Assessment of CMIP5 climate models and projected temperature changes in Northern Eurasia

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Data from CRU

0.74 ± 0.18°C/100yr

(Global Temperatures)

Data from CRU (IPCC, 2013)
Meteorological Disasters

Snowstorm, Southern China, 2008
Flood, Pear River, 2013
Drought, Northern China, 2009
Typhoon Haiyan, Philippines, 2013
<table>
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<tr>
<th>GCM</th>
<th>Model</th>
<th>Resolution</th>
<th>Source</th>
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Questions?

- Can IPCC-AR5 effectively reproduce the historical climate feature?

  It is generally accepted that the better a model performance in reproduce historical climate feature, the higher the reliability of the climate change projected in the future (Errasti, 2011)

- Can any method improve the IPCC model simulation further?

  Multimodel ensemble simulation will reproduce more agreement with observational data than that of any single model (Phillips and Gleckler, 2006)

  - Simple Model Averaging (Lambert and Boer, 2001)
  - Reliability Ensemble Averaging (Giorgi and Mearns, 2002)
  - Bayesian Model Averaging (Raftery, 2005; Duan, 2010)
Northern Eurasia accounts for 60% of the terrestrial land cover north of 40ºN and contains vast areas of wetlands, especially peatland (NEESPI 2004; Groisman and Soja 2009). Compared with low latitudes, the region, especially its northern areas, has been experiencing more dramatic environmental changes, including increasing temperatures, melting permafrost, changing precipitation and prolonged growing seasons (Groisman et al., 2006 2007).
2. Data and methods

**Observed Data**

Dataset: CRUTS3.1, Climatic Research Unit

Climate variable: Surface Air Temperature (SAT)

Duration: 1901~2005

Resolution: $0.5^\circ \times 0.5^\circ$
2. Data and methods

Simulated Data

Dataset: IPCC-AR5(24 models) + SMA + REA + BMA
Climate variable: Surface Air Temperature
Duration: 1950-2005 (historical) and 2006-2099 (scenarios)
Resolution: 0.5° × 0.5° after regridding
2. Data and methods

Three representative concentration pathways (RCPs) represent ‘low’ (RCP2.6), ‘medium’ (RCP4.5) and ‘high’ (RCP8.5) scenarios featured by the radiative forcings of 2.6, 4.5 and 8.5 W/m² by 2100, respectively (Meinshausen et al., 2011).
2. Data and methods

The Simple Model Averaging (SMA) is the simplest multi-model ensemble technique. Each model has the same weight \( w_k = \frac{1}{K} \), where \( K \) is the number of models) in the multi-model forecast (Casanova and Ahrens, 2009).

The Reliability Ensemble Averaging (REA) is a weighted average of ensemble members based on the “reliability” of each model (Giorgi and Mearns, 2002). The reliability factor of the \( k \)th model \( R_k \) takes into account the ability of each ensemble member to simulate the observed climate \( R_B \) and its degree of convergence in the projected climate change with respect to the other models in the ensemble \( R_D \).

\[
R_k = \left[ \left( R_{B,k} \right)^m \times \left( R_{D,k} \right)^n \right]^{1/(m \times n)} = \left[ \left( \frac{E}{|B_k|} \right)^m \times \left( \frac{E}{|D_k|} \right)^n \right]^{1/(m \times n)}
\]
2. Data and methods

The Bayesian Model Averaging (BMA) generates a probability density function (PDF), which is a weighted average of the pdfs centered on the forecasts. The BMA weights reflect the relative contributions of the component models to the predictive skill over a training sample. The combined forecast PDF of a variable $y$ is:

$$p(y \mid y^T) = \sum_{k=1}^{K} p(y \mid M_k, y^T) p(M_k \mid y^T)$$

where $p(y \mid M_k, y^T)$ is the forecast pdf based on model $M_k$ alone, estimated from the training period of observations $y^T$, and $K$ is the number of models being combined. $p(M_k \mid y^T)$ is the posterior probability of model $M_k$ being correct given the training data. This term is computed with the aid of Bayes’ theory:

$$p(M_k \mid y^T) = \frac{p(y^T \mid M_k) p(M_k)}{\sum_{l=1}^{K} p(y^T \mid M_l) p(M_l)}$$

Duan and Phillips, 2010 (JGR)
SMA

Model_1 = Model_2 = Model_3 = ... = Model_n

W1 = W2 = W3 = ... = Wn

REA  BMA

W1  W2  W3  ...  Wn

moderate  bad  good
3. Results

Figure 1. (a) Annual and (b) seasonal system bias of different AR5 GCMs with regard to mean temperature in Northern Eurasia during 1901-2005.
3. Results

Figure 2. (a) Linear trend of warming rate for the observations (black bar, left) and each CMIP5 model during 1901-2005; (b) the projected time to reach the 2°C temperature rise under different RCPs and the linear extrapolation of the observed trend in the most recent 50 years.
3. Results

Figure 3. Change of observed and simulated (a) annual mean temperature anomalies (relative to the 1970-1999) and (b) monthly mean temperature (during 1901-2005) in Northern Eurasia.
3. Results

Figure 4. The performance of the simulated results on decadal scales. (a) Taylor diagram for each model and ensemble simulation on decadal scale. (b) Ensemble SAT trend on decadal scale.
3. Results

\[ \delta = \left( \frac{\sum_k w_k(T_k - En)^2}{\sum_k w_k} \right)^{1/2} \]

- \( W_k \): weight of kth
- \( T_k \): the kth model output
- \( En \): ensemble result

Figure 5. The ensemble uncertainty of annual and seasonal simulated results with a 10-year moving average
3. Results

Figure 6. SAT projections over the 21st century using the BMA method
3. Results

Figure 7. Map of the linear trend of projected SAT by BMA under the RCP 26, RCP45 and RCP85 scenarios for the period 2006-2099
4. Conclusions

• Most of the GCMs overestimate the annual mean SAT in Northern Eurasia during the last century, and the bias mainly comes from DJF. GCMs can approximate the decadal SAT trend and the monthly mean SAT distribution, but the annual assessment of accuracy is relatively weak.

• The performances of the multi-model ensembles are superior to that of a single GCM. The decadal SAT variation in Northern Eurasia generated by the SMA, REA and BMA are almost identical, but the uncertainty generated by the BMA is the lowest.

• The projected SAT in Northern Eurasia by the BMA shows that SAT will increase under the three scenarios, with linear trends of $1.03^\circ$ C /100 yr, $3.01^\circ$ C /100 yr and $7.13^\circ$ C /100 yr for the RCP26, RCP45 and RCP85 scenarios, respectively.
Thank you!