Would Lagged Ensembles Increase Extended-range Forecast Skill?

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Challenges in Extended-range Forecasts

- Several challenges in predicting the atmospheric and terrestrial variability for the time scale from week-2 to week-4 due to relatively small predictable signal;

  - Influence on this time range from initial condition is weakening;

  - The time average is not large for the influence of the slowly varying boundary conditions (SST, sea Ice, soil moisture…) to emerge above the noise;

- A large forecast ensemble is required to extract the small predictable signal;

- In general, a limited set of ensemble is available at operational centers on a daily basis for S2S forecasts.

- For example, every day NCEP CFSv2 provides a total of 16 members for the 45-day target period.

- Using the current operational configuration, can the ensemble size be increased to better discern predictable signal and improve skill?

Z200 (PNA) Anomaly correlation skill with difference ensemble sizes (forecast from the same initial time)
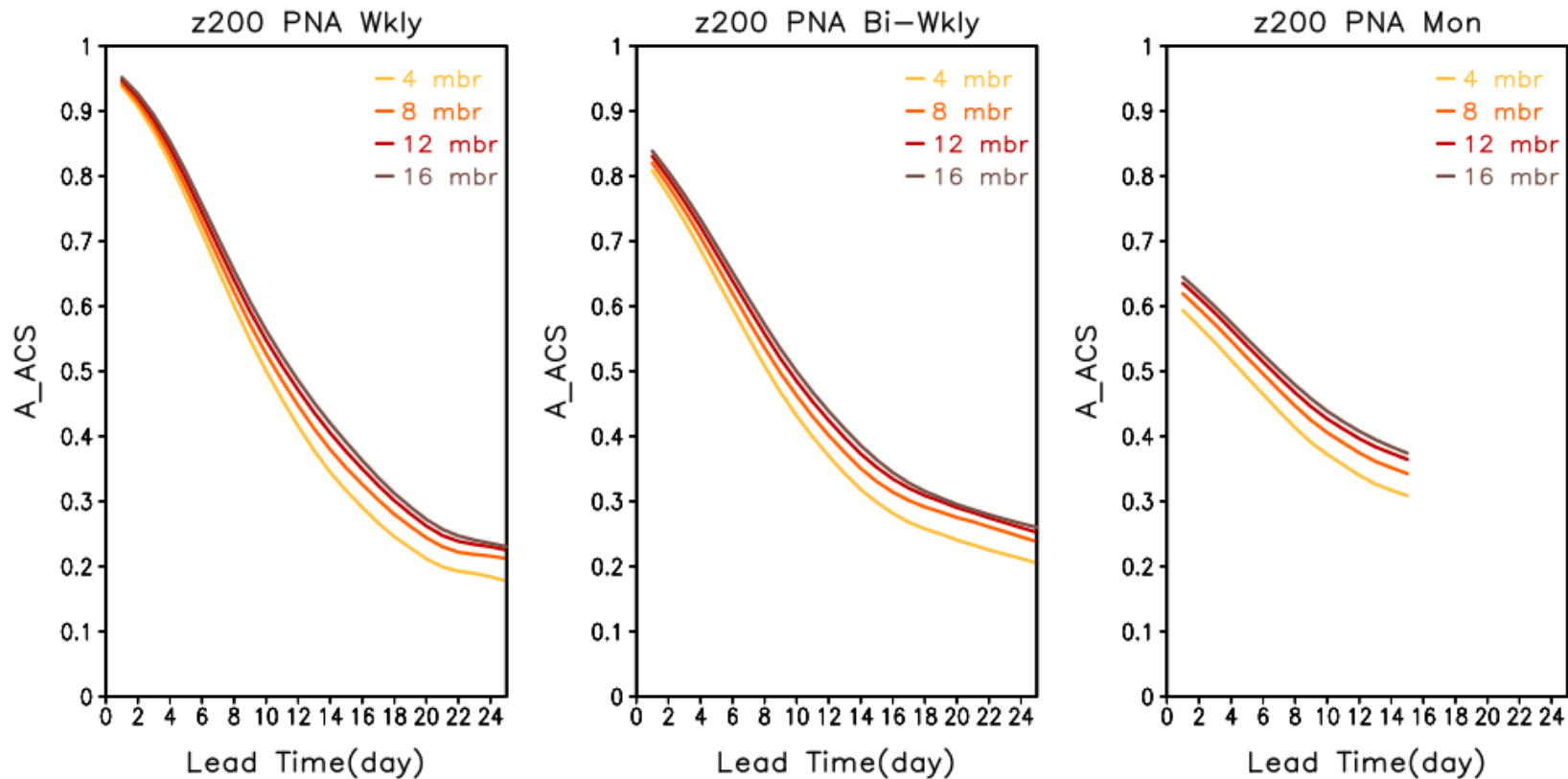
- **Forecast skill decreases with increasing lead time (-).**
- **Forecast skill increases with larger ensemble size (+).**

Question: Can the predictions gain skills from a lagged ensemble with inclusion of more members from longer lead times?

Analysis Approach

- Examine if the prediction skills can be improved from a lagged ensemble for predicting week2, week-3/4, and monthly anomalies? If yes, then,

  - ➢ For what lagged time the skill get the most improvements – the optimal lag time of the lagged ensemble?

  - ➢ Does the optimal lag time vary with the available number of forecast members from each initial date (for example, one member per day vs 4 members per day or 16 members)?

  - ➢ What is the optimal lag time and how much can prediction skill gain from a lagged ensemble based on CFSv2 current configuration (16 members per day)?

Data

- Ensemble forecasts from CFSv2 operational forecasts

  – Every day 16 members 45-day forecasts;

- Variables:

  – Precipitation (Prec); 2-meter temperature (T2m)

- Verification region and time period:

  – CONUS;

  – NDJFM 2011 → 2020 (9 years);

- Verification data:

  – Prec, the CPC unified daily gauge precipitation analysis;
  – T2m, the CPC global daily mean surface temperature;

Construction of lagged ensemble forecasts

Available forecasts per day	Lag 1-Day	Lag 2-Day	Lag 3-Day	...	Lag 9-Day	Lag 10-Day
16	16	2*16	3*16	...	9*16	10*16
15	15	2*15	3*15	...	9*15	10*15
...	...	...	...	...	...	...
3	3	2*3	3*3	...	9*3	10*3
2	2	2*2	3*2	...	9*2	10*2
1	1	2*1	3*1	...	9*1	10*1

Number of forecasts per day (vertical axis)

Lagged Ensemble Time (day) (horizontal axis)

- To assess the influence of lagged ensemble construction on the prediction skills
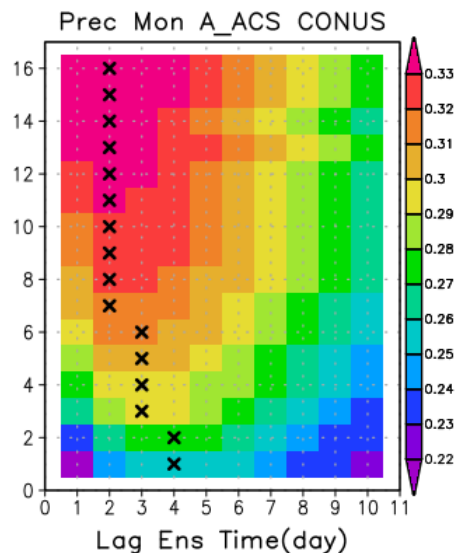
T2m Anomaly correlation skill (ACS) averaged over CONUS

Wky2
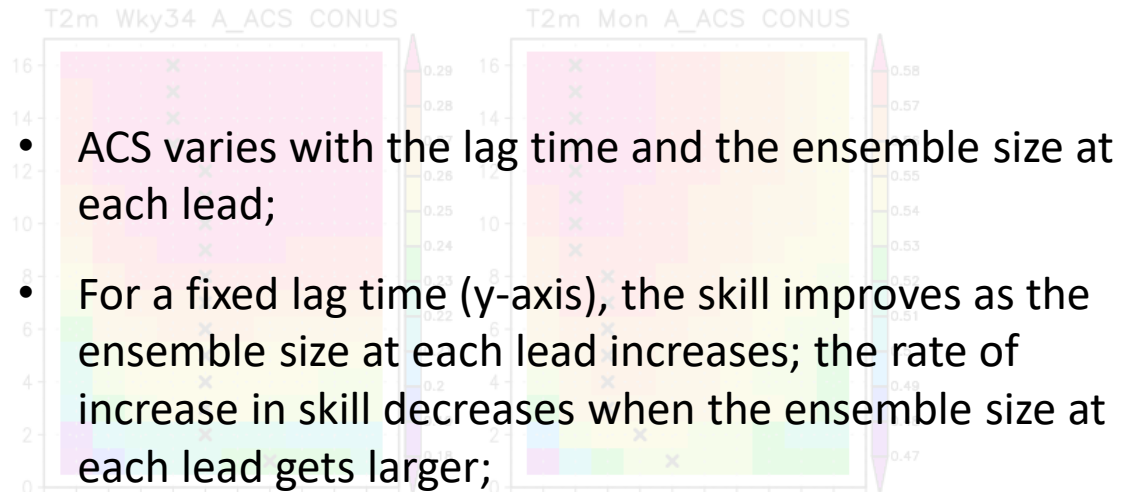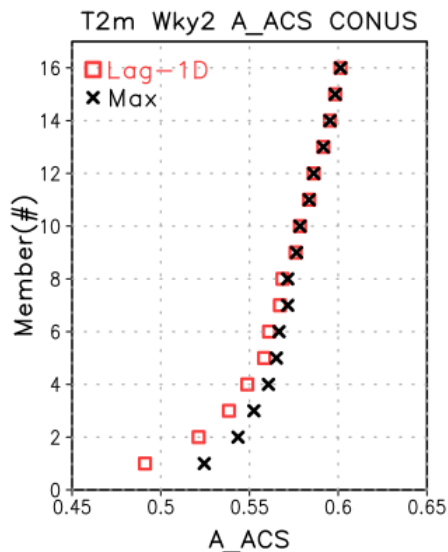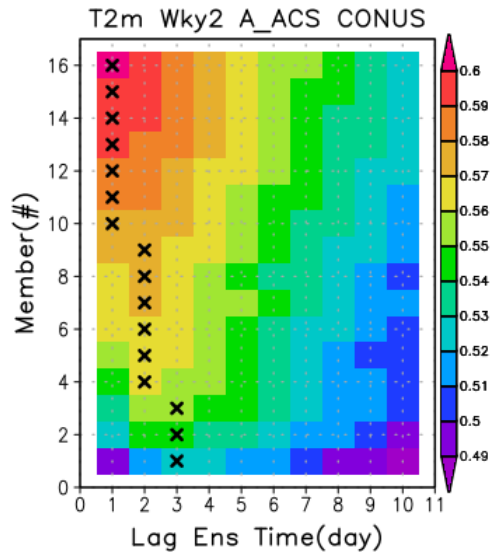
- ACS varies with the lag time and the ensemble size at each lead;

- For a fixed lag time (y-axis), the skill improves as the ensemble size at each lead increases; the rate of increase in skill decreases when the ensemble size at each lead gets larger;

- For a fixed ensemble size at each lead (x-axis), there is an optimal lag time at which the skill reaches its maximum.

- The optimal lag time decreases as the ensemble size at each lead gets lager;

- For small ensemble size at each lead time, more skill improvements from lagged ensembles;

T2m Anomaly correlation skill averaged over CONUS
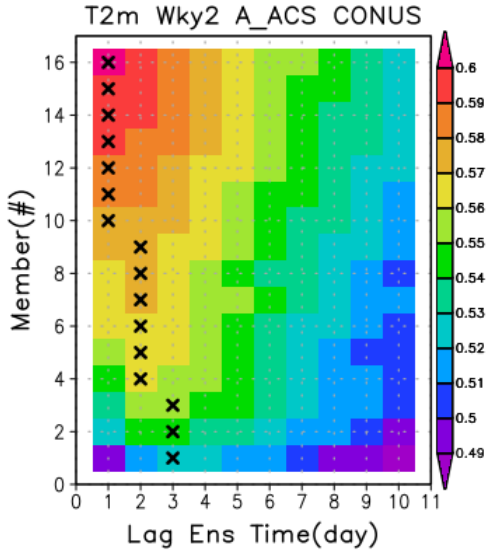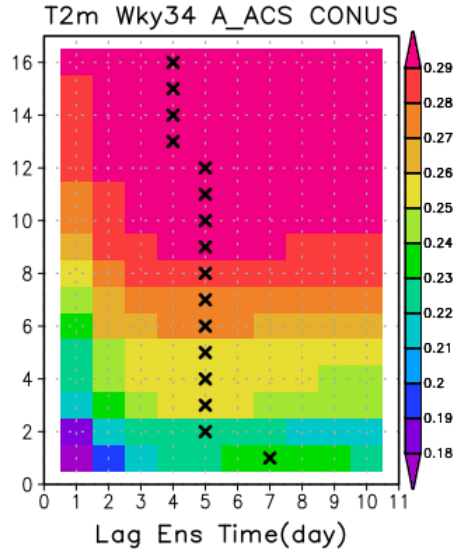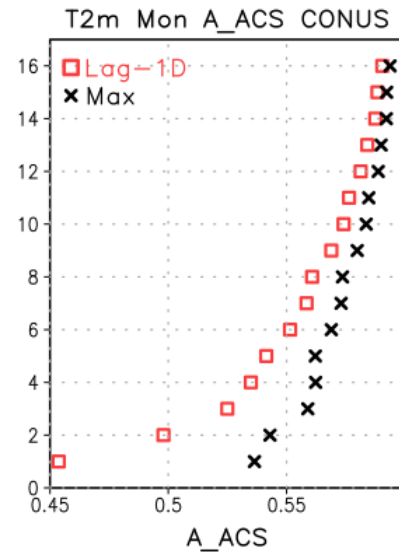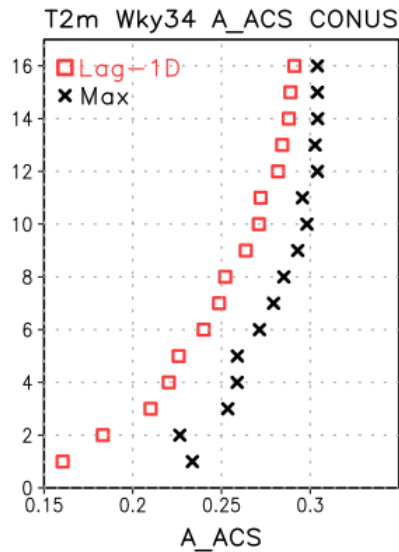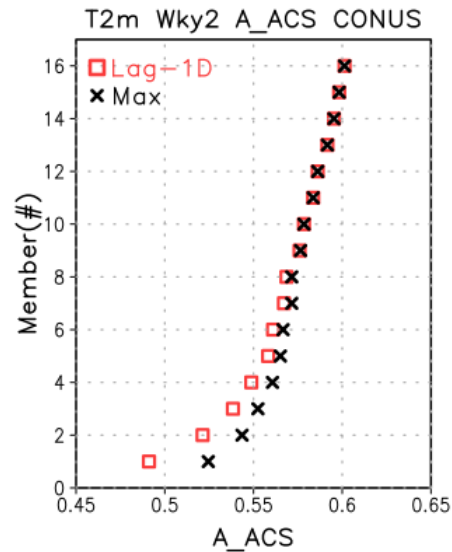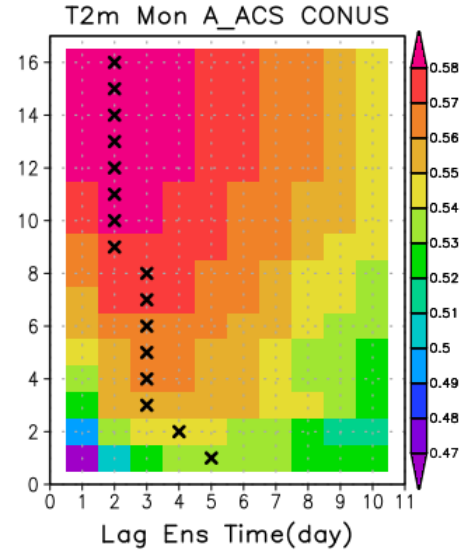
Prec Anomaly correlation skill averaged over CONUS
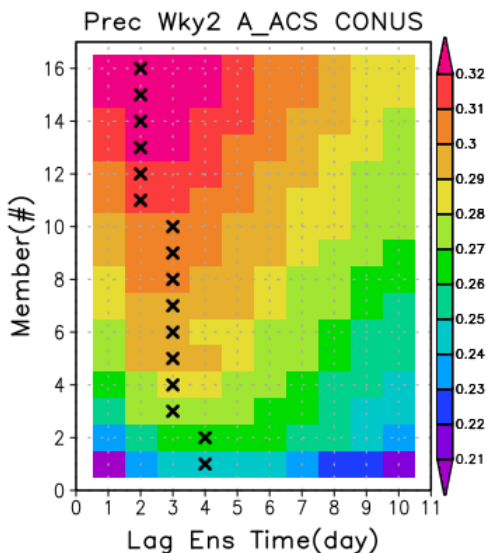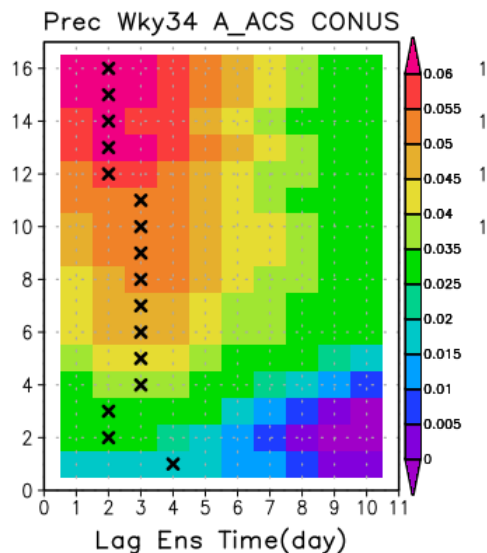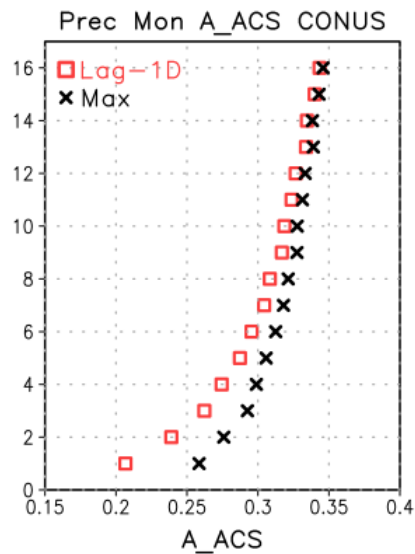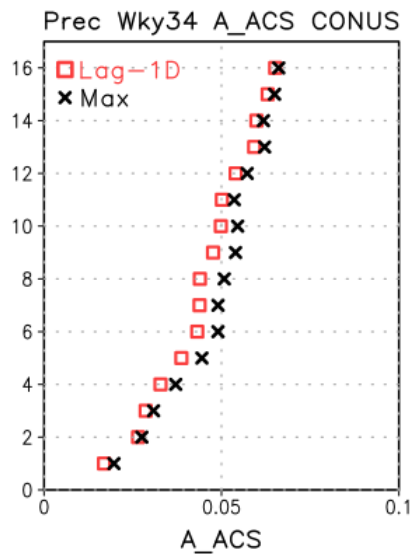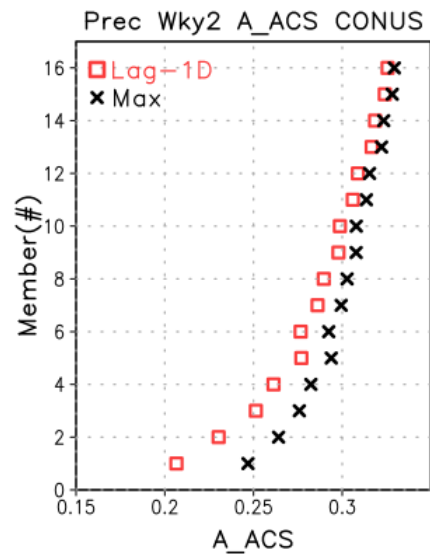
Wky2
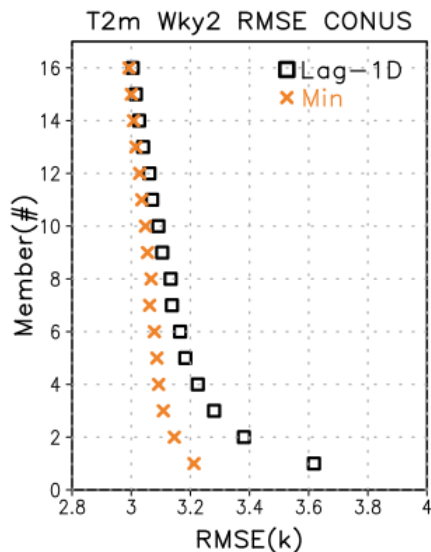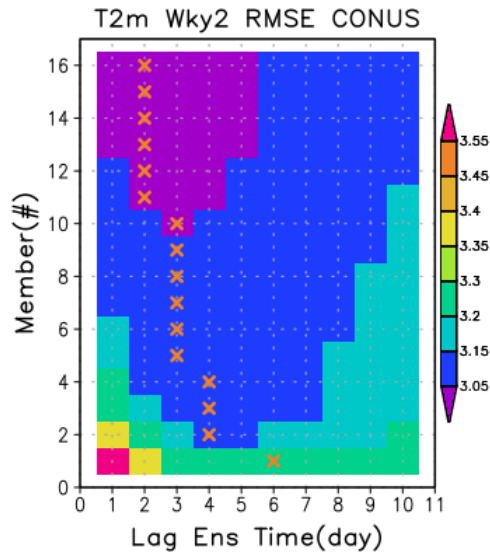

T2m Wky2 RMSE CONUS
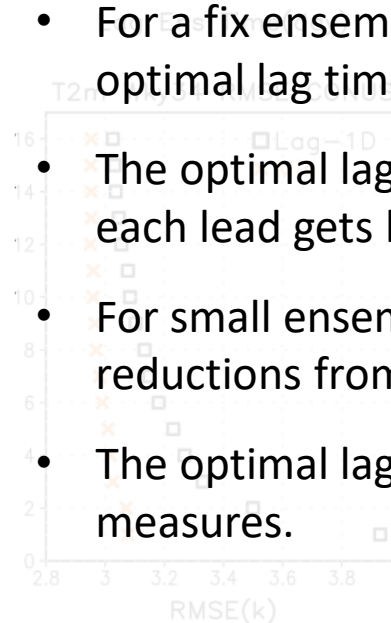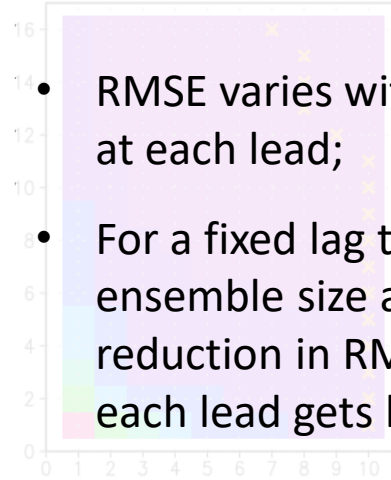
T2m Wky2 RMSE CONUS
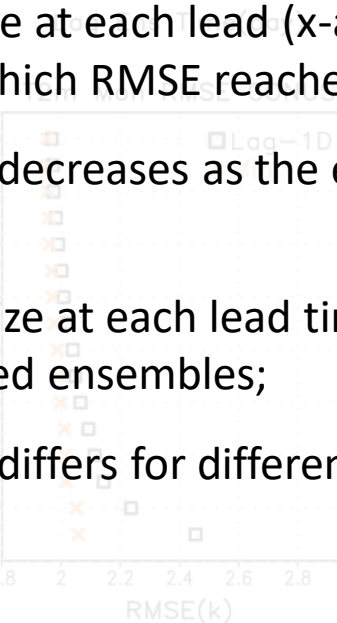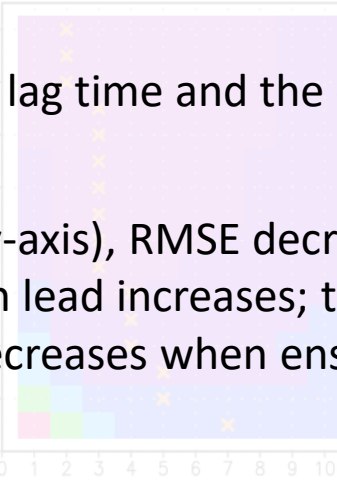
- RMSE varies with the lag time and the ensemble size at each lead;

- For a fixed lag time (y-axis), RMSE decreases as the ensemble size at each lead increases; the rate of reduction in RMSE decreases when ensemble size at each lead gets larger;

- For a fix ensemble size at each lead (x-axis), there is an optimal lag time at which RMSE reaches its minimum.

- The optimal lag time decreases as the ensemble size at each lead gets lager;

- For small ensemble size at each lead time, larger RMSE reductions from lagged ensembles;

- The optimal lag time differs for different skill measures.

T2m RMSE skill averaged over CONUS
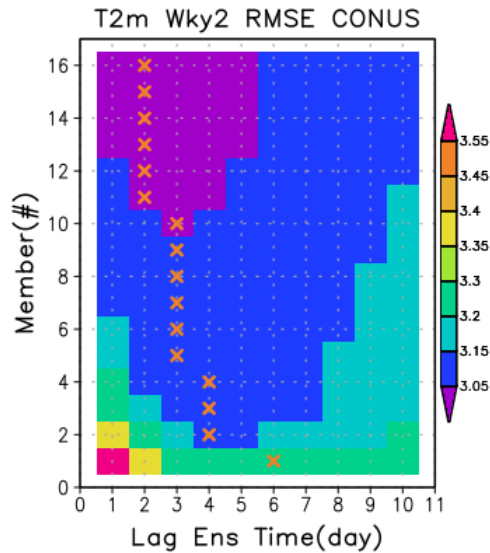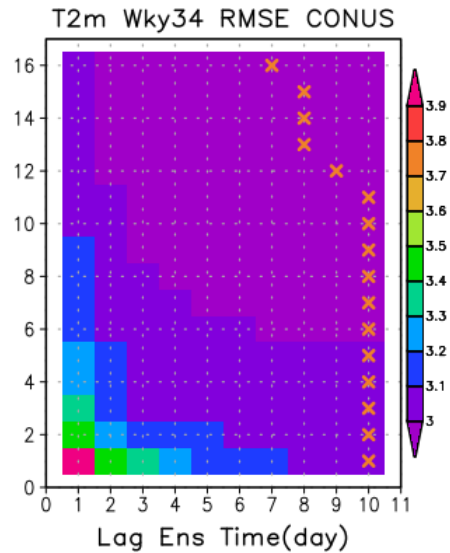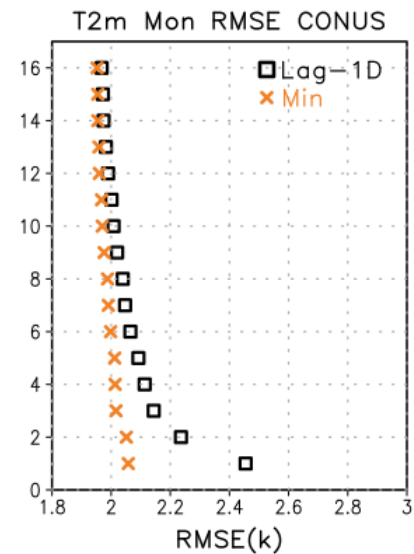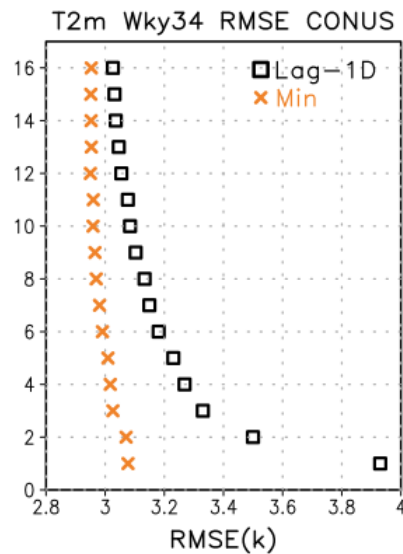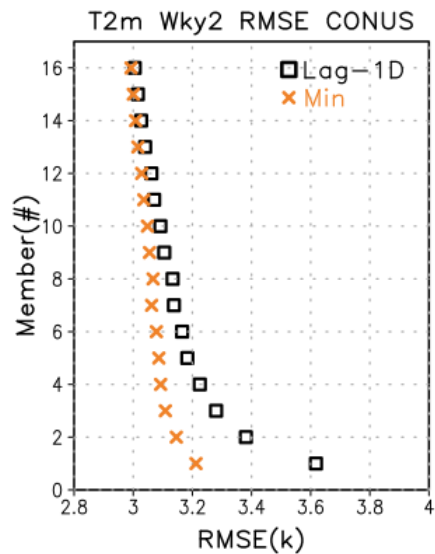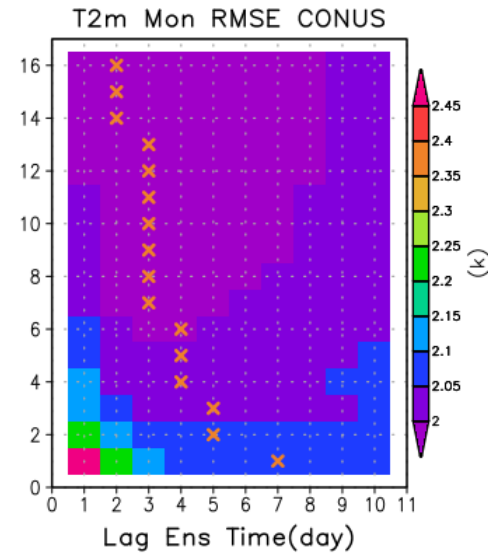
Prec RMSE skill averaged over CONUS
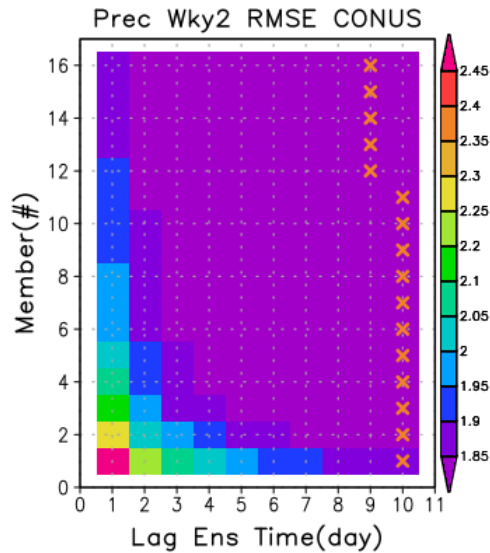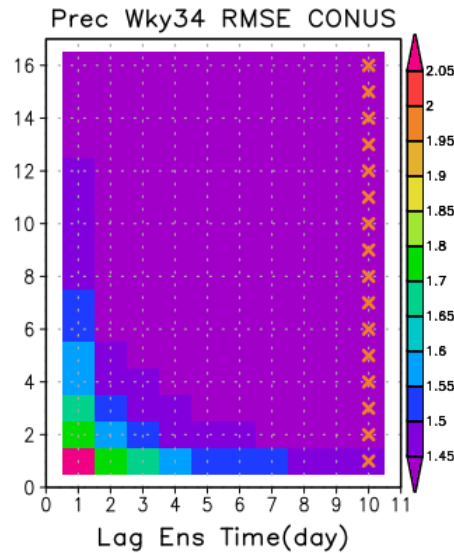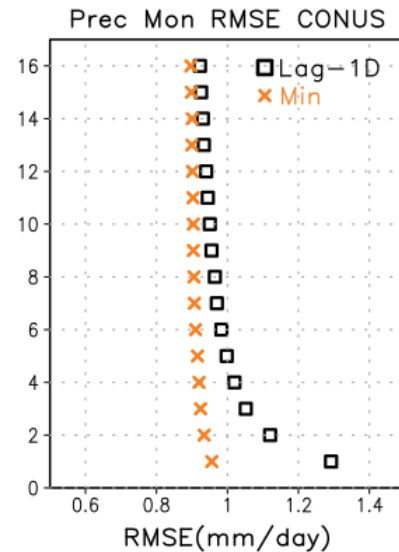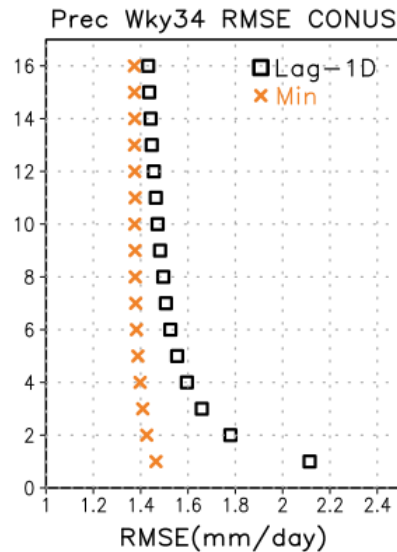
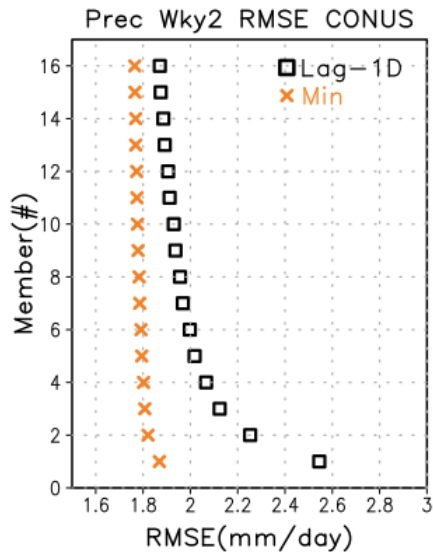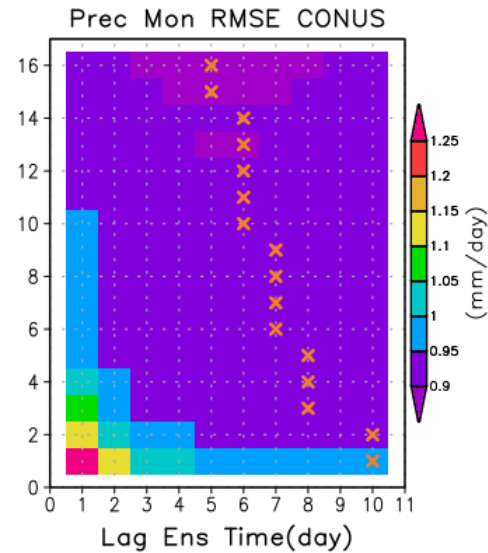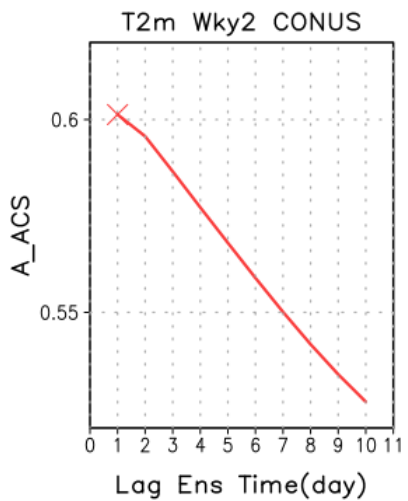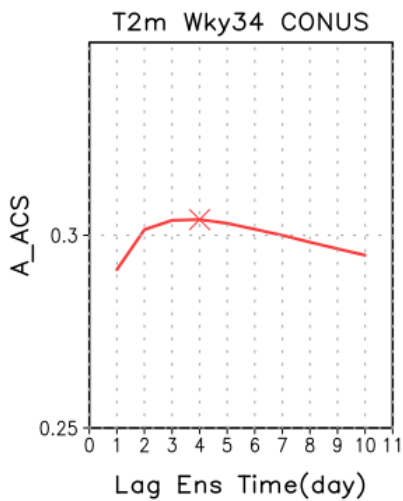# Optimal lag for the CFSv2 current configuration (16 members per day)

T2m CONUS
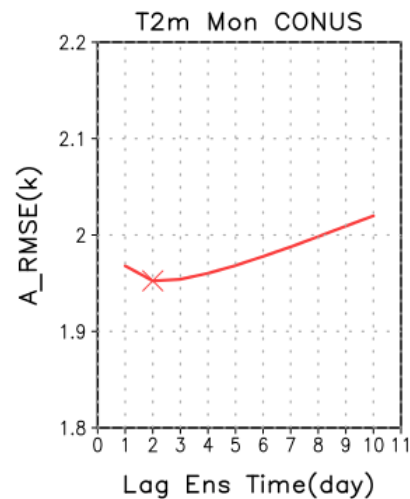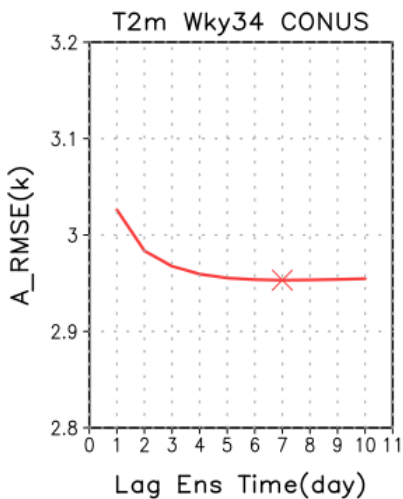
Precipitation CONUS
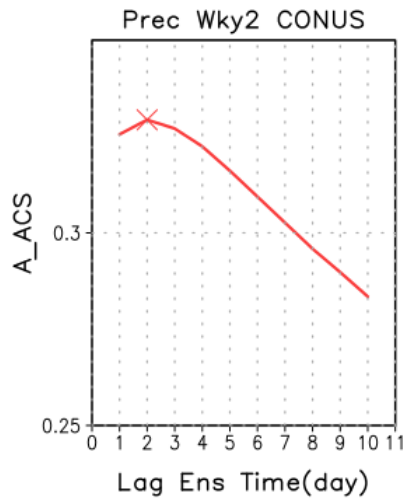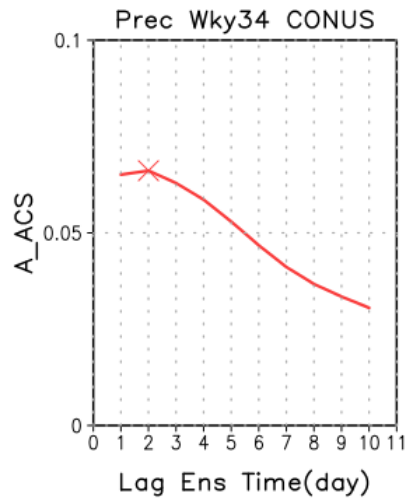
Summary

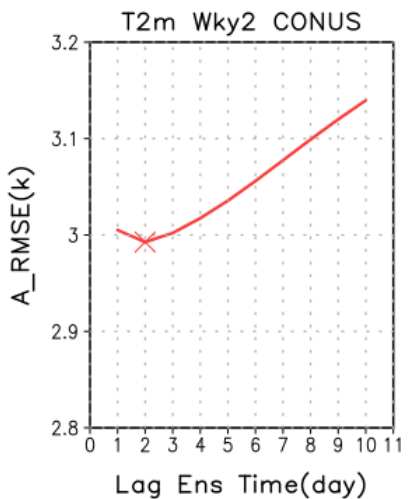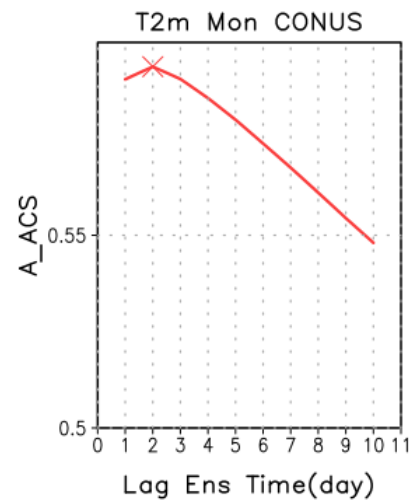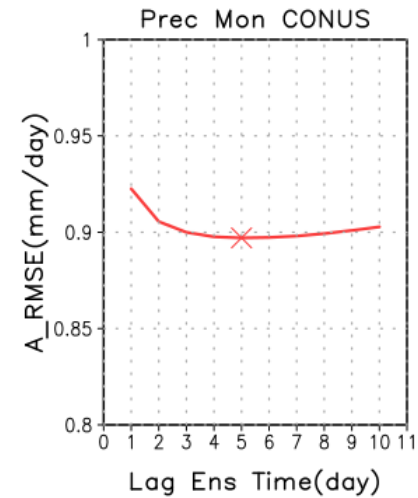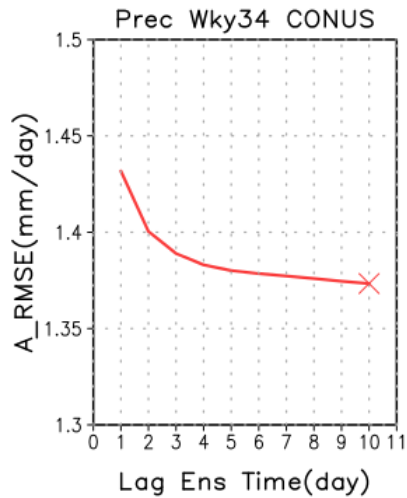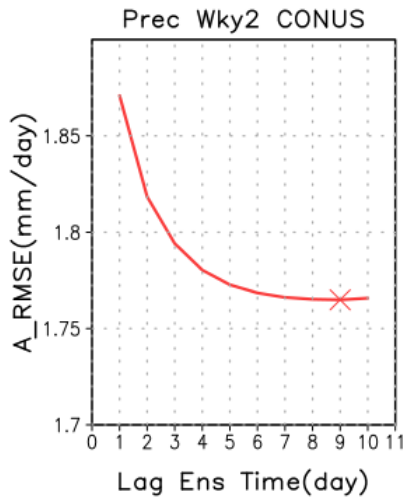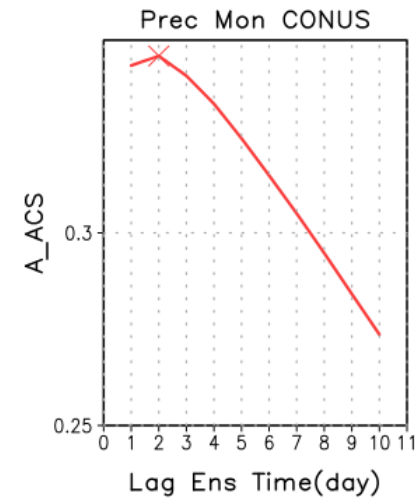- Skill improvement can be realized with lagged ensemble approach for extended-range forecasts: the potential for skill gains gets smaller as the ensemble size at each lead time increases.

- The optimal lag time at which skill reaches its maximum varies with the ensemble size at each lead, forecast variable, time scale, and skill measure.

- For CFSv2 current configuration (16 members per day), a small improvement can be realized with the lagged ensemble approach. In general, 2-days-lagged ensembles are reasonable for week-2, week-3/4, and monthly forecasts; while it can be extended to 4-days-lagged ensembles for T2m week-3/4 forecasts.