EPS AT NCEP:
historical (and personal) perspective

6th NCEP ensemble user workshop
NCWCP, 25-27 March 2014

Steve Tracton
NCEP Alumnus
Washington, DC

FORECASTING FORECAST SKILL

H. Tennekes, A.P.M. Baede and J.D. Opsteegh
Royal Netherlands Meteorological Institute
De Bilt, The Netherlands

No forecast is complete without a description of its uncertainty.

No forecast is complete without a description of its uncertainty.

Much easier to say than do in all respects, especially and crucially "selling" the conceptual nature, rationale, and value of EPS to forecasters, management, and users of forecasts.

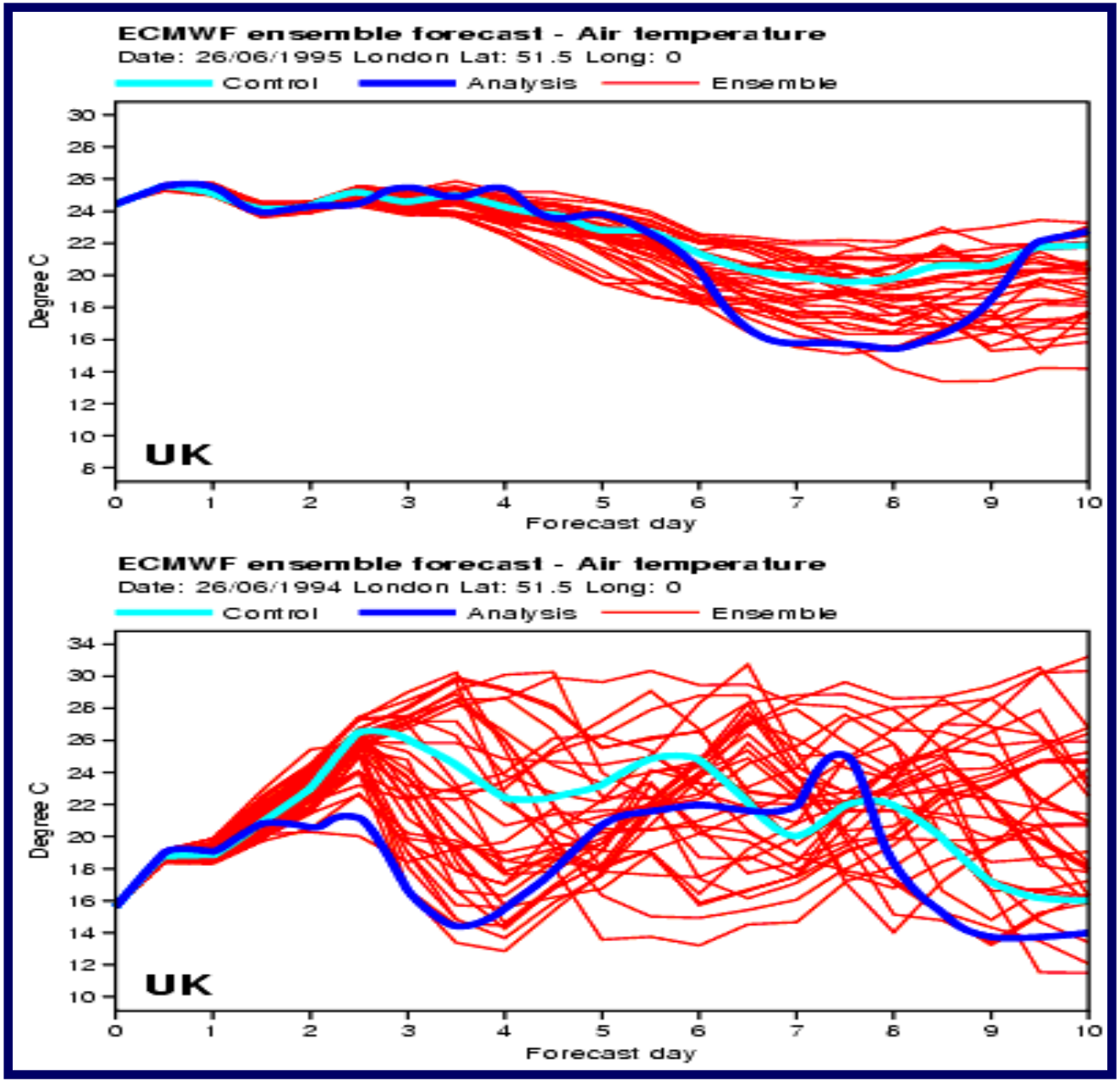
SCREAMING MESSAGE:

Weather Forecasts Will *ALWAYS Be Coupled With *Varying* Degrees of Uncertainty ("*Chaos* *Theory*)!**

EFFECT!!!

******TRUE EVEN WITH PERFECT MODEL !!!!*

After then (wrkshop)


ECMWF ensemble forecast - Air temperature
Date: 26/06/1995 London Lat: 51.5 Long: 0
Control
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Forecast day
ECMWF ensemble forecast - Air temperature
Date: 26/06/1994 London Lat: 51.5 Long: 0
Control
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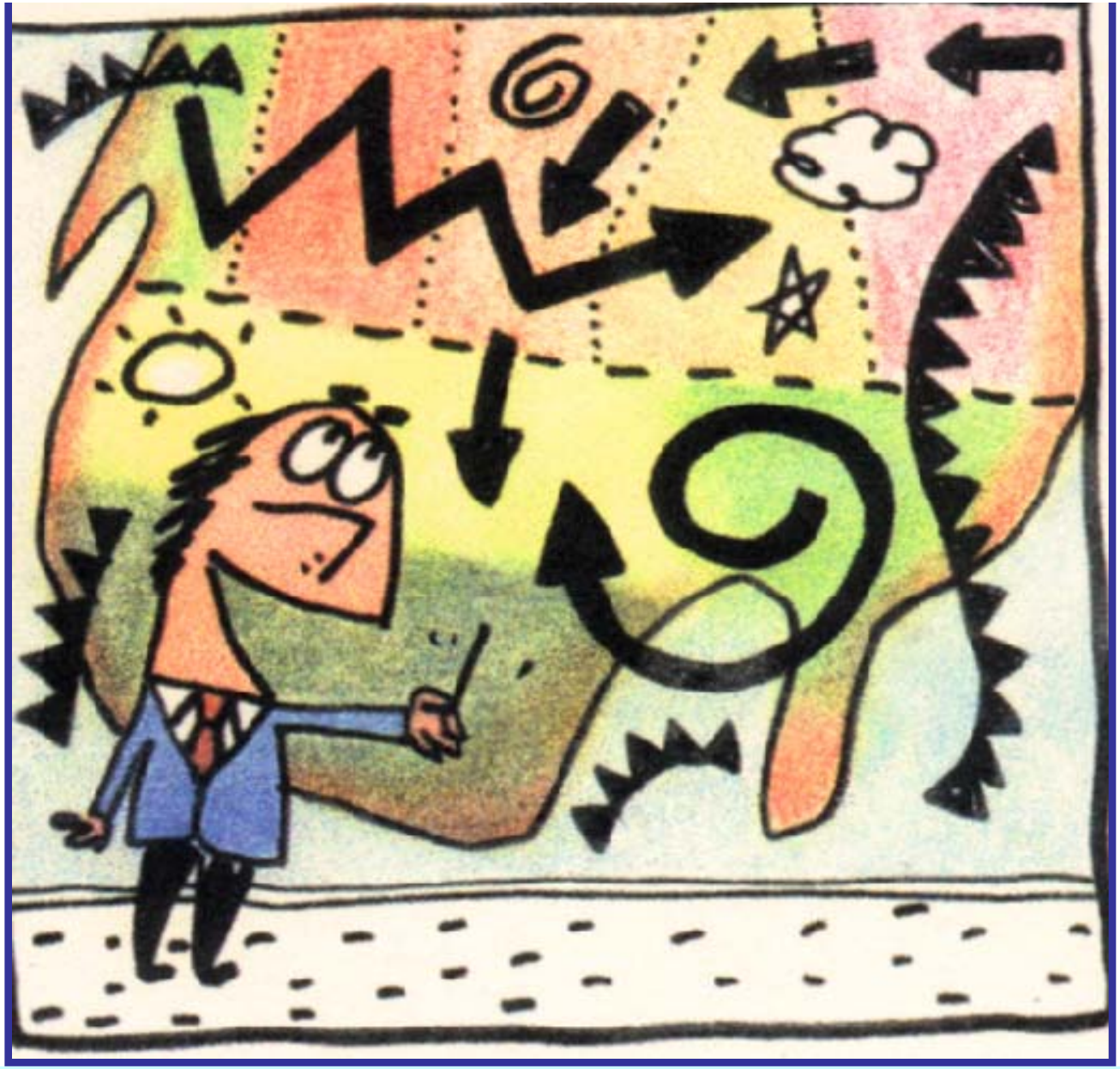
Forecast day

"PARADIGM BLINDNES"

The inability to conceive a new way of doing things



YOUR FORECAST HAS A 30% CHANCE OF BEING 70% CORRECT

NMC began operational ensemble prediction On 7 December 1992

NMCNOTES

Operational Ensemble Prediction at the National Meteorological Center: Practical Aspects

M. STEVEN TRACTON

Climate Analysis Center, National Meteorological Center, NWS/NOAA, Washington, D.C.

EUGENIA KALNAY

Development Division, National Meteorological Center, NWS/NOAA, Washington, D.C.

21 March 1993 and 26 April 1993

A Synoptic Evaluation of the NCEP Ensemble

ZOLTAN TOTH,* EUGENIA KALNAY, STEVEN M. TRACTON, RICHARD WOBUS,* AND JOSEPH IRWIN

National Centers for Environmental Prediction, Camp Springs, Maryland

(Manuscript received 9 April 1996, in final form 3 September 1996)

NMC began operational ensemble prediction On 7 December 1992

14 independent forecasts every day, verifying on days 1 through 10

Ensemble members generated through a combination of time lagging, Breeding of Growing Modes

NMC explicitly recognizes that forecasts are stochastic, not deterministic, in nature. There is no single solution, only an array of possibilities (A new era in operational numerical weather prediction (NWP), "*Wave of the future*")

Ensembles provide a rational basis for assessing the range and likelihood of alternative scenarios.

Expect that ensemble prediction will enhance the utility of NWP by

(a) providing a basis for the estimation and

(b) creating a quantitative foundation for probabilistic forecasting.

Major challenge is to condense the large amounts of information provided by ensembles into a user-friendly format that can be easily assimilated and used by forecasters and/or directly by users of forecast products

Implementation ensemble prediction relatively modest, it did provide the basis for development of operational experience with ensemble forecasting, and for research directed toward maximizing the utility of NMC's numerical guidance.

KEY CONSIDERATIONS

STRATEGIES FOR CREATING ENSEMBLES

-***PROCDEDURES FOR GENERATING INITIAL STATE PERTURBATIONS***

PERTURB OBSERVATIONS
RANDOM
TIME LAGGING
ANALYSES FROM OTHER CENTERS
"BREEDING"
SINGULAR VECTORS

PERTURBING MODEL

MULTI MODELS
PHYSICAL PARAMETERIZATIONS
STOCHASTIC PHYSIC
LATERAL BC'S
SURFACE BC'S
NUMERICS

OTHER CONSIDERATIONS

RESOLUTION - DOMAIN - ENSEMBLE SIZE

NOTE: OPTIMUM STRATEGY UNKNOWN (NO CONCENSUS)!!

IDEAL: EFFECTIVE/EFFICIENT SAMPLING OF ALTERNATIVE SCENARIOS, I.E., PROBABILITY DISTRIBUTIONS.

LIMITED COMPUTER RESOURCES GENERALLY REQUIRE COMPROMISES RELATIVE TO PERCEIVED OPTIMUM, E.G., MODEL RESOLUTION VERSUS ENSEMBLE SIZE)

KEY CONSIDERATIONS(CONT.)

PRODUCT DEVELOPMENT

OBJECTIVE:

CONDENSE LARGE AMOUNTS OF OUTPUT INTO A "USER FRIENDLY" FORM THAT PROVIDES RELIABLE ESTIMATES OF THE RANGE AND LIKLIHOOD OF ALTERNATIVE SCENARIOS

- **PRODUCTS CAN RANGE FROM DISPLAY OF ALL FORECASTS, SPHAGETTI DIAGRAMS, MEAN, SPREAD, CLUSTERS, FULL PROBABILITIY DISTRIBUTIONS**

CAN BE APPLIED TO VIRTUALLY ALL MODEL AND MODEL DERIVED PARAMETERS

SPAGHETTI CHARTS

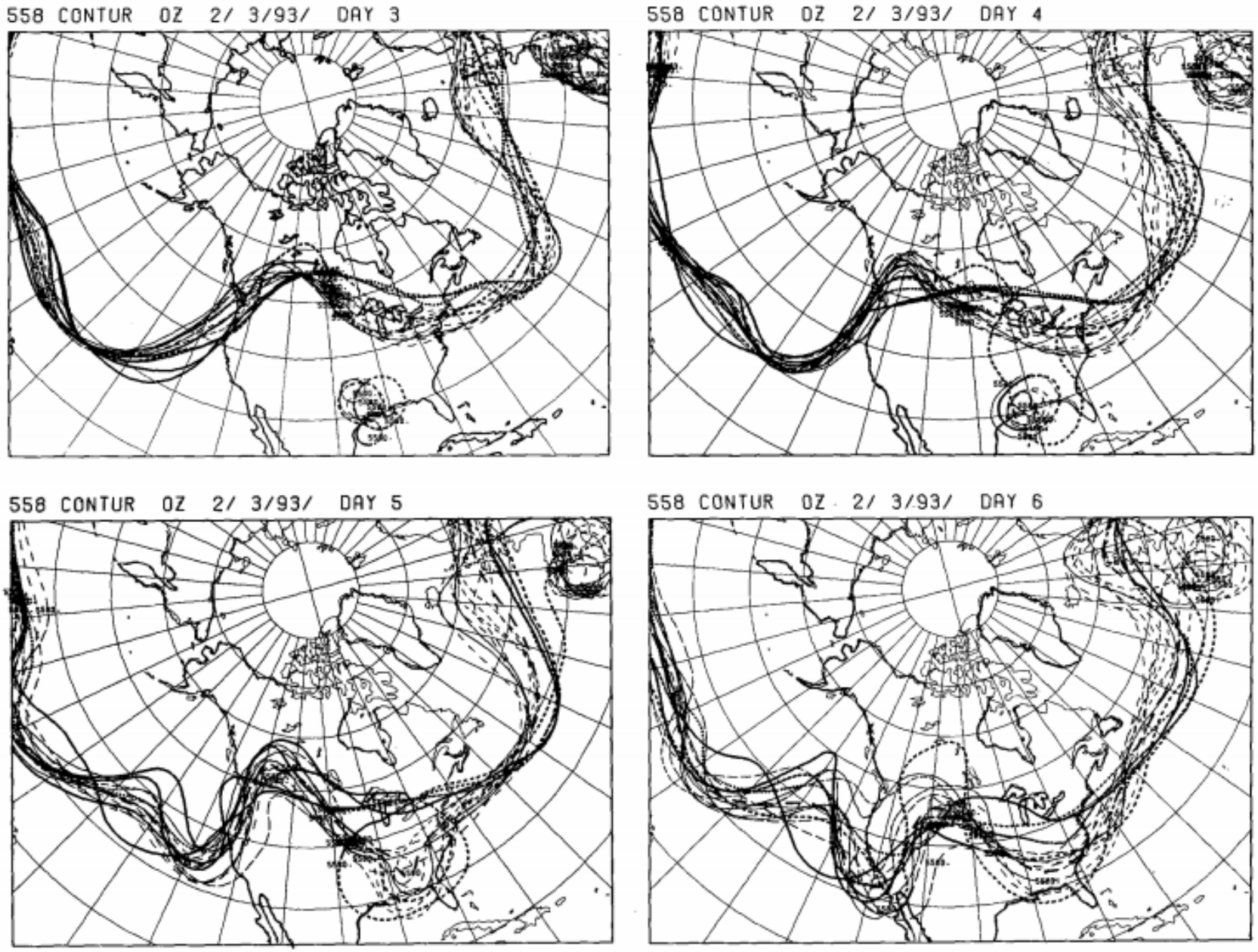


FIG. 12. Fourteen-member composite of the 558-dam contour for days 3, 4, 5, and 6 from 3 February 1993.

Day 4 Dominant Cluster vt 14 March 1993
“(Storm of the Century”)

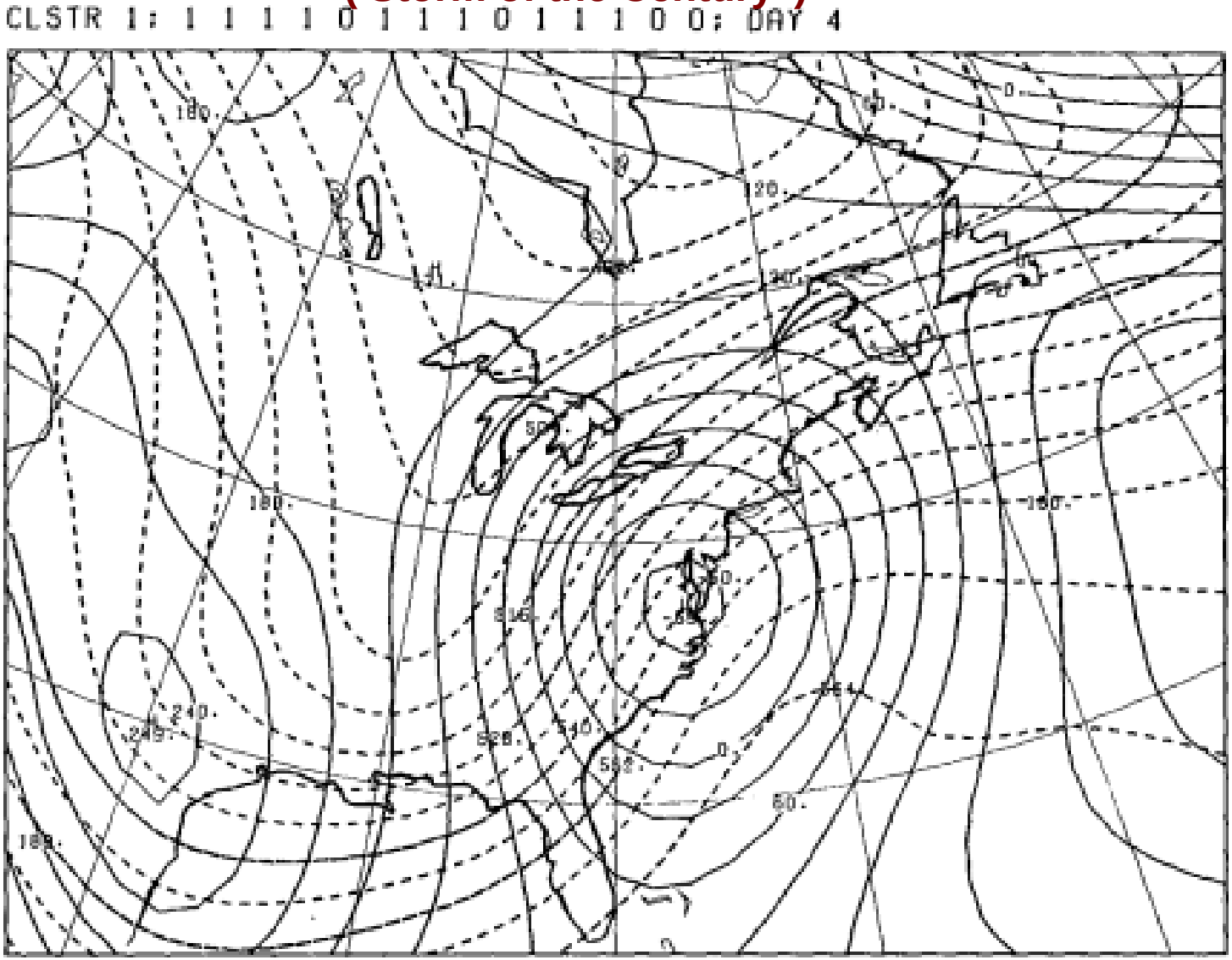


FIG. 8. Cluster 1 1000-mb height forecast (with 1000/500-mb thickness superimposed) from 10 March 1990 (“today”) and verifying 14 March 1993 (“Blizzard of ’93 case”). Units are m and dam for the 1000-mb height and 1000/500-mb thickness, respectively.

KEY CONSIDERATIONS(CONT.)

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  CAN BE APPLIED TO VIRTUALLY ALL MODEL AND MODEL DERIVED PARAMETERS

- STATISTICAL POSTPROCESSING (E.G., BIAS CORRECTIONS, CALIBRATION OF PROBABILITIES)
  ENSEMBLE OUTPUT STATISTICS (MOS)
- ADDITIONAL/ALTERNATIVE PRODUCTS

CONTINUAL INTERACTION AMONGST DEVELOPERS AND

VALIDATION

- STANDARD SKILL SCORES
- MEASURES OF SPREAD
- MEASURES OF RELIABILITY

EDUCATION AND TRAINING

NMCNOTES

Operational Ensemble Prediction at the National Meteorological Center: Practical Aspects

Finally, while the implementation described here was directed toward medium-range forecasting, it should be clear that the fundamental concepts apply equally well to short-range forecasting.

We expect that in the future, with expanded computer resources, it will be possible to perform short range ensemble forecasting by running a regional, (relatively) high resolution model

Led to development and operational implementation of the Short Range Ensemble Forecast system (SERF)

Very difficult to sell and garner support:

Arguments against (and resisted)

Regional models are skillful enough (uncertainties not significant)

Resources better devoted to increasing model resolution.

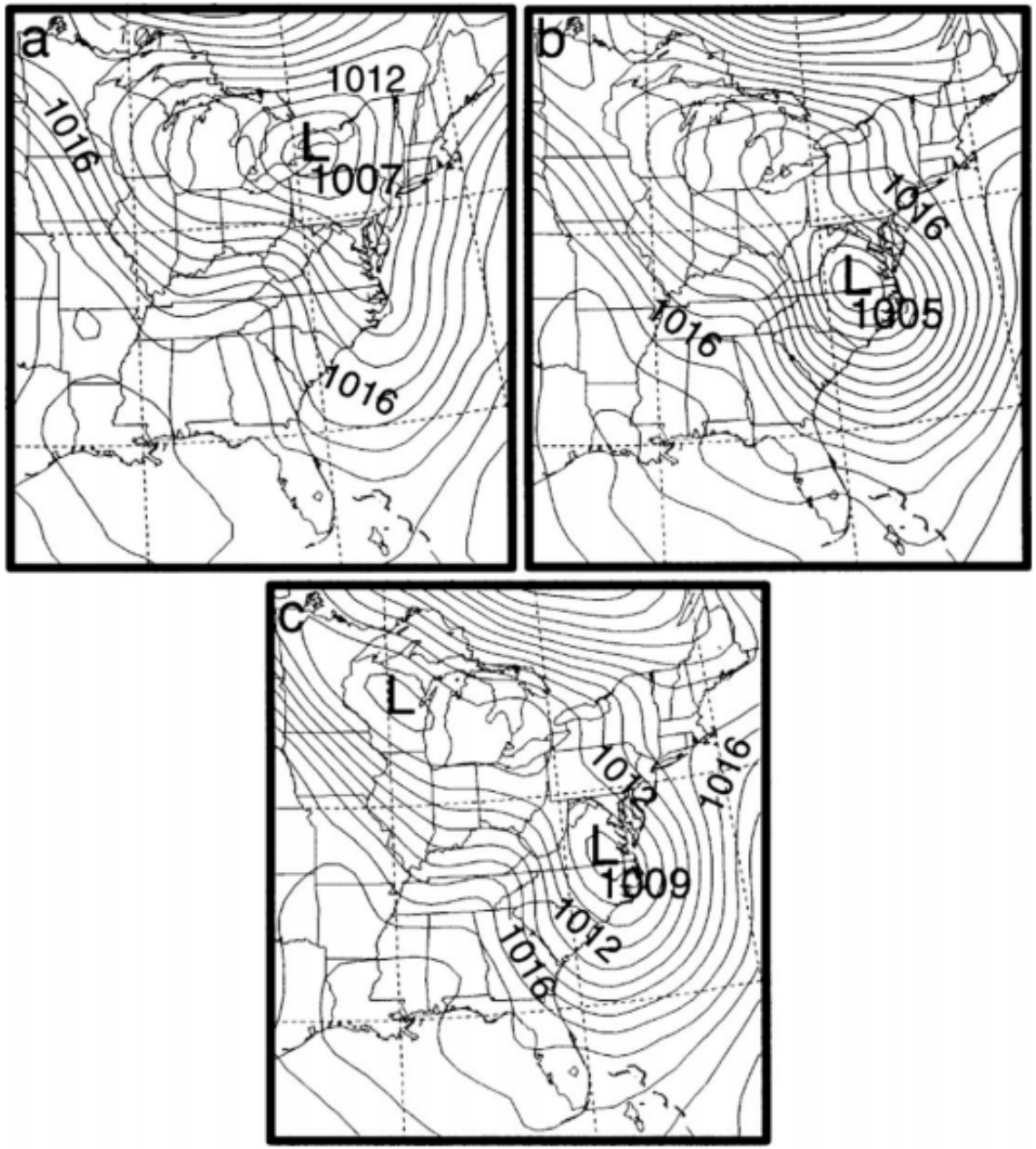


FIG. 1. Contours of sea level pressure (hPa) at 48 h, valid at 1200 UTC 22 Sep 1996, from an ensemble member with (a) no coastal cyclone, (b) a strong coastal cyclone and a weak parent cyclone, and (c) a combination of a coastal cyclone and a stronger parent cyclone.

Why Mesoscale Model Ensembles ??

CONSIDER!!!

- **Mesoscale models**
  - **– allow us to resolve features not in coarser models**
  - **– *But*: even small timing and placement errors can be significant in attempt to accurately forecast details (see Mass, et al., 3/02 BAMS!!!).**

•Any single model run is an all or nothing proposition =>

"One detailed mesoscale model based forecast could allow the user to make highly specific and detailed inaccurate forecasts." (after Grumm)

Surprise Snowstorm

Next ▶

(Joel Richardson — The Washington Post)

A battalion of snowplows clears Route 66. The sudden storm surprised even forecasters, who later predicted parts of the Washington regior could get up to 2 feet of snow.

Full Story

MAJOR SNOWSTORM AMBUSHES WASHINGTON

By Alan Sipress
Washington Post Staff Writer
Tuesday, January 25, 2000; 4:35 PM

A fierce snowstorm that battered Washington throughout the day is expected to bury the region with 12 to 18 inches by this evening. The storm closed federal, state and local government offices and area

Wednesday's Delays

- Full List

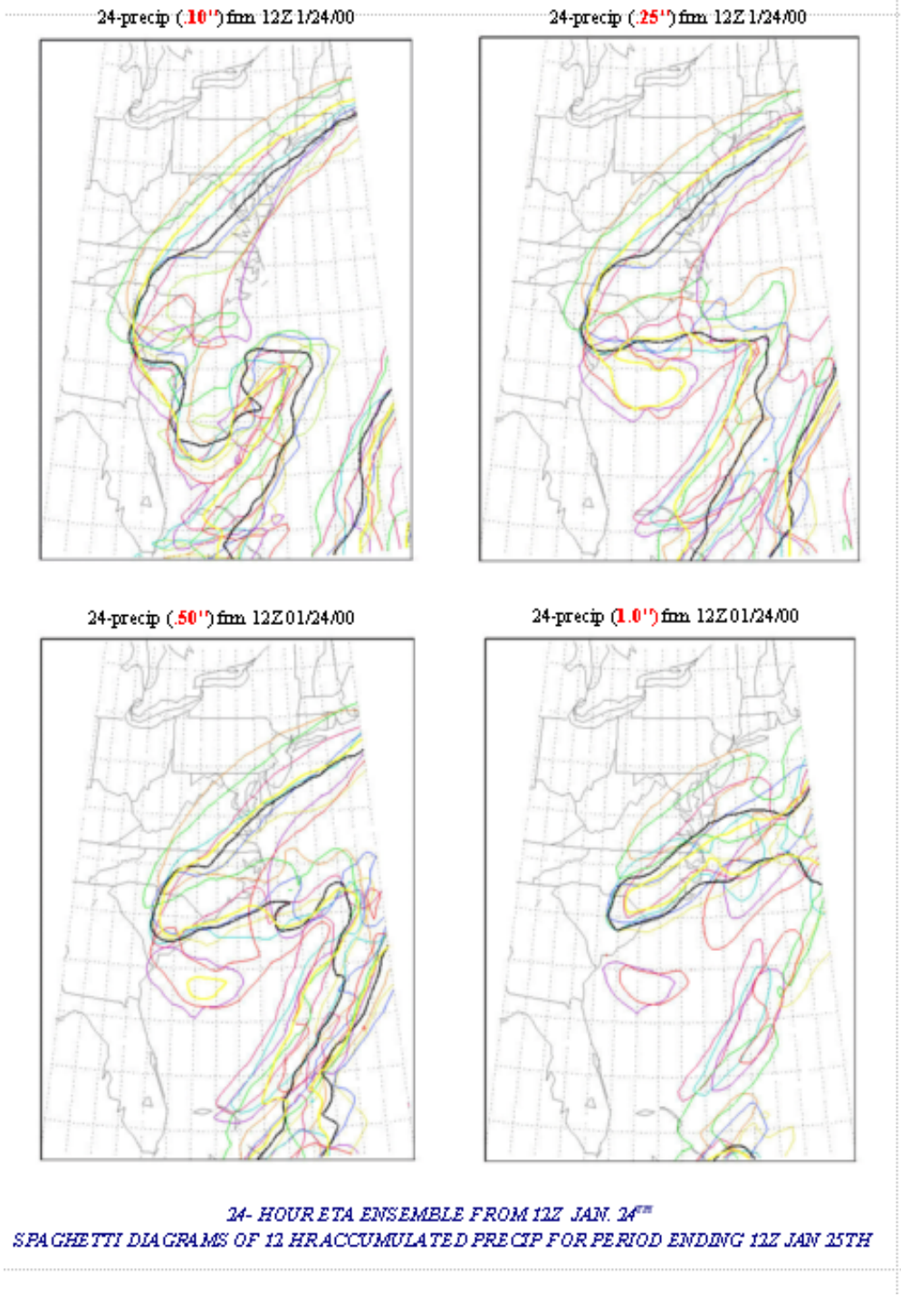
Traffic and Weather

- Live Traffic Reports
- Live Rail and Bus Reports
- Local Forecast

On the Web

- VDOT Winter Road Conditions Map

Not Good- especially when effecting DC (just after announce-ment of new Super Computer by NWSHQ



24- HOUR ETA ENSEMBLE FROM 12Z JAN. 24TH
SPAGHETTI DIAGRAMS OF 12 HR ACCUMULATED PRECIP FOR PERIOD ENDING 12Z JAN 25TH

Ensemble provides a clear "heads up" on morning of 24th for the *possibility* of a major snow event, especially when considered in context of independent information from satellite imagery and radar that suggested storm track closer to coast and precip further inland than available operational models were indicating

BOTTOM LINE

AVOID SURPRISES THROUGH DEGREE OF CONFIDENCE IN FORECASTS AND INSIGHT ON ALTERNATIVE SCENARIOS

In Particular:

‘Probability Forecasts are particularly useful, if not necessary, to provide early warnings of extreme weather events’

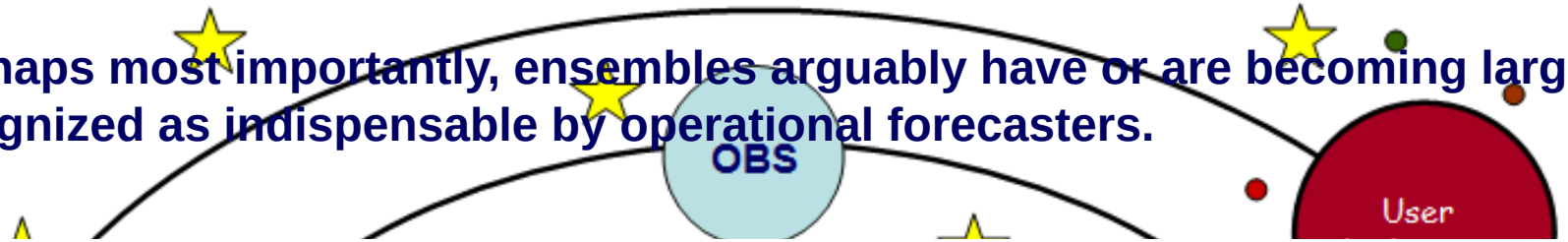
In the construct of NCEP's "Seamless Suite of Products" global and regional model ensembles permit estimates of forecast confidence/possibilities of specific weather events, first in the context of the requisite larger-scale circulation pattern at longer ranges and then in the details of the relevant weather system in the short range.

ULTIMATE GOAL

NWP PROCESS

(Following Nicholas Copernicus)

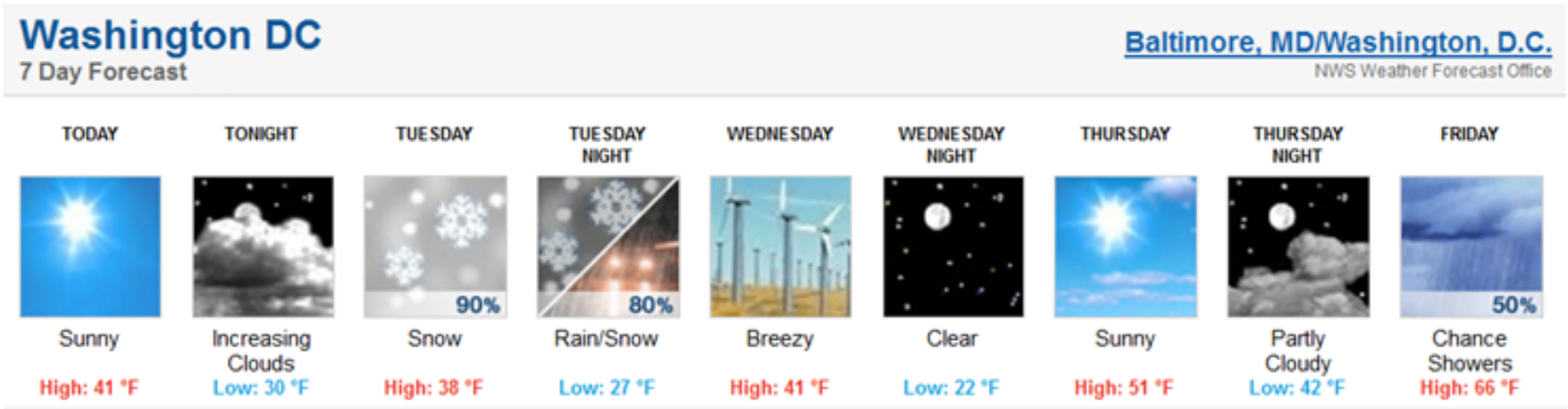
Perhaps most importantly, ensembles arguably have or are becoming largely recognized as indispensable by operational forecasters.



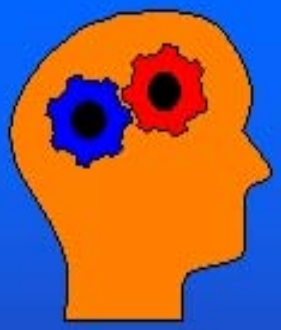
HOWEVER!

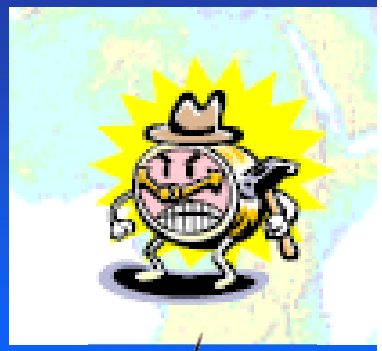
BIGEST MOST AGGREVATING and DISSAPOINTING STATE OF AFFAIRS

EVEN TODAY THIS EXEMPLIFIES THE PRIMARY OFFICIAL NWS FORECAST: DETERMINISM REMAINS ALIVE AND WELL



Question and Answer Time





"By adopting the ensemble approach and allowing for the possibility of providing reliable information on forecast uncertainties, the ultimate goal of NMC shifts away from just maximizing skill of model forecasts toward enhancing the total utility of NWP products."
"….. A key element for success in ensemble prediction is the sustained interaction between NMC and outside users." (Tracton and Kalnay, Weather and Forecasting, Sept. 1993)

"We foresee rapid growth in this area (probabilistic forecasting) fostered by a combination more sophisticated forecasting techniques and better ways of presenting probabilistic forecasts to decision makers". (A Vision for the National Weather Service; NRC and NWS Modernization Committee Report, 1999)

"We'll meet these expanding requirements, our (NWS) weather, space weather, air quality and water predictions and the information we disseminate need to be at the limits of the skill which science, technology, and a highly-trained workforce can provide. We are committed to expand these limits by …… including information on forecast uncertainty to enhance customer decision processes; by taking advantage of existing and emerging technologies to disseminate this information; by expanding technology base and a workforce trained to use all of these tools to maximum effect". (NWS Strategic Plan , Jan, 2005)

"It was agreed that the advances in the accuracy of numerical weather prediction have not translated into a significant increase in the utility of the forecasts." " ….The problem is not the good quality forecasts; it is the support for decision-making." (explicit reference to U.S. experience, THORPEX SERA Working Group Report, WMO, Geneva, January 2006).

SO WHAT GIVES ???

- ENSEMBLE PREDICTION – FROM EARLY 90'S ON, REVOLUTIONARY CHANGE IN THE THRUST OF OPERATIONAL NWP ("WAVE OF THE FUTURE"), THE OBJECTIVES BEING TO:

PROVIDES OBJECTIVE INFORMATION ON FORECAST UNCERTAINTIES (E.G., PROBABILITIES) FROM THE SPREAD (DIVERSITY) AMONGST ENSEMBLE MEMBERS

USE TO:

- Ascertain most likely deterministic prediction
- Confidence in deterministic forecast
- Same, plus identifying relative likelihood of alternative scenarios
- Full probability distribution – maximum information

NET RESULT – *POTENTIAL* TO ENHANCE UTILITY/VALUE OF NWP FOR VIRTUALLY ALL APPLICATIONS

WAVE OF THE FUTURE

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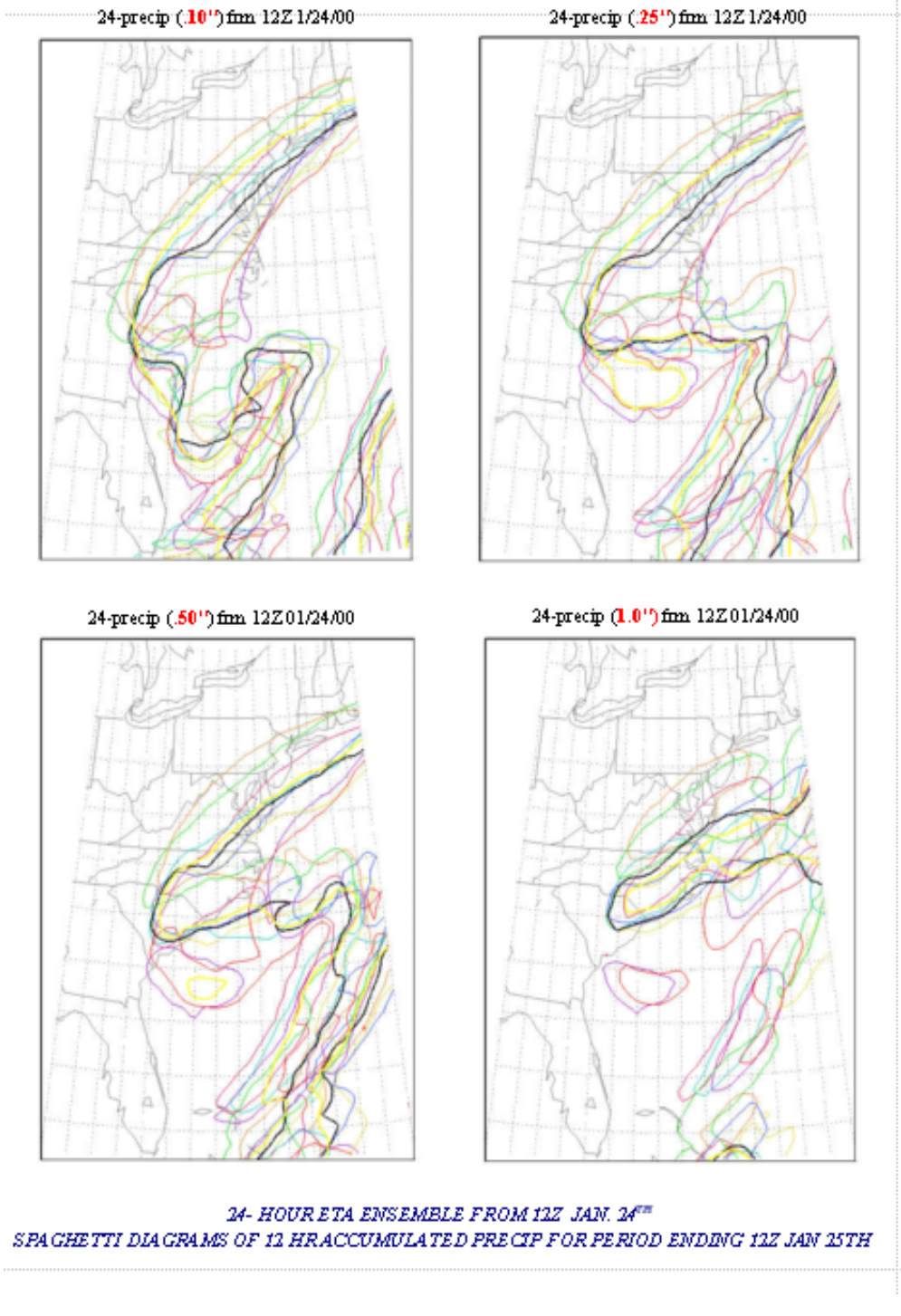
TYPES OF PRODUCTS

SPAGHETTI CHARTS

MEAN/SPREAD
PROBABILITIES
STORM TRACKS
CLUSTERS
VERTICAL PROFILES
METEOGRAMS
ENSEMBLE DERIVED MOS

CAN BE APPLIED TO VIRTUALLY ALL MODEL AND MODEL DERIVED PARAMETERS. For Example:

- SEVERE WEATHER INDICES
- AVIATION WINDS > THRESHOLD
- SENSIBLE WEATHER ELEMENTS (MODEL DERIVED/INFERRED)
- CIRCULATION INDICES (E.G., BLOCKING)



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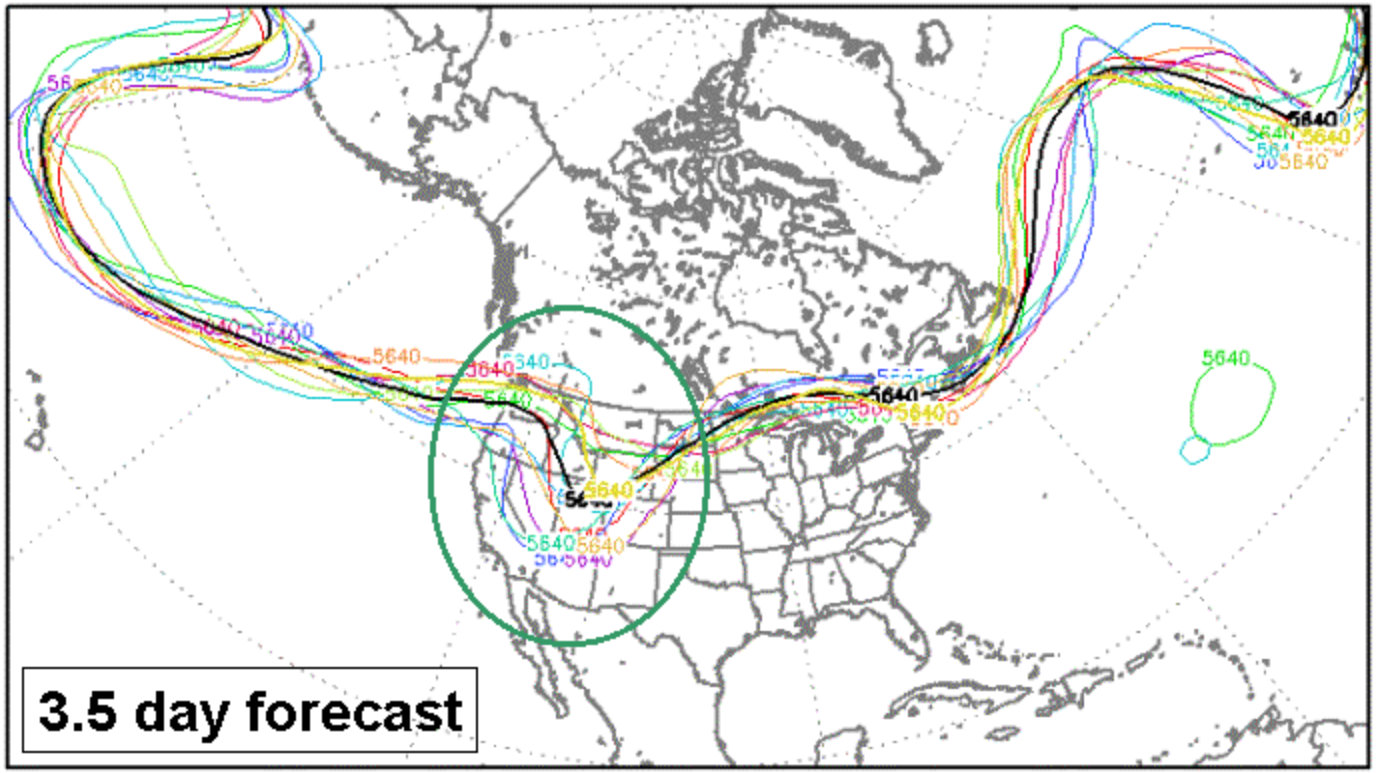
Chaos can reign even in the short-range!

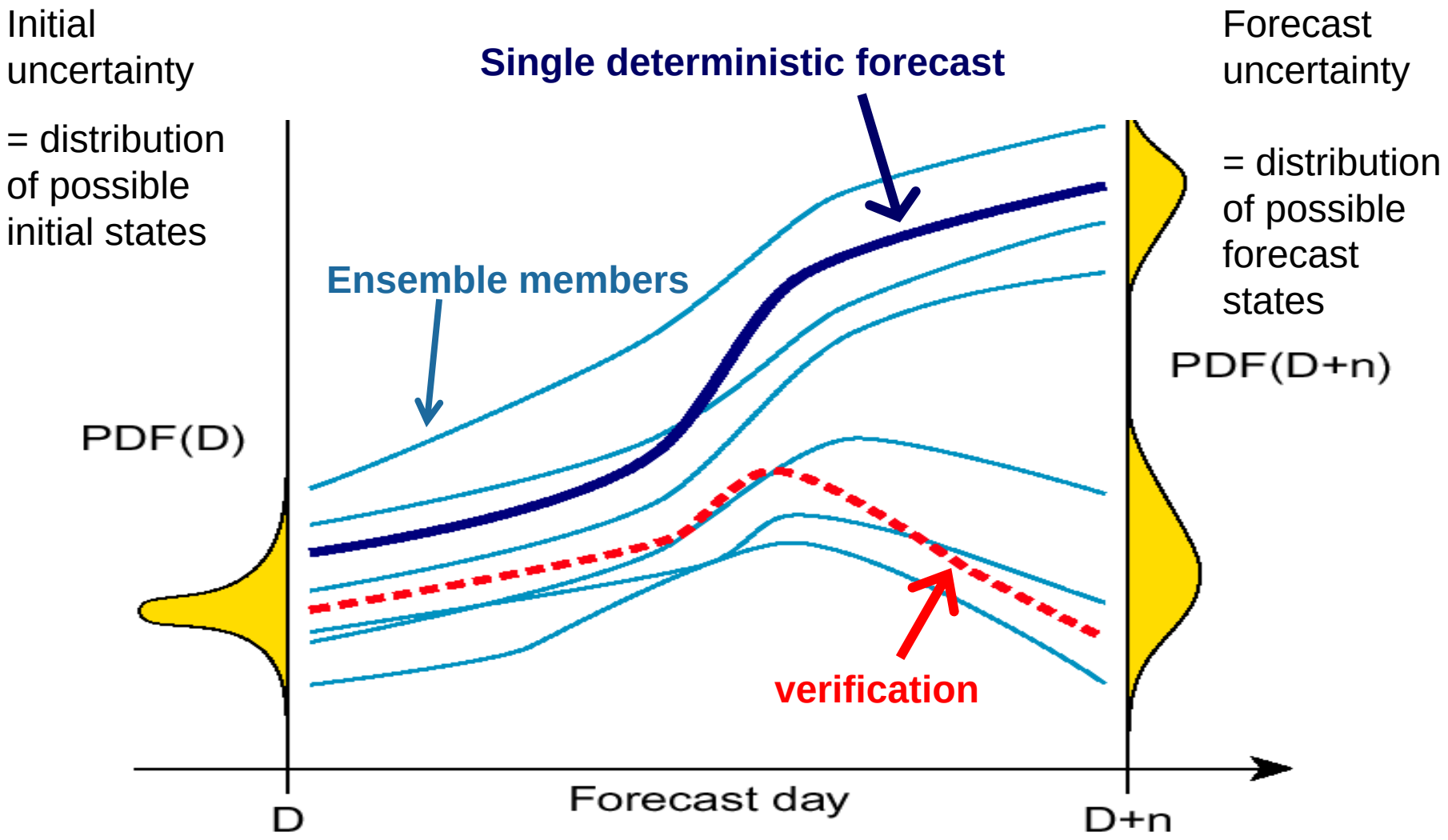
ens mean n1 n4 p2
06z oper run n2 n5 p3 p5
ens cntrl n3 p1 p4

040800 ens run valid 12Z11Apr02, 5640-m ht-hPa

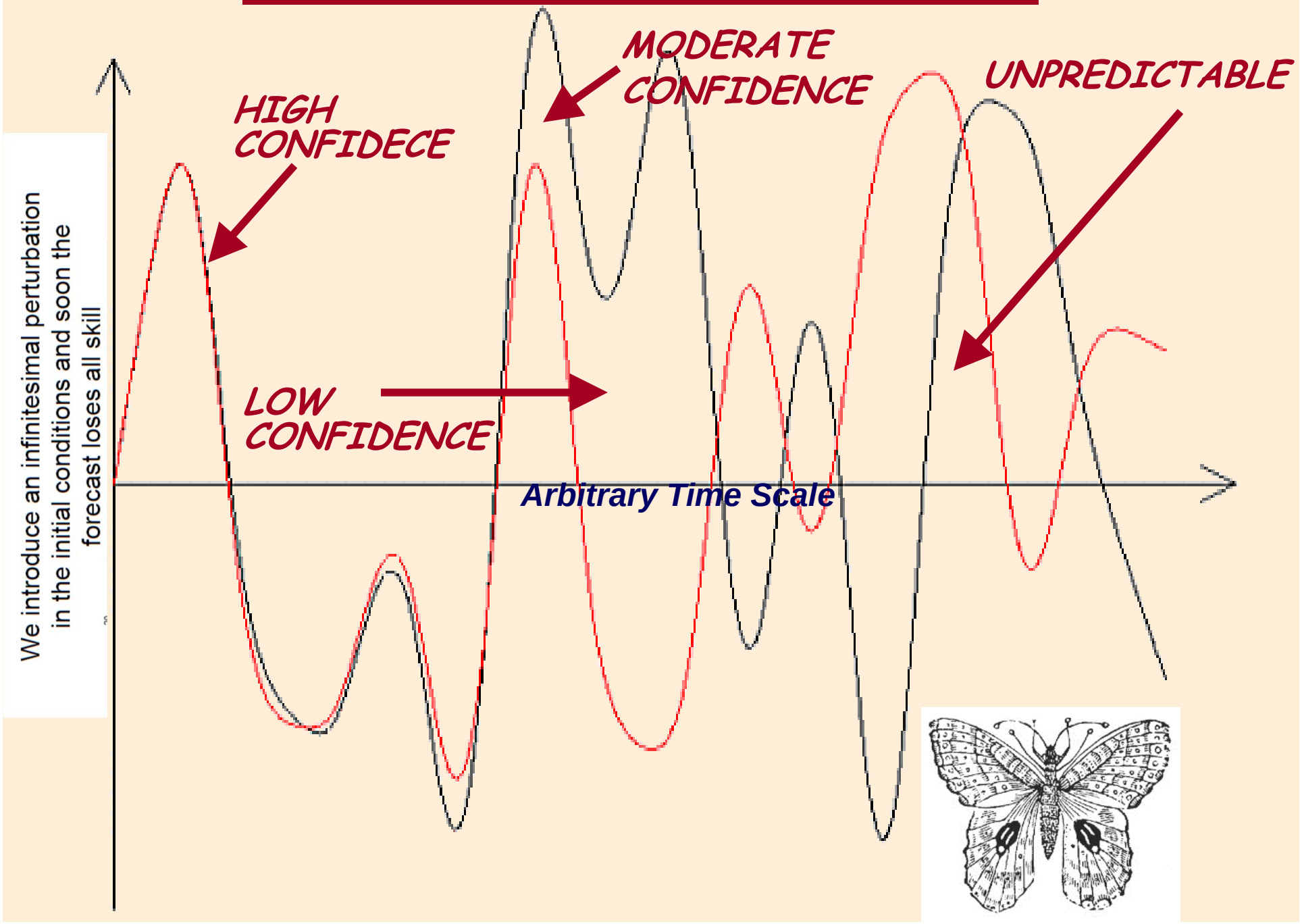


INFO on DISTRIBUTION of SCENARIOS:

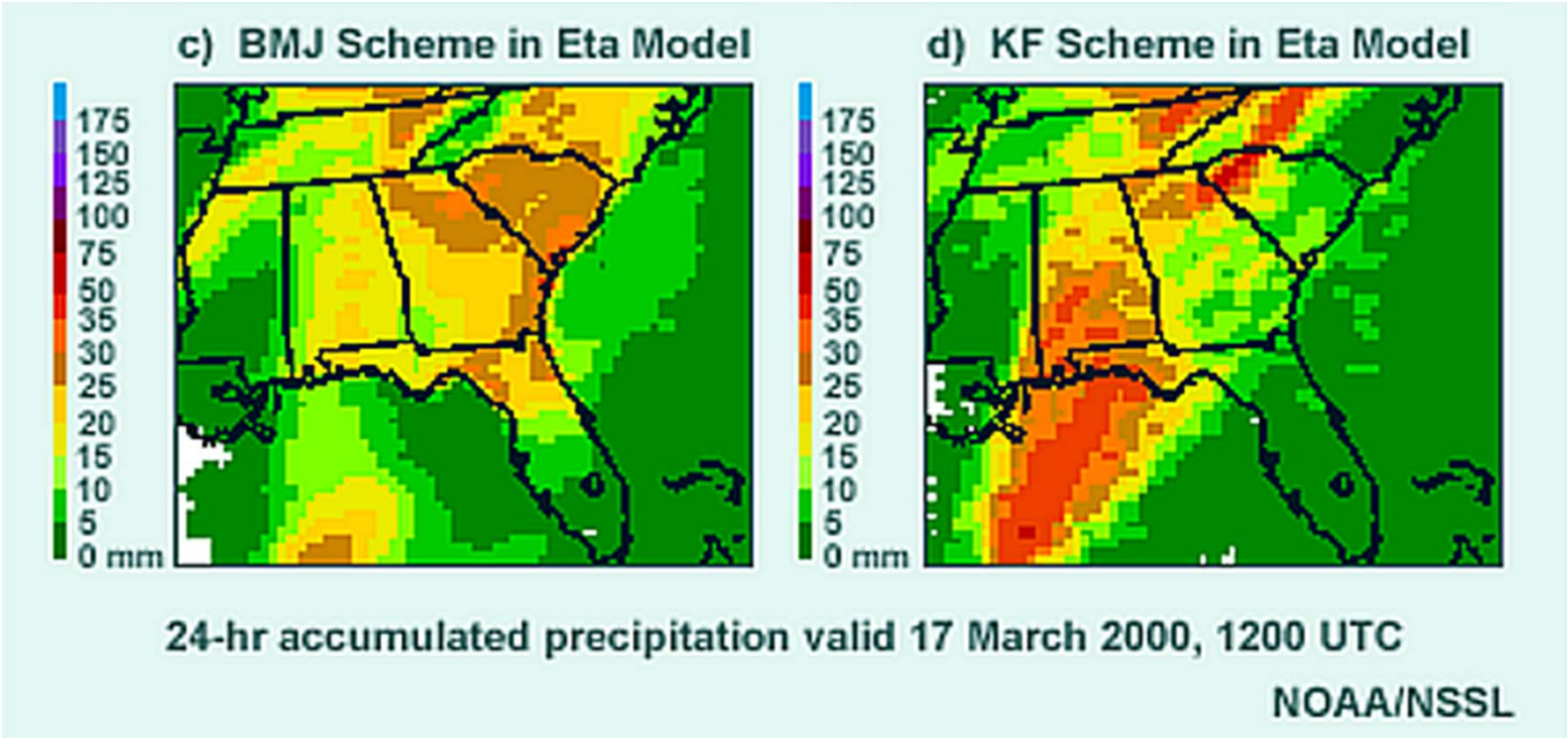
- how many scenarios - how likely is each - how sharply defined is each



BUTTERFLY EFFECT (CHAOS!!)



Uncertainties arise <u>also</u> because models are imperfect!!



Same Deterministic Model with Different Convection Schemes Results In Different Precipitation Forecasts

Completing the Forecast

Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts

Board on Atmospheric Sciences and Climate

What do we want an ensemble prediction system (EPS) to do?

- **Encompass the case dependent range of possible forecast scenarios by region, circulation system, sensible weather elements, etc.**

- **Provide the most skillful forecast probability distribution (PDF) within the range of possibilities**

- **Facilitate the communication of forecast uncertainty to the end-users**

SOME APPLICATIONS

➔ **FORECASTS OF ENSEMBLE MEAN, SPREAD, PROBABILITY DISTRIBUTIONS, ETC. OF ANY MODEL FIELD/PARAMETER OR QUANTITIES DERIVED THEREFROM** ➡

ENHANCES THE UTILITY OF FORECASTS!!!

➔ **IMPROVE DATA ASSIMILATION SYSTEMS**

➔ **ADAPTIVE/TARGETED OBSERVATIONS**

➔ **DATA SETS FOR FUNDAMENTAL RESEARCH ON PREDICTABILITY ISSUES**

How do we find the initial condition "errors" that will grow?

- **Singular vectors (ECMWF)**
  - **Seeks out non-linear growing atmospheric modes**
- **"Breeding" method for initial condition perturbations (NCEP, Toth and Kalnay, 1993)**
  - **Works out mathematically and practically to be roughly equivalent to singular vector method, but at a much lower cost**

Short-Range Ensemble Forecasts (SREF)

What?

- 5 Eta 48 km (control + 2 perturbation pairs)
- 5 Regional Spectral Model 48 km (control + 2 perturbation pairs)
  [RSM has old AVN/MRF physics, not upgraded version]
- 5 Eta members using Kain-Fritsch convective parameterization
- "Soon" 5 RUC members will be added
- "Soon"? 5 ARPS (CAPS at Oklahoma) members may be added

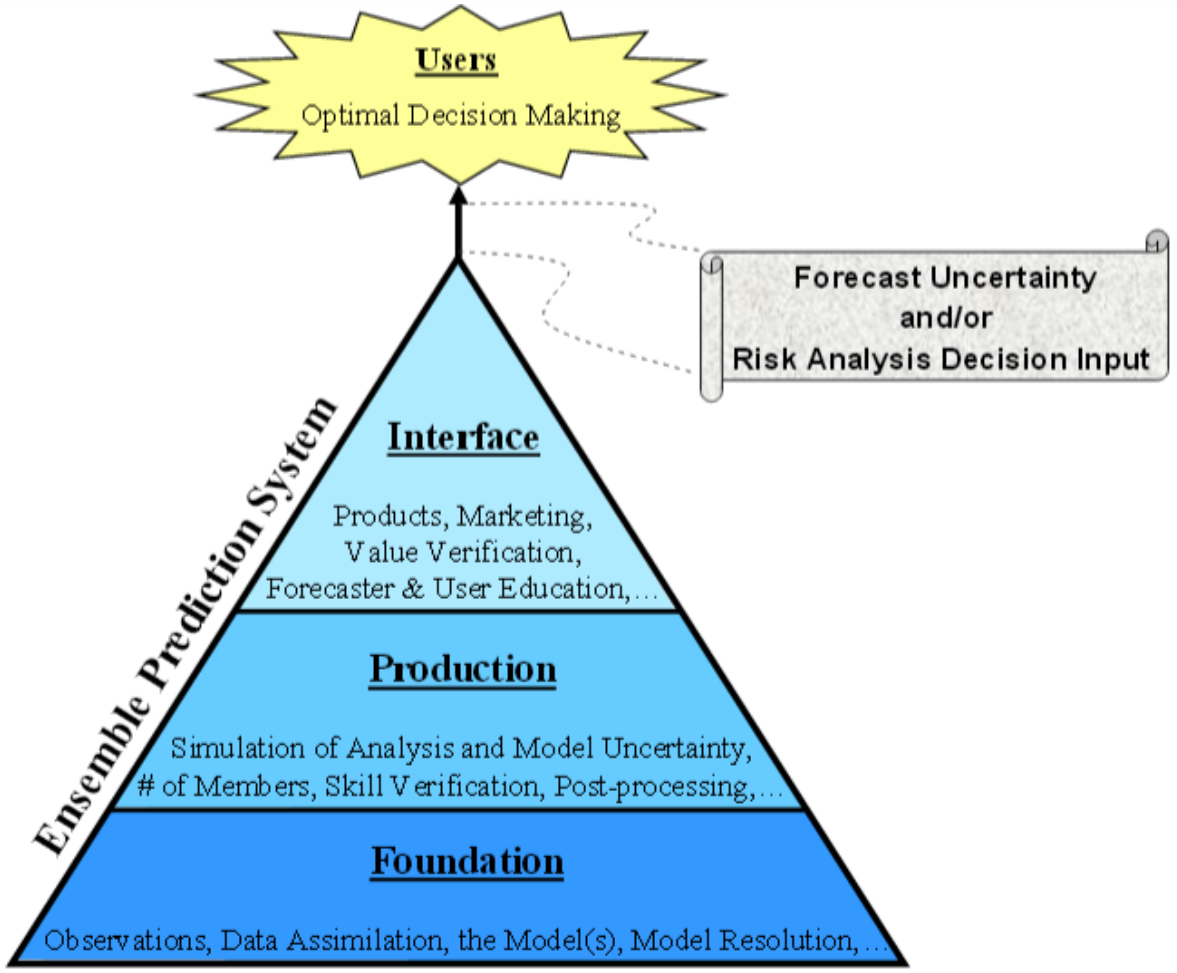
When?

- 21, 09 UTC in time for your use with 00, 12 UTC Eta to 63 hours

Status?

- To become officially operational NWS-wide fall 2002
- Output might get into AWIPS sometime in 2003
- New user-friendly web interface linked from SREF home page, which is http://wwwt.emc.ncep.noaa.gov/mmb/SREF/SREF.html

National Mesoscale Probabilistic Prediction:
Status and the Way Forward
A White-Paper Report from the *National Workshop on Mesoscale Probabilistic Prediction*,
23-24 September 2009



igure 1. Schematic of an ensemble prediction system and its focus on supporting user decision making.

MON. A.M.

SUN. A.M.

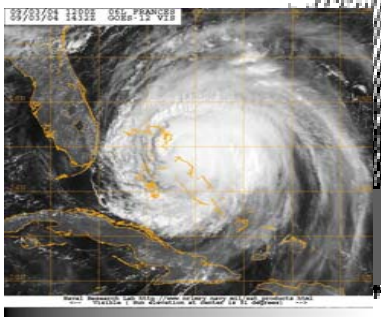
NOW WHAT??

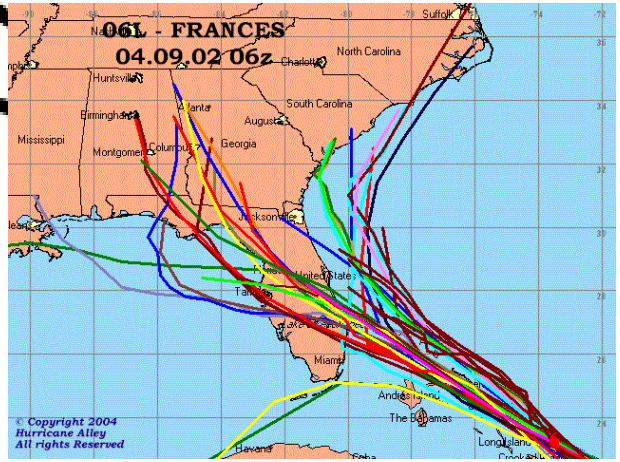
SAT. A.M.

FRI. A.M.

STORM TRACK

FORECASTER





ENSEMBLE PREDICTION –

From early 90's on, revolutionary change in the thrust of operational NWP *("Wave of the Future")*

Provides objective information on case dependent forecast uncertainties from the spread (diversity) amongst ensemble members

USED TO:

Ascertain most likely deterministic prediction

Confidence in deterministic forecast

Same, plus identifying relative likelihood of alternative scenarios

Full probability distribution – maximum information

NET RESULT –

Capability to enhance utility/value of NWP for virtually all user applications by incorporating uncertainties in risk analysis and decision making

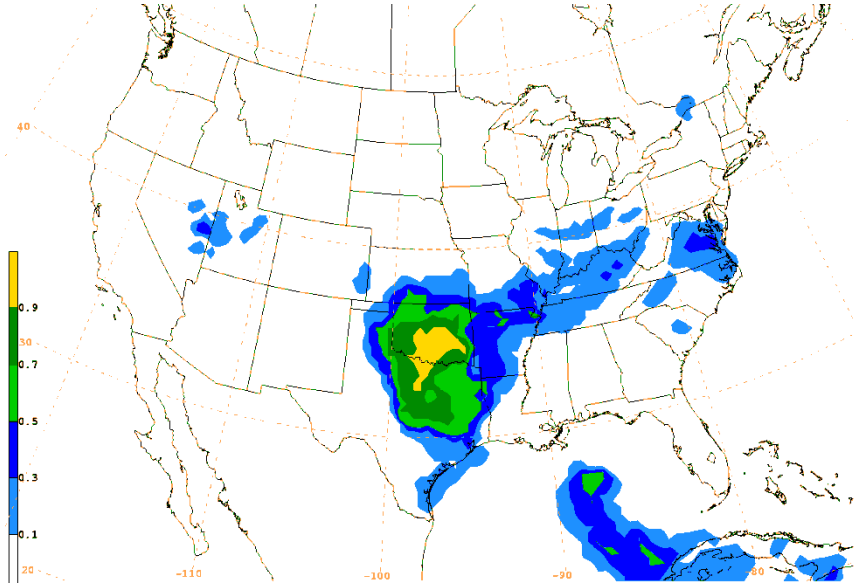
Especially important for high impact events (AVOID SURPRISES)

Looking back: Successes

Major advances in research and development of ensemble based global and regional NWP systems and strategies

Demonstrated "*enabling*" capabilities and prospective value
Identified limitations and outstanding challenges

Development of "*user friendly*" products and applications



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Looking back: Successes

Major advances in research and development of ensemble based global and regional NWP systems and strategies

Demonstrated capabilities and prospective value
Identified limitations and outstanding challenges

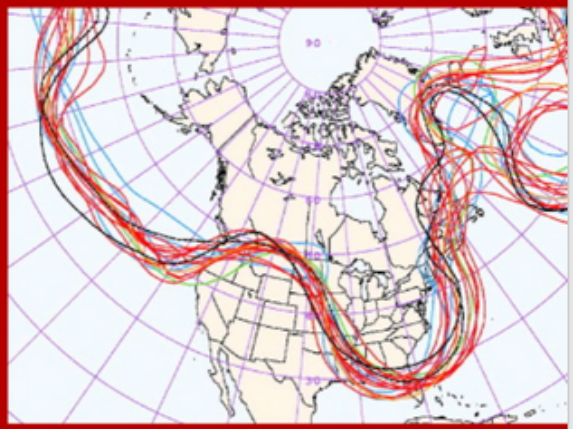
Development of "*user friendly*" products and applications

Education and training of essential concepts, rational and use of ensembles

Requires paradigm shift (a.k.a. "culture change") from "*deterministic thinking*" (single best forecast) to dealing with case dependent array of possible outcomes (uncertainty)

Eugenia Kalnay

Atmospheric modeling, data assimilation and predictability



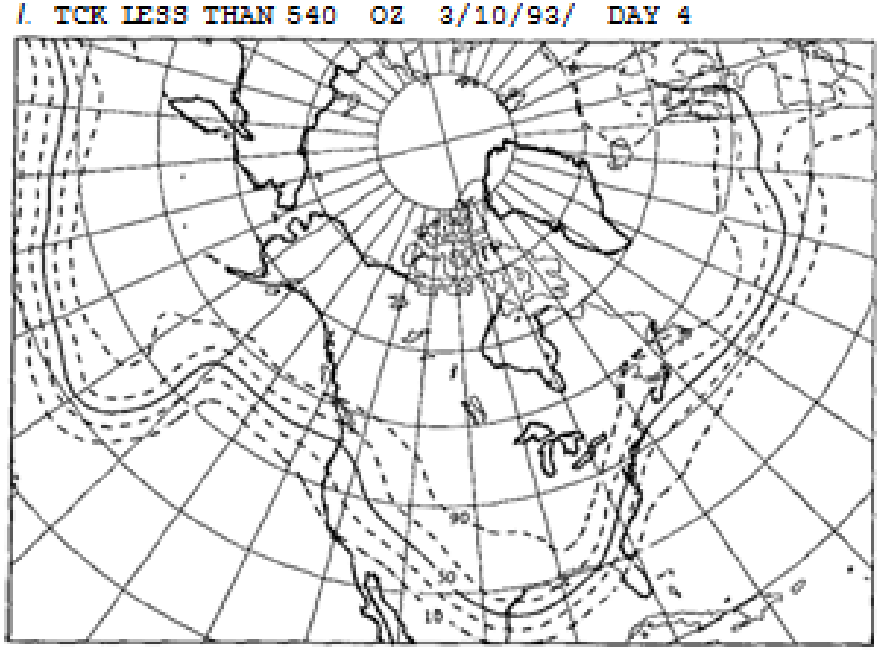


FIG. 14. Forecast probability from 10 March 1993 for the 1000/500-mb thickness to be less than 540 dam on 14 March 1993. Operationally, the 50% line is viewed generally as the line of equal chance for rain versus snow.

The Advancement of Weather Forecasting from an Art to a Science: Today's Prediction Capability of Extreme Weather, Short-term Climate and Water Events

Dr. Louis W. Uccellini
Director
National Centers for Environmental Prediction

The Future is Now!
Extending Prediction Capabilities into Decision Support Services

- Need to Quantify Uncertainty
- Introduction of Ensemble Forecasting

The NRC report (Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts) provi des the rati onal e, j usti f i cati on and, to a l arge extent, the broad conceptual means for the NWS to move forward proacti vel y wi th i ts partners to cl ose the gap between exi sti ng and i mprovi ng capabi l i ti es and thei r practi cal appl i cati ons i n deal i ng wi th forecast uncertai nty. It i s a l oud and cl ear cl ari on cal l to acti on.