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Development of Time-Phased, Multi-Model Ensembles for Improved Quantitative Precipitation Forecast (QPF) and Probabilistic QPF (PQPF)

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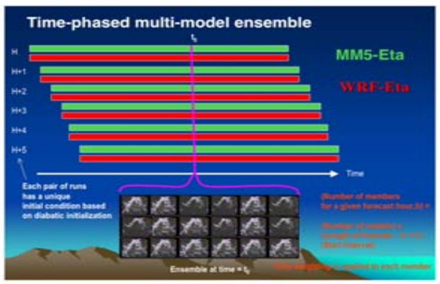
Introduction

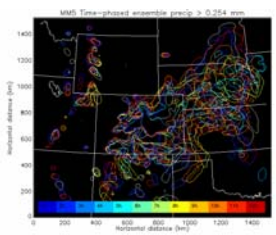
Precipitation is one of the most variable and difficult forecast fields even from the state-of-the-art numerical weather prediction (NWP) models. This is so partly because of the high uncertainty of the parameterizations of precipitation physics in these models and partly because of the inaccurate specification of the initial states of the atmosphere, especially the diabatic nature of such initial states.

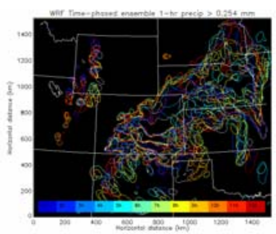
In view of the problems, a time-phased, multi-model ensemble system is developed for the improvement of quantitative precipitation forecast (QPF). The time-phased ensembles are obtained by using a set of forecasts from a particular NWP model initialized at different times, but validated at the same time. Such a method of ensemble generation is conjectured to be better at capturing time-evolving errors in the forecast initial conditions. The inclusion of multi-model ensembles may further reduce uncertainty in model physical parameterizations. In this study, we will present results and products from this research and development effort. In particular, time-phased, multi-model ensemble mean of QPF and probabilistic QPF for several case studies will be shown.



Model configurations

Model setup	WRF (ARW)	MM5
Grid dimension	128x128x31	128x128x31
Domain	West-central US	West-central US
Grid spacing	12km	12km
Dynamic core	Nonhydrostatic/mass coord.	Nonhydrostatic/sigma coord.
Physics	Microphysics: WSM 5-class Cumulus: no Surface: Noah LSM	Microphysics: Schultz(1995) Cumulus: no Surface: Noah LSM
Initialization	LAPS diabatic	LAPS diabatic
Lateral B.C.	NCEP-Eta	NCEP-Eta



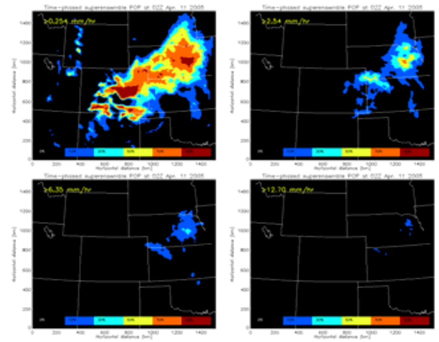


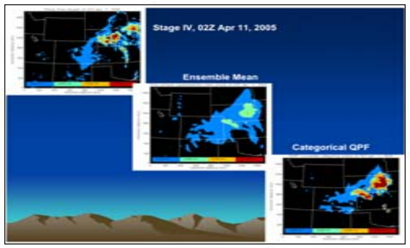
- **Time-phased multi-model ensemble mean of QPF:**

$$\hat{f}(x,t)=\sum_{n=1}^{N}\sum_{\tau=h}^{H} w_{n,\tau} f_{n,\tau}(x,t) \Big/ \sum_{n=1}^{N}\sum_{\tau=h}^{H} w_{n,\tau}, \quad x\in R^{b,l},\ t=\text{verif. time}$$

- **PQPF (POP):**

$$P^{\alpha}(x,t)=\sum_{n=1}^{N}\sum_{\tau=h}^{H} w_{n,\tau} p^{\alpha}_{n,\tau}(x,t) \Big/ \sum_{n=1}^{N}\sum_{\tau=h}^{H} w_{n,\tau}, \quad x\in R^{b,l},\ \alpha=\text{threshold},\ t=\text{verif. time}$$





- **Conversion of PQPF to CQPF:**

$$\text{CQPF}^{\alpha}(x,t)=\alpha\times \text{PQPF}^{\alpha}_{L(\alpha)}(x,t), \quad L(\alpha)=\text{threshold probability}$$

- **Launching threshold probability: 50%**
- **Deceleration towards high categories**

Conclusions

- A time-phased and multi-model ensemble system is developed using LAPS diabatic initialization scheme.
- These ensembles provide an improved QPF over a single deterministic forecast at higher thresholds, and with added values for user's decision making process (e.g., PQPF and CQPF).
- Ensemble mean did not improve rain/no-rain coverage or low thresholds with the increasing lead time.
- PQPF provides a new way for the improvement of QPF, and generally outperforms deterministic forecasts.
- CQPF may maintain high thresholds of rainfall, in comparison with deterministic and ensemble mean forecasts, but need careful selection of cutoff thresholds.

Brier Score (BS): $BS=\frac{1}{N}\sum_{i=1}^{N}(p_i-O_i)^2$

Brier Skill Score (BSS): $\text{BSS}=1-\frac{\text{BS}}{\text{BS}_{\text{ref}}}$