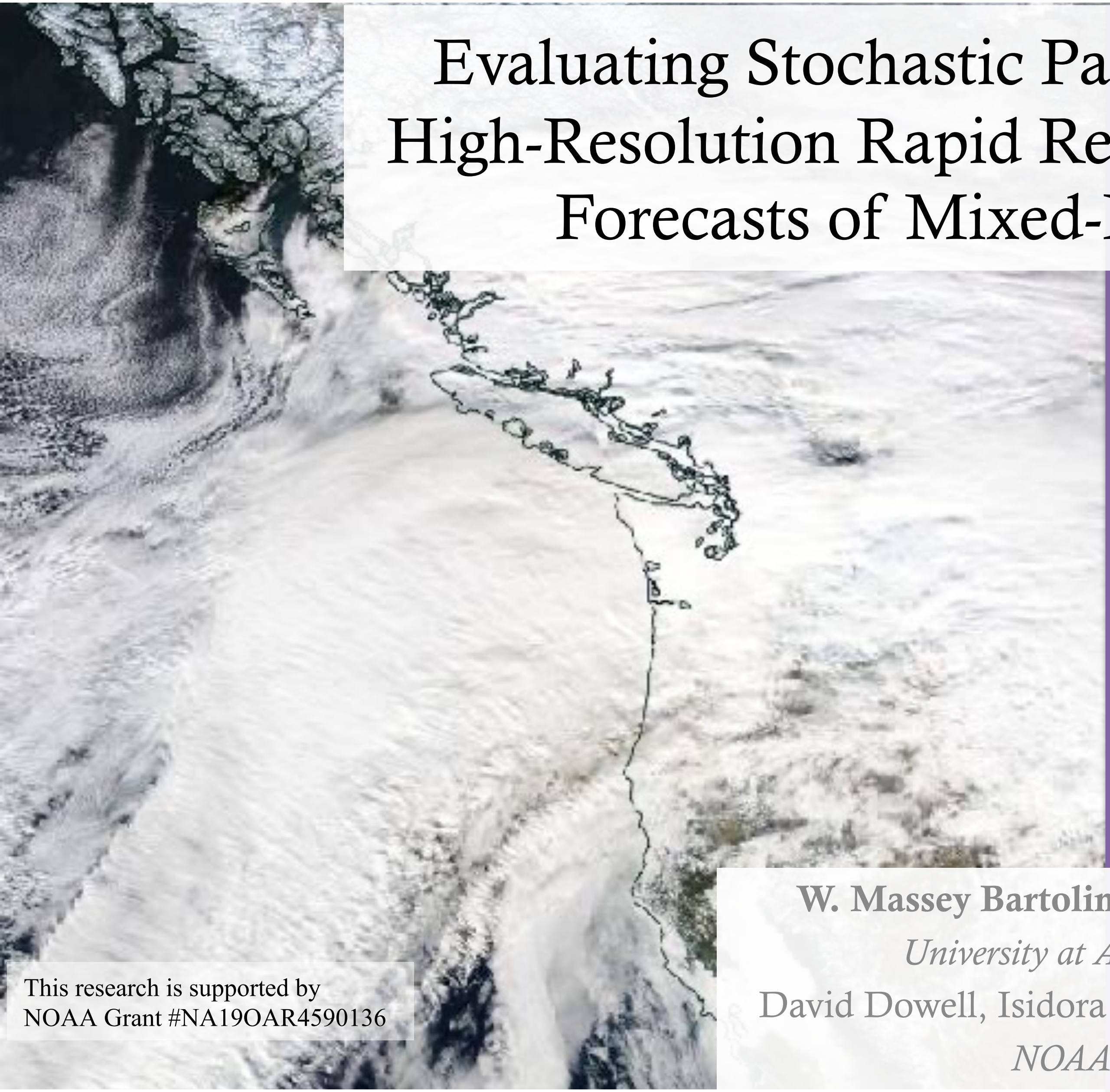
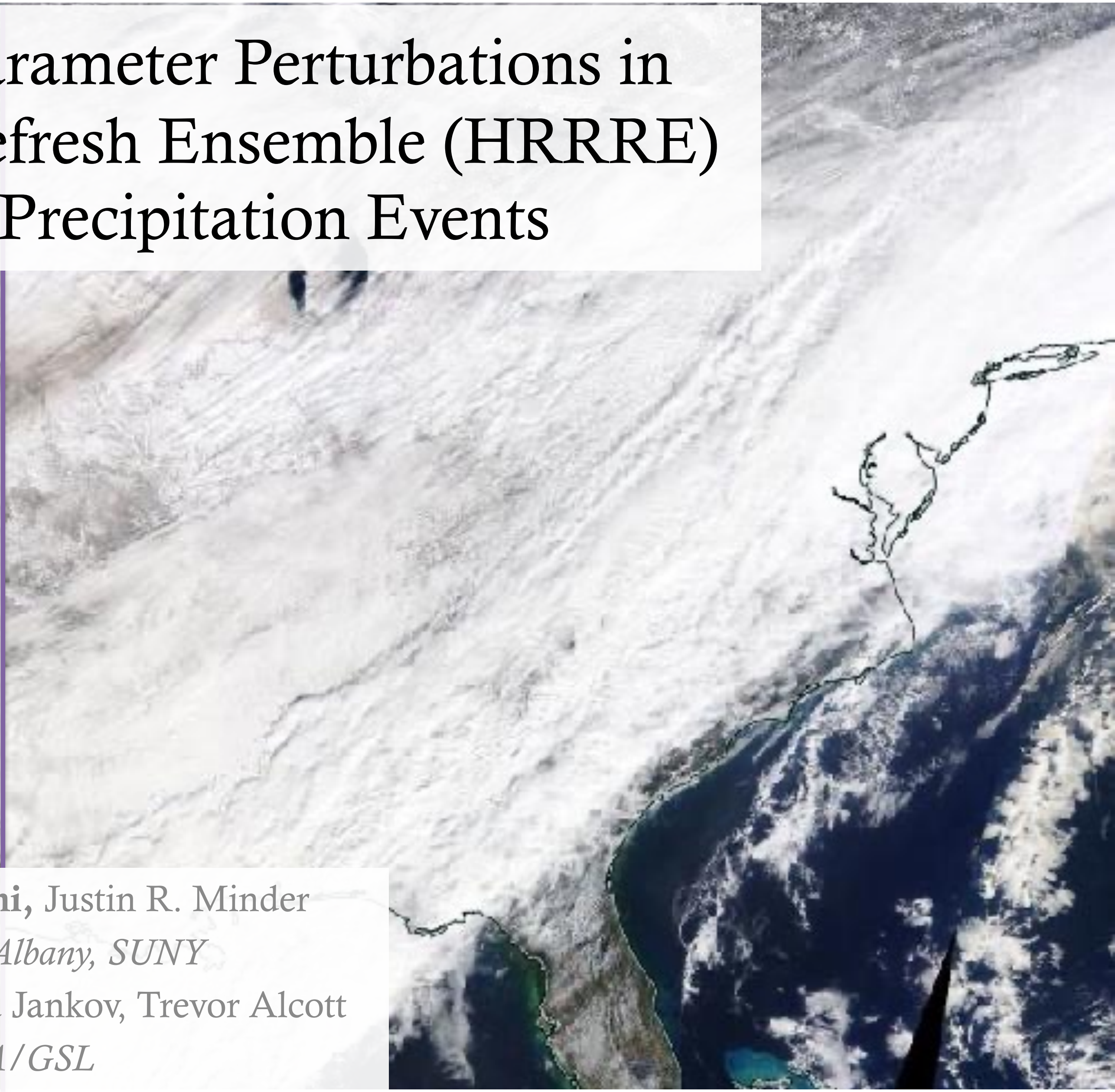




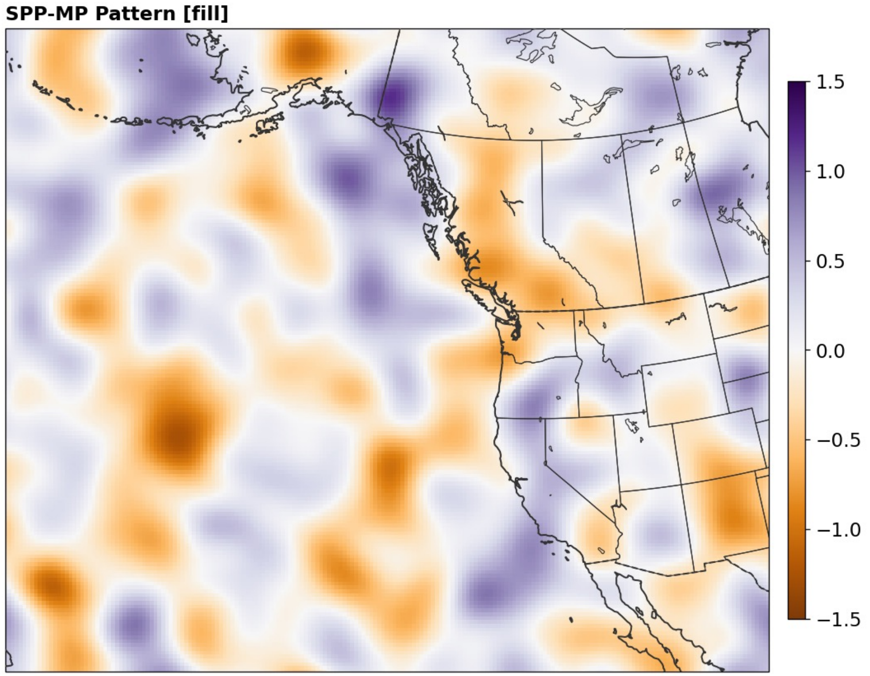
Evaluating Stochastic Parameter Perturbations in High-Resolution Rapid Refresh Ensemble (HRRRE) Forecasts of Mixed-Precipitation Events

W. Massey Bartolini, Justin R. Minder
University at Albany, SUNY
David Dowell, Isidora Jankov, Trevor Alcott
NOAA/GSL

This research is supported by
NOAA Grant #NA19OAR4590136

Introduction

- Motivation: exploring use of stochastic parameter perturbations (SPP) to improve ensemble prediction of winter precip. using High-Resolution Rapid Refresh Ensemble (HRRRE) framework
  - Using SPP, able to vary known uncertain parameters using physically-motivated range of values
  - Focus on SPP in planetary boundary layer (SPP-PBL) and microphysics (SPP-MP) schemes
- Future: U.S. modeling community heading toward single-physics ensemble (i.e., RRFS), once skill is competitive with multi-physics, multi-dycore ensemble (HREF)



Example of SPP pattern at one forecast time for a single ensemble member

Introduction

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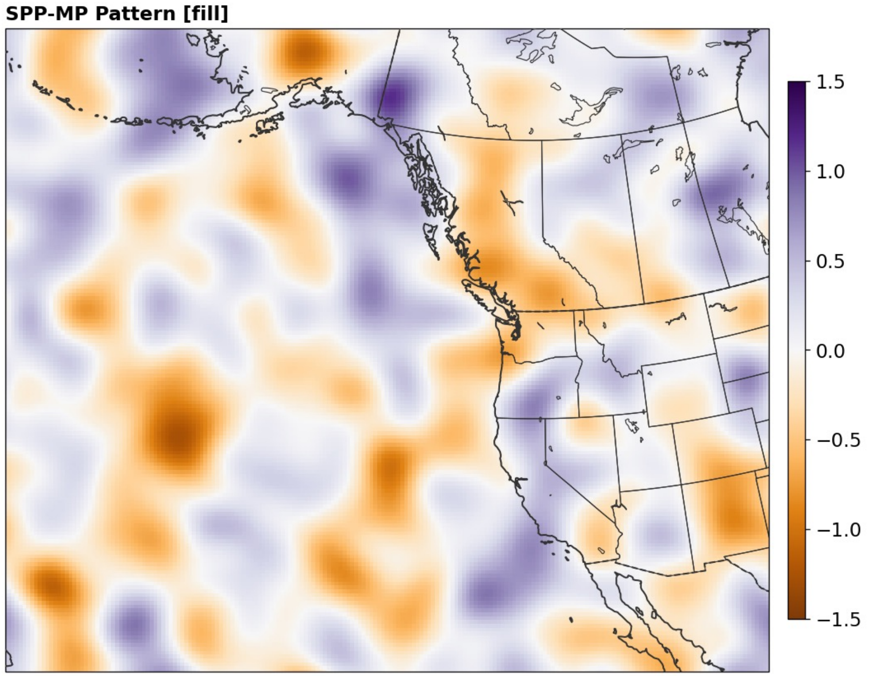


Example of SPP pattern at one forecast time for a single ensemble member

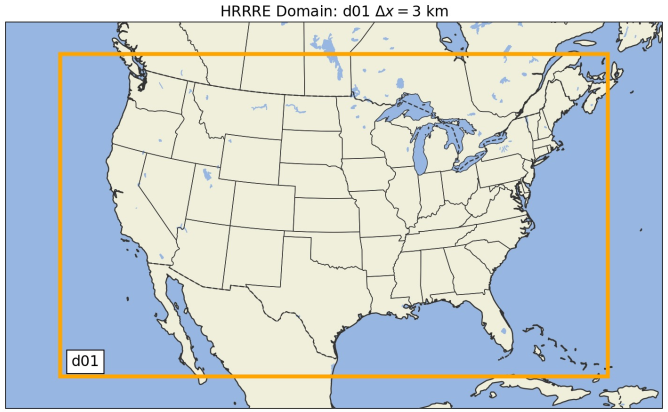
Goals of this presentation:

- Examine precip. spread characteristics between two ensemble configurations for two representative case studies, focusing on how SPP perts. affect mesoscale precip. variations
- Quantify differences in deterministic (ens. mean) and probabilistic forecast skill for near-surface thermodynamic, precipitation, and precipitation-type metrics

Physics uncertainty in high-res. ensembles

WPC-HMT: 2021-22 WWE Ensemble Configuration

- Forecasts run by NOAA-GSL (David Dowell, Isidora Jankov, Trevor Alcott)
- WRF v3.9+
- HRRRE configuration, with only SPP active (no SPPT)
- HRRRDAS ICs, GEFS BCs
- All forecasts initialized at 12 UTC and run for 48h, 21 total cases between Dec 2021 and Mar 2022
- MYNN Level 2.5 PBL scheme and Thompson-Eidhammer aerosol-aware MP
- **During WWE, tested two ensemble configurations (9 members each)**



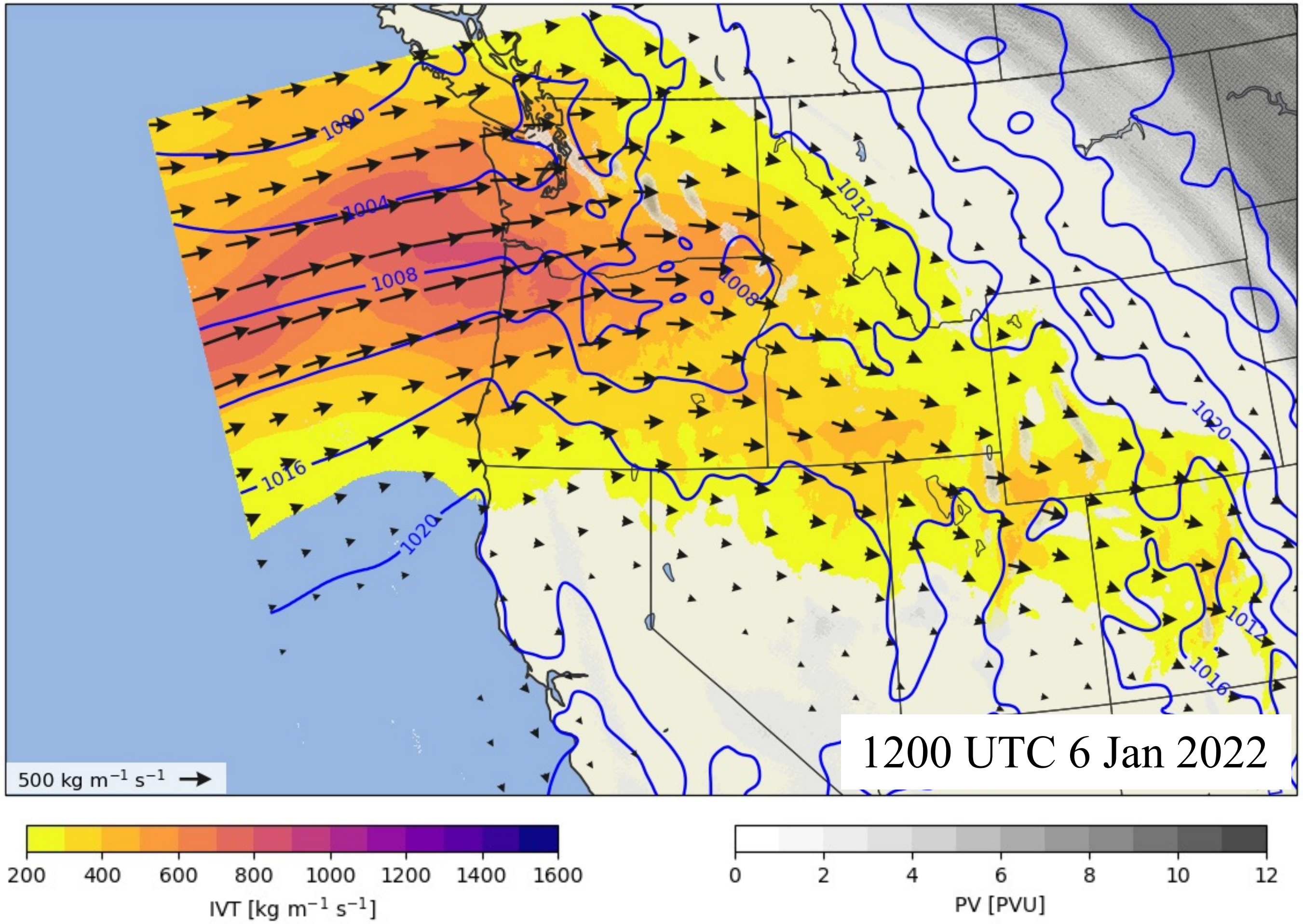
Abbreviation	ICs/BCs	Stochastic Physics	Decorrelation Scales	Notes
HRRRE_BASE **"baseline"**	HRRRDAS/GEFS members (varied)	SPP-LSM only	L = 150 km T = 72 h	
HRRRE_ALLSPP **"experiment"**	HRRRDAS/GEFS members (varied)	SPP-LSM, SPP-PBL, SPP-MP	L = 150 km T = 72 h	SPP-PBL includes PBL, SL, diffusion perts.; SPP-MP includes both existing and new perts.

5-7 January 2022

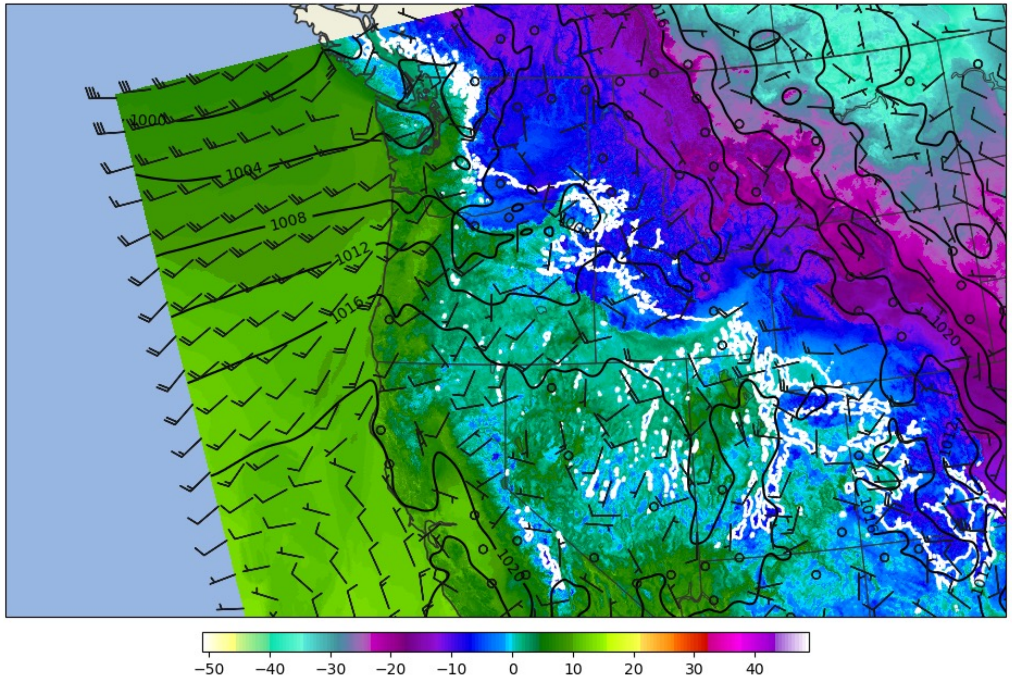
Pacific NW atmospheric river event, heavy coastal rain and flooding in Washington and Oregon, heavy snow east of the Cascades crest

Synoptic Overview

MSLP [contours, hPa], 250-hPa PV [fill, PVU], 1000-100 hPa IVT [fill/vectors, kg m^{-1} s^{-1}]



MSLP [contours, hPa], 10-m Wind [barbs, kt], 2-m Temperature [fill, °C], Freezing Level at Sfc. [white contour]



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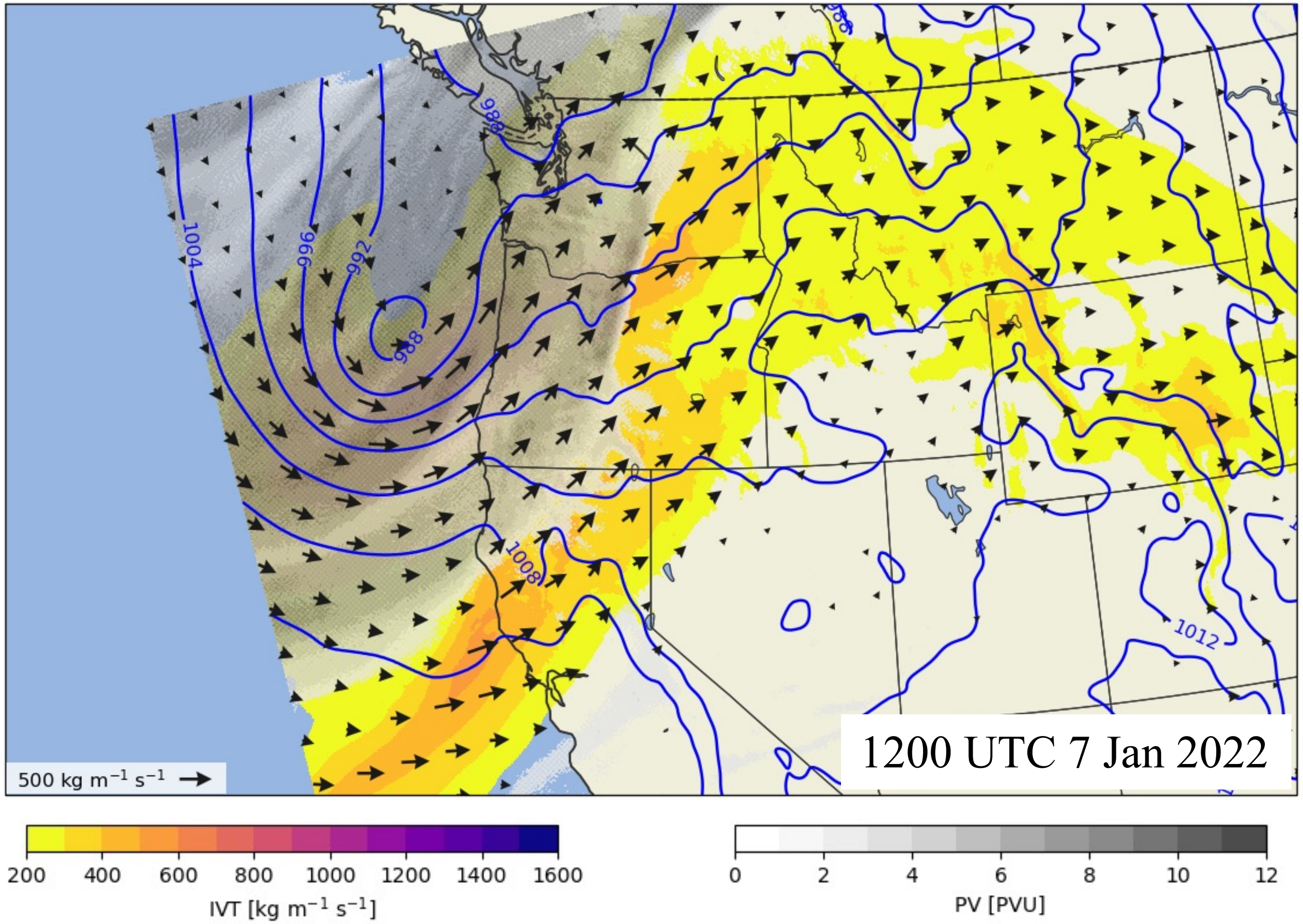
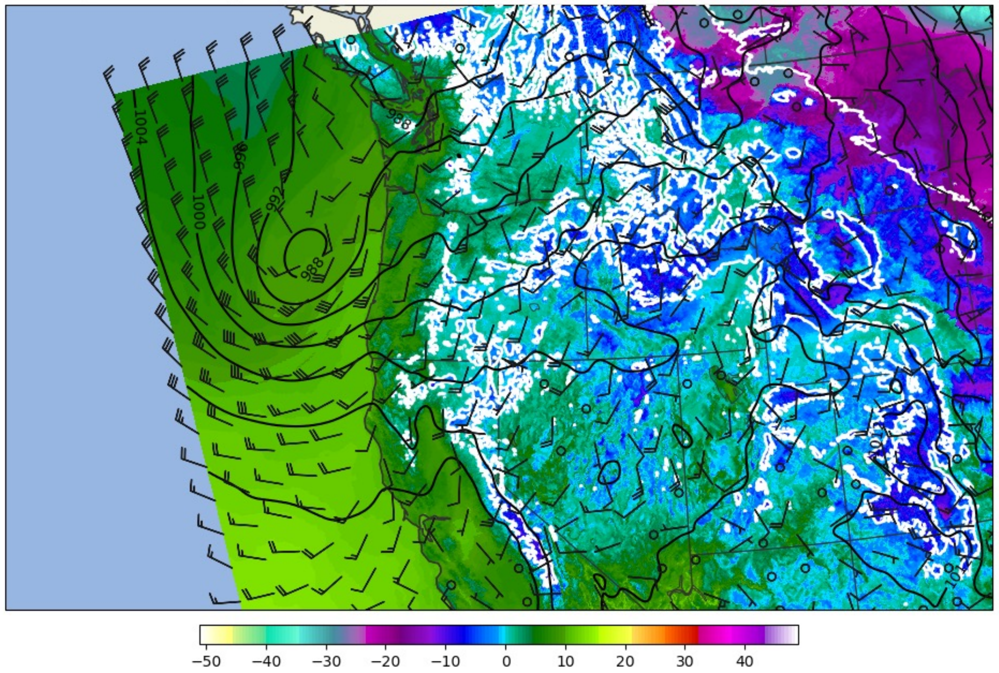
MSLP [contours, hPa], 250-hPa PV [fill, PVU], 1000-100 hPa IVT [fill/vectors, kg m^{-1} s^{-1}]

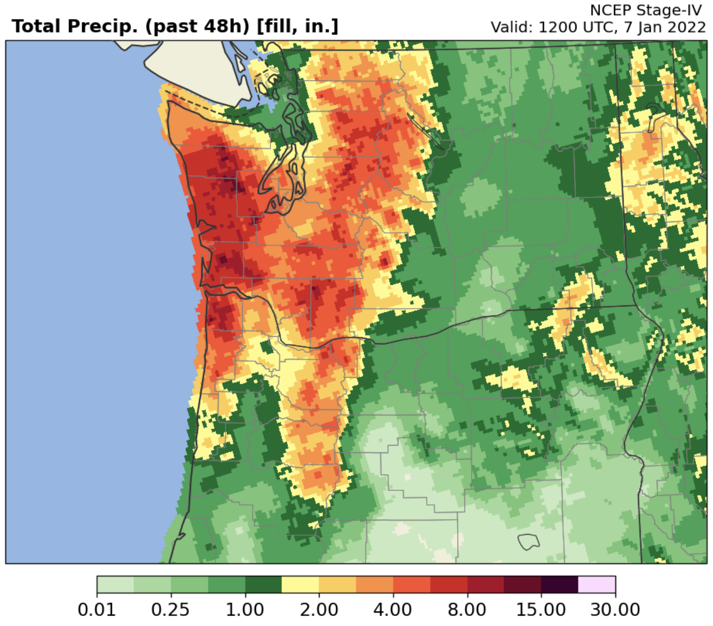


MSLP [contours, hPa], 10-m Wind [barbs, kt], 2-m Temperature [fill, °C], Freezing Level at Sfc. [white contour]

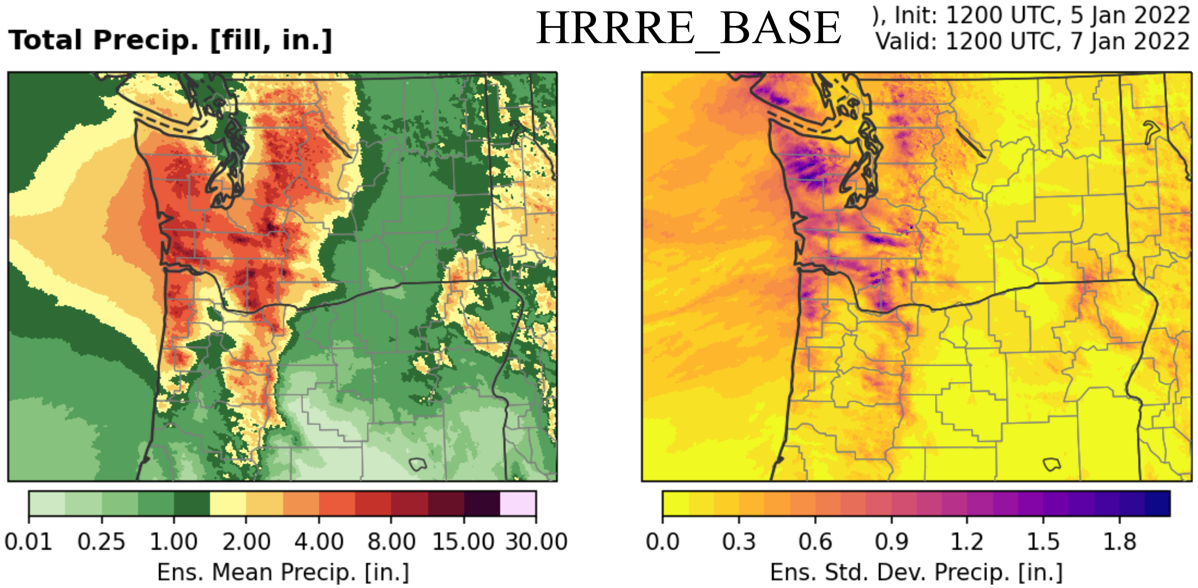


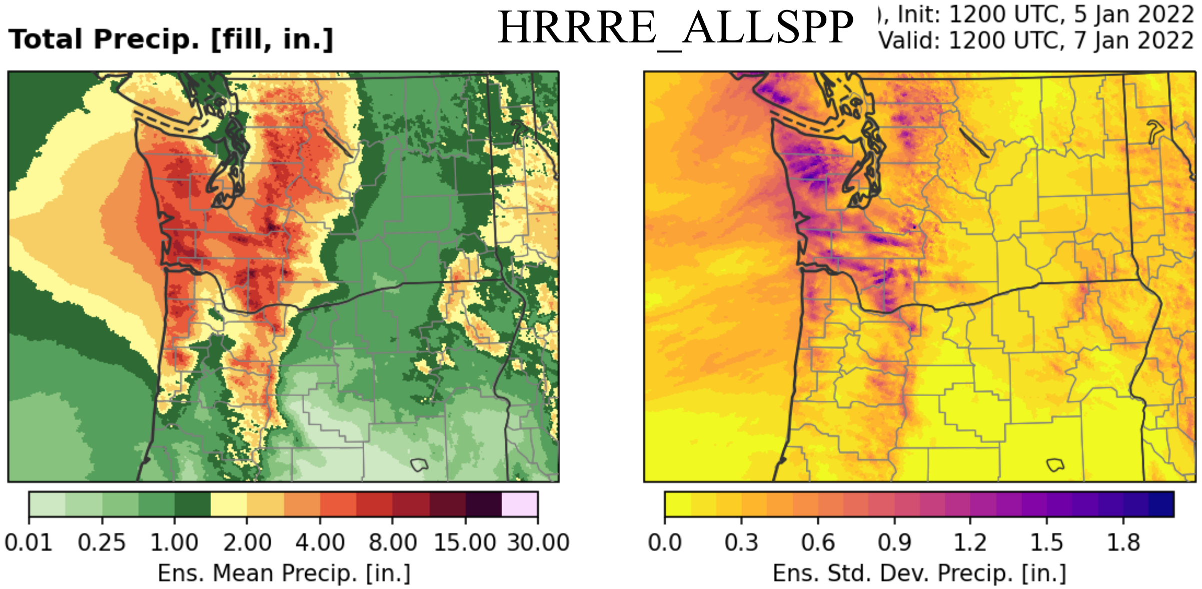
12z 5 Jan – 12z 7 Jan 2022

Stage IV



0.25 6.35 25.4 50.8 101.6 203.2 381 762 mm





12z 5 Jan – 12z 7 Jan 2022

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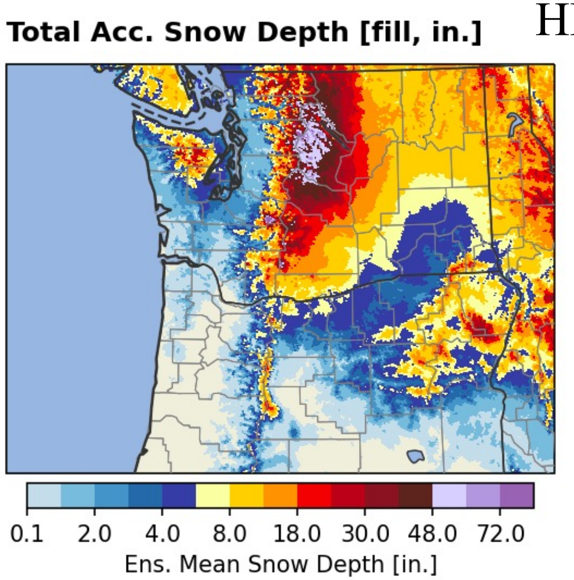
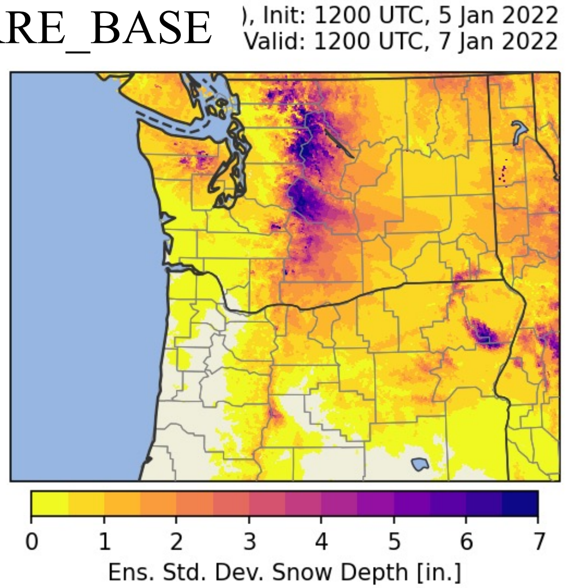
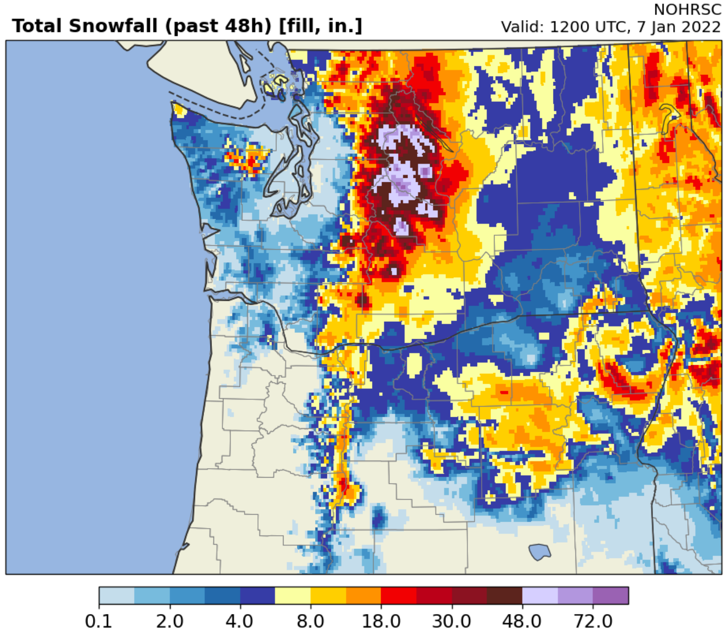


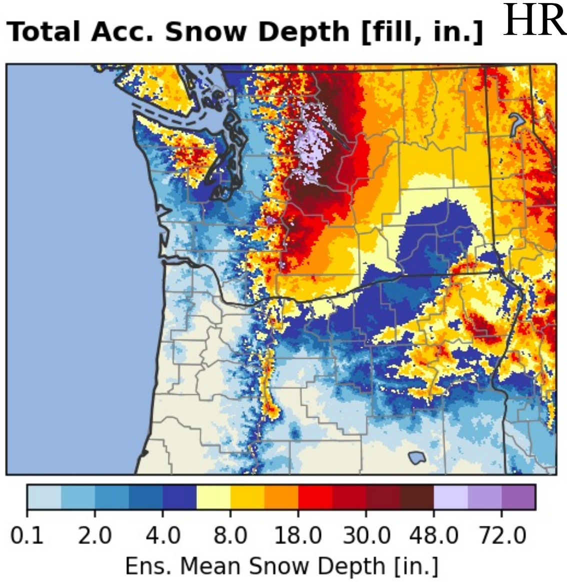


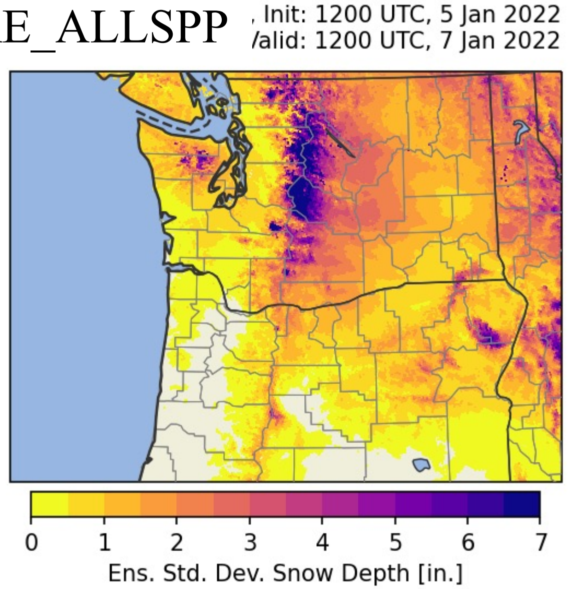
NOHRSC



0.25 5.1 10.2 20.3 45.7 76.2 121.9 182.9 cm

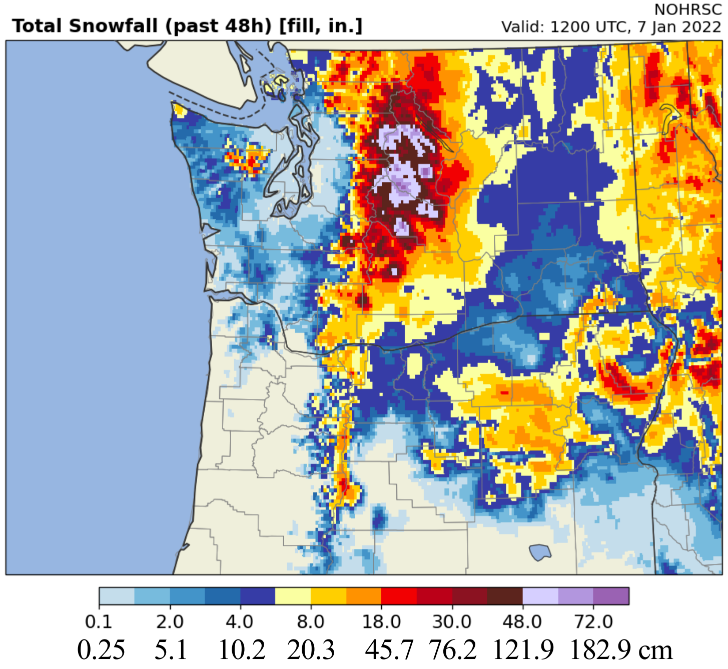
HRRRE_ALLSPP





12z 5 Jan – 12z 7 Jan 2022

NOHRSC



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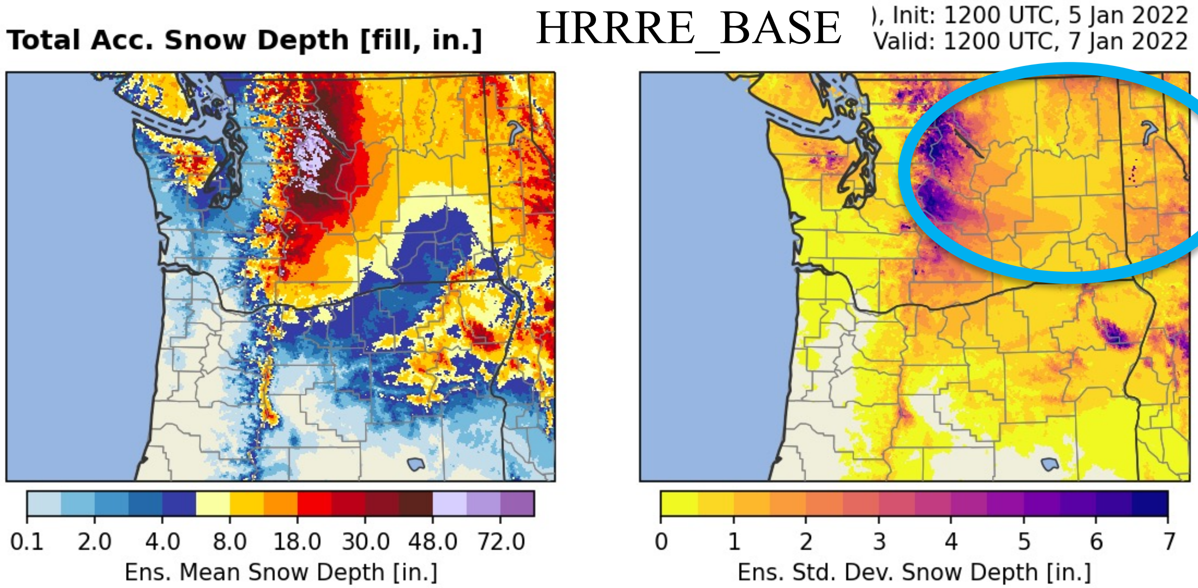
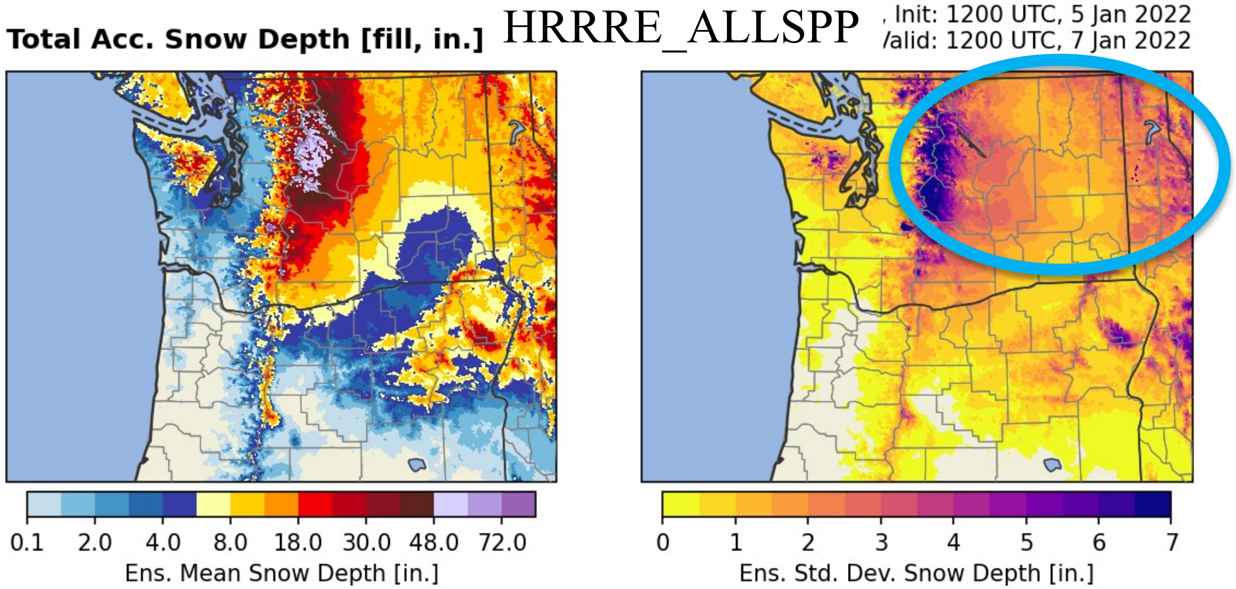
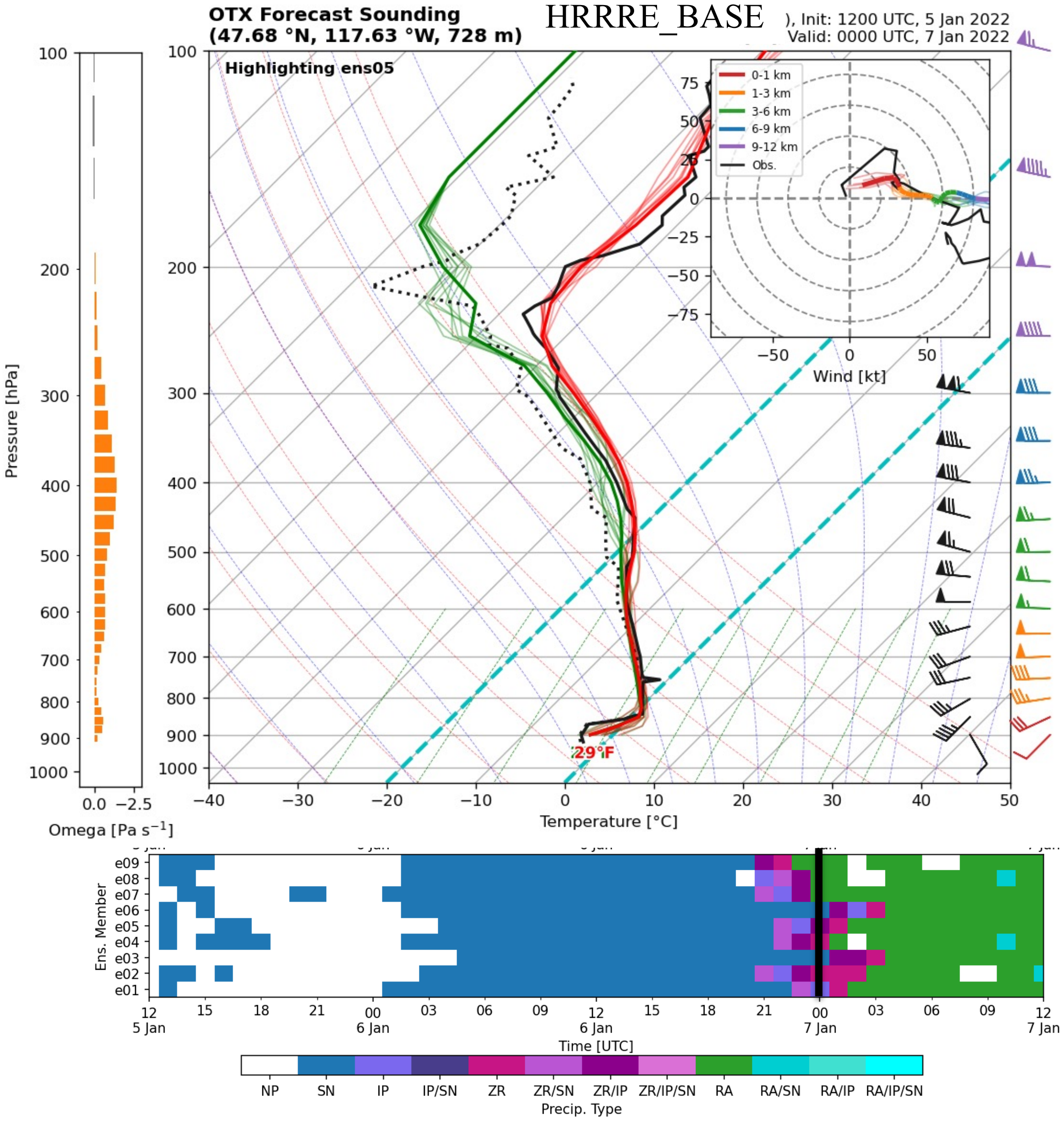
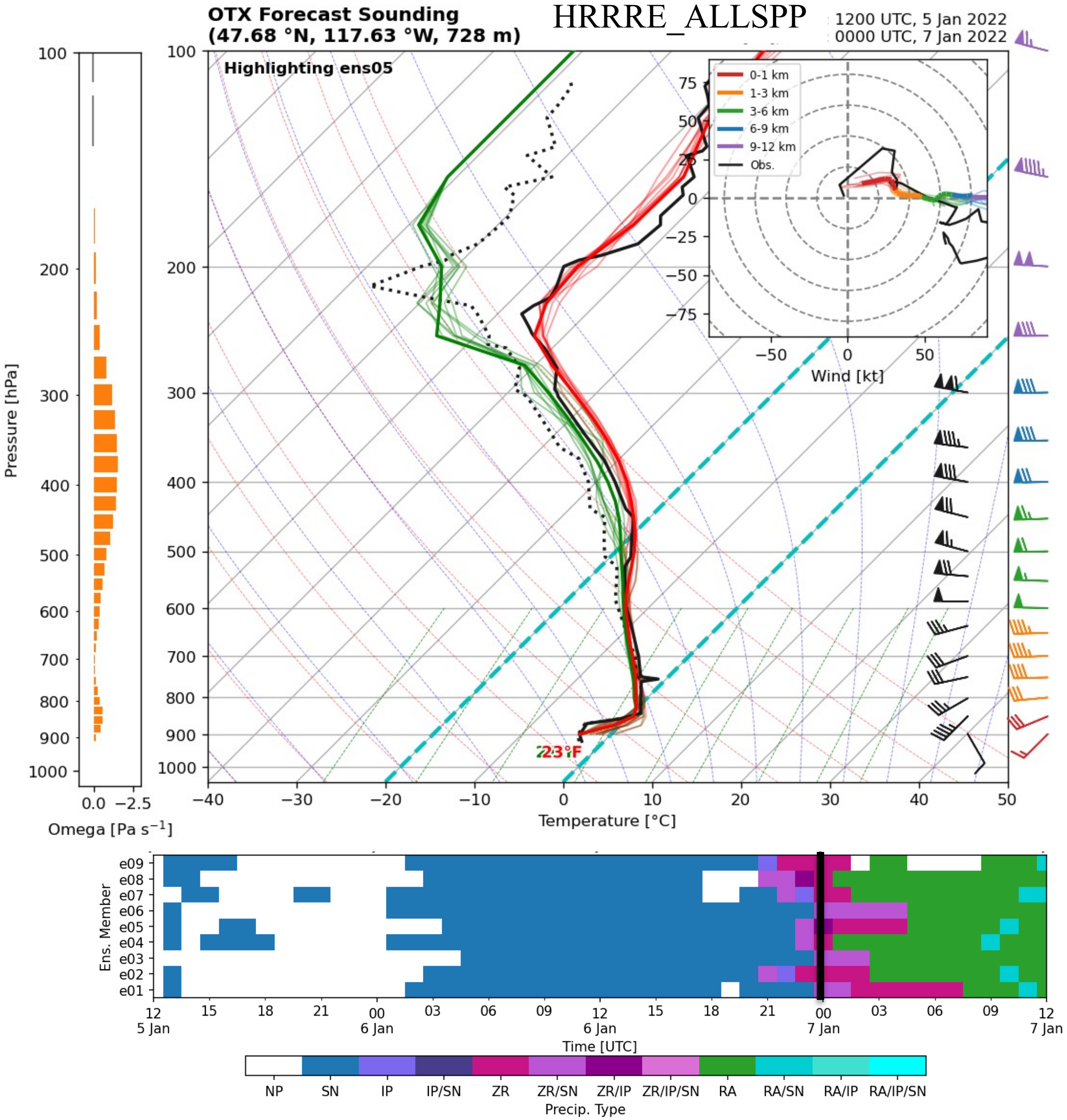


HRRRE_ALLSPP




HRRRE_BASE
OTX Forecast Sounding
(47.68 °N, 117.63 °W, 728 m)
), Init: 1200 UTC, 5 Jan 2022
Valid: 0000 UTC, 7 Jan 2022
Highlighting ens05
0-1 km
1-3 km
3-6 km
6-9 km
9-12 km
Obs.
Wind [kt]
29°F
Pressure [hPa]
Omega [Pa s^{-1}]
Temperature [°C]
Ens. Member
Time [UTC]
NP SN IP IP/SN ZR ZR/SN ZR/IP ZR/IP/SN RA RA/SN RA/IP RA/IP/SN
Precip. Type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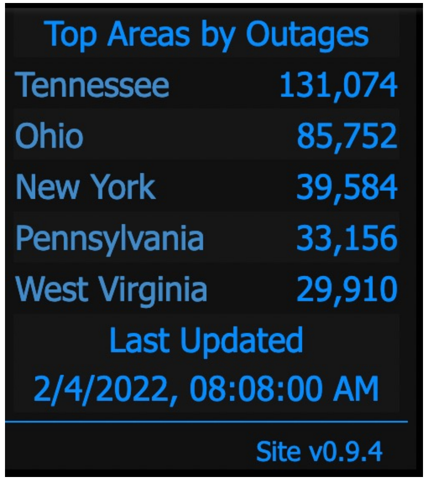
NP SN IP IP/SN ZR ZR/SN ZR/IP ZR/IP/SN RA RA/SN RA/IP RA/IP/SN
Precip. Type

Kingston, NY (photo credit: Albany Times-Union)



Top Areas by Outages	
Tennessee	131,074
Ohio	85,752
New York	39,584
Pennsylvania	33,156
West Virginia	29,910
Last Updated	
2/4/2022, 08:08:00 AM	
	Site v0.9.4

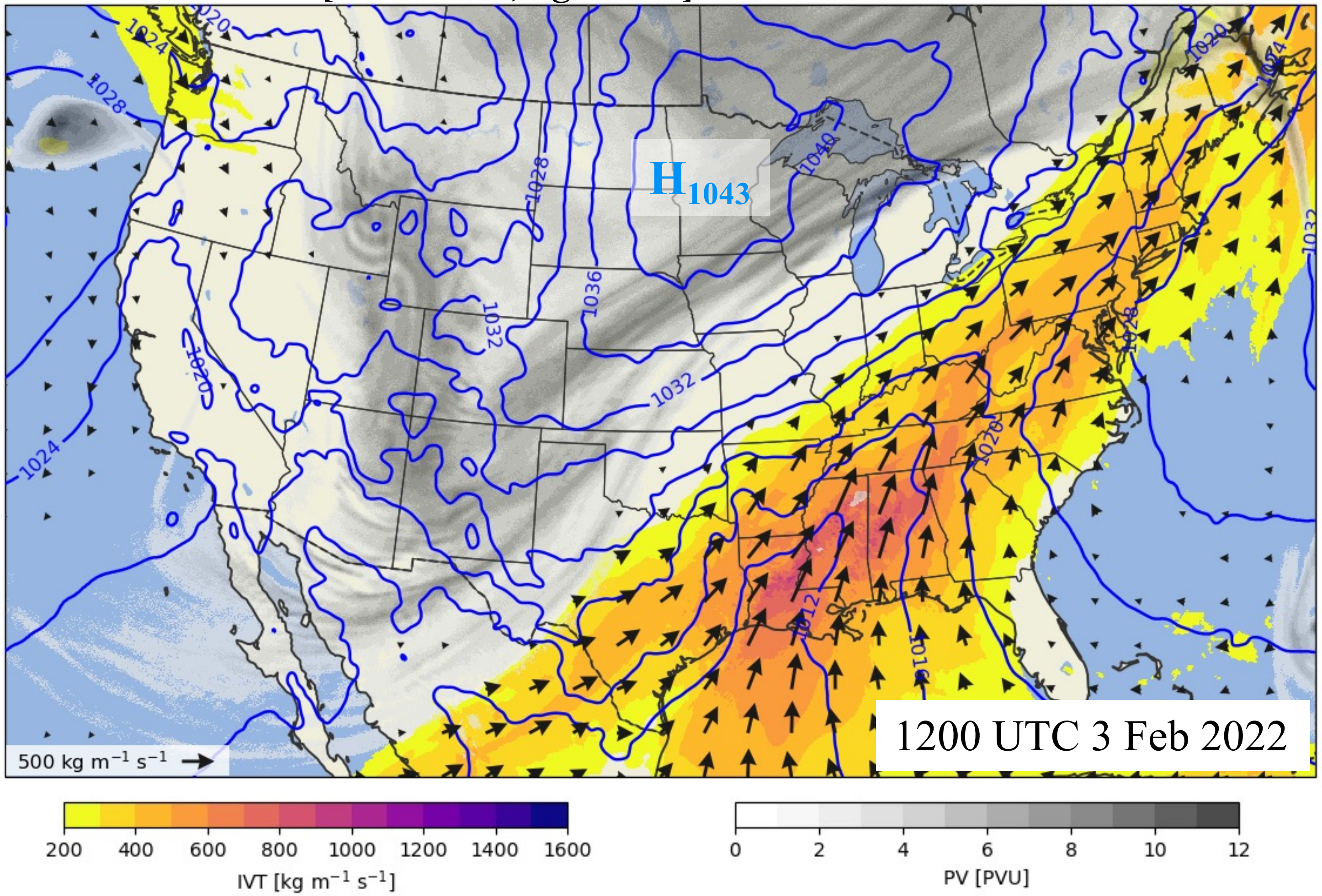
Archived snapshot of poweroutage.us tracker from 4 February

3–4 February 2022

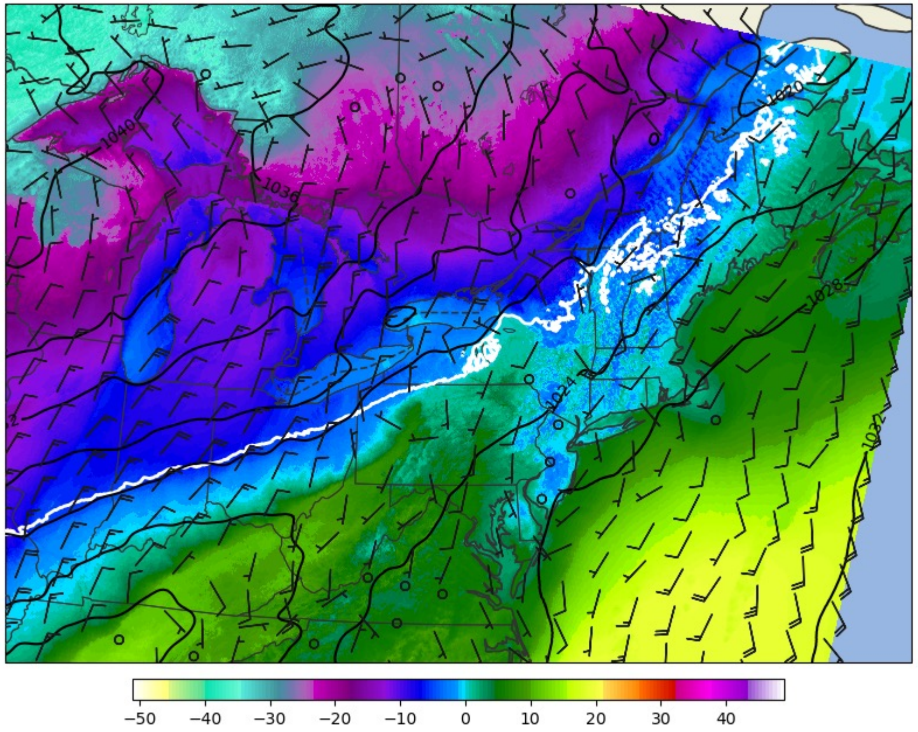
Many travel and power outage-related impacts across the US, from TX to the Northeast (e.g., significant >0.25” ice accretion in Mid-Hudson Valley south of Albany)

Synoptic Overview

MSLP [contours, hPa], 250-hPa PV [fill, PVU], 1000-100 hPa IVT [fill/vectors, kg m^{-1} s^{-1}]



MSLP [contours, hPa], 10-m Wind [barbs, kt], 2-m Temperature [fill, °C], Freezing Level at Sfc. [white contour]



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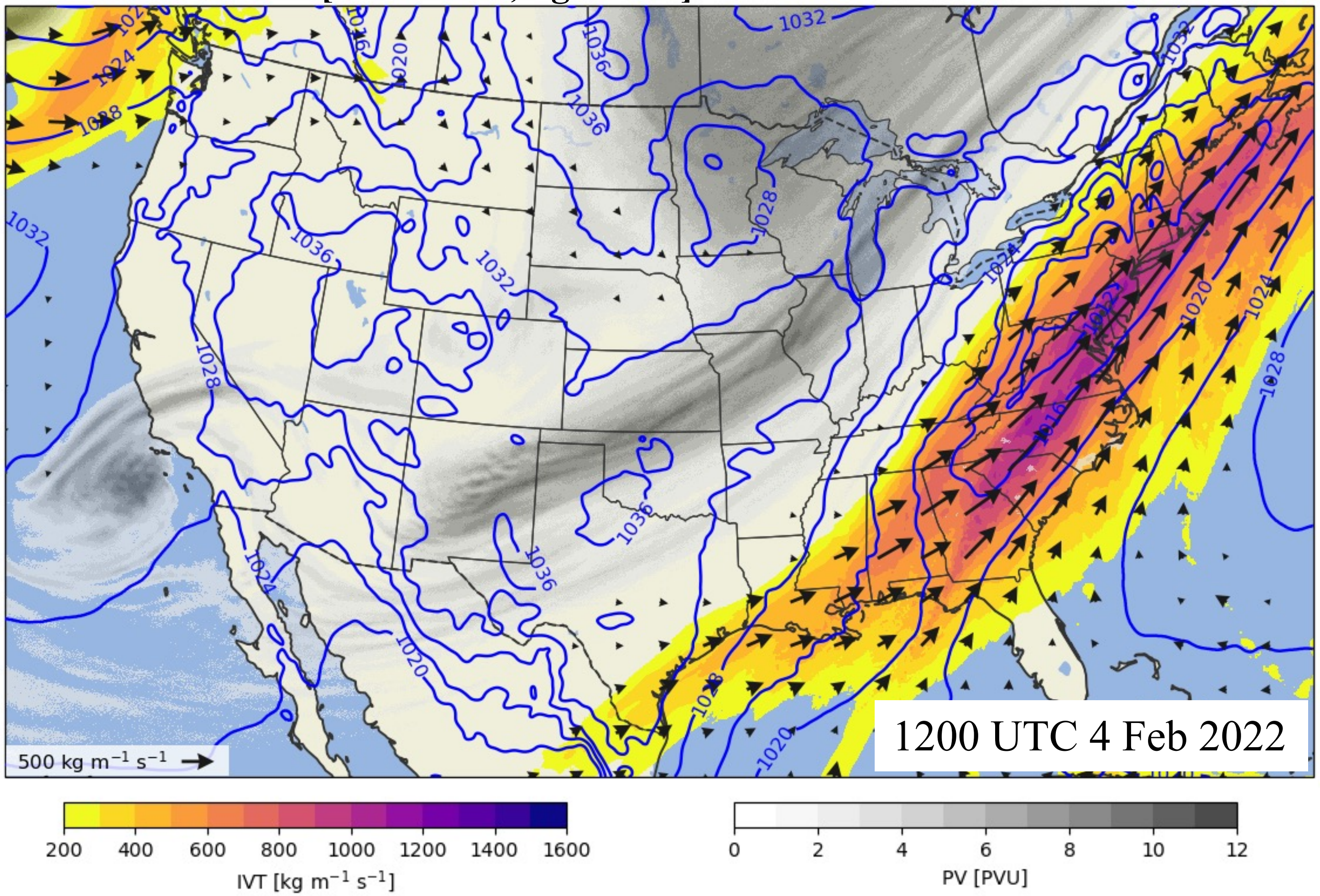

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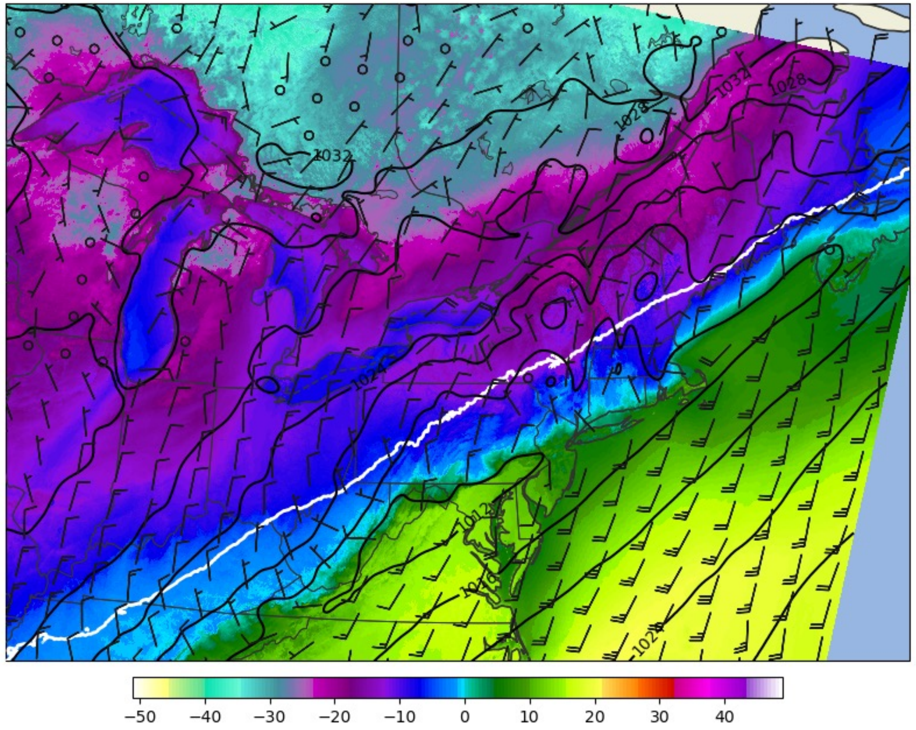
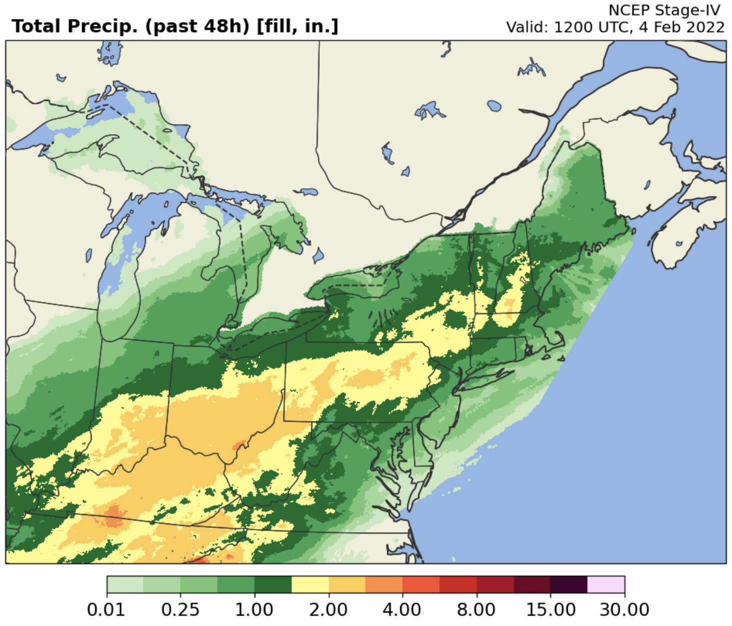


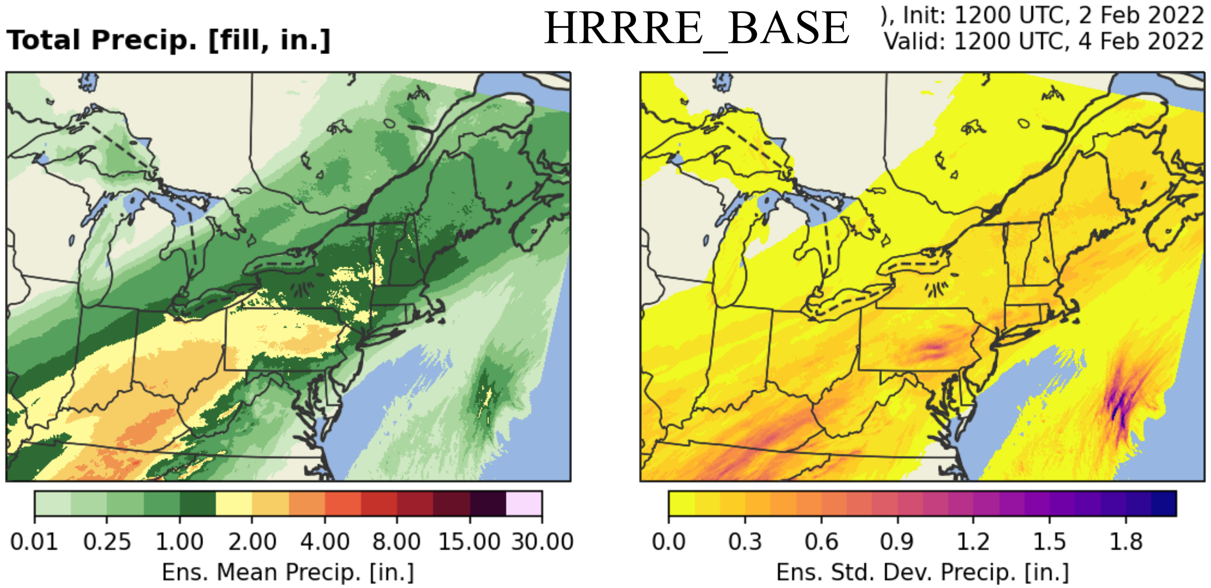
12z 2 Feb –
12z 4 Feb 2022

Stage IV



0.25 6.35 25.4 50.8 101.6 203.2 381 762 mm

HRRRE_BASE



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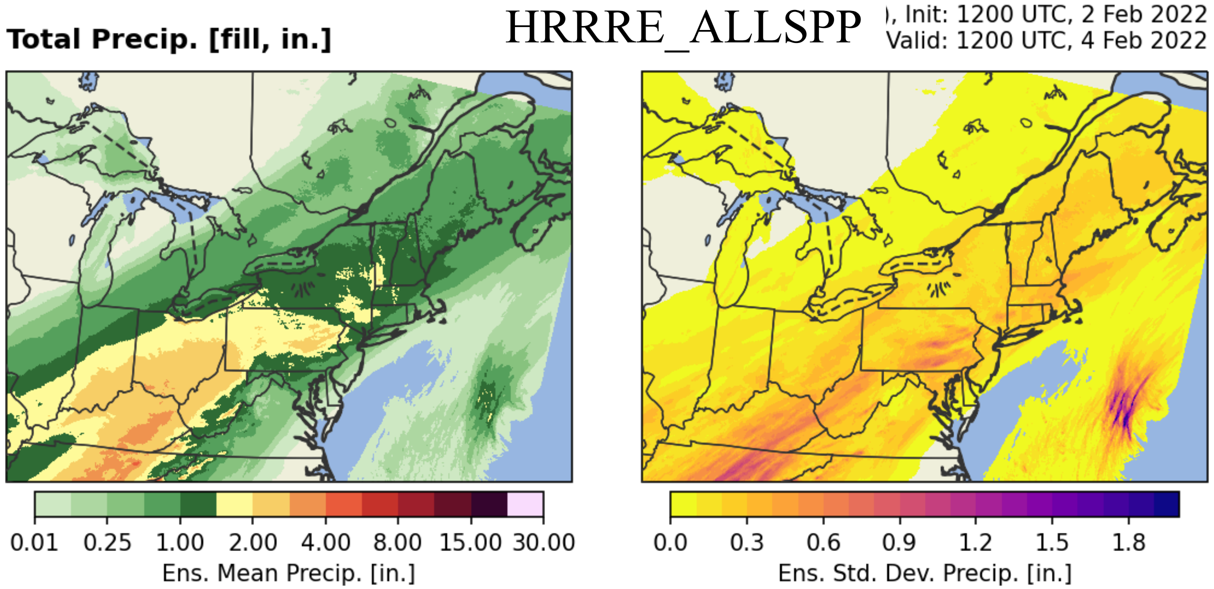
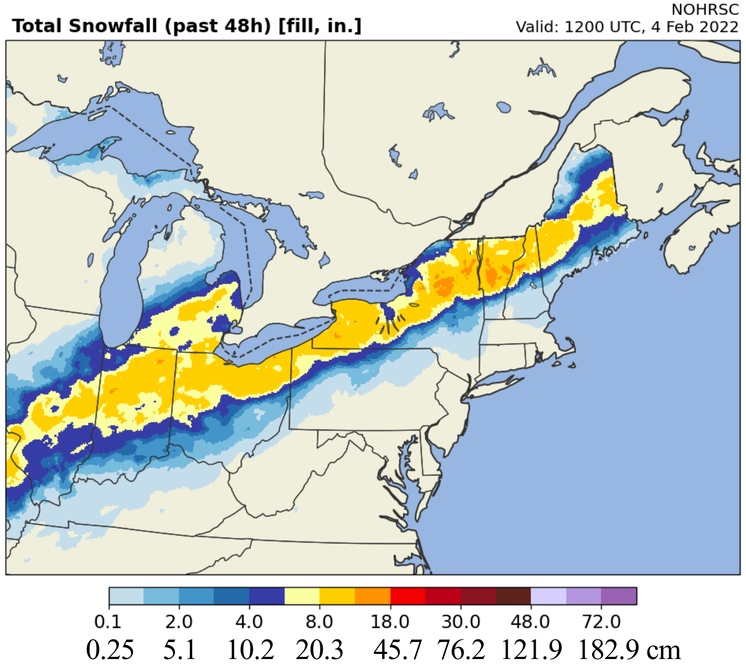


12z 2 Feb – 12z 4 Feb 2022

NOHRSC



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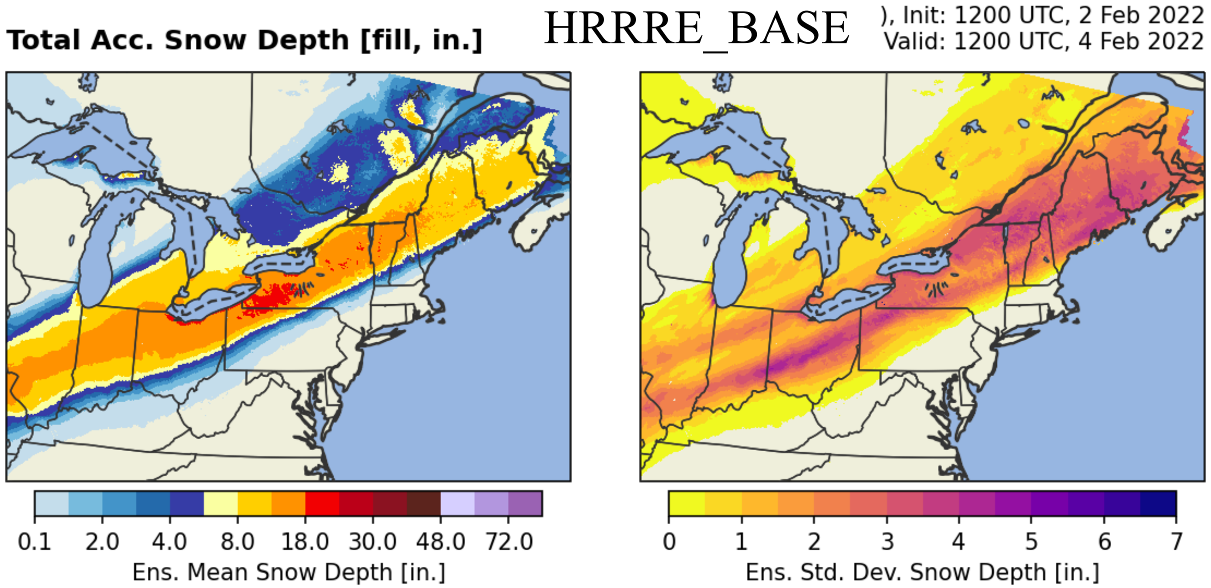

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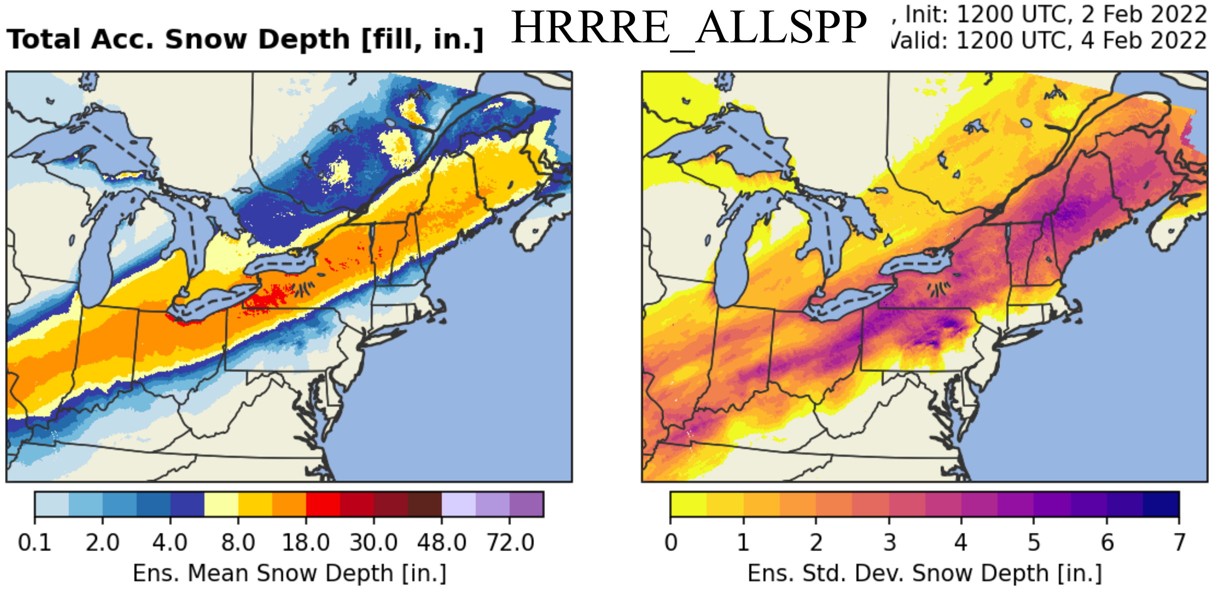
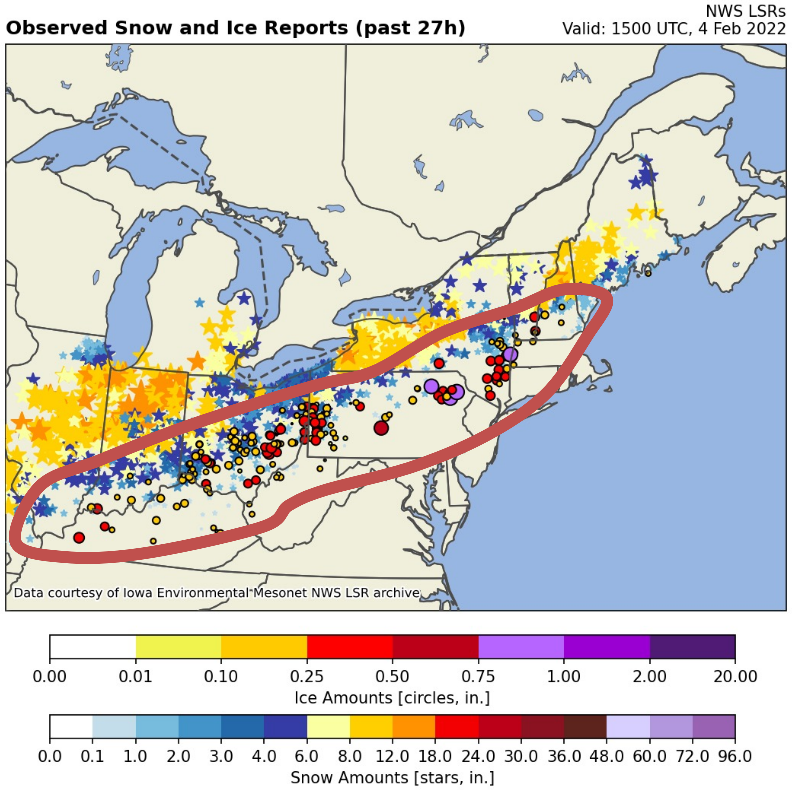


12z 2 Feb –
12z 4 Feb 2022

FRAM method (Sanders and Barjenbruch 2016)

NWS LSRs



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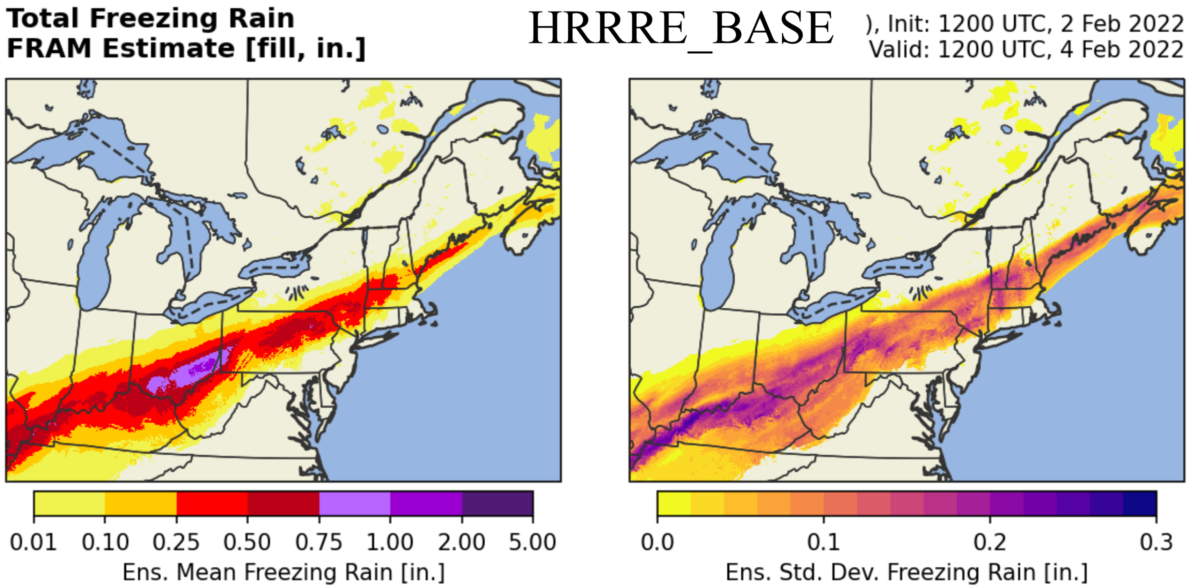

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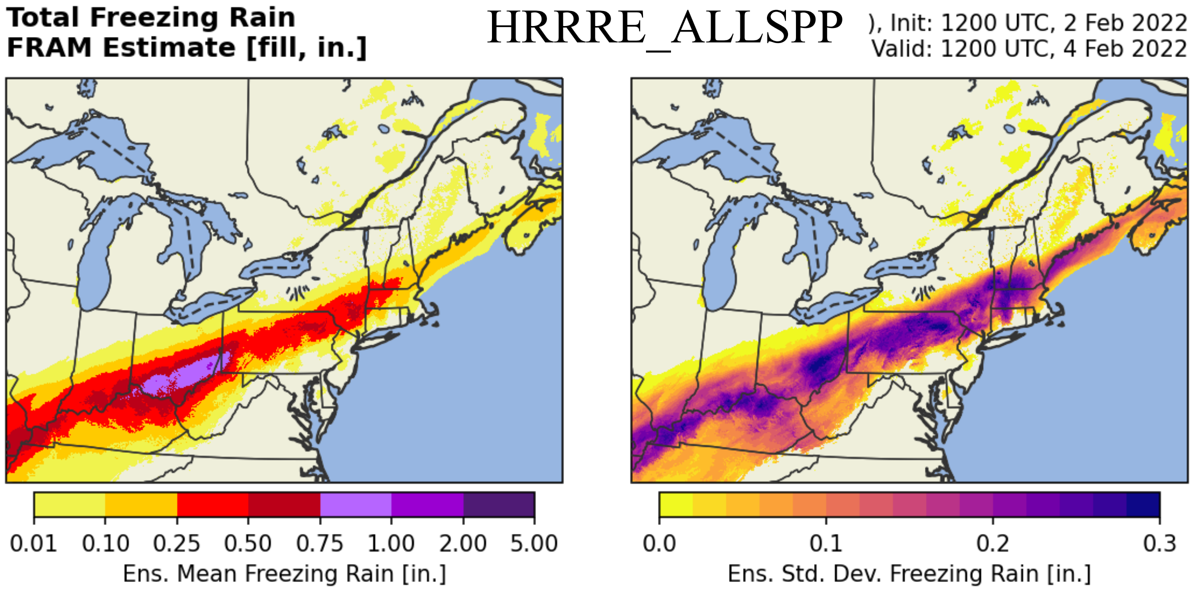
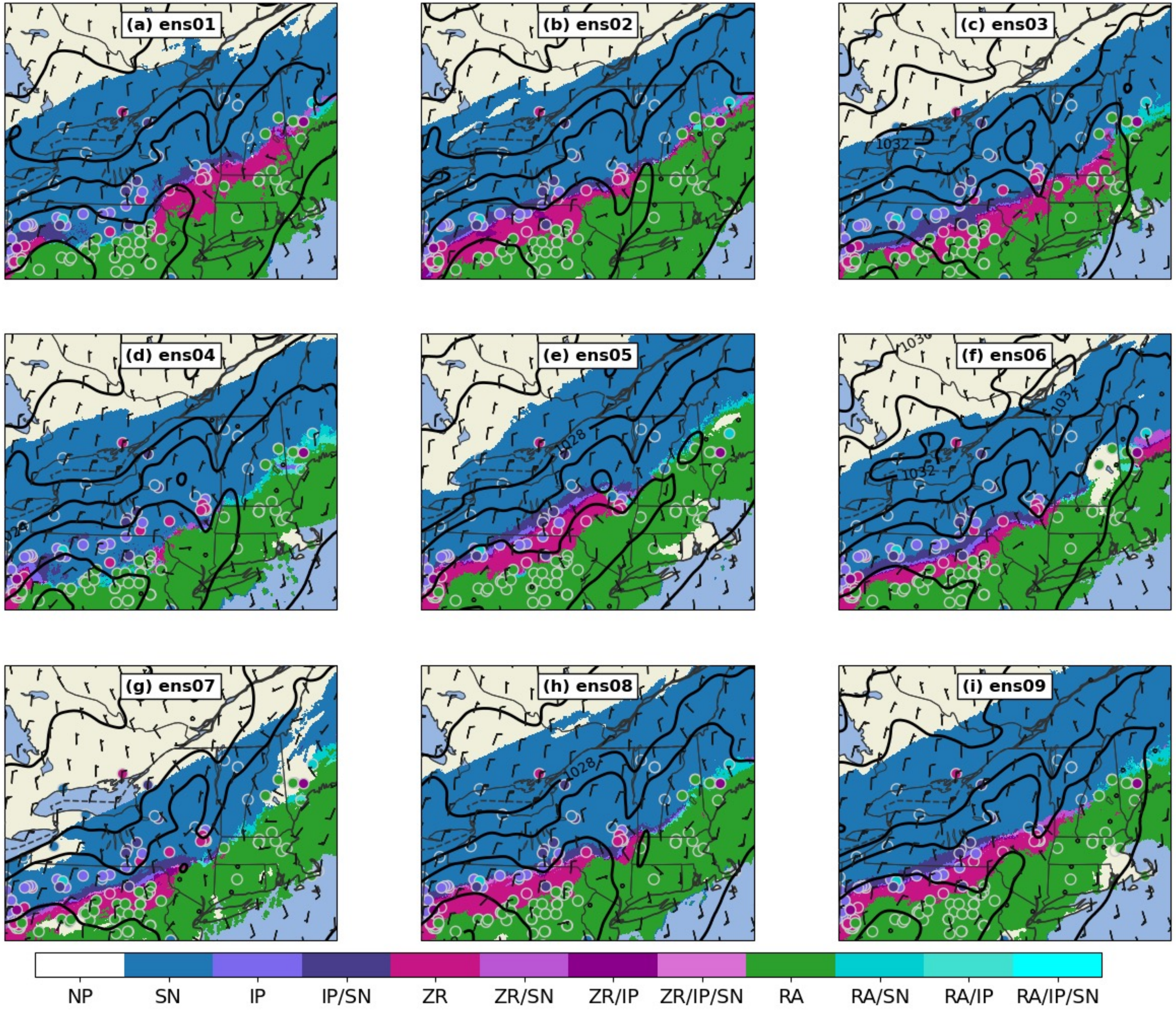


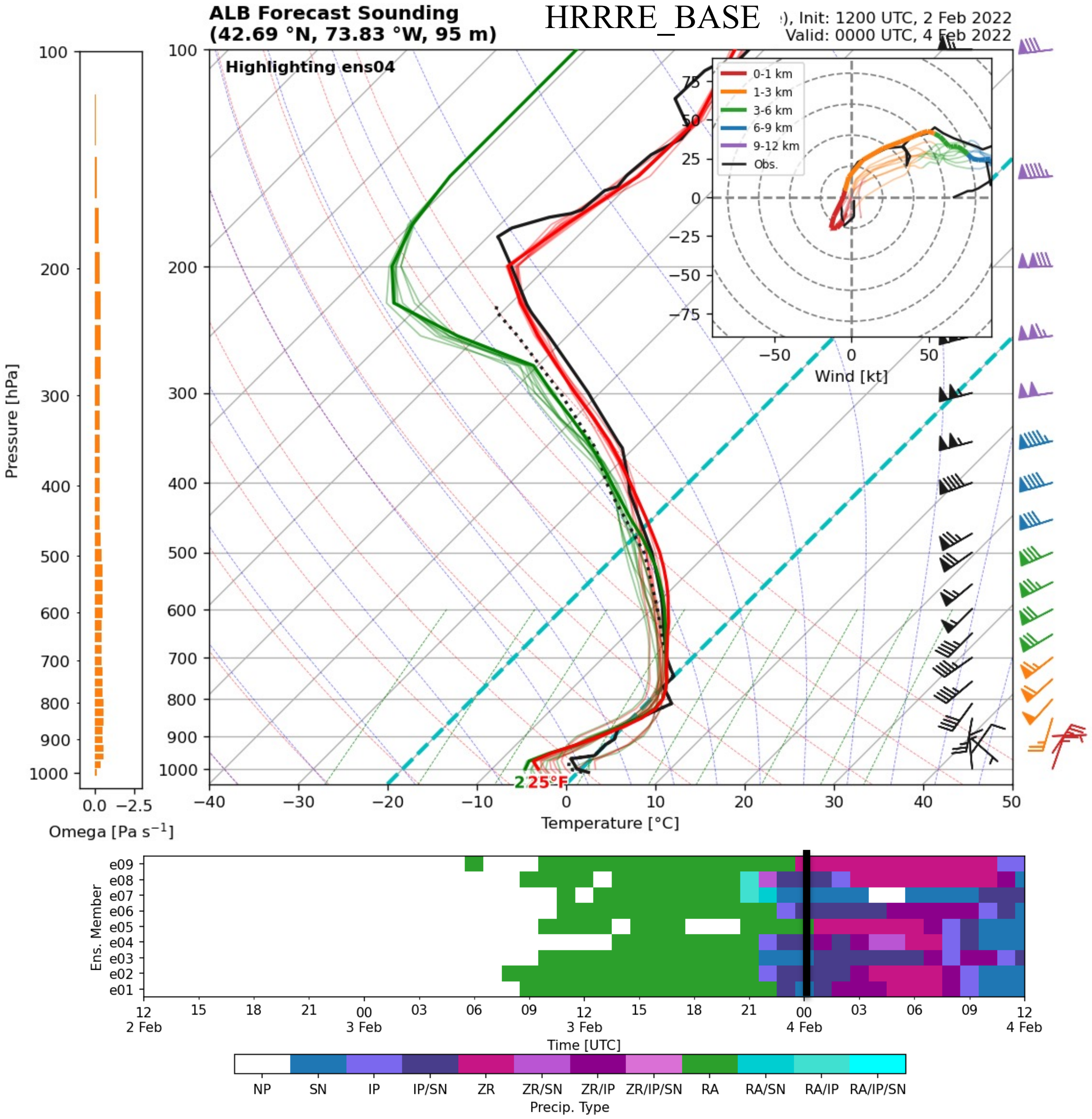
P-Type Spread

HRRRE_ALLSPP
Valid: 0000 UTC 4 Feb 2022

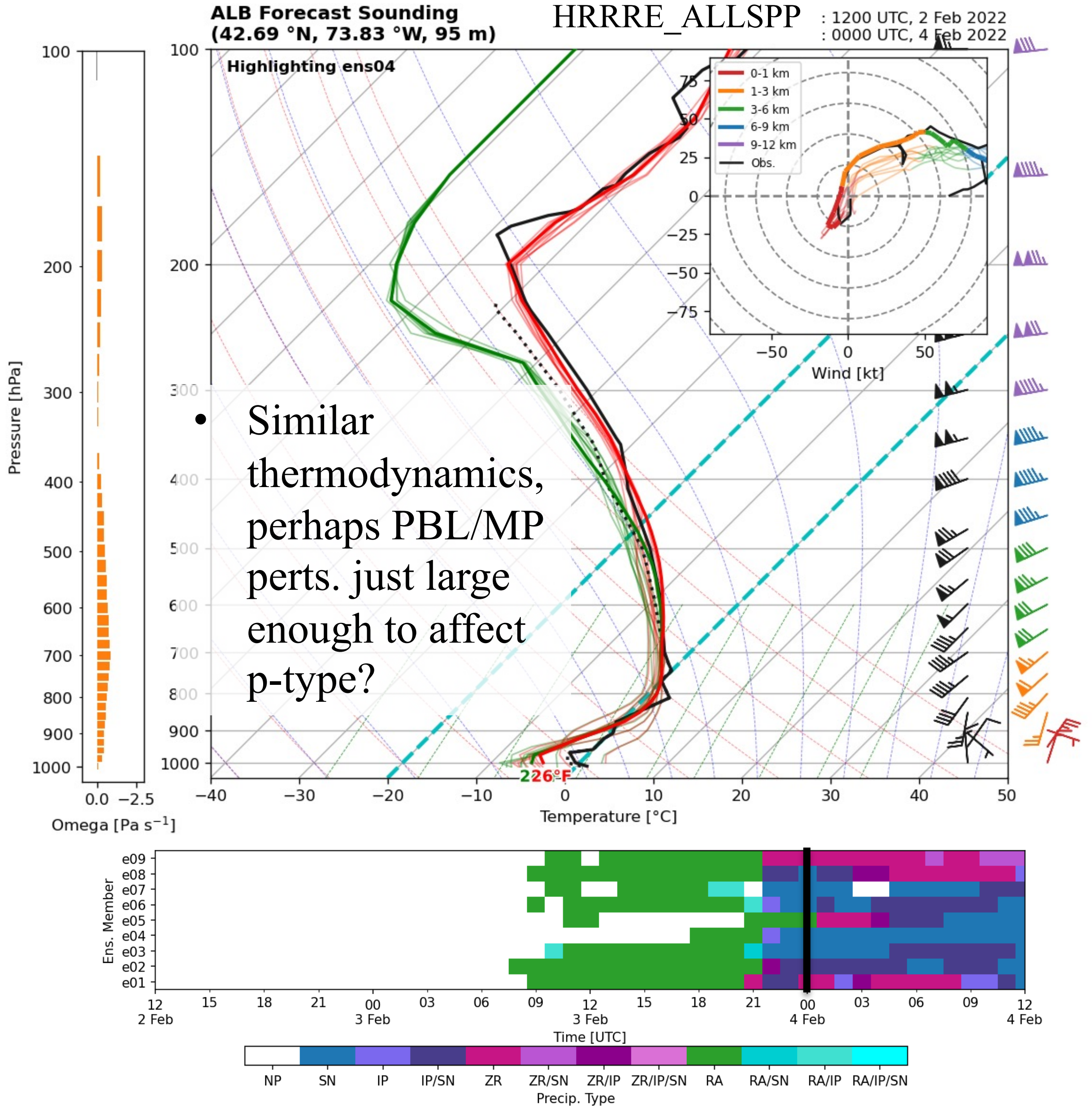


mPING reports (circles): 1-h window ending at forecast valid time

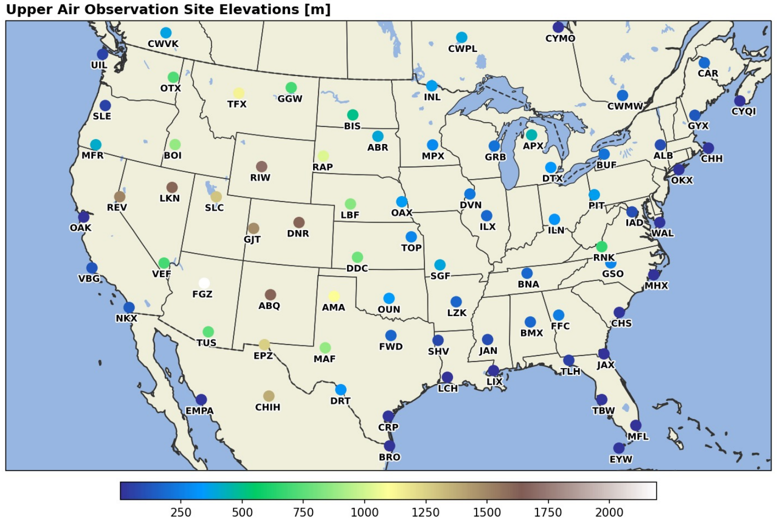
HRRRE_BASE

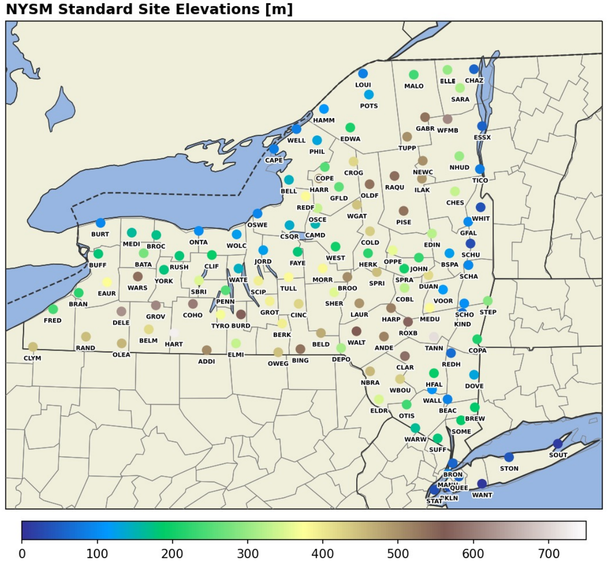


HRRRE_ALLSPP



- Similar thermodynamics, perhaps PBL/MP perts. just large enough to affect p-type?

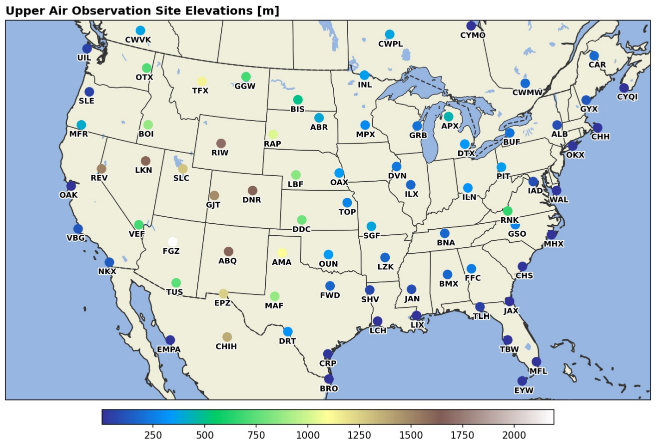


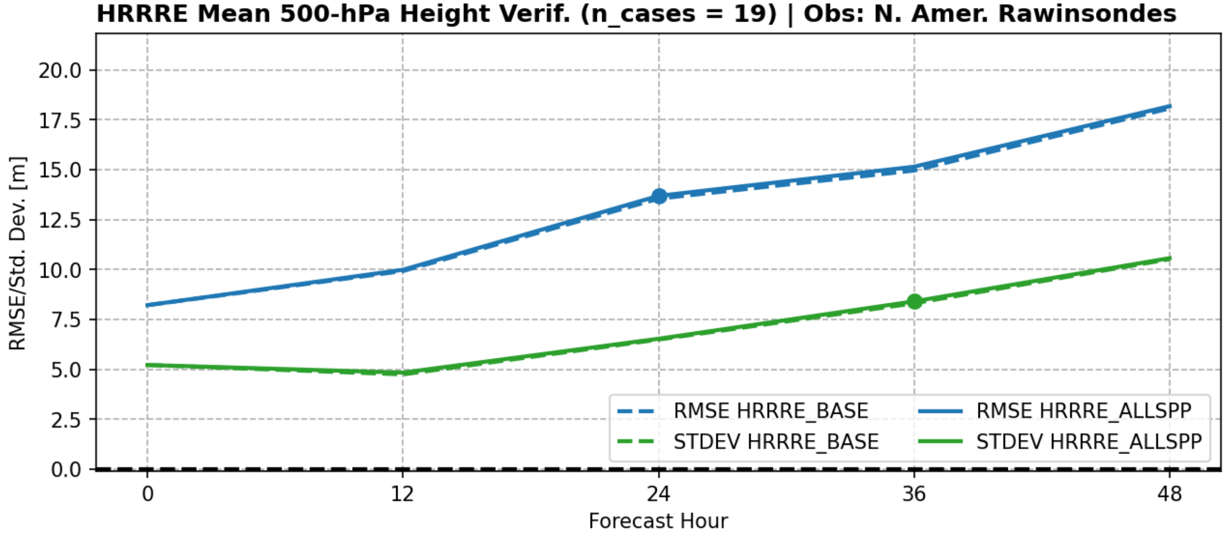


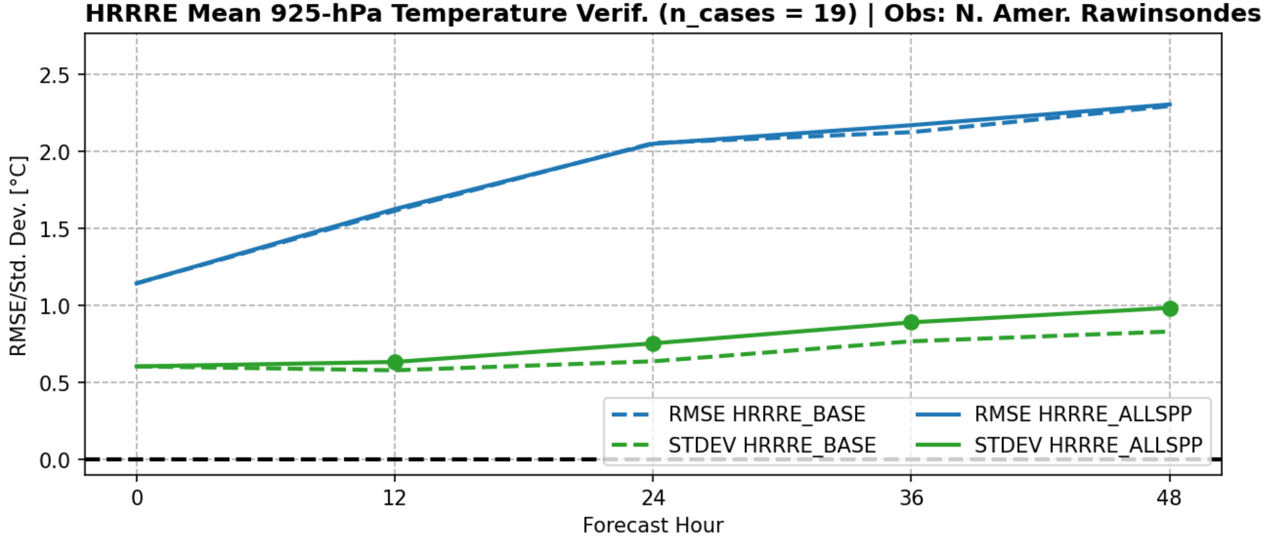
Thermodynamic Verification

Upper-Air Verification

- Verifying ens. mean against rawinsonde observations
- At upper levels (<700 hPa), ensemble verification nearly identical
- At lower levels (>850 hPa), SPP adds modest amount of temperature spread (perhaps increased variability in PBL mixing)

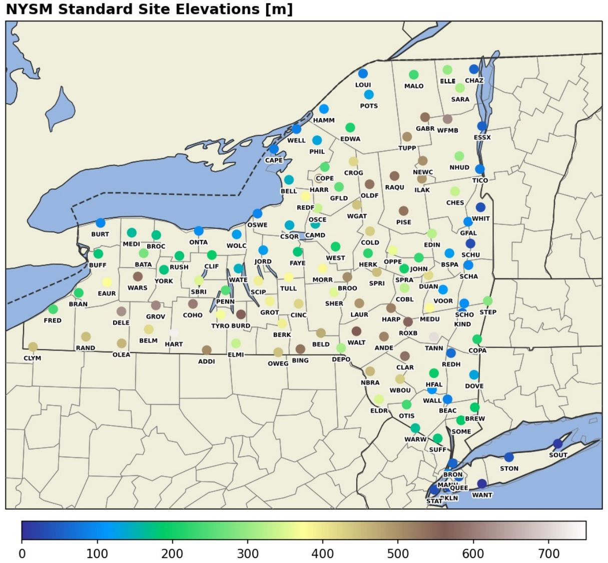


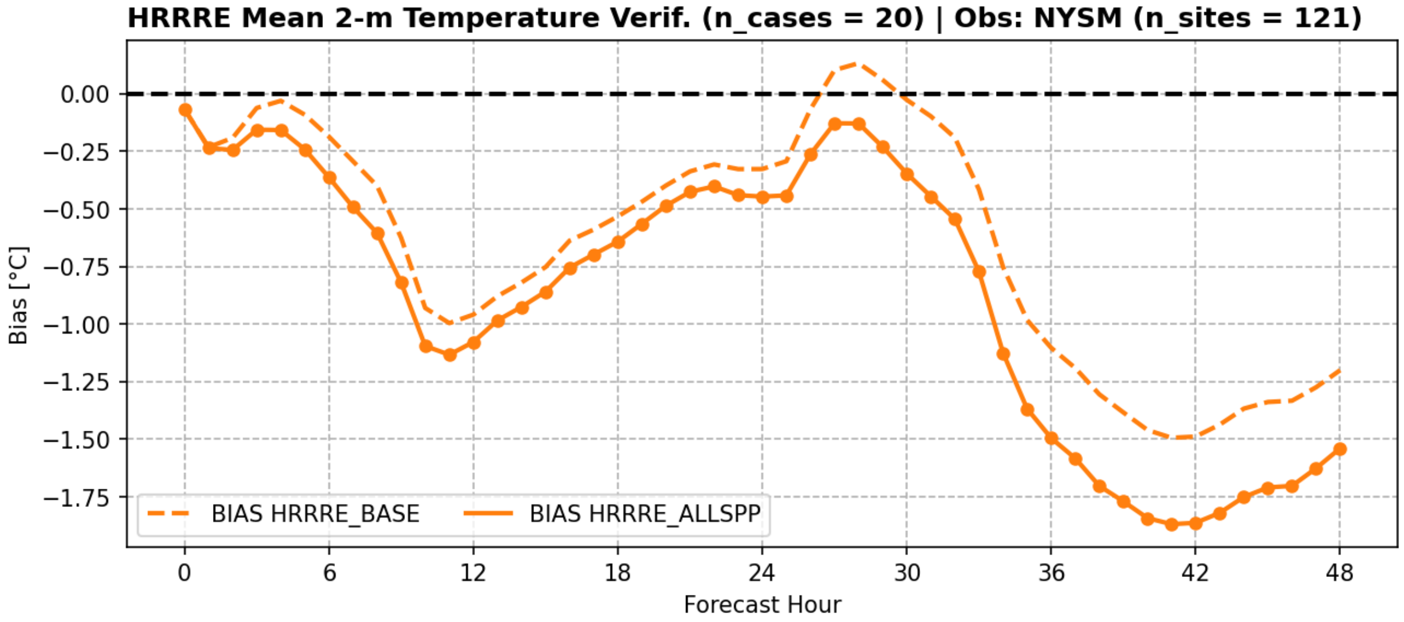


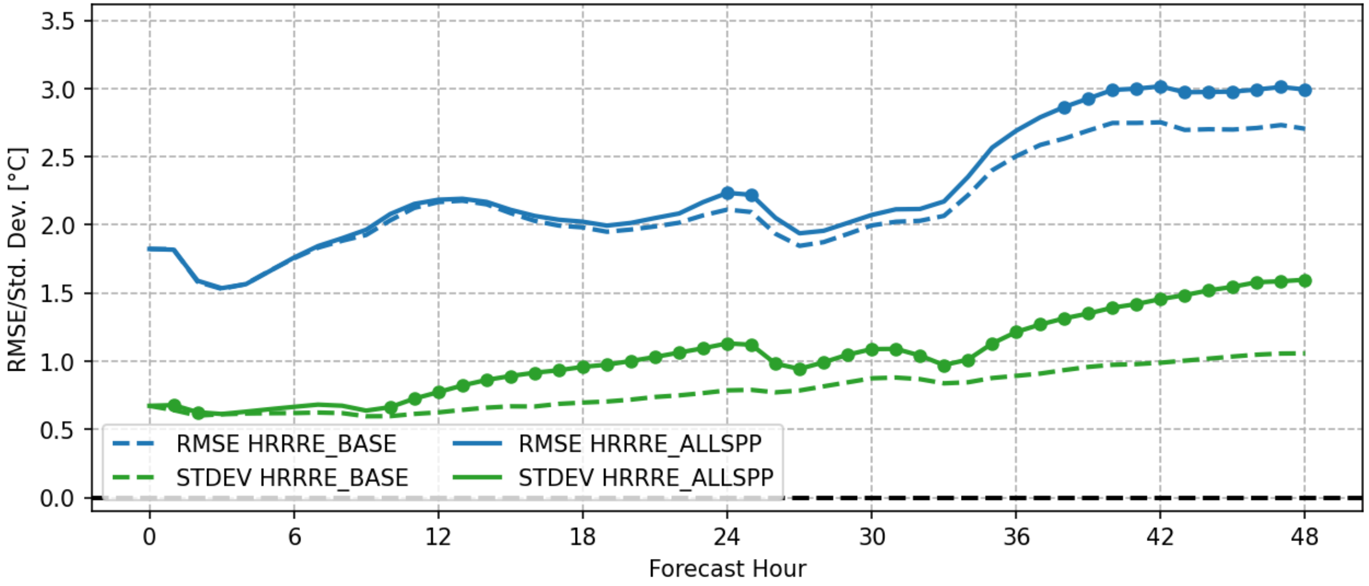


Near-Surface Verification

- Verifying ens. mean against NYS Mesonet observations
- Diurnal variations in ens. mean bias, larger cool bias at night
- Including SPP increases spread but also RMSE and bias







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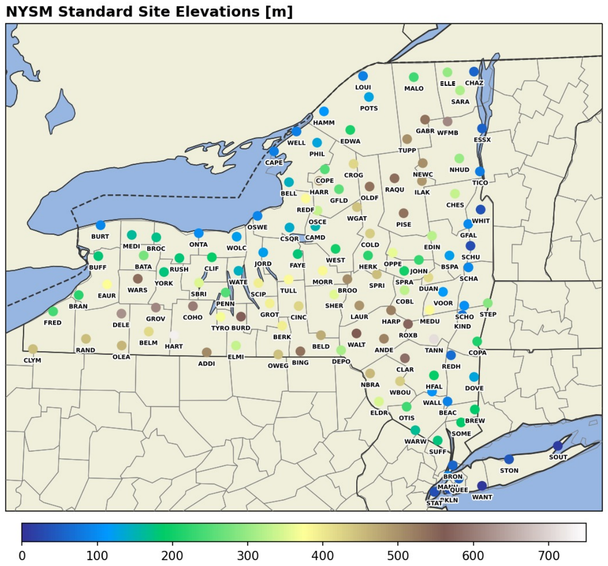
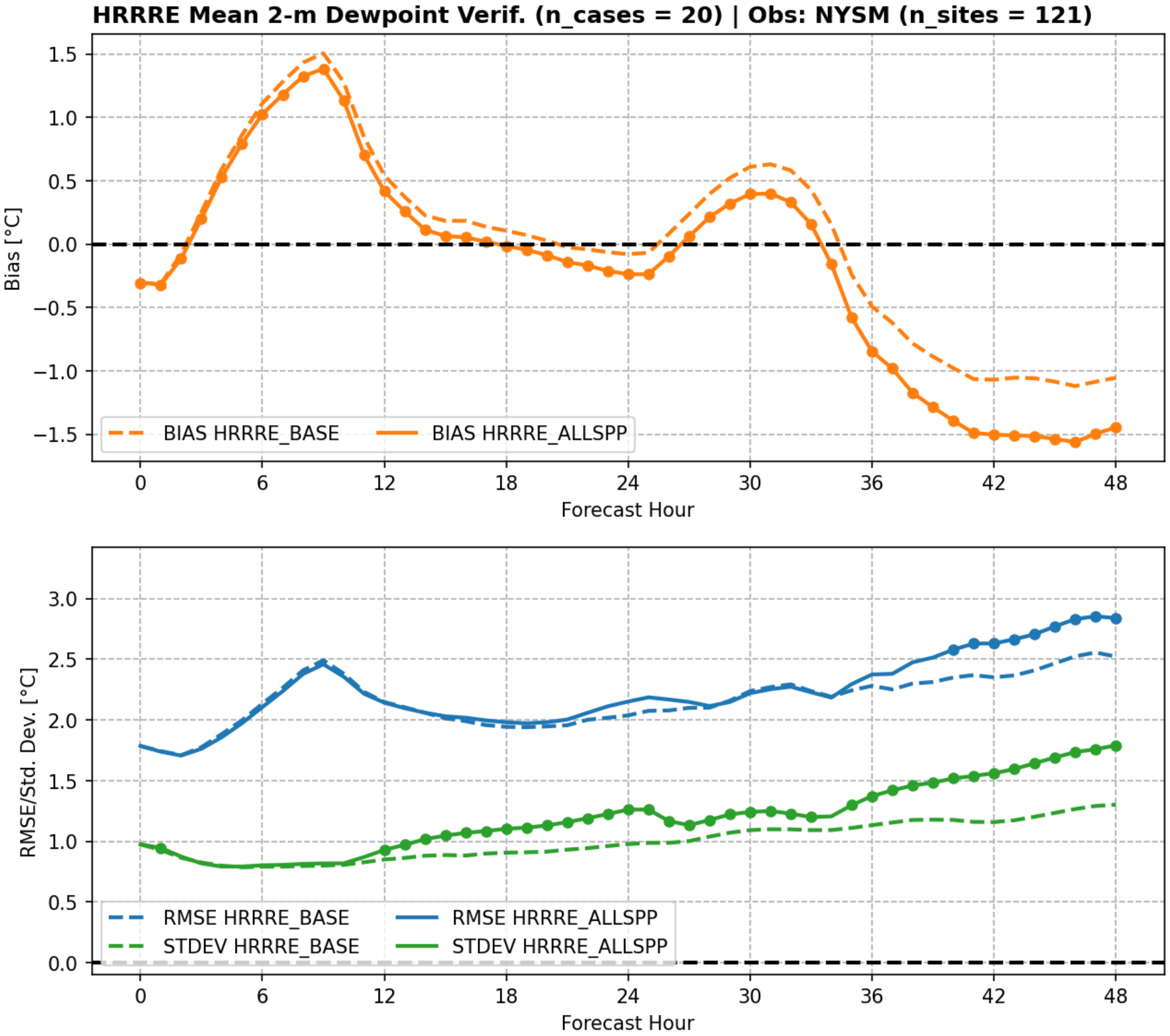
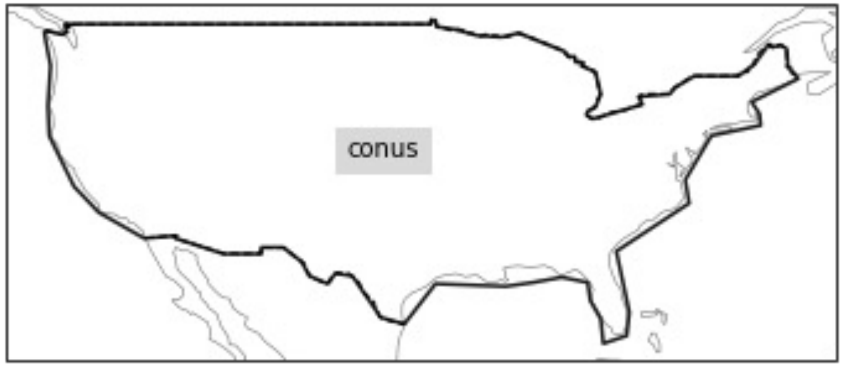


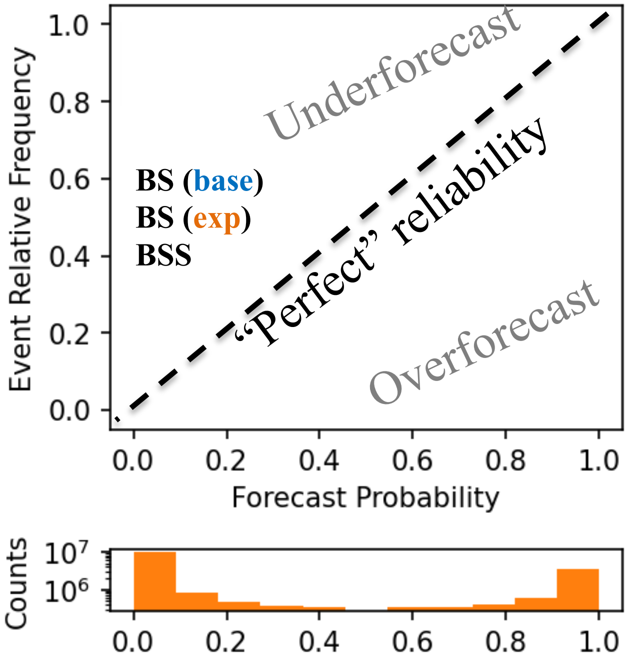




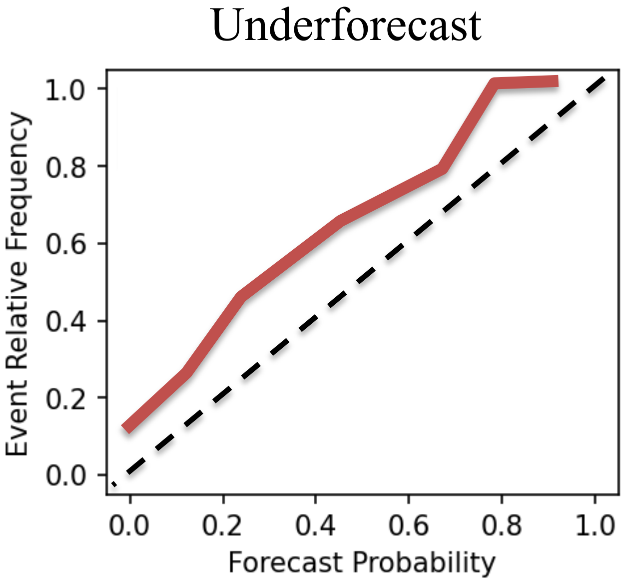
Precip., Snowfall, and P-Type Verification

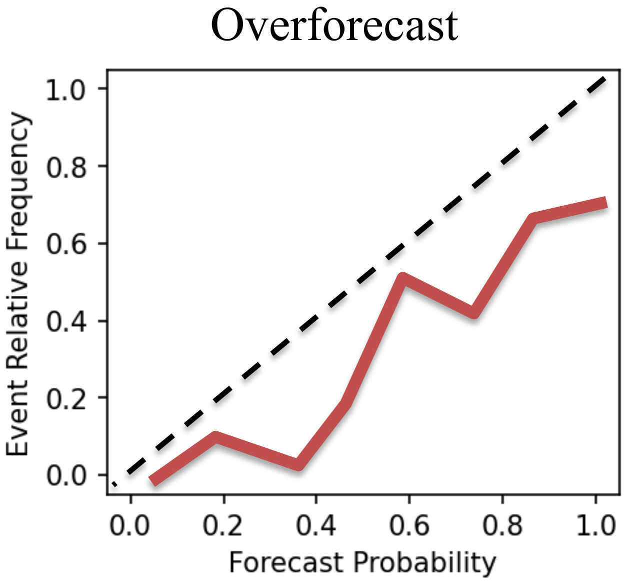
Reliability Diagrams 101

- Assessing ensemble forecast probabilities (precip. > threshold, in this case)
- Quantifying each ensemble's reliability using Brier Score [BS, (lower = better, 0 = "perfect")]

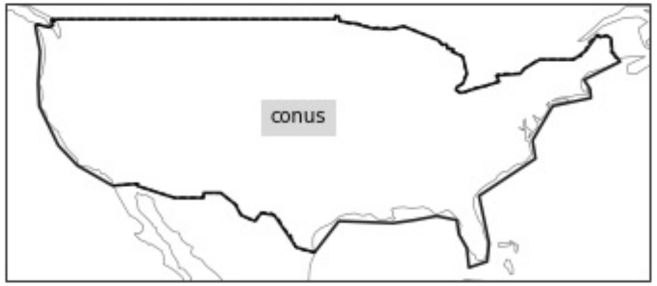


← Distribution of forecasts in each probability bin



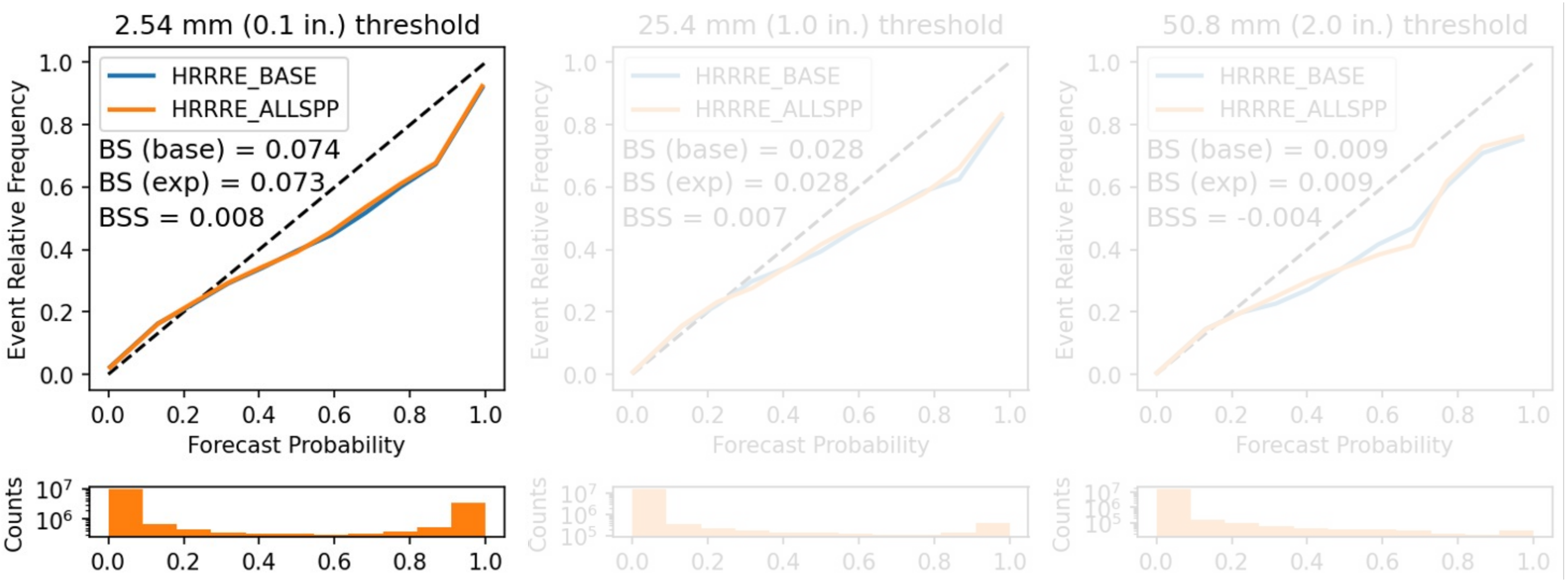


Precip. Verification (CONUS)

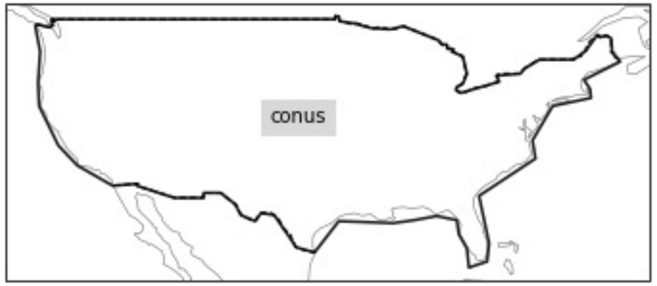


48-h precip. (Stage IV) – neighborhood probs. (25 km)

- Nearly identical performance of baseline and experiment forecasts
- Slight overforecast for higher probs.

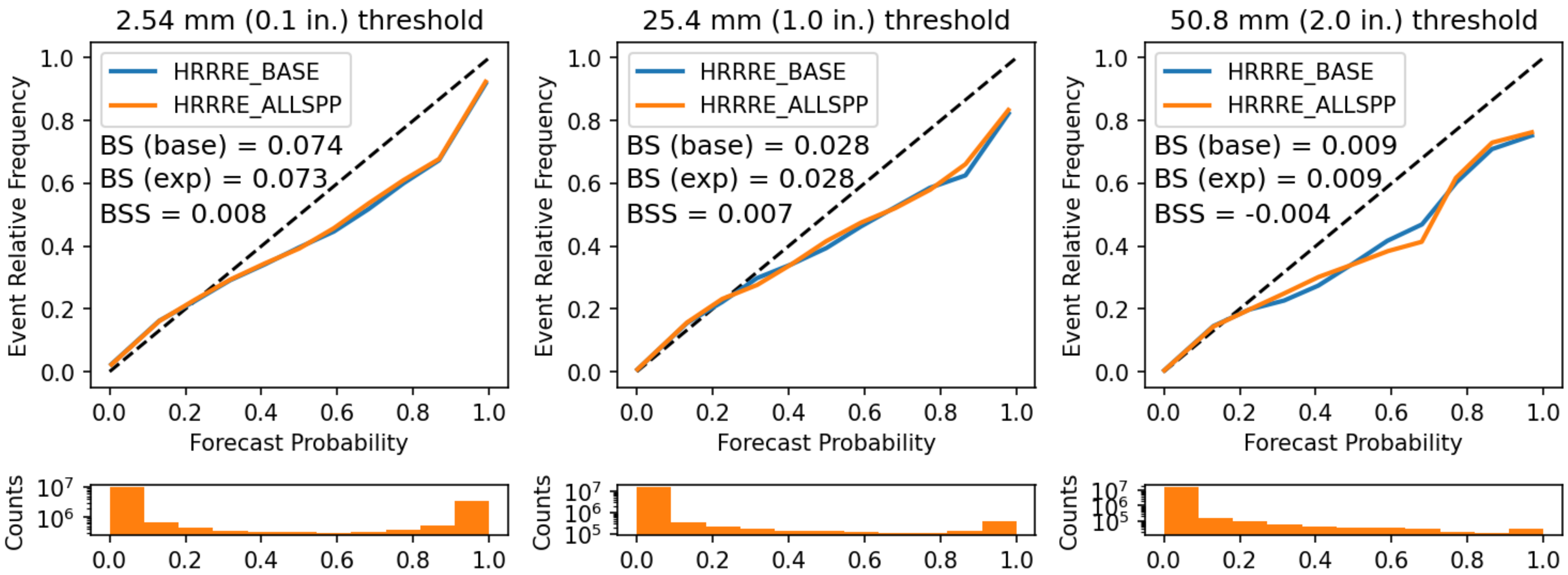


Precip. Verification (CONUS)

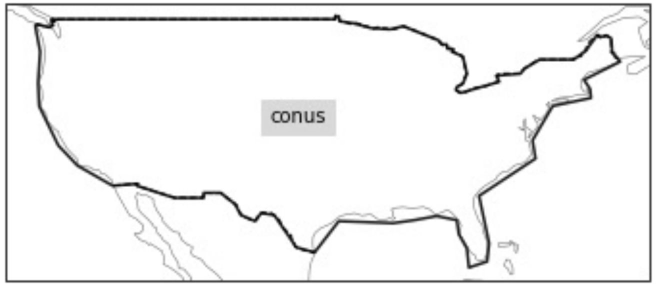


48-h precip. (Stage IV) – neighborhood probs. (25 km)

- Nearly identical performance of baseline and experiment forecasts
- Similar results using gridpoint probs.
- Regional verif. also produced similar results (not shown)



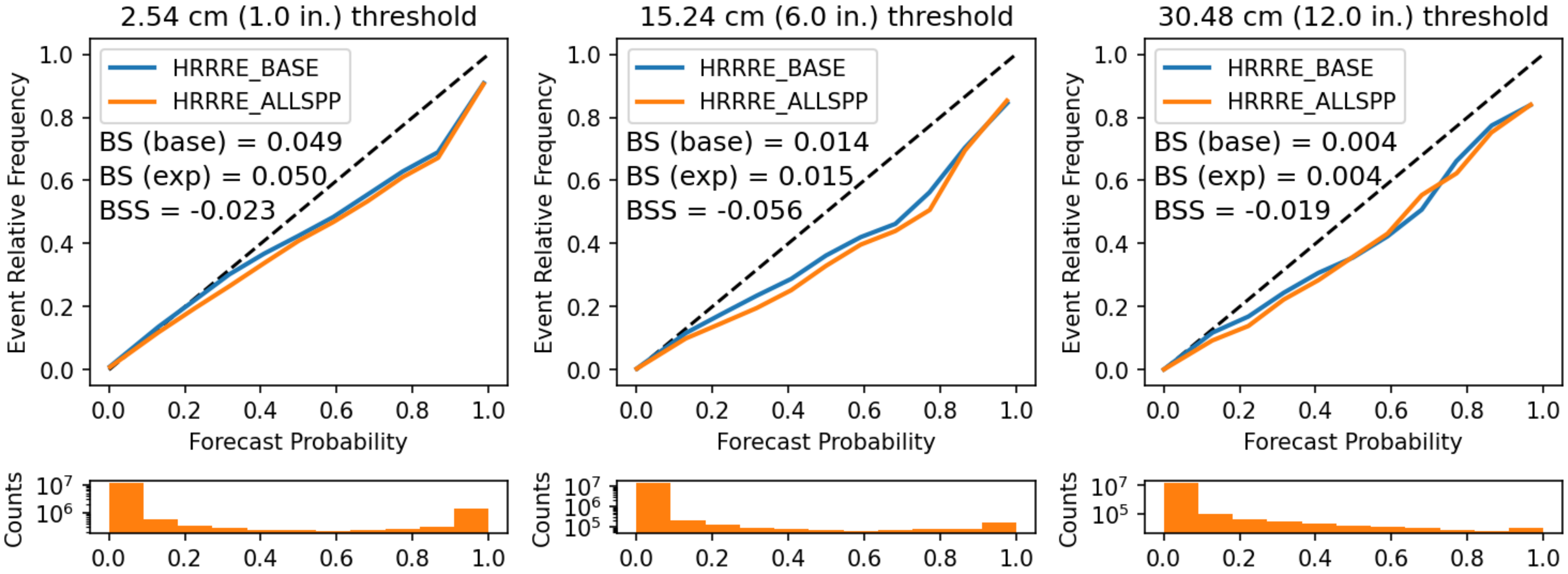
Snowfall Verification (CONUS)



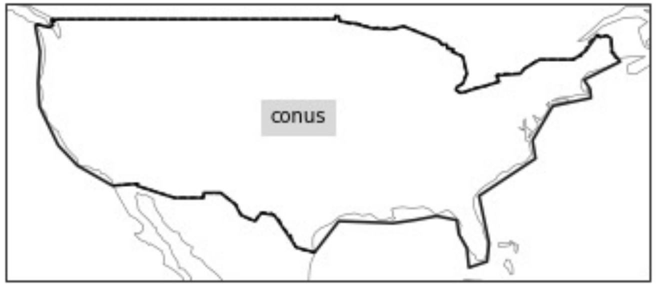
48-h snowfall (NOHRSC) – neighborhood probs. (25 km)

- Assuming fixed 10:1 SLR

- Nearly identical performance of baseline and experiment forecasts
- Slight overforecast for all snow thresholds



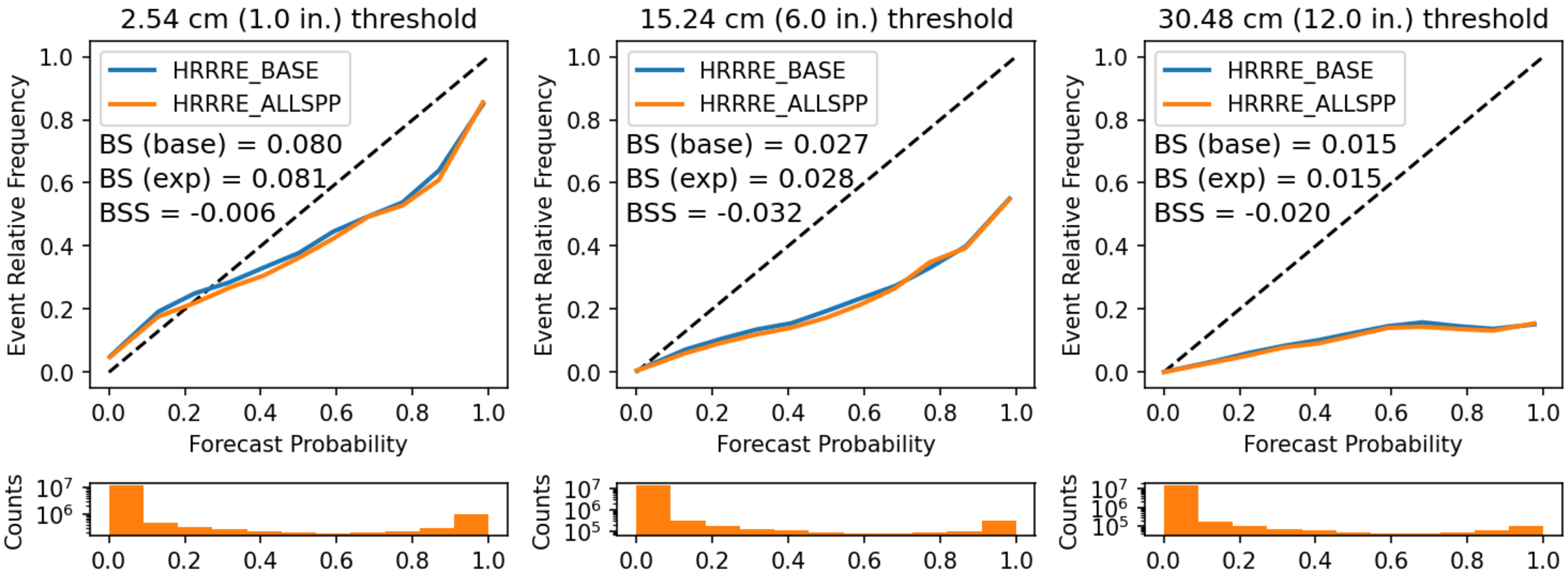
Snowfall Verification (CONUS)



48-h snowfall (NOHRSC) – neighborhood probs. (25 km)

- Variable SLR based on low-level temp. (HRRR method)

- Nearly identical performance of baseline and experiment forecasts
- Large overforecast for higher snow thresholds (>15 cm/6 in.)



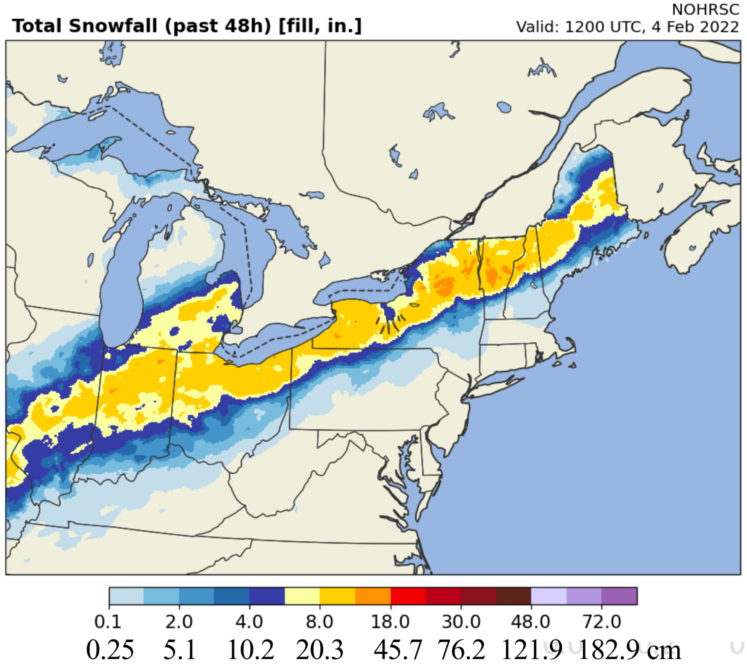
Snowfall Verification (C

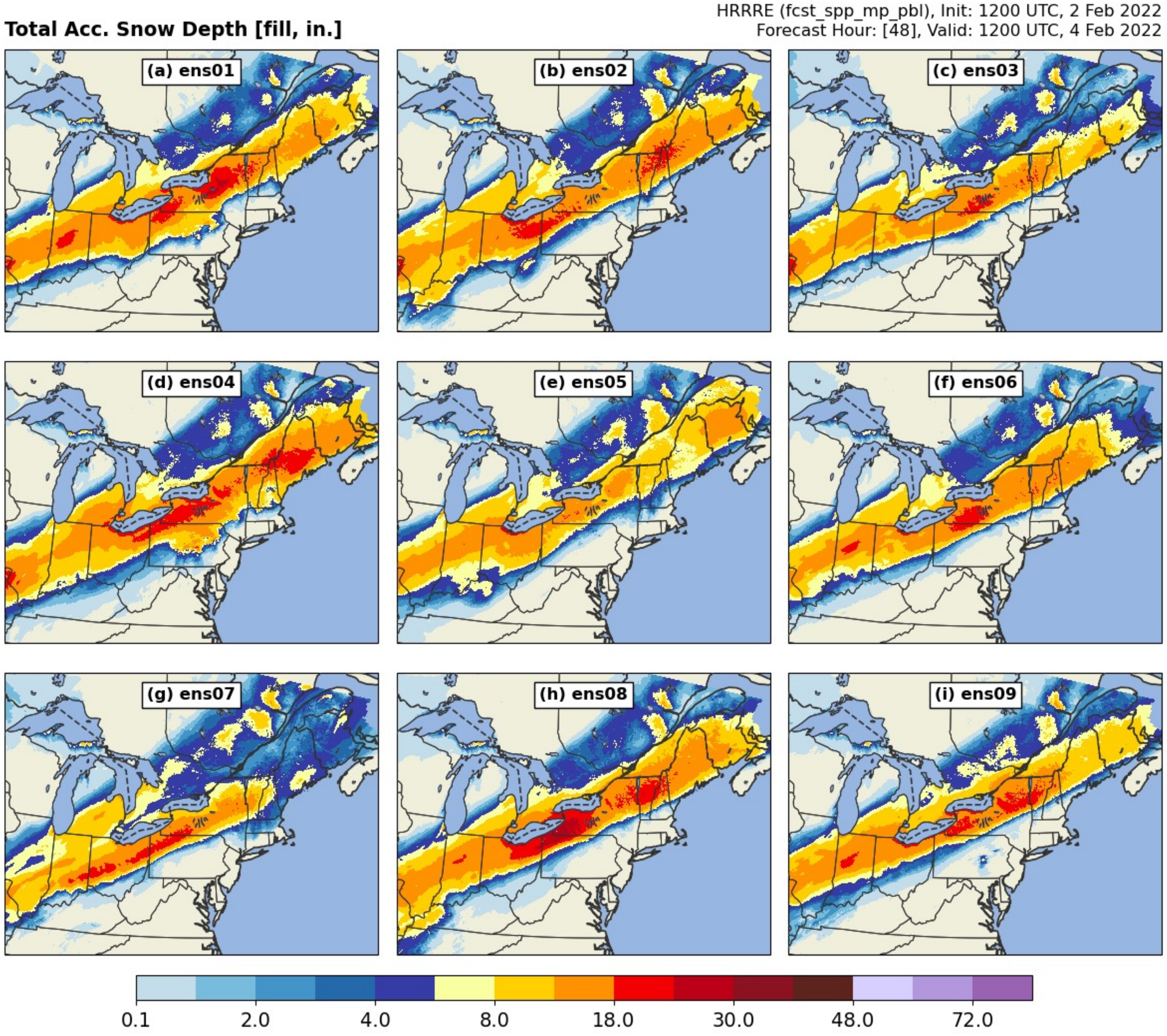
48-h snowfall (NOHRSC) – neighbo

- Variable SLR based on low-level t

- Nearly ident

NOHRSC



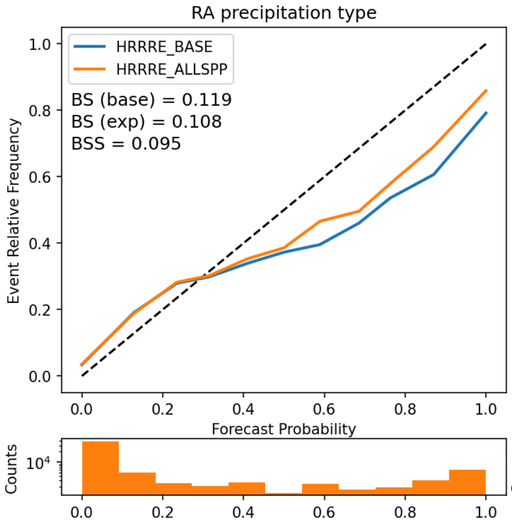


P-Type Verification (CONUS)

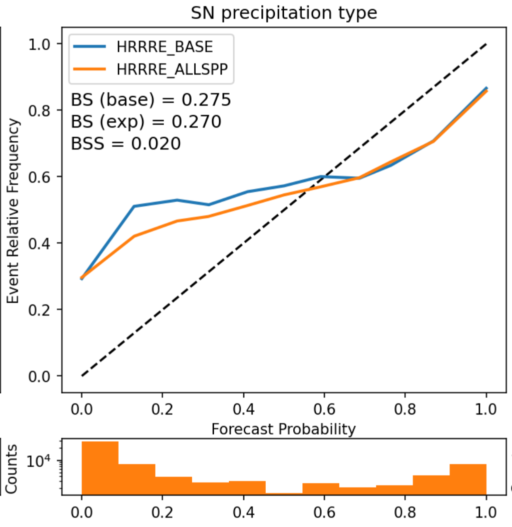
1-h precip. type (mPING) – nearest gridpoint to observation

- Similar performance of baseline and experiment forecasts, experiment has modest improvement for several p-types (rain, snow, freezing rain)

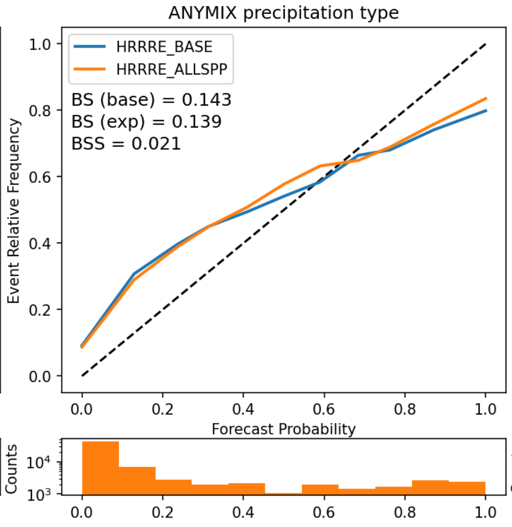
Rain



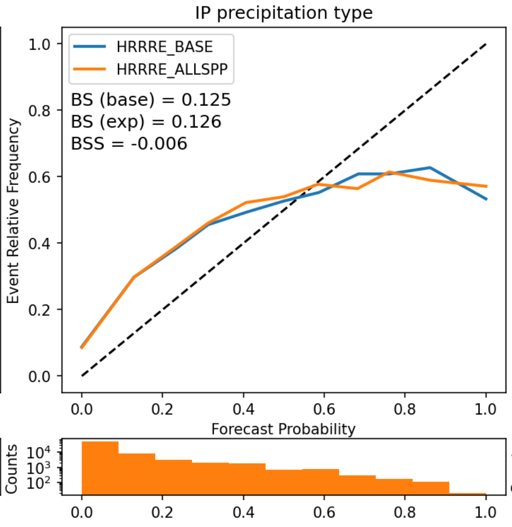
Snow



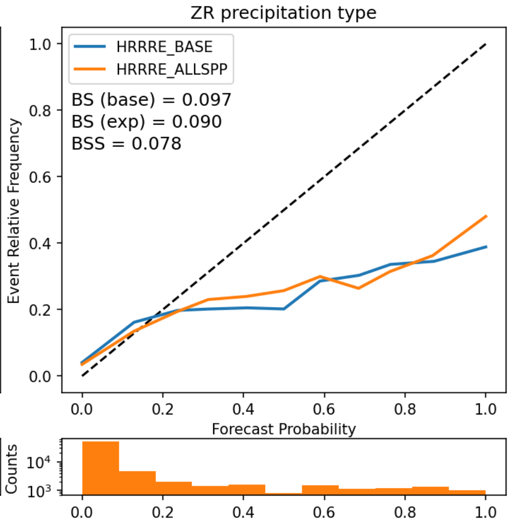
Any mixed precip. (IP, ZR)



Ice pellets



Freezing rain

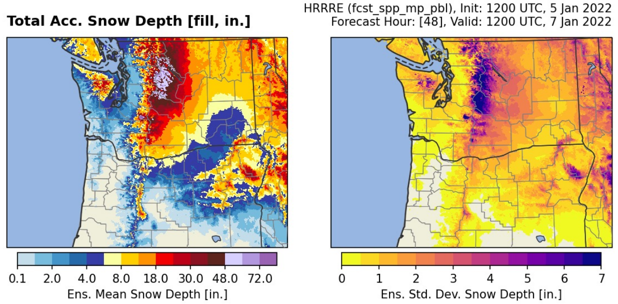


Baseline: IC/BC ens. with SPP-LSM perts.
Experiment: IC/BC ens. with SPP-LSM, SPP-PBL, SPP-MP perts.

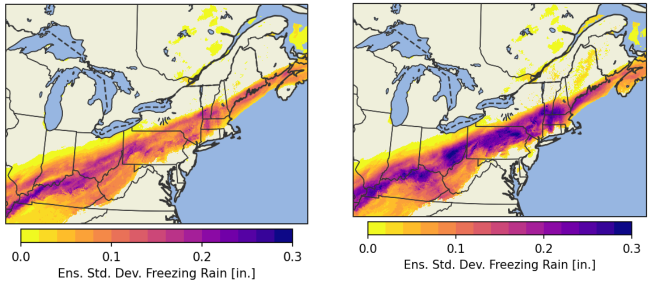
Conclusions

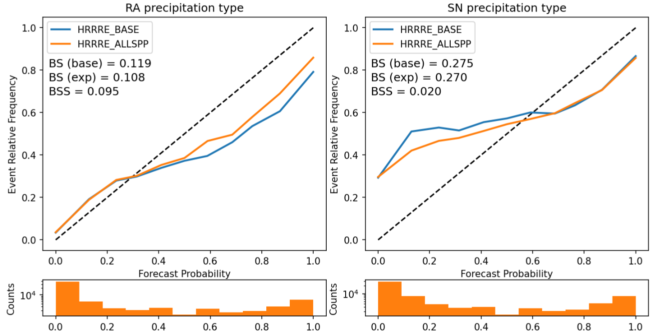
- **Pacific NW atmos. river case:**
  - Good forecast overall but coastal precip. dry bias
  - Similar precip. spread, experiment ens. has <u>increased snowfall spread</u> in lee of Cascades
- **Eastern U.S. mixed-precip case:**
  - Good QPF and ZR forecast, too-large snow depth forecast across interior Northeast
  - Similar precip. spread, experiment ens. has <u>increased p-type spread</u> (SN versus ZR) especially in transition zone
- **Verification:**
  - Ensembles have nearly-identical upper-level performance
  - Experiment ensemble has <u>more spread in near-surface temperature</u> (925 hPa, 2-m), but also larger RMSE and bias
  - Ensembles have similar performance in QPF and snowfall verification
  - P-type verification shows <u>modest improvement</u> in experiment ens. for RA, SN, ZR
  - Variable SLR method overforecasts larger snowfall amounts (> 6 in.) compared to fixed 10:1 SLR

Experiment



Baseline Experiment

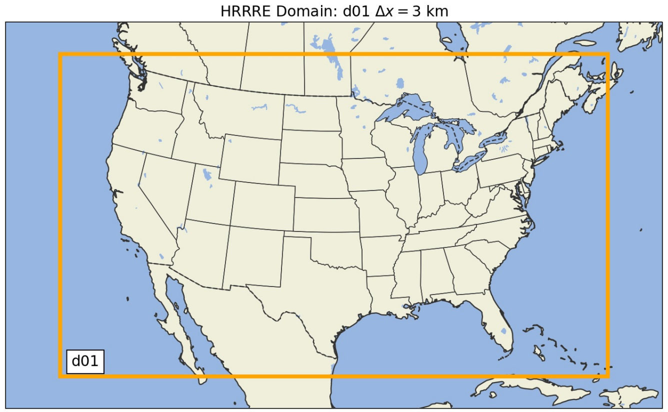




Physics uncertainty in high-res. ensembles

WPC-HMT: 2021-22 WWE Ensemble Configuration

- Forecasts run by NOAA-GSL (David Dowell, Isidora Jankov, Trevor Alcott)
- WRF v3.9+
- HRRRE configuration, with only SPP active (no SPPT)
- HRRRDAS ICs, GEFS BCs
- All forecasts initialized at 12 UTC and run for 48h, 21 total cases between Dec 2021 and Mar 2022
- MYNN Level 2.5 PBL scheme and Thompson-Eidhammer aerosol-aware MP
- **During WWE, tested two ensemble configurations (9 members each)**



Physics Scheme	SPP Parameters Perturbed
Planetary boundary-layer (MYNN-EDMF)	Eddy diffusivity, eddy viscosity, lateral entrainment rate, background water vapor specific humidity
Surface-layer physics (MYNN)	Aerodynamic, thermal, and moisture roughness lengths
Gravity wave drag (GWD-GSL)	Standard deviation of subgrid-scale terrain variations
Microphysics (Thompson-Eidhammer)	Graupel y-intercept param., cloud water shape param., activation frac. of CCN/IN, snow mass- and velocity-diameter coeffs., snow capacitance
Land surface physics (RUC LSM)	Surface emissivity, albedo, vegetation fraction
Horiz. diffusion (Smagorinsky)	Smagorinsky constant
Cumulus physics (Grell-Freitas)	Cloud-base mass flux closures