ACM 2017

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S1A Presentation

S1A-1 (Invited Talk)

Climate and ocean circulations during “the Boring Billion”

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The Boring Billion is referred to the era between approximately 1.8 and 0.8 billion years ago. Geological evidence suggests that no dramatic climate changes in the billions of years, at least in terms of permanent glaciation. The atmospheric oxygen maintained at a relatively low level without significant perturbations. Life had a certain degree of evolution with a quite gentle pace. Relative to the Great Oxidation Event (GOE, about 2.35 to 2.3 billion years ago) occurred previously, and the Snowball Earth Event (about 700 to 600 million years ago (Ma)) and Cambrian Explosion (about 540 million years ago) occurred afterwards, the billion years was so calm in all aspects that it is often referred to as “the Boring Billion”. This long-lasting state of quiescence is very special in the history of earth. How high CO2 concentration is required to maintain such a warm climate that had no glaciers, and how stable ocean stratifications are in the warm climate state are our motivation in this research.

To investigate the problems mentioned above, we use the Atmosphere Ocean General Circulation Model CCSM3. We perform two equilibrium simulations with two distinct continental configurations. One is reconstructed for 1540 Ma when continents mainly located in Northern Hemisphere high latitudes. The other one is for 1420 Ma when continental fragments located near the equator. The solar constant is set to be 10% weaker than that of the present day. It is found that the CO2 concentration has to be at least 20 times (7100 ppmv) higher than the present atmospheric level (PAL), so that there are no glaciers over both poles. The corresponding global mean surface temperatures are 19°C and 20°C for the 1540 Ma and 1420 Ma continental configurations, respectively. The largest mixed-layer depth in the high-latitude ocean is approximately 1200 m and meridional overturning circulation can reach depth of 3000 m with strength of 40 Sv for both continental configurations. The results indicate that ocean stratification is similar to that the present day in the warm climate condition, and that the anoxic deep ocean showed in observations might be due to biogeochemical processes, rather than dynamical processes.

S1A-2

Evaluation of a high-resolution historical simulation over China: Climatology and extremes

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China faces an increasing challenge in water resources in the coming decades; thus high-confidence climate projection is of particular importance for the country's future. In this paper, we evaluate the performance of a long high-resolution continuous simulation over China based on multiple observations and the corresponding historical simulation. The simulation is completed using the Weather Research and Forecasting (WRF) model driven by the Model for Interdisciplinary Research on Climate version 5 (MIROC5) in the context of the Coupled Model Intercomparison Project Phase 5. The results show that both MIROC5 and WRF can capture the distribution and variability of temperature over China, whereas WRF shows improvements, particularly for simulation of regional features. Compared with MIROC5, WRF can reproduce the spatial distribution, annual cycle, probability distribution, and seasonal evolution of the precipitation over mainland China and the sub-regions with better performance. The trend is of fundamental importance in the future projection estimations, and WRF shows better skill in simulating the annual mean precipitation trend. However, there is overestimation of precipitation in Southeast China while negative one in the middle latitude of China in WRF simulation, which can be traced back to model bias in atmospheric circulation and water vapor transportation in these regions. Several extreme climate indices are selected to further assess the model's performance in simulating climate extremes, WRF can well reproduce the main features with better model skill compared with MIROC5. The better performance of WRF indicates the necessity of the dynamical downscaling technique and the robustness of regional climate simulation in future regional climate projection over China.

S1A-3

Decadal change in factors affecting winter precipitation over eastern China

Jianqi Sun (Institute of Atmospheric Physics, Chinese Academy of Sciences)

The temporal and spatial distributions of winter precipitation variability over eastern China were analyzed on the basis of the empirical orthogonal function method. The results showed that the primary mode of winter precipitation variability over this area presented a homogeneous change during the study period, with a significant decadal change around the late 1980s. The factors that influenced winter precipitation variability over eastern China changed over different interdecadal periods. Before the late 1980s, the Eurasian (EU) mode and North Pacific Oscillation (NPO) mode were the two major atmospheric factors. After the late 1980s, the influence of the EU mode remained. However, the impact of the NPO weakened significantly, and a new Rossby Wave (RW) pattern became a key factor. Further analyses of both observations and numerical simulations indicated that the convective activity over the western tropical Pacific strengthened significantly around the late 1980s; the convection encouraged the RW mode and ultimately contributed to the anomalous winter precipitation over eastern China after the late 1980s. The results imply that the prediction of winter precipitation should consider different interdecadal backgrounds; otherwise, the changing factors could result in failure of the prediction over some decadal periods.

S1A-4

Interdecadal Variations in the Relationship between the Winter North Atlantic Oscillation and Temperature in South-Central China

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Interdecadal variations in the relationship between the winter North Atlantic Oscillation (NAO) and surface air temperature in China are investigated using observational and reanalysis data. Focus is on south-central China in which temperature variability is strongly related to the NAO. It is revealed that the relationship shows clear interdecadal variations in mid-winter during 1951-2015. A relatively weak in-phase relationship occurs before the early 1970s (P1), but a significant out-of-phase relationship dominates in the last two decades of the 20th century (P2), though it is clearly weaker from the late 1990s onwards. Observational evidence shows that such interdecadal variations are related mainly to variations in the spatial pattern and amplitude of the NAO. The northern center of the NAO shifted eastward over the second half of the 20th century. In addition, the amplitude of the center strengthened from P1 to P2, resulting in a perturbation in the atmospheric circulation response pattern over Eurasian mid-high latitudes. During P2, the eastward shift and amplitude intensification of the NAO favored a north-south dipole structure in circulation anomalies over the Asian continent, which tended to produce cold temperature anomalies in south-central China during the positive NAO phase and warm anomalies during the negative phase. However, in the past two decades the northern center of the NAO has weakened and retreated westward. This was concurrent with a weakening relationship between the NAO and temperature anomalies in south-central China and northern Eurasia, indicating weaker downstream impacts of the NAO in mid-winter.

S1A-5

Anomalous western North Pacific anticyclone intensity modulation driven by the El Niño/IOD relationship

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We investigate a role of the known relationship between El Niño and the Indian Ocean Dipole (IOD) in modulating the atmospheric circulation over the western North Pacific (WNP) region. As a result, observational and reanalysis products during the period of 1950-2016 give us a possibility that there is a modulation effect of the El Niño/IOD relationship on the El Niño-dependent WNP regional anomalous low-level anticyclone (WNP-AC) during its initial development period. That is, the WNP-AC is strongly developed with significantly increased circulation intensity when El Niño coincides with a positive phase of the IOD (i.e., strong El Niño/IOD relationship or El Niño/IOD coupled case). However, the WNP-AC circulation intensity is largely reduced by half when El Niño solely arises (i.e., weak El Niño/IOD relationship or El Niño/IOD decoupled case). It is further suggested that the changes in the tropical Walker circulation, which is likely associated with different El Niño/IOD relationship strengths, may play a role for the WNP-AC intensity modulation by inducing a more enhanced anomalous subsidence branch near the Maritime Continent over the Indo-Pacific region. Additional cross-correlation analyses also suggest a statistical implication that the Maritime Continent subsidence anomaly, which can be affected by anomalous ascending motions from either the Indian Ocean or the tropical Pacific, has a considerable impact on the WNP-AC intensity modulation driven by the El Niño/IOD relationship.

S1A-6

Linear and nonlinear hydrological cycle responses to increasing sea surface temperature

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An effective mechanism for determining tropical rainfall patterns in response to sea surface temperature (SST) increases with varying magnitude and horizontal distribution has not been developed thus far climate change studies. In order to examine changes in precipitation pattern with increasing SST, we conducted a series of atmospheric general circulation model experiments using a 30-year history of observed SST for which either globally uniform SST increases of 1 K, 2 K, 4 K or patterned SST increases have been imposed. Although the global mean precipitation linearly increases with the SST increase irrespective of its spatial distribution, regional precipitation changes were found to occur nonlinearly depending on the magnitude of the uniform SST increase. Owing to nonlinearity in the atmospheric circulation response, the regional hydrological sensitivity was larger with a smaller increase in SST. The precipitation response to the SST pattern was, however, quasi-linear to the magnitude of the SST change and can be separated from the response to the uniform SST increase. This study thus emphasizes the importance of relative amplitudes of uniform and structured SST increases for future rainfall projection.

S1A-7

Land-sea thermal contrast determines the trend of Walker circulation simulated in atmospheric general circulation models

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Strengthening or weakening of the Walker circulation can highly influence the global weather and climate variability by altering the location and strength of tropical heating. Therefore, there is considerable interest in understanding the mechanisms that lead to the trends in the Walker circulation intensity. Conventional wisdom indicates that a strengthening or weakening of the Walker circulation is primarily controlled by inhomogeneous sea surface temperature (SST) patterns across the tropical Pacific basin. However, we show that Atmospheric Model Intercomparison Project (AMIP) climate model simulations with identical SST forcing have different Walker circulation trends that can be linked to differences in land surface temperatures. More prominently, stronger land-sea thermal contrast leads to increases in the precipitation in South America as well as the sea level pressure in the eastern tropical Pacific through a local circulation, resulting in a strengthening of the Walker circulation trend. This implies that correctly simulating the land temperature in atmospheric models is crucial to simulating the intensity of the Walker circulation in the present climate as well as its future change