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Building sustainable science partnerships between early-career researchers to better understand and predict East Asia water cycle extremes

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"What, When, Where" information box

MEETING TITLE: Causes and Predictions of Extremes in the East Asian Water Cycle

WHAT: Thirty selected participants, representing the active early-career researchers in China and the UK, met to plan future science initiatives and establish long-term sustainable collaborations in understanding and predicting East Asia water cycle extremes.

WHEN: 17-19th September 2019

WHERE: Reading, UK

Introduction

Water security is a major threat to economic development and social welfare in East Asia (EA), particularly for countries with rapidly increasing water demand, such as China and other EA countries, due to population growth and water consumption pattern change. Climate change may increase the risk of hydro-meteorological extremes in EA, including more frequent floods and droughts (e.g. Sillmann et al., 2013; Zhou et al., 2014; Guo et al., 2016). Likewise, climate variability alters the risk of hydro-meteorological extremes, including those from tropical cyclones and monsoons (e.g. Wang et al., 2000, 2008; Camargo and Sobel, 2005). Numerical models, such as the Numerical Weather Prediction (NWP) models and the climate models in the Coupled Model Intercomparison Project Phase 5 (CMIP5), have become central in understanding the causes of variability and change in the EA water cycle and accurately predicting extremes. Recently, Chinese universities and research institutes have made considerable efforts to understand and predict EA water cycle extremes, which is highlighted by the rapid development of high-resolution earth system models that run on China's most powerful supercomputers. In the UK, intensive research has focused on identifying the causes of EA water cycle extremes and developing numerical models to predict these high-impact events, in part to develop UK capability to deliver global weather and climate services. These significant research achievements are mainly made through the efforts of early-career researchers (ECRs).

The workshop 'Causes and Predictions of Extremes in the East Asian Water Cycle' gathered early-career researchers (ECRs; less than 10 years since PhD award) working in China and the UK with a wide range of research interests in the EA water cycle. The workshop organisers also invited senior scientists to speak about the current challenges and opportunities in understanding and predicting EA water cycle extremes, to motivate ECR discussions of future collaborations. The workshop provided a venue to share recent research achievements in understanding and predicting EA water cycle extremes, and more importantly also a platform to develop future science initiatives and long-term sustainable partnerships between Chinese and UK ECRs. The workshop was held at the University of Reading, and organized by the National Centre for Atmospheric Science (NCAS), and the National Laboratory for Marine Science and Technology (QNLM) at the Ocean University of China. Thirty participants were selected covering universities (China: Ocean University of China, Sun Yat-sen University, Hohai University; UK: Universities of Edinburgh, Oxford and Reading), and national service centres for weather and climate science and forecast (China: the China Meteorological Administration, Institute of Atmospheric Physics (Chinese Academy of Sciences); UK: the Met Office, the Centre for Ecology & Hydrology, the National Centre for Earth Observation, and NCAS).

Held over two and a half days, the workshop included 23 ECR and four senior scientist talks, related to phenomena that drive EA water cycle extremes on timescales from synoptic to climate. Keywords from these 27 talks are presented in a word cloud (Figure 1). On each day, the workshop had 3 sections. First, ECRs presented their research, with talks organised by timescale (synoptic, subseasonal-to-seasonal and climate); secondly, one or two senior scientists discussed challenges and future opportunities in numerical modeling; finally, there were small-group discussions led by ECRs, with a task for each group to develop one or several topics for future UK-China collaborations for water-cycle research.

ECR talk highlights

In the workshop, ECRs presented research to distinguish the contributions of individual weather phenomena to EA water cycle extremes, based on observations and reanalyses. These approaches associate extreme rainfall to tropical cyclones (TCs), Tibetan Plateau Vortices (TPVs), *Meiyu* frontal rainbands, cold surges and persistent circulations such as quasi-stationary Rossby waves. A method for tracing moisture sources of rainfall was also presented, including applications to sources of TC-related rainfall and to separating the contributions to rainfall from mean and eddy moisture transports. ECRs have applied these useful tools to output from forecast models and high-resolution CMIP6 models. By continuing this analysis in the coming years, these evaluations will help to identify the sources of error in predictions and projections of the EA water cycle, including errors in the large-scale circulation or in the representations of local mesoscale and synoptic features (e.g. TCs and TPVs), and how these errors grow with lead time or depend on the state of large-scale phenomena such as ENSO.

ECRs also presented research on subseasonal-to-seasonal (S2S) phenomena relevant to the EA water cycle, including rapid-onset “flash” droughts and the northward progression of the summer monsoon, and their connections to large-scale climate variability such as the Pacific-Japan pattern, the Silk Road pattern and the Boreal Summer IntraSeasonal Oscillation (BSISO). ECRs showed that existing S2S models, including China’s FGOALS-f2 model, are able to predict summer drought and TC genesis. Evaluations of S2S predictions for other extreme phenomena, such as TPVs, are an active area of ECR research and UK-China collaboration, as is analysis of the teleconnections between S2S phenomena and synoptic extremes (e.g., how the BSISO modulates TC genesis in FGOALS-f2).

Interannual and decadal variability in the EA water cycle from the perspective of extremes is studied mainly by associating it with atmospheric and oceanic large-scale climate variability. In this research topic, one challenge is how to effectively isolate the impacts of each phenomena on EA water cycle. In the workshop, ERCs showed the potential addressing this challenge with sensitivity experiments in coupled general circulation models (GCMs), in which for example ocean temperature anomalies are imposed only in a certain ocean basin, to eliminate interactions between climate modes. Sensitivity experiments reproduce the observed teleconnections from the Atlantic Multidecadal Variability to climate over China, while it remains challenging for models to reproduce the observed effects of Pacific variability (i.e. ENSO and Interdecadal Pacific Oscillation) on the ‘North dry–South wet’ pattern in China. An active area of research and collaboration is identifying the dominant modes of variability for the EA water cycle, as well as whether these modes are independent. The sensitivity experiments performed so far highlight a novel approach to address these challenges in long-term EA water cycle variability, including extremes, through ECR-led collaborative model development and evaluation.

To address future projections of the EA water cycle under global warming and anthropogenic forcing, ECRs have analysed changes in both mean and extreme rainfall in CMIP5 models under different RCP scenarios. Across EA, the mean strength of the water cycle (including precipitation, evaporation and runoff) is likely to increase; the seasonal cycle is likely to intensify; and the frequency of drought and heavy rain events is likely to increase. These changes will present an increased risk of hydro-meteorological extremes for EA society. ECRs will continue to evaluate projections of other phenomena relevant for EA water cycle extremes, e.g. TCs, TPVs, the *Meiyu* front and flash drought. Workshop presentations demonstrated that uncertainty in EA water cycle projections, especially for extremes, remains substantial. ECRs plan to collaborate to understand whether this uncertainty is reduced in CMIP6 models, which typically have a higher horizontal resolution and updated model physics.

Outputs

The aim of the workshop was for ECRs to develop future science initiatives and long-term sustainable partnerships for water-cycle research in the next 5-10 years. To motivate ECR discussions of future research and collaboration, four senior scientists were invited to discuss the current challenges and opportunities for simulating EA water cycle extremes. After the senior scientist talks on each day, ECRs led small-group discussions, with each group appointing an ECR to report discussion outcomes to, and record feedback from, the wider workshop. Each group was tasked to develop one or several potential topics for future collaborations. ECRs benefited from in-depth discussions with other ECRs and senior scientists on research objectives and career-development opportunities, and also gained experience in planning international collaborations. The following summarises these collaboration topics, which ECRs are now developing into outline research proposals.

There is rapidly growing interest in developing high-resolution prediction systems for the EA water cycle. Chinese participants presented the newly developed high-resolution global and regional earth modeling systems in China, which are run on China's most powerful supercomputers. Several other weather and climate prediction systems in China were also introduced and mentioned in the workshop, e.g., FGOALS-f2, which features with a finite-volume dynamical core and includes a convection-resolving precipitation parameterization. UK participants presented the UK high-resolution model contributions to CMIP6. So far, evaluations of EA water cycle extremes in these models have been limited, presenting an opportunity for ECR-led research. The objective tools for diagnosing water cycle characteristics, developed by ECRs as mentioned above, will be extremely valuable for advanced process-level evaluation of these systems. ECRs believe these new systems will provide a good platform for collaborative research, which will in turn help to identify priority areas for further model development. Topics agreed between ECRs include extreme rainfall related to TCs and TPVs (including path and related moisture flux transport), EASM and droughts, and their teleconnections with climate variability.

Contemporary weather and climate forecast models share biases in simulating the Asian water cycle, e.g. dry biases in South Asia and wet biases in East Asia during the monsoon season. Many efforts have been made to reduce these biases, such as including ocean coupling, increasing model resolution and adjusting convection parameterisations. However, these efforts have had limited success, indicating the complexity and intractability of errors in water cycle simulation, at least when model development is performed in isolation. ECRs planned UK-China collaborative research in model development and evaluation, including running common sensitivity tests in UK and Chinese models, to help to understand the source of model error.

In the meantime, improved observations of the East Asian water cycle, across timescales, is urgently needed for model improvement. In recent years, remote sensing has provided essential observations of water cycle processes. For example, an ECR mentioned the High resOlution Land Atmosphere surface Parameters from Space (HOLAPS) framework, which ensures consistent estimation of surface water and energy fluxes between different satellite-based products. ECRs plan to use these products to verify models for EA water cycle extreme prediction in multi-dimensional domain.

Additionally, model parameterizations usually require years of development, particularly at global scales for lengthy coupled integrations. Parameterization typically happens to the parameters whose values are consistently poorly represented in models with respect to observations, due to the complexity of the climate system and the approximate descriptions on unresolved processes. Parameterizing a model to improve its performance on one phenomenon may degrade performance on others. Therefore, a number of parameterizations across different media (atmosphere, ocean and land) are normally tuned together. For example, over the ocean atmospheric convection needs to be parameterized together with parameterizations in sea surface temperature and salinity, while over the land it needs to be performed together with parameters tuning for soil moisture. ‘Parametrization scientists’, who well know the process-oriented error metrics both in models and in observations, have become an opportunity of new career for ECRs.

Modern forecast systems can predict well slowly-evolving modes of climate variability, but have less skill in predicting EA water cycle extremes (e.g. TC-related rainfall and drought) at user-relevant scales (e.g. local and regional average scales). For example, the MJO can be well predicted 3-4 weeks ahead in many models, and ENSO is predictable 6 months in advance. This suggests models may struggle to simulate the teleconnections from climate modes to the water cycle extremes. In the next 5-10 years, evaluation of teleconnections on timescales from intra-seasonal to decadal will be a key topic for UK-China ECR collaborations.

ECRs also planned to strengthen multidisciplinary collaborations on the impact of EA water cycle extremes. For example, with preliminary analysis based on observations, ECRs confirmed a close hydrological relationship between inter-annual variability in the water level of the Pearl River networks and southern China rainfall during the flood season. In the coming years, ECRs will work together on the predictability of the Pearl River networks, in terms of extreme events for river flow, water level and saltwater intrusions, on varying timescales, by leveraging predictions of the EA water cycle and its variability.

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Figure 1: Keywords of 27 talks given by participants in the EA water cycle workshop.