Advancing Drought Prediction Using an Analog-Year Model Combined with Dynamic Model Simulations

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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.
Objective

Climate Division 5 Precipitation

Observations

\[ f(PDO, MEI, SOI, \ldots) \sim \begin{cases} 
Pr(P > AN) \\
Pr(P \sim NN) \\
Pr(P < BN) 
\end{cases} \]

AN: Above Normal (> 66th Percentile)
NN: Near Normal
BN: Below Normal (< 33rd Percentile)
Drought Prediction Frameworks

Analog-Year Model Combined with Remote Sensing Observations

Analog-Year Model

Remote Sensing Observations

Analog-Year model conditioned on remotely sensed observations

Seasonal Precipitation Forecasts
Drought Prediction Frameworks

**Analog-Year Model Combined with Remote Sensing Observations**

- **Analog-Year Model**
- **Remote Sensing Observations**
- Analog-Year model conditioned on remotely sensed observations
- **Seasonal Precipitation Forecasts**

**Analog-Year Model Combined Dynamic Model Simulations**

- **Analog-Year Model**
- **Dynamic Model Simulations**
- Multi-Model Assessment Using the Expert Advice Algorithm
- **Seasonal Precipitation Forecasts**
Drought Prediction

Climate Division 5 Precipitation

Observations

Precipitation (in)

Year

f(PDO, MEI, SOI, ...)

\[ \begin{align*}
&\Pr(P > AN) \\
&\Pr(P \sim NN) \\
&\Pr(P < BN)
\end{align*} \]

AN: Above Normal (> 66th Percentile)
NN: Near Normal
BN: Below Normal (< 33rd Percentile)
Long-Term Precipitation and Climate Oscillation Indicators

I- 6-Month Forecast

Past Climate $f(\text{Precip}_{\text{Oct-Mar}})$

Forecast Period: Oct-Jan

Total Precip [in]

• Observation
• Forecast

Precip. Climatology
SOI$_{\text{Apr-Sep}}$
PDO$_{\text{Apr-Sep}}$
SPI$_{\text{Jun-Sep}}$
Preliminary Results

- Climate Index: $\text{SOI}_{\text{Apr-Sep}}, \text{PDO}_{\text{Apr-Sep}}$
- $\text{SPI}_{\text{Jun-Sep}}$

Forecast Period= Oct-Jan

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- BN...88%
- NN... 95%
- AN ...77%
Preliminary Results

- Climate Index: $\text{SOI}_{\text{Apr-Sep}}$, $\text{PDO}_{\text{Apr-Sep}}$
- $\text{SPI}_{\text{Jun-Sep}}$

Forecast Period = Oct-Mar

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BN...68%
NN...100%
AN...86%

Total Precip [in]
Drought Prediction Frameworks

Forecast Period= Oct-Jan

Total Precip [in]


Observation
Forecast

Analog-Year Model
Dynamic Model Simulations
Multi-Model Assessment Using the Expert Advice Algorithm
Seasonal Precipitation Forecasts
For $k = 1$ to $K$ ensemble members:

$$\lambda(\omega, \gamma) = \sum_{\omega \in \Theta} (\gamma(o) - \delta_{\omega}(o))^2 \quad \delta_{\omega} \in \{1, 0\}$$

$$w_0^1, w_0^2, ..., w_0^K = 1$$

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

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

NMME (Ensemble Mean)

NMME + AE

NMME + Analog-Year + AE

DJF Precipitation Forecasts - Percentage of captured Below Normal events
Drought Prediction

NMME (Ensemble Mean)

NMME + AE

NMME + Analog-Year + AE

DJF Precipitation Forecasts - Percentage of captured Above Normal events
Drought Prediction

NMME (Ensemble Mean)

NMME + Analog-Year + AE

DJF Precipitation Forecasts - Percentage of captured Negative Anomaly
http://www.nature.com/articles/sdata20141

http://drought.eng.uci.edu/
Drought Prediction Frameworks

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Drought Prediction

Analog-Year Model Combined with Remote Sensing Observations

Analog-Year Model

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Analog-Year model conditioned on remotely sensed observations

Seasonal Precipitation Forecasts

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Integration of AIRS Data into GIDMaPS

Precipitation (MERRA)

Soil Moisture (MERRA)

Relative Humidity (AIRS Data)
Farahmand et al. 2015; [http://www.nature.com/srep/2015/150225/srep08553/full/srep08553.html](http://www.nature.com/srep/2015/150225/srep08553/full/srep08553.html)
Probability of drought detection (i.e., fraction of detected drought) when Drought Onset (DO) based on SRHI is less or equal to that of SPI (a), mean lead time based on SRHI relative to SPI (months)(b).

Farahmand et al. 2015; [http://www.nature.com/srep/2015/150225/srep08553/full/srep08553.html](http://www.nature.com/srep/2015/150225/srep08553/full/srep08553.html)
Drought Prediction

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**Analog-Year Model**

**Remote Sensing Observations**

**Seasonal Precipitation Forecasts**

**Analog-Year Model** conditioned on remotely sensed observations

Water & Energy Cycle

Disaster Monitoring

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Amir AghaKouchak,
University of California, Irvine
Email: amir.a@uci.edu

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[Logos of NASA, NOAA, NSF, and JPL]