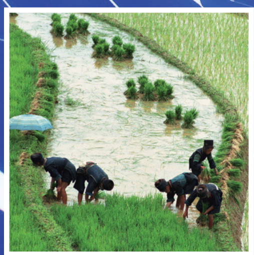
Proceedings of the WMO Regional Association VI (Europe) Conference on Social and Economic Benefits of Weather, Climate and Water Services

(Lucerne, Switzerland, 3–4 October 2011)



World Meteorological Organization
Weather • Climate • Water

PWS-23/ROE-1 (2012)

World Meteorological Organization
Regional Association VI (Europe)
Conference on Social and Economic Benefits (SEB)
of Weather, Climate and Water Services

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World Meteorological Organization

Geneva, March 2012

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: Publications@wmo.int

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Introduction

INTRODUCTION

The Regional Association VI (RA VI, Europe) at its Fifteenth Session (XV-RA VI, Brussels, Belgium, 2009) strongly encouraged further work to be done by its Members in the socio-economic assessment of weather, climate and water services in order to demonstrate better the benefits resulting from the products and services provided by the National Meteorological and Hydrological Services (NMHSs) to society and various economic sectors. Furthermore, Members were encouraged to contribute to the Madrid Action Plan (MAP) developed by the International Conference on "Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services", Madrid, 2007.

As a follow-up to the XV-RA VI recommendation, the World Meteorological Organization (WMO) organized, in collaboration with the Federal Office of Meteorology and Climatology of Switzerland (MeteoSwiss), and at the kind invitation of the Government of Switzerland, the “WMO RA VI Conference on Social and Economic Benefits of Weather, Climate and Water Services”, in Lucerne, Switzerland, from 3 to 4 October 2011. There were 71 participants at the Conference from 30 countries, 6 institutions and 2 United Nations (UN) Organizations, and 13 invited speakers who delivered lectures and presented case studies.

The objective of the Conference was to promote and encourage the conduct of socio-economic assessments and studies among the RA VI Members. The Conference provided a forum for discussing the outcomes of recent studies carried out by different Members and reviewing related methodologies.

The Conference provided material, and, in particular, a number of studies which are contained in these proceedings and which will be used in the development of guidelines on undertaking the analysis, assessment and demonstration of socio-economic benefits of meteorological and hydrological services. These guidelines will complement the development of demonstration and pilot projects and capacity-building and training activities on this subject.

These proceedings represent the collection of abstracts of papers delivered at the Conference. The abstracts and the corresponding Power Point Presentations can also be consulted on the WMO Website as follows:

ftp://ftp.wmo.int//Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/ .

LIST OF CONFERENCE KEY NOTE SPEAKERS, LECTURERS AND PRESENTERS

NO.:	EXPERT, TITLE AND ADDRESS:	PHOTOS:
1.	***Dr Christian PLÜSS*** ***Permanent Representative of Switzerland with WMO and General Manager of MeteoSwiss*** MeteoSwiss Krähbühlstrasse 58 CH-8044 ZURICH, Switzerland Tel.: +41 44 256 9288 Fax: +41 44 256 966 E-mail: Christian.Pluess@meteoswiss.ch	
2.	***Mr Ivan ČAČIĆ*** ***Permanent Representative of Croatia with WMO, President of RA VI (Europe) and Director of the Meteorological and Hydrological Service*** Meteorological and Hydrological Service of Croatia Gric 3, HR-10000 ZAGREB, Croatia Tel.: +385 1 456 5693 Fax: +385 1 485 1901 E-mail: cacic@cirus.dhz.hr	
3.	***Dr Laurent DUBUS*** ***Expert Researcher, Department of Fluid Mechanics, Energies and Environment, EDF Research and Development*** EDF - R&D MFEE/Groupe Météo Appliquée et Environnement Atmosphérique 6, quai Watier F-78401 CHATOU CEDEX, France Tel.: +33 1 3087 7664 Fax: +33 1 3087 7108 E-mail: Laurent.Dubus@edf.fr	

4.	***Mr Phil EVANS*** ***United Kingdom Met Office Government Services Director*** United Kingdom Met Office Fitzroy Road, Devon EXETER EX1 3PB, United Kingdom Tel.: +44 1392 88 6615 Fax: +44 1392 88 4400 E-mail: Phil.Evans@metoffice.gov.uk	
5.	***Mr Gerald FLEMING*** ***Chairperson, CBS/OPAG-PWS ICT PWS*** Met Éireann (The Irish Met. Service) 30 Parkview WEXFORD, Ireland Tel.: +353 1 80 64 208 Fax: +353 1 80 64 275 E-mail: gfleming@eircom.net	
6.	***Dr Thomas FREI*** ***Head of Support Division at MeteoSwiss*** MeteoSwiss Krähbühlstrasse 58 CH-8044 ZURICH, Switzerland Tel.: +41 44 256 9264 Fax: +41 44 256 9278 E-mail: Thomas.Frei@meteoswiss.ch	
7.	***Dr Jacqueline FRICK*** Gruppe Sozialwissenschaftliche Landschaftsforschung Eidg. Forschungsanstalt WSL Zuercherstrasse 111 CH-8903 BIRMENSDORF, Switzerland Tel.: +41 44 739 2563 Fax: +41 44 739 2215 E-mail: Jacqueline.Frick@wsl.ch	

8.	***Mr Daniel KULL*** ***Senior Disaster Risk Management Specialist*** The World Bank Global Facility for Disaster Reduction and Recovery, Sustainable Development Network 3 Chemin Louis-Dunant, CP 66 1211 GENEVA 20, Switzerland Tel.: +41 22 748 1015 Fax: +41 22 748 1030 E-mail: dkull@worldbank.org	
9.	***Dr Jeffrey K. LAZO*** ***Director, Societal Impacts Program*** Societal Impacts Program National Center for Atmospheric Research (NCAR) P.O. Box 3000 BOULDER, CO 80027 United States of America Tel.: +1 303 497 2857 Fax: +1 303 497 8401 E-mail: lazo@ucar.edu	
10.	***Dr Pekka LEVIÄKANGAS*** ***Principal Scientist, dr.tech.*** VTT - Transport & Logistics Systems VTT Technical Research Centre of Finland P.O. Box 1100 FI-90571 OULU, Finland Tel.: +358 20 722 2058 E-mail: Pekka.Leviakangas@vtt.fi	
11.	***Dr Sebastien NOBERT*** ***Research Fellow*** Department of Geography King's College LondonStrand, LONDON WC2R 2LS United Kingdom Tel.: +44 207 848 2761 E-mail: Sebastien.Nobert@kcl.ac.uk	

12.	***Professor Adriaan PERRELS*** ***Research Professor / Docent,*** ***Finnish Meteorological Institute*** ***and Government Institute for Economic Research VATT*** Finnish Meteorological Institute P.O. Box 503 00101 HELSINKI, Finland Tel.: +358 50 583 8575 Fax: +358 9 179 581 E-mail: Adriaan.Perrels@fmi.fi	
13.	***Ing. Laurent PERRON*** ***International Affairs of Météo-France*** Météo-France D2I/INT 1, Quai Branly F-75340 PARIS CEDEX 07, France Tel.: +33 1 45 56 70 52 Fax: +33 1 45 56 70 40 E-mail: Laurent.Perron@meteo.fr	
14.	***Mr David RICHARDSON*** ***Head, Meteorological Operations Section, European Centre for Medium-Range Weather Forecasts (ECMWF)*** ECMWF Shinfield Park READING, United Kingdom RG2 9AX Tel.: +44 118 949 9000 Fax: +44 118 986 9450 E-mail: David.Richardson@ecmwf.int	
15.	***Dr Federica ROSSI*** CNR-IBIMET Instituto di Biometeorologia National Research Council Via P. Gobetti 101 I-40129 BOLOGNA, Italy Tel.: +39 051 639 9007 Fax: +39 051 639 9024 E-mail: F.Rossi@ibimet.cnr.it	

16.	***Mr Axel THOMALLA*** ***Office of the President*** ***and International Affairs*** Deutscher Wetterdienst (DWD) Office of the President and International Affairs Frankfurter Str. 135 D-63067 OFFENBACH, Germany Tel.: +49 69 8062 4310 Fax: +49 69 8062 4130 E-mail: Axel.Thomalla@dwd.de	
17.	***Dr Saskia WILLEMSE*** ***Head of Research at MeteoSwiss*** MeteoSwiss Krähbühlstrasse 58 CH-8044 ZURICH, Switzerland Tel.: +41 44 256 9232 Fax: +41 44 256 9278 E-mail: Saskia.Willemse@meteoswiss.ch	

Keynote Speeches

Dr Christian Plüss
Permanent Representative of Switzerland with WMO
Federal Office of Meteorology and Climatology MeteoSwiss

(Lucerne, Switzerland, 30 September 2011)

KEYNOTE SPEECH I: SOCIO-ECONOMIC BENEFITS STUDIES – RATIONAL AND CHALLENGES

Ladies and Gentlemen,

I am very happy to give the first speech of this conference. This is an honor for me since I have only been half a year with MeteoSwiss and I am far from being an expert. Before starting my new function last May, I worked mainly in the Energy sector. Hence, I will give you a mix of an internal and an external view. Of course what I will be presenting today is strongly biased towards the Swiss perspective. I leave it up to you to decide if there are any similarities to the situation in your country.

My topic is based on the question: **Why is it so important for us to know the social and economic benefits of our services?**

MeteoSwiss conducted a recent study by an independent institute on the social and economic benefits of our meteorological services. We were very pleased with the outcome: the value of adequate meteorological information for the transport sector in Switzerland is higher than the total costs of our National Meteorological Service. You will learn more about this study during this conference through my colleagues. Can we therefore lean back and wait for a rise in our budget?

Most probably it is not that easy. During my past six months at MeteoSwiss I did not talk very often about meteorology. The main topics were financial and organizational subjects – my wife even teased me recently when she mentioned that since I work with MeteoSwiss I know less about the actual weather than before.

However, I realized that quite a few of my colleagues are not interested in talking about monetary and organizational issues – that is something for administrators and nut for meteorologists or climatologists. I think they better change their mind!

National weather services are, in many countries, in a transition phase from a relatively protected community towards service organizations, that have to compete - either with other governmental activities about governmental spending - or with private organizations in the market.

For most service providers **competition, costs and benefits** are part of their daily business. Not so for Meteorological Services: such questions are often treated with a feeling of uneasiness.

Let's talk about costs first. In Switzerland, the budget allocated to us – as it is the case for many other governmental tasks - has evolved historically. It is basically the total of costs for staff and infrastructure plus some projects. Quite often the budget allocated to projects is adjusted depending on the status of national finances. That worked fairly well in times with a sound national budget. But today, there are budget constraints everywhere and even in Switzerland we are facing budget cuts. And, usually the cuts are linear through governmental areas – independently of their absolute cost or their relevance to society. Of course we are complaining about such unfair methods which do not take into account the importance of our services.

Therefore, it is obvious that if we want to receive adequate funds in a tight budget environment, **we have to talk about benefits as well**. One argument I often came across is: "It's extremely difficult to define the benefits of our services".

But this is also the case for other economic benefits: take the acquisition of a bottle of excellent Bordeaux wine for instance: You know exactly how much the bottle costs, but the benefit is rather emotional and it is very difficult to attach a money tag.

But, I agree that it is difficult to quantify the benefits of meteorological services. An important reason is the fact that we are in the prevention business: prevention of adverse impacts of natural hazards, of aviation accidents or of false weekend planning. Prevention benefits are much harder to calculate than damage costs. If you take flooding as an example, the damage to infrastructure can relatively easily be estimated but what about the benefit of smart settlement planning based on long hydrological or climatological data series?

In the private sector, the concept of prevention is well established – it is called insurance. People are ready to pay money for such services as long as they understand the benefit. Meteorology is also a difficult discipline and since we have some experience with difficult tasks, we shouldn't be afraid of tackling this difficult discipline.

So, this is my first statement: **If we spend public money, the public has to understand what benefit we create with their money.** And here we definitely have potential for improvement; we have to explain openly our activities to society. We have to leave the scientific world and reach out to the public. We have to speak about our contribution to society. One small step is today's conference, but more steps will have to follow.

There is a second element in benefits: benefits are always related to something: benefits of better predictions, of better measurements, of faster results, etc. This means, if we are talking about benefits, we have to compare our efforts and results.

When talking to our existing or potential clients in Switzerland, I have usually been asked the same sort of questions:

- How accurate are our forecasts?
- Are they better than the forecasts of private company X?
- Can you deliver the service or data faster than others?

Based on these questions, a client will be deciding how much he/she is willing to pay for our services. At present, I have a very hard time to answer these questions. We need quantitative, understandable information about the quality of our services. We claim to be better than the private companies – so let's prove it. When talking about benefits, there is no way around comparing our services among us and with other providers of similar services. In other words: we need to **Benchmark our Services**.

When combining the costs – where we have a lot of experience – with the benefits – where we have less experience and quantify both then we have a cost/benefit analysis: This is my third statement: **We will have to integrate cost/benefit thinking in all activities**. For example: what is the benefit of developing an expensive high resolution model with a 1 km grid-space? Just a higher resolution forecast is not enough to answer that question. We will have to show who profits from this higher resolution. What decisions can be made smarter with such a new tool?

Just to clarify: I am by no means questioning the development of high resolution models. But the discussion, how much we will spend on a new model in the future must depend on the additional benefit we expect to create through model development.

Despite some clouds in the sky for our financial situation, I am optimistic about the future of Meteorological Services: there are many sectors that are increasingly depending on reliable whether and climate information:

Government: Natural hazards and climate change.

Finance: Globalization of Markets. Many commodities in agriculture.

Aviation: Increasing traffic leads to ever more demanding information accuracy.

Or take the **energy sector**: Switzerland and Germany plan to abandon nuclear Power. They will be more and more depending on renewable energy which is mostly weather dependent. The fraction of weather related energy production will dramatically increase with consequences on the grid, the prices and the energy trading.

In the context of tight federal budget the Swiss Government has decided to enact a new law in Meteorology by 2014, including the following elements:

1. Data liberalization;

2. Freeze of government spending;

3. Re-organization of MeteoSwiss into a State Agency with an own legal entity and the possibility to provide services also to the private sector.

The re-organization of MeteoSwiss has already started and we are working hard to integrate the following three main elements:

1. Increase **public relations activities**;

2. Start **benchmarking** our services, show how good we do our business and compare with others;

3. Integrate **cost/benefit analysis** in all activities.

The mere fact that this conference is actually taking place with the topics that are being covered, acknowledges the increasing awareness of the meteorological community for these issues. For me, it is absolutely vital that Meteorological Services know the social and economic impact of their services.

I wish you a very interesting conference.

Thank you for your attention.

Mr Ivan Čačić
Permanent Representative of Croatia with WMO and
President of Regional Association (RA) VI (Europe)
Meteorological and Hydrological Service of Croatia (DMHZ)

KEYNOTE SPEECH II:
SOCIO-ECONOMIC BENEFIT-STUDIES AS A HIGH PRIORITY OF RA VI

REVIEW OF THE WMO SOCIO-ECONOMIC ISSUES

Activities up to 2007

The World Meteorological Organization (WMO) events and publications relating to socio-economic issues date back to the 1960s. Important milestones were two major international conferences on Economic and Social Benefits of Meteorological and Hydrological Services, held in 1990 and 1994, respectively. Recommendations from both conferences have clarified the need for: 1) greater user and supplier interaction; 2) studies to identify user needs; 3) methodologies to assess benefits; and, 4) training.

In 2006, WMO, through the Public Weather Services (PWS) Programme (PWSP), established the "Task Force on Socio-Economic Benefits of Meteorological and Hydrological Services" to: 1) assess opportunities to improve the interactions between the providers and users of weather, climate and water services; 2) build an inventory of the existing decision-making tools incorporating weather, climate and water information; 3) assemble case studies of the use of weather, climate and water in decision-making; 4) develop a plan to provide WMO with guidance in how to assist National Meteorological and Hydrological Services (NMHSs) to fully assess and enhance the socio-economic benefits; 5) monitor the implementation of the plan; and, 6) to contribute to the preparations for the "WMO International Conference on Social and Economic Benefits of Weather, Climate and Water", Madrid, Spain, 2007.

In 2007, WMO organized a "RA VI Workshop on Socio-Economic Benefits" in Zagreb, Croatia, as one of the pre-events to the "WMO Madrid International Conference on Secure and Sustainable Living", with 78 participants from 22 countries, plus the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Sava River Commission.

Madrid Conference and Action Plan (MAP)

In 2007, WMO achieved a crucial milestone in evaluating, demonstrating, and enhancing the social and economic benefits of weather, climate and water services through organizing the "International Madrid Conference on Secure and Sustainable Living" which successfully provided a forum for dialogue among the producers and end-users of weather, climate and water information.

The Madrid Conference had three main objectives: 1) to assess how valuable are weather, climate and water information and services and how these benefits can be greatly increased; 2) to initiate and promote new approaches to the evaluation of the social and economic benefits of meteorological and related services in the research, education and applications communities; and, 3) to provide the basis for strengthened partnerships in the provision of meteorological and related services. Major socio-economic sectoral groups examined were: agriculture, water resources and the natural environment; human health; tourism and human welfare; energy, transport and communications; urban settlement and sustainable development and economics; and financial services.

The Conference established the Madrid Action Plan (MAP) with the overall objective to achieve, within five years, a major enhancement of the value to society of weather, climate and water information and services in response to challenges from rapid urbanization, economic globalization, environmental degradation, natural hazards and threats from climate change.

MAP has identified and focused on the challenges facing NMHSs in building stronger partnerships between provider and user communities at every level of society. It was expected that response to this challenges would increase awareness among decision-makers of social, economic and environmental benefits of improved use of meteorological and hydrological services. . In turn, decision-makers would be expected to provide increased support to NMHSs to carry out these benefits.

MAP had identified 15 Actions aimed at meeting the overall objective and to address: 1) partnerships - to develop relationships with partners, users and providers of weather, climate and water information; 2) developing capacity - to develop additional capacities beyond what is presently available in many NMHSs; 3) role of WMO on the international level, as well as the level of NMHSs; and, 4) other actions such as recognition by stakeholders and demand for additional services – which are prompting change in the production as well as use of services and communication.

Success in building partnerships with users, providers and others, as well as the development of enhanced capacity, is expected to lead to increased recognition by stakeholders and increased demand for additional services. Finally growing demand and recognition is prompting the need and capacity for change.

Soon after the Madrid Conference, WMO organized the second meeting of the "Task Force on Socio-Economic Benefits of NMHSs" to implement activities resulting from MAP, such as training activities (e.g., "Training Workshop on Assessment of Socio-Economic Benefits of Meteorological and Hydrological Services", Sofia, Bulgaria, 2008). The Task Force also continued its activity under the new name of "WMO Forum: Social and Economic Applications and Benefits of Weather, Climate and Water Services".

Commission for Basic Systems (CBS) Activities

A vital WMO mechanism in building up NMHSs potentials to deal with socio-economic issues is the Commission for Basic Systems (CBS).

In 2009, at CBS-XIV Session in Dubrovnik, Croatia, the Commission recognized that activities by NMHSs in priority areas such as product design, service delivery and partnerships with key sectors (e.g., energy, health, transport, tourism and urban environment) make direct contribution to national socio-economic sustainable development. The Commission further recognized effective communication of societal and economic benefits as a powerful tool in securing due support from governments for NMHSs. In addition, the Commission requested the CBS Open Programme Area Group (OPAG) on PWS to coordinate its work with the WMO Forum in addressing the socio-economic applications of PWS. The Commission also requested the PWS Programme to continue to provide guidance to Members on valuation of social and economic aspects of meteorological services.

In 2010, at CBS-XV Session in Windhoek, Namibia, the Commission recognized the particular importance of preparing a set of guidelines on "Communicating the Social and Economic Benefits and Impacts of Public Weather Services" and requested its early publication by PWS experts CBS-XV also recognized ongoing complementary collaboration and interaction between the OPAG on PWS World Weather Research Programme (WWRP), and the "WMO Forum: Social and Economic Applications and Benefits of Weather, Climate, and Water Services" and Regional Associations. This kind of complementary collaboration and interaction between such partners has strong synergy in the development and implementation of decision-support tools, assessment, quantification and demonstration of weather, climate and water services benefits and it avoids unnecessary duplication.

IMPLEMENTATION IN RA VI

Performance of the RA VI is based on the RA VI Strategic Plan (2008-2011) for the enhancement of the NMHSs in the Region. The RA VI Strategic Plan was the first successful attempt to downscale the WMO Strategic Plan by taking into consideration regional specifics, requirements and priorities. It was complemented with an Action Plan for implementation by the Members, in cooperation with regional partners and stakeholders. Expected Result (ER) 7 of the Action Plan calls on Members to share and undertake socio-economic studies to demonstrate the benefits of the meteorological, climatological and hydrological infrastructure and information. The RA VI Strategic Plan highlights the instrumental role of NMHSs in the economy and also shows the socio-economic benefit of investment in the provision of weather, climate and water related services - in partnership with users - to sources of funding and to decision makers (e.g., governments, European Union (EU)). Common methods of defining and determining the socio-economic benefits of RA VI NMHSs have become one of the priorities of the Region. Follow up activities are arranged by the "Draft RA VI Operational Plan 2012-2015" that is consolidated with the WMO Strategic Plan 2012-2015.

In order to improve the efficiency and effectiveness of regional activities up to the level of Strategic and Operational plans, RA VI has optimized its work structure already at the Fifteenth RA VI Session in Brussels, Belgium. Accordingly, the RA VI Management Group has been structured trough three working groups that are embracing flexible task teams as in-kind contributions of the NMHSs concerned.

The RA VI Working Group on Service Delivery and Partnership (WG-SDP), with its Task Team on Socio-Economic Benefits (TT-SEB), plays a crucial role in the process of the implementation of social and economic aspects of the work of NMHSs. In 2010, at the first meeting of the WG-SDP in Offenbach, Germany, the Chair of the TT-SEB presented the proposed activities and related deliverables. The TT-SEB was assigned to develop guidance on methodologies for assessment of socio-economic benefits of climate and weather services in the Region by: 1) reviewing the MAP; 2) analysing and developing an overview of existing studies; and by, 3) developing a web-based guidance table.

The RA VI Management Group also tasked the Chair of the WG-SDP to actively support the organization of the "WMO/MeteoSwiss RA VI Conference on the Social and Economic Benefits of Weather, Climate and Water Services". In cooperation with WMO Secretariat, the RA VI Conference was structured into four sessions: 1) Background to Socio-economic Benefits Studies; 2) Practical Steps to Prepare and Conduct a Socio-economic Benefits Study; 3) Benefits For Different User Sectors (Addressing Clients and Decision-makers); and, 4) Wrap-up and Recommendations.

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* The Power Point Presentation related to this keynote speech can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_Op_ICacic_SOB_RA6.pdf

Session 1:
Background to Socio-Economic Benefits Studies

Dr Jeffrey K. Lazo
National Center for Atmospheric Research (NCAR)
Boulder, Colorado, 80307 United States of America
E-mail: lazo@ucar.edu
Telephone: +1 303 497 2857
Website: www.sip.ucar.edu

ECONOMICS OF WEATHER

INTRODUCTION

Understanding the socio-economic impacts of weather and weather forecasting is a basis for prioritizing actions to mitigate and respond to weather events and for evaluating the benefits and costs of improvements in weather forecasts. What exactly should be evaluated, though, in an economic study depends on the goals of the end user of the information gained from such a study. Although studies can be undertaken for primary research - that is, out of purely intellectual curiosity - most economic studies are undertaken to answer specific policy questions or applied research needs. In this talk, I describe several empirical studies, each designed to answer different policy questions and each using different methods and using different resources.[1]

This discussion gives four examples of what the “economics of weather” means in terms of what is evaluated and why (i.e., objectives), how it is evaluated (i.e., methods and results), and how this information is used (i.e., policy making). These studies examine four different questions on the:

- economic impact of weather;
- value of current forecasts;
- value of improved forecasts; and,
- value of research to improve forecasts.

Economic Impact of Weather

The objective of Lazo et al. (2011) was to use valid economic theory, methods, and data to estimate the effect of weather variability on overall economic output in the United States of America. We first defined weather sensitivity as “the variability in economic output attributable to weather variability, accounting for changes in technology and changes in levels of economic inputs (i.e., capital, labor, and energy).” To assess weather sensitivity as defined, we used 24 years of economic data and weather observations to develop quantitative models of the relationship between state-level sectoral economic output and weather variability for the 11 non-governmental sectors of the U.S. economy. We used two temperature and two precipitation measures as proxies for all weather impacts. All 11 sectors had statistically significant sensitivity to weather variability. Using these 11 sectoral models, we then set economic inputs to recent historical averages and estimated economic output in the 11 estimated sector models, varying only weather inputs using 70 years of historical weather observations. We found that U.S. economic output varies annually by up to $485 billion of 2008 gross domestic product - about 3.4% - owing to weather variability. We identified U.S. states more sensitive to weather variability and ranked the sectors by their degree of weather sensitivity. Although not designed for use in specific policy analysis, the results of this study constitute reliable information on the magnitude and importance of weather impacts on the U.S. economy.

[1] Although there have been other studies of economics of weather and weather forecast, I cite four of my own studies for the purpose of illustration, not to claim to be the sole researcher in this area.

Value of Current Forecasts

The objective of the economic valuation component of Lazo, Morss, and Demuth (2009) was to obtain a "back-of-the-envelope" estimate of the value of current forecast information to U.S. households. We conducted a nationwide survey with more than 1,500 respondents to assess: 1) where, when, and how often they obtain weather forecasts; 2) how they perceive forecasts; 3) how they use forecasts; and, 4) the value they place on current forecast information. The survey was implemented online with access restricted to invited participants only. In addition to obtaining results on sources, uses, and perceptions, we were able to estimate that the average U.S. adult obtains forecasts 115 times per month, which totals to more than 300 billion forecasts annually for the U.S. public. Using a simplified valuation approach, we estimate the annual value of current weather forecast information to be approximately $286 per U.S. household, or $31.5 billion for all U.S. households. This compares favorably with total U.S. public and private sector meteorology costs of $5.1 billion a year (a benefit-cost ratio of 6.2 to 1.0). This information is useful for policy makers in justifying continued expenditures on all of the infrastructure, personnel, and dissemination of the current weather observation, modeling, and forecasting system. We do note that the "back-of-the-envelope" approach used here suggests the need for better methods to derive current value estimates.

Value of Improved Forecasts

The objective of Lazo and Waldman (2011) and Lazo et al. (2010) was to develop a non-market valuation survey to evaluate households' values for improved hurricane forecasts and warnings. Using rigorous survey development methods (expert input, focus groups, cognitive interviews, pretests, etc.), we designed the survey to examine fundamental aspects of households' perceptions of hurricane forecasts and warnings and their potential uses of and values for improved hurricane forecast information. The study was designed in part to examine the usability of survey research methods for exploring evacuation decision making and for eliciting values for improved hurricane forecasts and warnings. We used stated-choice valuation methods to analyze choices between potential forecast-improvement programs and the accuracy of existing forecasts. Using the resulting econometric model, we derived the value of an improvement in hurricane forecasts from the then-current level of accuracy to an intermediate level. The annual Willingness-To Pay, or WTP, for this average overall superior forecast (from baseline to intermediate levels on all attributes) is $14.34 per household. This initial small sample survey demonstrated the feasibility of valuing improvements in hurricane forecasts using non-market valuation methods. Working with the Hurricane Forecast Improvement Project (HFIP), ongoing work is building on this approach to derive benefit estimates of this potentially $200 million or more programs to improve hurricane forecasting. We are also building on this approach to integrate valuation methods with individuals' mental models of the hurricane forecast and warning system and with latent class modeling approaches. Results from these studies can be used in benefit-cost analysis of the HFIP.

Value of Research to Improve Forecasts

The objective of Lazo, Rice, and Hagenstad (2010) was to evaluate the potential benefits of the planned purchase of new supercomputing equipment for the U.S. National Oceanic and Atmospheric Administration (NOAA) for research to improve weather forecasting. The study was undertaken to meet the U.S. Office of Management and Budget (OMB) requirements for benefit-cost analysis for large investments by a U.S. federal agency. The study applied several economic methods applicable to benefit-cost analysis, including: 1) benefits transfer; 2) survey-based non-market valuation; 3) discounting; 4) value of statistical life; 5) expert elicitation; 6) influence diagramming; and, 7) sensitivity analysis. The potential societal benefits from the purchase of a new supercomputer for NOAA were estimated to be significant: the benefits in the household sector alone ranged from $34 million to $232 million (2002 U.S. dollars), depending on several assumptions. The benefits to selected segments of the agriculture economy were similar, as was the potential for avoided weather-related fatalities. Using the base-case assumptions, average total benefits from these three sectors were estimated at $116 million in present value

(2002 U.S. dollars). The analysis described here represents a lower bound on total benefits because it does not include several other industries that would also realize significant benefits, such as construction and energy. The net present value (the current value of all benefits over time minus the current value of all costs over time) of the investment in a new supercomputer for NOAA was estimated at $105 million (2002 U.S. dollars). The study was designed to meet regulatory requirements for a benefit-cost analysis study of a significant investment in research infrastructure.

CONCLUSIONS

I've briefly reviewed four economic studies to help policy makers in the hydrometeorological communities understand what economics has to offer, to illustrate a range of economic approaches to the value of weather impacts and forecasts, to illustrate some examples of economic value of the weather enterprise, and to suggest how this information is used in policy making. Through these illustrations I hope to have shown that, in undertaking any study, the researcher and the client/stakeholder need to agree on and be clear about: 1) what to value (i.e., objective of an economic study); 2) how to value (i.e., methods); 3) what level of detail or sophistication is required for the study; and, 4) what is information from the study going to be used for (i.e., will the study actually provide the necessary information for decision making?).

Although there has been much discussion about the need for economics in the weather enterprise, there has been surprisingly little valid and reliable peer-reviewed work published in this area. It is well past time to move beyond anecdotes and to further develop a capacity for studies that meet high standards (e.g., hold water at OMB). As with any body of knowledge (applied and theoretical), this will require: 1) multiple studies to provide validation; 2) studies to meet real world needs; and, 3) studies to further methods specific to weather topics. Supporting work in this area will require building knowledge and expertise both on the economics side (to understand the needs of the weather enterprise) and on the weather side (to understand the capabilities and outcomes of economic studies).

Ultimately, it is critical for the weather community to champion investments in scientifically valid socioeconomic analysis to support the needs of the weather enterprise.

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* The Power Point Presentation related to this keynote speech can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S1_Lazo_Economics_of_Weather.pdf

Mr Axel Thomalla
Chairperson, RA VI Working Group on Service Delivery and Partnership
Deutscher Wetterdienst (DWD)

OVERVIEW OF SOCIO-ECONOMIC BENEFITS STUDIES AND RELATED ACTIVITIES IN RA VI

INTRODUCTION

In recent years, the role of National Meteorological and Hydrological Services (NMHSs) in many European countries has changed. The European Union (EU) initiatives such as INSPIRE or PSI have influenced national legislation, generating an irreversible trend to an open data policy (e.g., the "Oslo declaration", 2009). In addition, SES II and increasing competition in commercial activities have pushed NMHSs to become more efficient. On the other hand, governments are increasingly forced to assess the return on their infrastructural investments. Therefore, in order to advise the governments on the benefits of investments in meteorological infrastructure and improved meteorological and climatological services, Socio-Economic Benefit studies have become an important tool to demonstrate the benefit from meteorological services and to justify public investments in meteorological infrastructure.

OUTCOME OF THE FIFTEENTH SESSION OF REGIONAL ASSOCIATION (RA) VI (EUROPE)

Following the outcome of the International Conference on Secure and Sustainable Living (also know as the "Madrid Conference") in 2007 and the Madrid Action Plan (MAP), at its Fifteenth Session, RA VI (Europe), encouraged its Members to carry out economic assessment of benefits of meteorological services to society. As the development of methodologies would be very important in enabling many NMHSs, especially those from less developed countries in the Region, to conduct socio-economic benefits assessments, the Association highlighted that the work programmes of the RA VI subsidiary bodies should address the question of how to improve the visibility of NMHSs through socio-economic studies.

It requested the RA VI Management Group (MG) to put high priority on the expected deliverables outlined in the RA VI Strategic Plan in terms of:

- Preparing guidance material for the Region on the assessment of socio-economic benefits of services and applications;
- Conducting training for the Region on issues related to the socio-economic aspects of their work;
- Measuring and documenting the socio-economic benefits of the products and services in RA VI;
- Documenting case studies and sharing best practices highlighting the Socio-Economic Benefits (SEB) of NMHSs in the Region.

The RA VI MG decided to establish the "Task Team on Socio-Economic Benefits (TT/SEB)" as a subsidiary body of the "Working Group on Service Delivery and Partnership (WG-SDP)".

The TT/SEB will give guidance on methodologies for assessment of socio-economic benefits of climate and weather services in the Region by providing a review of the: MAP; literature and projects, as well as guidelines for selecting a valuation method appropriate for a considered case supplemented with recommendations for follow-up. For this purpose the TT/SEB will also prepare a guidance table which indicates what Cost-Benefit Analysis (CBA) methods are applicable in what circumstances and what practical prerequisites are important for a sensible CBA application.

HOW TO ASSESS SEB

Meteorological services are more or less ”public goods“, which are used for decision making. The user groups are numerous and very diverse. Hence, it is very complex to assess the SEB for the entire set of meteorological services of NMHSs. Common CBA methods are described in a WMO Technical Document entitled, “National Meteorological and Hydrological Services, Their Partners and User Communities – Follow-up to the Madrid Action Plan – for Improved Social and Economic Benefits of Weather, Climate and Water Services” (PWS-19, WMO/TD No. 1510). In this regard, it should be noted that the benefits of meteorological services have to be evaluated separately for the different user sectors using different approaches (multi-model – multi-sector approach). Whilst the benefits to commercial users may be quantified quite well, it is very complex to express the impact of meteorological services on the public or on non-profit organizations (such as disaster management) in monetary terms. To evaluate the benefit of services to the public, the valuation is often based on the “Willingness To Pay” (WTP). The WTP is an approach by asking the tax payers what amount of money they would pay for a public service; in this regard, it should be noted that the results of valuation methods vary widely (INFRAS, 2008).

The CBAs of commercial user segments usually assess the benefits for the assumptions of perfect versus imperfect knowledge about weather events (decision-making methods). They require a close collaboration with users to understand their specific decision processes and related benefits. It is an apparent advantage of those assessments that the providers of services will get a detailed feedback from customers on their requirements, which helps to improve service delivery significantly.

A basic model of the value-chain illustrates how the benefit results from observation systems, Numerical Weather Prediction (NWP), and service delivery in different sectors (see Fig. 1 below). It should be noted that a single meteorological service or product will provide benefit to several sectors. Hence, it is necessary to appraise the SEB of different sectors separately with different evaluation models (M1, M2, …). It seems to be obvious that improved meteorological infrastructure will lead to an increased SEB by means of better meteorological services. It is therefore essential to develop methods that can give an indication of the Cost/Benefit ratio (C/B) of infrastructural investments by analyzing how the value chain is affected. In this regard, one should keep in mind that improved infrastructure will have a long term effect on the quality of services and the outcome is expected to appear with certain delay. However, for the time being available assessments of the cost-benefit of investments give more or less qualitative information or results of great uncertainty.

How could SEB studies influence the decisions of political stakeholders on investments? This is another pressing question which is not well captured in the actual discussion on SEB. To make sure that best use can be made of SEB assessments in terms of supporting necessary infrastructural investments, NMHSs are encouraged to exchange experiences as to how SEB studies could be effectively communicated to demonstrate the benefit of investments to decision makers.

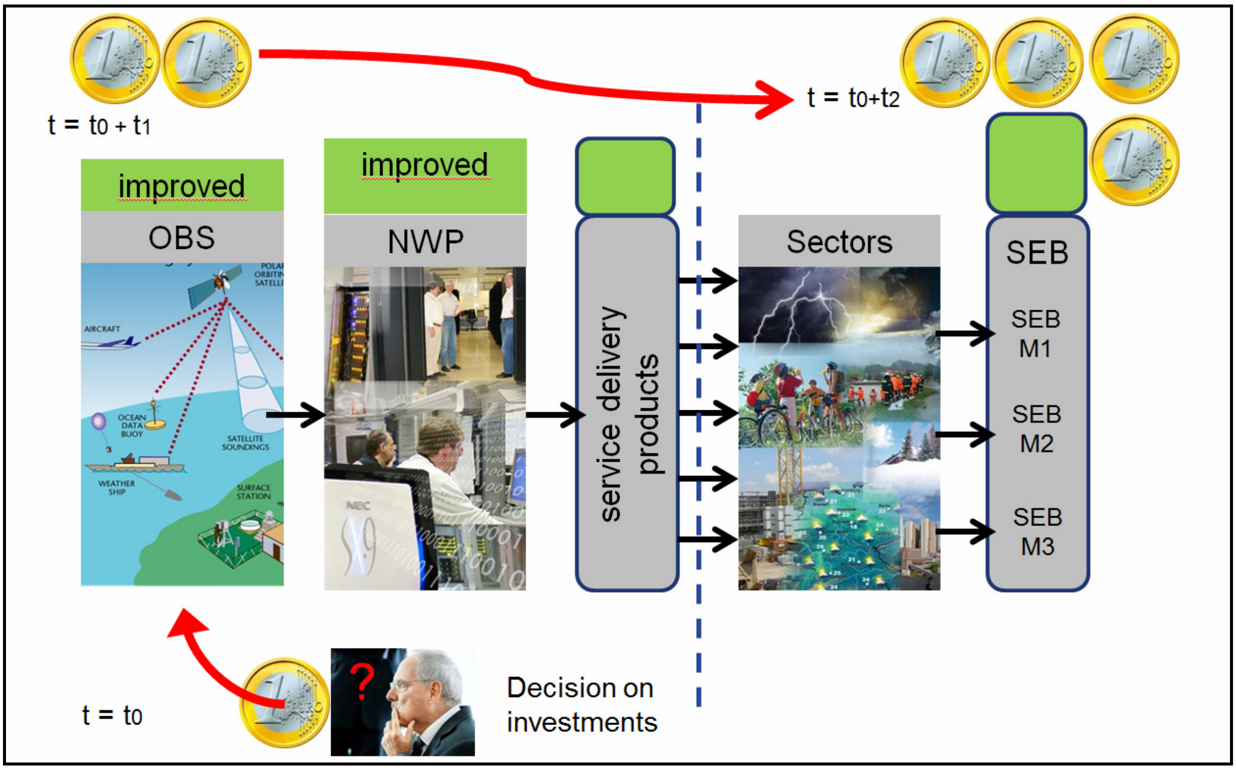

Fig. 1   Value Chain Model

SEB-RELATED ACTIVITIES IN RA VI

In order to get a more complete overview over SEB related activities of the RA VI Members, the WG-SDP launched an informal questionnaire in RA VI prior to the "WMO RA VI Conference on Social and Economic Benefits of Weather, Climate and Water Services", Lucerne, Switzerland, 3-4 October 2011. Answers were received from 25 Members. The results of this questionnaire will be further analyzed by the TT/SEB.

The main outcomes of the survey are given below:

- 21 NMHSs (84%) carried out user group surveys;
- 12 NMHSs (50%) tried to estimate the user benefits regarding their meteorological services;
- Seven (7) NMHSs had indicated that they have already experiences with SEB studies; four NMHSs made use of CBA based methods;
- 17 NMHSs (70%) planned to carry out a SEB study to justify funding from their governments; and,
- 17 NMHS (70%) asked WMO to provide additional guidance and a unified methodology on SEB studies. In addition, they expressed interest in sharing experience among Members and funding opportunities through WMO supported SEB projects.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S1_AThomalla_SEB_RA6.pdf

Dr Adriaan Perrels
Finnish Meteorological Institute (FMI)

SOCIAL COST-BENEFIT ANALYSIS OF AND FOR WEATHER SERVICES – AN OVERVIEW BACKGROUND

INTRODUCTION

There is a rising interest around the World for a better understanding of the economic and social value added of weather services (e.g., World Bank, 2008). In fact, Europe is somewhat trailing behind the developments in e.g., Australia and the United States of America (Katz and Murphy 1997; Anaman et al 1997).

There are various – not mutually exclusive – reasons to engage in evaluation of the economic and social value added of weather services. At least the following motivations can be distinguished:

- monitoring and enhancing customer satisfaction;
- justification of the use of public funding for weather service production;
- review of the equity effects of the service portfolio;
- preparation of pricing of services;
- preparation of appraising investment options; and,
- as part of (regular) Cost-Benefit Analysis (CBA)-based investment & Research & Development (R&D) prioritization within National Meteorological and Hydrological Services (NMHSs).

The first mentioned option is typically survey based. If these surveys are carried out regularly, e.g., each year or every second year, new developments in offered services should be recognizable in the feedback of relevant groups in the survey. In that case, no rigorous quantification, but at best association of cause and effects (satisfaction, volume of use, etc.) is reviewed. These surveys are a good or even indispensable basis to build a practice of socio-economic benefits assessment, whereas they also provide valuable input for maintaining and developing customer relations and to improve information products.

The other options entail quantification of – at least a part of – the benefits of weather services and may also entail assessment of attributable costs for the considered services. The remainder of this paper provides an introductory summary about this quantification, referred to as Social Cost-Benefit Analysis (SCBA), being distinct from commercial or private cost-benefit analysis.

Social Cost-Benefit Analysis (SCBA) in Nutshell

Essentially, in its basic form, a CBA aims to assess the annual expenditures (investment funding cost, operational cost, etc.) and the annual revenues for the estimated lifetime of a project. Yet, in practice, often not all required information is available, at least not in a quantitative format. A full blown CBA may get costly to perform, since it often entails extensive preparatory studies and economic modeling. In case a project is carried out for the general benefit of society, e.g., a hospital or a weather observation and forecasting system, the assessment is usually called a Social Cost-Benefit Analysis (SCBA). In that case, the scope of costs and benefits is wider and the valuation more complicated than for a business CBA, where external effects (on environment and public health) and distributional effects also have to be accounted for. If the benefits of an investment cannot be well measured in monetary terms, Cost-Effectiveness Analysis (CEA) can be applied, e.g., in case of life saving effects of traffic safety measures.

A key result of a CBA is the Net Present Value (NPV) of the flow of costs and benefits over the project lifetime of the considered service package.

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(x_t - y_t)}{(1+r)^t}$$

where x_t denotes the benefits accruing to the users of the weather service in year t, and y_t the cost of producing the weather service in year t, plus the possible cost of changes in users' operations in response to interpreting weather information; r denotes the discount rate (a kind of calculatory interest rate; in some countries, e.g., Germany, there is a prescribed level for public project appraisal), applied rates vary between 4% and 8% with 5% as most common value.

When there are various alternatives for the same project or even alternative investment options the use of the so-called Benefit-Cost-ratio (B/C-ratio) is recommended as it can be easily communicated. It should be larger than 1. In case of prioritization, the highest score can be put first.

$$\mathrm{BC-ratio} = \sum_{t=0}^{n} \frac{y_t}{(1+r)^t} \Big/ \sum_{t=0}^{n} \frac{x_t}{(1+r)^t}$$

It is also possible to use macro-economic indicators, such Δ%GDP; Δ% employment; etc. This is only useful when substantial investments or truly significant service packages are reviewed. It means that on top of the assessment of the NPV and B/C-ratio also a macro-economic model has to be used, which further raises the cost of performing the SCBA. If over time a sufficiently large repository of SCBA's for similar projects has been formed, it may be possible to establish indicative macro-economic multiplier effects and thereby convert NPVs directly into *approximate* GDP and employment effects without the use of macro-economic models (Perrels et al 2011).

The above listed indicators are only straightforward in case all considered effects have an observed market price and are subject to limited and tractable uncertainty only. Furthermore, the above list of indicators provides no clue of redistribution effects and neither of implications of market organization alternatives (monopoly, oligopoly, public service obligations, etc.). This means that in case a part of the users or a part of the considered services or the considered responses is operated via public services (i.e., without a market price, entailing subsidies, etc.) assessment gets more complicated. Also non-priced (side) benefits regarding public health or the environment often require most sophisticated approaches and/or pre-studies. This means that a Meteorological Service which engages for the first time in SCBA should seriously consider involving external specialists with experience in conducting SCBA. The most important basic element is the adequate delineation of the study – what services are to be assessed, what is the reference against which an improvement is assessed, what is the time frame of the assessed service, and what is the time frame of the study. It is also important to get at a fairly early stage an impression of the order of magnitude of the benefits in order to establish what level of assessment effort is reasonable in comparison to the expected benefits (and costs). Similarly, if during early stages of the study it becomes already clear that a very high (or very low), the B/C-ratio can be expected, it is often not useful to continue the SCBA.

In case the decision framework extends well beyond purely economic criteria, an SCBA can also be performed as part of a Multi-Criteria Decision Analysis (MCDA; e.g., Viqueira et al 2005).

From Cost-Loss Matrix to Weather Service Chain Analysis

Cost-loss pay-off matrix

It has been customary to cast weather service valuation question in the form of pay-off matrix in which a choice to protect or not is crossed with a situation with adverse weather and an alternative situation without adverse weather (e.g., Katz and Murphy 1997) as is summarized in Figure 1. The application requires that the probability of adverse weather ($Prob_{aw}$) is known (and sufficiently in advance of its realization so as to practically allow for measures). Moreover, the uncertainty range around the forecast probability of the adverse weather should be modest in order to make it plausible that regret is negligible. Under these conditions it is easy to see that protection should be chosen if $Prob_{aw} \times L > C$. In this simple case, an increase in the probability (forecast accuracy) obviously would raise the willingness to take protective measures.

Figure 1. *Simple pay-off matrix of protection or no protection in alternative weather conditions*

Action:	**Adverse weather:**	**Not adverse weather:**
Protection:	**C**	**C**
No protection:	**L**	**0**

If the uncertainty range around the forecast probability is significant and/or prevention cost are not the same in alternative weather conditions, the same approach could still be used, but its application gets more complicated. In both the simple and the complicated versions, the effect of improved average forecast certainty (i.e., higher probability), as well as the reduction of the variability in forecast accuracy can be assessed, *provided all other information is available.* Furthermore, the method implicitly assumes that all involved actors are perfectly informed, perfectly knowledgeable about options, and perfectly rational. In practice, these conditions are to a large degree fulfilled in aviation and to a fair degree in sea transport and electricity generation. For most other user groups this is usually not the case, and therefore additional analysis is necessary in particular about the extent to which imperfections in information use lead to inaction (assuming that the opposite – unnecessary action – occurs much less). To this end, *weather service chain analysis* is introduced.

Weather service chain analysis

The uptake and use of weather forecast services is subject to several ‘filters’ when considering the entire chain from weather information generation to response in the form of adapted behaviour or decisions by the end-user. In summary benefit potentials, which enhanced weather services could release, depend on the following steps before they turn into benefits (list starts at the receiver end), the extent to which:

1. weather forecast information is accurate;

2. weather forecast information contains appropriate data for a potential user (useful for a certain decision);

3. a decision-maker/owner has (timely) access to weather forecast information (access may be limited for technical, legal and economic reasons);

4. a decision-maker/owner adequately understands weather forecast information;

5. a decision-maker/owner can use weather forecast information to effectively adapt behaviour (e.g., harvesting earlier, storing in other place, postpone trip, etc.);

6. recommended responses actually help to avoid damage due to unfavourable weather circumstances; and,

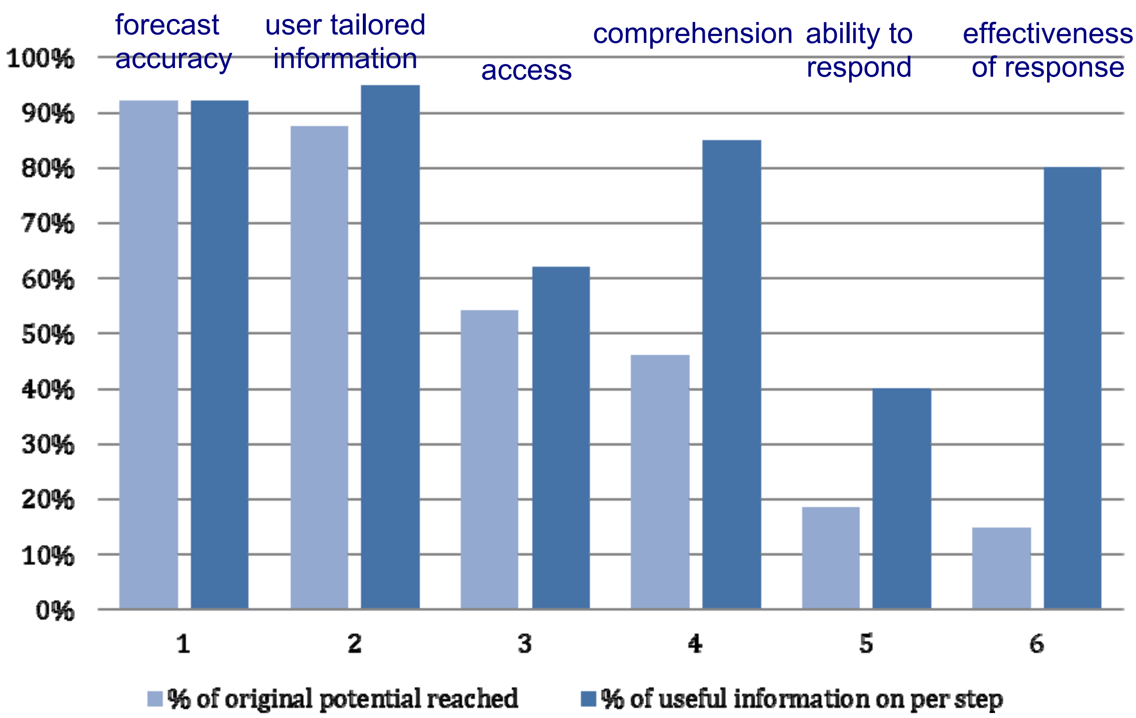
7. benefits from adapted actions or decisions are transferred to other economic agents (e.g., in road transport truckers often end up transferring benefits to clients due to fierce competition).

The impact of the intermediate information steps 2 to 6 will vary greatly among customer types. For professional – weather educated – customers, such as in aviation and marine navigation the ratings will be very high for these steps, and consequently the accuracy of the forecast as such (and perhaps the first customisation in step 2) carries a bigger weight. On the other hand, for most other users, the significance (and improvement potential) of the intermediate steps, dealing with information processing and forwarding, will weigh more.

As regards information for road users in Finland, a preliminary assessment was made of the decay per step (except for step 7 – redistribution effects) and the approximate resulting share addressed of the theoretical potential (see Figure 2).

According to preliminary analysis, currently only about 14% of theoretical potential is realized. This score equals a value of avoided damage of approximately 36 million Euros (€) per year. Under these circumstances, raising the forecast accuracy only would generate €3m. at most. On the other hand, raising (also) access and ability boosts the leverage of the investment in forecast accuracy.

Figure 2. *Estimated weather service chain filtering effects for road users in Finland**



*) NB! Preliminary results – source: Nurmi et al (2012)

CONCLUSIONS

In summary, the following messages can be identified regarding the evaluation of social-economic benefits of weather service and its use for decision-making regarding investment appraisal and prioritization regarding meteorological services.

- CBA can be useful for many reasons;
- CBA is well supported by user surveys;
- The costs and complexity of CBA should be commensurate to the expected benefits;
- The introduction of CBA will often require external advice;
- For many user groups cost-loss pay-off matrix approach needs to be extended with weather service chain analysis;
- Accuracy of the forecasts should rise beyond certain thresholds before their use picks up seriously , whereas:
  - with further progress in forecast accuracy the significance of the quality score of other steps in the service chain grows, and consequently; and,
  - the improvement of these quality scores should go hand in hand with forecast accuracy improvement to ensure sufficient leverage of meteorological investments.

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Mr Phil Evans
Government Services Director
Met Office, Exeter, United Kingdom

THE MET OFFICE EXPERIENCE OF MEASURING SOCIO-ECONOMIC BENEFITS

INTRODUCTION

The Met Office is the United Kingdom (UK)'s National Meteorological Service and provides weather and climate services in the UK and abroad for a variety of customers and users, including the public, civil contingencies, other UK government departments, civil and military aviation, surface transport, utility companies and the media. All Met Office funding comes through contracts with customers, whether government or commercial, with a turnover in 2010-11 approaching £200m. This paper describes the Met Office experience of using socio-economic studies. The next section describes the methodology and outcomes of the socio-economic benefit study of the Met Office Public Weather Service (PWS) conducted in 2007. This is followed by an example of how socio-economic benefits have been used in a recent investment case for increased High Performance Computing (HPC) and the final section outlines some considerations for future studies.

SOCIO-ECONOMIC BENEFITS OF THE MET OFFICE PWS

Overview

In 2007, the PWS Customer Group commissioned PA Consulting to carry out the first comprehensive analysis of the socio-economic benefits of weather services in the UK. The PWS Customer Group acts as the customer on behalf of the public for free at point of use weather services and to ensure that the services meet the operational needs of the public sector and provide value for money. At this time, the annual budget of the PWS was £83.2m and it provided services for ten (10) government departments and over 600 agencies in the UK. As the majority of the benefits of the PWS to the public and government services were less visible it was important to be able to quantify the economic value of the PWS.

Methodology

The study included several different areas for analysis. The impact of PWS on the public was based on previous information from ORC International Research in 2006/7. A total of 2,833 UK adults were interviewed, and from this a value of £7.30 average annual worth per adult was placed on direct services. The total economic value of £353.2m was then calculated by scaling this figure by the number of UK adults (48.4m). The utility of PWS to the public continues to be monitored through regular perception surveys, and by surveying the public's level of response following severe weather warnings.

For the value to government, three public sector bodies were reviewed in detail as case studies: the Cabinet Office (responsible for civil contingency), the Environment Agency and the Civil Aviation Authority. Stakeholders were also interviewed from five other client areas. The methodology for this analysis is illustrated in Figure 1. In addition, the study included an assessment of the benefits provided by the Met Office to the international community and through its work on climate prediction.

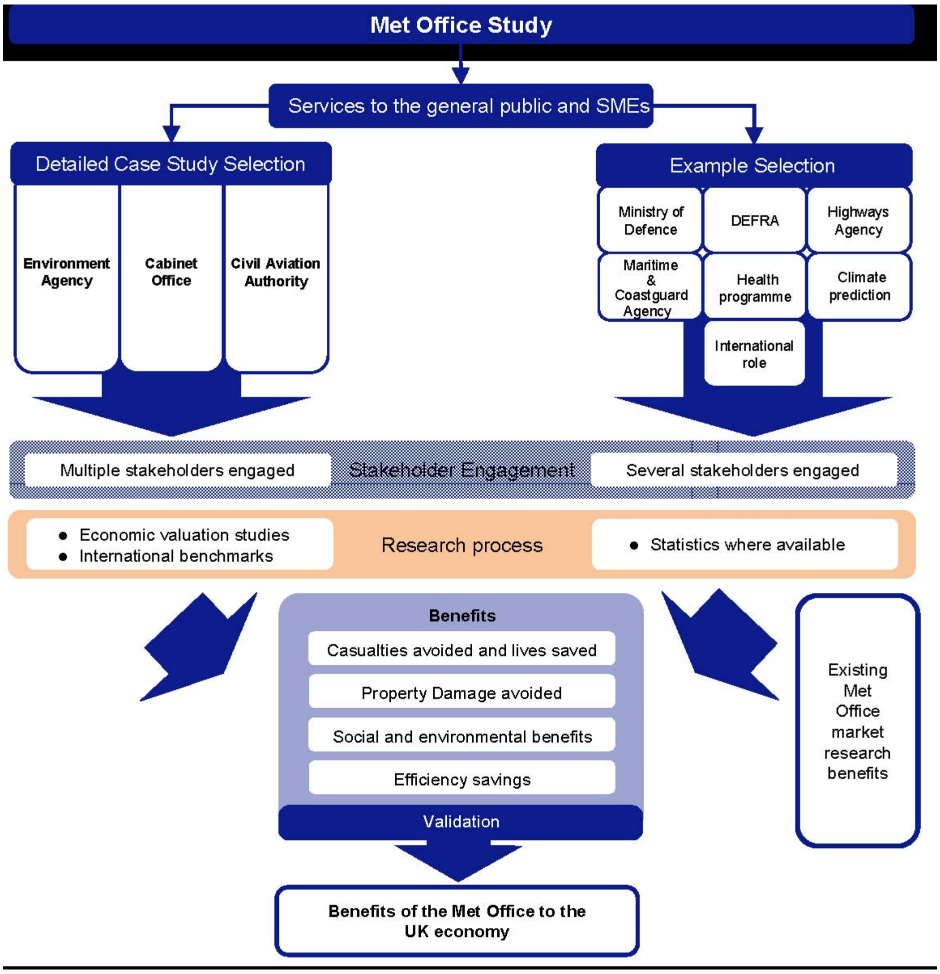

Figure 1: Schematic of the methodology used for the case studies in the 2007 PWS socio-economic benefit study.

Results

The results of the case studies are shown in Table 1. Using an estimated cost of a life of £1.478m the case studies gave a total benefit of £260.5m per annum. Added to the benefit of the direct services to the public of £353.2m, the study concluded that this represented an exceptional return on investment for the PWS budget of £83.2m. The study further concluded that the PWS demonstrably helps save lives, provides world class output and that greater benefit could be achieved with more accurate forecasts.

Department	Live Saved	Financial Equivalent of Lives Saved	Property Savings / Efficiency Gains	Total fiscal benefit
Cabinet Office	54	£79.8m	£4.1m	£83.9m
Environment Agency	-	-	£47.9m	£47.9m
Civil Aviation Authority	20	£29.6m	£99.1m	£128.7m
TOTAL	**74**	**£109.4m**	**£151.1m**	**£260.5m**

Table 1: Fiscal benefits derived from the three case studies from the 2007 PWS socio-economic benefit study.

USING SOCIO-ECONOMIC BENEFIT STUDIES IN INVESTMENT CASES

The conclusion from the 2007 study that greater benefit could be achieved from more accurate forecasts has proved important in preparing business cases for future significant capital investments in the Met Office's contribution to the European Meteorological Infrastructure. Socio-economic benefit studies were utilised in preparing the business case in the UK to approve investment in the EUMETSAT Meteosat Third Generation programme and for an increase in the Met Office HPC capability in 2008.

The HPC business case needed to be compliant with government guidance and provide a clear socio-economic case. The business case used the 2007 PWS study as a baseline and analysed the additional benefit that would be provided from an enhanced HPC capability. With the help of the Judge Business School at Cambridge University, quantitative estimates for additional socio-economic benefits were made for both PWS and climate prediction in relation to the potential HPC costs. A number of options were analysed in the business case with the chosen option showing a NPV for UK Society of ~£500m – a return significantly greater than the investment cost ~£50m.

CONSIDERATIONS FOR FUTURE STUDIES

One upcoming area of importance to government is the environmental impact of services, in particular, the reduction of CO_2 emissions. The 2007 PWS study estimated environmental savings for the civil aviation sector of 352,000 tonnes of CO_2 per annum as a result of Met Office services. Verifiable studies of CO_2 reduction as a result of improved forecasts and services are likely to prove an important component of future HPC business cases given the increased electricity consumption resulting from increases in computing power.

There remains a continued requirement for further socio-economic benefit studies, particularly in the light of government funding pressures. Governments will be looking for evidence of increasing return on investment from such studies. Hence, the Met Office will need to use future studies to target research and product development in areas where benefit to the taxpayer is greatest and can continue to be enhanced.

Reference:

"Met Office — The Public Weather Service's contribution to the UK economy"
http://www.metoffice.gov.uk/media/pdf/h/o/PWSCG_benefits_report.pdf

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S1_PEvans_SEB_MetOffice.pdf

Session 2:
Practical Steps to Prepare and Conduct a Socio-Economic Benefits Study

Dr Thomas Frei
Federal Office of Meteorology and Climatology MeteoSwiss

EXAMPLE I:
SWISS STUDY OF SOCIO-ECONOMIC BENEFITS OF METEOROLOGY: METHODS FOR STUDY DESIGN

Meteorological services involve the provision of information on the state of the atmosphere and the land surface. They provide data, information, forecasts and various related products, which are important for the smooth functioning of many aspects in economy, administration and society. The economic value or benefit of weather forecasts is in general improving financial and related outcomes resulting from the use of such forecasts. The merit of meteorological services cannot directly be deduced from the consumption of services. Rather, it emerges from the improvement of decisions made by economic stakeholders thanks to weather information.

This paper summarizes the methodological approach to perform studies on the social and economic benefits of meteorology.

The approach is shown in the following table with nine steps as it has been used to perform such studies in Switzerland:

Steps:	Tasks:
1.	Make or buy decision: who should perform your study?
2.	Partner in science for review: who is going to make a quality control of the study?
3.	Functional specification document: focus on key questions, which economic sector is most relevant for your Met Service?
4.	Identify potential contractors
5.	Evaluate tenders
6.	Process contracts
7.	Submit the work by contractor and partner for review
8.	Accept the study after quality control
9.	Disseminate the results

Two of the key factors for the success of a study area good functional specification document and a convincing strategy for the distribution of the study results. In general, a lot of resources are required for the design of the functional specification document in such a way that the study becomes a success. Often, this is done with too little attention. The same is true for the distribution of the results. It must be perfectly clear who the customers of your results are; who should know your results and understand them well; and how you can reach your stakeholders with the results.

The following page shows a few examples of the various possibilities for the distribution of the socio-economic studies in the Swiss press and also the way in which they were communicated.

Schweizerische Eidgenossenschaft
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Die Bundesbehörden der Schweizerischen Eidgenossenschaft

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Seite drucken

Wetterdienste - ein Gewinn für Staat, Gesellschaft und Wirtschaft

Zürich, 08.12.2009 - Etwa 80 Millionen Franken kostet das Bundesamt für Meteorologie und Klimatologie im Jahr. Der volkswirtschaftliche Nutzen übersteigt diese Kosten jedoch um ein Vielfaches. Erste Schätzungen gehen davon aus, dass die Schweiz mit den Dienstleistungen der MeteoSchweiz einen volkswirtschaftlichen Mehrwert von mehreren hundert Millionen Franken erzielt.

Eine neue Studie, die kürzlich in der Fachzeitschrift „Meteorological Applications" erschienen ist, quantifiziert erstmals den volkswirtschaftlichen Nutzen von MeteoSchweiz. Eine erste grobe Schätzung besagt: Die Investition von einem Franken in meteorologische Vorhersagemodelle oder Messsysteme erbringt im Schnitt einen volkswirtschaftlichen Nutzen von etwa fünf Franken. Den fünffachen „Gewinn" erhalten Staat, Gesellschaft und Wirtschaft, denn die Wetter- und Klimainformationen der MeteoSchweiz helfen, einerseits Schäden zu minimieren und damit Kosten zu senken, andererseits Prozesse zu optimieren und damit Einnahmen zu steigern.

Strassenwetterwarnungen zum Beispiel verhindern Staus und Verkehrsunfälle, Unwetterwarnungen schützen Menschenleben, Wetterprognosen garantieren einen sicheren Flugverkehr, Klimaszenarien ermöglichen eine nachhaltige Entwicklung von Tourismus und Landwirtschaft, Modellvorhersagen optimieren die Produktion alternativer Energien.

MeteoSchweiz - 1 Franken rein, 5 Franken raus
Die Studie, die MeteoSchweiz in Auftrag gegeben hat, untersuchte ausgewählte Kundengruppen des nationalen Wetterdienstes: Privathaushalte in der Schweiz sowie die wetterabhängigen Wirtschaftszweige Land- und Energiewirtschaft. Hochrechnungen von internationalen Bewertungen auf die Verhältnisse der Schweiz, d.h. auf die Anzahl der Haushalte, die Grösse der landwirtschaftlichen Fläche und den Energieverbrauch der Schweiz, kommen zum Schluss: die Schweiz erzielt mit Hilfe meteorologischer Dienstleistungen einen volkswirtschaftlichen Mehrwert von mehreren hundert Millionen Franken. Dem gegenüber stehen die Kosten für den nationalen Wetterdienst, die sich auf 80 Millionen Franken belaufen. Jede Einwohnerin und jeder Einwohner zahlt demgemäss um die 10 Franken pro Jahr für die Dienstleistungen der MeteoSchweiz. Eine erste grobe Schätzung ist daher, dass das Kosten-Nutzen-Verhältnis der MeteoSchweiz bei etwa 1:5 liegt. Zu ähnlichen Zahlen kommen Studien anderer Industrieländer. Sie variieren zwischen 1:4 und 1:6 für das Kosten-Nutzen-Verhältnis der nationalen Wetterdienste. Für Entwicklungsländer steigen diese Zahlen auf 1:50 und mehr.

Suchen auf admin.ch
suchen
Erweiterte Suche

Dateianhänge:
- Medienmitteilung (PDF) (pdf, 22kb)
- Thomas Frei (2009): Economic and social benefits of meteorology and climatology in Switzerland. Meteorological Applications (pdf, 173kb)

Zusätzliche Verweise:
- MeteoSchweiz

Tages-Anzeiger WIRTSCHAFT

Aboservice · Marktplatz · Züritipp · Wetter

ZÜRICH SCHWEIZ AUSLAND WIRTSCHAFT BÖRSE SPORT KULTUR PANORAMA LEBEN DIGITAL AUTO DOSSIERS

Unternehmen Konjunktur Geld Karriere Börse Vorbörsen-Bericht Bildstrecken Weiterbildungs-Spezial

DOSSIER: DIE FRAGE

Was kostet uns das Wetter?

Aktualisiert um 07:05 Uhr

Stichworte
- Die Frage

Während Regen und Sonnenschein nach wie vor gebührenfrei von der Natur zur Verfügung gestellt werden, ist die Information darüber nicht gratis. Es müssen Riesenmengen Daten gesammelt und ausgewertet werden, damit dann Wetterprognosen oder Klimatabellen an Land- und Gastwirte, Bauherren, Piloten oder Schulreiseleiter verteilt werden können. Der staatliche Wetterdienst Meteo Schweiz kostet im Jahr 80 Millionen Franken, etwa 10 Franken pro Einwohner. Jeder eingesetzte Franken, so hat Meteo Schweiz errechnet, erbringt einen volkswirtschaftlichen Nutzen von etwa 5 Franken. Zwar lässt sich das Wetter nicht steuern, aber die Informationen helfen, Schäden vorzubeugen oder wirtschaftliche Abläufe zu optimieren.

Erstellt: 29.04.2010, 07:05 Uhr

Wirtschaft

09:00
BASF übertrifft die Erwartungen der Analysten deutlich

08:22
Synthes steigert Umsatz deutlich

08:17
Wer will hier noch Ferien machen?

08:02
Siemens stockt nach stolzem Gewinn Jahresprognose auf

07:37
Schmolz & Bickenbach mit Umsatzeinbruch und Verlust

07:32
Panalpina erwartet hohe Busse in den USA

Meistgelesen in de

METEOROLOGICAL APPLICATIONS
Meteorol. Appl. **17**: 39–44 (2010)
Published online 10 August 2009 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/met.156

RMetS
Royal Meteorological Society

Economic and social benefits of meteorology and climatology in Switzerland

Thomas Frei*
Federal Office of Meteorology and Climatology, 8044 Zurich, Switzerland

ABSTRACT: National Meteorological Services provide meteorological data, information, forecasts and various related products, which are important for the smooth functioning of many aspects in economy, administration and society. The merit of meteorological services cannot be deduced directly from the consumption of services. Rather, it emerges from the improvement of decisions by economic stakeholders thanks to weather and climate information. These services are

Governments urge their National Meteorological and Hydrological Services (NMHSs) to provide maximum services and products to their citizens and customers. This is also the case in Switzerland and therefore the results of such studies are important to know and use.

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Frei Th., S. von Grünigen and S. Willemse. 2011. Economic benefit of meteorology for road traffic in Switzerland. Submitted to Meteorological Applications.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S2_TFrei_SwissStudy.pdf

Dr Jeffrey K. Lazo
National Center for Atmospheric Research (NCAR)
Boulder, Colorado, 80307 United States of America
E-mail: lazo@ucar.edu
Telephone: +1 303 497 2857
Website: www.sip.ucar.edu

EXAMPLE II: VALUE OF IMPROVED HURRICANE FORECASTS TO THE U.S. PUBLIC: AN APPLICATION OF NONMARKET VALUATION METHODS

INTRODUCTION

The objective of this paper is to briefly illustrate non-market valuation methods as an approach to valuing weather forecasts. We do this with an application to potential improvements in hurricane forecasts in the United States.

The 2004 and 2005 hurricane seasons woke the United States to the potential societal impacts of land-falling Atlantic hurricanes. The toll was greater than $175 billion in damage and at least 5,400 deaths throughout the Atlantic basin. Over the longer term, average annual normalized hurricane damage in the United States in the 1900-2006 period has been roughly a little over $7 billion (in 2006$) (NCAR Societal Impacts Program Extreme Weather Sourcebook http://www.sip.ucar.edu/sourcebook/).

Building on several post-Katrina assessments and other studies, the National Oceanic and Atmospheric Administration's (NOAA) "Hurricane Forecast Improvement Project Plan: An Integrated 10-Year Plan to Improve 1-5 Day Hurricane Forecasts" defines a set of aggressive metrics related to research for hurricane track and intensity improvements for 1, 2, 3, 4, and 5-day lead times, with a focus on rapid intensity change. The Hurricane Forecast Improvement Project (HFIP) [2] specified stretch goals and metrics as a function of user needs and scientific understanding, including:

- Reduce average track error in the Atlantic basin at Day 2 for the official National Hurricane Center (NHC) forecast;
- Reduce average intensity error in the Atlantic basin at Day 2 for the official NHC forecast;
- Reduce average track error for Days 1 through 5;
- Reduce average intensity error for Days 1 through 5;
- Increase probability of detection (POD) for rapid intensity change for Days 1 through 5;
- Decrease False Alarm Ratio (FAR) for rapid intensity change for Days 1 through 5; and,
- Quantify and reduce the uncertainty in the forecast guidance.

[2] Because HFIP goals have changed over time, the attributes and levels evaluated in this study are somewhat different than those stated in the original HFIP workplan.

Integrating project-appropriate social science research into the HFIP will yield invaluable information regarding the potential uses and values of the HFIP effort and will support the effort by identifying the potential benefits of improving hurricane intensity information. The work reported here was designed to meet the socio-economic research needs of the HFIP in coordination with ongoing research efforts at the National Center for Atmospheric Research's (NCAR's) Societal Impacts Program in a manner consistent with a set of broader social science research issues identified by Gladwin et al. (2007).

Because households are the end users of hurricane forecasts, it is important to understand the public's values for current forecasts and for improvements in forecasts. Estimates of the value of forecasts can be used to evaluate whether improved forecast accuracy and dissemination offer more benefit to society than the costs of alternative public investments such as infrastructure or improved forecasts of other hazards (Letson et al., 2007).

NON-MARKET VALUATION

Market prices may exist for benefit estimation if there is private-sector provision of weather, water, or climate information. For an economic assessment of benefits and costs, however, many of the important outcomes pertain to non-market goods and services. As a result, non-market valuation approaches are required for many benefits and potentially some costs. Economists use various well-established methods for non-market valuation. The main approaches to estimate non-market values via primary research are stated preference methods and revealed preference methods. Stated preference methods are survey based and include contingent valuation and conjoint analysis (Adamowicz et al. 1998; Ben-Akiva and Lerman 1985). For activities where there is no direct use of the resource, and thus no behaviours or expenditures available as a measure of preferences, economists have developed stated preference methods for directly eliciting preferences and estimating value.

Two common stated preference methods are the contingent valuation method and the conjoint/stated choice method. In the contingent valuation method, individuals are asked to directly state their value for a good or service-such as an improved hurricane forecast. With conjoint/stated choice methods, respondents rank choices (such as between two choices, A or B) instead of eliciting an answer to a single Willingness-To-Pay (WTP) question, as is common in contingent valuation studies. Stated choice methods use a hypothetical context in a survey format, with questions designed as choices between alternatives that include differences in goods and services. Costs are included as an attribute in choice sets to allow researchers to monetize the marginal benefits of changes in attribute levels. The alternatives that a subject prefers reveal information about his or her underlying values for the goods and services in those alternatives.

METHODS

The current effort built on a prior survey described in Lazo et al. (2010) with the attribute set adjusted to the goals of the HFIP. Additional focus groups, individual directed interviews, expert technical input, peer review, and pre-testing were all used to revise the survey. The survey was implemented online through Knowledge Networks (KN), which maintains a panel of respondents representative of the U.S. population. After initial pre-testing and revision to shorten the survey (from 33 minutes median time to complete to 20 minutes median time to complete), it was implemented in November 2010.

We received 1,218 responses from households in 155 coastal U.S. counties from Texas through North Carolina, representing a population of approximately 30 million people (9.9 million households). The sample is reasonably comparable to the population in terms of age, gender, ethnicity, education, and income. Weights derived by KN can be used to make the sample closely match the population, but were not used in the current reporting.

An important component of the analysis is the understanding an individuals' perceptions of their hurricane risk. To compare perceived risks to actual risks, we geo-located all households within one of six hurricane storm-surge risk zones ranging from no-risk to at-risk in the lowest category hurricane (Category 1 [Cat 1] on the Saffir-Simpson scale). Approximately 38%, or 11 million people, in the 155 counties sampled live in areas at risk from storm surge.

RESULTS

In addition to deriving economic estimates of the value of potentially improved hurricane forecasts, we explored respondents' sources, perceptions, understanding, and use of hurricane forecasts and warnings. These portions of the survey validate the valuation exercise, and here we briefly mention two aspects of perceptions and understanding.

To explore perceptions of actual risk, we asked respondents to rate their risk of property damage from wind and storm surge. Overall, those in Cat 1 surge zone areas recognized the increased likelihood of surge damage compared to those not in any surge zone (χ^2 = 56.97, df = 1, pr < 0.0001). There was not a significant difference in perceptions of wind risk between those in Cat 1 and those not in any surge zone (χ^2 = 2.33, df = 1, pr = 0.13). This would be considered a finding of correct perceptions, but on average those in Cat 1 zone perceived themselves to only be "somewhat" at risk from surge risk and that their storm surge risk was lower than wind risk, which in general is not the case for those at risk of hurricanes.

To further explore understanding of storm risk, we asked respondents about their level of agreement or disagreement with 10 statements about storm surge, some of which were correct and some of which were false. We aggregated their responses to these statements into an "understanding" index that ranges from 10 (all incorrect) to 50 (all correct). Although we found that those in Cat 1 surge zone have a better understanding of storm surge risks than those not in surge zones (χ^2 = 4.49, df = 1, pr = 0.034), overall this was a very minimal difference (35.41 versus 34.45 on our 50-point scale). More important here is that those in Cat 1 surge zones scored only 35 out of 50 (about 70%) on average on our composite understanding index. Although not a definitive indication of incorrect behavioural response to hurricane risks, this does raise a concern about how respondents will process future storm surge warnings if there is no change in risk education or information provision.

BENEFIT ESTIMATION

The valuation portion of the survey involved a conjoint analysis design with all choice sets comprising four forecast attributes and a cost attribute and all versions including one of three other forecast attributes. The four "all-respondent" attributes dealt with potential improvement in forecast accuracy with respect to: 1) time of landfall; 2) location of landfall; 3) maximum wind speed; and, 4) storm surge depth. The three attributes that varied randomly across respondents dealt with potential improvement in forecast accuracy with respect to: 1) rapid changes in wind speed; 2) a separate storm surge warning product; or, 3) an extended period covered by the forecasts. Each respondent was given eight different choice sets (out of 48 different choice sets developed using optimal experimental design methods), each including a follow-up question about preference for a "do-nothing" alternative. Given some item non-response, 1,201 respondents answered eight choice questions for a sample of 9,605 observations. The following table shows the parameter estimation results using a bivariate probit model that accounts for the follow-up question as well as the fact that each respondent answered multiple choice sets (i.e., intra-subject correlation).

Bivariate Probit, λ unconstrained, with a constant (n = 1201; obs = 9,650)							
	Expected Sign	Beta	t-stat		WTP / unit	St.Er. WTP	Unit
Constant		0.618	8.78		$-8.84	$-8.84	
Landfall Time	-	-0.070	-10.05		$1.01	$1.01	hours
Landfall Location	-	-0.011	-13.83		$0.16	$0.10	miles
Wind Speed	-	-0.006	-2.52		$0.09	$0.01	mph
Change in Wind	+	0.008	12.97		$0.11	$0.03	percent
Surge Depth	-	0.003	0.45		$0.04	$0.01	feet
Surge Information	+	0.038	1.58		$0.54	$0.09	yes/no
Extended Forecast	+	0.044	3.53		$0.63	$0.34	days
Cost	-	-0.070	-51.52				

Except for surge depth, all of the estimates had the expected sign when considering the unit of measurement and the direction related to an improvement in the attribute. For instance, an improvement in "Surge Information" is represented by a "Yes" response that was coded as a "1" compared to "No" coded as "0".

As a further illustration of the use of these results, we estimate a dollar value for a potential new product of a separate storm surge warning (Surge Information). By dividing the parameter estimate for Surge Information (0.038) by the Cost parameter estimate (-0.070), we obtain a marginal monetary value of this information of $0.54 per household. Although not a particularly large per household value, when multiplied by the 9,857,371 households in our sample area this yields an annual benefit of $5.3 million. This positive value is validated elsewhere in the survey in direct questions with respect to preferences for new storm surge warning information.

CONCLUSIONS

Our primary purpose was to illustrate the use of non-market valuation methods to potential improvements in weather forecasts and warnings. We provide additional results showing the use of the survey approach to assessing respondents' perceptions and understanding of risks and information. These additional results serve to better understand respondents' values and preferences and provide cross-validation of benefit estimates.

Non-market valuation uses theory-based methods to elicit values for products and services that don't have market prices. This allows policy makers to consider these values on a level playing field with other values and costs in assessing program options-such as potential improvements in hurricane forecasts and warnings. Given the non-market nature of public provision of weather forecasts and warnings (in the United States at least), it is critical to the weather enterprise to support studies evaluating potential benefits.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S2_Lazo_Value_of_Hurricane_Forecasts.pdf

Mr Daniel Kull
Senior Disaster Risk Management Specialist
World Bank Global Facility for Disaster Reduction and Recovery (GFDRR)

USER'S PERSPECTIVE: APPLICATION AND UTILITY OF WEATHER, CLIMATE AND WATER INFORMATION IN SUSTAINABLE DEVELOPMENT

Growing Demand in Developing Countries

Since the 1990's, the World Bank has invested in the modernization of hydrometeorological services as part of broader development support in sectors such as disaster reduction, agriculture and water resources management. As World Bank clients, low and middle income country governments are increasingly requesting technical projects and analytical work supporting the development and modernization of National Meteorological and Hydrological Services (NMHSs). Meeting these requests requires strong cooperation between scientific communities and financing systems to develop a more integrated approach to the financing, development and delivery of global to local weather, water and climate services.

The World Bank is currently determining how to improve its development assistance by increasing the availability of timely and relevant weather, water and climate information through NMHSs in client countries. In formulating a new business model to support the overall global weather enterprise, the World Bank and its partners will need to create more efficient investments at the national level, as well as optimize the use of scarce public resources, engaging in innovative approaches such as public-private partnerships.

To improve the support, utilization, development mainstreaming and financing of NMHSs' services both within the World Bank and by client governments, better estimates of the socio-economic costs and benefits of NMHSs, as well as the communication of the results, are needed. Concerned NMHSs and governments are in fact directly requesting support for such analysis of weather and climate services, for example in Central Asia, Ghana, Mozambique and Nepal.

Benefits of Reducing Risk

NMHSs' services provide decision-making support to both minimize socio-economic risks (reduce negative impacts of extreme weather) and maximize potential opportunities (for example adapt crop management to increase harvests). The World Bank socio-economic analysis of NMHSs' services has generally thus far focused on the benefits of reducing weather and climate-related risks, albeit in a range of different sectors including those that face weather/climate risks as well as opportunities (for example in agriculture).

The prevention and reduction of disaster risk is needed for development to be sustainable and is cost effective in protecting past, current and future economic growth (WB & UN, 2010). This is especially urgent due to increasing weather-related disaster risk as a result of climate change and poorly planned urbanization, among other factors. The focus on the NMHSs' benefits of reducing risk also recognizes that the "ability of NMHSs to meet national service needs is put to its most critical test when an extreme hydrometeorological event occurs" (WMO, 2011).

NMHSs modernization should however be framed (and communicated) as a 'no regrets' strategy for climate risk management, aimed at maximizing positive and minimizing negative outcomes. The 'no regrets' (more realistically 'least regrets') aspect means taking climate-related decisions or action that make sense in development terms anyway, whether or not a specific climate threat actually materializes (IRI 2007). NMHSs rarely distinguish between routine daily verses extreme and infrequent event forecasting, such that service improvements support day-to-day operations that reduce costs, while exercising the skills needed to cope with future extreme events (Rogers and Tsirkunov 2010).

Cost-Benefit Analysis in Sparse Data Contexts

The benefits of risk reduction are primarily avoided or reduced potential damages and losses, which are inherently complex to estimate. Disasters, in essence, are stochastic events and, as a consequence, most benefits of risk management are probabilistic and arise only in case of an event occurring. Accordingly, risk and benefits should be assessed in terms of disaster probabilities and corresponding consequences.

Often, in the context of a developing country, even given a good understanding of the system as a whole, challenges arise due to lack of data, expertise and high resource demands. Uncertainties in projecting future climate conditions and thus the probability of climate-related hazards add additional complexity. The exposure of people, assets and the environment to a certain hazard can be difficult to quantify, and analysis should account for changes due to current and future socio-economic, land-use and other trends. Socio-economic vulnerability is a multi-dimensional concept encompassing a large number of factors that even in data-rich environments can be challenging to quantify (Kull et al, in print).

Yet despite these challenges, cost-benefit analysis of risk reduction in a development context can be performed with a certain degree of confidence. However, attention needs to be given to the manner in which analyses are framed and conducted, which must be transparent and highly participatory with regards to the users of NMHSs' services. Consistent approaches and frameworks must be employed to identify and communicate (Moench et al, 2008):

- The analysis methods employed;
- Key data, their reliability and sources;
- Externalities and how these are incorporated in the analysis;
- Assumptions and the basis on which they are made, which in data-sparse environments often have a fundamental impact on the results; and,
- Sensitivity analysis and their implications for the results. This is required to identify the factors that have the largest impact on whether or not investments in NMHSs deliver robust socioeconomic returns under the wide array of possible conditions likely to occur in the future.

Without the above, concerned governments and other potential investors have essentially no basis for evaluating the validity of the results. For example, in terms of the benefits of early warning, issues such as willingness to take action, warning reliability and potential costs of taking inappropriate action must be explicitly considered (Rogers and Tsirkunov, 2010). Distributional aspects focused on identifying who will benefit must be considered in the analysis, especially in a development context (Kull et al, in print). For example, early warning tends to benefit all segments of society, while preventive infrastructure (like flood embankments) has historically benefited primarily the richer segments (WB and UN, 2010).

To further increase the robustness of cost-benefit analysis in a data-sparse context, if only ranges of potential benefits (and costs) can be estimated, the most conservative values should be employed (IFRC 2011). The results of a conservative analysis comparing the lowest potential benefits with the highest potential costs instil greater confidence for decision-makers.

Pragmatic Approaches

Due to the issues outlined above, as well as often resource limitations associated with project development budgets and timelines, pragmatic approaches to assess the socioeconomic benefits of NMHSs' services must be applied in developing countries. Within the World Bank's ongoing efforts to support the modernization of NMHSs, particularly in Eastern Europe and Central Asia, three independent yet complementary approaches have been developed and utilized (WB 2008).

Benchmarking is a simple approach to obtain information about damages caused by weather impacts. The method employs the available official statistics and expert assessment of the weather-dependence of a country's economy, meteorological vulnerability and existing NHMS provision, by first determining global benchmarks and then correcting these for the country-specific context (Tsirkunov, et al 2008). *Benchmarking* only accounts for direct losses which although seen as a constraint, also results in a conservative approach to benefits estimation (as avoided indirect losses are not considered).

Sector-specific assessment uses specially designed surveys of experts from weather-dependent sectors to compile information on direct and indirect losses from hazardous weather events and adverse conditions, and estimate changes in the share of preventable losses and costs of protective measures due to more accurate and timely hydrometeorological information and forecasts. The data is used to evaluate the marginal benefits of NMHSs' service improvement for each weather-dependent sector and the integral effect for the economy (Tsirkunov et al 2008).

Customized sociological surveys, based on a contingent valuation approach, aims to assign a monetary value to weather forecasts and warnings financed as a public good and provided free of charge to households (WB 2008). While such information is not captured by the benchmarking and sector specific approaches, the risks of double-counting through multiple analyses must be closely monitored.

Importance of User Needs

The above approaches point to the importance of identifying user needs through participatory consultative approaches. As service benefits are in fact the meeting of user needs, their assessment is key to developing successful NMHSs business models.

Market based approaches link specific user needs to the value of weather and climate services. For example, in India, Weather Risk Management Services (WRMS) charges PepsiCo's contract potato farmers 5% of their weather insurance premium (offered through a private insurance company) for weather data services, which amounts to $3.70/ha per year (IFAD and WFP 2010). While its services may be subsidized by utilization of data from the Indian Meteorological Department (IMD), this charged cost is based not only on assessments of cost recovery and target profits, but also on the realities and limitations of market willingness-to-pay.

As a counter-example, the Ukrainian Hydrometeorological Institute (UHMI) charges $6,500 for 30 years of data per weather station. Domestic insurers, however, are not prepared to invest this especially to develop new products, so they are considering installing their own stations, with costs to be split between the insurers and their clients, leading to higher premiums (IFAD and WFP 2010). A public-private partnership that shares benefits as well as risks might be an approach for UHMI to take advantage of this potential business opportunity.

Looking Ahead

Action 11 of the Madrid Action Plan (MAP) highlights the need to develop methodologies and capacity for quantifying the socio-economic benefits of NMHSs services (WMO, 2007). This commendable goal has not yet been achieved, particularly in developing countries.

The World Bank, through its programme on Strengthening Weather and Climate Information and Decision Support Systems (WCIDS), will continue to support the MAP by further refining and developing the methodologies and capacities used internally and in partnership with government to assess NMHSs services' socioeconomic benefits.

It must also be noted that current efforts by the hydrometeorological community to better quantify the socio-economic benefits of their services is not happening in isolation, with reference for example to broader European efforts currently underway through GEO-BENE[3] and EuroGEOSS[4]. As NMHSs do not operate in isolation, it is well worth considering participation in such broader multi-sectoral efforts.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S2_Dkull_Users.pdf

Dr Adriaan Perrels
Finnish Meteorological Institute (FMI)

MATERIAL AND GUIDELINES FOR REVIEWING SOCIAL-ECONOMIC BENEFITS

* This Power Point Presentation can be located at the following web-link:
ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S2_APerrels_SEB2.pdf

Dr Saskia Willemse
Federal Office of Meteorology and Climatology MeteoSwiss

CASE STUDY 1:
SWISS STUDY OF SOCIO-ECONOMIC BENEFITS TO THE TRANSPORT SECTOR
(RESULTS OF THE STUDY)

The economic benefit of meteorology in the Swiss transport sector amounts to at least CHF 86 to 100 million per year. This is the result of the first empirically based study carried out in this country, delivered at the beginning of 2011.

The study is based on a prescriptive model which assumes that meteorological information influences the decision-making process of business stakeholders. In this model, the economic benefit of meteorology is given by the difference between the costs of an action taken on the basis of meteorological information and an action taken without this information (which is the hypothetical reference situation). The study is limited to the benefit to private companies and state-owned institutions, whereas the benefit to the individual citizens is not considered, except for the cases where their action is influenced by the action taken by the companies and institutions mentioned above.

The factors of benefit due to meteorological information considered in the model are:

- increase of profitability in private companies;
- saving of resources in state-owned institutions;
- damage avoidance of public and private infrastructure and reduction of health costs due to accidents; and,
- individual benefit in terms of time savings.

The data used to derive the economic benefit were collected in 37 interviews, 23 in the domain of road transport, nine (9) in rail transport and five (5) in aviation. The interviews were carried out based on a standardized questionnaire with about 15 questions which were orally discussed with the partners. In some cases, additional clarifications were asked after the interview. The statement on the benefit to the whole Swiss transport sector was obtained by extrapolating the assessed benefit for the single institutions and companies.

Road transport

For the domain of road transport the calculated benefit amounts to CHF 66 to 80 million per year, which is the largest contribution to the total benefit to the transport sector.

The interviewed stakeholders in the domain of road transport are:

- Maintenance centers of national and regional roads. Local roads were not considered;
- National traffic management centers;
- Freight transport entrepreneurs (part-load traffic, cut and fill as well as pavement transport, winter road services on a contract basis); and,
- Public road transport companies.

The main meteorological factors influencing the state and therefore the accessibility and usability of the roads in Switzerland are snow, time, freezing rain and heavy rainfall and fog. Most of these conditions occur mainly in the winter; therefore, a large part of the economic benefit of meteorology in the domain of road transport is generated during the cold season. Different meteorological products are available for the domain of road transport. The most specific ones are forecasts describing the short-term evolution (up to 24 hours) of the crucial meteorological parameters with a time resolution of about one hour for special road sections. This kind of forecast is liable to pay and is used by the maintenance centres to predict the state of the road and to define the action to be taken. On the other, hand warnings are issued for specific dangers like slippery roads because of rime, freezing rain, snow or aquaplaning and are available free of charge to everyone.

Rail Transport

The economic benefit of meteorological information in the domain of rail transport in Switzerland is found to be of two orders of magnitude lower than the benefit obtained for road transport: CHF 0.3 to 0.4 million per year. The main reasons for this difference are that rail transport is probably less sensitive to the weather than road transport and that the railroad network is less dense than the road network.

The interviewed stakeholders in the domain of rail transport are:

- Passenger transport companies;
- Freight transport companies; and,
- Rail infrastructure operators.

The meteorological factors which have the most important influence on the operations of railroads are snow and ice, although heavy rainfall, lightning and windstorms can also affect them. As far as the weather forecasts are concerned, no specific products for railroads are offered on the market. Some railroad companies buy meteorological information with a higher resolution than the general forecast available at no cost. The economic benefit generated by meteorological information to the rail transport domain is typically connected with a low number of episodes in the course of the year.

Aviation

In the domain of aviation the economic benefit is assessed only for an isolated aspect and amounts to CHF 20 million per year.

The interviewed stakeholders are:

- The air traffic control companies;
- The airport authorities; and,
- Two airlines (pilots).

For two main reasons, the estimation could not be based on the same model as for road and rail transport:

- A hypothetical reference situation without weather information would not be realistic for aviation, as the whole domain would have to be organized in a different way; and,

- Aviation is an extremely international business. Swiss airlines and the airport authorities do not use only meteorological information issued by Swiss institutions and, on the other hand, foreign companies also use Swiss weather products. Therefore, it would be fairly impossible to separate the economic benefit of Swiss meteorological services to Swiss aviation from the benefit of foreign meteorological services.

Consequently, the estimation of the benefit was carried out with the following two approaches:

- The hypothetic reference situation “flight operations with bad quality of weather information (worse than today)”. This approach did not lead to the desired quantification of the benefit: the interviewed stakeholders confirmed that weather information is a prerequisite for the operation of airlines and airports, but meteorology plays a role in most domains of aviation and influences many aspects of profitability. It would have been necessary to define a model for each of these aspects, but this would not have been possible with the resources available for this study.

- A separate quantitative approach where the estimation of the benefit was restricted to the Terminal Aerodrome Forecast (TAF) for the airport of Zürich, issued by MeteoSwiss. This approach is based on a study by Leigh, Drake and Thampapillai (1995) for the airport of Sydney, Australia. It was adapted to the local conditions of the area of Zürich and the decision behavior of the stakeholders was defined by interviewing a few pilots. This procedure led to a quite well documented quantitative result, namely an economic benefit of TAF Zürich of CHF 20 million per year.

In conclusion, as the quantified economic benefit of meteorology to the domain of aviation was defined only for one special kind of forecast, it is expected that the effective total benefit is much higher than the CHF 20 million per year mentioned above.

Conclusions

In the table below, the assessed economic benefit is summarized for the three domains of transportation. Of the four factors of benefit mentioned at the beginning of this abstract, only the first two could be quantified at least partly. The damage avoidance and the individual benefit could not be defined either because the effect of meteorology on the considered stakeholders is too small or because the stakeholders could not say anything about their quantification.

	Factor of benefit:	
	Saving of resources in state-owned institutions (Mio CHF / y):	Increase of profitability in private company (Mio CHF / y):
Road transport:	52.6 – 56.4	13.3 – 23.7
Rail Transport:	0.14 – 0.18	0.16 – 0.22
Aviation:	-	20.03

As in all examined domains of transport it is not possible to completely quantify all aspects of economic benefit, the real total benefit of meteorology to the transport sector is expected to be clearly higher. Furthermore, as not all stakeholders make use of the best available information, there is also an additional potential benefit which is not exploited yet.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S2_Saskia_CaseStudy1.pdf

Dr Pekka Leviäkangas
VTT, Finland

CASE STUDY 2:
BENEFITS OF METEOROLOGICAL SERVICES IN CROATIA

ABSTRACT

This research looked into the benefits of hydrological and meteorological information services in Croatia. The benefits generated by the day-to-day services were investigated by beneficiary sectors. Each sector was studied by different researchers. The methods used were multiple: literature reviews and statistics, expert interviews and workshops, and analytical, conceptual and qualitative model building and modeling of expected impacts. Assuming that the annual budget of Croatian Hydro-Meteorological Service (DHMZ) was about 8 million € per year, this study concluded that the services delivered by DHMZ pay back the costs at least 3-fold each year. Taking into account all the excluded sectors, it was further concluded that the factual ratio is even higher. The results seemed to be in line with other research results. By improving the services, especially their delivery, substantial additional benefits can be generated, hence justifying the investments in the improvement of hydrological and meteorological services.

INTRODUCTION AND BACKGROUND

The development strategy for DHMZ, which was drafted during 2006-2007, contained the following elements: i) vision for 2020; ii) strategies until 2010 supporting the vision; and, iii) action plans for implementing the strategies. The Plan was initiated in 2006 and completed in 2007. The strategies were formulated to cover the following areas:

- Observation network and infrastructure;
- Information Technology (IT) and its architectural cornerstones;
- Production process of hydro-meteorological service products;
- Organizational structure;
- Human resources and capacities;
- Physical facilities; and,
- Economy, budgeting and finance.

The Plan was motivated by the goal of increasing the competitiveness and customer orientation of DHMZ. The approaching candidacy for European Union (EU) membership was also a strong background factor.

As a background document to justify the strategic development work, a socio-economic cost-benefit assessment was made for the services provided by DHMZ. Without a clear picture how the hydro-met services benefit the society, it is difficult to argue for strategic investments and more resources in general.

The implementation and the methods

The executed Implementation Plan of the study is shown below. The first step, which presents meteorological information services, was carried out through several fact-finding missions by VTT researchers. The costs were also pinned down during those missions. The following step, needs analysis, was done by arranging two customer-involving workshops, one in Espoo and one in Zagreb. The potential benefits were reported as well as a gap analysis. Gap analysis points out the differences between the current services and identified or potential customer needs. The final Action Plan 2010 was reported separately.

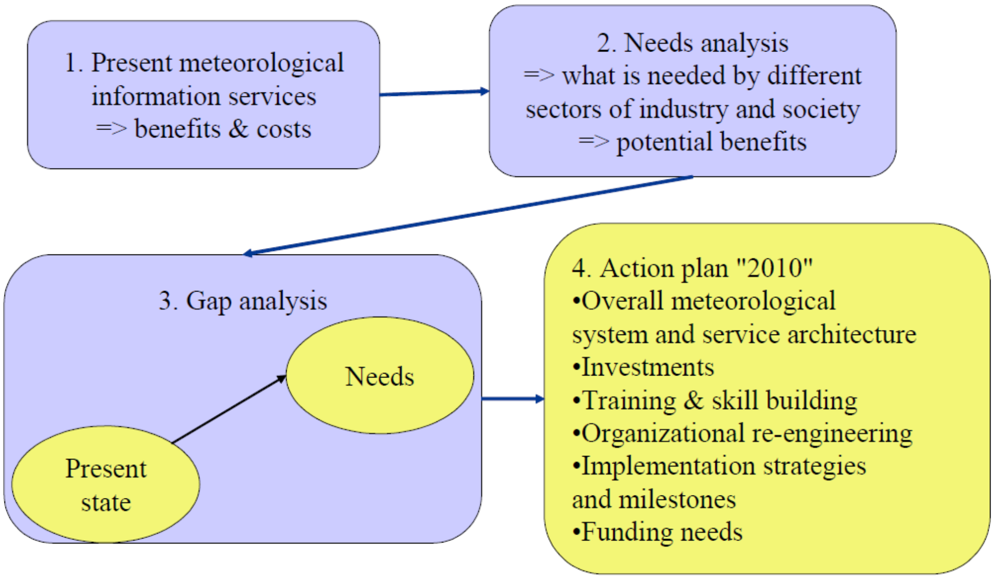

Figure. *The plan for the analysis of DHMZ*

For each analysed user sector, there were sector-specific methods applied, but there were common elements for them all, too. These were as follows:

- literature reviews and statistics;
- expert interviews and workshops; and,
- analytical, conceptual and qualitative model building and modelling of expected impacts.

Summary of potential economic benefits

A sufficient amount of information for the estimation of comprehensive economic benefits of DHMZ services was not available. Many of the related organizations did not compile statistics and some of the activities under consideration were handled by several organizations, making it difficult to evaluate the total impact of services. The maritime operations were estimated to benefit the most from the meteorological information services. A table summarizing benefits to different sectors is shown on the next page.

In summary, assuming that the annual budget of DHMZ was about 8 million € per year during the period of analysis, it was concluded that the services delivered by DHMZ paid the costs back at least 3-fold each year. Taking into account all the excluded sectors, it was further concluded that the factual ratio was even higher. The results seemed to be in line with other research results. By improving the services, especially their delivery, substantial additional benefits could be generated, hence justifying the investments in the improvement of hydrological and meteorological services.

Sector / Industry	Total benefits per year with current information (= current benefits) (million €/a)	Total benefits per year with perfect information (= potential benefits) (million €/a)	Notes
Transport			
-road	3.1–6.2	5–10	Main benefits in road safety and operational road maintenance
-rail	not assessed	0.15	Main benefits from time savings and track maintenance
-maritime and inland waterways	4.3–7.9	not assessed	
-aviation	12.2	15	Main benefits accrue from enhanced safety; because of already advanced services, the difference between current and potential benefits is not very significant
Construction and facilities management	0.5	1.5	Main benefits from *in situ* operations and long term damage prevention
Energy production and distribution	2.0	not assessed	Maintenance and operation of production plants and grid lines
Agriculture	5–10	15	Main benefits come from reduction of crop losses
Total for the analysed sectors	*27–39*	*37–42*	

Summary Table. *Benefits of DHMZ services in Croatia – "today" (2005) and the potential*

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S2_PekkaVTT_SEBCroatia.pdf

Session 3:
Benefits for Different User Sectors
(Addressing Clients and Decision-Makers)

Dr Sebastien Nobert
King's College, London

UNDERSTANDING AND COMMUNICATING FORECASTS' UNCERTAINTIES: REFLECTIONS ON THE USE OF ENSEMBLE PREDICTIONS IN EUROPEAN DISASTER MANAGEMENT

Environmental risks, or what have been commonly referred to as natural hazards in political and scientific arenas, have seen their literature growing rapidly in the last decade, with a particular focus on how to better communicate risk to the public (Renn, 1998). The interest in the interpretation and communication of risks by both experts and non-experts has been mainly influenced by the mental model approach (Fischhoff, 1995) which assumes that non-experts have an "'intuitive understanding' of risks, and that they can be helped to a better appreciation and consequently be placed in a position to make more informed decisions if they are given new information in a format that is consistent with their initial belief system" (Breakwell, 2001: 342). This approach has been the catalyst for many studies aimed at developing more effective ways of communicating risks and uncertainties to non-expert audiences, and has made it possible to identify behavioural processes affecting the lives of those receiving information from experts. Thus, having a good knowledge of non-experts has been a primary concern for this approach, allowing the development of an approach to risk communication that is adapted to help those with limited expertise to make informed choices in the face of uncertainty. This is related to what Gerd Giegerenzer (2002, 2005) refers to as the 'risk literacy' of non-experts, which draws on psychology and behavioural change theory to suggest that experts can provide the "right" information to non-experts if the cognitive needs of those non-experts are adequately addressed and understood.

With its focus on cognitive biases in their interpretation, deficit and mental models of risk communication tended either to ignore behaviour altogether (on the principle that good risk communication should inform, not influence, the decisions made by autonomous consumers and policy makers), or to theorise behavioural responses in terms of a simplistic rational actor paradigm of calculation and utility maximisation based on idealised cost-loss functions. These idealised cost-lost scenarios rarely acknowledge that the question of what is defined as valuable - and, thus, what needs to be protected from environmental hazards - is contingent on dominant discourses and practices infused by cultural values, and are not the products of objective rationalisation processes. With the improvement of computer power during the 1990s, the possibility to develop early warning systems became possible and this in turn, paved the way to new digital innovations such as the development of Numerical Weather Prediction (NWP) models. With NWP, meteorologists realised that by using a collection, or ensemble, of model runs each initialised with slightly different initial conditions, it became statistically possible to sample the uncertainty about them so that weather related hazards can be seen in advance. This technical development became the cornerstone of many national and international disaster risk reduction strategies (e.g., UN/ISDR 2004; IKSR 2005; IFRC 2009; Pitt 2007).

Drawing on 68 in-depth interviews conducted with operational forecasters, hydrologists, meteorologists and civil protection authorities from 17 European countries, as well as on participant observations conducted during the years 2008-2010, this paper seeks to go beyond the limited analysis offered by deficit and mental models in the communication of risk and uncertainties in order to show that other important restrictions to the communication of Ensemble Predictions (EPs) reside in the political nature of natural hazards management. By taking a closer look at the chain of operations involved in the production and communication of EPs, it becomes evident that communication problems are not simply attributable to the complexity of information received, but are rather caused by breakdowns occurring in the communication between different sets of actors, competencies and liabilities. For this reason, this paper applies a political science framework allowing it to capture where potential problems may surface in producing and communicating pre-warnings (Meyer et al., 2011). In turn, this framework reflects the non-linearity of action occurring when pre-warnings are sent and acted upon by both experts and non-experts such as operational forecasters and Civil Protection Authorities (CPAs). Hence, it encourages rethinking pre-warning responses and makes it easier to capture the non-linear nature of action by exploring three overlapping moments, each operating at different temporalities in the chain of alert production and dissemination.

The first breakdown moment can be defined as 'reception-attention'. This is where pre-warnings are sent to forecast users, but for practical reasons, (some as trivial as spam filters) the recipient does not receive the information, which, in turn, impacts the attention afforded to it. This is important because if the transmission of this information is unreliable, CPAs and other potential receivers might be distracted by other sources of information and might not pay attention to the probabilistic alerts. The second breakdown is related to the 'attention phase'. It becomes relevant when a warning is received but the recipient thinks that it is insufficiently credible either due to their lack of experience with EPs, or because they are used to other types of information which seem more reliable than what probabilistic forecasts are providing (such as "in house" deterministic models). The third and last breakdown occurs during the 'moment of action'. It occurs when CPAs need to organise the mobilisation in the field but their mandates - as well as their professional competences - do not allow them to use probabilistic information, thus prohibiting their prioritisation scenarios from functioning on probabilities.

These three breakdowns can overlap each other, and cannot be explained nor improved with deficit and mental models since they imply acknowledging the non-linearity of decisions occurring while receiving pre-warnings that are central to the success or failure of the communication of uncertain risks. Each of these moments offers an artificial decoupling, which makes it possible to interrogate with depth why early warnings of natural hazards may fail, but also suggest where improvement of probabilistic risk management and communication can be addressed.

The three moments identified in this article show why non-experts might not use probabilistic information properly or as experts think they should, despite having cutting-edge forecasting information at hand. However, by conceptualizing the different breakdowns occurring in the chain of action and appreciating these moments as dynamic rather than static and controllable, it becomes possible to show the relevance of thinking about breakdown moments as important sites where the negotiations between different types of actors and forms of information take place. Despite all the effort invested in the development of EPs and communication schemes reflecting mental models, this paper shows that ignoring the reflexivity of social actors involved in understanding, communicating and disseminating probabilistic forecasting information will only lead to inadequate adaptation strategies. Finally, this critical analytical exercise of breakdowns in the communication of pre-warnings reiterates the importance of looking beyond the technical and behavioural aspects of communication, and emphasises that the political and institutional dimensions of good communication are also crucial in using forecasting information, and thus should be taken more seriously by EPs proponents if they want to see their science used by non experts users.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_SNobert_Uncertainties.pdf

Mr David Richardson
European Centre for Medium-Range Weather Forecasts (ECMWF)

THE BENEFITS OF ENSEMBLE FORECASTS FOR RISK ASSESSMENT AND DECISION MAKING: MONTHLY AND SEASONAL PREDICTION

* This Power Point Presentation can be located at the following web-link:
ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_DRichardson_EnsembleForecasts.pdf

Dr Laurent Dubus
EDF R&D, Chatou, France

CASE STUDY 3: PROVIDER-USER COLLABORATION: PLANNING FOR THE ENERGY SECTOR

As human activities become more sophisticated and power-dependent, weather and climate increasingly pose both opportunity and risk for the energy industry and people in general. But risks are certainly rising faster than opportunities, and margins of action are decreasing. Hence, effective decision-making requires accurate and reliable information on weather and climate, at all time-scales, from the real-time to the seasonal range, and even beyond. In this paper, we describe the experience developed at the Electricité de France (EDF) in the last 30 years, and give some ideas as how to foster better provider / user relationships.

A WEATHER AND CLIMATE DEPENDANT SECTOR

The power sector includes both renewable and non-renewable resources, and covers a wide range of activities, from resource assessment, production, transport and distribution. As electricity can not be stored on a large scale, a strict balance between offer and demand is necessary at each time step. All the sector's activities depend on weather and climate conditions at all time horizons. Extreme events, such as heat waves or cold waves, wind storms or floods can of course have dramatic consequences on the production means or the electrical grid of a country. But, normal day-to-day weather variations also have impacts on load level and energy production, transport and distribution management, as well as energy prices.

The main dependence is certainly, in most countries, that of power demand on air temperature- cold conditions, implying heating, and warm conditions, implying cooling. In France for instance, an extra cold anomaly of one degree Celsius in winter requires an extra production of around 2,100 MW, the equivalent of 1.5 nuclear reactors or around 800 wind mills.

Hydro power is of course dependant on precipitation (water and snow), and temperature (which controls snow melting in spring). Precipitation, and hence stream flows, have a strong seasonal cycle, with higher inputs in spring and autumn, and dryer periods in summer and winter; they are very variable on the inter annual timescale, and can also vary a lot on the scale of a few weeks. For instance, in France, 2003 was very difficult for hydropower, with records of low and high flows beaten in the same year.

Other renewable sources, in particular wind and solar energy, are very fluctuating with their atmospheric sources, wind and solar radiation respectively. It is indeed very frequent to observe high ramps (rapid decrease or increase in production in a few minutes) that imply decrease / increase in production of more than 80% per cent for several minutes / hours. This is notably the case in north European countries, where wind energy already represents an important part of some countries' total energy production, with Germany being the most evident case.

Intermittency in power production is a major problem for distribution and transport networks, eventually leading to blackouts. Therefore, some countries and region have established rules to limit the installed capacity of production from intermittent sources. This is, for example, the case in French overseas territories (Guadeloupe, Guyana, La Réunion and Martinique) where non-predictable energy sources are limited to 30% per cent of the total installed capacity. This limit is about to be reached in La Réunion, and further development of wind and solar energy will rely on the possibility to accurately forecast the power at least one day ahead, or to modulate instantaneous power variations by storage capacities.

From a global point of view, according to the International Energy Agency (IEA)'s World Energy Outlook 2009, the world's electricity demand is projected to grow at an annual rate of 2.5% per cent up to 2030. If coal should remain the dominant fuel worldwide, the share of renewable energy should grow from 18% per cent in 2007 to 22% per cent in 2030 especially for wind and solar energy. Hence, the fluctuating nature of these two sources has to be dealt with urgently. Technological solutions, like energy storage, can bring some answers, but more accurate forecasts of the expected production and the associated uncertainties will be crucial for further development of these production means.

EDF'S EXPERIENCE

In the last 30 years, EDF has developed national and international collaboration with both scientific institutes and operational centres, among which Météo-France, the French National Weather Service, has a central role. But collaboration also exists with French laboratories (CERFACS, LMD, IPSL, University of Orsay, etc.) and international institutes and research or operational centres (European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom Met Office). The EDF Research and Development division (R&D) is also a frequent partner in French national and European projects (e.g., ENSEMBLES, ANEMOS, SAFEWIND) and, in this way works with many laboratories in Europe. Research experts are also networking in national and international organizations and take part in working groups. Expertise at the interface of weather, climate and energy has been shared with the World Meteorological Organization (WMO) in several for a such as the WMO Forum: Social and Economic Applications and Benefits of Weather, Climate, and Water Services; Madrid Conference in 2007; World Climate Conference-3 (WCC-3) in 2009, GEO (participation at the GEO 10-year Implementation Plan Reference Document in 2006, Earth Observation and Energy Management Expert Meeting in 2006 and other expert groups for example NATO Advanced Research Workshop Weather / Climate Risk Management for the Energy Sector, 2008. EDF's scientists also publish peer-reviewed papers, and participate in many national and international conferences (EGU, EMS/ECAM/ECAC, AGU, etc.). The ECMWF users' annual meeting is also an important source of information, and a place where users can express their requirements.

As stated above, Météo-France is of course EDF's main partner when speaking about weather and climate. In addition to EDF's participation in the "Conseil Supérieur de la Météologie", the body within Météo-France dedicated to users, partnership also exits in common research projects with the Centre National de Recherche Météorologique, Météo-France's research centre, and in the form of commercial contracts for the provision of data, forecasts and services. In addition to existing catalogue products, specific needs are generally addressed in partnership from the description phase to the final product delivery. The common process is to develop ideas based on operational needs in the frame of research projects, which, if successful, are then tested in near-operational conditions. This phase of evaluation is then transformed into a commercial contract when the usefulness of the new product or service has been verified. Such projects can of course be realized in partnership, but EDF also realizes autonomous projects, which use weather data and forecasts, from Météo-France and other centres, and then give rise to commercial contracts.

For the commercial part of this relationship, coordination teams have been officially set in place, and formal meetings, with feedback and event review mechanisms, take place at least twice per year. Complementary technical meetings are held on demand. During those meetings, in which both climate experts from Météo-France, EDF R&D, and end-users from EDF are present, case studies have been introduced in the last three years. They consist in analysing typical situations which were a problem for EDF (e.g., a forecast error in temperature of 5°C at D+1, due to low-level clouds). The meteorological situation is described, and allows explaining the forecast errors, pointing out difficulties and limitations of the forecasting process. This kind of exercise has been very useful to increase end-users' understanding of physical processes and weather prediction science. On the reverse side, these meetings also allow end-users to explain how they use weather information, and how the forecasts could be improved. This organization has proven very efficient to increase the quality of communication and mutual understanding. It relies essentially on the ability to communicate among the parties. That's why users' training and the provision of regular information to them is also an important point, to ensure an up to date knowledge of products and services, and to identify potential future developments of interest to the sector.

SOME SUGGESTIONS TO IMPROVE PROVIDER/USER COLLABORATION

Due to the high complexity of energy systems management on one side, and weather and climate science on the other side, EDF R&D plays an important role at the interface between providers and end-users of weather and climate information. Such an interface is important, and, when it cannot be provided by a user's dedicated division, it should be envisaged on the provider's side, or even by a third party. Some providers / users interfaces already exist (ECMWF users' meeting, Météo-France's Conseil Supérieur de la Météorologie, etc.) but their number and role should be further developed.

To face the world projected demand in electricity by 2030, IEA estimates that around US$ 26 trillion investments will be necessary (IEA, World Energy Outlook 2009). Reducing risks associated with these investments will necessitate acting on three fronts: 1. improving weather and climate data and forecasts; 2. improving the communication between providers and users; and, 3. improving users' decision-making processes. All these three areas are of equal importance, and any lack in one of them is likely to seriously affect the whole chain. If the first and third points are to be treated mainly by providers and users respectively, the problem of communication has to be addressed in close cooperation, because it is the essential link between both sides, and will influence the development of useful products and services that will be used efficiently. At the regional and international levels, WMO and other international institutions (the World Energy Council, for instance) play a major role of facilitator, notably by providing recommendations and guidance. A crucial key element is a close collaboration at the national level between National Meteorological and Hydrological Services (NMHSs) and users.

From a global point of view, in order to improve and rationalise the use of weather and climate information in the development of sustainable and reliable energy systems, many challenges have to be addressed:

- Raising awareness of the general public, scientists and decision-makers about potential impacts of energy consumption on climate and environment;

- Ensuring recognition that advances will require an investment in research to improve scientific and technical capabilities;

- Ensuring recognition that resources for hydro meteorological services are investments that are highly beneficial to the energy sector, and to the society, rather than expenditures;

- Maintaining and developing the operational capability of the services providers;

- Ensuring that the users are aware of and understand the limitations of data and forecasting and warning systems;

- Developing the use of short, medium and long-term weather and climate forecasts, with a particular focus on ensemble predictions;

- Understanding that failures will occur, but that the application of risk management approaches can minimize possible impacts, and that doing nothing will always be worse;

- Reinforcing the gathering of users' needs in NMHSs, and taking these needs into account upstream for the development of new products, rather than trying to fit independently designed products to needs.

Two important and complex problems have in particular to be addressed for the power sector: the use of ensemble prediction to allow estimation of uncertainties, and seamless prediction, to ensure a continuum in forecasts on different time scales.

In conclusion, energy is a prerequisite to economic and social development. Efforts from NMHSs and energy companies and agencies will be necessary at the local and the national scales, to meet each country's needs. Climate services, as defined by WMO, and which are under the scope of many projects, will certainly be a major contributor to sustainable energy systems development, as far as they take into account in an interactive approach and from an early stage the users' needs.

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* The Power Point Presentation related to this abstract can be located at:
ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_ LDubus_EDF.pdf

Dr Jacqueline Frick
Gruppe Sozialwissenschaftliche Landschaftsforschung
Eidg. Forschungsanstalt WSL

CASE STUDY 4:
FLOOD-RELATED WARNINGS AND THEIR COMMUNICATION: USER REQUIREMENTS, USER PERCEPTIONS, AND THE IMPACT OF FORECAST INFORMATION FOR DIFFERENT USER SECTORS

* This Power Point Presentation can be located at the following web-link: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_JFrick_flood_warnings.pdf

Dr Federica Rossi
Institute of Biometeorology - CNR
Bologna - Italy
Vice President CAgM-WMO

and

Dr Paolo Mannini
Director Agro-environmental Area
Consorzio Bonifica 2°grado
CER - Italy

CASE STUDY 5: SOCIO-ECONOMIC BENEFITS OF IRRIGATION ADVICE TO FARMERS AND ON SUSTAINABLE WATER USE

Agriculture is now facing increased pressure to provide food for a growing population. The Food and Agriculture Organization of the United Nations (FAO) estimations (2009) are to produce 70-100% more for an expected population of some nine billion by the middle of 21st century. Inequalities between industrialized and developing and least developed countries show evidence of malnutrition and food insecurity in the poorest parts of the globe, and increased consumer purchasing power and improved dietary expectances in others. Environmental emergence, climate change and variability pressures, land use changes and large greenhouse gas emissions due to agro-food systems, urge the agriculture sector to optimize productivity across a complex number of technical, socio-economic, environmental, rural development and sustainable use of resources (*Perry et al, 2010*).

National Meteorological and Hydrological Services (NMHSs) data and services are crucial tools necessary to provide scientific and technical instruments for a multi-functional agriculture, respectful of social and environmental priorities.

A recent study based on agro-climatic indices (*Trnka et al, 2011*) has indicated an urgent need for many European environmental zones to take adaptive measurements to either increase water availability or the drought resistance of their crops. Rain-fed agriculture is likely to face more climate-related risks. An increase in suitable management of irrigated crops is encouraged to overcome economic uncertainties. Agriculture is currently accountable for 85% of the global water consumption, and irrigated areas are expected to increase by a factor of 1.9 by 2050, mainly where water-scarcity is most intense, such as South European Countries (*Martindale, 2010*). In many of these countries, crop irrigation has been practiced for centuries, and it is the basis of economic and social activity. Water allows to maximize yield and its inter-annual stability, and in many cases, to improve the quality of the crop quality. The economic value assumed by water as an input to agro-ecosystems to produce commodities, is the sum of the ecological and cultural values offered form the ecosystem themselves when their multi-functional aspects are considered and exploited (*Tielborger, 2010*).

The decision to use irrigation water is often made at farming level. At this scale, the first economic impacts become evident, but, in general, the complex issue of improving Water Use Efficiency (WUE) at the catchment level requires both a strong and high degree of interaction between the NMHSs, research scientists, technical staff and policy-makers. Proper strategic (short-term) and tactical (long-term) solutions may consequently be adopted to drive towards increased sustainable and equitable food production, which at the same time, respect the environment.

Best practices may be defined as practical, affordable approaches to conserving water without sacrificing productivity, while at the same time, maximizing its use efficiency. An effort in this direction is represented by the DSS IRRINET PLUS, originally developed for the Emilia Romagna Region of Italy, is now progressively evolving towards the national IRRIFRAME system.

The IRRINET-PLUS is an implementation of the irrigation advice service via IRRINET. This system is free of charge to its users and is managed by Consorzio di Bonifica per il Canale Emiliano Romagnolo (CER), with the aim to support farmers with specific custom-built suggestions.

The first version of the IRRINET was established in 1984 by using public funding to test telematics in agriculture (Videotex), and evolved as a Web interface in 1999. Geographical Information System (GIS) extensions were provided in 2002, and in 2003 Web plus SMS (IrriSMS) service was first started. The software elaborates the irrigation advice for the main crops grown in the region on the basis of water balance, calculated by utilizing meteorological data (rain and evapo-transpiration) provided by the Regional Meteorological Service, soil data by Regional Geological Service and crop parameters collected by the CER technical service over thirty years of local experimentation. The suggestion about the amount of water needed and proper timing of irrigation is also supported by graphs showing the trend of soil humidity from the beginning of the irrigation season.

Farmers can register to become full-time users and archive their own farm data, which is stored in the system. Through this system, farmers are able to receive user-friendly advice on timing and amount of irrigation for the different crops via SMS or the Web.

So far, the estimated water saving allowed by using IRRINET (registered users are more than 1,000) is about 40-50 M cubic meters.

The innovation embedded in IRRINET-PLUS is aimed to offer the farmers an additional indication about economical opportunity resulting from any specific irrigation for a particular crop and at any phenological stage (yield response to water, based on FAO Paper 33). The cost of a single irrigation (water, energy and work, excluding mortgage of the irrigation system that is considered as a cost at farm level) is calculated according to the indications given by the farmers to the system. The productive value of the same irrigation is computed based on the plausible yield increment consequent to that same irrigation (corresponding to the amount of yield lost due to water stress and photosynthetic limitation related to missing irrigation). Economic convenience is then derived by fuzzy logic-based calculation.

Information which is simple and easily understood by farmers is provided in a colour coded format. A green light means real advantage, a yellow light an uncertainty, while a red light indicates a clear disadvantage).

Through upscaling IRRINET PLUS at basin and catchment levels (National IRRIFRAME project), it is possible to obtain the economic evaluation of possible production losses due to increasing drought and lower water supply, as well as economic evaluation of the rain events in given landscapes, economic evaluation of water table, and economic value gained from irrigation by an agricultural region.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_ROSSI_Irrigation.pdf

Mr Gerald Fleming
Head of Forecasting
Met Éireann (The Irish Meteorological Service)

WEATHER PRESENTATION AND DELIVERY - WHAT IS THE VALUE OF THIS AND HOW CAN WE MEASURE IT?

INTRODUCTION

It has always been clear that weather information has a value, and the improvements in meteorological science over recent decades have enabled forecasts of longer range and greater certainty, augmenting the value of weather information considerably. In approaching the question of placing a value on meteorological services, the work of Freebairn and Zillman provides a useful framework, dividing weather information into "Public Goods" and "Private Goods", with the intervening category of "Mixed Goods" relating to products and services which can be either "Public" or "Private", depending upon context or indeed upon national economic policy.

"Public Goods" and "Private Goods"

The value of weather products and services in the "Private Goods" category is clearly defined by what the market is willing to pay. This category encompasses bespoke weather services whereby specific weather information is sought by and provided to businesses that have very particular needs. It is a characteristic of such services that they are only provided to those who are willing to pay for them; they are not put into the public arena. This paper will concern itself with the category of "Public Goods"; that is, weather products and services which are made freely available to the end-user at the point of use (although there may well be contractual elements in the provision of such services, e.g. between weather providers and broadcast companies).

The key qualities of "Public Goods", according to Freebairn and Zillman , are defined by reference to the qualities of **Rivalry of Consumption** and **Costs of Exclusion**. The first quality is centred around the concept of whether the consumption of a product or service by Person A can affect the subsequent consumption of the same product or service by Person B. Weather information which has been put into the public arena clearly has no **Rivalry of Consumption**; one person hearing this information, and putting it to use in making a decision, has no impact on the subsequent use of the same information by a second person. The quality of **Costs of Exclusion** is based around the idea of whether or not one can readily prevent "free riders" (those who have not paid) from benefiting from a product or service. Again, in the case of weather information in the public arena, there is no possibility of limiting its use by any specific person or persons.

The Weather "Value Chain"

The value of a weather information product or service is the end-point of a "Value Chain" which stretches from weather observations through Information Technology (IT) communication and database systems, the forecast systems / Numerical Weather Prediction (NWP), the forecasters themselves, through the mechanism of delivery and presentation to the end-users. Each of the technical elements of the chain has a specific associated cost, but in reality the value of the system derives from the whole. It does not therefore seem to make much sense to try and attribute specific value to any particular technical element of the weather information chain, but to group these elements together into a kind of "black box" and focus instead on the value added at the presentation / delivery stage. From the fact that weather information in the public arena has no property of **Rivalry of Consumption**, it is clear that the benefit of the weather information to society will only be maximised when the greatest number of people possible receive that information and act upon it when making decisions. This implies that the effective presentation and communication of weather information is an intrinsic element in maximising the overall benefit – or value – of weather information to society. To put it another way, good communication of weather information can multiply its societal value in a manner which would be very difficult to achieve by, say, augmenting the observational network or improving the NWP models.

Different Kinds of Value

Before we go on to consider the value of weather information, we need to ask – what kind of value? For the purposes of this paper we will consider three distinct types of value:

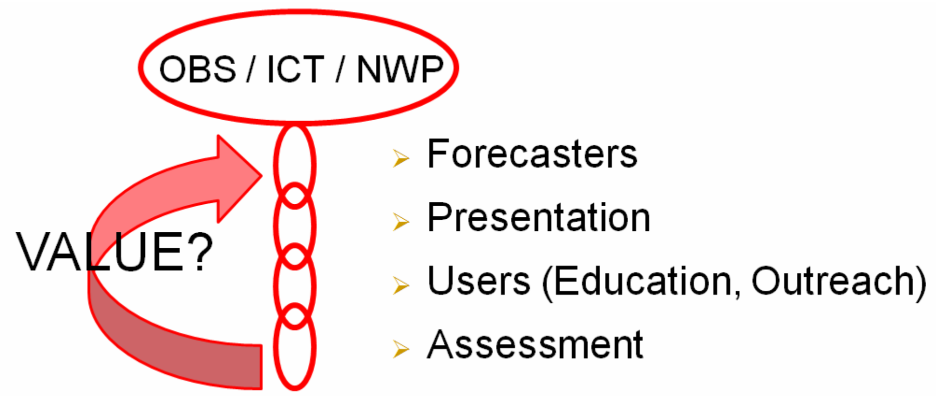
1. Value of weather information to society (the broadest definition);

2. "Brand Value" of weather information to National Meteorological and Hydrological Services (NMHSs) (what does the institution gain in value?); and,

3. Value in respect of the NMHSs' "Public Mission".

The latter two definitions are linked, but not identical. All NMHSs have a mission, usually defined around protecting the lives and property of the citizens. Suppose that a Meteorological Services issues a warning of imminent severe weather. This warning may be picked up and broadcast by a Television (TV) or radio station and transmitted to the public without any attribution to the Service. The "Brand Value" of the warning to the Service is thus zero, but the value in terms of the "Public Mission" of the Service may still be considerable if those who hear the warnings heed them and take appropriate action to mitigate the risk.

There is also a value implicit in the ability of users to understand and appreciate weather forecasts and warnings. A population which is well-educated in meteorological matters will derive greater benefit from weather information. Thus, the value of the presentation of weather information must include some element to reflect the public education and outreach activities that NMHSs might conduct, with a view to helping the public react appropriately to forecasts and warnings. A public that is engaged with its Meteorological Service through a process of assessment and feedback will also probably gain greater value from weather information, both routine and severe, so this is another part of the "Weather Presentation Value Chain" that may need to be considered. The different and distinct elements of the "Presentation Value Chain" are indicated below.



Broadcast Weather – TV and Radio

The presentation of weather information through broadcast media follows different models of operation, which flow from different legal imperatives, different broadast cultures, and sometimes nothing more than the relationship (good or bad) between the NMHSs and the broadcasters. One of the first aspects to examine is whether the weather broadast is really about the transmission of weather information, or is it primarily about the presenters ego, with the weather information merely in a supporting role. There is nothing wrong with weather presenters having an ego; indeed, it is a necessary trait for any media presenters, but the balance between presenter and content needs to be correct.

That said, good production values can contribute enormously to the successful transmission of weather information through the media. This concept of production values might encompass some or all of the following elements, depending on the medium:

1. Good weather graphics;
2. Quality camera / good lighting;
3. Top-class chroma-keyer;
4. Adequate technical back-up;
5. Wardrobe;
6. Make-up;
7. Scripting quality; and,
8. Voice quality / training.

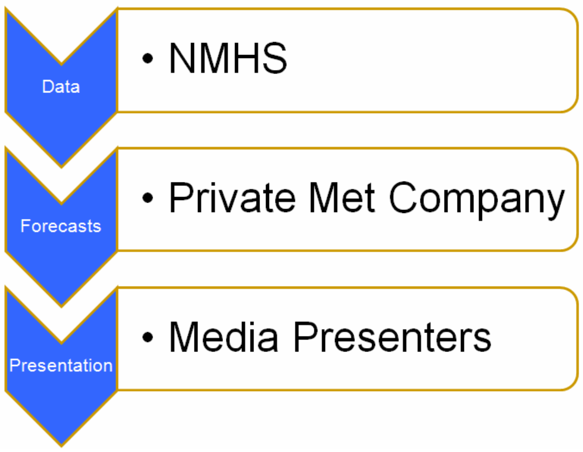
For all of these elements, NMHSs will usually rely on broadcasters; they are not part of the scientific meteorological world, but they can add significant value to the forecast nonetheless.

TV Weather Broadcasts – Different Organizational Scenarios

The arrangements through which weather broadcasts are prepared and presented vary considerably; here we consider four different scenarios which between them encompass most of the organizational structures.

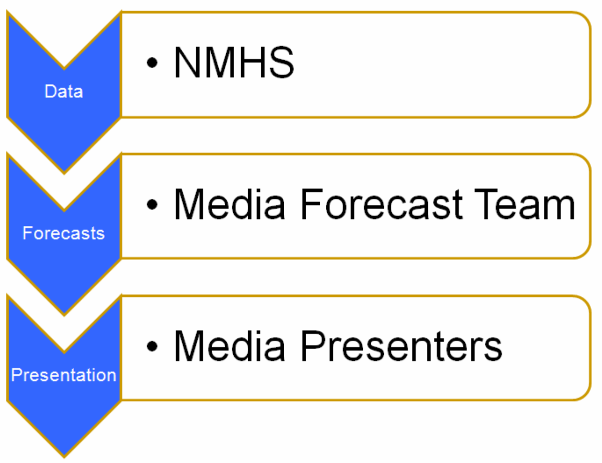
Scenario A

- NMHSs in the background
- Private Met Company between NMHSs and broadcasters
- No NMHSs' logos on-screen
- No NMHSs' recognition
- Official warnings may or may not be broadcast



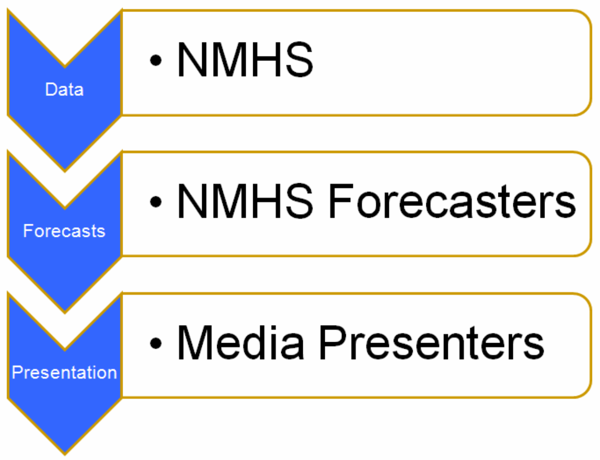
Scenario B

- NMHSs in the background
- Forecasters employed directly by the broadcaster
- No NMHSs’ logos on-screen
- No NMHSs recognition
- Official warnings will probably be broadcast



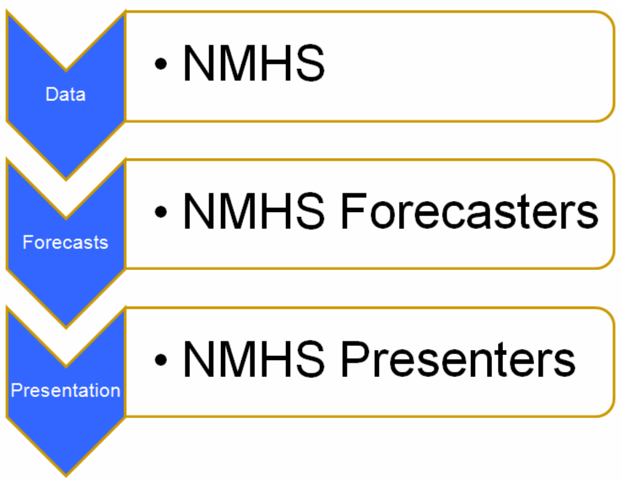
Scenario C

- NMHSs provide weather story
- Forecasters employed by NMHSs
- NMHSs’ logos on-screen
- Some recognition of NMHSs
- Official warnings will be broadcast



Scenario D

- NMHSs' weather story
- Forecasters / presenters employed by NMHSs
- NMHSs’ logos on-screen
- Full recognition of NMHSs
- Official warnings will be broadcast



Scenario D clearly offers the greatest value to NMHSs in terms of "Brand Value" and in terms of value to NMHSs respective missions. All of these scenarios might deliver a service of identical societal value, but the brand and mission related valuations will be different. We will return to these scenario definitions in the analysis below.

Broadcast Weather – Internet

It is a characteristic of the Internet that it enables everyone to be their own "broadcaster"; the set-up costs for web pages can be low, and the medium can support many different types of delivery, from text and still images through to sound, animation and video. However, the production values relevant for TV and radio will also be relevant to the Internet, and if they are absent the resulting service quality will be poor. This will mean that the website will simply not attract an audience. The Web offers nearly everyone the chance to be their own broadcaster, and it is therefore characterised by a vast range of possible sources of weather information, many coming from commercial companies but many also coming from amateur enthusiasts. The challenge for NMHSs on the Web is to attract users, and then to retain them with a site which interests, educates and entertains.

NMHSs will generally offer the information on their websites "free at the point of use"; it is notoriously difficulty to get web users to pay for content directly, as witnessed by the many efforts of newspapers to establish sustainable "pay per view" websites. However, NMHSs may commercialise their websites through sponsorship or through supporting advertisements. If NMHSs choose not to do this, then the costs of developing and maintaining the website must be justified by reference to the core public service mission of NMHSs.

The Value of Broadcast Weather

How does all this help us in our task of putting a value on weather presentation and communication? We could estimate the value of a TV or radio weather bulletin by reference to the advertising rates charged for ads "around" the bulletin. There is some basis for this; more successful TV and radio shows get moved to prime-time slots, and the advertising rates surrounding these shows increases accordingly; however, it would be difficult to create a direct relationship between advertising rates and societal value.

Similarly with the Internet, we could estimate the value of a website in terms of the sponsorship it could attract or the advertising costs which the "market" is willing to pay. In each of these cases, the key point will be the audience numbers. All broadcast values relate directly to audience size, and this relationship should hold also for weather bulletins - the more people see or hear them, the greater the value transferred to society.

A Different Approach

There are a number of studies in the literature which have attempted to estimate the total value of weather forecasts and warnings to society. The methodology has generally been through the conduct of a survey of representative numbers of the public, with questions as to how people access weather information and what they would be prepared to pay for the services they receive. These "Willingness To Pay" (WTP) studies have thrown up a range of values; for the purposes of this paper we will refer to the values and numbers in *Lazo et al, BAMS, June 2009)*. This paper reported on a WTP study and estimated the total societal value of weather information in the US to be $31.5 billion per annum. The paper also estimated the number of times annually a forecast or warning was received (we might use the word consumed) in the U.S. at 300 billion. Putting these figures together, we arrive at an estimate of 10 cents per forecast consumed. It is acknowledged that these figures can only be rough estimates; we might think of them primarily in terms of an "order of magnitude".

Based on this estimate, we can say that the total societal value of a weather broadcast is simply the value per forecast consumed multiplied by the audience numbers. Thus, a TV weather bulletin viewed by 700,000 people would have a societal value of USD $70,000 (or Euros €70,000 – given the broad uncertainty in the estimates the currency conversion factor is minimal). What about weather broadcast through different media? Should we apply a weighting factor to account for the differing power of different media? TV has graphics; radio only has voice; the internet is a busy place with many competing sites; newspapers are always out-of-date in that the forecast is generally 12-18 hours old when it hits the street. Weighting factors would need to be estimated for each individual country, and the weights thus estimated supported through analysis, but they might look something like this:

- TV: 1.0
- Radio: 0.6
- Web: 0.4
- Newspapers: 0.1

"Brand Value" to NMHSs

The valuations estimated in the section above relate to total societal value; if we want to estimate "Brand Value" to NMHSs then we need to carry the analysis somewhat further. The four scenarios defined earlier outlined four common organizational arrangements for the TV presentation of broadcast weather. Using these scenarios, we might introduce a second list of weighting factors to reflect the different brand values to the NMHSs:

- Scenario A: 0.10
- Scenario B: 0.15
- Scenario C: 0.30
- Scenario D: 0.40

Even in Scenario D, the primary "Brand Value" of the weather broadcast will be to the broadcaster itself; the Service would do well to achieve even 40% per cent of the total societal value of the weather presentation as a "Brand Value". These points have relevance in the real world. In the case where a Meteorological Service has a contract with a broadcaster to provide weather information / forecasts, there will be a contract cost. However, this contract cost relates only to the value of the weather information / forecast service to the broadcaster; the broadcaster will pay for the value it perceives to be getting. There may well, however be, an additional "Brand Value" to NMHSs themselves and this is almost never reflected in the contract cost. Thus, the total value of the service might be estimated as the sum of the contract cost and the "Brand Value" garnered by NMHSs.

"Value" to NMHSs' Missions

As mentioned above, the concept of "Value" to the missions of NMHSs is quite different to the concept of their "Brand Values". The "Value" to the mission is closely related to the ability of the Service to get the official forecast and warnings services to the public, and is not related to the perception of the public as to the source of the information. In these terms, the weighting factors above will need to be adjusted; the following terms might be suggested:

- Scenario A: 0.05
- Scenario B: 0.20
- Scenario C: 0.80
- Scenario D: 1.00

These numbers try to relate the value of the forecast presentation to the core missions of the NMHSs.

Different Measures of "Value"

We can see from this analysis that the concept of "Value" is closely linked to context. Market-price arrangements are clearly a crude and unsuitable tool with which to estimate the societal value of "Public Goods" such as weather information transmitted through broadcasts. To clarify the analysis above, we can consider again the case of the forecast, valued at 10 cents per individual consumption, and viewed by an audience of 700,000.

- Total "Value" to society is simply 10 cents X 700,00, or $70,000;
- "Brand Value" to NMHSs would be 40% per cent of societal value, or $28,000, if the forecast was delivered through TV under Scenario D arrangements;
- "Value" to the mission of NMHSs might be as high as $70,000 (TV, Scenario D) or as low as $3,500 (TV, Scenario A). The "Value" might be even lower if delivery were through the Internet or via newspapers.

CONCLUSIONS

The figures above are only illustrative; the aim of this paper is to outline a possible methodology for calculating the value of weather forecasts as presented in the media. It is clear that a lot of value can be gained or lost in the communications process. It is equally clear that the concept of the value of broadcast weather is a complex one, and relates not just to the different media but to the different arrangements that underlie the delivery and presentation of the weather information. If one is to ask "What is the value of a weather broadcast", the answer you get will depend very much on how you define the term "Value" – is it total value to society, value to the public missions of NMHSs, or "Brand Value" to NMHSs as organizations?

Despite these differences – or perhaps because of them – it would be of great benefit to have some rigorous economic surveys carried out to examine the value of weather broadcasts, if possible across a range of countries and contexts. It is clear that many NMHSs value their access to media, and through media to end-users, primarily in terms of the "visibility" provided to the organization – either the "Brand Value", the "Value" to NMHSs missions, or some combination of these. The generation of monetary values around these concepts would be of tremendous help to NMHSs, and would, in all likelihood, raise the profile of the importance of good communication and presentation of weather information, leading to a greater investment of resources in these key elements of the forecast chain.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_GFleming_Media.pdf

Mr Stéphane Hallegatte
The World Bank, Sustainable Development Network,
Ecole Nationale de la Météorologie, Météo-France and
Centre International de Recherche sur l'Environnement et le Développement
E-mail: hallegatte@centre-cired.fr

Speaker: Ing. Laurent Perron
International affairs, Météo-France
E-mail: laurent.perron@meteo.fr

THE VALUE OF HYDRO-METEOROLOGICAL INFORMATION

Hydro-meteorological information – including observations and forecasts at various time horizons – is used by almost all individuals and businesses. It is, however, extremely difficult to assess the social benefits derived from this information. First, each individual or business uses this information in a very specific way, making any comprehensive assessment impossible. Second, this information provides many non-market benefits, which are difficult to assess in the absence of observable prices and Willingness-To-Pay (WTP). To provide insight into these benefits, this note proposes an identification of benefit categories, organized according to the considered time horizon and the information user. In the case of France, it also estimates orders of magnitude for the corresponding benefits. This note suggests that the value of hydro-meteorological information in France lies between 1 and 8 billion Euros per year, i.e., between 4 and 30 times the cost of producing it. This is then followed by discussions of the economics of hydro-meteorological information.

NOW-CASTING AND SHORT TO MEDIUM TERM FORECASTS

Now-casting (from 0 to 6 hours), short-term forecasts (up to 3 days) and medium-term forecasts (up to 15 days) have three main applications: early warning for safety and prevention; private use by individuals; and optimization of economic production.

Early warnings for safety and prevention

Now-casting and short-term forecasts with time horizons up to a few days allow the anticipation and preparation for extreme events like heat waves, cold spells, windstorms, thunderstorms and floods. Corresponding benefits can be distributed in two broad categories: the protection of persons and assets (prevention) and emergency preparation.

Early warnings allow for the protection of persons and assets in many ways. Individuals can for instance avoid road trips when floods are forecasted, move vehicles out of flood zones, and implement mitigation actions (e.g., sandbagging). Organizations and businesses can do the same. For instance, schools and businesses can be closed to avoid unnecessary trips and risks. In case of intense events, evacuation is also possible.

Benefits of early warning can be large. In terms of assets, preparing a house before a hurricane (e.g., by draught proofing, blocking of windows to prevent a draft windows) can reduce damages by up to 50%.[5] A study in Germany[6] shows that in residential areas, one third of damages affects movable content, i.e., the house content that can be saved thanks to early warning by being moved out of vulnerable places (e.g., moved to the second floor). This

[5] Williams, B. A., 2002: *Fran, Floyd and mitigation policy*, Berry A. Williams and Associates, Inc.

[6] Merz, B., Kreibich, H., Thieken, A. & Schmidtke, R. (2004) Estimation uncertainty of direct monetary flood damage to buildings, *Natural Hazards And Earth System Sciences*, Vol. 4, 153-163.

proportion is only 10% in the case of infrastructure, but grows to 60% in services and 80% in the manufacturing sector.

According to Thieken et al.[7], a study on the Elbe and Danube floods in 2002 showed that 31% of the population of flooded areas implemented preventive measures. These measures included moving goods to the second floor of buildings (applied by more than 50% of the inhabitants who implemented prevention measures), moving vehicles outside the flood zone (more than 40%), protecting important documents and valuables (more than 30%), shutting down electricity and gas and unplugging electrical appliances (more than 25%) and installing water pumps (between 2 and 10%). For the 2002 floods, it has been estimated[8] that the warning and the following prevention measures reduced flood costs by about 6%.

Among the inhabitants who did not implement any measure, 65% said that they had been informed too late and that about 20% said they were not at home and could not do anything. For this population, it seems that an earlier warning would have allowed a better preparation and lower damages.

There is also a large potential benefit of early warning for businesses. The International Commission for the Protection of the Rhine[9] estimated that 50 to 75% of flood losses could be avoided thanks to emergency preparation measures. For instance, moving toxic materials and chemicals to safe places prevents local pollution (such as observed after hurricane Katrina flooded New Orleans). Machines and equipment can also be moved to avoid damages.

This potential benefit is, however, not easy to realize, especially because of the difficulty to communicate the warning. According to Kreibich et al.[10], 45% of businesses did not receive the warning from the authorities before the 2002 flood in Saxony, even though this warning was issued 20 hours before the flood occurred.

In spite of this problem, almost 70% of all businesses implemented emergency prevention measures, often thanks to informal contacts that helped disseminate the warning. According to this study, 7% of all equipment was fully protected, and 75% partially protected, thanks to these preventative measures. Concerning inventories and production, 10% could be fully protected, and 70% partially protected. The study shows that the warning timing was critical: businesses that protected their equipment or inventories were those that received the warning early enough.

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[7] Thieken, A.H., Kreibich, H., Muller, M. & Merz, B. (2007) Coping With Floods: Preparedness, Response And Recovery Of Flood-Affected Residents In Germany In 2002, *Hydrological Sciences*, 52, (5), October, 1016-1037.

Thieken, A. H., Petrow, Th., Kreibich, H. & Merz, B. (2006) Insurability And Mitigation Of Flood Losses In Private Households In Germany. *Risk Analysis* 26(2), 383–395.

Thieken, A.H., Muller, M., Kreibich, H. & Merz, B. (2005) Flood Damage And Influencing Factors: New Insights From The August 2002 Flood In Germany, *Water Resources Research*, Vol. 41, 1-16.

Kreibich, H., Thieken, A.H., Petrow, T.H., Muller, M. & Merz, B. (2005) Flood Loss Reduction Of Private Households Due To Building Precautionary Measures – Lessons Learned From The Elbe Flood In August 2002, *Natural Hazards And Earth Systems Sciences*, Vol. 5, 117-126.

[8] Tapsell et al., 2008, Modelling the damage reducing effects of flood warnings, Final report of the FLOODsite project, available on www.floodsite.net.

[9] International Commission For The Protection Of The Rhine (2002). *Non Structural Flood Plain Management – Measures And Their Effectiveness*, ICPR, Koblenz, 2002.

[10] Kreibich, H., Muller, M., Thieken, A.H. & Merz, B. (2007) Flood Precaution Of Companies And Their Ability To Cope With The Flood In August 2002 In Saxony, Germany, *Water Resources Research,* Vol. 43, (3) 1-15.

Finally, according to Carsell[11], a warning issued 48 hours before a flood allows reducing overall damages by more than 50%. According to the French insurers' organization (FFSA), floods cost them on average 500 million Euros per year in France[12]. It is estimated that non-insured damages are also about 500 million Euros per year. Assuming that the warning reduces losses by 10%, and if only half of the floods are forecasted, the benefits from early warnings could reach 50 million Euros per year. Using Carsell's estimate, and assuming that 75% of the floods can be forecasted, benefits would reach 400 million Euros per year[13].

Storms in France have cost on average about 900 million Euros per year between 1988 and 2007. If weather forecasts help reduce these losses by 10% or by 50% – thanks to the same actions as for floods – the corresponding gains lie between 90 and 450 million Euros per year. For floods and storms, the total could thus lie between 140 and 850 million per year.

It is more difficult to produce an economic estimate for individual safety. There are many weather-related threats to safety in France, such as the floods in the South of France (e.g., Nîmes in 1988 or in the Gars in 2002), winter storms (e.g., 1999 storms Lothar and Martin), heat waves (e.g., the 2003 summer) and cold spells (e.g., 1984-1985), and avalanches (e.g., in les Orres in 1998).

Severe winter-storms have a return period of about 10 years and often lead to dozens of casualties (e.g., 66 deaths in 1990, 47 in 1992 and 92 in 1999). Floods in the South of France also have a return period of about 10 years and provoke a few or a few tens of casualties when they occur. The 2003 heat wave caused about 15,000 deaths in France only, and the one in 2006 led to about 2,000 deaths. Avalanches cause on average 32 deaths per year, out of 4.5 million ski tourists[14].

It is difficult to assess how many lives are saved through prevention and early warnings each year, even though local actors consider these tools critical to ensure population safety. Examples of countries where early warning is considered seriously and where prevention emergency actions are well organized (e.g., Cuba) show that casualties can approach zero, except for really exceptional events.

Other cases need also to be considered, like technological catastrophes (accident in a chemical plant or a nuclear plant). In these cases, the capacity to forecast winds, and thus the trajectory of the contamination cloud, can easily save hundreds of lives. The need to predict the trajectory of radioactive leaks was recently illustrated in Japan by the Fukushima nuclear accident. Even though the likelihood for using this capacity is fortunately very small, avoided damages can be so large that this possibility needs to be accounted for in the social value of forecast capacities.

Even in non-extreme situations, hydro-meteorological information plays a large safety role in many activities linked to the sea (e.g., sailing), to mountains (e.g., hiking, skiing), and other outdoor activities. Specialized services help thousands of people avoid being surprised at sea by a storm. These services have a large audience and probably help avoid hundreds of accidents each year.

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[11] Carsell, K.M., N. D. Pingel, D.T. Ford, 2004: Quantifying the Benefit of a Flood Warning System. *Nat. Hazards Rev*, **5**(3), 131–140

[12] FFSA, Synthèse de l'étude relative à l'impact du changement climatique et de l'aménagement du territoire sur la survenance d'événements naturels en France available, on www.ffsa.fr, accessed on June 22, 2011.

[13] We assume here that false alarms have no cost, which is not the case, especially in case of large scale evacuations.

[14] Source : Dossier d'information « Avalanche » du Ministère de l'Aménagement du Territoire et de l'Environnement, 2000, available on http://www.prim.net.fr.

Even more importantly, this information is used for maritime and air transport.[15] For their optimal safety, these operations need detailed weather information. For instance, it is unlikely that passenger air travel could be safe enough to be commercially viable in its current form in the absence of meteorological information.

Another value of forecasts is the possibility to prepare emergency services before an event occurs. During the few hours before an intense weather event, much can be done to increase the efficiency of emergency services. For instance, during the 2002 floods in the Gard, 22 out of the 26 French helicopters able to do rescue airlifts were pre-positioned in the flood area, thanks to weather forecasts. According to local emergency services, this pre-positioning saved about one hundred lives, compared with a situation in which it would have taken hours to move helicopters to the affected areas. In Nîmes, some of the emergency services are located in the flood zone. In 1988, they were flooded and could not intervene during the emergency. Since then, emergency services have been moved to safer areas when floods are forecasted, to avoid a repetition of this situation.

Taking into account these numbers, one can assume that hydro-meteorological information saves at least 100 lives per year, which is a very conservative estimate. Using a value of 1 million Euros per human life as the "statistical value of a human life" as used in the "Boiteux" Report on the transport sector[16], the corresponding benefits can be estimated at 100 million Euros per year. Assuming that 500 lives are saved, this value would reach 500 million Euros per year.

It is important to stress that the benefits from forecasts depend largely and nonlinearly on their accuracy, and that threshold effects are important. For instance, if it were possible to predict flash-floods exactly, including their localization, it would be possible to evacuate the at-risk area, and reduce human losses to zero without any expensive investment in flood protection. But an evacuation cannot be decided if the probability of false alarm is too high (or if the warning area is too large). After only a few evacuations based on false alarms, the trust in the warning system is likely to disappear, and the warning system becomes useless. This problem is illustrated by the case of New Orleans, which had been evacuated twice previously on the basis of false alarms (hurricane George in 1998 and Ivan in 2004), making it more difficult to convince inhabitants to leave before hurricane Katrina struck. A limited improvement in forecast accuracy can thus lead to a large increase in social benefits, if the risk of false alarm becomes low enough to create and maintain trust and allow for significant prevention measures before emergencies.

Private use by individuals

Measuring the value of the private use of forecasts is difficult. It means measuring the WTP of users for meteorological services and information. Knowing if one can go for a picnic without risking heavy rain has a value; being able to decide a few hours in advance if a dinner can be organized outside or inside has a value; deciding whether to take an umbrella when leaving for work in the morning has a value. Each of these values remains small, but these decisions happen all the time and millions of people are making them. The aggregated value may thus be significant.

Stratus Consulting (Boulder, USA) conducted a survey of U.S. households for the National Oceanic and Atmospheric Administration (NOAA), to estimate their WTP for the weather information that is currently provided to them, and for potential improvement of this information.[17]

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[15] According to the « Bureau Enquête Accident », 7.5% of plane accident have meteorological causes (http://www.bea-fr.org/etudes/stat9798/stats1997-1998.htm)

16 Instruction Cadre relative aux méthodes d'évaluation économique des grands projets d'infrastructure, 2005, http://www.statistiques.equipement.gouv.fr/IMG/pdf/Instruction_cadre_maj_2005_cle147216.pdf

[17] Stratus Consulting, Jeffrey Lazo, Economic Value of Current and Improved Weather Forecasts in the U.S. Household Sector, November 22, 2002

The survey focused on normal conditions, and excluded extreme events and safety aspect from the analysis, so there is no double counting with the previous section. The survey arrived at a median estimate of US $109 per year and per household, with 86% of households ready to pay more than $ 10 and 80% more than $ 32.

Assuming that each French household is ready to pay at least 20 Euros per year, again a conservative estimate, the social benefit from weather information would be around 500 million Euros per year. WTP 80 Euros pushes the estimate reach 2 billion Euros.

Optimizing economic production

Hydro-meteorological information is widely used by industries and businesses to optimize their activities. Electricity producers use it to anticipate demand for electricity as a function of temperature, wind, etc., but also to forecast their production capacity, especially where renewable energies play a large role. Farmers and agro-businesses use it to decide on planting and harvest dates, on how to use fertilizers and other inputs, and on preventive measures in case of floods or heavy precipitations. Leisure businesses use weather forecasts to anticipate the number of clients, and to adjust their workforce. The textile industry and distributors use it to manage inventories, since many sales are found to depend significantly on weather conditions. The construction sector uses it to manage construction site, ensure worker safety, and maximize building resistance, which for example depends on weather conditions when the concrete is poured.

In all these sectors, weather forecasts increase productivity. Their use is growing worldwide, with many new businesses taking this information into account. It is useful to distinguish the social benefits that are currently extracted from hydro-meteorological information from the potential social benefits that could be extracted if this information was used to its full potential. The latter is likely to be much higher than the former.

To estimate the orders of magnitude at stake in France, one can start from the economic value added in those sectors considered as sensitive to weather conditions. In the case of agriculture, it is 34 billion Euros; for agro-business, it is 28,2 billion Euros; for energy, it is 32,5 billion Euros; for construction, it is 69,7 billion Euros; and for transport, it is 64.0 billion Euros. These sensitive sectors create more than 220 billion Euros per year for the French economy.

In the agricultural sector, a few studies assessed the productivity gains from short to medium-term weather forecasts. For instance, Wills et Wolfe[18] looked at the use of forecasts to optimize lettuce production in the state of New York, and found a $900 to $1000 gain per hectare and per year, i.e., a 10% increase in productivity.

In the energy sector, Roulston et al.[19] estimated the value of weather information to optimize wind power production and found a doubling in profits thanks to 1 and 2-day forecasts.

In the transport sector, a study by Leigh[20] estimated benefits from weather information at the Sydney airport, and found a benefit of 6.9 millions of Australian dollars (about 5 million USD) per year.

[18] Wilks, D.S. and Wolfe, D.W. (1998). Optimal use and economic value of weather forecasts for lettuce irrigation in a humid climate.*Agricultural and Forest Meteorology*, **89**, 115-130.

[19] Roulston, M.S., Kaplan, D.T., Hardenberg, J. and Smith, L.A. (2003). Using medium-range weather forecasts to improve the value of wind energy production. *Renewable Energy*, **28**, 585-602

[20] Leigh, R.J. (1995). Economic benefits of Terminal Aerodrome Forecasts (TAFs) for Sydney Airport, Australia. *Meteorological Applications*, **2**, 239-247.

In these few examples, a significant impact of weather information on productivity is observed.[21] Assuming that weather forecasts lead to value added gains between 0.1 and 1%, the corresponding value of this information would lie between 220 million and 2.2 billion Euros per year.

THE VALUE OF MONTHLY AND SEASONAL FORECASTS

Monthly and seasonal forecasts are still in their early stages, and accuracy remains limited in most regions of the world, including Europe. However, the potential for economic gains is huge.

Using the 2003 heat wave as an example, one can imagine potential preventative actions that could have been implemented with the availability of reliable seasonal forecasts. Farmers could have chosen crops that are less sensitive to water availability and high temperatures; water managers could have made sure that water reservoirs were full before the summer; water consumption restriction could have been anticipated to reduce the summer water stress (including biodiversity losses); electricity producers could have changed their maintenance planning to make sure that plants using sea water (and thus not dependent on river runoff) were operational during the summer; hospitals could have modified the vacation planning to make sure sufficient workforce were present during the heat wave; etc. Avoided losses would have been very large.

Seasonal forecasts could be used on a regular basis to manage water reservoirs and dams, to anticipate water use conflicts (between agriculture, electric production, domestic use and industrial use, but also between regions or countries[22]), and in agriculture.

Studies have been carried out in the agricultural sector, in particular using El Niño/Southern Oscillation (ENSO) forecasts. Meza et al.[23] offer a recent review of the growing literature that assesses the economic value of ENSO prediction (either a perfect prediction or a realistic one). These estimations lie between no-impact (for winter wheat in Ohio[24]) to US$ 700 per hectare (for tomatoes in South Florida[25]). Medje et Penson[26] investigated the value of a perfect seasonal forecast for corn production in the U.S. Corn belt (Illinois, Iowa, Indiana and Ohio) and found a value ranging between $1.3 and $2.9 billion over 10 years, i.e. between 0.9 and 2% of total production value. Hammer et al.[27] estimated the value of current seasonal forecasts for the

[21] It is important to acknowledge the risk of bias in the literature, published studies being the ones that find a significant impact of weather information on economic activity. To my knowledge, no paper has been published on *a lack* of such impact.

[22] The use of seasonal forecasts to manage the Sénégal river thanks to seasonal forecasts by the Organisation pour la Mise en Valeur du fleuve Sénégal (OMVS) is illustrative of what could be generalized.

[23] Meza, F.J., J.W. Hansen, and D. Osgood, 2008, Economic value of seasonal climate forecasts for agriculture: review of ex-ante assessments and recommendations for future research, *Journal of Applied Meteorology and Climatology*, 47, 1269-1286

[24] Hill, H.S.J., J. Park, J. W. Mjelde, W. Rosenthal, H. A. Love, and S. W. Fuller, 2000: Comparing the value of Southern Oscillation index-based climate forecast methods for Canadian and US wheat producers. *Agric. For. Meteor.,* **100,** 261–272.

[25] Messina, C., D. Letson, and J. W. Jones, 2006: Tailoring management of tomato production to ENSO phase at different scales in Florida. *Trans. ASABE,* **49,** 1993–2003

[26] Mjelde, J.W., and Penson, J.B. (2000). Dynamic aspects of the impact of the use of perfect climate forecasts in the Corn Belt region. *Journal of Applied Meteorology*, **39**, 67-79.

[27] Hammer, G.L., Holzworth, D.P., and Stone, R. (1996). The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. *Australian Journal of Agricultural Research*, **47**, 717-737.

production of wheat in Australia, and found a 20% increase in profit, and a 35% reduction in risk. Solow et al.[28] estimated the value of the current ENSO forecasts in the agricultural sector in the U.S. at $200 million per year (i.e., $1.57 per hectare) and that of a perfect forecast at more than $300 million. Considering the overall value added in the US agriculture sector, it corresponds to a 0.25% gain.

In the energy sector, Hamlet et al.[29] show that using a perfect ENSO forecast in the management of a hydroelectric dam in over the Columbia River in the U.S. would bring gains amounting to $40 to $150 million dollars per year, for a total production of $1.4 billion, i.e., a gain of between 3 and 10%.

If these forecasts were accurate enough, they could even be used by oil companies to forecast demand and prices, and to manage their inventories; they could be used by tourists to choose their destination, and by the tourism sector to anticipate tourist fluxes. These types of benefits are difficult to assess, but they are real.

These few studies identify – in precise cases – sources of large potential benefits. If these benefits could be captured – it is unlikely to be the case today – the value of these forecasts would be significant. Increasing value added by between 0.1 and 1% in the agriculture and energy sectors would bring benefits amounting to between 66 and 660 million Euros per year.

In developing countries, seasonal forecasts would also allow anticipate food security crises (e.g., in case of drought) and epidemics (e.g., malaria), allowing for prevention measures to be implemented, and for a more timely emergency response.

VALUES OF CLIMATE SCENARIOS AND PROJECTIONS

The value of long-term climate information is not well recognized yet. This is likely to change over the following decades, when the need for climate policy actions will become more evident. It is difficult to quantify the value of this information, but two components can be identified: one is the role of climate information in deciding about greenhouse gas emission reduction targets; the other is the role of climate information for infrastructure and land-use planning decisions.

The cost of greenhouse gas emission reductions to stabilize climate change is estimated at up to several percentage points of GDP. In parallel, the cost of inaction is estimated around the same orders of magnitude, even though very optimistic scenarios (i.e., negative cost) and very pessimistic scenarios (i.e., catastrophic impact on welfare) co-exist. Confronted with these two very large costs, policy decisions need to be made with the best available information. The potential cost of a bad surprise on how climate reacts to greenhouse gas emissions is sufficient to justify very significant investments in climate research. Unsurprisingly, policy-makers in many countries have responded to this need with an increase in public support to this research.

Concerning adaptation to a changing climate, many decisions should already be altered by climate change projections.[30] This is the case in sectors that are climate sensitive and where decisions have consequences over many decades (see Table 1). Building norms, electricity production and distribution infrastructures, flood protection, transport infrastructures, urban

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[28] Solow, A.R., Adams, R.F., Bryant, K.J., Legler, D.M., O'Brien, J.J., McCarl, B.A., Nayda, W., and Weiher, R. (1998). The value of improved ENSO prediction to U.S. agriculture. *Climatic Change*, **39**, 47-60.

[29] Hamlet, A.F., Huppert, D., and Lettenmaier, D.P. (2002). Economic value of long-lead streamflow forecasts for Columbia River hydropower. *Journal of Water Resources Planning and Management*, **128**, 91-101.

[30] Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change, *Global Environmental Change*, 19, 240-247.

planning, and many other decisions require climate information that now needs to include anthropogenic climate change information.

It can be shown that an inappropriate policy in terms of building norms could easily lead in unfavourable cases to adaptation spending equal to several percentage points of the GDP. Such spending can be avoided thanks to an anticipation of adaptation needs, such that capital can be adapted along its natural turn-over with no or little need for retrofit or capital early retirement.[31] Since adaptation costs could easily reach several tens of billions U.S. dollar per year at the global scale[32], ensuring that these investments are as efficient as possible is critical and could easily save billions of dollars in avoided retrofit needs.

Sector:	**Time scale:**	**Exposure:**
Water infrastructures (e.g., dams, reservoirs)	30–200 yr	+ + +
Land-use planning (e.g., in flood plain or coastal areas)	>100 yr	+ + +
Coastline and flood defences (e.g., dikes, sea walls)	>50 yr	+ + +
Building and housing (e.g., insulation, windows)	30–150 yr	+ +
Transportation infrastructure (e.g., ports, bridges)	30–200 yr	+
Urbanism (e.g., urban density, parks)	>100yr	+
Energy production (e.g., nuclear plant cooling system)	20–70 yr	+

Table 1: List of sectors in which climate change should already be taken into account, because of their investment time scales and their exposure to climate conditions. In this table, exposure is estimated empirically by the author.

As an illustration, in France, infrastructure capital stock (including housing) is at least worth 200% of GDP. If inappropriate climate information leads to the need to retrofit 1% of this stock per year over the next century, the total cost would be a 2% consumption decrease, i.e., a consumption loss of 30 billion Euros per year. Even if this retrofit need appears only in 2050, and with a 7% discount rate, this sum represents a net present value of 65 billion Euros, or an annual cost of 3 billion Euros per year.

The financial amounts at stake for climate change mitigation and adaptation are large and could reach several tens of billions of Euros per year in France in this century. It is likely that accurate information on future climate change, associated with efficient detection and attribution techniques, could easily allow for large savings on the cost of adaptation. A very conservative estimate is to assume that it corresponds to a gain of 100 million Euros per year; a more likely estimate is a gain of more than one billion Euros per year.

VALUE OF HYDRO-METEOROLOGICAL OBSERVATIONS

All of the above services depend on having good observations. Good observations are indeed the first requirement for good forecasts. Forecasting models need an initial state that is determined using as many observations as possible. These models are calibrated, validated, and improved thanks to a systematic comparison with observation. High-quality observations are thus a pre-requisite for high-quality forecasts.

The validation issue is particularly important for climate change: today one half of the climate models project a decrease in precipitations over West Africa, while the other half project an increase. Only observations will allow discriminating between these models, to know which trend

[31] *see Hallegatte, Hourcade et Ambrosi, Using Climate Analogues for Assessing Climate Change Economic Impacts in Urban Areas,* Climatic Change*, 2007, http://www.centre-cired.fr/forum/article238.html.*

[32] World Bank, 2009, The Economics of Adaptation to Climate Change, The World Bank.

is correct. More generally, progress in the climate science is highly dependent on the availability of new observations.

New products and services will require new observations, and new investments in observations. It would be very useful, for instance, to know more about the climate of the next decades, but natural variability will play a large role in determining this climate. Decadal prediction systems, which aim at predicting climate variability over 10 or 20 years, are dependent on a good initialization, but these systems do not need only atmospheric data, like the short-term weather forecasting models; they also need data on the ocean structure, which are very scarce today. It is very unlikely that reliable decadal predictions will become possible in the absence of new investments in ocean observation systems.

Considering the uncertainty in future climates, it is moreover crucial to intensify our monitoring of the climate system. If one mechanism has been missed by climate models, be it responsible for the amplification or the dampening of climate change, it is necessary to detect it as soon as possible to adjust mitigation and adaptation policies.

Hydro-meteorological observations are not only used in the hydro-meteorological domain. They are used by other scientific disciplines (e.g., biology, ecology). They are also used by economic actors: when a business uses weather forecasts to anticipate future sales, it does so by first investigating how sales in the past varied as a function of weather conditions. Without an easy and cheap access to hydro-meteorological information, this type of analysis, and the benefits that correspond, would be impossible.

One can claim, therefore, that observations are a requirement for all benefits that were discussed in the other sections, and that most of their value has also been included in previous estimates. To avoid double counting, no direct benefit is attributed to observation in this assessment, but it needs to be reminded that observations represent the basis on which everything else is built.

KNOWLEDGE SPILL-OVER

The production of hydro-meteorological information is a mix of infrastructure management and high-tech production. Many innovations – for instance in intensive computing or in fluid dynamics – have been developed to answer the modeling needs of the hydro-meteorological community, and are now used in many other domains.

The Japanese «Earth Simulator» super-computer has been financed to improve climate simulation but it is also a research project to improve computer power. The Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (CERFACS) proposes to industries (e.g., car engine developers) knowledge in terms of modeling and computing, creating knowledge spill-overs from the hydro-meteorological activity to other industries. These benefits cannot be estimated in monetary terms, but may be significant.

SUMMARY

This note emphasizes the difficulty of assessing the socio-economic value of hydro-meteorological information. But, it shows that this information is widely used, by many different actors, from individuals to large companies and governments. It is used to ensure the safety of the population, increase its welfare, increase productivity, economic growth and income.

The total benefits can be estimated with simple and uncertain techniques (see Table 2 below). Back-of-the-envelope calculations suggest that they exceed 1 billion Euros per year, i.e.; 4 times their production cost in France, and probably reach 8 billion Euros per year, i.e., 30 times their production cost. Moreover, the potential for larger benefits exist. Some of these benefits require information users to improve their use of existing information. Other benefits are dependent on the production of new information by hydro-meteorological services.

Time horizon:	Sector:		Minimum:	Likely:
Short to medium-term:	Safety:	Persons:	200	2,250
		Assets:	140	700
	Private Use:		500	2,000
	Production Optimization:		220	2,200
Seasonal:			?	?
Climate change:			100	1,000
Knowledge spill-overs:			?	?
TOTALS:			**1,160**	**8,150**

Table 2: Summary of estimated annual benefits from hydro-meteorological information in France, in million Euros per year.

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* The Power Point Presentation related to this abstract can be located at: ftp://ftp.wmo.int/Documents/PublicWeb/dra/eur/SEB_Conf_Oct2011/presentations/PPT_RA6SEB_S3_Perron_HydrometInfo_MF.pdf

Key Messages and Recommendations

KEY MESSAGES AND RECOMMENDATIONS

1. GENERAL

1. There is increasing interest for Socio-Economic Benefits (SEB) assessments among NHMSs.

2. The use of SEB assessments is increasing in RA VI NHMSs:

   a. user surveys are widely used and could provide input for SEB assessment;

   b. detailed SEB studies have been done by several Members in RA VI; more than 10 Members are also considering to carry out such studies in the near future.

3. To foster and expand SEB studies, general consensus exists among RA VI Members for cooperation in the following areas:

   a. sharing information and experience through a dedicated RA VI mechanism (e.g., a web platform providing access to available information);

   b. harmonization of methodologies and procedures for SEB analyses with possibility for their customization to specific scenarios;

   c. ensuring financial and human resources for SEB studies and analyses.

4. Incentives and pressure for NMHSs to perform SEB studies arise from (among others) competition for public funds and the need for demonstration of effectiveness and usefulness of services.

5. All available assessments show consistently that **benefits of services far outweigh costs**; also, users from different sectors confirm the benefits even if sometimes they are hard to quantify.

6. Value of SEB studies to different users and to NMHSs themselves is eventually realized through:

   a. Avoided cost / augmented benefit;

   b. Branding and improved communication with users and confidence in services.

2. RECOMMENDATIONS ON ELEMENTS OF SEB STUDIES

1. SEB assessment can be done for various purposes and expected outcomes. Understanding and defining these purpose and outcomes affect the choice of the most suitable method.

2. Given the complexity of SEB studies and limitations of resources for conducting them, a simplified approach to such studies is probably a suitable start for most Members.

3. Higher precision or more comprehensiveness of studies may be desirable or required but can drive up the cost of SEB studies.

4. To ensure positive impact on their performance, NMHSs should integrate SEB assessment in their regular planning and management, thus realizing their full benefits.

5. **Value chain concept** is helpful for prioritizing improvements in the service delivery process in order to optimize the overall impact of investments in observation and forecasting.

6. Quantification of benefits is difficult and may not always be necessary. Qualitative or comparative evaluation options could also provide useful output.

3. WAY FORWARD

1. A good selection of SEB-related methods and material is basically available but at issue is user friendly access. Thus, a SEB mechanism (e.g. web based platform) should provide links to available guidance regarding:

   a. Different modalities, methodologies and practical steps in conducting SEB studies;

   b. Examples of good practice, material from earlier workshops and other events;

   c. Data sources and data gathering/processing methods;

   d. Proceedings of the RA VI Conference on Social and Economic Benefits of Weather, Climate and Water Services (Lucerne, Switzerland, 2011).

2. For NMHSs conducting SEB study for the first time, involvement of external experts is recommended, in particular where the experience of NMHSs in SEB studies and "weather economics" in general is insufficient. Experienced external experts would augment credibility.

3. Though the discussion at the Lucerne Conference was focused on RA VI, SEB methodology is not region-specific, thus inter-regional exchange is useful.

4. Detailed understanding of client's use of the data and products provided by NMHSs is very helpful and essential for service improvement and innovation as well as for SEB assessment.

5. Importance of the integration of the SEB analysis into regular planning and management of NMHSs needs to be highlighted.

6. In considering the necessary budget for SEB studies (the lack of budget often being an excuse not to pursue such studies) NHMSs should regard and present this issue to decision-makers as an investment rather than an expense. NMHSs should look for relevant partners to raise funds for SEB studies, e.g., as part of projects funded through WB, EU, twinning mechanisms, etc.

7. Developed countries in RA VI should consider assisting less developed Members in terms of expertise and resources; NMHSs in need of such assistance should be proactive in looking for prospective partnerships.

8. Capacity building of NMHSs staff to be involved in SEB activities should be undertaken as an important activity. Cross-training events should be organized between NMHSs, and other disciplines such as civil protection officials and social scientists to build mutual understanding.

9. Given that the meteorological and hydrological products have reached a high degree of reliability and accuracy, NMHSs should concentrate on investing more resources to improve their communication with different users which would result in increased value of services and more efficient and effective decision-making.

For more information, please contact:

World Meteorological Organization

Communications and Public Affairs Office

Tel.: +41 (0) 22 730 83 14/15 – Fax: +41 (0) 22 730 80 27

E-mail: cpa@wmo.int

Development and Regional Activities Department

Tel.: +41 (0) 22 730 81 43 – Fax: +41 (0) 22 730 80 47

E-mail: divanov@wmo.int

Public Weather Services Division

Tel.: +41 (0) 22 730 83 33 – Fax: +41 (0) 22 730 80 21

E-mail: hkootval@wmo.int

7 bis, avenue de la Paix – P.O. Box 2300 – CH-1211 Geneva 2 – Switzerland

www.wmo.int

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