Improving seasonal drought prediction in California by combining statistical and dynamical models

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Motivation

Observed Precipitation Anomaly
DJF 2014

Predicted Precipitation Anomaly (mm/d)
DJF 2014 (Initialized: November)

North American Multi-Model Ensemble (NMME; Kirtman et al., 2014)

Low Predictability of Precipitation Forecasts in Dynamic Model Simulations
Motivation

Analog-year based models also offer low predictability.
Drought Prediction Framework

Analog-Year Model Combined with Dynamical Model Simulations

Analog-Year Model

Dynamic Model Simulations

Multi-Model Assessment Using the Expert Advice (EA) Algorithm

Seasonal Precipitation Forecasts
Analog-Year Model

Dynamic Model Simulations

Multi-Model Assessment Using the Expert Advice (EA) Algorithm

Seasonal Precipitation Forecasts
Dynamic Model Simulations

**8 models** (99 ensemble members):
- CMC1-CanCM3
- CMC2-CanCM4
- COLA-RSMAS-CCSM4
- GFDL-CM2p1-aer04
- GFDL-CM2p5-FLOR-A06
- GFDL-CM2p5-FLOR-B01
- 0NASA-GMAO-062012
- NCEP-CFSv2
Analog-Year Model

Multi-Model Assessment Using the Expert Advice (EA) Algorithm

Seasonal Precipitation Forecasts

Dynamic Model Simulations

Drought Prediction Framework
Analog-Year Model

A Bayesian statistical model based on multivariate probability distribution functions

\[ f(prcp|PDO, MEI, AMO) \]
Drought Prediction Framework

EA Algorithm to Weigh Ens. Members

Analog-Year Model

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Dynamic Model Simulations

Seasonal Precipitation Forecasts
Drought Prediction Framework

Mathematics Inside the EA Algorithm

For \( k = 1 \) to \( K \) ensemble members:
\[
\lambda(\omega, \gamma) = \sum_{o \in \Theta} (\gamma(o) - \delta_\omega(o))^2 \quad \delta_\omega \in \{1, 0\}
\]

\[
w_0^1, w_0^2, ..., w_0^K = 1
\]

\[
\phi_n(\omega) = -\ln \left( \sum_{k=1}^{K} w_{n-1}^k \times e^{-\lambda(\omega, \gamma_n^k)} \right)
\]

Solve \( \sum_{\omega \in \Theta}(s - \phi_n(\omega))^+ = 2, s \in \mathbb{R} \)

Set \( \gamma_n(\omega) = \frac{(s - \phi_n(\omega))^+}{2} \omega \in \Theta \)
\( \gamma_n \in \text{Pr}(\Theta) \)

\[
w_n^k = w_{n-1}^k \times e^{-\lambda(\omega_n, \gamma_n^k)}
\]

\( E_0^1, E_0^2, ..., E_0^K = 0 \)

Ensemble Member \( k: \gamma_n^k \in \Psi \)
Climate Response: \( \gamma_n \in \Psi \)
Observation: \( \omega_n \in \Theta \)

\[
E_n = E_{n-1} + \lambda(\omega_n, \gamma_n)
\]
\[
E_n^k = E_{n-1}^k + \lambda(\omega_n, \gamma_n^k)
\]
\[
E_n \leq \min_{k=1,...,K} E_n^k + \ln K
\]
Drought Prediction Framework

EA Algorithm to Weigh Ens. Members

Multi-Model Assessment Using the Expert Advice (EA) Algorithm

Seasonal Precipitation Forecasts

NMME Simulations

Forecast

1980 Now

Total Precip [in]
Observation
Forecast

Drought Prediction Framework

Analog-Year Simulations

Forecast

1980 Now
Drought Prediction Framework

EA Algorithm to Weigh Ens. Members

1950
1960
1970
1980
1990
2000
2010

BN AN

Forecast Period = Oct-Jan

Total Precip \[\text{in}\]

Precipitation

Forecast

1980 Now

Multi-Model Assessment Using the Expert Advice (EA) Algorithm

Seasonal Precipitation Forecasts

Equal Weights

Forecast

EA Weights

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EA Weights
Drought Prediction

NDJ, 2014

Observation

NMME (Ensemble mean)

NMME + Analog-Year + EA
Drought Prediction

Observation

NDJFM, 2014

NMME + Analog-Year + EA

NMME (Ensemble mean)
Drought Prediction

JFM (2006-07), Obs

JFM (2006-07), NMME

JFM (2006-07), Hybrid

DJF (2014-15), Obs

DJF (2014-15), NMME

DJF (2014-15), Hybrid
Drought Prediction

- Obs
- NMME
- Stat
- Hybrid

NDJ
NDJFM
DJFM

2010

Area [mi²]

Obs
NMME
Stat
Hybrid
Both dynamical and statistical precipitation forecast models have limited skill at seasonal to inter-seasonal scales in some regions, e.g. Southwest US.

The proposed hybrid climate forecasting model combines the potentials of dynamical and statistical models and finds the best prediction based on the historical performance of each model.

Overall, the hybrid framework performs better in predicting negative precipitation anomalies (10-60% improvement over NMME) than positive precipitation anomalies (5-25% improvement over NMME).

Questions?

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