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Workshop report

“Reconciling scientific capability with current and potential user needs at the seasonal to inter-annual timescale in Europe”

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1. Executive summary

The aim of this workshop was to engage directly with the scientific community developing the new generation of S2D climate prediction models to assess whether identified current and potential user needs can be fulfilled with available services or further research. Due to the diverse and large user needs identified in WP12, a few specific user needs were used as examples of particular organisations' needs in Europe. The eight examples selected represented different sectors, countries, and types of organisations in Europe as well as different types of information needs (e.g. seasonal or decadal, different weather parameters).

Workshop participants we allocated into six groups and assigned to one of eight user case studies to provide suggestions on: existing products that could be immediately used to satisfy those needs, post-processing to existing data in order to tailor it to the users' needs, further research required to fully satisfy those needs, and cross-cutting issues such as the expertise of the participants in the topic and the quality of the data. After discussing a case study for 15 minutes the groups would rotate to a different user case study, with each group doing four case studies.

User A was a Spanish organisation based in Castilla y Leon which provides support to farmers regarding harvesting and irrigation. They would like to have rainfall (mean) data for autumn and hail (total) data for spring with prediction lead time of 3 and 6 months, respectively. Ideally these forecasts would provide daily data at a spatial resolution of 7,000km^2 or higher if possible for the whole region.

Key findings: seasonal forecasts on rainfall are available but seasonal and short-term information on hail are currently not available; suggestions were made about ways of deriving information from existing data and post-processing existing data although ultimately it will depend on the exact data necessary by the farmers to make decisions; the need for forecasts with daily data to inform farmers' decision-making was questioned by the scientist community;

User B was a private wine company in Portugal which would like to have different types of forecasts with different predictions lead time. An example would be the need for monthly forecasts for temperature (mean and extremes) and rainfall (annual) with a prediction lead time of 18 month with a 9km^2 spatial resolution across Portugal.

Key findings: The Met Office decadal system already provides free temperature data with a prediction lead time of 18 months and 4 to 6 months; the Japanese decadal system can also provide 18 months prediction lead time; however, such forecasts have limited skill and would require calibration; the spatial resolution at 9km^2 for temperature requires validation whilst for precipitation would require further downscaling and station data; more research is required to downscale with terrain models.

User C was company in Croatia working on the generation (mainly hydro-power) and distribution of energy. They would like to have rainfall monthly data (above, below, average) with 1 to 3 months prediction lead time at a spatial resolution of 12,000km^2 although higher would be preferable.

Key findings: seasonal forecasts for precipitation freely available from ECMWF and IRI; need for downscaling and tailoring the data for specific river basins; need to perform bias correction, explore reliability and skill of the methods and assess operational capabilities; more research is required to develop an integrated hydrological model as well further develop downscaling methods and sources of predictability at seasonal/sub-seasonal timescales.

User D was an international insurance company working on weather derivatives. They would like to have monthly wind data up to 10 years with 1 month prediction lead time at the highest spatial resolution possible.

Key findings: wind data at those resolutions is not available but the CMIP5 decadal forecasts provide data on wind speed for 10m which at 100km or global scale; ECMWF, IC3 and Met Office also provide some data on wind; MIKLIP project explores wind data at 5km resolution for central Europe; but skill at decadal timescales is very low; need to understand decadal processes e.g. variability in the NAO and further research on post-processing (e.g. bias correction) methods; further research on wind is also needed (e.g. mechanisms influencing wind, influence of the NAO on wind) as well as a large investment and experts on wind and decadal forecasts.

User E was a Norwegian organisation responsible for planning, building and maintaining the national road system. They would like to have monthly data for precipitation combined with temperature and knowing how many days around zero

are expected. The information would be regarding winter months with three months prediction lead time covering the whole country.

Key findings: downscaled data on precipitation and snow are already being produced by the Norwegian national met service; need for bias and drift correction of seasonal forecasts as well as observations and climatology data; a few ideas were suggested for post-processing of existing data and further research e.g. to improve low confidence skill of snow forecast; influence of the North Atlantic Oscillation critical to the skill of seasonal predictions in Norway.

User F was a research and consultancy organisation in Denmark working on projects related to the water sector. They would like to have monthly rainfall and temperature data (mean and extremes) with 3 to 6 months prediction lead time for the whole year. In terms of spatial resolution they would like to have data covering catchments areas in Europe ideally with a $5km^2$ resolution.

Key findings: the weather parameters required by the user are available from IRI, NOAA, and ECMWF although not at the spatial resolution required (and with limited skill); EUPORIAS prototype on river flow forecasts for water resource management in France already developing this type of data (and expected to provide this data at a European level in the next 5 years); need for statistical and dynamical downscaling with observation data and hydrological models for catchment areas; more research is required on extremes (rainfall) although useful data on extremes is not certain; limitations on skill will always be an issue.

User G was an organisation involved in the promotion and communication of tourism activities in France. Although they currently don't use any weather and climate information they would like to know for example, what will be the seasonal forecast for snowfall in France during winter months with the highest spatial resolution possible.

Key findings: the Canadian system for snow forecast could be transferable to Europe; potential to learn from the EUPORIAS prototype focusing on winter conditions for UK transport; further observation data is required to represent snow as well as verification to tailor observations to snow and improve satellite data for snow cover; more research is required to increase resolution, modelling snow depth, and improve winter skill.

User H was a health organisation working on epidemiology in Italy focusing on the effects of temperature on health. They would like to have monthly forecasts of temperature (maximum and minimum) for summer months with a prediction lead time of 3 to 6 months. Regarding spatial resolution they would like to cover urban areas in Italy.

Key findings: relatively high skill in Southern Italy for seasonal forecasts for summer; spatial resolution is available for 25-30km grid from ECMWF; temporal resolution exists but not more skill than the mean; possibility of calibrating and downscaling the data for achieving the spatial resolution required at the urban scale; need for more analysis on extremes and thresholds; further research investment is required e.g. computer power, closer collaborations between scientists working at the global and micro levels; need to improve skill for summer months.

Overall, one of the main findings was that for all of the cases of users' needs discussed at the workshop there were no products available that could fully satisfy their needs (e.g. spatial or temporal resolution required, limited skill).

In many cases the available products could be explored by applying post-processing methods in order to approximate existing data to that required by the user, particularly with parameters such as temperature and precipitation but less so when focusing on parameters such as wind and snow.

Further research streams were suggested although, in many cases, a considerable investment in expertise and computational power would be necessary.

Finally, a better understanding of the types and chains of decision-making by the users and how this data is/would be utilised to inform such processes would also help to refine the quest for (and potentially the provision of) more adequate data able to satisfy those particular needs.

It is therefore critical that the scientific community developing S2D climate predictions engages with the users in order to better understand their current needs and inform the development of more adequate and usable data in the future.

2. Background and aim of the workshop

The aim of work package 12 (WP12) is to assess the users' needs with regard to seasonal to decadal (S2D) climate predictions across European sectors. To achieve this, a range of tasks were pursued including a systematic literature review, a workshop with European climate services providers, in-depth interviews with EUPORIAS stakeholders and other potential users, and a European survey of users' needs. The data collated throughout WP12 and, in particular, the information gathered during the interviews (and to some extent the survey) has improved our understanding of current and potential needs of European organisations in relation to S2D climate predictions.

The aim of this workshop was to engage directly with the scientific community developing the new generation of S2D climate prediction models to assess whether identified current and potential user needs can be fulfilled with available services or further research. Due to the diverse and large user needs identified in WP12, a few specific user needs were used as examples of particular organisations' needs in Europe. The eight examples selected represented different sectors, countries, and types of organisations in Europe as well as different types of information needs (e.g. seasonal and decadal, different weather parameters).

3. Workshop structure

The workshop took place at the joint day between the EUPORIAS and SPECS[1] general assemblies. This allowed participants working directly in the development of S2D climate prediction models from the SPECS community to attend as well as those involved in the EUPORIAS project.

The workshop started with a brief 20 minutes presentation of the main findings of WP12's research. The 20 participants were then organised into six groups (see Appendix 1 for list of workshop participants) and the remaining 90 minutes of the workshop consisted of a working session with the help of nine facilitators (see Appendix 1). Each group was allocated to one of eight tables. Each table was manned by a facilitator and included a printed description of a specific user need

[1] SPECS is an EU FP7 project and it stands for Seasonal-to-decadal climate prediction for the improvement of European climate services. For more see: http://www.specs-fp7.eu/

which covered the background of the organisation (user), its needs with regard to the weather parameters of interest as well as the temporal and spatial resolution required to satisfy the needs of that user. All user needs displayed at each table are included in section 4 below (text boxes).

Each group was asked to read the specific user need displayed on the table and discuss between themselves if such need can already be fulfilled with existing products or whether more research is needed. Different coloured sticky notes were provided, each corresponding to different categories (see table 1 below). Pink sticky notes were used to describe existing products already available and capable of satisfying the user need; yellow sticky notes for those products that exist but that would require some post-processing or tailoring to satisfy the need; and green sticky notes for those needs which require more research. Orange sticky notes were also provided to allow participants to identify cross-cutting issues such as the level expertise of the group in the area and the quality of the information in terms of robustness and skill.

Table 1 - Categories for discussion

<table>
<tr><th>Products available</th><th>Post-processing or tailoring needed</th><th>More research is needed in the next 15 years</th></tr>
<tr><td>- What product(s) can fulfil this user need?
- Where can one find it?
- How much does it costs?</td><td>- What type of tailoring is needed? e.g. bias correction, statistical/dynamical downscaling, data aggregation;
- How much will it cost? (in euros or person months of a post-doc)</td><td>- Describe the research that is needed to fulfil this user need (as detailed as possible)
- How much will it cost? (in euros or person months of senior and junior staff + computer resources)
What gives you confidence that this is achievable (e.g. laws of physics; emerging constraints)</td></tr>
<tr><td colspan="3">Cross-cutting questions:
• Rate your expertise of the area being discussed (low/medium/high expertise)
• Comment on the quality of the information currently or potentially available: is it scientifically credible or robust?
If unsure provide uncertainty ranges (e.g., 10-30 million Euros).</td></tr>
</table>

Each group spent 10-15 minutes discussing a specific user need and after that each group rotated to a different table with a different user need.

Figure 1 – Data collected during the workshop.

Following the workshop all the sticky notes collated were digitised and analysed. The findings were structured around each of the specific users' needs. The main findings are presented below.

4. Findings from the workshop

User A

Background: An organisation based in Castilla y Leon in the north of Spain providing support to farmers regarding harvesting and irrigation. They already provide climatological atlas to farmers to help them decide when to sow. Seasonal forecasts could be useful as it would help them provide support to the farmers in relation to the planting and harvesting time as well as understand potential water scarcity in the region.

Main parameters: Rainfall (mean) and hail (total).

Temporal resolution:

Rainfall - In June they would like to know how autumn rainfall is going to be to avoid drought. Prediction lead time of 3 months.

Hail - In October they would like to know how April/May is going to be to help them plan the harvest. Prediction lead time of 6 months.

Preference for forecasts with daily data.

Spatial resolution: 7,000km^2 but higher resolution would be preferable.

Facilitator: Catherine Vaughan

Groups: 1, 5, and 6

Products available

Group 1 identified rainfall as a critical element for the autumn and early winter seasons in this particular geographical area where there's a slight influence from El Niño with a bias towards greater precipitation. It also suggested that having weather information up to a month could be useful for decisions; this could also possibly be linked with seamless forecasting systems, as this is an emerging capacity.

According to the group, the International Research Institute for Climate and Society (IRI) provides freely available information on rainfall; both the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Met Office have relevant products but these are not freely available. The Spanish Met Service has some

information but the group was not entirely sure what would be available, especially regarding observations and information on aquifers. Seasonal information and even more short-term information on hail is not available, and not likely to be available, whilst for rainfall there are statistics of daily data available.

Group 5 identified available weather information, temperature data (where one can see the trends in changes in temperature which affects crops) and historical rain data. The group also wondered if historical records of hail data exist, which could potentially be used to understand variability and change. Existing models produce information on soil moisture, as this can be sensed from surface soil moisture from space.

Group 6 suggested that the user might obtain information associated with large-scale patterns circulations (e.g. ECMWF or Météo France) in the autumn months as a means to get temperature and precipitation at monthly scales. Other ideas put forward by the group were to either use seasonal forecast and then follow up with more short-term information, including weather information, and/or to use existing dynamical models from World Climate Service (which are commercial products) and then create their own statistical models. It was also mentioned that the Joint Research Centre (funded by the European Commission) has datasets and products on agriculture that could be of interest to this user.

Post-processing or tailoring needed

Regarding the need to further tailor or post-process existing data or products, the three groups proposed a few suggestions. Group 1 for example, suggested using rainfall data to produce daily data for post-processing or provide information on whether there is a higher chance of intense convection (although this information would not necessarily be useful for farmers). They also suggested learning from the existing EUPORIAS prototype on land management regarding simple downscaling to country scale and forecast presentation.

Group 5 mentioned soil moisture indices related to irrigation and using models to understand irrigation activities; information on river discharge could also help to indicate water availability. They also suggested the Met Office GloSea system, which produces net primary productivity for trees via land scheme (although this might not be useful or skilful). A final idea related to the possibility of running offline post-

processing models within seasonal system (e.g., at the Met Office for trees, atmospheric models, etc).

Finally group 6 suggested the need to tailor information from ECMWF in order to have useful data. They also mentioned the fact that most dynamic seasonal prediction systems produce soil moisture, net primary productivity of trees, river flow, etc (although again this may not be useful or reliable). They also suggested knowing the exact threshold or statistical mapping of monthly mean as well as the accumulate precipitation of 1 or 3 months. Using drought indices and feed to analogue for drought forecasts and crop modelling and irrigation needs were also discussed.

More research needed

In terms of the type of research required to satisfy the current needs of this user, Group 1 believes that models will be more realistic in ~70 years and that it will then be easier to provide daily data on rainfall. Bias correction on daily data for rainfall expected in a few years from now (~10 years); there's already one paper on this topic. Meanwhile, internal variability and hail damage is still a research topic.

Group 5 suggested using decadal trends. They also mentioned the need to understand snow and hail, which is not well studied. Given that climate has and is changing, there is a need to better understand impacts. In terms of lightening detectors and correlation with hail, this is now nearly impossible so even beginning to collect this data now would require several years to get the data. Finally group 6 commented that studying the factors influencing hail and how that can be predicted could potentially be a topic of research.

Cross-cutting issues

Group 1 questioned the need for daily data since in their view planting decisions don't require daily data. They also questioned whether mean rainfall and total hail were useful metrics for the farmers and wondered what specific questions were being asked by the farmers that required this kind of information. They also suggested that as hail damage is a random event the key issue may be whether financial markets are providing appropriate services rather than the development of appropriate climate services. In addition, the group suggested that if the farmers plan the sowing in 3 or 6 months in advance, they could potentially buy insurance to cover potential losses. Regarding the rainfall data and the accuracy required (70x100km

grid box) skill is low. The group considered themselves to have high expertise in this topic.

Group 5 questioned how accurate hail forecasts in the short-term are and also the type of actions that farmers could take in advance based on information on hail. They also mentioned the difficulty in analysing the months of June to August since these are very difficult to predict. They suggested farmers could potentially invest in drip irrigation if seasonal forecast shows a hotter summer. The group considered themselves to have medium to high expertise in this topic.

Group 6 mentioned that predictions for summer months exist through the World Meteorological Organisation Global Producing Centres, but that in this area, for this time, such forecasts are of low value and skill. For spring months, the general skill in Europe is low.

Similarly to the other two groups, Group 6 also stated that the information requested would not be of high quality and questioned whether the information requested was even useful to farmers. In addition, they also questioned the need for knowing weather conditions for harvesting that far in advance as in their view this tends to be planned days ahead not months in advance. They also commented that forecasts of total hail were not available and would likely not be useful even if it were and that thresholds could potentially have more value. The group considered themselves to have high expertise in this topic.

Key points

- Seasonal forecasts of rainfall are freely available from the IRI; available data from the ECMWF and Met Office but not in the public domain;
- Seasonal information and shorter-term information on hail not currently available;
- Suggestions on ways of deriving information from existing data were suggested e.g. use dynamical models from World Climate Service and create their own statistical models;
- Few suggestions were also proposed regarding post-processing of existing data although ultimately these will depend on the type of information needed

to aid decision-making by the farmers;

- In the coming years, models will eventually allow the availability of daily rainfall data (in seasonal forecasting) whilst internal variability, snow and hail are still very much research topics;
- A seamless forecasting system was suggested to provide forecasts up to a month (although skill decreases with time) and aid decision-making;
- Finally, the need for forecasts with daily data to inform farmers' decision-making was questioned by the climate scientists.

User B

Background: A private company working in viniculture in Portugal. They currently use 3-10 days weather forecasts and seasonal forecasts (as qualitative information) when these become available. Seasonal forecasts would be useful to help them manage the grapevine's growth cycle, input needs (labour, resources, etc), and marketing campaigns.

Main parameters: Temperature (mean and extreme) and rainfall (annual).

Temporal resolution:

From January to June (start of growth cycle):

- In January they want monthly forecasts with a prediction lead time of 18 months to assess production potential;
- Assess input needs: Monthly forecasts with 6 months prediction lead time;

From July to October (end of growth cycle):

- Assess irrigation needs: weekly with 12 months prediction lead time;
- To forecast production potential: weekly with 6 months prediction lead time;
- To evaluate ripening and quality potential: monthly with 3 months prediction lead time;
- To plan for harvest: daily with 3 months prediction lead time;

Spatial resolution: 9km^2 (but ideally 1km^2) across Continental Portugal

Facilitator: Rachel Lowe

Groups: 1, 2, and 6

Products available

Group 1 suggested that the Met Office provides 4 to 6 months prediction lead time for temperature from decadal and that same skill exists for precipitation; updating forecasts occur closer to target date.

Group 2 suggested that 18 month prediction lead time (as requested by the user) is available from decadal system and that 5 year mean is available from the Met Office decadal system. This information is free and provides yearly averages. Regarding

daily data this is provided up to 3 months prediction lead time and possibly with one month lead time.

Group 6 suggested that for the 18 months prediction lead time requested by the user could be potentially satisfied with the 12 months Japanese Frontier – Exchange; decadal system provides 3 years average with yearly averages. They also suggested the ECMWF Meteorological Archival and Retrieval System (MARS) with its quarterly 13 months 100km². This information is available free for research purposes but with a cost attached if used for operational purposes.

Daily resolution could use geopotential (ECMWF) forecasts (large scale circulations); NCEP - reanalyse 2.5 X 2.5 daily; observations.

Post-processing or tailoring needed

Regarding any potential post-processing or tailoring of existing data or products to satisfy the users' needs, group 1 suggested that for the forecasts with 18 months prediction lead time the ENSO forecast (empirical) could be better positioned and it would take 12 person/months to check the skill. Regarding spatial resolution of 9KM² for temperature this would require validation whilst for precipitation it would require further stations and downscaling. Regarding spatial scale, using a dynamical model like the Weather Research and Forecasting (WRF) model could get high resolution with 3 to 4 years person-months whilst statistical downscaling? would require stations for 1 to 2 years.

For group 2 forecasts with 18 months prediction lead time have limited skill and would require calibrating the skill; compare hindcasts to observations.

Group 6 did not suggest any post-processing or tailoring.

More research is needed

Group 1 suggested that for forecasts with 18 months prediction lead time the ENSO forecasts could be of interest as well as the decadal (initialise). Sunshine hour forecasts (short lead times) are currently available from the Japan Meteorological Agency (JMA)/Tokyo Climate Centre (TCC) and ECMWF.

Group 2 suggested that more research is required for downscaling with terrain models; spatial resolution of 9km ² is only available at weather forecast timescales (daily) and 3 month prediction lead time with daily data is not available.

Cross-cutting issues

Seamless predictions were mentioned by group 1 particularly those from a 10 day forecast up to a month although skill decreases with lead time. Temperature is valid at small scale but precipitation is not possible. Winter forecasts are better due to influence of the North Atlantic Oscillation.

Group 2 mentioned the drop of skill with longer lead times; whilst group 6 suggested downscaling climatology and using climatology for long leads times.

Key points

- The Met Office decadal system provides free temperature data with a prediction lead time of 18 months and 4 to 6 months; Daily data can be provided up to 3 months prediction lead time;
- The Japanese Frontier – Exchange decadal system can also provide 18 months prediction lead time;
- Forecasts with 18 months prediction lead time have limited skill and would require calibrating the skill;
- Spatial resolution at $9km^2$ for temperature would require validation whilst for precipitation would require further downscaling and stations;
- More research is required to downscale with terrain models;
- A seamless forecasting system was suggested from a 10 day up to a month forecast (although skill decreases with time).

User C

Background: An electric power company in Croatia working on the generation (mainly hydro-power) and distribution of energy. They focus on energy optimisation by forecasting energy consumption for the next day for all their customers. Based on that consumption forecast they then plan their plants operation. They also buy and sell energy. They currently use weather forecasts (next day and 2 weeks forecasts) as well as past observations to help them manage their hydro-power plants (based in rivers and small basins) and plan potential demand. They also use seasonal forecasts (precipitation and temperature) but only as qualitative information.

Seasonal forecasts would help them to manage reservoirs and river basins but also help them to be more efficient in terms of fuel trade and buying resources.

Main parameters: Rainfall (above, below, average).

Temporal resolution: Monthly data with 1 to 3 months prediction lead time.

Spatial resolution: 12,000km^2 but higher spatial resolution would be desirable.

Facilitator: Matteo De Felice

Groups: 1, 2, and 3

Products available

Group 1 suggested using gridded data and maps (national data) as a basic representation of rainfall; whilst group 2 discussed using precipitation maps at monthly scale (seasonal for sure) from WMO producing centres. Group 3 mentioned the ECMWF and IRI maps (3 months) which are freely available as well as climate data available from producers (e.g. IRI, NOAA).

Post-processing or tailoring needed

Regarding further post-processing or tailoring to existing data or products, group 1 mentioned that, assuming that a 'good' hydrological model is available, a 12 month post-doc could assess the skill of precipitation and river discharge. All groups suggested the need for downscaling and tailoring the data for specific basins. Group 2 also mentioned the need for 6 months post-doc time for working on the initial assessment. Group 3 suggested the need for bias correction and a total of 6 months

of a post-doc time to explore the reliability and skill (i.e. the methods) as well as 2 years of post-doc time to evaluate the operational capabilities.

More research is needed

Group 1 argued that an integrated hydrological model is feasible but more research is required; whilst group 2 suggested the need for better models and more research to have ‘good enough’ information. Finally group 3 argued that more research is needed on downscaling methods as well as more sources of predictability at seasonal and sub-seasonal timescales and high resolution.

Cross-cutting issues

All groups noted the higher predictability over winter due to for example the influence of the North Atlantic Oscillation (although no certainty about this predictability over Croatia). However, a post-doc could help to assess this. Group 3 also noted the low predictability of precipitation at seasonal scale.

Key points

- Potential for using gridded national data and maps as a basic representation of rainfall; or using precipitation maps at a monthly (or seasonal) timescale from the WMO producing centres;
- Seasonal forecasts for precipitation from ECMWF and IRI are also freely available;
- Assuming a ‘good’ hydrological model exists assessing the skill of precipitation and river discharge could take up to 12 months of post-doc time;
- Need for downscaling and tailoring the data for specific river basins;
- Need to perform bias correction, explore reliability and skill of the methods and assess operational capabilities;
- More research is required to develop an integrated hydrological model; as well further develop downscaling methods and sources of predictability at seasonal and sub-seasonal timescales.

User D

Background: An international insurance company working on weather derivatives. They already use monthly and seasonal forecasts in their decision-making but would like to use decadal predictions if skill existed to help justify long-term investments in wind farms.

Main parameters: Wind (average and extreme).

Temporal resolution: Monthly data up to 10 years with 1 month prediction lead time.

Spatial resolution: Highest resolution possible across Europe.

Facilitator: Melanie Davies

Groups: 1, 2, 3, and 4

Products available

All four groups agreed that such product is not currently available. However, they also noted that various international centres are already forecasting at decadal timescales and that particular research efforts are being made towards this type of products although specific information on wind is still quite limited. For example, decadal forecasts for wind speed for 10m is available from CMIP5 for 100 km grid boxes?. IC3 and the Met Office GloSea5 were also suggested by group 3 as sources of information on wind. Group 4 also mentioned that the MIKLIP project has looked at such information on a 5km resolution for central Europe; ECMWF already provides monthly, seasonal, and annual wind forecasts at some resolutions (e.g. 100km). However, skill at decadal timescales is very low.

Post-processing or tailoring needed

A better understanding of the decadal processes including the underlying processes and variability in the North Atlantic Oscillation was a key aspect raised by all four groups to further advance decadal wind forecasts. Group 1 suggested the need to investigate how future wind variability affects the long-term as well as the non-linearity of climate and the clustering of events.

Group 2 argued that North Atlantic temperatures could still provide some skill. They also suggested that research focusing on the resolution is needed as current data is provided at 100km but large scale drivers are still a main issue in this context. They also mentioned that providing these forecasts as monthly data is possible but not necessarily useful as this is mainly driven by large scale phenomena which correspond to seasons.

Group 3 suggested using CIMP5 data to explore the decadal predictability over past years and highlighted the need for research focusing on the initialisation of forecasts. Group 3 also suggested forecasting into the future using the Met Office GloSea5 model and that more research was needed to improve model resolution.

Both groups 3 and 4 argued for the need for further research to explore all types of post-processing (e.g. bias correction, etc) in order to advance decadal timescales.

The need to assess the skill over decadal timescales was also raised by groups 1 and 3 as a fundamental part of the work needed to advance this type of products.

In terms of resources required to advance this research, group 1 suggested the need for 1 post-doc to perform statistical analysis for 1 to 2 years. Group 3 suggested that research on predictability would require 2 people working for 2 years minimum, the model resolution would require 5 people for 5 years, and post-processing would require less time but would need additional computational investment. For group 4 the model resolution is essential and it would require 2 post-docs working for 5 years and additional computational costs dedicated to this type of project.

More research is needed

Group 1 posed a few critical issues that further research could help improve such as understanding the climate mechanisms influencing wind, understand how big is variability for decadal wind, explore the correlation between the North Atlantic Oscillation and its effect on wind, estimate skill for decadal wind forecasts, and finally improve model representation. The group suggested that an investment in the order of 10 million Euros would be necessary to support such project in its entirety.

Group 2 argued for the need for more research on wind as predictability was already found for other variables at decadal timescales; they also suggested inferring from sea surface temperature which does have skill at decadal scale.

Group 3 commented that although they have little confidence that the skill will change they believe that improving initialisation may lead to better predictability.

Group 4 argued for the need to dedicate a large project of millions of Euros to this topic as computational and research costs will be necessary to further advance decadal forecasts.

Cross-cutting issues

All four groups argued for the need to have more experts working on wind and decadal predictions. Group 4 added that at least 1 expert in wind speed is required as well as 2 experts in decadal forecasting. They also mentioned the poor quality of predictions for decadal timescales particularly in Europe. Group 1 considered themselves to have medium to high expertise in decadal predictions and wind whilst groups 2 and 3 considered themselves to have high expertise on these two topics. Group 4 was composed by two experts in decadal forecasting and 1 on wind speed.

Key points

- Wind data at the required resolutions not currently available but some efforts have been made recently such as the CMIP5 decadal forecasts for wind speed for 10m which is available at 100km grid boxes;
- ECMWF also provides monthly, seasonal, and annual wind forecasts at some resolutions; IC3 and the Met Office GloSea are also sources of information on wind; MIKLIP project also explores wind data at 5km resolution for central Europe;
- However, skill at decadal timescales is very low;
- Need for a better understanding of the decadal processes e.g. variability in the North Atlantic Oscillation in order to advance decadal wind forecasts;
- Need for further research on post-processing (e.g. bias correction) methods; as well as assess the skill over decadal timescales;
- Further suggestions were made regarding ways to further explore existing data e.g. research on the initialisation of forecasts;
- Further research on wind (e.g. mechanisms influencing wind, influence of the North Atlantic Oscillation on wind) as well as a substantial investment and

experts on wind and decadal forecasts is required to advance this type of predictions.

User E

Background: A Norwegian organisation responsible for planning, building and maintaining the national road system. Weather conditions are very important in the management and maintenance of roads particularly during winter months. They use weather forecasts for precipitation (rainfall and snow), and wind. They also use their own weather stations to monitor temperature and precipitation on their roads as well as run off data and flood forecasts. Seasonal forecasts would be helpful to help them plan their operations and manage external contracts for the winter period.

Main parameters:

- Precipitation combined with temperature (i.e. knowing if it's going to hit the roads as snow or rain);
- How many days around zero are expected (freeze and thawing);

Temporal resolution: Monthly data for the winter months with 3 months prediction lead time.

Facilitator: Felicity Liggins

Groups: 2, 3, 4, and 5

Products available

Of all four groups that discussed this particular user need only group 5 mentioned one existing product i.e. data on precipitation and snow being downscaled by the Norwegian national met service.

Post-processing/tailoring needed and further research

Group 2 suggested a number of ideas including: using the North Atlantic Oscillation forecast to infer snow days; the existence of seasonal forecasts for snow days; developing a 3 months research project in order to collate data on snow observations; assessing the availability of observations; calibrate the forecast based on assessment of skill (6-12 months to conduct research); and identify the need for daily data. They also suggested the need to explore the transition in seasons (spring & autumn) as these have less skill than winter North Atlantic Oscillation and more research is needed.

Group 3 mentioned that the product available for snow is global seasonal forecast with 300km resolution and therefore downscaling is needed to achieve a higher resolution. However, due to the low skill of monthly data further research is needed (up to 2 years). The group also mentioned that a coarse resolution forecast at 3 months might be available with a subsequent higher resolution forecast at 1 month. They also identified the need for bias and drift correction of seasonal forecasts; the need for observations and climatology data; as well as the need for data to be tailored to the user. They also suggested that 3 month prediction lead time is achievable although skill improves as period of prediction lead time decreases. However, currently there are no products able to satisfy the user' needs although some compatibility can be achieved through post-processing techniques.

Group 4 suggested that snow data could be achieved through an assessment of the relative merits of dynamical vs statistical downscaling although this would require one year of research. They also mentioned the need for interpolation and high resolution precipitation data needed for verification. There is also the broader issue of the costs attached to assessing seasonal forecasts. Finally, they mentioned the need for bias correction and downscaling for data already available although this would require 1 up to 2 years of research.

Group 5 suggested similar ideas to groups 2, 3 and 4, with the need to bias correct using an imperfect observational dataset a limiting factor in producing seasonal forecasts. They also suggested that local effects would need to be considered as small-scale features/events can have major impacts on the road network and that for nights, an assessment of days +/- 1 ˚C per season might be achievable in a research project lasting less than 12 months.

Cross-cutting issues

Group 2 mentioned that the skill of forecast in Norway is reflective of the North Atlantic Oscillation which is surprisingly predictable and, as a result, there's good credibility in looking and producing forecasts.

Group 3 also mentioned the influence of the forecasts of the North Atlantic Oscillation as critical to the skill of seasonal predictions over Norway; bias correction will reveal skill level of the system. However, skill in Europe is very low and it would

be better to concentrate on 1 month. The group considered themselves to have medium to high expertise in this topic.

Group 4 was unsure about the skill of model for Norway but thought that this could be lower than for southern Europe. The group also mentioned the lack of operational downscaled data and the computational costs that achieving that could incur. This group considered themselves as having medium expertise in the topic.

Group 5 mentioned the low confidence in skill of snow forecast at the moment but agreed that it could be improved with further research. They also referred to the predictability attached to the North Atlantic Oscillation and the existing confidence in the mechanisms versus the low confidence in skill in the area.

Key points

- Downscaled data on precipitation and snow being produced by the Norwegian national met service;
- Other product available is global seasonal forecast with 300km resolution which would require downscaling;
- Need for bias and drift correction of seasonal forecasts as well as observations and climatology data;
- A range of ideas for post-processing and further research were suggested including the potential for using the North Atlantic Oscillation to infer snow days, develop a small research project to collate data on snow (snow observations), calibrate the forecast based on assessment of skill, effect of local features/events on the road network, etc;
- Considerable costs attached to the assessment of seasonal forecasts;
- Influence of the North Atlantic Oscillation critical to the skill of seasonal predictions in Norway;
- Further research could improve low confidence in skill of snow forecast.

User F

Background: A research and consultancy organisation in Denmark working on projects related to all aspects of the water sector. The use of weather and climate information is dependent on the project at hand but they tend to use climatological information to inform hydrological modelling. They also use real-time and past weather forecasts, satellite data, historical data to forecast seasonal variability, and climate change projections.

Seasonal forecasts would be useful to help them set up forecasting systems for their clients to be able to best manage their reservoir operations all year round.

Main parameters: Rainfall and temperature (both mean and extremes).

Temporal resolution: Monthly data with 3 to 6 months prediction lead time. Forecasts for all year round.

Spatial resolution: Catchment areas all over Europe and ideally $5Km^2$.

Facilitator: Marta Bruno Soares

Groups: 3, 4, and 5

Products available

Of all the three groups only group 5 mentioned a few existing products that could be considered to satisfy this user' need. They suggested linking seasonal forecast with vegetation model similarly to what the EUPORIAS prototype on River Flow forecasts for water resource management in France is already doing. In this prototype they are using rainfall and temperature forecasts up to 7 months prediction lead time and providing data at 8km. The group also referred to the fact that predictability tends to be higher in the hydrological side of things than in the atmospheric. However, it was also noted that such predictability also varies depending on the season and region.

Post-processing or tailoring needed

Only group 3 suggested the need for statistical and dynamical downscaling but with observations and hydrological models for catchment areas.

More research is needed

Group 3 argued that all the parameters that the user is asking are already available from IRI, NOAA, and ECMWF although not at that spatial resolution and with limited skill at the monthly scale. Developing the method to go down to this spatial resolution would take around 5 years or more (and just to cover one part of Europe). Extremes (rainfall) are very hard to downscale and although there is some information on extremes ultimately it will depend on what the users need. Having said that, much more research is required on extremes and even after 5 years it may not be possible to have some useful data on extremes. Much of the predictability in extremes on seasonal to decadal timescales comes from skill in the mean. Smaller scales need nested very high resolution downscaling as being used for weather and climate.

Group 4 referred to some work being developed by SMHI and Wageningen University hydrological model (river flow) using rainfall and temperature all across Europe (although this is work in progress). The group also argued that in theory achieving this should be possible starting from General Circulation Models – dynamical downscaling – Regional Climate Models for Europe plus statistical downscaling (+ 2km) and hydrological information (information on catchment area is critical in this context).

This group also suggested correlating rainfall observations with the North Atlantic Oscillation index over particular regions and rainfall at 5km resolution as well as the need for a feasibility study regarding skill over Europe as in certain catchment areas this may be higher or lower.

Group 5 suggested that the work being developed by MétéoFrance is expected to be able to provide this data at European scale in the next 5 years.

Cross-cutting issues

Group 3 raised concerns regarding the fact that even if research allows us to get to that resolution, skill will always be an issue. Group 5 suggested assessing predictability using hindcasts as well as the need to further improve seasonal forecasts. All groups considered themselves to have medium to high expertise in this topic.

Key points

- All parameters required by the user are available from IRI, NOAA, and ECMWF although not at the spatial resolution required (and with limited skill);
- Possibility of linking seasonal forecasts with vegetation models similarly to the approach used in the EUPORIAS prototype on river flow forecasts for water resource management in France; this work by Météo France is expected to provide data at the European level in the next 5 years;
- Need for statistical and dynamical downscaling with observation data and hydrological models for catchment areas;
- More research is required on extremes (rainfall) although useful data on extremes is not certain;
- Work being developed by SMHI and Wageningen University on hydrological model (river flow) for all Europe using rainfall and temperature data;
- Limitations on skill will always be an issue.

User G

Background: An organisation involved in the promotion and communication of tourism activities in France. They don't seem to currently use any weather/climate information. However, as their work priorities revolve around the winter and summer tourism activities, they would be interested in having access to seasonal forecasts to help them plan ahead their seasonal operations.

Main parameters: Temperature, rainfall, sunshine, and snowfall.

Temporal resolution:

- In April they want to have a 3 month forecast for summer months regarding temperature, rainfall, and sunshine (all averages);
- In October they want to have a 3 month forecast for winter months regarding temperature, rainfall, sunshine, and snowfall (all averages).

Spatial resolution: Highest resolution possible.

Facilitator: Ghislain Dubois

Groups: 5 and 6

This discussion focused on snowfall.

Products available

Group 5 suggested that obtaining such data is technically feasible but that resort-size resolution would require observation data and using a tercile approach (above, below, average).

Group 6 mentioned the Canadian system for snow forecast which could be transferable to Europe. However, ERA interim reanalysis for Europe is not accurate and new one would be better – caution with verification and two regimes (persistence in winter and before any snow). They also suggested the existence of analogues (teleconnection indices) and the possibility of learning from the EUPORIAS prototype focusing on winter conditions for UK transport.

Post-processing or tailoring needed

Group 5 suggested the existing experience in downscaling in the shorter-term which could be adjusted and be used in seasonal timescales. They also mentioned the

need for observations in order to be able to represent snow e.g. near surface parameters calibrated. Only upper snow cover is so far represented in models.

Group 6 argued that existing models has snow but this is not translated into any specific product. They also mentioned difficulties in performing verification and the coarse resolution due to topography. In some case the prediction system is temperature driven (in UK there are precipitations but sometimes not enough coldness to get snow), on other cases it is precipitation driven (in the Alps it is sufficiently cold, but sometimes without precipitation). They also suggested using 'quantile' mapping for topography in order to predict on large scale and then downscaling. To perform verification it will be necessary to tailor observations (temperature, precipitation) for snow as well as improve existing observations and satellite data for snow cover.

More research is needed

Group 5 suggested that more research is needed to increase the resolution and the representation of the physics of precipitation. Currently there is information on cumulative depth and age/density of snow but we should be able to go from avalanche data to seasonal forecast. However, opening times for this type of tourism operators can be tricky and, as a result, it would be better to have seasonal forecasts for snow cover with a monthly prediction lead time. In addition, it would also be important to understand and have information on conditions favourable for producing artificial snow. Group 6 mentioned a general improvement in precipitation data but basic research on snow is required including modelling snow depth as well as an improvement in winter skill.

Cross-cutting issues

Group 5 argued that the quality of the information will depend on the capacity to model weather regimes / types, circulation biases. They added that there is a substantial inter-annual variability of predictability which, once established, weather regimes are stable some years and more chaotic other years.

Key points

- Canadian system for snow forecast could be transferable to Europe;
- ERA interim reanalyses for Europe is not accurate and a new dataset would be better;
- Potential to learn from the EUPORIAS prototype focusing on winter conditions for UK transport;
- Further observation data is required to represent snow (e.g. near surface parameters) as well as verification to tailor observations (T and P) to snow and improve satellite data for snow cover;
- More research is required to increase resolution, modelling snow depth, and improve winter skill;
- Quality of data dependent on capacity to model weather regimes and circulation biases.

User H

Background: A Health organisation working on epidemiology in Italy. Their work focuses on the effects of temperature on health. They are also responsible for running the Italian heating warning system particularly during summer months. For the warning system they use 3-day weather forecasts for temperature, relative humidity, wind speed and atmospheric pressure. Although they already use seasonal forecasts as an indication of what the next season is going to be (i.e. qualitative information) they would use it to manage their warning system if the reliability was higher.

Main parameters: Temperature (maximum and minimum).

Temporal resolution: Monthly forecasts for summer months with a prediction lead time of 3 to 6 months.

Spatial resolution: Urban areas between the 1,000km^2 (largest city) and 18km^2 (smallest city).

Facilitator: James Creswick

Groups: 4 and 6

Products available

Group 4 commented on the relatively high-skill that exists especially in southern Italy at the seasonal scale in summer. Regarding spatial resolution data is available 25-30km grid (T255 by ECMWF). They also suggested that there is good skill in regional climate simulation and so tuning not so difficult to achieve. Group 6 suggested using global seasonal predictions as this system could provide information (although at a coarser level) and then using European scale maps. The group also argued that temporal resolution exists but one should not expect more skill than the mean; also in Europe such maps would be available but not the raw data.

Post-processing or tailoring needed

Both groups suggested the possibility of calibrating and downscaling the data for achieving the spatial resolution requested at the urban level. Group 6 also added the need for downscaling for urban centres as a way of distinguishing between urban

and rural areas (e.g. when considering the urban heat island effect). The group also discussed the need for more analysis on extremes and thresholds.

More research is needed

Regarding further research, group 4 suggested using crowd-sourcing urban ambient temperature (apparent temperature) as a way of pursuing statistical downscaling. They also argued the difficulty in predicting extreme events (such as heat waves) which would require additional computer power. Group 6 suggested forging a closer collaboration between global researchers and those working at the micro level (e.g. urban scale). They also argued for the need to improve skill particularly during summer months (as there's currently more skill during winter) and the problematic of diurnal cycles of heat-island despite the standard output being of minimum and maximum temperatures.

Cross-cutting issues

Both groups argued that their expertise in this topic was average. Group 4 were certain about skill level in Italy and group 6 reiterated that skill and reliability were probably quite limited and they also suggested that some contribution from climate trends could be helpful.

Key points

- Relatively high skill in Southern Italy for seasonal forecasts for summer;
- Spatial resolution is available for 25-30km grid from ECMWF;
- Using global seasonal forecasts and then using European scale maps was also suggested as a potential way to obtain the required data;
- Temporal resolution exists but not more skill than the mean;
- Possibility of calibrating and downscaling the data for achieving the spatial resolution required at the urban scale;
- Need for more processing on extremes (e.g. heat waves) and thresholds;
- Possibility of using crowd-sourcing urban temperature as a way of pursuing statistical downscaling;
- Further research investment is required e.g. computer power, closer

collaborations between scientists working at the global and micro levels;

- Need to improve skill for summer months.

5. Conclusions

The aim of this workshop was to closely engage with scientists developing the next generation of seasonal to inter-annual climate prediction models in Europe and discuss the capability of fulfilling users' needs identified in EUPORIAS WP12. Particular examples of specific users' needs with regard to S2D climate predictions were used as the basis for discussion within the workshop participants. These examples, representing different countries, sectors, and types of organisation ranged from a private company producing wine in Portugal to a Norwegian public organisation responsible for maintaining the national road system.

Each of the user case studies generated stimulating discussions and a number of suggestions were made by participants including available products that could satisfy information needs as well as post-processing methods or further research required to deliver the information needed.

One of the main findings of this research was that for all of the users' needs discussed at the workshop there were no products available at the moment that could fully satisfy their needs, for example, due to the spatial or temporal resolution required. In many cases available products can be post-processed to approximate existing data to user requirements, particularly for parameters such as temperature and precipitation but less so for wind and snow.

Further research streams were also suggested by the scientific community although in many cases a considerable investment in expertise and computational power would be required.

To our knowledge, this workshop was the first attempt at reconciling the supply and demand of climate information at the S2D timescale in Europe in the context of climate services (i.e., for the benefit of society). Our study has several limitations. User needs and potential user needs in the context of S2D climate and climate impact predictions are extremely large and diverse across Europe. Selecting eight cases from a large number of user needs was a challenge and is ultimately problematic as needs tend to be specific to organisations and contexts (institutional, cultural, etc.). In this regard, European sector associations can play an important role in gathering and synthesising user needs per sector. In addition, running sectoral workshops (rather than one workshop for all user needs in Europe) could also be a

more productive way of allowing more direct interactions between users and modellers/producers.

At our workshop, one of the tables included the actual user (besides the facilitator) and it was noted by participants that having the end-user present was very helpful, allowing clarifications from both sides. Such iterative discussions also allowed for particular compromises to be reached by both the end-user and the climate scientists. For example, on the one hand, it allowed the end-user to better understand current limitations of the science underpinning S2D climate predictions but also to realise that particular products are available. On the other hand, it allowed the climate scientists to better understand decision-making processes and how climate information could help to inform them, thereby improving their understanding of the products required by the end-user. There are not enough climate scientists in Europe to have one-to-one discussions with all the users and potential users of S2D climate predictions. Therefore, realistically, there will always be a need to synthesise bottom-up user needs through rigorous social science research, trade or sector boundary organisations and consultancies.

Time was a major limitation as groups only had around 15 minutes to discuss each user need. Ideally the workshop would have been longer so as to allow each group to go through all eight tables in their own time. Running the workshop using groups saved us time, but may have introduced biases that are difficult to account for, e.g. group think and potential dominant voices within groups. A different approach to conducting this research would be to consult each scientist individually to minimise these biases although this would be more time consuming.

It was also clear that a better understanding of the types of decisions made by users and the ways this data is/would be utilised to inform processes would help to refine the quest for (and potentially the provision of) more adequate data able to satisfy particular user needs.

Appendix 1 – List of workshop participants and facilitators

Workshop participants			
Surname	**Name**	**Organisation**	**Country**
Bissoli	Peter	DWD	Germany
Bojariu	Roxana	Romania Meteo	Romania
Buontempo	Carlo	UK Met Office	UK
Céron	Jean-Pierre	Météo France	France
Dell'Aquila	Alessandro	ENEA	Italy
Dubus	Laurent	EDF	France
Falloon	Pete	UK Met Office	UK
Funk	Daniel	DWD	Germany
Graça	António	SOGRAPE	Portugal
Hawkins	Ed	University of Reading	UK
Merryfield	Bill	CCCMA	Canada
Müller	Wolfgang	Max Planck Institute	Germany
Munõz	Angel	IRI	USA
Nguyer	Sebastien	CNRS	France
Shonk	Jon	University of Reading	UK
Simmons	Adrian	ECWMF	Europe
Smith	Doug	UK Met Office	UK
Som de Cerff	Wim	KNMI	The Netherlands
Stockdale	Tim	ECWMF	Europe
Wyser	Klaus	SMHI	Sweden

Facilitators		
Surname	**Name**	**Organisation**
Bruno Soares	Marta	University of Leeds
Creswick	James	WHO
Davis	Melanie	IC3
De Felice	Matteo	ENEA
Dessai	Suraje	University of Leeds
Dubois	Ghislain	TEC
Liggins	Felicity	UK Met Office
Lowe	Rachel	IC3
Vaughan	Catherine	University of Leeds & IRI