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

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 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

OVERALL ISSUES / *RECOMMENDATIONS*

- *Enhance coordination of ensemble-related efforts*
  - Among NCO Service Center users
  - Between users and NCO / EMC developers
  - Between global and regional ensemble groups within EMC
    Share research, development, and operational procedures where possible
  - *Establish NCO / EMC / Service Centers Ens. Products Working Group*
  - *Continue (expand via telecom?) monthly Predictability Meetings*

- *Optimize NCO operational job stream with user input*
  - For improved integrated forecast decision support
  - *Periodically reevaluate job stream from user and science perspectives*

- *Reestablish Annual NCEP SOO Workshop*
  - Rotate focus of workshop among various topics
  - *Hold Ensemble User Workshop every 3-4 years*

ENSEMBLE CONFIGURATION - CURRENT STATUS

CONFIGURATION	Global	Regional
Cycles per day	*4*	*2*
Membership	*10*	*15*
Resolution	*T126L28 till 7.5 days* *T62L28 beyond*	*48km*
Model version(s)	*Single GFS*	*ETA (2 conv. schemes), RSM*
Initial perturbation	*Breeding*	*Breeding*
Boundary perturbations	*N/A*	*Global ensemble*

ISSUES -

COLLABORATIVE PROJECTS MUST ENABLE OPERATIONAL IMPLEMENTATIONS

- *Global*
  - North American Ensemble Forecast System – with Met. Service of Canada
    Post-processing & product development – Aimed at operational applications
  - THORPEX – NOAA, NA, & international collaborators
    Projects on initial and model related perturbations – Path to operations
- *Regional*
  - Northeast Energy Project – OAR & Industry collaborators
    Heat wave forecast related research – Should transition into operations
  - WRF – FSL, NCAR, USAF and other collaborators
    Potential for rapid development of next generation operational system

ENSEMBLE CONFIGURATION - RECOMMENDATIONS

- ***Global ensemble***
  - Implement hurricane relocation for perturbed initial conditions
    - Experiment with techniques used successfully with GFS system
  - Continue efforts to build multi-center ensemble
    - Combine NCEP, ECMWF, MSC, JMA, FNMOC ensembles
    - Best possible multi-model approach (with added benefits of initial condition variability)
- ***Regional ensemble (SREF)***
  - Consider running ensemble & hires ETA (WRF) control from same initial time
    - Utility of off-cycle ensemble (9 & 21Z) is limited when used with 12Z & 00Z controls
      - Differences between ensemble & hires control from different cycles hard to interpret
    - Closer coupling between ensemble & hires control allows proper interpretation of both
    - Alternative suggestions for computer resource allocation:
      - Increase less the resolution in future implementation for both ensemble & hires control
      - Decrease resolution for hires forecast beyond, eg, 36 hrs (if skill is not degraded)
      - Run ~5 initial/model perturbation members along with hires control, finish rest of ensemble later
      - Run 5 members from early, hires from final analysis, finish ensemble, run hires window for dominant clusters
      - Study feasibility of combining information from older ensemble with newer hires forecast (J. Du's suggestion)
  - Introduce 4 cycles per day – Run ensemble at 00, 06, 12, & 18Z
    - Will allow comparison of hires control and lowres ensemble, enhancing utility of both

ENSEMBLE CONFIGURATION - RECOMMENDATIONS

- ***Additional suggestions for both systems***
  - **Membership**
    Evaluate effect of increased membership in combination with post-processing gains
  - **Spatial resolution** – *As computational resources increase*,
    Increase ensemble resolution (~50-50% resources for hires control & lores ensemble)
  - **Initial perturbations**
    Continue research aimed at better quantification of initial uncertainty
  - **Model error representation**
    Continue research on stochastic model perturbations & model diversity

ENSEMBLE DATA ACCESS - CURRENT STATUS

- ***Global ensemble – 1x1 grid, pgrib, enspost, Sager file types***
  - NCEP Service Centers — All data available - Limited NAWIPS access
  - AWIPS — Limited data out to 84 hrs – need 180 hrs (WAFS?)
  - NCEP ftp servers — All data available
  - NWS server — 2 cycles only – Need to add 06 & 18Z cycles?
- ***Regional ensemble (SREF) – GRIB212 (40km)***
  - NCEP SCs — All data available – Limited NAWIPS access
  - AWIPS — No access to data – Need selected variables
  - NCEP ftp servers — Selected variables only – All data needed?
  - NWS server — None – Need to post data
- ***Issues:***
  - Disc space usage – Inefficient due to use of multiple file formats
    - Same data packaged in various formats for convenient access and historical reasons
  - Bandwidth limitations – Ftp overload due to data access limited to prepared files
    - Typical user needs only fraction of downloaded data
  - Increase in data volume – Need advance planning to facilitate future data access
    - Additional ensembles; Increased resolution, membership

ENSEMBLE DATA ACCESS - RECOMMENDATIONS

- ***Provide access to all ensemble data (including members)***
  - Allows optimal use of ensemble information by diverse user base
  - Should be feasible given low cost of disc storage space
    - Lower resolution ensemble has similar data volume to hires control
    - Temporary disc space limitations should be mitigated by
      - Freezing output resolution (or list of available variables)
- ***Facilitate user controlled access to data (e. g., NOMAD)***
  - Allow users to choose what they want to download by
    - Selecting members, variable, level, time and spatial domain of interest
    - Providing basic functionalities to manipulate data (eg, download derived statistics only – see Products Working Group recommendations)
  - Consider for NAWIPS, AWIPS, and ftp dissemination
  - Eliminates need for duplicate data files
  - Significantly reduces bandwidth requirements
  - Prototype system exists (NOMAD, all global ensemble data available)
    - As interim solution until system operational, introduce split pgrib files?
- ***Shift to use of GRIB2 format***
  - WMO sanctioned uniform format for ensemble data
    - Need for international ensemble data exchange (see Configuration WG)
  - x3 (for global) to x5 (for regional) reduction in file size

ENSEMBLE 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
    - 1st, 2nd moments of ensemble distribution
    - Spatio-temporal variations in 2nd moment
    - Tails of distributions
- ***No comprehensive operational post-processing in place***
  - MOS applied on individual members (global ensemble, MDL)
  - QPF calibration of 1st 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 attached list for NCEP Service Center requests
  - Type of product generation based on typical usage:
    - Every day - Generate centrally (NCO), produce multiple file formats
    - Occasionally - On demand, locally (NCEP Service Centers)
    - Interactively - On screen manipulation/interrogation (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 NOMAD)

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***			
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)***			

Additional basic GUI functionalities:

- Ability to manually select/identify members
- Ability to weight selected members

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 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

ENSEMBLE TRAINING

- ***CURRENT STATUS:***
  - NCEP Training Material available since 2002 (P. Manousos)
  - COMET professional training module to be released soon (B. Bua)
    Includes winter weather, severe weather, and general weather forecasting problems
  - Webcast module based on COMAP presentation by D. Bright (by 09/2004, B. Bua)
  - NWS WFO teletraining using VISITView (B. Bua, proposed)
    Practical use of ensembles
- ***ISSUES:***
  - Official NWS training opportunities/requirements not established
  - Training for professional national, international, and lay users needed
  - Share training resources nationally/internationally
- ***RECOMMENDATIONS:***
  - Establish NWS formal ensemble training requirements
  - Consider organizing AMS Ensemble Training Workshops
    Practicing broadcast etc meteorologists
    Emergency managers
  - Share training material on national/international level
    Establish NWS OS FAQ on ensembles
    NCEP/HPC International Desk – Spanish/Portugese translations of existing material
    Exchange ideas/material with WMO Ensemble Training initiative
    Contribute to Socio-Economic Applications part of intl. THORPEX research program