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Science and Technology for Disaster Prevention and Climate Resilience in Asia

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The role of science and technology (S&T) in preventing disasters and building resilience to climate change is featured in this paper, drawing primarily on the presentations and discussion of researchers, practitioners and policy makers from 31 institutions in 17 countries during the *Workshop on Natural Disasters and Climate Change in Asia*, held on 5–7 November 2012 in Bangi, Malaysia. Issues highlighted include advances in climate modelling and weather forecasts, with emphasis on information gaps; hazards and its cascading effects, focusing on current research and approaches; and the potential for land-based mitigation-adaptation strategies. Progress in mobilizing S&T to support disaster prevention and climate resilience is hindered by factors such as absence or lack of research, incomplete and non-existent scientific records, restricted access to data and capacity to innovate and transmit S&T, among others. The establishment of an Asian Network for Climate Science and Technology is proposed to provide and facilitate exchange of information and aid development of research co-ordination projects led by Asian researchers and possibly to act as a one-stop repository of global climate change related research too. The scope of the network would cover climate research with particular relevance to disaster resilience, including scientific capacity, which is all very distinct in Asia.

Key words: Science and technology; climate research; Asian climate change adaption; climate mitigation; climate change; policy; institutions; Workshop; climate modelling; weather forecasts; hazards; strategies; disaster prevention; Asian Network; Asian researchers

In early 2012, the Intergovernmental Panel on Climate Change (IPCC) issued the Special Report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)* (Figure 1). The report is an integrated perspective of three historically distinct groups of scientists. These are specialists in disaster recovery, disaster risk management and disaster risk reduction, who are mostly new to the IPCC; authorities in the areas of the physical science basis of climate change, who are generally associated with Working Group 1 of the IPCC; and experts in climate change impacts, adaptation, and vulnerability, who work under the auspices of Working Group 2 of the IPCC. Past IPCC assessments have focused primarily on extreme weather and climate events. Extreme weather and climate events contribute physically to risk of disasters, and in combination with human influence, the consequences can be severe. The past few years have seen advancement in the science of such events, their impacts and options for solutions. This has enabled the IPCC to conduct an assessment of scientific, technical and socio-economic knowledge within peer reviewed literature as of May 2011.

Disasters as defined in the IPCC-SREX refers to "severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" (IPCC 2012, p. 31). The hazardous physical events that cause disasters may be natural, human induced or a combination thereof. In many cases, extreme events are associated with disasters. However, depending on the physical and social conditions, non-extreme physical events, such as steady sea level rise can also lead to disasters, and this is reflected in most disaster databases (IPCC 2012). The IPCC-SREX focuses on the relationship between climate change and extreme weather and climate events, and also the impacts of these events on vulnerable societies. The challenge of dealing with extreme weather and climate events is framed as an issue in decision-making under uncertainty. Aspects covered include risk management; observed and projected changes in extreme weather and climate events; as well

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as exposure, vulnerability and losses resulting from such events. Adaptation options are also presented, from local to international scales. The implications for sustainable development are also emphasized.

The IPCC-SREX served as the basis to bring together researchers, practitioners and policy makers, representing the three historically distinct communities working on disaster issues, climate science and climate adaptation in Asia, to consider future needs for the region. This was the context for the *Workshop on Natural Disasters and Climate Change in Asia*, which was successfully held from 5–7 November 2012 at Hotel Equatorial, Bangi, Malaysia. The Workshop was also a follow-up to another regional meeting held in India the year before, which made a strong call for researchers in Asia to interact with each other and advance science and technology pertaining to climate change (Srinivasan & Hunt 2011).

The *Workshop on Natural Disasters and Climate Change in Asia* was jointly organized by the Southeast Asia Disaster Prevention Research Institute of Universiti Kebangsaan Malaysia (SEADPRI-UKM), the Cambridge Malaysian Education and Development Trust in Association with the Malaysian Commonwealth Studies Centre at the University of Cambridge, National Security Council of the Prime Minister's Department and the Ministry of Natural Resources and Environment. The collaborating institutions were the Advisory Committee on Protection of the Sea; City University of Hong Kong; Divecha Centre for Climate Change, Indian Institute of Science; UKM's Research Centre for Tropical Climate Change System and Institute of Climate Change; Asian University Network for Environment and Disaster Management (AUEDM); Asia Pacific Adaptation Network (APAN); and Asia Pacific Network for Global Change Research (APN). About a hundred participants from 31 institutions in 17 countries

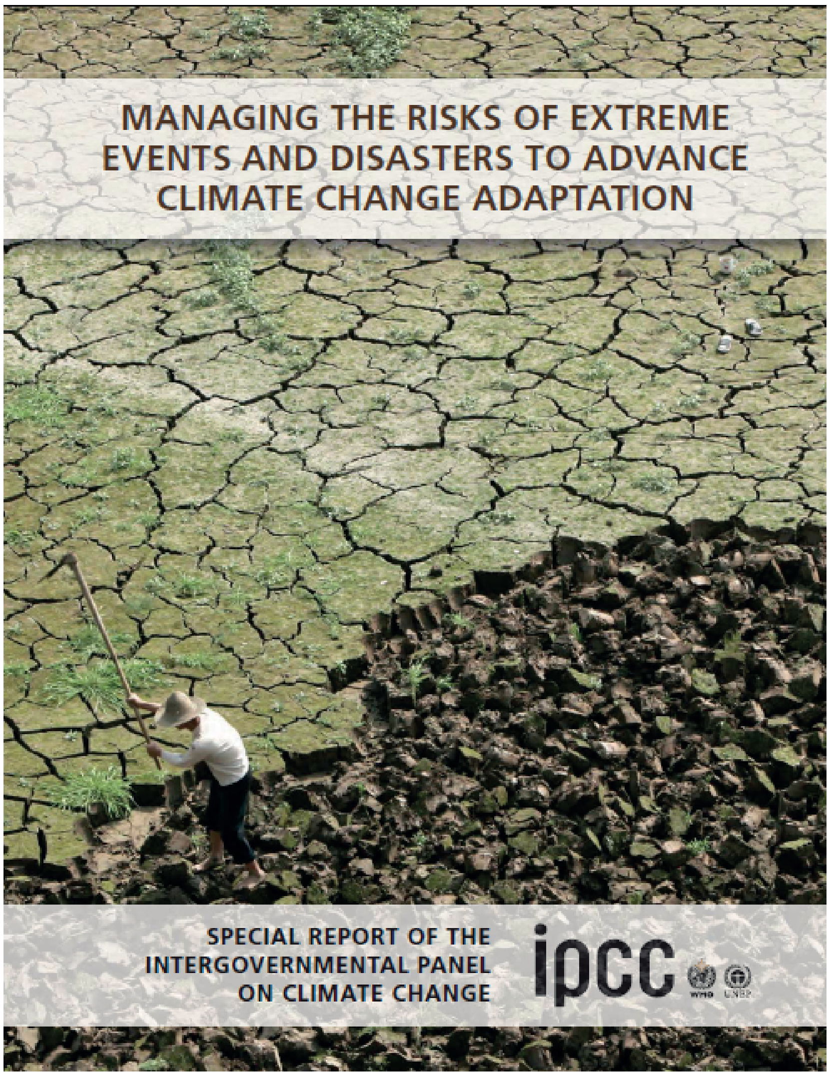

Figure 1. The Intergovernmental Panel on Climate Change released the *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)* in 2012. Extreme weather and climate events contribute physically to risk of disasters, and in combination with human influence, the consequences can be severe.

attended the three-day Workshop. An IPCC-SREX Keynote Address was delivered by Co-ordinating Lead Author Dr Padma N. Lal of Australia and this was followed by the presentation of a total of 30 invited technical papers.

This paper draws mainly on the presentation and discussion of researchers, practitioners and policy makers at the Workshop to feature the role of science and technology (S&T) in preventing disasters and building resilience to climate change in Asia. It commences with a brief account of advances in climate modelling and weather forecasts, with emphasis on information gaps. This is followed by a discussion on hazards and its cascading effects, focusing on current research and approaches. Subsequently, climate change mitigation and advances that may be applicable to the region is highlighted. A short discourse on challenges related to mobilizing S&T in Asia precedes the concluding remarks.

Climate Modelling and Weather Forecasts

Asia has complex and special geographical characteristics, which influence regional and local atmospheric and oceanographic phenomena and their interactions with the global climate. As in climate systems generally, it is also necessary to consider multi-scale interactions and chaotic pattern changes from the meso-scale to planetary scale motions. Research indicates that heavier rain associated with typhoons should be expected with climate change and at landfall such heavy rain will lead to more disasters associated with flooding (Chan 2012). Flooding is likely to be exacerbated since storm surge will be higher due to sea-level rise. Other extreme and damaging phenomena are associated with longer periods of heat, drought and rain among others, which several major computer models are now indicating as being more likely in future. S&T support is necessary to deal with the new challenges of risk management and climate adaptation in these changing conditions.

In Korea, a climate projections databank, the CORDEX-East Asia domain (50 km horizontal resolution) is currently produced by the National Institute of Meteorological Research, Korea Meteorological Administration and three universities in Korea i.e. Seoul National University, Yonsei University and Kongju National University (Cho *et al*. 2012). The Coordinated Regional Climate Downscaling Experiment (CORDEX) is supported by the World Climate Research Program to organize an international co-ordinated framework to produce regional climate change projections drawing on research communities over the world for climate change impact and adaptation studies. A major aim of the CORDEX initiative is to provide co-ordinated model evaluation and a climate projection framework, and an interface to the applicants of the climate simulations in climate change impact, adaptation, and mitigation studies. There are eleven CORDEX domains over the world, covering most of Asia, the western Pacific, Bay of Bengal, and the South China Sea. Of these, CORDEX-East Asia is the biggest and it is designed as a user-friendly web portal.

In Japan, the Earth Simulator Center is developing the Multi-scale Simulator for the Geoenvironment (MSSG), an ultra-high resolution coupled model that incorporates non-hydrostatic atmosphere, ocean, land and sea-ice model components, which is made tailored to high performance computing architectures (Takahashi *et al.* 2012). The MSSG is a coupled model with a nesting scheme between the globe and a region, capable of conducting seamless, comprehensive simulations with a single model for different scales ranging from the entire globe to urban areas. Research is now focused on understanding the relationship between heat island phenomena and increasing heavy rain in Tokyo, using simulations with ultra-high resolution MSSG. The goal is to provide insights on adaptation scenarios for the urban environment.

A regional forecast system has been developed for South Asia based on a regional model that can explicitly represent atmospheric convection and also provides a much improved representation of topographical influences on the local weather (Gordon 2012). The system, which was developed by the UK Met Office (4 km or 1.5 km resolution), yields forecasts that provide greater detail of parameters such as heavy rainfall amounts or maximum wind speeds that are important in severe weather. The fully operational forecast system is designed to be easily relocated to any geographical region.

Southeast Asia is host to the Severe Weather Forecast Demonstration Project (SWFDP) established by the World Meteorological Organisation (Gordon 2012). The main goals of the SWFDP are to improve severe weather forecasting, to improve the lead-time of warnings and to improve the interaction of National Meteorological and Hydrological Services with media, disaster management and civil protection authorities. Where the provision of forecasts is concerned, the global producing centres, which run the state-of-the-art global forecast systems, make their forecasts available to the region. The models used in the global forecasting systems typically have a resolution of 20 km – 50 km. These model forecasts are provided within the SWFDP via web portals along with guidance and interpretation provided by a specialist centre within the region.

Generally, better understanding is needed of how major modes of climate variability such as El Nino-Southern Oscillation, Indian Ocean Dipole and Madden-Julian Oscillation would be affected by anthropogenic warming and thus impact Southeast Asia, compared to East and South Asia. The current grasp is poor partly due to the inability of most climate models to simulate these phenomena for Southeast Asia, particularly Malaysia

(Tanggang 2012). Recent developments in the S&T of weather forecasting systems can now be applied in Southeast Asia to substantially enhance severe weather early warnings (Arribas 2012). Successful deployment into early warning systems requires research partnerships and enhanced capacity of National Meteorological Services, emergency responders and end-user communities (Figure 2).

Hazards and their Cascading Effects

Many countries in Southeast Asia are particularly vulnerable to climate-related hazards, such as floods, landslides, droughts and typhoons (Marley-Zagar 2012; Lwin 2012; Eko 2012). Coastal and low-lying areas in the region are also threatened by sea-level rise and storm surges, which cause coastal erosion (Pak 2012). Geological hazards such as landslides and subsidence, as well as technological hazards and environmental degradation are also influenced by climate variability and change depending on the circumstances (Pereira *et al*. 2012). Some areas may experience landslides, mudflows or slope failures, depending on the combination of extreme rainfall, saturated soil conditions and other factors. Others may experience flash floods, and environmental contamination may result where floodwaters overwhelm sewerage, waste disposal sites and other sources of pollution. The Fukushima nuclear disaster is an example of how a geological hazard (earthquake) can have a cascading effect to cause a technological disaster.

Research on the potential for such cascading hazards requires detailed knowledge of surface and subsurface conditions of the local area, in addition to potential factors that are influenced by changing climatic conditions. Such studies are commencing in Malaysia where all available information on the history of disasters and local geology is being utilised to develop a holistic and integrated approach for disaster prevention (Pereira *et al*. 2012). Delineation of areas that are highly susceptible to hazards and cascading hazards in the wake of climate change and variability should be given priority in the adaptation strategy of a country (Figure 3). Identification of vulnerable communities and their involvement in developing disaster risk reduction plans that also enhance climate resilience at the local level should also be emphasised.

In the Philippines, the Department of Science and Technology has launched the Nationwide Operational Assessment of Hazards programme to provide early warning to vulnerable communities through the use of advanced technology that enhances current landslide and flood vulnerability mapping (Lagmay 2012). The mission is to undertake disaster science research and development; advance the use of cutting-edge technologies; and recommend innovative information services for government funded disaster prevention and mitigation efforts. The use of S&T is complemented with the application of a bottom-up disaster prevention approach involving all stakeholders including academics to create resilient communities. For example, during the course of a flood event individuals provide informal information to expert centres on aspects such as the level of water in the street in relation to people's bodies (ankles, knees, chest etc.), and the direction and strength of water currents, obstructions caused by collapsing buildings, floating trees and vehicles, among others (Figure 4).

This is very useful, since even the best urban flood models and monitoring programmes require updated information to improve short-term prediction of flooding over urban and rural areas. The information is then interpreted so as to provide simple messages to communities — e.g. either to wait because the flood is receding or to evacuate because it is becoming more dangerous. This shows why investment in resilient communication networks, mobile phones and on-line operational centres is essential for protecting communities, especially those subject to repeated natural disasters.

Flooding in Thailand has been subject to many studies from various disciplines. Hydrological studies on the causes of flooding have contributed to the identification of short- and long-term flood prevention measures including dam operations protocols to prevent future flooding (Koontanakulvong 2012). The Strategic Committees and working teams that have been established by the Government of Thailand are now considering the measures for implementation.

In dealing with climate change, the Sikep Samin Communities of Indonesia believe that land should be valued, respected and venerated and that it is critical to preserve the balance of nature where over exploitation would lead to calamities such as floods and landslides (Eko 2012). The Sikep Samin Community is now trying to return to organic farming methods without chemical fertilizers and pesticides. Liquid fertilizer is made from natural products such as coconut water, water used to wash rice (Leri), Moringa leaves and banana stems that are fermented with molasses for about a month. The Community also draws on spring water from the Kars Region G. Kendeng to meet their irrigation needs. The Sikep Samin community has been found to be more adaptable to change in climate compared to other farming communities.

Many small glaciers located in low altitude range of the Indian Himalaya are losing mass at substantial rates and this could significantly influence their function as sources of water (Kulkarni 2012). There are major international programmes to study and understand the changing dynamics of Himalayan glaciers and its impacts on local communities. This is particularly relevant not only in the context of water availability but also with respect to

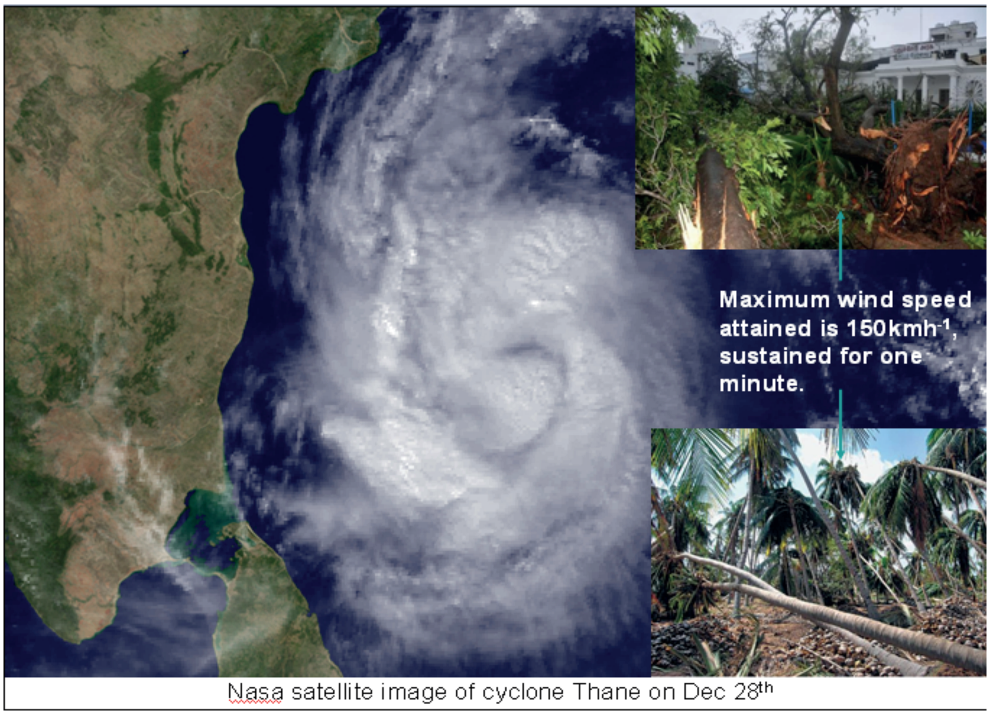

Figure 2. The NASA satellite image of Cyclone Thane on 28 December 2011 in India — the predicted tracks were accurate but warnings could have been further improved through enhanced partnership between the National Meteorological Service, emergency responders and end-user communities (Source: Julian Hunt, presentation at *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia).

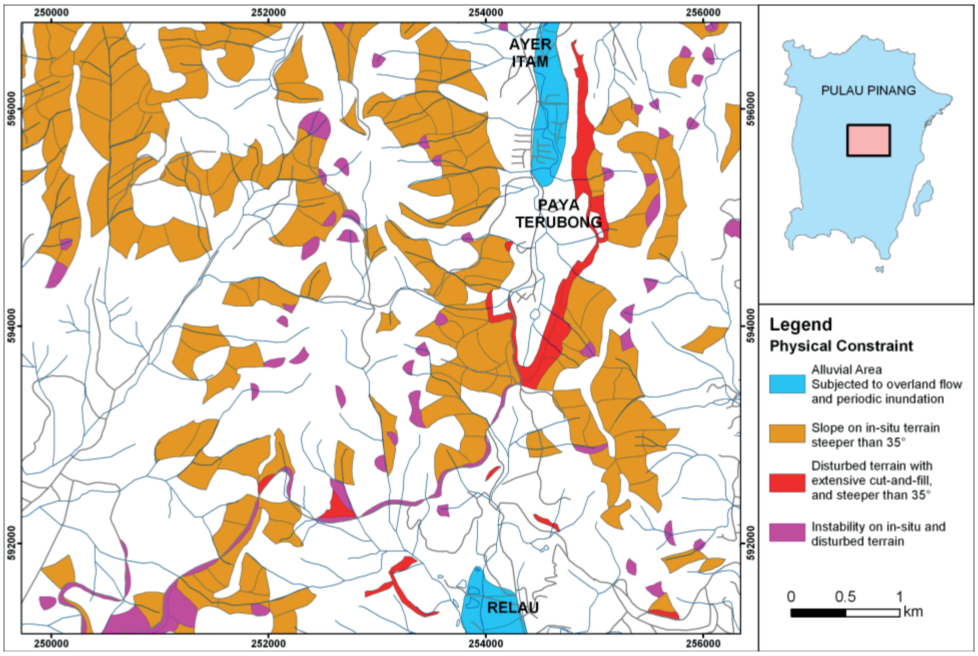

Figure 3. Terrain mapping conducted by the Minerals and Geoscience Department of Malaysia delineates areas that are susceptible to landslides and floods. Geological information serves as the basis to identify the potential for cascading hazards due to climate variability and change (Source: T.F. Ng, presentation at *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia).

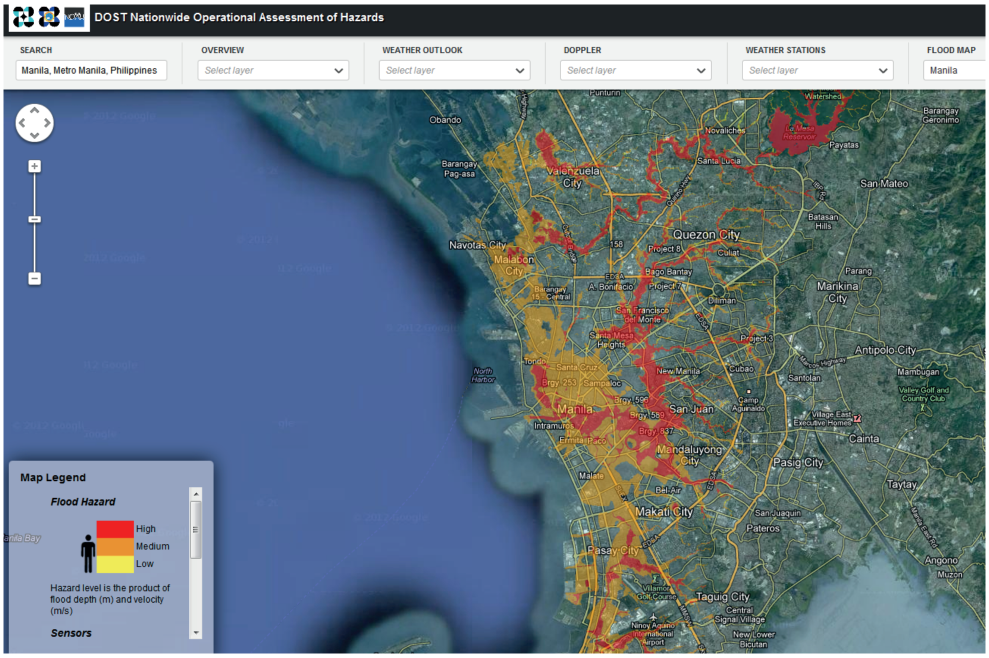

Figure 4. Nationwide Operational Assessment of Hazards — science and technology is complemented with information from stakeholders via the social media. During the course of a flood event in Manila, individuals provide informal information to expert centres (Source: A.M.F.A. Lagmay, presentation at *Workshop on Natural Disasters and Climate Change*, 5–7 November 2012, Bangi, Malaysia).

flooding, riverbank erosion and other cascading hazards that downstream riverbank communities may be exposed to.

Modelling also has a role to play in supporting informed decision-making with respect to hazards. Digital Elevation Models with enhanced LIDAR WIKI technology can be used in the GIS platform to create detailed 2D flooding simulations (Stelling 2012). Off-line models can support water management in terms of design, planning and control of urban and rural areas.

Precipitation in southern India is being artificially augmented cloud seeding using calcium chloride at altitudes between 1200 to 2500 metres above the mean sea level (Ghosh 2012). This process at best is about 20% certain; too expensive for developing countries. It is also controversial given its trans-boundary effects and lack of international protocols (Hunt & Pereira 2012). Seeding operations are likely to be more effective if they are planned with the aid of aerosol-cloud microphysical modelling studies. In particular this would enable the most suitable aerosol size distributions to be used (Ghosh 2012).

Natural changes in combination with human influences can result in increased tsunami inundation if the flow resistance of the bottom surface is decreased, e.g. by removing coral reefs or mangrove swamps. Also the more rapid sea level rise in equatorial regions will increase the impacts of tsunamis on coastal communities (Klettner 2012). High resolution 2D numerical simulations of the Navier-Stokes equation are found to be useful to model the momentum and energy of waves as a tsunami propagates in typical near shore topography over various geometries (Klettner 2012). Research is progressing to improve the model to delineate tsunami inundation in a changing climate. Geological, archaeological and historical evidence as well as indigenous knowledge can provide inputs to determine the frequency of past tropical cyclone events in coastal areas (Switzer 2012). Integrated research that incorporates geological analysis of long-term recurrence intervals with shorter records from historical archives, archaeology and indigenous knowledge is contributing to better infrastructure design, risk analysis and insurance pricing.

Mitigation and Climate Resilience

Global consumption of energy due to fossil fuel combustion has quadrupled over the last fifty years. Anthropogenic emissions of 34 Gt/yr have increased atmospheric greenhouse gases, particularly carbon dioxide from 315 to 385 parts per million from 1960 to 2012, and contributed to an increase in average global temperature by about 1ºC (Huppert 2012). The storage of carbon dioxide by pumping liquid or supercritical carbon dioxide into porous reservoir rocks, such as depleted oil and gas fields and regional saline aquifers, is a measure to restore balance and mitigate climate change. In the Sleipner natural gas field of Norway, carbon dioxide has been injected at the rate of about 1 Mt/yr since 1996 (Huppert 2012). The rate and form of carbon dioxide propagation can be improved by building on theoretical and experimental investigations of input of liquid of one viscosity and density from a point source above an impermeable boundary, either horizontal or slanted, into a porous medium saturated with liquid of different viscosity and density. Such investigations could be tested in Asia, to improve carbon dioxide injection rates for sequestration, taking into account cost factors.

Mitigation measures can extend beyond technological measures to reduce greenhouse gases to encompass integrated mitigation-adaptation strategies (Hunt 2009) although such strategies would depend on urbanization pathways and emissions scenarios. This is well illustrated by the studies in the Sun Corridor, which comprises the rapidly expanding metropolitan areas of Phoenix, Tucson, Prescott and Nogales in Arizona, United States. Scenario-based projections of the Sun Corridor growth through 2050, was coupled to an urban canopy model, to explore direct climate consequences of rapidly urbanizing megapolitan complexes (Georgescu 2012). Models based on a high Sun Corridor expansion scenario indicate that local summertime warming approaches 4ºC, with urbanizing regions primarily experiencing a 3ºC – 4ºC increase in near-surface temperature. The models indicate that the incorporation of 'cool' — e.g. vegetated irrigated-roofs would reduce this warming by about half, meeting the needs of both mitigation and adaptation. This has also been demonstrated in a number of Asian cities, notably New Delhi. The assessment of urban impacts should be expanded beyond a mere focus on mean temperature to include consequences for the entire climate system including the regional hydrologic cycle (Georgescu 2012).

Mobilizing Science and Technology

Advances in science and technology, drawing on more accurate observations, computations and communication, has led to improving the reliability and practical relevance of short- term and on-going warnings, which are highly effective in reducing the impacts of tropical typhoons, rainstorms, floods and other hazards (Hunt & Pereira 2012). However, in many countries of Asia, there are challenges in capitalising on such advances to benefit vulnerable communities. The importance of communication and education as well as the availability of low-cost technologies are vital.

Availability and access to data is critical for effective use of technology and infrastructure to benefit industry and communities that are exposed to hazards. Data sets on weather-related natural disasters and regional climate change and their social and economic consequences are limited in Asia, particularly in Southeast Asia. This shortcoming is compounded by limited access to scientific data in many sub-regions, particularly at the national level. In some countries, such as Italy, background data on the atmosphere and bodies of water is freely available to the public. This data is then used to provide personalised exposure information, which is then used by local communities and government to take preventive action.

Incomplete and non-existent scientific records pose uncertainties in the prediction of hazards. Sparse and/or incomplete existing records provide some estimates of the general nature and likelihood of occurrence of these hazards, but are usually of limited use for modelling and accurate prediction. In many places, methods are employed from geological, archaeological, social and historical studies to provide longer records and provide valuable insights into past impacts. However, the application of such methods is limited in the Asian region. The lack of understanding and knowledge gaps in various disciplines related to disaster and climate change research is disquieting.

Greater capacity to innovate and transmit S&T would enhance disaster and climate resilience in many parts of Asia. This is particularly relevant for Southeast Asia, where the Association of Southeast Asian Nations is initiating its first ever collaborative initiative to build capacity on climate change adaptation for disaster prevention. Institutional planning and co-ordination for development of multidisciplinary research programmes on disaster and climate resilience is needed at regional and national levels. Establishing strong networking among researchers and academics is critical for building capacity in multidisciplinary and integrated approaches that address natural disasters and climate change. This should be complemented with multi-stakeholder participation at the local level to enhance disaster and climate resilience (Pereira *et al*. 2009).

Scientists need to contribute to the provision of advisory services to governments and communities, even where there may be some disagreements between them. Ultimately governments and communities have to decide on which precautions to take before and during various hazards. They will be more confident if there is open discussion among scientists, who are informed by social experiences of disasters and the relevant controversies, as in the case of hazard prediction preceding and during earthquakes and volcano eruptions. The growing belief that the atmosphere and oceans should be deliberately engineered (geo-engineering) to combat climate change and its effects is another contentious issue that requires open and informed dialogue.

There are several networks on climate change and disaster risk reduction operating in Asia. These include the AUEDM, APAN and APN. However, these networks involve multi-stakeholders primarily policy and decision makers, practitioners, non-government organisations as well as researchers. There is no network that is dedicated solely to building capacity on disaster and climate resilience research, which is underpinned by socialised S&T. Such a network could bring together researchers from various disciplines to a multidisciplinary platform to build their capacity while simultaneously interacting with other multi-stakeholder networks, intergovernmental bodies and multi-lateral institutions operating in the region.

Given this scenario, it was agreed that the Asian Network of Climate Science and Technology will be established, involving a core group of institutions from Asia, where SEADPRI-UKM would take the lead with initial support from the Malaysian Commonwealth Studies Centre of Cambridge University. The Network will operate virtually (i.e. through websites) to provide information and develop research co-ordination projects led by Asian researchers, focussing on particular aspects of climate and disaster resilience specific to Asian conditions and phenomena. The scope of the network would cover climate projection and disaster resilience including scientific capacity, which is all very distinct in Asia. The proposed new network differs from existing ones through a focus on scientific aspects, while retaining disaster applications motivation. However there would be strong co-ordination with existing and planned networks involved in other areas of science and technology. A key activity will be to establish a web-based directory of researchers, their institutions, programmes and publications, which will be cross-referenced according to subject and area in Asia. Convenors of special topic groups will be identified and where possible these groups should make use of international and regional funding for meetings and activities; or have side meetings at international events. As the network expands and sustains itself, national co-ordinators could be appointed and funded in their own countries; similar to the European Research Community for Flow Turbulence and Combustion (ERCOFTAC).

CONCLUDING REMARKS

First of all strengthening S&T in Asia is essential both for applications and public understanding. This is the basis for improved disaster prevention and climate resilience to deal with hazards that prevalent in the region and rapidly growing populations that are vulnerable. Coasts, floodplains and unstable mountain slopes and deserts are among the regions exposed to hazards associated with climate variability and change. There has been considerable progress in S&T in dealing with some aspects of hazards, notably in climate modelling, weather forecasts as well as prediction of flood and coastal inundation, among others. Advances in climate change mitigation, particularly land-based mitigation-adaptation strategies are relevant to Asia.

Notwithstanding this, there are many issues that hinder progress in mobilizing S&T to support disaster prevention and climate resilience in the region. A particular problem is incomplete and non-existent scientific records, and restricted access to data. Many universities and government agencies in developing countries have centres of Information and Communication Technology and Geographical Information System, which are now being used to grow capacity and transmit S&T. Openness among scientists and scientific organisations (especially in relation to data being freely available as in the Italian model) as well as incorporation of all perspectives, particularly that of local communities and other stakeholders should play a greater role in disaster prevention and climate resilience.

The establishment of Asian Network for Climate Science and Technology (ANCST) is proposed to provide and to facilitate exchange of information and to aid development of research co-ordination projects led by Asian researchers, focussing on particular aspects of climate change and variability and of disaster resilience that are specific to the region. ANCST could possibly serve as a one-stop repository of global climate change related research too. The scope of the network would cover climate research with particular relevance to disaster resilience, including scientific capacity, which is all very distinct in Asia. There would be strong co-ordination with existing and planned networks involved in other areas of science and technology.

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