Danish International Development Agency

US Agency for International Development

UN International Strategy for Disaster Reduction

Asian Disaster Preparedness Center

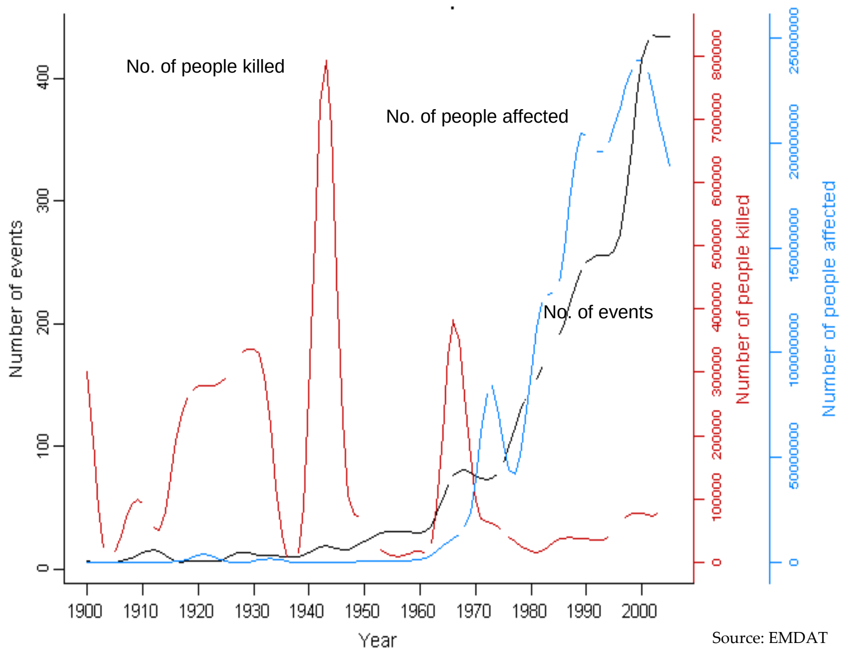
CONCEPT PAPER[1] on

Regional Severe Weather Forecast Research Support to National Meteorological Services

Meeting on Regional Cooperation on Early Warning
for Preparedness and Mitigation of Natural Hazards
12-14 July 2006, Bangkok, Thailand

1. Introduction

In the last three decades, improved early warning systems, in particular severe weather forecasting, along with enhanced disaster preparedness and response arrangements, have significantly reduced loss of lives despite an increase in the number of disaster events (refer to Figure 1). Development, along with increased population and environmental degradation, however, has increased the exposure of elements at risk and contributed to the increase in the number of people affected and the cost of damage from natural disasters (also refer to Figure 2). In Asia, specifically, where most economies are agriculture-based, hydro-meteorological hazards, such as tropical cyclone, flash flood, rain-triggered landslide, storm surge, heat/ cold wave, and drought exact heavy losses (refer to Figure 3). Increased crop intensity to meet increased production demands has rendered production systems vulnerable to climate risks.



Source: EMDAT

Figure 1. Number of natural disasters, and number of people killed and affected from 1900-2005

Despite advances in severe weather forecasting, currently available forecast products have lead times of up to 48 hours only, which is valuable for saving lives, but not adequate for reducing hazard risks on livelihood systems, entailing serious socio-economic setbacks in the aftermath of a disaster. A survey undertaken with vulnerable communities in Bangladesh reveals the desirability of having forecasts with improved lead times for reducing disaster risks (refer to Table 1).

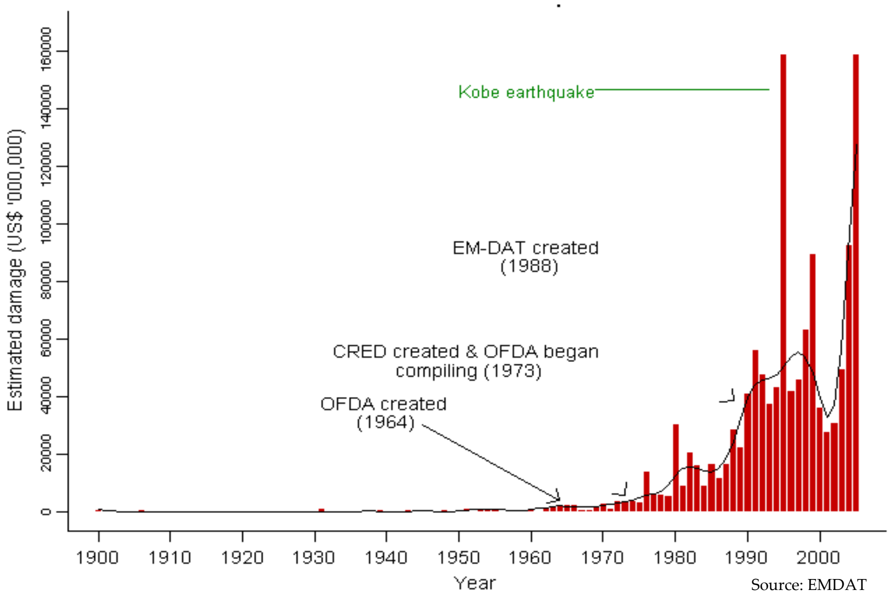


Figure 2. Estimated damage from natural disasters

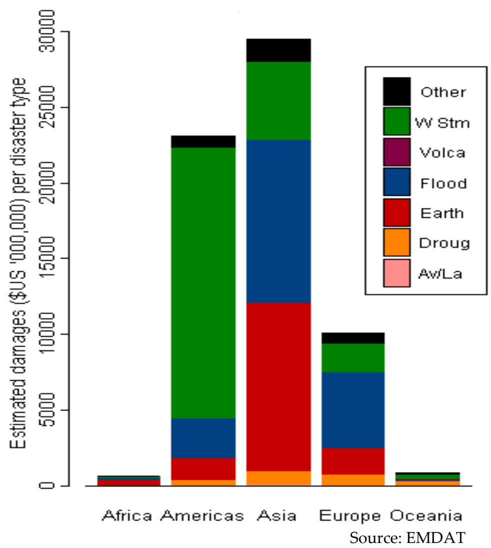


Figure 3. Average annual damages (US$) from 1990-2005

Table 1. Forecast lead time requirements by vulnerable communities in Bangladesh

Stakeholders	Forecast application	Lead time required
Farmers	Planting of dry season rice	Seasonal forecast
	Harvesting of crops	2 weeks
Fishermen	Planning for fish farming	Seasonal forecast
	Preparing fish trap and protecting pond by netting	1 week
Laborers	Agricultural employment	2 weeks
Boatmen	Homestead security	2 weeks
Traders	Market price, transportation of produce/ goods	1 week
Women	Managing homesteads	1 week

The delivery of timely and increasingly accurate weather forecasts is now possible with data-processing technology enhancement of space observations, and improvement in the performance of atmospheric models. Global meteorological centers now provide real-time forecast, with the use of global climate models in numerical weather prediction (refer to Table 2).

In the tropics, however, the domination of physical forcing on weather and climate systems makes weather prediction more challenging, particularly for operational forecasters in developing countries. Thunderstorms, squall lines, tropical cyclones, monsoon depressions, and western disturbances evolve through different scales: their genesis and development involve a complex interaction mechanism of mesoscale convective systems embedded in large-scale circulation.

Table 2. Operational global climate models in various meteorological centers

Institution	Country	Grid Spacing (km)	Number of layers
ECMWF	England	40	60
DWD	Germany	40	40
UKMO	England	60	38
Meteo France	France	25-130	41
Env. Canada	Canada	100	28
NOAA/NCEP	USA	60	42
Navy/NRL	USA	80	30
CPTEC	Brazil	90	42
BoM	Australia	75	29
NCMRWF	India	115	28
JMA	Japan	90	40
KMA	South Korea	90	30
Rushydromet	Russia	230	31
CMA	China	90	31

Non-hydrostatic mesoscale models, integrated with very high spatial resolution, have shown great potential in producing short-range (up to 3 days) prediction of these weather events with sophisticated physical parameterization (convection, radiation, boundary layer, land-surface processes). With increasing resolution, these models are also capable of resolving cloud-scale phenomena, with explicit representation of cloud microphysics and detailed representation of orographic features. These models, however, need to be customized and tuned suitably for the region. Also, quality initial and boundary conditions are needed, as they critically influence forecast performance of mesoscale models.

With significant resource requirements (trained personnel, hardware, and software) to customize these models to the region and test them, a regional arrangement to provide research support in severe weather forecasting could add value to national efforts. Following the US National Oceanic and Atmospheric Administration's (US NOAA) climate test bed model, a regional arrangement may be established to support national meteorological services

(NMSs) accelerate the transition of severe weather forecast research and development into improved operational climate forecasts, products, and applications.

2. Objectives of the Proposed Regional Severe Weather Forecast Research Support Arrangement

The broader goal of the proposed regional severe weather forecast research support arrangement is to accelerate the transition of severe weather forecast research and development into improved operational climate forecasts, products, and applications in the participating countries. The specific objectives are:

i) Assess scientific breakthroughs and new techniques that have potential for a direct influence on NMSs operations;
ii) Assist NMSs in the synthesis and implementation of these advances into operational climate forecasts;
iii) Develop new tools and applications, in a quasi-operational environment, that meet the criteria of good scientific performance, ease of use, and timely delivery to users;
iv) Stimulate model improvements in climate analysis and forecasting applications;
v) Facilitate the transfer of tested software to NMSs, incorporating adjustments necessary for the generation of climate forecast products that are forecaster-friendly and time efficient; and
vi) Prepare documentation, training materials, and performance evaluations of successful products to facilitate their use by NMSs.

Areas of research that may be considered initially are in numerical weather prediction of severe weather events, and seasonal climate prediction for local application.

3. Research Support in Numerical Prediction of Severe Weather Events

Taking advantage of improved accuracy and lead time offered by non-hydrostatic mesoscale models for severe weather prediction, the following activities are proposed:

i) Customize non-hydrostatic mesoscale models over Asia to provide improved severe weather forecast with 2-3 days lead time initially, and expand to provide forecast with 5-7 days lead time;
ii) Implement 3DVAR data assimilation system with weather research and forecasting (WRF) modeling, using special and additional observations from the region to improve mesoscale model initial conditions;
iii) Provide NMSs with severe weather forecasts on experimental basis;
iv) Test application of new forecast product;
v) Evaluate performance of forecast products;
vi) Assist countries to receive forecast technology for operationalization;
vii) Transfer the tested software to NMSs; and
viii) Document the methodology used, forecast products generated, and application process and experiences.

3.1 Mesoscale model development

The appropriate mesoscale model will be developed to initially generate short-range severe weather forecast with lead times of up to 3 days and, with subsequent model development, to generate medium-range forecast with lead times of up to 5-7 days. This model development requires:

i) Receipt of observation data from NMSs and data quality control. Observation data from NMSs are collected from a variety of platforms, such as land-based observing stations, aircrafts, satellite, weather radar, etc., hence are of differing levels of accuracy and quality. Data quality control is, therefore, necessary to build a coherent estimate of the atmospheric state. This would require distinct quality checks for each type of observation.

ii) Acquisition of global analysis/ forecasts for initial and boundary conditions. A number of operational meteorological centers (e.g. NCEP, ECMWF, UKMO, etc.) provide global analyses, along with forecast outputs, in near-real time. These data sets are utilized as initial and boundary conditions in mesoscale models for the generation of high-resolution local weather forecast.

iii) Re-analysis using observation data assimilation technique. Available global analyses from global forecasting systems have certain limitations, such as coarse resolution, and inadequate representation of localized mesoscale features due to the absence of region-specific high resolution observations to serve as initial condition for the mesoscale models, that make the mesoscale model unable to capture localized severe weather events. Refinement of the global analysis would be required through advance data assimilation techniques like 3DVAR/ 4DVAR. During mesoscale re-analysis, proper care has to be taken to incorporate local high resolution, as well as special observation data sets in the region, which are not transmitted normally through the Global Telecommunication System (GTS). Improved, high resolution re-analysis, while being used as initial condition in the mesoscale models, has a demonstrated potential to produce reliable forecasts. Additionally, the forecast skill of mesoscale model is always improved considerably after data assimilation for all types of severe weather events, irrespective of their differing nature.

iv) Ensemble forecasting. Although high resolution mesoscale models are capable of generating reliable location-specific forecasts of severe weather events after data assimilation, model forecasts still give inadequate information on how a specific event would likely behave. To remove this uncertainty, ensemble (super-ensemble) forecasting, utilizing a number of forecasts from a single (multiple) model(s) is used. Ensemble forecast has proved to be better than a single model forecast in detecting the probability of extreme weather events. A super-ensemble method would, therefore, be considered in improving location-specific prediction of severe weather events over the targeted domain.

3.2 Post processing and NWP product customization

The model output, which gives information on the future state of the atmosphere, may not be comprehensible to common users. Forecast products need to be organized in forms recognizable to end users (e.g. tables, weather charts, graphical display, animation, etc.) to serve as valuable inputs to many decision-making processes. Diagnostic analysis of appropriate model output visualization tools for product customization for various stakeholders is essential to figure out differences, and bring out meaningful information from forecast products.

3.3 Provision of forecasts to NMSs

Communicating user-friendly weather forecasts to a multitude of users, such as emergency managers, air traffic controllers, flood forecasters, utility companies, etc., in a timely manner poses another great challenge to NMSs. Advances in information communication technologies may provide some solutions. The value of forecasts to decision-makers is greatly enhanced if the inherent uncertainty can be quantified (probabilistic forecasts) through ensemble/ super-ensemble forecast systems. This is particularly true of severe weather events, which can cause damage to property and loss of life, that precautions may be well advised even if the event is unlikely, but possible.

4. Research Support in Seasonal Climate Prediction for Local Application

The breakthrough in the monitoring and prediction of El Niño Southern Oscillation (ENSO) in the last two decades has significantly improved statistical efforts to relate El Niño to its climate effects. The climate predictability that ENSO provides, however, is still not being used optimally. The application potential of seasonal forecasts is enormous, as it provides considerable lead time to modify users' decisions.

In the region, China Meteorological Agency's Beijing Climate Center, established in 2003, provides global and regional level seasonal climate prediction and interpretation. Opportunities exist for making use of Beijing Climate Center's forecast products, for further downscaling and having them tailor-made to match users' needs to make them useful for local application.

The following areas for research may be considered:

i) Downscaling for local application. Global ENSO index-based forecast readily available from global and regional climate centers are at too large a scale to be useful for site level planning. Downscaling, both at spatial and temporal scales, would be needed before forecasts may be used for local application.

ii) Delimitation of ENSO-sensitive areas, seasons, and sectors. Skilful forecasts are available only for some areas and seasons. It is therefore necessary to delimit specific climate sensitive zones, which are highly sensitive to ENSO indices, and wherespecific relationship exists between ENSO indices and local climate variability (as compared to other areas). After spatial delimitation of geographic zones, a temporal delimitation of a comparatively more ENSO sensitive season than other time periods needs to be undertaken. Forecasting efforts can then focus on these ENSO sensitive regions and seasons for particular sectors. This would facilitate the application of climate information at the local level.

5. Next Steps

The regional meeting of NMSs from 12-14 July 2006 in Bangkok would deliberate on the concept of establishing a regional arrangement to provide severe weather forecast research support to NMSs, and the next steps that would be taken, such as:

i) Identify current practice in short-, medium-, and long-range weather prediction by NMSs;
ii) Define current status of numerical weather prediction in the NMSs;
iii) Identify gaps and recommendations on how NMSs operations may be improved;
iv) Prioritize activities that may be undertaken at the regional level;
v) Define resource requirements to implement the proposed regional severe weather forecast research support arrangement (hardware, software, manpower, including budgets);

vi) Elaborate the data sharing mechanism to support numerical weather prediction at the regional level;

vii) Define requirements for improving data availability for numerical weather prediction in the region (e.g. enhancement of observation networks); and

viii) Define the institutional arrangement for providing severe weather forecast research support in the region.

[1] Developed with inputs from Dr. U.C. Mohanty, Center for Atmospheric Sciences, India Institute of Technology –Delhi; Ms. Susan Espinueva, Flood Forecasting and Warning, Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA); and Mr. Nathaniel Cruz, Weather Services Branch, PAGASA.