Investing in the Cascading Forecasting Process in Modernizing National Meteorological and Hydrological Services

Authors GFDRR/WB and WMO

Summary

There is growing awareness of the high societal and economic significance of weather, climate and hydrological information and services for climate resilience and disaster reduction and of the importance of making National Meteorological and Hydrological Services (NMHSs) the center of this support.

In collaboration with the World Meteorological Organization (WMO), the World Bank and development partners are focusing efforts to modernize entire NMHSs – through institutional strengthening, improving observation networks and forecasting, and strengthening service delivery.

Efforts have focused almost exclusively on national investments; however, the WMO Severe Weather Forecasting Demonstration Project (SWFDP) has shown that the lead time and reliability of high impact weather warnings are effectively improved through a three-layer cascading forecasting process that operationally links NMHSs with WMO regional and global centers. This approach requires broader investment, particularly to support regional frameworks of weather forecasting and training. By relying on the WMO Regional Specialized Meteorological Centers (RSMCs) for numerical weather prediction (NWP) support, NMHSs can free up resources to focus more on observations, impact forecasts and service delivery. This enables NMHSs with relatively small numbers of staff and limited resources to achieve a higher level of service delivery. Incorporating support for the cascading forecasting process evinced by the SWFDP in NMHSs modernization efforts is cost-effective and can contribute to the achievement of long-term sustainability of NMHSs.

The SWFDP has identified areas where investment is needed to ensure a sustainable cascading forecasting process. At present the process relies on in-kind support of WMO Members for the global centers that provide NWP and satellite-based products, and for regional centers that provide operational guidance to NMHSs. It has operated as a proof of concept, although it is operational in several regions – in particular, southern Africa, where it is functioning routinely since November 2006. Reliance on the cascading forecasting process requires assurance that the global production centers and RSMCs will be responsive to NMHSs needs. This entails a management system that provides effective oversight from the WMO secretariat on behalf of the Members and oversight of the regional centers by the NMHSs that depend on their products.

Limited support for the cascading forecasting process was built into regional projects financed by World Bank aimed at modernizing NMHSs – for example, the Central Asia

Hydromet Modernization Program. It is proposed that this effort be expanded significantly in future regional programs and national investment is aligned with the objectives of the SWFDP, which is now broadening its scope to longer-time scales in support of developing seamless early warning systems, thereby contributing to the Global Framework for Climate Services.

Several pilots, building on the existing SWFDP activities, should be proposed. The aim is to build greater synergy between NMHSs, RSMCs and global production centers and incorporate the approach into NMHSs modernization programs financed by the development community.

Funding for the operational management of the system of regional centers is also required within the WMO Secretariat to facilitate the transition from demonstration projects to operational systems within each of the WMO regions.

The outcomes from the ongoing SWFDPs and the proposed pilots should strengthen the argument for investment in regional and global centers as a cost effective, high benefit approach complementing the modernization of NMHSs through national programs and projects.

Introduction

Faced with a growing risk of weather and climate related disasters that can set back economic and social development for years, the global community needs to act quickly to strengthen National Meteorological and Hydrological Services (NMHSs). This strengthening should be done in a way that transforms weak NMHSs – especially in the developing world – into robust professional agencies capable of delivering the right information to the right people at the right time. Although the price tag of modernizing and sustaining NMHSs will be considerable, the rewards for the country and its citizens will be much higher.

The need to serve more elaborate societal needs, minimize growing economic losses from natural hazards and help countries adapt to climate change is increasing the importance of weather, climate and water information. Weather, climate and water adversely affect societies and economies through extreme events, such as tropical cyclones, floods, high winds, storm surges and prolonged droughts, and through high impact weather and climate events that affect demand for electricity and production capacity, planting and harvesting dates, managing construction, transportation networks and inventories, and human health (Rogers and Tsirkunov 2013b).

Costs of modernizing NMHSs

The key players are the NMHSs, which are the backbone of the global weather and climate enterprise. They are the authoritative source of weather, climate and water information, providing timely input to emergency managers, national and local administrations, the public and critical economic sectors.

NMHSs are small but important public sector agencies – with budgets of usually about 0.01 to 0.05 percent of national gross domestic product and total annual public funding globally

of more than US$15 billion. The problem is that their capacity has become so degraded in many regions over the past 15 to 20 years – primarily owing to underfunding, low visibility, economic reforms, undervaluing of S&T investments related to the environment, and in some instances military conflict – that they are now inadequate. As a result, globally, NMHSs in more than 100 countries – over half of which are in Africa –need to be modernized.

How much will modernization cost? A conservative estimate of high-priority modernization investment needs in developing countries exceeds US$1.5 billion to US$2.0 billion. In addition, a minimum of US$400 million to US$500 million per year will be needed to support operations of the modernized systems (staff costs plus operating and maintenance costs). These recurrent costs should be covered by national governments, but few have been ready to do so. Moreover, the amount of international support for the NMHSs is significantly below what is needed just for the high-priority items (Rogers and Tsirkunov 2013c).

Complicating matters is that internationally supported NMHSs modernization efforts in the developing world have achieved only limited success so far, owing to:

- A lack of government and development agencies' understanding of the value of the NMHSs and a lack of commitment to maintain their operations;
- A preoccupation with project time-scale installation of hardware without adequate provision for training, ongoing maintenance, consumables, and other continuing technical support;
- A multiplicity of uncoordinated projects from different donors, each with its own assistance policies, objectives, and equipment suppliers, without sufficient regard to the individual NMHS's entire needs, circumstances, and priorities; and
- The technical complexity of the projects.

What can be done to improve the track record of modernization efforts and help policy makers realize the urgent need to overhaul NMHSs?

Why are NMHSsimportant?

Weather, Climate, and Water Hazards

In recent years – thanks largely to advances in weather forecasting and improved understanding of the societal risks through assessment of the hazards – people have been better prepared for natural disasters. Despite an increase in the number of disasters and people affected since 1980, the number of people killed has not risen significantly. However, there is a huge concern that the number of people affected and the number of disasters will continue to rise and will in turn increase the number of people killed if governments and other stakeholders do not intervene. The reasons are many:

- An increasing number of people and assets are located in areas of high risk;
- Developing countries will continue to be exposed to frequent and extreme weather events as climate change exacerbates these extremes;
- The world's population continues to explode;

- The urbanization trend continues, with more people living in cities than ever before; and
- Weather- and climate-sensitive diseases claim more than 1 million lives eachyear; most are children under five years of age in developing countries.

Between 1970 and 2010, natural hazards killed about 3.3 million people (World Bank 2010). They also took a huge financial toll on human well-being. In 2011, about 206 million people were victims of natural disasters, and the economic impact was US$366 billion (UNISDR 2011). During a longer period, between 1980 and 2011, the total estimated financial cost from floods, droughts, and storms was more than US$3.5 trillion (Munich Re 2012).

Weather, Climate, and Water Forecasts

The NMHSs make a significant contribution to safety, security and economic well-being by observing, forecasting and warning of pending weather, climate and water threats. However, this contribution is rarely quantified, which often results in an undervaluing of the vital role that NMHSs play in a country's capacity to cope with meteorological and hydrological hazards. Also severely undervalued are the economic benefits of accurate weather, climate and water information to increase productivity and avoid losses.

Accurate forecasting depends on a network of global, regional and national remote and in situ observations of the atmosphere, oceans and land that are conducted by NMHSs and their partners. These observations are assimilated by a network of global and regional forecast centers, which have differentiated responsibilities for the production of global, regional and national products. This system ensures that large-scale numerical predictions – which are needed for a good national forecast but require enormous computing power – are created cost-effectively by a few NMHSs and supporting organizations on behalf of all Members of the WMO. The efficacy of this so-called "Cascading Forecasting Process" has been demonstrated in WMO Severe Weather Demonstration Project (WMO 2013a, b).

Alone, no nation would be able to provide the meteorological and hydrological services necessary to meet the essential needs of its citizens. But as WMO Members, countries agree on data-sharing arrangements, establish operational guidelines, implement best practices, and develop and use training opportunities. This international cooperation, however, depends on the continued investment of advanced countries in developing and supporting meteorological satellites, major computing facilities, and research and development. It also depends on regional investment in adapting global products for regional and national application. And it depends on national investment in maintaining NMHSs' observation networks and tailoring services to the needs of the population and specific economic sectors.

What Are the Obstacles to Better NMHSs?

Lack of Capacity of NMHSs

Despite their importance, many NMHSs in developing countries lack the capacity to provide even a basic level of services. The massive under funding of NMHSs has led to (a) a deterioration of meteorological and hydrological observation networks and outdated

technology, (b) a lack of modern equipment and forecasting methods, (c) poor quality of services, (d) insufficient support for research and development, and (e) an erosion of the workforce (resulting in a lack of trained specialists). As a result, substantial human and financial losses have occurred, which could have been avoided if weather and water agencies were more developed. Climate-resilient development requires stronger institutions and a higher level of observation, forecasting, and service delivery capacity. In addition, successful adaptation to the existing and future weather and climate variability is impossible without reliable and well-functioning NMHSs.

Lack of Investment in Regional and Global Centers

The problem is not limited to NMHSs. Despite the importance of the WMO regional, specialized and global centers in helping countries reach a high level of service (WMO 2013a), investment here is also limited, and the on-demand guidance from a WMO regional center that could be available to a country is often not. Although a national focus is primary, the benefit of international cooperation and collaboration must also be considered. Synergy between the different levels ensures that national data are available to improve model output at regional and global centers. The high value-added segment of the production chain with regard to numerical weather prediction and space-based observations is at the global level. At present, it is assumed that developed economies will continue to support this segment. But this assumption is becoming increasingly uncertain (WMO 2013a).

Key Principles for Modernizing NMHSs

In response to the growing risk of meteorological and hydrological hazards, the World Bank is following six principles for improving NMHSs in developing countries (Rogers and Tsirkunov 2013c):

Principle 1: Modernizing NMHSs in developing countries is a high-value investment

Although the challenges in modernizing NMHSs are great, so too are the potential benefits to societies coping with meteorological and hydrological hazards and the risks posed by climate change. Globally, our capabilities are the best that they have ever been. Scientific and technological advances continue to improve numerical weather and climate prediction. We now have the scientific skills to provide reliable warnings of extreme events and day-to-day weather forecasts that are more accurate, specific, and timely than ever before – and these skills continue to improve. However, they are often limited to developed countries, because NMHSs in developing countries lack the infrastructure to transfer and use these technologies.

Unfortunately, many governments fail to understand the societal value of the information and services that NMHSs should provide as a public service. This part of the so-called poverty trap – namely, the existing poor status of NMHSs – prevents the production of valuable data and information. Governments see no reason, therefore, for investing in NMHSs. But without investment, there are no new products and services, a situation that is manifest in poor or non existent meteorological and hydrological warnings. Substantial, well-targeted and long-term financial support and capacity building are needed to break this cycle, together with improved communication and advocacy campaigns.

One way to enhance government and broaden public understanding of what is at stake is to conduct socioeconomic studies that quantify the value of the public services resulting from NMHSs' strengthening. Such studies can also identify gaps in the current system and help prioritize elements of a modernization program. This process should be iterative so that stakeholders' expectations are realistic. Engaging all stakeholders, both internal and external to the NMHSs, is critical to the success of a modernization program. In Switzerland and the United States, studies show high economic returns from better NMHSs – with cost-benefit ratios of 1:4 to 1:6. And a recent World Bank study in Europe and Central Asia suggests cost-benefit ratios of 1:2 to 1:10 (Tsirkunovet al. 2007).

Principle 2: The financing and scope of modernization must be sufficient to be transformative

Financing and scope of modernization must be enough to change NMHSs with poor infrastructure, declining observation networks and weak forecasting capability into public service organizations capable of delivering timely and useful information to mitigate weather, climate and water risks to the public and sensitive economic sectors. New capabilities incur additional operating and maintenance costs, which governments must consider up front to ensure the sustainability of the modernization effort beyond the initial work program.

The appropriate operating models need to be recognized explicitly to ensure that the NMHSs meet their public service and international obligations. Governments need to recognize and support their NMHSs to protect lives, livelihoods, and property as a critical, publicly funded mission. Policies that may restrict the free and open exchange of meteorological and hydrological data should be avoided, and the public sector responsibilities of the NMHSs should be emphasized. Selecting an operating model goes hand in hand with establishing appropriate legislation to institutionalize the agreed mission.

Principle 3: Clear legal and regulatory frameworks for providing essential weather, climate and water services increase effectiveness

Broad engagement across government departments, agencies, and other institutions is essential for success. To achieve success, countries need legal and regulatory frameworks for providing meteorological and hydrological warnings, as well as for delivering other weather, climate, and water services. Such frameworks will enable all stakeholders to understand their respective roles and responsibilities and to act accordingly. Coordination across government agencies is difficult, if not impossible, without it.

Principle 4: Large-scale modernization programs should specifically include three components:

- *Institutional strengthening, capacity building and implementation support.* Strengthening NMHSs' legal and regulatory frameworks, improving their institutional performance as the main provider of weather, climate and hydrological information for the country, building the capacity of personnel and management, ensuring operability of future networks and supporting project implementation are all necessary to a large-scale modernization program.

- *Modernization of observation infrastructure and forecasting.* This component includes modernizing the NMHSs' observation networks and communication and ICT systems, improving the meteorological and hydrological forecasting systems, and refurbishing offices and facilities.
- *Enhancement of the service delivery system.* Such enhancement involves creating or strengthening the public weather services, climate services, and hydrological services and developing new information and value-added products for vulnerable communities and the main meteorological and hydrological dependent sectors. This component should include developing a national framework for climate services, considered within the context of the global framework for climate services.

Principle 5: Modernization of NMHSs should be considered within the wider regional and global context

It is important to understand which parts of the public meteorological infrastructure are best funded and operated at the local, national, regional, and global levels and to make investments accordingly. There is room for more efficient distribution and coordination of roles and responsibilities among these levels. Technological developments make it possible to generate more useful products at regional and global levels, which can underpin the services that NMHSs provide at the country level.

WMO regional centers and specialized centers are an integral part of the information system. The SWFDP has demonstrated that RSMCs can increase the capabilities of NMHSs by providing operational guidance based on the products created by the global modeling centers. There is significant potential for scaling up this effort. Strong regional and specialized centers can help sustain national modernization programs by supporting continuous technology infusion, thereby ensuring that the NMHSs are up to date (WMO 2013a, b). However, new financing mechanisms are needed to support the regional and global elements of the meteorological and hydrological system.

Principle 6: The World Bank and development partners have a vital role

The reason their role is so vital is simple: weather, climate and water services area key public good, and better resilience to climate variability and change is a key element of a broader sustainable development and green growth agenda.

Since the mid-1980s, the World Bank has prepared and implemented more than 150operations with some elements supporting NMHSs, but relatively few were aimed at modernizing the whole system. Rather, the investments were structured as small-scale activities within water resource management, agriculture, or emergency operations. The approach was often piecemeal, emphasizing efforts to patch up services by supplying individual sensors and partial systems, without a strong connection with the national meteorological services or users.

But since the mid-1990s, the focus has shifted toward development of a more holistic approach. And today, most efforts involve modernizing entire NMHSs –through institutional strengthening, improving observation networks and forecasting, and strengthening service delivery. In collaboration with the WMO, the World Bank has an advisory role in helping to inform governments of the high societal and economic

significance of weather, climate and hydrological information and services and of the importance of making meteorological and hydrological agencies the center of this support. The World Bank is also helping NMHSs raise their profiles in their respective governments by using the results of economic assessments, cost-benefit analyses and analytical work, along with identifying priority investment needs and facilitating financial support. The main instruments used by the World Bank are traditional lending and technical assistance projects – and it is investigating how to use the new financial instruments of climate adaptation and climate investment funds.

The modernizing of NMHSs relies on WMO to provide scientific and technical guidance, and understanding of documented best practices for capacity development, including methods of implementation, especially in relation to the establishment of effective national meteorological warning programmes.

The Cascading Forecast Process

WMO 2013a and WMO 2013b provide the technical insight into the WMO SWFDP and the cascading forecasting process. The aim of the SWFDP is to ensure that forecast information readily available in the Global Centers is used effectively in operations by developing countries. NMHSs should be able to use this information to improve severe weather forecasts, improve the lead-time and reliability of warnings and improve the interaction of the NMHSs with the media, disaster management, civil protection and the public.

The SWFDP is organized as a three-level system (Cascading Forecasting Process). The Global Data-Processing and Forecasting System (GDPFS) is operating by the leading global centers housed in the most advanced NMHSs. These centers provide the underpinning capability for weather forecasts and warning services for all WMO Members (WMO 2013a). Many of the latest advances in NWP and ensemble prediction system techniques, which use multiple model runs can only be operationally implemented by the most advanced centers, which have the computational capacity. The latest global NWP systems, for example, are capable of resolving convection on grid-lengths of 4km, which is particularly useful for severe weather forecasting in tropical and sub-tropical regions; however, these systems can only be supported by these large centers WMO 2013c).

These GDPFS centers also provide nowcasting systems for very-short range forecasting of severe weather based on extrapolation of satellite and other data (WMO 2013a).

The global centers primarily focus on developing automated products, which must then be interpreted for specific geographical regions. This is the role of the RSMCs, which combine and synthesize global-scale products, information from other regional centers, and sometimes their own limited-area models, to provide daily guidance for short-range (1-2 days) and medium range (up to 5 days) on specific high impact meteorological hazards to NMHSs within their region of responsibility. The RSMCs also maintain websites and data portals, and liaise directly with the NMHSs providing human guidance when required.

This enables the NMHSs to focus on producing timely and accurate advisories and warnings for their users – emergency managers, civil protection and so on.

The Importance of the Cascading Forecasting Process in NMHSs Modernization Programs

The Cascading Forecasting Process Versus Stand-alone NWP

Most modernization efforts have focused on building infrastructure within the NMHSs. Built into this approach, but not sufficiently well developed, is the need to strengthen the synergy between the NMHSs and the regional and global centers.

In many instances NMHSs want to develop sophisticated in-house numerical weather prediction systems for their general forecasts and they are often encouraged to do this by the research community, or contracted parties outside of the WMO community.

Modernization of the forecasting infrastructure must explicitly consider the advantages of the cascading forecast process over a stand-alone investment in high end computing infrastructure and the staffing required for this activity. They must also consider the trade-off between investment in national NWP capacity and investment in service delivery. In many instances, NMHSs focus on trying to build technical capacity at the expense of delivering better services to their stakeholders.

The Cascading Forecasting Process—Global Products Centers, RSMCs, and NMHSs—should be the preferred approach ensuring that the global products of the major numerical prediction centers could be fully utilized by even the most capacity limited NMHSs. In turn these NMHSs would always have access to the most advanced products and could focus using this information in their alerting and warning services.

SWFDP and NMHS Modernization

Up to now the WMO SWFDP has operated largely independently of major donor- supported NMHSs modernization efforts. Relatively little support from these national efforts has been directed to the SWFDP and in some instances the SWFDP has not be considered as a component of the NMHSs modernization plans at all. At the same time, many NMHSs in modernization need to shift investments to establishing an effective meteorological warnings programme.

Limited funding has been made available as a part of the Central Asia Hydromet Modernization Program (CAHMP), which also provides national support to Kyrgyz Republic and Tajikistan. Both countries have limited forecasting capability and will continue to have limited numbers of skilled forecasters for the foreseeable future, despite investment in training and infrastructure. The cascading forecasting process offers a way to provide a higher level of services than would otherwise be possible by providing specific guidance on hazardous weather.

Efforts are underway to strengthen the NMHSs of Viet Nam, Cambodia and Lao PDR. As a part of this effort, with the support of World Bank managed East Asia and Pacific AusAID Infrastructure for Growth Trust Fund (EAAIG), the World Bank is developing a program aimed at regional integration of hydrometeorological forecasting and early warning in the lower Mekong Basin. This program would support the upgrading and enhancement of the RFSC Ha Noi to become a RSMC with the capacity to provide regional support for the SWFDP Southeast Asia (WMO 2013a). The program will also help to improve the use of

forecasting products and improve warning services in Viet Nam, Cambodia and Lao PDR (Rogers and Tsirkunov 2013a).

It is also recognized that accelerating SWFDP activities in the Pacific Region may jump start modernizations where the capacity of the NMHSs is very low and human resources could be most usefully deployed on service delivery with greater reliance on forecast production through the SWFDP. Despite the large number of global centers with interests in this region, regional weaknesses also need to be addressed and the means of operating sustainably one or more regional centers must be found.

Strengthening WMO Global Products Centers and Regional Specialized Meteorological Centers

Investment Strategy

Long-term investments in the regional framework, including the RSMCs infrastructure and human resources are needed to ensure that they have the capacity to meet and sustain the needs of their users. This includes education and training, support for information technology and communication, and ongoing operations and maintenance.

Current investments in the hydro-meteorological system are through:

1. Specialized donor supported programs, such as the Pilot Program for Climate Resilience (PPCR), which is providing funding for several large scale modernization efforts of NMHSs;
2. Countries accessing credits or grants from the international financial institutions (e.g. World Bank) and UN Agencies (e.g. UNDP) to support NMHSs modernization programs;
3. Regional and bilateral donor driven initiatives that can incorporate both regional and national activities;
4. Donor support directly to SWFDP.
5. WMO supported voluntary contribution program (VCP). It provides support for training, capacity building and minor investments.

At present there are a limited number of options to sustain operational funding for this system. It is expected that NMHSs, following donor funded capital investment, will support their operations and maintenance through increments in their operating budgets. This is a challenge in most countries, which should be addressed by interactions between the donors the Ministries of Finance and Ministries of Planning. World Bank which has well established contacts with senior officials of these ministries in virtually all developing countries can play important role in this process.

The problem is even more complex for regional centers, where the stable source of operational support needs to be identified. Seen in the broader context of weather and climate resilience, they should be candidates for support from climate investment funds (World Bank 2012) or a specially created multi-donor trust; recognizing that this system

would guarantee capacity and sustainability within developing countries' NMHSs through the Cascading Forecasting Process.

In the short-term investment is needed to transition the SWFDP to a fully operational program. This would provide assurance for commitments to the Cascading Forecasting Process from national and regional investment programs.

Funding for the operational management of the system of regional centers is also required through a project office housed within the WMO Secretariat. This office would facilitate the transition from demonstration projects to operational systems within each of the WMO region, the geographical expansion of the activities and extension of the Cascading Forecasting Process to climate services. Proposed pilots will help to define the scope of the future financial support for this system.

Managing the development through regional partnerships

The regional framework will necessarily include an organizational and governance structure. If new sources of financing outside of the host country area are found, RSMCs will need to operate with an appropriately representative board structure that includes all collaborating partners. This would ensure that the RSMCs properly met the needs of their users/investors, including those that invest in-kind. Since all of these centers are WMO entities, creating such a mechanism should not be too difficult and could be harmonized among WMO regions. Selection of senior staff, budget allocation and program direction would require regular review by the board to reach consensus and approval. It would also require support for the WMO to provide a Secretariat function that coordinates the activities, especially in the early stages of project development and implementation, as well as in resource mobilization, planning, prioritization, implementation, and evaluation.

Piloting RSMC/SWFDP Support

Demonstrating the benefit of investment in RSMCs and the SWFDP process can be done in 2-3 pilots. This may include cost-benefit assessment of the global/regional system versus the current business as usual and purely national option. This would be evaluated through long-term support for SWFDPs enabling them to be fully operational within client NMHSs. A clearer assessment of the investment required would be made at this pilot stage allowing donors and beneficiaries to determine the most cost effective way to deliver the level of hydro-meteorological services needed within client countries. It should be possible to demonstrate a high level of continuity of operations at the national level where the meteorological services have on-demand support from fully staffed and functional regional centers that can meet the needs of several countries simultaneously.

The proposed pilots may include (WMO, 2013a):

1. Sustaining and strengthening existing RSMCs to create a fully functional regional centres aimed at regional integration of hydro-meteorological forecasting guidance;

2. Expanding the role of existing RSMCs with activity specialization in Tropical Cyclones into an RSMC with activity specialization in forecasting hazardous hydro-meteorological phenomena;

3. Establishing new RSMCs/RFSCs to support the SWFDP in new regions.

{Pilots could be identified during the workshop}

The outcomes from the ongoing SWFDPs and the proposed pilots should strengthen the argument for additional investment in regional and global centers as a cost effective, high benefit approach to modernizing NMHSs.

References

Munich Re. 2012.*Topics: Annual Review—Natural Catastrophes, 2011*. Munich: Munich Re.

Rogers, D. and V. Tsirkunov, 2013a: Emergency Preparedness: Weather, Climate and Hydromet Services. In Jha, Abbas K. and Zuzana Stanton-Geddes, Eds 2013. *Strong, Safe and Resilient: A strategic Policy Guide for Disaster Risk Management in East Asia and the Pacific*. Directions in development. Washington, DC: World Bank.

_____, 2013b: Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services. *WMO Bulletin*, in press.

_____, 2013c. Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services. Directions in Development. Washington, DC: World Bank, in the press.

Tsirkunov, Vladimir, SergeyUlatov, MarinaSmetanina, andAlexanderKorshunov. 2007. "Customizing methods for Assessing Economic Benefits of Hydrometeorological Services and Modernization Programmes: Benchmarking and Sector-Specific Assessment." In Elements for Life, Tudor Rose, WMO

UNISDR (United Nations International Strategy for Disaster Reduction). 2011. "Preparing for RIO+20: Redefining Sustainable Development." Discussion paper, UNISDR, Geneva, October 10.

WMO - World Meteorological Organization, 2013a: SWFDP and its Future Directions Towards Strengthening/Sustaining WMO's Operational Centres. Conference Paper

_____, 2013b. SWFDP Regional Frameworks and their Impact in Developing and Least Developed Countries. Conference paper.

_____, 2013c. Anticipated Advances in Numerical Weather Prediction (NWP), and the Growing Technology Gap in Weather Forecasting. Conference Paper.

World Bank. 2010. *Natural Hazards, UnNatural Disasters: Effective Prevention through an Economic Lens*. Washington, DC: World Bank.

_____, 2012.*Toward a Green, Clean, and Resilient World for All: A World Bank Group Environmental Strategy 2012–2022.* Washington, DC: World Bank.