ECMWF Copernicus Procurement

Invitation to Tender

COPERNICUS PROJECT C3S_34c

Annex 2 to the Framework Agreement

ITT C3S_34c
ISSUED BY: DWD
Date: 26 September 2019
Version: 4

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1 Executive Summary

The Copernicus Climate Change Service (C3S) has a critical role to ensure that the service meets the needs of a range of users for high-quality data and information on near- to medium- to long-term climate change.

The ITT that this proposal addresses asks for recommendations on robust definition and adoption of methods for post-processing of forecast data and case studies to articulate the benefits of decadal predictive information to the decision making of real users.

A contract team of four institutions (BSC, CMCC, DWD, Met Office) with years of experience in seasonal to decadal prediction, three of which currently produce decadal predictions operationally with state-of-the-art earth system models and represent the European contributors to the WMO Global Producing Center for Annual to Decadal Climate Prediction (GPC ADCP) including the Lead Center, offers to provide a robust, credible and reliable encoding standard for forecasts and products. This standard will be developed upon the foundations which were already laid down in other projects. It will consider existing standards, like for example, Decadal Climate Prediction Project (DCPP) data in ESGF nodes, WMO's Commission of Climatology, and current standards followed by C3S for other activities, like seasonal forecasts and climate projections. To develop these data standards, discussions with the data-standard community will be initiated, and will be facilitated through a workshop at one of the partner's facilities in Barcelona (also part of this offer).

Similarly, a robust definition of methods for post-processing of forecast data including the generation of multi-model products comparing different formulations and best practises for forecast quality assessment will be provided to the C3S at the end of the contract. These aspects will be illustrated using the DCPP-A simulations. A comparison between the European multi-model, that currently provides forecasts operationally, and the global multi-model will be carried out.

Four case studies involving four individual stakeholders as real users of decadal prediction data will be delivered to C3S. The stakeholders come from the sectors infrastructure, insurance, agriculture and energy, which will cover a large field of user needs and result in a broad range of candidate products for the possible addition of decadal prediction data to the C3S portfolio. Each partner of the contract team will be working on one case study. The data used in the case studies, as well as the post-processing software will be made available to the C3S at the end of the contract. Furthermore, we plan to introduce these case studies to a wider audience at the 2020/2021 C3S General Assembly.

The main contractor of the contract team will be DWD. As the main contractor, DWD will lead work package (WP0) on management and coordination. Work package (WP1) on forecast data encoding and products will be led by BSC and the work package on case studies (WP2) will be led by the Met Office.

2 Track Record

2.1 Introduction

The following proposal is submitted by a seasoned contract team which is constituted of four institutions: Deutscher Wetterdienst (DWD), the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC), UK Met Office (Met Office) and the Centro euro-Mediterraneo sui Cambiamenti Climatici (CMCC).

The team has documented capabilities in all the scientific and technical aspects related to providing decadal climate forecasts, engaging with users and developing respective climate services. All partners contribute to the World Meteorological Organization Lead Centre for Annual to Decadal Climate Prediction (WMO LC ADCP) and all current WMO recognised European Global Producing Centres for these predictions are represented in this contract team. Met Office is the WMO Lead Centre for ADCP which also collects predictions from outside Europe and thereby extends the frame to other countries outside Europe.

Table 1 List of contract team members and their relative contribution to the contract

Contractor	Legal details	Legal representative	Address	% of the contract value terms for which contractor will be responsible
DWD	Public Sector Organisation	Prof. Dr. Gerhard Adrian, President of DWD	Frankfurter Straße 135, 63067 Offenbach, Germany	29
BSC	Public Sector Organisation	Prof. Mateo Valero Cortés, Director of BSC	C/Jordi Girona 31, 08034 Barcelona Spain	29
Met Office	Public Sector Organisation	Kyle Lischak, Head of Legal	Fitzroy Road, Exeter, Devon EX1 3PB, United Kingdom	22
CMCC	Private Law Body	Dr. Antonio Navarra, President of CMCC	Via Augusto Imperatore 16, 73100 Lecce, Italy	20

2.2 Deutscher Wetterdienst (DWD)

The **Deutscher Wetterdienst** (DWD, www.dwd.de) is the National Meteorological Service of Germany. Founded on national law, its core task is the provision of services for the protection of life and property in the form of weather and climate information. This includes the meteorological safeguarding of aviation and marine shipping and the warning of meteorological events that could endanger public safety and order. DWD has other important tasks such as the provision of weather and climate services to the government, the federal states, and the institutions administering justice.

In addition, DWD is entrusted with the fulfilment of international commitments by the Federal Republic of Germany with respect to meteorological and climatological issues. The DWD thus coordinates the meteorological interests of Germany at a national level in close agreement with the German government and represents Germany in intergovernmental and international organisations such as, for example, the World Meteorological Organization (WMO). The president of DWD, Prof. Gerhard Adrian, is also the current president of the WMO.

DWD's spectrum of activity is very wide and comprises of weather observation and forecasting, research and development, climate monitoring and modelling of projections as well as climate forecasts, development of precautionary measures to avoid weather-related disasters and to provide support for disaster risk reduction, advice, information and services on meteorology and climatology to commercial and non-commercial users, national and international cooperation in meteorological and climatological activities.

DWD is the national German user coordination institution for the Copernicus services on atmosphere (CAMS) and climate change (C3S). In this context it represents the German user interests in the EU Copernicus User Forum. At the national level, DWD was involved in the national COPERNICUS programme with three contracts, OCEAN-EVAL, NOCO, and GUAMO. While the first contract developed an evaluation tool running operational for the German Climate Forecasting System (GCFS) with focus on oceanic parameters, the NOCO contract supported the national coordinator of CAMS and C3S installed at DWD and provided coupled regional climate projections of the regional climate model COSMO-CLM coupled to the ocean model NEMO for the North and Baltic Sea. The overall objective of the contract GUAMO (Utilisation of GMES Urban Atlas for urban climate modelling) was to utilize Copernicus Land Monitoring Services datasets for urban climate simulations supporting the generation of urban climate services for climate resilient urban planning.

The DWD participates in the contract C3S_513 EQC-SIS, which focuses on the implementation of an Evaluation and Quality Control framework for the Sectoral Information Systems. DWD is especially involved in the design and development phase, the user requirements analysis as well as the user engagement activities for dedicated sectors.

The DWD is also involved in the C3S_512 EQC-CDS contract, lead by BSC. The aim is to develop a concept for a quality assessment of the Climate Data Store (CDS) of the Copernicus Climate Change Service (C3S) and the data records contained therein, to carry out the quality control and to provide the users of the CDS with the information for quality assurance. The tasks of the DWD are to contribute to the definition of international standards in the area of user involvement, user needs and provision of quality information for users and to contribute to the generation, processing, standardisation and analysis of climate prediction and projection data for the Copernicus Climate Data Store (CDS).

Concerning the infrastructure/technical equipment relevant for the proposed work, the DWD maintains comprehensive technical infrastructure for the collection, analysis and archiving of meteorological data. High performance computing facilities are available for staff members for contract related activities that require the handling and processing of high-volume datasets. As member state of ECMWF, DWD has an appropriate account of computing and archiving resources at ECMWF HPC, which will partly be used for this service in order to optimise the fast data availability for the climate data store.

Collaborating with University of Hamburg (UHH) and the Max Planck Institute for Meteorology (MPI-M), DWD is providing seasonal forecasts with the German Climate Forecasting System (GCFS) for the C3S Climate Data Store. The DWD coordinated contract C3S_433 and now contract C3S_330 with this topic. In addition, this group at DWD has been involved in other national and EU projects on decadal and seasonal-to-decadal climate predictions such as the research project ERA4CS CLIM2POWER and the national research project MiKlip.

MiKlip (https://www.fona-miklip.de) is the major national project on developing a decadal climate forecast system that is organized around a synthesis module and four research modules on initialization, processes, regionalization and evaluation. Several research groups from Germany including scientists from the DWD participate in MiKlip. The DWD contributed to investigations in dynamical downscaling of MPI-ESM decadal hindcasts for Europe and in the operational and application aspects of the global climate forecast system. The scientific part of the project ended October, 2018. Currently, DWD is in the process of transferring technology and research results towards an operational system for decadal predictions. This transition phase to operations will end by October 2019. After the end of the MiKlip project, DWD will apply the global MiKlip decadal forecasting system for operational use which will conclude in the first operational decadal forecast issued in 2020.

2.3 Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC)

The Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC, https://www.bsc.es) is a research centre active at both national and international levels. The BSC combines unique high performance computing facilities and in-house top research departments on computer, life, Earth sciences and in computational applications in science and engineering. The BSC is the main provider of public supercomputing services in Spain, including not just the access to cutting-edge computers and technology, but also top-of-the-range training and education, the development of purpose-built applications for both public and private actors and first-class innovation. The BSC also coordinates the interests in supercomputing at the national level via the Red Española de Supercomputación and represents Spain in international initiatives such as PrACE, the Research Data Association and the Big Data Value Association. The BSC has a total staff of about 640 employees.

Headed by Professor Francisco J. Doblas-Reyes, the Department of Earth Sciences of the Barcelona Supercomputing Centre-Centro Nacional de Supercomputación (BSC-CNS), BSC-ES henceforth, is one of the most active groups in air quality and atmospheric composition modelling, climate prediction and climate services in Europe. The department is currently composed of about 100 people, including technical and support staff, structured in four distinct but closely interacting research groups: the Earth System Services, Atmospheric Composition, Climate Prediction and Computational Earth Sciences. The BSC-ES mission consists in performing research on and developing methods for environmental forecasting, with a particular focus on the atmosphere-ocean-biosphere system. This includes managing and transferring technology to support the main societal challenges through the use of models and data applications in high-performance computing (HPC) and Big data infrastructures. It also includes the dissemination of real-time air quality and climate information based on its research expertise in collaboration with both the Spanish national, regional and local authorities and the World Meteorological Organisation (WMO). All the BSC infrastructure and support is available to the BSC-ES members: a 13 PFlop supercomputer, a long-term storage, commodity computational facilities with both physical and virtualised environments, a solid project management team, and the outstanding collaborations with researchers in computing sciences.

The BSC-ES international activity includes the coordination of the two World Meteorological Organisation (WMO) regional centres specialised in sand and dust warning and forecasting, as well as the participation in climate services initiatives like the Climate Services Partnership (CSP). The operational functioning of the WMO regional centres is ensured jointly with the Spanish weather service, AEMET, with whom the Department enjoys an excellent and long-term collaboration. Members of the BSC-ES participate in committees of the World Climate Research Programme (WCRP), such as CLIVAR, the Working Group on Seasonal-to-Interannual Prediction (WGSIP) and the WCRP Modelling Advisory Council. The BSC, through the activities of the BSC-ES, was recently designated as a Global Producing Center of Annual-to-Decadal Climate Prediction by the WMO.

Two of the BSC-ES groups will be involved in this offer. The Climate Prediction group aims at developing a climate forecast system based on the EC-Earth model and performs regular assessments of the characteristics of this forecast system compared to all other operational and quasi-operational systems available in the world. The Earth System Services group ensures that the outcomes of the department reach society, both in the public and private sectors, and continuously sample the needs of a range of users in the insurance, agriculture and renewable energy sectors.

Over the past five years, the BSC members have participated in several projects and contracts relevant to this offer:

- The FP7 EUPORIAS (EUropean Provision Of Regional Impact Assessment on a Seasonal-to-decadal timescale; 2012-2016) project intended to improve our ability to maximise the societal benefit of seasonal forecasts by engaging with a range of users. Working in close relation with a number of European stakeholders, this project aimed to develop a few fully working prototypes of climate services addressing the needs of specific users. The time horizon was set between a month and a year ahead with the aim of extending it towards the more challenging decadal scale. The main outcome of EUPORIAS was the development and the delivery of robust and usable probabilistic predictions of the impact of high risk events.
- The C3S_512 (Quality Assurance for the Climate Data Store; 2018-2021). This contract aims at developing a solution for the EQC function to respond to the needs identified in previous contracts using a continuous user-engagement process. This project addresses the challenges posed by providing an overarching EQC service for the whole CDS and an independent quality assessment for a number products (seasonal forecasts, climate projections and in-situ observations). The lead contractor is the BSC.
- The C3S_51 Lot 3 QA4Seas (Quality Assurance for Multi-model Seasonal Forecast Products; 2016-2018) contract, one of the precursors of the evaluation and quality control (EQC) function, developed a strategy for the EQC of the multi-model seasonal forecasts provided by the C3S. The assessment was user driven and, through surveys, provided a map of user needs, identifying those features that should be prioritised. The outcome of the seasonal forecast quality assurance module was used to perform a gap analysis of the current information available to users and to develop a prototype of the EQC system that illustrated the strategy proposed for the future development of the climate data store (CDS). The lead contractor was the BSC.
- The Horizon 2020 EUCP (The European Climate Prediction system project; 2017-2021) has four objectives: 1. Develop an innovative ensemble climate prediction system based on high-resolution climate models for Europe for the near-term (~1-40years), including improved methods used to characterise uncertainty in climate predictions, regional downscaling, and evaluation against observations. 2. Use climate prediction systems to produce consistent, authoritative and actionable climate information. This information will be co-designed with users to constitute a robust foundation for Europe-wide climate service activities to support climate-related risk assessments and climate change adaptation programmes. 3. Demonstrate the value of climate prediction systems through high-impact extreme weather events over the recent past and near future, for, and with, targeted end users. 4. Develop, and publish, methodologies, good practice and guidance for producing and using authoritative climate predictions for 1-40 year timescale. The system will combine initialised climate predictions on the multi-annual timescale with longer-term climate projections and high-resolution regional downscaling.
- SPECS (Seasonal to decadal Prediction for the Climate improvement of European Climate Services; 2012-2017) was an FP7 project that undertook research and dissemination activities in order to deliver a new generation of European climate forecast systems, with improved forecast quality and efficient regionalisation tools such as to produce reliable, local climate information over land at seasonal-to-decadal time scales, and provide an enhanced communication protocol and services to satisfy the climate information needs of a wide range of public and private stakeholders.

2.4 UK Met Office (Met Office)

The Met Office was founded in 1854 and has since been the UK's National Meteorological Service. It is now a UK-government trading fund employing around 2000 staff including meteorologists, hydrologists, climate scientists, IT and support staff. The Met Office supplies operational data, products and services to many countries throughout the world 24 hours a day, 7 days a week, 365 days a year. It has always been at the forefront of meteorological scientific advancement, and in the last few decades has become a recognised world-leading organisation in climate science through its Hadley Centre for Climate Science and Services. The Met Office delivers world-class operational monthly, seasonal and decadal predictions and provides climate projections and advice. An independent review commissioned by the UK government in 2007 concluded that: "It is beyond dispute that the Met Office occupies a position at the pinnacle of world climate science".

There is a long history of operational near-term climate forecasting at the Met Office. Its Global Seasonal forecast system (GloSea) became operational in 2003 and benefits from parallel model developments for climate and weather prediction. For example, the system has employed interactive sea ice physics for many years, based on the model formulation for long-term climate prediction. The Met Office was among the first National Meteorological Services to gain World Meteorological Organization (WMO) status as a Global Producing Centre (GPC) for seasonal forecasts in 2006 and routinely provides ensemble forecasts to the current C3S Seasonal Prediction Service and the WMO-designated Lead Centre for Multi Model Long Range Forecast Ensembles at the Korean Meteorological Agency. It plays a regular role in WMO Regional Climate Forums, providing forecast input and advice for many regions worldwide. The Met Office played a leading role in the development of initialised decadal climate predictions. Met Office scientists transformed the field of decadal prediction when they published a 2007 Science journal paper outlining the first initialised climate forecasts for the coming decade. Since 2010, the Met Office has been coordinating an informal global multi-model exchange of decadal forecasts and disseminating the combined forecast information. In 2018, in recognition of the growing success of these efforts, the Met Office was officially designated the WMO Lead Centre for Annual to Decadal Climate Prediction (ADCP) and is one of the four WMO GPCs for Annual to Decadal Climate Prediction, with all European GPCs being partners in this proposal. The Met Office also co-chairs the Decadal Climate Prediction Project (DCPP) which contributes to both the 6th Coupled Model Intercomparison Project (CMIP6) and to the WCRP Grand Challenge on Near Term Climate Prediction (NTCP).

Met Office scientists regularly lead high-profile scientific papers on global and regional decadal climate prediction skill via detailed analysis of physical mechanisms. For example, the first skilful multi-year predictions of tropical Atlantic hurricane frequency from an initialised climate model (Smith et al 2010). A 2014 paper successfully forecast the climatic impacts of a predicted cooling of the North Atlantic sub-polar gyre over the coming 5 years, including an observed reduction in North Atlantic tropical cyclone activity (Hermanson et al 2014) and skilful predictions of the winter North Atlantic Oscillation (NAO) a season ahead (Scaife et al 2014) a year ahead (Dunstone et al 2016) and a decade ahead (Smith et al 2019). Another recent paper presented the first skilful prediction of Northern European summer rainfall (Dunstone et al 2018), using very large lagged ensembles from the Met Office decadal prediction system. The Met Office has also recently uncovered a potentially crucial paradox in forecasts for the North Atlantic that remains unresolved and has important implications for ensemble size and the generation of probabilistic forecast information (Scaife and Smith 2018).

The Met Office Hadley Centre has a long history of participation in European Union funded activities through their Research and Innovation Framework Programmes, and related to seasonal prediction.

Examples include leading the PRIMAVERA, EUCP, ENSEMBLES projects and the EUPORIAS project on sectoral applications of seasonal forecasts. Key participation in the PREDICATE and DEMETER projects and the EMULATE, DYNAMITE and SPECS project in which we investigated sources of long-range prediction skill. In the EUPORIAS and IMPREX projects, we have/are investigating the requirements for applications of seasonal forecasts and we are actively developing seasonal climate services for hydrology (IMPREX), transport (via the UK Government Department for Transport) and energy (with UK energy providers and the C3S ECEM project). The Met Office was also one of the original core providers of operational seasonal forecast data to the Copernicus Seasonal Forecast Service and continues in that role. We are a trusted partner in these projects and deliver agreed project outputs on time and in full, as demonstrated by our existing multi-year commitment and delivery to the Copernicus Climate Change Service for seasonal predictions.

2.5 Centro euro-Mediterraneo sui Cambiamenti Climatici (CMCC)

The Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) is a nonprofit research foundation. CMCC's mission is to investigate and model our climate system and its interactions with society to provide reliable, rigorous, and timely scientific results, which will in turn stimulate sustainable growth, protect the environment and develop science driven adaptation and mitigation policies in a changing climate. CMCC collaborates with experienced scientists, economists, and technicians, which work together in order to provide full analyses of climate impacts on various systems such as agriculture, energy, ecosystems, coasts, water resources, health, and economics. CMCC also supports policymakers in setting and assessing costs, mitigation, and adaptation policies.

CMCC acquired portfolio of research projects includes 265 funded projects: 37 funded projects in FP6 and FP7, 37 funded projects in H2020 and 191 funded projects under other EU and international research grants. In about a half of the implemented projects, CMCC acted as the coordinator.

The CMCC has ranked first in the area of Earth Sciences, and second in the area of Agricultural science (according to "quality of research" index) within the evaluation of the scientific research quality, conducted by the National Agency for the Evaluation of Universities and Research (ANVUR). The evaluation —whose main criteria were relevance, originality and international standing in selected scientific areas— was relative to the years 2011–2017 and it involved 134 institutions, such as Universities, Research Agencies and Consortia. These results confirm the preceding evaluation for the years 2004–2010 that also resulted in ranking CMCC at the top levels of the Italian research system.

CMCC scientists have a well-established experience in computational modelling of the global climate system. Through the years CMCC developed several generations of global climate models (GCM) that contributed to different phases of the CMIP effort (from CMIP3 to forthcoming CMIP6) informing the IPCC WG1 activities. Under the EU COPERNICUS program, CMCC contributes to the C3S operational, multi-model seasonal forecast system, with its own seasonal prediction system.

CMCC activities in decadal prediction started in 2009, in the framework of the EU-funded FP7 COMBINE project. In that occasion, CMCC developed a decadal prediction system based on the CMCC-CM model, following the CMIP5 near-term prediction protocol, thus contributing to the IPCC AR5 WG1 effort. Since then, CMCC scientists have been involved in several EU-funded initiatives, partly or fully related to decadal prediction and predictability. These include JPI-Climate, and H2020 Blue-Action and EUCP projects. In the context of the CMIP6-endorsed DCPP project, CMCC has developed an updated decadal prediction system based on the CMCC-CM2 model. This system will be used to deliver decadal hindcasts and forecasts following the DCPP protocol, contributing to the CMIP6 effort.

CMCC also has a well-established and renowned experience in the field of seasonal forecasts with over 20 years of continuous development. Most recently, in the framework the Copernicus Project C3S_433 Pre-Operational Phase of a multi-model seasonal forecasting system, CMCC has implemented in a fully operational configuration its most recent seasonal prediction system (SPS3 with 50 ensemble members) and all the associated procedures, script environment, data post-processing, transfer, archiving and backup strategies, organization and provision to run the system operationally.

In addition, CMCC holds strong expertise in the development and implementation of climate services at different time-scales in the framework of FP7 and H2020 projects, and C3S tenders (e.g., CLIM-RUN, CLARA, Clim-Tour). CMCC has recently entered the private market having direct collaborations with important stakeholders in the agriculture and renewable energy sectors. In particular, tailored products were made available for implementation in the decision-making process by extracting usable information and indicators from multi-model climate predictions.

CMCC participation to these European and international efforts is granted by the availability of its own SuperComputing Center (SCC) HPC facility. This HPC infrastructure will ensure the production of the simulations planned for C3.

CMCC has also been involved in several FP, H2020 and ERA4CS projects. Currently, these include (among others) PRIMAVERA, CRESCENDO, Blue-Action, EUCP, MEDSCOPE (coordinated by CMCC) and WINDSURFER.

3 Quality of Resources to be Deployed

3.1 Description of Resources

The tasks offered in this proposal will be implemented by an experienced team of researchers from Deutscher Wetterdienst (DWD), the Barcelona Supercomputing Center (BSC), UK Met Office (Met Office) and Euro-Mediterranean Center on Climate Change (CMCC). The contractor and subcontractors are able to mobilise highly-qualified human resources and are well-placed to execute the tasks of the contract. The proposed team of researchers, software engineers and managers possess the range of required skills and considerable experience in the assessment of decadal climate forecasts and a well-established history and reputation in climate services.

The partners participating in this offer have partly a long history of collaboration, both bilateral and on contract team-level. The team has documented capabilities in all the scientific and technical aspects related to decadal climate forecast. The team consists of the three European institutions contributing to the World Meteorological Organization Global Producing Centre for Annual to Decadal Climate Prediction (WMO GPC ADCP). The individuals involved are of the highest scientific and technical calibre.

The following table lists the skills of team members at the time of submitting the offer.

Table 2: List of key personnel and their engagement in months

Title	Broad description of work in relation to Service	Person	Qualifications	Effort / engagement in months
Contract leader	Ensures the correct execution of the contract from both the technical, scientific and administrative point of view	Barbara Früh (DWD)	Dr in Science and Head of Climate Projections and Climate Predictions	2, as in kind contribution
Service Manager	Supervision of the technical infrastructure needed for data exchange and application of multi-model analyses	Klaus Pankatz (DWD)	Diploma in science, experience in developing operational suite for decadal predictions	3, as in kind contribution
Scientist	Supervision of a case study on the	Andreas Paxian (DWD)	Dr in Science, experience in	2, as in kind contribution

	application of decadal climate predictions in water management (infrastructure)		developing user-oriented decadal prediction products	
Scientist	Case study application with Wupperverband	To be hired (DWD)	-	16
Team leader	Definition of operational and metadata standards and user-oriented forecast quality assessment	Francisco Doblas-Reyes (BSC)	PhD in Atmospheric Physics and department head	7.69
Scientist	Multi-model decadal prediction forecast quality assessment	Louis-Philippe Caron (BSC)	PhD in Atmospheric Sciences	11.47
Scientist	Case study on the application of decadal climate prediction to the agricultural sector	Albert Soret (BSC)	PhD in Environmental Engineering	4.75
Scientist	UK Met Office lead scientist and leader of work package 2	Nick Dunstone (Met Office)	PhD in Physics and team leader for Climate Dynamics Group	2
Team Leader	UK Met Office coordination and link to WMO activities including WMO Lead Centre for Annual to Decadal Climate Prediction (ADCP)	Adam Scaife (Met Office)	PhD in Meteorology and Head of Monthly to Decadal Climate Prediction; Professor and Head of Section	0.5
Scientist	Case study on the application of decadal climate prediction of North Atlantic cyclones for the (re)insurance industry	Julia Lockwood (Met Office)	PhD in Physics	10.25
Scientist	Definition of operational and technical metadata standards with application to WMO Lead Centre ADCP	To be hired (Met Office)	-	4,85
Team Leader	CMCC lead scientist	Silvio Gualdi (CMCC)	PhD in Geophysics, MSc in Physics. Head of Climate Simulations and Predictions Division	2

Scientist	Scientific consultant	Stefano Tibaldi (CMCC)	MSc in Physics, Professor	1, as in kind contribution
Scientist	Analysis of ensemble decadal predictions	Alessio Bellucci (CMCC)	PhD in Oceanography	4
Scientist	CMCC lead scientist	Panos Athanasiadis (CMCC)	PhD in Meteorology, MSc in Environmental Physics	4.5
Scientist	Development of climate service in co-operation with end-user (ENEL)	Stefano Materia (CMCC)	PhD in Geophysics	3
Scientist	Scientific analysis of decadal hindcasts and application to case study (CMCC)	To be hired (CMCC)	-	6.5

3.2 CV's of Key Personnel

Table 3 lists the names of the key personnel involved in the contract. All CVs are available in Annex I.

Table 3 List of key personnel CV's

Organisation	Key personnel
DWD	Barbara Früh Klaus Pankatz Andreas Paxian
BSC	Francisco Doblas-Reyes Louis-Philippe Caron Albert Soret
Met Office	Nick Dunstone Adam Scaife Julia Lockwood
CMCC	Panos Athanasiadis Stefano Materia Alessio Bellucci Silvio Gualdi

4 Technical Solution Proposed

4.1 Introduction

C3S, operated by ECMWF, is a significant European investment, enhancing Europe's capacity to adapt to climate change and reinforcing Europe's world-leading position on climate action and policy. The services will be based on a combination of world-class, authoritative data and tools following an advanced understanding of the public sector and market needs. The services will stimulate the market for climate services in Europe by overcoming the recognised barriers to entry, and hence will foster economic growth as well as societal benefits.

The contract team (DWD, BSC, Met Office, and CMCC) offers a technical solution based on two work packages, technical infrastructure for data encoding, processing and evaluation (section 4.2) and case-studies (section 4.3). The work package technical infrastructure offers the development of multi-model analysis techniques for decadal predictions and a recommendation for the implementation of a data-standard facilitating the exchange of model output between producing centres and users of the data. Furthermore, recommendations for post-processing techniques and evaluation methods are given. In the work package case studies, the decadal climate forecasts will be applied for the specific needs of selected users. The intention is to respond to the special needs of users and to achieve a high level of skill for their special climate service.

4.2 Technical infrastructure for data encoding and processing

4.2.1 Data origin

All data used for developing the recommendation of the data standard, post-processing, evaluation and multi-model analysis methods, as well as for the case studies, will be taken from the Decadal Climate Prediction Project (DCPP; Boer et al., 2016). However, the forecast initialised in November 2020 will be performed with the earth system models used at the contributing institutions (see Table 4).

Table 4 List of models used and their specifications

Institution	Model name	Atmospheric resolution	Ensemble size hindcast/forecast	Max. hindcast period depending on lead time
DWD	MPI-ESM-HR	~100 km (T127)	10/10	1960-2018
BSC	EC-Earth	80 km (T155)	10/10	1960-2018
Met Office	DePreSys4	~60 km (N216)	10/10	1960-2018
CMCC	CMCC-CM2	100 km	10/10	1960-2018

4.2.2 Technical infrastructure

The technical infrastructure for the data dissemination and the generation of products considers two main aspects:

- The formulation of recommendations for the standards needed for the production, exchange and dissemination of ensemble decadal predictions, dealing with the definitions to encode such data that are compatible with the currently established practices in the climate science community.
- The need for robust definitions of methods for the post-processing of the decadal forecasts and the evaluation of the forecast quality of the derived products for their adoption in an operational context.

Standards to encode and document metadata for both data and forecast products are necessary in an operational context. In the recent past, the research community has formulated some recommendations to standardise the decadal predictions with the goal of favouring the use of near-term climate information in real climate-sensitive applications. This has been the case of the CMIP-endorsed Decadal Climate Prediction Project (Boer et al., 2016), but also of the FP7 SPECS project. The creation of well-defined standards was motivated in previous instances because the data has been made available from community repositories. Many gaps have been left in the definition of these standards though. Standards in decadal forecast data should still consider aspects like the need for and advantages of using an ensemble dimension and more than one time axis (to uniquely identify the forecast start date, forecast period and validation time) in NetCDF files, the best way to uniquely identify both forecast systems and experiments in the metadata, the file naming that can help both users and data handling, the requirements for timely delivery of the forecasts (deadlines for the production workflow), etc.. On top of this, standards are required to identify the way forecast products (post-processed from forecast data) have been produced, an aspect also known as provenance, so that both traceability and reproducibility are ensured (Bedia et al., 2018).

The formulation of standards also needs to take into account the requirements formulated by WMO's Commission of Climatology and the minimum standards outlined in the WMO GDPFS Global Data-Processing and Forecasting System and also to consider recent advances in standards used with other C3S data types (seasonal forecasts, climate projections) in terms of metadata and delivery procedures, among others. In this context, the formulation of recommendations of any further standards for decadal prediction should engage into a discussion with the community. The goal is to avoid creating yet another standard disconnected from the rest of the community and to lead the coordination of this kind of definitions at the global scale.

Forecast system, data and product documentation are also essential elements for the quality assurance of both data and products, and a central contribution to the Evaluation and Quality Control (EQC) function of the C3S. Appropriate responses to the EQC requirements should be built at the time of defining operational standards for decadal prediction.

Concerning the second aspect, best practices for the formulation of multi-model products and the implementation of a real-time forecast quality assessment are still needed in an operational context. The technical solutions for the product generation have two different aspects:

- the robust definition and adoption of methods for post-processing of forecast data including the generation of multi-model products comparing different formulations
- best practices for forecast quality assessment that can feed the EQC of the decadal forecasts

In the past, these two objectives have been illustrated with simulations from coordinated experiments, but with no systematic assessment nor a list of recommended standards necessary for an operational context.

The forecast quality assessment process should start with the acknowledgement that forecast systems are not assessed in their entirety, but that in practice only forecast products can be evaluated. For instance, the estimation of probability forecast metrics like the ranked probability skill score are only performed for one variable and implies the transformation of the forecast data into a probability distribution, which involves specific choices on the data processing that might make the conclusions not relevant to other variables, products or metrics. It should also be acknowledged that forecast quality assessment is multi-faceted and that conclusions about the quality of a product can only be extracted considering simultaneously several metrics. The metrics used will consider the impact of using small ensembles by employing fair versions of the scores (Ferro et al, 2008; Ferro, 2014). Several benchmarks have been considered to measure skill against, e.g., persistence, climatology, uninitialised runs and empirical systems. However, a list with their specific properties is not yet available. Finally, forecast quality is typically measured ignoring the observational uncertainty role in the metrics, which given how far in the past hindcasts go can have a substantial contribution to the total uncertainty.

The exploration of the multi-model approach necessarily involves the comprehensive assessment of its relative merits with respect to the use of single forecast system to generate forecast products (Doblas-Reyes et al., 2013). The multi-model technique is expected to result in improved decadal climate prediction products. The relative merits of the multi-model technique in improving aspects of the forecast quality of the decadal predictions (Goddard et al., 2013) have also been addressed in the past, but much still remains to be clarified in terms of, for instance, reliability (where the multi-model technique should lead to more robust and trustworthy forecast uncertainty estimates than single forecast systems) and accuracy. To quantify the potential benefit, decadal climate forecasts from the institutions involved (MPI-ESM, DePreSys, EC-Earth, CMCC-CM2) will be used to formulate multi-model forecast probabilistic products that will be compared with both the single forecast systems and the larger multi-model managed by the Lead Centre. Temperature, sea level pressure and precipitation have traditionally been used in previous efforts (Smith et al., 2019) and will also be the basis of the work in this offer. In this comparison, the data from the forecast systems will be previously bias adjusted using a range of approaches implemented in standard freely-available software, such as Freva (developed in the framework of the MiKlip project), to reduce first-order systematic errors. The cost in terms of uncertainty and forecast quality of this recalibration needs to be illustrated as it is well known that both are affected by post-processing techniques, which should be applied in full cross-validation mode in the hindcasts.

Still in the context of the generation of user-relevant forecast products based on multi-model sources, user engagement exercises have identified the need for coherent climate stories that go beyond the ten-year horizon offered by current decadal forecasts. Initiatives like the H2020 EUCP project are trying to address this need by exploring methodologies that can bring together the best of the initialised and uninitialised climate simulations to reach time horizons that go up to 20 or 30 years.

4.3 Case studies

To demonstrate the capability and applicability of decadal climate prediction products DWD, BSC, Met Office and CMCC propose to perform several case studies including the application to the real-time forecasts initialised in November 2020. The tenderers cover a broad range of potential applications. More case studies than required in the ITT will be provided on a voluntary basis in order to handle the fact that some case studies might not succeed.

4.3.1 Infrastructure sector: Water management with Wupperverband (DWD)

The Wupperverband (https://wupperverband.de) manages water level (during floods and droughts) and water quality of the Wupper catchment in North-Rhine-Westphalia in Germany including water dams. First user contact to Wupperverband has already been established within the German MiKlip project on decadal climate predictions. The Wupperverband is strongly interested in decadal predictions of temperature, precipitation and droughts. Concerning the latter, they have expressed an interest in direct information on predicted drought conditions, e.g. the Standardized Precipitation Index (SPI) or the Standardized Precipitation-Evapotranspiration Index (SPEI, Paxian et al., 2018) or the extreme indices of the CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI, http://etccdi.pacificclimate.org/), or in the predictive potential of the input parameters for the calculation of such drought indices, e.g. air humidity, radiation or wind. High spatial resolution of predictions would be very much appreciated by the stakeholder for regional and local planning. Furthermore, the benefit of decadal climate prediction products would be higher if multi-year seasonal or half-year means of considered variables could be provided for certain lead times.

For improving the skill of the decadal forecast for the Wupper catchment, DWD plans to use existing high-resolution decadal predictions of the statistical downscaling method EPISODES (Kreienkamp et al., 2018) over Germany (12.5 km) and the Freva evaluation system developed within the MiKlip project to perform probabilistic skill analyses and real-time decadal prediction products. Prediction skill might be improved by statistical recalibration towards observational data using the Decadal Climate Forecast Recalibration Strategy (DeFoReSt) of Pasternack et al. (2018). Both ensemble mean and probabilistic skill scores are determined. First results of probabilistic prediction skill of EPISODES against high-resolution HYRAS observations (Rauthe et al. 2013, Krähenmann et al. 2018) applying the ranked probability skill score (RPSS, Ferro et al. 2008, Wilks 2011) are shown in Fig. 1. Strong skill of decadal predictions is found against the reference forecast observed climatology over Germany, especially for temperature. The EPISODES results are further compared to MPI-ESM from which global boundary conditions are taken.

The presentation of the final real-time decadal predictions initialised end of 2020 will be user-oriented and developed considering user feedback in order to support decision making. The data of the statistical downscaling EPISODES over Germany can be delivered, whereas the Freva software package can be used under free BSD license and the software to calculate ETCCDI extreme indices is open-source.

4.3.2 Agriculture sector: Crop yield with the Joint Research Center (JRC) (BSC)

Since the beginning of the 21st century, Europe has experienced a series of extreme summer droughts (Spinoni et al., 2019). For instance, the year 2018 was characterized by one of the worst droughts recorded in Europe, particularly over the Northern part of the continent. This event has also been identified as the sixth in a series of extreme summer drought that began in 2003 with heat

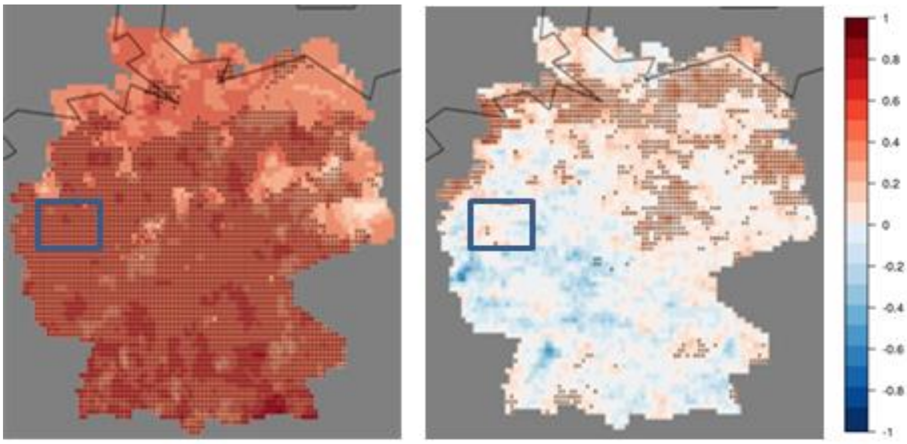

Figure 1: Probabilistic decadal prediction skill of recalibrated EPISODES predictions for 4-year mean temperature (left) and precipitation (right) for lead-year period 1–4 and 12.5 km spatial resolution over Germany: RPSS compared to the reference forecast observed climatology. Observations have been taken from HYRAS. The Wupper catchment is marked in blue and crosses denote significant skill scores at a significance level of 95 %.

waves across the entire European continent (Ionita et al., 2017).

The agriculture sector has been hit particularly hard by these continuing drought conditions: crop failure, low productivity and pasture losses have all contributed to severe economic losses during those years. Because the impact of severe drought is expected to increase over the upcoming decades due to anthropogenic climate change (Spinoni et al., 2018), there is a need for effective planning and adaptive actions, in particular at the multi-annual timescale.

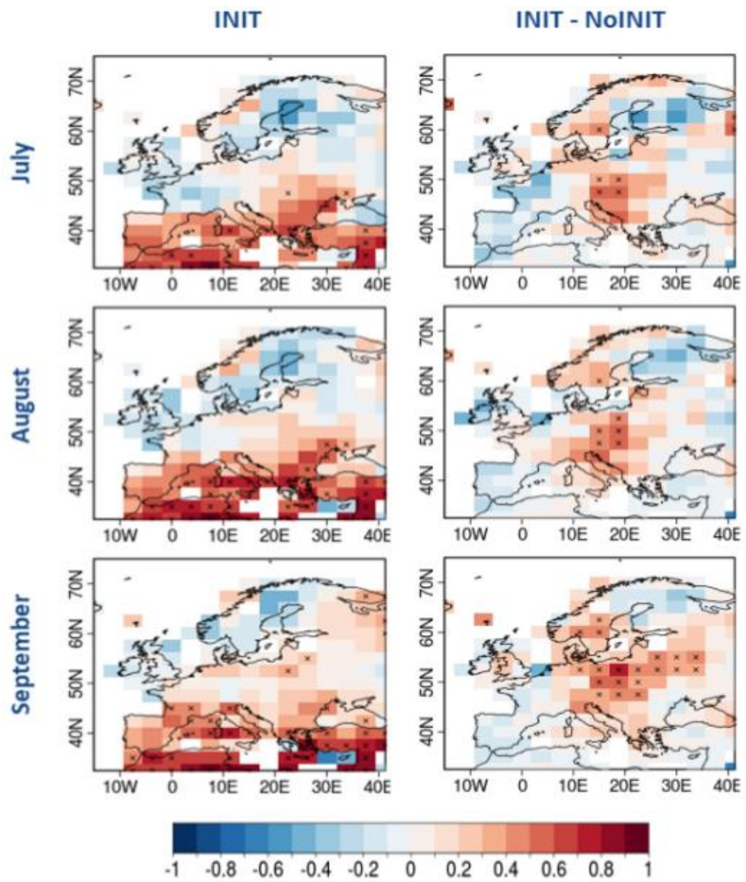

Figure 2: Ensemble-mean correlation coefficient of the SPEI6 index for the summer months (July to September) averaged over forecast years 2 to 5. The first column corresponds to the correlation of the initialized decadal simulations (INIT) while the second column shows the difference in correlation between initialized and uninitialized climate simulations (INIT-NoINIT). Dotted grids represent values statistically significant at 95% confidence level for SPEI6. The ensemble is composed of 6 forecast systems (CanCM4, EC-Earth v2, GFDL-CM2p1, HadCM3, MIROC5 and MPI-ESM-LR), which are initialized every November 1st between 1960 and 2005.

Although the essential climate variables are useful in indirectly accounting for the evolution of drought conditions affecting agriculture, drought assessment studies have traditionally relied on a variety of indicators. Meteorological drought indicators such as the Standardized Precipitation-Evapotranspiration Index (SPEI) are widely used in operational drought monitoring and early warning systems. SPEI is based on the climatic water balance (precipitation minus potential evapotranspiration) accumulated over a given number of months (Stagge et al., 2017).

Until now, little attention has been given to the evaluation of multi-annual drought conditions using drought indices and, particularly, on the added-value of initialized predictions over uninitialized climate simulations (Paxian et al., 2019). No study has yet assessed the regional forecast quality of decadal prediction systems at forecasting the seasonal evolution in drought conditions using drought indices. Such a study will be of great interest for decision makers in the agricultural sector, as the multi-annual forecasts of seasonal droughts coincide with the strategic planning of many stakeholders (Bruno Soares et al., 2018).

This case study aims at assessing the forecast quality of decadal predictions at forecasting seasonal drought conditions on a multi-annual time scale (e.g. over the forecast period 2 to 5 years) using SPEI indices and relate them to wheat and maize yield production at the global scale using local harvesting dates. We will also evaluate the skill of the index components (precipitation and potential evapotranspiration, in this case) to assess to what extent the individual components contribute to the overall skill. The forecast quality of the initialized experiments will be compared to the uninitialized simulations to assess the relative roles of both initialization and external forcing in providing multi-annual predictive skill (see Fig. 2 for an illustration).

The final goal is to determine whether this product can provide useful, and ultimately actionable, information to a number of stakeholders, with whom contacts have already been established in the agricultural sector (Decathlon for cotton, Codorniu for wine, Joint Research Centre for non-irrigated crops).

4.3.3 Insurance sector: Tropical and extratropical cyclones with Willis Research Network (Met Office)

The Met Office will further develop its existing relationship with the (re)insurance sector via the Willis Research Network (WRN; http://www.willis.com/willisresearchnetwork/) that works to integrate public science with (re)insurance communities in order to improve risk decision making. Here we focus on two regions where European (re)insurance companies are exposed to natural hazards: i) North Atlantic tropical cyclone frequency that can impact Carribbean and US east coast (during June-November), and ii) Northern European winter windstorm frequency. Both of these physical phenomena exhibit variability on multi-annual to decadal timescales which can lead to low frequency variability in financial losses. Here we will focus on developing prototype decadal climate services that could help provide skilful forecasts of changing risk information for the (re)insurance industry.

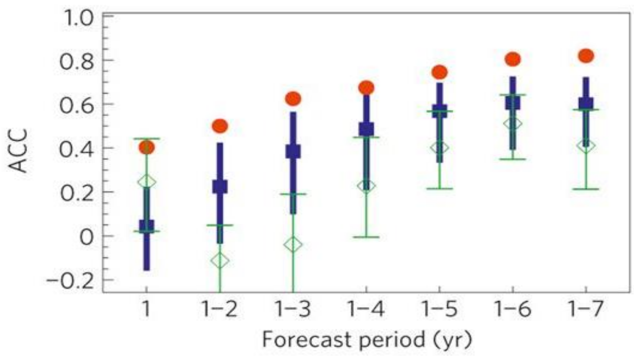

Figure 3: reproduced from Smith et al 2010 Nature Geoscience paper. It shows the correlation skill for hindcasts (1960-2009) of tropical Atlantic storm frequency from initialised decadal predictions (red dots) and how this increases as a function of forecast period. Note the improvement of initialised predictions over the uninitialised climate projections (blue squares) and a persistence forecast (green diamonds).

Our primary focus is on tropical Atlantic cyclone frequency where previous scientific publications (e.g. Smith et al 2010, Caron et al 2014, 2015, 2018) have shown skill in predicting multi-annual to decadal variability using initialised decadal prediction systems, see Fig. 3 for illustration. Model experiments show that this decadal skill is likely linked to low frequency North Atlantic sea surface temperatures (the Atlantic Multidecadal Variability) driven by ocean dynamics related to initialising the Atlantic Meridional Overturning Circulation (e.g. Dunstone et al 2011, Hermanson et al 2014) and also the changes in external forcing factors (e.g. anthropogenic aerosol emissions, Dunstone et al 2013). We will revisit the decadal skill in North Atlantic tropical cyclone frequency using the latest Met Office CMIP6 decadal hindcasts, updating and simplifying the methods to focus on simpler (and potentially more skilful) large-scale circulation predictors. We will liaise on a regular basis with (re)insurance industry experts, using the Willis Research Network project partner, to develop a useful demonstrator product which translates into (re)insurance sector losses. This will show utility over the hindcast (retrospective forecast) period and provide probabilistic uncertainty information to support decision making, with an example forecast made from November 2020. We will also investigate the utility of increased ensemble size and information from multi-model forecasts.

Our secondary focus is on European winter windstorm frequency which is strongly modulated by the phase of the North Atlantic Oscillation (NAO), the dominant mode of regional large-scale atmospheric circulation. Whilst traditionally extratropical circulation skill has been a more challenging prediction problem than in the tropics, recently NAO prediction skill has been demonstrated on seasonal (e.g. Scaife et al 2014), interannual (e.g. Dunstone et al 2016) and decadal (e.g. Smith et al 2019) timescales. We will make use of storm footprints made from daily and sub-daily climate model data from the EU H2020 PRIMAVERA project to establish links between storm losses and large-scale climate indices. We will liaise with (re)insurance industry experts to investigate the potential for a useful climate service to be developed and on what timescale this should focus on.

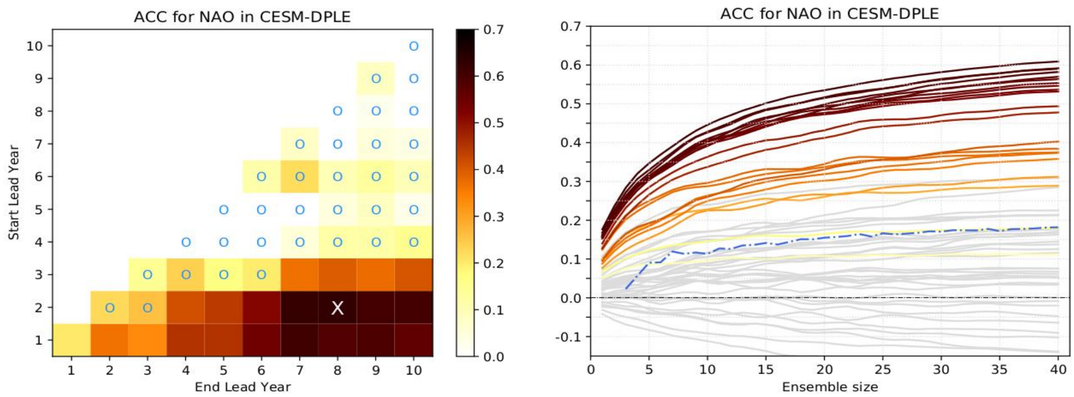

Figure 4: The predictive skill for the CESM-DPLE ensemble-mean measured by the Anomaly Correlation Coefficient (ACC) for the North Atlantic Oscillation. On the left, each cell below the diagonal corresponds to a different lead-year range defined by the start lead-year (ordinate) and the end lead-year (abscissa). The markers (o) indicate not statistically significant correlations. The X marker indicates the lead-year range with the highest ACC (0.63). On the right, the respective skill is computed as a function of the ensemble size (averaged for all possible combinations). Each line corresponds to a different lead-year range. Lines in colour correspond to statistically significant correlations for the full ensemble (N=40) following the same colour code as in the left panel.

4.3.4 Energy sector: Hydropower and solar energy with ENEL-GP (CMCC)

Enel Green Power S.p.A. is an Italian multinational renewable energy corporation. Enel Green Power has operations in over 30 countries in different continents. It generates energy mainly from hydropower (28.1 GW), wind (10.6 GW) and solar (3.7 GW) sources. Near-term climate variability has a large impact on these energy sources, and thus skillful decadal predictions can be of real value for ENEL-GP and other similar users. According to the skill that will be detected via the multi-model analysis (WP1), CMCC will provide probabilistic climate forecasts and indicators tailored to meet the needs of renewable energy production in different parts of the world (referring to: investment, mode of operation, risk assessment and adaptation). The significant predictive skill that has been recently documented for the NAO and other Euro-Atlantic circulation regimes [Smith et al. (2019)] can certainly benefit a wide range of societal applications and it provides a guide for the above-mentioned climate service. Figure 4 demonstrates even higher NAO skill for the Community Earth System Model Large-Ensemble Decadal Predictions (CESM-DPLE), according to which similar skill may be expected over Europe for variables like precipitation [Simpson et al. (2019)], wind and solar radiation.

ENEL and CMCC have already worked closely together developing a service that benefits from multi-model seasonal predictions, in particular regarding hydropower applications. Through this past, two-way interaction ENEL and CMCC have gained a high level of mutual acquaintance with the world lying on the other side, referring to the needs, possibilities, types of operation, limitations, variety of products, etc. This acquaintance provides an excellent base and a starting point for developing new climate services on a longer timescale (utilizing decadal predictions). As regards hydropower applications, ENEL could benefit from predictive information covering a range of different climatological aspects. For instance, it will be of interest to supply information regarding near-term trends in total annual precipitation along with its spatial and seasonal distribution, respective precipitation rates, the partitioning between snow and rain (temperature dependent), potential evaporation, frequency and duration of droughts, etc. This effort will benefit from both the output of dynamical models and the existing statistical relationships between large-scale variables and predictands over the regions of interest, allowing the production of decadal predictions targeted on specific geographic areas. In the first phase of the contract (M0-M3), ENEL, which offers a group of personnel representing different types of activities within the company (e.g. financial risk assessment, investments, managing power output, general planning), will work together with CMCC to identify best opportunities for assimilating the climate information available. In a second phase (M4-M14) and in successive loops of a "progress, feedback and improvement" process, CMCC and ENEL will build a multiple-component service focusing on hydropower. Then, in the final phase (M13-M18) the applications comprising that take part in the service will be evaluated in a number of different ways (usability, financial benefit, reliability, etc), and a detailed report will be included (in Deliverables 2.6.1-4) including a letter of evaluation from the user (ENEL).

4.3.5 Interaction of case studies with each other (WP2) and with recommended evaluation methods (WP1)

All case studies are coordinated in WP2. For each case study, the analysis protocol follows the steps of post-processing and evaluation of forecast quality outlined before. An essential part of each case study will be a robust skill analysis comparing past forecasts with observations as well as providing information on uncertainty. Even if the case studies work on different subjects and are highly user-focused and specialised, a two-way interaction between different case studies in WP2 and recommended methods for the evaluation of decadal predictions from WP1 is planned. Regular teleconferences will be held to share progress and discuss analysis methodologies. Thus, different case studies can learn from and advise each other in order to find the best way to reach skilful user-oriented decadal prediction products.

Furthermore, a minimum set of evaluation standards for decadal predictions (on a “best endeavours” basis) will be agreed on in WP1 and used by all case studies to harmonize the applied methods where appropriate and deemed beneficial. However, not all evaluation methods used and developed in WP1 can be adopted in WP2 because the case studies are focussed on very different user-specific products. Those cases where no uniform methods can be applied will be stated explicitly. The development of case studies will also lead to feedback on the definition of standard evaluation methods for decadal predictions in a two-way interaction, e.g. stating which theoretically recommended methods would or would not work in practice with user-oriented products.

A mid-term meeting in month 8 will assess whether each of the initially proposed case studies are likely to succeed (provide a useful demonstration of a decadal climate service) and if this is not the case then appropriate remedial actions (e.g. different forecast systems or product definitions) will be suggested for how to proceed (for discussion with ECMWF). Furthermore, the uptake of WP1 information in WP2 and the feedback from WP2 to WP1 will be evaluated.

4.3.6 Presentation and delivery of case studies

In order to showcase the findings of these case studies, a dedicated event will be organized by ECMWF. This will most likely be scheduled at the same time as the C3S General Assembly to be held at the end of 2020 or beginning of 2021. To prepare this event, the mid-term project meeting will discuss the results of all case studies and develop a strategy for presentation. A standard format for presenting the case studies to C3S and the users will be agreed on. Therefore, two deliverables covering all case studies are planned:

The first deliverable will cover for each individual case study the description of the user needs, the proposed decadal prediction products, the applied data sets, the post-processing methods, the skill scores, the results of skill analyses (plots) as well as the real-time prediction products based on 2020 initialisations (plots) including estimates of uncertainty. The report will also contain documentation for users describing the content and functionality of the case study as well as the feedback of the user on the usability of the developed products. This is likely to take the form of a short (~2 page) standalone 'factsheet' for each successful case study giving information relevant for the user of that climate service, together with a longer appendix where the technical details will be explained more fully.

The second deliverable will provide the datasets, software tools for post-processing and graphics used for compiling the report. The software will be made available to C3S via a FTP-server set-up by DWD for that purpose. The data can be accessed by C3S from this server and be copied to a storage area inside their DMZ.

Inputs to C3S communication material to promote the results and conclusions of the analysis undertaken will be provided when required.

4.4 Summary of equipment

Table 5: Equipment to be used for provision of the Service

Equipment	Describe Relevant Function	List each work package for which equipment will be used	Owned / To be Purchased / To be Leased
Pre-existing Technology			
Freva (Framework)	The Freie Universität Evaluation System (Freva) is a software framework for scientific IT	WP1, WP2	Use permitted under FreeBSD license

	infrastructures on HPCs. The technology starts, monitors and combines scientific applications and data retrievals including customized KPIs in web and shell for research projects.		
Freva (Plugins including control scripts)	The Freie Universität Evaluation System (Freva) contains modules which are written in python, R, NCL, Fortran and IDL	WP1, WP2	Use permitted under Gnu General Public License (GPL) and Creative Commons Attribution 4.0 License
CMCC: All utilized software (pre-existing) to prepare the data, evaluate the predictive skill relevant to the case study and integrate the climate service / produce output.		WP1 / WP2	Use permitted under GNU public licenses
Crop calendar	Global data set of monthly irrigated and rainfed crop areas around the year 2000 (MIRCA2000)	WP2	Creative Commons BY-SA 4.0 license
s2dverification	General purpose forecast quality analysis package in R that is parallelised (multi-core and multi-node versions) and installed on the CDS machine.	WP1, WP2	Use permitted under GPLv3
CSTools	Climate services R package for s2d predictions, including bias adjustment and plotting of	WP1, WP2	Use permitted under Apache2

	products		
Global decadal climate predictions	The global decadal predictions applied for skill analyses and forecasts	WP1, WP2	Earth System Grid Federation (ESGF) data download after registration
Regional decadal climate predictions from EPISODES	The regional decadal predictions applied for skill analyses and forecasts of the infrastructure case study	WP2	Terms of use of DWD: commercial purposes - unrestricted use The General Terms and Conditions of Business and Delivery apply for services provided by DWD (http://www.dwd.de/EN/service/terms/terms.html)
Global and regional observations and reanalyses	The observations and reanalyses applied for skill analyses of decadal predictions	WP1, WP2	freely available if source is acknowledged
Integrated Technology			
Planned Assets			
Post-processing and plotting scripts for common presentation standard	Post-processing and Visualization of case study products	WP2	Covered under Clause 3.4.3 of the Framework Agreement.

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5 Management and implementation plan

5.1 Introduction

DWD will be the main contractor in this proposal, manage the effort and subcontract three other institutions producing their own decadal climate predictions (BSC, Met Office, CMCC) and applying decadal forecasts for user oriented case studies (DWD, BSC, Met Office, CMCC). The coordinator and the subcontractors have expertise in the provision of decadal climate forecasts and in the development of climate services complementary to each other, while there is also an important overlapping of expertise to ensure that sufficient backup exists to cover the contract objectives and deliverables in case of problems.

5.2 General organisation

5.2.1 Contract Coordination

The coordination will be achieved by Dr Barbara Früh. Beyond coordination, DWD will maintain an interface with ECMWF, to ensure that the contractors have access to all the necessary information, to collect information that allows the standardisation of the contract outcomes, and to participate directly in most of the contract activities.

Dr Barbara Früh is the Head of the “Climate Projections and Climate Forecasts” unit of the “Central Climate Office” and leads a group of about 20 scientific staff members responsible for climate modelling and application activities at DWD. She has around 25 years of experience in climate research with a wide range of research issues (radiative transfer modelling in cloudy and aerosol loaded atmosphere, downscaling mesoscale meteorological data in complex orography, triggering mechanisms of convective precipitation, analysis of extreme events). She joined the DWD in 2008. She is coordinator of the C3S_330 and also involved in C3S_512 contract. In addition, she is coordinating the international CLM-Community who is employing and further developing the regional climate model COSMO-CLM.

Mr Klaus Pankatz will be the Service Manager of C3S_34c being in charge of the day-to-day management of C3S_34c, monitoring of planning and progress in the implementation, liaising with ECMWF contract officers, coordinating the reporting to ECMWF and the coordinator, monitoring the proposal for corrective and preventive actions, facilitating the communication with ECMWF and the subcontractors, setting up of contract meetings and contract reviews. The backup for Klaus Pankatz will be Dr Andreas Paxian.

Klaus Pankatz is a research scientist at DWD since 2016. He has 8 years of experience in near-term climate prediction and modelling. At DWD, he works on the operational suite which will start the production of yearly decadal predictions in 2020. Within the MiKlip project, he was involved in the development of the prototype decadal prediction system and the development and transfer of statistical evaluation tools to DWD.

The Administrative Manager, Mr Thorsten Plath, is in charge of monitoring of the financial and administrative implementation of the contract, supporting the team and subcontractors in the implementation of the financial rules and requirements derived from the Framework Agreement, supporting the contract team in preparing their financial payment requests and dealing with the formalities of the financial reports and of the financial checks and audits.

5.2.2 Subcontracts

Two subcontractors of the DWD (Met Office and BSC) will each lead a thematic work package (WP) aimed at tailoring the tasks to the main expertise of each subcontractor thus achieving maximum efficiency. The third subcontractor, CMCC, will contribute to the development of the tasks, and milestones, and the accomplishment of the deliverables with their well-recognised expertise in multi-model ensemble evaluation and case-studies tending to user needs.

5.2.3 Work packages

The contract is structured in two technical and one management and communication work packages (WPs).

WP0 will ensure the management of the contract, including reporting and linking to C3S, the partners and other relevant C3S contractors, and the communication across the other WPs. WP1 will assess the technical infrastructure for the decadal prediction data to be submitted to C3S and users. WP2 will engage with potential users of decadal predictions to develop case studies of data usage and skill analysis.

Table 6: List of work packages and work package leaders

WP	WP Title	Name of WP Leader
WP0	Management and Coordination	Klaus Pankatz, DWD Deputy: Dr Barbara Früh
WP1	Technical aspects for data encoding and processing	Dr Louis-Philippe Caron, BSC Deputy: Prof. Francisco Doblas Reyes
WP2	Case studies	Dr Nick Dunstone, Met Office Deputy: Prof. Adam Scaife

5.2.4 Communication

Monthly remote conferences with subcontractors will be scheduled to document progress. These teleconferences will allow the contractor to prepare the monthly teleconferences and regular review meetings will be held with ECMWF, discussing the current status of the contract. It will also be an opportunity to discuss technical and scientific problems and to mitigate risks for the contract.

In the event that any issue arises that requires solution, the first point of contact will be the contract coordinator. The Service Manager will be responsible for working with C3S to agree on an action plan to resolve the issue, informing the steering committee of the progress until a satisfactory resolution has been reached. In the event that escalation is required, C3S will contact the contract leader.

5.2.5 Travel expenses

Travel expenses will be expected for one face-to-face mid-term meeting in Offenbach in June 2020. In addition, a community workshop on ‘Data Standards for Climate Predictions’ will be organised to discuss the different requirements on data standards with a focus on decadal forecasting in Barcelona in spring 2020. This meeting will be organised in coordination with as many relevant agencies and initiatives as possible (CMIP and WCRP, WMO’s Commission of Climatology, etc.), always subject to approval by C3S. Some meetings with individual users involved in the case studies are assumed to take place when required. The participation of some of the contract representatives at the Copernicus General Assemblies should also be enabled in November 2019 and the following one in 2020. If the dedicated event for showcasing the results of the case studies is separate from the Copernicus General Assembly, additional financial resources must be earmarked to cover costs.

Table 7: List of meetings in C3S_34c

Meetings foreseen in C3S_34c

M4-M7	Workshop: "Data Standards for Climate Predictions"
M8	Mid-term meeting; all WPs
TBC	Participation in the C3S General Assembly 2020/2021

5.2.6 Audit

DWD does not have an auditor. As with other C3S contributions of DWD we propose a statement of the Chief Financial Officer (CFO) or equivalent of DWD.

5.2.7 Data Protection

There are no plans to collect personal information. However, it is noted that the DWD adheres to the EC legislation and organisational guidelines with regard to the protection of any personal data (including EU Directive 95/46/EC).

5.2.8 Custody of Deliverables

ECMWF will take care of the deliverables. According to WP2 description, means to conduct the user case studies will be transferred to ECMWF at the end of the contract.

DWD will have all means in place for the repository and archiving of the deliverables not archived by ECMWF during and after (at least 6 years) the contract.

Master copies of all deliverables will be stored at DWD during the full duration of the Framework Agreement.

5.3 Organigram

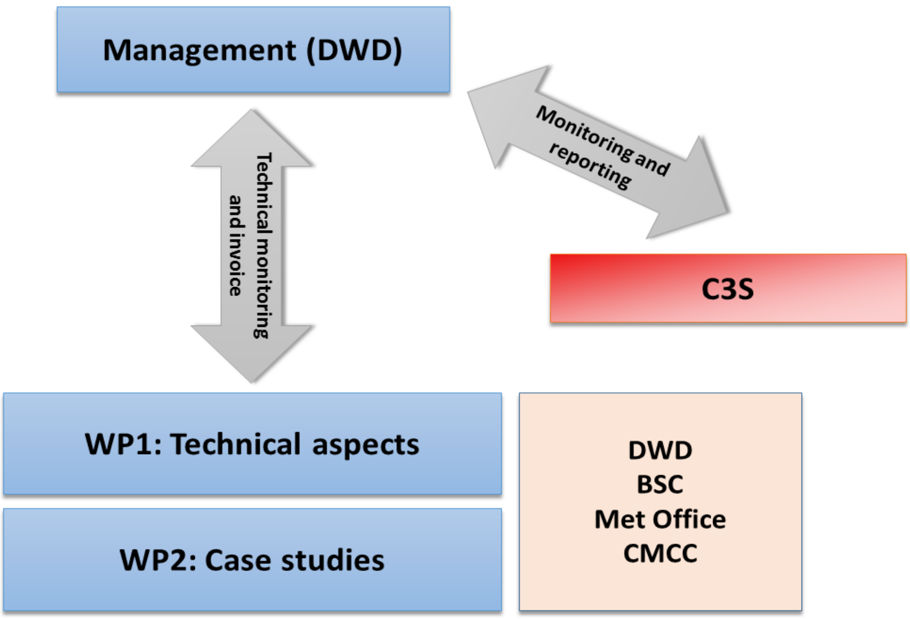

Figure : Organigram

5.4 Gantt chart and PERT chart

	Year	2019		2020												2021			
	Month	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18
WP	Tasks	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mrz	Apr
WP0	Task 0.1																		
	Task 0.2	M0.2.1	M0.2.2	M0.2.3	M0.2.4	M0.2.5	M0.2.6	M0.2.7	M0.2.8	M0.2.9	M0.2.10	M0.2.11	M0.2.12	M0.2.13	M0.2.14	M0.2.15	M0.2.16	M0.2.17	M0.2.18
	Task 0.3							M0.3.1											
	Task 0.4									M0.4.1									
	Task 0.5																M0.5.1		
WP1	Task 1.1						M1.1.1							D1.1.1		D1.1.2			
	Task 1.2									M1.2.1				D1.2.1				D1.2.2	
WP2	Task 2.1									M2.1.1			M2.1.2						
	Task 2.2												M2.2.1				M2.2.2		
	Task 2.3												M2.3.1				M2.3.2		
	Task 2.4												M2.4.1				M2.4.2		
	Task 2.5												M2.5.1				M2.5.2		
	Task 2.6													D2.6.1 D2.6.3				D2.6.2	D2.6.4

DWD | Met Office

BSC | CMCC | Collaboration

Figure 1: Gantt-chart

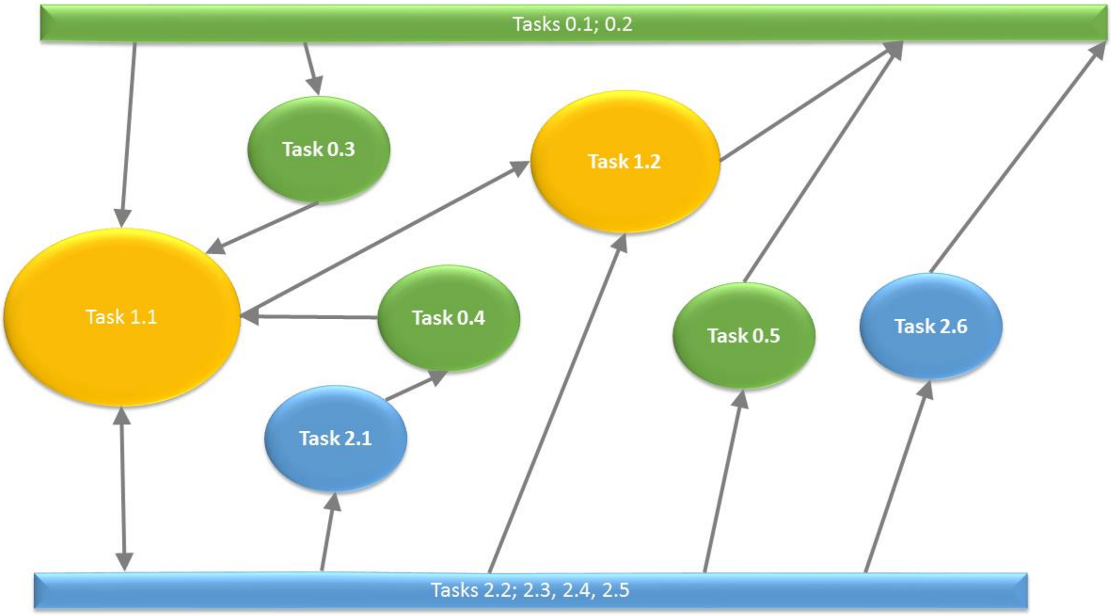

Figure 2: PERT-chart

5.5 Work package description

Table 8: Work packages

Work package #	WP0	**Start/End date**	**M1/M18**
Work package title	**Management and coordination**		
Participants (person months)	DWD (5 + in kind contribution), BSC (0.5), CMCC(1), Met Office(0.5)		
Other main direct cost elements	Organisation of a mid-term meeting, an international workshop on data standards, and an event to showcase the findings of the case studies at the C3S General Assembly; travel costs: C3S_34c meetings, workshop on data standards and C3S general assembly; audit costs		

Main objectives

This work package will ensure the management of the contract, including reporting and links to ECMWF, the partners and other relevant C3S contractors.

Description of activities

Task 34c.0.1 (DWD, CMCC; M1 - M18) contract management plan, strategy for the communication within the contract team and with C3S coordination. Monthly teleconferences and regular review meetings will be held with ECMWF to ensure the monitoring of the proceedings of the contract.

Task 34c.0.2 (DWD; M1 - M18) monitoring the deliverables and milestones, provision of brief quarterly reports, annual reports and the final report. Minutes of monthly remote conferences with subcontractors

Task 34c.0.3 (BSC; M4 - M7) Workshop on data standards for climate predictions: A community workshop on 'Data standards for climate predictions' will be organised to discuss the different requirements on data standards in Barcelona in spring of 2020, with a focus on decadal forecasting. This meeting will be organised in coordination with as many relevant agencies and initiatives as possible (CMIP and WCRP, WMO's Commission of Climatology, etc.), always subject to approval by C3S. A letter of support from a key representative of the group in charge of defining strategies for data documentation, storage and dissemination of CMIP simulations for the workshop is already attached. This commitment of such a community is very important to reach a long-standing agreement that makes C3S pave the way for a globally acceptable standard. The workshop aims at developing a common standard for the identification of both data and products, which should be agreed with the rest of the community, accepted by the WMO Lead Centre and developed in collaboration with the C3S_512 contract (EQC for the CDS, led by BSC) for compatibility with other Copernicus activities.

Task 34c.0.4 (DWD; M6 – M8) organisation, preparation, and realisation of the mid-term meeting

Task 34c.0.5 (Met Office, DWD, CMCC, BSC; M11 - M16) organisation, preparation, and realisation of the event to showcase the findings of the case studies

Deliverables and Milestones

D34c.0.2.1-2019 (DWD, M1) Report: Finalized Implementation plan 2020
D34c.0.2.2-2020 (DWD, M4) Report: Draft Implementation plan 2021
D34c.0.2.3-2020 (DWD, M12) Report: Finalized Implementation plan 2021
D34c.0.2.5-2019Q4 (DWD, M3) Report: Quarterly Report Q4 2019
D34c.0.2.6-2020Q1 (DWD, M6) Report: Quarterly Report Q1 2020
D34c.0.2.7-2020Q2 (DWD, M9) Report: Quarterly Report Q2 2020
D34c.0.2.8-2020Q3 (DWD, M12) Report: Quarterly Report Q3 2020
D34c.0.2.9-2020Q4 (DWD, M15) Report: Quarterly Report Q4 2020
D34c.0.2.10-2021Q1 (DWD, M18) Report: Quarterly Report Q1 2021
D34c.0.2.11-2019 (DWD, M3) Other: Preliminary financial information 2019

D34c.0.2.12-2019 (DWD, M15) Other: Preliminary financial information 2020 D34c.0.2.13-2019 (DWD, M15) Other: Preliminary financial information 2021 D34c.0.2.14-2019 (DWD, M4) Report: Annual Implementation Report 2019 D34c.0.2.15-2019 (DWD, M16) Report: Annual Implementation Report 2020 D34c.0.2.16-2019 (DWD, M8) Report: Copy of prime contractor's general financial statements and audit report 2019 D34c.0.2.17-2019 (DWD, M8) Report: Copy of prime contractor's general financial statements and audit report 2020 D34c.0.2.18-2020 (DWD, M18) Report: Copy of prime contractor's general financial statements and audit report 2021 D34c.0.2.19-2019 (DWD, M8) Report: Letter from Chief financial Officer specific to C3S contract 2019 D34c.0.2.20-2019 (DWD, M18) Report: Letter from Chief financial Officer specific to C3S contract 2020 D34c.0.2.21 (DWD, M18+60 days): Report: Final Report to include Appendices reporting implementation in Q2 2021 and year 2021 respectively M34c.0.1.1 (DWD, M3): Technical note: Provision of table of Key Performance Indicators (KPI) M34c.0.1.2 (DWD, M4): Technical note: Recruitment at DWD M34c.0.2.1-18 (DWD, M1-18): Report: Monthly remote conferences with subcontractors M34c.0.3.1 (BSC, M7) Report: Minutes of the workshop on data standards for decadal forecasting M34c.0.4.1 (DWD, M9) Report: Minutes of the face-to-face mid-term meeting M34c.0.5.1 (Met Office, M16) Report: Conclusions of the case study show-case event

Work package #	WP1	**Start/End date**	**M1/M17**
Work package title	**Forecast data encoding and processing**		
Participants (person months)	BSC (14.91), CMCC (7), DWD (4), Met Office (5.35)		
Other main direct cost elements	Travel costs: mid-term review meeting and C3S general assembly; data storage		

Main objectives

This WP will develop recommendations for the production of decadal forecasts/hindcasts and a set of derived products, developing standards for the identification and dissemination of both data and products and the documentation of the systems. It will also produce a framework for the quality assessment of the resulting products and illustrate the benefits and relative merits of the multi-model technique. Best practices will be formulated in discussion with the activities of the Lead Centre for Annual-to-Decadal Climate Prediction.

Description of activities

This WP addresses the need for robust definitions of methods for the post-processing of the decadal forecasts and the evaluation of derived products for their adoption in an operational context. The work includes providing requirements for the technical infrastructure required for the production, exchange and dissemination of ensemble decadal predictions, dealing with the definition and adoption of standards for encoding such data, compatible with the currently established practices in the climate science community. Best practices for the implementation of a real-time forecast quality assessment and the formulation of multi-model products, with the assessment of its relative merits with respect to the use of single forecast system products, will be also discussed. The recommendations formulated will be based on the work made by the research community to favour the use of near-term information in real climate-sensitive applications and, as such, will be based on the experience of previous research projects where user requirements have been gathered but not synthesised. Data from the DCPP-A and B CMIP6 experiments and a set of observational references and reanalyses will be used to illustrate the recommendations, taking into account that the data will reside in community repositories to ensure compatibility of the recommended rules with any well-established standards.

Task 34c.1.1 (BSC, Met Office, CMCC, DWD; M1-M15) Encoding standards for forecasts and products: Standards for the search, identification and dissemination of both forecast data and products for multi-model systems following the C3S criteria of free accessibility to robust, credible, quality-controlled data and information will be collected and presented to C3S with a critical analysis. Any additional standards needed will be developed after discussion with the community (a workshop is planned in WP0 to ensure that the recommendations stand a chance to become the default standard for decadal prediction), taking into account the solution currently in use for research purposes (DCPP data in ESGF nodes following the CMOR convention), the requirements formulated by WMO's Commission of Climatology, and considering current standards followed by C3S for other data types (seasonal forecasts, climate projections). The standards will consider aspects like the need for and advantages of using an ensemble dimension and more than one time axis (to uniquely identify forecast start date, forecast period and validation time) in the NetCDF files with the forecast data, the best way to identify both forecast systems and experiments in the metadata and the requirements for a provenance solution for the forecast products. Requirements (e.g. forecast system documentation) will also be discussed with the goal to feed the Evaluation and Quality Control function of the C3S. The Met Office will ensure compatibility of new data standards with WMO Lead Centre prediction activities. A minimum list of variables and their frequencies to be disseminated by C3S, including all realms available (atmosphere, ocean, sea ice), will be provided.

Task 34c.1.2 (DWD, BSC, CMCC, Met Office; M4-M17) Product generation and forecast quality assessment recommendations: This task focuses on two particular aspects: 1) the robust definition and adoption of methods for post-processing of forecast data including the generation of multi-model products comparing different formulations and 2) best practices for forecast quality assessment that can feed the EQC of the decadal forecasts. Both aspects will be illustrated using the DCPP-A simulations, with a special focus on the subset of forecast systems from the four participating producing centres. The relative merits of the multi-model technique in improving aspects of the forecast quality of the decadal predictions, with particular attention to reliability and accuracy, will be summarised using mainly temperature and precipitation data with appropriate benchmarks. A comparison of the European multi-model that currently provides real-time forecasts (and, hence, could be a timely source of decadal prediction data for C3S) and the global multi-model forecasts collected by the WMO Lead Centre that uses all the available forecast systems worldwide will be carried out. DWD will use the method of recalibration on the multi-model system. Recalibration includes correction to bias, drift, conditional errors and ensemble spread. The impact of the observational reference uncertainty will be taken into account through the use of more than one reference dataset and the effect of the sample size will be taken into account through the use of fair scores or bootstrap resampling. The multi-model product examples will include the ensemble mean anomalies for a set of regions, maps of the most likely tercile, key indices (global mean temperature, Atlantic multi-decadal variability and interdecadal Pacific oscillation indices, standard estimates of extremes and user-relevant indicators). Finally, given that the (uninitialized) climate projections offer the possibility to further the prediction horizon into the future beyond the ten year horizon, the approaches currently being explored by the EUCP H2020 project to formulate coherent climate information products beyond the ten years typically considered in decadal prediction will be reported. The methods used and developed in WP1 will be adopted in WP2 as they become available and deemed beneficial for WP2. A minimum set of evaluation standards for decadal predictions (on a "best endeavours" basis) which will be used by all case studies will be agreed on.

Deliverables and Milestones

D34c.1.1.1 (BSC, M13) Report: Draft recommendations for encoding standards for decadal forecast data and products
D34c.1.1.2 (BSC, M15) Report: Recommendations for encoding standards for decadal forecast data and products.
D34c.1.2.1 (BSC, M13) Report: Draft recommendations on forecast quality assessment for decadal predictions
D34c.1.2.2 (BSC, M17) Report: Recommendations on forecast quality assessment for decadal predictions.
M34c.1.1.1 (Met Office, M6) Report: Description of the Lead Centre activities and interaction with a potential C3S decadal prediction service.
M34c.1.2.1 (CMCC, M9) Report: Description of forecast assessment performed for decadal predictions in research.

Work package #	WP2	Start/End date	M1/M18
Work package title	Case studies		
Participants (person months)	Met Office (11.75), BSC (8.5), CMCC (12), DWD (7)		
Other main direct cost elements			

Main objectives

To demonstrate the capability and applicability of decadal climate prediction products, DWD, BSC, Met Office and CMCC will perform one case study each including up-to-date forecasts up to 10 years ahead covering the proposed sectors. All case studies follow an analysis protocol including post-processing, skill analysis and uncertainty information, e.g. via bootstrap resampling or fair scores.

A two-way interaction between different cases studies in WP2 and recommended methods for the evaluation of decadal predictions from WP1 is planned, e.g. via regular teleconferences. The minimum set of evaluation standards ("best endeavours") for decadal predictions of WP1 will be used by all case studies to harmonize the applied methods where appropriate and deemed beneficial. Those cases where no uniform methods can be applied because the case studies are focussed on very different user-specific products will be stated explicitly. The development of user-oriented case studies will also feedback on the definition of theoretical standard evaluation methods.

A technical note following the mid-term meeting will describe the analysis protocol undertaken by each case study, assess whether each of the studies are likely to succeed (provide a useful demonstration of a decadal climate service) and if this is not the case then appropriate remedial actions will be suggested for how to proceed (for discussion with ECMWF).

A standard format for presenting the case studies to C3S and the users will be agreed on at the mid-term meeting. The report is likely to take the form of a short (~2 page) standalone 'factsheet' for each successful case study giving information relevant for the user of that climate service, together with a longer appendix where the technical details of the forecast methodology, datasets, evaluation methods and further information will be explained more fully. Furthermore, the datasets and post-processing software used for compiling the report will be provided.

Description of activities

Task 34c.2.1 (Met Office, DWD, BSC, CMCC; M11-M12): common standard for presenting the case studies to be discussed at mid-term meeting.

Task 34c.2.2 (DWD; M1-M17) Case study on infrastructure sector - for details see Section 4.3

Task 34c.2.3 (Met Office, BSC; M1-M17) Case study on insurance sector - for details see Section 4.3

Task 34c.2.4 (BSC, CMCC, DWD; M1-M17) Case study on agriculture sector - for details see Section 4.3

Task 34c.2.5 (CMCC, BSC; M1-M17) Case study on energy sector - for details see Section 4.3

Task 34c2.6 (DWD, Met Office, BSC, CMCC; M13-18): collect data and evaluation tools used for the case studies.

Deliverables and Milestones

D34c.2.6.1 (Met Office, M13) Report: Draft package of case studies on the capability and applicability of decadal climate prediction products
D34c.2.6.2 (Met Office, M17) Report: Package of case studies on the capability and applicability of decadal

climate prediction products D34c.2.6.3 (DWD, M13) Data/software: Draft data and post-processing software for performing the case studies D34c2.6.4 (DWD, M18) Data/software: Data and post-processing software for performing the case studies M34c.2.1.1 (Met Office, M9) Technical note: Report on current status of analysis in each of the 4 case studies and decision on the way forward M34c.2.1.2 (Met Office, M12) Technical note: Common presentation standard of case studies for showcase event and subsequent reports M34c2.2.1 (DWD, M13) Technical note: Status of user-oriented forecast quality analysis and real-time predictions for case study on infrastructure M34c2.2.2 (DWD, M16) Technical note: Completion of user-oriented forecast quality analysis and real-time predictions for case study on infrastructure M34c2.3.1 (Met Office, M13) Technical note: Status of user-oriented forecast quality analysis and real-time predictions for case study on insurance M34c2.3.2 (Met Office, M16) Technical note: Completion of user-oriented forecast quality analysis and real-time predictions for case study on insurance M34c2.4.1 (BSC, M13) Technical note: Status of user-oriented forecast quality analysis and real-time predictions for case study on agriculture M34c2.4.2 (BSC, M16) Technical note: Completion of user-oriented forecast quality analysis and real-time predictions for case study on agriculture M34c2.5.1 (CMCC, M13) Technical note: Status of user-oriented forecast quality analysis and real-time predictions for case study on energy M34c2.5.2 (CMCC, M16) Technical note: Completion of user-oriented forecast quality analysis and real-time predictions for case study on energy

5.6 Key Performance Indicators

Table 9: Key Performance Indicators

KPI #	KPI Title	Performance Target and Unit of Measure	Frequency of Delivery	Explanations / Comments
1	Contract management	Percentage of deliverables submitted on time: target 100%	Annually	To be included in the annual report
2				
3				
4				

The full list of KPIs will be decided between DWD and ECMWF and documented in Milestone M34c.0.1.1.

5.7 Risk management

Table 10: Risk Register for each Work package

Work package: WP0					
Risk Name	**Description**	**Likelihood**	**Impact**	**Response Strategy**	**Period**
R2: Staff availability and disruption	Risk of key staff assigned to the service not being available (at the start of their work or being unavailable), resulting in the objectives of the service not being	2	2	Reliance on single points of expertise will be reduced at all times by making sure that multiple team members are able to work on the service, by documenting task progress and by identifying redundancies.	M1-M18

	delivered, or delivered late			Each partner has identified personnel in their department that can cover for any lack of availability of the team members due to new duties, illness or any unforeseen need for reallocation of the personnel mentioned in the proposal.	
R3: Delay on hiring non-permanent staff	Several positions will have to be filled with non-permanent staff, which requires announcing the positions and going through a selection process	2	2	The recruitment process will start as early as possible. In the time the position is not filled, already hired and identified personnel at the institutions will cover the tasks to be performed.	M1-M18

Work package: WP1					
Risk Name	**Description**	**Likelihood**	**Impact**	**Response Strategy**	**Period**
R4: Lack of agreed standard for data encoding and dissemination	Given that several options of standards for encoding and dissemination of climate data exist, there is a risk of not reaching an agreement for decadal prediction	2	3	Agree a minimum set of standards compatible with the WMO Lead Centre and Copernicus.	M1-M15
R5: Lack of agreed standard for post-processing and evaluation	Given that several options of standards for post-processing and evaluation of climate data exist, there is a risk of not reaching an agreement for decadal prediction	2	3	Agree a minimum set of standards compatible with the WMO Lead Centre and Copernicus	M1-M17

Work package: WP2					
Risk Name	**Description**	**Likelihood**	**Impact**	**Response Strategy**	**Period**
R6: Case studies run into problems	Some case studies might run into problems or turn out to be less successful.	2	3	Meeting to be held at M8 to analyze progress in each case study and with all partners and ECMWF decide on the way forward. A Milestone Report will document the conclusions of this meeting	M6-M12
R7: Lack of agreed standard for	Case studies are too different to find a common standard	3	1	The tenderers will agree on a minimum standard format for case studies.	M1-M18

case studies	for presenting.				
R8: User terminates cooperation	Some case studies might not be successful because user terminates cooperation	2	3	The tenderers will cover more case studies to be able to deliver at least the expected 2-4.	M1-M18

Work package: WP0					
Risk Name	**Description**	**Likelihood**	**Impact**	**Response Strategy**	**Period**
R9: availability of forecasts for 2020 initial conditions	The forecasts for 2020 initial conditions of a partner might not be available or coming late	1	2	Since it is very unlikely that the 2020 forecasts from all partners will not be available in time (three of the four centers have an operational commitment in the WMO GPC-ADPC). The case studies will all use the forecasts available.	M14 – M18
R10: Budget cut due to Brexit	The UK leaving the EU may have financial consequences on availability of funds.	1	4	review of possible mitigation with ECMWF when more information is known and if the risk comes to reality	M1 – M18
R11	UK entities no longer eligible for Copernicus	1	1	review of possible mitigation with ECMWF when more information is known and if the risk comes to reality	