Environment and Climate Change Canada

Centre Update

WGNE39

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Overview

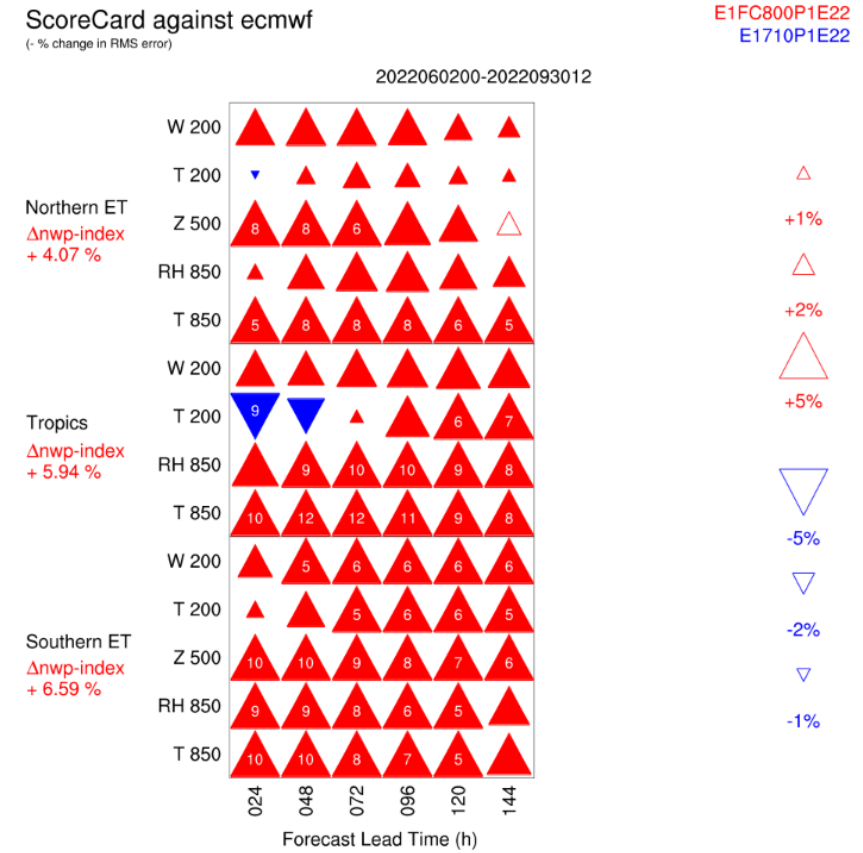
- Operational system upgrades in 2024
  - Major upgrade to the global ensemble prediction system
  - Moderate upgrades to deterministic and high-resolution systems
- Current experiments with machine learning
  - Graphcast fine-tuning and effective resolution
  - Spectral nudging towards ML inferences
- Future improvements
  - Next major upgrade expected in 2026

Global Ensemble Prediction System

- The Canadian Meteorological Centre (CMC) runs the Global Ensemble Prediction System (GEPS), which underwent a major upgrade in 2024:
  - 256-member EnKF was replaced with LETKF
  - Analyses are recentered on the deterministic 4DEnVar analysis
  - Scale-dependent localization
  - Elimination of climatological part of the background error covariance (B) matrix
  - Grid spacing reduced from 39 km to 25 km
  - Updates to model error representation
  - Upgrade of the NEMO version used in GEPS forecasts, including Delta-Eddington radiative flux transfer
- Improvements to guidance are highly significant

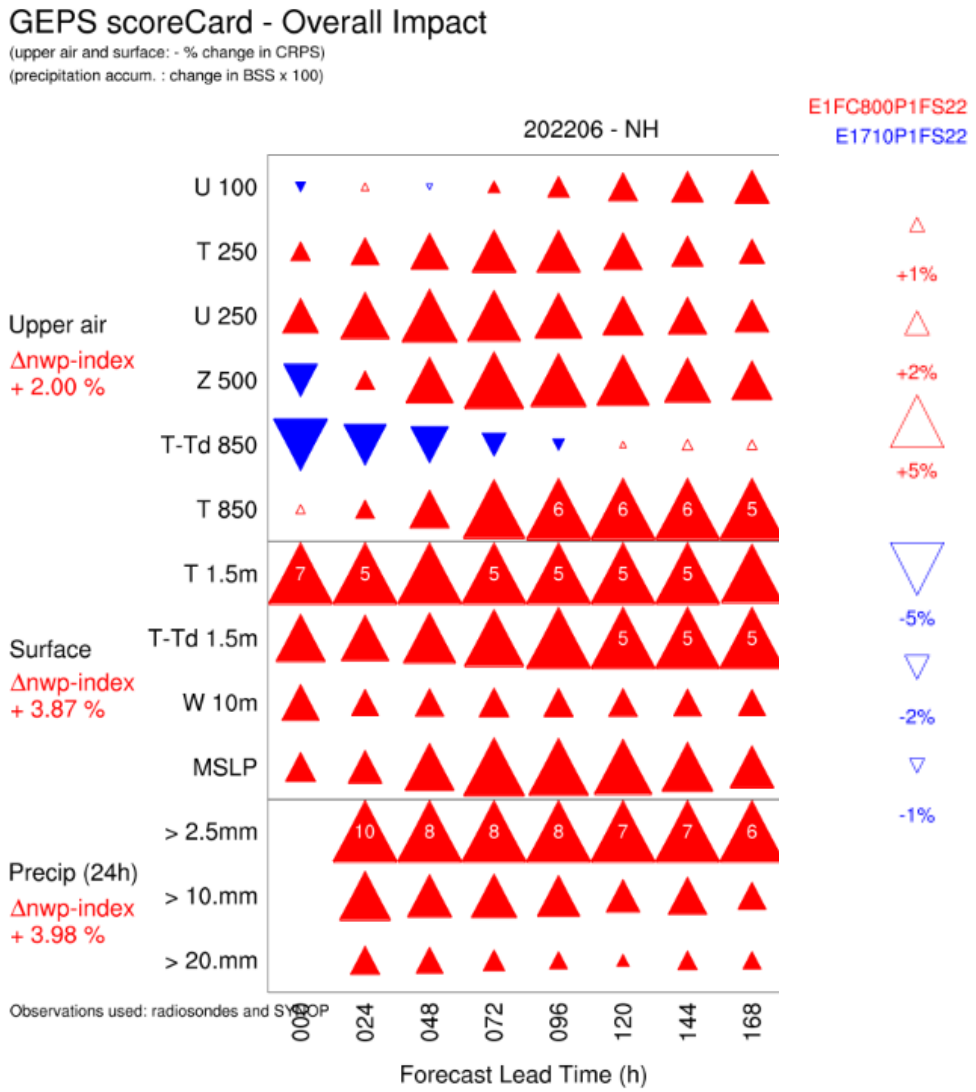
GEPS Control Member

- Increased resolution brings the GEPS control member to the grid spacing of the former deterministic model, a well-tested configuration
- Significant improvements are observed in the control member
- Some parameter adjustments were used to reduce biases:
  - increase in the cloud ice effective radius to reduce an upper-tropospheric warm bias



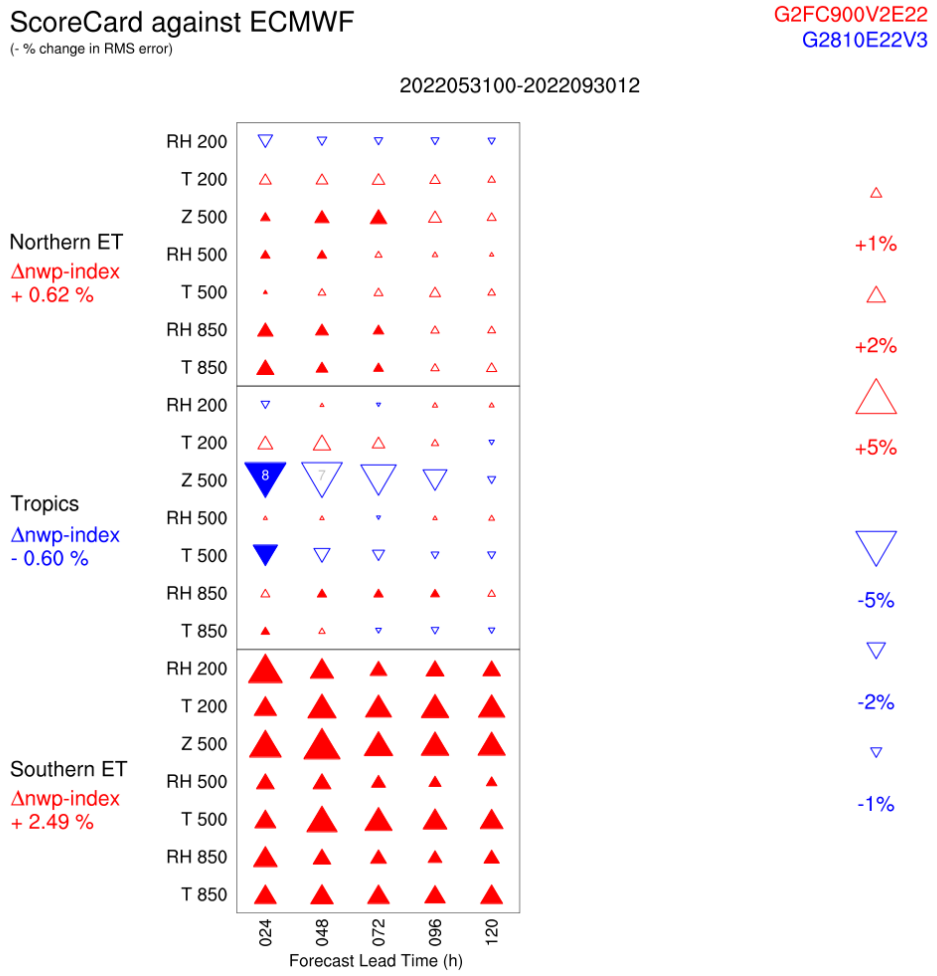
GEPS Probabilistic Forecasts

- Coupled GEPS forecasts from 20 sub-sampled analyses:
  - Additive inflation
  - Stochastic kinetic energy backscatter
  - Stochastically perturbed parameterizations (SPP)
- Some retuning of SPP was needed to reduce over-dispersion:
  - Reduction in upstream-point error model within the dynamical core
  - An expected cost of maintaining SPP



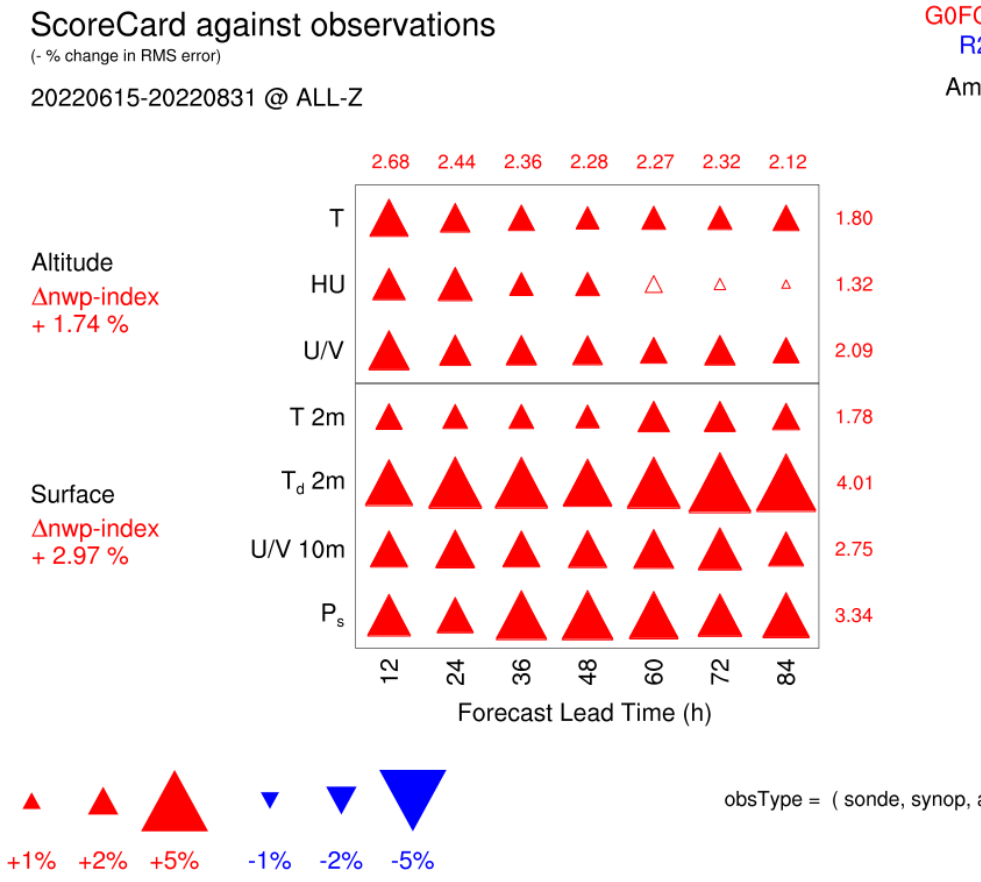
Global Deterministic Prediction System

- Upgrades to the 15-km GDPS in 2024 were modest:
  - All-sky assimilation of ATMS temperatures and AMSUB/MHS moisture
  - Additional assimilation of SWOB and METAR
- Improvements are noted particularly in the Southern Hemisphere as a result of the increased resolution/quality of the B-matrix from the GEPS
- This is one of the first times that the B-matrix has had a notable impact on deterministic scores



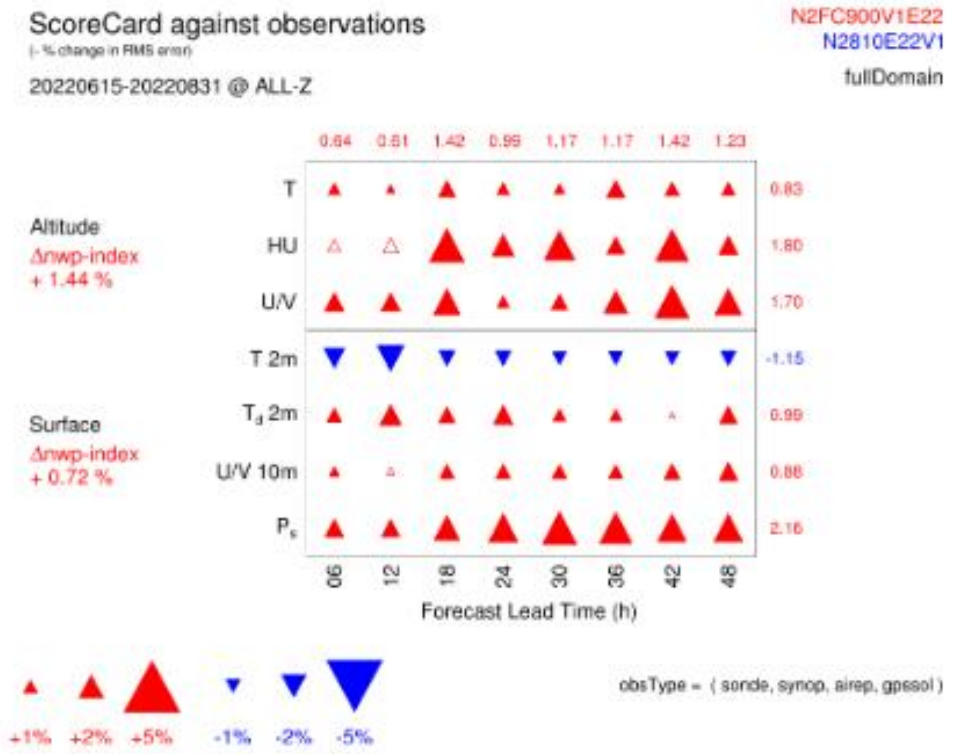
Regional Deterministic Prediction System

- With the GDPS at 15 km, the 10-km RDPS was eliminated from the operational suite
  - Reduce the number of operational systems (~40)
- A 10-km configuration of the GDPS added to the global suite in a discontinuous cycle:
  - Maintains resolution for services / users
  - Maintains resolution of piloting data for operational LAMs
- Both assimilation and forecasts benefit from the global domain, with results significantly improved over the former RPDS



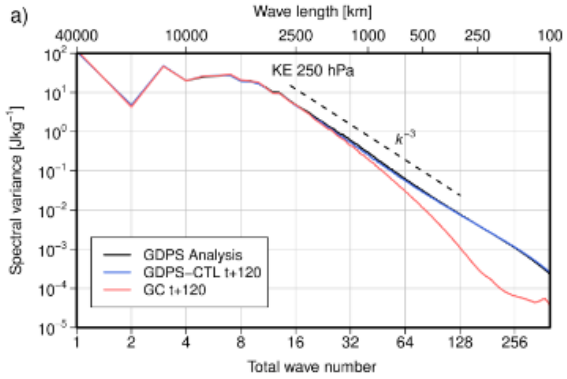
High Resolution Deterministic Prediction System

- Minor/indirect upgrades to the 2.5-km HRDPS:
  - Major updates to the independent surface analysis cycle (Caldas) used to initialize surface properties
  - Analysis increments computed using 25-km GEPS B-matrix (increased resolution)
  - Piloting data provided by 10-km global
  - Reduced filtering of resolved orography and corresponding TOFD reduction
- Improvements to scores are modest

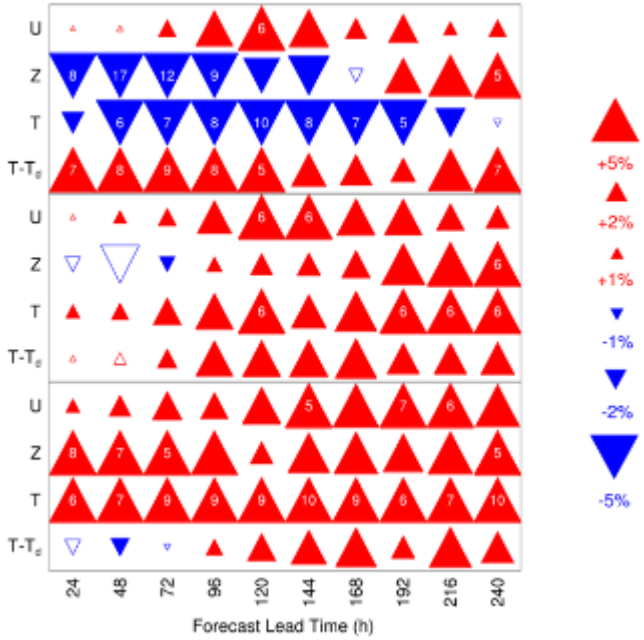


Experiments with Machine Learning

- Focus of modelling research is on reanalysis-trained full-system emulation rather than component replacement
- Most efforts are focused on Graphcast:
  - Model and pre-trained parameters are freely available
  - Training / fine-tuning is more complicated
  - Evaluation includes comparison at equivalent effective resolution
- Retraining of 13-level 0.25° Graphcast is currently underway, but GPU resources are very limited

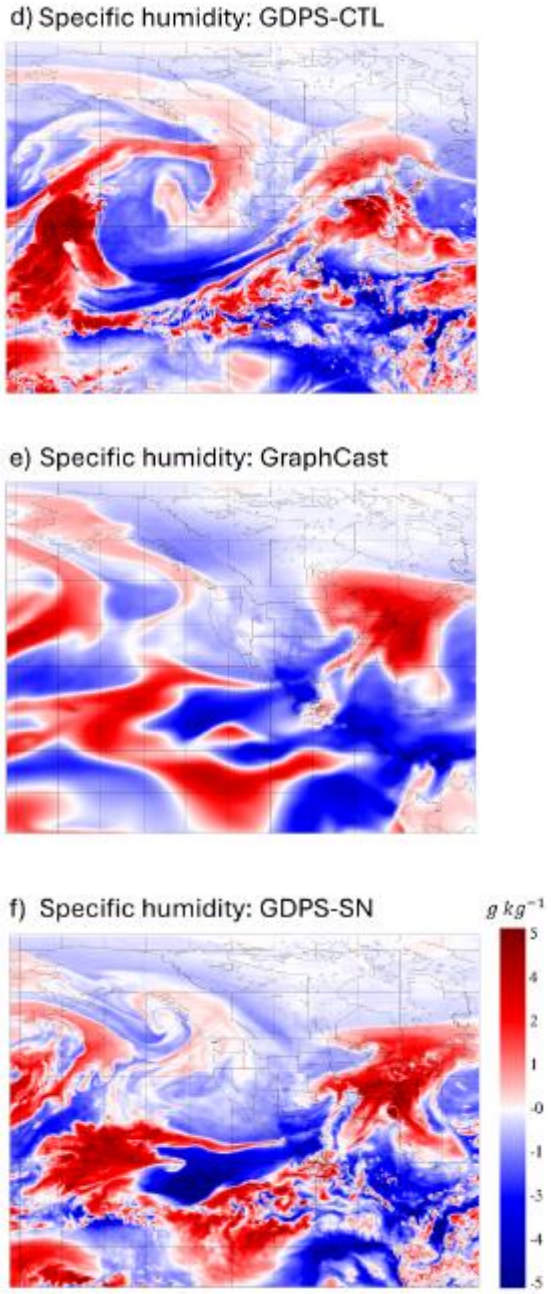


b) Low res. – Boreal winter



ML-Based Spectral Nudging

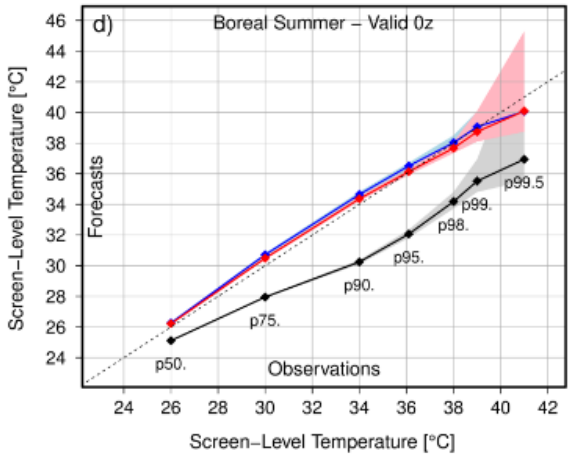
- ML-based inferences appear to be very good for large-scale features (smaller scales are removed as unpredictable)
- The global deterministic model can be spectrally nudged at large scales (>2500 km) to improve medium-range predictions:
  - Smaller scales are “filled” naturally by the physically based model
  - Balance and internal consistency is ensured
  - The full suite of coherent operational outputs can be produced

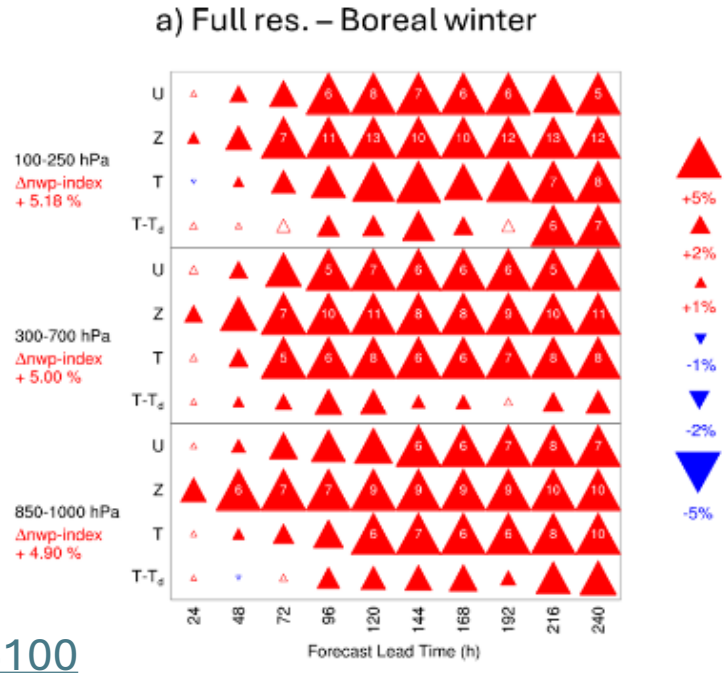


Example for 850 hPa specific humidity.

ML-Based Spectral Nudging

- Nudging-based hybridization allows the system to predict extremes (physical model) while improving medium-range guidance (ML model)
- An experimental version will be implemented once from-scratch Graphcast training complete
- Significant potential for improvement:
  - 37-level Graphcast suffers from a lack of fine-tuning but will require less vertical interpolation for nudging
  - Tests at ECMWF of nudging with model-level AIFS inferences are very promising





https://arxiv.org/pdf/2407.06100

Future Work (Physically Based Models)

- Major update to land surface and atmospheric physics for the high resolution deterministic prediction system
- Introduction of a new semi-Lagrangian dynamical core that eliminates the need for off-centering in all systems
- Further resolution enhancement in global ensembles (to 10 km spacing), including replacement of deterministic with control member
- Introduction of a cycling high-resolution LAM ensemble
  - Replaces the current 20-member 10 km downscaling from global ensemble analyses
  - Target grid spacing is ~6km