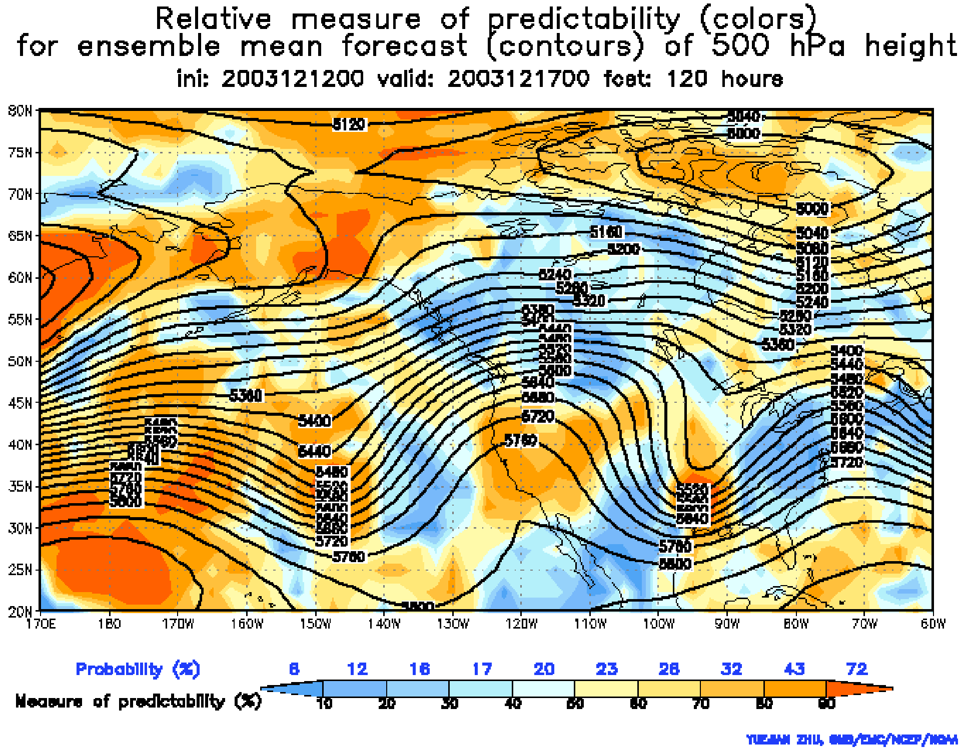


By Tim Marchok

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

ini: 2003121200 valid: 2003121700 fcst: 120 hours





1. By using equal climatological bins (e.g. 10 bins, each grid points)

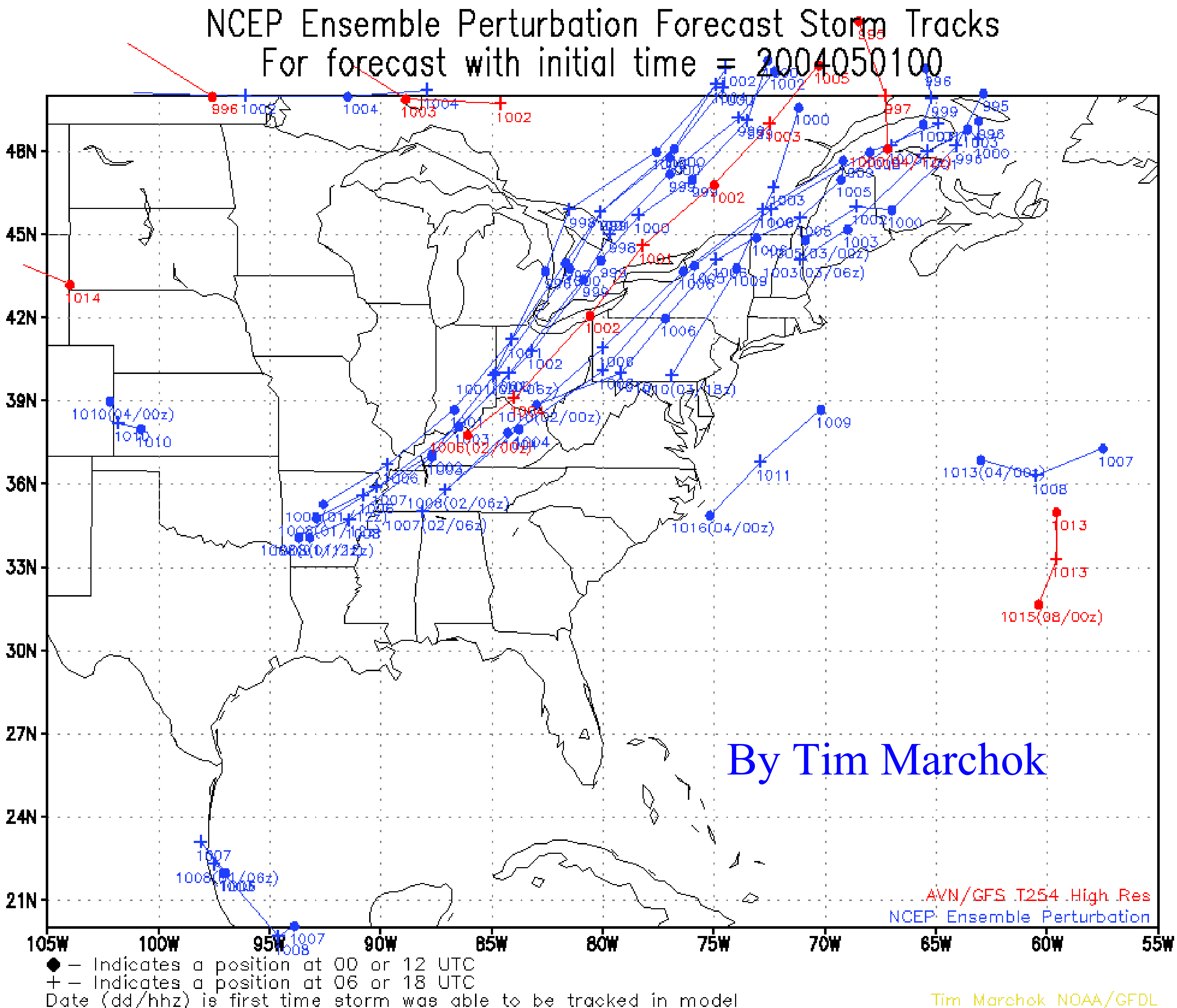
2. Counts of ensemble members agree with ensemble mean, (same bin)

3. Construct n+1 probabilities for n ensemble members from (2).

3. Regional (NH, weighted) Normalized Accumulated Probabilities (n+1)

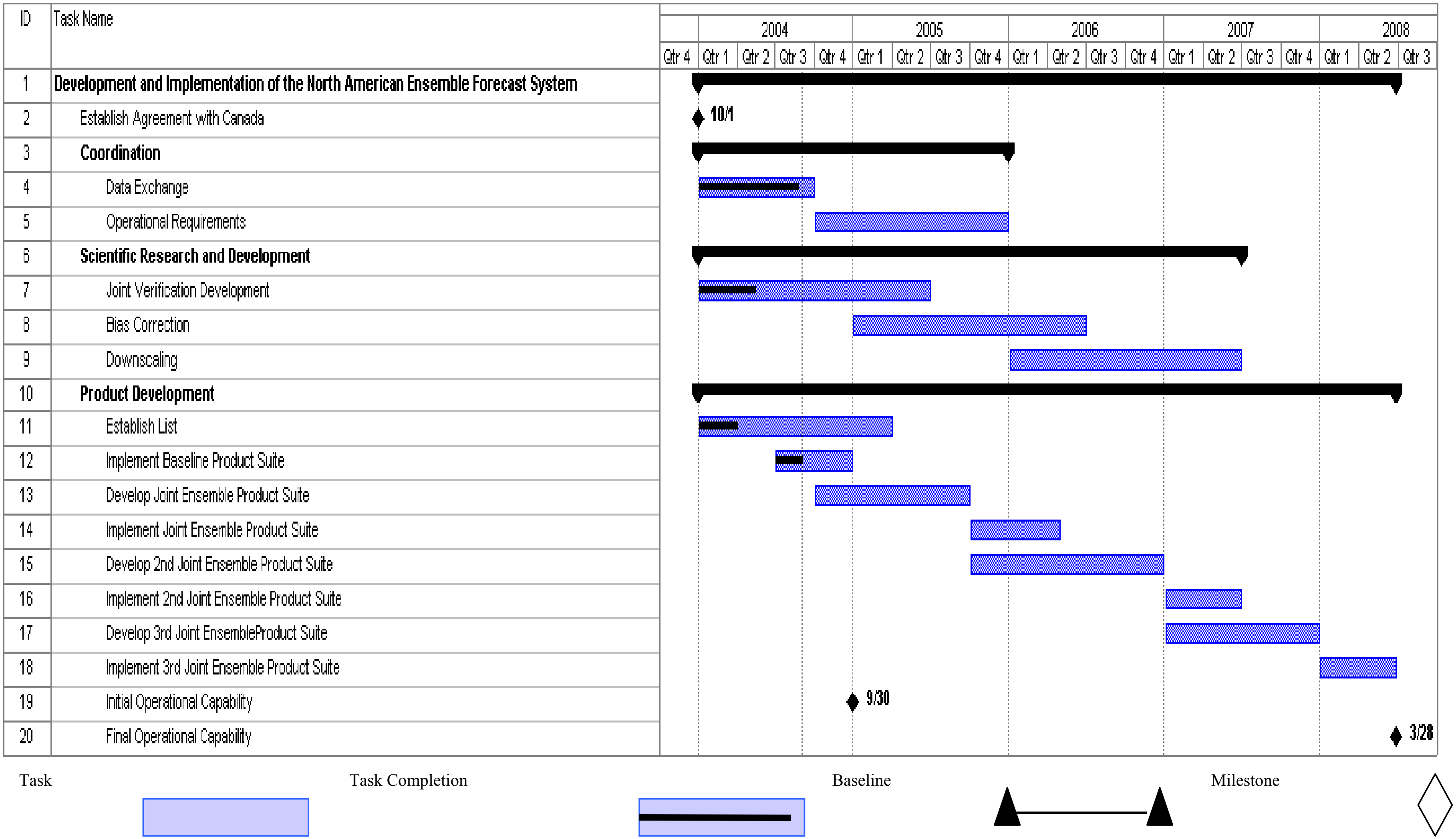
4. Calculate RMOP based on (3), but 30-d decaying average.

5. Verification information (blue numbers): historical average (reliability)


NCEP Ensemble Perturbation Forecast Storm Tracks
For forecast with initial time = 2004050100
48N
45N
42N
39N
36N
33N
30N
27N
24N
21N
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
By Tim Marchok
AVN/GFS T254 High Res
NCEP Ensemble Perturbation
● – Indicates a position at 00 or 12 UTC
+ – Indicates a position at 06 or 18 UTC
Date (dd/hhz) is first time storm was able to be tracked in model
Tim Marchok NOAA/GFDL

PROGRESS, PERFORMANCE MEASURES

Schedule (FY)



ID
Task Name
2004
2005
2006
2007
2008
Qtr 4
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Qtr 1
Qtr 2
Qtr 3
1 Development and Implementation of the North American Ensemble Forecast System
2 Establish Agreement with Canada
10/1
3 Coordination
4 Data Exchange
5 Operational Requirements
6 Scientific Research and Development
7 Joint Verification Development
8 Bias Correction
9 Downscaling
10 Product Development
11 Establish List
12 Implement Baseline Product Suite
13 Develop Joint Ensemble Product Suite
14 Implement Joint Ensemble Product Suite
15 Develop 2nd Joint Ensemble Product Suite
16 Implement 2nd Joint Ensemble Product Suite
17 Develop 3rd Joint EnsembleProduct Suite
18 Implement 3rd Joint Ensemble Product Suite
19 Initial Operational Capability
9/30
20 Final Operational Capability
3/28
Task
Task Completion
Baseline
Milestone

Performance Parameters

The NWS portion of the US-Canadian North American Global Ensemble Forecast System Development and Implementation.

Improvement in Ensemble Forecasts				
Requirement		Threshold	Actual	Variance
Ensemble Mean 3-14 Day Lead Time	30-Day Mean Error Reduction (%)	50%	TBD	TBD
	RMS Error Reduction (%)	10%	TBD	TBD
Number of Joint Ensemble Members		>20	TBD	TBD
Improvement in Ensemble-based Probabilistic Forecasts	3 Day	6 Hours	TBD	TBD
	7 Day	12 Hours	TBD	TBD
	10 – 14 Days	24 Hours	TBD	TBD

BEYOND IOC

BEYOND IOC – OPEN ISSUES

1) NEED 2ND WORKSHOP

Jump start detailed planning and coordination in areas of

- Bias correction
- Product development
- Verification

Fall 2004 at NCEP?

2) FUTURE TELECOMMUNICATION NEEDS

Will current ftp process be adequate in future?

- Increased volume of data due to higher resolution & more members
- Wide-range operational use may demand more reliability?

Switch to GRIB2

- Factor of 3 reduction in data volume due to more efficient packing
- WMO standard, preferred for future multi-center data exchange
- Advance planning needed, implement in 1-2 yr timeframe

3) COMMON OR DIFFERENT PRODUCT SUITE?

Different emphasis on 2 sides:

- MSC – Fully automated forecast process, SCRIBE
  - Automated products for selected sites, final products?
- NWS – Larger role for human forecaster, IFPS
  - Intermediate guidance products on NDFD grid?

BEYOND IOC – OPEN ISSUES - 2

4) ENSEMBLE CONFIGURATION

What horizontal/vertical resolution; How many members?

Formal configuration requirements, or quality driven choices?

MINIMAL (PREFERRED) CONFIGURATION FOR THE GLOBAL ENSEMBLE FORECAST SYSTEMS OPERATIONAL AT CMC AND NCEP

FEATURE	2005	2008	
Forecast lead time (days)	16	16 (35)	
Number of cycles per day	2 (4)	4	
Number of ensemble members	10 (20)	20 (50)	
Model resolution (km)	120 (90)	80 (60)	
Number of vertical levels	28 (42)	42 (64)	

DETAILED DISCUSSIONS

BIAS CORRECTION

PRODUCTS

VERIFICATION

BASED ON

2ND ENSEMBLE USER WORKSHOP

May 18-20 2004, NCEP

DRAFT

RECOMMENDATIONS

Based on presentations and working group discussions

June 1 2004

WORKING GROUP PARTICIPANTS (26)

CONFIGURATION

Co-leaders: Jun Du and Mozheng Wei

Participants: Rick Knabb, Richard Wobus, Ed O'Lenic, Dingchen Hou

DATA ACCESS

Co-leaders: Yuejian Zhu and David Michaud

Participants: David Bright, Minh Nguy, Kathryn Hughes

STATISTICAL POST-PROCESSING

Co-leaders: Paul Dallavalle & Zoltan Toth

Participants: Keith Brill, Andy Lough, DJ Seo, David Unger

PRODUCTS & TRAINING

Co-leaders: Jeff McQueen and Pete Manousos

Participants: Paul Stokols, Fred Mosher, Paul Janish, Linnae Neyman, Bill Bua, Joe Sienkiewicz, Binbin Zhou

ADDITIONAL WORKSHOP PARTICIPANTS (15)

Steve Tracton, Mike Halpert, Brian Gockel, Brent Gordon, Mark Antolik, Barbara Strunder, Andrew Loughe, Michael Graf, Dave Plummer, Steve Schotz, Jon Mittelstadt, Malaquias Pena, Glen Zolph, Steve Lord, David Caldwell

ENSEMBLE STATISTICAL POSTPROCESSING - CURRENT STATUS

- **NWP models, ensemble formation are imperfect**
  - Known model/ensemble problems addressed at their source
    - No “perfect” solution exists, or is expected to emerge
  - Systematic errors remain and cause biases in
    - 1^{st}, 2^{nd} moments of ensemble distribution
    - Spatio-temporal variations in 2^{nd} moment
    - Tails of distributions
- **No comprehensive operational post-processing in place**
  - MOS applied on individual members (global ensemble, MDL)
  - QPF calibration of 1^{st} moment (global ensemble, EMC & CPC)
  - Week 2 calibration with frozen system (global ensemble, CDC)
- **Issues:**
  - Users need bias-free ensemble guidance products
    - Bias-corrected ensemble members must be consistent with verification data
  - Algorithms must be relatively cheap & flexible for operational applications
    - Post-process on model grid first, then “downscale” to NDFD grid / observs?
  - Level of “correctible” details depends on
    - Bias signal vs. random error noise ratio
    - Sample size of available forecast/observation training data pairs
      - Relatively small sample for short-med. ranges – Capture regime dependent bias?
      - Much larger for extended ranges – Capture climatological bias via frozen system?

ENSEMBLE STATISTICAL POSTPROCESSING - RECOMMENDATIONS

- Develop techniques for two-stage statistical post-processing:
  - 1) Assess and mitigate biases on model grid with respect to analysis fields
    - Feedback to model / ensemble development
    - 1st moment correction based on: Time mean error; Cumulative distributions
    - 2nd moment correction based on: Time mean ratio of ens mean error & spread
    - Post-processed forecasts bias corrected with respect to reanalysis fields
      - Generate anomaly forecasts using global/regional reanalysis climatology
  - 2) Downscale bias-corrected fcsts from model grid to NDFD/observatn locations
    - "Smart" interpolator for bias correction and variance generation on fine scales
      - Multiple regression (MOS); Bayesian methods; Kalman Filtering; Neural nets
    - Apply downscaling methods on bias-corrected fields (no lead time dependence)
      - Use large reanalysis and corresponding observational data base (&/or NDFD analysis fields)
  - To describe ensemble-based pdf forecasts, use 3-parameter distributions
    - Test two methods, find best fitting analytic distribution (out of ~25 candidates)
      - Simple method: Fit actual ensemble data
      - Kernel approach: Find best fit to climate data, then apply it on each member w/weight

ENSEMBLE STATISTICAL POSTPROCESSING - RECOMMENDATIONS

- Operationally implement post-processing techniques
  - Apply basic bias-correction techniques centrally (NCO) to serve wide user base
    - Post-process all variables used from the ensemble (first model, then derived variables)
  - Disseminate bias-corrected forecasts on lowres ensemble model grid
    - Save disc and bandwidth resources
    - Keep raw forecast fields also accessible for special user processing needs
  - Use additional post-processing (if any) locally to address special needs, eg:
    - Hurricane forecasting

ENSEMBLE PRODUCTS - CURRENT STATUS

- **Product development software**
  - Some functionalities exist
    - Scattered around different developers/platforms/users
      - NCO operations
      - NAWIPS official build
      - NAWIPS development by NCEP SOOs
      - AWIPS
      - Other platforms
- **Products generated centrally by**
  - NCO Limited number of gridded products (operational)
  - EMC Additional set of gridded and web-based products (non-operational)
- **Issues:**
  - Lack of standard/common software toolbox for ensembles
    - Missing functionalities
    - Multiple software versions of existing functionalities
    - Duplication of efforts
  - Lack of comprehensive, well designed set of products
    - Non-standard set of products/displays (global vs. regional ensembles, etc)
    - NAWIPS, AWIPS requires access to products (web not enough)
    - Need for operationally generated and supported web product suite

ENSEMBLE PRODUCTS - RECOMMENDATIONS

- Develop a software toolbox for interrogating ensemble data
  - Establish development team - NCO, EMC, NCEP Service Center experts
  - Compile list of required functionalities – See attached list
  - Develop standard software package (subroutines) for each functionality
    - Work in NAWIPS framework
    - Ensure software (subroutines) are portable to different platforms
    - Ensure batch and on demand processing capabilities
    - Provide interactive processing/display capability where needed
    - Offer subroutines for use by AWIPS and broader inter/national community
    - Consider WRF, NAEFS, THORPEX applications
- Establish operational/local product generation suites
  - Use standard software toolbox for product generation
  - Identify list of products – See template on next page
  - Type of product generation based on typical usage:
    - Every day - Generate centrally (NCO), produce multiple file formats
    - Occasionally - On demand (NCEP Service Centers)
    - Interactively - On screen manipulation (NAWIPS)
  - Distribute centrally generated products within NAWIPS, AWIPS
  - Set up and maintain operational NCEP ensemble product web page
    - Post products on web page for use by broader community
    - Provide limited interactive query tools if desired (example within NOMADS)

ENSEMBLE PRODUCTS - FUNCTIONALITIES

For each functionality, NCEP Service Centers provide list of variables/levels for which central/local generation of products is needed: *MSLP, Z,T,U,V,RH, etc, at 925,850,700,500, 400, 300, 250, 100, etc hPa*

	FUNCTIONALITY	***CENTRALLY GENERATED***	***LOCALLY GENERATED***
1	Mean of selected members		
2	Spread of selected members		
3	Median of selected values		
4	Lowest value in selected members		
5	Highest value in selected members		
6	Range between lowest and highest values		
7	Univariate exceedance probabilities for a selectable threshold value		
8	Multivariate (up to 5) exceedance probabilities for a selectable threshold value		
9	Forecast value associated with selected univariate percentile value		
10	Tracking center of maxima or minima in a gridded field (eg – low pressure centers)		
11	Objective grouping of members		
12	Plot Frequency / Fitted probability density function at selected location/time (lower priority)		
13	Plot Frequency / Fitted probability density as a function of forecast lead time, at selected location (lower priority)		

ENSEMBLE VERIFICATION – CURRENT STATUS

For lack of time, this topic was not discussed at the workshop

- Global ensemble verification package used since 1995
  - Comprehensive verification stats computed against analysis fields
  - Inter-comparison with other NWP centers
- Regional (SREF) verification package
  - Basic measures computed routinely since 1998
  - Probabilistic measures being developed independently from global ensemble
- Issues
  - Need to unify computation of global – regional ensemble verification measures
  - Unified framework must facilitate wide-scale national/international collaboration:
    - North American Ensemble Forecast System (collaboration with Met. Service Canada)
    - THORPEX International Research Program
    - WRF meso-scale ensemble developmental and operational activities
  - Facilitate wider community input in further development/enhancements
    - How to establish basis for collaboration with NCAR, statistical community, etc

ENSEMBLE VERIFICATION - RECOMMENDATIONS

- Design unified and modular ensemble/probabilistic verification framework
  - Data handling/storage
    - Use standard WMO file formats as ensemble data input
    - Allow non-standardized user/site specific procedures
  - Computation of statistics
    - Establish required software functionalities (scripts) and verification statistics (codes)
    - Jointly develop and share scripts/subroutines with standard input/output fields
    - Improvements to common infrastructure benefit all
    - Comparable scientific results, independent of investigators
  - Access/display of output statistics
    - Explore if standard output file format(s) feasible? Use text or FVSB-type files?
    - Develop/adapt display software for interactive interrogation of output statistics
      - Examples: FVS display system; FSL approach to WRF verification

- Develop and implement new verification framework
  - Utilize existing software and infrastructure where possible
  - Direct all internal ensemble-related verification efforts toward new framework
  - Share work with interested collaborators
    - Meteorological Service of Canada (subroutines, L. Wilson and colleagues)
    - FSL (display tools, A. Laugh)
  - Make new software available to national/international community
    - Coordinate further development with wider community (WMO, etc input)

ENSEMBLE VERIFICATION – DESIGN SPECIFICATIONS

Compute statistics selected from list of available

- Point-wise measures, including:
  - RMS, PAC for individual members, mean, median
  - Measures of reliability (Talagrand, spread vs. error, reliability components of Brier, RPSS, etc)
  - Measures of resolution (ROC, info content, resol. comps. of BSS, RPSS, potential econ.value, etc)
  - Combined measures of reliability/resolution (BSS, RPSS, etc)
- Multivariate statistics (e.g., PECA, etc)
- Variables & lead times –make all available that are used from ensemble

- **Aggregate statistics as chosen in time and space**
  - Select time periods
  - Select spatial domain (pre-designed or user specified areas)
- **Verify against observational data or analysis fields**
  - Scripts running verification codes should handle verification data issues
  - Use same subroutines to compute statistics in either case
  - Account for effect of observational/analysis uncertainty?
- **Define forecast/verification events by either**
  - Observed/analyzed climatology, e.g., 10 percentile thresholds in climate distribution
    - Automatically compute thresholds for forecast values
  - User specified thresholds – automatically compute corresponding climate percentiles
  - Ensemble members (like in Talagrand stats) – compute climate percentiles
- **Facilitate the use of benchmarks**:
  - Climatology, persistence, or specified prior forecast data set
- **Prioritize and find balance between**
  - Flexibility vs. complexity; operational vs. research use, etc

2nd NCEP Ensemble User Workshop

SUMMARY RECOMMENDATIONS

- **OVERALL** - Enhance coordination of ensemble-related efforts
  - Establish ensemble product working group
  - Continue with monthly Predictability meetings
  - Hold Ensemble User Workshops (part of reestablished SOO workshops)
- **CONFIGURATION**

Global ensemble: Implement hurricane relocation for perturbed initial conditions
Continue efforts to build multi-center ensemble

Regional (SREF) ensemble: Ensemble run should be coupled closer with hires control (same initial time)
Run 4 cycles per day

- **DATA ACCESS**
  - Provide access to all ensemble data (including members)
  - Facilitate user controlled access to data (e.g. NOMAD, on demand, not on rigid schedule)
- **STATISTICAL POST-PROCESSING (BIAS CORRECTION)**
  - Develop techniques for two-stage statistical post-processing
  - Operationally implement post-processing techniques
- **PRODUCTS**
  - Develop a software toolbox for interrogating ensemble data
  - Establish central/local operational product generation suites
- **VERIFICATION**
  - Design & develop unified and modular ensemble/probabilistic verification framework
- **TRAINING**
  - Establish NWS formal ensemble training requirements
  - Contribute to Ensemble Training Workshops, international activities (AMS, WMO), etc

POTENTIAL FUTURE EXPANSIONS

NEW AREAS OF COMMON INTEREST IN RESEARCH/DEVELOPMENT

LINKS WITH THORPEX

NAEFS
FUTURE JOINT RESEARCH OPPORTUNITIES

Ensemble configuration -

Model resolution vs. membership, etc

Representing model errors in ensemble forecasting –

High priority research area, collaboration possible

Initial ensemble perturbations –

Compare 2 existing systems, may improve both

Ensemble forecasting on different scales:

Regional ensemble forecasting:	No activities at MSC, maybe in 2 yrs
3-6 weeks – seasonal:	Opportunities for research collaboration

NAEFS
LINKS WITH THORPEX

THORPEX TIP adapted multi-center ensemble concept

- Ensembles collected and processed at multiple sites
- Products made available internationally

NAEFS plan can serve as a draft for "blueprint" of multicenter concept

- MSC, NCEP should play proactive role
  - Careful considerations for operational application
  - Model that (we hope) will work
- Benefits from international collaboration
- Service to underdeveloped countries

THORPEX TIP calls for IPY collaboration

- IPY of great interest to both countries
- Opportunity for joint IPY-related activities
- US strawperson proposal (Parsons, Shapiro, Toth)

Other promising areas under THORPEX TIP?

PROPOSAL FOR IPY-RELATED THORPEX FIELD CAMPAIGN

International Polar Year (IPY):

Multi- and interdisciplinary international research experiment in 2007-2008

Study areas of strongest climate change impact

Research in both polar regions

Strong links to the rest of the globe

THORPEX – Global Atmospheric Research Program (GARP):

Accelerate improvements in skill/utility of 1-14 day weather forecasts

- Long-term (10-yrs) research program in areas of:
  - Observing system, data assimilation, numerical modeling/ensemble, socioec. appl.
- Strong link with operational Numerical Weather Prediction (NWP) centers
- International program under WMO
- *Planning initiated with discussions about North Pacific experiment =>*

Opportunities for IPY - THORPEX Collaboration

Joint THORPEX-IPY Observing period –

- Major opportunity for accelerating observing system design work
- Improved weather forecasts for IPY activities
- Scientific investigations:
  - Link between weather and climate processes
  - Mid-latitude – Polar interactions

PROPOSED NORTH PACIFIC THORPEX REGIONAL CAMPAIGN (NP-TREC)

2-MONTH FIELD PROGRAM DURING IPY

Joint THORPEX – IPY Observing Period, Winter of 2007/08

1) **Utilize enhanced IPY polar observing system in NWP** – *(2 yrs) Advantages for THORPEX*
   - Ensure real-time accessibility of data (for NWP centers, through GTS transmission)
   - Explore targeted use of IPY polar data on forecasts over NA (cold air outbreaks, etc)
   - Consider special enhancement of IPY data if needed
2) **Enhance atmospheric observations in NW Pacific** – *(2 mos) Contributing to IPY activities*
   - Manned and unmanned aircraft, driftsonde, satellite, etc
   - Extension of operational NWS Winter Storm Recon coverage (northeast Pacific)
   - Targeted to improve Alaskan (and Northern Canadian) forecasts
   - Study mid-latitude – polar interaction on daily time scale
3) **Evaluate effect of enhanced observing system on forecasts** – *(2 mos) Mutual benefits*
   - Study combined effect of North Pacific (NP-TREC) & polar region (IPY) observations
     - 2-3 days – Polar regions of NA; 3-14 days – NA, NH, Global domains

PLANNING:

a) Interface with IPY - International THORPEX coordination

b) Develop detailed US plan – Coordinate within NA

c) Start scientific work (eg, OSSE) as soon as possible

d) NP-TOST for testing new components of observing system (2006)

Opportunities for THORPEX:

Assessment of major observational enhancements over polar regions

Scientific collaboration on time scales of weather/climate interface

Benefits for IPY:

Link to mid-latitude weather processes (science and organizational)

Improved targeted weather forecasts

Improved sea ice & air quality forecasts

Ample time for planning coordinated field program - Possible joint funding opportunities

IOC CEREMONY

Coinciding with 2nd NAEFS Workshop in Fall 2004?

At opening of workshop?

NOTES FROM THE MEETING

Action items:

1) MSC to provide NCEP with T_{min}, T_{max} & CAPE data by end of August 2004 for IOC (J.-G. Desmarais)
2) Upgrades to either system need to be coordinated with other side - monitor "change management structure" to prevent IOC & later implementation problems (D. Michaud & J. G. Desmarais)
3) Develop plan on both sides for switch to GRIB2 format by next implementation, January 2006 (B. Gordon & R. Hogue)
4) Organize second NAEFS workshop at NCEP in Sept-Nov timeframe, to coincide with IOC ribbon tying ceremony (Z. Toth & J. G. Desmarais)
5) Develop strawperson plan for ensemble configuration upgrades (Z. Toth & G. Brunet)
6) Review telecommunication alternatives for current ftp data exchange based on current and projected data volume
   a) Quantitatively assess reliability/speed of ftp transfer to NCEP from MSC (& ECMWF) (B. Gordon)
   b) Determine if ftp reliability & speed is acceptable for users (NCEP Service Center SOOs)
   c) What other telecommunication routes are available, at what cost? (B. Gordon)
      Current volume per cycle is ~1-2G;
      Projected data volume in next 3-5 yrs: 4-10G (2x membership, 2x variables, 2x resolution (double resolution only for near surface variables); factor of 3 saving with GRIB2 = 3-5 times increase)
   d) If cost is acceptable, budget for needed increase in reliability and/or disc and bandwidth usage (NCO Director)
   e) If cost too high, consider, eg., freezing resolution for data exchange (Z. Toth & J.-G. Desmarais)
7) Assess cost associated with, and find funding sources for making long term ensemble forecast archive accessible to extramural researchers, eg, expansion of NOMAD system (J. Alpert)