HYDROLOGIC APPLICATIONS FOR THE NORTH AMERICAN ENSEMBLE FORECAST SYSTEM (NAEFS)

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OUTLINE

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- IMPLEMENTATION SCHEDULE
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- BASIC PRODUCTS
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- FUTURE EXPANSION
- NEW NWP PARADIGM

NAEFS ORGANIZATION

Meteorological Service of Canada MSC	***National Weather Service, USA NWS***
PROJECT OVERSIGHT	
Michel Beland, Director, ACSD	Louis Uccellini (Director, NCEP/NWS)
Pierre Dubreuil, Director, AEPD	Greg Mandt (Director, OST/NWS)
Jim Abraham, MRB	Steve Lord, EMC
PROJECT CO-LEADERS	
Louis Lefaivre (Implementation)	Zoltan Toth (Science)
Gilbert Brunet (Science)	David Michaud / Brent Gordon (Impl.)
JOINT TEAM MEMBERS	
Meteorological Research Branch MRB	*Environmental Modeling Center EMC*
Peter Houtekamer, Herschel Mitchell,	Bo Cui, Richard Wobus, Yuejian Zhu
Lawrence Wilson	*NCEP Central Operations NCO*
	HPC Peter Manousos
Canadian Meteorological Center CMC	*NCO* Scott Jacobs
Yves Pelletier, Gerard Pellerin,	*Climate Prediction Center CPC*
Richard Verret, Alain Patoine,	Ed O'Lenic,Mike Halpert, David Unger
Manon Lajoie	*NWS* Richard Grumm, Fred Branski

National Meteorological Service of Mexico (NMSM) joined in Nov. 2004

Acknowledgements to: J. Whitaker, T. Hamill, Y. Gel

PROJECT DESCRIPTION

International project to produce operational multi-center ensemble products

- Combines global ensemble forecasts from Canada & USA
  - 40+ members per cycle, 2 cycles per day from MSC & NWS
    - 6-hourly output frequency (instead of current 12-hourly)
    - Replaces current 26 members once a day setup

- Generates products for
  - Intermediate users
    - E.g., weather forecasters at NCEP Service Centers (US NWS)
  - Specialized users
    - E.g., hydrologic applications in all three countries
  - End users
    - E.g., forecasts for public distribution in Canada (MSC) and Mexico (NMSM)

- Prototype ensemble component of THORPEX Global Interactive Forecast System (GIFS)
  - Operational outlet for THORPEX research using THORPEX Interactive Grand Global Ensemble (TIGGE) archive

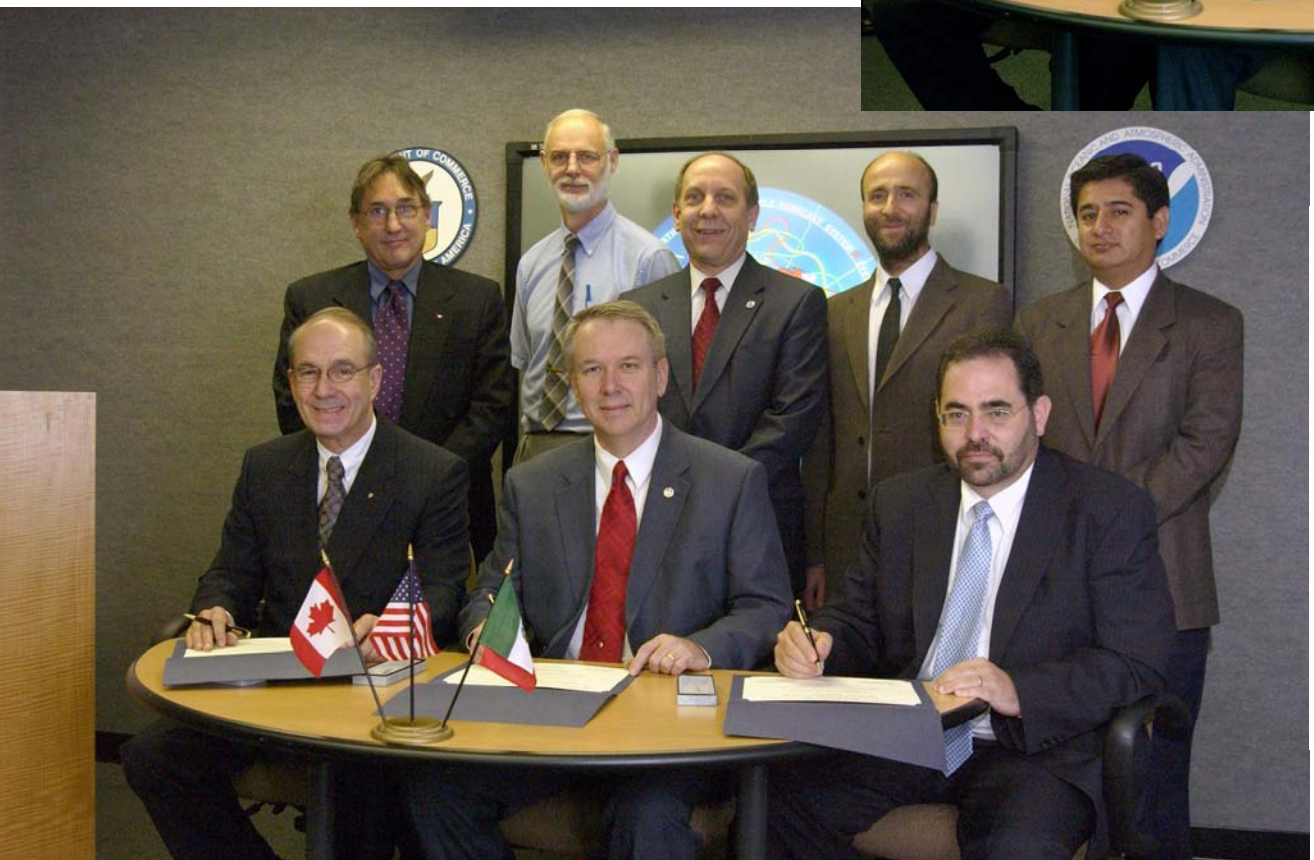
ANTICIPATED BENEFITS

- Improves probabilistic forecast performance
  - Earlier warnings for severe weather
    - Lower detection threshold due to more ensemble members
    - Uncertainty better captured via analysis/model/ensemble diversity
- Provides Seamless suite of forecasts across
  - International boundaries
    - Canada, Mexico, USA
  - Different time ranges (1-14 days)
- Saves development costs by
  - Sharing scientific algorithms, codes, scripts
    - Accelerated implementation schedule
    - Low-cost diversity via multi-center analysis/model/ensemble methods
  - Exchanging complementary application tools
    - MSC focus on end users (public)
    - NWS focus on intermediate user (forecaster)
- Saves production costs by
  - Leveraging computational resources
    - Each center needs to run only fraction of total ensemble members
  - Providing back-up for operations in case of emergencies
    - Use nearly identical operational procedures at both centers to provide basic products
    - Offers as default basic products based on unaffected center's ensemble

PROJECT HISTORY & MILESTONES

- February 2003, Long Beach, CA
  - NOAA / MSC high level agreement about joint ensemble research/development work (J. Hayes, L. Uccellini, D. Rogers, M. Beland, P. Dubreuil, J. Abraham)
- May 2003, Montreal (MSC)
  - 1st NAEFS Workshop, planning started
- November 2003, MSC & NWS
  - 1st draft of NAEFS Research, Development & Implementation Plan complete
- May 2004, Camp Springs, MD (NCEP)
  - Executive Review
- September 2004, MSC & NWS
  - Initial Operational Capability implemented at MSC & NWS
- November 2004, Camp Springs
  - ***Inauguration ceremony & 2nd NAEFS Workshop***
    - Leaders of NMS of Canada, Mexico, USA signed memorandum
    - 50 scientists from 5 countries & 8 agencies
- March 2006, MSC & NWS
  - 1st Operational Implementation
    - Bias correction
    - Climate anomaly forecasts
- March 2007, 2008, MSC, NWS
  - Follow-up implementations
    - Improved and expanded product suite

INAUGURATION CEREMONY



The National Oceanic and Atmospheric Administration
of the United States,

The Meteorological Service of Canada and

The National Meteorological Service
of Mexico

Recognizing the importance of scientific and technical international cooperation in the field of meteorology for the development of improved global forecast models;

Considering the great potential of model diversity to increase the accuracy of one to fourteen day probabilistic forecasts;

Noting the significant international cooperation undertaken to develop and implement an operational ensemble forecast system for the benefit of North America and surrounding territories;

The signatories, hereby inaugurate the North American Ensemble Forecast System at Camp Springs, Maryland, USA, on this 16th Day of November 2004.

Brig. Gen. David L. Johnson, USAF (Ret.)
National Oceanic and Atmospheric Administration
Assistant Administrator for Weather Services

Dr. Marc Denis Durnil
Assistant Deputy Minister
Meteorological Service of Canada

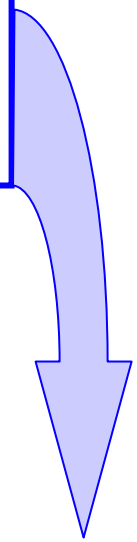
Dr. Michel Rivergaux
Head of Unit
National Meteorological Service of Mexico

TENTATIVE IMPLEMENTATION SCHEDULE

- March 2006
  - 1st NAEFS product suite
    - NCEP operational web pages (incl. Caribbean & South American products)
      - "Experimental" status for first 60 days
    - NAWIPS grids for NCEP service centers
    - NDGD grids
- Feb 2006
  - Bias correction, Weighting, Climate anomaly (BWC) algorithms
- Dec 2005
  - BWC Codes/scripts delivered to NCO
- Nov 2005
  - Operational data exchange established
- Oct 2005
  - BWC Codes/algorithms exchanged between MSC-NCEP
- Sept 2005
  - Decision regarding BWC & Product implementation details

CONCEPT OF OPERATIONS

1. Exchange ~50 selected variables
   - Use GRIB2 to reduce volume of data
2. Generate basic products using same algorithms/codes
   - Reduce systematic error
     - Bias estimation
   - Combine two ensembles
     - Determine weights
   - Express forecast in terms of climatological anomalies
     - Prepare & compare forecast with reanalysis climate distribution
3. Generate center-specific end products
4. Evaluate & provide feedback for improvements
   - Verification using same algorithms
   - User feedback



2. MSC-NCEP basic production suite
   - Same algorithms/codes used at both centers
     - Duplicate procedures provide full backup in case of problems at either end
     - If one component of ensemble missing, products based on rest of ensemble
   - Basis for different sets of center-specific end products
     - Ensures consistency between end products even if their format is different
   - All basic products to be made available via ftp to user and research community

BASIC PRODUCTS

- NAEFS basic product list
  - Bias corrected members of joint MSC-NCEP ensemble
    - 40 members, NAEFS variables, GRIB2
    - Bias correction against each center's own operational analysis
  - Weights for each member for creating joint ensemble
    - 40 members, NAEFS variables, GRIB2
    - Weights depend on geographical location (low precision packing)
  - Climate anomaly percentiles for each member
    - 40 members, NAEFS variables, GRIB2
    - Non-dimensional unit, allows downscaling of scalar variables to any local climatology

- Issues – Products to be added in future years
  - No bias correction on precipitation (& possibly on few more problematic vars.)
    - *Need reliable and bias-free satellite-based analysis of precipitation rates*
      - Collaborators needed – CPC, NESDIS?
  - Climate anomalies provided for 15 most frequently used variables
    - Need to process reanalysis data to describe climatology for rest of variables

END PRODUCTS

- End product generation
  - Can be center specific
  - Need to conform with procedures/requirements established at different centers
- End products generated at NCEP
  - Based on prioritized list of requests from NCEP Service Centers
    - Graphical products (including Caribbean, South American, and AMMA areas)
      - NCEP official web site (gif)
      - NCEP Service Centers (NAWIPS metafile)
    - Gridded products
      - NAWIPS grids
        - » NCEP Service Centers
      - GRIB2 format
        - » Products of general interest (Possible ftp distribution, no decision yet on products)
        - » NDGD (10-50-90 percentile forecast value + associated climate percentile)
- End products generated at MSC
  - TBD
- End products generated jointly
  - Experimental probabilistic Week-2 forecast
    - Fully automated, based on basic products: bias corrected, weighted climate anomalies
      - Can become official product once performance reaches current operational level

DETAILS

- Data exchange
  - Coordination needed with Yves Pelletier from MSC (Brent Gordon)
    - Switch to GRIB2 format
    - New file structure (files containing NAEFS variables only)
    - Operational transmission arrangements
      - NCEP pushes its data to MSC
- Basic products
  - Bias correction (Bo Cui, Dave Unger)
    - First moment method works, accepted for use by both parties
    - Second moment correction
      - Moment adjustment & Bayesian Model Averaging, BMA methods to be compared
      - May or may not be included in 1st operational implementation
  - Weighting (Bo Cui, Dave Unger)
    - Skill, Ridging, BMA methods to be compared
  - Climate anomalies (Yuejian Zhu)
    - Detailed algorithm to be developed
- End product generation
  - One stream to generate multiple product formats (Dave Michaud)
    - Start with highest priority items from prioritized list from Service Centers (Z. Toth)
    - Required NAWIPS tools ready by Sept & Dec 2005 (Maxine Brown)
    - Default graphical setup to be developed & JIF'd for web display (Maxine Brown)
    - NAWIPS graphical products using web default display (Dave Michaud)
    - NAWIPS & GRIB2 product generation as part of one product stream (Dave Michaud)

DETAILS - 2

- Product distribution
  - NAEFS basic products (Brent Gordon)
    - 3 new data sets, in addition to raw NCEP global ensemble data
      - Use GRIB2, low precision (for weights & climate anomalies) to control resource requirements
    - Must be made available via ftp for
      - Community use
        - » Real time forecasts
        - » Archive for research (THORPEX-TIGGE)
      - Backup in case of problem at either generating center
    - Resource implications
      - ***HPSS disc storage***
      - Ftp servers
        - » ***NCDC is to post & keep ensemble data?***
  - NAEFS end products
    - Supercede current global ensemble products based on NCEP ensemble only
      - As NAESF products are introduced, they replace current NCEP products
    - NCEP official web site
      - Public
      - NAEFS partners/users
        - » Central & South America
        - » Africa (AMMA)
        - » Polar regions (IPY)
        - » ***HEPEX – What special hydrological information?***

FUTURE IMPLEMENTATIONS

- Add missing and newly developed
  - Basic products, eg
    - Bias-corrected precipitation
    - Climate anomalies for most variables
    - Generate/use of new reforecast ensemble data set? (AWFA, CDC collaboration)
  - End products, eg
    - Wind speed, direction

- Incorporate ensemble data from other centers
  - FNMOC
  - UKMet

- Unified evaluation/verification procedures

- Strengthen relationship with THORPEX
  - Consider further expanding system
    - Possible redesign?
      - Stronger link with smaller group of partners
      - Looser collaboration with others

EXPANSION OF NAEFS

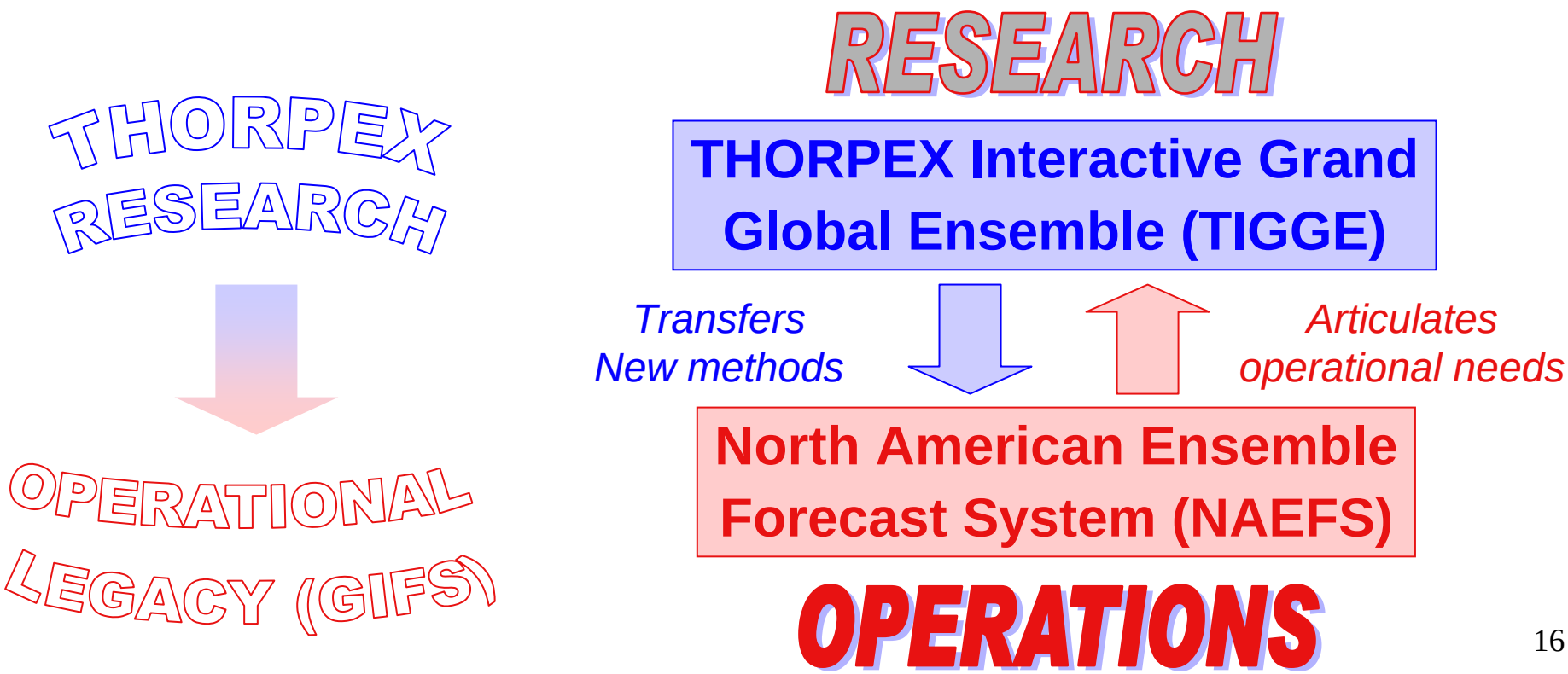
- Discussions with other centers for expansion of NAEFS
  - Experimental status - March 2006
  - Operational status – 2007-2008
    - UKMet – Agreement
    - FNMOC, AFWA – Expert discussions
      - Need to formalize, use operational centers' forum (COPC)
      - Product distribution
  - Issues
    - Name change from NAEFS to Global Ensemble Prediction System (GEPS)
    - ***Disc space requirements will grow***

- Other centers that expressed interest in learning more about NAEFS
  - ECMWF, NCMRWF, JMA, KMA

- Link with THORPEX Interactive Grand Global Ensemble (TIGGE)
  - THORPEX research organized in 4 science Working Groups
    - TIGGE data base supports ensemble-related research
  - NAEFS – GEPS provides
    - Testing in and transition to operational use
    - Real time forecast data for demonstration projects

NAEFS & THORPEX

- Expands international collaboration
  - Mexico joined in November 2004
  - UK Met Office to join in 2006
- Provides framework for transitioning research into operations
  - Prototype for ensemble component of THORPEX legacy forecst system:
    Global Interactive Forecast System (GIFS)



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	**Sept 2004**	**June 2004**
Precip type	**Sept 2004**	**Precip type**
T_{max}	**June 2004**	**2m**
T_{min}	**June 2004**	**2m**
WAM	**2005-2006**	**2005-2006**

Black : data exchanged in early 2004
Blue : items added to CMC and NCEP production by July 2004
Red : items added to CMC production by October 2004
Green: items in development (CMC) and testing (NCEP) by June 2005

ENSEMBLE PRODUCTS - FUNCTIONALITIES

List of centrally/locally/interactively generated products required by NCEP Service Centers for each functionality are provided in attached tables (eg., *MSLP, Z,T,U,V,RH, etc, at 925,850,700,500, 400, 300, 250, 100, etc hPa)*

	FUNCTIONALITY	***CENTRALLY GENERATED***	***LOCALLY GENERATED***	***INTERACTIVE ACCESS***
1	Mean of selected members *Done*			
2	Spread of selected members *Done*			
3	Median of selected values *Sept. 2005*			
4	Lowest value in selected members *Sept. 2005*			
5	Highest value in selected members *Sept. 2005*			
6	Range between lowest and highest values *Sept. 2005*			
7	Univariate exceedance probabilities for a selectable threshold value *FY06?*			
8	Multivariate (up to 5) exceedance probabilities for a selectable threshold value *FY06?*			
9	Forecast value associated with selected univariate percentile value *Sept. 2005 - FY06?*			
10	Tracking center of maxima or minima in a gridded field (eg – low pressure centers) *Sept. 2005, Data flow FY06?*			
11	Objective grouping of members *FY08?*			
12	Plot Frequency / Fitted probability density function at selected location/time (lower priority) *FY07?*			
13	Plot Frequency / Fitted probability density as a function of forecast lead time, at selected location (lower priority) *FY07?*			

Additional basic GUI functionalities:

- Ability to manually select/identify members
- Ability to weight selected members *Sept. 2005*

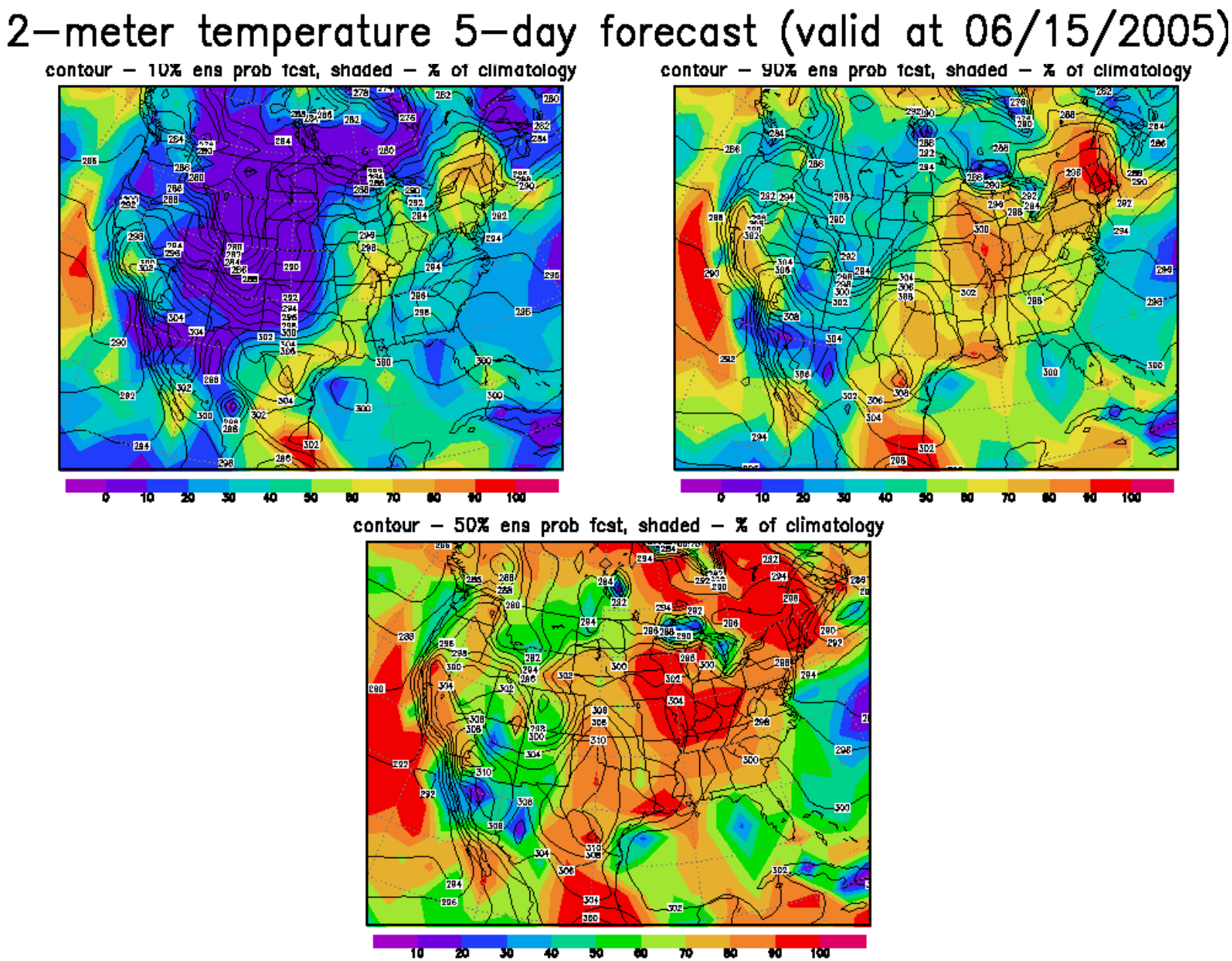
Potentially useful functionalities that need further development:

- Mean/Spread/Median/Ranges for amplitude of specific features
- Mean/Spread/Median/Ranges for phase of specific features

ENSEMBLE PRODUCT REQUEST LIST FROM NCEP SERVICE CENTERS - *EXCERPT*

PR	FUNCTIONALITY	CENTRALLY MADE PRODUCTS	CENTER
1	Mean of selected members (Web)	Z: 500mb, 700mb, 850mb	**HPC,SPC,OPC,TPC**
2		T (K): 500, 700, 750, 800, 850, 900mb	**HPC,OPC,TPC**
2		Wind: 250, 500, 700, 850mb	**HPC,OPC,TPC**
3		Z: 250mb	**HPC,SPC**
3		MSLP	**OPC,TPC**
3		T (K): 925, 300, 250, 200mb	**OPC,TPC**
3		Wind: 10m, 925, 300, 200mb	**OPC,TPC**
4		Z: 925mb	**SPC**
4		Trop Height	**AWC**
4		Climatological mean 500 mb heights	**SPC**
4		Climo variance in 500 mb heights	**SPC**
4		1000-500 mb thickness	**SPC**
4		pmsl	**HPC**
4		pmsl ≤1000mb, 980, 960	**SPC**
4		Trop Temp	**AWC**
4		T (K): BL	**HPC**
4		T (F): 2m (≥ 70)	**SPC**
4		T 850 (C): ≤2 , ≤ 0 , ≤ -2	**SPC**

ENSEMBLE 10-, 50- (MEDIAN) & 90-PERCENTILE FORECAST VALUES (BLACK CONTOURS) AND CORRESPONDING CLIMATE PERCENTILES (SHADES OF COLOR)



BACKGROUND

NOAA SERVICE GOAL: ACCELERATE IMPROVEMENTS IN 3-14 DAY FORECASTS

NOAA SCIENCE OBJECTIVE: REVOLUTIONIZE NWP PROCESS

TRADITIONAL NWP

Each discipline developed on its own

Disjoint steps in forecast process

Little or no feedback

One-way flow of information

Uncertainty in process ignored

NEW NWP

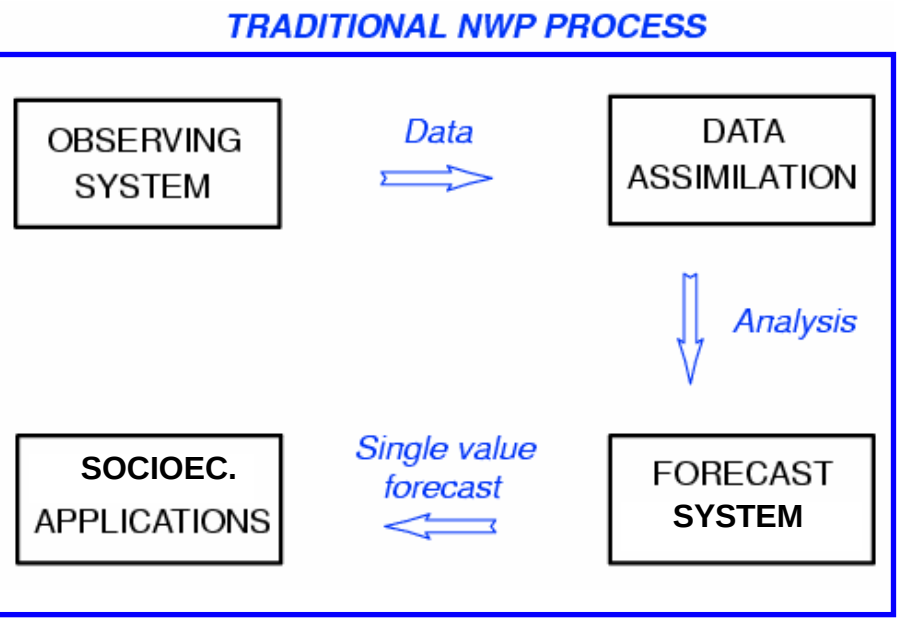
Sub-systems developed in coordination

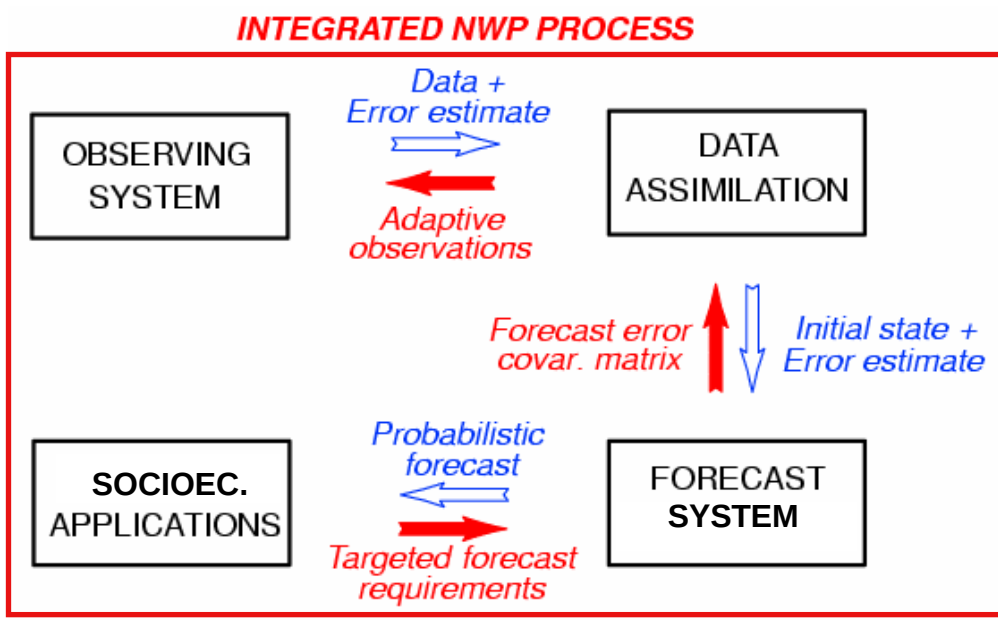
End-to-end forecast process

Strong feedback among components

Two-way interaction

Error/uncertainty accounted for





INTEGRATED, ADAPTIVE, USER CONTROLLABLE

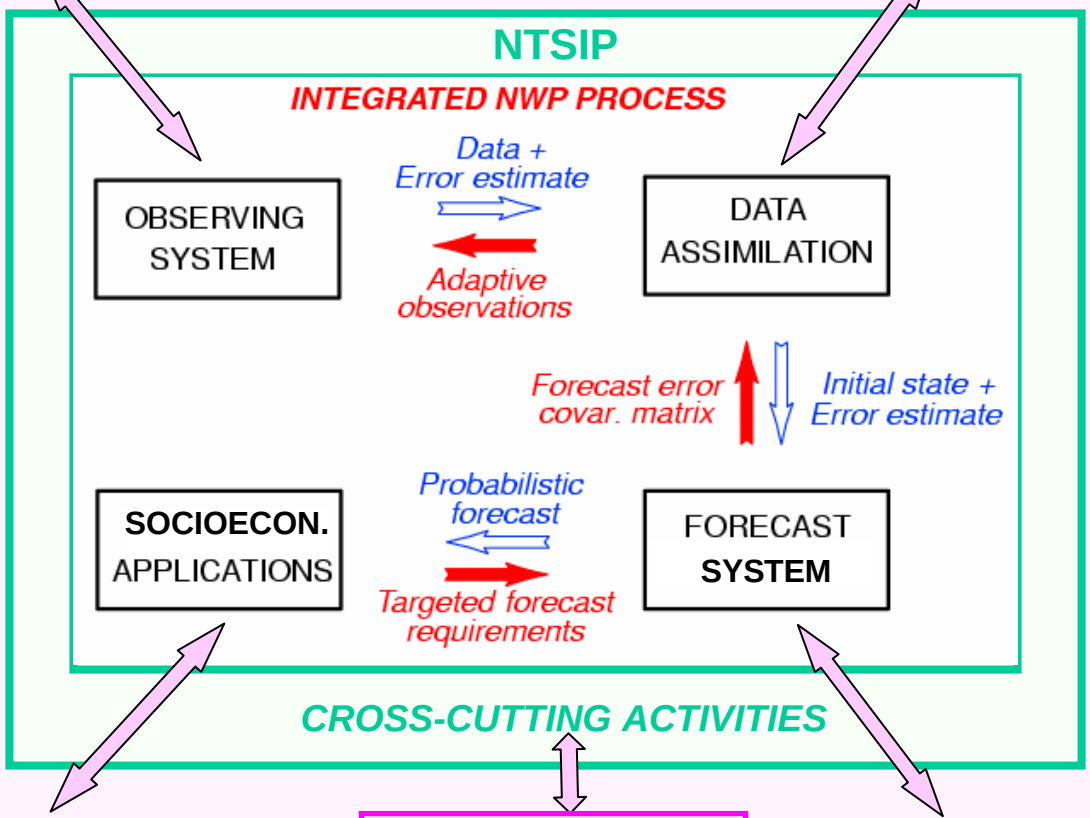
DIRECT LINK BETWEEN

NOAA THORPEX SCIENCE AND IMPLEMENTATION PLAN *(NTSIP-2002)* AND THORPEX INTERNATIONAL SCIENCE PLAN & THORPEX IMPLEMENTATION PLAN *(TIP)*

TIP

TIP – "OBSERVING SYSTEM"

TIP – "DATA ASSIMILATION…"

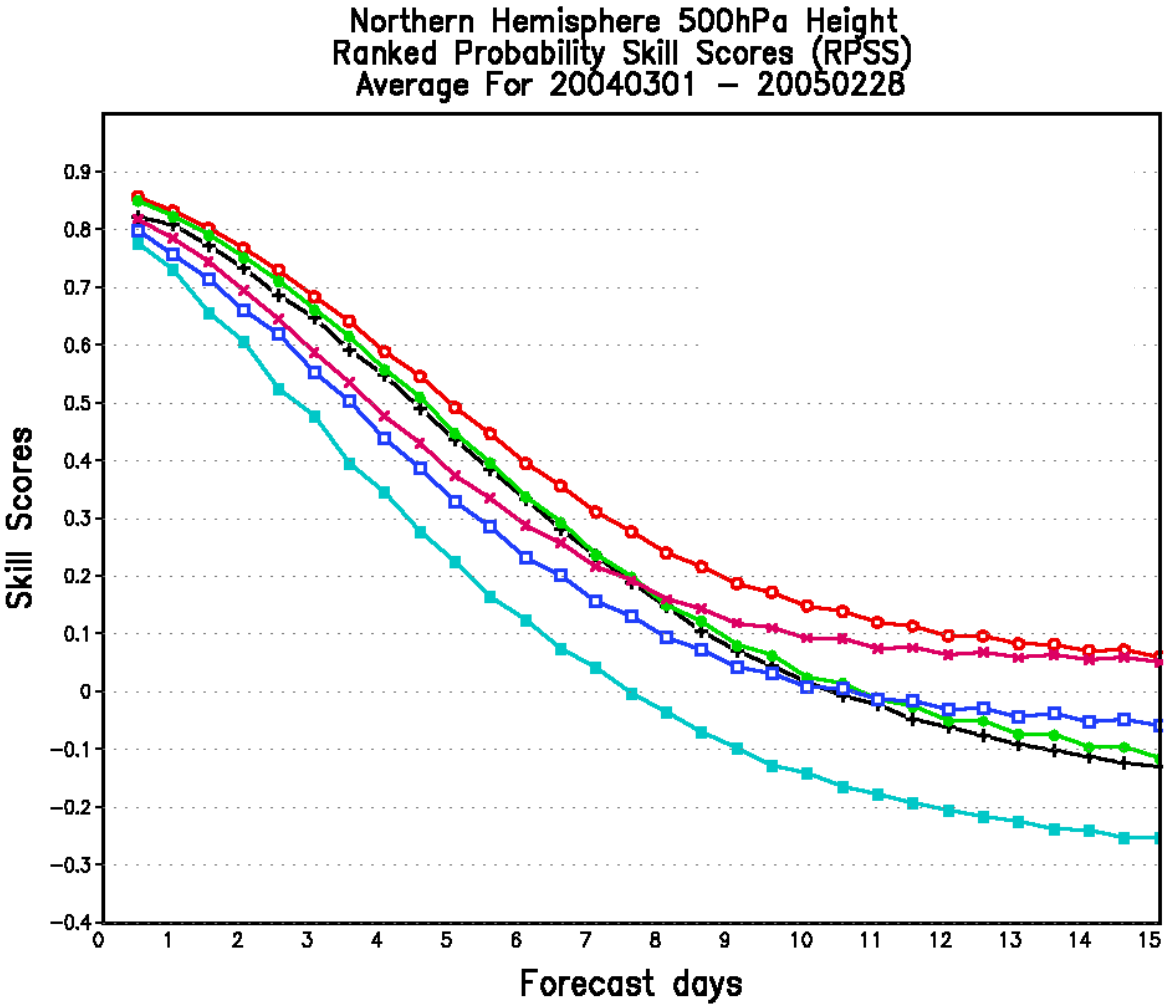


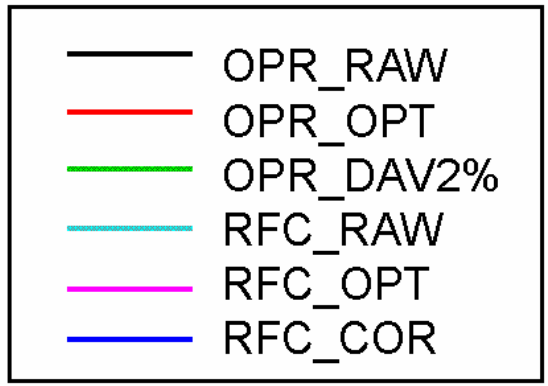
TIP – "SOCIAL & ECONOMIC APPLICATIONS"

GLOBAL INTERACTIVE FORECAST SYSTEM (GIFS)

TIP – "PREDICTABILITY & DYNAMICAL PROCESSES"

RPSS: 500 mb Height, Northern Hemisphere
March 2004 – February 2005





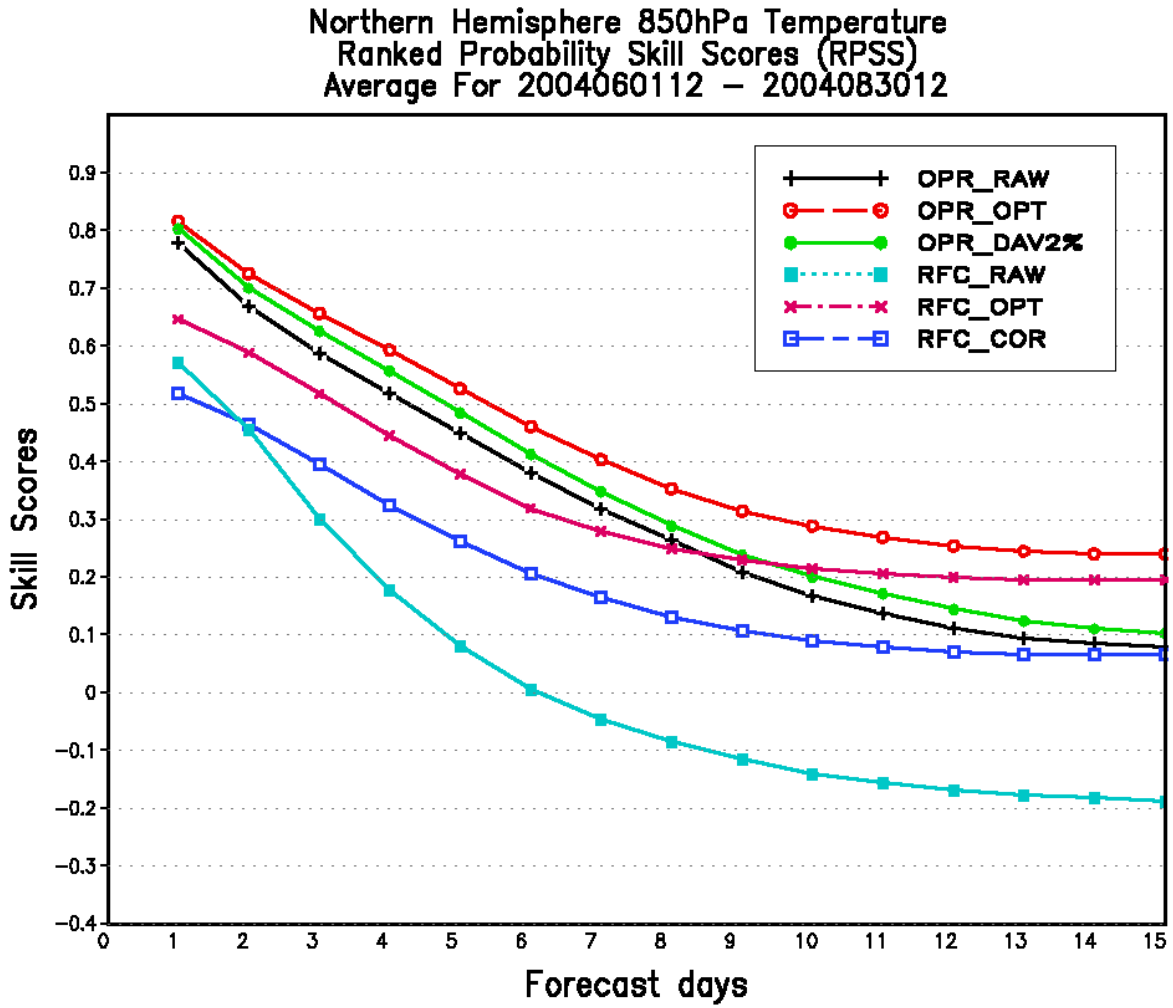
OPR_DAV2%

RPSS improved for all lead time

RFC_COR

significant improvement for all lead time vs. RFC_RAW

RPSS: 850 mb Temperature, 2004 Summer Northern Hemisphere




NORTH AMERICAN ENSEMBLE FORECAST SYSTEM
SYSTÈME DE PRÉVISION D'ENSEMBLE NORD-AMÉRICAIN
SISTEMA CONJUNTO DE PRONÓSTICOS DE AMÉRICA DEL NORTE