DOCUMENTATION OF THE DESIGN AND DEVELOPMENT STRATEGY FOR THE UIP ON CLIMATE SERVICES FOR ENERGY

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Summary

The concept of climate services has the aim to make climate information user-oriented through products tailored to the user needs. Climate services refer to the transformation of climate-related data, together with other relevant information, into customized products. In this way, predictions, trends, economic analyses, or counselling on best practices are considered climate services.

This report describes the design and development strategy for a User Interface Platform (UIP) on climate services addressed to the energy sector. The service is aimed to improve the understanding of sub-seasonal to seasonal wind and solar predictions for the energy sector and to help users understand and manage climate-related risks and opportunities in the renewable energy sector. Some applications of climate predictions include the planning of maintenance and operations, energy trading, estimation of budgets, or planning decisions to meet the balance between energy supply and demand.

The appropriate development of a UIP providing graphical visualizations that help communicate climate data is fundamental to the provision of climate services. Graphical visualizations are necessary to spread climate information and products beyond the developers' community, helping the user to interpret and use the information as simply and quickly as possible. In this way, awareness about the potential of the application of climate predictions is raised and probabilistic information is put into a usable form for decision-makers. However, designing intuitive and meaningful visual representations of climate data faces a variety of challenges. This report describes some of these challenges and explains how they have been addressed in the development of an improved UIP for the energy sector.

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1. Introduction

The final outcome of the RESILIENCE project is a web-based platform on **climate services for energy** which supports network management decisions that need to be taken to achieve a balance between energy supply and demand. The service is aimed to improve the understanding of sub-seasonal to seasonal wind and solar forecasts for the renewable energy sector, helping stakeholders understand and manage climate-related risks and opportunities. This climate service originates from the interaction with the different actors dealing with climate and energy in both the research and industry fields, and will be disseminated among and beyond these target groups via a User Interface Platform (UIP). During the design stage of the platform, the focus was put on the structure and layout of the climate service. Special attention was given to ensure its compatibility with activities from international initiatives like IRENA Global Atlas, the Climate Services Partnership-CSP, the Joint Programming Initiative-JPI Climate, the Copernicus Climate Change Service, the Climate Investment Fund-CIF, etc. Facilitating feedback and smooth interactions between users and the climate service was regarded as crucial (Hewit et al. 2013), and that step was included into the core design of the service. Recommendations to improve forecast visualisation were also carefully followed, like the selection of appropriate colour scales, the development of a suitable design, or the exploration of the most effective way to display complex concepts such as skill and reliability. These “best practices” together with the users’ suggestions were implemented within the UIP to tailor the communication of climate prediction information to the needs of users from the energy sector.

The next sections contain a list of design recommendations obtained from previous works analyzing how climate information is provided by different Global Producing Centers (GPCs). After that, the decisions that have been adopted in the design of the UIP are described in another section, putting special attention at how the recommendations are adopted, and presenting some examples of the type of climate information provided in the UIP. The aim is to obtain an improved UIP that increases user’s interest in climate information while facilitating their interaction and understanding. The report finishes with a conclusions section that also describes future steps in the communication of climate information to users.

2. Recommendations for an improved UIP

With the aim to create a web-based UIP focused on climate services for energy, current approaches for the visualisation and communication of seasonal climate predictions were revised (Steffen 2014; Davis et al. 2016). Several interviews and workshops with end-users to test the usefulness and usability of sub-seasonal to seasonal probabilistic forecasts were done. Also, the websites of thirteen Global Producing Centres (GPCs) were visited to assess the availability, accessibility, visualisation and description of seasonal predictions. As a result, a set of recommendations for the UIP were compiled and are listed below (Table 1). They are divided in three categories according to their relevance for accessibility, visualisation or understanding of scientific information.

***Table 1**. Summary of recommendations to improve accessibility, visualisation and description of seasonal climate predictions.*

Accessibility
• Freely accessible information (or option to grant access for scientific reasons) • Website availability in English in order to improve a wider dissemination of the information • Easily-accessible forecast information (the number of clicks from the website homepage used as a proxy for information accessibility; the fewer clicks the better) • User-friendly website (e.g. clear structure, standardized search options…)
Visualisation/Presentation
• Self-explanatory titles containing relevant information: variable, period, units, legend and region • Explanatory text that clarifies terminologies and helps with graphs' interpretation • Comprehensive information provided in the maps legend • Latitude and longitude labels and a latitude-longitude grid on maps provided • Standardized selection of colours in accordance with other GPCs to facilitate understanding of when a climate prediction is above-normal, near-normal and below-normal. For example, blue colors should consistently be assigned to below-normal temperature (colder) and red colors to above-normal temperature (hotter). Selection of effective colors dealing with visual constraints (e.g. color blindness)
Scientific information

- Enough scientific background information provided to improve user's understanding of the main scientific concepts related to climate forecast information (e.g. skill, reliability, lead-time)
- Link between forecast and verification information clearly made to facilitate access to the full range of information and a more comprehensive understanding
- Short explanatory texts on how maps, graphs and colour scales should be interpreted for the adequate use of products, with a link to more specific explanations
- Consistency in the use of terminology to facilitate user understanding and browsing through different GPCs' websites

2.1. Improving accessibility

The UIP has been allocated in the Earth System Services (ESS) website, where the different climate services offered by the Earth Sciences Department in the Barcelona Supercomputing Center (BSC) are listed. It is entirely in English and it has been designed to be user-friendly, clean, and to provide information of climate services from a user perspective always keeping their link with science and innovation. With this intention, typographies that recall technology have been selected for the titles of the body text.

The UIP can be accessed under the menu "Our Services", where it has been divided in two different services: (1) *Advancing Renewable Energy with Climate Services (ARECS)*, where users with different backgrounds (scientists, stakeholders, etc.) will be able to find different dissemination material related to the topic of climate predictions for energy, and (2) an *Image Catalogue*, a repository of images targeted to users with a scientific background, where they will be able to find more technical information on climate predictions. Images are in .png format and can be freely accessed and downloaded (Figure 1). With just 2 clicks, the user can access one service or the other:

1. ARECS

   This service is constituted by different sections (

   Figure **2**):

   - *ARECS Homepage*, with information about the importance of climate services for managing the risks and exploiting the opportunities of future variability in wind and solar resources over monthly to decadal timescales by understanding its impact on supply and demand. Applications of climate services to this sector are divided in 4 different groups: Prepare/Plan/Evaluate and Manage.

   - *About*, section containing a brief description of the ARECS initiative, with its mission and vision and information regarding funding.

- *Resources*, a section divided in two types of contents: general resources and scientific resources.

  General resources:

  - Newsletters, with seasonal climate prediction bulletins from previous winter seasons. These forecasts are compared to the observations with the aim of showing how climate predictions can guide decision-making in the energy stakeholder chain.

  - Factsheets, where climate concepts that are more complex to understand by non-specialists are clearly explained, such as: the different time horizons used for climate prediction, the quality assessment (skill) and reliability of climate predictions, the added value of climate predictions (the weather roulette concept), the place occupied by climate information in the energy stakeholder chain, etc.

  - Related material, a catchall for additional dissemination and communication material, such as videos, technical papers, outreach reports, posters and presentations.

  - Cases studies, giving a comparison between climate predictions and what actually happened for past key events (particular place and moment of interest) relevant for the industrial partners. The idea behind these case studies is to assess if the risk of unexpected energy network misbalances between supply and demand could have been minimized with the forecast information.

  Scientific resources:

  - Technical notes, which are scientific reports or scientific papers with the main results of the RESILIENCE project. They discuss different topics such as the estimation of intra-seasonal and inter-annual variance, or the impact of NAO and El Niño on wind speed. They are mainly directed to specialized audiences and linked with the image catalogue service (described below). Thus, for more information about the images contained in the catalogue, the user is referred to the corresponding technical note. Likewise, as not all the images generated from the research work can be included in a technical note, the user is also referred to the image catalogue, a repository where all the images generated are stored.

  - Publications, with a list of publications from the ESS group related to the topic of climate predictions for the renewable energy sector.

- *Frequently asked questions* (FAQ), containing answers to recurrent questions from users or common doubts that have been identified to create misunderstanding.

- *Glossary*, with the definition of climate- and energy-specific terms.

- *Other links of interest*, directing the user to other projects and initiatives related to climate predictions for energy (Project Ukko http://project-ukko.net/, CLIM4ENERGY https://climate.copernicus.eu/clim4energy, the IRENA Global Atlas http://irena.masdar.ac.ae, the HPC4E project https://hpc4e.eu/, etc.)

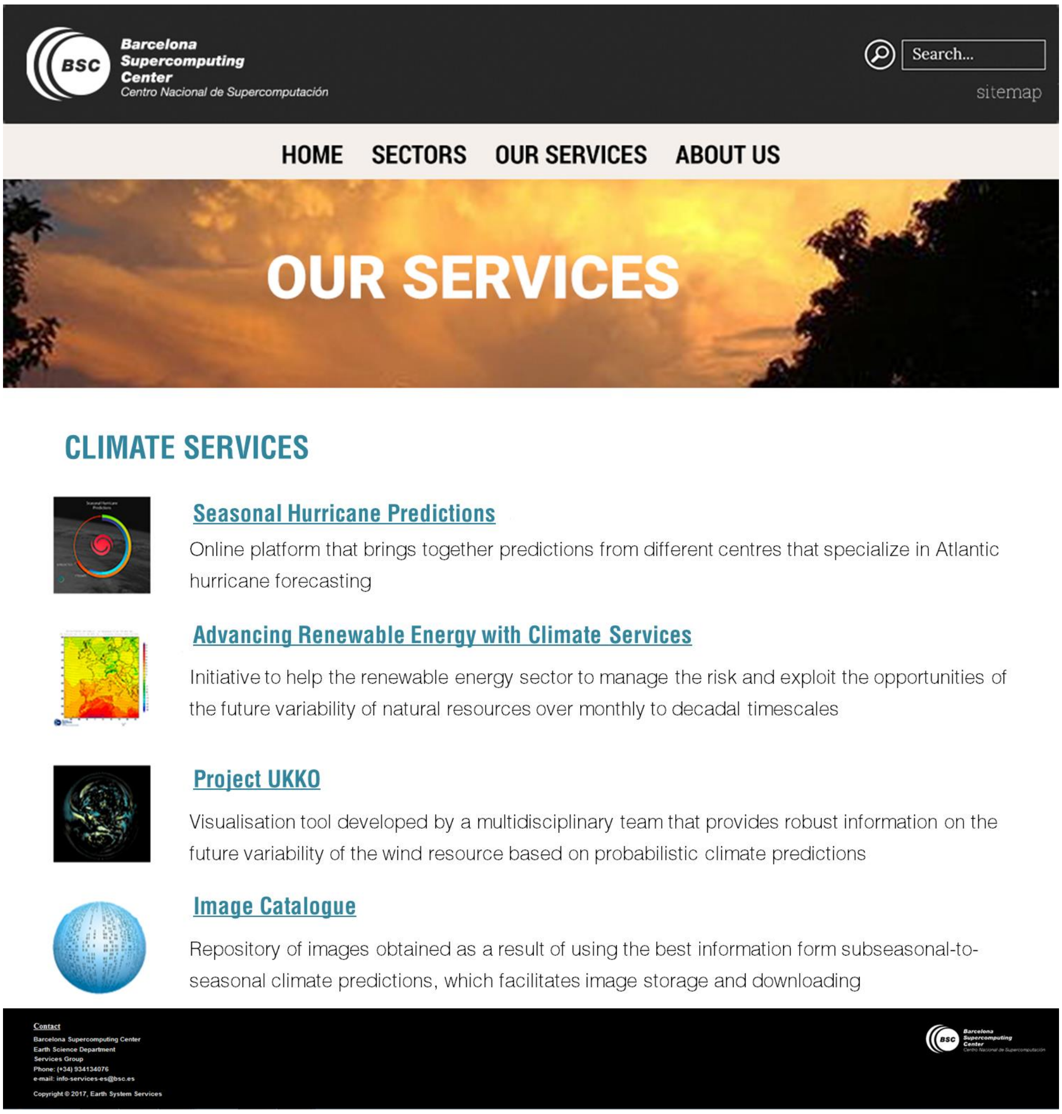


***Figure 1**. Draft of the climate services section under the menu "Our Services", with a direct access to the UIP.*
Note that the UIP is divided in two different sections: Advancing Renewable Energy with Climate Services (ARECS) and Image Catalogue. Note that two additional services from the Earth Sciences Department - Seasonal Hurricane predictions and Project Ukko - are also listed in this section.

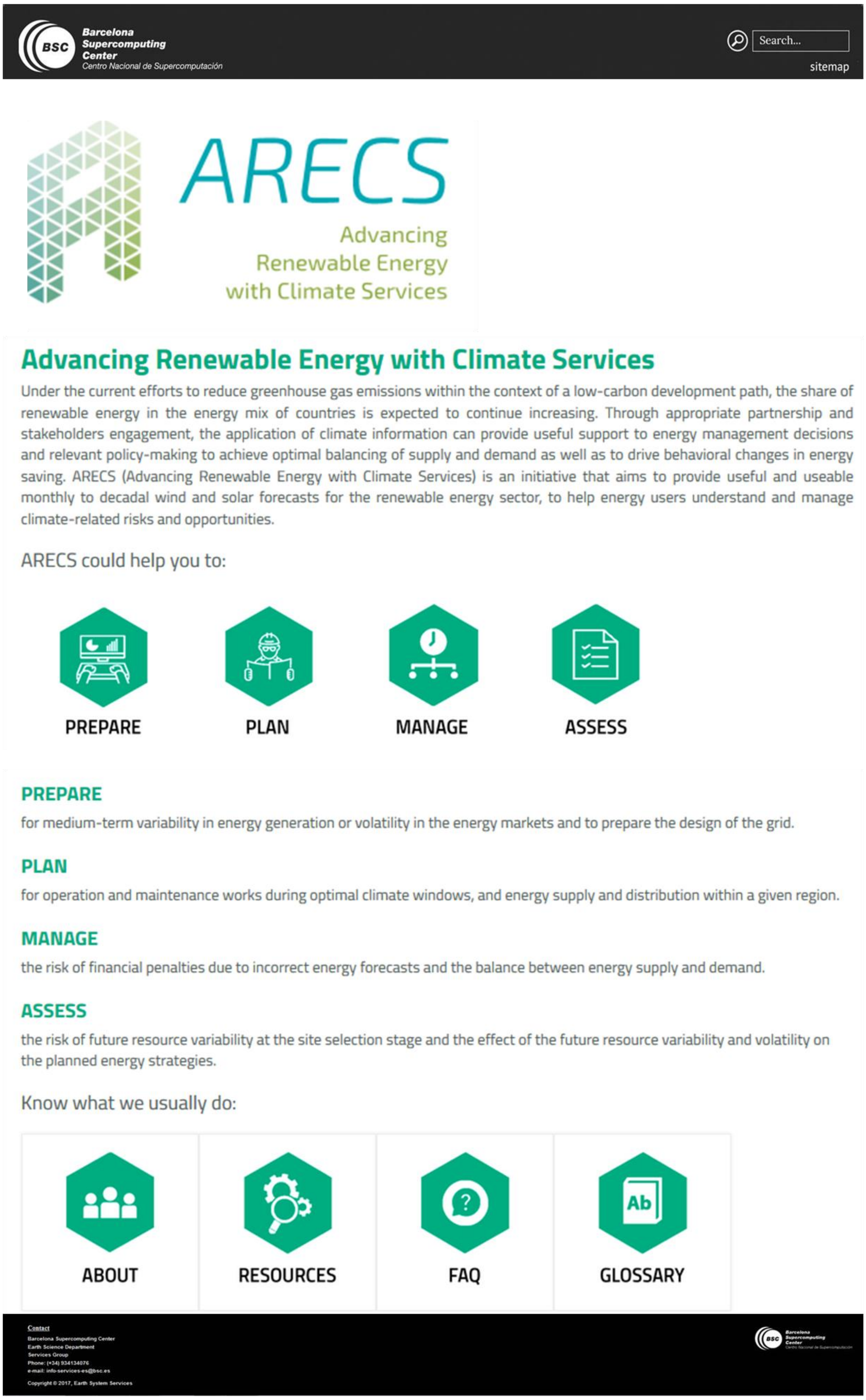


Figure 2. *Draft of the section Advancing Renewable Energy with Climate Services.*

2. Image Catalogue

This service is constituted by 3 different sub-sections:

- *The image repository*, where images are organized in different entries according to the research topic (e.g. weather regimes, storm tracks, seasonal forecast quality assessment, etc.). By clicking on each of them, the user can find a list of different entries (Figure 3) containing a general description and thumbnails of the images contained in the specific entry. When many types of images are available in the same entry, they have been divided in different groups in order to facilitate navigation. When relevant, the description contains a link to the corresponding technical note, a document with more detailed information on the work presented.

- *About the catalogue*, with information on what is the catalogue, why it has been developed and to which audience it is directed.

- *How to cite*, where a standard format for citation purposes is given. Users will have the possibility to use the images contained in the Catalogue, always with the corresponding source citation:

  ESS-BSC Catalogue. Earth System Services, Earth Sciences Department, Barcelona Supercomputing Center, accessed <access date>*, www.bsc.es/ESS/catalogue*.

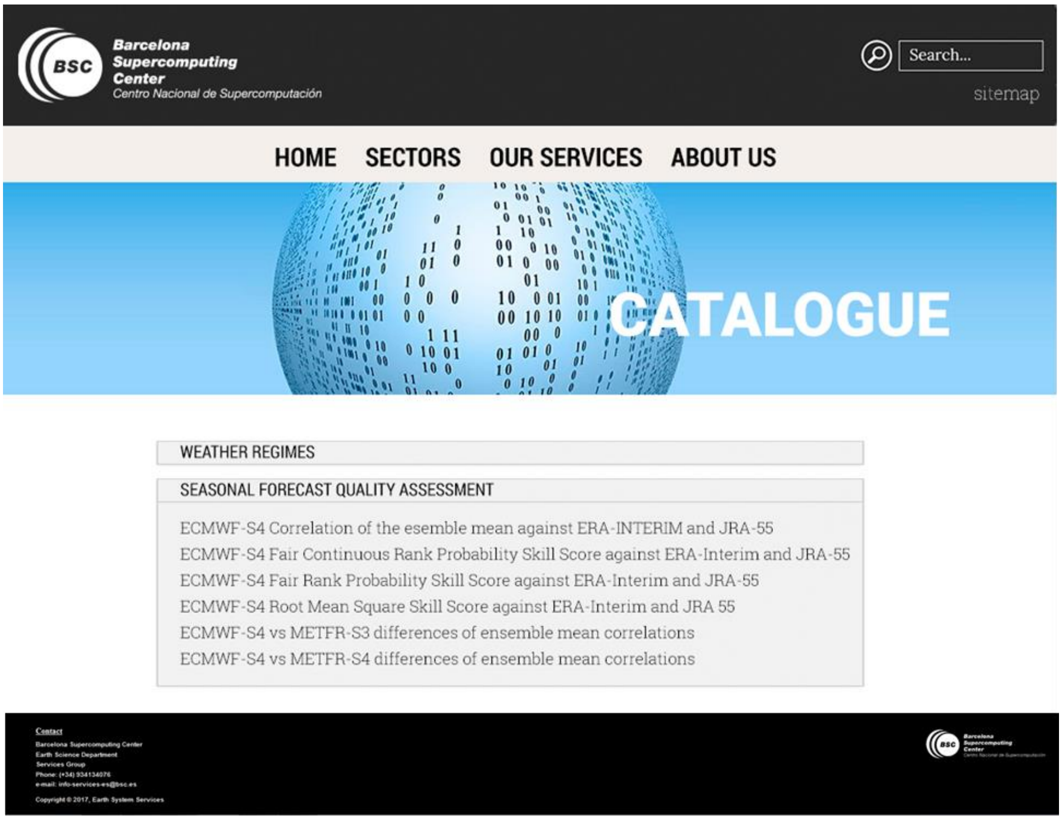


Figure 3. *Homepage of the image catalogue with the example of a topic containing a list of entries.*

2.2. Improving visualization

This section is mostly related with the part of the UIP dealing with the image catalogue. First, it has to be taken into account that there is not just a single way to classify images, and that the selected method will very much depend on the final purpose of the catalogue and the type of users it is directed to. Entries with a very descriptive title were used in order to facilitate user's search. When a particular entry is selected a short description and thumbnails of the images are presented. From there, an image gallery can be opened with a single click on the thumbnails, allowing a full resolution view of the images with the possibility to download them. All figures in the catalogue follow a common set of guidelines in order to improve visualisation and, at the same time, be consistent in terms of image formatting (**Error! Reference source not found.**). This set of guidelines has been created taking into account the recommendations for visualisation/representation listed in Table 1. Conventions have been established for the title and footnote. Thus, image titles should be self-explanatory, indicating the name of the dataset, variable and type of information displayed in the first line, and the target season or month and period of study in the second line. See an example below:

ECMWF-S4 / 10m wind speed / Correlation of the ensemble mean /
DJF / 1982-2015

The footnote can have the following information when applicable: start date, region of study, reference dataset, bias correction, meaning of hatched/pointed/contoured areas and the type of mask applied. The logo of the BSC also appears in the lower right part of the footnote.
All the geographical images contain a latitude-longitude grid on the map and information about the units in the legend. Standardized colors in accordance to other GPCs have been used and, in some cases, the use of a different luminance for the colour bars was prioritized, which allows preserving the figure information also when converted to black and white format (Stauffer et al. 2015).

2.3. Improving scientific information

It is important that stakeholders understand the uncertainties of the provided climate information. This must be communicated effectively while highlighting at the same time the utility of the climate service, so that stakeholders can better decide how to use it.

The UIP contains enough information to facilitate non-expert navigation. This background information is provided through the materials already described in the ARECS section: the factsheets, the glossary and the section on frequently asked questions. Other resources containing more technical information (such as newsletters, case studies or the image catalogue) are also provided. When relevant, the user is referred to the appropriate factsheet describing the different concepts mentioned or to the technical reports generated within the RESILIENCE project, for clarification purposes. For the case studies and the newsletters with the bulletin for the previous season, a link between forecasts and verification metrics is always made in order to inform about how well a particular climate event can be predicted in a particular place and time. Another aspect that has also been thoroughly considered is terminology. In this sense, the IPCC guidance on consistent treatment of uncertainties has tended to be adopted as much as possible, for example, to communicate the uncertainties in the predictions using probabilities (likelihoods) and confidence levels (Mastrandrea et al. 2011).

3. Climate information provided in the UIP

In this section, examples of information that can be accessed through the UIP are shown. On the one hand, communication and dissemination materials such as factsheets, newsletters or case studies are presented, together with materials directed to scientific audiences such as technical notes and scientific publications. On the other hand, images contained in the catalogue repository are shown.

Factsheets: by the end of the RESILIENCE project, seven different factsheets have been generated and are accessible from the UIP (Figure 4). The topics described in these factsheets are:

- Probabilistic predictions for the energy sector: knowing how rain, wind and temperature are likely to be in the next months and seasons can help anticipate societal energy needs and avoid mismatches between energy demand and supply.

- The temporal horizons of climate science: depending on the time scope, predictions can be split into different categories that are retrospective forecasts, weather forecasts, climate predictions and climate projections.

- Seasonal wind speed predictions: seasonal wind predictions need to be subjected to different steps in order to be tailored to the requirements of the energy sector, and therefore to be useful for the decision-making of wind energy users.

- Reliability of climate predictions: information about the reliability of climate predictions is crucial for any user of climate information, in order to know how useful these predictions are to support their decision-making.

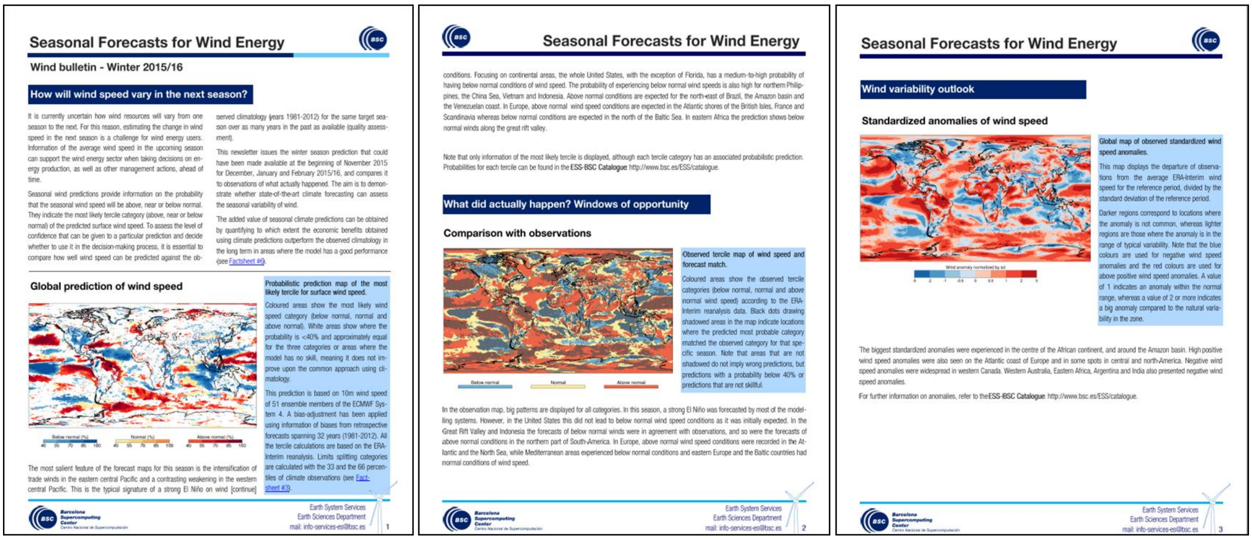
- Quality assessment of climate predictions: quantifying the quality of a prediction is important to know whether the forecast represents an improvement with respect to the average conditions over the last years and, at the same time, also informs about the reliability of the prediction.

- The added value of climate predictions: consists in quantifying to which extent the economic benefits obtained using climate predictions outperform the climatology in the long-term in areas where the model has a good performance.

- The use of climate information in the wind stakeholder chain: having accurate forecasts of wind power is becoming increasingly important for many stakeholders in the wind energy sector.

Figure 4. Example of factsheets that can be found in the UIP.

Newsletters: maps detailing global seasonal climate forecast information for the previous winter seasons are made available online via the UIP in the form of 3 different wind bulletins (for winter 2013/14, 2014/15 and 2015/16) (Figure 5). Such climate information is always accompanied by the corresponding verification of the forecasts. Therefore, seasonal predictions are only provided for those areas where the forecast system provides an improved forecast with respect to the climatology. Additional information such as an outlook of wind variability is also provided. The principal aim of these factsheets is to engage with stakeholders in the availability and potential use of seasonal climate forecasts within the renewable energy sector. By providing information on the past seasons, it creates the necessary framework for all the actors to engage in a regular dialogue that allows assessing the impact of using climate predictions several weeks or months in advance on the energy system balance.



Seasonal Forecasts for Wind Energy

Wind bulletin - Winter 2015/16

How will wind speed vary in the next season?

It is currently uncertain how wind resources will vary from one season to the next. For this reason, estimating the change in wind speed in the next season is a challenge for wind energy users. Information of the average wind speed in the upcoming season can support the wind energy sector when taking decisions on energy production, as well as other management actions, ahead of time.

Seasonal wind predictions provide information on the probability that the seasonal wind speed will be above, near or below normal. They indicate the most likely tercile category (above, near or below normal) of the predicted surface wind speed. To assess the level of confidence that can be given to a particular prediction and decide whether to use it in the decision-making process, it is essential to compare how well wind speed can be predicted against the observed climatology (years 1981-2012) for the same target season over as many years in the past as available (quality assessment).

This newsletter issues the winter season prediction that could have been made available at the beginning of November 2015 for December, January and February 2015/16, and compares it to observations of what actually happened. The aim is to demonstrate whether state-of-the-art climate forecasting can assess the seasonal variability of wind.

The added value of seasonal climate predictions can be obtained by quantifying to which extent the economic benefits obtained using climate predictions outperform the observed climatology in the long term in areas where the model has a good performance (see Factsheet #6).

Global prediction of wind speed

Probabilistic prediction map of the most likely tercile for surface wind speed.

Coloured areas show the most likely wind speed category (below normal, normal and above normal). White areas show where the probability is <40% and approximately equal for the three categories or areas where the model has no skill, meaning it does not improve upon the common approach using climatology.

This prediction is based on 10m wind speed of 51 ensemble members of the ECMWF System 4. A bias-adjustment has been applied using information of biases from retrospective forecasts spanning 32 years (1981-2012). All the tercile calculations are based on the ERA-Interim reanalysis. Limits splitting categories are calculated with the 33 and the 66 percentiles of climate observations (see Factsheet #3).

The most salient feature of the forecast maps for this season is the intensification of trade winds in the eastern central Pacific and a contrasting weakening in the western central Pacific. This is the typical signature of a strong El Niño on wind [continue]

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Seasonal Forecasts for Wind Energy

conditions. Focusing on continental areas, the whole United States, with the exception of Florida, has a medium-to-high probability of having below normal conditions of wind speed. The probability of experiencing below normal wind speeds is also high for northern Philippines, the China Sea, Vietnam and Indonesia. Above normal conditions are expected for the north-east of Brazil, the Amazon basin and the Venezuelan coast. In Europe, above normal wind speed conditions are expected in the Atlantic shores of the British Isles, France and Scandinavia whereas below normal conditions are expected in the north of the Baltic Sea. In eastern Africa the prediction shows below normal winds along the great rift valley.

Note that only information of the most likely tercile is displayed, although each tercile category has an associated probabilistic prediction. Probabilities for each tercile can be found in the **ESS-BSC Catalogue** http://www.bsc.es/ESS/catalogue.

What did actually happen? Windows of opportunity

Comparison with observations

Observed tercile map of wind speed and forecast match.

Coloured areas show the observed tercile categories (below normal, normal and above normal wind speed) according to the ERA-Interim reanalysis data. Black dots drawing shadowed areas in the map indicate locations where the predicted most probable category matched the observed category for that specific season. Note that areas that are not shadowed do not imply wrong predictions, but predictions with a probability below 40% or predictions that are not skillful.

In the observation map, big patterns are displayed for all categories. In this season, a strong El Niño was forecasted by most of the modelling systems. However, in the United States this did not lead to below normal wind speed conditions as it was initially expected. In the Great Rift Valley and Indonesia the forecasts of below normal winds were in agreement with observations, and so were the forecasts of above normal conditions in the northern part of South-America. In Europe, above normal wind speed conditions were recorded in the Atlantic and the North Sea, while Mediterranean areas experienced below normal conditions and eastern Europe and the Baltic countries had normal conditions of wind speed.

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Seasonal Forecasts for Wind Energy

Wind variability outlook

Standardized anomalies of wind speed

Global map of observed standardized wind speed anomalies.

This map displays the departure of observations from the average ERA-Interim wind speed for the reference period, divided by the standard deviation of the reference period.

Darker regions correspond to locations where the anomaly is not common, whereas lighter regions are those where the anomaly is in the range of typical variability. Note that the blue colours are used for negative wind speed anomalies and the red colours are used for above positive wind speed anomalies. A value of 1 indicates an anomaly within the normal range, whereas a value of 2 or more indicates a big anomaly compared to the natural variability in the zone.

The biggest standardized anomalies were experienced in the centre of the African continent, and around the Amazon basin. High positive wind speed anomalies were also seen on the Atlantic coast of Europe and in some spots in central and north-America. Negative wind speed anomalies were widespread in western Canada. Western Australia, Eastern Africa, Argentina and India also presented negative wind speed anomalies.

For further information on anomalies, refer to the **ESS-BSC Catalogue**: http://www.bsc.es/ESS/catalogue.

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***Figure 5**. Example of newsletter that can be found in the UIP.*

In each of the corresponding bulletins, the predicted wind speed map is represented by 3 different categories (Figure 6) corresponding to below-normal, normal and above normal wind speed. Each category is represented by a different colour (blue, yellow and red) and the probabilities within each category are displayed with the same colour but using different colour shades. Therefore, the user is not only able to see which is the most likely category predicted but also which is the probability of this prediction to occur. In all cases, only predictions over the 40% probability are displayed. Areas with a probability under 40% and areas without skill (meaning that for these areas the seasonal prediction doesn't improve upon the climatology) are not displayed in the map. This does not mean that no prediction is obtained for those areas, but we prefer not to show the result because there is not added value relative to the current approach using the prediction given by the climatology. Thus, prediction maps not only represent predictions but are also the result of a prediction quality assessment.

The wind speed forecasts for the winter were compared with observations (Figure 7). This allows demonstrating how climate forecasts, if issued in an operational context, could provide extra information about the wind speed variability in some areas. Note that, for the sake of consistency, the colours used to represent observed categories correspond to those used for the same categories in the prediction map (blue, yellow and red for below-normal, normal and above normal wind speed).

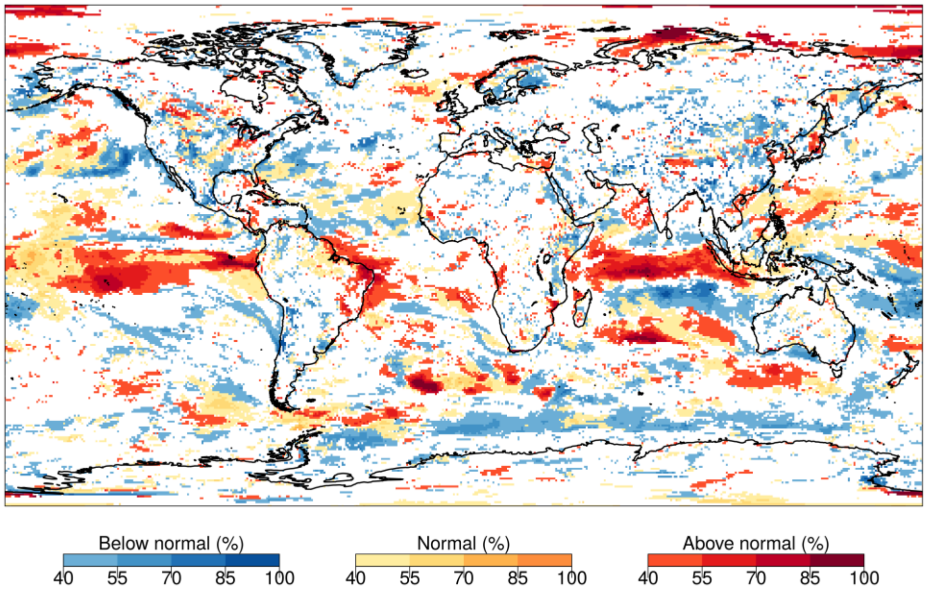


Figure 6. Example of map with a global prediction of wind speed.
Coloured areas show the most likely wind speed category (below normal, normal and above normal) and its percentage probability to occur. These categories show where the model improves upon the current approach using the climatology. Normal represents the average of the past. White areas show where the probability is <40% and approximately equal for the three categories, or areas where the model has no skill, meaning it does not improve upon the prediction using the climatology.

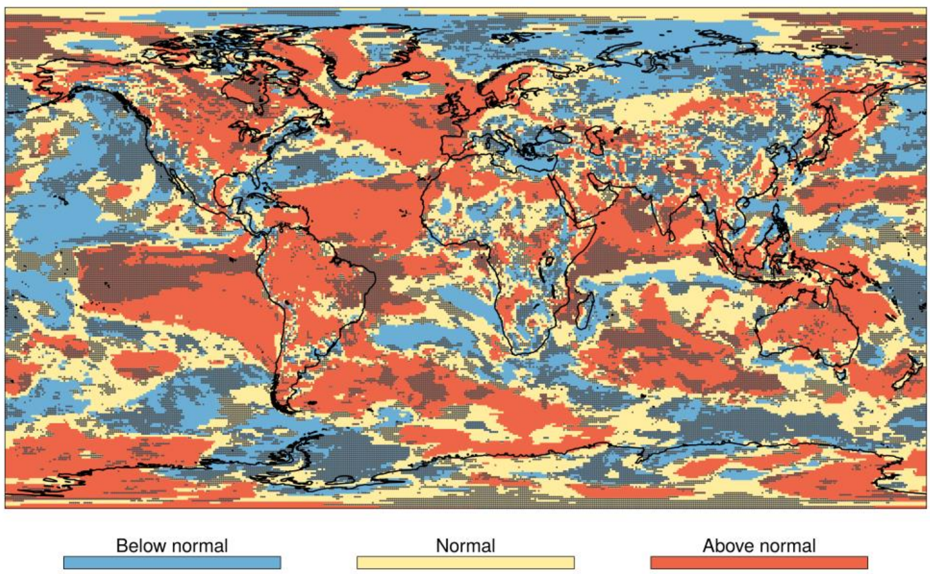
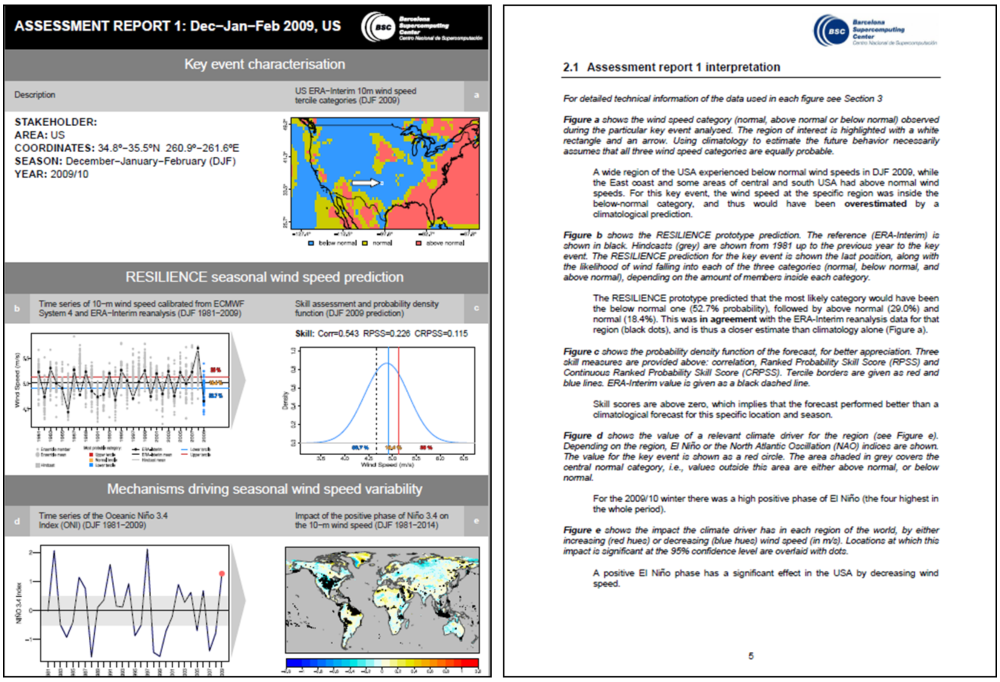


Figure 7. Example of map with observations and forecast matches.
Coloured areas show the observed tercile category according to the ERA-Interim reanalysis data, and darker areas indicate the locations where the predicted most probable category matched the observed category for that specific 2013/2014 winter.

Case studies: analysis of specific key events from the past can demonstrate the role of climate predictions to anticipate them (Figure 8). The different analyzed key events of seasonal wind speed variability identified by industrial partners are listed in Table 2.



2.1 Assessment report 1 interpretation

For detailed technical information of the data used in each figure see Section 3

Figure a *shows the wind speed category (normal, above normal or below normal) observed during the particular key event analysed. The region of interest is highlighted with a white rectangle and an arrow. Using climatology to estimate the future behavior necessarily assumes that all three wind speed categories are equally probable.*

A wide region of the USA experienced below normal wind speeds in DJF 2009, while the East coast and some areas of central and south USA had above normal wind speeds. For this key event, the wind speed at the specific region was inside the below-normal category, and thus would have been **overestimated** by a climatological prediction.

Figure b *shows the RESILIENCE prototype prediction. The reference (ERA-Interim) is shown in black. Hindcasts (grey) are shown from 1981 up to the previous year to the key event. The RESILIENCE prediction for the key event is shown the last position, along with the likelihood of wind falling into each of the three categories (normal, below normal, and above normal), depending on the amount of members inside each category.*

The RESILIENCE prototype predicted that the most likely category would have been the below normal one (52.7% probability), followed by above normal (29.0%) and normal (18.4%). This was **in agreement** with the ERA-Interim reanalysis data for that region (black dots), and is thus a closer estimate than climatology alone (Figure a).

Figure c *shows the probability density function of the forecast, for better appreciation. Three skill measures are provided above: correlation, Ranked Probability Skill Score (RPSS) and Continuous Ranked Probability Skill Score (CRPSS). Tercile borders are given as red and blue lines. ERA-Interim value is given as a black dashed line.*

Skill scores are above zero, which implies that the forecast performed better than a climatological forecast for this specific location and season.

Figure d *shows the value of a relevant climate driver for the region (see Figure e). Depending on the region, El Niño or the North Atlantic Oscillation (NAO) indices are shown. The value for the key event is shown as a red circle. The area shaded in grey covers the central normal category, i.e., values outside this area are either above normal, or below normal.*

For the 2009/10 winter there was a high positive phase of El Niño (the four highest in the whole period).

Figure e *shows the impact the climate driver has in each region of the world, by either increasing (red hues) or decreasing (blue hues) wind speed (in m/s). Locations at which this impact is significant at the 95% confidence level are overlaid with dots.*

A positive El Niño phase has a significant effect in the USA by decreasing wind speed.

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Figure 8*. Example of case study that can be found in the UIP.*

Table 2*. Key events available in the ARECS UIP. Note that the first three letters refer to the season (i.e. AMJ stands for April-May-June, Spring)*

Case study	**Key events**
Case study 1	AMJ 2010 South Brazil
	AMJ 2010 Southernmost Brazil
	DJF 2014 North-East Brazil
Case study 2	DJF 2009 US (x 2)
	DJF 2010 US (x 2)
	DJF 2013 US (x 2)
	DJF 2014 US (x 2)
Case study 3	DJF 2009 Finland
	JFM 2010 Denmark
	JFM 2010 UK

Images: images are organized in different galleries (**Figure 9**). All the images created for the image catalogue have been generated through an R-script developed for the purpose of having a consistent format. The images can be downloaded from the UIP (Figure 10 and Figure 11). The protocol for the title and footer is described in **Error! Reference source not found.**.

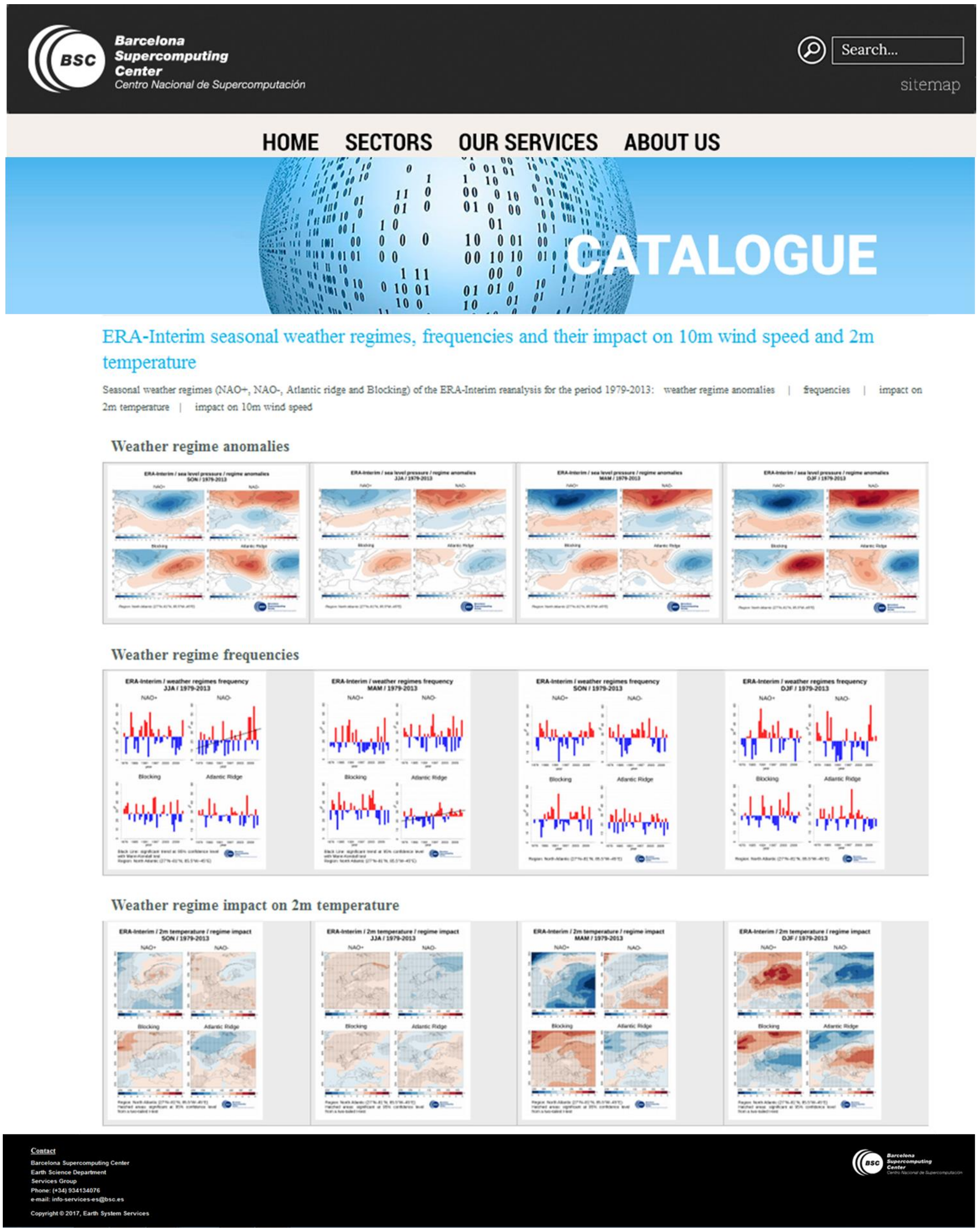

Figure 9. Example of structure of a gallery in the image catalogue.

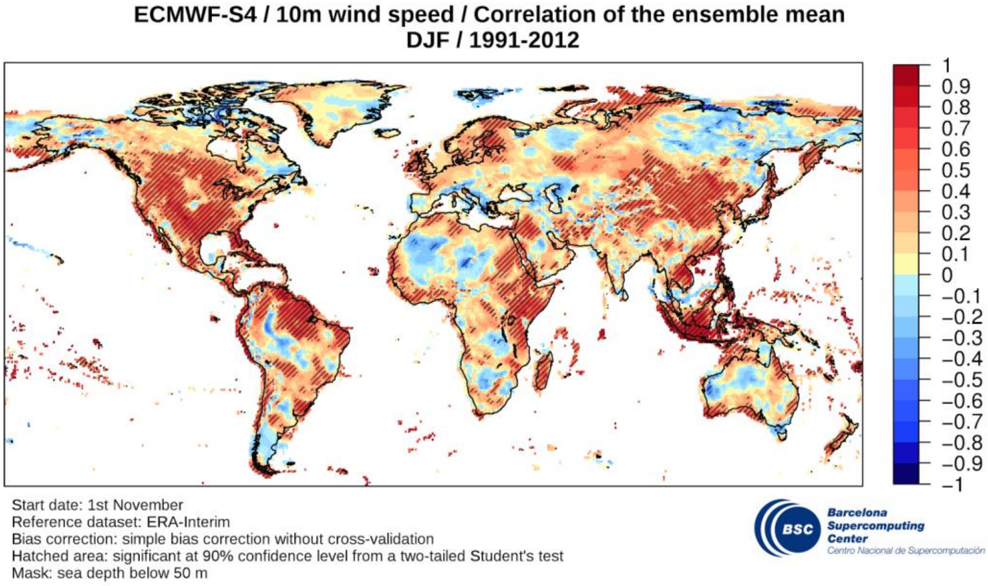

Figure 10*. Example of image contained in the UIP catalogue.*
The map displays the correlation of the ensemble mean of 10m wind speed predictions from ECMWF-S4 and ERA-Interim reanalysis for winter season (DJF) over the period 1991-2012. Blue colours indicate negative correlations, yellow colour indicates no correlation and red colours indicate positive correlations. Note that regions where the correlation is significant at 90% confidence level are highlighted by hatched areas.

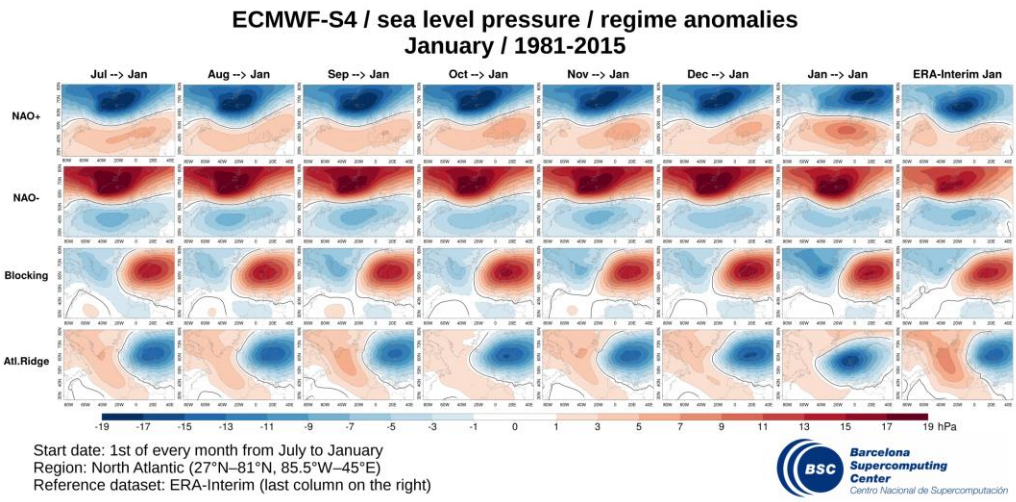

Figure 11*. Example of a multi-panel image contained in the UIP catalogue.*
The map displays the weather regime anomalies for the NAO+, NAO-, blocking and Atlantic ridge of the sea level pressure from ECMWF-S4 for the month of January over the period 1981-2015. The different columns correspond to different start dates, except the last column with displays the ERA-Interim reanalysis 'observations'. Blue colours indicate negative regime anomalies, white colour indicates near zero anomalies and red colours indicate positive regime anomalies. The black line shows a zero regime anomaly.

4. Conclusions and future steps

The main focus of this study was to improve communication and visualisation of sub-seasonal to seasonal climate prediction information. To do so, a set of recommendations that were identified through the interaction with end-users and stakeholders of climate-sensitive sectors has been followed. These recommendations are integrated in a UIP for the renewable energy sector that is constituted by two different parts: *Advancing Renewable Energy with Climate Services*, providing access to dissemination and communication material on the topics of climate and renewable energy, and an *image catalogue*, providing access to more technical information in image format. The UIP is aimed to become a reference in the field of climate services for the renewable energy sector and, at the same time, will help to establish a way of advancing towards an improvement of accessibility, visualisation and understanding of climate service products.

The solid link built between the climate and energy research created by the RESILIENCE project, has allowed the co-design of this UIP. In fact, the UIP communication strategy is designed to be based on an on-going iterative feedback process between partners and experts from the climate and energy sectors. This climate service tool enables the industry to use reliable predictions of temperature and wind speed at sub-seasonal to seasonal time scales. Unlike weather information, which is already used in the management of the energy network, few climate service tools are applied to minimise climate-related risks to the energy network. By assessing the likelihood of climate risks and their impact several weeks or months in advance, some decisions can be modified to adapt operational strategies, avoid possible financial penalties and increase the resilience of the energy system as a whole.

Additionally, the results of the RESILIENCE project, disseminated via this renewable energy web-based UIP, are expected to provide a better scientific understanding and guidance to the players concerned (e.g. energy network operators, regulatory authorities, etc.). Network operators, for example, could minimise the risk of an unbalanced energy system requiring costly decisions to be taken. This allows the energy industry to grow and adapt in an efficient and flexible manner and, in turn, stimulates the growth of renewable energies.

Future work will be needed to continue incorporating the feedback of users to improve the UIP. Other capabilities have been discussed to be improved in the future. These include an update of the image catalogue, where the idea is that the entries are replaced by a search engine, allowing the users to select a particular type of dataset, variable, location and/or time period automatically (see the website of the Australian Government Bureau of Meteorology as an example, http://www.bom.gov.au/climate/data/). Besides, although the climate service protocol and methodologies developed within the UIP were initially developed for the renewable energy sector they can also be applied to many other sectors influenced by climate over sub-seasonal to seasonal timescales. Potential sectors are agriculture, water management, health or insurance, for example. Future steps in the development of a communication and visualization strategy for climate predictions should also consider other climate-sensitive sectors.

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