AWIPS Requirements White Paper: RWP0036

Red highlights by Z. Toth

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Title: Ingest, Store, Locally Process, and Display Ensemble Grids (Priority 1.7)

A. Requirements

All functionality listed, below, should be implemented NLT AWIPS Build 5.1 release in the core software.

1. AWIPS shall **ingest ensemble grids** listed in Table 1.
   Note: Ensemble grids have extensions on the GRIB file PDS described on the web page:
   http://sgi62.wwb.noaa.gov:8080/ens/info/ens_grib.html
2. AWIPS shall allow users to select ensemble grid, parameter, time step, level, and threshold value using the "Volume Browser"; ensemble display mode (spaghetti, mean, spread, max/min, probabilities, and member clustering) shall also be selectable within the **"Volume Browser";** AWIPS shall allow users to select individual ensemble members for display in D-2D from the "Volume Browser".
3. AWIPS shall generate and display **"mean"** contour depictions on D-2D from all available ensemble members for a given ensemble grid (to include QPF, MSLP, 850mb Temperature, 500mb and 250mb height grids). Note: "mean" of ensemble members = sum(over i) [em(i)]/n
4. AWIPS shall generate and display **"spread"** contour depictions on D-2D from all available ensemble members for a given ensemble grid (to include QPF, MSLP, 850mb Temperature, 500mb and 250mb height grids). Note: "spread" of ensemble members (i.e, standard deviation) = sqrt{(1/n)*sum(over i) [mean-em(i)]**2}
5. AWIPS shall display **"spaghetti"** contour depictions on D-2D of all ensemble grids by parameter; each member will be loaded to D-2D using a different color. Valid threshold values for spaghetti contour maps are:
   - MSLP: 1000mb, +/- 4mb increments within 40mb
   - 850mb Temperature: 0C, +/- 5C increments within 25C
   - 500mb Height: 5400m, +/- 60m increments within 300m
   - 250mb Height: 10140m, +/- 120m increments within 600m

6. AWIPS shall generate and display **"minima and maxima"** value plots of each ensemble member for a user selected ensemble grid (MSLP, 850mb Temperature, 500mb and 250mb height grids); each ensemble member shall be loaded to D-2D using a different color; each minima and maxima value will be labeled with its magnitude and associated ensemble member.
7. AWIPS shall generate and display **"probability distributions"** in D-2D from each ensemble member threshold (example: Probabilistic Quantitative Precipitation Forecast (PQPF)) for a given parameter, level, and time ensemble grid at or above (below) a user defined exceedance threshold (PQPF example: 0.10, 0.25, 0.50, or 1.00 inch) selected within the "Volume Browser"
8. AWIPS shall allow individual **ensemble members** on "spaghetti" contour depictions to be toggled on and off on D-2D
9. AWIPS shall give users the option to **save locally generated ensemble grids** (mean, spread, probability) for use by other applications (GFE, IFPS, etc).
10. AWIPS shall allow display of ensemble grids on D-2D from the **grid "Family" menu** as contours:

    Ensemble Family Sub-Menu

    - MSLP (Mean + Spread (image))
    - MSLP (Spaghetti, all members for 1000mb)
    - MSLP (Spaghetti, all members for 1008mb)
    - MSLP (Min/Max Pressure Plot)
    - 850mb Temp (Mean + Spread (image))
    - 850mb Temp (Spaghetti, all members for 0C)
    - 850mb 0C Isotherm Exceedance Probability (at or below)
    - 500mb (Mean + Spread (image))
    - 500mb (Spaghetti, all members for 5400m)
    - 500mb (Spaghetti, all members for 5640m)
    - 500mb (Spaghetti, all members for 5820m)
    - 500mb (Min/Max Height Plot)
    - 250mb (Mean + Spread (image))
    - 250mb (Spaghetti, all members for 10140m)
    - 250mb (Spaghetti, all members for 10620m)
    - 250mb (Min/Max Height Plot)
    - 1000-500mb Thickness (Spaghetti, all members for 5400m)
    - 1000-500mb Thickness (Spaghetti, all members for 5280m)
    - PQPF Probability Distribution (0.10 inch, at or above)
    - PQPF Probability Distribution (0.25 inch, at or above)
    - PQPF Probability Distribution (0.50 inch, at or above)
    - PQPF Probability Distribution (1.00 inch, at or above)

    Examples of above products: http://sgi62.wwb.noaa.gov:8080/ens/enshome.html

Table 1: AWIPS 5.1 Ensemble Grids						
	Projection/Resolution	**Runs/Day**	**Number of Time Steps @ Interval**	**Number Ensemble Members/Run**		**Number of Thresholds**
				00Z	**6,12,18Z**	
250mb Height	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
250mb Wind (u,v)	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
250mb Height	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
250mb Wind (u,v)	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
500mb Height	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
500mb Wind (u,v)	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
500mb Height	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
500mb Wind (u,v)	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
850mb Temperature	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
850mb Height	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
850mb	AWIPS 211/80Km	4	29	12	11	N/A

Temperature	AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km		0-168hr @ 6hr steps			
850mb Wind (u,v)	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
MSLP	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
MSLP	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
12hr PQPF	AWIPS 201/381Km	2	20 @ 12hrs (12-240hrs)	12	11	0.1, 0.25, 0.50, 1.00 inch
12hr PQPF	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	28 6-168hr @ 6hr steps	12	11	0.1, 0.25, 0.50, 1.00 inch

See also TPB for increase to Global Ensemble Resolution:
http://sgi62.wwb.noaa.gov:8080/ens/tpb200004.html

All functionality listed, below, should be implemented NLT AWIPS Build 5.2 release in the core software.

11. AWIPS shall **ingest, store, and display ensemble grids** listed in Table 1, 2, 3.
12. AWIPS shall generate and display in D-2D **combined probability distributions** from two or more individual probability fields (example: combined probability distributions from precipitation equal or more than 0.10 inch probability and probability of surface temperature fields)
13. AWIPS shall allow users to **interactively pick valid threshold levels** for redisplay of spaghetti and probability distribution plots
14. AWIPS shall allow users to **sample frequency distribution** of parameter spread (histograms) on any planar ensemble parameter displayed on D-2D at the cursor location, with frequency of occurrence on the y-axis and parameter value on the x-axis. Frequency distribution plots shall be toggled on from the right mouse button pop-up window "sample" toggle; **geo-location**

for sampling will be accessed though the cursor location. Also, AWIPS shall allow users to sample frequency distribution via the cursor when **two probabilities are combined** (as in requirement #12). In this case, AWIPS shall create a 3-D plot with the first parameter on the x-axis, the second parameter on the y-axis, and the frequency on the z-axis. AWIPS shall also allow users to toggle on sampling of ensemble grids for the following statistical probes: max/min, mean, and probability (if available).

15. AWIPS shall allow users to **group ensemble members** by grouping their spatial distributions using set algorithm thresholds or by users defined "n" number of clusters for a user specified geographical area (selectable for the entire grid or interactively for a grid subset). AWIPS shall allow users to group ensemble members by specifying the highest, lowest, and middle solutions for "n" number of ensemble members **for a user specified parameter and spatial region**. AWIPS shall also allow users to group ensemble members using clustering algorithms. Once grouped, AWIPS shall allow users to perform mean, spread, probability, spaghetti, and max/min processing and display actions on the ensemble subset group.
16. AWIPS shall allow users to generate and display the **probability values on D-2D between two user selected valid thresholds**; probability shall be generated from user input for a single time step or for a range of time (ex. probability of rain between 0.50 and 1.00 inch or temperature between 20 and 25C at a user selected time step or interval).
17. AWIPS shall allow users to generate and **display spaghetti, mean, spread, max/min, and probability distributions D-2D plots from clustered (classified) ensemble members**
18. AWIPS shall give users the option to **include** relevant parameters from NCEP (ex. RUC, Eta, AVN, MRF) **and non-NCEP (UKMET, ECMWF) grids as members** in the generation and display of ensemble depictions (spaghetti, max/min, mean, spread, probability). Option to include standard grids as members in ensemble depictions should be selectable within the "Volume Browser".
19. AWIPS shall allow users to **archive ensemble data and later play back on AWIPS**. Users should have the ability to select "all" ensemble data for a specific data type in the database or select individual ensemble data during the archiving process.

Table 2: AWIPS 5.2 Ensemble Grids (in addition to 5.1 grids)

	Projection/Resolution	Runs/Day	Number of Time	Number Ensemble Members/Run	Number of Thresholds

			Steps @ Interval	00Z	6,12,18Z	
250mb Temperature	AWIPS 201/381Km	2	21 @ 12hrs (240hrs)	12	11	N/A
250mb Temperature	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
500mb Temperature	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
500mb Dew Point	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
700mb Temperature	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
700mb Dew Point	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
850mb Dew Point	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
Freezing Level Height	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
Freezing Dew Point	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
10m AGL Wind (u,v)	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
2m	AWIPS 211/80Km	4	29	12	11	N/A

Temperature	AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km		0-168hr @ 6hr steps			
2m 12Hr Max/Min Temperature	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	15 0-168hr @ 12hr steps	12	11	N/A
2m Dew Point	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	N/A
2m 12Hr Minimum Dew Point	AWIPS 211/80Km AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	15 0-168hr @ 12hr steps	12	11	N/A
Probabilistic Surface Precip Type	AWIPS 211/80Km AWIPS 207/95Km	4	29 0-168hr @ 6hr steps	12	11	Freezing Rain, Ice Pellets, Snow, Rain
Probabilistic Tropical System Winds (PTSW)	AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	35-63Kt, 64-95Kt, 96-113Kt, 114-135Kt, >135Kt
Probabilistic Marine (10m) winds	AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	15Kt, 25Kt, 35Kt, 50Kt, 65Kt
Probabilistic Marine Significant Wave	AWIPS 207/95Km AWIPS 210/80Km AWIPS 225/80Km	4	29 0-168hr @ 6hr steps	12	11	2m, 4m, 6m, 8m, 10m

Table 3: AWIPS 5.2 Short-Range Ensemble Forecasting (SREF) Grids (0-2 Day Guidance)

	Projection/Resolution	Runs/Day	Number of Time Steps @ Interval	Number Ensemble Members/Run		Number of Thresholds
				00Z	6,12,18Z	
10m AGL Wind (u,v)	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	N/A
2m Temperature	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	N/A
2m Dew Point	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	N/A
3hr PQPF	AWIPS 212/40Km AWIPS 216/45Km	4	16 3-48hr @ 3hr steps	12	11	0.01, 0.05, 0.1, 0.25, 0.50, 1.00 inch
Probabilistic Broken (>5/10) Clouds (AGL)	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	200, 500, 1000, 1500, 3000, 5000 ft
Probabilistic Surface Precip Type	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	Freezing Rain, Ice Pellets, Snow, Rain
Probabilistic Convective Wind (PCW)	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	25Kt, 35Kt, 50Kt, 65Kt
Probabilistic Hail (PH)	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	0.25, 0.50, 0.75, 1.00 inch
Tornado	AWIPS 212/40Km AWIPS 216/45Km	4	17 0-48hr @ 3hr steps	12	11	N/A

B. Description

NCEP ensemble forecasts will be added to the AWIPS Satellite Broadcast Network (SBN) containing variables (500 hPa height, mean sea level pressure, 850 hPa temperature, and 12-hour accumulated precipitation) for all ensemble members , and for all lead times from 0 to 240 hours. The individual forecasts are identified by a special ensemble GRIB PDS extension.

Global ensemble forecasts have been produced as part of the NCEP operational suite since December 1992. Different ensemble based products have been generated and distributed, through various channels, to a wide range of users both nationally and internationally. Evaluation of the quality of the products indicate that the ensemble forecasts can provide substantial economic value, beyond that provided by the higher resolution control forecast, for a wide range of users.

Background Info:

NCEP Global Ensemble Forecasting System:
http://sgi62.wwb.noaa.gov:8080/ens/tpb200003.html

NCEP Short Range Ensemble Forecasting System:
http://lnx48.wwb.noaa.gov/SREF/SREF.html

Definitions:
From Global Ensemble Forecast System Page -
http://sgi62.wwb.noaa.gov:8080/ens/tpb200003.html#PRODUCTS

Spaghetti Plot - Display of all individual ensemble member values, as contours, for a specified value. A selected contour level of a given variable is plotted on the same figure for each individual ensemble member. It provides a quick overview of all ensemble forecasts. Note that in areas of small gradients, large differences in the spaghetti lines may occur, without the ensemble members being substantially different.

Mean (first moment) - This is the most basic forecast guidance from the ensemble. Due to the ensemble's ability to filter out unpredictable events, this field gives a better estimate for the expected value of the future state of the atmosphere. Note that because the unpredictable, often smaller scale events are selectively filtered out, this field is smoother than any of the individual forecasts. It is therefore essential to consider other information from the ensemble, like ensemble spread and/or single contour plots, along with the ensemble mean, that can reveal the variability exhibited by the ensemble members that contribute to the mean. (mean = sum(over i) [em(i)]/n)

Spread (second moment) - The standard deviation around the ensemble mean is considered another basic guidance product, indicating the variance of ensemble members around the mean. (spread = sqrt{(1/n)*sum(over i) [mean-em(i)]**2})

Maxima/Minima Plots - Plots of the "minima and maxima" value for each ensemble member for a given time step and ensemble grid.

Probability Distributions - This is considered the most important and comprehensive product based on an ensemble. For any given weather event that need to be predicted, the number of ensemble forecasts indicating that event is counted. The ratio of forecasts predicting the event, over the total number of forecasts is the relative forecast frequency that can be interpreted as a probabilistic forecast.

Cluster - Sorting ensemble members by their proximity or distribution; These are statistically derived products that attempt to capture prevailing and important aspects of the ensemble forecasts (Tracton and, 1993; Atger, 1999). Their primary purpose is to condense information and they should not be considered more than alternative ways of representing the forecasts. The notes made for ensemble mean forecasts are also relevant for cluster means.

Normalized Spread (Mean) - Spread are divided by the average spread from the preceding 30 days; normalization is accomplished at NCEP during grid generation. It is for the detection of anomalously high or low spread (indicating low or high predictability, respectively), irrespective of lead time and geographical location.

C. Decisions/Assumptions

- Ability of NCEP to deliver Ensemble model data in AWIPS compliant GRIB format
- Ensemble data is stored in GRIB format; however, the AWIPS grid decoder will not recognize some of the parameters associated with Ensemble data such as the model perturbation series.

D. Known Reference Documents

DRG RC #2472

E. Points of Contact

AWIPS 5.0 Focus Group: Kevin Scarab WRH, Jason Burkes WRH, Ed Mahoney WFO BUF
Initial RWP Submitter: Josh Korotki, WFO PBZ
AWIPS 5.1 Review: Fred Mosher AWC, Josh Watson ERH

OM/AWIPS Focal: Dave Helms NWS/OM (301)713-1867, x116
NCEP Focal Point: Zoltan Toth NCEP/EMC, Steve Tracton NCEP/EMC

Additional Information:

Focus Group Background:

Office_and_POC: PBZ/Josh Korotky

Description: Add a full suite of NCEP Ensemble Forecast Products, including experimental products. These should include spaghetti plots, probabilistic precipitation forecasts, ensemble cluster sets, height and Ensemble spread plots, and multi panel depiction of individual ensemble member solutions for mean sea level pressure, upper air plots, etc.

Impact_to_Operations: There is increasing recognition of the operational utility of Ensemble forecasts, especially in medium and long range forecasting. Ensemble spread plots and cluster plots are also useful for evaluating the potential for significant weather developments, and for assessing the validity of individual model run solutions in the short range.