CONTRIBUTIONS TO INTERNATIONAL INITIATIVES

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Summary

It is of strategic interest for the RESILIENCE project to link to international initiatives for energy and meteorology, climate prediction and climate services. Although to date there is a lack of comprehensive sources of information on climate predictions for energy, several international initiatives have developed communication tools or research topics related to the use of climate predictions for the energy sector. The RESILIENCE climate service has taken into account the communication approaches or research priorities of these initiatives to ensure they are complementary and compatible. One of these initiatives is, for example, the IRENA Global Atlas for Solar and Wind Energy, which uses a GIS interface to communicate information on global wind and solar resource assessments from the past. Another example can be found in the Global Earth Observations for Energy, which develops a database for Earth observations to which the RESILIENCE climate service links to take advantage of energy-related variables. Moreover, the Climate Services Partnership (CSP) has a dedicated section for climate service case studies to which the RESILIENCE User Interface Platform (UIP) can contribute and that is the first example in its range. In addition, the RESILIENCE climate service for energy has been represented in many events organized by these different international initiatives and, wherever possible, it has taken advantage of the opportunity to co-design the communication material and tools with them.

The RESILIENCE project builds on the identification of user needs and the joint collaboration with other research groups established for the advancement of the energy sector. These groups are the European Energy Research Alliance (EERA), of which the group at BSC is a member; the European Technology Platform for Wind Energy (TPWind), where our group contributes to the activities of the working groups "Wind conditions" and "Grid intergration"; the Global Earth Observation System of Systems (GEOSS), where BSC is contributing to its "Global Atlas for Solar and Wind" for the International Renewable Energy Agency; and the COST Action "Weather Intelligence for Renewable Energy (WIRE)", where BSC is involved to design a research line on prediction time scales beyond the two weeks. Although wind speed and temperature forecasting is included in one way or another in the research carried out by international initiatives and programmes, their focus to date has mostly been focused on short term weather forecasting or long term climate projections. The time scales of RESILIENCE, focusing on subseasonal-to-seasonal predictions, will therefore extend and complement the activities of these international initiatives.

Contents

Index of tables

1. Introduction

The threat of climate change requires immediate action to mitigate its impacts and foster adaptation capacity of several social systems thereby increasing resilience and minimizing risks, costs and losses (IPCC 2014). Access to credible weather and climate information is a key pathway to improve human resilience to climate variability and change (Wise et al. 2014). Advances in the science behind climate predictions are creating an unprecedented potential to provide climate forecasts over the coming months, seasons and decades (Doblas-Reyes et al. 2013).

The RESILIENCE project aims at contributing to climate change mitigation and adaptation by providing a comprehensive assessment, description and dissemination of probabilistic forecasts tailored to the energy sector. The project will bring a sound contribution to the development of climate services as it offers original information to feed better risk management decisions related to the balance of energy supply and demand and management of electricity grids.

This report summarizes the contributions to international initiatives derived from the RESILIENCE project, such as participation in international conferences, alignment with initiatives like the Climate Services Partnership (CSP) and the Global Framework for Climate Services (GFCS), and a series of other research projects and initiatives as described in the following sections. The report also describes the refinement of the RESILIENCE User Interface Platform (UIP) and the co-design of communication material and tools so as to be compatible with climate services international initiatives. These activities have a particular effect in terms of fostering the dissemination of climate services among different audiences, such as users from the energy sector, policymakers and research organisations.

2. International Initiatives

2.1. Participation in international initiatives

The Barcelona Supercomputing Center (BSC) team working on the RESILIENCE project has participated in a series of events summing up to 10 workshops, 6 conferences and 4 other events as shown below (**Table 1**, **Table 2** and **Table 3**).

Table 1. Participation in workshops

Workshop/Presentation title	Year	Place	Audience	Geographical reach
Climate change communication & user engagement: a tool to anticipate climate change	2017	Manchester, UK	Scientific community, industry, policymakers, NGOs	Global
NEWA general meeting and workshop. First results on predictability assessment.	2016	Perdigão, Portugal,	Scientific community	Global
From day ahead to decadal wind power forecasting	2015	CENER, Pamplona, Spain	Industry	Spain
RESILIENCE and Project Ukko Launch	2015	Paris, France	Industry	Global
Oral presentation - From day ahead to decadal wind power forecasting	2015	Pamplona, Spain	Scientific community & industry	Europe
European Wind Energy Association EWEA Technology Workshop. Climate forecasts for site selection: a new generation of risk management tools	2015	Helsinki, Finland	Industry	Europe
Knowledge for Climate adaptation boot camp	2015	Amersfoot, The Nederlands	Industry	Europe
Climate KIC boot camp	2014	Valencia, Spain	Industry	Europe
Knowledge for Climate Final	2014	Rotterdam, The Netherlands	Industry	Europe
Climate KIC Final	2014	Rotterdam, The Netherlands	Industry	Europe

Table 2. Participation in conferences

Conference/Presentation title	Year	Place	Audience	Countries addressed
Predictability assessment of climate predictions within the context of the New European Wind Atlas project (NEWA)	2016	Wind Europe Summit 2016. Hamburg, Germany	Scientific community	Global

Climate predictions, predictability assessment for the New European Wind Atlas project (NEWA)	2016	16th EMS Annual Meeting. Trieste, Italy	Scientific community	Global
Presentation/Display of Project Ukko in the exhibition area	2016	International Climate Change Adaptation: "Adaptation Futures". Rotterdam, The Netherlands	Industry, Policy makers, Scientific community	Global
Climate prediction and climate services activities at the Barcelona Supercomputing Center	2016	ECRA meeting. Brussels, Belgium	Scientific community	European countries
International colloquium on "Large Wind-power plants: Interaction, control and integration"	2015	Leuven, Brussels	Scientific community (research)	Global
A semi-operational prototype to forecast wind power from weeks to months ahead	2015	EWEA annual Event. Paris, France	Industry	Global

Table 3. Participation in miscellaneous activities

Activity	Title	Year	Place	Audience	Countries addressed
Climateurope festival	RESILIENCE –Climate predictions for the wind energy sector	2017	Valencia, Spain	Scientific community, policy makers, industry, funders	European countries
ECRA meeting	Climate prediction and climate services activities at the Barcelona Supercomputing Center	2016	Brussels, Belgium	Scientific community (research)	European countries
Visit Institute for Atmospheric and Climate research (IAC)	Climate prediction for Climate Services	2016	ETH, Zürich,	Scientific community (research)	Global
Open house activity of the Barcelona Supercomputing Center for the water management industrial sector	Invited speaker - Seasonal and Sub-seasonal climate predictions	2015	Barcelona, Spain	Industry	European countries

2.1.1. International projects

The Earth System Services group at BSC has been involved in a number of international

projects that are aligned with the objectives of the RESILIENCE project either because their aim is to improve seasonal-to-decadal (S2D) predictions or because they are centred in the energy sector needs on climate services.

Currently BSC is leading the SPECS European project that aims to improve the climate prediction systems, and it is a partner in the EUPORIAS European project that concentrates primarily on improving the use of S2D predictions in Europe through climate services. EUPORIAS and SPECS were companion proposals in the 7th framework programme and despite being independent projects, there is a close communication and interaction between both of them.

The team is also a partner in the PREFACE European project and in two European projects within the Horizon 2020 programme: PRIMAVERA and IMPREX. PREFACE aims to improve the understanding and capabilities to predict tropical Atlantic climate and its impacts; PRIMAVERA aims to deliver novel, advanced and well-evaluated high-resolution global climate models tailored and actionable by sector-specific end-users such as the energy sector; and IMPREX aims to improve the prediction and management of meteorological and hydrological extremes which might have an impact on energy facilities, energy production and management. BSC also participates in the ERA-NET project NEWA for the preparation of the New European Wind Atlas that will include seasonal and sub-seasonal wind predictions.

BSC is also collaborating in the CLIM4ENERGY project, which aim at responding to the Copernicus Climate Change Service (C3S) objectives. CLIM4ENERGY contributes to C3S by demonstrating the added value of tailored climate information for the transitioning European energy sector. Finally, the group is also participating in the Climateurope project that aims to build a network of researchers, users, policy-makers and other stakeholders showing a joint interest in climate observations, modelling and services. Below there is the detailed information on the partners, collaborating countries, BSC contribution and funding awarded for the projects named above.

- SPECS
    - Title: Seasonal-to-decadal climate Prediction for the improvement of European Climate Services
    - Partners: (20) BSC, INPE, MPG, KNMI, UOXF, METEOF, VERFACS, NILU, ENEA, UNIVLeeds, UNEXE, MetNo, Vortex, MetOffice, SMHI, CNRS, UREAD, CSIC, ECWMF, UHAM
    - Countries: Brazil, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, UK,
    - BSC Contribution: Project coordinator
    - Total budget: 11,989,174€
    - More information in www.specs-fp7.eu

- EUPORIAS
    - Title: EUropean Provision Of Regional Impact Assessment on a Seasonal-to-decadal timescale

- o Partners: (24) Met Office, TEC, ENEA, Meteo Swiss, UC, Predictia, AEMET, DHI, WU, DWD, BSC, KNMI, IDL-University of Lisbon, University of Leeds, SMHI, University of LUND, Meteo France, CETaqua, IPMA, WFP, WHO, Future Everything, EDF, Meto-RO
  - o Countries: Denmark, France, Germany, Italy, Netherlands, Portugal, Romania, Spain, Sweden, Switzerland, UK.
  - o BSC Contribution: Partner, WP leader and energy case study representative.
  - o Total budget: 12 962 917€
  - o More information in www.euporias.eu

- **PREFACE**
  - o Title: Enhancing PREdiction oF Tropical Atlantic ClimatE and its impacts
  - o Partners:(28), University of Bergen, University of Kobenhavns, CERFACS, IRD,, Méteo-France, University Pierre et Marie Curie, Leibniz-Institut für Ostseeforschung Warnemünde. Johann Heinrich Von Thuenen-Institut, Christian-Albrechts-Universitaet, Universita ca Foscari Venezia, Wageningen University, Havforskningsinstituttet, Uni Research, BSC, Universidad Complutense de Madrid, University of Reading, Instituto Nacional de Investigação Pesqueira, Ministry of Fisheries and Marine Resource, University of Cape Town, Instituto Nacional de Desenvolvimento das Pescas, Institut National de Recherche Halieutique, Institut Sénégalaise de Recherche Agricole-Centre de Recherches Oceanographiques de Dakar-Thiaroye, Université Cheikh Anta Diop de Dakar, Université d'Abomey-Calavi, Centre de Recherches Océanologiques, University of Nigeria, Université Libre de Bruxelles.
  - o Countries: Norway, France, Denmark, Germany, Italy, Netherlands, Spain, United Kingdom, Angola, Namibia, South Africa, Cape Verde, Morocco, Senegal, benin, Cote d'Ivore, Nigeria, Belgium.
  - o BSC Contribution: Partner and WP leader
  - o Total budget: 12,170,344.87€
  - o More information in www.preface.b.uib.no

- **PRIMAVERA**
  - o Title: PRocess-based climate sImMulation: AdVances in high resolution modelling and European climate Risk Assessment
  - o Partners: (19) Met Office, UREAD, KNMI, SMHI, CERFACS, MPG, UCL, BSC, CMCC, AWI, UOXF, CNR, ECMWF, NERC, UNIVLEEDS, SU, STFC, PREDICTIA, DKRZ
  - o Countries: Belgium, France, Germany, Italy, Europe, Netherlands, Spain, Sweden, UK
  - o BSC Contribution: Partner, WP leader and energy case study representative
  - o Total budget: 14,967,970€
  - o More information in https://www.primavera-h2020.eu/

- **IMPREX**
  - o Title: IMproving PRedictions and management of hydrological EXtremes

- Partners: (23) KNMI, ECMWF, SMHI, IRSTEA, PIK, ARCTIK, BSC, METOFFICE, TUC, UREAD, HZG, Deltares, IVM, ADELPHI, HKV, FW, CET, UPVLC, POLMIL, CIMA, GFZ, BfG, WFN
- Countries: Belgium, France, Germany, Italy, Europe, Netherlands, Spain, Sweden, UK
- BSC Contribution: Partner, WP leader and energy case study representative.
- Total budget: 7,996,850€
- More information in http://www.imprex.eu/

- NEWA
  - Title: Development of a new European Wind Atlas
  - Partners: (31) DTU, DNV-GL, Vestas, 3E, KULeuven, Nazka Mapps, ATMM-PRO, Cenaero, IWES, ForWind, IPE, ERI VIRAC, UL, LEGMC, UPORTO, INEGI, IPMA, LNEG, CENER, CIEMAT, UCM, UIB, BSC, BSC, UU, WeatherTech, TÜBITAK MRC, IZTECH, METUWIND, ITU, BORUSAN
  - Countries: Belgium, Denmark, Germany, Latvia, Portugal, Spain, Sweden, Turkey
  - BSC Contribution: Partner and development of a decision support tool based in probabilistic climate predictions.
  - Total budget: 15,054,038€
  - More information in http://euwindatlas.eu/

- CLIM4ENERGY
  - Title: Climate For Energy
  - Partners: BSC, Finnish Meteorological Institute, Météo-France, Met Office, Swedish Meteorological and Hydrological Institute, BG Group, EDF, EDPR, FINGRID Oyj, METSÄTEHO OY, NENA AS, RTE, SHELL, STATKRAFT, VATTENFALL.
  - Countries: Spain, France, Germany, Finland, Sweden, United Kingdom.
  - BSC contribution: Design, production, documentation, demonstration of use of the wind power generation indicator.
  - Total budget: 1.599.399,52€.
  - More information in http://clim4energy.climate.copernicus.eu/

- Climateurope
  - Title: European Climate Observations, Modelling and Services (ECOMS2).
  - Partners: BSC, Met Office, ANR, CMCC Foundation, IC, ECMWF, GERICS, CNRS, KNMI, RHMSS, SMHI.
  - Countries: Spain, United Kingdom, France, Italy, Germany, Netherlands, Serbia, Sweden.
  - BSC contribution: Partner.
  - Total budget: 2.994.373 €.
  - More information in http://www.climateurope.eu/

2.1.2. Peer-reviewed publications

As a result of the activities of the RESILIENCE project, 5 peer-reviewed publications have already been produced as shown in the table below. All these publications have been submitted to journals with high impact factors which also reinforces possibilities of dissemination and international impact.

Table 4. List of peer-reviewed publications

Title	Authors	Publication	Publisher	Status	Year
Uncertainty in recent near-surface wind speed trends	Verónica Torralba, Francisco J. Doblas-Reyes and Nube Gonzalez-Reviriego	Environmental Research Letters	IOPScience	Submitted	2017
Climate change communication & user engagement: a tool to anticipate climate change	Marta Terrado, Isadora Christel, Dragana Bojovic, Albert Soret and Francisco J. Doblas-Reyes	The Handbook of Climate Change Communication	Springer	Accepted	2017
Transforming climate model output to forecasts of wind power production: how much resolution is enough?	Dave MacLeod, Verónica Torralba, Melanie Davis and Francisco J. Doblas-Reyes	Meteorological Applications	Wiley Online Library	Accepted	2016
Seasonal climate prediction: a new source of information for the management of wind energy resources	Verónica Torralba, Francisco J. Doblas-Reyes, Dave MacLeod, Isadora Christel and Melanie Davis	Journal of Applied Meteorology and Climatology	American Metereology Society (AMS)	Under review (minor changes)	2016
Introducing design in the development of effective climate services	Christel, I., Hemment, D., Bojovic, D., Cucchietti, F., Calvo, L., Stefaner, M. and Buontempo, C.:	Climate Services	Elsevier	Submitted	2016

2.2. Refinement of the web-site to be compatible with climate services international initiatives

The outcomes of the RESILIENCE project are disseminated among and beyond the stakeholders from the renewable energy sector via a User Interface Platform (UIP): Advancing Renewable Energy with Climate Services (ARECS) www.bsc.es/ess/arecs. This is a shared point with other international initiatives on climate services that also have the UIP as one of their pillars, such as the Global Framework for Climate Services (GFCS). The idea behind having a UIP is to provide a structured means of bringing together providers and users of climate services. The UIP enables interactions that help define user needs and provider capabilities, tries to reconcile the needs with those capabilities, and eventually promotes effective decisions based on climate information. Outcomes targeted by ARECS that are in agreement with the aims of other international initiatives on climate services are:

- Obtaining feedback from user communities: for example, through attendance to workshops, conferences and other related activities described in section 2.1 of this document, where project results have been presented and discussed with users. In addition, users are also encouraged to provide feedback directly through ARECS via the *Join Us* section.

- Building dialogue between climate service users and those responsible for the observation, research and information system: this dialogue is obtained through face-to-face meetings with particular users, which apart from allowing monitoring, evaluation and learning, also create capacity building and provide some lessons for both users and providers of climate information. Within the RESILIENCE project, dialogue with users has allowed the elaboration of case study reports, which correspond to the analysis of key events corresponding to a specific location and time that are of interest for particular industrial partners. Case studies are available through the *Resources* section of ARECS.

- Improving climate literacy in the user community and literacy of the climate community in user needs: climate literacy in the user community has been enhanced through the use of different dissemination materials created for this purpose. These materials, available in ARECS, are constituted by factsheets describing different aspects of seasonal predictions that can be complex to understand by non-experts, as well as videos explaining different concepts of climate predictions for the energy sector, or even smartphone applications. This information is completed by the *Glossary* and the *Frequently Asked Questions* sections, specifically directed to the user community. On the other hand, literacy of the climate community in user needs is also a point covered in ARECS, with a section describing the needs of the renewable energy sector that can benefit from climate prediction information. Some of the needs identified are the preparation before medium-term variability in energy generation, the planning of operation and maintenance works, or risk management and assessment of future resource variability. In this same line, a report "Climate predictions as a remedy for blackouts", describing the views of particular climate and energy stakeholders has been sent for publication to the newsletter of the Climate Services Partnership initiative.

Finally, different links of interest directing the user to other national and international projects and initiatives related to climate predictions for energy can be found in ARECS with the aim to connect the outcomes of the RESILIENCE project and put them in the context of these international initiatives (i.e. the Climate Services Partnership, the Global Framework for Climate Services, the International Renewable Energy Agency or the New European Wind Atlas, among others).

2.3. Refinement of the web-site to be compatible with climate services international initiatives

As mentioned, RESILIENCE builds on key lessons from other similar climate service related projects such as CLIM-RUN (2011-2014), EUPORIAS (2012-2017) and SPECS (2012-2017). These projects along with the Global Framework for Climate Services (GFCS) initiative conducted for

the first time a study to establish a visual communication protocol for probabilistic forecasts. The study investigated challenges associated with climate information visualisation and communication while also identifying ways to improve this for probabilistic seasonal climate forecasts. As a result, a set of recommendations was defined (Terrado & Gonzalez-Reviriego 2016), that have been incorporated in the design of the communication material and tools made available through the ARECS UIP.

Recommendations were based in the analysis of many aspects of Global Producing Centers' (GPC) websites (Davis et al. 2016), including the fact whether a login was required, the number of clicks from the GPC's homepage to the required information, or the availability of the website in English. Other aspects focused on the forecast products available and their types, time periods and how far in advance the information was issued (i.e. lead-time). The corresponding forecast verification products and type were also assessed in a similar way to the forecasts. The appearance of a legend, indication of units, type of labels and the colours used in the legend were also examined.

Parallel to the study, the workshop "Working Group on Seasonal Predictions for Wind (SP4Wind)" was organized by BSC, in which a range of companies and organizations involved in the Spanish and European energy network operations (EDPR, EDF, Alstom, Iberdrola, EnBW, MeteoLogica, AWS Truewind or Vortex among others) were contacted, interviewed and invited to participate in the workshop. The aim of the workshop was to continue to build a collaborative forum to support the dissemination of seasonal prediction information for the wind industry and to facilitate the exchange between experts and users. The session ended with a final open discussion on various topics related to the integration of climate predictions in the wind industry workflows, such as: reliability of predictions, value-added compared to climatology, integration with El Nino and NAO information and potential improvement in the analysis of anomalies and extreme events. Among the participants in the exhibition the main target user that showed interest were intermediary companies that already provided short term weather predictions for wind resource assessments. The workshop gathered 11 attendees from: General Electric Spain, EDF R&D, AWS Truepower, ZSW, WeatherTech, SIEMENS, ENECO, Iberdrola Renovables, Casa dos Ventos and Meteo-France.

To improve communication, all the feedback gathered from users was integrated in the communication materials that can be found in the UIP. As a result, the approach adopted to visualize probabilistic forecasts has been to present them in categories e.g. terciles or quintiles. In some cases, the probability of the most likely category is provided, where the categories are formulated with respect to a climatological reference. Probabilistic forecasts are accompanied by forecast verification, which addresses the accuracy (how close the forecast probabilities are to the observed frequencies), the skill (how the probabilistic forecasts compare with some reference system) and the utility (the economic or other advantages of the probabilistic forecasts) aspects.

3. Conclusions

The RESILIENCE project builds on and represents an important contribution to existing projects on climate predictions for the energy sector. This statement is endorsed by various contributions to workshops, conferences and other communication activities directed to different audiences at the national, international and global level. The project makes an important contribution to climate service international initiatives in terms of enhancing the consideration of users' feedback in the co-production of climate services, the improvement of both climate literacy in the user community and literacy of the climate community in terms of user needs, and the dissemination and communication of the project outcomes via ARECS, the RESILIENCE UIP. ARECS complements international initiatives through the development of communication material and tools readily available to the different users in the energy chain. This material aims to communicate the potential of climate predictions as well as to provide recommendations and guidance in their application to decision-making. At the same time of contributing to the international initiatives, the project also gets feedback from these initiatives and from different actors that complement and enrich the project's view.

4. Acknowledgements

5. References

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