Institute for Environmental Analytics

新观点

VIEWpoint

Putting climate science into plain language

New resources for decision-makers

Climate services

Features & interviews

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Climate Science for Service Partnership (CSSP) China

Met Office

Newton Fund

VIEWpoint - putting climate science into plain language

This handbook translates the science of the Climate Science for Service Partnership (CSSP) China project into a series of feature articles and interviews. It is designed to appeal to a wide range of readers including climate service providers and users, and those outside the research community who are tasked with making strategic plans and decisions that need to take into account our changing climate.

It reflects the scientific research of CSSP China, a successful collaboration since 2014 between China and the UK, supported by the UK-China Research and Innovation Partnership Fund (which is supported in the UK by the Newton Fund). Chinese and UK institutions have worked closely together, including the China Meteorological Administration, the Institute of Atmospheric Physics/Chinese Academy of Sciences, the UK Met Office and related universities.

This handbook has been produced by the Institute for Environmental Analytics through VIEWpoint (Visualisation Innovation Engagement Web-enabled), a project to share CSSP China's cutting-edge climate research with the widest possible audiences through a range of high quality, accessible resources. You will also find clear signposts to indepth scientific information. It is available to read, download and share in English and Mandarin and also online at www.viewpoint-cssp.org/handbook

All the resources featured in these pages - and more - are freely available at the website produced by the Institute for Environmental Analytics: www.viewpoint-cssp.org including a searchable catalogue of the 340+ scientific papers published, training videos, data visualisations of prototype climate services and a glossary of climate terms.

We hope you find these resources useful in addressing the challenge of climate change - a challenge that we have researched as an international community so that we can protect our planet together as an international community.

Sally Stevens, Handbook Editor
Communications & Engagement Manager at the Institute for Environmental Analytics
March 2021

Use this QR Code to visit the VIEWpoint CSSP China website

Download this handbook to read and share at the VIEWpoint CSSP China website using this QR Code

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FOREWORD

By Her Majesty's Ambassador to the People's Republic of China

Climate change is one of the defining challenges of our time, it is remarkable how far we have come in our understanding, yet we are not doing enough to limit dangerous climate change.

The UK and China are global leaders in science and technology, together we produce knowledge at the forefront of human understanding. With both countries investing record amounts in science and technology and leading by example with pledges to become net zero economies around the middle of the century, the stage is set for the UK and China to address the challenge of climate change head on.

> *"The stage is set for the UK and China to address the challenge of climate change head on ... There will be no effective solution to climate change without science and technology.*

The UK and China have cooperated on science since the 17th century and we have had a government-to-government relationship on science and technology for over 40 years. The seven year-long UK-China Research and Innovation Partnership Fund, funded in the UK by the Newton Fund, has been a landmark in our cooperation to drive economic development and tackle global challenges such as climate change, antibiotic resistance and food security, to name just a few.

One of the most successful programmes under the Partnership Fund is the Climate Science for Service Partnership (CSSP) which also marks its seventh year.

This year China hosts the 15th Conference of the Parties to the UN Convention on Biological Diversity, and the UK will host the 26th Conference of the Parties to the UN Framework Convention on Climate Change (COP26). This offers a unique opportunity to secure meaningful global commitments to address the linked threats of climate change and biodiversity loss.

There will be no effective solution to climate change without science and technology. Therefore, I am delighted to introduce this handbook, a remarkable summary of the transformative science that is accelerating our understanding of climate change and how we manage that change. As we move on from the COVID-19 pandemic, we need a green and resilient recovery. This handbook sets out the hard science showing the extent of climate change and the threat to our way of life, but also demonstrates ways to ensure climate resilience.

We must all challenge ourselves to do our utmost to challenge climate change.

Dame Caroline Wilson DCMG
Her Majesty's Ambassador to the People's Republic of China

Dame Caroline Wilson DCMG
Her Majesty's Ambassador to
the People's Republic of China

Professor Lianchun Song
Director-General of the National Climate Centre of the China Meteorological Administration

WELCOME TO THE CSSP CHINA HANDBOOK

By Professor Lianchun Song

As a Co-leader of the CSSP China programme from the China Meteorological Administration (CMA), I am pleased to see the release of this handbook on the main results of CSSP China and to recommend it in good faith to the providers and users of climate services.

> *"The CSSP China programme is recognized as the most fruitful Sino-British meteorological cooperation project of the longest duration and largest participation*

In the 21st century, the greatest challenge facing China and the UK is the climate risks posed by increased climate variability and extreme events in the context of climate change and global warming, which threaten food security, water security, energy security, ecological security, etc.

In mid-2014, the second-generation climate system model of CMA, which had just started operation, was insufficient to simulate and predict the upper-middle atmosphere and East Asian climate, allow for understanding of the roles and mechanism of the driving factors behind climate anomalies in East Asia, a time when the operational capacity-building of the detection and attribution of extreme events just began.

The Met Office's GloSea5 seasonal forecasting model system, which was put into operation just one year before, revealed an unclear performance for Asia and adjacent oceans. It is against this background that the CSSP China programme was launched in June 2014 with the aim of establishing a long-term and stable strategic partnership between China and the UK in the field of climate operation and research to enable the climate science to underpin climate services further.

Today, the CSSP China programme is recognized as the most fruitful Sino-British meteorological cooperation project of the longest duration and largest participation.

Over the past seven years, we have carried out in-depth co-operative research and development in the areas of detection and attribution of extreme events, large-scale climate dynamics and climate model development, achieving a lot of results. What is more gratifying is that these results have been widely applied to climate services in China. This handbook contains the initiatives and successes of selected cooperative applications. 2015–2020, which may be considered as the warmest six years on record, has experienced the strongest El Niño events as well as extreme events such as heatwaves, heavy precipitation, severe cold surge, serial/concurrent typhoons, widespread droughts and floods. Thanks to the application of cooperative results, losses and damages arising therefrom add up to less than six years ago. It is believed that the publication of this handbook will facilitate the translation of more climate science findings into climate services.

Professor Lianchun Song, Director-General of the National Climate Centre of the China Meteorological Administration

WELCOME TO THE CSSP CHINA HANDBOOK

By Professor Tianjun Zhou

CSSP China has promoted the collaborations between the Institute of Atmospheric Physics/ Chinese Academy of Sciences (IAP), the UK Met Office and related universities. In the past five years, a total of 92 IAP scholars, postdoctoral and graduate students have visited UK scientific and educational agencies for academic exchange, workshop and meetings, and meanwhile 89 UK scientists have visited IAP.

> *"Significant progress has been made in four fields*

Supported by CSSP China, the UK and Chinese scientists have co-authored many research papers, which have been published in international journals including Nature Communications, Science Advances, BAMS, QJRMS, AAS etc., and have made significant progress in the following four scientific fields:

1. Climate change detection and attribution

A homogenized long-term Chinese climate dataset was developed, which facilitated demonstrating many facts of regional climatic changes such as the warming pattern in China during the past century. The IAP and UK scientists have jointly detected and quantified the role of anthropogenic forcing (particularly greenhouse gas emissions) in the changes in climate extremes including compound hot extremes, extreme precipitation and droughts.

2. Climate variability and hydrological cycle

The IAP and UK scientists have collaboratively worked on the understanding of climate variability of extreme drought events which greatly affect water availability in China. The human influence on the terrestrial water storage (TWS) depletion in the Yellow River and Huai River basin are quantified. Based on the large ensemble PPE simulation of the Met Office climate models, the contribution of internal variability and external forcing to the observed decadal decline and recent recovery of South Asian summer monsoon rainfall have been identified.

3. Climate prediction

The Met Office seasonal forecast system has been used in the research of seasonal prediction of the Yangtze River basin summer rainfall. The skilful prediction is found to be sourced from convections around the Maritime Continent. The joint work has led to a successful climate service prototype on the operational forecast of the Yangtze River Basin rainfall, acting as a good reference for seasonal forecast consultations in meteorological departments since 2016.

4. Convection-permitting modelling:

The Met Office Unified Model (MetUM) at convection-permitting scale (~4km) has been used in East Asian summer rainfall simulations. This is the first set of seasonal long CPM simulations over East Asia. The added values of the CPM over East Asia are identified.

On behalf of the IAP, I would like to take this opportunity to express my gratitude to the UK and Chinese scientists participating in CSSP China for their productive work, and to the Newton Fund, the Met Office, China Meteorological Administration and the Bureau of International Cooperation of the Chinese Academy of Sciences for their strong support. We look forward to having more fruitful results from China-UK cooperation in the future.

Professor Tianjun Zhou
Director General of IAP

Professor Tianjun Zhou
Director General of the Institute of Atmospheric Physics /
Chinese Academy of Sciences

Professor Sean Milton
Associate Director of Foundation Science, Met Office,
UK Project Executive for CSSP China

WELCOME TO THE CSSP CHINA HANDBOOK

By Professor Sean Milton

It has now been seven years since we began the Climate Science for Service Partnership (CSSP) China project.

From the outset the aim was to bring together the combined expertise of the UK and China in climate research to advance scientific understanding and address the shared global challenge of tackling climate change. In that time, we have built a vibrant research community across the UK and China and, I hope you will agree, we have achieved some important milestones. This handbook, put together by the VIEWpoint project, shares some of the CSSP China highlights.

The project has grown into a mature, mutually beneficial collaboration spanning more than 30 UK and Chinese partners and involving over 200 scientists. Before the restrictions of the Covid-19 pandemic, we organised more than 80 exchange visits in which researchers spent time collaborating at their project partners' institution, in some cases for up to two years. These exchanges have been invaluable in developing innovative science for services and upskilling the next generation of climate scientists.

So far, we have published more than 340 papers (and counting!) in peer-reviewed journals across a broad range of topics including:

- predictability in seasonal forecasts for China
- East Asian Monsoon dynamics and water cycle
- global climate dynamics
- advances in model development
- key research on observations and data retrieval from across the historical record
- prototype climate services across several sectors including water, energy and agriculture.

> *"The science developments have achieved the core purpose of 'Science into Service' and are being used for the global good*

The science developments have also achieved the core purpose of 'Science into Service' and are being used for the global good. CSSP China research has informed Shanghai's 2017-2035 Master Plan, helped dam operators prevent flooding along the mighty Yangtze River and been used in the UK's National Flood Resilience Review. Scientific advances made here are shared globally through the wider Weather and Climate Science for Services (WCSSP) Programme, accelerating progress and delivering maximum impact to benefit other countries.

As we mark five years since the Paris Agreement and with COP26 on the horizon, UK-China science and innovation demonstrated in the CSSP China project is essential for a climate resilient future both in China and across the globe.

Professor Sean Milton
Associate Director of Foundation Science,
Met Office,
UK Project Executive for CSSP China

USING THE VIEWpoint HANDBOOK

This handbook is your guide to the resources produced by the VIEWpoint project. It provides easy access to climate science research and the emerging climate services developed by the successful Climate Science for Service Partnership (CSSP) China.

On these pages we share highlights of the world-class scientific research of CSSP China which is a collaboration with the China Meteorological Administration (CMA), the Institute of Atmospheric Physics Chinese Academy of Sciences (IAP CAS), Chinese universities and UK universities and organisations, which are led by the Met Office. The CSSP China project started in 2014 and has already produced more than 340 published scientific research papers. It is supported by the UK-China Research and Innovation Partnership Fund (supported in the UK by the Newton Fund).

Who can use this handbook?

Whether you are an experienced climate scientist, an early career researcher, involved in developing policy in national or local government, delivering climate services or making strategic planning decisions within a business, you will benefit from this handbook.

It guides you to cutting-edge scientific information and training resources to support decision-making, with signposts to further reliable information. This handbook also features links to digital versions of the content that can be shared and downloaded and data visualisations designed for a wide range of audiences with varying levels of technical knowledge.

Download and share the resources

VIEWpoint is a CSSP China project from the Institute for Environmental Analytics, a UK organisation that has produced a wide range of high-quality materials to support evidence-based decision-making to address climate risks leading to lasting benefits for China, the UK and international governments.

In this handbook you can:

- Read interesting features that give insight behind the science in layperson's terms
- Follow links to digital training resources, climate data tools and demonstrators of prototype climate services
- Read summaries of research and infographics produced for decision-makers from a wide range of backgrounds
- Follow links to videos designed for technical and non-technical decision-makers
- Share and download resources.

This wide range of content covers the sectors of Energy, Agriculture, Water, Health, Infrastructure and Cities. Each feature is marked with a colour-coded tab to show which sectors it is relevant to as well as a guide to the resources available (see facing page).

There is also an introduction to the online searchable catalogue (www.viewpoint-cssp.org/catalogue) of the more than 340 scientific papers that have been published during the lifetime of CSSP China. This is a unique compilation of research, much of which is already in use, informing plans and strategic decisions in support of China's pledge to achieve net zero by 2060. Read more about the catalogue on page 15.

VIEWpoint CSSP China website

This handbook should be used in association with the VIEWpoint CSSP China website which is accessible internationally. As well as being able to access resources mentioned in this handbook, you will find data visualisations for prototype climate services, a glossary of climate terms and an online, downloadable version of this handbook. Visit www.viewpoint-cssp.org

CSSP CHINA THEMES

The themes covered in the CSSP China Project are reflected in the contents of this handbook and are labelled in the colour-coded VIEWpoint logos on the outer edge of each page.

Shenzhen landscape, Image: Davi Costa / Shutterstock.com

ENERGY

WATER

CITIES

INFRASTRUCTURE

AGRICULTURE

HEALTH

TRAINING RESOURCES

SCIENCE INSIGHTS

BRIEFING NOTES

The CSSP CHINA PROJECT

By Jamie Mitchell, Met Office

CSSP China has brought together a wide range of disciplines, all working together to build a solid foundation for the challenging but crucial task of developing new climate services that can support climate-resilient economic development and social welfare in both countries.

This diverse community includes academics who make the scientific advances, the private sector (such as Arup) who take the science and transform it into something that can be used to help make decisions (such as the climate risk assessment tool) and also communication and visualisation experts (The Institute for Environmental Analytics) who translate the science so that it can be understood and accessed by a wide range of audiences in both countries and beyond.

Having such a range of skills and tools to draw upon has benefitted the project immensely and meant we have achieved more than if only one discipline had tackled the problem.

The project contributes authoritative climate science to the United Nations Sustainable Development Goals, which aim to achieve a better and more sustainable future for all. The interconnectedness of sustainability means that the project contributes to many of the 17 Goals, from food security (Goal 2) to resilient infrastructure (Goal 9), and from sustainable cities (Goal 11) to strengthening partnerships (Goal 17).

At its heart, CSSP China supports climate action (Goal 13), in particular target 13.1 (strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries and regions around the world), by developing new climate services that support climate-resilient economic development and social welfare in both China and the UK. For example by helping dam operators prevent flooding along the mighty Yangtze River, informing Shanghai's 2017-2035 Master Plan and supporting the UK's National Flood Resilience Review. Central to the achievement of CSSP China has been the focus on building new relationships, many of which will last well beyond the lifetime of the project. From the start it has been clear that together we are more effective at tackling global challenges such as climate change, than we are alone. The exchange programme has been very successful – with individual scientists (many of whom are in the early stages of their career) spending significant amounts of time (in some cases up to two years) working in their partner institutes.

This has not only strengthened the analytical, problem-solving and communication skills of the people involved but also enhanced their visibility and profile internationally.

Many have spoken of the value and importance of sharing the new knowledge and expertise gained with their own institutions when they return home. Just as importantly it has opened them up to a new culture and way of working and therefore brought fresh ideas to tackling problems of global importance such as climate change.

These relationships have been strengthened and solidified by the many science workshops, where all partners meet to discuss their research and map out what they want to achieve in the next year together. These face-to-face visits (pre Covid-19) were an extremely effective way of setting up strong and resilient partnerships which are still running well, despite the move to virtual meetings.

We look forward to the next time we can meet our partners in person and the long continuation and success of this project.

Jamie Mitchell
Met Office

CATALOGUE OF PAPERS – A LASTING LEGACY

By Hui Jia, Institute for Environmental Analytics

A curated catalogue of 340+ publications supported by CSSP China has been produced and published on the VIEWpoint CSSP China website: www.viewpoint-cssp.org/catalogue

By archiving all the published papers in one place, the catalogue enables easier access to the key scientific knowledge produced under CSSP China on fundamental climate science, the specifics of climate, climate change and climate services.

The online catalogue is freely accessible and can be used by researchers and other users around the world wanting to know the details of the scientific methods and results.

Gathering the papers into one public site will continue to fulfil CSSP China's aims of helping to inform a wider base of scientists, engineers and other users. The indexed, searchable catalogue has the added advantage of using themes so users can filter results by different topics of interest.

The publications cover a variety of topics, from fundamental research (e.g. assessment of satellite instruments), to development of state-of-the-art climate models (e.g. integrated model for urban transport), to assessment of model skills for specific sectors (e.g. wind speed assessment for the energy sector), to development and application of climate services (e.g. seasonal forecasts of tropical cyclones).

These records are organised into a bibliographic database, with abstracts (where available), digital object identifiers (DOIs) and the keywords tagged provided by publishers (where given). In addition, a key feature of this curated catalogue is the key-theme-based tags created by VIEWpoint according to the CSSP core sectors, including:

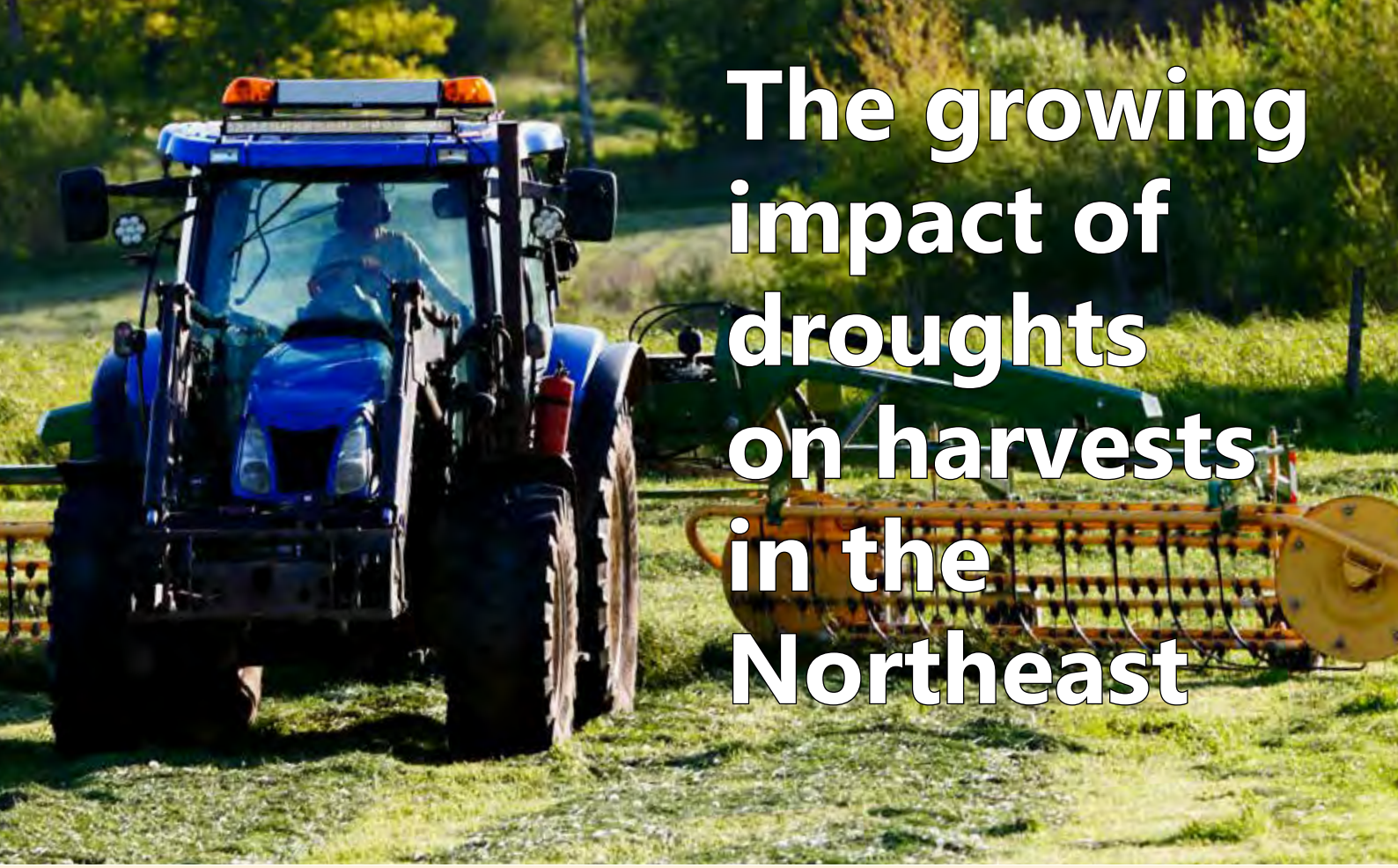
- air quality
- energy
- water resources
- cities
- food security.

Furthermore, plain language tags, such as extreme events, storms, flooding, droughts, and long-term risks, are also adopted to indicate common areas of interest to stakeholders.

VIEWpoint has made this vast scientific resource available in one place, through the VIEWpoint CSSP China website, as a lasting legacy for the continuous use of data, knowledge and applications for the benefit of scientists, engineers and others in the multi-disciplinary world of climate services, including end-users.

Scan this QR code to visit the online catalogue at www.viewpoint-cssp.org/catalogue

The VIEWpoint CSSP China catalogue is a comprehensive, searchable database of the project's scientific papers. You can explore it at www.viewpoint-cssp.org/catalogue



The growing impact of droughts on harvests in the Northeast

Image: Christian Lagerek / Storyblock.com

"This change in characteristics would be expected to increase their impact across the food system ... and are more likely to need a multi-agency response"

– Jemma Davie, Project Scientist working in Climate Security at the Met Office

FOOD SECURITY IN CHINA

By Sally Stevens, Institute for Environmental Analytics

Research into the impact of our warming climate on China's food supply chain has implications that reach around the world.

It is also helping to improve resilience in the UK food supply chain and to better understand risks to global food security.

The Food Security In China research was carried out by scientists at the Met Office, the National Climate Centre at the China Meteorological Administration (CMA) and the Southern University of Science and Technology in Shenzhen (SUSTech). It focused on the Northeast region which forms part of China's 'maize belt'.

Multiple bread basket failure

The CSSP China Food Security project has developed work, published in 2017, exploring the potential for simultaneous multiple failures in key major crop-producing areas of the world - known as 'bread baskets'. By combining data on air temperature and rainfall, based on climate model simulations representative of the period from the 1970s to the present, it concluded that there is a 6% chance per decade of maize yield being reduced (yield shock) by drought in both the USA and China in the same year.

Jemma Davie is a Project Scientist in Climate Security at the Met Office. She worked on the CSSP China research that looked at multi-bread basket failure, drought, yield relationships to sea surface temperature (SST) and seasonal predictions of adverse summer climate conditions.

She says: "Different aspects of our research looked at climate conditions in the Northeast region of China and the likelihood of

water shortage or water excess and also applied it to soybean, wheat and rice crops.

"China and the USA are where the vast majority of maize is produced, so simultaneous yield shocks in both countries would reduce the availability of maize globally, with knock-on effects for trade.

"We have also applied the methods as part of different projects to other countries, including within Europe and other areas from where the UK imports its wheat supply."

More severe drought over a wider area

The research found that in a warming climate, future droughts in Northeast China are more likely be severe and connected into one large area, rather than consisting of several disconnected smaller areas of drought. This change in drought characteristics would be expected to increase their impact across the food system, requiring a more co-ordinated and strategic response by decision-makers across the region.

Image: Pixabay

Jemma explains: "Our analysis on the output data of climate simulations shows a shift from drought that affects lots of small pockets of agricultural land to larger, joined-up areas being affected towards the end of the century, using a combined temperature and precipitation-based definition of drought. However, the metric we use affects the results - this shift to larger areas being affected is not evident for a precipitation-only based drought definition.

"Large-scale droughts are likely to be driven by a combination of global and local influences - which may include the El Niño Southern Oscillation (ENSO) and East Asia Jet. Future droughts are generally expected to be larger in area and therefore more likely to need a multi-agency response that is co-ordinated across regions."

Sea Surface Temperatures and seasonal predictions

The ability to give an early indication of crop-threatening conditions would be a valuable tool for strategic planners and decision-makers in the food supply chain.

Jemma says: "We are researching potential links between Sea Surface Temperatures and crop yields and exploring which areas of the global oceans are important as potential predictors of crop yield in China; for instance are Sea Surface Temperatures in the Tropical Pacific during winter and summer a good predictor of growing conditions that will influence maize yield? We also looked at the way we define what adverse climate conditions are and finding thresholds that give the best skill in predicting whether there will be a yield shock or not, to limit potential false alarms."

The next step for the Food Security project is to quantify the risk of adverse climate conditions in North China and the Northeast China Plain, links to the winter climate and how it relates to the following summer, and whether this can be developed into a seasonal forecast as an annual climate service.

Work is focused on developing the research into climate service tools, informed by feedback from potential users in China. A questionnaire is being sent to farmers, industry decision-makers and policymakers to tailor a decision-support tool to their specific needs.

Find out more about the CSSP China Food Security research - page 53

Download and share CSSP China resources

Use this QR code to download the Met Office Food Security in China infographic

Weather conditions carefully recorded by sailors long ago are helping us to plan for our future

Image: Nikolay Vorobyev/Unsplash

"There are 'lost' archives around the world, historic weather observations by the millions ... we are finding them, digitising them and feeding them into our climate modelling systems"
– Dr Philip Brohan, Climate Scientist at the Met Office

HISTORIC DATA RESCUE

Dr Philip Brohan, Climate Scientist, Met Office

The Yangtze is one of the world's great rivers – rising in the Tibetan plateau and running for more than 6,000km through central China – past the cities of Wuhan, Nanjing and Shanghai – to its outlet in the East China Sea. In the summer of 1931, the river flooded, killing perhaps 2million people in the deadliest natural disaster of the 20th century.

Why did this happen? What was it about 1931 that caused the flood and, critically, what can we learn from this event about future flood risk?

If we could go back in time by 90 years we could monitor and forecast the flood: collecting observations of temperature, pressure and rainfall from local weather-stations and ships, and using those in our modern sophisticated weather-forecast models. Then we could say exactly what happened and why. Climate researchers in 2021 working on the CSSP China programme are attempting just this sort of time travel – looking back into libraries and archives for observations made during the flood and combining those historical observations with today's computerised climate models to build new reconstructions, and learn about future risks.

Although the flood was in China, researching it requires international coordination: we need historical weather observations from China, we need historical observations from nearby countries and from British and American ships, and we need specialist skills in historical weather modelling – in reanalysis.

How do climate records from the past make a difference to our future?

Dr Philip Brohan, a Met Office Climate Scientist, says: "We are using records of the past to predict the future. If we didn't have past records of extreme weather events, we wouldn't be able to put future expectations into context; to know whether an extreme weather event has happened before; is what we are forecasting better or worse than what has happened in the past?

"All of our knowledge about what is likely to happen in the future relates to having good knowledge of what happened in the past. If we can reconstruct extreme weather events in the past, and the conditions that led to them, we can predict with much greater confidence and certainty what is likely to happen in the future."

With funding from CSSP China, historic records from around the world are being gathered by the ACRE project (Atmospheric Circulation Reconstructions over Earth), combined with near real-time weather observations and fed into global reanalyses to re-run models of Earth's changing climate.

Philip says: "There are 'lost' archives around the world, historic weather observations by the millions, in dusty museum basements, shipping company archives, maritime coastguard records, even personal diaries. We are finding them, digitising them and feeding them into our climate modelling systems."

The China Meteorological Administration (CMA) is leading the hunt for historic data records within China, the Met Office is adding records from stations in India and South-East Asia. Ship records are also critical – weather observations were made by ships of many nationalities in the seas around China. We even have a few observations gathered sailing on the Yangtze itself – the river is navigable inland for thousands of kilometres.

Philip says: "The direct relationship with CMA that we have through CSSP China provided us with weather observations that we need to produce a good enough forecast. Without the partnership and CSSP

Continues ...

resources we would not be able to attack this issue at all."

How will using historic data make a difference in China?

The reanalyses are being carried out by the National Ocean Atmospheric Administration (NOAA) and the University of Colorado. The results are used by scientists in the UK in attribution studies to find out what conditions brought about such devastating flooding of the Yangtze River in 1931, with much more reliable results thanks to the historic data. The vital question is – could it happen again?

Philip says: "Because it is not a model but a combination of model and observations - a reanalysis - we are able to get a much more precise model output. Then we can experiment by varying some of the conditions and seeing how the outcome would change. For instance, 1931 was an El Niño year, that was a key factor but what happens if we remove El Niño from the model? How will the risk of severe floods change?

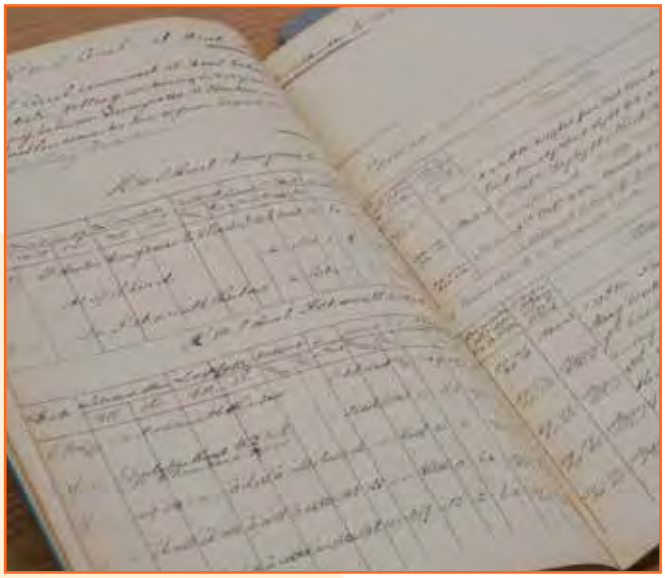
We have demonstrated that reanalysis-based attribution is a useful way of identifying what contributed to extreme events.

"We also hope to demonstrate with great confidence what are the meteorological drivers of extreme weather and then add confidence that we are going to get predictions right. Our aim is to bridge the gap between things we can predict with great confidence, like climate warming, and severe weather like large scale floods that cause great loss of life and damage in particular countries. The UK – and in particular the Met Office – has a tremendous international record in attribution.

"The ACRE partnership has made it possible to get people together to do this. Over the next year we are going to get some radical new results to really understand the 1931 Yangtze River flood. We also hope it will inspire other partnerships.

"The approach we are taking is also useful for attributing severe weather events in other places around the world so it can be used much more widely. Every country in the world has its own severe weather events which it wants to attribute."

Read more about CSSP China attribution workshops - pages 28-30



Above and right: Old records of weather conditions, many discovered in historic shipping logs, are being used to build more precise computerised climate models. Images, CSW Associates – Data Services.

We need your help to save historic data

Everything we know about past weather depends on the observations made by sailors decades ago and recorded in their logbooks. To use those observations for science, we need to read those old logbooks and transcribe their contents. This is a massive task and we rely on the help of thousands of volunteers. If you can spare an hour to read some history and rescue some weather records, please join us at https://www.oldweather.org/

"It has been a huge amount of work from many people and it has been very successful"
– Dr Philip Bett, Senior Scientist in Impacts of Climate Variability at the Hadley Centre

YANGTZE RIVER BASIN SEASONAL FORECASTS

By Sally Stevens, Institute for Environmental Analytics

Improved skill in seasonal forecasting of China's heavy summer rainfall is supporting key early decisions to manage the risk of treacherous flooding in the Yangtze River Basin.

The forecasts, issued in early spring and updated again before the summer, are the result of close collaboration between climate scientists at the UK Met Office, the China Meteorological Administration (CMA) and Institute of Atmospheric Physics (IAP).

They give a probability of above or below average rainfall in the summer ahead to support those making life-saving and economically vital decisions about how much water should be released from the many dams along the river and its tributaries to avoid flooding, at the expense of maintaining hydroelectric energy supplies.

Co-developing climate services

Through CSSP China, Met Office Hadley Centre researchers and applied climate scientists have worked closely with the CMA and its Regional Climate Centres on the timing and geographical areas covered since the first trial seasonal forecast was issued in 2016. The outcome is an operational seasonal forecast that has been refined to meet stakeholder needs and the process is now being used as a template to co-develop other climate services in China and around the world.

Dr Philip Bett, Senior Scientist in Impacts of Climate Variability at the Hadley Centre, liaised between the Met Office's climate scientists and applied climate services teams, and the organisations in China responsible for making decisions based on seasonal forecasts for the Yangtze River Basin. He says: "I found it very rewarding to work on something that is

Continues ...

Matching solutions to needs for the wet season

The Yangtze River Basin, image: Shutterstock

both so scientifically robust and meets the needs of partner stakeholders in China. Producing the trial seasonal forecast for the Yangtze River Basin in 2016, and then refining it to meet more closely the needs of those making decisions has meant we have a prototype to be able to produce more and similar kinds of climate services in the future."

How is the Yangtze River Basin seasonal forecast produced?

In 2014 Met Office CSSP China researchers began using its global seasonal forecasting system, GloSea5, to look in greater detail at how it performed in East Asia and the Yangtze River Basin, which had been devastated by flooding in 1998 with massive loss of lives and huge economic losses.

GloSea5 is an ensemble climate prediction system, producing a set of forecasts that give an indication of the range of possible outcomes to provide a probabilistic forecast of future conditions.

A trial seasonal forecast was presented in May 2016 to the Spring Consultation Meeting in Wuhan, where the CMA gathered with representatives of Regional Climate Centres of the 10 provinces through which the Yangtze flows, as well as water and energy managers.

Over two days of discussion and feedback, it became clear that the forecast needed to be delivered earlier in the year and, as well as looking at the whole vast river basin, looking at two distinct regions - upstream and downstream of the pivotal Three Gorges Dam - would be more useful. So changes were made to give the forecasts longer lead times and greater spatial resolution than before.

Philip says: "The Yangtze has such different characteristics along its length that upstream and downstream are important distinctions when you are managing the dam."

Generally, four forecasts are released each year, in February, March, April and May, and these cover the May-June-July and June-July-August periods. From 2020, an additional forecast was included in each release, focusing on the June period in particular, which usually sees the peak in rainfall.

How is the CSSP China seasonal forecast used?

Forecasts cover the whole basin, as well as the upstream and downstream regions separately. Philip adds: "We make sure we clearly show the range of uncertainty using error bars, and how the forecast compares to previous years."

The Spring Consultation Meeting informs strategic planning decisions on how much water in the reservoir behind the dam should be released ahead of the heavy summer rainfall season. This aims to reduce the risk of flooding in the densely populated and valuable agricultural and industrial areas downstream while at the same time avoiding disruption to the dam's energy production as much as possible. Philip comments: "The decisions you take on the basis of a seasonal forecast are really different from decisions you take on a day-to-day or week-to-week timescale.

"The success of the Yangtze River Basin Seasonal Forecast comes from not just taking the seasonal forecast model output and blindly using it, but in finding ways of post-processing the data to maximise skill; continually doing the user engagement as well as the robust science and carefully producing something useful and important to the stakeholders, keeping high levels of realism about the certainty and uncertainty.

"There has been a huge amount of work by many people and it has been seen as very successful within the CSSP China project, including with our Chinese colleagues."

Why does it matter?

The Yangtze River is the third longest river in the world and its 6,300km length (3,915miles) snakes from the glacial meltwaters of the Tibetan Plateau, through mountains, steep valleys and the important hydroelectric power source that is the Three Gorges Dam.

It serves shipping ports in the industrial cities Chengdu, Chongqing, Wuhan, Nanjing and branches out into a densely populated delta of lakes, tributaries and marshes before reaching Shanghai at its mouth

Strategic planning decisions relating to the operation of the Three Gorges Dam are taken in the spring. Image, Shutterstock

on the East China Sea. Its basin covers a fifth of China's land mass and is home to one third of China's population. Its fertile agricultural lands contribute nearly half of China's crop production and more than two thirds of its rice, and are also important for fish production. But the Yangtze River's water levels fluctuate hugely and it is prone to devastating flooding with 60%-80% of its precipitation falling in the summer monsoon season.

The Three Gorges Dam is the world's largest power station and in 2018 its output exceeded 100billion kilowatt hours while at the same time managing small and medium-sized floods experienced during that year's heavy rainfall in the upper reaches of the river.

What is next and what can we learn from the process?

In addition to the new single-month June forecast launched in April 2020, another service already being issued by CSSP China and based on the prototype is seasonal forecasts of tropical cyclones in East Asia. A working prototype has also been developed for a wind speed seasonal forecast.

Philip reflects: "It is important to appreciate that none of the steps in co-developing a service like this are easy or trivial. The unique thing for the Met Office's CSSP team is that we combined the efforts of the climate researchers and the climate service scientists. The benefit of the CSSP funding having a clear scientific development aspect, as well as a climate service aspect, is that climate science research and applied climate science have been able to work alongside each other and with users, over seven years, and that is quite rare but very important."

Read about the wind speed seasonal forecast on page 24

Dr Philip Bett is a senior scientist in the Impacts of Climate Variability team within the Monthly to Decadal Variability & Prediction area of the Met Office. His research focuses on developing new ways of using seasonal forecasts, often with applications in the energy sector in the UK, Europe and China.

New research enables earlier planning for storm landfalls

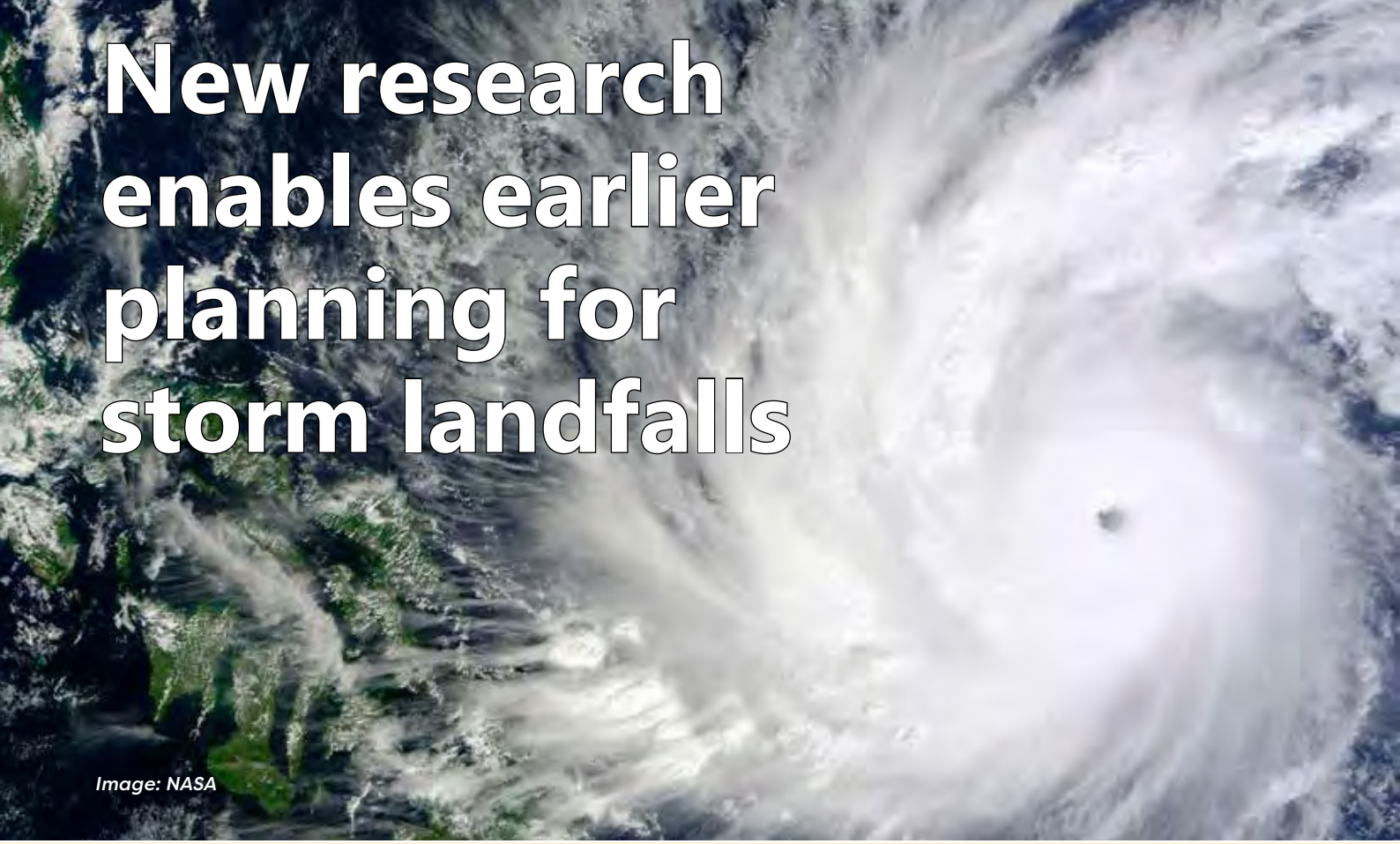


Image: NASA

"We are keen to find additional organisations to work with in China"

– Dr Tim Mitchell, Climate Scientist at the Met Office

SEASONAL FORECASTING OF TROPICAL CYCLONES

By Sally Stevens, Institute for Environmental Analytics

Tropical cyclones are one of the most destructive major disasters that can strike – torrential rain, powerful winds, tidal waves, floods, landslides, buildings destroyed, fatal injuries, economic losses and long-term disruption are left in their wake. China already suffers more than most countries with its extensive Eastern and Southern coastline exposed to the Western Pacific ocean basin – the origin of the highest number of tropical cyclones each year.

To support adaptation to the increasing threat China and other cyclone-prone countries are facing, the CSSP China project has delivered a prototype Seasonal Forecast for Tropical Cyclones climate service to predict the likely number of tropical cyclones making landfall along China's Eastern Coast in the coming summer. The real value of this service, developed by the Met Office, is that, unusually, it forecasts landfall rather than only predicting the number likely to develop in the ocean basin in the season.

The first trial forecast was issued in May 2019. Responding to feedback from China that an earlier forecast would be of greater value for decision-making, the prototype was further developed to the extent that the first forecast for June, July and August was issued on March 1st, 2020, followed by an update on April 1st that year and a further refined forecast on May 1st.

How are the tropical cyclone seasonal forecasts produced?

The Met Office has worked in partnership with the China Meteorological Administration (CMA) and China's Institute of Atmospheric Physics (IAP) as part of the CSSP China project, and continues to reach out to users in China for further feedback. The forecasts are based on the

Met Office's renowned GloSea5 seasonal forecast system, which has shown a high level of skill – or accuracy – for predicting the risk of tropical cyclones making landfall in East China.

Dr Tim Mitchell, a Met Office Climate Scientist working on CSSP China, says: "Historically seasonal forecasts for tropical cyclones anywhere in the world have usually been for entire ocean basins but what is really important is to know about the chances of one making landfall on a particular stretch of coastline. People have been trying for some time but there just hasn't been much skill in forecasting areas in which a tropical cyclone might make landfall.

"What we are now able to do is look at various large-scale factors in the atmosphere and in oceans and the statistical relationships to large-scale features in the climate system, to predict the likely number of tropical cyclones making landfall along this stretch of coastline.

"At the Met Office we have developed a seasonal forecast model that does a very good job of representing what is likely to happen. The Met Office model is one of the best in the world and particularly skilful in the western Pacific where these cyclones form and develop."

How are the forecasts used to protect people and economies?

The Met Office forecast focuses on the heavily populated East China Coast, including the Yangtze River Delta and Shanghai, vital areas for industry and agriculture for China and the world.

The CMA receives the Met Office's Seasonal Forecast for Tropical Cyclones in the context of its own work to develop climate services supporting decisions in the energy, water, agricultural and industrial sectors, and disaster risk management planning along the East coast of China. It is constantly facing the challenge of changing weather hazard patterns in the world's changing climate and the need for more reliable data, and at the earliest possible time, to inform effective decisions to minimise loss and damage.

The forecasts cover China's summer – June-August, when the country braces for its heaviest months for tropical cyclones – but the country's risk analysis and policy decisions start in early spring.

In 2019 the Met Office forecast was in the middle of the range of possibilities, as there was no indication to suggest an unusually 'busy' or 'quiet' season. The long-term average for this strip of coastline is three tropical cyclones in a summer. In the event, three tropical cyclones passed through the designated area.

In July tropical storm Danas (also known as Falcon) caused most damage in the Philippines. In early August tropical cyclone Lekima made landfall in China, affecting 5million people in the Zhejiang coastal province and its largest city, Hangzhou. It was reported that 90 people died and 1million people were evacuated from their homes; 250,000 people were evacuated from Shanghai; 34,000 homes were damaged. Towards the end of August severe tropical storm Bailu swept in over China, hitting Fujian, having weakened after striking in Taiwan.

Tim says: "In May 2019 colleagues visited China to present the first trial forecast in person to the CMA and had direct conversations with the people who would be using it. The feedback we received from our Chinese colleagues was that it would fit best into CMA's process if we could produce the forecast earlier in the year. On our return to the UK we found we could produce a forecast for June, July and August on March 1st which still had a level of skill. That was issued for the first time in 2020 and it was followed by updated forecasts on April 1st and May 1st."

Next steps

The research has potential for wider, global use in the future. In the meantime, Tim says: "We are keen to find additional organisations in China to work with us on the prototype to develop it even further, organisations that would use the information we are producing to make real-world decisions. They don't necessarily need to be big set ups."

Contact Dr Tim Mitchell by email tim.mitchell@metoffice.gov.uk

Read more - Page 42

THE IMPLICATIONS OF CLIMATE CHANGE FOR TEA PRODUCTION: CHALLENGES AND OPPORTUNITIES

By Sally Stevens, Institute for Environmental Analytics

Are there any worries that cannot be eased by pausing to savour a refreshing cup of good quality tea? In an uncertain world how can we ensure that millions of tea-drinkers can still rely on relaxing with an exquisitely flavoured cup of tea in the future?

Scientists are exploring the potential impact of climate change on the delicate tea plants that provide tea-drinkers worldwide with a refreshing and calming brew.

China is not only the largest tea-producer in the world, producing 2.8million tonnes in 2019, according to the National Bureau of Statistics China, Chinese people have also been savouring cups of tea for more than 5,000 years.

Yunnan is the largest tea-producing province (480.9k hectares in 2019, reports the National Bureau), followed by Guizhou, Sichuan and Hubei, and it is in Yunnan that China's most popular variety of post-fermented tea, Pu'er, is grown. Skills in cultivating tea plants and harvesting the leaves have developed over thousands of years, with farmers gaining deep knowledge and understanding of the plants' sensitivity to extremes of weather. But how will our changing climate affect this vital agricultural industry in the future? And can the findings give an insight into the relationship between food production and climate elsewhere in the world? Understanding the influences of past weather events and the potential impact of future changes in climate on tea production is important for planning how to protect, develop and adapt tea cultivation, especially in Yunnan Province which is regarded as unique in the world in terms of landscape and climate characteristics. The research has also provided UK scientists with opportunities to explore different aspects of climate model evaluation over the region and to develop new best practice in engagement with a range of users, for the benefit of the wider climate services community.

The history of tea production in the wild tea forests of Baoshan, in Yunnan, dates back more than 3,000 years. Its climate and landscape make it one of the most suitable areas for the best crop for Pu'er Tea which is highly valued for its ability to be aged for decades, developing in depth and texture. Trees here can be hundreds of years old, their roots having grown deep into mineral-rich soil.

This is where Chinese scientist Dr Shaojuan Li, associate professor at the School of Urban and Environment, Yunnan University of Finance and Economics, began her research as part of the CSSP China project. She talks about her findings and the messages it has for tea growers:

Question: Why is understanding China's changing climate so important for tea production?
Answer: The growing state of tea plants is very sensitive to climate variability and change, and the latter directly impacts tea yield and tea quality. With global warming and frequent occurrence of extreme climate in China, tea production has been significantly affected. It is very important to understand China's changing climate, especially in tea-producing areas. The quality of the tea and the crop yield are affected by different precipitation events, including periods of prolonged rainfall, continuous dry events and heavy rainfall.

To our knowledge, our research work is the first study devoted to exploring tea price, different steps of the tea primary processing, and their relationship with multi-decadal climate records. Tea areas in China are widely distributed in different climatic zones, with significant differences in geographical location and climatic conditions.

Considering that the growth state of the tea plant is directly affected by climate variability and change, it is very important

For all the tea in China ...

"To our knowledge, this is the first study devoted to exploring tea price, different steps of the tea primary processing, and their relationship with multi-decadal climate records"

– Dr Shaojuan Li, Associate Professor

Image: Shutterstock

to study the influence of multi-timescale climate events on production in different famous tea areas of China, especially in Yunnan, where there is still a lack of research. In addition, understanding the influences of past multi-timescale weather events and the potential impact of future climate changes on tea production is very important to develop and adapt tea cultivation.

Q: Are there opportunities for further research?

A: Because of the special geographical location and climate conditions, the Baoshan tea area has superior climate advantage resources with excellent tea quality, sometimes even better than other famous tea areas in Yunnan, China. Therefore it has good tea crop species, which can be processed into the best black tea and Pu'er tea. And there are still many undeveloped areas for wild tea cultivation in Baoshan that have great potential for exploration and research value. In the future, we can consider further developing high quality tea products from the Baoshan tea area. Furthermore, the relationship between extreme temperature events and tea production will be evaluated in our future work. The existing research is based on the Baoshan tea area, and the further research can be broadened to other tea areas.

Q: Where can we find out more?

A: More information can be found on the Chinese Government's official website, in officially published books and academic articles. Having finished the first stage of our research work, our paper 'The Influence of Multi-timescales Precipitation Events on Tea Production: A Case Study from Baoshan, Yunnan, China' will be officially published in due course.

Dr Shaojuan Li is an Associate Professor at the School of Urban and Environment, Yunnan University of Finance and Economics. She has almost 16 years' experience in climate change, climate modelling and the impact of climate change on cash crops production in mountainous regions.

Joint efforts are unlocking the lessons of severe weather

Image: Shutterstock

"It gives both countries better ideas of what is driving climate change in China and better understanding"

– Prof Simon Tett, University of Edinburgh

ATTRIBUTION WORKSHOPS

By Sally Stevens, Institute for Environmental Analytics

CSSP China's Attribution Workshops have produced some of the programme's most effective, efficient and robust published scientific collaboration in a successful format that is being replicated around the world.

It brings leading scientists and early career researchers in China and the UK together to produce scientific papers examining the extent of the impact of anthropogenic climate change on specific recent extreme weather events in China. It has proved so successful that the workshop template is being applied to CSSP attribution activities in other global regions and to other climate projects. Dr Sarah Sparrow, climateprediction.net (CPDN) Programme Co-ordinator at the Oxford e-Research Centre, is involved in CSSP Brazil, and describes the Attribution Workshops as 'learning by doing' adding: "Most of the participants are early career researchers and we warn them when they sign up that it will be hard work but by the end of the week they will have the basis of a paper to take away and finish for publication."

Published papers are a highly prized and respected measure of achievement in China's scientific community, as well as an important way of sharing findings among the country's widespread climate services community.

A new approach to producing climate research papers

The Attribution Workshops present an innovative and collaborative approach to writing papers with all members of each study group expected to contribute equally.

This requires subtle monitoring of each group's dynamics by the organisers. They support the development of abstracts but are clear that the participants

– for some of whom this will be their first published paper - are the people doing the research and drafting the paper. In some cases the outcome of the workshop will prompt further and wider research and study resulting in further papers to other journals.

Professor Simon Tett, Chair of Earth Dynamics and Modelling at the University of Edinburgh, has been involved in several CSSP China projects and says: "The science gained is really useful on both sides, it gives both countries better ideas of what is driving climate change in China and better understanding."

6 steps to a successful attribution workshop

1. Preparation: Around 10-15 participants join the workshop, each nominating an extreme weather event to study. They are split into three groups of five. Each group is led by two trainers – one from China and one from the UK - and studies one of the events selected by the organisers.

2. Data: Organisers place participants into groups to ensure an even spread of skills and they are tasked with seeking approval and bringing relevant data to the workshop. The participants bring local data to include in the studies, such as recorded temperatures or rainfall cross the region.

3. Training: The workshop opens with an overview of the attribution method following a process for risk-based evaluation of extreme events published by Dr Friederike Otto, of the Environmental Change Institute, in 2017.

4. Opening task, defining the extreme event: The first task is to properly define what the event is, that by duration and geographical area it represents a class of events. Sarah explains: "We work quite closely with the participants at this stage because often it will be the first time they have had to think about an extreme weather event in this way but it is vital for a meaningful outcome."

5. Progress and feedback: Regular informal presentations on progress within each group and the group as a whole, each day and at the end of the week, facilitate feedback and build skills and confidence.

6. Producing a research paper: From the very start participants know they are expected to contribute to producing the draft of a research paper by the end of the week. Organisers support in drafting abstracts and participants continue to collaborate to complete papers after the workshop, ready for submission to a chosen journal, or a special issue, as in the Supplement to the Bulletin of the American Meteorological Society (BAMS) in January 2020.

Building communications skills

One activity key to the success of the workshops is a daily presentation by each study group to the entire group, with feedback from the trainers and from their peers. This helps progress to be monitored and compared by the trainers, improves each group's focus and builds skills in a semi-formal, relaxed environment.

"Over a week everyone takes a turn at presenting," says Sarah. "For many it will be the first time they have stood up to present to a group in English. It helps them to see common themes, share ideas and grow more confident in presenting."

On the final day of the workshop each group delivers a combined presentation on their study which has led to an increase in post workshop interactions between the participants.

Maintaining momentum and next steps

As awareness of Attribution Workshops spreads, the remit maybe extended to give stakeholders the opportunity to join participants for the final showcase presentations.

In addition, longer workshops could include training in communicating the results of the research to stakeholders and policy-makers, producing written summaries and/or video explainers which would be published alongside publication of the research paper.

Over the course of each workshop organisers use the opportunity to talent-spot potential future workshop trainers with the ultimate aim of forming a team of climate scientists able to foster doing attribution studies and to undertake studies in the host country, independently of the workshops. International Attribution

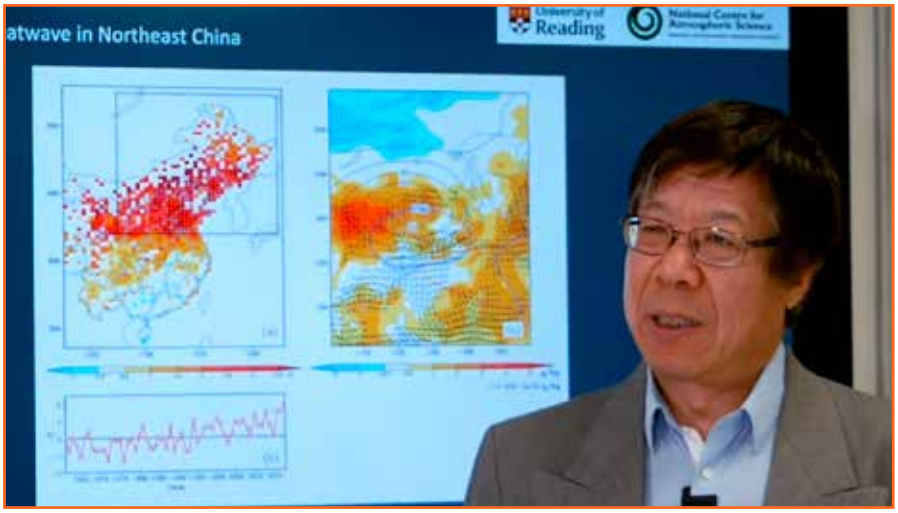
Continues ...

Workshops can bring together scientists studying climate in different global regions – one has already been held for Brazilian and Chinese early career researchers. Working in national groups on relevant extreme events and sharing daily presentations, allows common themes to be identified and shared as well as nurturing continued international collaboration on climate change.

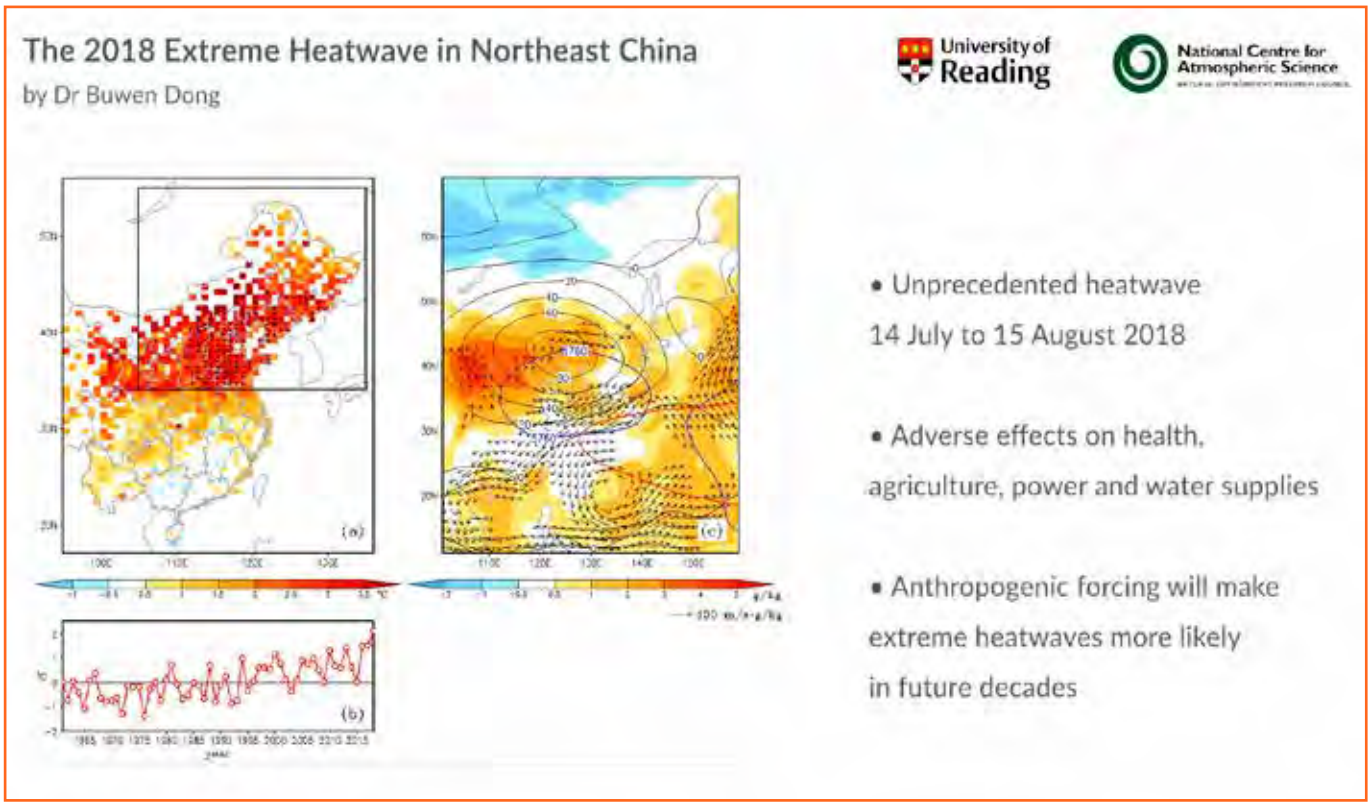
During the Covid-19 travel restrictions a CSSP Brazil virtual Attribution Workshop successfully trialled a new format: including a group working on the impacts of the extreme event alongside the attribution group and it included a communication skills session for all.

In the future, all three groups could be tasked with studying the same extreme event, one taking a standard approach; one focusing on large scale dynamics that led to the event occurring and one focusing on the impacts of the event. This would result in a fuller picture at the end of the workshop. Further post-workshop development could be to run a hydrological model and weave in more social science, getting the participants to think more broadly and about how different aspects of an extreme event might be linked.

Investigating heatwaves in China under climate change - read more about attributing extreme weather events on page 34.



Dr Buwen Dong, above, discusses his work on attribution workshops in a VIEWpoint video. His research covered the extreme heatwave in Northeast China from July 14 – August 15, 2018, which had adverse effects on health, agriculture, power and water supplies. He concluded that anthropogenic forcing will make extreme heatwaves more likely in future decades (below).
Use the QR code on the facing page to watch the video.



"We held 4 workshops and so far we have published 9 scientific papers"

– Dr Buwen Dong, NCAS

UNTANGLING THE NATURAL FROM THE MAN-MADE

By Vicky Lucas, Institute for Environmental Analytics

One of the most successful elements of CSSP China has been the initiative to hold Attribution Workshops for scientists and early career researchers, with a number of these mutually beneficial events held in the UK and China. These workshops have allowed the careful analysis of extreme weather events in China, to establish the repercussions of climate change in influencing episodes of dangerous weather across the country.

Climate attribution is a particularly challenging task in meteorology. There has always been wild weather, but are storms getting stronger, are heatwaves more intense or wildfires more widespread?

Attribution studies investigate, for a well-defined large-scale event, to what extent did human emissions of greenhouse gasses augment that incident? The technique of climate attribution looks carefully at significant events, often within a few weeks or months of them occurring, to rigorously determine the extent to which anthropogenic climate change affected the severity, duration or frequency.

Following the thread

In the summer of 2018, Northeast China was affected by an unprecedentedly long and intense heatwave. The China Meteorological Administration (CMA) issued 33 consecutive days of high temperature alerts through July and August.

On July 30th that year, the number of heat-related hospital admissions broke the historical record in Shenyang, a city with a population of 8million.

In a short video interview, produced by VIEWpoint for the CSSP China project, Dr Buwen Dong, of the UK National Centre for Atmospheric Science (NCAS) at the University of Reading, speaks about the Attribution Workshops and the heatwave of 2018 (use the QR code, below, to watch the video).

The resulting scientific paper, initiated in a CSSP China Attribution Workshop, described that the prolonged high night-time temperatures experienced are, in particular, much more common with the anthropogenic contribution of climate change.

Weaving together

The persistent night-time heatwaves - like the summer of 2018 in Northeast China - are extremely rare in the natural world, about a 1 in 500-year event, but they have now become a 1 in 60-year event with the addition anthropogenic warming. In the CSSP China workshops, delegates and trainers collaborate intensely. They firstly identify large-scale events for investigation and then spend a few days outlining and analysing together, and then continue to collaborate on research once back home. The aim and achievement of the workshops has been numerous jointly published scientific papers, strengthening the formal and nurturing the informal research connections between China and the UK.

Buwen says: "We aimed to publish our research in the annual Bulletin of the American Meteorological Society (BAMS) special issue about extreme weather events that have happened in the previous year. As it turned out, we were very successful. We held four workshops in total and so far we have published nine papers, including seven in the 2020 BAMS special editions, with another three submitted and currently in revision. The papers cover quite a range of different topics, for example, drought and heavy precipitation, as well as heatwaves."

Read more and watch the video

Anthropogenic Influences on the Persistent Night-Time Heat Wave in Summer 2018 over Northeast China (Ren et. al, 2020)
https://doi.org/10.1175/BAMS-D-19-0152.1
Scan the QR code (right) to watch the video

Step-by-step way to test the climate resilience of our cities

Shanghai. Image: Leslin Liu, Pixabay

"Climate change is happening, it is urgent that we better understand and prepare for future climate"

– Maria Sunyer Pinya, Arup

CLIMATE RISK ASSESSMENT OF INFRASTRUCTURE

By Vicky Lucas, Institute for Environmental Analytics

A step-by-step tool to assessing the risk that climate change poses to city buildings and infrastructure has been developed for Chinese cities.

Developed by global engineering, design and consultancy firm, Arup, the Climate Risk Assessment of Infrastructure Tool has been designed to be used by a wide range of planners and decision-makers.

The structured assessment builds on Arup's previous work in China, developing a hands-on, user-led climate risk framework. A revision was carried out under CSSP China to include quantitative values of climate projections, build on the risk assessment approach and to present the user with a suite of options to reduce the risk.

Designed for planners and decision-makers

Maria Sunyer Pinya, Senior Climate Change Consultant at Arup, says: "Climate change is happening; our infrastructure assets might not be ready for the future climate, we need to start understanding and preparing for future climate.

"The Climate Risk Assessment of Infrastructure Tool is a step-by-step way for planners and decision-makers to assess the impacts of climate change on the built environment, making sure the infrastructure can withstand higher temperatures or changes in rainfall patterns in the second half of this century.

Maria presented the tool at VIEWpoint's webinar, run with the China-Britain Business Council, for infrastructure professionals in January, 2021. It is designed for policymakers and decision-makers to gain a high-level understanding of climate change risks for infrastructure.

It guides the user through an overview of current and future risks and points to whether a more detailed risk assessment might be required for a certain infrastructure section, such as a section of road or rail, and it encourages users to consult and work together with other stakeholders such as asset managers or engineering and design teams to gain a better insight on potential impacts.

Arup's Climate Risk Assessment Tool takes the user through the process step-by-step which makes it suitable for a wide range of professionals.

Supporting UN Sustainable Development Goals

The framework is aligned with and contributes to the UN Sustainable Development Goals, such as Goal 9 on building resilient infrastructure, Goal 11 on sustainable resilient cities and Goal 13 to combat climate change and its impacts.

Maria adds: "The tool has worldwide relevance. Whilst the process was initially developed with four case study cities in China - Beijing, Shanghai, Wuhan and Shenzhen - it is applicable to many other locations and set up to be easily tailored to any other location in the world. The need to adapt to climate change is a reality in all cities in the world."

One of the positive outcomes of the work is that the framework helps decision-makers to appreciate climate change projections and their inherent uncertainties. The results from a climate change data analysis are not a unique number (e.g. percentage increase in extreme rainfall) but a range, this uncertainty needs to be considered and embeded in design. That makes it important for the tool to provide effective guidance to help users go through a number of steps and account for uncertainty as a whole rather than in individual parts and to consult others responsible for, or with knowledge of, an infrastructure asset.

Another benefit for the Arup team is to have learnt more about enabling users to use and interpret quantitative climate projections and combine that information with qualitative impact assessments.

Next steps

Maria adds: "The tool development has been highly iterative and required consideration on how the user is going to perceive the output because the user needs to interact and remain engaged, not to just be passive as when reading a report. To achieve this relevance, Arup brought together a range of expertise into one discourse, including those on rail engineering as well as extreme weather events." After gathering further feedback from users and making adjustments based on those comments, the next phase for the tool development would be to make it applicable to other infrastructure types and extreme weather events. Currently the focus is on road and rail, and for rainfall and temperature, but it could, for example, be extended to water utilities or digital infrastructure.

Read more about the Arup Climate Risk Tool on page 39.

Maria Sunyer Pinya is project manager of the Arup Climate Risk Assessment of Infrastructure Tool. She studied for a PhD in Denmark, examining and quantifying uncertainty in climate change data, specifically extreme rainfall data for insights into future flooding.

The main finding of Maria's PHD work was that the uncertainties in climate change projections should not be an excuse to not act. Adapting to a changing climate is a large task, and there is need to embed this uncertainty in our adaptation and resilience efforts.

Investigating heatwaves in China under climate change

Image:, Pixabay

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.01

Focus

As part of CSSP China a series of workshops have taken place to allow researchers to apply attribution techniques used in the UK to extreme events in China. Attribution is the process of determining the extent that anthropogenic climate change had a role in an extreme event. One workshop revealed that using sea surface temperatures closer to those naturally occurring at the time of a heatwave was then better able to reproduce the event in climate modelling and this result has fed back into how attribution is approached in the UK.

Importance

In CSSP China attribution workshops the delegates study extreme events of their choosing, so when record breaking temperatures occurred in July 2017, reaching 40.9°C in Shanghai, this was selected for research and publication (Chen et. al 2019). The heatwave caused severe impacts on public health and agriculture.

The workshop and paper investigated if anthropogenic warming has increased the likelihood of these kinds of heatwaves over central eastern China. Such a heatwave, over five days, was found to be ten times more likely under anthropogenic climate change.

Approach

Attribution research is carried out by simulating the climate under a range of situations to establish if and how often the extreme event can be reproduced with and without climate change.

The range of situations is provided by modelling the climate hundreds of times, each of the ensemble having slightly different selections to represent uncertainties in meteorological systems.

At the workshop the ensemble was not able to produce such high temperatures as experienced in central eastern China – leaving the researchers to look more closely at the model inputs.

It was found through further work that by including global sea surface temperatures closer to those observed in 2017 resulted in a significantly more faithful simulation of the climate and subsequent prediction of frequency and risk of similar heatwaves.

The magnitude of the risk depends on sea surface temperatures used (Sparrow et. al, 2018).

Next Steps

Attribution of recent extreme events is an active area of climate research. Findings such as the importance of including a plausible range of sea surface temperatures to capture high temperatures over land, is part of the process of discovery and improvement of predictions.

The CSSP China workshop and further research over the following year resulted in changes to the inputs to the Met Office operational attribution system to take account of the influence of observed sea surface temperatures patterns.

References

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SUSTAINABLE DEVELOPMENT GOALS

VIEWpoint has produced a series of Explainers, translating CSSP China research into plain language to encourage the sharing of the climate research with the widest possible audience. Download and share them using the QR code (see facing page)

Increasing flash floods in a drying climate: dual challenges facing Southwest China

Rural area in Yunnan Province, Southwest China
Image: Chan Xiao (NCC, CMA)

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.02

Focus

Increasing flash floods against a drying climate background have been observed during the past 15 years in Southwest China, which poses new challenges for climate adaptation and water resources management. Xiao et al. (2018) analysed high-resolution precipitation observations and found that this contradictory trend is expected to continue in coming decades under a warming climate.

Importance

Southwest China, located in the subtropics close to 25°N, is to the southeast of the Tibetan Plateau. The region is characterized by clearly distinctive dry winters and springs. This region is highly vulnerable to extreme rainfalls due to its unique terrain which is complex and mountainous. Such terrain facilitates the formation of strong rainfall and thus leads to landslides and flash floods.

Subtropical regions are generally expected to become drier in a warming climate worldwide. In line with this, Southwest China is increasingly prone to drought, while Southeast and Eastern China are generally getting wetter.

However, a contradictory trend of increasing extreme rainfall and more flash floods against a drying climate has been observed during the past 15 years in the region. The drought-affected crop area has more than doubled since 1971 in Yunnan Province while area of crops affected by flash floods has increased by 96%, according to historical records from the Chinese Ministry of Agriculture.

Approach

Rainfall changes were examined using hourly and daily gauge observations between 1971 and 2013 collected from a measurement network of 142 stations in Southwest China.

Yunnan Province. Image: Charlottees, Pixabay

A decrease in both the annual and wet season precipitation over Southwest China was seen 1971–2013. A significant decreasing trend of total summer rainfall in the past 15 years was found at almost all stations in the region. However, precipitation extremes (the intensity of rainfall during the wettest 5% of hours) have steadily increased, consistent with recent annual statistical records of droughts and flooding as reported by the Chinese Ministry of Agriculture.

Next steps

This contradictory trend in Southwest China is expected to continue in coming decades under a warming climate as suggested by future projections (Wang et al. 2014; Wu et al. 2015). Given this trend and sensitivity to climate changes of this region, policymakers and the public should prepare for not only drought-induced water shortages but also increasing flash floods. In particular, considering this poor region is highly dependent on agriculture, preparation well ahead of the imminent expected changes in climate warrants urgent attention.

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SUSTAINABLE DEVELOPMENT GOALS

Tibetan Plateau Vortices: a comparison of tracking methods

Tibetan Plateau, Image: Unsplash

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.03

Focus

Tibetan Plateau Vortices (TPVs) can develop into storms that can cause heavy rainfall and catastrophic flooding over the Yangtze River Basin. TPVs are often identified too late to issue effective warnings, therefore reliable tracking and detection methods are needed. As part of CSSP China, automated TPV tracking methods were investigated in comparison with manual tracking methods to understand the evolution process of TPVs and their impact.

Importance

TPVs are a type of weather system that originates over the Tibetan Plateau during the extended summer season (April–September). Some move off the plateau to the east and cause heavy rainfall, leading to catastrophic flooding in the Yangtze River Basin ,home to one third of China's population. For instance, a series of TPV-triggered heavy rainfalls in mid-June 2008 (Chen et al., 2015) forced 1.3million people in South China to evacuate and caused an economic loss of more than 10billion RMB (MCA of China, 2008). Therefore, accurate prediction of TPV tracks has been a key concern of Chinese researchers for decades.

Currently, it is difficult to identify and track TPVs, especially at the early phase of their lifecycle. This difficulty is mainly due to lack of observational data over the west Tibetan Plateau, where TPVs originate. Rapid and reliable detection methods are needed urgently to allow more time to give effective flood warnings.

Approach

Current tracking methods include manual and automated tracking: the former relies on case-by-case observation-based analysis by experts while the latter makes use of climate model outputs.

A thorough comparison between manual and automated tracking was carried out as part of the CSSP China project and revealed that the automated method can identify TPVs further west at their crucial earlier stages compared with manual tracking (Curio et al., 2018).

In addition, along with global climate model outputs, automated tracking can benefit understanding of the spatial distribution and annual cycle of TPVs. Using automated tracking, Curio et al (2019) found TPV-associated precipitation can account for up to 40% of the total precipitation in Sichuan Province in July, confirming that TPVs can have a strong influence on the precipitation downstream of the Plateau.

Next steps

Compared to manual methods, automated tracking is more objective and reproducible; more over it allows for earlier detection of TPVs. There is potential for the automated method to be incorporated in NWP-based workflows to improve the forecast skill of TPVs and to increase the lead time for TPV-related flood warnings. Meanwhile, the experience and in-depth knowledge of TPVs acquired from the skill of conventional manual methods can inform and refine automated methods to improve automated TPV tracking.

This research is the first time TPV events have been examined in a high-resolution global climate model, helping to deepen knowledge of the mechanisms and patterns of TPVs, enabling better understanding and prediction.

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SUSTAINABLE DEVELOPMENT GOALS

What will shape future Beijing haze events and air quality?

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.04

Beijing haze event at Palace Museum Image: Pixabay.com

Focus

In China, air pollution is most severe in Beijing and its surrounding area. Understanding how changes in aerosol emissions influence both the frequency and intensity of haze events in the region is important for informing future mitigation strategies.

Importance

Air pollution has become one of the major issues in China due to the rapid economic development and urbanisation in recent decades and it poses a great threat to public health. Beijing (home to 20 million people) and its surrounding area is the most polluted region.

The Chinese Government implemented the 'Atmospheric Pollution Prevention and Control Action Plan' in 2013 and there have been dramatic reductions in emissions of the gases and particulates that contribute to poor air quality e.g., sulphur dioxide (SO_2) emissions reduced by 59% between 2013 and 2017 (Zheng et al., 2018). However, haze events still frequently occur in Beijing.

Changes in aerosol emissions may affect haze events through their influence on large-scale weather conditions in addition to their direct contribution to the haze composition. As rapid reductions in aerosol emissions in China are likely to continue in future, it is important to understand how these changes will influence both the frequency and intensity of haze events for mitigation strategy design.

Approach

As part of the CSSP China project, Zhang et al. (2020, in review) investigated future changes in weather conditions associated with haze events in the Beijing Region, and the severity of haze events during these weather conditions through the mid-21st century under two different aerosol emission scenarios. They have quantified the incidences of haze events in a future climate and the influence of aerosol mitigation efforts, by modelling of conditions conducive to haze via the Haze Weather Index (HWI), which is related to the Air Quality Index (AQI).

They found that weather conditions that favour Beijing haze events (warmer conditions with weakened winds and increased moisture) will be more frequent in future, but the haze events may be less dangerous in terms of intensity if aerosol emissions continue to reduce in the future.

Next steps

There is large uncertainty in future aerosol emission pathways both in China and other adjacent countries, such as India which has overtaken China as the world's largest emitter of anthropogenic sulphur dioxide (SO_2) (Li et al. 2017). An improved understanding of the competing effects of aerosol emission changes on future haze events in the Beijing Region is beneficial to future policy making regionally and globally.

The study (Zhang et al. 2020, in review) implies that benefits to the local air quality, and hence human health, from air quality control policies outweigh their dynamic climate impact, which is of great importance to inform the future mitigation strategy. The air pollution control policy should continue.

Moving forward, a prototype climate timescale haze service with projections of HWI is currently under development at the Met Office and will allow for enhanced mitigation for downstream users.

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SUSTAINABLE DEVELOPMENT GOALS

Efficient assessments of the Fengyun-3 satellite instruments to improve weather forecasts

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.05

Satellite image of Earth, Image: WikiImages, Pixabay

Focus

As part of CSSP China project, nine instruments of the Chinese Fengyun-3 satellites have been assessed against short-range forecasts from the Met Office global Numerical Weather Prediction system. The findings from the assessments have been fed back to the China Meteorological Administration (CMA) whilst the incorporation of some products in operational forecast has significantly benefited the Met Office global forecast system.

Importance

Satellite observations are a key method for observing the Earth, offering a valuable stream of measurement data with global coverage. As part of China's Fengyun (FY) programme, there are FY-3 polar orbiting satellites comprising four satellites FY-3A - FY-3D, with 11 high-performance detection instruments. They are an important source of observational data for applications in weather forecasting, global climate change studies, disaster monitoring, and specialised activities (e.g., aviation, marine activities). Currently, many countries use FY-3 satellite data.

To make use of satellite observations, a fundamental requirement is a detailed and thorough assessment of instrument data quality. However, as conventional observation-based assessment, such as matching satellite data with conventional observations, can typically take several decades, more efficient approaches need to be adopted to accelerate the process.

Approach

With the aim of reducing the delay between launch and successful application in climate services to less than a decade, several Chinese instruments of the FY-3 series have been assessed by comparing satellite observations against simulations of recent climate history and short-range forecasts from the Met Office global forecasting models, identifying biases and developing correction schemes where necessary. This method has proven to be able to accelerate the overall assessment process in recent years.

Three Microwave Humidity Sounders, three Microwave Temperature Sounders and two Microwave Radiation Imagers on board the FY-3B, 3C, and 3D missions have been thoroughly assessed and prepared for operational use. Together, these instruments provide valuable information on surface and atmospheric temperature, humidity and ice particles.

In parallel, the Hyperspectral Infrared Atmospheric Sounder (detecting temperature, humidity, and trace gases) on board the FY-3D mission, has also been assessed and work is ongoing to evaluate the potential benefits from an operational use of its data.

Next steps

The thorough assessments have allowed rapid feedback to the CMA of observation data quality for efficient and timely redesign and correction.

As part of the CSSP China project, the three humidity sounders, the two radiation imagers and one temperature sounder are, or have been, used operationally and have significantly contributed to improvements in the 24-hour forecast accuracy. 2020 marked the 50th anniversary of China's Fengyun meteorological satellite programme. Another significant milestone was that observations from the programme were used in the UK's global weather forecast model for the first time, which has significantly benefited the Met Office global forecast system.

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SUSTAINABLE DEVELOPMENT GOALS

Arup climate risk tool: protecting your infrastructure under climate change

Image: Erdenebayar Bayansan, Pixabay

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.06

Focus

Arup has created a climate service that enables infrastructure planners, engineers and project managers in Chinese city authorities to assess the impacts of future climatic extremes, such as high temperatures or high rainfall, on critical infrastructure systems and to identify solutions to enable adaptation.

Based on research undertaken through the CSSP China project, the decision support tool provides easy access to an ensemble of trusted global climate model (GCM) datasets. The changing severity of hazards under future climate scenarios can be quantified and combined with the user's knowledge of city infrastructure to assess risk and plan for targeted adaptation.

Importance

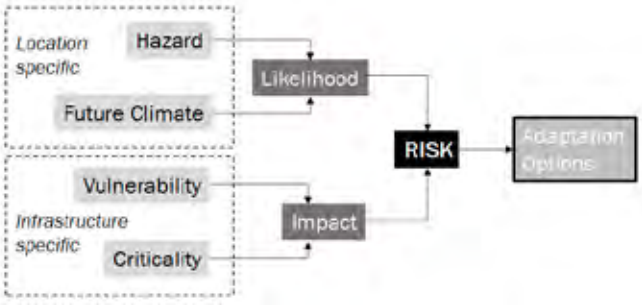
Built infrastructure, such as transport, water and energy systems, ensure the effective functioning of cities and support quality of life. Damage or failure due to extreme heat or rainfall is likely to become more severe and/or more frequent due to future climate change, making future-proofing an essential part of planning, designing and operating infrastructure.

Historical records of temperature or rainfall extremes provide inadequate guidance in a changing climate. Arup's tool is accessible and provides direct, focused access to the trusted climate model data needed to assess future conditions, with clear explanations to support interpretation.

Approach

Users are guided through a process (above, right) to combine data from global climate models with user expert knowledge on:
Vulnerability: how sensitive a system is to failure in climate extremes.
Criticality: how vital a system is for the functioning of the economy, society, and other dependent systems.

Vulnerability and criticality are combined to give a



Information flow in the Arup climate risk tool

systematic evaluation of potential hazard impacts for a particular infrastructure system in a given location as the climate changes. Overall risk is determined and the user is guided to identify practical adaptation methods or technologies, to help prioritise investments to improve resilience.

Next steps

Arup's climate service tool, training and guidance resources have been implemented for four cities (Beijing, Shanghai, Wuhan and Shenzhen). For these cities, the tool can now be used to support decision making. Next steps include extending the tool to other cities.

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SUSTAINABLE DEVELOPMENT GOALS

High-resolution revolution brings insight into China's climate

Image: Vitor Dutra Kaosnoff, Pixabay

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.07

Focus

The lack of a long-term dataset at fine resolution has limited understanding of China's varied and complicated climate. A high-resolution (25km) dataset, recently developed by the Met Office, better represents year-to-year variations and confirms a sustained increase in temperature since the 1850s, while maintaining consistency with the global climate.

Importance

China experiences varied climates and weather extremes (e.g., heatwaves, floods) and has shown a widespread warming trend. To understand the full picture, continuous, homogeneous and unbiased long-term observational records are essential. However, pre-1950s records of surface climate are sparse in many parts of China, especially in western regions. Although satellites can provide fine-scale datasets with increasingly comprehensive coverage, they are only available from 1979. While some attempts have been made to extend the period of the existing dataset by using global climate models, poor performance is still seen over China due to coarse spatial resolution of the global dataset. To better represent China's regional climate, while maintaining consistency with the global climate, there is an urgent need for a dataset with global climate features and local orographic details at a finer resolution.

Approach

Amato et al. (2019) attempted to resolve some of the limitations by downscaling the horizontal spatial resolution of a global dataset (20CRv2c) over China. It provides winds, temperature and humidity at a spatiotemporal resolution of 200km and 6 hourly. A historical climate dataset with finer spatial resolution over China (20CR-DS) from 1851 to 2010 was generated with available output at daily/monthly time scales, by using a Met Office high-resolution climate model to extend the effects of large-scale climate processes to regional scale (25km).

The strength of the downscaled dataset is that it can represent spatial and temporal trends realistically, despite a small warm and seasonal wet bias. It can represent China's climatological annual cycle (in temperature and precipitation), particularly over areas with sparse observations such as the Tibetan Plateau. Moreover, the dataset can better signify the interannual variability and trends in observed temperature since 1901, with confirmation of a significant and sustained increase in temperature since the 1850s.

Next steps

20CR-DS is the first reanalysis dataset downscaled over China for the 20th century and the latter half of the 19th century. It is an imperative first step towards a deepened understanding of the patterns and drivers of high-impact events over China such as heatwaves, droughts, and precipitation. With valuable fine resolution and being freely available as monthly averages in a standard (NetCDF) format, the dataset is expected to be widely used in future scientific analysis, impact studies and the development of climate services. The Met Office has produced Python-based tutorials for 20CR-DS in a more computationally efficient (Zarr) format in Jupyter Notebooks, and examination of higher frequency datasets (daily, 3-hourly and hourly) is ongoing. More recently, a 20CR-DS-based prototype climate service is in development for air quality control in China; which may improve regional projections of the Haze Weather Index.

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SUSTAINABLE DEVELOPMENT GOALS

Safer operation for urban rail transport: wind risk warning system

Image: PublicDomainPictures, Pixabay

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.08

Focus

People in big cities rely on urban rail transport, but these systems can be vulnerable to strong winds. As part of the CSSP China project, an integrated wind risk warning system was developed and assessed to support the network operation and contingency planning.

Importance

Along with rapid urban growth comes an expanding urban rail transport system in the coastal city of Shanghai, home to more than 24 million people. The Shanghai Metro system is the world's second biggest by route length, which comprises 676km of lines and 414 stations. Currently around 11.8 million passengers use it every day.

Urban rail transport is vulnerable to severe weather conditions which can seriously affect the rail operations. In Shanghai, the damaging winds of typhoons making landfall can influence the stability of carriages and even lead to derailment, causing significant economic loss and casualties.

Thus, it is crucial to better understand the impact of such adverse weather conditions on rail vehicles' performance and to assess risk levels for the rail network operation and contingency planning. In particular, an early warning system is needed urgently.

Approach

Han et al. (2020) developed an integrated wind risk warning system for rail transport. It comprises high-resolution wind data from observations or model predictions, a vulnerability model to evaluate the influence of the wind on rail carriages, and a risk assessment system to issue warning alerts.

The warning system has been assessed for the 59km-long Shanghai Metro Line 16 (45km of elevated tracks) in the southeast of Shanghai. The southern section of Line 16 is exposed to typhoons almost every year. In the scenario of typhoon Chan-hom making landfall on 11 July 2015, risk levels along the whole Shanghai Metro Line 16 were determined and areas with high to very-high risk identified (above). In the morning of that day, the trains on Line 16 in the areas with high risk were slowed down in real rail operation, which indicates a useful risk assessment provided by the warning system.

The determined wind risk of Shanghai Metro Line 16 (Han et al. 2020)

Next steps

This integrated wind risk warning system for rail transport can provide finer scale warning information for safe rail operation in strong winds. By using the predictions of wind conditions from computer simulations, the system has the skill in forecasting safety risk level of the rail network and issuing real-time warnings. The system has been made available to the Shanghai Shenlong Metro Group since July 2016. It also has potential to be applied to other cities with overground rail systems that are vulnerable to strong winds.

Reference

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SUSTAINABLE DEVELOPMENT GOALS

A promising outlook: skilful seasonal forecasts for energy sectors in China

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.09

Wind farm in Xinyang, China. Image: Vista Wei, Unsplash

Focus

Wind power is becoming increasingly important as China aims to reduce both greenhouse gas emissions and air pollution by extending its use of renewable energy. The Met Office seasonal forecast system has robust skill in forecasting winter wind speeds in some regions in China which provides a promising basis for seasonal forecast services for the wind energy industry.

Importance

China has strong motivation to increase its adoption of clean renewable energy, driven by commitments to reduce both greenhouse gas emissions and air pollution to meet its target of Net Zero by 2060. Wind power is thus becoming increasingly important: by August 2020, the total installed wind power capacity exceeded 220 million kilowatts, the highest of any country, with a utilisation rate of 97% (National Energy Administration, 2020).

Accurate forecasts of wind speed are key to the planning, development and operation of wind farms. In China, skilful forecasts are in particularly urgent demand in northern and southern coastal areas, where a large number of wind farms are distributed.

Approach

Bett et al. (2017) investigated the ability of the Met Office's global seasonal forecasting system in predicting meteorological variables relevant to the energy sector in China, including near-surface wind speed. Their results suggest the Met Office's system has skill in predicting winter (December-January-February) wind speed in parts of China, in particular a south-eastern coastal region near the South China Sea (SE China), and a region in northern-central China (NC China).

Furthermore, Lockwood et al. (2019) assessed the winter wind speed prediction over these regions, finding that high and robust skill is seen. These results hold for two independent sets of forecasts over different historical time periods. Their detailed research also identified the large-scale predictors that are the source of predictability in the two key regions. For example, the predictability of wind speed in southeast China comes from the model's ability to predict the El Niño Southern Oscillation.

Next steps

The Met Office seasonal forecast system has robust skill in forecasting winter wind speeds in southeast and north-central China, indicating the potential for the development of seasonal climate services for the wind energy sector with estimates of forthcoming renewable electricity supply in autumn for the coming winter. The skill in forecasting near-surface winter wind speeds also applies to winds at typical wind turbine hub heights.

However, the forecast system has no skill in summer wind forecast across most of China, which decision-makers should bear in mind when using this seasonal forecast.

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SUSTAINABLE DEVELOPMENT GOALS

Correcting urban bias in large-scale temperature records in China

Shanghai Image: wei zhu, Pixabay

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.10

Focus

A robust temperature record allows for a deep understanding of the mechanisms that impact on local and regional temperatures. Temperature measurements are often affected by their surroundings which can cause a bias. Urbanisation is probably the most common source of systematic bias in land surface temperature records. There is considerable uncertainty in the bias especially in regions where urban expansion is rapid. Wang, Tett, and Yan (2017) found that increasing urban land fraction (the proportion of surrounding area that is developed) increased minimum temperatures yet had negligible impact on maximum temperatures for Eastern China.

Importance

In developing nations, urbanisation is rapid and dynamic, causing biases in land surface temperature records at local and regional levels. Climate models are best used for large-scale average changes in temperature and are not directly comparable to local measurements in rapidly urbanising regions such as Eastern China. As human populations are concentrated in cities, if we want to quantify the changing risk of extreme temperatures to cities based on climate model projections, we need to apply a correction for the impact of urbanisation at local and regional levels.

Approach

A corrected daily surface air temperature dataset observed at 753 meteorological observation sites in China from 1980–2009 [Li and Yan, 2009, 2010] was combined with a reanalysis dataset and a long-term land cover dataset made from multiple data sources [Hu et al., 2015]. For each site the trend in urban land fraction for the nearest 10km x 10km pixel was calculated.

The temperature trend observed at each urban site is assumed to be the sum of large-scale temperature trends, local urban temperature trends and 'noise' which represents unknown processes.

Reanalysis data provide the most complete picture currently possible of past weather and climate, being a blend of observations with past short-range weather forecasts rerun with modern weather forecasting models. The reanalysis data was used to represent the long-term temperature trends. Local warming was assumed to be proportional to urban land fraction.

The urban impact on maximum temperature was small and statistically insignificant, however it increased minimum temperature, with a change from 0% to 100% urban fraction leading to an increase of 1.7±0.3°C, with urban warming being responsible for ~9% of the trend in regional minimum temperature for Eastern China for 1980-2009.

Next steps

Urban land fraction is an important factor when determining local urban warming but other factors include anthropogenic heating, the degree of urbanisation and the local background climate.

Previous techniques have relied on population data for calculating urbanisation but these data are often out of date, this methodology is more robust and could be applied to other regions.

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SUSTAINABLE DEVELOPMENT GOALS

Flood footprint assessment: a new approach for impacts and recovery

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.11

Image: Jéan Béller, Unsplash

Focus

For investment in flood risk management options, it is crucial to identify the 'blind spots' in critical infrastructure and vulnerable sectors in economic supply chains and social networks. The Flood Footprint Model enables measurement of the indirect economic impact of natural disasters and allows for different post-flood economic recovery plans to be explored by policy-makers. It focuses on post-disaster demand and supply imbalances, the distribution of remaining resources and the role of producer and consumer adaptive behaviour.

Importance

Many studies pay close attention to the social and economic impacts of natural hazards, such as floods, and are often focused primarily on direct losses (short-term physical impacts on natural resources, people, capital stock, and other tangible assets). However, these are only a fraction of the total loss. Indirect loss refers to the economic impact and/or loss resulting from flood-induced losses, delays, disruption of economic activities and the costs of reconstruction.

Direct economic loss due to a natural disaster is often estimated by government authorities or insurance companies through first-hand data surveys and interviews, or it is calculated using disaster models based on physical properties (e.g. infrastructure). There are four main approaches to estimating the indirect economic losses of a natural disaster: post-disaster economic surveying; econometric modelling "(these are both from primary data sources); input-output (IO) and computable general equilibrium models. In particular the IO-based Adaptive Regional Input-Output (ARIO) model is one of the most significant contributions in the area of natural disaster impact assessment (Hallegatte, 2008)

Approach

The concept of a 'flood footprint' (first proposed by Mendoza-Tinoco et al. (2017)), belonging to the ARIO class of models is applied to characterise the total (direct and indirect) economic impact of a flood. The idea is extended to include the role of consumer and producer flexibility and adaptability, and the role of alternative options in starting and maintaining the recovery process.

Two assumptions are made: one is that foreign relations are stable in the pre-disaster situation; and the other is that imports, as external resources, are allowed during the post-flood recovery period.

Next steps

This study offers a broader perspective to disaster risk analysis and management and offers several post-flood economic recovery plans to policymakers by simulating various recovery conditions in the aftermath of a flood, such as alternative labour (workforce) or infrastructure recovery plans. However, since there is as yet little statistical data about how sectors and economic systems recover after a disaster, critical testing of the model is still difficult.

More specific information on novel recovery methods and impacts needs to be collected and more effort needs to be put into future research. Because sudden-onset catastrophes seldom come alone and are rarely confined to single regions, the model will be continually improved and applied to single/multiple disaster events in single/multiple regions.

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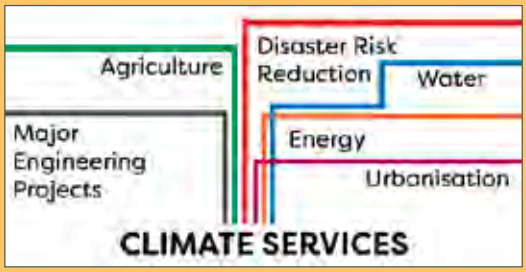
SUSTAINABLE DEVELOPMENT GOALS

Working together: the China Framework for Climate Services (CFCS)



Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.12

Focus

There is a growing need to improve our understanding of how the climate has varied in the past and how it could change in the future to mitigate and prepare for natural disasters. The use of climate information in decision-making can improve society's understanding, perception of and preparedness for, climate-related hazards and improve economic outcomes. The China Framework for Climate Services (CFCS) is a collaboration to inform decision-makers of the social and economic benefits of incorporating climate impacts into future design, drawing on and further developing scientific knowledge and capability in China and worldwide.

Importance

China suffers from a wide range of meteorological disasters, such as floods, droughts, typhoons, heat waves, frosts, haze and sandstorms, with many of these disasters becoming more frequent, in part attributed to climate change.

Climate information is needed to help avoid or mitigate the possible impacts of meteorological disasters on planning implementation. Climate services include the process of generating, providing and using climate information in such a way as to assist in decision-making for both current and future conditions (Hewitt et al. 2012).

Approach

The CFCS aims to provide timely, accurate, and tailored climate services that reduce the vulnerability of society to climate-related risks and guide future adaptation to climate change across a wide range of industry sectors.

The CFCS provides multiple types of outputs such as: climate service, monitoring, prediction and assessment products depending on the user's needs, all of which require interdisciplinary expertise. The climate services are developed by interdisciplinary teams of climate scientists, social scientists, researchers, forecasters, and communication specialists.

The CFCS also aims to improve collaboration between climate service providers and users to promote mutual understanding of the benefits of using climate data for planning in sectors such as: infrastructure, energy and agriculture. Users can obtain historical and real-time observations, as well as outputs from climate models covering historical and future periods, to monitor and assess extreme weather and climate events through a specialist user interface.

The CFCS governance structure brings together all relevant national participants to work together to improve climate service delivery at the national scale.

Next steps

When surveyed, 88% of users of the CFCS were satisfied with the service (2017-2019). Another sign of success is scientific contributions; 816 scientific papers were published from 2014-2019.

The CFCS is working towards the transition of climate research to operational climate services that are relevant, tailored and usable to support long-term planning in sectors such as agriculture.

The skill of climate predictions is also continually being improved to aid decision-making on disaster prevention and mitigation methods.

References

Wang et al., 2020 DOI:10.1175/WCAS-D-19-0121.1

Hewitt et al., 2012 DOI:10.1038/nclimate1745

www.viewpoint-CSSP.org

VIEWpoint 新观点

Produced by VIEWpoint, a CSSP China project from the Institute for Environmental Analytics, highlighting research and improving the uptake of climate services developed in the partnership, through accessible resources.

Institute for Environmental Analytics

SUSTAINABLE DEVELOPMENT GOALS

Examining airflow around tall buildings using a 3D model

Beijing cityscape Image: Li Yang, Unsplash

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.13

Focus

Tall buildings (>50m height) are becoming increasingly common in urban areas and can affect the urban climate locally and across neighbourhoods. Tall buildings also interact with low-rise buildings. Compared to tall buildings in isolation, the presence of a low-rise canopy of smaller buildings displaces the building wake (the flow of air immediately behind the building) vertically, so that flow speeds are reduced over longer distances downwind well-above street-level. Current pollution dispersion and urban air quality models do not capture this so may predict pollutant spread incorrectly.

Importance

Based on current UN estimates, by 2050 over 6.6billion people (68% of the world's population) will be living in cities. Across the world, tall (>50m height) and super-tall (>300m) buildings define the skylines of many large cities and will continue to become more common.

Tall buildings, in isolation or as clusters, affect the urban micro-climate of local surroundings and the neighbouring region. The impact on aerodynamics (e.g. local flow distortions, long-range wake effects), radiation budget (e.g. the shadows buildings cast) and components of the surface energy balance (e.g. storage of heat in building materials, anthropogenic heat emissions) can be large compared to low-rise buildings. Tall buildings strongly change pedestrian-level winds in the surrounding streets and the flow field above the roofs of low-lying buildings. This affects pollutant pathways, which may affect disease transmission, and the overall ventilation potential of cities. Flow interactions between tall and low-rise buildings also change the structure of the wind fields behind tall buildings.

Approach

A 1:200 scale 3D-printed model is used within a wind-tunnel to represent a (simplified) region of central London which contains three buildings taller than 32m

City buildings and street layout featured in a simplified 3D model

(tallest is 134m). Buildings are represented by blocks, without small-scale façade details (*above*). The model is positioned on a turntable to allow different wind directions to be explored and different configurations of the model are used: tall buildings only, low-rise only and tall and low rise combined to represent the real-world case. These measurements remove some of the complexity of the real-world atmosphere, whilst capturing the mean flow behaviour.

Next steps

Understanding and quantifying tall-building impacts on the near-surface atmosphere over cities is essential. Computerised forecasting models (e.g. weather prediction, air quality) need to take into account the urban roughness and often large range of wind-field effects caused by tall buildings.

References

Hertwig et al., 2019 DOI:10.1007/s10546-019-00450-7

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SUSTAINABLE DEVELOPMENT GOALS

Increasing summer rainfall intensity during the past four decades observed in China

Image: Pexels, Pixabay

Explainer

Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.14

Focus

Climate change increases the moisture-holding capacity of the atmosphere and consequently the potential risks of extreme rainfall and flash floods. The maximum hourly summer rainfall intensity has increased by about 11.2% on average, found from the analysis of continuous hourly gauge records for 1971–2013 from 721 weather stations in China. Depending on the region, the risk of droughts (due to decreased rainfall) and flash floods (increased limited duration high-intensity rainfall) increased. Moisture availability alone cannot explain the rate of intensification of precipitation extremes.

Importance

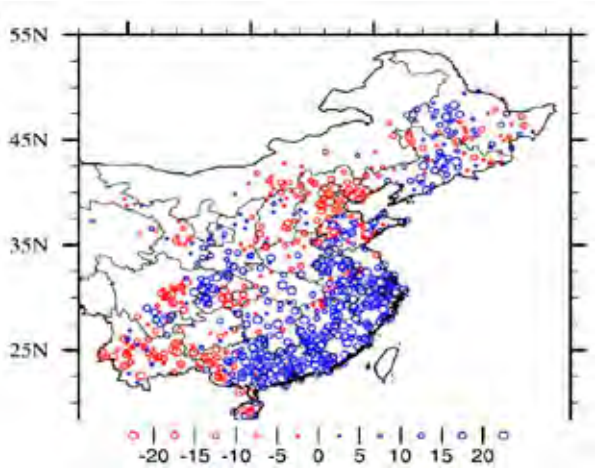
Urban flooding has increased over China in recent decades due to rapid urbanisation and outdated drainage systems being unable to cope.

Increasing extreme precipitation accompanies a rapidly warming climate. During the period 1971–2013, the regionally averaged maximum summer hourly precipitation has increased by 11.2% over China. A survey by the residential development department in China has found that 62% of 351 Chinese cities were flooded at least once between 2008 and 2010. Continuing climate change will further strengthen the hydrological cycle with increased mean rainfall and extremes, and may increase flash-floods. Without forward-looking measures, the implied economic damage may be devastating.

Previous analysis has considered only daily precipitation records, but hourly and daily precipitation records can lead to very different conclusions. Existing studies use either a small number of observational sites or a short period of time.

Approach

721 weather stations were selected from over 2,400 observational sites for the summer months of June, July, and August (when the bulk of the rainfall occurs) over the period 1971–2013 to ensure missing data at each site are no more than 5%.



Linear trends (mm/10y) of summer total precipitation

The hourly quality controlled daily mean surface air temperature and precipitation data in China were analysed for 1971 to 2013.

Next steps

This work infers that it is probably the extreme convective summer rainfall which continues to intensify, but further investigation is urgently needed. The summer total precipitation has shown contrasting patterns with strong upward trends over Southeast China but decreasing trends over North and Southwest China, increasing the risks of flash-floods and droughts (above). Moisture availability alone cannot explain the rate of intensification of precipitation extremes.

References

Xiao et al., 2016 DOI:10.1038/srep38506

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VIEWpoint 新观点

Produced by VIEWpoint, a CSSP China project from the Institute for Environmental Analytics, highlighting research and improving the uptake of climate services developed in the partnership, through accessible resources.

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SUSTAINABLE DEVELOPMENT GOALS

Daily satellite monitoring of crop drought conditions: developing a service

Maize growing Image: Pixabay

Explainer

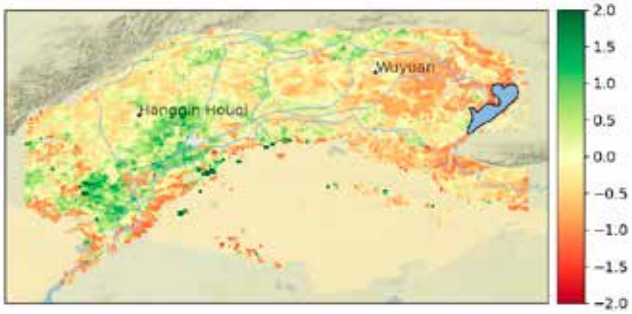
Accessible research from Climate Science for Service Partnership (CSSP) China, for decision-makers No.15

Focus

Satellite data offers daily automated monitoring of large agricultural areas to indicate emerging drought conditions and the system developed in CSSP China is a prototype near real-time remote monitoring service of crop condition at field-scale resolution.

Importance

From government agencies to insurance companies to small-scale farmers, a wide range of stakeholders have been identified as having an interest in current drought conditions likely to affect crop health and yields. Satellite monitoring offers near real-time diagnosis of the condition of crops, which can be streamlined into an automated service for early warning of emerging drought.



10-day mean crop condition example (negative values = dry/stress)

Approach

Building on existing research, seven areas of critical agricultural production have been chosen to develop the service, from the arid Plain of Inner Mongolia in the north (40°N, 108°E) to subtropical Guangxi in the south (23°N, 109°E). These areas have established irrigation systems, so the crop stress diagnosis is that of 'agricultural drought' – both lack of rainfall and limits on irrigation and where this water scarcity has consequences for crop growth.

The diagnosis of the crop condition has been carried out on 15 years of satellite measurements of land surface temperature and vegetation colour for each satellite image pixel. The current situation for each pixel is compared to this baseline of historic records to determine where the new observation sits in an index, where anomalously low (negative) values indicate dry conditions and high values indicate that water is not a limiting factor in crop growth (*above right*). A composite using 10 days' data avoids gaps due to cloud cover.

Next steps

This system is at the operational prototype stage to create maps of crop stress for users. The significant advantages of this system are that:

- crop condition can be detected at a relatively high resolution, about one kilometre
- the method is not sensor dependent, so other satellite data sources can be used
- the use of mapped anomaly data makes differences easier to spot
- a computationally efficient algorithm allows a near-real time operation, with the potential for results to be delivered within a few hours of the satellite pass.

These results, across some remote parts of China, could be easily accessed anywhere in the world. The analysis of the historic dataset from 2002 to 2017 has shown that some areas are becoming more drought prone, especially from 2014 onwards.

References

Tang et al., 2010 DOI:10.1016/j.rse.2009.10.012

Hu et al., 2019 DOI:10.1016/j.agrformet.2019.107707

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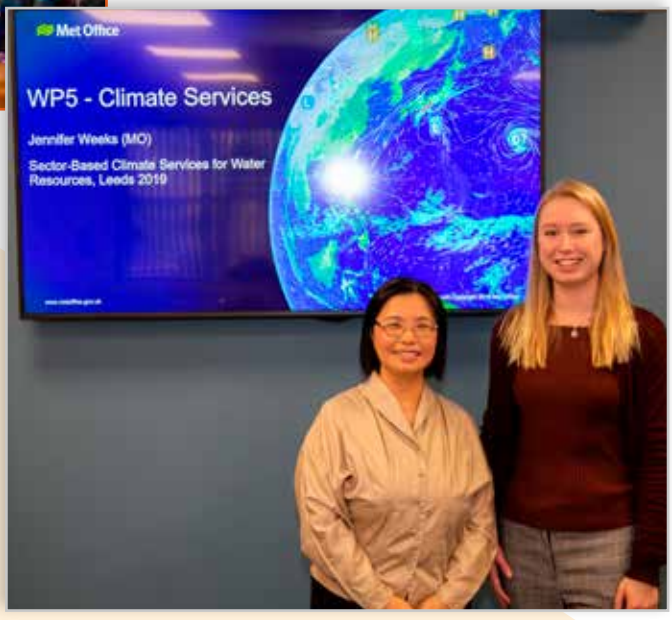
SUSTAINABLE DEVELOPMENT GOALS

CSSP China team photo: Scientists from China and the UK are pictured, above and below left, in Edinburgh in September 2019, at the last annual workshop that was held in person, before the Covid-19 travel restrictions.

Below: Jennifer Weeks, Climate Services Scientist, International Climate Services, Met Office, pictured with Prof Yim Ling Siu, Lecturer in Environmental Risk Management at Leeds University, which hosted a Chinese delegation from the South-North Water Transfer Project (East Line) in December 2019.



Below left, Dr Fabien Carminati, a Senior Scientist at the Met Office, pictured at CMA headquarters in Beijing in March, 2018.

Met Office | Newton Fund

Assessing China's risk to climate related extremes

What is UNSEEN (UNprecedented Simulation of Extremes with ENsembles)?

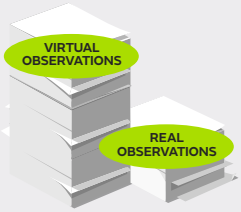
Innovative technique

Simulates extreme events that haven't been recorded yet but could occur.

Super computer modelling

Enables multiple simulations of the current climate.

Virtual observations



Creates library of virtual observations increasing available data by one hundredfold.

What does UNSEEN tell us?

Extreme summer temperatures in China

In Southeast China, there is a 10% risk of an unprecedented hot summer month*

*July or August

UK winter rainfall extremes

30% risk of record rainfall occurring in at least 1 region* in any given Winter (Oct-Mar)

*England and Wales - UK's National Flood Resilience Review (2016)

Global maize supply resilience

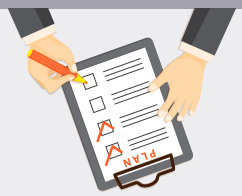
6% risk of maize crop failure simultaneously in China and USA over coming decade.

How can UNSEEN benefit decision makers and global populations?

Understanding risk of extreme events

Improves knowledge of extremes. Events of a higher magnitude than experienced are possible under the current climate.

Building climate resilience



Anticipating high-impact events enables estimation of risks and forward planning.

Global food security

Understanding risk of simultaneous crop failure which would result in supply falling and prices rising.

UNSEEN - UNprecedented Simulation of Extremes with ENsembles – is a technique developed as part of the Climate Science for Service Partnership (CSSP) China. The technique has since been used to simulate high-impact events in China, UK and globally. This includes through the Strategic Priorities Fund UK Climate Resilience programme and new work within the UK aid-funded Asia Regional Resilience to a Changing Climate (ARRCC) programme.

ARRCC
Asia Regional Resilience to a Changing Climate

CSSP China is part of the Weather and Climate Science for Service Partnership Programme, supported by the UK-China Research and Innovation Partnership Fund as part of the Newton Fund.

SUSTAINABLE DEVELOPMENT GOALS

13 CLIMATE ACTION

17 PARTNERSHIPS FOR THE GOALS

The Met Office has produced a series of infographics, you can download and share them using the QR code on each one.

Met Office | Newton Fund

Seasonal forecast service for the Yangtze River Basin

The Climate Science for Service Partnership (CSSP) China project has developed a prototype service, which delivers forecasts of summer rainfall for the Yangtze River Basin months in advance. Advanced warning of above or below average rainfall and river flow help inform water management organisations in the region to take action to prevent flooding, manage water resources and generate hydroelectric energy.

WHY IS THE YANGTZE RIVER BASIN IMPORTANT?

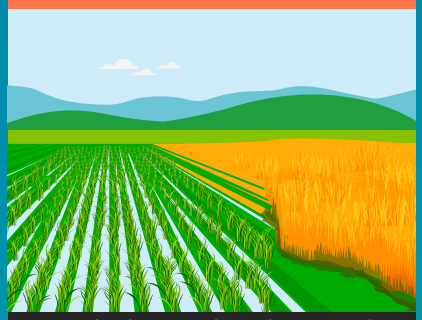
Population

Home to 1/3 of China's population

Urban centres

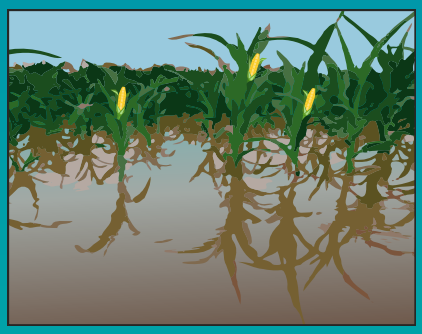
Major cities and economic centres located along the river

Agriculture



Key agricultural region producing about 70% and 50% of China's rice and grain respectively

WHAT CHALLENGES DO WEATHER AND CLIMATE BRING TO THE REGION?



Large-scale drivers of weather and climate, such as El Niño, can lead to strong changes in rainfall in the Yangtze River Basin, leading to increased risk of flooding or drought. For example the strong 1998 El Niño event resulted in over 3,000 deaths, over 13 million homeless people and over $20 billion worth of damage in the region.*

HOW DOES THE SEASONAL FORECAST HELP SUPPORT ROBUST DECISION-MAKING?

Skilful prediction of summer rainfall

Computer models can predict summer rainfall over the Yangtze River Basin in advance, especially during active El Niño events such as in 2016

Advance warning of high-impact events

The prototype forecast service began in summer 2016 and has run each year since, supporting effective management of hydroelectric dams to alleviate flood and drought impacts

Continual improvement of forecast

The project is working with users to tailor the forecast further to ensure it meets their evolving needs and makes use of the latest forecast capability

The Climate Science for Services Partnership (CSSP) China project is working to develop climate service prototypes in other sectors that impact people's lives such as food security. CSSP China is delivered under the UK-China Research and Innovation Partnership Fund (funded in the UK by the Newton Fund).

* Source: ftp://ftp.ncdc.noaa.gov/pub/data/extremeevents/specialreports/China-Flooding-1998.pdf

Met Office | Newton Fund

Urban Climate Services in CSSP China

Cities in China are densely populated and major economic centres, with an estimated 60% of the population living in urban areas[1]. Many cities in China are affected by weather and climate hazards such as heatwaves, heavy rainfall and typhoons. The frequency and intensity of such events may change in the future. Urban characteristics such as the urban heat island and impermeable surfaces can increase climate risks and adversely affect human comfort, productivity and efficiency of city assets.

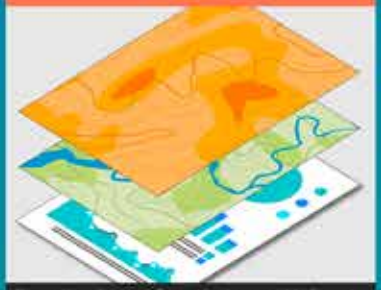
The Climate Science for Service Partnership (CSSP) China[2] is using scientific research to develop prototype urban climate services that will provide robust climate information for city decision makers to plan for the future and help cities become more resilient to climate change.

WHAT ARE THE BENEFITS OF URBAN CLIMATE SERVICES?

Increasing city resilience

Creating a city level evidence base of climate hazards to help cities prepare for climate impacts and demand on city services.

Useful tools for decision making



Presenting climate information in a useable format to help city stakeholders make effective decisions and inform policy.

Adaptation and strategic planning

Tailored climate information highlighting areas of the city most vulnerable to climate impacts to inform adaptation, strategic planning and urban design.

URBAN CLIMATE SERVICES IN DEVELOPMENT

City Packs

Factsheets comprising high level, non-technical summaries of climate change projections for individual cities and the science behind them.

Urban Heat Services

Mapping of current and future heat hazards, integrated with socio-economic and landuse data to identify vulnerable areas in the city.

Urban Flooding

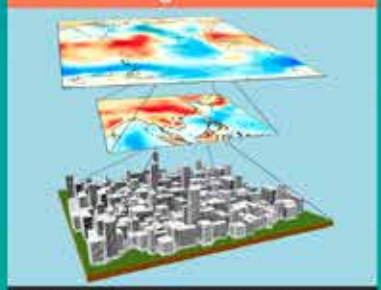
Using high resolution climate model data to provide information on current and future tropical cyclone hazards and urban flooding.

WHAT RESEARCH CAN FEED INTO URBAN CLIMATE SERVICES?

Modelling extreme heat events

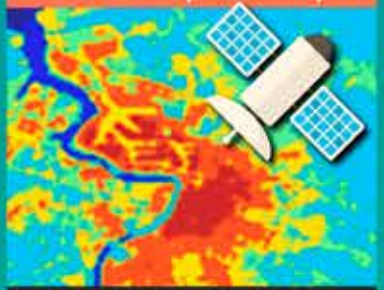
Using high resolution climate data to analyse current and future changes in heat stress and extreme heat events such as heatwaves in Chinese cities.

Urban Modelling



Developing high resolution climate models over China to better represent urban processes, capture extreme events and assess impacts at city level.

Land Surface Temperature Analysis



Using data from satellites to better understand how the urban heat island has changed across Chinese cities as the city has developed.

[1] https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=CN

[2] CSSP China is part of the Weather and Climate Science for Service Partnership Programme, supported by the UK-China Research and Innovation Partnership Fund as part of the Newton Fund. For more information, see https://www.metoffice.gov.uk/research/approach/collaboration/newton/cssp-china/index

Food Security in CSSP China

Farming in China is essential to its economy and the well-being of its people. The Chinese government has set new food security targets for the country, including a focus on self-sufficiency and water sustainability. China produces nearly a fifth of the world's cereal grains including maize, wheat and rice, so national agriculture is essential to food security globally. Therefore, better understanding of the risks to farming from climate variability and change offers huge socio-economic benefits to China and across the world.

Scientific research in Climate Science for Service Partnership (CSSP[†]) China is being used to help communities make better decisions for farming, to ensure sustainable agriculture, and to stay safe and thrive.

How can research benefit agriculture?

Building resilience to extreme weather

Providing information on the most up-to-date risk of extreme weather events will help communities build climate resilient agriculture and food systems.

Strategies for increasing crop yield

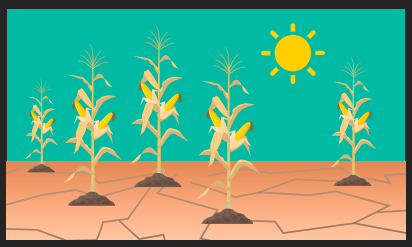
Using adaptation strategies to optimise yield, such as crop rotation.

Developing crop warning systems

Developing tools to help users better anticipate potential damage to crops.

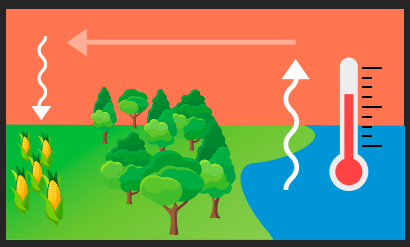
What does our latest research show?

Current risks to crop production



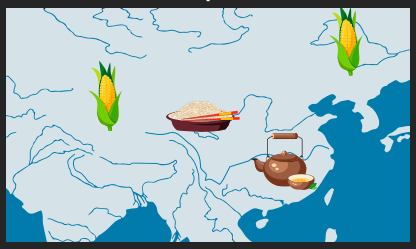
Research has shown there is a 5% chance per year of a larger area drought than any previous event, and roughly a 6% chance per decade of simultaneous maize crop failure in China and the USA.

Predicting unfavourable conditions



Research has identified a link between sea surface temperature patterns in different oceans and yield of maize across North and North-east China. This has potential to provide advance warnings of unfavourable conditions for growing crops.

Where and how crops are affected



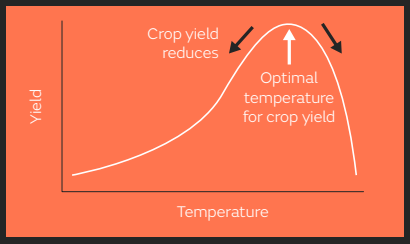
Research can help to understand and quantify factors affecting agricultural yield. This is performed through the analysis of water use and crop health indicators.

How do scientists know this?

Modelling extreme weather events

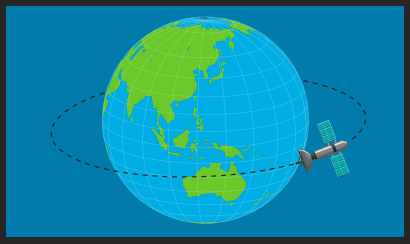
Using the latest climate models to simulate the most extreme weather events that are physically plausible (the UNSEEN* method).

Crop response to extreme weather



Using observations and models to understand how crops are affected by changes in temperature and rainfall.

Satellite mapping of crop risks



Using images from the Copernicus Sentinel satellite database, which can be used to monitor crop stress and impact on yield.

Find out more

[†]CSSP China is part of the Weather and Climate Science for Service Partnership Programme, supported by the UK-China Research and Innovation Partnership Fund as part of the Newton Fund. For more information, see https://www.metoffice.gov.uk/research/approach/collaboration/newton/cssp-china/index

*UNprecedented Simulation of Extremes with ENsembles (UNSEEN) – a novel method used to predict extreme weather events, see https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/wcssp/unseen-infographic.pdf

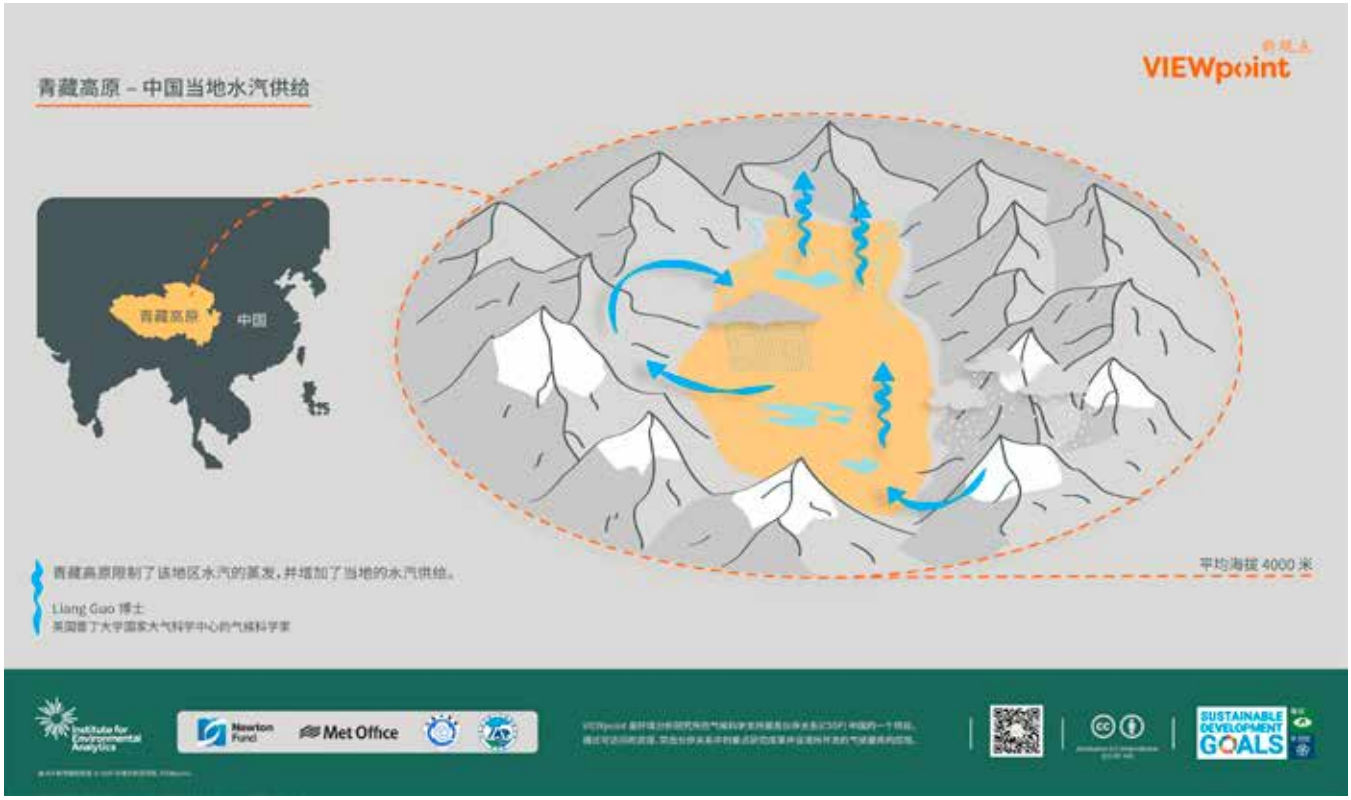
UNDERSTANDING WATER RESOURCES

The National Centre for Atmospheric Science (NCAS) collaborated with colleagues in the Netherlands and China to create the PERCHANCE tool, which helps in understanding potential issues around water resources and water availability.

The tool traces the origins of water which falls as rain over China and has revealed three key facts:

1. The majority of rain over China, except the monsoon season, comes from land rather than the sea.
2. The Mediterranean sea and the Black sea, despite being far away, play an important role in winter due to the strong westerly jet and the frozen land surface.
3. Because of the local topography, local moisture recycling is stronger over the Tibetan Plateau.

VIEWpoint has produced a video in plain language about the PERCHANCE research.
Scan the QR code to watch the video



VIEWpoint DEMONSTRATORS

By Dr Jon Blower, Institute for Environmental Analytics

The CSSP China project has produced a wealth of excellent research that has huge practical impact in understanding and dealing with climate change. The new knowledge and data will form the basis of operational climate services to be delivered to users in many sectors of industry and government across China and around the world.

Delivering climate services requires close cooperation and co-design between service providers and end users, and so the Institute for Environmental Analytics has developed a set of demonstrators for the VIEWpoint project to act as a showcase and to engage potential future climate services users. They are available on the VIEWpoint website, www.viewpoint-cssp.org

Planning to cope with increasingly hot cities

The Surface Urban Heat Island (SUHI) demonstrator has been developed in collaboration with the Met Office in the UK. Satellite data have been processed to provide a set of maps of land surface temperature at 1km resolution. These provide valuable information about the SUHI effect, where temperatures within cities are consistently higher than their surrounding rural areas, causing negative impacts on human health and comfort. This demonstrator shows how surface temperatures can vary considerably within cities and can change over time, enabling decision-makers (such as local government and healthcare professionals) to plan developments and interventions to mitigate the consequences of excess urban heat. The demonstrator focuses on four Chinese cities – Beijing, Shanghai, Guangzhou and Xi'an – but the underlying data are available for the whole of China.

Decision support for water resource managers

The integrated Climate–Water Resources Management (iC-WRM) tool, developed with the University of Leeds, is a user interface that allows water resource managers to explore future river levels for a range of climate and time slice scenarios. Using the Upper Yellow River region as a test case, and the outputs of a hydrological model of the region, the tool allows users to compare river levels for a number of different future climate change projections of rainfall and temperature, and different water allocation plans. The comparisons of monthly mean flow values, daily outflows and flood frequency curves provides the user with the means to evaluate future water availability under a changing climate compared with recent conditions.

Monitoring the health of crops in near-real time

The VERDANT demonstrator showcases a new capability, developed at the University of Leicester, for daily automated monitoring of large agricultural areas using satellites. Analysis of historical data has shown that some areas have become more drought-prone in recent years and so this service provides a means to monitor droughts and crop conditions in near real time, approximately at the scale of individual fields.

A unique feature of this capability is that results can be delivered within a few hours of the satellite passing over the area, even in remote areas. The demonstrator provides some example data from this research, showing how different conditions can be observed and diagnosed.

The three demonstrators are freely available to use at the VIEWpoint CSSP China website www.viewpoint-cssp.org/demonstrators
Scan the QR code to visit the website demonstrators page

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Why is it so important to control sulphate aerosols? A complex role in a warming climate

Briefing Note | A briefing on research from the Climate Science for Service Partnership (CSSP) China for decision-makers in China No.01

Human-made aerosols, such as sulphate aerosols due to increased industrialisation, have a detrimental impact on human health and a wider influence on our climate. This affects, for example, rainfall patterns and therefore our food and water supplies. Gaining a better understanding of the role that sulphate aerosols have on climate and health is essential for better decision-making and a balanced management of climate and air quality mitigation measures.

Aerosols start as emissions from burning fossil fuels and last only a few weeks. Tropospheric sulphate aerosols act as condensation nuclei that cause cloud cover to increase. They are also a source of acid rain. When sulphate aerosols reach the stratosphere, they can remain there for months and affect global temperatures for as long as a year. Sulphate aerosols in the stratosphere scatter radiation from the sun and absorb radiation from the Earth causing a cooling effect.

Impacts of sulphate aerosols in China

Health - China has become one of the regions with the largest human-made aerosol loading due to rapid industrialisation (Lu et al. 2011). The World Health Organization (WHO) estimates that ambient air pollution caused 4.2 million premature deaths worldwide in 2016, of which 40% occurred in China (World Bank, 2020).

Food - sulphate aerosols may influence the Asian summer monsoon and regional rainfall, and induce profound impacts on food supply (Bartlett et al, 2018) given that 40% of the Chinese population directly relies on agriculture (World Bank, 2019).

Water - in cities experiencing heavy air pollution (e.g. Beijing), air pollutants, including sulphate aerosols, can also contaminate water resources via polluted rainfall, exacerbating water shortages (Kokkonen et al. 2019).

Climate - sulphate aerosols can interact with climate both regionally and globally, inducing changes in global mean temperature, weather extremes and diurnal temperature range, to name a few. (Wilcox et al. 2018).

The benefits of a better understanding of the effects of sulphate aerosols

- **Climate mitigation measures bring benefits for air quality** – reducing greenhouse gases (GHGs) can provide an additional reduction in the daily exposure of the population to high levels of air pollutants (Turnock et al. 2019).
- **Asian sulphate aerosols and drying in Northern China are linked** - the weakening of the East Asia summer monsoon was caused by increased Asian sulphate aerosols and hence the reduced precipitation over northern China during the latter half of the 20th century (Tian et al. 2018; Dong et al. 2019).
- **Near-term impacts of future sulphate emissions pathways on our climate** - sulphate aerosols emissions are expected to decrease rapidly throughout the 21st century and lead to enhanced East Asian summer monsoon over East Asia. The magnitude of changes is sensitive to the future emissions pathways (Wilcox et al. 2020).
- **Limited off-set effect of sulphate aerosols on climate warming** - sulphate aerosols partially off-set the warming of GHGs due to their cooling effect. This cooling effect can be small, localised and temporary relative to GHG warming (Luo et al 2020; Wilcox et al. 2020).

Beijing, Image: Brady Bellini, Unsplash

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SUSTAINABLE DEVELOPMENT GOALS

These Briefing Notes, produced by VIEWpoint, collate some of the most pressing themes of CSSP China in plain language, particularly designed for those in industry and government across China and around the world. Download and share them using the QR code on the facing page

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Briefing Note

Why is it so important to control sulphate aerosols? A complex role in a warming climate

Implications

China is taking important measures to tackle air pollution, greatly improving air quality while achieving rapid socio-economic development, by:

- upgrading industrial and residential energy sources (Crane and Mao 2015)
- employing advanced technologies (Xinhua Net, 2019)
- carrying out global collaborations (World Bank, 2020)

There is still much to do, however, as pollutant concentrations in some Chinese megacities are above WHO guidelines values. If the wider and complex impacts of sulphate aerosols are not taken into consideration (e.g. the competition between sulphate aerosols and GHGs, the interaction between decreasing Chinese emission and increasing Indian emission), poor decision-making may not only exacerbate haze events and food and water shortage, but also lessen the impact of the achievements already made on health via air pollution control.

Air Pollution in Shanghai Image: Photoholgic, Unsplash

China has greatly improved air quality while achieving rapid socio-economic development. Since the implementation of the "Atmospheric Pollution Prevention and Control Action Plan" in 2013, aerosol emissions have dramatically decreased, with sulphur dioxide (SO_2) reduced by 59% in 2017 compared to 2013 (Zheng et al., 2018).

Recommendations

- Continuing with **air pollution control policy**. Haze events (e.g. in Beijing) will be less intense if aerosol emissions keep coming down, even though the weather that favours haze events might be more frequent in future (Zhang et al. 2020).
- Continuing the investment in **monitoring emissions**, e.g. establishing and maintaining a national network for monitoring emissions and climate response.
- Further support and funding for **global collaborations,** e.g. World Bank Program.
- Finding a balance between **competing challenges** such as boosting the economy, improving air quality and stabilising future climate, especially for developing countries like China with a large population living around the poverty line.
- Combining **mitigation measures** – air quality control and climate mitigation measures need to work side by side.
- Considering the **limited off-set effect** of sulphate aerosols on temperature – this off-set will only impact the regional climate in the short-term therefore cannot be considered as a climate mitigation measure.
- Testing and adopting **new cutting-edge technologies** to improve the efficiency of energy usage, to monitor climate response and to control rainfall pollution.
- Engaging in the **development of climate services**, e.g. the decadal prototype climate service for air quality control with projections of haze weather index at the Met Office, to allow tailored service for downstream users.
- **Raising awareness** of the impacts of sulphate aerosols among the public to empower the population, highlighting the benefits of reducing aerosol emissions in their lives.

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By Hui Jia, with thanks to Buwen Dong and Laura Wilcox (National Centre for Atmospheric Science / University of Reading)

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Urban flood control in coastal mega-cities: Shanghai

Briefing Note

A briefing on research from the Climate Science for Service Partnership (CSSP) China for decision-makers in China No. 02

An integrated framework for the assessment of flood risk mitigation strategies under future uncertainties in coastal mega-cities has been developed (Hu et al., 2019). The framework includes a decision-support tool that has been applied to central Shanghai. The results show that drainage capacity plays a dominant role and that the trade-offs between grey and green flood mitigation solutions need to be considered to reduce the risk of flooding.

Mega-cities and climate change

With a population greater than 10 million, mega-cities are typically the most prominent centres of population and economy in a country (United Nations, 2018) and therefore well placed to play a leading role in responding to climate change challenges.

In a warming climate, coastal mega-cities (e.g. Shanghai) will face increasing flood risk caused by increased precipitation (under the current protection standard) which poses a significant challenge for flood protection planning. Rapid urbanisation, which is associated with anthropogenic heat and artificial land cover, may lead to urban rain island effect with localised inundation events as a consequence. Moreover, land subsidence and sea level rise have caused a decrease in urban drainage capacity in coastal cities. In addition to these complex physical factors, long-term planning to manage flood risk will be further challenged by uncertainty in socio-economic factors and contested stakeholder priorities.

Understanding the extent to which these factors will increase the risk of flooding is key to taking actions in a warming climate.

A planning-support tool, which considers the entire cascade of factors and its uncertainties, provides a promising framework to address the challenges of increasing flood risk, and to inform adaptation and mitigation strategies.

Key findings

- **Flood risk decision-support tool developed** - the tool takes into account the uncertainty in future rainfall patterns and intensity, the physical and economic damages resulting from extreme rainfall events and the cost-effectiveness of different mitigation options.
- **Tool applied to a coastal mega-city** - the framework was implemented to the reoccurrence, in the 2050s, of a record-breaking extreme rainfall event in Shanghai. Different factors causing uncertainty of future extreme flood events were identified and assessed to support future planning for flooding protection in Shanghai.
- **Sea-level rise and land subsidence key concerns for flood control** - a decrease in the capacity of urban drainage systems, caused by sea level rise and land subsidence, will play a dominant role in worsening future inundation risks in central Shanghai.
- **Combination of grey and green infrastructure** - the negative environmental impacts of grey solutions (e.g. deep tunnel construction) and the environmental benefits of green ones (e.g. Sponge City in China) are difficult to measure and typically underestimated by planners. A combination of grey and green infrastructure is preferred, taking into account their environmental impacts while reducing inundation risk.
- **Knowledge co-creation** – given future uncertainty and conflict of priorities, a knowledge co-creation process that includes scientists, policy-makers, infrastructure experts and other stakeholders is crucial for a trade-off analysis of alternative flood control solutions.

Urban Flood Image: Kelly Sikkema, Unsplash

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Implications

When dealing with the risks and uncertainties posed by future climate change, there is an increased demand for wise and visionary decision-making. One area that still needs attention is the co-development of climate services to engage both providers and users to bridge the gap between the scientific research and practical applications.

The Climate Science for Services Partnership China (CSSP China) programme provides a good opportunity to enable better management of the risks of climate variability through the strong strategic collaboration it has established between scientists, policy-makers, and stakeholders. (Golding et al.,2017).

Huangpu River, Shanghai. Image: Pixabay

Recommendations

- **Employment of planning-support frameworks for decision-making.** Such frameworks can enable city planners and other stakeholders to take into account multiple factors and their uncertainties for flood control under climate change.
- **Consideration of future climates and human activities.** For future flood control, a proactive planning strategy is required to strengthen drainage capacity affected by sea level rise and land subsidence.
- **Balancing between grey infrastructure and green solutions.** Trade-offs between these measures for flood risk management should be considered by city planners, especially when planning new cities, e.g. Xiong'an New Area in China.
- **Establishing synergies between different actors and sectors.** Engagement between decision-makers, scientists and sectoral experts should be encouraged. This will motivate applied research and thus potentially produce solutions that are more tailor-made and effective.
- **Increasing capacity in the utilisation of climate information.** Raising awareness of climate change among decision-makers is needed, together with a capacity-building campaign in the effective use of climate information.

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By Hui Jia

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Risks to food security in China under climate change

Briefing Note | A briefing on research from the Climate Science for Service Partnership (CSSP) China for decision-makers in China No. 03

The CSSP China project is investigating how climate change will affect agricultural systems in Northeast China. This research will be used to create accessible climate information which can be used to help Chinese government officials, industry and the public to make climate-informed decisions in the near and long-term future.

Drought is the dominant climate-related hazard affecting agriculture in Northeast China. China produces 30% of the global maize supply, and 30% of this is grown in the Northeast Farming Region (NFR), making it a critically important region for national production. Assessing drought characteristics over recent decades can help to improve our understanding of the large-scale climate drivers of drought and the relationship between drought and maize yield. Understanding these processes will enable the impacts of drought events to be better understood in the future.

How can this work on food security help to support decision-makers?

The China Meteorological Administration (CMA) and the Met Office are investigating climate-related risks to food security. This information will help those making decisions about agricultural and food systems in China to plan on annual to decadal timescales. For example, understanding the current and future risk of drought in the NFR will help local government and farmers determine what measures could be taken during times of water shortages to prevent a poor harvest.

This work supports the agricultural risk management priority outlined in the China Framework for Climate Services (CFCS). Ultimately, understanding the links between climate and crop yield will help inform decisions, creating a more productive and resilient agricultural industry in China.

New findings from CSSP China

The CSSP China project has provided a platform for scientists in the UK and China to develop models and scientific tools to understand the impact of climate change on life in China and worldwide. There are three main areas of research being developed for food security:

1. **Modelling extreme weather events** - Using the latest climate models, extreme weather events can be simulated that could feasibly occur in reality but have not yet been observed. This new method is called UNSEEN (UNprecedented Simulation of Extremes with ENsemble) and creates a collection of virtual observations using state-of-the-art climate models. This information can help communities build climate-resilient agriculture and food systems.
2. **Crop responses to extreme weather** - Observations and climate models are used to understand how crops are affected by changes in temperature and rainfall. Research has found that changes in the strength of the jet stream affect growing conditions for maize across North and Northeast China (Kent et al. 2019). This research could be used to develop a seasonal maize forecast which could help implement strategies for maximising crop yield.
3. **Satellite mapping of crop risks** – Crop stress can be monitored using images from the Copernicus Sentinel satellite data. This information can be used in combination with observational weather data to develop crop warning systems, potentially in the form of a mobile app.

Figure 1: Droughts affecting maize in Liaoning Province, 2020 (sina.com

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China is the world's largest agricultural economy and one of the top global food producers, accounting for ~18% of the world's cereal grains, ~29% of the world's meat and ~50% of the world's vegetables (Ghose. 2014). Food security is one of the main goals of China's agricultural policy (Huang and Rozelle. 2009). Understanding the risks facing the food and agriculture system can help decision-makers develop long-term plans.

The following questions are important to consider when assessing climate risks to the agricultural system:

- What are the key climate hazards that affect the food system?
- How might these hazards change in the future?
- How can information about present and future climate help decision-makers to build a more resilient food system?

Why focus on the Northeast Farming Region?

The NFR accounts for ~30% of Chinese maize production yet maize grown there is particularly sensitive to climate-driven hazards, such as drought, because it is predominately rain-fed.

Drought is the dominant cause of climate-related disasters in the region leading to a loss of agricultural production (Figure 3). Unexpected decreases in maize yield will not only cause huge economic losses, but will have negative impacts on prices, trade and national and global food security.

Collaboration between the Met Office and CMA has demonstrated the need for adaptation and mitigation measures to reduce the impact of climate change on the NFR. CSSP China aims to co-develop climate services with decision makers in the NFR to help them manage risk.

What are risks to food security?

Drought is a major risk to agriculture in Northeast China (Boxes 1&2), the impact on crops can be devastating and depends on a range of factors such as severity, duration, area and frequency, as well the crop type and stage of growth.

Severe droughts, as seen in 2014, (Box 1) have had large-scale impacts on agriculture and on the livelihoods of people in China. Research in CSSP China aims to build on existing knowledge to improve the understanding of droughts and drought risk in China.

[Continues ...]

Box 1: CASE STUDY - Severe drought in Liaoning, July and August 2014

In July and August 2014, seven provinces in North China experienced a severe drought. For some areas, it was the most serious drought since 1951 (Wang and He, 2015).

Northeast China had considerably less rainfall during these summer months, affecting Jilin and Liaoning. Figure 2 shows how total water resources in Liaoning (grey) were significantly lower in 2014 than in previous years.

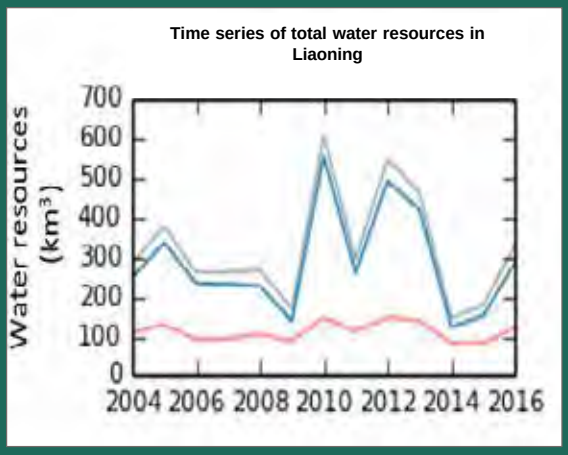

Figure 2: Time series of total water resources by province (grey, km³), and the contribution from surface water (blue, km³) and groundwater (red, km³). Source: National Bureau of Statistics in China.

News articles reported that Liaoning authorities had 'mobilized more than two million people' and 'invested 592 million yuan' in response. A national drought relief emergency response was triggered by the National Committee for Disaster Reduction and the Ministry of Civil Affairs. The local government started emergency water projects, including dispatching water tankers, cloud seeding to induce rain and digging wells to find alternative sources of water. Despite this, the 2014 drought caused maize production to decrease by ~4 million tons (approximately 5% of total maize production) (Wang et al. 2020).

It demonstrated how severe weather events can impact food security and livelihoods. Information and knowledge gained from collaborative research and partnerships are vital to help inform decisions and prepare for future climate change.

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Briefing Note

Risk to Food Security in China under Climate Change

Under current climatic conditions, there is a 5% chance each year of a drought occurring (Kent et al. 2019) which is larger in area than any previously observed event (Box 2). Agriculture accounts for nearly 65% of all water usage in China, including both surface and groundwater sources (Pope. 2017). Research conducted by CMA and the Met Office predicts there could be an increased water requirement for maize irrigation by the middle of the century which will increase the risk of extreme water shortages in the NFR (Xu et al. 2019). These water shortages are projected to occur mid-season, an important developmental time for the maize crop. Improving irrigation in the region will be crucial to sustain current maize yields.

How can the region adapt?

Using the latest research findings from CSSP China, farmers, policymakers, scientists and the agricultural industry are creating tools to deliver relevant climate information. These tools will be tailored to decision-makers and will help advanced planning for actions such as irrigation and adjusting the crop calendar.

Maize Harvest
Pixabay.com

"Understanding the climate risk to food production is a vital part of building resilient and sustainable food systems. We are working with partners in China to understand how maize production can be affected by drought and flood conditions both now and in the future. The aim is to develop a skilful seasonal forecast system which will give early warnings, allowing farmers and decision-makers to better prepare for these hazardous events."

- Dr Edward Pope

CSSP China Scientist, Met Office

Box 2: Unprecedented Events in the Current Climate

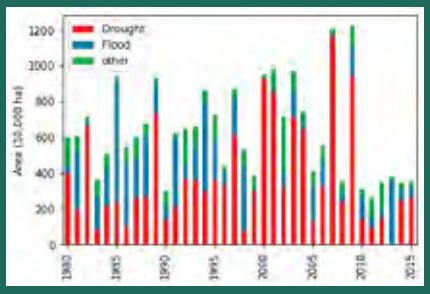

Figure 3: Reported area affected by drought, floods, and other hazards across cropland in the NFR where droughts are the main hazard.

Droughts are the dominant hazard in the Northeast Farming Region (Figure 3), a key area for maize growth.

CSSP China researchers used a number of climate models, with slightly different starting conditions, to generate a dataset of thousands of simulations of the current climate (Figure 4 – grey lines). These model runs produce 80 times as much data as the equivalent observational dataset (1981-2010) (blue line). This helps scientists understand the variability of the current climate and improves knowledge of extreme climate events, such as droughts (red dots).

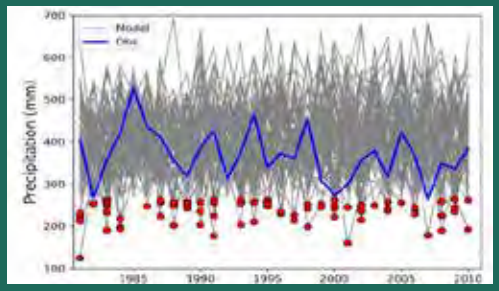

Figure 4: Climate model runs of precipitation (grey lines) compared to precipitation observations (blue line) over the NFR 1981-2010. Red dots highlight results that showed a record low precipitation. In total the model produced 81 record dry events (Kent et al. 2019).

This research shows there is a 5% annual chance of a drought occurring which is greater in area than any previously observed (Kent et al. 2019). It suggests the expected risk of a major drought is significantly underestimated if based only on the observational record.

The results from these model simulations are also being used to identify key large-scale atmospheric circulation patterns associated with NFR rainfall variability and maize yield. This information could be used to create a climate service which delivers seasonal information to farmers about potential drought risk.

By understanding the current and future risks of record drought events, decision-makers can initiate plans to make the agricultural industry in China more resilient to climate change and create a more food-secure future.

Implications and recommendations for the Northeast Farming Region

Without effective adaptation, the warming climate in the NFR could lead to a reduction in maize yield. Government, the agricultural industry and local farmers need to take action to reduce risk to crops from extreme climate events. These include:

- Engaging in and directing **the development of climate services**, e.g., a seasonal forecast of adverse growing conditions for maize, with users specifying their needs to allow for a more tailored service.
- Assessing current drought exposure and identifying areas with **different levels of droughts risk**.
- Strengthening **intersectoral collaboration** among the emergency management, water, agriculture, and climate sectors for the design of **long-term** irrigation infrastructures, and **short-range** mitigation strategies.
- Issuing guidance for farmers to **benefit from the increasing heat** in a warming climate.
- Estimating crop water requirement **at different growth stages** to optimise irrigation and guarantee water resource amid drought events.
- Developing **more efficient irrigation technologies** and **motivating more efficient use of water resources** by adopting incentive-based approaches, e.g., water rights transaction across different households and sectors (Di et al.2020; DRCMWR, 2018).

Next steps

Working with agricultural experts in China, the Met Office can design tools to deliver the information users need to make climate-conscious decisions. The Met Office wants to learn about the choices that are made about crops, farming and food sales, and will share information about current and projected future climate in the Northeast Farming Region. By working together, the Met Office, CMA, businesses, and local communities can help to create a more resilient and food secure future for China. Scan the top QR code (below right) to contact the Met Office on WeChat.

"The drought events will not only directly impact the productivity but could also harm the agriculture by inducing pest disasters, etc. An advanced seasonal forecast of drought events could benefit mitigation strategy planning, as emergency supplies are needed in response to such disasters."

- Yanhua Wang
Agricultural expert, CIECC

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By Stacey New and Hui Jia, with thanks to Jennifer Weeks, Rosie Oakes, Tyrone Dunbar and Nicola Golding

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Communicating uncertainty in climate and extreme weather forecasting

Briefing Note | A briefing on research from the Climate Science for Service Partnership (CSSP) China for decision-makers in China No. 04

The language of climate science can be a barrier to the take-up of valuable research, regardless of its importance and relevance. Even among climate scientists speaking the same language, differing definitions of common terminology can be an obstacle, leading to glossaries accompanying some reports. Bring in a completely different language – such as Mandarin – and a structurally different decision-making process for and by users, and the challenge expands.

However, it a challenge that Climate Science for Service Partnership (CSSP) China has approached in the same way as all its joint climate research – collaboratively.

Deterministic v probabilistic forecasts

Research into communicating uncertainty in climate information for China, (Andrea Taylor et al), led by the University of Leeds, conducted interviews with climate scientists and potential users from China and the UK, covering the hydropower, water, urban, agriculture, aviation, commercial and academic sectors.

Discussions on how best to communicate climate services (such as seasonal forecasts which are presented as A4 documents) to high-level decision-makers in China found a strong preference for deterministic information (such as a prediction of an actual temperature or amount of rainfall), which was echoed by potential new users. While some experienced users said they welcomed probabilistic information (encompassing the uncertainty around projected information), deterministic information was seen as highly important for maintaining credibility and engaging decision-makers at the highest levels.

Furthermore, while current users expressed an overall preference for receiving probabilistic forecast information, the level of probability they required was often unrealistically high, for instance above 80%. They were less inclined to engage with probabilities lower than 60%, which were deemed to lack credibility.

This desire for forecasts to be linked to extremes or user-defined thresholds, rather than historical averages, was expressed throughout the interviews with current and potential users of seasonal forecasts.

A new glossary of commonly mis-translated climate terms

English is widely used as the common language of science around the world but to encourage the take-up of science from the CSSP China project within China, many of the resources produced have been translated in Mandarin. Translating the idiosyncrasies of frequently-used climate terms has been challenging as has a lack of terms in the language to express uncertainty in climate forecasts and projections.

CSSP China has taken steps towards addressing the recommendations overleaf:

- **Arup's climate risk tool for infrastructure, produced as part of CSSP China, includes a glossary of climate terms.**
- **The Met Office and the Institute for Environmental Analytics have compiled a glossary of the most commonly confused translations, published on the VIEWpoint website. This is a working document to which further comments and suggestions can be added.**
  www.viewpoint-cssp.org/glossary

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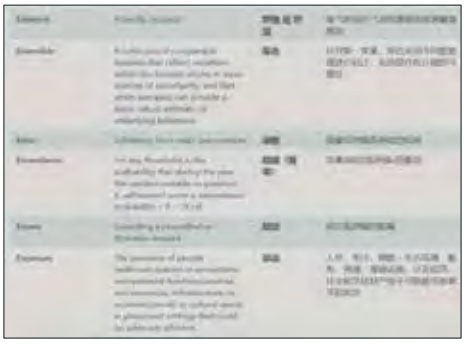
Implications

Managing user expectations of what climate science can feasibly provide is crucial, especially if tailoring climate information products to decision-relevant thresholds or seasonal extremes, where high probabilities of exceedance may be rare.

For both Chinese and UK experts, there is a need to balance what users want against what can be reasonably provided, for instance a probabilistic threshold of 80% would very rarely be reached in seasonal forecasting.

The participants recognised a trade-off between providing detailed explanations and overloading users with information, as well as a need to tailor this information to a diverse range of users.

Although this research found a belief among the participants that probabilistic information should be communicated, opinions on how to do this varied. This could be addressed through training in uncertainty in forecasting for end-users, for intermediaries advising decision-makers as well as for decision-makers themselves, but also for climate scientists who are communicating probabilistic information to them.



An English-Mandarin glossary of commonly misunderstood or mis-translated climate terms is featured on the VIEWpoint CSSP China website at www.viewpoint-cssp.org/glossary

Recommendations

- Take into account that end-users of climate information **may** not always be final decision makers, but rather technicians and analysts who advise them.
- Work towards providing information for user-relevant thresholds and extremes (rather than being above/below the historical averages), subject to the underlying forecasting science being able to support this.
- Keep explanations, justifying forecasts, for example, concise. Long technical descriptions are unlikely to be directly consulted.
- Include decision-relevant advisory statements.
- Use summary boxes at the top of the first page of seasonal forecasts, written in plain language, to highlight the most important information – the headline message.
- Developing Chinese terminologies to be able to talk about different aspects of uncertainty and products that enable academic users to integrate uncertainties into their work, will assist improved climate communication.
- Specific training for climate scientists, users and decision-makers could help address a perception that adherence to procedures and hierarchy within the delivery processes may have an importance that goes above and beyond the information itself.

Further reading:

Andrea Louise TAYLOR, Sam GRAINGER, Suraje DESSAI, Yim Ling SIU & Marta BRUNO SOARES (2021) Communicating Uncertainty in Climate Information for China: Recommendations and Lessons Learned for Climate Services
http://jmr.cmsjournal.net/article/doi/10.1007/s13351-021-0118-y

Blog by Andrea Taylor: https://cdr.leeds.ac.uk/news/andrea-taylor-communicating-uncertainty-in-climate-information-in-china/

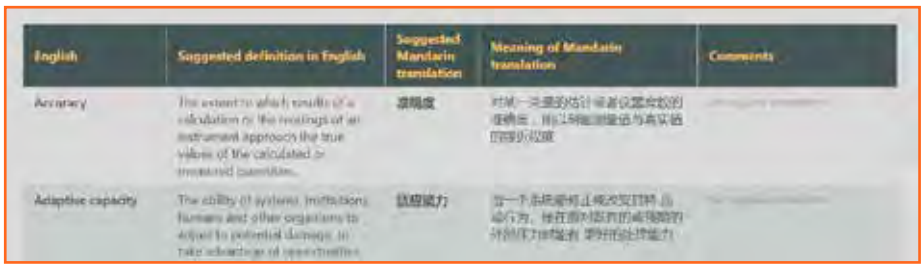
In 2018 the IPCC (Intergovernmental Panel on Climate Change) published a glossary of terms used in the context of its report 'Special report: Global warming of 1.5°C'
https://www.ipcc.ch/sr15/chapter/glossary/

By Sally Stevens, with thanks to Andrea Taylor

GUIDE TO CLIMATE SCIENCE TERMINOLOGY

By Jennifer Weeks, Met Office

A key part of making the research produced by CSSP China as widely available as possible has been translating resources into Chinese, as well as into plain English. In both cases scientists – and non-scientists – came across challenges in using some climate terms meaningfully as well as accurately.



English	Suggested definition in English	Suggested Mandarin translation	Meaning of Mandarin translation	Comments
Accuracy	The extent to which results of a calculation or the readings of an instrument approach the true values of the calculated or measured quantities.	准确度		
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities	适应能力		

Thus the CSSP China glossary was born - designed to be an evolving resource, providing suggested translations of climate science terms from English to Chinese.

You can find the full glossary online at the VIEWpoint website www.viewpoint-cssp.org, or use the QR code below.

Here we have shared a selection of terms that are most frequently commonly misunderstood by non-scientists or those that have been difficult to translate into Chinese based on our experience.

In the full glossary we have also provided translations for special terms used in the demonstrators and resources produced by VIEWpoint and CSSP China that have non-conventional definitions.

We hope this glossary will be widely used by those looking for accurate English-Chinese climate science translations in the future, both within climate science and those making climate-related decisions across all sectors, including policy-makers and audiences at the United Nations global climate conference, COP26, taking place in November 2021.

The full glossary can be downloaded, shared and printed to be used as a quick guide for translators.

It is important to note the language used in climate science is constantly evolving and the precise definition could change in the future.

If you have any additional suggestions for terms on this list, please email WCSSPProgrammeOffice@metoffice.gov.uk

Turn to pages 64-65 to read the VIEWpoint Briefing Note 'Communicating uncertainty in climate and extreme weather forecasting'.

Acknowledgements:
We would like to thank all the scientists, translators and proof-readers involved in the CSSP China project for their help in compiling the glossary. We would also like to thank Ms Zheng Lin (IAP), Prof Yinlong Xu (CAAS) and Dr Lei Huang (CMA) for proof-reading these terms.

Scan the QR code on the left to visit the full online CSSP China glossary of climate change terms.

Scan the QR code on the right to listen to a podcast with advice on how to communicate climate science with confidence.

GLOSSARY

Term in English 英文术语	English Definition 英文定义	Term in Chinese 术语中文翻译	Chinese Definition 中文定义	Comments 注释
Skill	A statistical evaluation of the accuracy of forecasts or the effectiveness of detection techniques.	技巧	信号侦测手段的有效性	Definition from American Meteorological Society (2021). Available at: https://glossary.ametsoc.org/wiki/Skill (accessed 03/03/2021)
Ensemble	A collection of model simulations characterizing a climate prediction or projection. Differences in initial conditions and model formulation result in different evolutions of the modeled system and may give information on uncertainty associated with various errors.	集合	针对某一变量，综合采用不同数据源进行估计，从而提升估计值的可靠性	Adapted from IPCC AR5 WGII (2014).
Predictability	The extent to which future states of a system may be predicted based on knowledge of current and past states of the system.	可预报性	基于历史数据，对于未来状态的可预测程度	Definition from American Meteorological Society (2021). Available at: https://glossary.ametsoc.org/wiki/Predictability (accessed 03/03/2021)
Confidence	The robustness of a finding based on the type, amount, quality and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement across multiple lines of evidence.	信度	被测量参数的测量值的可信程度	Definition from IPCC SR1.5 (2018).
Likelihood	Probability of a hazard event occurring.	可能性	给定特定观测值后，描述模型参数是否合理	Definition used in ARUP's city tool.
Surprises	Low probability, high consequence events	突发事件	低可能性但会产生重大影响的事件	
Probability	The chance that a prescribed event will occur, represented as a pure number p in the range $0 \leq p \leq 1$.	概率	某事件可能发生的百分比	Definition from American Meteorological Society (2021). Available at: https://glossary.ametsoc.org/wiki/Probability (accessed 03/03/2021)
Reliability	The degree of correspondence between forecast probabilities and observed relative frequencies.	可靠性	指采用同样的方法对同一对象重复测量时所得结果的一致性程度	
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences	适应能力	指一个系统能修正或改变其特 质或行为，使在面对既有的或预期的外部压力时能有 更好的处理能力	Term used in Arup's city tool. Definition from IPCC SR1.5 (2018).
Risk	The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain.	风险	气候相关危害与人类和自然系统的暴露度和脆弱性相互作用而产生不良后果的可能	Term used in Arup's city tool. Definition from IPCC SR1.5 (2018).
Error	Difference from exact true number	误差	测量结果偏离真值的程度	Avoid using 'mistake', 'wrong' or 'incorrect' in definition.
Uncertainty/ certainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable	不确定性/ 确定性	由于信息缺失或者对已知甚至可知信息的不同见解而产生的不完善的知识状态	Definition from IPCC SR1.5 (2018).
Reliability	The degree of correspondence between forecast probabilities and observed relative frequencies.	可靠性	指采用同样的方法对同一对象重复测量时所得结果的一致性程度	Also: 预测概率与观察到的相对频率之间的对应程度。
Extreme weather event	An extreme weather event is an event that is rare at a particular place and time of year, normally as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations.	极端天气事件	极端天气事件是指一年中特定地点和时间很少发生的事件。通常情况下，极端天气事件的罕见程度相当于或者低于与观测值预估的概率密度函数的10%或90% 。	Adapted from IPCC AR5 WGII (2014)
Normal	The average value of a meteorological element over any fixed period of years that is recognized as a standard for the country and element concerned.	正常值	某一气象要素在任何固定年限内的平均值，该平均值被认定为有关国家/地区和有关要素的标准。	Definition from American Meteorological Society (2021). Available at: https://glossary.ametsoc.org/wiki/Normal (accessed 03/03/2021)

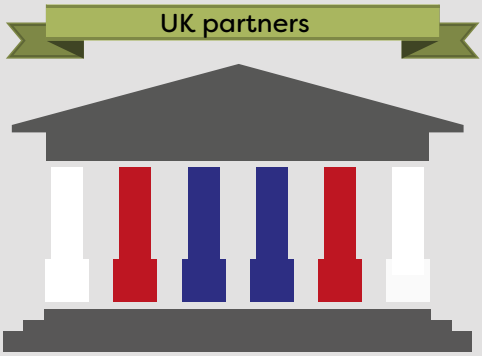
340+ Papers Published

30 early career researchers trained in attribution science

100 UK scientists

100 Chinese scientists

CSSP China in numbers



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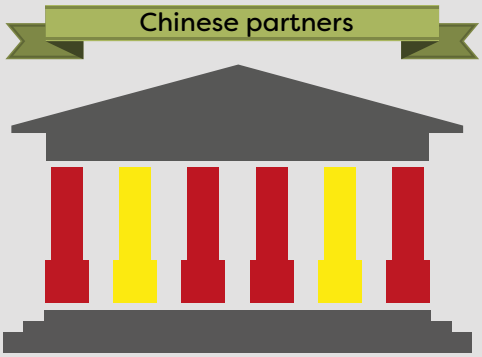

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80+ scientist exchange visits

Infographic by Andy Wan, Institute for Environmental Analytics