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WP 6.1 Pilot Applications

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WP number and title	6.1 Pilot Applications			
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	PU	PU - Restricted to other programme participants, including the Commission services		
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1. Executive summary

The implementation of the FP7 EU funded project *Seasonal-to-Decadal Climate Predictions for the improvement of European Climate Services,* SPECS, through different work packages (WP) and research themes (RT) provided a comprehensive set of knowledge, data, experiments and tools which allowed to assess the state of the art of the seasonal products and to better understand usage of seasonal predictions services for different industries and applications.

SPECS WP 6.1 explored the use of current seasonal prediction technology for the renewable energy sector (RE). Different pilot applications studies and investigations were carried out during the project to illustrate and to visualize real RE applications cases to assess added value, quality and potential use of seasonal prediction for wind and solar energy using latest seasonal predictions technology.

The present report provides a series of outcomes, recommendations and by-products for the use of seasonal climate predictions products for users and stakeholders from the RE sector based on the gained experience and outcomes from SPECS WP 6.1.

The report is divided in three sections:

1. *Analysis of the use and demand of seasonal predictions products by RE industry*: we present conclusions and recommendation on the use of seasonal prediction product for RE sector , elaborated in conjunction with industry stakeholders through different meeting which took places at different wind industry specialized fora;
2. *Analysis of seasonal predictions quality*: an assessment of current reliability of seasonal predictions for wind industry is presented based on SPECS recommendations and following guidelines from the project WPs;
3. *Information for RE sector*: a set of *Frequently Asked Question* (FAQ) for use seasonal product by RE industry are included in the report as support material for diffusion of the seasonal products.

We aimed with this work to summarize current demand of seasonal prediction, to inform on the current status of the technology for RE applications and to provide evidence and motivation to promote and to boost the seasonal product usage among an industry, which being powered by "climate" depending sources, can benefit of a new generation of seasonal prediction technology developed by SPECS project.

2. Project objectives

With this deliverable, the project has contributed to the achievement of the following objectives (see DOW Section B.1.1.2):

No.	Objective	Yes	No
1.	To achieve an objective exhaustive *evaluation* of current forecast quality from dynamical, statistical, and consolidated systems to identify the factors limiting s2d predictive capability		x
2.	To test specific hypotheses for the improvement of s2d predictions, including novel mechanisms responsible for high-impact events using a *process-based verification* approach		x
3.	To develop innovative methods for a comprehensive *forecast quality assessment*, including the maximum skill currently attainable		x
4.	To facilitate the *integration of multidimensional observational data* of the atmosphere-ocean-cryosphere-land system as sources of initial conditions, and to validate and calibrate climate predictions		x
5.	To achieve an *improved forecast quality at regional scales* by better initialising the different components, an increase in the spatial resolution of the global forecast systems and the introduction of important new process descriptions		x
6.	To assess the best alternatives to characterise and deal with the *uncertainties in climate prediction* from both dynamical and statistical perspectives for the increase of forecast reliability		x

7.	*To achieve reliable and accurate local-to-regional predictions* via the combination and calibration of the information from different sources and a range of state-of-the-art regionalisation tools		x
8.	*To illustrate the usefulness* of the improvements for specific applications and develop methodologies to better communicate actionable climate information to policy-makers, stakeholders and the public through peer-reviewed publications, e-based dissemination tools, multimedia, examples for specific stakeholders (energy and agriculture), stakeholder surveys, conferences and targeted workshops	X	
9.	*To support* the European contributions to *WMO research initiatives* on s2d prediction such as the GFCS and enhance the European role on the *provision of climate services* according to WMO protocols by creating examples of improved tailored forecast-based products for the GPCs and participating in their transfer to worldwide RCCs and NHMSs.		x

3. Detailed report on the deliverable

3.1 Analysis of use and demand of seasonal predictions products by RE industry

a. Background

New generation of seasonal predictions products developed by international efforts and projects like SPECS are expected to support the demand of information for different industries that relies on weather and climate information and data.

During the last two decades, Renewable Energy (RE) sector and industry grown exponentially driven by a mature technology, market development and the society demand to find alternatives to global warming emission produced by traditional fossil based energy sources.

RE sector gained a very significant penetration in the global energy market boosted by the work of policy makers and multiple industry actors. RE industry is foreseen to keep growing with the expansion to new regions like China, Middle East, India, Southeast of Asia, Central and South America and Africa and the improvements of the technology like new offshore wind turbine designs and concentrated solar power. On another hand, the global initiative to keep global warming under the 2 degrees target relies and requires the RE sector to play a fundamental role in achieving the emission reduction objectives.

b. Demand of Seasonal prediction product by RE industry

Different group and peer-to-peer meetings with RE industry stakeholders were hold at different specialized forums as part of SPECS WP 6.1. The objective of these meetings were to:

1. Better understand the RE seasonal users' needs of seasonal prediction products and services ;
2. Communicate potential usage of seasonal predictions for the RE industries ;
3. Promote SPECS project and other existing initiatives on climate forecasts ;
4. Define SPECS WP 6.1 pilot applications ;
4. Elaborate a *wish-list* from the feedback obtained from industry stakeholders ;
5. Prepare the fact-sheet and FAQ focus on RE industry

The distribution of the stakeholders who attended the meetings was: developers 30%, manufacturers 20 %, consultants 10%, asset managers 10%, utilities and grid operator 10%, and insurance & traders 20%.

The RE stakeholder meeting took places in the following forums:

Table 1 : RE industry meetings					
Industry event	Place	Date	Presentation at Event	Format	Contacts
EWEA Annual Event 2014	Barcelona	June 2014	Yes	Specific session	18
EWEA Wind Resource Workshop	Helsinki	June 2015	Yes	Peer to peer	15
EWEA Annual Event 2015	Paris	November 2015	Yes	Specific session	10
Windpower Brazil 2015	Rio de Janeiro	August 2015	No	Peer to peer	5
EWEA Forecasting Workshop	Leuven	September 2015	Yes	Booth and peer to peer	14
AWEA Wind Resource Assessment Seminar	New Orleans	September 2015	Yes	Peer to peer	11
Wind Europe Analysis of Operating Wind Farms Workshop 2016	Bilbao	October 2015	Yes	Peer to peer	13

The conclusion from the different discussions held and the feedbacks obtained from the several stakeholders made possible to draw a potential usage and application context for the RE sector, mostly focused on wind power industry. The conclusion are summarized in the table 2.

Table 2: Seasonal predictions products context for RE (Wind Power)					
Potential benefits	❏ Climate variability risk mitigation ❏ Portfolio Modeling ❏ Energy mix and security ❏ Operation and maintenance				
Major barriers for usage	Lack of information of products and usage	Poor skill and limited predictability	Communication of uncertainty of seasonal products	Visualization and understanding forecasting products	Limited data access and lack of RE specific variables
Action to overcome / mitigate barriers	➔ Improve access to online seasonal prediction information and tools ➔ Improve communication of seasonal predictions (for ex: split context in levels of expertise) ➔ Create a network and working group with information provider and users ➔ More peer review papier and contribution to specialized fora				

In the next section, a short description of the different topics addressed in table 2 are presented.

B1. Benefits of seasonal products for wind industry

A. Climate vulnerability and risk prevention

Climate vulnerability impact grows as wind energy market size grows. RE relies on a weather and climate-driven 'fuel' which requires a precise and accurate characterization of climate variability at either project feasibility and operational stage. Moreover, the global expansion of the RE market made critical the understanding and prediction of anomalous climate events as new markets are being developed in regions which are affected by strong interannual climate variability. Moreover, anomalies in the seasonality of wind resources is a major player in the annual revenues risk assessment, especially during the first pentad of operation of the project where return of investment is more critical.

Stakeholders brought attention to the new markets development in regions like India and Northeast of Brazil where wind resources are strongly marked by a seasonal cycle (monsoons, trade winds) which, in conjunction with weak grid integration, motivate the need of advance of information of

anomalies of the wind average conditions one or two seasons ahead. It is also important to note that some of the new market regions present more robust climate predictability and predictions can offer higher skills.

B. Portfolio modeling

Along with climate vulnerability, the requirement of portfolio modeling for industry actors with assets in multiple regions affected by diverse climate patterns have been pointed out as potential application and motivation for developing wind industry specialized seasonal prediction product

C. Energy mix and security

From the point of view of grid operators, there is a need to define scenarios for the demand and supply context. Access reliable of information of climate anomalies with an horizon of one season will have a key role in optimizing the network balance and improving energy security The interplay rol between demand (for instance: driven by temperature) and RE sources (hydro, solar and wind) has a potential value to explore within the frame of seasonal predictions.

D. Operation and Maintenance strategies

For very complex operational projects where environmental conditions are main drivers of the reliability of windfarm generation, information on the extreme seasons and events occurrences is critical.
Two critical regions for applications are underlined: offshore regions, where operation and maintenance is strongly conditioned by accessibility to the projects and cold climates regions, where icing and extreme low temperatures have an important impact on production losses.

Wind industry foreseen both regions as ones of the most important market development areain the present and near future as indicated by current trends in North and Baltic Sea and other maritime

regions (Korea and USA) and cold climate regions (Canada, Scandinavia, Central Asia, USA). Thus, stakeholders indicated that prediction of climate extreme anomalies information in these regions will have a direct return on investment to optimize project profitability operating in such critical environmental conditions areas.

3.3 Seasonal prediction quality for RE, a test case study: Wind Industry

One of the main barrier for the usage of seasonal products, as concluded from the stakeholders meeting, is the lack of information on the reliability of the current seasonal products for RE applications. On the other hand, the notion of reliability, as employed in seasonal prediction field, is not very well understood or integrated by the RE community. Mismatch between the notion of reliability and skill is inherited from the confusion on the usage probabilistic output. In fact, the typical metrics employed in the seasonal prediction community (brier scores family, reliability diagram, ROCS etc) are mostly unknown among potential end users at the wind industry backend. As results, there is a general perception, and belief, among the wind industry, if we take as representative the conclusion meeting held, that the seasonal products are not yet ready for usage and historical data (for instance, downscaled Reanalysis products) can provide better tools to assess climate risk assessment for next season conditions. On the other words, wind industry community relies on climatology information, easy to understand and to obtain, rather than in seasonal predictions products.

Therefore, one priority objective for SPECS project to promote seasonal prediction among the RE sector community is to provide a clear and simple analysis of the performance of seasonal products for RE applications using simple metrics that can be communicated with few words. From the feedbacks, a green light-like skill category of use was suggested to facilitate communication of the quality and reliability of the seasonal products.

On the basis of this recommendation from the stakeholders, the approach proposed by Weisheimer and Palmer (2014) was selected and replicated for wind industry predictions. More information on these approach can be found in SPECS fact sheet #3 March 2015.

The Weisheimer approach aims to translate the usual reliability diagram into 5 categories that provide a clear indicator on the quality of the predictions. The objective is to label these categories so they can very easily understood by a wide community of users, with no previous background on verification and reliability analysis of climate probabilistic predictions.

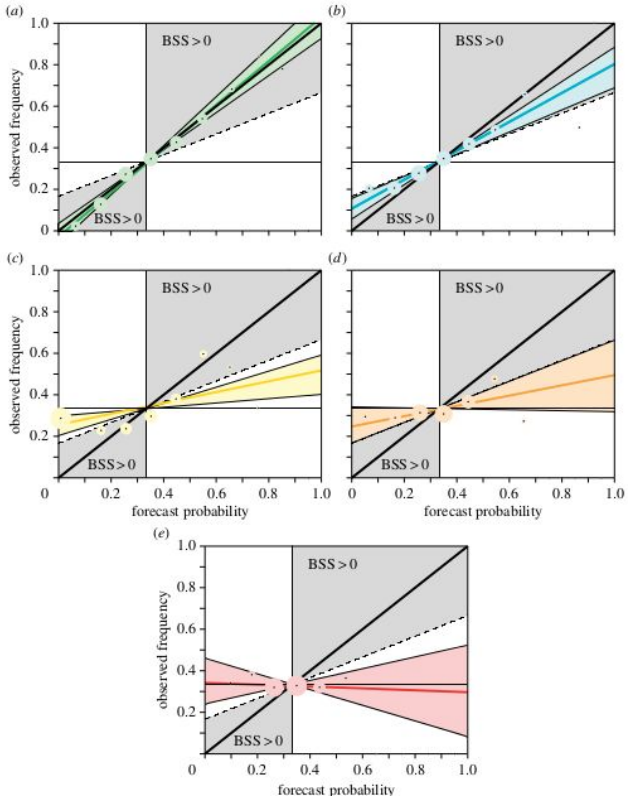
The reliability diagram describes the statistical relationship between the forecast probabilities and the observed frequencies which the event actually happened. Thus, the reliability diagram provides an answer to the following questions:

1. Does prediction and observation have a 1:1 relationship? A measure of the linear regression between predicted and observed frequencies event can be derived from the reliability diagram parametres;
2. Does prediction improve the climatology? A direct visual method to detect when prediction beat the climatology is also provided. Note that climatology is employed as main baseline benchmark for the predictions.

The seasonal prediction quality mapping employed in this work relies on classification of the reliability diagram into 5 categories labeled as: useful, still useful, marginal useful, not useful and dangerous. The categories distinguish different mapping of the relationship between the observed occurrence and predicted probabilities. The different categories are described in the reference work (Weisheimer and Palmer ,2014) and presented in Figure 1, were the different reliability diagram categories 'realization' are shown.

Figure 1: Reliability categories employed in the analysis according to Weisheimer and Palmer (2014)

5 perfect 4 still useful 3 marginally useful 2 not useful 1 dangerous



In the present quality analysis of wind conditions seasonal prediction, the events *to be predicted* were defined by terciles statistics which delimited low, near average and high wind speed threshold, as defined in table3.

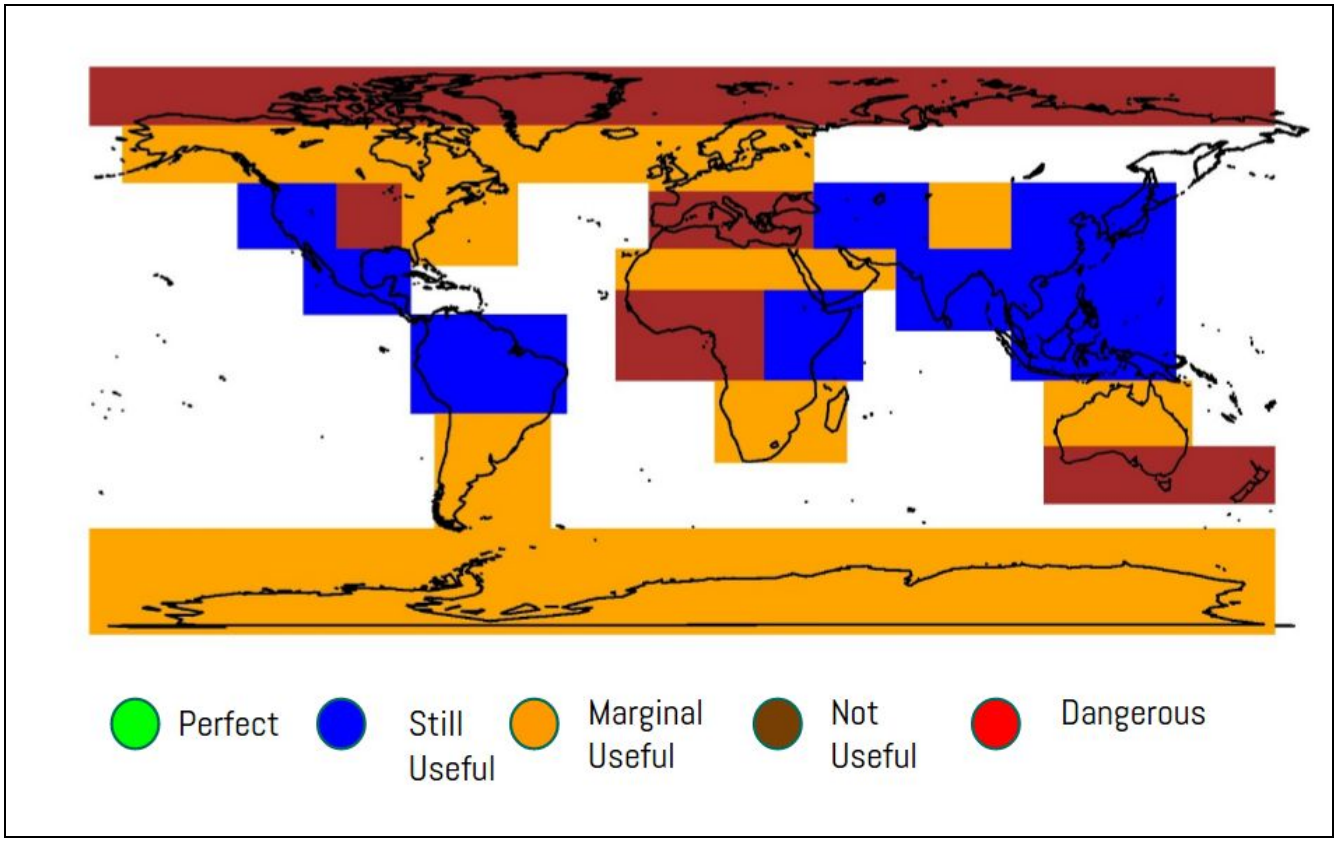
Table 3: Definitions of events employed in the reliability analysis	
Event	Definition
low wind conditions	Wind speed lower than climatological lower tercile threshold
near average conditions	Wind speed between lower and higher tercile threshold
high wind speed conditions	Higher than climatological higher tercile threshold

Predictions from ECMWF operational global forecasts System 4 were employed to map the seasonal predictions for different regions. 10m zonal and meridional daily velocities were employed to derive the absolute monthly wind speeds time series. S4 was produced at the beginning of each month for forecast lead times of seven months into the future using 51 ensemble members. ECMWF S4 were made available for project SPECS through the data dissemination gateways. ECMWF ERA Interim climatology was employed as baseline observations.

The present reliability classification was made employing the same 15 climatic regions used in Weisheimer and Palmer (2014). All grid points for each region were aggregated together to populate a unique 'prediction' set in order to reduce uncertainty due to small sample size. Simple bias correction method were employed subtracting climatology from differences on a cross-validation leave-one-out mode.

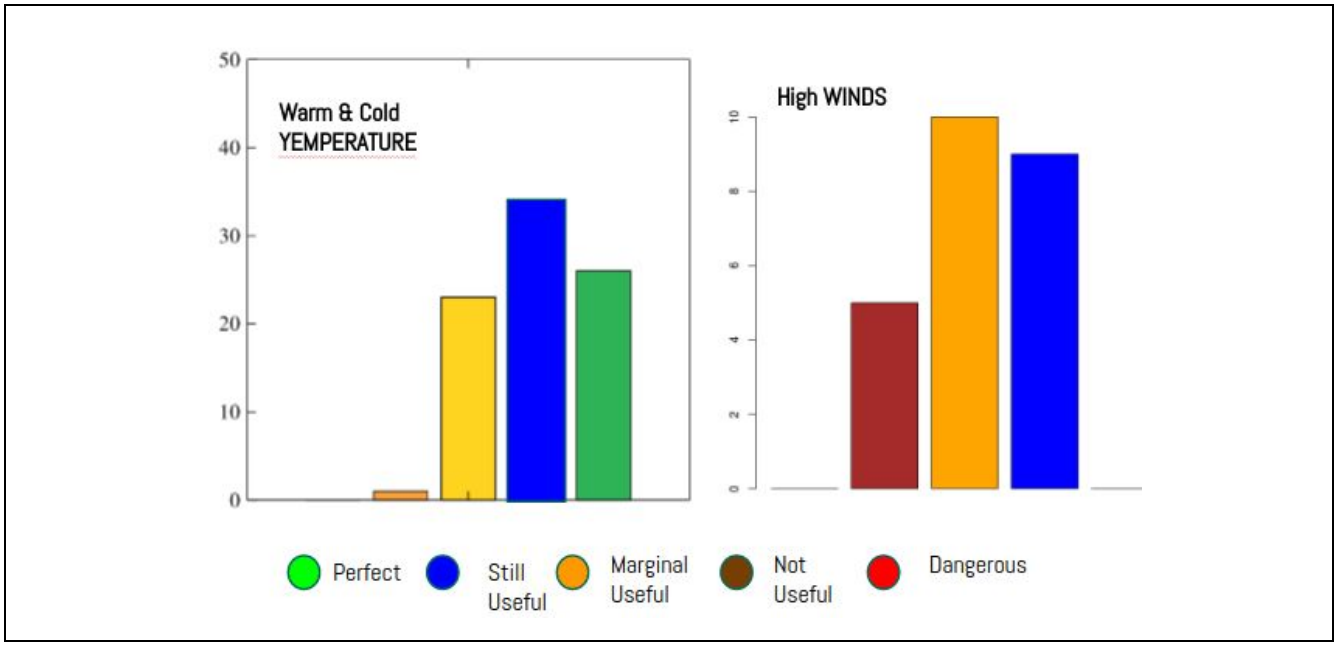
The results of reliability classification for boreal winter (december to february) higher wind event (higher than 3rd tercile) are shown in Figure 2 as an illustration of the results.

Figure 2: Seasonal prediction reliability categories for ECMWF S4 DJF high wind conditions (above 3rd tercile) for the 15 regions employed in the analysis



In order to better assess the overall performance of wind events prediction, the distribution of the obtained categories for wind (high events) and temperature (warm and cold events) can be compared (figure 3). The main difference from temperature and wind predictions are found in the absence of "perfect" prediction for wind while intermediate categories, still useful and marginal useful are represented with similar distribution.

Figure 3: Distribution of categories for temperature warm and cold events and high winds events for ECMWF S4 for DJF predictions



In summary, results from the comparison between temperature and wind predictions shows potential to improve wind prediction to relocate still useful regions into perfect categories.

It is recognized that size of the domain have an impact on the results and it is recommended to redo the analysis using domains which represent the actual potential wind resource regions, which have a much intense 'wind' signal.

3.3 Seasonal prediction for Re: Frequently Asked Question

As part of the WP 6.1 products, a set of frequently asked question (FAQ) has been elaborated. The objective of the FAQ is to answer the main recurrent questions addressed by end users among the RE sector. Learnings from the meetings held during the project with different stakeholders has been employed to build the following FAQ.

1. **What's seasonal prediction ?**

Seasonal predictions provide estimation of the change in the likelihood of a climatic event happening in the coming months.
For instance, the target of the seasonal prediction for wind power is to provide the odds for next season wind speeds to be above or below certain threshold rather than assessing wind speeds absolute values.
You can check SPECS Fact Sheet #1 (October 2014) for more details and information on seasonal predictions.

2. How do we produce seasonal prediction?

Seasonal predictions are produced by a combination of dynamical and statistical models.
Global Climate Models (GCM) are employed to represent the dynamic evolution of the atmosphere and ocean system, while different statistical procedures and methods are employed to correct bias/error, derive and process output information, and localize the prediction (downscaling). For all these tasks, long-term historical observed data are required.
Usually GCM for seasonal predictions are run to span up to 12 month ahead.

3. What are the GCM ?

Global Climate Models (GCM) are numerical representation of the evolution of the atmosphere and ocean (and ice and land). GCM are run operationally by climate services every calendar month to provide the potential evolution of the main meteorological variables (temperature, precipitation, pressure and wind components) for the coming months. Actually, GCM are also employed in the Reanalysis production as well, and as for the Reanalysis, they require input observed conditions of the state of the atmosphere, ocean and land.

4. One or several predictions ?

Because the chaotic nature of the atmosphere and the imprecise representation of the initial conditions, GCMs need to be initialized with multiples choices in the physics and the actual input data. These lead to an ensemble of predictions which capture the spread of the potential evolution of the atmosphere and the target variable we want to predict. This is the reason for seasonal prediction products output to be expressed in terms of probabilities of a variable to fail in certain threshold

5. Who provides seasonal predictions ?

Seasonal predictions are provided by reference specialized institutions. As for weather forecasting, the hardcore of making the prediction requires a large knowledge and expertise which is only possible for reference climate services centers. Computing facilities, earth observing processing data and climate modeling expertise are required to build and operate a seasonal prediction service.
Example of main seasonal predictions providers are European Center for Medium Range Weather Forecast (ECMWF), MetOffice, National Center for Environmental Prediction (NCEP), Environmental Canada, International Research Institute on Climate and Society (IRI).
Several international efforts are carried out to join forces to provide multimodel predictions that benefits of using different technologies and the expertise of multiple institutions.

6. Which potential application for seasonal predictions

There are many industries and applications that benefice of the use of seasonal predictions.
Agriculture early warning system, health programs planning and disaster risk assessment have been one of the main success stories in seasonal predictions.

7. Which variables can predicted and provided in the seasonal products?

Temperature and precipitation have been the main target variables as society demand is focused on these two basic parameter. For instance, energy demand depends on the temperature and hydropower is linked to precipitation. Food and agriculture are constrained by the hydro-cycle as well. Tourism industry is also very dependent on rain and cold/heat waves. Disease epidemic is strongly controlled by the combination of both variables.
Nevertheless, with the new technologies and the improvement in the seasonal predictions other variables are being incorporated to the seasonal prediction chain, including wind speed and solar radiation.

8. Can we use seasonal predictions for wind and solar energy?

Of course. Wind speed and solar radiation prediction can be obtained directly or derived from the different main seasonal predictions data providers.

9. Why seasonal predictions are not very known among the wind industry ?

Wind industry has focused on short-term predictions as the intraday and day ahead market was a priority. It was only recently that seasonal prediction started to prove as reliable technology to offer next season wind conditions mapping probabilities.
SPECS envisaged to promote the use of the latest seasonal prediction technology among the RE industry and to understand which are the actual demand that the different wind and solar industry stakeholder demand.

10. Which applications can be explored for seasonal predictions in the wind industry ?

Main application areas in the wind industry for seasonal predictions are

- ❏ Climate variability risk mitigation
- ❏ Portfolio Modeling
- ❏ Energy mix and security
- ❏ Operation and maintenance

10. How do we measure the quality and reliability ?

As seasonal predictions provide probabilities of an event to occur, we need to enlarge our deterministic 'language' to assess the quality of a seasonal prediction products. There are different metrics that are employed to assess the skill, confiability and sharpness of the probabilities to capture different events. We recommend SPECS Fact Sheet #3 for a more in detail review and description on climate forecast reliability.

11. Can I do assess the reliability with two or three years of observed data at my windfarm ?

No; seasonal predictions requires a set of individual seasons episode large enough to cover at least 20 to 30 events (20 to 30 years of data). Obviously, there is no availability of wind industry data that spans over such a large period. As an alternative, Reanalysis are employed as observational proxy, which is justified by the high standing quality of current Reanalysis projects (MERRA2, ERA-Interim etc …).

11. Can we get reliable and useful information for seasonal predictions for RE?

In short, yes. Results from SPECS project analysis show that seasonal prediction for wind conditions events is useful in many regions and the use of the prediction improve on average the climatology baseline information.
On the other hand, there are different downscaling techniques that can be employed to localize seasonal prediction to take into account regional and sub-regional drivers and modulation. On this subjetc, we recommend SPECS deliverable D52.1 Review of the different statistical downscaling methods for s2d prediction [http://specs-fp7.eu/sites/default/files/u1/SPECS_D52.1.pdf]

12. How are the predictions of wind comparing to temperature and precipitation?

Seasonal predictions for wind requires more effort in validation for real usage. Nevertheless, one season ahead predictions for wind events can show a similar performance as for temperature for many regions and seasons

13. Which regions are more predictable ?

Northeast of Brazil, USA North West and South India are regions where seasonal predictions for wind provide good performance

14. How seasonal predictions for wind can be improved ?

SPECS project has identified different target areas to improve seasonal predictions. The task list is very wide but we can define the following action to improve current wind seasonal predictions: improvements in the initialization of the modeling chain, enhancements in GCM physics and dynamics including better resolution, empirical prediction and calibration methods and more sensitivity to user's need.

15. Where I can get more information?

SPEC project web page is an excellent gateway to find resources and more in-deep information of the current technology advances in seasonal predictions, http://specs-fp7.eu.
Along with SPECS, its sister project, EUPORIAS is also an excellent initiative to compile information on climate services applications http://www.euporias.eu/

4. References

Weisheimer, A. and T.N. Palmer (2014), On the reliability of seasonal climate forecasts. J.R.Soc. Interface, 11, 20131162.

SPECS fact sheet #3 March 2015
http://specs-fp7.eu/sites/default/files/u1/SPECS_FactSheet_reliability_n3_final.pdf

5. List of publications

A series of contributions to different wind industry events have been produced as part of WP 6.1 development:

- Lizcano et al (September 2015), Wind resource seasonal forecast outcomes from SPECS project, paper presented at EWEA Forecasting Workshop, Leuven, Belgium
- Lizcano et al (September 2015),What We Can Expect Today from Newest Generation of Seasonal Forecast System for Wind Industry Applications, paper presented at AWEA Wind Resource & Project Energy Assessment Seminar 2015, New Orleans, USA
- Lizcano et al (March 2014), How many year are enough? Advancing knowledge of low frequency wind resource variability, paper presented at EWEA Annual Event 2016, Barcelona, Spain
- Lizcano et al (June 2014), Return on Investment of Seasonal to Decadal Wind Resource Forecasting, paper presented at International Conference on Energy and Meteorology 2014, Toulouse, France

Plan for future publication:

The results showed in this deliverable will be part of a future publication which will include an update and revision of section 3.2 including a comprehensive list of results. Publications will be sent to peer-review journal in either climate predictions and wind energy areas.

6. Efforts for this deliverable

How many person-months have been used up for this deliverable?

Partner	Person-months (actual)	Person-months (in-kind)	Period covered
1	Gil Lizcano	14	9-48
2.	Abel Tortosa	7	9-48
6.	Elies Campmany	3	30-48
7.	Pau Casso	3	30-48
Total		27	

7. Sustainability

Seasonal predictions services for the wind industry are still in a *work-in-progress* stage in terms of product development, room for improvement, validation exercises, usage tuning and dissemination.

WP 6.1 aimed to explore seasonal product application for RE sector, with focus on the wind industry. Meeting industry stakeholders was a very productive. We were able to establish a dialogue with end users to understand the actual barriers on the product usage by the community. During the project, we came across a strong established perception or belief that seasonal predictions are not useful. Limited predictability for certain very mature wind industry region is a fact that has to be recognized but efforts are needed to move the development of seasonal products forward as wind market explores new markets where predictions show a proven reliability.

However, the interest on the topic was significative and the industry is willing to see more example of real prediction products focused on the wind power generation technology.

Along with the internal perception within the wind industry, thelimited access to wind predictions is a major barrier. Most of the operative climate service don't provide wind speeds information as part of the output products.

During the execution of WP6.1, a natural synergy has been created with EUPORIAS project, as many of the background question addressed in the initial stage of work was partly covered by EUPORIAS. On the other hand, we were able also to provide feedback and support to EUPORIAS demo project UKKO.