

APEC Climate Symposium 2014

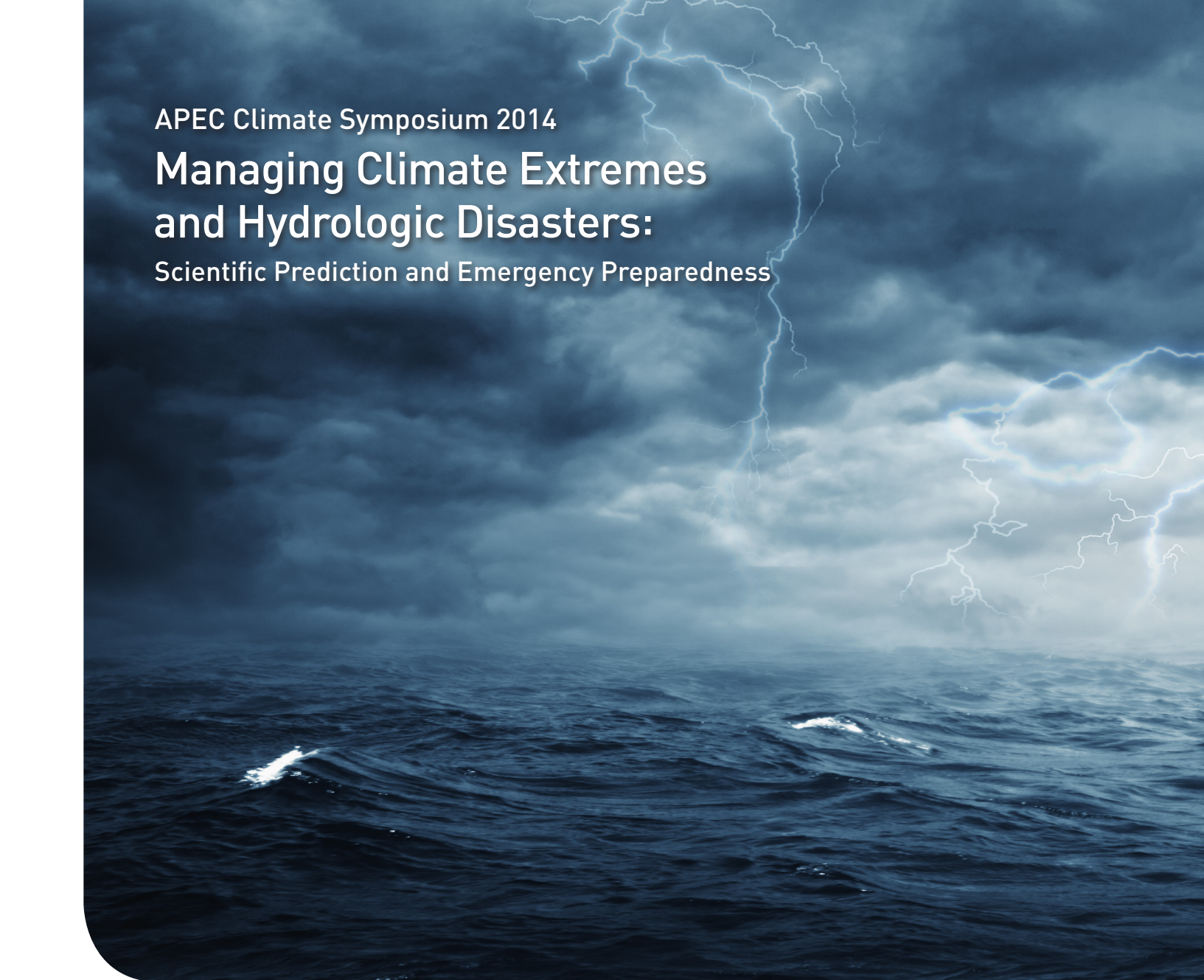
Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness



Nanjing, China
October 27-29, 2014





APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

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Welcome Message

On behalf of the organizers, the APEC Climate Center is delighted to welcome you to Nanjing, China for the APEC Climate Symposium (APCS) 2014. The APEC Climate Center has developed this conference to advance climate science to help better manage and mitigate the impacts of climate extremes and hydrological disasters.

With various participants hailing from many different developed and developing countries coming together to share their experiences, this event provides a unique opportunity for all economies dealing with extreme weather to learn from the experiences of economies that have historically dealt with floods, typhoons, and other water related issues.

It is our hope that participants will return to their home countries enriched by the information and case studies shared over the next couple days and can apply their learning towards reducing the vulnerability of their regions to climate extremes.

APCS 2014 would not have been possible without the strong support of our valuable partners. I would like to offer our sincere gratitude to all of the members of the Organizing Committee members and our co-hosts at the Nanjing University of Information Science & Technology, as well as to all the speakers and participants.

We hope that you enjoy the symposium.

Thank you.

Chin-Seung Chung
Director, APEC Climate Center

Organizers



APEC Climate Center (APCC)

The Asia-Pacific Economic Cooperation (APEC) Climate Center is a leading climate information service provider in the Asia-Pacific region. We provide climate forecasts and information services, conduct research and development activities, and organize capacity building initiatives in the Asia-Pacific region and with developing countries. APCC was established in 2005 with the endorsement and warm welcome of the APEC senior officials and leaders. We annually organize the APEC Climate Symposium, which provides a forum for various scientists, academics, policy-makers and other stakeholders to share the latest science innovations in climate prediction and explore climate information applications.

In addition to organizing events, APCC provides operational services such as monthly seasonal outlooks and climate monitoring and prediction products, as well as conducting climate change R&D and supporting online tools and data services. At APCC, we strive to strengthen scientific and technological cooperation across the APEC region in order to help economies and societies deal effectively with the consequences of current and future climate-related hazards through the provision of climate information, research and technical support.



Nanjing University of Information Science & Technology (NUIST)

We are delighted to be working together to host the 2014 APEC Climate Symposium with the APEC Climate Center. Nanjing University of Information Science & Technology (NUIST) was founded in 1960 as the Nanjing Institute of Meteorology and was later renamed to its current name in 2004. In 1978, it was designated as one of the key institutions of higher learning in China. NUIST is a national-level key university co-constructed by the Jiangsu Provincial People's Government, the Ministry of Education of the People's Republic of China, the China Meteorological Administration (CMA) and the State Oceanic Administration of the People's Republic of China. It was designated as the Jiangsu Pilot University of Comprehensive Educational Reform. The university has a complete higher education system with undergraduate, postgraduate, doctoral programs as well as post-doctoral research centers. The discipline of Atmospheric Science ranks No. 1 in the national discipline evaluation conducted by the Ministry of Education of China in 2012, which has a great influence in the world. Currently, the university has over 30,000 undergraduates, more than 1,500 full-time teachers.

In recent years, sticking to the guideline of open and collaborative development, NUIST has been developing metrological services in China, the local economic and social development, performing remarkable achievements in talents cultivation, scientific research, social service and other various undertakings, greatly expanding its school-running space and enhancing its comprehensive strength. NUIST will promote further reform, collaborative innovation, talent cultivation, hi-tech innovation capacity, all to make NUIST a first-class key university in China.

Speakers

Opening Remarks & Congratulatory Address



Dr. Chin-Seung Chung

Director, APEC Climate Center

Dr. Chin-Seung Chung joined the APEC Climate Center as the Director in April 2010 after four decades of professional experience in government services. Since his arrival, Dr. Chung has steered APCC toward becoming one of the leading research centers providing climate information to the Asia-Pacific region. APCC contributes to prediction and monitoring activities of weather and climate in the Asia-Pacific region and supports capacity-building by providing climate information services and technical support for the reduction of economic losses due to adverse climate conditions.

Prior to his position at APCC, Dr. Chung was a Dean and Professor at the Korea Development Institute (KDI) School of Public Policy Management. He received his Ph.D. in Economics from the University of Georgia in 1983 and commenced a career in government service at different institutions. Dr. Chung served as the Deputy and Vice Minister at the Korean Ministry of Environment. While he was working at the Ministry, he was a Head Negotiator for the Korean Delegation for the COP3 meeting of the UN Framework Convention on Climate Change, at which the Kyoto Protocol was adopted in 1997. He was also the President of the Korea Environmental Economic Research Association, as well as a Senior Research Fellow at the Korea Development Institute for twenty-two years from 1972-94. He has lectured at Stanford University, the Korea Advanced Institute of Science and Technology (KAIST) and Sogang University. He has conducted research and published books and numerous articles related to industrial trade and environmental issues. He is the author of Economic Development and Economic Policy in Korea (2006) and Environmental Policy at the Age of Decentralization in Korea (1993).



Prof. Jianqing Jiang

President and Vice Chancellor, Nanjing
University of Information Science & Technology

Prof. Jianqing Jiang is the President and Vice Chancellor of Nanjing University of Information Science & Technology. He is responsible for overall administrative affairs. He has many duties including being a member of the Teaching Instruction Sub-committee for Metallic Engineering and Metallurgical Engineering Majors under the Ministry of Education. He is also the Standing Director of Instrument Materials Society of China Instrument and Control Society, a member of Material Science Branch of Chinese Society for Metals, a member of Youth Committee of Chinese Materials Research Society, Deputy Chief of Materials Section of the 4th Natural Science Foundation Committee of Jiangsu Province, and a member of the editorial board of Functional Materials.

Prof. Jianqing Jiang has been engaged in teaching and the research of materials science and engineering. His research mainly focuses on high-performance metal materials, inorganic optical functional materials and film materials, etc. He has presided over more than 20 projects such as '863' national projects, published over 100 academic theses. Additionally, he owns 30 state authorized invention patents. He won Second Prize in the State Science and Technology Advancement Award Competition and additionally won Second Prize for the State Teaching Award. He has been selected into the second-level personnel to be cultivated in '333 High-level Talents Training Project' and the new-century outstanding talent to be cultivated by the Ministry of Education and he has received a special allowance from the State Council.

Speakers

Opening Remarks & Congratulatory Address



Dr. Alan Bollard

Executive Director, APEC Secretariat

Dr. Alan Bollard is the Executive Director of the APEC Secretariat based in Singapore, the body that promotes trade, investment and sustainable economic growth in the Asia-Pacific. Dr. Bollard advances APEC's agenda by executing APEC's work programmes as mandated by Leaders and Ministers. Prior to joining APEC, Dr. Bollard was the Governor of the Reserve Bank of New Zealand from 2002 to 2012. In that position, he was responsible for monetary policy and bank regulations, helping steer New Zealand through the global financial crisis.

From 1998 to 2002, Dr. Bollard was the Secretary to the New Zealand Treasury. As the government's principal economic adviser, he managed the Crown's finances and helped guide economic policy. He has served as New Zealand's Alternate Governor to the International Monetary Fund, the Asian Development Bank and the World Bank. From 1994 – 2008, he was the Chairman of the New Zealand Commerce Commission.

Dr. Bollard has also designed a computer simulation game called OIKONOMOS where you play at being Minister of Finance. He wrote a best-selling account of the GFC called Crisis: One Central Bank Governor and the Global Financial Collapse. Dr. Bollard has a PhD in Economics from the University of Auckland. He has since been awarded several honorary doctorate degrees. In 2012, he was honored as a Companion of the New Zealand Order of Merit.



Mr. Sangchan Gu

Consulate General of the Republic of Korea in Shanghai

Mr. Sangchan Gu was appointed the Consul-General, Korean Consulate General in Shanghai, China in June 2013. From 2008 to 2012, he was a member of the Republic of Korea National Assembly. While in the National Assembly, Mr. Gu served as an Executive Member of Foreign Affairs, Trade and Unification Standing Committee. Additionally, from 2008 to 2012, he was the President of the Korea-China Cultural Research Association.

In 2008, he was a Special Envoy of the President to the People's Republic of China. He also formally served as a Special Assistant for Public Relations for Ms. Geun-hye Park (the current President of the Republic of Korea) while she was the chairperson of the Hannara (Grand National) Party. Sangchan Gu received his MA from Dongguk University in Seoul, Korea, where he also later served as a professor.



Prof. Lianchun Song

Director, Nation Climate Center

Dr. Lianchun Song is currently the Director-General of the National Climate Center, of the China Meteorological Administration (CMA). From 1986 to 1994, he worked in the area of Climate impact assessment in National Meteorological center in CMA. From 1994 to 1999, he served as the Director of Climate Data Center in National Meteorological Center, CMA and then as the Assistant Director-General of the National Meteorological Center. From 2001 to 2006, Dr. Song served as the Director-General of the Gansu Meteorological Bureau and then from 2006 to 2007 as the Director-General of the Department of Forecasting Service and Disaster Mitigation in CMA. He was the Director-General of the Meteorological Observation Center of CMA from 2007 to 2010.



Prof. Bin Wang

Chair, Department of Meteorology, University of Hawaii

Dr. Bin Wang is a professor and chair at the Department of Meteorology and a team leader for the Asian-Australian Monsoon Research at the International Pacific Research Center at University of Hawai'i.

He has published over 220 research articles and 11 book chapters in the field of atmosphere and ocean dynamics, climate dynamics and tropical meteorology. He has edited "The Asian Monsoon" book in 2006. His research has made a considerable impact as evidenced by his citation rate of 4,814 times during 2006-2010. Wang has brought about \$6 million in research grants to the University of Hawai'i since 2000.

Wang's many contributions to the climate research community include serving as co-chair of the CLIVAR/Asian-Australian Monsoon panel, co-chair of Science Steering Committee of the Asian Monsoon Years (2007-2012), He served as an editor for the Journal of Atmospheric Sciences.

Speakers

Keynote



Dr. David Rogers

Global Facility for Disaster Reduction and Recovery

Dr. Rogers is President of the Health and Climate Foundation (HCF), an international non-profit organization dedicated to finding solutions to climate related health problems and supporting partnerships between health and climate practitioners. Prior to founding HCF, Dr. Rogers held various appointments in government, the private sector and academia. These include Chief Executive of the UK Met Office; Vice President, Science Applications International Corporation; Director of the Office of Weather and Air Quality at the US National Oceanic and Atmospheric Administration; Director of Physical Oceanography at Scripps Institution of Oceanography, and Associate Director of the California Space Institute, University of California, San Diego, USA. Currently, Dr. Rogers is a senior advisor to the World Bank on modernizing National Meteorological and Hydrological Services.

Dr. Rogers has a Ph.D. (1983) from the University of Southampton and Bachelor of Science degree (1980) from the University of East Anglia, UK. He has published extensively in the fields of oceanography, meteorology, climate, environment and organizational development.



Dr. Zhiyu Liu

World Meteorological Organization

Dr. Liu Zhiyu has degrees in Engineering Hydrology (BS in China, MS in Ireland, and PhD in Italy), and many years working with national hydrological forecast centre of China, and extensive experience in projects on hydrologic modelling and operational system development.

He is currently held responsible for hydrological forecasting, technological guidance, training, central management of water resources data and program management, and international collaboration in his capacity as Deputy Chief Engineer and Professor of Hydrology and Water Resources at the Bureau of Hydrology, Ministry of Water Resources of China.

Dr. Liu has been an active member of Working Group on Hydrology of WMO, OPACHE of WMO-CHy and WGH of UNESCAP/WMO Typhoon Committee since 1996 and a member of China National Committee for IAHS since 2002. He is now a member of the Advisory Working Group of the WMO Commission for Hydrology leading the activities of hydrological prediction and forecasting, and the Vice-Chair of WGH of UNESCAP/WMO Typhoon Committee. He is also a member of Editorial Boards of Journal of China Hydrology, and an invited reviewer for ASCE Journal of Hydrologic Engineering in USA, Hydrology Research (Formerly Nordic Hydrology) in UK, and Water Science and Engineering, Water Resources and Power, etc. Dr. Liu has made 6 books/proceedings published and authored or co-authored over 40 publications in the above field of interests in recent 10 years.



Mr. Arjunapermal Subbiah

Regional Integrated Multi-Hazard Early Warning System

As the Director, A.R Subbiah, has operational responsibility for the RIMES Regional Early Warning Centre. He provides strategic direction and leadership for translation of policies, established by the RIMES council, into programs.

With 25 years of experience assisting countries in developing multi-institutional and multi-disciplinary mechanisms to manage natural hazards, Subbiah held senior positions with the Government of India and was involved in policy formulation and implementation of development and disaster risk reduction programs till the late 1990's. Subsequently, Subbiah held the post of Director, Climate Risk Management and Team Leader for Early Warning Systems at Asian Disaster Preparedness Centre and evolved and implemented a multi-country Climate Risk Management program and regional multi-hazard project that eventually transformed into RIMES as an inter-governmental and international institution in 2009. Subbiah has been one of the main reviewers of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX).



Dr. Konstantine Georgakakos

Hydrologic Research Center

Dr. Konstantine P. Georgakakos is the Managing Director of the Hydrologic Research Center in San Diego, California. He is also an Adjunct Professor with the Scripps Institution of Oceanography of the University of California, San Diego, and with the Department of Civil and Environmental Engineering of The University of Iowa. He has held positions of Research Scientist IV with the Scripps Institution of Oceanography, of Associate Professor with tenure at the Department of Civil and Environmental Engineering of The University of Iowa, and of Research Engineer with the Iowa Institute of Hydraulic Research. He holds Master of Science and Doctor of Science degrees from the Massachusetts Institute of Technology. He has authored or co-authored more than 130 publications regarding various areas of Hydrology, Hydrometeorology, and Hydroclimatology. He is the primary author of several software packages pertaining to real time flow prediction for operational use by Agencies such as the U.S. Army Corps of Engineers and the U.S. National Weather Service.

Dr. Georgakakos is a Fellow of the American Meteorological Society and a member of the American Geophysical Union, the American Society of Civil Engineers, the American Association for the Advancement of Science, and the New York Academy of Sciences. He has supervised several large-scale international technology transfer projects in Africa, Europe, Central and South America.

Program

October 27, 2014 (Monday)		APEC Climate Symposium 2014
08:00-09:00	Registration	
09:00-09:45	Opening Ceremony	MC: Ms. Hannah Kim (Head of External Affairs Department, APEC Climate Center/Korea)
09:00-09:05	Opening Remarks	Dr. Chin-Seung Chung (Director, APEC Climate Center/Korea)
09:05-09:10	Opening Remarks	Prof. Jianqing Jiang (President, Nanjing University of Information Science and Technology/China)
09:10-09:15	Video Congratulatory Address	Dr. Alan Bollard (Executive Director, APEC Secretariat/Singapore)
09:15-09:20	Congratulatory Address	Mr. Sangchan Gu (Consulate General of the Republic of Korea in Shanghai/Korea)
09:20-09:25	Congratulatory Address	Prof. Lianchun Song (Director, Nation Climate Center/China)
09:25-09:30	Congratulatory Address	Prof. Bin Wang (Chair, Department of Meteorology, University of Hawaii/USA)
09:30-09:45	Commemorative Plaque Presentation and Photo Session	
09:45-10:00	Coffee Break	
10:00-12:40	Session I Keynote Presentations	Chair: Dr. Jinho Yoo Rapporteur: Mr. Joseph Larsen
10:00-10:40	Impact Forecast and Warning Services	Keynote – Dr. David Rogers (Global Facility for Disaster Reduction and Recovery/USA)
10:40-11:20	Priorities of the WMO Commission for Hydrology	Keynote – Dr. Zhiyu Liu (World Meteorological Organization/China)
11:20-12:00	Economics of Early Warning System	Keynote – Mr. Arjunapermal Subbiah (Regional Integrated Multi-Hazard Early Warning System/Thailand)
12:00-12:40	Operational Prediction for Flash Flood Warning and Reservoir Management – Utility for Climate Impact Studies	Keynote – Dr. Konstantine Georgakakos (Hydrologic Research Center/USA)
12:40-14:00	Lunch / Location: Nanqi Hotel	
14:00-18:30	Session II Climate Forecasting for Water Management	Chair: Dr. Yuriy Kuleshov Rapporteur: Mr. Joseph Larsen
14:00-14:30	From Prediction To Scenario Analysis: An Australian Perspective	Dr. Bryson Bates (Centre for Environment and Life Sciences, CSIRO/Australia)
14:30-15:00	Ensemble Forecasting Of Seasonal Streamflow Using Climate Forecasts as Inputs	Dr. Quan Jun Wang (Water for Healthy Country Flagship, CSIRO/Australia)
15:00-15:30	A Seasonal Streamflow Forecasting Service for Australia: Methods, Implementation and Way forward	Dr. Julien Lerat (Environment and Research – Forecast Systems, BOM/Australia)
15:30-15:45	Coffee Break	
15:45-16:15	Seasonal Forecasting of Climate Extremes: Droughts and Floods	Dr. Yuriy Kuleshov (National Climate Centre, BOM/Australia)
16:15-16:45	A Seamless Framework for the Global Monitoring and Prediction of Droughts	Prof. Eric Wood (Princeton University/USA)
16:45-17:15	The Available Water Climatology (AWC) and its Applications	Prof. Hi-Ryong Byun (Pukyong National University/Korea)
17:15-17:30	Coffee Break	
17:30-18:00	Wrapping-up and Discussion	
18:30-20:00	Welcoming Reception hosted by NUIST / Location: Nanqi Hotel	

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October 28, 2014 (Tuesday)

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09:00-12:45	Session III Managing Risk from Droughts and Water Scarcity	Chair: Prof. Ximing Cai Rapporteur: Mr. Joseph Larsen
09:00-09:30	Impact of Climate Change on Agricultural Land and Water Sustainability – A Global Projection	Prof. Ximing Cai (University of Illinois at Urbana-Champaign/USA)
09:30-10:00	U.S. Drought Trends	Prof. Dennis Lettenmaier (University of Washington/USA)
10:00-10:30	Cost-Effective Variety can Reduce Variety in Real World: Diversity in Water Infrastructure System	Prof. Heekyung Park (Korean Advanced Institute of Science and Technology/Korea)
10:30-10:45	Coffee Break	
10:45-11:15	Utilizing APCC multi model seasonal forecast to support planning and operation of dams in South Korea	Dr. Ilwon Jung (APEC Climate Center/Korea)
11:15-11:45	Droughts And Water Security in South-Eastern Australia: Science and Management	Dr. Francis Chiew (Land and Water - Black Mountain Christian Laboratory, CSIRO/Australia)
11:45-12:15	National Disaster Response Strategies for Droughts of China -From Integrated Risk Governance Perspectives	Dr. Qian Ye (Integrated Risk Governance Project/China)
12:15-12:45	Wrapping-up and Discussion	
12:45-14:00	Lunch / Location: Nanqi Hotel	
14:00-18:00	Session IV Changes in Hydrological Extremes: Floods and Typhoons	Chair: Prof. Eric Salathé Rapporteur: Mr. Joseph Larsen
14:00-14:30	Developing Climate Scenarios and Management Tools to Reduce Vulnerability to Future Flood Risk	Prof. Eric Salathé (University of Washington/USA)
14:30-15:00	Impact Assessment of Typhoon and Related Storm Surge Considering Climate Change	Dr. Nobuhito Mori (Disaster Prevention Research Institute/Japan)
15:00-15:30	A Review On Heavy Rainfall Out of Tropical Cyclone Envelope	Prof. Lian-shou Chen (Chinese Academy of Meteorological Sciences, CMA/China)
15:30-15:45	Coffee break	
15:45-16:15	Hydrometeorological Variability and its Integrated Flood Risk Assessment for the Korean Han River Basin during different El Niño Phases	Dr. Sunkwon Yoon (APEC Climate Center/Korea)
16:15-16:45	Temporal Downscaling of Hydrometeorological Variables for Mitigating the Impacts of Climate Change on Water Disasters	Prof. Taesam Lee (Geyongsang National University/Korea)
16:45-17:15	Climate Variations Link to Extreme Streamflows	Dr. Swadhin Behera (Application Laboratory, JAMSTEC/Japan)
17:15-17:30	Coffee break	
17:30-18:00	Wrapping-up and Discussion	

Program

October 29, 2014 (Wednesday)		APEC Climate Symposium 2014
09:00-12:45	Session V Climate Impacts on Water Quality	Chair: Prof. Heejun Chang Rapporteur: Mr. Joseph Larsen
09:00-09:30	Impacts of Climate Change On Stream Temperature in the Pacific Northwest Of USA	Prof. Heejun Chang (Portland State University/USA)
09:30-10:00	Adapt to What? Projections of Direct Impacts of Climate Change on Surface Reservoir Water Quality in Australia and Taiwan	Dr. Leon van der Linden (Australian Water Quality Centre/Australia)
10:00-10:30	Climate Change Impacts on Agricultural Non-Point Source Pollution by Considering Uncertainty of CMIP5	Dr. Jaepil Cho (APEC Climate Center/Korea)
10:30-10:45	Coffee Break	
10:45-11:15	Extreme Hydroclimatic Events and Environmental Quality: Use-Inspired Characterization of Change, Thresholds and Transitions	Dr. Shaleen Jain (University of Maine/USA)
11:15-11:45	Heat Waves, Precipitation and Water related Disease Vector in Drought and Flood Prone Areas of West Bengal, India	Dr. Jyotish Basu (West Bengal State University/India)
11:45-12:15	The Taihu Eddy Flux Network: An Observational Program on Energy, Water, and Greenhouse Gas Fluxes of a Large Freshwater Lake	Prof. Xuhui Lee [Nanjing University of Information Science and Technology/China]
12:15-12:45	Wrapping-up and Discussion	
12:45-14:00	Lunch / Location: Nanqi Hotel	
14:00-17:45	Session VI Wrap-up & Panel Discussion	Chair: Prof. Bin Wang Rapporteur: Mr. Joseph Larsen
14:00-14:20	Session II Wrap-up	Dr. Yuriy Kuleshov
14:20-14:40	Session III Wrap-up	Prof. Ximing Cai
14:40-15:00	Session IV Wrap-up	Prof. Eric Salathé
15:00-15:20	Session V Wrap-up	Prof. Heejun Chang
15:20-15:35	Coffee Break	
15:35-17:45	Panel Discussion	Panelists: Dr. David Rogers, Dr. Zhiyu Liu, Dr. Konstantine Georgakakos, Prof. Eric Wood, Dr. Quan Jun Wang
17:45-18:00	Closing Remarks	Dr. Chin-Seung Chung

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Session I

Keynote Presentations

Impact Forecast and Warning Services

Dr. David Rogers
(Global Facility for Disaster Reduction and Recovery/USA)

Priorities of the WMO Commission for Hydrology

Dr. Zhiyu Liu
(World Meteorological Organization/China)

Economics of Early Warning System

Mr. Arjunapermal Subbiah
(Regional Integrated Multi-Hazard Early Warning System/
Thailand)

Operational Prediction for Flash Flood Warning and Reservoir Management – Utility for Climate Impact Studies

Dr. Konstantine Georgakakos
(Hydrologic Research Center/USA)

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TITLE: IMPACT FORECAST AND WARNING SERVICES

David P. Rogers

Global Facility for Disaster Reduction and Recovery, World Bank

Abstract Summary: It is no longer enough to provide a good hazard forecast or warning, people are now demanding information about what to do to ensure their safety and protect their property. Many people still die, and socio-economic costs associated with hydrometeorological hazards continue to rise, due, in part, to a lack of appreciation and understanding of the impacts and consequences of hydrometeorological hazards to their well-being. This paper introduces the concept of Impact Forecast and Warning Services, which focuses not on what the hazard will *be*, but on what the hazard will *do*. In partnership with the World Meteorological Organization (WMO), the Global Facility for Disaster Reduction and Recovery (GFDRR) is helping National Meteorological and Hydrological Services (NMHSs) make the paradigm shift from meteorological forecasting, to forecasting the impact of hazards.

1. INTRODUCTION

The Global Facility for Disaster Risk Reduction (GFDRR) and the World Meteorological Organization (WMO) have together and separately focused on strengthening the capacity of National Meteorological and Hydrological Services (NMHSs) to provide the best possible warnings of hydrometeorological hazards. All recognize that the usefulness of these warnings is predicated on the ability of people to use the information to take effective action. Hence institutional strengthening and improving the observing and forecasting systems and quality of warnings is a necessary but not sufficient step to mitigating the adverse consequences of hydrometeorological hazards; it also requires NMHSs to work with emergency services and others (disaster reduction and civil protection agencies) to interpret forecasts into a form that results in appropriate actions (Rogers and Tsirkunov 2013). This is a new area for many NMHSs, since it requires extensive knowledge of how meteorology and hydrology affects day-to-day activities, the vulnerability of infrastructure, and the likely behavior of people during an emergency. None of which may be available within National Meteorological Services or National Hydrological Services in developing countries some of which already struggle to produce basic meteorological and hydrological forecasts and services.

This has a number of implications for the future of NMHSs; in particular, the kind of skills required to understand how the weather impacts society and to develop the necessary tools to more effectively inform users. It may be argued that forecasting disaster risk and forecasting hydrometeorological impacts is beyond the remit of meteorologists and hydrologists. However, since the risks and impacts associated with extreme weather events are dynamic and significant, NMHSs are probably best equipped to predict their impact. And, in some countries, those affected are demanding more than statements of expected weather conditions from their NMHSs (WMO 2012).

2. WHY DO GOOD WEATHER FORECASTS OFTEN RESULT IN POOR OUTCOMES?

There are numerous examples, where the meteorological hazard was well forecast, but the impact was underestimated. The most notable recent example is Tropical Cyclone Haiyan (Yolanda), which struck the Philippines as a Category 5 storm on November 7 2013. As of 14 January 2014, 6,201 people were reported dead, 28,626 injured and 1,785 are still missing. More than sixteen million were affected and the current estimate of damage to infrastructure and agriculture is more than US\$827 million (NDRRMC 2014). Many of the deaths were caused by the storm surge that resulted from the wind, which reached a maximum ten-minute sustained velocity of 275 km per hour. Would lives have been saved with better knowledge of the specific impacts of this storm? Most likely, yes. Accurate warnings were issued by the meteorological agency – PAGASA – for heavy rain and winds in time, and the government deployed planes and helicopters to the regions most likely to be affected. However, this was still not enough. Had there been better knowledge of the risks, particularly of the storm surge, it is likely that more extensive evacuations from exposed areas could have taken place sooner (WMO 2014a).

3. TOWARDS IMPACT FORECASTS

What could have been done differently? The risk associated with a hydrometeorological hazard depends on knowing how that hazard impacts humans, their livelihoods and assets. This requires an understanding of exposure and vulnerability. Exposure refers to the inventory of elements in an area in which hazardous events may occur (who and what is impacted). If the population and economic resources were not located in (exposed to) potentially dangerous settings, no problem of disaster risk would exist.

Exposure is a necessary, but not sufficient, determinant of risk. It is possible to be exposed, but not vulnerable; for example, by living on a floodplain, but having sufficient means to modify building structure and behavior to mitigate potential loss. However, to be vulnerable to a hazard, it is also necessary to be exposed. Exposure is time (t) and space (x) dependent.

Vulnerability refers to the susceptibility of exposed elements, such as human beings, their livelihoods and property to suffer adverse effects when impacted by a hazard. Vulnerability is related to predisposition, sensitivities, fragilities, weaknesses, deficiencies, or lack of capacities that favor adverse effects on the exposed elements. Vulnerability is situation specific, interacting with the hazard to generate risk. Therefore, vulnerability may also be time and space dependent.

The risk of impact is the conditional probability and magnitude of harm attendant on human beings, their livelihoods and assets because of their exposure and vulnerability to a hazard. The magnitude of harm may change due to response actions to mitigate the risk, to changes in the hazard during the course of the event, and to changes in exposure.

These are most commonly written in the form

$$|Risk\ of\ Impact\ (x, t)| \\ \equiv |Hazard\ (x, t)| \cup |vulnerability\ (x, t)| \cup |exposure\ (x, t)|$$

where \cup is the union of the sets of hazards, vulnerabilities and exposures. While these factors are well known, they are not generally used to forecast changes in risk.

Several countries are now using this approach to forecast impacts. For example, in the UK, the Met Office provides forecasts of risk of overturning vehicles on roads due to winds. Generally the risk of overturning does not coincide with the highest winds.

4. CONCLUSIONS

These concepts have now been included in WMO guidelines on impact-based forecast and warning services (WMO 2104b). New World Bank projects designed to increase resilience are focusing on impact forecasting as a part of strengthening multi-hazard early warning systems. New training opportunities are also being developed and the China Meteorological Administration (CMA) Shanghai Meteorological Service has proposed to develop an impact forecasting simulator. This would enable retrospective studies of the impact of tropical cyclones to inform the development of new multi hazard early warning systems.

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TITLE: PRIORITIES OF THE WMO COMMISSION FOR HYDROLOGY

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Abstract Summary: This paper presents briefly the priorities of the WMO Commission for Hydrology. The programme of work adopted by the Commission for the period 2013-2016 focuses on five thematic areas: Quality Management Framework – Hydrology; Data Operations and Management; Water Resources Assessment; Hydrological Forecasting and Prediction; and Water, Climate and Risk Management. Data Operations and Management is a new theme, while the others continue and expand on activities from the previous period. The new Data Operations and Management theme was established largely to oversee the testing, evaluation, and potential adoption of WaterML 2.0 as a WMO standard for information exchange. WaterML 2.0 is designed to facilitate the exchange of hydrological data in a common format. If the recommendation is made to adopt it, and CHy concurs, then WaterML 2.0 could be registered as a joint WMO/ISO standard. In addition to the five thematic areas, Congress has tasked the Commission with contributing to several WMO priorities, including the Global Framework on Climate Services (GFCS), the WMO Integrated Global Observing System (WIGOS), Disaster Risk Reduction (DRR) and Capacity Development.

Keywords: *Priorities, WMO, CHy, Water, Climate, Risk Management*

Major activities addressed in the work plan of the theme area of Water, Climate and Risk Management include: (a) Assist in the implementation of water-related initiatives within the Global Framework for Climate Services (GFCS) ; (b) Prepare a note/overview guidance material on how to use regional climate modeling (i.e. long-term climate scenarios) in strategic hydrological management; (c) Prepare a comprehensive report on downscaling approaches for hydrological applications and their associated uncertainties, including commenting on existing case studies; (d) Prepare a state-of-the-art report/bibliography on hydrological analysis and modeling approaches in data sparse conditions; (e) Compile guidance and detailed procedures on essential steps in the analysis of vulnerability to water-related impacts, especially in relation to adaptation to climate variability and change; and (f) Provide advice and guidance with respect to the availability of climate data and climate model results for undertaking impact studies in support of adaptation to climate variability and change; (g) Compile case studies and provide guidance on extended hydrological prediction for water resources management including information on related climate drivers.

Seasonal forecasting and the development of hydrological services based on these forecasts was an area in which the water sector had a significant role to play. Countries are seeking hydrological products based on seasonal forecasts. There was a need for better information on the quality and limitations of seasonal forecasts and also their potential benefits to hydrological services, especially in terms of seasonal prediction of river flows. The focus in the area of seasonal forecasting should continue with high priority under the Extended Hydrological Prediction activities. Linkages should continue to be established with the Commission for Climatology (CCI), the GFCS and NMHSs also undertaking activities in this area.

TITLE: ECONOMICS OF EARLY WARNING SYSTEM

A.Subbiah

The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES)

Abstract: National Meteorological and Hydrological Services (NMHSs) of many countries in the Asia Pacific region are focused on providing basic forecast requirements for high-frequency, high-impact hazards, such as cyclones. High-frequency, but low-impact hazards, such as storms and floods, are not given much attention, although cumulative economic impacts are huge. With some investment, these NMHSs can build their capacities to provide value-added services to meet user requirements for weather and climate information, in addition to actionable, longer-lead time early warning information. The benefits of such value-added services, in the form of early warning information for long-lead (3-10 days) forecast, as well as seasonal forecast, are elaborated through several case studies.

TITLE: OPERATIONAL PREDICTION FOR FLASH FLOOD WARNING AND RESERVOIR MANAGEMENT - UTILITY FOR CLIMATE IMPACT STUDIES

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and

Scripps Institution of Oceanography, UCSD, La Jolla, California, USA

Abstract: The presentation will first outline the experience of the Hydrologic Research Center, a not-for-profit corporation in San Diego, California, USA and partner organizations in developing and sustaining systems for regional and national operational flash flood warning and systems for regional integrated water supply forecast and reservoir management worldwide. The system design, based on adaptive warning and management, will be discussed, together with examples of system operational application in collaboration with forecasters and reservoir managers. Accounting for multiple sources of uncertainty is an important component of these systems and the uncertainty modelling that allows risk-based management will be presented. In the second part of the talk the use of these systems for assessing the impacts of projected climate change for flash flood disaster occurrence and multi-site, multi-objective reservoir management will be exemplified. It is shown that flash flood occurrence frequency is projected to increase in Southern California, while adaptive multi-site and multi-objective reservoir management is necessary to reduce projected climatic impacts in Northern California. The selected list of references below provides the technical background for this presentation. Additional information may be found in the references cited and at the HRC web site: <http://www.hrc-lab.org>.

Keywords: *Operational Flash Flood Forecasting Worldwide, Disaster Management, Reservoir Management, Regional End-to-end Systems for Forecasting and Reservoir Management*

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APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness

Session II

Climate Forecasting for Water Management

From Prediction To Scenario Analysis: An Australian Perspective

Dr. Bryson Bates

(Centre for Environment and Life Sciences, CSIRO/Australia)

Ensemble Forecasting Of Seasonal Streamflow Using Climate Forecasts as Inputs

Dr. Quan Jun Wang

(Water for Healthy Country Flagship, CSIRO/Australia)

A Seasonal Streamflow Forecasting Service for Australia: Methods, Implementation and Way forward

Dr. Julien Lerat

(Environment and Research – Forecast Systems, BOM/Australia)

Seasonal Forecasting of Climate Extremes: Droughts and Floods

Dr. Yuriy Kuleshov

(National Climate Centre, BOM/Australia)

A Seamless Framework for the Global Monitoring and Prediction of Droughts

Prof. Eric Wood

(Princeton University/USA)

The Available Water Climatology (AWC) and its Applications

Prof. Hi-Ryong Byun

(Pukyong National University/Korea)

APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness



TITLE: FROM PREDICTION TO SCENARIO ANALYSIS: AN AUSTRALIAN PERSPECTIVE

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Abstract Summary: Extreme hydrological events such as floods, storm surges, landslides and droughts have always impacted human settlements. However, concern is growing that anthropogenic climate change is and will increase the number and severity of water-related disasters. In response, dialogue between climate information providers and water managers and planners has continued to grow over the last 10 to 20 years. While substantial progress has been made, a number of fundamental problems remain due to: ongoing differences in professional perspectives and training; unrealistic expectations regarding the accuracy and precision of climate information on both sides; and a decision making environment characterised by high and possibly irreducible levels of uncertainty and a low degree of control. I will describe each of these issues and the key challenges associated with them.

Keywords: *Prediction, Forecasting, Projections, Scenario Analysis, Weather, Climate Variability, Climate Change*

1. INTRODUCTION

Discussions and debate about future climatic conditions often include terms such as predictions, forecasts, projections and scenarios. In many cases they are used interchangeably and are rarely carefully defined in practice. This has subsequently led to confusion amongst scientists and policy makers about what climate change impact and vulnerability assessments actually represent and how they should be carried out. The current emphasis on baselines (i.e. the assumption of stationarity), the use of ensembles of climate change projections and the resulting high levels of uncertainty have meant that these assessments have had to date little or no impact on water resources planning and management practice in Australia and elsewhere.

This presentation will examine the climate change impact and vulnerability assessment process from the perspective of a hydroclimatologist who has actively engaged with water resources managers and planners for the last 16 years. The topics to be covered include:

- definitions of predictions, forecasts, projections and scenarios (MacCracken, 2001)
- approaches to systems planning for different levels of uncertainty and control (Peterson et al. 2003)
- the detection of non-stationarity in hydroclimatological time series (Bates et al. 2012)
- the sources and propagation of uncertainty in climate change projections (Whetton et al. 2012)
- adaptation strategies that are robust to a wide range of plausible futures (Lempert and Schlesinger, 2000; Pittock et al. 2001; Dessai et al. 2009)
- the need to include disciplinary perspectives beyond those of the climate and hydrologic sciences
- prudent action under climate uncertainty

While the use of probabilistic approaches is highly desirable for conventional risk assessment purposes, I will highlight and discuss the many limitations of current approaches to their construction and the large number of knowledge gaps that exist. I will argue that given the state-of-the-art of climate change impact assessment it should be used as a means of increasing preparedness rather than securing an accurate and precise prediction or forecast. Increasing preparedness entails risk mitigation planning through the development and implementation of adaptation strategies that:

- enhance opportunities and reduce threats
- articulate trigger points for action and contingency plans
- are socially and economically acceptable
- are robust to a small number of carefully-selected, alternate, plausible futures ('storylines')
- involve continuous monitoring, planning and evaluation

Such an approach can reduce or eliminate the element of surprise that can distort operational rules and practices and frustrate development efforts.

2. CONCLUDING REMARKS

The purpose of assessments of climate change impacts of and vulnerability to water-related disasters should be to reach robust prevention and mitigation strategies that work well under present as well as a wide range of plausible future conditions. Such an approach reduces sensitivity to climate and hydrologic model inaccuracies, uncontrollable and irreducible uncertainty and violated planning assumptions. It is also likely to enhance social acceptability. The focus should be on preparedness rather than prediction, and collaboration between climate scientists and water managers and planners that is based on respect and trust. Consideration needs to be given to a modest number of projections in order to avoid “paralysis by analysis”. When the consequences of failure are assessed to be medium to high, the analyst should specifically consider the implications of plausible events that have a low probability and high impact.

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TITLE: ENSEMBLE FORECASTING OF SEASONAL STREAMFLOW USING CLIMATE FORECASTS AS INPUTS

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Abstract Summary: A model for generating forecast guided stochastic scenarios (FoGSS) is developed. The model includes a module for post-processing GCM climate forecasts and a module for hydrological modelling including uncertainty. It generates forecasts of monthly volumes of streamflow for up to 12 months ahead in the form of ensemble time series. As forecast skill decreases with lead time, the forecasts become more like stochastic scenarios that follow the historical distribution of streamflow. The performance of the FoGSS model is evaluated on 20 catchments in Australia. For most catchments, forecasts of monthly streamflow are only skilful at very short lead times (< 3 months). However, forecasts for some locations and seasons can be skilful for many more months ahead. Forecasts of cumulative streamflow are much more skilful than forecasts of monthly streamflow. As cumulative streamflow is more relevant to water planning, skilful forecasts of the cumulative streamflow are valuable. Ensemble forecasts of monthly and cumulative streamflow are shown to be statistically reliable in conveying forecast uncertainty. The FoGSS model adequately represents the rainfall forecast uncertainty, hydrological uncertainty (other than rainfall forecast uncertainty), persistence in streamflow, and uncertainty propagation for up to 12 months ahead.

Keywords: *Seasonal Forecasts, Climate, Streamflow, Stochastic Scenarios, Ensemble*

1. INTRODUCTION

The Australian Bureau of Meteorology (the Bureau) and CSIRO developed an operational service that delivers ensemble forecasts of total streamflow volumes for the following three months. Forecasts are updated monthly. Results from a user survey conducted by the Bureau indicated that key water agencies are positive about the current seasonal streamflow forecasting service. However, many agencies have expressed strong interest in forecasts of monthly and cumulative streamflow volumes for up to 12 months ahead. In many Australian catchments, skilful forecasts are not attainable for extended lead times. However, beyond skilful lead times, the water agencies are very interested in stochastic scenarios, which can be used in conjunction with skilful forecasts as inputs to water allocation models for forward planning and operations.

To meet this user demand, a model for generating forecast guided stochastic scenarios (FoGSS) is developed. The model generates forecasts of monthly volumes of streamflow for up to 12 months ahead, in the form of ensemble time series. As forecast skill decreases with lead time, the forecasts become more like natural stochastic scenarios that follow the historical distribution of streamflow. In this note, we provide a brief description of the FoGSS model and results of an assessment on 20 catchments.

2. MODEL DESCRIPTION AND ASSESSMENT METHOD

The FoGSS model includes a module for post-processing GCM climate forecasts and a module for hydrological modelling including uncertainty. Monthly catchment rainfall forecasts up to 12 months ahead are produced by post-processing outputs from the predictive ocean atmosphere model for Australia (POAMA). The post-processing follows a calibration, bridging and merging (CBaM) method described by Schepen and Wang (2014a; 2014b).

A monthly water partition and balance model (WAPABA) is used to convert a rainfall forecast to a streamflow forecast (Wang et al., 2011). Time series forecasts of streamflow are produced through a sequence of bias correction, updating and uncertainty propagation for each month up to 12 months ahead (Wang et al., 2014).

Twenty catchments from Queensland, New South Wales, Victoria, Tasmania and Western Australia are selected to assess the performance of the FoGSS model. We produce retrospective forecasts for the period of 1982-2009. We use leave-five-years-out cross validation in our assessment. For a forecast event, we exclude the streamflow data of the year in which the event starts and of the subsequent four years from use in model calibration. To calibrate hydrological model and error model parameters, streamflow data from 1980 onwards are used.

We assess two forecast variables. The first is monthly volume of streamflow. Forecasts are assessed separately for each combination of forecast target month (January to December) and lead time (0 to 11 months). The second is cumulative volume of streamflow for various accumulation periods. Forecasts are assessed separately for each combination of forecast start month (January to December) and accumulation period (1 to 12 months). We assess ensemble forecast performance using the continuous ranked probability score (CRPS), the

root mean square error in probability (RMSEP) score, PIT uniform probability plots, and forecast quantile plots (Wang and Robertson, 2011).

3. RESULTS AND CONCLUSIONS

Figure 1 shows two example ensemble forecasts for the Barron River above Picnic Crossing, in northern Queensland. For each forecast, only 10 ensemble members are shown in the plot, but the forecast median and quantile ranges are computed from 990 members.

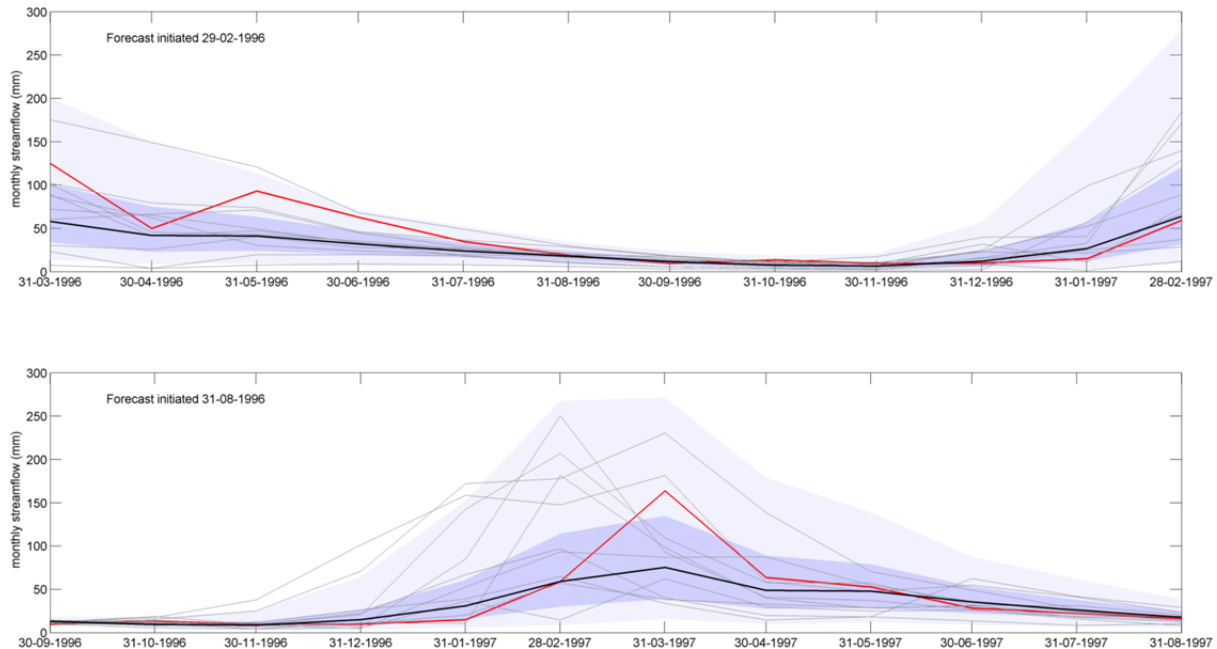


Figure 1. Two ensemble forecasts of monthly streamflow out to 12 months (grey lines, sample forecast ensemble members; dark line, forecast median; darker shaded area, forecast [0.25, 0.75] quantile range; lighter and darker shaded area, forecast [0.05, 0.95] quantile range; red line, observed streamflow).

Overall, forecasts of monthly streamflow are only skilful at very short lead times (< 3 months) for most of the catchments. However, forecasts for some locations and seasons can be skilful for many more months ahead. Forecasts of cumulative streamflow are much more skilful than streamflow of individual months. As cumulative streamflow is more relevant to water planning, skilful forecasts of the cumulative streamflow are valuable.

Forecasts of monthly streamflow and cumulative streamflow are both shown to be statistically reliable in conveying forecast uncertainty. The FoGSS model adequately represents the rainfall forecast uncertainty, hydrological uncertainty (other than rainfall forecast uncertainty), persistence in streamflow, and uncertainty propagation for up to 12 months ahead.

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TITLE: A SEASONAL STREAMFLOW FORECASTING SERVICE FOR AUSTRALIA: METHODS, IMPLEMENTATION AND THE WAY FORWARD

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Abstract Summary: This paper presents the Seasonal Streamflow Forecasting service developed by the Bureau of Meteorology to assist water managers with improved decision making for water resource allocation planning and environmental flow management in river basins with intensive water uses. The service produces three months ahead forecasts of streamflow volumes for 74 locations in eastern Australia. The forecasts are generated using the Bayesian Joint Probability (BJP) statistical model that predicts flow for a three month ahead period based on antecedent flow conditions and selected climate indices. Once the model is calibrated over historical records, forecasts are generated using an independent data set to evaluate forecast performance. After nearly four years of continuous operation, the service is now undergoing a major upgrade with an expansion of the coverage across Australia and a refinement of the modelling method using a combination of the statistical and dynamic approach. The latter introduces a significant change in the modelling method by implementing hydrological models at a daily time step forced by Global Circulation Model (GCM) downscaled rainfall forecasts. The analysis of retrospective forecasts results suggested that statistical and dynamic methods have complementary model performance, which will be harnessed by the development of a merging method able to retain the best of both approaches at individual forecast location.

Keyword: Seasonal streamflow forecasts, uncertainty, hydrological modelling, Bayesian statistics

1. INTRODUCTION

Hydrological conditions in Australia are among the most variable on earth (McMahon et al., 1987) with prolonged periods of droughts such as the ‘Millennium drought’ that occurred between 1997 and 2009 across most parts of eastern Australia. This variability has a profound impact on the management of water resources in Australia, and more specifically on the management of risks associated with water supply for urban use, irrigation and for environmental needs.

On 26 January 2007, following a prolonged period of severe drought and rapidly diminishing water supplies, the Australian Prime Minister announced the National Plan for Water Security, a 10-point plan significantly enhance Commonwealth involvement in the nation’s water affairs (Vertessy, 2013). This reform triggered a series of actions focusing on the quality and coverage of Australia’s water information including the creation of a Seasonal Streamflow Forecasting Service (SSF) operated by the Bureau of Meteorology since December 2010 (www.bom.gov.au/water/ssf). The SSF service now provides forecasts at 74 locations in 32 river basins located across eastern Australia.

2. DATA AND METHODS

Probabilistic 3 month ahead streamflow forecasts for the SSF service are derived using a statistical modelling approach called the Bayesian Joint Probability model (BJP; Wang et al., 2009). Forecasts are updated every month for 74 key water supply locations in eastern Australia (see Figure 1a).

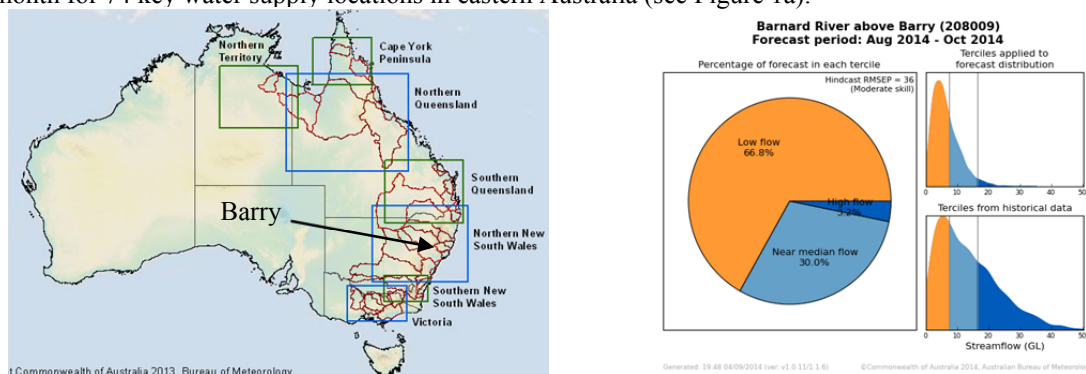


Figure 1: (1a) Spatial extent of the seasonal streamflow forecast locations across Australia (74 locations at Sep 2014). (1b) Forecast distribution derived from the Bayesian Joint Probability model, historical reference distribution (1950-2010) and tercile forecasts derived from the historical reference distribution for the Barnard River at Barry, Murrumbidgee River Basin

The BJP model uses statistical relationships between climate indices, recent catchment conditions and historical rainfall and streamflow at a location to forecast streamflow for the next three months. The BJP model assumes that a transformed set of streamflows and their predictors follow a multivariate normal distribution. A typical model comprises a predictor of the antecedent catchment conditions represented by recent observed streamflow, one climate index predictor and, a streamflow predictand and may require up to 13 parameters. Model parameters and their uncertainty are inferred using a Bayesian formulation, which is implemented through a Markov Chain Monte Carlo (MCMC) sampling method. Forecasts are made by conditioning the multivariate distribution on predictor values and are represented by a 5000 member ensemble in terms of whether below median, near median, or above median flows are more likely (see Figure 1b). The BJP model is calibrated against historical data and verified on independent datasets for each period (e.g. JFM, FMA... DJF). This procedure is developed for the period of available streamflow records in which 1-year is left out of the model calibration and is used for forecast verification.

3. DISCUSSION AND CONCLUSION

After nearly four years of continuous operation, we are currently going through major upgrades of its products. First, the SSF team is investigating more than 100 new locations in Tasmania, South Australia, Northern Territory and Western Australia. While the SSF service has provided high quality forecasts in eastern Australia, it is expected that expansion to new areas will face several challenges such as weaker connections between streamflow and climate indices. This may reduce the quality of seasonal forecasts, and extreme dry conditions (especially in Northern Territory and Western Australia) where statistical models may struggle to reproduce long sequences of dry periods followed by intense flooding.

Second, in order to provide an alternative to statistical models when forecast skill is low, a dynamic modelling method is currently being developed as part of the SSF service upgrade. The method starts by downscaling a set of 155 ensemble rainfall forecasts from the POAMA GCM (Hudson et al., in press) to the catchment scale using the analogue method (Timbal et al., 2008). These forecasts are used as inputs to the GR4J hydrological model (Perrin et al., 2003). The uncertainty introduced by GR4J is estimated via a Bayesian calibration method (BATEA, Kuczera et al., 2006) providing a posterior distribution of model parameters and parameters associated with model residuals (e.g. standard deviation of residuals). This procedure generates 6200 ensembles of daily time series which are aggregated to three monthly, and finally post-processed to remove seasonal biases.

Analysis of hindcast results suggested that statistical and dynamic methods have complementary performance, and supports development of a merging method able to retain the best of both approaches at each forecast location. We expect that the two modelling methods combined with the merging approach will lead to significant improvement over current forecast products, and provide valuable inputs for the management of water resources in Australia.

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TITLE: SEASONAL FORECASTING OF CLIMATE EXTREMES: DROUGHTS AND FLOODS

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Australian Bureau of Meteorology

Abstract Summary: Droughts and floods frequently affect island countries in the Western Pacific. The impacts of such climate extremes on the countries are severe and the costs of damage can amount to large fractions of gross domestic product. In some cases, climate extremes affect countries to such an extent that governments declare a national state of emergency, as occurred in Tuvalu in 2011 due to the severe drought's impact on water resources. Here we demonstrate that seasonal climate predictions based on outputs of dynamical climate models can be efficiently used for forecasting regional dry or wet conditions. The developed seasonal climate prediction products are now disseminated to the National Meteorological Services of 15 island countries in the Western Pacific through a range of web-based information tools assisting them in preparing tailored seasonal climate outlooks. We conclude that seasonal climate predictions could provide governments and local communities of small island countries with vulnerable economies with valuable assistance for informed decision making for adaptation to climate variability and change.

Keywords: *Climate extremes, Droughts, Floods, Seasonal climate forecasting*

1. INTRODUCTION

Increases in the frequency of extreme weather and climate events and the severity of their impacts on the natural environment and society have been observed across the globe in recent decades. Not surprisingly, the impacts are most felt in the least developed countries which have limited adaptive capacity and financial reserves. In this paper, recent examples of extreme climate events and their impacts on the island countries in the Western Pacific are described.

To implement effective early warning systems with a goal of reducing the impacts of climate variability, climate change and extreme climate events such as droughts and floods on the natural environment and society, authorities of island countries develop various action plans and adaptation measures. One of the most cost-effective and easy-to-implement ways to adapt to climate variability and change is for the authorities to make informed decisions based on the latest achievements of climate science and to efficiently use seasonal climate prediction products which forecast expected rainfall over the coming season (next three months). Here we discuss how the timely utilization of seasonal climate prediction information could assist in adaptation to climate change and reduce the hardship which society experiences as the result of climate extremes.

2. DROUGHTS AND FLOODS IN THE WESTERN PACIFIC

The Pacific Climate Change Science Program (PCCSP), the Pacific Adaptation Strategy Assistance Program (PASAP) and their successor, the Pacific Australia Climate Change Science and Adaptation Planning Program (PACCSAP) are part of the Australian Government's commitment to address high priority climate adaptation needs in vulnerable countries in the Asia-Pacific region. Over the past five years, a number of significant outcomes have been achieved through the Pacific Programs contributing to strengthening the capacity of partner countries in the Western Pacific through the provision of regional climate information and tools supported by extensive training. This paper is focused on achievements of the Pacific Programs on seasonal forecasting of rainfall and its potential application to reduction of impacts of droughts and floods.

2.1. RAINFALL VARIABILITY IN THE WESTERN PACIFIC

Droughts, floods and tropical cyclones are the most destructive extreme meteorological events which affect countries in the Western Pacific. In this region, floods are typically associated with tropical cyclones or tropical disturbances and droughts are usually related to the El Niño - Southern Oscillation (ENSO). Rainfall distribution is closely related to the ENSO variability, and the position and intensity of the key climate features namely the Intertropical Convergence Zone, West Pacific Monsoon and the South Pacific Convergence Zone. Therefore the impact of climate extremes varies from country to country in the Western Pacific depending on the country's geographical location with respect to these features. For example, in Samoa flooding is often associated with excessive rainfall related to strong La Niña events (e.g. severe flooding in 2001 caused damage to about 1,300 buildings in Apia). On the other hand, a strong 2010/2011 La Niña event brought severe drought to southern parts of Tuvalu.

2.2. THE 2012 FIJI FLOODS

Severe floods frequently affect major infrastructure, transportation, business and property in Pacific Island Countries. Often significant flooding is attributed to a tropical cyclone or a tropical depression, as it occurred in 2012 in Fiji.

A tropical depression remained stationary over Fiji's Northern and Eastern divisions from 21 to 25 January 2012 causing widespread heavy rainfall and strong winds. Above average rainfall in the preceding three months across most of the country associated with persistent La Nina conditions, and heavy rains associated with the tropical depression lead to unprecedented flooding and landslides, with a state of emergency being declared. Eight people were reported to have died in the floods and thousands were displaced, with about 3,500 people placed in temporary shelters. Damage was caused to crops and infrastructure, with estimated losses of about FJ\$ 40 million.

Just two months later, another severe flood devastated the country. The March 2012 flood was the worst flood to affect Fiji in recent times in terms of both the magnitude and the damage to properties. On the 28 March, a tropical depression which was moving slowly over Fiji for almost a week, became stationary west of Viti Levu. Overnight on the 29 March, the tropical depression underwent rapid development which triggered widespread rain. Torrential rain and subsequent flooding resulted in landslides and destruction of major roads and bridges, significant losses to business and residential properties. The total damage caused by the March 2012 flood was estimated at around FJ\$70 million.

2.3. THE 2011 TUVALU DROUGHT

On the other side of hydrological extremes are droughts which also frequently affect islands of the Pacific impacting on the countries to a various degrees of severity depending on the drought's length. The 2011 Tuvalu drought severely impacted a small island nation inhabiting coral atolls in the Pacific. Water resources in Tuvalu are heavily dependent on an abundant rainfall, with small water tanks providing the main potable source of water. If the country experiences a prolonged rainfall deficit, it results in critical shortage of water. This prolonged drought episode was related to a strong La Niña event which affected the region in 2010-11. Typically, during La Niña years, oceanic waters are cooler than average in the region of the Western Central Pacific. As a result of oceanic cooling, atmospheric convection is suppressed and hence the rainfall amount in southern Tuvalu during La Niña episodes is below average. In 2011, a number of countries and territories in the region, including Samoa, Tokelau and Tonga were affected by La Niña-induced rainfall deficit; however, Tuvalu was particularly seriously impacted. At Funafuti, rainfall was the lowest on record with only 515 mm (36% of the long-term average of 1,430 mm) received between May to October.

On the 28 September 2011, the government of Tuvalu declared a state of emergency due to critically low water supplies. Households were rationed to about 40 litres (two buckets) of fresh-water a day as some parts of Tuvalu had just a two day supply of water left. The situation was critical and to relieve stress on the population of Tuvalu, the governments of Australia, Japan, New Zealand and South Korea immediately began delivering fresh water supplies and portable desalination plants.

3. SEASONAL CLIMATE PREDICTION – EFFECTIVE WAY TO ADAPT TO CLIMATE VARIABILITY AND CHANGE

Under the PASAP and the PACCSAP programs research has been conducted to evaluate the skill of the coupled dynamical climate model POAMA (Predictive Ocean Atmosphere Model for Australia) for predicting seasonal rainfall.

The probability of accumulated rainfall falling in the lower climatological tercile (i.e. an elevated risk of below average rainfall) for the Western Central Pacific in 2011 was predicted by POAMA. The POAMA-based seasonal forecast issued in February 2011 for the three-month period February-March-April (FMA) predicted that the rainfall deficit in the area of Tuvalu would continue, with the ensemble mean forecast quantity of seasonal rainfall about 225 mm below average (Figure 1, left panel). Subsequent forecasts from POAMA, produced monthly, consistently indicated that rainfall deficits would likely continue, e.g. the forecast for August-September-October (ASO), issued in August 2011, predicted a rainfall deficit greater than 225 mm (Figure 1, right panel) with high probability (over 87.5%, Figure 2, left panel). Thus, information available from POAMA from the beginning of 2011 consistently indicated high probability of continuing drought in the region. If used in a timely manner, such information could be used as a trigger for early preventive actions to reduce the impact of water shortages on the local population.

POAMA has high skill in predicting seasonal rainfall over the Pacific region and the model's outputs could be used with confidence for forecasting both rainfall deficit leading to droughts and excessive rainfall potentially leading to floods. In Figure 2 (right panel), high probability (above 75%) of wetter than normal seasonal conditions is predicted by POAMA in the area of Fiji for January-February-March (JFM) 2012. Exacerbated by additional rainfall from stationary tropical depressions, the 2012 Fiji floods in January and

March were amongst the most devastating natural disasters for the country in the past few decades. Using information about predicted excessive seasonal rainfall, informed decisions could be made by the authorities and local communities to take preventive measures well in advance of the potential flooding and hence save lives and reduce impacts of the disaster.

4. CONCLUSIONS

An increase in the frequency of weather and climate extremes is one of the expected consequences of the increased anthropogenic greenhouse gas concentrations and will likely have even stronger negative impacts on the natural environment and society in the future. This should be taken into consideration by authorities of Pacific Island Countries and aid donors when developing strategies to adapt to the increasing risk of more climate extremes. Here we demonstrated that the modern science of seasonal climate prediction is well developed, with current dynamical climate models being able to provide skilful predictions of regional rainfall two-three months in advance. The dynamic climate model-based forecast products are now disseminated to the National Meteorological Services of 15 island countries in the Western Pacific through a range of web-based information tools. We conclude with confidence that seasonal climate prediction may be an effective tool at the regional level to provide governments and local communities of island nations in the Western Pacific with valuable assistance for informed decision making in adaptation to climate variability and change.

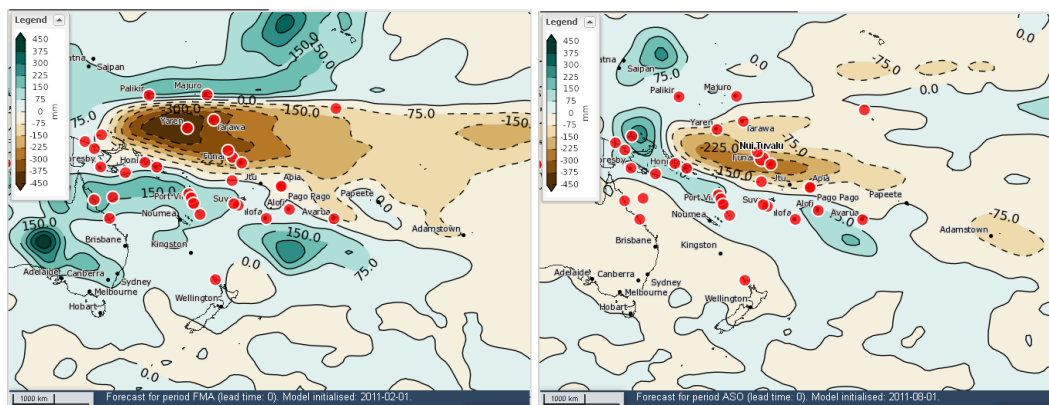


Figure 1. POAMA-based prediction of seasonal rainfall anomalies in the South Pacific region. The seasonal forecasts issued in February 2011 for three-month period (FMA, left panel) and for ASO (issued in August 2011, right panel).

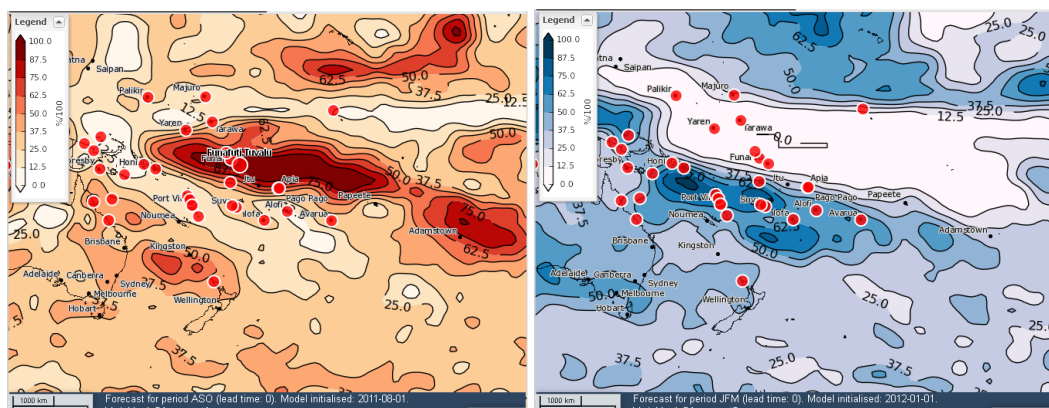


Figure 2. Left panel: Probability of accumulated rainfall in the lower climatological tercile (more than 87.5% in the region containing Tuvalu) predicted by POAMA for ASO 2011. Right panel: Probability of accumulated rainfall in the higher climatological tercile (more than 75%) predicted by POAMA for JFM 2012.

5. ACKNOWLEDGEMENT

D. Jones, H. Hendon, A. Charles, A. Cottrill, K. Shelton and R. de Wit contributed significantly to research on seasonal climate prediction and development of climate information tools described in this paper. PASAP and PACCSAP projects have been supported by the AusAID and DCCEE.

TITLE: A SEAMLESS FRAMEWORK FOR THE GLOBAL MONITORING AND PREDICTION OF DROUGHTS

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Abstract: The Global Earth Observation System of Systems (GEOSS) Water Strategy (“From Observations to Decisions”) recognizes that “water is essential for ensuring food and energy security, for facilitating poverty reduction and health security, and for the maintenance of ecosystems and biodiversity”, and that water cycle data and observations are critical for improved water management and water security – especially in less developed regions. The GEOSS Water Strategy has articulated a number of goals for improved water management, including flood and drought preparedness, that include: (i) facilitating the use of Earth Observations for water cycle observations; (ii) facilitating the acquisition, processing, and distribution of data products needed for effective management; (iii) providing expertise, information systems, and datasets to the global, regional, and national water communities.

There are several challenges that must be met to advance our capability to provide near real-time water cycle monitoring, early warning of hydrological hazards (floods and droughts) and risk assessment under climate change, regionally and globally. Current approaches to monitoring and predicting hydrological hazards are limited in many parts of the world, and especially in developing countries where national capacity is limited and monitoring networks are inadequate.

This presentation describes the development of a seamless monitoring and prediction framework at all time scales that allows for consistent assessment of water variability from historic to current conditions, and from seasonal and decadal predictions to climate change projections. At the center of the framework is an experimental, global water cycle monitoring and seasonal forecast system that has evolved out of regional and continental systems for the US, Africa and South America. The system is based on land surface hydrological modeling that is driven by satellite remote sensing precipitation to predict current hydrological conditions, flood potential and the state of drought. Seasonal climate model forecasts are downscaled and bias-corrected to drive the land surface model to provide hydrological forecasts and drought products out 6-9 months. The system relies on historic reconstructions of water variability over the 20th century, which forms the background climatology to which current conditions can be assessed. Future changes in water availability and drought risk are quantified based on bias-corrected and downscaled climate model projections that are used to drive the land surface models. For regions with lack of on-the-ground data we are field-testing low-cost environmental sensors and along with new satellite products for terrestrial hydrology and vegetation, integrating these into the system for improved monitoring and prediction. We provide an overview of the system and some examples of real-world applications to flood and drought events, with a focus on Africa and South America.

TITLE: THE AVAILABLE WATER CLIMATOLOGY (AWC) AND ITS APPLICATIONS

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Abstract Summary: This study points the weaknesses of the existing Precipitation Climatology (EPC) that has considered the water-related environments with extensive properties like daily, monthly and annual precipitation, and proposes a new method to change it into an intensive property using Available Water (AW) that is remained precipitation after runoff and evapotranspiration. Because AW varies along time pass and quantifies the spatiotemporal distribution of water environment neither time limit nor timely distribution of precipitation, it digitizes objectively the danger of the water-related disasters like drought, flood, inundation, land slide, soil collapse etc. and the early warning of them became much easier than before. Therefore the prediction of water related disasters became possible not only by the water specialists but also by the general public. Additionally, not only the season division like Water Abundant Season (WAS) and Little Water Season (LIWAS), but also the classification of the local climate regions like Much Water Climate (MWC) and Little Water Climate (LWC) became possible. Moreover spatiotemporal distribution of water-resources world-wide that is important to whole ecosystem has digitized for use in operations and researches. Conclusive proposition is that the earlier the change from EPC to AWC, the faster development of the climatology will be.

Keywords: Available water climatology, water related disasters, flood, land-slide, water abundant season.

1. INTRODUCTION

Through history, water-related environment were dealt with hourly, daily, monthly and annual amount of precipitation that are extensive properties. For example, the water-environment of 1st September is considered to be affected by the precipitation accumulated from 1st till 31st of August with same weight every day. However, this study found critical problems on this tradition. The effect of rain fell at 1st August is never same with and entirely different from the one of 31st August because big part of water from the precipitation in 1st August has flown away and almost all of the water from the precipitation in 31st August has remained until 1st September. Therefore we developed a new concept of Available Water (AW).

2. CALCULATION OF AWRI, LWI, SWI

AWRI curve is a time series of precipitation that the random distribution of precipitation including many zeroes is changed to the one without zeroes. Byun and Lee (2002) developed it as (1).

$$(1) \quad AWRI = \sum_{n=1}^i \left[\left(\frac{\sum_{m=1}^n P_m}{n} \right) \right]$$

where, P_m is precipitation m days before. 'i' is 365 at first. If the anomaly of the date is positive or negative consecutively for 'j' days 'i' becomes 365+ (j-1). With changed 'i', AWRI and its normal value recalculated every time. 'i' return to 365 when the anomaly of the date changes between positive and negative. This is the most important merits of this study. Therefore, the duration of water deficit or sufficient is decided first and next the severity the extent of anomaly is calculated.

Long Term Remained Index (LWI, Byun et al., 2014) also uses (1) but time dependent reduction function is adopted during the recent 24 hours. Short term Remained Index (SWI, Byun et al., 2014) deals with the data only for 24~72 hours. With these scheme, the random distribution of bars in Fig. 1 that means daily (Fig. 1a) and hourly (Fig. 1b) precipitation has changed to curves that means the intensive properties of precipitation.

3. RESULT AND DISCUSSION

Byun and Lee (2002) is another adoption of the intensive property of precipitation. It has used Available Water (AW) in the season classification. After that Park et al., (2014) and Kim et al., (2014) succeeded to define the Water abundant season (WAS) and Little Water Season (LIWAS) in Korea. WAS was defined as the duration that the normal AWRI per date is above median. The biggest median is Seongsan (271mm) and the smallest is Uiseong (136mm). LIWAS was defined as the duration of the

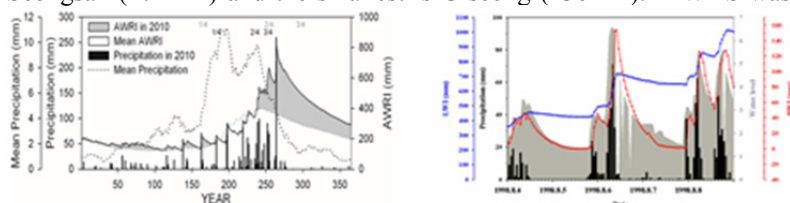


Fig. 1. Time series of water related indexes. Gray area show water surplus than normal (a) and water level in Jungryang river (b). Black bars denote daily precipitation (a) and Hourly precipitation (b).

consecutively lowest 25% of normal AWRI that is 92 days. The biggest criteria is Geojae (205mm) and the smallest at Uiseong (108 mm). Big differences of water environment in a small distance were clearly digitized. Also they succeeded to define the much water climate and the small water climate. In similar branch of this study, Lee (2012) has succeeded to quantify the annual fluctuation of water resources and its distribution of the world that is very hard in EPC.

Byun and Wilhite (1999) has made EDI using AW likes and solved the general problems of the common drought indexes. Some studies announced that EDI is the best drought index through the world (Dogan et al., 2012; Morid et al., 2006, Kim et al., 2009). Drought maps on Korea, Japan, North Korea and Australia have made or in progress.

Recently, Byun et al., (2014) has succeeded to evaluate the danger of water-related disasters using the intensive property of hourly precipitation (so to speak, LWI and SWI) and made it possible the early warning of water related disasters like flood, inundation, land slide and soil flow, earth collapse etc. It was adopted at the case of successive heavy rains occurred at August 1998 with 790 mm of accumulated precipitation for 9 days. 5 days of them appeared at Fig. 1b. It shows clearly that the random distribution of hourly precipitation has changed to a series of digital numbers that denote the timely concentration of water resources. Also, it became clear that when LWI is above 470mm, the Eastern Trunk Road of Seoul always inundates. The bigger the LWI is the more dangerous disasters occurred. Another sign is that SWI calculated for 24 hours coincide well with water level of the Jungryang River.

4. CONCLUSION

It is known that climatology using AW is much useful than EPC in detection of the danger of water-related disasters, in the division of seasons and climate regions and in the detection of the spatiotemporal distribution of 4 dimensional water-resources. The earlier the changes into AWC occurs, the more beneficial it will be for human.

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**Managing Climate Extremes
and Hydrologic Disasters:**
Scientific Prediction and Emergency Preparedness

Session III

Managing Risk from Droughts and Water Scarcity

**Impact of Climate Change on Agricultural Land
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U.S. Drought Trends

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APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness



TITLE: IMPACT OF CLIMATE CHANGE ON AGRICULTURAL LAND AND WATER SUSTAINABILITY – A GLOBAL PROJECTION

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Ven Te Chow Hydrosystems Laboratory, Civil and Environmental Engineering, University of Illinois at Urbana-Champaign

Abstract Summary: Climate change is likely to alter agricultural land suitability and water requirements and availability significantly as a result of changing temperatures and precipitation across the globe. We assess the change in land suitability and crop water deficits (the difference between crop evapotranspiration and precipitation that is effective for crop growth) (including rainfed and irrigated) under current (1961-1990) and projected climates (2070-2099). The most up-to-date crop data and ensemble climate projections from six General Circulation Models (GCMs) under two emission scenarios (A1B and B1 employ CO₂-equivalent GHG concentrations of 850 and 600 ppmv, respectively; B1 represents a greener economy) were utilized for the assessment. The land assessment shows that total global arable land area is likely to decrease by 0.8% ~ 1.7% under scenario A1B and increase by 2.0% ~ 4.4% under scenario B1. Regions characterized by relatively high latitudes such as Russia, China and the U.S. may expect an increase of total arable land by 37% ~ 67%, 22% ~ 36% and 4 ~ 17%, respectively; while tropical and subtropical regions may suffer different levels of lost arable land. For example, South America may lose 1% ~ 21% of its arable land area, Africa 1% ~ 18%, Europe 11% ~ 17%, and India 2% ~ 4%. The water assessment shows that despite the universally rising mean temperature, crop water deficits are likely to decline slightly at the global scale, although changes vary by region. Regionally, Africa and China are likely to benefit from lower water requirements, but the impacts on other regions, including Europe, India, South America and the United States, are subject to the land use types (rainfed or irrigated) and the uncertainty involved in the assessment approaches.

Keywords: *Climate change, agricultural land, crop water requirement, water availability, global assessment*

1. INTRODUCTION

In this study we provide a biophysical-based assessment of the climate change effect on agricultural land and water by using more comprehensive crop information and explicitly considering climate change projection uncertainty. For the land assessment, following questions related to possible changes in global agricultural land availability given the uncertain projections of climate change: Do different regions and the world as a whole expect significant changes in agricultural land availability? What will be the distribution of these possible changes throughout the world? What is the likelihood of the changes by region? We address the following key questions: how much will current irrigation requirements (i.e., WD for irrigated crops) and WD for rainfed crops be mitigated or aggravated as a result of climate change and which regions will see these changes in WD? More broadly, what will the global situation of agricultural water use be under climate change? By addressing these questions, we provide a global picture of agriculture water use together with its corresponding likelihood of occurrence under the various climate change scenarios. Through this analysis, implications for regional agricultural development considering water and land conditions will be discussed.

2. DATA AND METHODOLOGY

Different General Circulation Models (GCMs) provide different (and even conflicting) projections for one region, so two data ensemble approaches, Simple Average Method (SAM) and Root Mean Square Error Minimization Method (RMS), are adopted given the assumption that ensemble of the GCMs provides more reliable climate prediction than any single GCM (Laurent and Cai, 2007). Two representative CO₂ emission scenarios (A1B & B1) are used to represent a range of emission levels: A1B projects greater rates of greenhouse gas (GHG) emissions than B1, assuming CO₂-equivalent GHG concentrations of 850 parts per million by volume (ppmv), compared to 600 ppmv under B1. Global datasets for land suitability assessment are adopted from Cai *et al.* (2011), including present soil properties, temperature, humidity index (HI), land slope, and land cover. Crop-wise water requirements of 26 crops are assessed, employing the most up-to-date crop data (Zhang and Cai, 2013).

3. RESULTS AND DISCUSSION

Figures 1 illustrates the distribution of the effects on agricultural land predicted under A1B-RMSEMM and B1-SAM, which represent the largest global arable land decrease and increase, respectively. As can be observed from the two images, arable land is likely to increase at the higher latitudes of the northern and southern hemisphere, including Canada, Russia, northern China, southern Argentina, and the northern U.S. Shrinking arability will likely occur at lower latitude locations, such as western Africa, Central America, western Asia, the south-central U.S., as well as northern and central South America. Africa, Europe, India, and South America may expect varying levels of

reduction, -1% ~ -18%, -11% ~ -17%, -2 ~ -4%, and -1% ~ -21% respectively, while Russia, China, and the U.S. may benefit from climate change with increases in arable land of 37% ~ 67%, 22% ~ 36% and 4% ~ 17%, respectively.

The change in WD for both irrigated and rainfed crops varies largely by region. Comparing the annual irrigation requirement changes for the aggregated crops between the projected climate and the reference climate (A1B-SAM scenario) (Figure 2 left) indicates that the western US, southern Africa and northern Australia may expect substantial decreases in irrigation requirements, whereas the southeastern U.S., northeastern South America, and northwestern India may have significant increases. Eastern Europe and southern China are likely to have minor increases, while western Europe and northern China are likely to experience slight decreases. Comparing the annual WD for rainfed crops of the two time periods (Figure 2 right), indicates western Sub-Saharan Africa may have to face a more severe water situation, with greater deficits, whereas water concerns in other parts of Africa may be reduced to some extent as a result of smaller water deficits. Water conditions in the western U.S. and northern China may also be improved, but the eastern U.S. and southern China are likely to have a slightly greater water deficit. Southern India, the west coast of South America and western Europe may have a smaller water gap in rainfed areas, while northern India, eastern Europe, the northern Amazon, and northeast South America are likely to experience varying levels of water deficit increases.

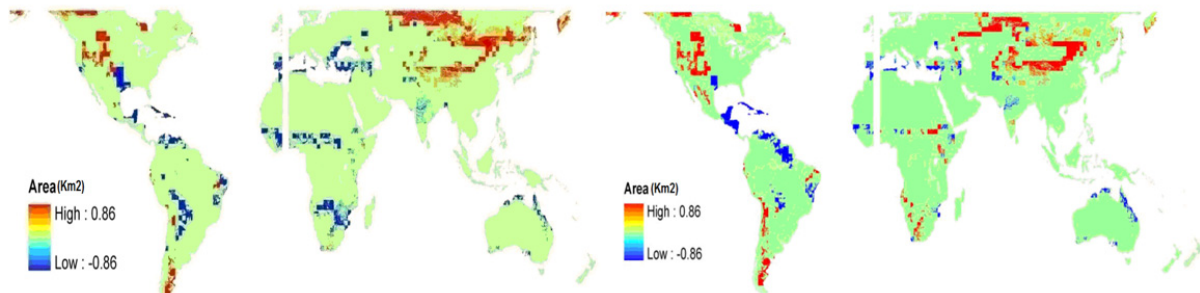


Figure 1: Changes of potential arable land under A1B-RMSEMM (left) and B1-SAM (right)

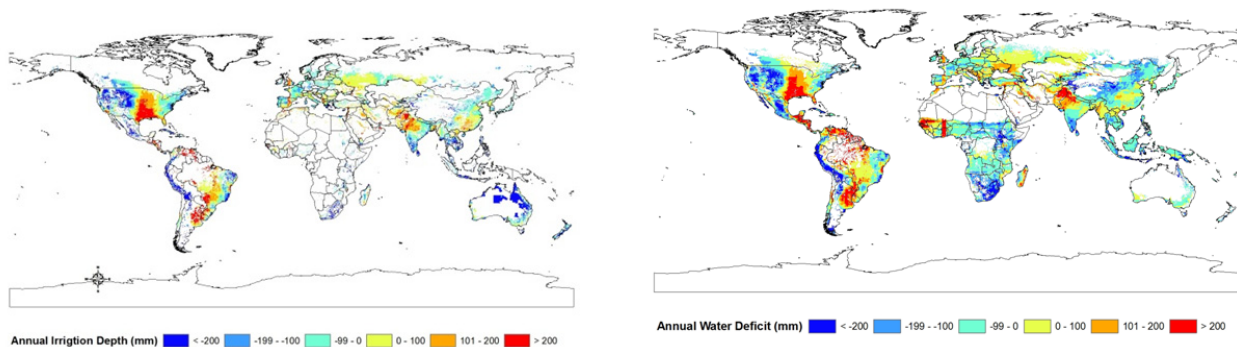


Figure 2: Irrigation requirement changes for irrigated areas (left) & water deficit changes for rainfed areas (right) of 26 crops between 2070-2099 and 1961-1990 under A1B-SAM scenario.

4. CONCLUSIONS

Agricultural adaptations to climate change are necessary measures to sustain the world's agriculture, which are addressed considering the possible changes of both land and water. The adverse impacts of climate change require new irrigated areas or higher irrigation demands for some regions; while climate change can reduce irrigation while remaining suitable for cultivation in other regions; new agricultural land may emerge in some areas with reasonable productivity for rainfed crops. These situations imply different agricultural adaptations in different regions.

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TITLE: COST-EFFECTIVE VARIETY CAN REDUCE VARIETY IN REAL WORLD: DIVERSITY IN WATER INFRASTRUCTURE SYSTEM

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Abstract Summary: From experience of many water-related disasters, it is recently much concerned that water infrastructure system gets more vulnerable due to high uncertainty of climate change and its relevant disasters. Many scholars in various fields suggest that securing diversity (variety) in system is a best way to respond to the uncertainty. In real world, however, it is hard to have it with more response actions due to budget constraints. Thus this study aims to examine optimal combination of water resources infrastructures which is most effective to given budgets by using Modern Portfolio Theory. Based on a drought case study in Korea, average return and risk of each water resource infrastructure for water supply, are established. Then, expected return and risk of each feasible portfolio are estimated by varying each asset's share. Finally, the efficient set of portfolio, called 'efficient frontier' is identified for a given return or risk level. Using the efficient frontier, a portfolio of cost-efficient options is identified as a desirable one to practically construct diversified infrastructure system under budget constraints of real world.

Keywords: *Uncertainty, Disasters, Diversification, Modern portfolio theory, Risk management, Drought*

1. INTRODUCTION

Due to climate change, many countries and cities are suffering from water-related disasters such as droughts and floods of which frequency and intensity have increased since the last century. This leads to raising a great concern for vulnerability, resilience and other response actions. The concern is also deepened in many cases due to high uncertainty of climate change and the relevant disasters.

Many scholars in various fields such as military, financial asset management, energy, and urban management suggest diversification in system to cope with the uncertainty and variety of relevant perturbations. In the field of cybernetics, it was suggested that only variety in control options can force down variety of the perturbations. It is the law of requisite variety that is well known as "only variety can destroy variety" (Ashby, 1957).

In real world, however, it is impossible to have more response actions especially with water infrastructure, due to budget constraints, than various and highly uncertain disasters. It is also impossible, as a result, to prevent all the water-related disasters. What can be done is only to reduce their impacts and do our best to save human lives. This leads for us to think of cost-effective securement of diversity (=variety) in infrastructure system to realistically apply the "law of requisite variety" for effectively dealing with various and highly uncertain water-related disasters. It is in this study called cost-effective variety' which can reduce variety.

In this regard, this study aims to quantitatively prove the hypothesis that, under budget constraints, it is more effective and applicable to construct diversified infrastructure system with cost-efficient options, rather than maximize diversity in system through application of all counteractions. To achieve this, using a drought case study in Korea, optimal combination of water resources infrastructures is examined, which is most effective to given budgets.

2. METHODOLOGY

In 2008, a severe drought occurred at the Gwangdong reservoir, which is located on Gangwon province in Korea. Most of the damage was concentrated in Taebaek city (about 2.4 million USD) due to its larger reliance on the Gwangdong reservoir. According to Cha et al. (2012), it was projected that intensity of drought would be more intensified and the damage by water scarcity during the 2030s~2050s was estimated to be more than 50 million USD. Thus, using this Gwangdong drought case and the concept of 'cost-effective variety', optimal combinations of water resources infrastructures are analyzed to deal various droughts in terms of magnitude and frequency.

As the available water resources in the Taebaek city, the conventional dam water, reclaimed water and rain water are considered. To find optimal mix of water resources, Modern Portfolio Theory (MPT, Markowitz, 1952), that is widely used to find an optimal portfolio of assets under uncertainty in the area of financial investment and services, is applied.

First, average return and risk on individual assets, i.e., each water resource, are established. The risk in MPT is defined as variation or standard deviation of returns. In this study, the return is defined as the amount of available water for investment and operation cost of water resources infrastructure, m³/month/USD. Instead of variance (second moment for the average) as risk, the semivariance, which measures downside risk relative to expected goal of each return on water resources, is used since returns above the goal return are desirable in water

supply. Then, expected return and risk on feasible portfolio are estimated by varying each asset's share. Finally, the efficient set of portfolio, called 'efficient frontier' is identified with consideration for budget constraints. The decision makers can select a portfolio among the efficient ones in accordance with risk and return preferences.

3. RESULTS AND DISCUSSION

The calculated returns and variances shown in the Table 1 describe that the expected return of dam reservoir for water supply is highest, but the variation in returns is also relatively high for the investment. This implies that cost-effectiveness on average is high when the government decides to invest in heightening primary dam reservoirs. However, the drawback of this strategy is that risk (variance) is also high as well, since the Gwangdong dam water only is a resource to the city. Therefore, the high dependence on dam reservoir needs to be reduced by diversifying water supply infrastructures.

Figure 1 shows the efficient frontier on the portfolios that consist of the three assets, i.e. dam water, reclaimed water, and rain water, for water supply. It is shown that the risk of individual portfolios decreases as the share of relatively low risky asset (e.g. reclaimed water) increases. The points in the below efficient frontier are portfolios of water resources assets for enhancing diversity. The points on the efficient frontier as the highest return for a given risk level represent mixes that consist of two water resources (i.e., Dam water and reclaimed water) which have relatively high return, by reducing the share of rain water. In other words, it is noted that, a portfolio of high return water resources only, i.e., dam and reclaimed water, is closer to efficient frontier, despite lower level of diversification, than a portfolio of all three water resources having a maximum level of diversity. Therefore, the authors believe that it is more desirable to construct portfolio with cost-efficient options for enhancing diversity in water infrastructure system, especially under budget constraints in real world.

Table 1. Expected return, variance, and standard deviation (SD) for individual assets

Assets	Expected return	Variance	Standard deviation
Dam water	2.7481	0.0747	0.2732
Reclaimed water	1.6005	0.0011	0.0330
Rain water	0.5477	0.0821	0.2865

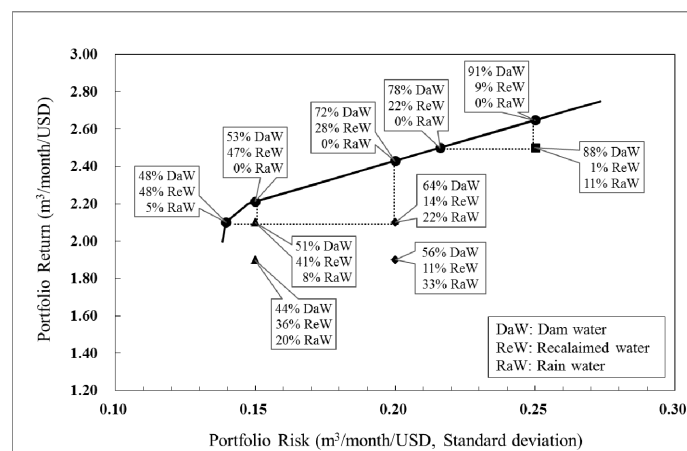


Figure 1. Optimal mixes of water resources in Taebaek city

4. CONCLUSIONS

Many experts emphasize diversity (=variety) in system is necessary to cope with uncertainty of system disturbances. Increasing it is much costly in real world, which leads us to developing more practical ways to deal with the disturbances. The example case analysis highlights that cost-effective portfolio of options having relatively high return is more desirable to practically construct diversified infrastructure system under budget constraints of real world. As demonstrated, the MPT framework is helpful to examine optimal mixes of options under budget constraints and to offer more robust mixes. Therefore the authors suggest that the MPT framework can be an effective tool to devise out options of 'cost-effective variety'.

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TITLE: UTILIZING APCC MULTI MODEL SEASONAL FORECASTS TO SUPPORT PLANNING AND OPERATION OF DAMS IN SOUTH KOREA

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Abstract Summary: Periodic seasonal droughts in South Korea are a burden for ensuring reliable water supplies by multi-purpose dams. Reliable long-range dam inflow forecast can help dam operators' decision-making for covering water supply planning and management to minimize possible drought damages. This study investigated that the utility of APEC Climate Center (APCC) multi-model ensemble forecasts in predicting dam inflow of major dams with up to 3-months lead-time. Our results showed the potential utility of seasonal dam inflow prediction during dry season, indicating APCC MME seasonal climate forecast can be useful information for developing proactive water supply plans and better preparing seasonal droughts in South Korea.

Keywords: *Seasonal forecast, dam, water supply, drought*

1. INTRODUCTION

Multi-purpose dams in South Korea serve important roles in providing approximately 65 percent of total water supply (12.2 billion m³/yr). These dams typically start to store water in mid-September after the period of frequent rainstorms and occasional typhoons had ended and to supply domestic, agricultural, industrial and environmental water uses during dry seasons (Jung et al., 2013). Recent Korean dam operators are facing challenges in using traditional methods of water management and dam operation because of changing climate.

Over the past three decades intensified seasonality in precipitation and streamflow in South Korea has been a burden to the dam operation. Some studies have emphasized significant trends in historical seasonal streamflow, increasing wet-seasonal flow and decreasing dry-seasonal flow attributed to precipitation changes (e.g., Bae et al., 2008). These changes have influenced to more intense spring droughts in South Korea.

From September 2008 to April 2009, the northeastern region of South Korea received only 15% of normal precipitation which led that fifty-thousand people have suffered a restriction of the water supply. In 2012, the worst agricultural drought in 104 years caused severe damage to agricultural and livestock industries, resulting in price hikes in some farm products. This year spring and early summer drought broke records in the lowest dam storage levels in Soyang, Chungju, Hoengseong, and Boryeong dams.

Advances in the climate science of seasonal prediction have created significant potential for improving water resources management practices at longer lead-times (Wood and Lettenmaier, 2006). The APCC, one of lead groups of global seasonal climate prediction, is providing operational 3-month and 6-month lead dynamical seasonal forecasts through the multi-model ensemble (MME) technique.

To evaluate the utility of the APCC seasonal climate forecasts in the dam inflow prediction, this study employs dynamic water balance models, a simple bias correction of climate forecasts, and the Bayesian Model Averaging (BMA) technique, which are needed to product the multi-model ensemble (MME) of hydrologic prediction. The performance of the monthly-based dam inflow prediction was tested using hindcasts for a 23 year period, 1983-2005.

2. CONCLUSIONS

The seasonal hydrologic forecasts based on 1-month lead APCC MME climate forecasts can provide useful dam inflow forecast skill for the dry season. However, there was no significant forecast skill for the wet season, especially June and September. Therefore, the seasonal hydrologic forecasts can offer useful information on how much dam inflow can be expected during the dry season which is a great interest to the dam operators regarding with sustainable water supply.

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TITLE: DROUGHTS AND WATER SECURITY IN SOUTH-EASTERN AUSTRALIA: SCIENCE AND MANAGEMENT

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Abstract Summary: The long, severe and unprecedented 1997–2009 Millennium drought in south-eastern Australia highlighted the significant challenges in managing water resources in a highly variable hydroclimate. This paper describes the features of the Millennium drought and projections of drier conditions and more frequent droughts in the future. The paper also discusses adaption and water reforms in regional areas and urban centres stimulated by the extreme conditions of the Millennium drought and projected declines in future water availability.

Keywords: Hydroclimate variability, Water resource management, South-eastern Australia, Millennium drought

1. HYDROCLIMATE VARIABILITY AND WATER RESOURCES MANAGEMENT IN AUSTRALIA

Australia is the driest populated continent and has the lowest runoff coefficient in the world. There is also considerable variation in Australia’s rainfall and runoff, spatially and temporally (see Figure 1a and 1b). Australia has a thin wet margin in the north, east and south-west coasts but the rest of the continent is dry. The year-to-year variability of Australian river flows is highest in the world and potential evaporation from Australia’s dry landscape is high. These present significant challenges to water management in Australia, where water resources in some regions are fully or over allocated, while other regions remain largely undeveloped.

The challenges to water resources management is particularly evident in south-eastern Australia, which generates more than half of Australia’s agriculture income and supports more than half of Australia’s population. Many catchments in the region are water stressed and water supply is likely to decline because of climate change and other development drivers. Demands for water continue to increase from expanding population, irrigation, industries, mining and the formal inclusion of environmental water allocations (Prosser, 2011).

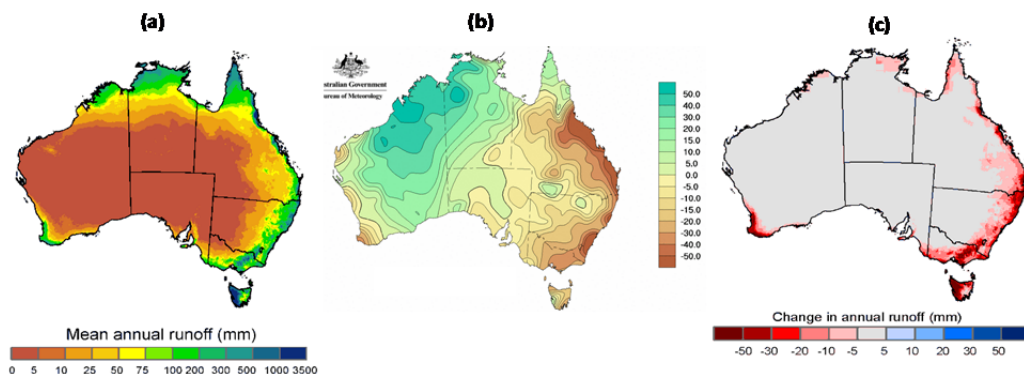


Figure 1 (a) Mean annual runoff (mm), (b) rainfall trend (1950–present) (mm/decade), and (c) projected (median) decline in mean annual runoff (mm per 1°C global warming)

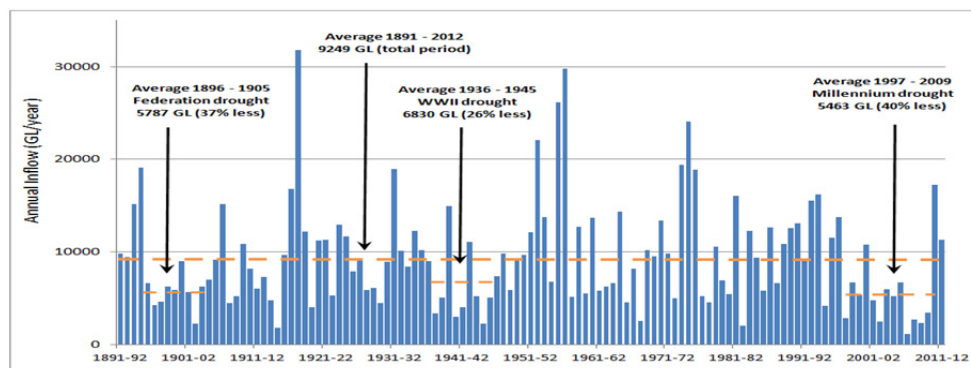


Figure 2 Annual Murray River Basin inflow series

2. DROUGHTS, DECLINING RAINFALL TREND AND FUTURE WATER SECURITY IN SOUTH-EASTERN AUSTRALIA

The annual time series of inflows in the Murray River Basin (the main river system in south-eastern Australia) in Figure 2 shows that runoff (and rainfall) can vary considerably from year to year. The annual runoff in a wet year can be more than ten times greater than the annual runoff in a dry year. There are also persistent wet periods (e.g., most of late-1940s to mid-1970s) and persistent dry periods (“Federation” Drought around 1900, “World War Two” drought around 1940, and 1997–2009 “Millennium” drought) lasting more than a decade.

The 1997–2009 Millennium drought was unprecedented in the 110 years of reliable hydroclimate records. It resulted in declining reservoir storage levels, several years of severe water restrictions in cities and urban centres, years of low irrigation water allocations and major environmental impacts. Water sharing arrangements in several basins were suspended because they were not designed for such extreme conditions. As most of Australia’s water use is in south-eastern Australia, the drought had a substantial economic, environmental and social impact.

The amplification of the annual rainfall reduction in the runoff was more severe in the Millennium drought compared to previous droughts because of (i) significant decline in cool season rainfall in the Millennium drought (cool season rainfall has continued to remain low even after the drought was broken by high summer rainfall) when most of the runoff in south-eastern Australia occurs, (ii) lack of any high rainfall years during the Millennium drought, and (iii) higher temperatures driving greater evaporation (Potter and Chiew, 2011; Chiew *et al.*, 2014). The decline in the cool season rainfall has been partly attributed to climate change, with warmer temperatures driving the expansion of the Hadley cell, pushing the cool season mid-latitude storm tracks further south away from the southern Australian land mass (CSIRO, 2012; Post *et al.*, 2014). Global climate models also reproduce this mechanism, and practically all the climate models project a drier future winter for this region. Integrated climate and hydrological modelling project declines in future water availability across south-eastern Australia (Figure 1c; Chiew *et al.*, 2009; Teng *et al.*, 2012). These multiple lines of evidence indicate that water availability in south-eastern Australia is likely to decline in future, and whilst the inter-annual and inter-decadal variability will remain high, droughts will be more frequent and potentially more severe.

3. ADAPTATION THROUGH POLICY AND MANAGEMENT

The Millennium drought and projected declines in future water resources in south-eastern Australia are already stimulating adaptation. A significant water reform is currently being implemented in the Murray-Darling Basin, where water infrastructures are being upgraded, irrigation water use efficiency improved, irrigation water entitlements purchased to return water to the environment, and flexible and adaptive water sharing plans are being developed to cope with current and future climates. The reform includes establishing effective water markets to adapt to demand and shift water use patterns toward higher value uses. In the state of Victoria, water corporations must develop water supply-demand strategies that consider a range of plausible future climate change projections, as well as the possibility of an immediate return to the conditions experienced during the Millennium drought.

Adaptation in major cities and urban centres has focussed on augmenting water supply and reducing demand through water conservation programs. This include securing new supplies that are more resilient to major climate shocks (including building desalination plants in Perth, Melbourne and Sydney) and using alternative sources like sewage recycling and stormwater for non-potable water.

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TITLE: NATIONAL DISASTER RESPONSE STRATEGIES FOR DROUGHTS OF CHINA -FROM INTEGRATED RISK GOVERNANCE PERSPECTIVES

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Abstract Summary: Dominated by extremely variant Asian monsoon, China has had a long history with drought which dramatically influences the stability of economy and society of the country. During the past thirty-five years, with a fast growth rate in both national economy and urban population combining with the impact of global climate change, impacts of droughts are intensifying and spreading from local to region and even nationwide and have led to considerable social, economic, and ecological losses. With great efforts of building a variety of engineering projects at different scales to combat drought by the government at all levels, China achieves a great success in agricultural production. In recent years, China government has begun to shift its focus from emergency response with heavy physical intervention to a comprehensive, proactive and preparedness risk governance approach. In this presentation, the context of drought in China and the current countermeasures are described first. Then, the new challenges learned from recent drought disasters are explored. Third, from integrated risk governance perspectives, the future improvement based on better understanding the complexity of the drought disaster and its regionality associated with trend/variation/extremes in national drought response governance strategies is discussed. The opportunities of coping with drought risks are also suggested.

KEYWORDS: *China, Drought Disasters, Complexity, Integrated Risk Governance*

1. INTRODUCTION

In the vast territory of China, climate is dominated by extremely variant Asian monsoon. Throughout its history, China has experienced frequent and serious drought disasters and it was the main cause of large scale death and social disruption. With an increasing trend since 1950, droughts have accounted for nearly 35 percent of annual agricultural losses caused by all natural disasters in China (Song et al. 2003). Due to its insidious, slowly developing nature, in recent years, coinciding with global climate change and China's fast economic growth and urbanization, the increasing drought disasters put food security, ecological equilibrium, social stability and sustainable economic development at risks.

To combat with drought disasters, a five-level administrative structure was established in 1950, i.e., the State Flood Control and Drought Relief Headquarter (SFCDRH), River basin Committees, Provincial-level, Regional-level and County Level FCDRH. In the past sixty years, SFCDRH is in charge of implementing China's drought relief policy under the direct leadership of the State Council according to the National Drought Relief Regulations with most emphasis on the drought prevention, relief and mitigation

2. CHALLENGES AND OPPORTUNITIES

The recent severe drought events occurred in China have affected vast areas and lasted for comparatively long periods and imposed a profound, long-term impact on the economy, society, and ecological environment at local, regional and national level. Although the current highly centralized structure responded successfully to these events in terms of saving lives and ensuring local food security and social stability, there are many issues in need of discussion, especially in the process of shifting drought disaster risk management from a crisis response approach to a risk management approach.

Clearly, in the context of global climate changes, there are many new challenges when dealing with impacts of drought events, including effects of disaster chain due to the increasing degree of connectivity in space and among sectors, lacking of better scientific understanding and communication between sciences and other stakeholders, and ways of integrating vulnerability-reducing, resilience-improving, and adaptation-enhancing measures for drought disaster preparation, emergency response, restoration and reconstruction.

To meet the challenges of dealing with the drought disasters at different spatial-temporal scales, there are great opportunities in the action dimension such as changes in institutional dimension by adapting an integrated approach, strengthening capacity in social dimension in order to optimize safety fortification, disaster relief and rescue and emergency response, and innovations in economic dimension to build up more reliable financial structures for risk sharing.

3. SUMMARY

For the purpose of achieving sustainable socio-economic development, China government is now in the process of enhancing the national ability to cope with drought risk by better understanding the complexity of drought risks, focusing on dealing with the regionality of drought risks induced by trends, variations and extremes, and exploring the potential opportunities of getting benefit when meeting the new challenges induced by drought disasters.

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APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness

Session IV

Changes in Hydrological Extremes: Floods and Typhoons

Developing Climate Scenarios and Management Tools to Reduce Vulnerability to Future Flood Risk

Prof. Eric Salathé
(University of Washington/USA)

Impact Assessment of Typhoon and Related Storm Surge Considering Climate Change

Dr. Nobuhito Mori
(Disaster Prevention Research Institute/Japan)

A Review On Heavy Rainfall Out of Tropical Cyclone Envelope

Prof. Lian-shou Chen
(Chinese Academy of Meteorological Sciences, CMA/China)

Hydrometeorological Variability and its Integrated Flood Risk Assessment for the Korean Han River Basin during different El Niño Phases

Dr. Sunkwon Yoon
(APEC Climate Center/Korea)

Temporal Downscaling of Hydrometeorological Variables for Mitigating the Impacts of Climate Change on Water Disasters

Prof. Taesam Lee
(Gyeongsang National University/Korea)

Climate Variations Link to Extreme Streamflows

Dr. Swadhin Behera
(Application Laboratory, JAMSTEC/Japan)

APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness



TITLE: DEVELOPING CLIMATE SCENARIOS AND MANAGEMENT TOOLS TO REDUCE VULNERABILITY TO FUTURE FLOOD RISK

Eric P Salathé Jr.

University of Washington, USA

Abstract Summary: Puget Sound's major rivers and their floodplains deliver a wealth of economic, social and environmental benefits. However, development and other activities in Puget Sound have degraded more than 70% of floodplains threatening salmon populations, impacting water quality, and limiting the extent to which these areas can regulate flood waters and support other natural river functions. Planning is complicated by the variety of stakeholders and interests, resulting in uncoordinated and often conflicting efforts to manage these critical areas. This talk will describe the coordinated efforts of scientists, engineers, and managers to assess and respond to flood risk in the lower Snohomish River basin. The goal of these projects is to enable scientists to work in tandem with practitioners from project conception to completion, identifying research needs and products that can be used to inform decisions. Case studies will be used to illustrate the spectrum of activities from research into extreme precipitation to multi-stakeholder decision-making and "on the ground" flood management.

1. INTRODUCTION

Intense short-term weather events produce some of the most important environmental hazards and present significant challenges to land managers, disaster response agencies, and land owners. For the Northwest, events of particular concern include heavy precipitation and flooding both in the winter and summer, heat waves, storms with high-wind and lightning, and drought. Global climate model results suggest substantial changes in the geographical and seasonal distribution of a broad range of extreme events with climate change. These events depend on processes that are not well represented either by global models or the observing network, and it is not clear whether statistical downscaling methods can adequately represent changes in these processes in a future climate. An emerging tool, regional climate models can explicitly represent the mesoscale processes that control the timing, intensity, and extent of extreme events and can produce local climate responses quite different from those indicated by global models combined with statistical downscaling. This study examines the emergence of extreme events as indicated in both global climate models, statistical downscaling, and regional models and applies that information to management decisions. Two case studies of flood risk management from urban areas in the Puget Sound region will be used to illustrate ongoing efforts to use climate information.

2. FLOODPLAIN AND LAND USE MANAGEMENT

This study quantifies the joint impacts of changes in river flooding, sea level rise, and storm surge on future flood risk for basins in the Puget Sound region. The uncertainty in projections is quantified using considering high, middle, and low projections for both river flooding and sea level rise. Finally, we evaluate the relative importance of sea level rise and river flooding in driving changes in flood risk in the basin. Results from this work are incorporated into a decision support tool developed by The Nature Conservancy (TNC) to support multi-objective floodplain management.

Puget Sound's major rivers and their floodplains support productive agriculture, sustain important fisheries, enable recreation and provide other functions essential to quality of life in the region. However, development and other activities in Puget Sound degrade floodplains threatening salmon populations, impacting water quality, and limiting the extent to which these areas can regulate flood waters and support other natural river functions. The variety of problems caused by the loss and degradation of floodplains has triggered responses from an array of stakeholders and interests, resulting in uncoordinated and often conflicting efforts to manage these critical areas. To address this challenge the Nature Conservancy launched Floodplains by Design, a collaborative effort to improve decision-making by providing information to align isolated objectives and integrate disconnected stakeholders. A key component of this strategy is the development of a decision support tool designed to provide data and data visualizations to guide floodplain management. Working with local partners in Snohomish County, TNC developed the Floodplain Resilience tool to incorporate information related to flood risk, salmon recovery and other objectives to better inform project prioritization and coordination among diverse partners.

3. DAM AND RESERVOIR MANAGEMENT

The U.S. Army Corps of Engineers completed an investigation of potential climate change impacts to the Green River basin, Washington, and an exploration of possible water management vulnerabilities and adaptations at Howard Hanson Dam based on climate change projections. The dam is a multipurpose project owned by the U.S. Army Corps of Engineers and is operated for flood risk management, fisheries management, and municipal water supply for the City of Tacoma. Historically, flood season on the Green River has occurred between November and February and the refill of the reservoir has occurred between late February and June. The primary concern of this study was to investigate the possibility of overlapping flood and refill seasons in the future. Simulated hydrology for the study covered a 30-year historical time period and two future time periods, extending to 2069. A Global Climate Model was dynamically downscaled using the Weather Research and Forecasting model to create the forcing datasets.

Reservoir regulation was modeled using the simulated hydrology to assess potential vulnerabilities in the Hanson Dam water control plan. Regulated downstream flows exhibited higher peak flows and more instances of flooding in the future simulations. The timing of flooding in the Green River basin did not appear to shift significantly in the future time periods. While simulated spring floods were slightly larger in the future time periods, they were easily managed using current reservoir operations. More significantly, the future simulated spring flows were generally lower than historical flows and required earlier refill completion dates for conservation storage. Conservation refill success was not impaired but the earlier conservation storage, combined with overall lower spring flows, appeared to hinder successful refill of municipal storage in the future.

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TITLE: IMPACT ASSESSMENT OF TYPHOON AND RELATED STORM SURGE CONSIDERING CLIMATE CHANGE

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1. INTRODUCTION

Recently, impact assessment studies on climate change have been carried out based on climate models, *e.g.* General Circulation Model (GCM). The future projection experiments employing climate models have indicated the cyclogenesis frequency of tropical cyclones will decrease whilst the intensity of cyclones will increase as a result of climate change (Knutson *et al.*, 2010). It has also been projected that extreme values of wind speed of typhoons will increase in the northwest Pacific Ocean (Mori *et al.*, 2013). Potential of storm surge risks due to the increase in typhoon intensity will increase in Japan coast, and enormous disaster may be induced.

In the projection of future storm surge, the results may contain uncertainty by several reasons: difference of climate models, model resolutions, and greenhouse gas emission scenarios, sensitivity to typhoon course to storm surge. Therefore, it is difficult to evaluate uncertainty in bay scale due to low occurrence probability of storm surge locally. Although evaluation of possible maximum storm surge risk is important in a long-term design of coastal defence structures, the storm surge risk depends not only on typhoon's intensification but also on typhoon's track shift due to climate change. We have investigated uncertainty of possible maximum storm surge projections by different approaches as follows.

2. RESULTS AND DISCUSSION

The uncertainty caused by typhoon characteristics, followings can be considered: typhoon track (shift and rotation), typhoon translation speed, and intensity change due to climate change. The calculations are performed by changing these elements to evaluate the difference in results. Surge-WAVE-Tide coupled model (SuWAT) developed by Kim *et al.* (2009) is employed as the storm surge model. Numerical storm surge simulations forcing with empirical typhoon model have been conducted targeting the Ise Bay including Nagoya of Japan, which suffered the severest storm surge disaster by typhoon Vera, so called Ise-wan typhoon, in 1959.

Figure 1 shows relationship between maximum storm surge and changed typhoon tracks. When typhoon track shifted 18.5 km eastward and rotated 20 degree anticlockwise, storm surge becomes highest at Nagoya, which is 1.34 m larger than the original track. Sensitivity of typhoon track, translation speed, and future change of central pressure of typhoon to storm surge is discussed targeting Ise Bay. **Figure 2** shows time series of storm surge in Nagoya by the assuming intensified future typhoon. The impact of sensitivity of typhoon track on storm surge is larger than the changes in typhoon intensity. It is found that the four factors, 1) typhoon intensity change, 2) horizontal track change, 3) rotational track change, and 4) translation speed change, have similar order impact on the storm surge and precious impact assessment will be required for future projections of storm surge.

It is also important to discuss sensitivity of typhoon track on storm surge for impact assessment of extreme storm surge. We have been developed track perturbation method changing initial position of tropical cyclone keeping coherent structures (Oku *et al.*, 2014). **Figure 3** shows minimum central pressure of typhoon Vera by track perturbation. Although the storm surge is sensitive to intensity and track, this method can make assessment of track changes to storm surge dynamically. Based on the similar method, a pseudo global warming experiments can be conducted changing sea surface temperature (SST). **Figure 4** shows the estimated mean maximum storm surge of 2013 Typhoon Haiyan at Tacloban by the present climate and pre-industrial age. The means and standard deviations of maximum water surface elevation indicate about 20% increase of storm surge from pre-industrial age to present.

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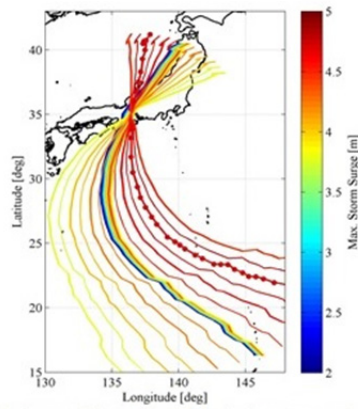


Figure 1 Relationship between maximum storm surge and changed typhoon tracks'

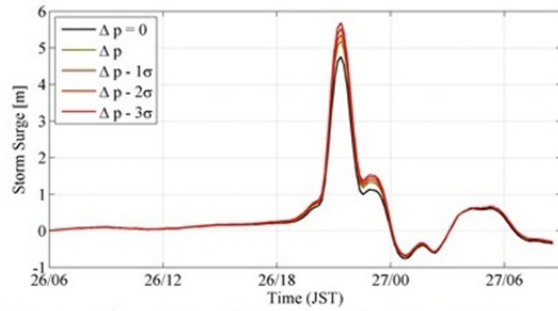


Figure 2 Time series of storm surge in Nagoya by the pseudo intensified future typhoon with worst track'

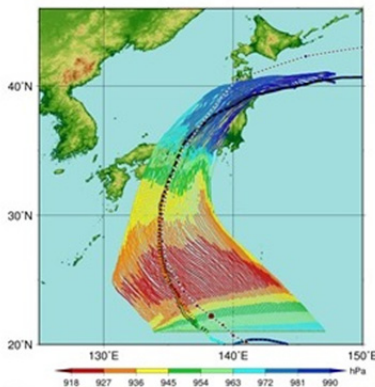


Figure 3 Minimum central pressure of typhoon Vera by track perturbation'

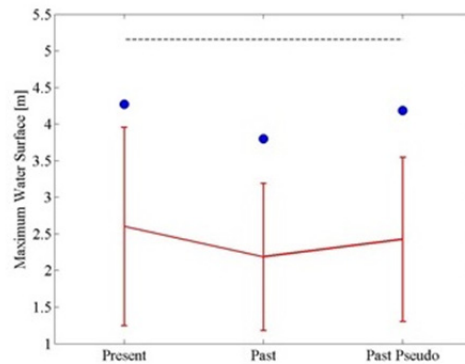


Figure 4 Mean and SD of maximum water surface elevation of 2013 Typhoon Haiyan at Tacloban

TITLE: A REVIEW ON HEAVY RAINFALL OUT OF TROPICAL CYCLONE ENVELOPE

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Abstract Summary: Landfalling tropical cyclones would bring about very heavy rainfall in its envelope (including eyewall and spiral rain band). Apart from the rainfall inside the tropical cyclones' (TCs) envelope, there are rainfall out of TC envelope produced by TCs as well. This is a small probability event and difficult for operational forecast. Rainfall out of TC envelope can be categorized into three types; namely the pre-TC squall rain, coastal topographic rain and TC remote precipitation (TRP). The major mechanism of those rains out of TC envelope is reviewed in this paper. It could be a certain reference for operational forecast.

Keywords: Tropical cyclone (TC), Rainfall, out of TC envelope

1. INTRODUCTION

People usually attach more importance to the heavy rainfall corresponding to tropical cyclone, especially the rainfall inside the TC envelope, such as very heavy rainfall produced by TC eyewall, spiral rainband, or rains associated with mesoscale vortices or shear line in the envelope of TC. On the other hand, apart from those rainfall inside the TC envelope, very heavy rainfall would occur in an area out of the TC envelope even more distant from the TC circulation. Such a rainfall areas are totally separated from the rain area inside TC envelope. The occurrences of those TC outside rainfall are closely related to the existence of the TC which can be categorized as pre-TC squall rain, topographic rain and remote precipitation. This paper will review the mechanism of those TC outside rainfall.

2. PRE-TC SQUALL RAIN

Some TCs are carrying a squall line ahead of a TC and its motion often agreeing to the TC motion direction. The research (Meng et al. 2012) showed that there are 43% typhoons carrying a squall line ahead of it. Squall is a strong convective and high instable stratification band with size of 200-300 km long. The pre-TC squall line would be composed of microscale system of thunderstorm even tornadoes which will bring about very heavy rainfall and high impact weather.

Pre-TC squall line could be generated from a convergent line between the TC south easterly flow and the environmental north westerly flow (Fig.1). Sometime a weak convergent belt is pre-existent in lower layer over ocean which could be activated when a TC is approaching, the interaction between TC and environmental flow could provide the convergent belt with instable stratification as well as the convective available potential energy (CAPE) to help it growing into a pre-TC squall with heavy rainfall.

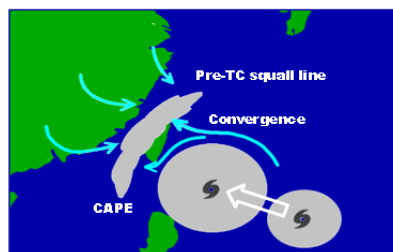


Figure 1. Schematic diagram on genesis of the pre-TC squall line.

3. TOPOGRAPHIC RAINFALL

Topographic effect could lead to asymmetric distribution of rainfall associated with a landfalling tropical cyclone. When a TC approaches land, the terrain convergence in windward shore would help to increase more extensive rain area and stronger rain rate than the rainfall in lee wind shore. The topographic rainfall occur usually away from the TC, when a TC is approaching the coast or making landfall. A topographic convergent belt will be formed along the windward shore. It would help to increase the rainfall rate and distribution. Observational facts showed that more extensive rainfall area in windward side than it in lee shore side of the coast.

Case study (Duan and Chen et al., 2005) showed that when a typhoon Fitow (0114) cut across the Qiongzhou Strait north to Hainan island. A mesoscale vortex is occurred in a convergent zone between the Wuzhi mountain in Hainan island and north-westerly peripheral winds of typhoon Fitow. Very heavy rainfall was produced by the mesoscale vortex away from typhoon Fitow.

Asymmetric distribution of landfalling TC rainfall is not only appeared in China, but also in Japan.

Japanese scientist study the typhoon Meari (0122) (Akihiko, 2006) made landfall at Kyushu and find the three remote rain masses occurred in Kii Peninsula where is 500km east away from the typhoon Meari. One of the three rain mass was depend upon a mountain range in Kii Peninsula.

4. TC REMOTE RAINFALL

Some offshore tropical cyclones can produce heavy precipitation in an area in front of and distant away from cyclone. The distant between the rain area and TC center could be exceeded 1000km or so. It can be called tropical cyclone remote precipitation (TRP) (Fig.2) (Cong and Chen et al., 2012). Statistics showed that only 14.7% offshore and landfalling typhoons occur TRP (1971-2006) which is a small probability events and a great challenge for operational forecast. TRP event is not only happened in China but also in Japan (Wang and Wang et al., 2009) and in United States who called it as predecessor rain events (PREs).

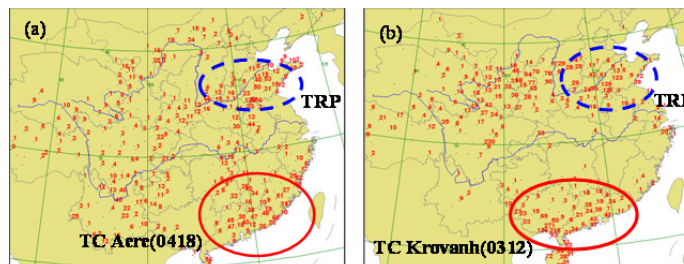


Figure 2. TRP events for two typhoons. TRP for typhoon Aere (26-28 Aug. 2004) (a) and typhoon Koravanh (25-27 Aug. 2003) (b).

Statistics showed that high frequency of TRP events are appeared in July and August. And the TRP distribution is often extensive and usually last around two days. There are two high frequent region of TRP in China. The one is in Bohai sea and its marginal land region and the another is in the middle of western North China.

Essentially TRP is a result from the interaction between the offshore typhoon and a mid-latitude westerly trough. The moisture transport ability are quite different for individual offshore typhoons. Some of them can transport moisture to a distant area in mid-latitude and in front of a westerly trough to increase rainfall and the others just keep the moisture inside the TC circulation. Apart from the moisture transport of TC and westerly trough, topographic effect could help to increase the rate of TRP. Typhoon Vicente (1208) create a TRP event in Beijing area (Li et al., 2014). The famous Beijing 721 catastrophe is closely related to the TRP from typhoon Vincent which was in the southern east coast of China.

A numerical simulation has been conducted. The results showed that the TRP would remarkably be reduced if typhoon intensity is decreased or typhoon is removed, as well as the strength of westerly trough is decreased. Topographic effect is another important role to help increasing the TRP.

5. SUMMARY

There are three types of TC rainfall occurring in a area out of TC envelope. Pre-TC squall is a mesoscale convective system which brings about heavy rainfall. Usually the squall line could be growing up from a convergent belt in front of TC which is in between of the TC peripheral south easterly winds and environmental northwesterly winds. Topographic effects also can produce a rain area out of TC envelope. Windward shore or mountain slope could increase the rain rate and distribution away from TC. TRP event is a result from the interaction between offshore TC and mid-latitude westerly trough. The rain rate and distribution of TRP would hinge upon the moisture transport of typhoon, strength of westerly trough and terrain effect.

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TITLE: HYDROMETEOROLOGICAL VARIABILITY AND ITS INTEGRATED FLOOD RISK ASSESSMENT FOR THE KOREAN HAN RIVER BASIN DURING DIFFERENT EL NIÑO PHASES

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Abstract Summary: In this study, we investigated the characteristic changes in precipitation and runoff that occur in the Korean Han River Basin and its sub-basins in association with the cold-tongue (CT) and warm-pool (WP) El Niño phases during spring and summer. Also we performed a case study to develop an integrated flood risk index (FRI) considering hydrologic, socio-economic, and ecological components to assess watershed-based flood hazards and vulnerability. Findings are during the WP El Niño years, rainfall in spring and its coefficient of variation were higher than long-term normal precipitation, and during the CT El Niño years, summers tended to be drier than in climatologically normal years, and increased runoff was seen for 95.8% of all basins. The average value of integrated flood risk results during different phase of ENSO conditions exhibited during CT El Niño (57.7%), La Niña (41.2%) and WP El Niño (57.0%). Despite the relatively small sample size and lack of data, the research presented here provides a quantified assessment of Han River flood risk combined with an integrated view of risk assessment and management for stakeholders and decision-makers.

Keywords: Hydrometeorological variability, CT/WP El Niño, Integrated Flood risk, Han River Basin

1. INTRODUCTION & METHOD

The seasonal characteristics of hydrometeorological variability are closely related to global climate phenomena and climate changes (Wang et al. 2000; Kim et al. 2012; Yoon et al. 2014). Therefore, investigating the correlation between climatic factors and hydrologic data (such as precipitation and streamflow) is very important for the accurate prediction and management of water resources (Horel and Wallace 1981; Pizarro and Lall 2002; Kim et al. 2012). However, regional hydrologic variability has a complex relationship with climate, including effects across the hydrologic cycle rather than being limited to independent phenomena. Changes in global climate systems have significant consequences for water resources, which are closely associated with weather in the short term and climate phenomena in the long term. The aim of the present study was therefore to use the CT/WP El Niño categorization results of Ren and Jin (2011) to determine their relationships with precipitation and runoff in the Korean Han River Basin and its sub-basins. Moreover, it may provide in developing seasonal hydrologic estimates conditioned upon large-scale climate state for stable water supply and flood risk management in a changing climate.

The effect of different phases of ENSO events on the spring and summer precipitation and runoff characteristics was analyzed by adopting the classification criteria proposed by Ren and Jin (2011) for hydrologic variables from 24 sub-basins. We used two new indices (N_{CT} and N_{WP}) from a simple nonlinear transformation proposed by Ren and Jin (2011) to distinguish a CT El Niño from a WP El Niño. The equation is defined as follows:

$$\begin{aligned} N_{CT} &= N_3 - \alpha N_4 \\ N_{WP} &= N_4 - \alpha N_3 \end{aligned} \quad \alpha = \begin{cases} 2/5, & N_3, N_4 > 0 \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

Here, N_3 and N_4 indicate indices for Niño3 and Niño4, respectively, and N_{CT} and N_{WP} are new indices based on a simple transformation from Niño3 and Niño4 indices.

The assessment of flood risk and vulnerability in this study is based on district disaster system theory, based on the definition of risk expressed by Eq.1 (Maskrey, 1989):

$$\text{Risk} = \text{Hazard} + \text{Vulnerability} \quad (2)$$

Thus, this study derived a FRI model incorporating hazard and vulnerability as the following functions:

$$\text{Flood Risk Index} = \text{function} (H_i, S_j, E_k) \quad (3)$$

where H_i represents the hazardous hydrological index, S_j the socio-economic index incorporating a vulnerability criteria, and E_k the ecological index incorporating a vulnerability criteria.

2. DATA DESCRIPTION

The hydrometeorological data used in this research were precipitation and runoff data collected from 1966 to 2007 by the Water Management Information System (WAMIS 2012). We have used daily precipitation data, provided by the Korean Meteorological Administration (KMA, 2012; <http://kma.go.kr>), and a number of geographic information system (GIS) layers were generated in digital format by using Arc GIS 9.3 software to study flood risk and vulnerability in the Han River Basin. The monthly ENSO data used in this research were

obtained from the National Oceanic and Atmospheric Administration (NOAA). Among the data collection sites, observation data from Niño3 (5°S–5°N, 150°–90°W) and Niño4 (5°S–5°N, 160°E–150°W) sites are known to have strong correlation with El Niño (Trenberth 1997). The SST data provided by the Hadley Center, called HadISST, were used to investigate the correlation between and large-scale atmospheric circulation patterns. This dataset, which is available on the Internet (URL: <http://www.cpc.ncep.noaa.gov/data/indices>), has a spatial resolution of 1° × 1° and is (Rayner et al. 2003).

3. RESULTS AND DISCUSSION

The seasonal variability in precipitation and runoff over the Korean Han River Basin for the CT/WP El Niño years can be summarized as follows: Firstly, during the WP El Niño years, precipitation in spring and its CV were higher than long-term normal precipitation. Secondly, in the CT El Niño years, summers tended to be relatively drier than in climatologically normal years, although the variability in precipitation during the summer was lower. Lastly, significant increases in summer precipitation and runoff were seen in the WP El Niño years. These increases mostly occurred in a central-southern region of the Han River Basin. However, summer runoff data showed a relatively dry tendency, with high variation during CT El Niño periods. This study also divided the research periods into the strongest different SST conditions (CT/WP El Niño and La Niña). The results from the hydrological hazards analysis indicate that the CT El Niño year was increased 1.5% of IFR more than WP El Niño year. And also the La Niña year appear decreasing tendency than CT/WP El Niño years from 22.0% to 24.0%. Changes in the classification of risk zones between CT/WP El Niño and La Niña were noted: recorded of 8.1-8.6% increase in the very-high-risk zone, a 7.12 % increase in the high-risk zone, a 9.70% decrease in the medium-risk zone, a 0.15% decrease in the low-risk zone, and a 2.71% increase in the very-low-risk zone.

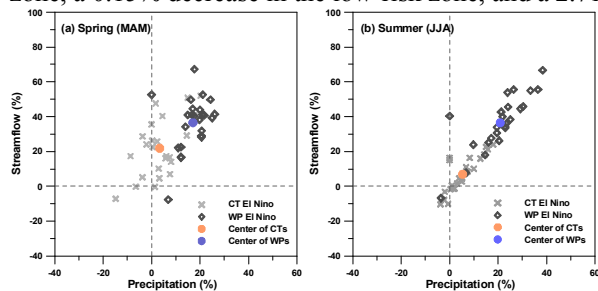


Figure 1. Percentage anomalies (departures from the 1971–2000 normals) showing changes between precipitation and streamflow for the spring (MAM) and summer (JJA) seasons during different ENSO types over the Han River basin and its sub-watersheds.

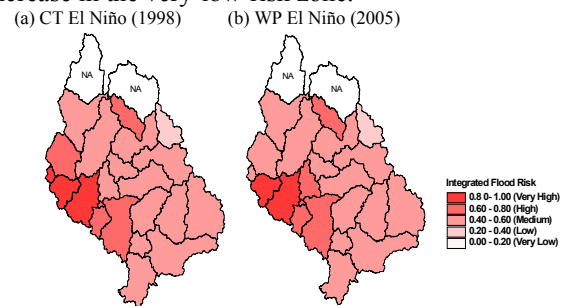


Figure 2. Assessment of the integrated flood risk index (IFRI) over the Han River basin, Korea. (a) shows the strongest CT El Niño phase in 1998, and (b) shows the strongest WP El Niño phase in 2005.

4. CONCLUSIONS

Investigation of the correlations between climatic factors and hydrologic variables are also required to establish stable water supplies and realistically adaptable strategies for resilience against extreme events in a changing climate. Further Examination and understanding of the synergistic impacts of large-scale atmospheric circulations and the evolution of the emerging El Niño conditions on local climate and hydrology will require additional studies using physical mechanism-based numerical simulations to reduce the uncertainties. Also, an analysis of possible factors leading to increases in flood hazard in the Han River basin should be conducted on the basis of this research. We expect more effective policy standards to reduce flood risk in developing areas. Therefore, great efforts in water resource management are necessary during under CT/WP El Niño conditions.

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TITLE: TEMPORAL DOWNSCALING OF HYDROMETEOROLOGICAL VARIABLES FOR MITIGATING THE IMPACTS OF CLIMATE CHANGE ON WATER DISASTERS

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Abstract Summary: Temporal and spatial downscaling of hydrometeorological variables has been widely employed for analyzing the impacts of climate change on hydrometeorological variables as well as mitigating the impacts especially from water driven disasters. In the current study, a decent temporal downscaling method based on stochastic simulation is presented and compared. For temporal downscaling, nonparametric techniques such as k-nearest neighbor resampling (KNNR) and kernel density estimate (KDE) are used to downscale the daily precipitation to hourly. The results are tested on Korea area. The results are concluded that the presented temporal downscaling methods can be reasonable alternative to downscale the hydrometeorological variables to study the climate change impacts on water disasters such as floods and droughts.

Keywords: Temporal Downscaling, Spatial Downscaling, Climate Change, Water Disasters, Precipitation

1. INTRODUCTION & METHOD

The outputs of global climate models (GCMs) provide superb areal coverage for assessing future impacts of climate change (Orlowsky et al., 2008). For analyzing the local impacts of climate change, downscaling of GCM outputs are required. Furthermore, the supplied outputs are in general monthly or at most daily. However, finer time scale data is critical especially for assessing the future variations of water disasters since small or medium size watersheds outflow only in a few hours. Therefore we applied the recently developed temporal downscaling method to downscale the daily data to hourly.

The applied method is based on nonparametric techniques such as k-nearest neighbor resampling (KNNR) and kernel density estimate (KDE) as well as Genetic Algorithm (Lee et al., 2010) in order to produce new patterns different from historical patterns (Lee and Jeong, 2014). Given that the observed daily and hourly data are available, the target future daily data is downscaled by (1) from the observed hourly data, selecting two candidate hourly dataset whose sum is close to target daily data; (2) two hourly datasets are mixed with Genetic Algorithm procedure (i.e. crossover and mutation); (3) finally, the final hourly values is adjusted so that the sum of the final hourly dataset is the same as the target future daily data. This method is applied to South Korea and the impacts on extreme precipitation events were analyzed.

2. DATA DESCRIPTION

Daily and hourly precipitation data from the Korea stations, which are shown in Figure 1 covering the time range 1971 to 2010, are employed to present the performance of the temporal downscaling. The Korean peninsula is climatologically influenced by the Siberian air mass during winter and the Maritime Pacific High during summer. Approximately two thirds of the total precipitation is concentrated in the summer. Therefore, the flood control system is an important aspect of this study. Also, daily precipitation maxima occur during summer. Therefore, the results for the month of August are displayed. The climate change scenarios of daily precipitation were provided by the Korea Meteorological Administration (KMA) to the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways 8.5 (RCP8.5 and RCP4.5) from the year 2011 to the year 2099. KMA produced the regional climate projections for Korea with 12.5-km resolution using the dynamical downscaling method (the atmospheric regional climate model HadGEM3-RA, i.e., Hadley Centre Global Environment Model version 3) from a global climate change projection obtained by using a coupled atmosphere-ocean general circulation model (GCM), HadGEM2-AO (version 2 of the atmosphere-ocean coupled model of the Hadley Centre Global Environment Model), with approximately 135-km resolution for RCP8.5 and RCP4.5. The HadGEM3-RA of the RCP projection was bias-corrected using linear scaling method (Lenderink et al., 2007) on a daily time scale.

Observation Stations

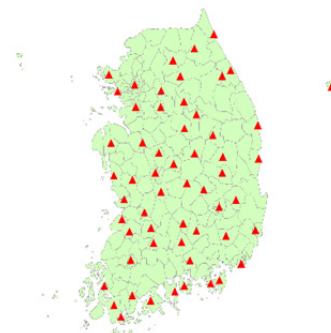


Figure 1 Locations of the employed weather stations for South Korea

3. RESULTS AND DISCUSSION

The daily precipitation for the future period (2011-2099) were downscaled employing the nonparametric skills (KNNR and KDE) and illustrated in Figure 2. The spatial distribution of historical maximum precipitations for 6th, 12th, and 18th hours are presented in top panels of Figure 2. The west side of South Korea has higher maximum values than the east side while in 12th hour, the maximum is rather smaller than the other hours. In 18th hour, the high values are rather spread over the country.

The anomaly of the maximum precipitation of RCP8.5 from the historical at each hour is presented at the bottom panels of Figure 2. The results indicated that the south coast of the country shows the significance increase over the all the hours and slight increase at the mainland for 6 and 12th hours while significant increase is presented at the middle part of the country for 18th hour. This result indicates that flood risk might increase in the south coast area in the future according to the 8.5 emission scenario.

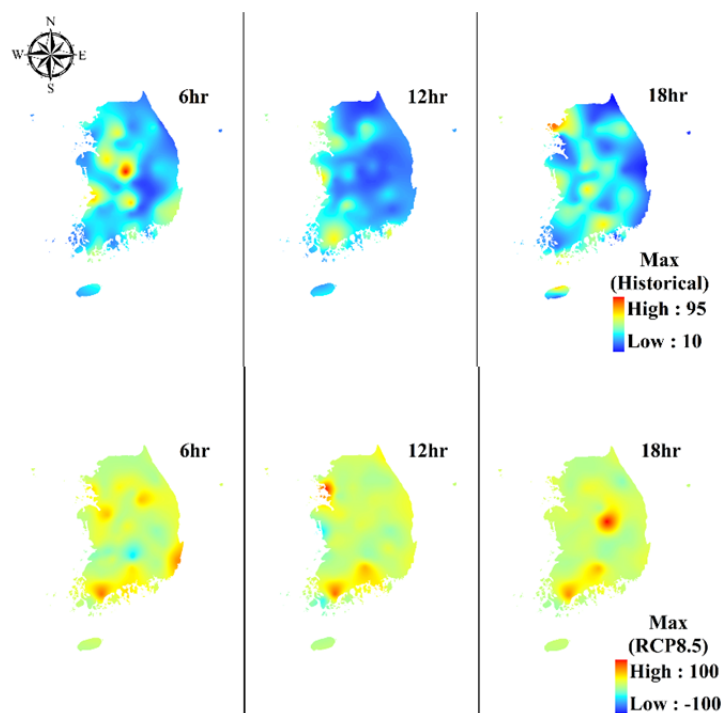


Figure 2. Historical hourly maximum precipitation (top panels) and its difference (bottom panels) from RCP8.5 for 6th hour (left panels), 12th hour (middle panels), and 18th hour (right panels)

4. CONCLUSIONS

The current study presents the downscaling method that disaggregate the daily precipitation data to hourly employing nonparametric approaches such as KNNR and KDE. The downscaled scenario RCP8.5 presents that the maximum precipitation might increase in the future. We concluded that the presented downscaling method is a good alternative to downscale the daily data to sub-daily data for assessing the impacts of water disasters especially at small or medium size watershed.

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TITLE: CLIMATE VARIATIONS LINK TO EXTREME STREAMFLOWS

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Abstract: The variation in seasonal streamflow significantly affects the ecosystem and in particular the human population dependent on the river. Climate variations, besides several other factors such as the physical characteristics of a river basin, hydrologic response to rainfall and changes in land use, could significantly influence the streamflows through the rainfall variations over the river basins. Here we provide a couple of examples to show the impact of El Niño/Southern Oscillation (ENSO), ENSO Modoki and Indian Ocean Dipole (IOD) on the streamflows of two rivers on either sides of the Pacific Ocean.

In the first case study, the extremely-low discharge events of the Paranaíba River basin of Brazil is seen to be associated with the El Niño Modoki phenomenon during austral summer season of December-February. Extreme events are identified based on their persistent flow for seven days and more after taking retention time into consideration. Ninety percent of the extremely low discharge events are found to occur during the peak streamflow seasons of December-February when the positive phases of the ENSO Modoki give rise to central Pacific warming. However, surprisingly none of the low-stream-flow events were associated with canonical El Niño events.

Away from Amazon basin, in the Maritime Continent, the Citarum River streamflows of Indonesia is seen to be dominantly influenced by the phases of the Indian Ocean Dipole besides a significant relation to ENSO. Extreme low streamflows of the Citarum River are associated with the positive IODs in addition to El Niño except for one independent event of 1977. Because the seasonal peak streamflow coincides the peak season of IOD, the IOD is found to be dominantly linked with the extreme low streamflows concurrently as well as a season ahead. Most of the extreme events of high-streamflows were on the other hand are related to La Niña conditions of tropical Pacific besides the negative phases of IOD.

APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness

Session V

Climate Impacts on Water Quality Typhoons

Impacts of Climate Change On Stream Temperature in the Pacific Northwest Of USA

Prof. Heejun Chang
(Portland State Uni./USA)

Adapt to What? Projections of Direct Impacts of Climate Change on Surface Reservoir Water Quality in Australia and Taiwan

Dr. Leon van der Linden
(Australian Water Quality Centre/Australia)

Climate Change Impacts on Agricultural Non-Point Source Pollution by Considering Uncertainty of CMIP5

Dr. Jaepil Cho
(APEC Climate Center/Korea)

Extreme Hydroclimatic Events and Environmental Quality: Use-inspired characterization of change, thresholds and transitions

Dr. Shaleen Jain
(Uni. of Maine/USA)

Heat Waves, Precipitation and Water related Disease Vector in Drought and Flood Prone areas of West Bengal, India

Dr. Jyotish Basu
(West Bengal State Uni./India)

The Taihu Eddy Flux Network: An Observational Program on Energy, Water, and Greenhouse Gas Fluxes of a Large Freshwater Lake

Prof. Xuhui Lee
(Nanjing University of Information
Science and Technology/China)

APEC Climate Symposium 2014

Managing Climate Extremes and Hydrologic Disasters:

Scientific Prediction and Emergency Preparedness



TITLE: IMPACTS OF CLIMATE CHANGE ON STREAM TEMPERATURE IN THE PACIFIC NORTHWEST OF USA

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Abstract Summary: We investigated the effects of air temperature and streamflow on stream temperature in selected streams of the Pacific Northwest of USA that represent heterogeneous hydrologic landscape. Using spatially downscaled daily climate data and observed daily hydrology data, daily maximum stream temperature is best explained by a combination of 15 day moving average of daily air temperature and streamflow. Together with reduction in streamflow, rising air temperature can increase stream temperature up to 2.4 degree Celsius by the 2080s. Stream temperature rises modestly in groundwater-fed streams in high elevations, illustrating that groundwater can buffer the effect of climate warming and reduced surface flow. In contrast, lowlands surface-water fed streams that lack riparian vegetation will be most vulnerable to climate change since stream temperature is projected to increase most. Our results suggest that climate adaptation in water resources and fishery management should be implemented at a local scale.

Keywords: *Air Temperature, Streamflow, Stream Temperature, Resilience*

1. INTRODUCTION

Stream temperature is a barometer of aquatic ecosystem health. Warmer stream temperature can accelerate in stream biogeochemical cycles, increasing the concentrations of pollutants and fish mortality rate. In the Pacific Northwest (PNW) of USA, the occurrence of salmonid species is highly dependent on the presence of cold water. Thus, the accurate simulation of stream temperature is important for sustainable water resources and fishery management. Climate change is likely to reduce summer precipitation and increase summer air temperature, thus reducing summer flow in most streams in the PNW of America (Mote and Salathe 2010). Such changes in air temperature and streamflow are likely to lead to increases in stream temperature. However, the response of each stream to changes in a range of future climate and hydrology across heterogeneous landscape has not been fully studied. The objective of this study is to assess the effects of air temperature and streamflow on stream temperature in selected streams that represent different hydrologic landscape under different future climate conditions.

2. DATA AND METHODOLOGY

We used two sets of hydroclimatological data for our analysis. First, spatially interpolated daily minimum and maximum air temperature from the University of Idaho Interactive Numeric and Spatial Information Data Engine (INSIDE) (Abatzoglou 2013), and mean daily streamflow from the U.S. Geological Survey were used to estimate daily maximum stream temperature for each site. Second, spatially downscaled future climate data obtained from the INSIDE and simulated daily streamflow from the Willamette Hydrologic Model were used to project future changes in daily maximum streamflow. We used three GCMs – GFDL (low), MIROC (middle), and Hadley (high) – because these GCMs represent a possible range of future climate change in the study area. We developed regression equations based on observed daily air temperature and streamflow for each station. The coefficients of these regression equations were used to project possible future changes in stream temperature around the 2050s and 2080s.

3. RESULTS AND DISCUSSION

Daily maximum stream temperature is highly positively associated with both daily minimum and maximum temperatures and is negatively related to 15 day moving average of daily streamflow. Together with 15 day moving average of daily streamflow, either the combination of 15 day moving average of daily maximum air temperature and daily minimum air temperature or the combination of 15 day moving average of daily minimum air temperature and daily maximum air temperature explain over 90% of the variation of daily maximum stream temperature. More variations were explained by these independent variables in lowland streams, while regression model's predictability somewhat declines as elevation rises and groundwater input increases. With expected rises in air temperature (up to 4 degree Celsius under high climate change scenario), daily stream temperature is expected to rise by 2.4 degree Celsius, however, the range of changes varies by location. In particular, when lowland riparian areas are not vegetated, stream temperature increases most. These results suggest that water resources and fishery managers should take into account such spatial variability of stream responses to climate change.

4. CONCLUSIONS

The use of spatially downscaled gridded daily climate data set provides unique opportunity to link weather variability with hydrology data to project possible changes in stream temperature in a changing climate. Together with shift in the timing and volume of streamflow, rising air temperature will have significant impacts on stream temperature, particularly in lowland streams. Groundwater-fed streams may be more resilient than streams that are primarily fed by surface water. Future work will compare the results of our statistical models with those of a process-based model such as SWAT-temp and identify possible driving forces of such changes across heterogeneous hydrologic landscape.

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TITLE: ADAPT TO WHAT? PROJECTIONS OF DIRECT IMPACTS OF CLIMATE CHANGE ON SURFACE RESERVOIR WATER QUALITY IN AUSTRALIA AND TAIWAN

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Abstract Summary: Adaptation to future climate by water utilities will require informed decisions about investment in appropriate water treatment and head works infrastructure to deal with challenges to both water quantity and quality. Strategies are required that deliver safe, aesthetically pleasing water to customers at a reasonable price. Changes in prevailing meteorology will alter the properties of water stored in surface water reservoirs, predominantly due to changes in water temperature and the regime of thermal stratification. Notably, the solubility of gases, the growth rates of planktonic organisms, and sediment biogeochemical processes are directly influenced by environmental temperature. Thermal stratification influences the access of light resources by photosynthetic organisms and the exchange of gases between the water column and the atmosphere. De-oxygenation of the hypolimnion (bottom waters) facilitates biogeochemical processes which may compromise water quality; either directly (release of reduced metal ions), or indirectly (release of phosphorus and ammonia, thereby feeding algal growth). The many interacting biogeochemical processes make it difficult to predict resulting water quality without the use of dynamic models. Coupled hydrodynamic-ecological models are a useful tool to integrate and project the potential impacts of water quality. In this work, they are applied to incremental temperature scenarios and downscaled global circulation model (GCM) outputs for a reservoir in Australia (Happy Valley Reservoir) and Taiwan (Hsinshan Reservoir), respectively. Simulated growth of cyanobacteria in incremental temperature scenarios demonstrated similar sensitivity as observed in empirical studies and with space-for-time approaches. Elevated temperature resulted in predictions of poorer water quality in Hsinshan Reservoir, resulting from intensified thermal stratification. An increased likelihood of, oxygen depletion in the hypolimnion, growth of nuisance cyanobacteria and release of undesirable soluble metals from sediments may be expected in a warmer climate. Adaptation to these impacts may be possible through a combination of catchment remediation, reservoir intervention and investment in enhanced water treatment infrastructure.

Keywords: *Climate Change, Reservoir, Stratification, Water Quality Modelling*

TITLE: CLIMATE CHANGE IMPACTS ON AGRICULTURAL NON-POINT SOURCE POLLUTION BY CONSIDERING UNCERTAINTY OF CMIP5

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Abstract Summary: This study investigates the changes in non-point source (NPS) pollutant loads in the Mankyeong watershed for the 30-year future period (2011-2040) with consideration of the uncertainties in the climate change scenario data. Changes in NPS pollutant loads within the Saemangeum watershed for future period were assessed using SWAT. Ten GCMs and one RCM with a grid size of 12.5km for the RCP 8.5 scenario were used for the climate change data and non-parametric quantile mapping method was used for downscaling and bias correction of six major variables (precipitation, maximum temperature, minimum temperature, wind speed, solar radiation, and relative humidity). The downscaled weather variables were used as input to the calibrated and validated Soil and Water Assessment Tool (SWAT) model for simulating the changes of future NPS pollutant loads. The bias-corrected data appropriately reproduced the spatial and temporal patterns of the NPS pollutant load which was derived using observed weather data. It can be concluded that sediment and TP loads are sensitive to changes in the characteristics of climate variables by showing increase trend in most of the subwatersheds. In addition, the possible uncertainty range based on minimum and maximum values for the sediment, TN, and TP loads were quite wide. Looking at the temporal distribution, the uncertainty ranges for both sediment and TP were higher during the wet season from June to September. Therefore, it will be necessary to develop adaptation measures for reducing the impacts of climate change on NPS pollution.

Keywords: *RCPs, Climate Change, Non-point source pollution, Sediment, Total Nitrogen, Total Phosphorus, SWAT*

1. INTRODUCTION

The generation and movement of non-point source (NPS) pollutants are sensitive to changes in spatial and temporal patterns of rainfall and its quantity. However, relatively little research was conducted about changes in NPS pollution according to climate changes (Hwang et al., 2006; Lee et al., 2008; Wu et al., 2012; Zhang et al., 2011), while potential climate change impacts on water quantity have received much attention. The climate change impact assessment studies showed that the largest growth of NPS pollutant loads was occurred for the rainy season. In the case of long-term projects, such as the Saemangeum project, it is necessary to take into account the changes in NPS pollutant loads under climate change. Therefore, the objectives of this study are 1) to evaluate the reproducibility of used climate data by comparing spatial and temporal patterns of pollutant loads derived from climate models to those based on the observed data for the same historical period and 2) to analyze the changes in NPS pollutant loads within the Saemangeum watershed for the next 30 years, taking into account the uncertainty of climate change scenarios.

2. DATA AND METHODOLOGY

In this study, non-parametric quantile mapping method was used for downscaling and bias correction of the Representative Concentration Pathway 8.5 (RCP8.5) scenario data from ten Global Climate Models (GCMs) and one Regional Climate Model (RCM). Thirty years of data from 1976-2005 was used for the analysis of the historical period while 30 years of RCP 8.5 scenario data from 2011-2040 was used for future climate change projections. The Soil and Water Assessment Tool (SWAT) model was selected for predicting the long-term behavior of hydrology and contaminants at the Mankyeong watershed. The model was calibrated and validated using measured data for 2010 and 2011, respectively. The trial-and-error method was used for the model calibration procedure. In order to assess changes in pollutant load entering into Saemangeum Lake under climate change, changes in the pollutant load entering streams (pollutant load from HRUs to streams) within each subwatershed were analyzed.

In regards to the reproducibility of the historical period, information on how the climate change scenario data reproduces the hydrological and water quality mechanism within the watershed was gained by comparing the results generated using the climate model-based weather data to the results produced using the observation-based data for the same historical period. For considering the uncertainty of the future period, in addition to the change in the mean value by multi-model ensembles (MME), additional information such as the range of minimum and maximum values according to the various climate models was provided for decision-making. Therefore, in this study, the changes in the total pollutant load from HRUs to streams under climate change scenarios were analyzed for each subwatershed, considering the reproducibility and uncertainty of climate change information for the historical and future periods, respectively.

3. RESULTS AND DISCUSSION

About the reproducibility for the historical period, the sediment load from HRUs to streams based on observed data (OBS) showed a range of 0.018-2.56 ton/ha/yr, while MME mean of the pollutant loads using 11 climate models (MME) showed a range of 0.025-2.91 ton/ha/yr. The differences, defined by $(\text{MME-OBS}) / \text{OBS} \times 100$, in sediment loads according to the use of two different weather inputs showed a range of -0.59 to 64.2% depending on the characteristics of each subwatershed. Similarly, the differences in TN and TP loads showed the range of -14.6 to 72.9% and -4.5 to 35.5%, respectively, depending on the subwatersheds. The bias-corrected data appropriately reproduced the spatial and temporal patterns of the NPS pollutant load. About the uncertainty for the future period, sediment showed an average increase of 13.1 to 142.5% within subwatersheds, when the sediment load based on the MME mean for the future period was compared to the sediment load based on the MME mean for the historical period (Figure 1). TN and TP showed an average increase of -13.4 to 49.5% and 0.40 to 127.6% within the subwatersheds, respectively.

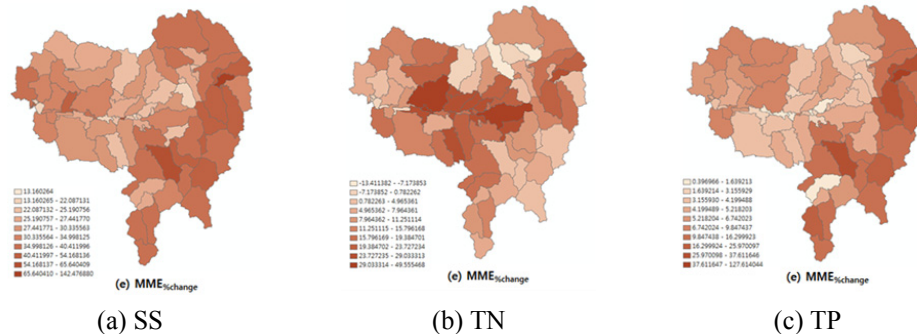


Figure 1. Results of the uncertainty analysis for sediment, TN, and TP: spatial distribution of the increase rate of the pollutant load based on MME mean.

Within the hot spot subwatershed, sediment load based on the MME mean for the future period increased 14.3% compared to the sediment load based on the MME mean for the historical period. However, the TN load based on the MME mean for the future period decreased by -4.2%. TP showed similar trend as the sediment by showing 5.8% increase in the TP load based on MME mean. The possible uncertainty range for the sediment, TN, and TP loads were quite wide, showing -50.8 to 367.3%, -34.5 to 196.3%, and -49.9 to 284.1%, respectively.

4. CONCLUSIONS

Changes in NPS pollutant loads within the Saemangeum watershed for the 30-year future period (2011-2040) were assessed using SWAT model with consideration of the uncertainties in the climate change scenario data. The rates of change in sediment, TN, and TP loads within each subwatershed under the RCP8.5 future scenario showed an average increase of 13.1 to 142.5%, -13.4 to 49.5%, and 0.40 to 127.6%, respectively, compared to the pollutant load based on the MME mean for the historical period (1976-2005). It can be concluded that sediment and TP loads are sensitive to changes in the characteristics of climate variables by showing increase trend in most of the subwatersheds. In addition, the possible uncertainty range based on minimum and maximum values for the sediment, TN, and TP loads were quite wide. Looking at the temporal distribution, the uncertainty ranges for both sediment and TP were higher during the wet season from June to September. Therefore, it will be necessary to develop adaptation measures for reducing the impacts of climate change on NPS pollution, considering that NPS pollutant loads are very sensitive to the changes in climate variables.

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**TITLE: EXTREME HYDROCLIMATIC EVENTS AND ENVIRONMENTAL
QUALITY: USE-INSPIRED CHARACTERIZATION OF CHANGE,
THRESHOLDS, AND TRANSITIONS**

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Abstract: The location, timing, frequency and severity of hydroclimatic extremes strongly influence variability and change in environmental quality. Based on mounting evidence linked to the disruption of societal and ecosystem health induced by weather and climatic extremes, it is clear that a broad characterization of environmental quality is necessary. To this end, for water resources systems, consideration of a suite comprised of water quantity, quality, and ecosystem health offer a reasonable starting point. Three case studies are used to motivate joint analyses of environmental quality and their links to appropriately scaled climatic variables: (a) typhoons and their impact on streamflow and ecologically-relevant variables, (b) the commingling effects of temperatures and precipitation variability on lake ice-out and water quality, and (c) characterization of nonstationarity in the seasonality of precipitation and streamflow extremes, with particular attention to human and environmental systems decision and lifecycle calendars. In all three case, analysis frameworks benefit from an a priori consideration of human-environmental systems contexts, and at the same time afford opportunities to appropriate tailor information to increase the likelihood of use and knowledge uptake for decision-making and climate adaptation.

TITLE: HEAT WAVES, PRECIPITATION & WATER RELATED DISEASE VECTOR IN DROUGHT AND FLOOD PRONE AREAS OF WEST BENGAL, INDIA

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Abstract Summary: The paper attempts to address the occurrence of heat waves in relation to human mortality pattern in India and the distribution of disease vectors like malaria, dengue and the incidence of diarrhea diseases. The objectives of the paper are four fold. First is to examine the association between heat waves and mortality pattern due to heat waves in India. Second is to examine the impact of precipitation on the disease vector like malaria in India. Third, is to examine how climate change affects the distribution of disease vectors in the flood prone and drought prone regions of West Bengal, India. Fourth, is to identify the adaptation options of the households to reduce the risk of climate change. The paper utilizes time series data on temperature and precipitation, number of heat waves and deaths of human lives, number of malaria cases from the various reports of Indian Metrological Department for period 1978 - 2008. In addition, the paper is based on field survey results of two districts such as one is drought prone district and other is coastal flood prone district in West Bengal in 2011. The results of the study showed that there is a positive and significant relation between the heat wave deaths and temperature rise in India and there is also a positive and significant relation between precipitation and death rate due to malaria. Diarrhea, malaria and skin diseases which are caused by water are the common diseases prevailed in both the study area. The paper also identified the household's adaptation strategies like boiling of water for drinking purposes, use of net from mosquito, use of sanitation and migration. The paper has important policy implication for improving water quality.

Keywords: *Heat waves, Mortality pattern, Distribution of diseases, Sanitation, Migration.*

1. INTRODUCTION

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has focused that by 2100 the global temperature would increase by 1.8 °C–4 °C and which has effect on increased heat-related mortality and morbidity and greater frequency of infectious diseases like diarrhea, cholera and other bacterial diseases. The Fourth Assessment Report of IPCC (2007) has also highlighted the possible increase in vector-borne diseases spatially and temporally due to rise in temperature and precipitation. The World Health Organization (WHO, 2002) estimated that climate change was responsible for approximately 2.4% of World wide diarrhea and 6% of malaria in some middle income and low income countries like India. The paper attempts to address the occurrence of heat waves in relation to human mortality pattern in India and the distribution of disease vectors like malaria, dengue and the incidence of diarrhea diseases. The objectives of the paper are four fold. First is to examine the association between heat waves and mortality pattern due to heat waves in India. Second is to examine the impact of precipitation on the disease vector like malaria in India. Third, is to examine how climate change affects the distribution of disease vectors in the flood prone and drought prone regions of West Bengal, India. Fourth, is to identify the adaptation options of the households to reduce the risk of climate change.

2. DATA AND METHODOLOGY

The paper utilizes time series data on temperature and precipitation, number of heat waves and deaths of human lives, number of malaria cases from the various reports of Indian Metrological Department for period 1978 - 2008. Regression analysis is done to estimate the effects of temperature on heat wave human mortality and to estimate the effects of precipitation on malaria cases. As the data set comprises time series in nature, before doing regression analysis we have applied unit root test and the Augmented Dickey Fuller test (ADF test) is employed for this purpose. After conforming the data are stationary we have applied regression analysis to show the impact of temperature rise on heat wave deaths and precipitation on malaria death. The paper is also an empirical study based on data collected through field survey. Two villages from flood prone area of coastal Sunderbans in West Bengal with 202 households and other two villages from drought prone district of Bankura in West Bengal with 120 households in 2011 are taken into the analysis.

3. RESULTS AND DISCUSSION

As we have considered two variables like number of deaths (Dt) and average maximum temperature (Tt) for the months of April, May and June, the dependent variable is given by the number of deaths while the

independent variable is denoted by the maximum temperature. The result of the unit root test is presented in Table 1. From this table we have found that these two variables are stationary at level. As the variables are stationary at level we have regressed the number of deaths (Dt) on the maximum temperature (Tt). The result of regression analysis is shown in Table 2. It is observed from Table 2 that there is a positive and significant relation between the number of heat wave deaths and temperature rise. As temperature rises there is an increase in number of heat wave deaths and vice versa.

Table 1. Unit root test by ADF test Statistic

Variable	ADF value at level	1% critical value
Number of Death	5.315	3.71
Maximum temperature	4.16	3.71

Table 2. Results of the impact of temperature rise on human deaths in India

Dependent variable	Co-efficient	T value	F value	Adjusted R square
Dt	367.27	3.38	19.49*	.39

Note: * represent significant at 1% level ; DW= 2.01

In order to understand the impact of precipitation on death due to malaria disease in India we have checked unit root test and the result is shown in Table 3. The result of the unit root test shows that death rate (MDt) and precipitation (Rt) are stationary at the first difference. After checking stationary test we have regressed death rate due to malaria on precipitation. The result of the regression equation is presented in Table 4. The result shows that there is a positive and significant relation between precipitation and death rate due to malaria (Table 4). The higher is the precipitation and higher is the death rate due to malaria.

Table 3. Unit Root Test by ADF Test statistic

Variable	ADF test statistic (at level)	ADF test statistic (at first difference))	Critical value at 1% level
MDt	1.36	6.11	3.75
MRt	4.64	7.67	3.75

Table 4. Results of the impact of precipitation on malaria deaths in India

Dependent variable	Co-efficient	T value	F value	Adjusted R square
Log Kt	.947	52.82	2790.41*	0.99

Note: * represent significant at 1% level; DW= 2.01

The results of the field survey showed that diarrhea, malaria and skin diseases which are caused by water are the common diseases prevailed in both the study area. The paper has identified the household's adaptation strategies like boiling of water for drinking purposes, use of net from mosquito, use of sanitation and migration

4. CONCLUSIONS

From the above analysis it is found that there is a positive and significant relation between the heat wave deaths and temperature rise in India. As temperature rises there is an increase in number of heat wave deaths and vice versa. In addition, there is a positive and significant relation between precipitation and death rate due to malaria. The higher is the precipitation and higher is the death rate due to malaria. In the coastal area of Sunderban and drought prone areas the common climate related diseases are malaria, diarrhea, low vision problems, skin diseases and other heart related diseases. The paper has identified the adaptation options of the households like the use of net from mosquito, use of sanitation, migration & boiling of water for drinking purposes.

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TITLE:THE TAIHU EDDY FLUX NETWORK: AN OBSERVATIONAL PROGRAM ON ENERGY, WATER, AND GREENHOUSE GAS FLUXES OF A LARGE FRESHWATER LAKE

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Abstract Summary: Lakes are an important component of the climate system. They provide moisture for precipitation, buffer temperature variations, and contribute to regional atmospheric carbon budgets. In this article, we describe an eddy covariance (EC) mesonet on Lake Taihu, a large (area 2400 km²) and shallow (depth 2 m) lake situated in the heavily populated Yangtze River Delta, China. The mesonet consists of five lake sites, representing different biological attributes and wind-wave patterns, and a land site near the lake shore. Common to all the sites are standard EC instruments for measurement of the momentum, sensible heat, water vapor and CO₂ flux. One site is also equipped with laser-based analyzers for precise measurement of the CO₂, CH₄, and H₂O mixing ratios and their isotopic compositions. To our best knowledge, this is the first lake eddy flux mesonet. Early results reveal evidence of biological and pollution controls on the surface-air fluxes of energy, momentum and greenhouse gases across the lake. The data will be used to address five science questions: 1) Are lake-air parameterizations established for deep lakes applicable to shallow lakes? 2) Why are lake-land breeze circulations less prevalent in the Taihu lake basin than lake basins in northern latitudes? 3) How do algal blooms alter the lake-atmosphere interactions? 4) Is this eutrophic lake a source or sink of atmospheric CO₂? 5) Does the decay of algal and macrophyte biomass contribute significant amounts of CH₄ to the atmosphere?



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