Performance of Precipitation Forecasts from a Convection-Permitting Ensemble Relative to Operational Guidance over the Western United States

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MOTIVATION

- Convection-permitting ensemble modeling systems are required to ***capture the large spatial variability*** and ***quantify the inherent uncertainty*** of precipitation forecasts in areas of complex terrain
  - Ensemble modeling systems remain largely untested at convection-permitting grid spacings (4-km or less) over the western U.S
  - Experimental NCAR Ensemble (10 members at 3-km) serves as ideal platform for QPF validation study of next generation NWP

OBJECTIVES

- *Determine the advantages of QPF from a cloud-permitting ensemble forecast system over complex terrain in the western US*
  - Deterministic: How well does a single member of the NCAR Ensemble predict characteristics of precipitation?
  - Probabilistic: What is the *reliability* and *resolution* of probabilistic QPF from all 10 members of the NCAR Ensemble?

MODEL DATA

Model	Resolution	Convection Permitting?	Forecasts Used
NCAR Ensemble Ctrl. (Member 1)	3-km	Yes	Hours 12-36 from 00Z
HRRRv1	3-km	Yes	Hours 3-15 from 09Z and 21Z
NAM-4km	4-km	Yes	Hours 12-36 from 00Z
NAM-12km	12-km	No	Hours 12-36 from 00Z
GFS	0.5° (~28-km)	No	Hours 12-36 from 00Z
NCAR Ensemble (10 Members)	3-km	Yes	Hours 12-36 from 00Z
GEFS (20 Members)	1.0° (~55-km)	No	Hours 12-36 from 00Z
ECMWF Ensemble (50 members)	0.5° (~28-km)	No	Hours 12-36 from 00Z

Table 1: Models used in study. Red shading indicates single member, deterministic models. Blue shading indicates multi-member, ensemble models. All data from 2015/2016 cool season.

VALIDATION RESULTS

Deterministic Validation: Seasonal Precipitation Bias

- **Spatial (PRISM):** Similar biases among all models, non convection-permitting models under-predict (bias < 1) in mountains, low spatial variance in *NCAR Ens. Ctrl.* and *HRRR*
- **Point (SNOTEL):** Strong (~1) bias from *NCAR Ens. Ctrl.* and *GFS, HRRR* and *NAM-4km* over-predict (bias >1)

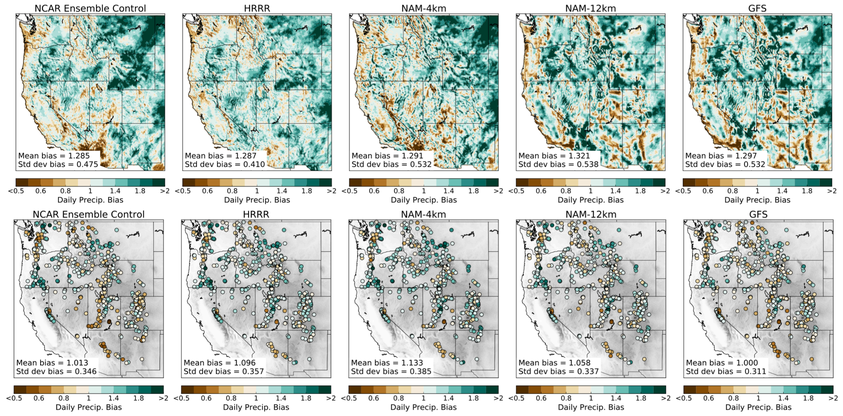

Figure 2: Precipitation bias for 2015/2016 cool season relative to PRISM (top) and SNOTEL (bottom)

NCAR Ens. Ctrl.	*high accuracy* – modest spread, slight over-prediction of large events
HRRR	*high accuracy* – minimal spread, slight over-prediction of events of all sizes
NAM-4km	*fair accuracy* – modest spread, significant over-prediction of events of all sizes
NAM-12km	*fair accuracy* – modest spread, under-prediction of large events
GFS	*poor accuracy* – large spread, significant under-prediction events of all sizes

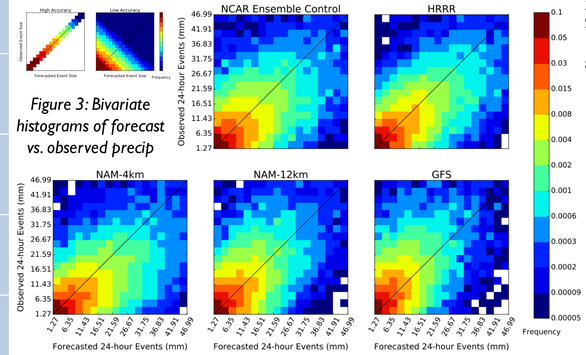

Figure 3: Bivariate histograms of forecast vs. observed precip

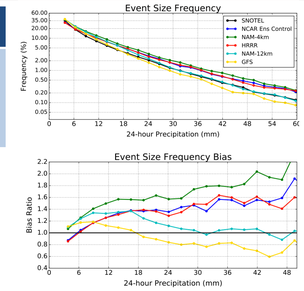

Figure 4: Frequency of 24-hr precip events compared to SNOTEL

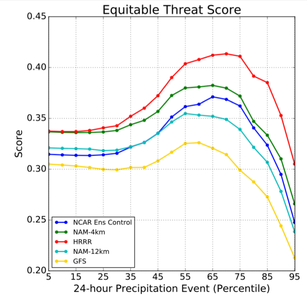

Figure 5: Equitable Threat Scores calculated using percentile thresholds

Probabilistic Validation: Reliability Diagrams

- Over-confidence exhibited by all models (least so by NCAR Ensemble)
- Strongest BSS (higher is better) from NCAR Ens., while GFS struggles

	Brier Score	Reliability	Resolution	Uncertainty	Brier Skill Score
NCAR (Upper Quart.)	0.161	0.015	0.070	0.216	0.253
GEFS (Upper Quart.)	0.214	0.045	0.048	0.217	0.014
ECMWF (Upper Quart.)	0.202	0.047	0.061	0.216	0.063
NCAR (Upper Dec.)	0.087	0.010	0.032	0.109	0.199
GEFS (Upper Dec.)	0.102	0.012	0.019	0.110	0.065
ECMWF (Upper Dec.)	0.095	0.011	0.024	0.108	0.116

Figure 6: Reliability and sharpness diagrams with relevant statistical metrics

OBSERVATIONAL DATA

SNOTEL

- Located in upper elevations
- Long-term storage gauges that report hourly precip to one-tenth of an inch (2.54 mm)
- Daily (12Z to 12Z) precip used

PRISM

- PRISM Group at Oregon State University
- Used to reveal model climatology
- 4-km gridded daily (12Z to 12Z) precip data
- Uses point data, spatial data, and a digital elevation model

** All data from 2015/2016 cool season*

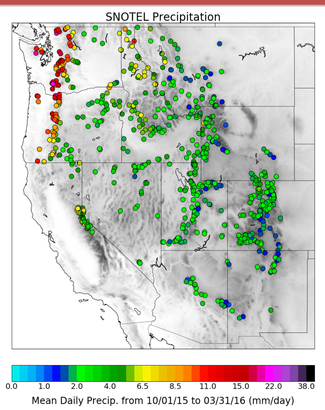

Figure 1: Location and mean daily precip of SNOTEL sites

SUMMARY

- ***Short range QPF from a single member of a convection-permitting ensemble performs very well relative to operational NWP over the western US***
  - NCAR Ensemble Control has strong bias (~1), moderate/high accuracy, modest ability capturing large events
  - HRRR performs similarly well, but has advantage of shorter range forecasts
- ***Short range QPF from a convection-permitting ensemble performs best compared to GEFS and ECMWF Ensemble over the western US***

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**See regional results on poster 1177*

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