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Improving user engagement and uptake of climate services in China

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ABSTRACT

The needs of decision makers in China are being used to develop climate science and climate services through the Climate Science for Services Partnership. Focusing on examples of work for the energy and urban sectors, this paper outlines the approach taken and gives case studies of climate service development. We find that there is great opportunity for climate service development within the existing China Framework for Climate Services, and for enhancing the science that underpins such services. We also find challenges unique to the socio-economic and cultural environment in China, which must be taken into account when developing climate services here, as well as challenges common to all climate service development.

1. Introduction

There has been a rapid expansion in the demand for climate information to aid decision-making. Indeed, the concept of "climate services" is becoming increasingly widespread; in this paper we define climate services simply as the provision of climate information that assists decision-making. However, the development and delivery of suitable climate services, and the scientific capability underpinning the services, often fall short of sufficiently meeting the users' requirements.

The momentum of research programmes and funding opportunities means that in most areas the underpinning science required to fulfil climate service requirements is still fundamentally driven from a top-down perspective of scientific capability, with monitoring and modelling developments pursuing complexity, completeness, and understanding of the earth system. The notion of user requirements (i.e. bottom-up) driving a significant portion of scientific research remains a challenge, but is increasingly being recognised as an essential notion. In addition, interfaces and engagement between the providers and users of climate services are relatively new, or far from active if they exist at all.

In 2012 the World Meteorological Organisation established the Global Framework for Climate Services (GFCS, Hewitt et al., 2012), with the vision to "*enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale.*" Climate services became better understood as providing climate information to support decision-making, and more specifically climate services '*require appropriate engagement along with an effective access mechanism and must respond to user needs.*' The GFCS, and at a national level the 'National Framework for Climate Services' provide a clear and structured approach to the development of climate services, and the science to support those services.

The Climate Science for Services Partnership China (CSSP China, http://www.metoffice.gov.uk/research/collaboration/cssp-china) is developing climate science and climate services which are fundamentally driven by the needs of decision makers in China, in a small number of carefully identified priority sectors. The partnership involves scientists in the UK working closely with Chinese scientists, climate service providers in China and their key users, to drive scientific research, and develop climate service opportunities. Four key areas of underpinning science are being developed with the aim of developing scientific understanding and supporting climate service development: climate monitoring, attribution and reanalysis; global dynamics of climate variability and change; East Asian climate variability and extremes; and development of models and climate projection systems. The underpinning science

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is both driven by, and contributes strongly to a fifth area of research and activity: climate services development.

This paper outlines the approach taken in CSSP-China, focusing on climate service development activities. CSSP-China exemplifies the approach of developing climate services based jointly on user needs and scientific capability. The section below gives some background to the current landscape for climate services in China. The following sections demonstrate the approach taken to develop the National Framework for Climate Services in China, and to start to develop prototype climate services for priority sectors. Finally, recommendations are given for future climate service activities, drawn from the experience of this partnership so far.

2. Surveying the landscape

Climate Services in China have developed alongside climate science since the 1950 s, with rapid development since the mid-1990 s. The National Climate Centre at the China Meteorological Administration (CMA) was established in 1995, and immediately began responding to demand for climate forecasts of longer lead-times for better planning of potential impacts of extreme weather such as droughts and floods.

The landscape for climate services development in China is in many ways highly advanced, providing excellent examples of operational climate services developed through strong user interaction, science capability and technology. Climate service provision and use in China is at the same time both uniquely simplified and complex. A large proportion of sector-specific activities and service providers are State managed, and many are closely linked into the government hierarchy or in equivalent government structures. This means that many climate service providers are already in close dialogue with their end users, and without the complex market mechanisms dominating service requirements in many other countries, the requirements of users are less focused on gaining competitive edge and more on efficient use and transfer of resources.

The climate services landscape in China is, on the other hand, extremely complex, due in most part to the sheer scale of the country – equivalent in some ways to climate services across the whole of Europe or Africa. CMA, the National Meteorological Service, has overall responsibility for climate research and development, and maintenance and development of observations and monitoring programmes. The Beijing Climate Centre, part of CMA, is responsible for provision of services and decision support to the central Chinese government, for instance for national climate change scenarios, and for wider regional activities with neighbouring countries such as the Regional Climate Outlook Forum. Climate services to regional or provincial users within China are then provided by the 31 regional or provincial climate centres. Further to this there are 14 meteorological bureaus at sub-provincial city level, some of which also provide climate services for urban areas. Thus a hierarchy exists for the transfer of information and delivery of services within the climate/meteorological community. Beyond this community a much wider network of national, provincial and local bodies with responsibility and requirement for the delivery and uptake of climate services.

An initial study in CSSP-China (Nobert et al., 2015) looked at the social, communicational and political dimensions of climate services in China and identified major gaps between demand for climate information and the institutional realities. Drawing on social science methods, the team of researchers from the University of Leeds and Beijing Normal University documented and identified specific needs and interests for climate service development in China. Findings indicate that although there is a strong appetite for seasonal forecasting in particular from a high level of governance and from private (and semi-private) users such as energy companies, there are also significant barriers to the use of probabilistic predictions outside the realms of high-level civil servants and climatologists (just as in Europe, e.g. Dessai and Bruno Soares, 2015; Bruno Soares and Dessai, 2016). These barriers involve important questions related to trust in science and in the scientists developing such tools, but also to trust in the capacity to use uncertain information in a political context that is demanding precise information. The ways in which Confucian and neo-Confucian concepts are influencing social relations within Chinese society are also affecting the ways in which science is viewed, and also the ways in which forecast information is received and dealt with: for example, in China, the person who communicates a risk message could be as important, if not more important than the information itself. Elements of Chinese culture (see for instance Yao, 2002) also mean that in Chinese risk management in recent decades has focused more on post-disaster response than on anticipation (Chen, 2012, 2016). It is clear that these factors will need to become key considerations when developing climate services in China.

3. Developing a National Framework for climate services

China has a well-developed National Framework for Climate Services. The China Framework for Climate Services (CFCS) is a 'customer-oriented service platform acting on government, relevant sectors and users' demand....It works to benefit all walks of life under the rationales of coordinated development, opening, cooperation, and joint participation' (China Meteorological News Press, 2015). The CFCS is closely aligned with the Global Framework for Climate Services (GFCS) and identifies key activities under each of 5 areas: climate observation and monitoring, climate modelling and prediction, climate service information system, users' interface platform, and capacity development. In 2013, China completed the preparation of an implementation plan for the CFCS (outline of the CFCS shown in Fig. 1). During the period of 2014–2015, a range of pilot projects were begun in six priority sectors, including agriculture and food security, disaster risk management, water resources, energy, towns, and human health. During the following 5 years, the CFCS aims to cover all climate-sensitive sectors, based on recommendations from and evaluation of the pilot projects.

One aim of CSSP China is to support the development of the China Framework for Climate Services in partnership, through focused engagement with key sectors, prioritisation of development activities, growth of underpinning science, and prototype climate services. Chinese climate services have a strong focus on seasonal prediction with a wide array of operational services, whereas the UK has a strong reputation historically for its offering on longer climate change timescales. CMA has built relationships with a variety of sector-based stakeholders, and it became clear during visits to some of these that there are opportunities for the UK and Chinese Met Services to work closely together to strengthen and deepen these relationships. Priority sectors and key activities to be developed under CSSP China were identified (energy, water resources, urban environments, and agriculture and food security), which will contribute strongly to the China National Framework for Climate Services.

As an initial step under the CSSP, scientists from the UK and China developed a road map for climate services in China and used this to recommend and prioritise activities for the partnership. These activities draw directly on the underpinning science development in CSSP China. Engagement activities with priority sectors took place, initially focusing on the energy and water sectors. Specific methods for engagement have included:

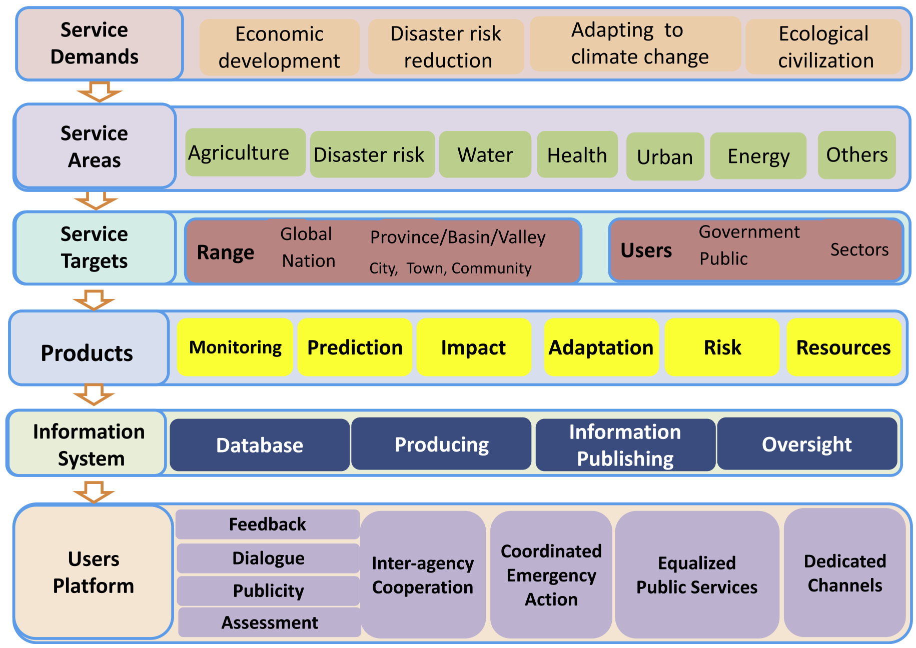

Fig. 1. China's Framework for Climate Services.

- Stakeholder meetings, based around knowledge exchange, largely to understand user requirements and current services received.
- Production of communications materials, giving clear, non-technical overviews of key advances in the underpinning science and the benefits of this science to users.
- A user workshop for the energy sector, with a mixture of knowledge exchange and capacity building, particularly around the area of seasonal forecasting.

From these activities it has been possible to identify underpinning science developments that would strengthen climate service activities and may be pursued under science themes of CSSP China, including the need for a high resolution reanalysis dataset for China (currently a global dataset is used and downscaled to higher resolution using a regional climate model); attribution of costly extreme climate and weather events, including assessment of likelihood of future events; improved capability of modelling urban areas; and a clearer understanding and communication of the skill of seasonal forecasts, in particular for key impact relevant variables.

Further activities following the aim of user engagement and knowledge exchange will be undertaken to better understand the needs of key sectors, and to work closely with specific users to underpin the development of prototype climate services. Some examples of these users and services are given in the next section.

4. Prototype climate services for priority sectors

The rest of this article focuses on two key areas of service development, tailored to priority sectors in China: energy, and urban environments. User engagement has been focused on these sectors with a clear aim to better understand the needs of users for more robust decision-making. Parallel to this, science capability has been developed through collaboration between scientists in China and the UK in order to better meet climate service requirements.

4.1. Prototype climate services for the energy sector

An initial assessment demonstrated the strength of climate services for the energy sector currently provided in China, and the strong underpinning research that has supported them, considering energy demand, supply, balancing, and infrastructure risk. The assessment also identified opportunities for climate service development to support strengthening of the user interface through deeper engagement, and investigation of new scientific solutions to better inform decisions. These decisions focused on renewable-energy resource forecasting on seasonal timescales and longer-term risk mapping; the balancing of renewable energy resources across China, and resilience of large energy infrastructure.

Following this, collaboration between scientists at CMA and the Met Office has considered near term climate predictions of energy relevant metrics from the Met Office seasonal forecasting system, GloSea5 (MacLachlan et al., 2015), using various measures of skill and reliability (Bett et al., 2017a, in preparation). This work has shown significant skill in predicting wind speeds and irradiance in winter (DJF) for parts of China, and for temperature in some areas during summer (JJA). Where these regions intersect with key areas of current or future energy production, such as wind/solar farms or urban areas of high energy demand, these findings demonstrate an opportunity for the development of future climate services based on this skill.

4.1.1. Case study: Prototype seasonal forecasts for the Yangtze river basin

From the beginning of the CSSP China collaboration, stakeholder discussions with the hydropower industry in the Yangtze region have demonstrated a clear need for forecasts of rainfall on seasonal timescales, particularly for the summer flood season. These forecasts have a dual purpose of allowing the users to provide accurate power forecasts to their customers (the State Grid), and in managing and maintaining the vital flood protection properties of the dams. Parallel to this, Li et al. (2016) demonstrated that the Met Office seasonal forecast system (GloSea5) shows significant skill for summer rainfall and river flow in the Yangtze river basin. In addition, the strong El Niño event in the winter of 2015–2016 also suggested elevated risk of flooding along the Yangtze in the following summer, by analogy to the devastating floods in 1998 (e.g. Ye and Glantz, 2005), suggesting the potential for a useful and skilful climate service meeting the decision-making needs identified.

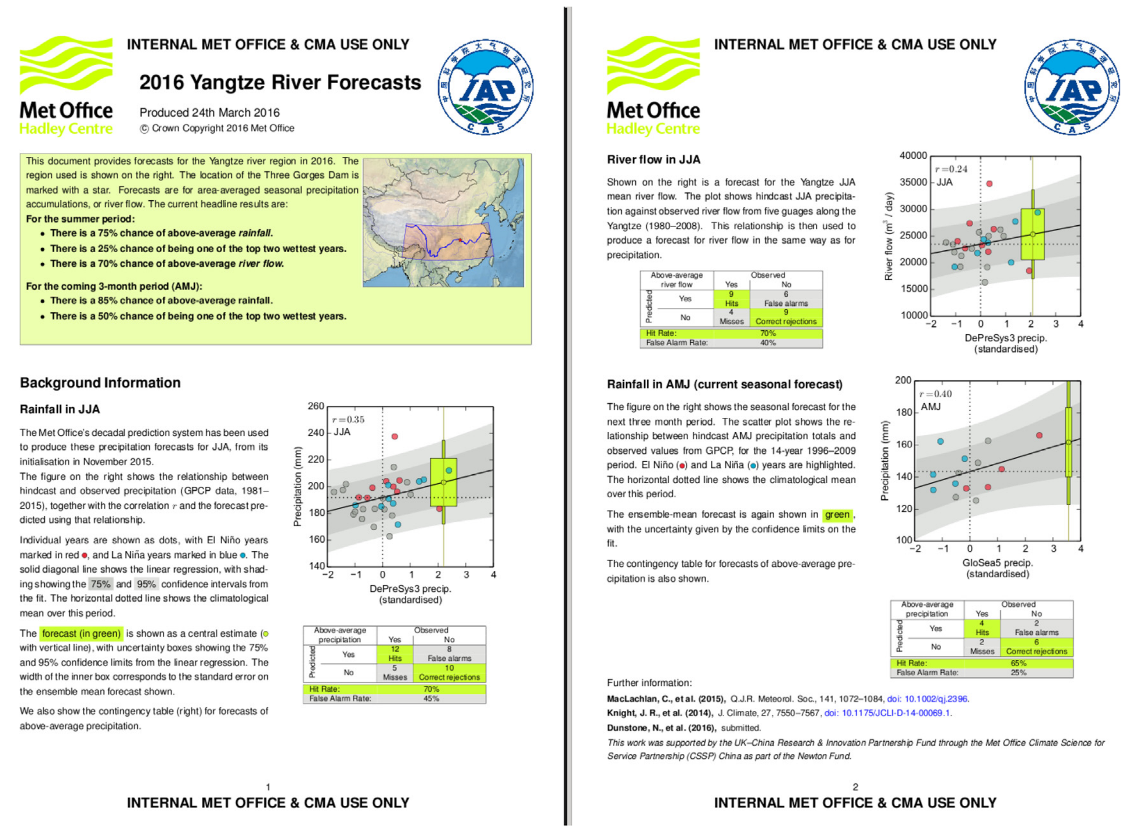

Fig. 2. Example (March) seasonal forecast prototype climate service for the Yangtze River Basin, demonstrating the uncertainty in the forecasts.

The reliance of these decision-makers on forecast accuracy for both flood protection and energy provision poses a challenge for climate services, where the developing and incomplete state of the science requires care to be taken in the provision of such information to decision makers, where decisions hold significant risk. A prototype climate service was therefore trialled, with scientists at the Met Office producing a real-time seasonal forecast for the Yangtze river basin throughout the spring and summer of 2016, delivered through colleagues at CMA for further dissemination to key stakeholders throughout the season. This trial allowed the delivery of new and potentially useful information, while, through close interaction with decision makers, aiming to ensure appropriate interpretation of the uncertainty in the forecasts, and to assist robust decision-making. The forecast presented each month gave headline messages for the coming season (probabilities of above-average conditions), followed by a more detailed description, with graphics, of how the latest forecast and its uncertainties related to the relationship between observations and historical model performance based on hindcast data (Fig. 2, technical details are described in Bett et al., 2017b, in prep).

As expected from the strong El Niño, the summer precipitation forecasts showed consistently high probabilities for above-average rainfall in the Yangtze basin, as well for as above-average river flow based on naturalised flow data provided by Chinese colleagues. This prototype forecast is being evaluated following the flood season both in terms of the forecast skill and the user uptake of information. This information will help assess the value of the service and also make improvements to further meet the needs of these specific users.

4.2. Prototype climate services for urban environments

The work on climate services for urban environments has evaluated current efforts in China and highlights potential development of services, identified through a questionnaire distributed to producers and users through the Shanghai Institute of Meteorological Science (SIMS), and CMA (Grimmond et al., 2015). This work has found that climate services for urban environments in China are well developed, and focus mainly on extreme precipitation and heat. This focus has important regional differences: climate services related to human health are most common in East China, especially in Beijing, Shanghai, Guangzhou and Nanjing; air quality (or haze) services are delivered in most provinces, while those related to sand storms are delivered in northern China (Grimmond et al., 2015). Benefits of these services have also been evaluated, and include reduction of accidents, better allocation of resources, advanced warnings, and improved health of vulnerable populations (e.g. the young and elderly).

4.2.1. Case study: Developing city based climate services for Beijing

The city of Beijing currently receives climate services from the Beijing Municipal Climate Centre, mostly regarding information for multi-decadal urban planning. Examples of climate services include modelling of ventilation through parts of the city to aid building design in areas vulnerable to heat stress. Climatic conditions leading to extreme heat, cold, flooding, drought, and reduced air quality affect Beijing, however such extremes and their impacts on the urban environment are not sufficiently well modelled at present, presenting a strong limitation to the development and use of climate services.

As an initial step to enabling further development of urban climate services in Beijing, the performance of the SUEWS model (Järvi et al., 2011, 2014; Ward et al., 2016) has been evaluated. The SUEWS model is applied in the Anhuaqiao neighbourhood of central urban Beijing with 1.5 km × 1.5 km domain for simulation (see Fig. 3, area shown within the red borders) and resolution of 100 m × 100 m. For each grid area, the site-specific surface cover information is estimated based on remote sensing data.

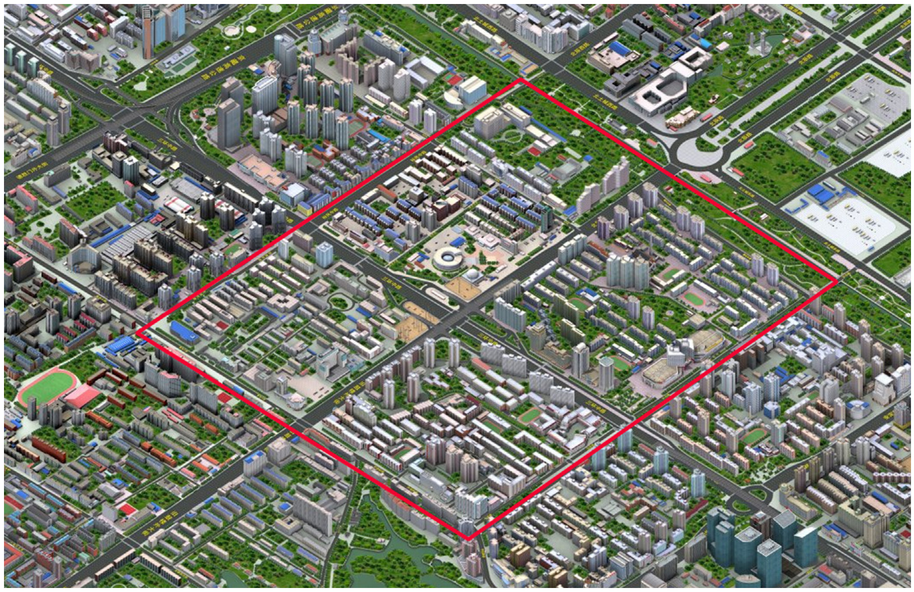

Fig. 3. Anhuaqiao neighbourhood simulation located in the red borders. (For interpretation of the references to colour in this figure, the reader is referred to the web version of this article.)

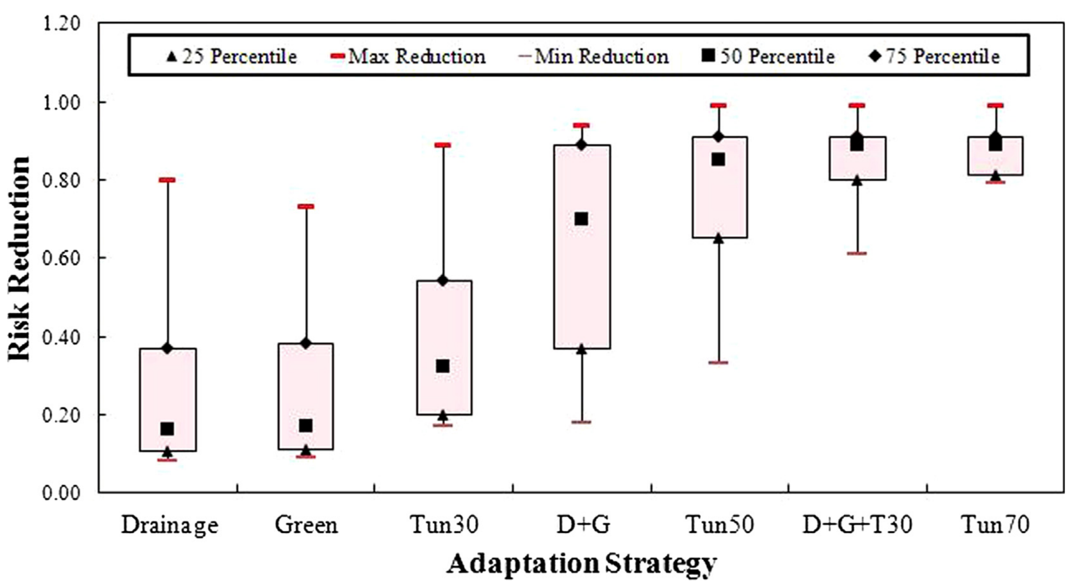

Fig. 4. Example of an assessment of a variety of adaptation strategies for future flood prevention in Shanghai. Adaptation strategies or combinations are as follows: Drainage: drainage enhancement, Green: green vegetation area, Tun30: deep tunnel with 30% of precipitation absorbed, D + G: Drainage and Green, Tun50: deep tunnel with 50% of precipitation absorbed, D + G + T30: Drainage, Green and tunnel with 30% precipitation absorbed, Tun70: deep tunnel with 70% of precipitation absorbed. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Results are promising for the implementation of SUEWS in further developing climate services for urban environments in Beijing. For instance the characteristics of the diurnal cycle are well captured, and SUEWS performs well in simulating net radiation, and the median variations of simulation for sensible heat and storage heat match well with the observational data. However, the simulations for surface latent heat flux are less consistent and some differences exist between observed and modelled energy balance components reaching the maximum value during the daytime.

Further improvement in urban modelling for Beijing is now supporting early stages of climate service development in further areas. Potential applications of this model have been identified, for instance in services advising on increasing resilience of city infrastructure and services to a changing climate; and in services simulating the micro-climatic impact of further urban growth either expanding into rural or suburban areas or increasing density of existing urban areas. Fundamental to this area of service development has been the strong exchange of information and knowledge between different groups of experts. An expert in climate service provision for Beijing spent time with climate services scientists at the Met Office evolving ideas and sharing expertise, and time was also spent at Reading University with experts on urban climate. This interdisciplinary and international exchange has demonstrated its benefits here and will contribute strongly to the development of enhanced climate services in both the UK and China.

4.2.2. Case study: Flood risk assessment for Shanghai

Collaboration between Shanghai Climate Centre (SCC), Shanghai Water Engineering Design & Research Institute (SWEDRI), The School of Oriental and African Studies (SOAS, University of London), and the Met Office, has aided the design and evaluation of policies and strategies for Shanghai's flood risk reduction and disaster prevention, and provided scientific data and advice on simulation tools to improve Shanghai's sustainable urban planning.

In order to investigate Shanghai's current flood defence and weak points, a field survey was conducted, finding that even though the current sea wall and river embankment were designed to withstand floods of a 1000 year return period, the possibility of overtopping and breaching cannot be neglected when considering future sea level rise and extreme storm surges. In fact, current evidence suggests that the occurrence of exceeding the designed water level (6.27 m) has decreased from a return period of 1000 years (1984 design standard) to 200 years (2004 design standard) in the Huangpu River, the main river across downtown Shanghai (Ke, 2014). A further activity involved a delegation from Shanghai local government and SCC visiting London to share experiences in flood risk management.

The project study used Robust Decision Making (RDM) theory and a flood model driven by downscaled climate model simulations (using the Met Office PRECIS system, Jones et al., 2004) to quantify Shanghai's future inundation risk. The RDM method (Lempert et al., 2013) is a 'Bottom-up' theory: rather than using computer models and data to describe a best-estimate of the future, RDM runs models based on hundreds to thousands of different sets of assumptions to describe how plans perform in a range of plausible futures. This study examined Shanghai's future inundation risk under climate change conditions in 1000 future scenarios describing the uncertainties in features such as future precipitation, the urban rain island effect, and a decrease of urban drainage capacity. Strategies such as drainage enhancement, green areas, urban deep tunnels, and their combinations, were applied to this study, and their performance was quantified under each scenario (Fig. 4). A briefing based on this work was delivered to Shanghai Municipal Government and advice on adaptation strategy will continue to be provided as this research is continued.

5. Learning so far

This paper highlights the breadth of activities being undertaken in the CSSP China project, focusing on climate service development work. This research has also highlighted a number of learning points, which it would be useful to share at this point with the wider community.

Firstly, the importance of cultural and socio-economic situation in the provision of climate services. The background to China's climate services landscape in Section 2 of this paper demonstrated some key differences to climate service provision in many Western countries, and experiences through the activities described in Sections 3 and 4 further showed the nuances in cultural beliefs, etiquette, and expectation which are fundamental to successful climate service provision in China. Understanding the social and economic situation in which activities are carried out, in any country, should therefore always be a pre-cursor to climate service development. In particular, understanding governance structures and interactions are an essential part of climate service development and delivery.

Secondly this experience highlights some of the benefits and challenges of collaboration in the development of climate services. Through this bi-national collaboration the development of scientific understanding is accelerated, allowing partners to tap into both international connections for observations and modelling development, and regional and local expertise without which climate research could not succeed. Specific to climate services, the combination of international expertise and in-depth local understanding of the workings of national, provincial and municipal governance and economics in China has been fundamental to the success of this work so far. Beyond this, the collaboration of climate service experts, climate scientists, and sector specialists, both in the UK and China has driven research and service development, which could not have been considered without such interdisciplinary collaboration. Naturally the combination of different research approaches and collaborative working across cultures, languages and time zones brings its own challenges. One key factor in overcoming these issues has been the exchange of scientists between the UK and China and between service providers and academia, proving highly beneficial in the building of relationships and the acceleration of strong service development.

Finally two issues which pervade all development of climate services are beginning to influence the collaboration: i) that the depth (or lack of depth) of engagement with potential users can determine the success or failure of a climate service; and ii) the fundamental issue of balancing provision of robust science with provision of useful information. Further activities under CSSP China will enable us to explore these key issues in greater depth and hopefully provide further experience in how to address them to improve the development of climate services in general.

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