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Configuration and Technical Details of Winter Suite in the National Blend of Models, Version 5.0

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Overview

The National Blend of Models (NBM) v5.0 Winter Suite is an advanced post-processing system designed to deliver high-resolution calibrated winter weather guidance. The suite produces a comprehensive array of products, including deterministic and probabilistic snow and ice accumulation, Snow-to-Liquid Ratio (SLR), Snow Level, Precipitation Type, and Snow Depth forecasts among others. Product availability by region for the Alaska (AK), CONUS (CO), and Hawaii (HI) domains can be viewed here: Winter Elements by Region.

The system leverages a 100-member multi-model ensemble to drive its probabilistic distribution. In v5.0, the QMD (Quantile Mapping) system continues its specific role of processing individual member QPF data, which then serves as an engine for snow and ice accumulation calculations. While the fundamental application of QMD remains consistent, v5.0 introduces Expert Weighting for both deterministic and probabilistic forecasts to improve consistency between the two.

Scientific Process & System Improvements in v5

QMD QPF & The Winter Suite

The individual member **QMD QPF** data remain the foundation for snow and ice accumulations for non-Convective Allowing Models(CAMs)/RAP inputs.

- **Supplemental Locations:** v5.0 utilizes supplemental locations for QMD QPF (CONUS only).
- **Blockiness:** Removal of the 9-point stencil has remedied legacy "blockiness" issues.
- **Thresholding:** Precipitation amounts < 0.254 mm per 6 hours are set to 0 to reduce "drizzle" artifacts.
- **Model Inputs:** Addition of Hi-RES ECMWF data and removal of SREF.

Model Upgrades

- **High-Resolution ECMWFE Integration:** Includes 0.2° resolution for all 50 members with hourly

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data through 72 hours (48 in NBM with time lag).

- **Canadian Suite Replacement:** SREF inputs are removed and replaced with 10 Canadian members (GDPS, 5 GEPS, RDPS, and 4 REPS).
- **GEFS Enhancements:** Surface variables (Tmp, RH, Wind, MSLP, PTYPE) are increased to 0.25° resolution through 240 hours.

Thermal & Melting Logic

- **Inversion Preservation:** If a surface inversion is detected and the DMO 2-m temperature is colder than the downscaled temperature, the DMO value is preserved to maintain freezing rain signals.
- **DsTW Transition:** The system now utilizes Downscaled Wet-Bulb Temperature (DsTW) rather than dry-bulb temperature for the frozen/freezing precipitation to rain flagging logic.
- **Flagging Routine:** The threshold for snow/ice flagging was raised to 38°F (from 33.8°F), allowing the Cobb Melting Algorithm to manage the primary melting physics.

Probabilistic & Weighting Changes

- **Expert Weighting Transition:** Both deterministic and probabilistic forecasts now utilize Expert Weighting. Operational probabilistic forecasts shift from equal weighting (1% each) to predefined unequal weights that prioritize higher-resolution inputs.
- **Expanded Distribution:** Added P1 and P99 distribution amounts for all winter elements (Snow/Ice amounts, Snow Level, and Snow Ratio) across CONUS, Alaska and Hawaii.
- **Data Maximization:** The system now includes 6-hour input forecasts in the 24/48/72-hour snow and ice accumulation calculations. This allows CAMs to contribute to longer-period totals even if they do not cover the entire duration. See more below under the “Gap Weighting” section.
- **New 6-H forecast projection:** Addition of 6-H forecast projection starting at T-1 for NBM Cycles 01/07/13/19Z (e.g. 24-H snow forecast for 13Z NBM starts at 12Z and runs through projection 23.)

New v5.0 Products

- **Probability-Matched Mean (PMM):** Applied to snow and ice accumulations to highlight corridors of highest accumulation potential. More on PMM here: PMM Procedure
- **Calibrated Exceedance Probabilities:** New calibrated probabilities for snow amounts (e.g., Prob > 6") to complement probabilistic existing guidance.
- **Deterministic/Probabilistic Snow Depth:** Introduced at the request of the fire weather community.
- **Instantaneous Temperature and Dew Point (QMD):** Allows the NBM to generate percentiles and probabilities which allow the user to assess potential outcomes for temperature values at a particular time, as opposed to using only min/max values

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- **Probabilistic Apparent Temperature (QMD):** To assess apparent temperatures in probabilistic space.

Model Suite & Structural Updates

The winter system utilizes a 100-member multi-model ensemble (MME) to drive its outputs.

Model/Members	Resolution (km)	NBM v5.0 Updates/Role in Winter Suite	Cycles Available
HRRR (1)	3 km	High-resolution Convective Allowing Models (CAMs) are prioritized for early projections.	All 24 hours
HRRRX (1)	3 km	High-resolution Convective Allowing Models (CAMs) are prioritized for early projections.	00/06/12/18Z
HiRes FV3 (1)	3 km	High-resolution Convective Allowing Models (CAMs) are prioritized for early projections.	00/12Z
HiRes ARW (1)	3 km	High-resolution Convective Allowing Models (CAMs) are prioritized for early projections.	00/12Z
HiRes ARW2	3 km	High-resolution Convective Allowing Models (CAMs) are prioritized for early	00/12Z

(1)		**projections.**	
NAM Nest (1)	**3 km**	**High-resolution Convective Allowing Models (CAMs) are prioritized for early projections.**	**00/06/12/18Z**
RAP (1)	**13 km**	**High-frequency short-range guidance.**	**All 24 hours**
RAPX (1)	**13 km**	**High-frequency short-range guidance.**	**03/09/15/21Z**
CMC RDPS (1)	**10 km**	**New Canadian Regional Deterministic solution useful for days 2-3.5 when CAMs drop out.**	**00/06/12/18Z**
CMC REPS (4)	**10 km**	**New Canadian Regional Ensemble system useful for days 2-3 when CAMs drop out.**	**00/06/12/18Z**
GFS (1)	**13 km**	**Core Global U.S. physics based deterministic model.**	**00/06/12/18Z**
CMC GDPS (1)	**15 km**	**New Canadian Global deterministic input.**	**00/12Z**

GEFS (30)	**25/50 km**	**Surface variables increased to 0.25° resolution through 240 hours in v5.**	**00/06/12/18Z**
ECMWF E (50)	**18 km**	**0.2° resolution from 0.5° for all 50 members; hourly through 72 hours (48 in NBM) in v5.**	**00/12Z**
CMC GEPS (5)	**50 km**	**New Canadian Global ensemble diversity for probability spread.**	**00/12Z**

Winter Weighting Schema

v5.0 moves away from the 1% equal-weighting of the 100 model inputs used in V4.3. Both deterministic and probabilistic forecasts are now expert weighted. Note that non-Cams/RAP use direct model output (DMO) QPF.

NBM v5.0 Winter Weights: Early Projections

Model Category	Model Member	Latest Update (NBM Cycle)	Weight (%)
High-Res (CAMs)	**HRRR**	**Hourly**	**16.0%**
	HRRRX	**03/09/15/21Z**	**6.0%**

	HiResARW	**04/16Z**	**10.0%**
	HiResARW2	**04/16Z**	**10.0%**
	HiResFV3	**04/16Z**	**12.0%**
	NAMnest	**03/09/15/21Z**	**12.0%**
Short-Range	**RAP**	**Hourly**	**5.0%**
	RAPX	**00/06/12/18Z**	**3.0%**
	CMC RDPS (QMD)	**01/07/13/ 19Z**	**2.7%**
	4 CMC REPS (QMD)	**01/07/13/ 19Z**	**2.7% / member**
Global/Ens	**GFS (QMD)**	**01/07/13/ 19Z**	**2.0%**
	CMC GDPS (QMD)	**07/19Z**	**2.0%**

	30 GEFS (QMD)	**01/07/13/ 19Z**	**0.1% / member**
	50 ECMWFE (QMD)	**01/13Z**	**0.1% / member**
	5 CMC GEPS (QMD)	**07/19Z**	**0.1% / member**

NBM v5.0 Winter Weights: Later Projections (Beyond ~72 hrs but depends on specific element.)

Model Category	Model Member	Weight (%)
CAMs / Short-Range	**All Others**	**0.0% (Dropped out)**
Global Det.	**GFS**	**8.0%**
	CMC GDPS	**7.0%**
Global Ens.	**50 ECMWFE (QMD)**	**50.0% (1.0% each)**
	30 GEFS (QMD)	**30.0% (1.0% each)**

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	5 CMC GEPS (QMD)	**5.0% (1.0% each)**

Examples included of specific elements weighting for the NBM 13Z cycle through time:

Hourly Forecasts
6-Hour Forecasts
24-Hour Forecasts
Snow Level Forecasts

Model Precipitation Type Processing

This section details the technical workflow for preparing and refining precipitation type (Ptype) data within the NBM v5.0 winter suite. The system produces data for four discrete types: Snow, Ice (ice pellets/sleet), Freezing Rain, and Rain, which serve as standalone products and critical inputs for subsequent snow and ice accumulation calculations.

Downscaled Model Ptype Data Preparation

Models: ECMWFE, GEFS, CMC (RDPS/REPS/GDPS/GEPS), and GFS.

- **Standard Ingest:** Binary Ptype datasets are ingested from raw model GRIB2 data and reformatted to TDLPACK.
- **ECMWFE Transformation:** Raw ECMWFE Ptype is provided as a single multi-value dataset. This is transformed into four binary datasets using the mapping below:

ECMWFE to MDL Ptype Mapping		
ECMWFE Value	**ECMWFE Ptype**	**MDL Ptype**
0	**None**	**None**
1	**Rain**	**Rain**

3	**Freezing Rain**	**Freezing Rain**
5	**Snow**	**Snow**
6	**Wet Snow**	**Snow**
7	**Mixed Rain and Snow**	**Rain**
8	**Ice Pellets**	**Ice**

- **CMC Rate and Dominant Type Selection:** Because CMC models do not provide binary Ptype, the system utilizes precipitation rates (kg/m²/s) for Snow, Ice Pellets, Freezing Rain, and Rain.
  - **Rate Calculation :** Converts accumulated precipitation into discrete rates. The window is set to 1 hour for RDPS, 3 hours for REPS, and shifts from 3 to 6 hours for global models (GDPS/GEPS) at later projections.
  - **Dominant Assignment :** Assigns a binary "1" to the type with the largest rate. In the event of a tie, the Order of Severity priority is: (1) Freezing Rain, (2) Snow, (3) Ice Pellets, (4) Rain.
  - **Null Handling:** If rates for all four types are 0, the grid point is set to 0.0 (no precipitation).

Regional Refinement and Thermal Logic

Once the data is reformatted and regridded to the NBM 2.5 km (CO) or 3.0 km (AK) domains, several refinement subroutines are executed in a single run:

- **Ptype Conflict Resolution:** Ensures only a single Ptype is active per grid point. If multiple types contain a "1", priority is given following the decision tree: (1) Snow, (2) Ice, (3) Freezing Rain, (4) Rain**.**
- **Approximate Downscaling:** Calculates a downscaled 2-m temperature to identify areas too warm to support snow. This routine mimics GFE "smart init" logic using available geopotential heights and temperatures**.**

- **DsTW Flagging:** Flags instances (value = 10) where an active Ptype is thermally inconsistent. Snow is flagged if the Downscaled Wet-Bulb Temperature (DsTw) is > 38F; Freezing Rain is flagged if DsTw is > 32F.
- **Thermal Type Flipping:** Reverses flagged types to Rain in the following order:
  - Grid points with flagged Snow change to Rain.
  - Flagged Snow values are changed to no Snow.
  - Grid points with flagged Freezing Rain change to Rain.
  - Flagged Freezing Rain values are changed to no Freezing Rain.
- **Elevation-Based Correction:**
  - If a grid point is above the calculated snow level and contains Rain, the Ptype is changed to Snow.
  - For any point where both Rain and Snow are now set (due to elevation correction), the Rain value is set back to no rain.

Remaining Model Data Preparation

Models: HIRESW_FV3, HRRR, NAMNest, RAP, WRF_ARW, WRF_MEM2.

- **Regridding:** Binary PTYPES are read from GRIB2, converted to TDLPACK, and regridded to regional NBM domains.

SLR Methods

This section details the NBM computed Snow-to-Liquid Ratio (SLR) by integrating four distinct scientific methodologies into a final blended product.

Cobb Method

The Cobb method is a physically-based, top-down algorithm that estimates snow density by constructing vertical atmospheric profiles at every grid point. It focuses on identifying where snow crystals are actively growing and weights their density based on moisture and lift.

Profile Construction and Vertical Resolution

The routine builds a high-resolution vertical profile by fetching model data for Geopotential Height, Temperature, Relative Humidity (RH), and Vertical Velocity.

- **Search Range:** The system searches model levels every 25 hPa, beginning at 925 hPa and extending up to 300 hPa.
- **Terrain Integrity:** To avoid erroneous terrain-induced artifacts, levels below 925 hPa are excluded. Only levels physically above the terrain height are considered in the final calculation.
- **Smoothing:** A 25-point smoother is applied to the vertical velocity field at each individual level to ensure spatial consistency across the grid.

Core Calculations at Each Level

For every valid vertical level in the profile, the routine performs three critical operations:

- **Vertical Velocity Scaling:** The vertical velocity is converted into upward motion (positive value). This motion is then scaled by the square of the Relative Humidity (RH). This scaling ensures that dry layers (RH < 80%) do not contribute significantly to the final snow ratio.
- **Base SLR Determination:** The routine assigns a base snow ratio for each level using a polynomial relationship based on temperature.
- **Thermal Stability Averaging:** To increase calculation stability, a three-pass average is performed at each level. The routine calculates ratios for the forecast temperature (T), T - 1F, and T + 1F , then averages these results to arrive at a stable base slr for that level.

Final Blending and Output

Once the individual layer ratios are computed, the routine produces a single weighted result:

- **Weighted Summation:** The final SLR for a grid point is the sum of the layer ratios, each weighted by that layer's vertical velocity contribution relative to the total vertical velocity across the entire profile.
- **Physical Limits:** If temperatures are too warm (above 3.0°C), the snow ratio is forced to zero.
- **Final Refinement:** The resulting grid of blended snow ratios undergoes a final 25-point smoother before being passed to the snow accumulation routines.

Max Temperature Aloft Method

This method estimates SLR based on the maximum temperature found within the troposphere.

- **Layer Analysis:** Identifies the maximum temperature in the layer between 2000 feet above ground level (AGL) and 400 hPa.
- **Polynomial Relationship:** It applies a 5th-order polynomial relationship to this temperature to derive the snow ratio. If temperature data is missing, it calls a separate routine to compute the tropospheric profile.

Thickness Method

This is a synoptic-scale approach that uses the vertical depth of a specific atmospheric layer.

- **Layer Calculation:** Fetches geopotential heights at 850 hPa and 700 hPa to determine the thickness of that specific layer.
- **Linear Equation:** The resulting thickness is inserted into a linear equation ($SLR = -0.16559 \times Thickness + 263.35$) to estimate the ratio.

Blended SLR

This routine serves as the master integrator, combining the methodologies above into a single consistent grid.

- **Integration:** It takes an equally weighted average of the Cobb, MaxT Aloft, and Thickness methods .
- **WPC-Roebber Integration:** It also incorporates the WPC-Roebber snow density product, converting its density values into a snow ratio (e.g., 1000/*Density*) for the GFS only.
- **Consistency Checks:** The routine performs grid consistency checks to ensure all input methods (terrain and model fields) align properly before final computation.

Model SLR Methods Usage

Model	Snow Ratio Techniques
HRRR	50% Cobb, 50% MaxTAloft
HRRRX	50% Cobb, 50% MaxTAloft
RAP	50% Cobb, 50% MaxTAloft
RAPX	50% Cobb, 50% MaxTAloft
HiResARW	50% Cobb, 50% MaxTAloft
HiResARW2	50% Cobb, 50% MaxTAloft

HiResFV3	50% Cobb, 50% MaxTAloft
NAMNest	50% Cobb, 50% MaxTAloft
GFS	33% Cobb, 33% MaxTAloft, 33% Roebber (through model 84-H)
GEFS	33% Cobb, 33% MaxTAloft, 33% 850-700mb thickness
ECMWFE	33% Cobb, 33% MaxTAloft, 33% 850-700mb thickness
CMC GDPS	33% Cobb, 33% MaxTAloft, 33% 850-700mb thickness
CMC RDPS	33% Cobb, 33% MaxTAloft, 33% 850-700mb thickness
CMC REPS	50% MaxTAloft, 50% 850-700mb thickness (No Cobb due to lack of Vertical Velocity Information.)
CMC GEPS	50% MaxTAloft, 50% 850-700mb thickness (No Cobb due to lack of Vertical Velocity Information.)

Model Snow Level

The NBM is designed to calculate a grid of snow levels (measured in feet above sea level) by determining the highest altitude where falling snow is expected to transition into rain.

Core Scientific Methodology

The routine estimates the snow level based on vertical atmospheric profiles of wet-bulb temperature and geopotential height.

- **Definition of Snow Level:** The altitude where the wet-bulb temperature first crosses above 0.5° Celsius (approximately 273.65 Kelvin).
- **Search Direction:** The calculation constructs a profile from model fields fetched every 25 hPa (from 1000 hPa up to 100 hPa). The search is performed from the top of the profile downwards, ensuring only the highest crossing level is considered the snow level.
- **Interpolation:** For models with limited vertical data (such as GEFS), the code performs a pressure-weighted interpolation to fill in missing levels for higher accuracy.

Processing Logic

- **Grid Consistency:** The routine ensures that geopotential height and temperature grids are equivalent in dimension before beginning calculations.
- **Profile Construction:** It builds a vertical profile at each grid point using available levels.
- **Threshold Detection:** It identifies the altitude where the atmosphere warms beyond the 0.5°C threshold. If the wet-bulb temperature at the top of the profile is already above this threshold, the snow level is set to that highest geopotential height.
- **Terrain Handling:** Based on requests from the Western Region, the calculation includes model levels that may be technically below ground level to ensure a consistent grid. Final values are constrained to be no less than zero.
- **Smoothing:** A 9-point smoother is applied to the final output grid to remove computational noise and ensure spatial consistency.

Variable Output

The final results are returned as geopotential heights converted from meters to feet above sea level (ASL).

Model Snow/Ice

This section details the technical logic for 1-hour and 6-hour snow and ice accumulation routines. The snow routines calculate accumulation by parsing Quantitative Precipitation Forecast (QPF) based on conditional precipitation type probabilities and applying a dynamic Snow-to-Liquid Ratio (SLR). Ice accumulation is calculated using the Freezing Rain Accumulation Model (FRAM), which converts liquid QPF into flat ice accretion.

1-Hour Snow

- **Purpose:** Computes hourly snowfall and sleet amounts for short-range guidance.
- **Temporal Disaggregation of 6-H QMD QPF:** The foundational 6-hour QPF from the QMD system is first broken down into 1-hour increments:
    - **Hourly Division:** The routine fetches the downscaled 6-hour QPF and divides it by six to arrive at an initial "average" 1-hour rate.
    - **Temporal Setup:** For each 6-hour period (e.g., hours 1–6, 7–12, etc.), these equal hourly values are assigned to a time series array (QPF01) covering all necessary hourly projections.
- **Savitzky-Golay Temporal Smoothing:** To prevent abrupt "stair-step" artifacts between 6-hour blocks, the routine applies Savitzky-Golay smoothing.
    - **Filter Application:** The routine uses a least-squares polynomial fit to ease the transition between the 6-hour windows.
    - **Parameters:** It utilizes a specific filter configuration which considers two points before and after each hourly value to compute a smoothed signal.
    - **Efficiency:** All 1-hour projections are smoothed in a single pass the first time the routine is called, and the resulting SIGNAL is saved for use in all subsequent hourly projections.
- **Logic:** Multiplies 1-hour QPF by the SLR and the conditional probability of snow.
- **Variable Use:** Uses 1-hour QPF (directly or interpolated from 3/6-hour data), period-averaged SLR, and downscaled wet-bulb temperature.
- **Sleet Handling:** Sleet is included in the total snow amount, calculated using a fixed 2:1 ratio relative to liquid equivalent.

6-Hour Snow

- **Purpose:** Aggregates hourly accumulation into 6-hour blocks for deterministic and probabilistic products.
- **Summation Method:** The 6-hour total is derived by summing six individual 1-hour increments.
- **Consistency:** Interpolates 3-hourly or 6-hourly SLR and wet-bulb data to an hourly scale to ensure sub-period physical consistency.

Detailed Cobb Melting Algorithm:

Cobb Melting SLR Method.pdf

A critical update in NBM v4.3 was the implementation of a Weighted Wet-Bulb (Tw) Function within the Cobb logic to better match the NWS Forecast Builder approach.

- **Initial Threshold:** Melting initially begins when the surface wet-bulb temperature (Tw) is at or above 32F.
- **Melt Factor Calculation:** The routine calculates a "Melt Factor" by comparing the precipitation rate to a power-law function of the wet-bulb temperature (using a 1.3 exponent).
- **Weighting Uncertainty:** Because relying on a single forecast Tw is risky in marginal setups, the algorithm now calculates three potential melt rates: the actual forecast Tw, Tw - 1F, and Tw - 2F.

- **Final Blend:** These three rates are weighted (actual forecast highest, -2 degrees lowest) to produce a final QPFMELT factor.
- **SLR Adjustment:** If the melt rate is extreme (e.g., Tw ≈ 38F and light precip), the SLR is set to zero. Heavy precipitation rates can "overpower" the melt, allowing accumulation at higher temperatures.

1-Hour Ice

- **Purpose:** Computes hourly flat and line ice accretion.
- **FRAM Inputs:** Requires hourly QPF (uses QMD/SAVGOL like 1-H snow if available), conditional freezing rain probability, surface wind speed, and wet-bulb temperature.
- **Efficiency Calculation:** The Ice-to-Liquid Ratio (ILR) is determined by three factors:
    1. **Wind Speed Factor:** Higher winds increase horizontal moisture flux and heat removal.
    2. **Wet-Bulb Factor:** Colder wet-bulb temperatures promote quicker freezing through evaporative cooling.
    3. **Precipitation Rate Factor:** Efficiency decreases as precipitation rates increase, as water has less time to freeze before runoff occurs.

6-Hour Ice

- **Aggregation:** Like the snow routine, this sums six 1-hour FRAM increments to produce 6-hour flat ice totals.
- **Variable Handling:** Interpolates 3/6-hourly wind and wet-bulb data to the hourly scale for precise accretion modeling.

Blended Precipitation Type Forecast

Core Methodology

The system generates weighted probabilities for four distinct precipitation types: Snow, Rain, Freezing Rain, and Sleet.

- **Binary Input Processing:** The script ingests binary forecasts (0 or 1) for each precipitation type from individual model members.
- **Weighted Averaging:** It calculates a weighted average of these binary values across the 100-member ensemble. For example, if members representing 60% of the total expert weight forecast "Snow" at a grid point, the raw probability for snow is 60%.
- **Cycle Retrieval:** This routine like all of the winter forecasts uses a 2-day lookback to find the nearest valid cycle for each model to ensure the ensemble is as complete as possible.

Normalization and Consistency

A critical step in the blending process is ensuring that the final probabilities are physically realistic across all types.

- **Normalization Logic:** After calculating raw probabilities for all four types, the system checks the sum at every grid point. If the combined probability of Snow, Rain, Freezing Rain, and Sleet exceeds 100%, the values are normalized.
- **Calculation:** If the sum is > 100%, each individual type's probability is multiplied by (100 / Total Sum) to ensure the final total is exactly 100%.
- **Expert Weighting:** The process uses lead-time dependent weights (e.g., prioritizing CAMs like HRRR in the short term) to provide better skill and give a more realistic feel for extremes and variability.

Blended SLR and Snow Level Forecast

Deterministic (Expert Mean) Logic

- **Weighted Mean Calculation:** The final forecast field is a simple weighted mean of all models with available data for the given lead time.
- **Normalization:** Weights are loaded from a CSV (e.g., `winter_weights.csv`) and normalized so they sum to 1.0 based solely on the models found for that specific cycle.
- **Snow Level Refinement:** Because snow level forecasts can be noisy, a 9-point smoother is applied to the final weighted mean field to reduce computational artifacts.

Weighted Percentile Forecasts

This process generates a range of 15 probabilistic outcomes (1st through 99th percentiles) to represent forecast uncertainty.

- **Weighted Quantiles:** Rather than a simple average, this script computes weighted quantiles across the multi-model ensemble. Each model's forecast value is given an importance factor based on its assigned expert weight.
- **Percentile Thresholds:** The script specifically calculates the following 15 values: 0.01, 0.05, 0.10, 0.20, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, 0.75, 0.80, 0.90, 0.95, and 0.99.
- **Consistency:** For Snow Level, the 9-point smoother is applied to *each* individual percentile field to ensure spatial consistency across the entire probabilistic distribution.

Blended Snow and Ice Forecast

Deterministic (Expert Forecast) Method

The deterministic expert weighted mean represents the "most likely" snow or ice accumulation. It is calculated by utilizing either 1 or 6 hour model forecasts.

- **Weighting Strategy:** v5.0 uses a lead-time dependent expert weighting schema.

High-resolution Convective Allowing Models (CAMs) like the HRRR (16%) are prioritized in early projections (up to ~72 hours).

- **Ensemble Integration:** Beyond ~72 hours, weights shift toward global ensembles, with the ECMWFE (50%) and GEFS (30%) becoming primary drivers as CAMs/regionals drop out.
- **Accumulation Period:** 24, 48, and 72-hour totals are computed by summing consecutive 6-hour forecasts to maximize data availability and to ensure temporal consistency/prevent longer-term totals from being lower than shorter-term ones. See more below under the “Gap Weighting” section.

Weighted Threshold Probabilities

These products provide the probability of exceeding specific thresholds (e.g., Prob >= 6" of snow).

- **Smooth Probability Function:** Accumulations from each model are converted into smooth probabilities using a sigmoid-based function. Transition widths for these functions are scaled to the threshold size (e.g., 15% of the threshold for snow) to ensure realistic gradients.
- **Weighted Averaging:** A weighted average of these individual model probabilities is calculated per grid point based on the expert weights.
- **Spatial Smoothing:** A Gaussian filter is applied to the final blended grid to reduce model-resolution artifacts and produce a spatially consistent forecast.

Weighted Percentile Forecasts

Percentiles provide a range of potential outcomes, from the "low end" (P1) to the "high end" (P99).

- **Quantile Calculation:** specifying percentiles (1st through 99th) is achieved by computing weighted quantiles from the accumulated model data.

Pseudo Setup (100 Members)

We'll split the members into three categories based on their forecast:

- **Group 1: The Dry Members** (25 members)
  - Forecast: 0.0"
  - Expert Weight: 0.006 each (Total weight for group = 0.15)
- **Group 2: The Main Consensus** (50 members)
  - Forecast: 2.0"
  - Expert Weight: 0.012 each (Total weight for group = 0.60)
- **Group 3: The Heavy Snow Members** (25 members)
  - Forecast: 6.0"
  - Expert Weight: 0.010 each (Total weight for group = 0.25)

Total weight check: 0.15 + 0.60 + 0.25 = 1.00.

The Percentile Calculation

To find the percentiles, the code "stacks" these models from lowest to highest and tracks the cumulative weight.

Snow Amount	Model Count	Total Weight for Group	Cumulative Weight
0.0"	25	0.15	**0.15**
2.0"	50	0.60	**0.75**
6.0"	25	0.25	**1.00**

Calculating the Percentile Results

The code looks for the point where the cumulative weight threshold is crossed.

- **10th Percentile:** We look for 0.10. This falls within the first group.
  - Result: 0.0"
- **50th Percentile (Median):** We look for 0.50. Since 0.15 < 0.50 < 0.75, this falls squarely in the 2.0" group.
  - Result: 2.0"
- **75th Percentile:** We look for 0.75. This is exactly at the boundary of the 2.0" group.
  - Result: 2.0"
- **90th Percentile:** We look for 0.90. Since 0.75 < 0.90 < 1.00, this falls into the 6.0" group.
  - Result: 6.0"

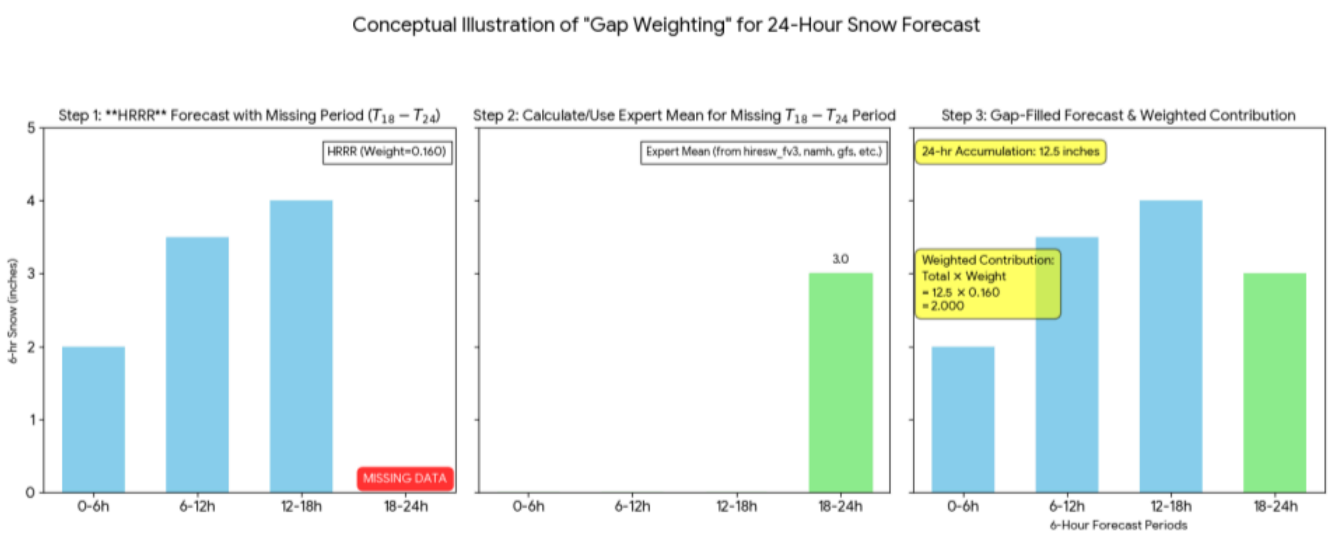
Consistency: Like the deterministic forecast, the 24/48/72-H forecasts are derived from 6-hour model accumulations to maintain physical consistency across time periods.

Gap Weighting (Model Dropout Logic)

"Gap Weighting" is a critical v5.0 improvement used when certain models (typically short-range CAMs) do not cover the entire accumulation window.

- **The Problem:** In previous versions, if a model like the HRRR ended at hour 18, it could not contribute to a 24/48 or 72-hour total, wasting valuable short-range skill.
- **The Solution:** v5.0 fills missing 6-hour periods for a model using an expert mean derived from all other models available for that specific period.
- **Calculation Flow:**
    1. **Period Identification:** For a 24/48 or 72-hour forecast, data is required for 6-hour blocks.
    2. **Filling Gaps:** If a model is missing any 6-hour block in a 24/48 or 72-hour window, (e.g. HRRR), the system calculates a weighted average for each of the incomplete 6-hour blocks remaining in the time window (expert mean) using all available models for which snow amounts are available.
    3. **Complete Model Total:** This "expert-filled" block(s) is added to the model's actual data to create a full 24/48 or 72-hour accumulation across the requested period.
    4. **Final Blend:** The resulting gap-filled model total is then multiplied by its assigned expert weight and integrated into the final blend.

This allows the NBM to leverage the high skill of short-range models for as long as they are available without introducing "jumps" or artifacts in the forecast when they drop out. Example illustration below:



Blended Snow/Sleet >.25 inch Liquid Equiv (%) Forecast

This product calculates the 24-hour probability that frozen precipitation (snow or sleet) will exceed a specific liquid equivalent (.25”) threshold.

Primary Calculation:

It determines the final probability by multiplying the 24-hour QMD PQPF (Probability of Quantitative Precipitation Forecast) by the average "expert-weighted" probability of snow or sleet across that same 24-hour window.

Operational Process:

1. **Data Retrieval:** It fetches the 24-hour PQPF grid based on a specific threshold (e.g., 0.25") and performs a "lookback" to sync the QMD model cycle with the current Blend projection.
2. **Temporal Averaging:** It collects 3-hourly probabilities for both snow and sleet. At each grid point and time step, it selects the maximum value between snow and sleet, then averages these values over the 24-hour period.
3. **Grid Processing:** Using OpenMP for parallelization, it computes the final product (PQPF x Average Frozen Probability) for every point on the grid.

Snow Depth Forecast

Snow Depth Documentation