Seasonal predictability of summer precipitation over the Huaihe river basin with multiple APCC models

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The economic loss caused by meteorological disasters between 1990 and 2006, with the annual average of 177.9 billion RMB.

1. Introduction
1. Introduction

Seasonal predictions of hydrologic variables, such as streamflow, have great economic value in sectors such as water resource management, reservoir operation, hydropower plants, and agriculture.

HAP Focus on

- Seasonal hydrologic forecasting
- Water cycle and drought monitoring
- Climate change projections and adaptation
1. Introduction

Eric F. Wood, Lifeng Luo, Princeton University
Study Basin

Huaihe River Basin:
basin-averaged annual precipitation—888 mm

Severe floods occurred frequently since 2000
<table>
<thead>
<tr>
<th>Data/Model</th>
<th>Institute</th>
<th>Ens</th>
<th>Period</th>
<th>Resolution</th>
<th>Exp Type</th>
<th>SST</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP (CFS)</td>
<td>NCEP/NWS/NOAA(USA)</td>
<td>15</td>
<td>1981-2006</td>
<td>T62,L64</td>
<td>CMIP</td>
<td>Predicted</td>
</tr>
<tr>
<td>CWB spectral</td>
<td>CWB (CHN. Taipei)</td>
<td>10</td>
<td>1981-2005</td>
<td>T42,L18</td>
<td>SMIP2/HFP</td>
<td>Predicted</td>
</tr>
<tr>
<td>GCPS (GCPS)</td>
<td>SNU(Korea)</td>
<td>12</td>
<td>1979-2009</td>
<td>T63,L21</td>
<td>SMIP2/HFP</td>
<td>Predicted</td>
</tr>
<tr>
<td>GDAPS_F (GDAPS)</td>
<td>CPD/KMA(Korea)</td>
<td>20</td>
<td>1979-2009</td>
<td>T106,L21</td>
<td>SMIP2/HFP</td>
<td>Predicted</td>
</tr>
<tr>
<td>JMA (JMA-CGCM)</td>
<td>JMA (Japan)</td>
<td>5</td>
<td>1979-2008</td>
<td>TL95,L40</td>
<td>SMIP2/HFP</td>
<td>Predicted</td>
</tr>
<tr>
<td>IRI (ECHAM4.5)</td>
<td>IRI(USA)</td>
<td>24</td>
<td>1980-2005</td>
<td>T42,L19</td>
<td>AMIP</td>
<td>Observed</td>
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<tr>
<td>MGO (MGO AM2)</td>
<td>MGO (Russia)</td>
<td>6</td>
<td>1979-2004</td>
<td>T42,L14</td>
<td>SMIP2</td>
<td>Observed</td>
</tr>
<tr>
<td>HMC (SL-AV)</td>
<td>HCR (Russia)</td>
<td>10</td>
<td>1981-2003</td>
<td>1.125*1.40625, L28</td>
<td>SMIP2/HFP</td>
<td>Persistent</td>
</tr>
<tr>
<td>MSC_GM2 (CCCma GCM2)</td>
<td>MSC (Can.)</td>
<td>10</td>
<td>1979-2003</td>
<td>T32, L10</td>
<td>SMIP2/HFP</td>
<td>Persistent</td>
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<tr>
<td>MSC_GM3 (CCCma GCM3)</td>
<td>MSC (Can.)</td>
<td>10</td>
<td>1979-2003</td>
<td>T63, L32</td>
<td>SMIP2/HFP</td>
<td>Persistent</td>
</tr>
</tbody>
</table>

10 models from APCC Multi-model prediction system
<table>
<thead>
<tr>
<th>Model/Obs</th>
<th>Period</th>
<th>Temporal Res.</th>
<th>Horizontal Res.</th>
<th>Variable</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Models</td>
<td>1981-2003</td>
<td>monthly</td>
<td>2.5°*2.5°</td>
<td>P(mm/d)</td>
<td></td>
</tr>
<tr>
<td>CMAP</td>
<td>1979-2009</td>
<td>monthly</td>
<td>2.5°*2.5°</td>
<td>P(mm/d)</td>
<td>Xie and Arkin, 1997</td>
</tr>
</tbody>
</table>

Model and observation data used in this study
The spatial distributions of predictability (R) for the hindcasted summer mean precipitation over the Huaihe region from 1981-2003.

\[ \sigma_{INR}^2 = \frac{1}{Y(M-1)} \sum_{i=1}^{Y} \sum_{j=1}^{M} (X_{ij} - X_i)^2 \]

\[ \sigma_{SST}^2 = \sigma_E^2 - \frac{1}{M} \sigma_{INR}^2 \]

\[ = \frac{1}{Y-1} \sum_{i=1}^{Y} (\bar{X}_i - \bar{X})^2 - \frac{1}{M} \frac{1}{Y(M-1)} \sum_{i=1}^{Y} \sum_{j=1}^{M} (X_{ij} - X_i)^2 \]

\[ r = \frac{\sigma_{SST}^2}{\sigma_{INR}^2} \]

\[ R = \frac{r}{1 + r} \]

\( R=0 \), without predictability
\( 0<R<0.5 \), low predictability
\( R>0.5 \), high predictability

ANOVA (Rowell and Folland et al., 1995)
Method by Koster et al. (2004)

(a) Scatter plot for the idealized predictability analysis, showing the degree to which the model can “predict itself” on regional averaged scale. The x axis represents the “truth” and the y axis represents the “forecast”. 23 points are from the 23 years (1981-2003). The solid line is the 1:1 line; (b) the idealized predictability of 10 models with different lead time, each model is lined with colors, as marked in the top left corner of the panel.
How to make a distinction between the 10 models?
Different boundary SST forcing data

(a) persist_sst
HMC, MSC_GM2, MSC_GM3

(b) obs_sst
IRI, MGO

(c) predict_sst
CFS, CWB, GCPS, GDAPS_F, JMA

(d) MME—10 models
**Interannual Variability**

<table>
<thead>
<tr>
<th>ACC/RMSE</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>JJA</th>
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<tbody>
<tr>
<td>PREDICT_SST</td>
<td>0.26/0.21</td>
<td>0.2/0.19</td>
<td>0.36/0.18</td>
<td>0.38/0.12</td>
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<tr>
<td>Total MME</td>
<td>0.17/0.22</td>
<td>0.22/0.19</td>
<td>0.3/0.18</td>
<td>0.28/0.12</td>
</tr>
<tr>
<td>PERSIST_SST</td>
<td>0.12/0.23</td>
<td>0.14/0.2</td>
<td>0.06/0.2</td>
<td>0.25/0.13</td>
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<tr>
<td>OBS_SST</td>
<td>-0.1/0.24</td>
<td>0.150.2</td>
<td>0.3/0.2</td>
<td>-0.01/0.13</td>
</tr>
</tbody>
</table>

**Skill decrease**
Spatial distribution of temporal correlation between the observed and hindcasted July precipitation over the Huaihe River region

MME Predictive skill
First EOF modes of July mean precipitation for observation and 4 MMEs

The predict_SST MME is the best to reproduce the first eigenvector of the observation among the 10 models, while the persist_SST MME makes the poorest performance.
Second EOF modes of July mean precipitation for observation and 4 MMEs

The second eigenvector of the July precipitation in the Huaihe region are better reproduced by the 10 models than the first. The time series in 1987, 1988 and 1997 of PC2 are fitted quite well to the observation.
Schematic map for the Bayesian Merging methodology, with solid gray for raw forecast, dash black for Prior distribution and solid black for posterior forecast.
Multimodel Bayesian Merging

Fig 9. Posterior distribution updated with all seven models forecast (solid black) for the forecast of December 1998 monthly mean SST over selected grid.
BM Method for each grid

(35N, 115E)
BM of July 1989 on (35N, 115E)

The red line is the pdf of single model BM posterior forecast, green line is the pdf of model raw forecast with ensembles, Blue bar is the frequency distribution of climatology.
BM of July 1989 on (35N, 115E)

**JMA**

- OBS = 7.95
- Clim. Fcst = 4.92
- JMA BM Fcst = 6.47
- JMA RAW Fcst = 2.82

**MGO**

- OBS = 7.95
- Clim. Fcst = 4.92
- MGO BM Fcst = 6.46
- MGO RAW Fcst = 5.57

**MSC_GM2**

- OBS = 7.95
- Clim. Fcst = 4.92
- MSC GM2 BM Fcst = 4.98
- MSC GM2 RAW Fcst = 3.35

**MSC_GM3**

- Clim. Fcst = 4.92
- MSC GM3 BM Fcst = 5.14
- MSC GM3 RAW Fcst = 3.74
MBM of July 1989 on (35N, 115E)

10 models

Percentage rainfall anomalies for CMAP, MME and MBM respectively
## Precipitation Fcst of July 1989 on (35N, 115E)

<table>
<thead>
<tr>
<th>Models</th>
<th>OBS(mm/d)</th>
<th>Climatology</th>
<th>Model Raw Fcst</th>
<th>Model BM Fcst</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFS</td>
<td>7.95</td>
<td>4.92</td>
<td>2.84</td>
<td>5.03</td>
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<tr>
<td>CWB</td>
<td>7.95</td>
<td>4.92</td>
<td><strong>6.53</strong></td>
<td>5.2</td>
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<tr>
<td>GCPS</td>
<td>7.95</td>
<td>4.92</td>
<td><strong>5.11</strong></td>
<td>4.94</td>
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<td>4.88</td>
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<tr>
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<td><strong>6.47</strong></td>
</tr>
<tr>
<td>IRI</td>
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<td>4.92</td>
<td>4.29</td>
<td><strong>5.02</strong></td>
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<td>MGO</td>
<td>7.95</td>
<td>4.92</td>
<td>5.57</td>
<td><strong>6.46</strong></td>
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<td>7.95</td>
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<td>3.29</td>
<td><strong>5.2</strong></td>
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<td>MSC_GM2</td>
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<td>4.92</td>
<td>3.35</td>
<td><strong>4.98</strong></td>
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<td>3.74</td>
<td><strong>5.14</strong></td>
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<tr>
<td>10_models</td>
<td>7.95</td>
<td>4.92</td>
<td>5.47</td>
<td><strong>5.57</strong></td>
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</table>
The seasonal predictability of summer rainfall over Huaihe basin by 10 APCC climate models has been evaluated, it’s found that, although the potential predictability from 10 APCC models is relatively low, the Multi Model Ensemble (MME) method can increase the model predictability. However, the efficiency for MME differ from different MME Groups, with the highest prediction skill for Predict_SST MME.

Further EOF analysis shows that, The first dominant EOF mode has been quite well captured by the “Predict_SST” MME, with TCC about 0.3; for the second eigenvector, it has been well reproduced by the 10 models than the first mode, and the PCCs are all about 0.9
Bayesian Merging approach shows its potential to increase the seasonal rainfall prediction in Huaihe River Basin, and this method can also offer an effective way to statistically downscale information form large scale to smaller scale, that are suitable for hydrological applications.

Will the blended EOF-Bayesian Merging method further increase the model prediction skill?