Challenges in Communicating Climate Forecast Information to Decision-Makers

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i. Abstract

Despite the strong dependence of certain sectors (energy, health, tourism, insurances, etc.) on weather and climate variability, and several initiatives towards demonstrating the added benefits of integrating probabilistic climate forecasts into decision-making processes, these forecasts are still under-utilised within the sectors. Improved communication is fundamental to stimulate the use of climate products by end-users. This study focuses on improving the visualisation and communication of climate forecast information, paying special attention to seasonal to decadal (s2d) timescales. As an example of a climate-sensitive sector, the renewable energy sector is examined.

The overall aim of this study is to establish a communication protocol for the visualisation of probabilistic climate forecasts, which does not currently exist. Global Producing Centres (GPCs) show their own probabilistic forecasts with limited communication between different centres, a fact that complicates the understanding and consistency among products for the end-user. A communication protocol for both the visualisation and description of climate forecasts can help to introduce a standard format and message to end-users across different climate-sensitive sectors. It is hoped that this work will facilitate the improvement of decision-making processes relying on climate forecast information and enable their wide-range dissemination based on a standardised approach.

ii. Acknowledgments

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iii. Table of Contents

List of Abbreviations:

APCC	Asia-Pacific Economic Cooperation Climate Center (APEC)
BCC	Bejing Climate Center
BMU	Ministry of Germany for the Environment, Nature Conservation and Nuclear Safety
BoM	Bureau of Meteorology
CLIM-RUN	Climate Local Information in the Mediterranean Region Responding to Users Needs
CPTEC	Centro de Previsão de Tempo e Estudos Climáticos
CSP	Climate Service Partnership
ECMWF	European Centre for Medium-Range Weather Forecasts
ENES	European Network for Earth System Modelling
EU	European Union
EUPORIAS	European Provision of Regional Impacts Assessment in Seasonal and Decadal Timescales
FiTs	Feed in Tariffs
GFCS	Global Framework for Climate Services
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit (= German Society for International Collaboration)
GPCs	Global Producing Centres
ICTP	International Centre of Theoretical Physics
IC3	Institut Català de Ciències del Clima
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRI	International Research Institute for Climate and Society
KMA	Korea Meteorological Administration
MSC	Meteorological Service of Canada
NOAA	National Oceanic and Atmospheric Administration
PIK	Institute of Potsdam for Climate Impact Research
RE	Renewable energies
S2d	Seasonal to decadal
SPECS	Seasonal-to-Decadal Climate Prediction for the Improvement of European Climate Service
SAWS	South African Weather Services
TCC	Tokyo Climate Centre
WMO	World Meteorological Organization

List of Figures and Tables:

1. Introduction

1.1 Research Objective

For climate-sensitive sectors (e.g. energy industry, health, agriculture, water resource management, tourism, insurances, etc.) climate forecast are useful tools to better plan for the future. Seasonal to decadal (s2d) climate forecasts have been developed over the last years. These help to predict the climate over timescales ranging from months to decades. Therefore they serve as an important tool to integrate in decision-making processes.

Improved communication is fundamental to stimulate the use of climate forecast information within decision-making processes, so that highly climate-dependent industries are able to adapt to climate variability and change. In the realm of the Global Framework for Climate Services (GFCS) initiative, and subsequent European projects: Seasonal-to-Decadal Climate Prediction for the Improvement of European Climate Service (SPECS) and the European Provision of Regional Impacts Assessment in Seasonal and Decadal Timescales (EUPORIAS), this study investigates the challenges in the visualisation and communication of seasonal forecasts. Here, the focus is on renewable-energy policy makers, who are central to enhance climate services for the energy industry. However, the results of this paper can be extended to other weather and climate-sensitive sectors.

The overall objective is to promote the wide-range dissemination and exchange of actionable climate information based on seasonal forecasts from Global Producing Centres (GPCs). This thesis examines the existing main barriers and deficits. Examples of probabilistic climate forecasts from different GPCs are used to make a catalogue of current approaches, to assess their advantages and limitations and, finally, to recommend better alternatives. Interviews have been conducted with individuals from different sectors to receive feedback for the improvement of current visualisation techniques of forecasts. The aim is to establish a communication protocol for the visualisation of probabilistic climate forecasts, which does not yet exist. GPCs show their own probabilistic forecasts with limited consistency in their communication system across different centres, which complicates the understanding for the end-user. The recommended communication protocol for both the visualisation and description of climate forecasts can help to introduce a standard format and message to end-users from other climate-sensitive sectors.

Although the importance of s2d forecast visualisation has gained more weight and some progress has been made to advice visualisation techniques (IPCC, 2011; Jupp et al., 2012; Slingsby et al., 2009), there is still room for improvement. Therefore, this paper investigates current state-of-the-art visualisation and communication of s2d forecasts in a decision-making context.

1.2 Research Questions

This thesis addresses the challenges related to the visualisation and the communication of seasonal to decadal (s2d) climate forecasts.

Here, communication refers to the act of exchanging information. Visualisation can be defined as a technique that helps others to see the data in order to help them better understand the information provided.

The questions addressed in this study are as follows:

1. How can the communication (usefulness and usability) of climate forecast information to decision-makers be improved?
2. How can the visualisation and understanding of s2d forecasts be optimized?
3. What are the main barriers to the wide-range dissemination and exchange of climate information based on s2d forecasts? How can they be overcome and what are the alternatives?

1.3 Thesis Structure

The thesis is structured as follows:
Chapter 2 deals with the background analysis. The reader is introduced to terminologies of climate specific terms such as seasonal to decadal climate forecasts, probability forecasts and climate services. The third chapter is the methodology part. In the fourth chapter the results of the GPCs' comparison, the interviews and questionnaires are being presented. Chapter 5 introduces the discussion, which integrates the results and refers back to the main questions of the thesis and how they can be answered. Finally this paper concludes with a brief summary and recommendations for improving communication and visualisation of climate forecast information.

For the elaboration of this work mainly peer-reviewed literature and the websites of the GPCs are used. For the explanation of terminologies such as probabilistic forecasts and verification methods Jolliffe and Stephenson (2003) is an important reference. Other relevant sources are found on the WMO, BMU, IPCC and IRENA websites.

2. Background

2.1 Climate Science

Climate plays an essential role in all aspects of human life. Climate describes the average weather conditions measured over long timescales (months to decades). This fact distinguishes it from weather, which describes the way the atmosphere behaves in hours/days/weeks (see Figure 1). If we focus on climate change, the timescale is determined by long-term changes (multi-decadal), whereas shorter-term climate variation is referred to as climate variability. Climate variability can be represented by periodic or intermittent changes related to El Niño, La Niña, volcanic eruptions, or other changes in the Earth system (NASA, 2008). During El Niño Southern Oscillation (ENSO) events the atmosphere responds to tropical sea surface temperature (SST) anomalies, which makes seasonal climate forecasts of temperature and precipitation possible for specific seasons and locations, particularly in the tropics. But also cold years, flood events, seasonal droughts, storm surges, extreme wind speeds, freezing conditions, heat waves, etc. are examples of variability in climate (UNDP/UNEP/GEF, 2012).

2.1.1 Seasonal to Decadal Climate Forecasts

There are forecasts of the expected climate conditions for the next one to six months (see Figure 1). Decadal forecasts cover the timescale up to ten years. Current approaches used for producing seasonal climate forecasts include the use of physically based dynamical global climate models, regional climate models, empirically based statistical models, or a combination of dynamical and empirical models. These four approaches produce probabilistic forecasts for expressing the existing uncertainties in the forecasting process. To address uncertainties in model formulation the multi-model ensemble approach is used (Coelho & Costa, 2010).

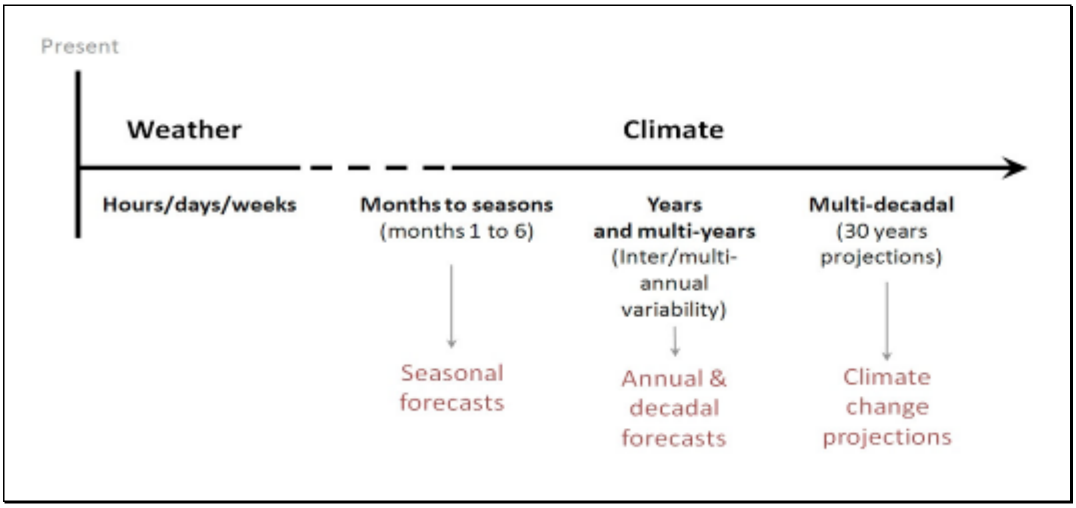

Figure 1: Climate and Weather (EUPORIAS, 2013)**.**

2.1.1.1 Probability Forecasts

The most consistent way to convey forecast uncertainty information is by the probability of the occurrence of an event. When forecasting the climate in probabilistic terms, it reflects a way of quantifying uncertainty. This can be expressed in numerical probability values (percentage), which are assigned to the forecast. Usually the numbers range from 0 to 100 or 0 to 1, being 0 for no certainty and 1 or 100 for a high certainty. The distinction between validation (forecast system's characteristics) and verification (forecast system's predictive skill) is as relevant in probabilistic as in deterministic forecasting (Persson, 2013).

The forecasts can be visualised in different ways, e.g. terciles, quintiles, etc. Terciles are three ranges of values of a variable, which define the lower, middle, and upper thirds (terciles) of the climatologically expected distribution of values. Quintiles instead are divided into five equal intervals. The most likely category stand for the category that presents the highest forecast probability value.

Any probabilistic forecast should be accompanied by a verification of past performance. Probability verification can address the accuracy (how close the forecast probabilities are to the observed frequencies), the skill (how the probability forecasts compare with some reference system) and the utility (the economic or other advantages of the probability forecasts) (Jolliffe & Stephenson, 2003).

A number of different methods exist to create verification maps, e.g. ROC, Brier skill score, Gerrity score, Reliability Plot, Correlation, etc. (see Appendix 1. Glossary).

Forecasts are intrinsically probabilistic. As Armour (2013) argues simply because a result does not exactly correlate to an estimate does not mean the estimate was wrong or even that it was inaccurate. If a project is estimated as having a 20% likelihood of success and it "fails" by overrunning the budget or the schedule, perhaps the project was flawed but arguably the estimate was accurate since it forecasted a high probability of failure.

Global Producing Centres (GPCs) deliver data regarding forecasts and verification information. The GPCs can provide a probabilistic assessment of specific weather events and climate conditions over time – a vital tool for decision-making in various sectors (BMU, 2013).

2.1.2 Climate Services

In the field of climate services the World Meteorological Organization (WMO) has provided important leadership. The WMO launched a Global Framework for Climate Services (GFCS). The GFCS initiative intends to create a climate service structure to enable better risk management through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale (WMO, 2013). These objectives are relevant to today's society as access to credible forecast data, supported by guidance from the science community, could lead to significant advances in society's ability to effectively prepare for and manage climate-related risks (Hewitt et al., 2013). For instance, this could include disaster risk management and insurance programs.

Climate services refer to the communication of climate information to the public or a specific user in climate-informed decision-making. The Climate Service Partnership (CSP), an initiative for climate service development, represents a platform for knowledge sharing and collaboration aimed at promoting resilience and advancing climate service capabilities worldwide. The CSP also ensures that the best available climate science is effectively communicated among agriculture, water, health, and other sectors, to develop and evaluate mitigation and adaptation strategies.

Thanks to scientific progress we are able to obtain knowledge about past, current and future climatic conditions which is necessary to deliver climate service to decision-makers (BMU, 2013). Under the 7th framework programme the European Commission funded the European Provision of Regional Impacts Assessment in Seasonal and Decadal Timescales (EUPORIAS) project, which aims to improve the community's ability to maximise the benefits and to better manage the challenges arising from climate variability. EUPORIAS objectives are to improve preparedness, business and competiveness, reduce costs and increase effectiveness approaching climate-based decisions (Hewitt et al., 2013).
Another project linked to EUPORIAS is SPECS (Seasonal-to-Decadal Climate Prediction for the Improvement of European Climate Services) (Hewitt et al., 2013). SPECS is led by the Institut Català de Ciències del Clima (IC3) in Spain, which will deliver a new generation of climate prediction systems for s2d time scales, to provide actionable climate information for a wide range of users (Doblas-Reyes, 2012).
Both projects, EUPORIAS and SPECS, aim to develop reliable climate information systems based on s2d climate forecasts. This paper is in line with the objectives of the SPECS project, namely the improvement of the visualisation and understanding of s2d predictions.

Climate Local Information in the Mediterranean Region Responding to Users Needs (CLIM-RUN) is another related project, which was established to contribute to the creation in the Mediterranean area of a climate services network. CLIM-RUN also intends to improve the exchange of information between scientists and stakeholders. Therefore, stakeholders are being involved in the design of a communication protocol, where climate information is transferred from the researchers to the stakeholders in order to develop suitable adaptation measures (CLIM-RUN, 2013).

2.2 Energy and Climate

For development to be sustainable, the delivery of energy services needs to be secure and have low environmental impacts. To be environmentally benign, energy services must be provided with low environmental impacts and low greenhouse gas (GHG) emissions (IPCC, 2011). Compared to traditional fossil fuels (coal, oil, gas), renewables offer this opportunity within the energy sector. Hence the importance of implementing RE in future energy scenarios grows, as well as the need for more robust info to support the related decisions such as what is the optimum energy mix, and what is the risk to security of energy supply with each scenario, and what are the needed market drives.

2.2.1 Renewable Energies

All societies require energy services to meet basic human needs and to serve productive processes (IPCC, 2011). The global demand for energy supplies is growing rapidly. The International Energy Agency estimates that world energy demand will rise by 40% between 2011 and 2035 (Swiss Reinsurance Company Ltd, 2013). Because of this rapid growth in demand, it is of great importance to invest in a sustainable energy source for the future. The use of renewable energies (RE) has increased considerably over the last decades. Table 1 shows the total primary demand for renewable energy by region and scenario, in megatonne of oil equivalent (Mtoe). The growth rate from 2010 until 2035 will vary depending on whether new policies, current policies or other scenarios are considered.

	1990	2010	New Policies 2035	New Policies 2010-35*	Current Policies 2035	Current Policies 2010-35*	450 Scenario 2035	450 Scenario 2010-35*
OECD	277	443	1 005	3.3%	861	2.7%	1 393	4.7%
Americas	153	199	461	3.4%	402	2.9%	686	5.1%
United States	100	131	338	3.9%	298	3.3%	522	5.7%
Europe	98	208	423	2.9%	373	2.4%	533	3.8%
Asia Oceania	26	36	121	5.0%	86	3.6%	173	6.5%
Japan	15	18	63	5.2%	39	3.2%	89	6.7%
Non-OECD	847	1 241	2 073	2.1%	1 840	1.6%	2 500	2.8%
E. Europe/Eurasia	40	47	103	3.2%	84	2.3%	165	5.2%
Russia	26	22	53	3.6%	41	2.6%	101	6.3%
Asia	497	676	1 133	2.1%	955	1.4%	1 412	3.0%
China	211	284	483	2.1%	401	1.4%	629	3.2%
India	140	182	287	1.8%	247	1.2%	335	2.5%
Middle East	2	2	33	11.5%	19	9.1%	68	14.8%
Africa	196	339	483	1.4%	478	1.4%	500	1.6%
Latin America	112	177	322	2.4%	305	2.2%	355	2.8%
Brazil	66	117	210	2.4%	200	2.2%	230	2.8%
World	1 124	1 684	3 079	2.4%	2 702	1.9%	3 925	3.4%
European Union	74	184	384	3.0%	338	2.5%	481	3.9%

* Compound average annual growth rate.

Note: Includes traditional biomass.

Table 1: Total primary demand for renewable energy by region and scenario (IEA, 2012)**.**

In the Intergovernmental Panel on Climate Change (IPCC) report (2011) renewable energy considered sources are biomass, solar energy, geothermal heat, hydropower, tide and waves and ocean thermal energy and wind energy. RE is defined as any form of energy from solar, geophysical or biological sources that can be restored by natural processes at a rate that equals or exceeds its rate of use and is obtained from the continuing or repetitive flows of energy occurring in the natural environment (IPCC, 2011).

It is important to note that the EU introduced the targets 20-20-20 not only to reduce greenhouse gas emissions but also to stimulate RE projects: by 2020 the EU aims to improve its energy efficiency by 20%, increase the share of renewable energy to 20% and develop an environmentally safe carbon geological storage policy (UE, 2011).

2.2.2 Wind power

In particular, the production of wind energy has increased in the last years (see Table 2). Wind turbines now provide more than 1 percent of global electricity, and wind is the fastest growing energy supply sector (Moomaw, 2008).

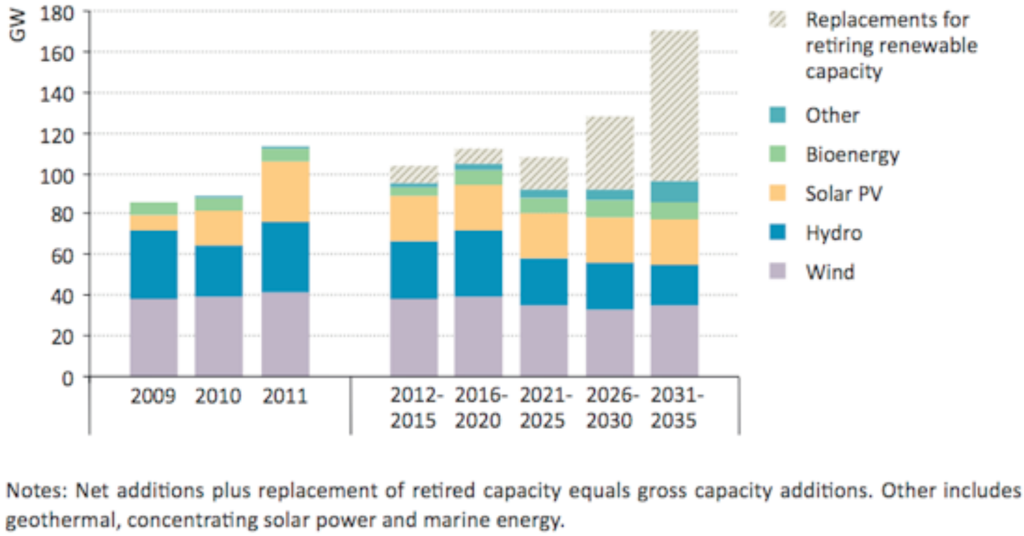

Figure 2: World average annual renewable-based capacity additions by type in the New Policies Scenario (IEA, 2012)**.**

Wind also achieves the highest level of market penetration in the European Union (EU), where it accounts for almost one-fifth of electricity generated in 2035, compared with less than 5% in 2010. Growth is also strong in the United States, China and India, in each of which wind reaches a share of 6-8% of electricity supply by 2035 (IEA, 2012). Investment in wind power is higher than for any other source, at $2.1 trillion, representing 35% of total investment in renewables capacity (IEA, 2012).

2.2.3 Wind power and Climate

Wind power production is closely linked to wind resources and its variability over climate timescales. The risk that this poses to the sector has an impact on the decision-making for wind projects, planning, operations, policy and the wider energy market. To guarantee the economic viability of future wind scenarios and investments, information, especially wind speeds over the coming seasons, years or decades is becoming of major importance. Forecasting climate could reduce the vulnerability of the sector and minimise the risks energy stakeholders are exposed to.

2.3 Renewable Energy Policy

Government policies have been essential to recent growth in the renewable energy sector. Renewables have been supported by governments to stimulate economies, enhance energy security and diversify energy supply (IEA, 2012).

2.3.1 Strategic Decision-Making Process and Climate

To make well-informed and efficient decisions in renewable energy policy, decision-makers and their advisors have to make use of climate information, as renewables are highly dependent on meteorological conditions. Therefore, climate variability represents a risk to RE power generation (e.g. wind resources over space and time vary significantly). This is often not taken into consideration within decision-making processes. Information is crucial for the provider-user relationship. Due to different perspectives, there is often a gap between what providers understand as useful and what users recognise as usable information.

Because probabilistic forecasts are inherently uncertain by their nature, explaining the level of uncertainty associated with a particular forecast product is vital. User needs are sector specific. Therefore, the exchange and dialogue between the user and the provider is important to make well-founded decisions. Based on this exchange, climate information products and services have to be customised to the needs of individual users in order to be considered in decision-making processes (BMU, 2013).

Policy and industry decision-makers approach the market in a variety of ways. For instance, industries aim to create a financially lucrative market that is also stable and law abiding. Politicians introduce taxes and subsidies, which create a regulatory environment for effective use of the resource (IPCC, 2011). These market-oriented regulations provide government support for resource control. One of them, the Feed in Tariffs will be explained in the following paragraph.

2.3.2 Climate-Sensitive Decision

Feed in Tariffs (FiTs) is an example for a policy in the renewable energy sector. It represents a relative new energy policy which incentivises the implementation of renewable energies. Across Europe, the implementation of FiTs was incentivised by the EU directives in 2001 and 2009, enabling renewable energy to overcome the significant barriers to entering the energy market (EWEA, 2013). Germany benefited from this policy since its FiT law introduction in 1990. Known as the Renewable Energy Act (Erneuerbare-Energien-Gesetz) issued by the Ministry of Germany for the Environment, Nature Conservation and Nuclear Safety (BMU) the FiT mechanism promoted job creation, international exports and carbon savings as well as investment security for renewable energies (Mendoça & Jacobs, 2012). The wind energy sector has particularly made important benefits thanks to the premium-FiTs, which have been implemented in several European countries. Offering the end-user a payment for the generation of renewable energy, they function as an aid to help meet the Government's renewable energy generation targets. FiTs offer the producer of RE a guaranty of payment for x years (depending of the country and the source of energy, e.g. solar, wind).

As an important consequence for the efficient use of FiTs, climate forecasts are needed in order to optimise the calculation of these payments. One of the requisites for FiTs is to obtain information on energy generation over climate timescales and how it can shape the future energy system as a whole. In Germany, for instance, studies have been conducted to investigate the best possible integration of renewable energies to the grid system (Consulting GmbH, 2011). Evaluating the costs, energy consumption, infrastructure, future scenarios, etc., the authors of these studies analyse different variants until 2020. The FiT price can be set to facilitate the desired changes to the energy system based on the climate available resources. Figure 3 illustrates the development of renewables from 2010-2020 in Germany considering three variables: 1. Installed power 2. Generated energy 3. Gross volume of payments. The increasing number of on- and offshore wind energy, shown in green colours, is of interest in terms of climate forecasting for wind.

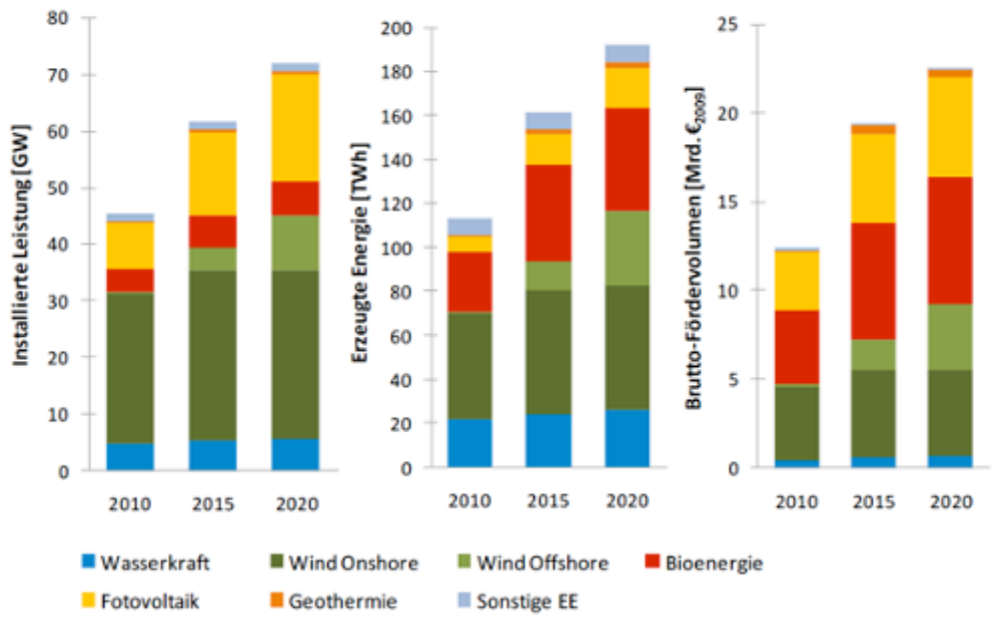

Figure 3: Development of the renewable energies in Germany (Consulting GmbH, 2011)**.**

FiTs can be seen as an effective mechanism to introduce renewable power quickly but only if it is combined with adequate supporting conditions, including planning, approvals and grid connection (Mendoça & Jacobs, 2012). The overall trend of the wind FiTs is a reduction in the tariff as the wind market becomes more competitive. Climate information providers can tailor the information for stakeholders to help with the decision-making processes (Coelho & Costa, 2010). This could improve the use of FiTs and the development of renewable energy infrastructures, e.g. FiT prices will shape the market by understanding the variability of future wind power. This can strengthen policy strategies and support for further investment in RE and the return on investment via better management of RE power once in oparation.

2.4 Decision-Maker/Stakeholder

As an important player in the field of RE policy the Ministry of Germany for the Environment, Nature Conservation and Nuclear Safety (BMU) is targeted as a stakeholder of wind energy projects. Already in 2008, Germany had the largest installed capacity of wind turbines (IPCC, 2011) and currently the BMU considers that wind energy offers the most extensive opportunities for expansion.

Against this background it is interesting to focus on the needs of the ministry regarding climate forecast information and the risks it faces in the decision-making processes for wind production investment and RE generation capacity. It is therefore timely that the question is asked regarding how far s2d forecasts can help to minimise the uncertainties and to improve the identification of the wind potential in Germany over the subsidy timeframe. This can affect the FiTs subsidy value, which can be reduced when a sector requires less start up-support due to its risk reduction.

As stated in the 2009 BMU report for adaptation and mitigation strategies the BMU relies on retrospective climate information in order to plan for the future, for example for risk management, energy supply, insurance economy (BMU, 2006). There is and assumption made here that past climate information will reflect the future, which is not necessarily the case. Therefore, wind forecast information might help to determine investment possibilities.

The largest country shares of annual investment in wind energy were by Germany and the US (EREC, 2007). Figure 4 shows that the share of Germanys investments between 2004 and 2030 will increase continuously.

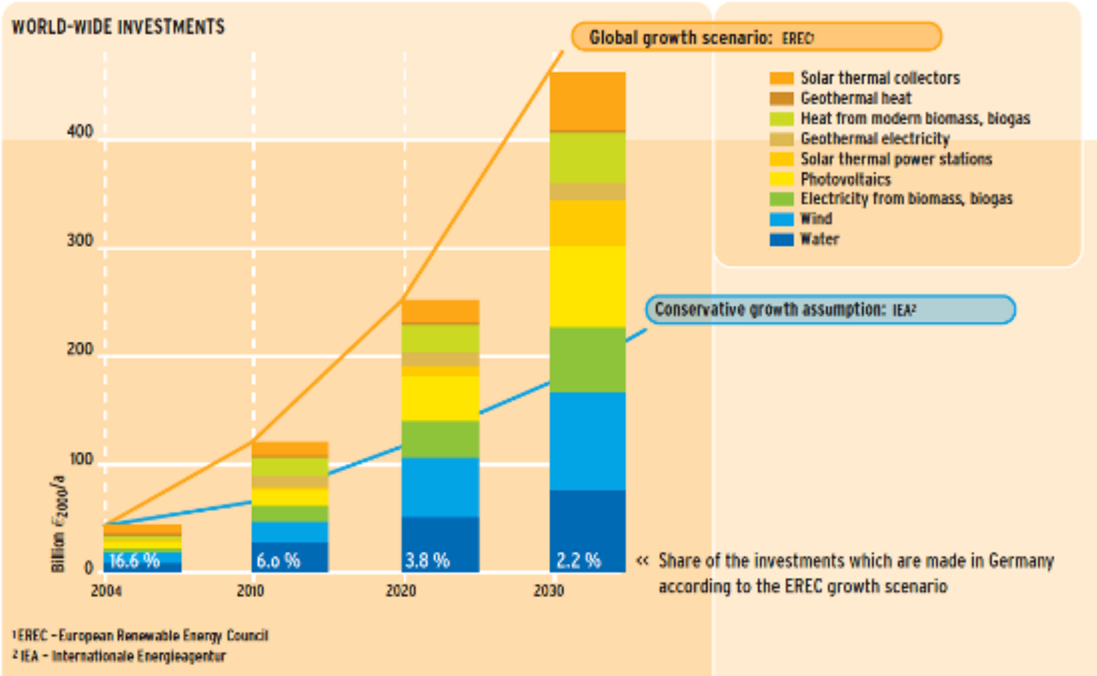

Figure 4: World-wide Investments of renewable energies (BMU, 2006)**.**

In the same report on "Renewable Energy- Employment Effects" the BMU analyses in Figure 5 the export and employment scenarios of RE. Although divided into four different outcomes it can be seen, that even the "pessimistic scenario" offers an increasing investment in RE.

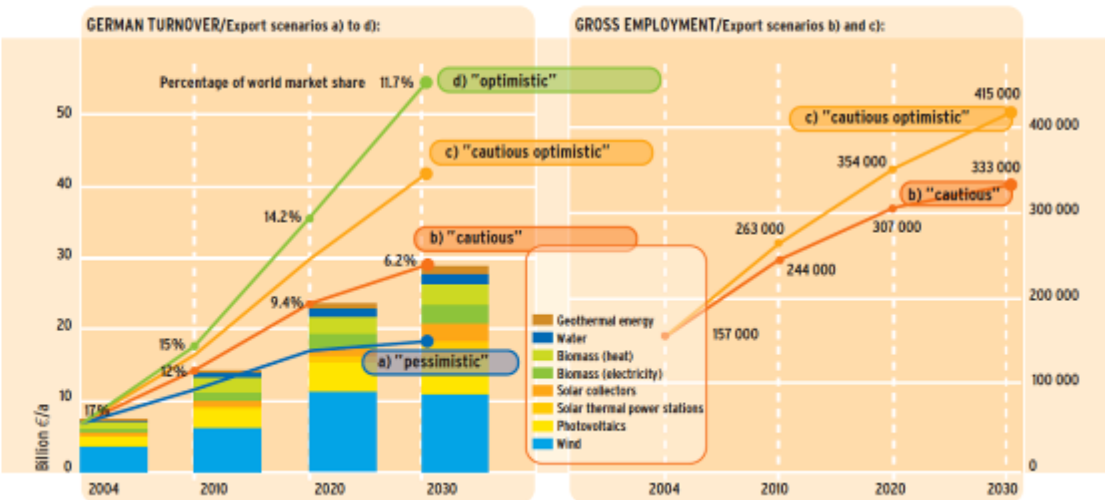

Figure 5: Turnover of German businesses domestically and abroad, as well as the corresponding gross employment effects until 2030 for various export scenarios (bars represent the investments in export scenario b) (BMU, 2006)**.**

This panorama shows that in order to better manage the increasing investment in renewables it is important to minimise the risks, due to climate variability (see background chapter 2.1 Seasonal to decadal climate forecasts).

2.4.1 The Ministry of Germany for the Environment, Nature Conservation and Nuclear Safety (BMU) and Partner Organisations

The GIZ (Deutsche Gesellschaft für internationale Zusammenarbeit = German Society for international collaboration) is crucial to the decision-making process of the BMU, who defines itself the world's leading provider of international cooperation services for sustainable development. The GIZ consults its partners for the choice of useful climate information sources. They act on behalf of the BMU jointly with the Institute of Potsdam for Climate Impact Research (PIK) in order to develop a new internet platform (Ci-grasp) that offers information regarding climate change, vulnerabilities and adaptation measures (GIZ, 2013).
Also the GIZ insists that decision-makers should be well informed of where to find adequate literature, visualisation tools and online databases. Specialists can help to interpret graphics and data and show the end-user which options they have to act.
In partner projects the BMU and the GIZ focus on improvement of energy management and climate friendly energy policy (GIZ 2013b).

2.5 Climate Information for the Energy Decision-Making Process

For energy decision-making processes there is a variety of retrospective-related climate information available. An important and comprehensive information platform on the potential of renewable energy offers the IRENA (International Renewable Energy Agency) Global Atlas. It provides resource maps from leading technical institutes worldwide and tools for evaluating the technical potential of renewable energies bared on past climates. It can function as a catalyst for policy development and energy planning, and can support investors in entering renewable energy markets (IRENA, 2013). Wind resource maps are also accessible. Particularly for Germany, they are provided by the German Weather Service (Deutscher Wetterdienst). These maps offer information regarding wind speed and depending on the region the specific wind conditions for possible wind energy investment. Figure 6 displays an example of a wind map that shows in which regions the installing of wind turbines can be worthwhile. Red means a bad suitability, yellow a moderate and green a good suitability.

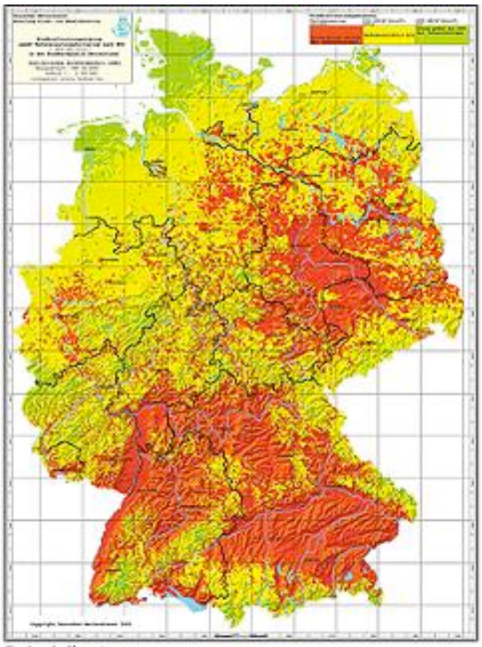

Figure 6: Suitability for wind power use (DWD, 2014).

The European Network for Earth System Modelling (ENES) represents a Portal Interface for the Climate Impact Communities that offers climate information to the energy sector. It is their task to offer trends in the climate, which affects the energy consumption (e.g. colder winters imply more heating), calculate impacts and vulnerabilities and identify adaptation strategies (ENES, 2013).

When dealing with uncertainties for future projections, the BMU integrates climate forecast information in decision-making processes (BMU, 2006). This information is important for the management of threats that can appear from changing weather conditions, for instance, extreme weather events such as heavy storms, which can challenge the stability of installations and infrastructures of renewables (e.g. wind turbines). Another example for the use of climate forecasts is the physical planning of the land (e.g. where to position new wind turbines). Also, natural catastrophes, which

have increased in the last years, have obliged the German government to integrate more energy supply strategies in decision-making processes (BMU, 2006).
The German Weather Service and the Potsdam Institute for Climate Impact Research (PIK) are important organisations that work towards building a robust data supply network of reliable climate forecast scenarios, to better meet these challenges and make decisions. Nevertheless the BMU report points out that for improving planning for the future, there is still a lack of forecasts covering seasonal to decadal timescales (BMU, 2009).

Because energy decision-makers are dependent on climate information the Global Producing Centres also are essential for the energy sector. Especially their role in providing s2d climate information for end-users is relevant for the decision-making processes.

2.6 Conclusion

In the context of renewable policy decisions (for wind energy), there remains still a large uncertainty of future wind resource variability, with only historical climate future information being used to make decisions at present. There is potentially lack of useful and usable climate information required to minimise the uncertainty of future wind resources. This encompasses the central topic of this thesis: challenges in the visualisation of climate forecasts and how it can be improved in order to optimise its understandability.
Consequently, the lack of this information leads to the ineffective use of climate information in decision-making processes. Additionally, a variety of barriers exist, which hinder the useful integration of climate information in decision-making, such as cultural differences between science and society, policies that favour "pure basic research" over "use-inspired research", political and power asymmetries between scientists and users and differences in what constitutes expertise (McNie, 2013). Studies have shown that, for forecasts to be useful to their stakeholders, there was a need to "translate" forecasts into "resource vulnerability and impacts" products relevant to stakeholder concerns (McNie, 2013). Some of these useful products

included technical reports explaining likely impacts of short-term and long-term climate variability and change, climate-forecast evaluation tools, vulnerability assessments, newsletters reporting on the latest climate and resource information and guides for incorporating climate information into government policymaking (McNie, 2013).

Other studies have shown that there was also a need for “actionable science”. Asrar et al. (2013) state that stakeholders need actionable (timely, accessible, and easy to understand) climate information to guide decisions. Furthermore it is important, that the relationship between climate scientists and users of climate information may be improved to ensure the effective use of the provided data (Coelho & Costa, 2010) and optimise the decision-making processes.

3. Methodology

This chapter focuses on the comparison of graphics from various GPCs to analyse the availability, accessibility and visualisation of seasonal climate forecasts. This is helpful for any decision-maker, since the aim is to compare and visualise the different approaches the GPCs use in order to show climate forecast data and verification information.

Secondly, this chapter explains the methods used for conducting interviews and assessing questionnaires. This section investigates the needs and opinions of stakeholders and non-scientists. Of special interest is the use of seasonal and decadal climate forecast information as well as the evaluation of different figures showing probabilistic forecasts.

Finally, participants of the 2nd CLIM-RUN workshop held at the International Centre of Theoretical Physics (ICTP) were consulted in different workshops regarding their evaluation of finding probabilistic forecasts and verification graphics from several GPC websites. They were also asked about how to integrate s2d forecasts in decision-making processes.

3.1 Inventory

To address the central questions of this thesis the overall objective is to assess the understandability of probabilistic forecasts analysing existing visualisation techniques. The objects of investigation are several GPCs listed on the webside of the World Meteorological Organization (WMO, 2013). These GPCs for Long Range Forecasts form part of the Global Data-Processing and Forecasting System (GDPFS), initiated by the WMO in 2006. It helps the GPCs to adapt well-defined standards aiding the consistency and usability of the output: a fixed forecast production cycle, a standard set of forecast products and WMO-defined verification standards (WMO 2013).

3.1.1 Availability and Accessibility of Climate Forecasts

In Table 2 "Availability and accessibility of climate forecasts – Forecast products" a total of 13 GPCs are compared namely:

1. Met office
2. International Research Institute for Climate and Society (IRI)
3. European Centre for Medium-Range Weather Forecasts (ECMWF)
4. Asia-Pacific Economic Cooperation (APCC) Climate Center (APEC)
5. Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)
6. Bureau of Meteorology (BoM)
7. Bejing Climate Center (BCC)
8. Climate Prediction Centre (CPC) National Oceanic and Atmospheric Administration (NOAA)
9. Tokyo Climate Centre (TCC)
10. Korea Meteorological Administration (KMA)
11. Meteo-France
12. Meteorological Service of Canada (MSC)
13. South African Weather Services (SAWS)

GPCs	Met office	IRI	ECMWF	APCC	CPTEC	BoM	BCC	NOAA	TCC	KMA	Meteo-France	MSC	SAWS
Login required	No	No	No	Only for verification	No	Yes	No	No	No	No	Yes	No	No
Are the websites in English?	Yes	Yes	Yes	Yes	Yes/partly	Yes	Yes/partly	Yes	Yes	Yes	No	Yes	Yes
Availability of scientific explanation/ description of the various maps on their website	Yes	Yes	Yes	Yes	Yes	Yes	Partly	Yes	Yes	Yes		Yes	No
Forecast types													
Mean anomaly			x			x					No info		
Prob upper tercile			x		x	x							
Prob middle tercile			x		x	x							
Prob lower tercile			x		x	x							
Most likely tercile		x	x		x		x		x				x
Ensemble forecast										x			x
Probability of categories													
Tercile categories	x		x	x		x	x	x	x	x		x	
- above-normal	x			x		x	x	x	x	x		x	x
- near-normal	x			x		x	x	x	x	x		x	
- below-normal	x			x		x	x	x	x	x		x	x
Outer quintile categories	x												
- Prob for lowest 20 %			x										
- Prob for highest 20 %			x										
Two categories	x												
Lead time/Period													
Lead time 0 Month												x	No info
Lead time 1 Month			x			x	x	x	x	x		x	
Lead time 2 Month			x			x	x						
Lead time 3 Month			x	x	x	x	x		x				
Lead time 4 Month			x			x	x						
Lead time 5 Month				x		x	x						
Lead time 6 Month						x	x						
Lead time 7 Month							x						
Lead time 8 Month							x						
Lead time 9 Month							x						
Lead time 10 Month							x						
Lead time 11 Month							x						
Lead time 12 Month							x						

Months 2-4	x	x					x						
Months 3-5	x	x					x						
Months 4-6	x	x					x						
Months 5-7		x											
Region													
Global	x	x	x	x	x	x	x	x	x			x	x
Other	x	x	x	x	x	x	x	x	x	x			x
Issued													
Since 1981						x							
Since 1982						x	x						
Since 1995						x	x	x					
Since 1997		x				x	x	x					
Since 2004		x		x		x	x	x					
Since 2006		x	x	x		x	x	x				x	
Since 2008		x	x	x	x	x	x	x				x	
Since 2009	x	x	x	x	x	x	x	x				x	
Since 2010	x	x	x	x	x	x	x	x	x			x	
Since 2011							x	x				x	
Since 2012							x	x				x	
Since 2013							x	x					x
Since 2014	x	x	x	x	x		x	x	x	x			
What variables do they forecast?													
2 m temperature	x	x	x	x	x	x		x	x	x		x	x
500 hPa geopotencial height	x			x	x		x						
200 hPa height (anomaly)										x			
850 hPa temperature	x			x			x			x			
Precipitation	x	x	x	x	x	x	x	x	x	x		x	x
Pressure	x												
Sea surface temperature	x		x				x	x	x	x			
Mean sea level pressure			x			x				x			
Sea level preasure anomaly					x					x			
Wind							x						
Nino3.4							x						
Outgoing Longwave Radiation						x							

Table 2: Availability and accessibility of climate products – Forecast.

Table 2 summarises which climate variables are available at each GPC and which they have in common. The first aspects that are compared refer to more general information of the websites.

- Is a login required?
- Are they available in English?
- Does the GPC provides a scientific explanation/description of their maps?

The second section focuses on the forecast products.

- Which forecasts are available?
- Does it show the probability of categories?
- Which time periods are covered?
- Other variables include the region and when the information is issued.

The last section assesses the variables the GPCs forecast (on a seasonal climate forecast basis).

Table 3 “Availability and accessibility of climate forecasts – Verifications” shows the different verification approaches available, which firstly, includes the verification types (ROC, GROC, Brier skill score, Correlation anomaly, etc.).

Secondly, the category (tercile, quintile, etc.) and the skill category are shown. The final section compares the lead-time and the variables each GPC provides.

GPCs	Met office	IRI	ECMWF	APCC	CPTEC	BoM	BCC	NOAA	TCC	KMA	Meteo-France	MSC	SAWS
											No information*		Not able to open**
Verification types													
ROC maps	x						x						
ROC skill score					x				x				
ROC plots	x				x								
ROC curve				x					x				
ROC score		x	x	x			x		x			x	
- above-normal		x					x						
- near-normal		x					x						
- below-normal		x	x				x						
ROC diagrams		x										x	
ROC for lower third			x									x	
ROC for upper third			x									x	
Reliability plots	x												
GROC (Generalized ROC)		x											
Individual forecast score		x											
Brier skill score				x					x				
Realiability diagram				x	x				x			x	
Correlation anomaly			x		x								
Ranked probability skill score					x			x					
Gerrity score					x								
Mean squared skill score					x		x			x		x	
Average skill for this period						x							
Anomaly Correlation Coefficient										x			
Amplitude error										x			
Heidke Skill Score								x					
Bias error										x			
Category													
Tercile categories	x								x				
- above-normal	x					x		x	x				
- near-normal	x					x		x	x				
- below-normal	x					x		x	x				
Outer quintile categories	x												
Two categories	x												
Skill Category													
Measures of Discrimination		x											
Measures of Resolution and Reliability		x											
Measures of Unconditional Bias		x											
Measures of Number of Hits		x											
Measures of Value		x											
Lead													
0 month lead								x				x	
0.5 month lead		x						x					
1.0 month lead						x	x		x			x	
1.5 month lead		x											
2.0 month lead							x						
2.5 month lead		x											
3.0 month lead							x						
3.5 month lead		x											
Variable													
2 m temperature	x	x	not found	x	x	x	x	x	x			x	
Precipitation	x	x	x	x	x	x	x	x	x	x		x	
500 hPa geopotencial				x						x			
Mean sea level pressure										x			
Sea surface temperature									x	x		x	
850 hPa temperature				x						x			

*Sent request for information but did not receive an answer
** Page not found

Table 3: Availability and accessibility of climate products – Verifications.

3.1.2 Current Visualisation Techniques

Table 4 evaluates the different visualisation techniques used by the GPCs to illustrate the probabilistic forecast for precipitation, issued November 2009 for the December – January – February (DJF) 2009/2010 period and its verification (see Appendix 2. for forecast and verification graphics). Precipitation was selected for further analysis, as this variable is available at all GPCs. The 2009 DJF forecast was selected, since this period was marked by a strong El Niño event and seasonal forecasts tend to be more accurate when this event happens. Seasonal climate forecasts have been shown to have some skill in parts of South America including areas of Brazil (Goddard & Mason, 2002).

GPCs	Met office	IRI	ECMWF	APCC	CPTEC	BoM	BCC	NOAA	TCC	KMA	Meteo-France	MSC	SAWS
The probability forecasts focus on the DJF 2009-2010 season for									only DJF 2010/2011 available		No information		only OND 2013 available
Forecast													
Forecast product (title)	Probability of tercile categories	Probabili-ty most likely category	Probabil-ity most likely category	Probabi-lity of tercile	Probability most likely tercile	Tercile Probabilities	Most likely Catego-ries	Seasonal Prec probability forecast	Proabibility Forecast, most likely category of Precipitation	Ensemble Forecast		Forecast Probabi-lity	Probabilistic seasonal forecasting
Number of clicks required from the initial website to find the forecast	6	3	6	3	3	Information provided by the GPC	2	google search	7	4		2	3
Information in title/lettering													
Forecast type	x	x	x	x	x	x	x	x	x	x		x	x
Probability of categories	x	x	x		x	x	x	x	x				x
Region (Global)					x	x							
Period (DFJ 2009/2010)	x	x	x	x	x	x	x	x	x			x	x
Variable (precipitation)	x	x	x	x	x	x	x	x	x	x		x	x
Issued (November	x	x	x		x	x	x	x	x			x	
Other data													
Indication of units		x	x	x	x				x	x		x	x
Existence of legend	x	x	x	x	x	x	x	x	x	x		x	x
Longitude labels	x	x	x	x	x	x	x	x	x	x			
Latitude labels	x	x	x	x	x	x	x	x	x	x			
Colours used (main colours, shadings are not included)													
white	x	x	x	x	x	x	x	x		x		x	x
yellow	x	x	x		x	x	x	x	x			x	x
orange	x	x	x	x	x	x	x	x					x
red			x		x			x					
purple												x	
light blue	x	x	x				x	x	x				x
blue		x	x		x		x	x	x				x
green		x		x		x		x	x	x		x	
brown		x		x		x		x	x			x	x
grey		x		x		x			x			x	x
black													
Numer of different	5	11	9	17	9	18	5	13	11	9		30	9
Existence of latitude-longitude grid				x				x		x		x	

Table 4: Current Visualisation Techniques- Probabilistic Forecasts.

For both the visualisation of forecast and verification graphics, the same set of criteria were assessed.

GPCs	Met office	IRI	ECMWF	APCC	CPTEC	BoM	BCC	NOAA	TCC	KMA	Meteo-France	MSC	SAWS
The verification graphics focus on the DJF season for precipitation													not available
Verification													
Verification type	ROC	Generalized ROC (GROC)	ROC skill score	no data	Correlation	Average Rainfall skill for this	ROC Area above	Heidke Skill Score	ROC	Anomaly Correlation Coefficient	No info	ROC (lower and upper tercile)	
Number of clicks required from the initial website to find the forecast	6	4	3		4	provided by the GPC	2	3	3	5		google search	
Information in title/lettering													
Verification type	x	x	x		x	x	x		x	x		x	
Probability of categories	x		x										
Region (Global)					x								
Season (DFJ)	x	x	x		x	x	x		x			x	
Variable (precipitation)	x	x	x		x	x	x		x	x		x	
Other data													
Indication of units									x				
Existence of legend	x	x	x		x	x	x		x	x		x	
Longitude labels	x	x			x	x	x		x	x		x	
Latitude labels	x	x			x	x	x		x	x		x	
Colours used (main colours, shadings are not included)													
white		x	x		x					x		x	
yellow	x	x	x		x		x		x				
orange	x		x		x		x		x	x			
red	x		x		x		x		x	x			
purple	x	x	x				x			x			
light blue	x		x				x		x	x		x	
blue		x	x		x		x		x	x		x	
green		x					x					x	
brown												x	
grey	x	x				x							
black						x				x			
Nr of different colours	6	8	13		9	3	10		11	9		13	
Existence of latitude-longitude grid							x			x			

Table 5: Current Visualisation Techniques- Probabilistic Verifications.

The first section assesses the difficulty of finding the forecast/verification data. As an indicator of accessibility the number of "clicks" necessary from the initial GPC website to reach the actual graphic was counted.

The following section shows the variables that appear in the title/lettering. These include the forecast product/verification type, the probability of categories, the region, the variable, the period and when it is issued.

The third section evaluates additional data, for example the indication of units, legend, labels etc. The colours used and the number of different colours in the legend is finally examined.

3.2 Stakeholder Engagement

The interviewees were chosen from different sectors: The environment and urban planning, universities, energy industry, research sectors, landscape planning and RE organisations. Some interviews were conducted directly with the interviewee, whilst others responded to the questionnaire electronically.

The questionnaire is divided into five sections. The first section focuses on general information of the person:

- Name of the institution
- Can you tell me a bit of your organisation and the work it does?
- At what geographical scale does your organisation operate? (International, national, regional, local) Please underline.
- What is your role in the organisation?

The second section contains questions regarding the use of seasonal to decadal (s2d) climate forecast information.

- What do you think of seasonal to decadal forecasts?
- Does your organisation use seasonal to decadal forecasts?
  - i. If yes,
    1. For which timescale?
    2. For what is the information used?
  - ii. If not,
    1. Why not? (Lack of predictability, costs for accessing such data, not aware)
- Are you aware of any other organisations that are using seasonal to decadal climate forecast information?

The third section has the title "Dealing with uncertainty".

- What do you think are the main problems regarding the uncertainty of seasonal to decadal forecasts?
- Seasonal to decadal forecasts usually come with information about the degree of uncertainty in the forecast.
  - i. Do you consider this information as relevant?
  - ii. Which probability (in percentage) should the forecast have in order to be useful? (100% percent = perfect forecast)

In the fourth section the interviewees were asked about the central questions of the thesis.

- How can the communication of climate forecast information to (renewable energy) policy makers be improved?

- What are the main barriers to the wide-range dissemination and exchange of actionable climate information based on s2d forecasts? Are there alternatives?

In the last section interviewees were presented with four graphics (two forecasts and two verifications), which they had to evaluate on the basis of five questions.

- How do you evaluate the comprehensibility? Do you think there is too much information in the graphic?
- How do you evaluate the map's legend?
- How do you evaluate the lettering (titel)?
- How do you evaluate the colourfulness?
- In your opinion, which are the deficiencies? Do you have any suggestions how to overcome them?

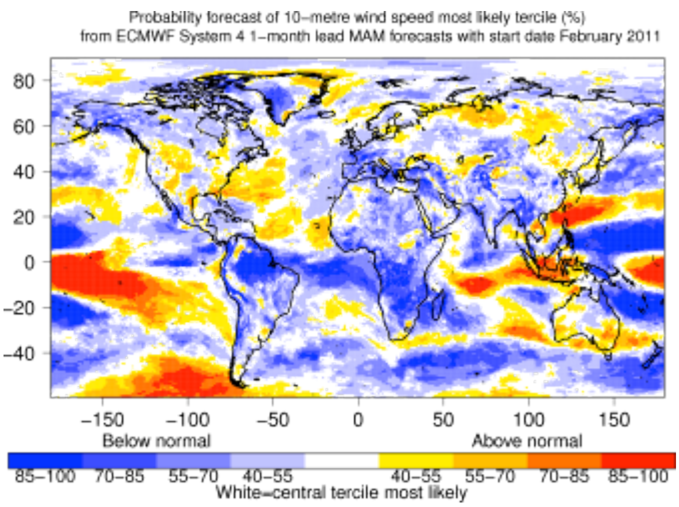

Figure 7: Probability forecast (wind) most likely tercile1-month lead MAM (IC3).

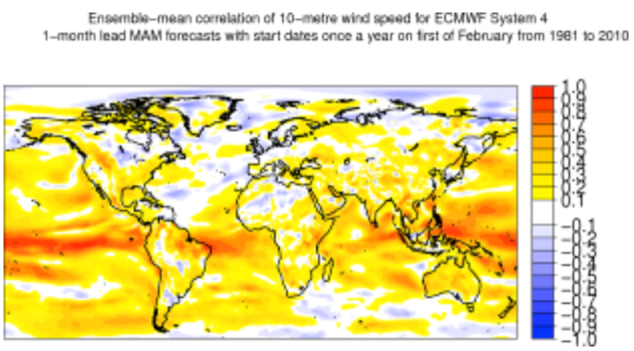

Figure 8: **Ensemble-mean correlation wind forecast 1-month lead MAM** (IC3).

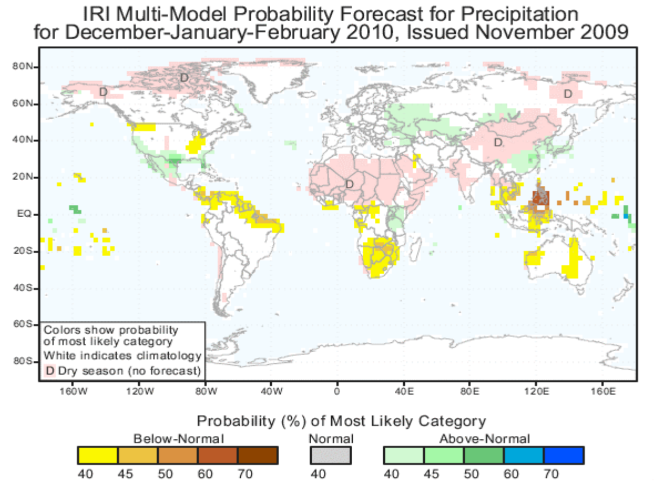

Figure 9: Probability forecast (Precipitation) of most likely category (IRI).

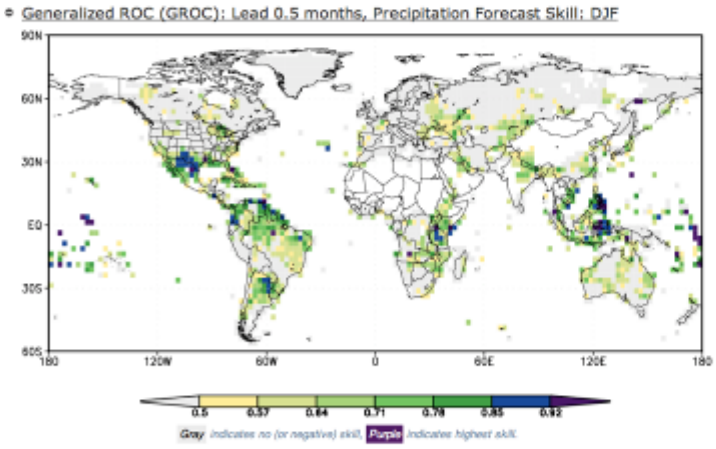

Figure 10: Generalized ROC (GROC) Precipitation Forecast Skill DJF (IRI).

3.3 CLIM-RUN Workshops

The 2nd CLIM-RUN School "Building two-way communication: A week of Climate Services" was held at the ICTP from the 2-6 December 2013 in Trieste. The majority of presentations and workshops were held on communication and visualisation techniques. Participants were scientists and meteorologists.

During one of the sessions the practical part was designed using the methodology of this study. The first task consisted of finding the probabilistic forecasts and verification information of the GPCs. Participants had to find the seasonal forecast corresponding to the December January February (DJF) 2009/2010 precipitation information used for the tables. Participants were working in teams to find the relevant graphics from the GPC from the WMO allocated to them. This exercise was useful to introduce them to the GPCs websites and make them familiar with seasonal to decadal forecasts as well as verification data.

For the next exercise the participants had to evaluate a case study. They had to put themselves in the position of an energy manager in Eastern Brazil. Each group had a probabilistic seasonal forecast graphic of DJF 2009/2010 precipitation, 1 month lead and if available the corresponding verification information. With this data they had to decide whether they should use their hydropower water reserves now or save them for the coming months.
Before they answered the final questions they had to analyse the information regarding the forecast and the verification. The conclusions can be found in Table 7 (see Appendix).

A third task was to answer to the final section of the questionnaire the stakeholders were given (Section 3.2). The objective was to give an even broader perspective on the assessment of the forecast and verification graphics.

4. Results

This chapter evaluates the results, examining first the outcomes of the comparison between the GPCs, followed by the assessment of the questionnaires and thirdly including the analysis of the CLIM-RUN participants' responses.

4.1 GPC evaluation and comparison

In the first section of Table 2 it can be seen that all GPCs, except APCC, BoM and Meteo-France have free access to their climate forecast data. At this point it must be added that the BoM GPC grants users access for research purposes. Most of them have in common the availability of a scientific explanation or description of their maps on the website, BCC has some text but not a full scientific explanation and SAWS has no explanation. The websites are in English with the exception of CPTEC, BCC (parts are translated to English) and Meteo-France (website only in French).
The second part of Table 2 indicates which forecast types are provided. The most commonly available forecast is displayed as "most likely tercile" which appears in IRI, ECMWF, CPTEC, BCC, TCC and SAWS. From Meteo-France it was not possible to obtain data, therefore this GPC was not included in the further analysis.
As for the period the most common lead-time is one month (ECMWF, BoM, BCC, NOAA, TCC, KMA, MSC) and three months lead (ECMWF, APCC, CPTEC, BoM, BCC, TCC). Almost all GPCs provide forecasts since 2009, 2010 and 2014 (exception SAWS only for 2013). Precipitation is the only variable that all GPCs offer on their website.

In Table 3 the comparison between different verification techniques is made. The ROC score (IRI, ECMWF, APCC, BCC, TCC, MSC) and the mean squared skill score (CPTEC, BCC, KMA, MSC) are available at most GPCs. Usually the categories are displayed in terciles (only Met office shows the forecast in terciles and quintiles). All GPCs present the verification of precipitation forecasts.

In Table 4 the comparison of the different visualisation techniques used by the GPCs is assessed. The number of clicks required to access the forecast data also varies. At BCC and MSC the user needs two "clicks" to access the forecast information, whereas at IRI, APCC, CPTEC and SAWS three "clicks" are required from the initial website. The rest has a different number of "clicks". This indicates that the forecast information at some GPCs is more easily accessible, which can imply a preference for the user when choosing a GPC.
When analysing the lettering of the forecast graphics Table 4 shows that nearly all GPCs indicate the forecast type, the period forecasted (exception KMA) and the variable (precipitation). Other data (such as the indication of units, existence of a legend and longitude and latitude labels) is not shown in all forecast graphics. Met office, BoM, BCC and NOAA do not display a unit. There are no longitude and latitude labels at MSC and SAWS. Only the APCC, NOAA, KMA and MSC have a latitude-longitude grid. Also the number of different colours varies depending on the GPCs ranging from five to thirty colours.

Table 5 summarises the comparison of the verification graphics of all GPCs. The most common verification type is the ROC type (Met office: ROC, IRI: Generalized ROC (GROC), ECMWF: ROC skill score, BCC: ROC Area above normal tercile, TCC: ROC, MSC: ROC lower and upper tercile). For the APCC Centre the user needs to login, therefore, no information is available. The verification graphic from SAWS was not possible to open due to technical problems. For the KMA a PDF document was available next to the forecast data, where different verification methods were listed. For this study the Anomaly Correlation Coefficient was chosen, since other GPCs also offer this verification type.
Viewing the number of "clicks" from the initial website to the verification data it appears that BCC needs two, ECMWF, TCC and NOAA three, followed by IRI, CPTEC and KMA with four "clicks" and Met office with six. The verification graphic from the BoM GPC was provided directly from the centre. The MSC verification was found via a google search.
When comparing the information in the title all centres indicate the verification type (except NOAA), the period (except NOAA and KMA) and the variable precipitation. Only CPTEC indicates the region in the lettering. This evaluation indicates that all GPCs have equally comparable information in their lettering.

An additional factor is the close link between forecast and verification information. This varies strongly depending on the GPC. Some display the information together and some have complete different paths in finding the forecasts and their verification.

The following interviews have assessed the forecast and verification graphics in a more detailed way including opinions of individuals.

4.2 Conducting Interviews

For this part, five individuals were interviewed or sent a questionnaire. The results from the interviews and questionnaires have a heterogeneous outcome. Due to the format of the questionnaire, which contained mainly open questions it was difficult to quantify the results. Measurable results are shown in Table 6. The first column represents the category, the second column shows the subcategories and the last column stands for the answers of the interviewees (I1-I5).

Categories	Subcategories	Interviewees				
		I1	I2	I3	I4	I5
1. Sector	Environment and urban planning - University	X				
	Energy industry		X			
	Landscape planning			X		
	Research of climate impact				X	
	Research - RE organisation					X
2. Sd2	Helpful and relevant					
	Helpful but not relevant	X			X	
	Not helpful because it is too uncertain		X	X	X	X
3. Use of s2d	Use it					
	Does not use it	X	X	X	X	X
4. Reasons for not using it	No need	X		X		X
	High uncertainty		X		X	

5. What is the minimum % of uncertainty acceptable	90%		X			
	75% For sensitive sectors 90%	X				
	80%			X		
	No answer				X	X
6. Forecast maps	Partly understandable	X		X		
	Not understandable		X		X	X
7. Verification maps	Partly understandable	X		X		
	Not understandable		X		X	X

Table 6: Evaluation of results from interviewees.

Firstly, it can be seen that the individuals work in different sectors including the environment and urban planning, universities, energy industry, research sectors, landscape planning and RE organisations.

Secondly, their opinions regarding s2d forecasts are shown. Four individuals answered that they are helpful but not relevant to make decisions. I2 said they are not helpful because they are too uncertain. In the questionnaire all specified that they were overall sceptical about s2d forecasts because climate is too chaotic to predict and that forecasts tends to be uncertain. Nevertheless, it is useful to have these outlooks as an orientation, but one has to be careful with their interpretation stated I1 and I5.

The third category refers to the use of s2d forecast information. None of the individuals use this data. The reasons are displayed in the fourth category. Three individuals (I1, I3, I5) answered that they do not need it for their work and the other two responded that it is too uncertain. This result supports the statement of Falloon et al. (2013) saying that despite the recent effort to develop underpinning climate prediction science for seasonal to decadal (s2d) climate predictions, there has been relatively little uptake and use of s2d climate forecasts by users for decision-making in Europe.

The fifth category deals with the degree of uncertainty of the forecast information. Individual I2 stated that the problem regarding uncertainty is that it often represents no reliable information for investors, requesting that the forecast should have at least an accuracy of more than 95%. This means that the probability in which the forecasted outcome will actually occur, should be at least 95% in order for investors of the energy sector to make the investment. This individual argued that it is very important that the forecasts are as accurate as possible, since the investment projects related to renewable energies include large sums of money.

The interview partner I3 said that the degree of uncertainty should be 80%. I1 argued that the percentage of certainty should be at least 75% and for more sensitive sectors (e.g. agriculture) 90% to better estimate the ecological damages, although it has to be considered that a 100% skillfull forecast does not exist. The interviewee answered that the main problems regarding the uncertainty of s2d forecasts are the increase of dust concentration (e.g. volcano eruptions in the stratosphere which results in global-dimming) and that simulations have to be adapted constantly because the initial climate conditions are changing. Also, the influence of meta emissions from emerging countries such as China, Brazil and India play an important role. Another problem is the rise of the sea level and that the climate system is an open system, which makes it even more difficult to predict.

Individual I4 said that problems arise due to the initial problem of data value. I4 also said that the uncertainty increases with a longer forecast time.

All interviewees agreed that the degree of uncertainty in the forecast is an important aspect to communicate.

Category 6 focuses on the forecast information the interviewees were given to analyse. All agreed that the graphics are difficult to understand given that there is not enough explanatory information (e.g. a description or interpretation of the graphics). Overall, the meaning of the legend remains unclear, even to among the scientists interviewed. A common observation was that the title does not explain the graphic. Also, the terminology used is unclear (e.g. tercile, ECMWF, MAM). These should be marked with an asterisk and have an explanation. Another critique was that longitude and latitude labels were missing. The choice of colours is generally accepted. It was additionally criticised that there are no measures or units, e.g. percentages, metre per second, height, etc.

Suggestions from the interviewees include that the title and the descriptions should be modified to make the graphic more understandable; they should be self-explanatory. At a glance it should be clear what is shown and how the colours should be interpreted. Another suggestion is to include a zoom view.

The evaluation of the verification maps is similar to that of the forecast graphics. All agreed that the title is unclear, as well as the terminology (e.g. ensemble-mean correlation), which should be explained. The interviewees (I3, I4, I5) thought that the colour choice was “comprehensible”, “good” and “fair”. I4 and I5 stated that the colours are misleading.

There is a variety of outcomes to the interviewees’ responses concerning the key questions of this thesis. Regarding the question how can the communication of climate forecast information to decision-makers be improved? the individuals answered at first confirming that there is an urgent need of improvement. Secondly, what could be done is the establishment of climate centres with advisors (professionals), who know the subject and have connections to climate scientists/ institutes/ universities to contrast the information and to avoid incorrect statements (see energy transition in Germany). It is important to create connecting links to enable the exchange of information for both sides because often the communication is missing. Also improving the degree of certainty of the forecasts can help to create better relationships among scientists and decisions-makers. For the energy sector specifically, the improvement of communication is important because it could enable to better program the production of energy supply and adapting it to the demand.
Interviewees said that it would be helpful that climate scientists synthesize their data and are always aware of the degree of uncertainty in the communication. This underlines the above-mentioned aspects that the forecast data should be tailored in order to meet users needs.

The other key question refers to the barriers, which hinder a wide-range dissemination and exchange of actionable climate information based on s2d forecasts.
Individuals I1, I2, and I4 think that the main barriers are the insufficient exchange of unfiltered and freely accessible data (e.g. only IPCC summary for policy makers, German Weather service) and that information is often paid for. Economic reasons are also named, which hamper the dissemination. Another barrier is the degree of uncertainty of s2d forecasts and its unreliability. Furthermore, interviewees said that this information and the sectors of application are not yet well known.

4.3 CLIM-RUN Results

4.3.1 Finding Forecast and Verification Information

Participants had some difficulties in finding the probabilistic forecasts and verification information. Only three out of twelve groups were able to find the information. This was the China Meteorological Administration (CMA)/Bejing Climate Centre (BCC), Met Office (United Kingdom) and APEC (Asia-Pacific Economic Cooperation) Climate Centre (APCC), Republic of Korea. The main barrier was the lack of user friendliness the web pages offered. Most of them are difficult to browse and not intuitive when it comes to finding information. Also the language was a problem: Meteo-France is in French and the Centre for Weather Forecasts and Climate Studies/National Institute for Space Research (CPTEC/INPE) and KMA are only partly in English. Another hindrance to access the information was that some GPCs required the user to log in (e.g. Meteo-France and APCC). In general the participants were surprised about the degree of difficulty in accessing the forecast and verification information, which they shared in the discussion round. The outcomes reflect the difficulties to find the forecast and verification information on the GPCs websites. It is of great importance to optimise the search options to facilitate to access this data, for instance, by creating a standard outlay website for all GPCs to help the user navigate through the information. GPCs that require a small number of clicks to find the forecast graphics are generally easier to handle than the ones with more than five clicks.

4.3.2 Forecast and Verification Information in Decision-Making Processes

For the second exercise, participants had to interpret the forecast and verification graphics in order to take decisions regarding the management of water reserves for energy generation. The reference period of DJF 2009/2010 was used for a precipitation forecast with one month lead time. This task was interesting for participants because they were asked to integrate probabilistic forecasts and verification information in their decision-making process.

Two groups were given the graphics from the Met office GPC (see Appendix 4.1 and

4.2). One group decided that the forecast shows a big uncertainty and that they would not use the forecast information for this year. The other group stated that they were going to use the water now because the most probable tercile is above-normal and the skill score lies between 0.7 and 0.8, which means that the skill is relatively high.

One group analysed the IRI GPC (see Appendix 4.3). They concluded that the data was clear to understand. The forecast indicates a 40-45% below-normal precipitation for the season. Although the verification does not show forecast skill, the group decided to use the hydropower water resources now.

The next two groups had the graphics from the ECMWF centre (see Appendix 4.5 and 4.4). The first one found out that the forecast indicates a 40-80% probability above normal precipitation in the whole region. The verification does not forecast skill – it is not better from using the long-term average distribution know as climatology. Therefore, this group would not use the forecast in their decision-making process. Instead, they would make use of climatology data to make decisions.
The second group could not answer the questions. There were too many unfamiliar terms in the graphics in order to identify the forecast and verification information and to make a decision. The participants did not know what a tercile, System 3 and DJF meant. Also they did not know what the percentages mean and the abbreviation "prob." stood for.

The next group analysed the APCC Centre (see Appendix 4.6). There was no verification data available, only the forecast information. They pointed out that the forecast shows a 60-70% decrease in precipitation in DJF 2009/2010. For hydropower planning the available data especially the lack of verification is not enough for decision-making, but still it shows some decrease in rainfall. They decided that the reservoirs should be kept filled for the coming season for normal operation of power plant reducing the downstream flow in case there is a below normal precipitation season.

The last two groups were given the CPTEC forecast and verification graphics (see Appendix 4.7 and 4.8). The first group identified that the forecast indicates a severe decrease of precipitation. The verification did not support the forecast very much.

This group would therefore not use the forecast information for their decision-making process and chose to reserve the reservoir water to insure sufficient power over winter for energy needs.

The second group answered that the forecast and the verification predicted, that there will be a likely below-normal rainfall. They concluded that it is best to use the hydropower in the next season and not at present.

Note that there is a full range of decision taken based on the different GPC data. This also highlights the human aspect on the use of probabilistic information versus the amount if risk an individual is willing to take.

4.3.3 Feedback from Participants regarding Visualisation Techniques

The participants were given the final section of the questionnaire (section3.2), which deals with the visualisation of forecast and verification graphics. There are the four maps, two forecasts and two corresponding verification maps, which the interviewees were given. Each graphic has five questions concerning the graphic's comprehensibility, the legend, the lettering, the choice of colours and the limitations.

The first graphic shows the probability wind speed forecast (IC3) (see Figure 6). Participants answered that the comprehensibility was "ok" and that there is not too much information in the graphic. One added that the explanation for the title is missing.

The second question regarding their evaluation of the legend showing below/above/normal forecast categories had similar results. Overall it was considered as "good". Two answered that the percentage (%) unit is missing for most likely category and one included that the white part of the legend has to be divided into percentages as the other colours do.

The lettering was also seen as "ok" but it can be specified what MAM means. As for the colours, the opinions were different. Half of the participants answered that the use of the colours is "clear". The rest indicated that in their opinion the colours are not adequate. Suggestions were made to include units, explain terminologies such as MAM, tercile and add a little explanation.

The next graphic shows the ensemble-mean correlation of the probability wind forecast (IC3) (see Figure 7). All participants answered that there is enough information in the graphic concerning the comprehensibility. One added that the map scale is too big for this kind of information. The legend was criticised because there are no units, also are the labels that indicate the latitude and longitude missing.

The lettering was evaluated as “good” and “ok” but it was also mentioned that it is necessary to explain what is being is correlated.

The colours were considered “fine” and “ok” but also as “bad” because they do not depict exact numbers in the map.

There are several deficiencies identified: An explanation about the fields being correlated and the significance of correlation should be included. There should be latitude and longitude labels so that everybody can read the map and locate the countries and refer to them. Also there is a lack of description. The colours could be more discrete to make the scale visible and more understandable.

On the following graphic the probability precipitation forecast from the GPC IRI can be seen (see Figure 8). Most of the participants said that the map is comprehensible. One answered that it is difficult to understand because it is not clear what the colour white stands for. Another one added that it remains unclear why in the normal range the percentage is 40%. Also it was said that the scale is too big.

The map’s legend, which illustrates the below-normal, normal and above-normal categories, was evaluated from “good” and “excellent” to “very confusing”. One was not sure if all categories of the scale are present on the map.

The title /description was overall considered as “good”.

The colours were evaluated from “ok” to “poor” and really confusing because you cannot distinguish between normal and above-normal and they are not intuitive.

As deficiencies, the colours were named. They should be changed and be more discrete. In particular it was suggested that there should be more colours in the normal category. The white colour and the dry season D, should be marked bigger and explained more. The description was also said to be too brief.

The related verification graphic represents the generalized ROC (GROC) of the precipitation forecast (IRI) (see Figure 9). The comprehensibility and the legend of this verification graphic were “fine” and “clear”. The lettering is “good” but the

meaning of ROC is missing and it is necessary to specify what fields are being correlated.
The colours are seen as “good” but maybe not intuitive (red would be best).
Suggestions were, to include an explanation of GROC and ROC. One participant especially liked this graphic because of the detail it provides and how the colours are presented. He suggested that non-scientists would be able to use this information.

The next chapter links the results to the existing scientific debate, and gives answers and possible conclusions as well as recommendations to the key questions of this thesis.

5. Discussion

General conclusions from the results are firstly, that each GPC has different communication and visualisation tools for climate information, which is confusing for the end-user. Secondly, individuals interpret information very differently and have diverging expectations. Thirdly, decision-making is related to the amount of risk an individual is willing to take and his tolerance towards risk. Training on how to interpret probabilistic information can be helpful to increase end-users understanding of climate information.

Based on quantifiable scores the Met office, IRI, ECMWF, CPTEC, BCC, NOAA, TCC, KMA, MSC, SAWS and the BoM (for research purposes) are beneficial for all users since there is no login required to access the forecast and the verification data. All GPCs websites (except CPTEC, KMA and Mete-France) are in English, which favours the dissemination of the information. A common layout for forecasts and verifications would be helpful as well as a standard use of forecast type and verification type and to put the verification information next to the forecasts. This also includes standard explanations and fundamental information regarding terminologies. Furthermore, the choice of colours should be the same and the access to the information from the homepage.

Another important outcome and relevant to the user is how to find the information on the website. The “number of clicks“ are one indicator, another is the website’s outlay (how the information is presented, how intuitive the website is, etc.). It can be said from the results of the CLIM-RUN participants that there is a close relationship between how to find the forecast information and the number of “clicks“. Forecast information was easier to find, when there were only two or three “clicks” required. Therefore, one recommendation to the GPCs to make the data more easily accessible is to have as few “clicks” as possible from the initial website to the forecast data and to have a standardised design of the website in order to better find the information, e.g. direct link/tab from homepage, Examples with two “clicks” are BCC and MSC and three “clicks” IRI, APCC, CPTEC and SAWS.

The results of the interviews showed that there was an overall scepticism in future forecasts and that the graphics were hard to understand due to the lack of information/explanations. Although the limitation of the interviews was that there were only a few interviews conducted, the qualitative outcome helped to understand that there is a need for clear, standard explanation of skill interpretations and use of low skill information.

Not all GPCs have latitude and longitude labels, which, regarding the feedbacks of the interviewees, would be helpful. Furthermore the interviewees criticised that some graphics do not have units, so they could not understand the numbers displayed on the graphic. Although some of the graphics were partly understandable the problem was that there was information missing to interpret the data. The interviewees said that the lettering must be self-explanatory.

There is no evident relationship between the number of colours and the evaluation of these. More important is the colour choice. Usually for precipitation forecasts blue was preferred for above-normal (wetter than usual conditions) and red for below-normal (drier than usual conditions).

Another important point from the interviewees' outcomes is that all considered information about the degree of uncertainty as important data. When assessing skill information for impacts in s2d climate forecasts it is important to highlight that the skill can vary considerably depending on the region and the lead-time. Regarding the skill question Falloon et al. (2013) state that in order to meet the needs of users it is necessary to better tailor s2d skill assessments. Therefore, users have to improve their understanding of their needs for s2d climate forecast information. For example unrealistic end-user expectations of skill needs better user understanding that skill is never able to reach 100% due to chaotic nature of the atmosphere. A low skill forecast is still able to provide additional information to help, at least, to guide decisions.

It appears that improving the end user's understandability of s2d forecasts is one key outcome and also communicating uncertainty to decision-makers is an important concern for optimising the use and usability of climate forecast data and skill assessments, which can also help to improve the relationships among scientists and decision- makers (Katz et al., 2013).

Concerning the analysis of the interviewees' responses it has become evident that due to the format of the questionnaire (only open questions) it was complex to quantify the answers. To improve further research it would be recommendable to use the multiple-choice format for conducting interviews and more interviews are needed.

Nonetheless, the interviewees' suggestions offer concrete solutions to improve the understanding of s2d forecasts, which is one of the central questions of this thesis, e.g. to have tailored end-user websites specific to their decision-making processes as well as clear and concise forecast information.

The Advancing Renewable Energy with Climate Services (ARECS) initiative can be named here as an example to create a climate service prototype providing the user with basic guidance on the use of s2d forecast information. ARECS involves and informs stakeholders in order to develop an operational s2d climate service for the renewable energy sector. They offer links for users to access to s2d climate service descriptions and videos to engage. Papers, posters and presentations at renewable energy events could be made available to communicate the results and assessments of climate s2d forecasts (Davis, 2012).

The results of the interviews have underlined the existing gap between the scientific data available and the information needed by decision-makers (Asrar et al., 2013). It has become evident that there is a need to improve the communication of climate forecast information to decision-makers. This can be done with the establishment of climate centres with professionals, who advise end-users, such as already existing organisations like the GIZ or the PIK. Users needs should be taken into account when tailoring climate information.

Regarding the main barriers, which hinder a wide-range dissemination and exchange of actionable climate information based on s2d forecasts, the insufficient exchange of tailored, and freely accessible data was mentioned by the interviewees and that climate information and climate-sensitive sectors are both not well-known. The barriers should be investigated in the context of tailored case studies. The ARECS initiative, mentioned above, already addresses the better understanding and dissemination of s2d forecast information in an effective way for the renewable energy sector.

From the CLIM-RUN workshop several important conclusions can be drawn. In relation to the search of climate information at the GPCs website, one outcome is to facilitate the search for the forecast and the verification data for end-users. This can be achieved by improving the usability and user friendliness of the GPCs website, e.g. clearer web design, putting forecast and verification in the same place, together with standardised search options that could be implemented at all GPCs.

With respect to the other exercise, where participants were asked to include forecast and verification information in decision-making processes, it can be seen that even among scientists, there still remain doubts regarding the interpretation of the maps. To improve the communication of climate forecast information to end-users it is therefore important to include explanatory descriptions of the maps as well as tailored information depending on their needs. It can be noticed that the interpretation of the graphics from the workshop participants shows strong similarities with the interviewees' answers. The results delivered from the participants regarding the visualisation techniques show the following aspects: Firstly, most suggestions were made concerning the inclusion of units and explanations of terminologies (such as MAM, tercile, ROC, GROC, etc.) as well as a brief description of the map and the significance of correlation. Secondly, the lack of the longitude and latitude labels, which are especially important for non-scientists was most criticised. Thirdly, another deficiency identified was the choice of colours. Overall they should correspond to a category.

These answers indicate that for the visualisation of the forecast and verification data to be more useful and understandable, these mentioned aspects should be applied. This answers the second central question, which deals with how to improve the visualisation of s2d.

These outlined solutions can help to improve the use of climate decisions for forecast information in all climate-sensitive sectors. Coming back to the example of the renewable energy sector discussed in the background section, stakeholders and decision-makers such as the BMU and other energy agencies could benefit from such changes suggested above in the following way: In first place, the information they require (for investment, operational risk management, etc.) could be provided already tailored by these climate centres regarding their needs. In second place, barriers such as economic questions, cultural differences between science and society and the gap between scientist and decision-makers can be overcome by further developing sector tailored initiatives (e.g. ARECS) and by introducing specific programs that should facilitate that both sides can help understand each other better. Fourthly, integrating climate forecast information in decisions-making processes could help to deal with uncertainty for future projections. Finally, the improvement of the accessibility of climate information as well as the optimisation of visualisation techniques can contribute to establish important climate service prototypes. Especially tailored information for end-users and improved climate services in form of websites or information centres can help to integrate climate information efficiently in decision-making processes.

6. Conclusions and Recommendations

The background chapter of this thesis introduced the reader to climate sciences bridging this topic to a concrete example of a climate-sensitive sector, namely the RE industry and how s2d climate forecasts can help to improve decision-making processes within this sector. The BMU was used as the targeted stakeholder to show to what extent forecasts may shape policy decisions e.g. FiTs. This is one existing example, which illustrates how information about future climate can improve societies resilience in climate-dependant sectors.

The main focus of the study were the challenges regarding the communication and visualisation of climate forecast information to end-users and stakeholders of climate-sensitive sectors. The results of this research show that fundamental changes have to be made within existing accessibility options and visualisation techniques of forecast information in order to improve the communication between scientists and users. Different suggestions were made by the interviewees and participants of the CLIM-RUN Workshop on how to optimise climate services. The outcomes of the results and discussion sections offer concrete solutions to the three research questions. The communication of climate-forecast information to decision-makers can be improved by establishing centres, which connect both sides. In this sense, users needs and the understanding of scientists as to which information is relevant to stakeholders for decision-making processes are being integrated in decision-making processes. What was also said to be important is the improvement of the understandability of s2d forecasts and also communicating uncertainty to policymakers in order to optimise the relationships among scientists and decisions makers. Regarding how to improve the communication and visualisation of climate forecast information, a set of recommendations have been prepared (see below).

Concerning the main barriers that hinder the wide-range dissemination and exchange of climate information it can be said that data should be more freely accessible and filtered depending on the users needs. The ARECS initiative is a good example to follow for investigating the better understanding and dissemination of s2d forecast information and how to engage and inform end-users in order to develop an operational s2d climate service.

The main contribution of this study besides the described solutions from the interviewees and CLIM-RUN participants is the following recommendation sheet for GPCs for how to improve the accessibility and visualisation of climate forecast information.

Recommendation sheet for GPCs:

Accessibility:

- Helpful for users to have freely accessible information (offer the option to grant access for scientific reasons).
- Websites should be translated to English in order to improve the wide dissemination of the information.
- Forecast information should be easily accessible: No more than three clicks from the initial website.
- Improve user friendliness of website e.g. by introducing standardised search options at all GPCs.

Visualisation/Presentation:

- Include latitude and longitude labels and a latitude-longitude grid.
- Titles should contain information regarding variable, period, indication of units, a legend and region. They must be self-explanatory.
- It would be helpful to have an explanatory text, which clarifies terminologies and how the graphic and colours should be read/interpreted.
- Colours: have a standardized selection of colours across all GPCs, in order to know exactly when it is above-normal, near-normal and below-normal. For example, blue colours should consistently be assigned to above-normal precipitation (wet) and red colours to below-normal (dry).

Decision-makers from various climate-sensitive sectors could benefit from improved communication, visualisation and understanding of climate products if these recommendations are adhered to. They can be seen as a direct outcome of the SPECS objectives contributing to the improvement of the visualisation and understanding of s2d predictions.

Further work needs to be conducted by implementing the standardisation options at the GPCs regarding accessibility and visualisation and towards the development of climate services prototypes as it already has been started from the WMO (GFCS), CSP, EUPORIAS, SPECS, CLIM-RUN and ARECS.

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iv. Appendix

1. Glossary

Anomaly
Anomaly means the deviation of a measurable unit, (e.g. temperature, precipitation) in a given region over a specified period from the long-term average, for the same region.

Brier Skill Score
Brier skill score is conventionally defined as the relative probability score compared with the probability score of a reference forecast. Like the ROC, it shows the degree of correct probabilistic forecast discrimination, even if the forecasts have biases or calibration problems. However, unlike ROC, GROC is generalized to encompass all forecast categories (below, near, and above normal) collectively, rather than being specific to a single category.

Climate
Climate describes the way the atmosphere behaves over long-term timescales.

Climate change
Climate change is determined by long-term changes in the climate over multi-decadal timescales. The changes may be due to natural or human-induced causes.

Climate model
A climate model is a mathematical model that quantitatively describes and simulates the interactions between the atmosphere and underlying surface (e.g., ocean, land, and ice).

Climate variability
Climate variability means climate fluctuations above or below a long-term average value.

Climatology
1. Is the description and scientific study of climate.
2. Is a quantitative description of climate showing the average values of climate variables over a region.

Communication
Communication means the exchange of information by speaking, writing, or using some other medium.

Correlation Coefficient
The Correlation Coefficient is a statistical concept that measures how well trends in the predicted values follow trends in actual values. The coefficient describes a number between 0 and 1. If there is no relationship between the predicted values and the actual values, the correlation coefficient is 0 or very low (the predicted values are no better than random numbers). As the strength of the relationship between the

predicted values and actual values increases, the value of the correlation coefficient increases toward 1.0. A perfect fit gives a coefficient of 1.0. Thus the higher the correlation coefficient, the better.

Climate science
Climate science describes the study of the climate.

Climate services
Climate services are the communication of climate information to the public or a specific user.

Decadal
Decadal means a consecutive ten year period.

Deterministic forecast
Deterministic forecasts states what is going to happen, when and where.

El Niño
El Niño is a periodic warming of surface ocean waters during a phase of ENSO in the eastern tropical Pacific along with a shift in convection in the western Pacific further east than the climatological average. These conditions affect weather patterns around the world. El Niño episodes occur roughly every four-to-five years and can last up to 12-to-18 months.

Energy
Energy describes usable power (heat, electricity, etc.) and also the resources for producing such power.

Ensemble Forecast
Ensemble forecasts are multiple forecasts from an ensemble of slightly different initial conditions and/or various versions of models. The objective is to improve the accuracy of the forecast through averaging the various forecasts, which eliminates non-predictable components, and to provide reliable information on forecast uncertainties from the diversity amongst ensemble members. Forecasters use this tool to measure the likelihood of a forecast.

ENSO (El Niño-Southern Oscillation)
ENSO refers to El Niño/ Southern Oscillation, or the combined atmosphere/ocean system during an El Niño warm event. The ENSO cycle includes La Niña and El Niño phases as well as neutral phases, or ENSO cycle, of the coupled atmosphere/ocean system though sometimes it is still used as originally defined. The Southern Oscillation is quantified by the Southern Oscillation Index (SOI).

Feed in tariffs (Fits)
Fits are an energy policy, which incentivises the implementation of renewable energies offering the end user a guaranty payment for x years for the generation of renewable energy. They function as an aid to help meet the Government's renewable energy generation targets.

Forecast
A forecast is an estimation based on special knowledge of the future state of the atmosphere with respect to temperature, precipitation, and wind. Weather forecasts are now routinely provided for up to 14 days in advance and climate forecasts for seasonal and longer timescales.

Forecast verification
A forecast verification is a method to assess a posteriori how skilful or valuable a forecasting system or single forecast was.

Gerrity score
The Gerrity Skill Score (GSS) is the recommended skill score for the three by three contingency tables calculated for Level 3. It uses all entries in the contingency table and it does not depend on the forecast distribution. It does not reward conservative forecasting, but rather rewards forecasts for correctly predicting the less likely categories. Smaller errors are penalized less than larger forecast errors. This is achieved through the use of the scoring matrix.

GROC
Like the ROC, the GROC shows the degree of correct probabilistic forecast discrimination, even if the forecasts have biases or calibration problems. However, unlike ROC, GROC is generalized to encompass all forecast categories (below, near, and above normal) collectively, rather than being specific to a single category.

Heidke Skill Score
The Heidke Skill Score (HSS) compares how often the forecast category correctly match the observed category, over and above the number of correct "hits" expected by chance alone.
This score utilizes the number of correct and incorrect category hits. The values range from -50 to 100. A score of 100 indicates a perfect forecast and a score of -50 indicates a perfectly incorrect forecast. Scores greater than 0 indicate improvement compared to a random forecast and indicate skill.

Hindcast
A hindcast is a forecast made in retrospective mode.

La Niña
La Niña is a periodic cooling of surface ocean waters in the eastern tropical Pacific along with a shift in convection in the western Pacific further west than the climatological average. These conditions affect weather patterns around the world. La Niña is a phenomenon in the equatorial Pacific Ocean characterized by a negative sea surface temperature departure from normal (for the 1971-2000 base period), averaged over three months, greater than or equal in magnitude to 0.5°C in a region defined by 150°W-160°E and 5°N-5°S (commonly referred to as Niño 4).

Lead Time
Lead time is defined as the time elapsed between when the model was run (the model start date) and the forecast date.

Mean
Mean is the arithmetic average, or the middle point between two extremes.

Probability
Probability is a chance, or likelihood, that a certain event might happen.

Probability forecast
A probability forecast is a technique for forecasting that relies on different methods to establish an event occurrence/magnitude probability. Probabilities are usually stated either as a percentage, which may range from 0 ("The event will definitely not occur") to 100 ("The event will definitely occur"), or as a numerical value between 0 and 1. Values between 0 and 100 or between 0 and 1 represent the different degrees of uncertainty.

Probability of most likely tercile
Lower, central and upper tercile categories are defined using the climatological distribution. The most likely category shows the probability for the tercile that presents the highest forecast probability value.

Quintile
The quintile categories are defined in an analogous way to the tercile categories such that each quintile category has occurred equally frequently in the model climatology, and the baseline probability for any category is therefore 20%, with each category expected to occur, on average, once in five years. Thus forecasts of the probability for outer-quintile categories provide information on the likelihood of conditions more 'out-of-the-ordinary' than defined by outer tercile categories. The proportion of ensemble members falling into the lower or upper quintile category gives the forecast probability for that category.

Reliability Plot
A reliability plot shows how well the forecasts probabilities correspond to the subsequent observed relative frequencies of occurrence, across the full range of issued forecast probabilities. This is examined for each of the forecast categories individually (below, near or above-normal).

Renewable energies
Renewable energies are any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. Renewable energies are obtained from the continuing or repetitive flows of energy occurring in the natural environment and include resources such as biomass, solar energy, geothermal heat, hydropower, tide and waves and ocean thermal energy, and wind energy.

ROC (Relative Operating Characteristics**)**
The ROC measures the ability of the forecast to discriminate between two alternative outcomes, thus measuring resolution. It is not sensitive to bias in the forecast, this means that it says nothing about reliability. A biased forecast may still have good resolution and produce a good ROC curve, which means that it may be possible to improve the forecast through calibration. The ROC can thus be considered as a measure of potential usefulness and is conditioned on the observations.

Seasonal to decadal climate forecasts
Seasonal to decadal climate forecasts are forecasts, of the expected climate conditions, for the next one to six months.

Skill score
The term "skill" in relation to forecasts means a measure of the performance of a forecast relative to some standard. The standard, which is often used, is the long-term (30-year) average (called the climatology) of the parameter being predicted. Thus, skill scores measure the improvement of the forecast over the standard.

Tercile
Tercile means a set of data arranged in order with values that partition the data into three groups, each containing one-third of the total data. To define these terciles, the historical data is arranged in order from lowest to highest and then the data is partitioned into three groups. The lowest third of the data values are defined as the lowest tercile, the middle third of the values are the middle tercile and the upper third of the values are the upper tercile.

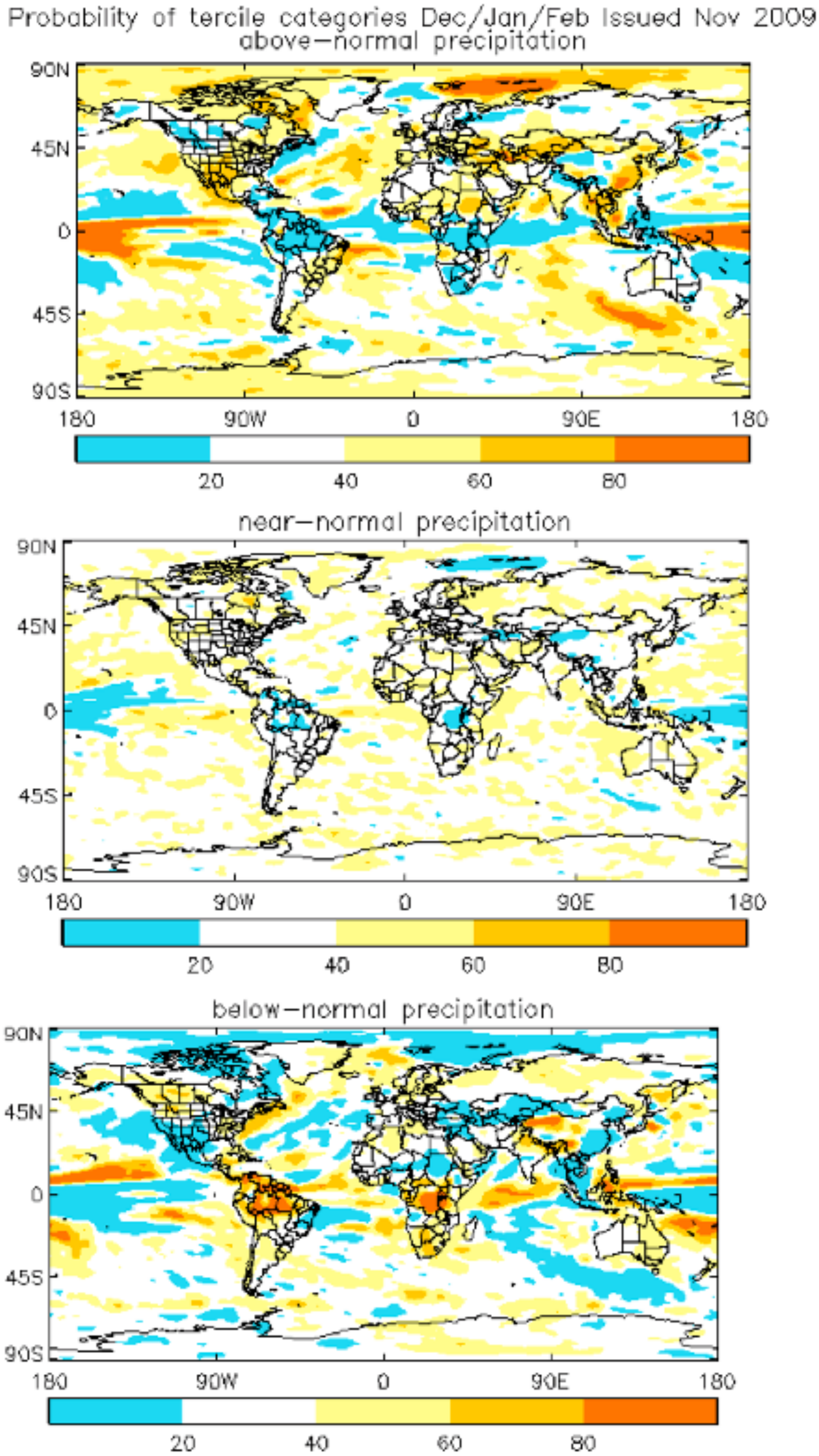
Uncertainty
Uncertainty describes the amount of possible inaccuracy and it represents the degree to which a data set may be in error from predicted values.

Visualisation
Visualisation refers to a technique that helps others to see the data in order to help them better understand the information provided.

Weather
Weather describes the way the atmosphere behaves at the scales of hours/days/weeks.

2. Forecast and Verification Graphics

1. Met office
Forecast



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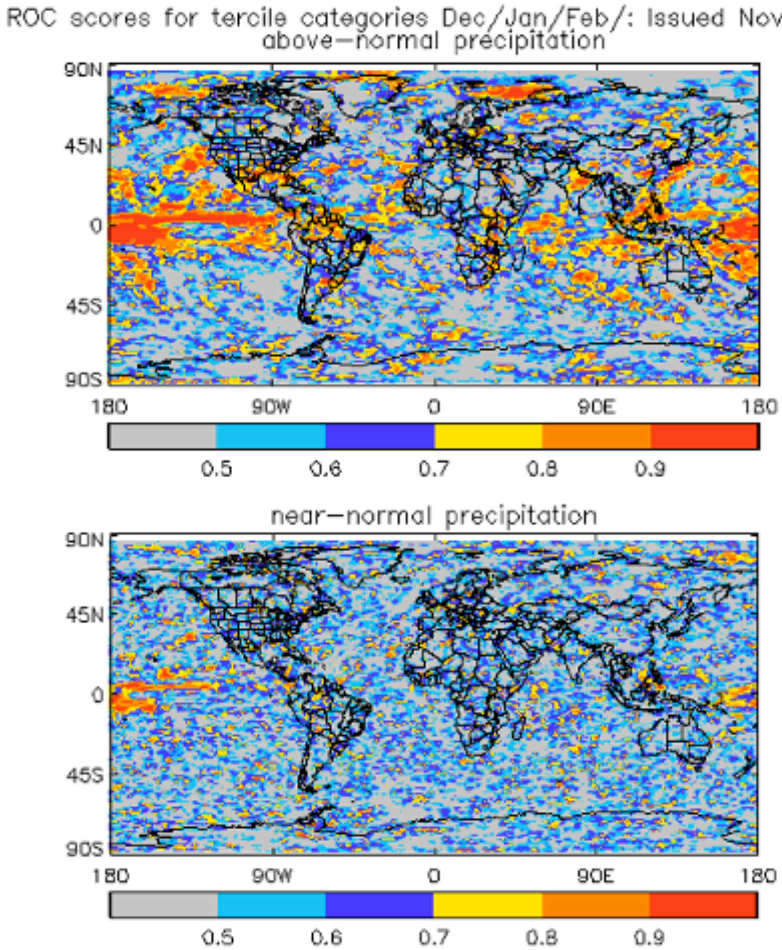

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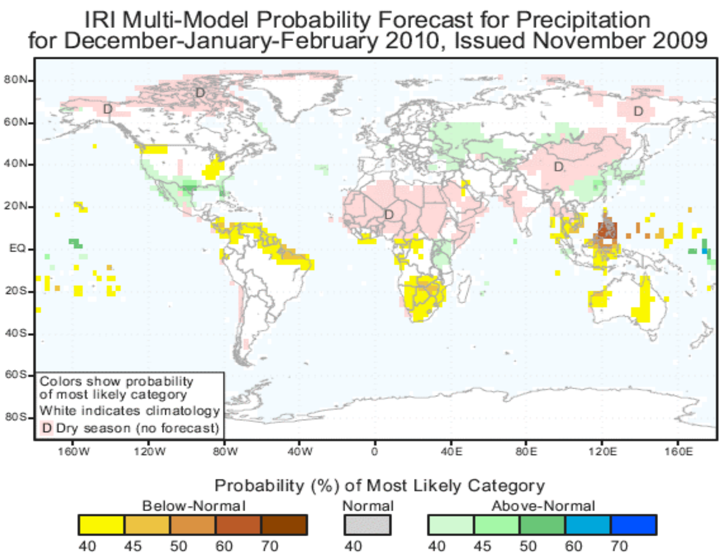
Forecast



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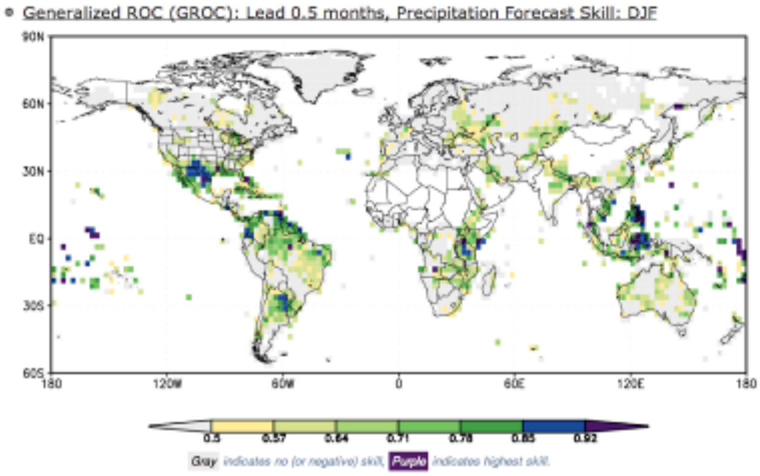

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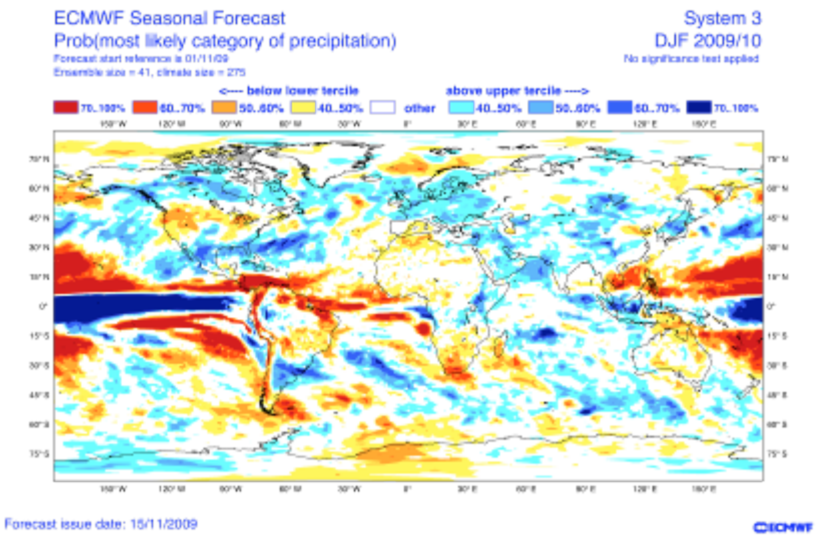
Forecast



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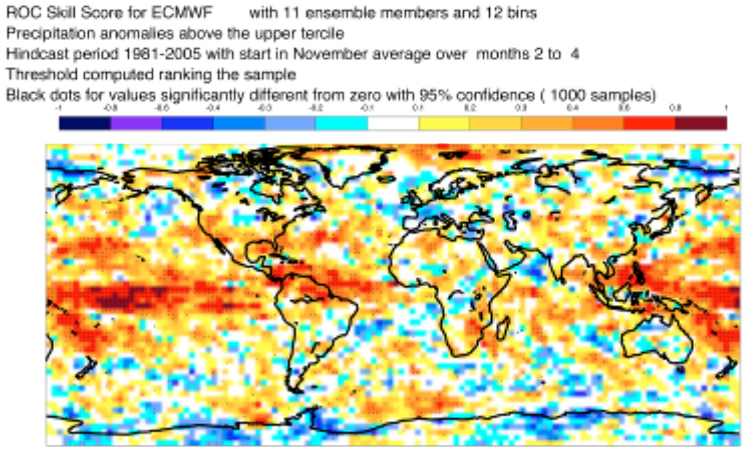
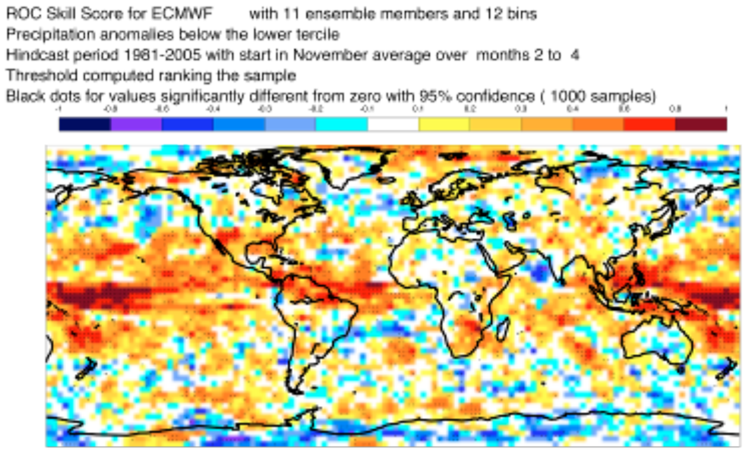
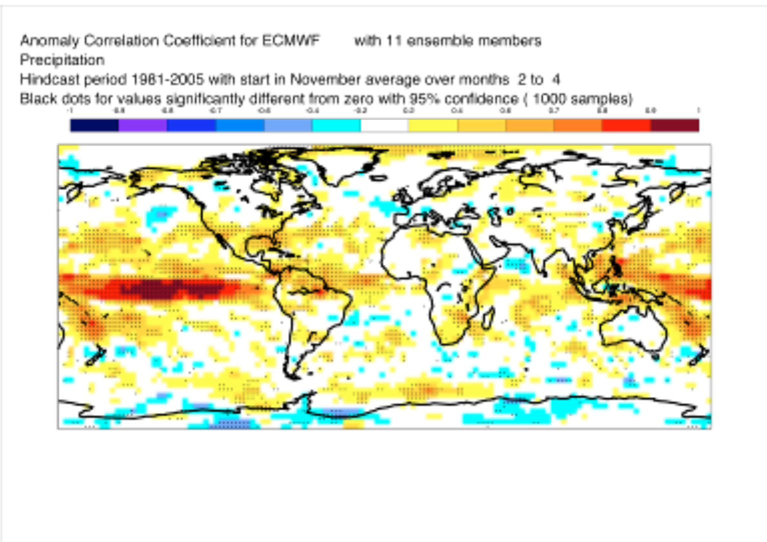
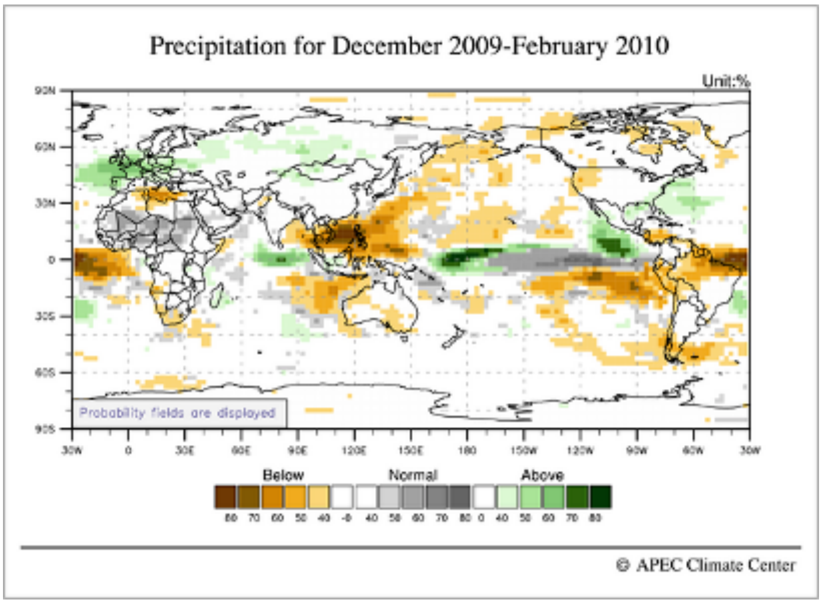






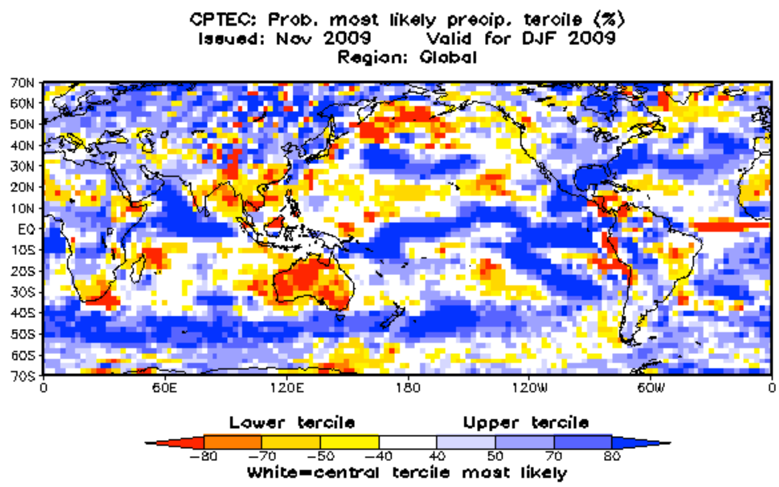
4. APEC
Forecast



Verification

Need to log in

5. CPTEC
Forecast



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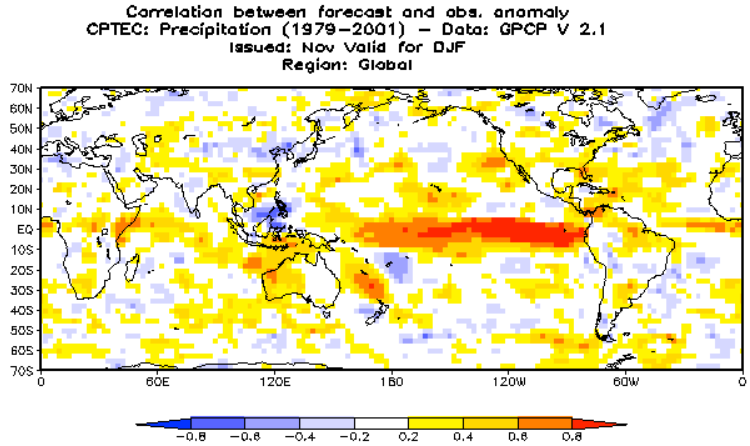
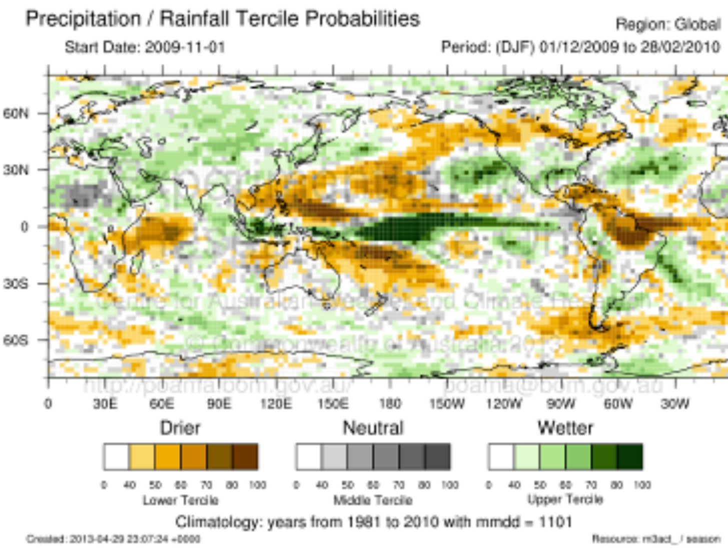


6. BoM

Forecast



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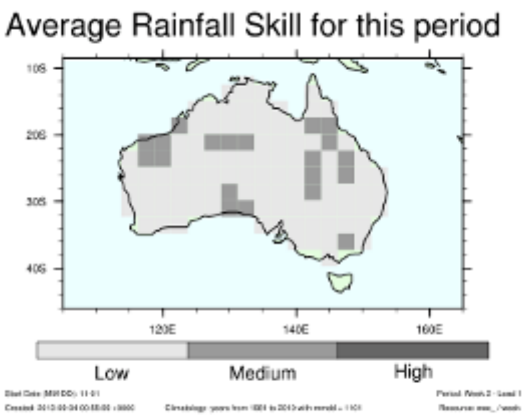
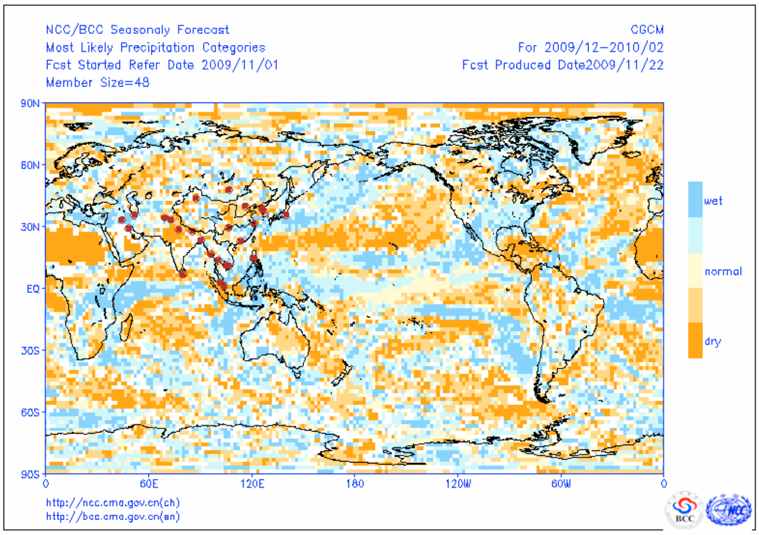


This indication of performance is based on correlation (r) skill for this time of year. Low: r < 0.3; Medium: 0.3 < r < 0.6; High: r > 0.6.

7. BCC
Forecast



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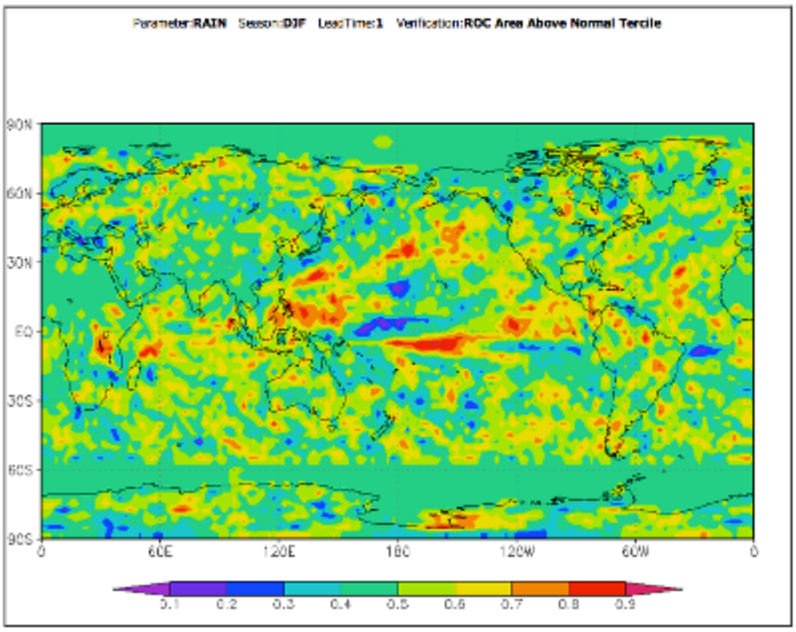
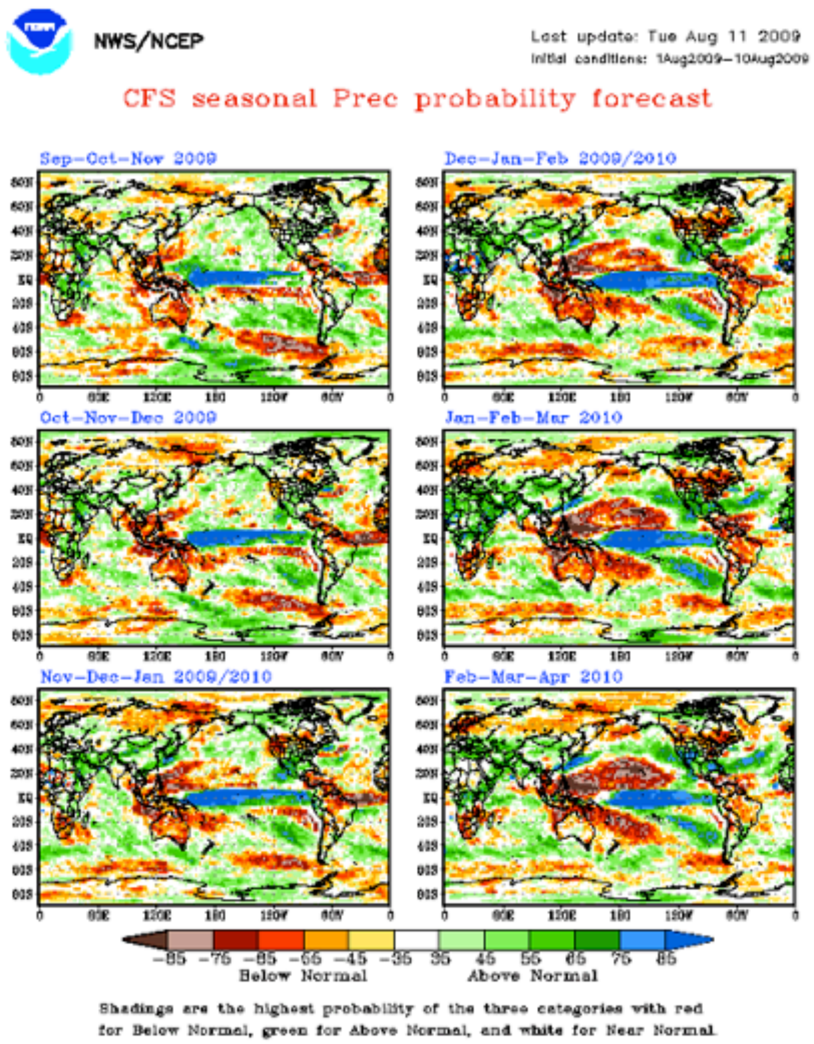
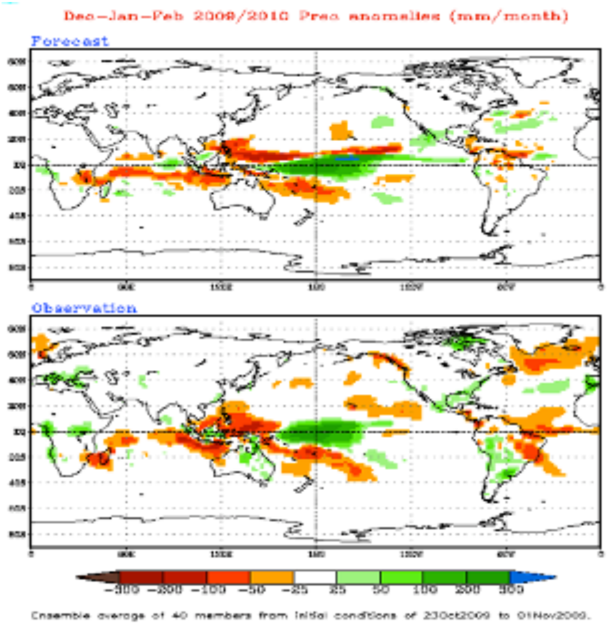


8. NOAA
Forecast

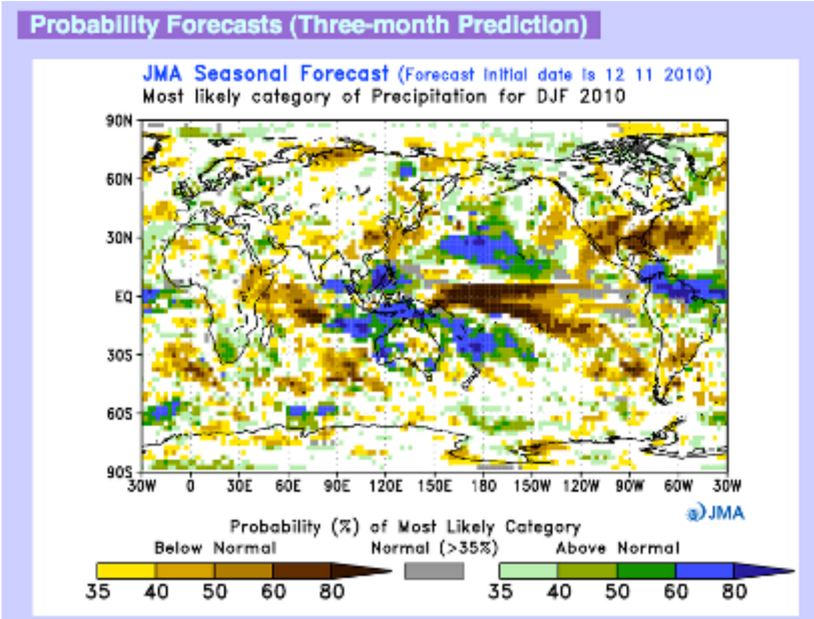


Verification



9. TCC

Forecast



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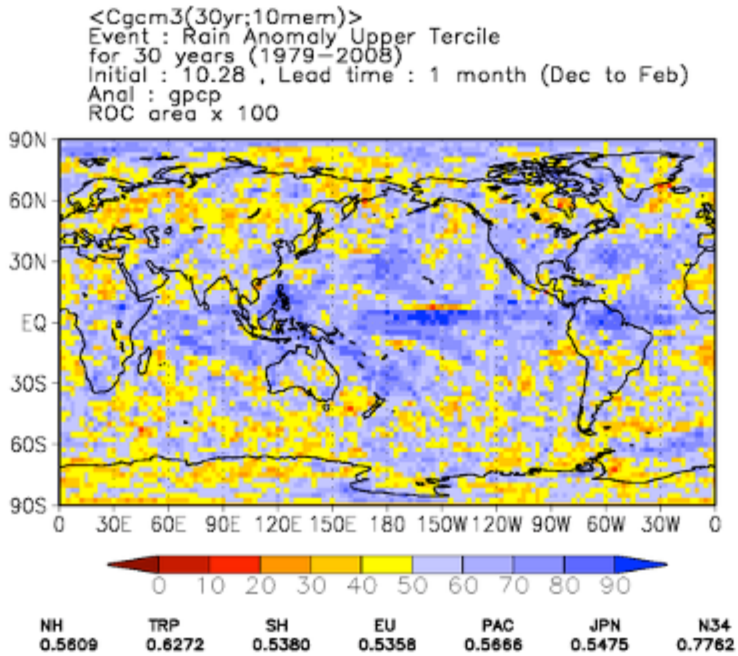
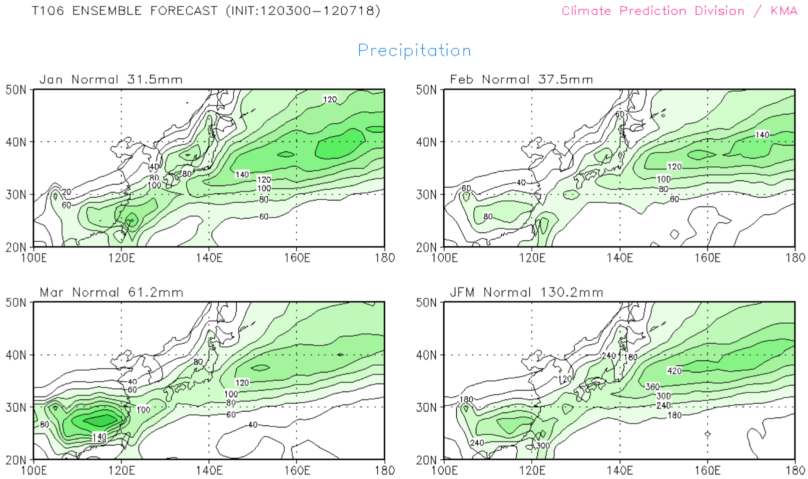
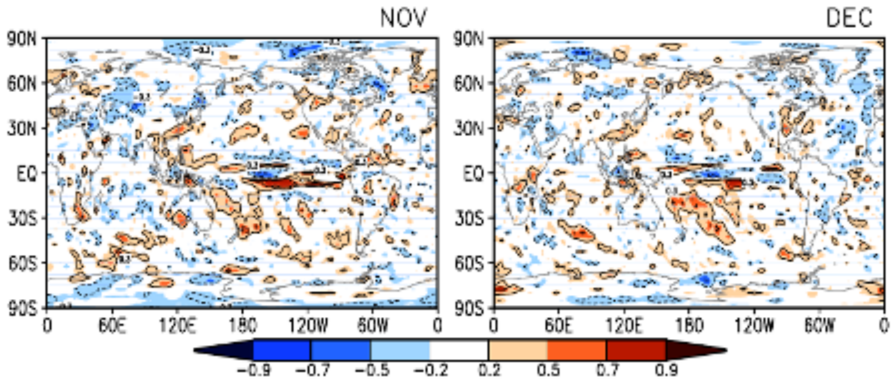


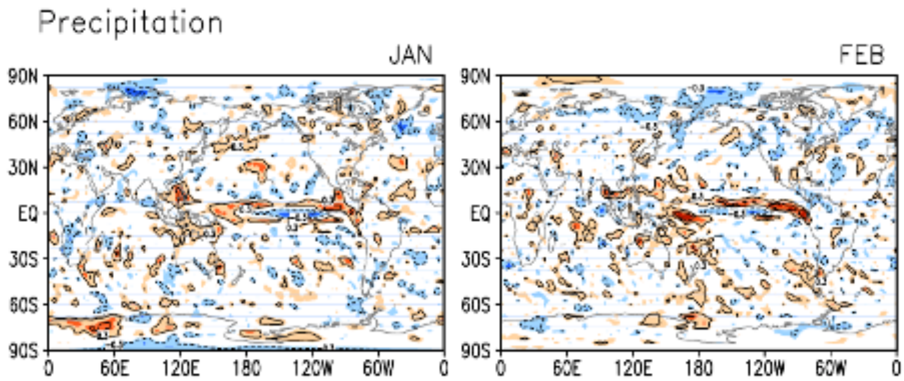
10. KMA

Forecast



Verification

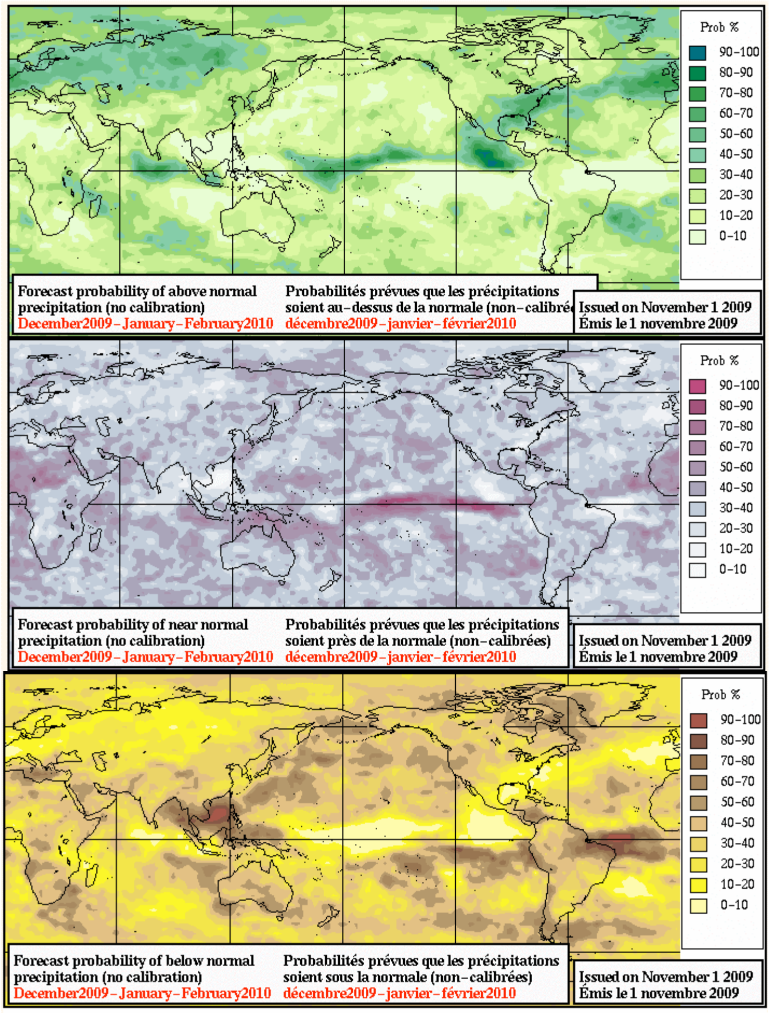




11. Meteo-France

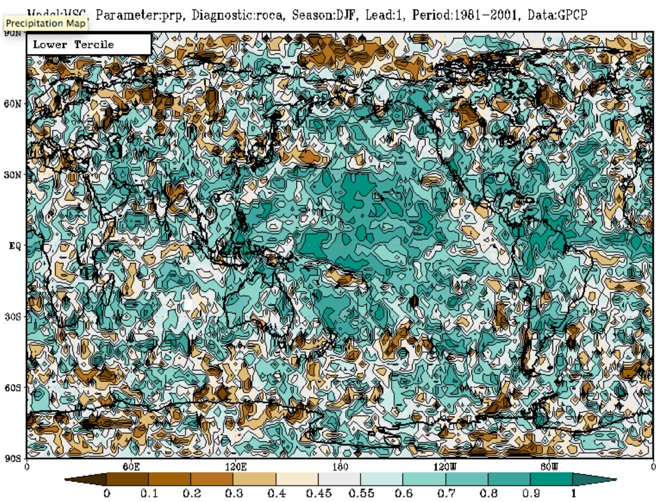
No information for forecast and verification

12. MSC
Forecast

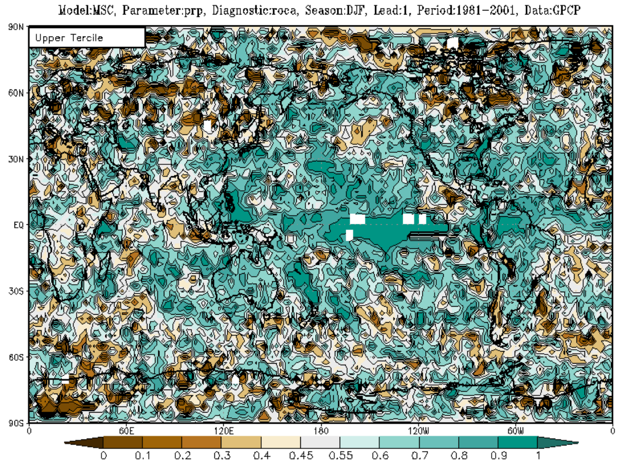


Verification

Lower tercile:

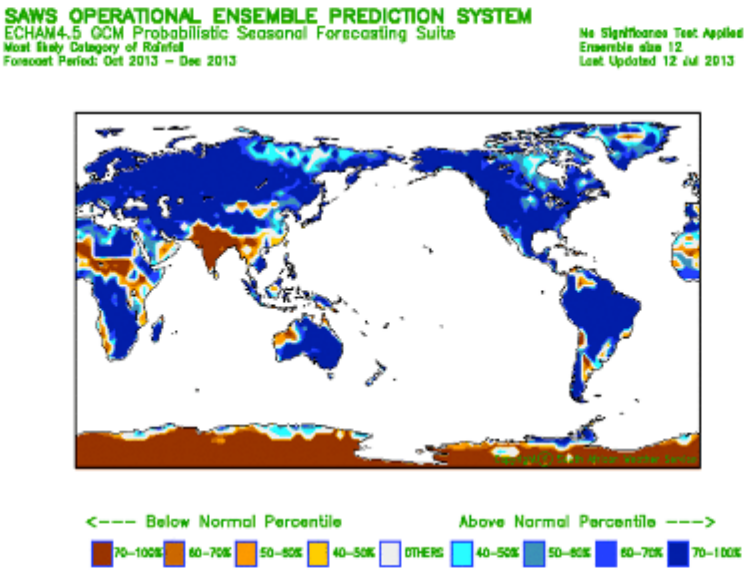


Upper tercile:



13. SAWS

Forecast



Verification

Not able to open verification page

3. Questionnaire

3.1. Transcript Interviewee 1

1. Name of the Institution: University of Kaiserslautern, department of urban planning, Kaiserslautern, Germany

They operate at regional and local geographical scale.
The interviewee is the department's coordinator.

---

2. Use of seasonal to decadal (s2d) climate forecast

He was overall sceptical about s2d forecasts and modelling since there is a high degree of uncertainty. Climate is too chaotic in order to be able to deliver precise forecasts and satisfactory results. In his opinion it is possible to make a reliable forecast for the next 72 hours. Otherwise the forecasts are highly error-prone (see IPCC report). Nevertheless it is useful to have these outlooks but one has to be careful with their interpretation.

---

3. Dealing with uncertainty

He states that the main problems regarding the uncertainty of s2d forecasts are the increase of dust concentration (e.g. volcano eruptions in the stratosphere) → Global-dimming. Simulations have to be adapted constantly because their starting situation is changing. Also the influence of meta emissions from emerging countries such as China, Brazil, India plays an important role.
Another problem is the rise of the sea level and that the climate system is an open system, which makes it even more difficult to predict. He sees with concern that there is a growth among climate sceptics.
He thinks that the degree of uncertainty is relevant information. See the last IPCC report regarding their misinterpretations. It does not exist a 100% forecast. For him the percentage of certainty should be at least 75%, for more sensitive sectors (e.g. agriculture) 90 % to better estimate the ecological damages.

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4. Main questions of the Masters thesis

He thinks the communication of climate forecast information to renewable energy policy is definitely in need of improvement. What could be done is the establishment of climate resorts with advisors, who know the subject and have connections to climate scientist/ institutes/ universities to contrast the information and to avoid incorrect statements (see energy transition). It is important to create connecting links to enable the exchange of information for both sides because often the communication is missing.
He thinks that the main barriers are the insufficient exchange of unfiltered and freely accessible data (e.g. only IPCC summary for policy makers, German Weather service) Info is often charged.

---

5. Models

He criticised that even for a professional the title and the lettering did not offer enough information in order to interpret the graphics. He said he could not understand the meaning of the numbers in the legend.

Graphic 1
This graphic is not understandable even for scientists. It is not clear how the numbers in the legend are to be interpreted. Are these percentages (tercile)? The lettering does not explain in a comprehensible way what is shown. The terms and the terminology remain unclear e.g. tercile, ECMWF, MAM. Include explanation of these, e.g. with asterisk. The indication of longitude and latitude is missing.
The colours are ok but to simplify the results there should only be red and blue.
In general the graphic is good but the lettering should be modified to make it more understandable. At a glance it should be clear what is shown.
He would suggest to include in the title that it is a wind forecast, which is measured in 10 m height and how the colours should be interpreted.
Also include which is the initial/average value (e.g. 4,5 meters per second)
The lettering must be self-explanatory.

Graphic 2
It is not clear what is correlated. Which value? This graphic is confusing after you have seen the other graphic (wind forecast), since the colours have a different significance.
In the legend on the right side it would be more helpful to include the percentages instead of 1 - 0- -1.
As for the colours only show 5 colours: red, orange, yellow, light blue, blue
His recommendations are to include the average (delta 1981-2010) and show all the units in percentages.

Graphic 3
Unclear what numbers and units mean. Not comprehensible. There is no initial value.
Better employ red to indicate drier seasons (instead of yellow).

Graphic 4
Not comprehensible. Better to indicate which years are reference.

3.2 Transcript Interviewee 2

1. Name of the Institution: Gas Natural Fenosa, Spain

Energy commercialisation operating at an international scale.
Business Analyst

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2. Use of seasonal to decadal (s2d) climate forecast

There is a high degree of uncertainty. We are incapable of predicting tomorrow's weather. The institution does not use s2d info.

---

3. Dealing with uncertainty

Problems regarding uncertainty: No reliable information for investors. Relevant to show the degree of uncertainty in the forecast. The forecast should have at least a probability (in percentage) of >95%.

4. Main questions of the Masters thesis

Improving degree of certainty
Economic barriers and the info is not reliable

5. Models

Graphic 1
For him the comprehensibility is cero. Because the lettering does not explain the graphic (what are numbers below?, are these percentages?, numbers on the left side should explain what they stand for: latitude, longitude, unclear what 10 meter means (speed?))
The colourfulness is ok.
To improve comprehensibility the measures/units (percentage, meters per seconds, speed, height...) should be indicated.

Graphic 2
Same as in Graphic 1: more info concerning measures (numbers on the right side). Unclear what the negative numbers mean.
Colourfulness is misleading because the colours let the user believe the degree of certainty is high, but in reality the mayor part of the map is yellow (20% skill).
The graphic is not understandable. It seems the graphic is manipulative to give the impression that there is a higher degree of certainty.
It has to explain the numbers, what means 9.0 and 1.0 etc.

Graphic 3
Not comprehensible. Units missing. Colours and numbers are misleading. Helpful to have a latitude-longitude grid.

Graphic 4
Bad comprehensibility. Units missing. Information in the lettering is missing that explains the graphic. Bad choice for colours.

3.3 Transcript Interviewee 3

1. Name of the institution: KLA Kipar Landschaftsarchitekten GmbH, Germany and Italy

Landscape Architecture and urban planning in an international context
Managing director

2. Use of seasonal to decadal (s2d) climate forecast

Since the models are each time more precise, this kind of information will be relevant in the future to predict climate anomalies and to react to these.

His organisation doesn’t work with s2d info because the reliability hasn’t been very high in the forecasts and the changes in climate haven’t been very radical.

3. Dealing with uncertainty

He thinks that the information of the degree of uncertainty is important, for him a useful forecast should be 80%.

4. Models

Graphic 1
He states that the legend on left side and under the map is missing and that it is a bad layout. The colourfulness is comprehensible.

Graphic 2
He also criticises the layout of this graphic.

Graphic 3
The map’s legend is not clear. Bad resolution.

Graphic 4
Comprehensibility ok.

3.4 Transcript Interviewee 4

1. Name of the Institution: Rheinland-Pfalz Kompetenzzentrum für Klimawandelfolgen, Germany

Study of impacts of climate change in one region in Germany (Rheinland-Pfalz) + adaptation strategies, climate change information systems.
The interviewee is responsible for analysing the possible impacts of climate change in the water, analysis of climate data and climate projects.

2. Use of seasonal to decadal (s2d) climate forecast

Not (yet) relevant for their work. He states that the main problem for s2d forecasts is the unreliability. Other organisations that use s2d are Deutscher Wetterdienst, Agrarmeteorologie

3. Dealing with uncertainty

Regarding the problems of uncertainty he says that it is because of the initial value problem. Also the uncertainty increases the longer the timescale of the forecasts is. Therefore it is essential to indicate the degree of uncertainty in the forecast.

4. Main questions of the Masters thesis

The climate scientists should synthesise their data to the relevant aspects and always be aware of the degree of uncertainty in the communication.
He thinks that this information is not yet known and that the sectors of application are not known as well. The barriers should be investigated within case studies.

5. Models

Graphic 1
He states that this graphic does not contain enough information to make it understandable to non-professionals. What misses in the lettering is data regarding the represented variable and its unit as well as the reference area.
He does think the choice of colours is adequate.

Graphic 2
Same as Graphic 1. Also the definition Ensemble-Mean-Correlation should be unknown to most of the non-professionals as well as their interpretation.
In other graphics he criticises the colours red and green (dyschromatopsia).
What also is problematic is the use of abbreviations that are not explained.

Graphic 3
Not comprehensible because the information is not enough to understand the graphic.
Colours are problematic. Lettering is not sufficient in order to interpret forecast.

Graphic 4
A non-scientist would not understand this graphic. Most of them do not know how to read the scale. Information missing e.g. explain terminologies. Colours are good.

3.5 Transcript Interviewee 5

1. Name of the Institution: CMES Collective, Spain

The organisation analyses the depletion of fossil fuels and how renewable energies can give solutions to this problem. They operate in Spain but want to extent to Europe.

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2. Use of seasonal to decadal (s2d) climate forecast

They think s2d forecasts could be very helpful but dificult to get exact results. The organisation does not use with s2d forecasts.

---

3. Main questions of the Masters thesis

He thinks that it is very important to improve the communication of climate forecast information to renewable energy policy makers because this would enable to better program the production, adapting it to the demand.

---

4. Models

Graphic 1
He thinks that the map's legend is insufficient because the lettering of the longitude and latitude is missing. The use of colours is good.
His suggestions are to include a zoom view.

Graphic 2
He states that it is difficult to interpret the legend. He is unfamiliar with the units. Colours are good. Zoom view is his suggestion.

Graphic 3
It is not clear what the D means and there are areas which do not have colours (white implies data is missing?). Colour choice is regular. He points out that the indication of the longitude and latitude is helpful. The lettering is fine. Zoom view missing.

Graphic 4
This graphic is not very comprehensible. The legend is not understandable. The resolution is bad. Include zoom.

4. Table for Participants of the CLIM-RUN Workshop

GPC CHOSEN:	
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months?
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply?
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	
Number of clicks required from the initial website to find the forecast	
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	
Information in title/lettering. Does it mention:	
Forecast type?	
Probability of categories?	
Region (Global)?	
Period (DJF 2009/2010)?	
Element (precipitation)?	
When issued (November 2009)?	
Other data. Does it show:	
Indication of units?	
Is there a legend?	
How understandable is it? (1-10)	
Longitud?	
Latitude?	
Colours used (main colours, shadings are not included)	
white	
yellow	
orange	
red	
purple	
light blue	
blue	
green	
brown	
grey	
black	
Numer of different colours	
Evalutaion of colours (1-10)	
Existence of broken lines?	
Evaluation of the understandability (from a non-scientist point of view) (1-10)	
Verification Analysis	
Is the data difficult to find? (1-10)*	
Number of clicks required from the initial website to find the forecast	
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	
Information in title/lettering. Does it mention:	
Verification type?	
Probability of categories?	
Region (Global)?	
Period (DJF 2009/2010)?	
Element (precipitation)?	
When issued (November 2009)?	
Other data. Does it show:	
Indication of units?	
Is there a legend?	
How understandable is it? (1-10)	
Longitud?	
Latitude?	
Colours used (main colours, shadings are not included)	
white	
yellow	
orange	
red	
purple	
light blue	
blue	
green	
brown	
grey	
black	
Numer of different colours	
Evaluation of colours (1-10)	
Existence of broken lines?	
Evaluation of the understandability (from a non-scientist point of view) (1-10)	
Conclusions from table: + **Answer to the original question:** - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision-making process? Why? - if Yes, what decision would you make? Why? - if No, what decision would you make? Why?	

Table 7: GPC assessment and decision-making for energy supply

4.1 Group 1

GPC CHOSEN:	Met office
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months? ✓
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply? no → above-normal 50% →
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	
Number of clicks required from the initial website to find the forecast	
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	- Probability of tercile categories - ~~below~~ above normal → need zoom
Information in title/lettering. Does it mention:	
Forecast type?	✓
Probability of categories?	✓
Region (Global)?	✗
Period (DJF 2009/2010)?	✓
Element (precipitation)?	✓
When issued (November 2009)?	✓
Other data. Does it show:	
Indication of units?	✗
Is there a legend?	✓
How understandable is it? (1-10)	7
Longitud?	✓
Latitude?	✓
Colours used (main colours, shadings are not included)	
white	✓
yellow	✓
orange	✓
red	✓
purple	
light blue	
blue	✓
green	
brown	
grey	
black	
Numer of different colours	5
Evalutaion of colours (1-10)	3 5
Existence of broken lines?	✗
Evaluation of the understandability (from a non-scientist point of view) (1-10)	8
Verification Analysis	
Is the data difficult to find? (1-10)*	
Number of clicks required from the initial website to find the forecast	
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	- ROC scores for tercile categories
Information in title/lettering. Does it mention:	
Verification type?	✓
Probability of categories?	✓
Region (Global)?	✗
Period (DJF 2009/2010)?	✓
Element (precipitation)?	✓
When issued (November 2009)?	✓
Other data. Does it show:	
Indication of units?	✓
Is there a legend?	✓
How understandable is it? (1-10)	7
Longitud?	✓
Latitude?	✓
Colours used (main colours, shadings are not included)	
white	
yellow	✓
orange	✓
red	✓
purple	
light blue	✓
blue	✓
green	
brown	
grey	✓
black	
Numer of different colours	6
Evaluation of colours (1-10)	3
Existence of broken lines?	✗
Evaluation of the understandability (from a non-scientist point of view) (1-10)	1
Conclusions from table: + **Answer to the original question:** - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision-making process? Why? - If Yes, what decision would you make? Why? - If No, what decision would you make? Why?	We are going to use the water now because the most prob. tercile is above normal and the skill score between 0.3 – 0.8

4.2 Group 2

GPC CHOSEN:	MET-OFFICE uk.
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months?
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply?
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	2
Number of clicks required from the initial website to find the forecast	∞
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	PROBABILITY BIG UNCERTAINITY
Information in title/lettering. Does it mention:	
Forecast type?	YES
Probability of categories?	YES
Region (Global)?	GLOBAL
Period (DJF 2009/2010)?	YES
Element (precipitation)?	YES
When issued (November 2009)?	YES
Other data. Does it show:	
Indication of units?	YES
Is there a legend?	YES
How understandable is it? (1-10)	9
Longitud?	YES
Latitude?	YES
Colours used (main colours, shadings are not included)	
white	NO
yellow	YES
orange	YES
red	NO
purple	NO
light blue	YES
blue	NO
green	NO
brown	NO
grey	NO
black	NO
Numer of different colours	5
Evaluation of colours (1-10)	9
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	8
Verification Analysis	
Is the data difficult to find? (1-10)*	2
Number of clicks required from the initial website to find the forecast	∞
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for ~~temperature~~ precipitation?	ROC SCORE VERIFICATION
Information in title/lettering. Does it mention:	
Verification type?	YES
Probability of categories?	YES
Region (Global)?	YES
Period (DJF 2009/2010)?	YES
Element (precipitation)?	YES
When issued (November 2009)?	NO
Other data. Does it show:	
Indication of units?	YES
Is there a legend?	YES
How understandable is it? (1-10)	9
Longitud?	YES
Latitude?	YES
Colours used (main colours, shadings are not included)	
white	NO
yellow	YES
orange	YES
red	YES
purple	NO
light blue	YES
blue	YES
green	NO
brown	NO
grey	YES
black	NO
Number of different colours	6
Evaluation of colours (1-10)	3
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	2
Conclusions from table: + **Answer to the original question:** - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision-making process? Why? - If Yes, what decision would you make? Why? - If No, what decision would you make? Why?	The forecast shows a big uncertainty and we wouldn't use the seasonal forecast this year. I are going to use hydropower as normal

4.3 Group 3

GPC CHOSEN:	IRI.
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months?
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply?
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=difficult, 10 = v.easy	
Number of clicks required from the initial website to find the forecast	
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	Probability Forecast Below normal between 40-45%
Information in title/lettering. Does it mention:	
Forecast type?	Yes (IRI Multi-Model Probability forecast for precipitation)
Probability of categories?	Yes
Region (Global)?	Yes
Period (DJF 2009/2010)?	Yes
Element (precipitation)?	Yes
When issued (November 2009)?	Yes
Other data. Does it show:	
Indication of units?	No
Is there a legend?	Yes
How understandable is it? (1-10)	8
Longitud?	Yes
Latitude?	Yes
Colours used (main colours, shadings are not included)	Yes
white	Yes
yellow	Yes
orange	Yes
red	Yes
purple	
light blue	
blue	
green	Yes
brown	Yes
grey	
black	
Numer of different colours	6
Evaluation of colours (1-10)	7
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	8
Verification Analysis	
Is the data difficult to find? (1-10)*	
Number of clicks required from the initial website to find the forecast	
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	Precipitation forecast skill
Information in title/lettering. Does it mention:	
Verification type?	Yes
Probability of categories?	Yes
Region (Global)?	Yes
Period (DJF 2009/2010)?	Yes
Element (precipitation)?	Yes
When issued (November 2009)?	No
Other data. Does it show:	
Indication of units?	No
Is there a legend?	Yes
How understandable is it? (1-10)	8
Longitud?	Yes
Latitude?	Yes
Colours used (main colours, shadings are not included)	
white	Yes
yellow	Yes
orange	
red	
purple	Yes
light blue	
blue	Yes
green	Yes
brown	
grey	
black	
Numer of different colours	5
Evaluation of colours (1-10)	8
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	5
Conclusions from table: + **Answer to the original question:** - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision-making process? Why? - If Yes, what decision would you make? Why? - If No, what decision would you make? Why?	The data was clear enough for all to use although the forecasts could not be validated Indicates a 40-45% below normal forecasts for the season. It does not support in full the validation although it forecast above rains below normal. I will use my hydropower water reserves. Because the forecasts cannot be validated.

4.4 Group 4

GPC CHOSEN:	ECMWF
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months?
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply?
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	10
Number of clicks required from the initial website to find the forecast	-
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	Prob (most likely category of precipitation) - PP will be normal to below normal.
Information in title/lettering. Does it mention:	
Forecast type?	~~Probability~~ Yes
Probability of categories?	yes
Region (Global)?	yes
Period (DJF 2009/2010)?	yes
Element (precipitation)?	yes
When issued (November 2009)?	yes
Other data. Does it show:	
Indication of units?	yes (%)
Is there a legend?	yes
How understandable is it? (1-10)	10
Longitud?	yes
Latitude?	yes
Colours used (main colours, shadings are not included)	yes
white	yes
yellow	yes
orange	yes
red	yes
purple	NO
light blue	yes
blue	yes
green	NO
brown	NO
grey	NO
black	NO
Numer of different colours	9
Evaluation of colours (1-10)	10
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	5
Verification Analysis	
Is the data difficult to find? (1-10)*	10
Number of clicks required from the initial website to find the forecast	-
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	-
Information in title/lettering. Does it mention:	
Verification type?	Yes
Probability of categories?	NO
Region (Global)?	yes
Period (DJF 2009/2010)?	yes
Element (precipitation)?	yes
When issued (November 2009)?	NO
Other data. Does it show:	
Indication of units?	NO - but is ~~not~~ without dimension
Is there a legend?	yes
How understandable is it? (1-10)	4
Longitud?	NO
Latitude?	NO
Colours used (main colours, shadings are not included)	
white	yes
yellow	yes
orange	yes
red	yes
purple	yes
light blue	yes
blue	yes
green	NO
brown	NO
grey	NO
black	yes (black dots)
Numer of different colours	13
Evaluation of colours (1-10)	10
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	5
Conclusions from table: * **Answer to the original question:** 1) - what does the forecast indicate for DJF season 2009/10? 2) - how much does the verification support this forecast? 3) - would you use the forecast in your decision-making process? Why? - If Yes, what decision would you make? Why? 4) - If No, what decision would you make? Why?	1) indicates a probability between 40% - 80% (in the whole region) of precipitation between lower tercile. 2) not good at all. It does not ~~beat~~ default climatology 3) NO, there is no significantly anomaly correlation coefficient different from 0 in the area of interest. 4) In this case I would make use of climatology to make a decision.

4.5 Group 5

GPC CHOSEN:	ECMWF
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months? NO
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply? YES.
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	3
Number of clicks required from the initial website to find the forecast	
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	ECMWF seasonal forecast The wind speed is below normal with highest prob.
Information in title/lettering. Does it mention:	
Forecast type?	seasonal forecast (YES)
Probability of categories?	most likely category (YES)
Region (Global)?	Yes
Period (DJF 2009/2010)?	Yes
Element (precipitation)?	yes
When issued (November 2009)?	YES.
Other data. Does it show:	
Indication of units?	Yes.
Is there a legend?	YES
How understandable is it? (1-10)	6
Longitud?	Yes — would be better with labels and grid lines
Latitude?	Yes
Colours used (main colours, shadings are not included)	
white	Yes ✓
yellow	Yes ✓
orange	Yes ✓
red	Yes ✓
purple	NO ✗
light blue	YES ✓
blue	Yes ✓
green	NO ✗
brown	NO ✗
grey	NO ✗
black	NO ✗
Numer of different colours	9
Evolutation of colours (1-10)	8
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	3
Verification Analysis	
Is the data difficult to find? (1-10)*	1.
Number of clicks required from the initial website to find the forecast	
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	ROC Skill Score, Anomaly mean correlation. good in the NE, worse SE
Information in title/lettering. Does it mention:	
Verification type?	ROC S.S. A.M. correlation (YES)
Probability of categories?	NO
Region (Global)?	Yes
Period (DJF 2009/2010)?	NO → Implied DJF, but not for the period
Element (precipitation)?	Yes
When issued (November 2009)?	Yes
Other data. Does it show:	
Indication of units?	NO
Is there a legend?	A colorbar
How understandable is it? (1-10)	1
Longitud?	NO
Latitude?	NO
Colours used (main colours, shadings are not included)	
white	Yes ✓
yellow	Yes ✓
orange	Yes ✓
red	Yes ✓
purple	Yes ✓
light blue	Yes ✓
blue	Yes ✓
green	NO ✗
brown	NO ✗
grey	NO ✗
black	NO
Numer of different colours	3
Evaluation of colours (1-10)	5
Existence of broken lines?	
Evaluation of the understandability (from a non-scientist point of view) (1-10)	
Conclusions from table: + **Answer to the original question:** - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision-making process? Why? - If Yes, what decision would you make? Why? - If No, what decision would you make? Why?	

4.6 Group 6

GPC CHOSEN:	APEC Climate Center
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months?
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply?
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	5
Number of clicks required from the initial website to find the forecast	N/A
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	Seasonal forecast upper part (eastern) shows upto 60% decrease whereas South-eastern part is showing normal.
Information in title/lettering. Does it mention:	
Forecast type?	Yes
Probability of categories?	Precipitation
Region (Global)?	Global
Period (DJF 2009/2010)?	DJF 2009/2010
Element (precipitation)?	Y
When issued (November 2009)?	Y
Other data. Does it show:	
Indication of units?	%
Is there a legend?	Yes
How understandable is it? (1-10)	7
Longitud?	Y
Latitude?	Y
Colours used (main colours, shadings are not included)	
white	Y
yellow	X
orange	Y
red	Y
purple	N
light blue	N
blue	N
green	Y
brown	Y
grey	Y
black	N
Numer of different colours	15
Evaluation of colours (1-10)	7
Existence of broken lines?	Y
Evaluation of the understandability (from a non-scientist point of view) (1-10)	5
Verification Analysis	
Is the data difficult to find? (1-10)*	No verification
Number of clicks required from the initial website to find the forecast	N/A
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	N/A
Information in title/lettering. Does it mention:	
Verification type?	N/A
Probability of categories?	N/A
Region (Global)?	N/A
Period (DJF 2009/2010)?	N/A
Element (precipitation)?	N/A
When issued (November 2009)?	N/A
Other data. Does it show:	
Indication of units?	N/A
Is there a legend?	N/A
How understandable is it? (1-10)	7
Longitud?	N/A
Latitude?	N/A
Colours used (main colours, shadings are not included)	
white	
yellow	
orange	
red	
purple	
light blue	
blue	
green	
brown	
grey	
black	
Numer of different colours	
Evaluation of colours (1-10)	
Existence of broken lines?	
Evaluation of the understandability (from a non-scientist point of view) (1-10)	
Conclusions from table: + **Answer to the original question:** - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision-making process? Why? - If Yes, what decision would you make? Why? - If No, what decision would you make? Why?	It shows 60-70% decrease in pptn in DJF 2009/10. For hydropower planning the available data is not enough for decision making. But still it shows some decrease in rainfall the reservoirs should be kept filled for coming season for normal operation of power plant reducing the downstream flow. Situation might be different if the reservoir is also acting as flood detention reservoir.

4.7 Group 7

GPC CHOSEN:	CPTEC.
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months? YES SAVE RESOURCES UNLESS TORRENTIAL EVENTS.
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply? YES
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	3
Number of clicks required from the initial website to find the forecast	
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	
Information in title/lettering. Does it mention:	
Forecast type?	~~[illegible]~~ Percentage of increase / decrease
Probability of categories?	
Region (Global)?	Local → GLOBAL DATA TO ESTIMATE LOCAL
Period (DJF 2009/2010)?	DJF 2009
Element (precipitation)?	Precipitation
When issued (November 2009)?	YES
Other data. Does it show:	
Indication of units?	NO
Is there a legend?	YES
How understandable is it? (1-10)	4
Longitud?	YES
Latitude?	YES
Colours used (main colours, shadings are not included)	BLUE TO RED ALGORITHMIC DECREASE
white	✓
yellow	✓
orange	✓
red	✓
purple	NO
light blue	✓
blue	~~NO~~ ✓
green	NO
brown	NO
grey	NO
black	NO
Numer of different colours	9
Evalutaion of colours (1-10)	
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	2 - DIFFICULT
Verification Analysis	
Is the data difficult to find? (1-10)*	
Number of clicks required from the initial website to find the forecast	
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	
Information in title/lettering. Does it mention:	
Verification type?	Correlation of forecast vs Anomalies
Probability of categories?	
Region (Global)?	L
Period (DJF 2009/2010)?	✓
Element (precipitation)?	✓
When issued (November 2009)?	✓
Other data. Does it show:	
Indication of units?	NO
Is there a legend?	YES
How understandable is it? (1-10)	✓
Longitud?	
Latitude?	
Colours used (main colours, shadings are not included)	
white	SAME AS ABOVE BUT DIFFERENT ORDER
yellow	CONFUSING
orange	
red	
purple	
light blue	
blue	
green	
brown	
grey	
black	
Numer of different colours	9
Evaluation of colours (1-10)	
Existence of broken lines?	NO
Evaluation of the understandability (from a non-scientist point of view) (1-10)	2 - DIFFICULT
Conclusions from table: +	
Answer to the original question: - what does the forecast indicate for DJF season 2009/10? → Severe decrease of precipitation, - how much does the verification support this forecast? → Little - would you use the forecast in your decision-making process? Why? → Not really, because its not accurate - If Yes, what decision would you make? Why? - If No, what decision would you make? Why? → Reserve water to suffice for energy needs	

4.8 Group 8

CHOSEN:	CPTEC.
The decision maker:	I am an energy manager in Eastern Brazil
The decision timing:	Immediate decision (November 1, 2009) for the coming season starting in December 2009
The decision to be made:	Should I use my hydropower water reserves now or save them for the coming months?
Question to ask:	Is there a risk of a lower-than-normal precipitation in DJF season that could lead to low hydropower supply?
The forecast and its verification:	December/January/February (DJF seasonal forecast) 2009-2010 precipitation, 1 month lead time
Forecast Analysis	
Is the data difficult to find? (1-10)* 1=v.difficult, 10 = v.easy	10
Number of clicks required from the initial website to find the forecast	3-4
Description of forecast type - what kind of forecast is it? - what does it indicate about the precipitation variability for the DJF season 2009/10?	NORMAL FORCAST 9 IN MOST OF THE PLACES
Information in title/lettering. Does it mention:	
Forecast type?	1 MONTH LEAD
Probability of categories?	LIKELY IT WILL BE BELOW NORMAL
Region (Global)?	GLOBAL
Period (DJF 2009/2010)?	DJF 2009/2010 Yes
Element (precipitation)?	Yes
When issued (November 2009)?	1 NOV. 2009
Other data. Does it show:	
Indication of units?	NO
Is there a legend?	YES
How understandable is it? (1-10)	5
Longitud?	Yes
Latitude?	Yes
Colours used (main colours, shadings are not included)	Yes
white	Yes
yellow	Yes
orange	Yes
red	Yes
purple	NO
light blue	NO
blue	NO
green	NO
brown	Yes
grey	NO
black	NO
Numer of different colours	9
Evaluation of colours (1-10)	5
Existence of broken lines?	Yes
Evaluation of the understandability (from a non-scientist point of view) (1-10)	4
Verification Analysis	
Is the data difficult to find? (1-10)*	9
Number of clicks required from the initial website to find the forecast	3-4
Description of verification type - what kind of verification is it? - what does it show about the skill of a DJF seasonal forecast for temperature?	Above normal percentile
Information in title/lettering. Does it mention:	
Verification type?	1 month lead correlation between forecast & obs
Probability of categories?	normal - slightly
Region (Global)?	Yes
Period (DJF 2009/2010)?	Yes
Element (precipitation)?	Yes
When issued (November 2009)?	Yes
Other data. Does it show:	
Indication of units?	NO
Is there a legend?	Yes
How understandable is it? (1-10)	6
Longitud?	Yes
Latitude?	Yes
Colours used (main colours, shadings are not included)	
white	Yes
yellow	Yes
orange	Yes
red	NO
purple	NO
light blue	NO
blue	NO
green	NO
brown	NO
grey	NO
black	NO
Numer of different colours	3
Evaluation of colours (1-10)	8
Existence of broken lines?	Yes
Evaluation of the understandability (from a non-scientist point of view) (1-10)	7
Conclusions from table: +	The forecast & verification are not properly predicted, There will be normal & likely above normal rainfall
Answer to the original question: - what does the forecast indicate for DJF season 2009/10? - how much does the verification support this forecast? - would you use the forecast in your decision making process? Why? - if Yes, what decision would you make? Why? - if No, what decision would you make? Why?	there will be a likely below normal rainfall and to check the validity of the forecast use the hydro power as NO problem.

5. Additional data

1. Tables (2,3,4,5,7) and forecast and verification graphics
2. Questionnaire

Please visit the following link to access the data:

https://www.dropbox.com/sh/lz2uxylvl8biy6s/bwMOK5EAT4