Using WINTRE-MIX observations to evaluate high-resolution forecast models

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https://www.eol.ucar.edu/field_projects/wintre-mix
High-resolution numerical forecasts of p-type

Overview

Numerical weather prediction (NWP) models run at high-resolution are a crucial tool for p-type forecasting

- Horizontal grid spacing ~3km, comparable with features of interest
- Can explicitly represent important effects of terrain and storm features
- Sophisticated treatment of cloud/precipitation, turbulence, and land surface processes
- P-type can be diagnosed from model output
High-resolution numerical forecasts of p-type

Using ensembles for probabilistic forecasting

- **Ensembles**: suite of distinct model forecasts used to map out range of possible outcomes
- Ensemble **members** may differ in
  - starting conditions
  - numerical approximations
  - representation of uncertain processes
- Ensembles are crucial tools for generating **probabilistic forecasts**
High-resolution numerical forecasts of p-type

Using ensembles for probabilistic forecasting

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![48-h Freezing Rain FRAM Estimate [fill, in.]](https://worldview.eastdata.nasa.gov/)

- (g) 10th Percentile
  - Init: 1800 UTC, 3 Feb 2022

- (h) 50th Percentile
  - Init: 1800 UTC, 3 Feb 2022

- (i) 90th Percentile
  - Init: 1800 UTC, 3 Feb 2022

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The HREF and HRRRE ensembles

High-Resolution Ensemble Forecast system (HREF)
- 3-km horizontal grid spacing
- Operational NWS model
- 10 members differ in:
  - *Initial and boundary condition source*
  - *Initialization time*
  - *Dynamical core*
  - *Physics parameterizations (e.g., clouds, turbulence)*
- Members may have biases relative to each other

High-Resolution Rapid Refresh Ensemble (HRRR-E)
- 3-km horizontal grid spacing
- Experimental model, run by NOAA-GSL
- 9 members are differ in:
  - *Perturbations to initial and boundary conditions*
  - *Perturbations to physics parameterizations*
  - Members are “equally likely”

<table>
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<th>LBC's</th>
<th>PBL</th>
<th>Microphysics</th>
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</table>
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Questions

• How well do modern high-resolution ensembles predict winter p-type?

• Do ensembles (or individual members) have systematic biases that we should consider?

• How can ensembles be improved?

Use WINTRE-MIX data and archived high-res. forecasts to examine these (will show “Intensive Observing Period #5 (IOP5) here)
IOP5: Mesoscale overview

2-m Temperature
10-m winds (full barb = 5m/s)

0000 UTC 23 February 2022

Observed/diagnosed p-type

Snow & Ice pellets
Freezing rain
Rain

https://www.eol.ucar.edu/field_projects/wintre-mix
IOP5: HRRRE dominant p-type vs. observations

Too much rain, too little freezing precip
IOP5: HRRRE ensemble-mean event-average temperature vs. observations

Storm Average Temperature [fill, °C].
HRRRE (fcst_spp_mp_pbl) Mean

1800 UTC 22 Feb. 2022 to 0600 UTC 23 Feb. 2022

Ensemble-mean is warm biased
IOP5: HRRRE warm vs. cold member event-average temperature vs. observations

Even the coldest members are too warm.
IOP5: HRRRE event-average temperature spread and error

- **Shading:** standard deviation across ensemble members (higher values suggest less confidence)
- **Markers:** root mean square error of ensemble forecast relative to observations (higher values = worse forecast)

Ensemble recognizes uncertainty, but is under dispersive especially near US-CAN border
IOP5: *HREF* temperature & $p$-type vs. observations

0000 UTC 23 February 2022

Too warm and too much RA vs. FZRA near US-CAN border
Forecasts of rain instead of FZ rain due to temperature biases
IOP5: HREF temperature & p-type vs. observations @ Trois Rivieres, QC

Ensemble members struggle with forecasting FZ rain vs. ice pellets
Summary

- WINTRE-MIX observations provide a rich resource for detailed evaluation of forecast models

- For IOP5, high-resolution ensembles (HREF, HRRRE) captured important mesoscale features influencing p-type but struggled with:
  - Maintaining shallow low-level cold air in the St. Lawrence Valley
  - Producing sufficient spread in temperature
  - Predicting freezing rain to ice pellet transition

Next steps

- Compare models with other WINTRE-MIX datasets
- Examine other WINTRE-MIX cases
- Use long-term observational datasets to see how ensemble biases generalize over many storms
- Use controlled model experiments to isolate sources of bias and test improvements

https://worldview.earthdata.nasa.gov/
https://www.eol.ucar.edu/field_projects/wintre-mix
Extra slides

https://www.eol.ucar.edu/field_projects/wintre-mix
Initialized: 02/17/2022 at 12:00Z. Forecast Valid: 02/18/2022 at 03:00Z.