Deliverable Report

Advancements in the prediction systems from international efforts

The Added Value of Seasonal Climate Forecasts for Integrated Risk Management Decisions (SECLI-FIRM)

EU H2020 Project (ref. n. 776868)

D2.6: Report on the capability of the very latest advancements in the prediction systems from the ongoing international efforts to overcome limitations in forecasting the key predictands for the case study applications.

[Dissemination level: Public]

Version Table

Name/Party	Description	Date
G. Geertsema (KNMI)	Draft one	01/03/21
G. Geertsema (KNMI)	Draft two	19/03/21
G. Geertsema (KNMI)	Final version	31/03/21

Internal Review Table

Name/Party	Description	Date
José Vidal (UL)	WP leader review	25/03/21
Alberto Troccoli (UEA)	Project Leader's final review	30/3/2021

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1 Introduction

Seasonal and sub-seasonal forecasts is a relative new area of research and apart from the well-established predictability effects on longer lead times due to ENSO related behaviour of temperature and precipitation in the tropics, the predictability in other regions is yet to be established. SECLI-FIRM has investigated the potential added value of seasonal and sub-seasonal forecasts for end-users by conducting nine different case studies which have been defined in close collaboration with the end-users. Both the possibilities as well as the limitations in the forecasting skill have been investigated using different post processing techniques and different verification metrics. Feedback to and from the international prediction community has been established through workshops organised by SECLI-FIRM, participation in international seminars and conferences, and the organisation of special sessions at international conferences. The key parameters most relevant for the case studies are temperature, wind speed, precipitation, wave heights, solar irradiation and snow cover. Many of these parameters are also the main focus of interest for the international prediction community. For wave heights it can be argued that a separate discussion is not useful since there is a large overlap with wind forecasts.

Standard seasonal forecasts provide typically anomalies probabilities for a three-month period, for example two-meter temperature anomalies over Europe. It can be argued that such a forecast is necessary for a first assessment of the feasibility of useful seasonal forecasts, however it can be doubted whether this information is useful for every end-user. For some applications a forecasted 3-month average can be useful. For example, for a drought index, it can be useful to have a forecast which enables precautious actions to be taken by water suppliers, farmers and fire brigades already several months ahead and based on a 3-month average. For other end-users' higher time resolutions may be necessary, for example 1-monthly averages or even 1-week averages. SECLI-FIRM has addressed 3-month averages but also higher time resolutions have been investigated. Methods to increase the skill and usefulness of seasonal forecasts include the use of multi-model ensembles, statistical post processing, machine learning techniques, weather patterns or statistical downscaling using local information such as topography and local observations. All these techniques are used by both the wider prediction community and in the SECLI-FIRM. The advantage in SECLI-FIRM is that through the case studies and the stakeholder engagement the skill can be assessed from an end user's added value perspective.

For skill scores the range of options is large: anomaly correlation, absolute error, root mean square errors, brier skill scores, continuous ranked probability scores, etcetera; all have their advantages and disadvantages. Often combinations of skill scores are needed to inform end-users of the added value regarding probabilistic forecast for the different case studies. The choices available in combining multi model ensembles and assessing the added value are large and interaction and feedback with the larger prediction community is beneficial to all involved. The interaction with the larger prediction community is a joint effort in all SECLI-FIRM

work packages, but it is useful to also refer specifically to WP5 which is dedicated to Stakeholder engagement, communications and exploitation of results.

WP5 has provided very accessible information via a free webinar series, flyers, through social media such as Twitter and LinkedIn and a web portal[1] housing reports and latest news. Articles have been published[2], stakeholder workshops delivered and the project newsletter has over 285 subscribers. Video animations summarising case study aims have been made and promoted[3].

The seasonal and sub-seasonal topic is very broad and engagement with the larger prediction community is necessary to combine the research efforts as efficiently as possible, to reach any significant and robust advancement in prediction systems aspects such as physical processes, representation, resolution and phenomena which may through teleconnections improve the skill of the forecasts on longer lead times. Recently for example the potential of sudden stratospheric warming for sub-seasonal forecast skill in the Northern hemisphere has been discussed, the debate is ongoing.

In this report the attendance and presentations given at seminars and conferences is documented as well as the organisation of special sessions at international conferences. Chapter 2 discusses the conferences attended in the first period, i.e., the starting phase of the project. In chapter 3 the conferences attended in the second period of the project are discussed. In this phase of the project the first preliminary results were presented at different conferences and workshops. Engagement and feedback from conferences, seminars and workshop discussed in chapters 2 and 3 focussed on the scientific results and these meetings were primarily attended by scientists. SECLI-FIRM has also disseminated results to a wider audience and acquired feedback from stakeholders and potential end-users. Examples of the engagement and feedback from the wider audience is provided in chapter 4. Chapter 5 is the discussion and conclusions section.

2 Meetings attended in the first period of the project

2.1 WCRP 2018 conference, Boulder (17-21 September 2018)

The World Climate Research Programme (WCRP) and the World Weather Research Programme (WWRP) jointly organised the “International Conferences on Subseasonal to Decadal Prediction”, held in Boulder, USA, on 17-21 September 2018. At the conference, the development of a Grand Multi-Model Ensemble (MME) and seasonal forecast optimization activity planned in SECLI-FIRM was presented and discussed with the major providers to the SECLI-FIRM MME that were represented at the meeting. On the other hand, updated

[1] http://www.secli-firm.eu
[2] https://www.openaccessgovernment.org/seasonal-climate-forecasts/100258
[3] https://www.youtube.com/watch?v=kYICNVNYJUM

information about the seasonal forecast providers plan and developments for the future has been collected.

The institutions that are not currently providing their own seasonal forecasts through Copernicus C3S, NMME and/or APCC has been as well invited to voluntarily contribute to SECLI-FIRM with their seasonal hindcasts:

- An agreement with Dr. Yuhei Takuya (Japan Meteorological Agency - Meteorological Research Institute) has been discussed to provide seasonal hindcasts from their system under a non-disclosure agreement.
- A new prediction system is being developed at Nanjing University (China) that promise to extend prediction performance compared with other available systems. Nanjing University might be interested in sharing their hindcasts with SECLI-FIRM when the new system is released.
- The ability of latest developments in the prediction system based on EC-Earth (http://www.ec-earth.org) to overcome the skill limitations over Europe in boreal winter has been discussed and so the possibility to include EC-Earth hindcasts in SECLI-FIRM MME (at least for the winter season) advised.

2.2 Work visit to ECMWF (8 – 19 October 2018)

A visiting period of 2-weeks was organized at ECMWF in order to work closely with their Earth system predictability Department and C3S seasonal climate forecast team. During the visiting period of WP2-Leader Andrea Alessandri at ECMWF (8-19 October 2018) a collaborative effort with experts at ECMWF has been established to analyse and compare the results of latest ECMWF System5 (SEAS5) with the previous System4 (SEAS4). The performance and limitations still affecting ECMWF SEAS5 that could be limiting the performance for the applications in case studies considered in SECLI-FIRM have been discussed. Particular focus has been dedicated on the skill limitations over the European domain and possible strategies to exploit local signal as well as remote teleconnections. Of particular relevance for WP2, process-based advancements in SEAS5 are expected by creating a link and synergy with the EU H2020 PROCEED project. Preliminary results show quite limited skill over Europe in the winter season that is affecting SEAS5 similarly to previous SEAS4 and this could be a major issue for the applications in SECLI-FIRM. Process-based developments preliminary tested in PROCEED appear to improve significantly over Europe and sensitivity experiments with SEAS5 will be conceived by ECMWF colleagues to identify and promote significant advancements of the predictions that could feed the successful applications in SECLI-FIRM.

The possibility to have seasonal forecasts of waves (of particular relevance for case study 6) from SEAS5 was discussed with Jean Bidlot and Tim Stockdale. A meeting with relevant people from the Earth System predictability department and of the Research and Development department (Tim Stockdale, Gianpaolo Balsamo, Gabriele Arduino, Souhail Boussetta, Margarita Choulga, Joe McNorton) was organised to discuss about the future plans and establish continued and effective collaboration.

Several working meetings were organized with members of the Copernicus C3S seasonal climate forecast team to discuss the technical problems and design a strategy on how to overcome the unsatisfactory downloading speed of the seasonal forecasts from the C3S data store. As a strategy to reduce waiting time in downloading, C3S seasonal climate forecast team decided to increase their off-line storage in order to make directly available some part of C3S seasonal forecasts to avoid the slow retrievals from tape-storage via MARS system.

2.3 EGU 2019 General Assembly, Austria (7-12 April 2019)

The organization of a scientific session at EGU2019, 7–12 April 2019 (Austria) was co-sponsored by SECLI-FIRM. The new session "Challenges in climate prediction: multiple time-scales and the Earth system dimensions"[4] was proposed and convened. A special focus has been put on the use of operational climate predictions (C3S, NMME, S2S) and to climate-prediction research and application projects such as SECLI-FIRM and parallel exercises (e.g., EUCP, APPLICATE, PREFACE, MIKLIP, MEDSCOPE and S2S4E). At both oral and poster sessions very fruitful exchange of information between parallel projects was accomplished and preliminary results from SECLI-FIRM presented and discussed. Side meetings with SECLI-FIRM partners were as well organized to discuss in detail how to progress in the interaction between seasonal forecasting optimization and end-user needs. The institutions that are not currently providing their own seasonal forecasts through Copernicus C3S, NMME and/or APCC has been as well approached to possibly voluntarily contribute to SECLI-FIRM with their seasonal hindcasts.

An overview of the activities and planning in SECLI-FIRM was also presented at the interdisciplinary session on "Climate Services – Underpinning Science" to further contribute in the dialogue between users and providers of climate information that requires the establishment of a dialogue between subjects, who often have limited knowledge of each other's activities and practices.

2.4 International workshop on Climate Prediction, Taiwan (3-4 June 2019)

The International Workshop on Climate Prediction: Past, Present and Future' from 3 to 4 June 2019 was held at the Central Weather Bureau (CWB) in Taiwan. The workshop was jointly hosted by CWB and APEC Climate Center (APCC).

The purpose of the workshop has been (i) to bring together the scientists and producers who are at the forefront of sub-seasonal and seasonal climate prediction, with a major focus on ensemble forecasting and (ii) to strength interaction and enhance partnerships between the research and operational communities.

[4] Session description: https://meetingorganizer.copernicus.org/EGU2019/session/31725

All MME seasonal forecast providers were present at the meeting, including the organiser centre (APCC) which is the leading centre collecting the operational seasonal predictions from the Asian Pacific community and still not enough involved in SECLI-FIRM as desirable.

WP2-leader Andrea Alessandri was invited to give a talk at the workshop to report on the latest developments in Grand Multi-Model seasonal predictions (based on what published in Alessandri et al 2018 and on the planning and preliminary results in SECLI-FIRM project). The results shown in the presentation provided many contents for the subsequent discussion fostering continuous improvement in the use of the Grand-MME approach.

A side meeting was organized with Director of Director of APCC (Dr Won-Tae Kwon), Jin-Ho Yoo (Head of Climate services and Research Department of APCC) and Dr. Young-Mi Min (Senior Scientist, Climate Prediction group). It was agreed to strengthen cooperation between APCC and SECLI-FIRM activities for the Grand-MME development; to this aim sharing of efforts and data are envisaged.

2.5 Conclusions from the Climate Prediction Workshop, Taiwan (3-4 June 2019)

The recommendations of the workshops as highlighted in the final panel discussion are as follows:

- Model deficiencies are still the major issue to be tackled and continuous effort has to be dedicated on this matter. This might be a slow process, but it is agreed that this message has to be addressed to all frameworks (WMO, EU H2020, NSF) to organise and support all suitable activities.
- Seamless development of climate predictions has to be addressed. In particular, sub-seasonal to seasonal forecasts relies on the developments of models that are used for weather forecasts and share the same tools. However, priority has been given so far to minimize modelled biases. This creates the risk for compensation of errors by tuning poorly constrained parameters in particular over land, where evidence for this problem appears to be likely happened. It is recommended to reconsider parameter tuning done in the last decades and pursue more process-based seamless developments of prediction systems across scales.
- In the meantime, modelling tools are improved, the viable strategy to maximise skill of seasonal climate predictions for end-users application appears the multi-model approach. The example of SECLI-FIRM and the approach to select only the models that can contribute to increased skill appears currently a suitable way to produce optimised information for end-users.
- Coordination and cooperation in the frame of WMO panels is necessary to make sure a better strategy is implemented for the development of seamless prediction systems and improved information for end-users.

3 Meetings in the second reporting period of the project

3.1 Introductory remarks

The First Progress Management and Technical Report as provided in D6.5, covered a 10-month period from October 2018 to July 2019. In the period thereafter many changes have affected task T2.6. The Covid-19 pandemic has severely affected conferences, seminars, workshops and other interaction facilities. The work package and task leader, Andrea Alessandri, has left KNMI and returned to Italy, which at that time was in complete lockdown. Even though the severe impact of the Covid-19 pandemic on people's livelihoods, the sessions foreseen in the SECLI-FIRM work program have continued. Dr Alessandri had already organized and prepared the special session at the EGU during his KNMI employment. The conference was in a totally different format than foreseen and was amongst the first conference sessions in a digital format. The effectiveness and the interest in the sessions can be seen as a great success. Indeed because of the digital format the sessions could be attended by everyone interested in the topic.

This task is strongly tied with the outreach activities employed in work packages 1, 3, 4 and 5. Stakeholder meetings, workshops, web meetings and other communications and engagement activities will be described in the other work packages. Obviously, the dissemination and exploitation of the results is an ongoing task in which all members of the project participate and to which many members of the project, both from the project team as well as from the advisory board, contribute.

Engagement and feedback with international prediction community has been very actively pursued during the period which has been covered by the Second Progress Report, in which the results of attendance and contribution to various international conferences is outlined in the following sections. A scientific session at the EGU2020 has been co-sponsored and convened by SECLI-FIRM and was attended by many SECLI-FIRM members.

3.2 ECMWF Annual Seminar 2019, Reading (2-5 September 2019)

The 2019 ECMWF Annual Seminar 2019 on sub-seasonal and seasonal forecasting: recent progress and future prospects reviewed recent advances in the understanding of the predictability at the sub-seasonal and seasonal time scales. At the seminar the predictable processes and the predictability drivers were presented and discussed. The seamless forecasting system developed in SECLI-FIRM for CS6 and the predictability in the region under consideration was discussed in private meetings. The seamless approach does not overcome the skill limitations, but it can help the end-user to understand the information better. The annual seminar provided information regarding the latest updates on seasonal forecasts and teleconnection indices. Specifically, ideas for the MME related techniques and options were of interest for the case studies 1 to 5. The seminar highlighted the importance of using the NAO

index to obtain extended range forecasts more accurately in Europe, especially for severe cold events. Additionally, prediction skills could be improved by using MJO as well.

Unsurprisingly, during the Seminar it became clear once more that to demonstrate skill in S2S forecasts a few weeks ahead for the relatively small scale of the North Sea at which CS6 is focused, will be a challenge. Nevertheless, there might be large scale phenomena, like the NAO, that can help in identifying periods in which meaningful skill can be expected.

Some of the presentations gave insight into alternative tools to present forecasts and assess forecast skill.

3.3 Climate Change and Energy Transition on the Mediterranean, Paris (21 -22 Nov 2019)

The conference on Climate Change and Energy Transition on the Mediterranean aims at Cross-Fertilization between academics, industrial communities, policy makers and stakeholders[5]. This conference and the associated workshops focused on the effect that climate change might have on energy resources and energy demand in the Mediterranean along with potential mitigation and adaptation strategies in the area. Furthermore, the goal of the workshops was to promote cross-fertilization debate between the attendees, which included academics, public stakeholders and the representatives from the energy industry. In this context, the work carried out by SECLI-FIRM had many similarities and was presented by Kristian Nielsen throughout several workshops' sessions, where tailored seasonal forecast was discussed as a potential tool to help mitigate the projected increase in frequency of extreme climate/weather events that would impact the production of renewable energy as well as energy demand. Kristian Nielsen mainly focused on the case studies related to the Mediterranean area (CS4 and CS5) during these discussions.

In addition to these workshops, several useful face to face interactions were made during the conference that allowed to share experiences from the work carried out in SECLI-FIRM and to get feedback and ideas on developed techniques. In particular, during the poster sessions, different approaches on how to determine the economic value of weather and climate forecasting were discussed in the context to the poster by A. Dupré et al (2020). The main topic was the value of testing the added economic value of having a perfect forecast in order to better put in perspective how much the added value of adding actual seasonal climate forecast was in the SECLI-FIRM project. This would partly highlight the importance of how this information is added in decision making and the relative importance of such forecasts.

Also, different strategies for the estimation of low wind conditions from ERA5 reanalysis data in respect to station observations were discussed, in the context to the poster by Molina, M.O

[5] https://www.cigre.org/event/workshop/2019/FR/palaiseau/climate-change-and-energy-transition-on-the-mediterranean

et al. (2019). The discussion here focused on evaluations of reanalysis against observations. Experiences and results of the work carried out regarding such an evaluation of precipitation over areas of complex topography in Colombia in regard to CS5 were shared

3.4 AGU 2019 Fall meeting, San Francisco (9-13 December 2019)

One of the SECLI-FIRM project members co-organized the session “Challenges in Climate Prediction: Seasonal-to-Decadal Climate Predictability and the Earth System Dimension”[6] at the American Geophysical Union Fall Meeting 2019, on 10 December 2019.

3.5 EGU 2020 General Assembly, Online (4-8 May 2020)

The session “Challenges in climate prediction: multiple time-scales and the Earth system dimensions”[7] was organised for the second time and convened by Andrea Alessandri. The challenges in the Earth system science in providing reliable climate predictions on sub-seasonal, seasonal, decadal and longer timescales have been addressed in this session. Many SECLI-FIRM project members have shown at this conference the latest developments from SECLI-FIRM sub seasonal to seasonal forecast, addressing aspects required for the end-user application, such as quality assessment, multi-model combinations, bias adjustment, downscaling, and so on.

An increasingly important aspect for climate forecasting applications is the use of downscaling methods based on dynamical or statistical approaches or their combination, necessary to generate time series and fields with an appropriate spatial or temporal resolution.

On behalf of the SECLI-FIRM community presentations were given by Franco Catalano who presented a novel model independence methodology to improve multi-model seasonal forecasts combination, Mattia Callegari on predicting water discharge on alpine catchments with downscaled seasonal forecasts, Andrea Alessandri presented the grand multi-model seasonal forecasts in the SECLI-FIRM project, Alice Crespi discussed the downscaling and bias correction of seasonal forecasts to support climate services for the alpine regions. Other sessions regarding seasonal forecasting were attended by other colleagues, for example Folmer Krikken et al presented the dissemination of seasonal fire weather information for stakeholders and researchers.

The online sessions were discussed using displays with the presentations uploaded beforehand and each author was asked to give a 1-2 sentences introduction possibly highlighting one central point of the results to start the discussion. With 16 displays the time including questions was about 6 minutes per display.

[6] Session description: https://agu.confex.com/agu/fm19/meetingapp.cgi/Session/81836
[7] Session description: https://meetingorganizer.copernicus.org/EGU2019/session/31725

Franco Catalano presented the SECLI-FIRM work as follows: “Multi-model ensembles (MMEs) are powerful tools in dynamical climate prediction as they account for the overconfidence and the uncertainties related to single model ensembles. The potential benefit that can be expected by using a MME amplifies with the increase of the independence of the contributing Seasonal Prediction Systems. To this aim, a new metric, the Brier Score Covariance (BScov) has been developed in order to assess the relative independence of the prediction systems in the probabilistic information they provide. The new BScov metric has been used to optimize model selection and combination strategies with a particular focus on the most relevant variables for energy applications.”

An example of an introduction is for example the introduction of Mattia Callegari who presented work performed in the SECLI-FIRM project: “We present a statistical method based on support vector machine for monthly water discharge prediction. The considered predictors are ERA-5 data to describe the initial catchment state and ECMWF’s seasonal forecasting systemin (SEAS5) temperature and precipitation downscaled and bias-corection on the ERA-5 grid to describe the runoff contribution during the forecast period. The method has been tested over an alpine catchment in Ulten Valley, South Tyrol, Italy, which is managed by 6 artificial reservoirs for hydropower production.”

Andrea Alessandri summarised the SECLI-FIRM presentation as follows: “The aim of the SECLI-FIRM project is to bridge the gap between seasonal climate forecasters and end-users decisions in the energy sector by employing a comprehensive set of techniques. The use of Grand-MME is key strategy for the optimisation of forecasts. It is shown that combining prediction systems into the SECLI-FIRM Grand-MME improves significantly the performance and that more skill is gained by combining independent systems. In particular, we consider here one case study for precipitation over Italy, generally retained hopeless case. We show that, by maximizing skill using SECLI-FIRM MME, 1-month-lead seasonal prediction of rainfall over Italy significantly correlates with ERA5 (r=0.56 in summer and r=0.64 in winter)”.

Alice Crespi presented SECLI-FIRM related work as follows: “We present a downscaling and bias-correction framework for seasonal forecasts of main meteorological variables over the Alpine area. The seasonal forecasts provided by the ECMWF’s seasonal forecasting system over the period 1982-2018 were re-gridded by a bilinear interpolation from the 1°x1° original fields onto the target 0.25°x0.25° resolution and bias-corrected by the quantile-mapping procedure using ERA-5 data for the calibration. The accuracy of final fields was evaluated and tested also with respect to other downscaling approaches. The post-processed forecasts of temperature and precipitation were included into a runoff prediction system for the hydropower production of an Alpine catchment.”

UL provided support in preparing the material and contributed to preliminary discussions for both the presentations carried out by Andrea Alessandri and Franco Catalano about the Multi Model Ensembles potential, as a tool to provide extra skill of seasonal forecasts. In addition, Kristian Nielsen attended these sessions to further contribute to the discussions.

The session was attended by 104 active users, the number of questions was between 5 and 10 per presentation.

3.6 Challenges in Energy-Climate Modelling, online (22-23 June 2020)

Supported by the H2020 PRIMAVERA project the workshop "Next generation challenges in Energy-Climate Modelling"[8] took place in June 2020. The online workshop discussed risks posed by climate variability and change and uncertainty in power system operations and planning were discussed. Hazel Thornton (Met Office) was on the organizing committee, and the workshop was also attended by Philip Bett (Met Office).

3.7 Webinar: Transition to a climate service company, online (7 July 2020)

On 7 July 2020 a webinar for the Laboratory of Oceanography and Climate: Experiments and Numerical Approaches (LOCEAN) was given on "Transition to a climate service company but contributing to the European research project SECLI-FIRM." This 45-minute online webinar was presented by Victor Estella-Perez to his former research laboratory LOCEAN in Paris, which was attended by ca. 30 people. He presented the general background of UL as company and the company's on-going contribution to the SECLI-FIRM project. In particular, the webinar covered the general description of the SECLI-FIRM project with a focus on UL's contribution to CS5. The main topic presented was the description of the forecasting of river flow based on the Random Forest machine learning method and to present some initial results of this method in relation to the specific needs from the end user in this case study.

3.8 AEIT International Conference, Catania Italy (23-25 September 2020)

At the AEIT (Italian Association of Electrical, Electronics, Automation, Information and Communication Technology) conference, preliminary results from case studies 1, 2 and 3 were presented. More and more companies need accurate weather services to manage the growing renewable resource. The conference provided an adequate platform to promote SECLI-FIRM and the principle of close collaboration between science and application.

The main results presented at the AEIT showcase the potential of the SEAsonal forecast System 5 (SEAS5), for which in the case studies the added value for Enel's decision-making process has been assessed. The impact on the best hedging strategy is evaluated through a comparison of climatology, seasonal forecasts and actual weather data. Preliminary results on SEAS5 show that temperature values tend to fit ERA5 climatology. Improvements with respect to ERA5 climatology are observed for wind and total precipitation variables over the domain's relevant for Enel. These results are published in G. Piccioni *et al* 2020.

[8] https://research.reading.ac.uk/met-energy/next-generation-challenges-workshop

3.9 Climate forecasting for energy - S2S4E, online (4 December 2020)

The conference on Climate forecasting for energy - S2S4E and OpenMod joint workshop was organized online on 4 December 2020[9] and attended by UL. This conference was very related to SECLI-FIRM's work in topics such as accessing the science of sub seasonal to seasonal forecast and the use of this information in energy modelling and decision processes. Kristian Nielsen attended this workshop, which provided a great platform and an opportunity to share SECLI-FIRM's results and to compare results and methods among the attendants. This was especially relevant during the virtual interactive poster session that allowed a free "movement" among the different posters, where especially information of MME combinations and the possible improvement of skill for this strategy together with hydrological modelling methods and experiences were shared through several discussions. The preliminary conclusion which was shared by all attendants is that for some areas and variables an optimal combination of a subset of the different models outperforms the combination of all models. In general, the optimal combination consists of 4 to 5 models. The specific combination of models depends on the skill scores used, but often if not always the ECMWF seasonal climate forecast is part of the optimal combination. Furthermore, strategies for a test of the statistical significance of this improvement was discussed. The importance of the choice of reanalysis dataset was discussed, as this can artificially favour the skill of some models such as ECMWF SEAS5 when tested against ERA5.

4 Examples of results disseminated for the wider community

4.1 Communicating scientific results

Different methods have been employed to show the results from the different techniques to increase the skill of seasonal forecasts. From SECLI-FIRM Report D2.3 results showing the effect of post processing are repeated here. There are of course many examples to choose from, what we show here is only meant as a teaser. More on this topic can be found in the deliverables from work packages 3 and 4.

In Figure 1 a result presented in Piccioni et al. (2020, there in Fig. 14) is reproduced showing results for Case Study 3 for the daily wind profiles. The plot shows wind profiles over March 2016 derived from SEAS5 monthly values (light blue), the actual ERA5 daily 10-m wind speed (blue) and the normal daily values (red). The example shows that with SEAS5 daily forecasts at M-1 show wind variations which compare better to the ERA5 observations than the climatology derived from ERA5. (M-1 are forecasts which are initialized one month before March 2016).

Figure 2 (figures from SECLI-FIRM D2.2) shows the change in root mean square error (RMSE) of the forecasts after post processing, for temperature and precipitation respectively. The post

[9] https://s2s4e.eu/newsroom/climate-forecasting-for-energy-event

processed temperature forecast RMSE improves the forecast over eastern Europe/Russia, with little change or a degradation over Western Europe. Over Europe the post processing method does not improve the rainfall forecasts.

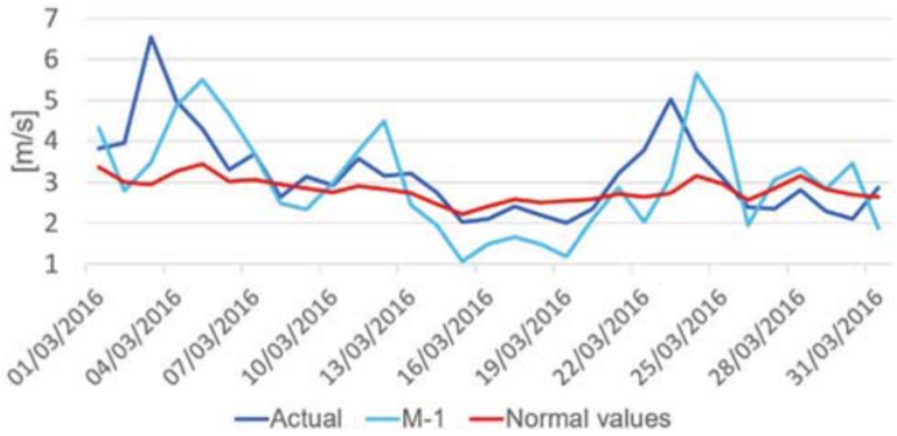

Figure 1 Comparison of daily profiles from ERA5obs (blue), SEAS5 forecasts at M-1 (light blue) and ERA5 climatology (red). For details see Piccioni et al. 2020, figure 14

4.2 Outreach and future perspective

Work continues to try to address the "signal-to-noise problem", both through investigating potential physical causes in models, highlighting its impacts in different contexts, and developing statistical post-processing techniques to work around it. The problem highlights the need for calibration of forecast probabilities rather than relying on the raw ensemble distribution. As an example of a post-processing method developed to help this problem, the approach developed by Stringer et al. (2020), based on NAO analogues, is now being used for the UK Hydrological Outlook, to inform hydrological modelling in the UK.

Other ongoing work has focused on if and how seasonal forecasts might be used and communicated in different contexts around the world. Ongoing development work in South Asia has focused on assessing need, skill and reliability, and the communication of seasonal forecast information (ARRCC project SCIPSA[10]). Work on fire risk in South America has shown how probabilistic climate forecasts can be used as part of a highly targeted early warning system, aiming to get actionable information to appropriate local agencies (Anderson et al., 2020 a, b).

[10] https://www.metoffice.gov.uk/services/government/international-development/strengthening-climate-information-partnerships-south-asia-scipsa

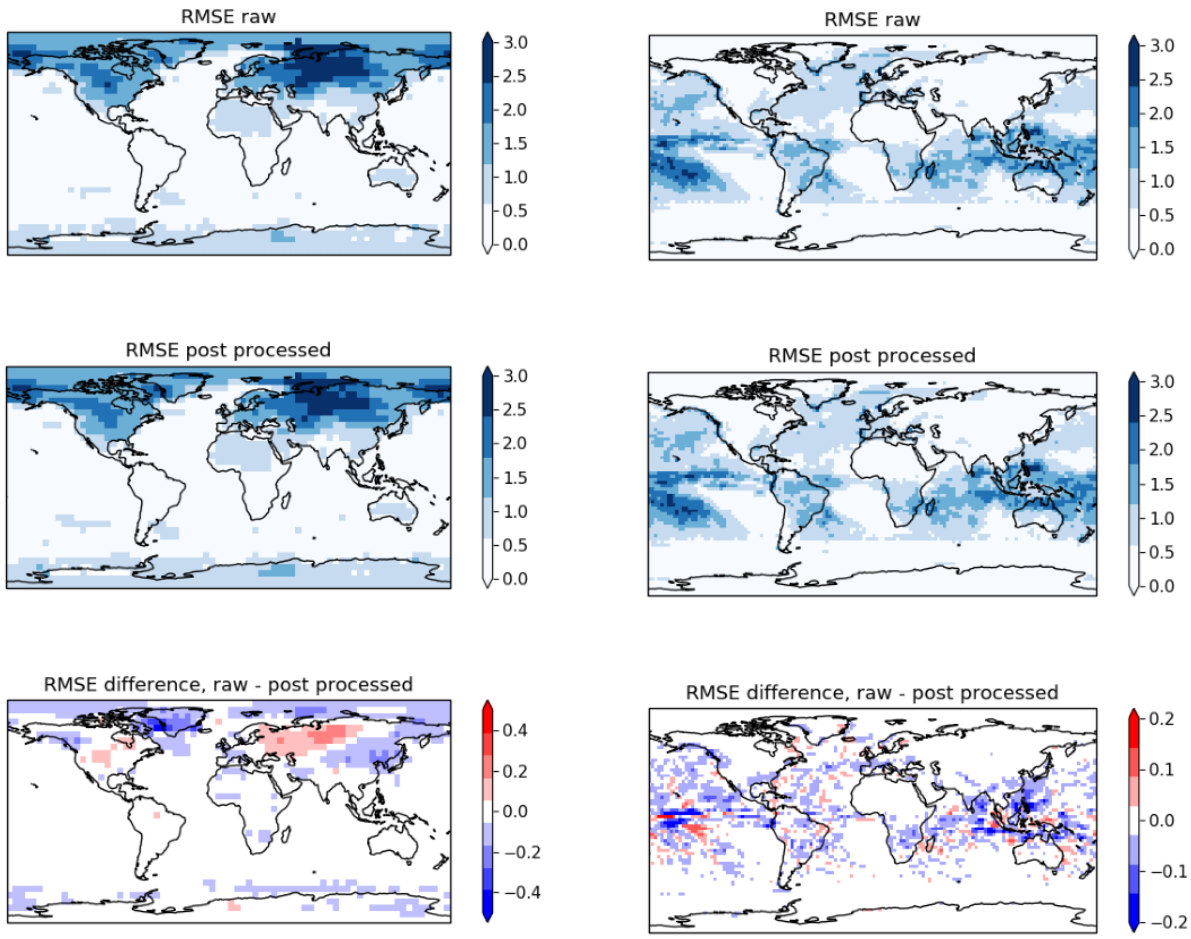

Figure 2 The Root Mean Square Error (RMSE) of 2m temperature (left) and winter mean precipitation rate (right) for the raw multi-model ensemble mean (upper), the post-processed ensemble mean (middle) and the difference (lower). In the lower panel red shows the signal inflation/sub-selection method gives an improvement in forecast temperature, blue a degradation (For details see SECLI-FIRM report **D2.2**).

Philip Bett (Met Office) presented at a webinar hosted by the China–Britain Business Council (CBBC, March 2021) on "Seasonal climate prediction, with applications for wind energy and Yangtze rainfall". The topic of the CBCC event[11] was "How can Climate Science Today support Renewable Energy Projects in China?"

Regarding exploiting seasonal forecast skill and how to make optimal use of it, is a continued topic of discussions in the scientific seasonal forecasting area. Met Office SECLI-FIRM

[11] http://www.cbbc.org/events/2021/march/how-can-climate-science-tools-support-renewable-en

members discuss work similar to the SECLI-FIRM project with colleagues on Newton-funded projects like CSSP China[12], CSSP-Brazil[13] and ARCC[14], which are all focused outside Europe.

4.3 Communications to and for a wider audience

The interaction with the larger prediction community is a joint effort from all SECLI-FIRM members. The importance of interacting with the larger prediction community, but also a wider audience including end-users and other potential stakeholders is such that a specific work package (WP5) is dedicated to Stakeholder engagement, communications and exploitation of results. Knowledge regarding the needs and requirements of the end-users and stakeholders is vital to the success and usefulness of the complex and cpu- and disk storage intensive research that is required for seasonal forecasts where of the added value of the forecasts is by no means trivial to assess. There are many different methods and metrics to verify the seasonal forecasts in a statistical sense, but in real world decision making statistical verification information from historical results are not always, or maybe even only rarely, sufficient to have confidence in a forecast for the coming months that requires costly decisions with large impacts. For end-users and stakeholders dedicated verification (and or skill assessment) techniques have to be applied. There for it is necessary to inform this wider audience of the work done in SECLI-FIRM and present the results.

Examples of communication and dissemination to a wider audience are (the webinars are free and can be viewed any time when convenient):

- CS1 video animation https://www.youtube.com/watch?v=kYICNVNYJUM&t=21s
- A webinar on 'Climate Services for the Energy Industry' in Sept 2020 was attended (real time) by over 50 participants, and is available via http://www.secli-firm.eu/2020/09/07/climateservicesforenergy
- A webinar 'Climate Services for the Hydropower Sector' in November 2020 was attended (real time) by over 55 participants. It is available via http://www.secli-firm.eu/2020/11/03/1800 and http://www.secli-firm.eu/2020/12/03/climate-services-for-the-hydropower-sector-webiar-overview
- How seasonal climate forecasts can contribute to energy and water industry management is elucidated in 'Environment News' December 16, 2020. Alberto Troccoli explains in the article the goals of the Europe's H2020 project SECLI-FIRM and illustrates the why and how of explains in this article why and how SECLI-FIRM aims to contribute to accurate seasonal climate forecasting in order to reduce risk and cost for energy and water busines, see https://www.openaccessgovernment.org/seasonal-climate-forecasts/100258

[12] https://www.metoffice.gov.uk/research/approach/collaboration/newton/climate-science-for-service-partnership-china
[13] https://www.metoffice.gov.uk/research/approach/collaboration/newton/cssp-brazil/index
[14] https://www.metoffice.gov.uk/services/government/international-development/arrcc

Summaries of the SECLI-FIRM Stakeholder events which were held during the project until now can be found here http://www.secli-firm.eu/events. A few of the many highlights of these workshops are:

- The first stakeholder workshop showed that there is a large overlap between the planning horizon for Thames Water and for TenneT, even though the commodity differs largely (water versus electricity), the planning horizons are similar. This means for SECLI-FIRM that research results can be useful for both industrial areas.
- Decision trees were developed for each case study, where the interaction between research, development and end-user during the workshop was vital for an iterative discussion to develop the decision trees.
- The SECLI-FIRM webinar organized 12 November 2020 showed results from the SECLI-FIRM consortium for hydro energy from two different regions, the Alpine Catchments, hydro resources in Colombia. A third presentation was from the CLARA project showing a smart climate hydropower tool.

5 Discussion and conclusions

Seasonal forecasts as made available through C3S can potentially provide large benefits for different sectors such as agriculture, forest maintenance, water suppliers and health (Doblas-Reyes 2010, Krikken et al 2020). The close collaboration between scientists and end-users of seasonal and sub-seasonal forecasts has increased the awareness of end-users of the cpu and disk usage intensity of these forecasts.

During SECLI-FIRM the scientists have become increasingly aware of the complexity of investigating and communicating skill information. Whereas ENSO is the main source of seasonal skill in the global seasonal forecast models, the NAO which is another index used in determining European climate variability has limited skill on a seasonal forecast time range. Effects of other indices are still under investigation.

The raw ensemble seasonal forecast models are being calibrated and used in multi model ensembles and processed using different advanced techniques. The comparison of different methods used for different case studies have shown added value with respect to climatology in some cases, providing useful and added value for specific applications. The ability of a multi-model seasonal forecasting system to forecast the probability of extremes can be very useful.

The potential of seasonal forecasts of an increase of skill over climatology can be beneficial for hedging and planning purposes even if the increase in skill is only small. Results have been shared with wider stakeholder and prediction communities through webinars, conferences and dedicated workshops. Further disclosure of results is 2021 foreseen in two workshops, the SECLI-FIRM web portal, social media and the EGU conference.

The conclusions reached in 2019 at the Climate Prediction Workshop in Taiwan still hold, in particular:

- The development of seamless climate predictions is important. Sub-seasonal to seasonal forecasts relies on the developments of weather prediction models.
- The use of multi-model approach can maximise skill of seasonal climate predictions for end-users

Seasonal climate forecasts show limited skill in the European domain, but the skill in winter related to the NAO is high enough to be useful. Sub-seasonal forecasts related to the NAO related can also be reasonable. The same is true for persistence in coastal and snow-affected areas and soil moisture effects on probability of heat waves.

For hydro-energy and drought seasonal forecasts can show reasonable skill on a sub- to seasonal range. Discussions of an SSW effect on a (sub)seasonal time scale are under debate. In the tropical regions El Niño teleconnection effects result in reasonable skill.

The research into the added value from the employment of statistical models combined with dynamical models in a multi-model framework show promising results (see SECLI-FIRM D2.2). Different statistical techniques are employed to create a set of statistical models to predict the 2-meter temperature and precipitation. Each model uses several predictors, such as the CO2 equivalent forcing, persistence, warm water volume and the El-Niño 3.4 index.

For the large-scale climate indices, the pacific decadal oscillation (PDO), Atlantic multidecadal oscillation (AMO), the Indian ocean dipole (IOD) and the North Atlantic Oscillation (NAO) and the El-Nino southern oscillation (ENSO), are considered to provide predictive power on lead times in the order of months.

Recently van Oldenborgh et al. (2021) advocate in a joint publication of KNMI, the Red Cross Climate Centre and operational ENSO prediction centres an improvement to the presently used Niño3.4 index. The authors argue that the traditional Niño3.4 index has a trend due to global warming which is not related to the impacts from El Niño. The authors propose the “relative Niño3.4 index” that does not have the trend and separates ENSO more cleanly from global warming. They show that the relative Niño3.4 index performs better and more consistently. This is an interesting result also for the SECLI-FIRM applications.

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Grant Agreement n. 776868