2016 HMT-WPC Winter Weather Experiment

Draft Program Overview & Operations Plan

25 January – 19 February 2016
Weather Prediction Center
College Park, MD

Updated: 17 December 2015

1. Experiment Overview

The Weather Prediction Center (WPC) Winter Weather Desk (WWD) provides graphical, gridded, and text guidance as well as collaborative forecast services to National Weather Service (NWS) Forecast Offices (WFOs) during pending winter weather events. The deterministic WPC forecasts serve as a unified guidance dataset while the post-processed probabilistic forecasts help increase awareness of winter weather forecast uncertainty.

In an effort to support improvements in winter weather forecasts, the Hydrometeorology Testbed at WPC (HMT-WPC) began hosting an annual winter weather experiment in 2011. These experiments bring together members of the operational forecasting, research, and academic communities to address winter weather forecast challenges. Previous experiments have focused on exploring the utility of high-resolution models, model implicit snowfall forecasting techniques to improve both deterministic and probabilistic snow and ice forecasts in the Day 1-3 time frame. In the past two experiments, there was also a focus directed at probabilistic forecasts in the Day 4-7 period. The results of past WWEs lead to operational changes at WPC, such as:

- Externally issued product will switch from the probability of winter precipitation (SN/IP/ZR) exceeding 0.10" to the probability of snow and sleet exceeding 0.25"
- The 0.10" threshold presented dispersion issues, was at or below daily climatology for parts of the inter-mountain west, and the mosaic of 3 p-types may be somewhat abstract for the user
- A 0.05" freezing rain threshold will be issued internally at WPC
- The 0.01" threshold for freezing rain was determined to be over dispersive

The 2016 WWE will provide an opportunity for participants to explore innovative deterministic and ensemble-based snowfall forecasting techniques for the short range. The focus will be on exploring the utility of both convection-allowing and non-convection-allowing high-resolution models as well as downscaling snowfall forecasting techniques during the Day 1-2 time period. For the first time, the experiment will explore the 6-12 hour time period for the purpose of identifying regional and temporal peaks in snowfall intensity. Snowfall rate parameters and high resolution reflectivity will be available for examination in both NCEP's North American Model (NAM) Parallel and an experimental version of the High-Resolution Rapid Refresh (HRRR) provided by the Earth System Research Laboratory (ESRL). The 2016 experiment will also provide an opportunity for a first cold-season look at the performance of the (HRAM3), a combination of various model downscaling techniques under development at WPC, and several probabilistic winter weather parameters offered by the new HRRR Time-Lagged Ensemble (HRRR-TLE) which is also being developed at ESRL.

Currently, WPC produces the National Forecast Chart (NFC), an impacts-based weather overview product for Days 1-3. The winter precipitation hazards for this product begin with the 30% probability of exceeding WFO watch/warning criteria for snow and ice generated from the

WPC Watch Collaborator. Using the WPC Watch Collaborator thresholds and an array probabilistic guidance, the 2016 WWE will generate a product exclusively identifying winter hazard thresholds over a Day 2 (or Day 3) period for the Continental United States (CONUS).

Finally, to increase exposure to the experimental datasets and concepts being tested in the WWE, a daily forecast briefing will be provided for interested NWS WFOs by WWE participants. These briefings will help highlight the experimental datasets and provide an opportunity for WFO forecasters to ask questions and provide feedback.

2. Science and Operations Goals

The goals of the 2016 Winter Weather Experiment are to:

- Explore the Experimental HRRR and HRRR-TLE for winter weather forecasting.
- Explore the utility of the parallel 3 km NAM Nest for winter weather forecasting.
- Explore the utility of the prediction of convective mesoscale snow banding by using increased spatial and temporal resolution of convection-allowing models (CAMs).
- Examine the utility of the WPC Watch Collaborator tool
- Create a probabilistic winter hazards impacts-based product.
- Enhance collaboration among NCEP centers, WFOs, and NOAA research labs on winter weather forecast challenges.

3. Experiment Operations

The experiment will be conducted for four weeks beginning 25 January 2016 in the WPC-OPC Collaboration Room at the NOAA Center for Weather and Climate Prediction (NCWCP) in College Park, MD.

Week 1: January 25 – 29, 2016 (Monday – Friday)
Week 2: February 1 – 5, 2016 (Monday – Friday)
Week 3: February 8 – 12, 2016 (Monday – Friday)
Week 4: February 16 – 19, 2016 (Tuesday – Friday)

Experiment participants will be paired with a WPC Winter Weather Desk forecaster to form a collaborative forecast team. These forecast teams will use a combination of operational and experimental model guidance to create experimental 24 hr deterministic snowfall forecasts for weather systems of interest during either the Day 1 (12 – 12 UTC) or Day 2 time period. The daily forecast domain will cover a multi-state area centered on the storm system of interest, and priority will be given to events that feature impactful frozen precipitation intensity. Participants will be asked to draw contours of 1, 2, 4, 8, 12, and 20 inch snowfall amounts across the forecast domain. In most cases, storms originally investigated during the Day 2 period will continue to be investigated the following day during the Day 1 time period.

Participants will then issue a probabilistic forecast to accompany the deterministic snowfall for high-impact snowfall rates within this domain (valid 12 – 12 UTC):

1.) The probability of exceeding 1"* of snowfall per hour over the Day 1 forecast (*threshold may be adjusted down to 0.5" or up to 2" as weather pattern dictates).
2.) The indication of the time period within which the high-impact rate of snowfall is expected to occur.

If no high-impact snowfall rates are expected in Day 1, participants will produce a probabilistic icing forecast for freezing rain:

1.) The probability of receiving >= 0.05" of ice
2.) 10, 30, 50, 70, 90% likelihood of occurrence

In addition to these short-term deterministic snowfall and probabilistic snowfall rate forecasts, participants will be asked to create a probabilistic Day 2 (or Day 3) winter weather hazards impact-based product. The WPC Watch Collaborator thresholds for meeting the snow and ice criteria at which a watch or warning may be issued will be used as a baseline. The forecasters will then subjectively enhance the hazards product based on probabilistic guidance and the CONUS-wide county warning area criteria.

- Begin with Watch Collaborator 30% likelihood of meeting/exceeding watch criteria for both snow and freezing rain
- Use probabilistic guidance and deterministic guidance to build levels of impact severity
- Use watch criteria CWA color-coded map as guidance for regional impact variability
- Indicate areas that will be impacted by various winter hazards beyond reaching watch/warning criteria thresholds:
    - heavy snow which may exceed watch/warning criteria in less than 6 hours
    - significant icing (greater than 0.05")
    - ice glaze that may impact roadways (trace to 0.1") during commute times
    - high winds (winds may reach or exceed threshold for blizzard conditions, typically sustained 35 mph or higher over several hours)
    - rapidly falling temperatures
    - precipitation transition zones

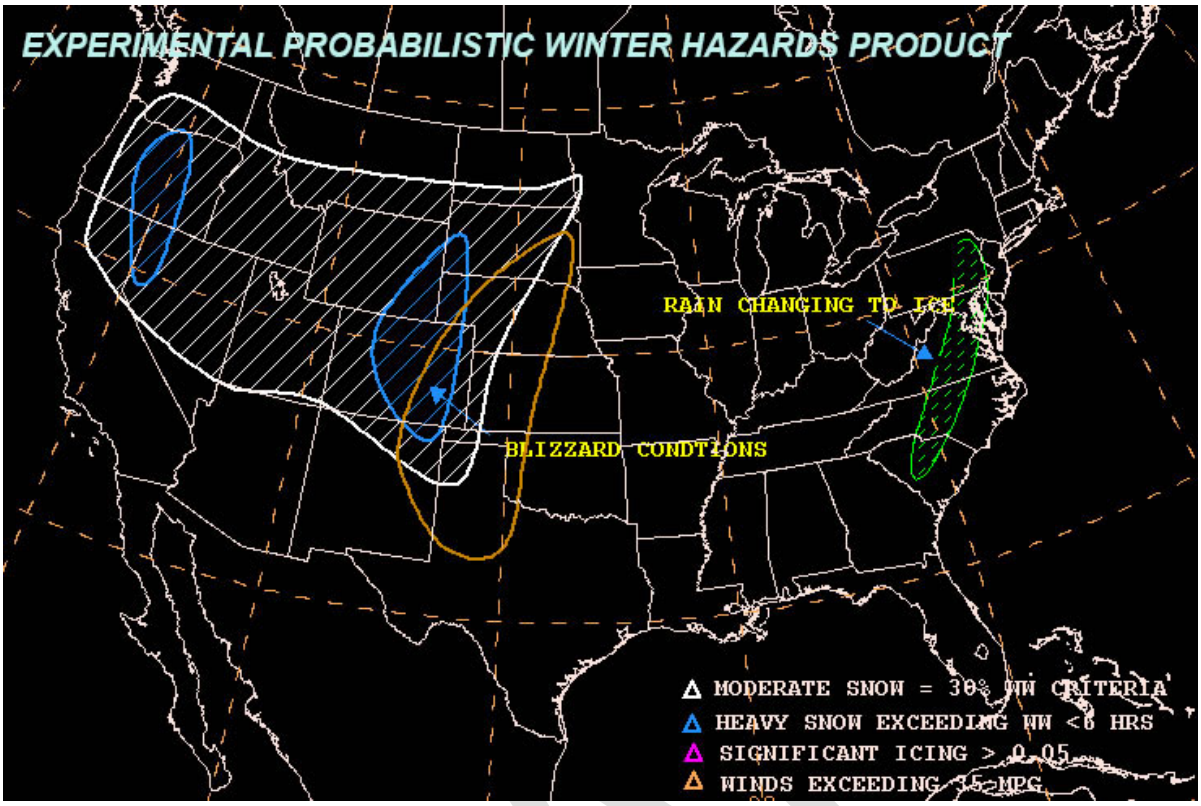

Figure 1. Example of an enhanced winter hazards map to be created in the afternoon session.

After generating each forecast, participants will be asked to explain their forecast rationale and illustrate any forecast challenges in a forecast discussion presentation. Throughout the forecast process, participants will be encouraged to identify images that help explain the forecast. These images will then be incorporated into a forecast discussion that will serve as the focal point of a weather briefing provided to interested local NWS offices each afternoon.

Finally, participants will have the opportunity to subjectively evaluate the performance of both the experimental forecasts and the experimental model guidance. In addition, at the end of each week participants will be asked to provide feedback about the utility of the available experimental forecast tools.

In the event that there is no suitable winter weather during either short-term forecast period, alternate activities may include examining the experimental data and techniques through a previous winter event, and/or exploring the practice of producing a probabilistic forecast for the Day 2-3 outlook period.

Daily Schedule

A brief orientation session will be held at 8:00 am on the first day of each week to explain the motivation and organization of the experiment as well as the data being evaluated.

8:00am – 9:45am Determine the daily forecast area and time period (Day 1)
Using 00 UTC and any available 12 UTC guidance, issue an experimental 24 hr deterministic snowfall forecast for the 12 – 12 UTC period.

9:45am – 10:00am Break

10:00am – 11:30am Additional to this forecast, probabilistically indicate areas in which snowfall rates may meet or exceed 1" per hour and when this peak may occur -OR- produce a probabilistic freezing rain forecast if no high rate events are expected.

Prepare forecast discussion.

11:30am – 12:30pm Lunch

12:30pm – 1:00pm Weather briefing to interested local WFOs

1:00pm – 2:30pm Subjective evaluation/verification

2:30pm – 2:40pm Break

2:40pm – 4:00pm Produce probabilistic Day 2 or Day 3 winter hazards impact-based product

4. Guidance for Experimental Day 1-2 Deterministic Forecasts

In addition to the full multi-center suite of deterministic and ensemble guidance available to WPC forecasters, participants will be asked to consider several different snowfall forecasting data sets and techniques while preparing their Day 1-2 deterministic snowfall forecasts. Participants will also have access to an experimental short range HRRR Time-Lagged Ensemble system from the Earth System Research Laboratory (ESRL) as well as WPC's PWPF ensemble that is used to derive WPC's probabilistic winter precipitation forecasts. Model implicit snowfall guidance will also be available for participants. Table 1 summarizes the model guidance that will be the focus of the short range portion of the experiment, and more information about each dataset is provided below.

Table 1. Featured Day 1-2 guidance for the 2016 HMT-WPC Winter Weather Experiment. Experimental guidance is shaded.

Provider	Model	Resolution	Forecast Hours	Notes
EMC	NAM Nest	4 km	60	The operational NAM Nest is a higher resolution nest of the 12 km parent NAM
EMC	SREF (26 members)	16 km (32 km display)	87	Two dynamical cores (ARW and NMMB, 13 members each); Vertical resolution from 35-40 levels, mostly in the PBL; greater diversity in model initial conditions, perturbations, physics
EMC	GEFS (21 members)	55 km	168	Semi-Langrangian; GSI/EnKF hybrid analysis; vertical resolution of 64 levels
WPC	PWPF ensemble (68 members)	20 km	72	Operational PWPF ensemble includes the WPC deterministic forecast, SREF members, GFS mean, ECMWF mean, and deterministic NAM, GFS, CMC, and ECMWF; SLR is an average of multiple techniques
EMC	NAMX	3 km	84	3 km CONUS and 3 km Alaska nest
ESRL	HRRR-TLE (high-resolution time-lagged ensemble)	3 km	12	Neighborhood ensembling approach calculated over a 3 km grid of time-lagged HRRR deterministic members
ESRL	HRRRX	3 km	24	Deterministic Experimental HRRR
WPC	HRAM3E Ensemble	5 km	36	WPC additive downscaling adjustment to hi-res multi-model ensemble
WPC	HRAM3G Ensemble	5 km	36	WPC multiplicative downscaling adjustment to hi-res multi-model ensemble
WPC	HRAM3 Precipitation Type	5 km	24	Probabilistic precipitation type algorithms applied to the downscaled QPF of the HRAM3 Ensemble
SPC	OPRH	12 km NAM (40 km display)	18	Snowfall rate >=1”/hr predictor driven by the NAM40X using the calculation of RH x Omega x PW over the -12 to -17C layer
NSSL	WRF NSSL	4 km	36	High resolution, convective allowing model over the CONUS.

Operational Guidance

NCEP North American Model Nest (NAM Nest)

The NAM Nest is a 4 km nest of the 12-km parent NAM, which covers the CONUS and features full use of the global Ensemble Kalman Filter (EnKF) members as part of its data assimilation system. The nest is available at 00, 06, 12 and 18 UTC.

NCEP Short Range Ensemble Forecast System (SREF)

The SREF is a 26-member, 16 km ensemble consisting of an equal distribution of WRF-ARW, and NMMB members (Appendix A). For 2 m temperatures less than 5°C, SLR is derived as follows:

$$SLR = .5(273.15 - T_{2m}) + 8$$

The SLR is capped at a maximum ratio of 28:1.

WPC PWPF Ensemble

The WPC PWPF Ensemble is a 68-member, 20 km ensemble that is generated internally by WPC and is used extensively in the WPC Winter Weather Desk forecast process. The ensemble membership consists of all 26 SREF members, 5 randomly selected GEFS members, 25 randomly selected ECMWF European ensemble (ECENS) members, and members consisting the latest operational NAM, GFS, GEFS mean, CMC, ECMWF, ECMWF mean (ECENS) runs. The WPC 24-hour deterministic snow or freezing rain accumulation forecasts is also an ensemble member serving as the mode or "most likely" solution providing the variance of the distribution. Snowfall from the WPC PWPF Ensemble is calculated using a snow-to-liquid ratio derived from an average of the Roebber technique (Roebber et al. 2007) applied to the NAM, the Roebber technique applied to the GFS, a fixed 11:1 snow-to-liquid ratio, and Baxter seasonal climatology.

GEFS

The Global Ensemble Forecast System (GEFS) is a weather forecast model made up of 21 ensemble members (including the GFS). The GEFS attempts to quantify the amount of uncertainty in a forecast by generating an ensemble of multiple forecasts, each minutely different, or perturbed, from the original observations. With global coverage, GEFS is produced four times a day with weather forecasts going out to 16 days. The GEFS is a Semi-Langrangian model with a horizontal resolution of 55 km from 0-168 forecast hours. GEFS has 64 hybrid levels in its vertical resolution to match the GSI/EnKF hybrid analysis system.

Experimental Guidance

SPC OPRH Snowfall Rate Technique

Currently, the Storm Prediction Center (SPC), which is responsible for issuing the winter Mesoscale Discussion for heavy snow, is utilizing a simple ingredient-based technique for identifying areas in which snowfall rates may exceed 1" per hour within the forecast period. SPC forecasters have found anecdotal correspondence between the absolute magnitude of OPRH values and hourly snowfall rates (- 1 OPRH value $\approx$ 1" per hr; – 2 OPRH value $\approx$ 2" per hr). OPRH strives to physically represent processes involved in heavy snowfall rates [i.e., microphysics (dendritic growth), lift within this favorable layer.] The technique can be applied to any model. During the WWE, OPRH will be applied to the NAM40X. Below is an explanation of the OPRH calculation:

- The temperature is checked at every pressure level (i.e., 25 mb) to see if it falls between -12 and -17C.
- If that a grid point satisfies that criterion, the PW (in) is calculated (based on the mixing ratio) for that 25-mb layer.
- The RH (0-1) and omega (microbars/s) for that level are then multiplied together. The sum of this product is taken for each level between -12 and -17C.
- Finally, the average product of RH x omega is multiplied by the PW over the -12 to -17C layer to get OPRH.

EMC NAMX

Resolution increased from 4 km operational NAM Nest to 3 km. Snowfall rates derived from snow water equivalent (SWE) parameter and a 10:1 snow-liquid ratio (SLR). 00Z and 12Z cycles will be available.

EMC/ESRL HRRR-TLE (high-resolution rapid refresh time-lagged ensemble)

A preliminary version of the HRRR-TLE will be provided by ESRL for use in the experiment. This CONUS version of the ensemble will have a 3 km resolution, and use 3-5 time-lagged HRRR initializations to predict the probability of exceeding several snowfall rate and accumulated precipitation thresholds. The HRRR uses Thompson physics and applies a standard 10:1 snow-liquid ratio for calculating snowfall rate.

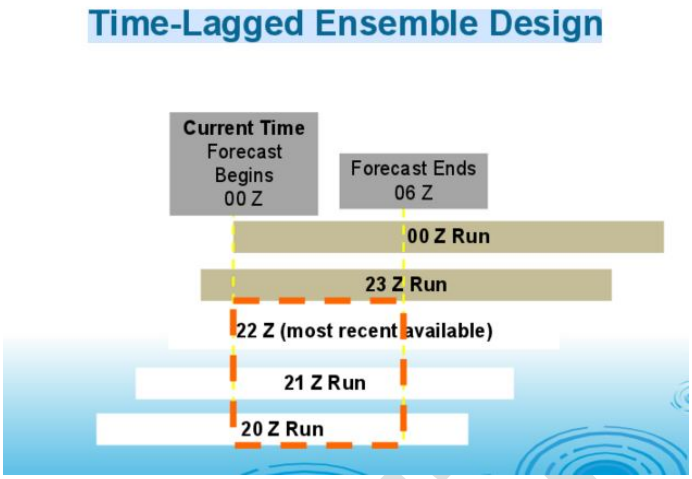

Figure 2. Proposed membership characteristics of the HRRRTLE for use in the winter weather experiment.

EMC/ESRL Experimental High-Resolution Rapid Refresh (HRRRX)

The Experimental HRRR (HRRRX) in the WWE Experiment was initialized with the latest 3-D radar reflectivity using a digital filter initialization (radar-DFI) technique (via the parent 13 km RAP) and provided data hourly. The HRRRX uses grid-point statistical interpolation (GSI) hybrid data assimilation and broadens and weakens the forcing applied from radar reflectivity data assimilation to reduce excessive convective storm development early in the HRRR cycle. Replacing the Rapid Radiative Transfer Model (RRTM)/Goddard radiative schemes with the RRTMG (RRTM with General Circulation Model applications) for both long wave and shortwave, the HRRRX features an enhanced planetary boundary layer (PBL) scheme, increased roughness length values to help reduce a high surface wind speed bias, seasonally-varying vegetation fraction, an update to the land-surface model and updated microphysics.

WPC HRAM3 Dynamic Downscaling

WPC has implemented several new approaches to downscaling based on using high-resolution numerical model QPF along with ensemble based probabilistic information. One approach produced an additive downscaling correction. Another method produced a multiplicative downscaling factor. These methods were applied to the WPC pseudo bias corrected ensemble QPF (ENSQPFBC) to create a set of experimental downscaled QPFs, each known as a High-Resolution Adjusted Mean (HRAM). These experiments use a multi-model ensemble from ENSQPFBC along with three high resolution QPF forecasts (NAM nest, HIRESW NMMB, and HIRESW ARW). The high-resolution QPF forecasts are remapped to the 5-km WPC NDFD superset grid using the area average preserving remapping built into GEMPAK. The high-resolution QPF forecasts are posted at 5-km resolution.

The high-resolution QPFs do not have projection times beyond 48 hrs. To time match the forecasts to the valid times of the WPC “final” QPF cycles (00 and 12 UTC), the most recent high-resolution QPF is used with the forecast hour set to match the valid time of the WPC

forecast. QPF projection hours 006 through 036 at 6-h increments on the WPC forecast timeline are downscaled. These projection hours determine valid date-times. The 00 UTC downscaling begins at 1740 UTC; the 12 UTC downscaling commences at 0540 UTC. The high-resolution QPF cycles available at that time are used. Table 1 below gives the usual cycle time associated with each WPC cycle time for each of the three high-resolution models.

Table 2. High-resolution QPF model cycle times utilized for downscaling forecasts projected from the WPC initial cycle times.

High-Resolution Model	Model cycle time for WPC 00 UTC cycle	Model cycle time for WPC 12 UTC cycle
NAM nest	12	00
HIRESW NMMB	12	00
HIRESW ARW	12	00

HRAM3E is an additive downscaling adjustment and HRAM3G is a multiplicative downscaling adjustment. All of the methods make use of a probability determined by computing the relative frequency of QPF exceeding the ENSQPFBC QPF in a multi-model ensemble and one minus that probability.

WRF NSSL

Daily, real-time runs of the Weather Research and Forecasting (WRF) model are generated using 256 processors on the Jet HPC cluster (Raytheon/Aspen Systems) in Boulder, CO. The current configuration includes:

- WRF version 3.4.1
- MYJ BL/turbulence parameterization
- WSM6 microphysics
- RRTM longwave radiation
- Dudhia shortwave radiation
- Noah land-surface model
- Positive definite advection of moisture
- 4 km grid length (1200x800)
- 35 vertical levels
- Time step 24s

Initial and boundary conditions are obtained from interpolation of the routinely available 40km NAM Model fields obtained from EMC/NCEP, using the WRF Preprocessing System (WPS). Initialization time is 00 UTC and 12 UTC and forecast length is 36 h.

6. Summary

The 2016 Winter Weather Experiment will focus on exploring the utility of both convection-allowing non-convection-allowing high-resolution models and downscaling snowfall forecasting techniques during the short range (Day 1-2) time period for the purpose of the identification of regional and temporal peaks in snowfall intensity. Additionally, experimental datasets will be tested for high-resolution model techniques to address the challenges of forecasting the location and intensity of heavy snow bands and explore the use of ensembles to develop probabilistic winter forecasting tools for specific thresholds. The datasets tested during the experiment and their role in the experimental forecast process will support valuable advances in WPC's Winter Weather Desk, and foster collaboration between NCEP centers, WFO's, and the research community.

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