Super-Ensemble Statistical Forecasting of Monthly Precipitation over the Contiguous US, with Improvements from Ocean-Area Precipitation Predictors

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Definitions

- Ensemble: A weighted mean of multiple estimates
  - Traditionally used for GCM forecast runs with different initial conditions

- Statistical Ensemble: A weighted mean of different statistical estimates
  - Ensemble members may have different predictors, different predictor regions, or use different statistical models to give different estimates

- Super Ensemble: Use ensemble-averaging weights that reflect the accuracy of each member

Predictor & Predictand Areas: N.H. Oceans and Contiguous US

Regions for predictors: OI SST and GPCP P

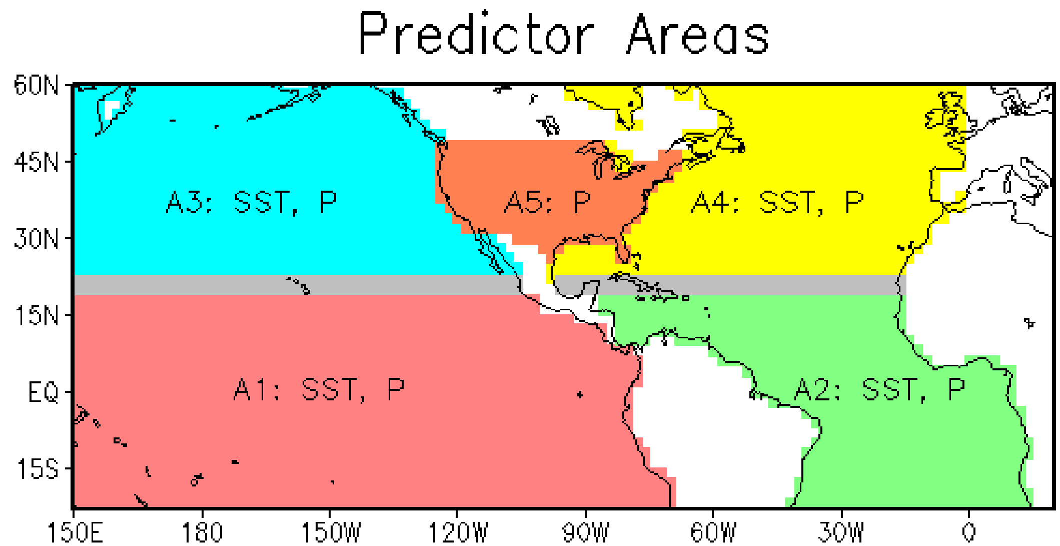
4 Ocean predictor areas with 20°N-23°N overlap

Regions likely to influence P_{US}, similar to Lau et al. (2002) areas

Predictors for ensemble:

- Ocean area $SST_k(t-1)$
- US area $P_{US}(t-1)$
- Ocean area $P_k(t-1)$

Always predict $P_{US}(t)$ anoms



Two Models: CCA and JEOF

- CCA
  - Decomposes predictor and predictand fields using EOFs
- JEOF
  - Simultaneous EOF of normalized predictor and predictand fields
- Predictors are leading SST and P, predictand is US P
- Super-ensemble weights use cross-validation skill of each forecast

Data & Evaluations

- GPCP precipitation and OI SST
  - 1997-2014 1dd GPCP averaged to monthly, compute anomalies

- Cross-validation testing of 0-lead monthly forecasts
  - Omit all data for the year of analysis and 3 months on either side of the year
  - Data from month t-1 to predict month t

- Correlations used to evaluate skill and improvements

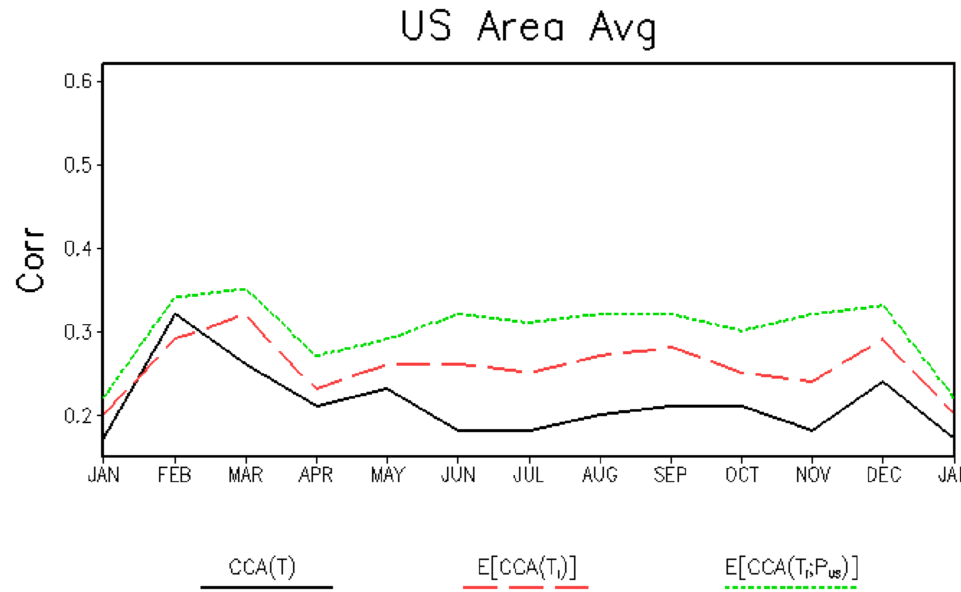
Annual Cycle of US Average Skill

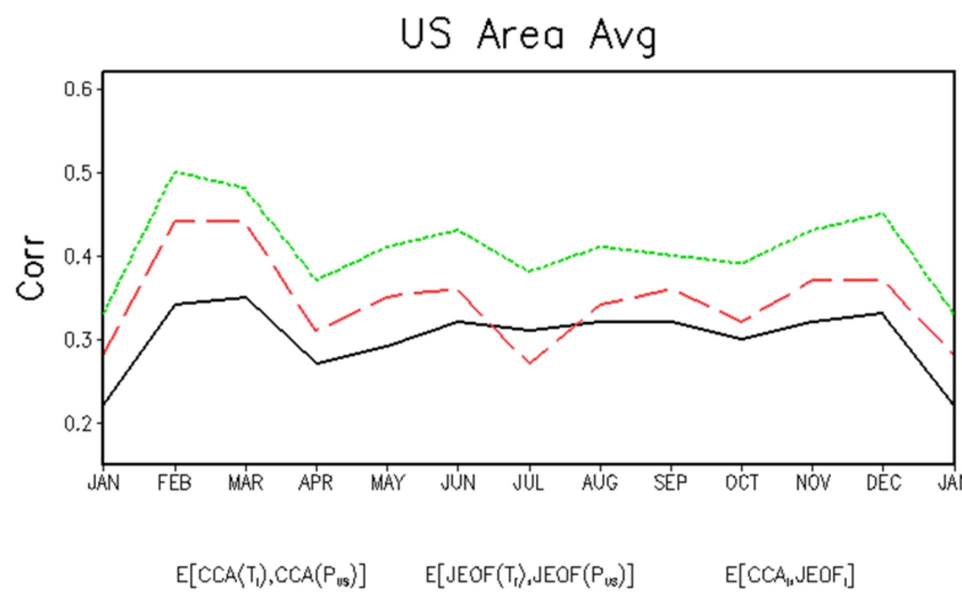
Ensemble CCA using SST(t-1) regions better than CCA using the same SST(t-1) combined (upper panel)

Ensemble improved more when including prediction from P_{US}(t-1)

Using SST(t-1) and P_{US}(t-1) predictors, JEOF better than CCA and using both is best (lower panel)

More models and super ensemble method gives improvements



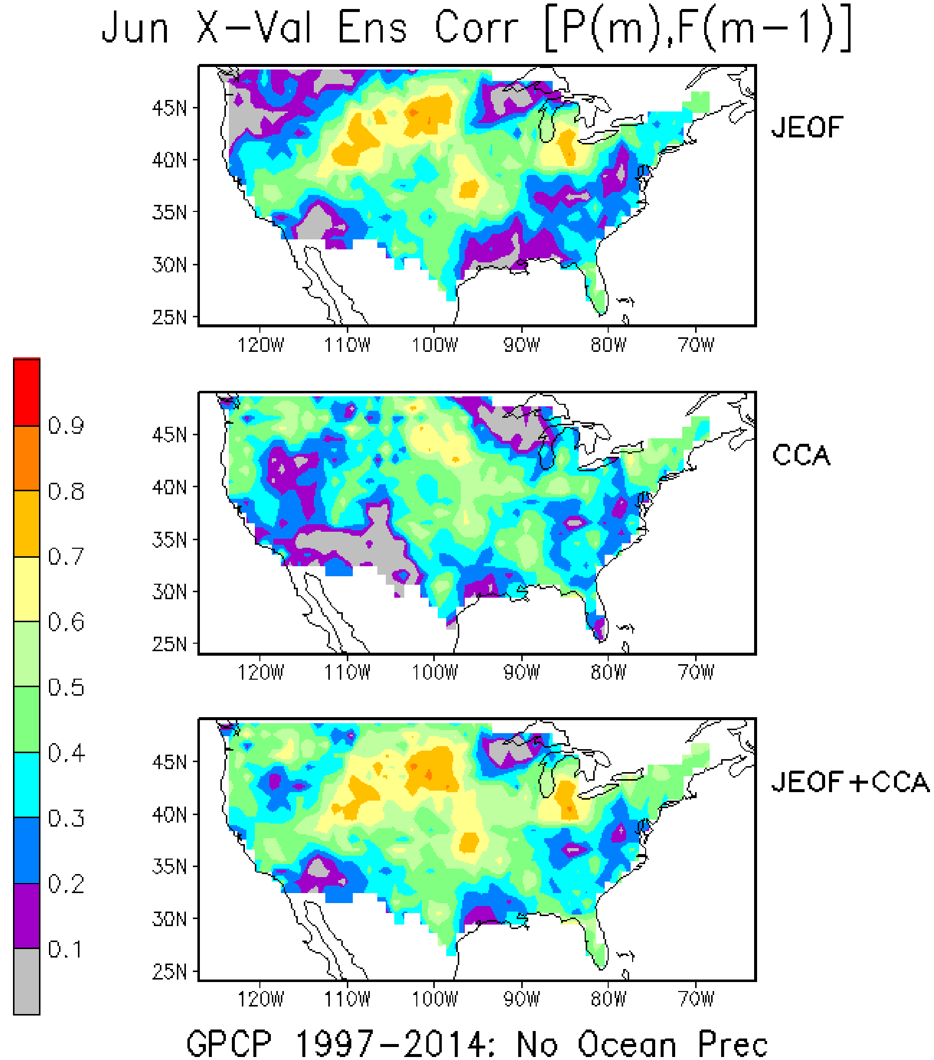


Cross-Validation Precipitation Anomaly Correlation: June, no oceanic precipitation

JEOF and CCA skill patterns similar, but not identical

Regions of high skill different in different models

Super ensemble using both takes the best of each



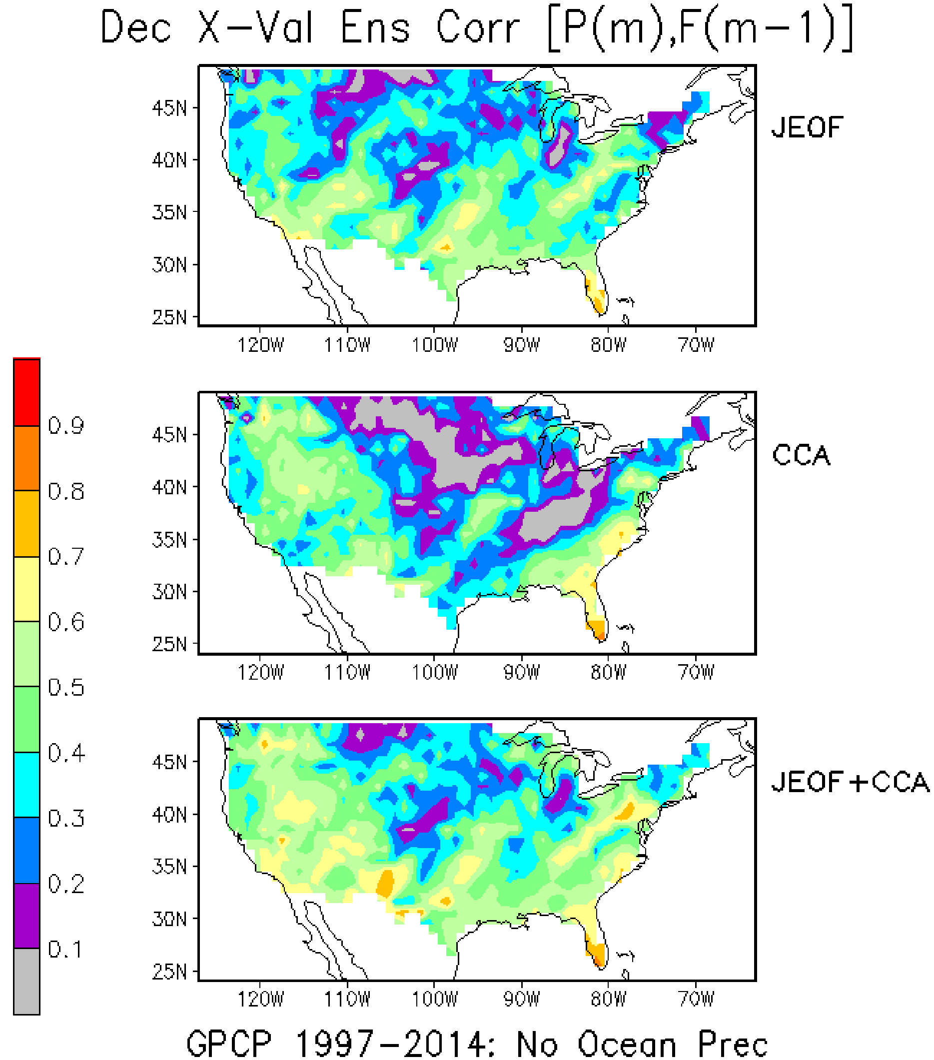
Cross-Validation Precipitation Anomaly Correlation: December, no oceanic precipitation

Both JEOF and CCA show skill gaps but in different regions

Using both expands the region of good skill

Methods Conclusions:

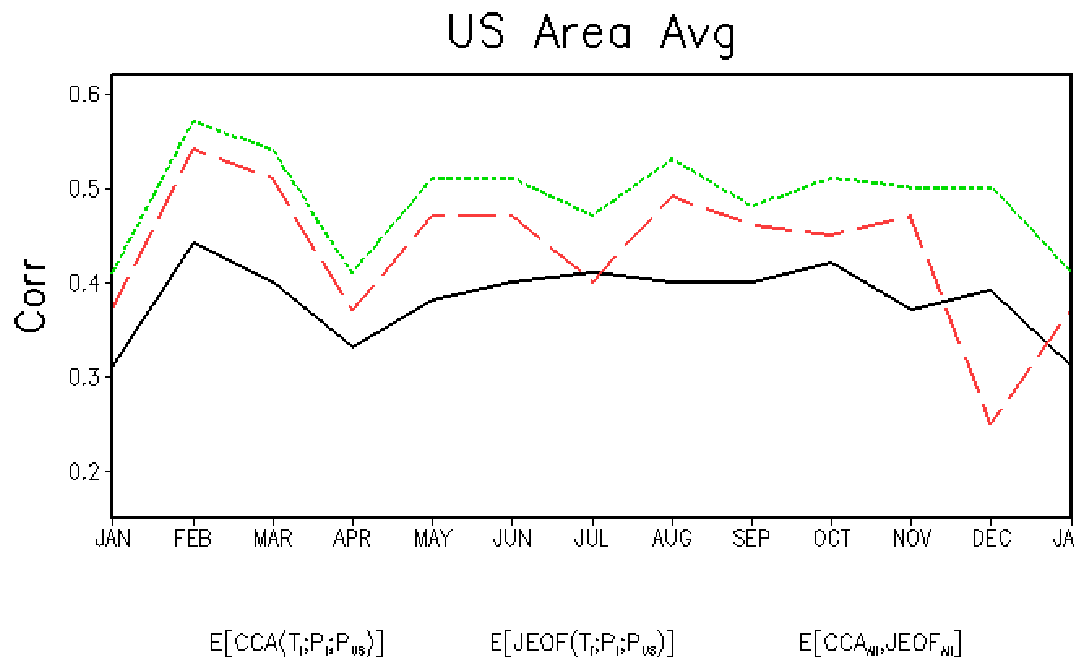
1) Ensembles dividing predictors into regions improves skill
2) Using ensemble members from multiple models also improves skill



Including Oceanic Precipitation in 4 Regions

Skill increases when including members with ocean area P(t-1) predictors

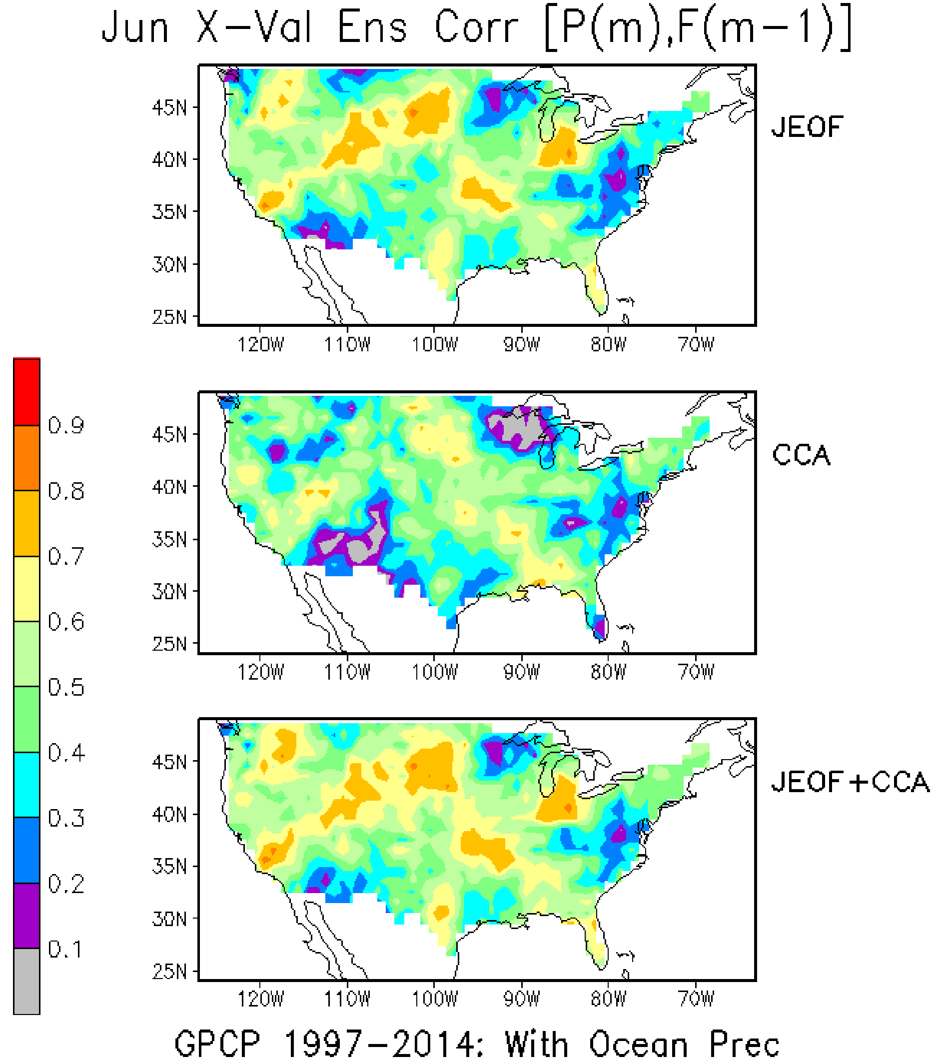
JEOF better than CCA, using both is best



Cross-Validation Precipitation Anomaly Correlation: June, with oceanic precipitation

Ocean P ensemble members improve both JEOF and CCA

JEOF still better, and combining them still gives higher skill

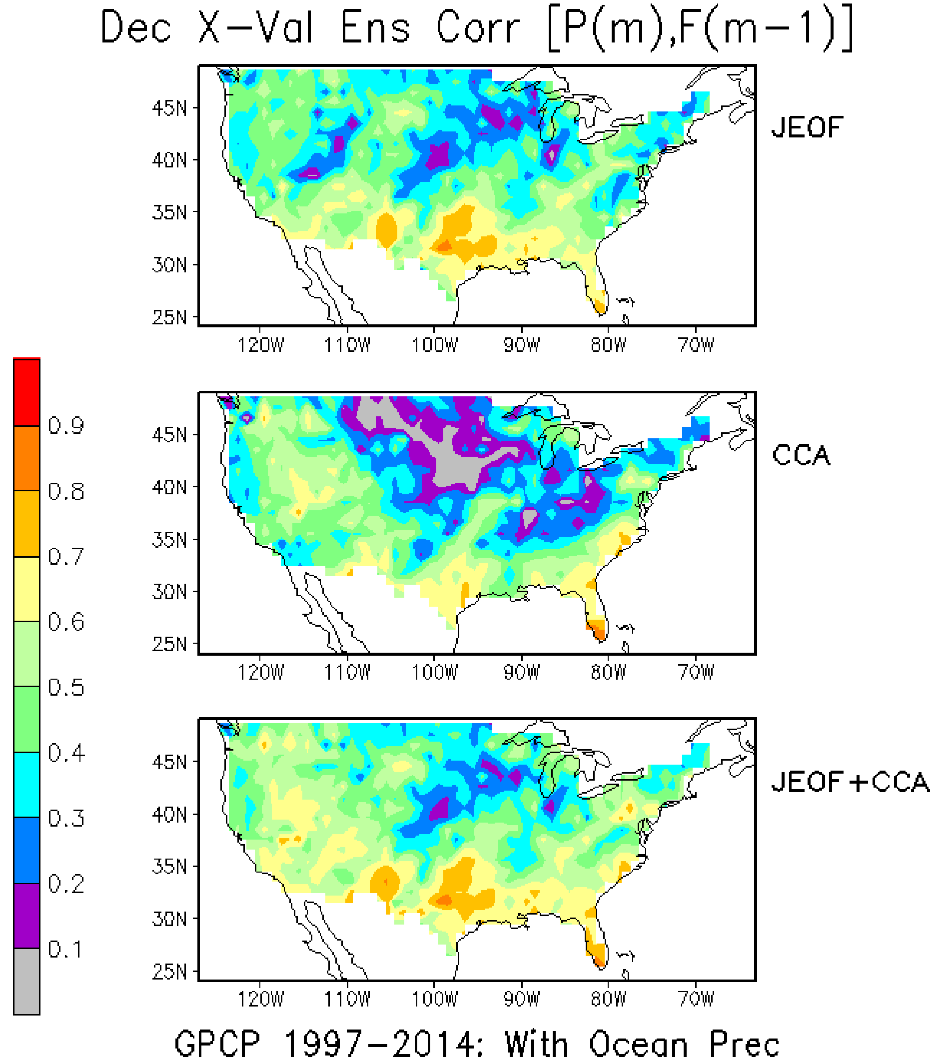


Cross-Validation Precipitation Anomaly Correlation: December, with oceanic precipitation

More regions with higher skill than the case with no oceanic precipitation: satellite-based P improves the forecast

Best skill apparently from ENSO

Low-skill regions for both JEOF and CCA not improved by combining them



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Skill from more than ENSO

- Skill from Tropical Pacific area SST or Precip important but not the whole story
- Combining with forecasts using SST and Precip from other regions doubles average correlation
- All averages omit no-skill regions (correlations < 0)

Temporal cross-validation correlations against GPCP computed for each month (1997-2014), averaged over the contiguous US and annually.

Predictors	CCA	JEOF
T_{TPac}	0.20	0.18
P_{TPac}	0.21	0.23
$E[T_i, P_{US}]$	0.31	0.35
$E[T_i, P_i, P_{US}]$	0.39	0.45

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Overall Improvements from oceanic precipitation

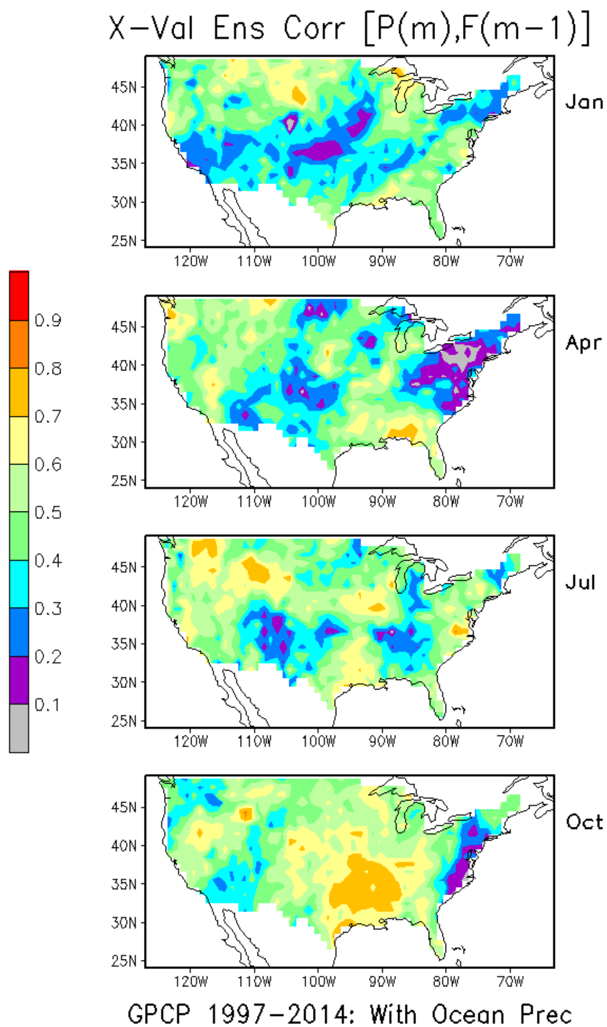
- Adding satellite-based $P_i(t-1)$ predictors improves ensembles

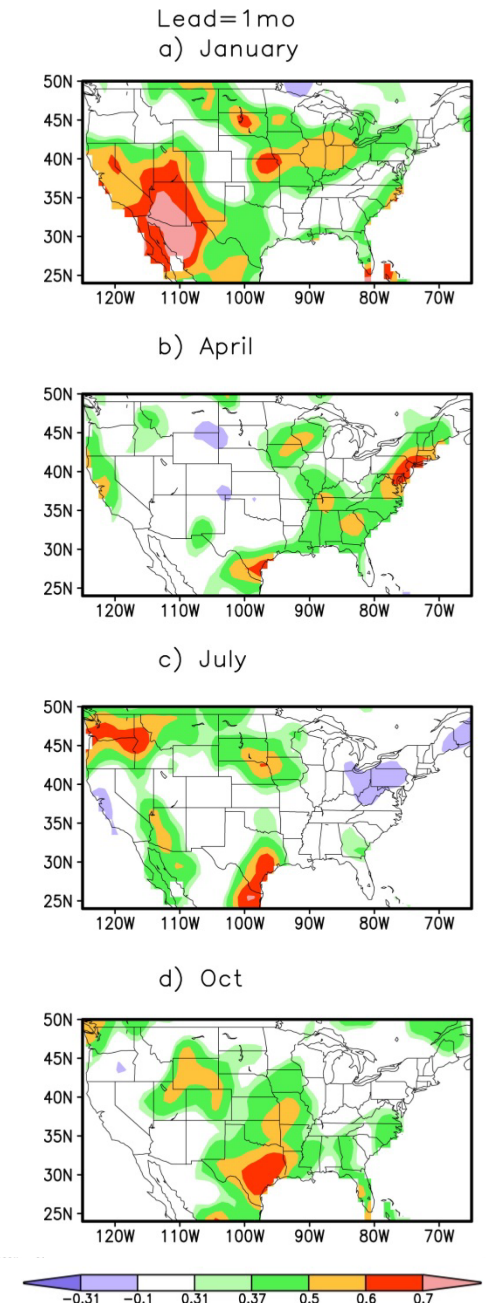
Temporal cross-validation correlations against GPCP computed for each month (1997-2014), averaged over the contiguous US and annually.

Predictors	CCA	JEOF	JEOF+CCA
$E[T_i, P_{US}]$	0.31	0.35	0.42
$E[T_i, P_i, P_{US}]$	0.39	0.45	0.50

Comparisons to Similar NAMME Tests

Similar Skill Levels but in Different Regions





From Mo and Lettenmaier (2014, J. Hydromet.)

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Conclusions

- Super-ensemble-statistical forecast are better than non-ensemble forecasts
  - Method improvements include using multiple statistical models and super-ensemble averaging weights
- Ocean-area precipitation predictors improve US-area precipitation forecasts
  - Additional predictors add skillful members to the ensemble and give higher ensemble skill
  - Many other predictors may give skill and improve the forecast, including different statistical predictors and estimates from numerical models; more testing is needed