Convocatorias 2017
Proyectos EXCELENCIA y Proyectos RETOS
AGENCIA ESTATAL DE INVESTIGACIÓN

AVISO IMPORTANTE

En virtud del artículo 16 de la convocatoria **NO SE ACEPTARÁN NI SERÁN SUBSANABLES MEMORIAS CIENTÍFICO-TÉCNICAS** que no se presenten en este formato.

Es obligatorio que la memoria contenga los tres apartados (A, B y C). La parte C de la memoria no podrá exceder de 20 páginas.

Lea detenidamente las instrucciones para rellenar correctamente esta memoria, disponibles en la web de la convocatoria.

Parte A: RESUMEN DE LA PROPUESTA/SUMMARY OF THE PROPOSAL

INVESTIGADOR PRINCIPAL 1 (Nombre y apellidos)**:**

Francisco Doblas Reyes

INVESTIGADOR PRINCIPAL 2 (Nombre y apellidos)**:**

TÍTULO DEL PROYECTO: Predicción decadal del clima para los servicios climáticos y la adaptación en el futuro cercano

ACRÓNIMO: CLINSA

RESUMEN Máximo 3500 caracteres (incluyendo espacios en blanco):

El acceso a la información sobre el clima en escalas de tiempo interanuales a decadales basadas en predicciones del clima se ha convertido, dada la estrecha relación entre el cambio climático y la variabilidad natural del sistema climático, en un reto social para muchos sectores socio-económicos, como la seguridad alimentaria y la energía.

El reto de predecir el clima global en escalas de tiempo interanuales a decadales de forma fiable y precisa requiere la capacidad de simular adecuadamente tanto la variabilidad del clima como el cambio climático antropogénico, y la capacidad para dar al sistema de predicción las mejores condiciones iniciales posibles de manera que las simulaciones estén en fase, en la medida de lo posible, con la evolución del clima observado. El Departamento de Ciencias de la Tierra del Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) es capaz de abordar este desafío utilizando su sistema global de predicción climática basado en el modelo EC-Earth. EC-Earth ha sido usado recientemente en experimentos de predicción del clima, incluyendo simulaciones de las desaceleraciones y aceleraciones de clima global, un aspecto que recientemente ha provocado intensas discusiones. Una nueva versión de EC-Earth estará disponible en breve, con características que la hacen particularmente interesante para el desarrollo de un sistema de predicción decadal.

El proyecto CLINSA aborda la creación de un sistema de predicción decadal a través de dos actividades que están estrechamente ligadas. En primer lugar, se propone el desarrollo de una capacidad para la realización de predicciones decadales que incluyan una contribución de predicción retrospectiva como la formulación de predicciones en tiempo real de acuerdo con el protocolo del Decadal Climate Prediction Project de la sexta fase del Coupled Model Intercomparison Project (CMIP6). Estas simulaciones serán analizadas en términos del choque inicial, de su error sistemático y deriva, de la calidad de las predicciones y de las fuentes de previsibilidad, atendiendo en particular las peticiones formuladas por usuarios potenciales. Las simulaciones serán comparadas con otras similares llevadas a cabo como parte de fases anteriores de CMIP, otros sistemas internacionales y una referencia empírica bien establecida, en combinación con una validación exhaustiva frente a datos observacionales.

En segundo lugar, los resultados obtenidos serán utilizados para ilustrar los beneficios potenciales de la predicción decadal en varios sectores (energía renovable, rendimiento de ciertos cultivos, y riesgos en el sector reasegurador). La motivación de esta actividad procede de la evidencia de que las pocas predicciones decadales disponibles actualmente son de difícil acceso, mal entendidas, no adaptadas a necesidades específicas y, por lo tanto, infrautilizadas por los usuarios. Prototipos basados en una variedad de fuentes de información de predicción decadal se desarrollarán en colaboración con las instituciones interesadas en un proceso de co-producción. El fin último es dar respuesta a las necesidades que se han identificado aplicando el paradigma de los servicios climáticos. Los prototipos se diseminarán a través de la User Interface Platform de la web del Departamento.

Estas dos actividades, desarrolladas de manera sincronizada, podrían permitir que este tipo de información llegue a aquéllos que son vulnerables a la variabilidad interanual y decadal.

PALABRAS CLAVE: Predicción climática, modelización del clima, cambio climático, servicios climáticos

TITLE OF THE PROJECT: Decadal climate prediction for near-term climate services and adaptation

ACRONYM: CLINSA

SUMMARY Maximum 3500 characters (including spaces):

The access to climate information valid on interannual-to-decadal time scales based on climate predictions has become, due to the intimate link between the long-term climate change to the natural variability of the climate system, a societal challenge for a range of socio-economic sectors such as agriculture and energy.

Taking up the challenge of skilfully and reliably predicting the global climate on interannual-to-decadal time scales relies on the ability to adequately simulating both climate variability and the anthropogenic climate change, and on the capability to give the forecast system the best initial conditions possible to phase in the simulations with the observed climate evolution. The Earth Sciences Department of the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) is able to take this challenge using its global climate forecast system based on the EC-Earth model. EC-Earth is now able to perform climate prediction experiments, including simulations of the decelerations and accelerations of global climate, an aspect that has recently triggered heated discussions. A new version of EC-Earth will be made available soon, with features that make it particularly suitable for a decadal climate forecast system.

The CLINSA project addresses the challenge of developing a decadal climate forecast system through two main activities that are closely connected and that build one on the other. First, it proposes the development of a capability for the formulation of decadal predictions, including both a full hindcast contribution to the Decadal Climate Prediction Project of the Sixth phase of the Coupled Model Intercomparison Project (CMIP6) and the regular formulation of real-time forecasts. These simulations will be analysed in terms of initial shock, systematic error and drift, forecast quality and sources of predictability, attending in particular some of the requests formulated by the potential users of these simulations. They will be compared with similar simulations performed as part of previous

CMIP exercises, other real-time international systems and a well-established empirical benchmark, combined with an exhaustive validation against the latest generation of observational data sources.

As a second main activity, the knowledge and climate data obtained will be used to illustrate the potential benefits of decadal prediction in several sectors (in particular renewable energy and crop yield estimation). The motivation of this activity comes from the evidence that the few probabilistic decadal predictions currently available are difficult to access, poorly understood, untailored to specific needs, and therefore under-utilised by end-user groups. Several prototypes based on a range of decadal prediction information sources will be developed in collaboration with governmental and private institutions in a co-production process. The goal is to respond to the needs that will have been jointly identified using the climate services paradigm. For instance, the regions of interest will be defined by the users. The outcome will be communicated via the Department's web-based User Interface Platform.

These two activities, developed in a synchronised way, could ensure that this type of climate information reaches both industry and society in a timely and usable manner for appropriate, cost-effective management, planning and adaptation decisions.

KEY WORDS: Climate prediction, climate modelling, climate change, climate services

Parte B: INFORMACIÓN ESPECÍFICA DEL EQUIPO

B.1. FINANCIACIÓN PÚBLICA Y PRIVADA (PROYECTOS Y/O CONTRATOS DE I+D+I) DEL EQUIPO DE INVESTIGACIÓN (repita la secuencia tantas veces como se precise hasta un máximo de 10 proyectos y/o contratos).

1. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes
   Referencia del proyecto: QA4Seas
   Título: Quality Assessment Strategies for Multi-Model Seasonal Forecasts
   Investigador principal (nombre y apellidos): Francisco Doblas Reyes
   Entidad financiadora: ECMWF (Copernicus Climate Change Service)
   Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/07/2016-30/09/2018
   Financiación recibida (en euros): 731.214,40€ (total Budget 1.681.760€)
   Relación con el proyecto que se presenta: está muy relacionado
   Estado del proyecto o contrato: concedido

2. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes
   Referencia del proyecto: Clim4energy
   Título: Climate for Energy
   Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Coordinator Robert Vautard, CEA)
   Entidad financiadora: ECMWF (Copernicus Climate Change Service)
   Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/01/2016-31/03/2018
   Financiación recibida (en euros): 180.000€ (total budget 1.599.399€)
   Relación con el proyecto que se presenta: está muy relacionado
   Estado del proyecto o contrato: concedido

3. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes
   Referencia del proyecto: Climateurope, GA 689029
   Título: European Climate Observations, Modelling and Services - 2
   Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Coordinator Chris Hewitt, Met Office)
   Entidad financiadora: H2020
   Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/12/2015-30/11/2020
   Financiación recibida (en euros): 225.000€ (total budget 3.052.435€)
   Relación con el proyecto que se presenta: mismo tema
   Estado del proyecto o contrato: concedido

4. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes
   Referencia del proyecto: ERA4CS, GA 690462
   Título: ERA for Climate Services
   Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Coordinator Philippe Bougeault, ANR)
   Entidad financiadora: H2020
   Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/01/2016-31/12/2020
   Financiación recibida (en euros): 207.500€ (total funding budget 25.000.000€)
   Relación con el proyecto que se presenta: está muy relacionado
   Estado del proyecto o contrato: concedido

5. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes, Eleftheria Exarchou, Pierre-Antoine Bretonnière
   Referencia del proyecto: PRIMAVERA, GA 641727

Título: PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment
Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Coordinator Malcolm Roberts, Met Office)
Entidad financiadora: H2020
Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/11/2015-31/10/2019
Financiación recibida (en euros): 1.277.425€ (total budget 11.000.000€)
Relación con el proyecto que se presenta: está muy relacionado
Estado del proyecto o contrato: concedido

6. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes, Verónica Torralba
Referencia del proyecto: IMPREX, GA 641811
Título: IMproving PRedictions and management of hydrological Extremes
Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Coordinator Bart van den Hurk, KNMI)
Entidad financiadora: H2020
Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/10/2015-30/09/2019
Financiación recibida (en euros): 240.000€ (total budget 7.996.850€)
Relación con el proyecto que se presenta: está muy relacionado
Estado del proyecto o contrato: concedido

7. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes, Eleftheria Exarchou, Pierre-Antoine Bretonnière
Referencia del proyecto: PREFACE, GA 603521
Título: Enhancing prediction of tropical Atlantic climate and its impacts
Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Coordinator Noel Keenlyside, Univ. Bergen)
Entidad financiadora: FP7
Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/11/2015-31/10/2017
Financiación recibida (en euros): 266.569€ (total funding budget 8.999.433€)
Relación con el proyecto que se presenta: está muy relacionado
Estado del proyecto o contrato: concedido

8. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes, Eleftheria Exarchou, Pierre-Antoine Bretonnière
Referencia del proyecto: SPECS, GA 308378
Título: Seasonal-to-decadal climate Prediction for the improvement of European Climate Services
Investigador principal (nombre y apellidos): Francisco Doblas Reyes (Also coordinator)
Entidad financiadora: FP7
Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/11/2012-31/01/2017
Financiación recibida (en euros): 1.615.305,75€ (total budget 8.224.862€)
Relación con el proyecto que se presenta: mismo tema
Estado del proyecto o contrato: concedido

9. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes
Referencia del proyecto: EUPORIAS, GA 308291
Título: European Provision of Regional Impact Assessment on a Seasonal-to-decadal timescales
Investigador principal (nombre y apellidos): Virginie Guemas (Coordinator Chris Hewitt, Met Office)
Entidad financiadora: FP7
Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/11/2012-31/01/2017

Financiación recibida (en euros): 697,963€ (total funding budget 8.969.180,25€)
Relación con el proyecto que se presenta: mismo tema
Estado del proyecto o contrato: concedido

10. **Investigador del equipo de investigación que participa en el proyecto/contrato (nombre y apellidos)**: Francisco Doblas Reyes
Referencia del proyecto: RESILIENCE
Título: Quality Assessment Strategies for Multi-Model Seasonal Forecasts
Investigador principal (nombre y apellidos): Francisco Doblas Reyes
Entidad financiadora: MINECO
Duración (fecha inicio - fecha fin, en formato DD/MM/AAAA): 01/01/2014-31/12/2016
Financiación recibida (en euros): 273.460€
Relación con el proyecto que se presenta: mismo tema
Estado del proyecto o contrato: concedido

B.2. RELACIÓN DE LAS PERSONAS NO DOCTORES QUE COMPONEN EL EQUIPO DE TRABAJO (se recuerda que los datos de los doctores del equipo de trabajo y de los componentes del equipo de investigación no se solicitan aquí). Repita la siguiente secuencia tantas veces como precise.

It does not apply.

Parte C: DOCUMENTO CIENTÍFICO. Máximo 20 páginas.

C.1. PROPUESTA CIENTÍFICA

1. Los antecedentes y estado actual de los conocimientos científico-técnicos de la materia específica del proyecto, incluyendo, en su caso, los resultados previos del equipo de investigación y la relación, si la hubiera, entre el grupo solicitante y otros grupos de investigación nacionales y extranjeros. Si el proyecto aborda un tema nuevo, deben indicarse los antecedentes y contribuciones previas del equipo de investigación que justifiquen su capacidad para llevarlo a cabo.
1. The state-of-the-art of the scientific and technical knowledge in the specific topic of the project, including, if relevant, the previous results of the research team and the link, if applicable, between the applying group and other national and international groups. When the project addresses a new topic, the previous knowledge and contributions by the research team that justify its capability to implement it should be described.

The Global Framework for Climate Services (GFCS), created under the governance of the World Meteorological Organisation (WMO), has illustrated the increasing need for action-oriented regional climate information for the next decades for economic, industrial and public planning, as well as to provide critical support in areas such as food security, insurance, renewable energy and disaster preparedness. Providing climate information a few years in advance requires predicting both the radiatively forced climate change and the superimposed internal climate variability (Hawkins and Sutton, 2009). These two sources of variability should be adequately modelled in a successful climate forecast system. However, whereas the long-term global warming trend of the past 60 years can be modelled relatively well, the regional aspects of the variability are not well reproduced beyond some aspects of the temperature distribution (IPCC, 2013).

The term "decadal prediction" encompasses predictions on annual, multiannual to decadal time scales. The possibility of making skilful forecasts on these time scales, and the ability to do so, is investigated by means of predictability studies and retrospective predictions (also known as hindcasts) made using the latest generation of climate models (Doblas-Reyes et al., 2013) or empirical-statistical methods (Suckling et al., 2016). Skilful decadal prediction of relevant climate parameters is a key deliverable of the Grand Challenge of Near-Term Climate Prediction promoted by the World Climate Research Programme (WCRP) to lead to the operationalisation of an annual five-year global outlook.

For a successful decadal prediction it is important that both the externally forced and internally generated components of the system are initialized and it is also useful to diagnose their contributions to the skill of the hindcasts and forecasts. The enhancement of skill due to the initialization, measured with respect to a simulation that has not been initialised or a naïve forecast such as the climatology, is greatest in the first few years and becomes less so at longer forecast ranges where skill is provided mainly by the externally forced component (Guemas et al., 2015). In any case, Doblas-Reyes et al. (2013) among others show that although there is skill in future decadal climate information, the benefit of the initialisation is limited to some regions like the North Atlantic basin and there are substantial disagreements between the forecast systems.

To make progress beyond the first steps taken towards the development of decadal forecast systems taken during the Fifth Phase of the Coupled Model Intercomparison Project (CMIP5), the preparations towards the sixth phase of CMIP (CMIP6) is revisiting the experimental design to pave the way towards the creation of real-time forecast systems that can satisfy the needs for multiannual future climate information formulated by a range of user communities.

The Decadal Climate Prediction Project (DCPP) is a CMIP6-endorsed model project that consists of three components, each of which comprises a central "core" and additional desirable, but less central, experiments and integrations (Boer et al., 2016). Differences in the CMIP6 experimental protocol compared to that of CMIP5 include more frequent hindcast start dates and larger ensembles of hindcasts for each start date intended to provide robust estimates of skill (García-Serrano and Doblas-Reyes, 2012) and the addition of ongoing quasi-operational experimental decadal forecasts (Smith et al., 2013). This has led to the formulation of two of the components of DCPP: component A, the hindcasts, and component B, the forecasts. Components A and B are directed toward the production, analysis and application of annual, multiannual to decadal forecasts. A major output of these components is a multi-model archive of retrospective and real-time forecasts, which will serve as a resource for the analysis, understanding, and improvement of near-term climate forecasts and forecasting techniques and of their potential application (e.g. Caron, et al., 2015).

The analysis of available observations for initialising forecasts, the improvement of the models used in the production of the forecasts, post-processing of forecasts including bias adjustment, calibration and multi-model combination, together with the production and application of probabilistic decadal forecasts, are all research aspects that are far from being solved. As it has been the case for weather forecasting, continued improvement in each of the components of a decadal forecast system is expected to yield improvements in decadal prediction skill (Marotzke et al., 2016), and this is the hope in the community building the EC-Earth climate model, which is about to release a new version of the system more adapted towards the climate prediction problem.

Beyond its scientific interest, climate variability is one of the key factors influencing a number of socioeconomic processes. For instance, it affects grape and wine production (Fraga et al., 2014), affecting the suitability of certain grape varieties to a particular region as well as the type and quality of the wine produced. Prolonged high temperature and/or frost outside the usual winter period can have a negative impact on some crop yields. The ability to reliably and accurately anticipate climate changes over the coming years is essential to develop optimal strategies for both the management and the adaptation to near-term climate change.

For climate prediction information to be useful, usable and accessible to the users, it must be tailored to their needs, which should be identified a priori, and made readily available (Cash et al., 2003). A pre-requisite is for the predictions to be reliable and offered as a single product, instead of large sets of simulations from different origins, an aspect that requires the development of calibration (Schefzik et al., 2013) and combination methods (Rodrigues et al., 2014). The outcome is a product or a service that is applicable and of value to risk management decisions. These climate services, needed to bridge the knowledge gap between climate scientists and industry, are not yet always available for all users (Graham et al., 2011). In addition, the value of the climate information produced is not well understood and its inherent uncertainty, which at times is expressed in their probabilistic nature, means that they could be difficult to interpret and apply in decision making processes. As a result, they remain underused. The community of meteorologists is aware of this and has been addressing the problem for a long time, while the climate community is aware that climate services are needed to define scientifically sound measures of adaptation to climate variability, especially to unusual events, but has reacted only recently (Buontempo et al., 2014).

Two of the key requisites of GFCS consist in strengthening climate research capabilities and improving the interaction between climate information providers and final users (Hewitt et al., 2012). The recent creation of decadal climate prediction, resulting from an ongoing climate research effort, is increasing confidence in their usefulness and triggering a growing demand for this type of climate information. Addressing the second requisite involves the development of tailored climate predictions and their application to specific risk management decision. For this to be achieved, improved coordination between climate scientists and stakeholders, as well as with planning and operational decision makers in society and industry is needed. In parallel, standardisation of end-product communication and dissemination is needed. This can be undertaken in a rich process known as co-production (Cash et al., 2006).

Key lessons have been learned by the research team in their participation in past national and international projects in this field that can be now applied to a range of sectors and to a time scale that has been somehow neglected by most climate research institutes around the world. Examples of the role played by the applicant team are its active participation in the relevant initiatives of the World Climate Research Programme and the contacts established with the Copernicus Climate Change Service. While CLINSA will leverage invaluable resources from these projects and initiatives, the CLINSA project will cover aspects that these projects and initiatives did not consider when they were designed. These aspects are a) the focus on multiannual and decadal climate time scales, which are relevant for operations in the several industries and public planning sectors, b) the focus on climate variability and prediction over the regions that really matter to the users, be it Europe or elsewhere where both skill and socioeconomic interests coincide, c) the development of a climate service that has commonalities across different user communities, d) communication of the climate service for the energy and agriculture sectors via a User Interface Platform (UIP) that will facilitate the co-production and stimulate a bottom-up interaction with the users, and e) the development of targeted communication material explaining what climate predictions are to those sectors.

In this context, the questions that the CLINSA proposal aims at addressing are:

1. What is needed to build a reliable and skilful global decadal forecast system?
2. What are the main characteristics of the predicted climate and the sources of predictability?
3. How can this information be used to inform a range of sectors about the aspects of the near-term climate variations that are most relevant to them?

The CLINSA project will build on the experience from the applying team, which is a leader in Europe in the field of climate prediction for climate services. The team has recently executed the MINECO-funded RESILIENCE project, where it has demonstrated its ability to develop climate services for the wind-energy sector based on sub-seasonal and seasonal predictions and built solid links to a range of stakeholders, and participates or has participated in a number of European projects covering several aspects of the problem.

At the Spanish level, the applying team stands as the national reference in global climate prediction and one of the pioneers in climate services. It has already contributed to decadal prediction research exercises for a few years. The list of international groups working on the topic with which the team maintains close collaborations is:

1. The Decadal Prediction Team of the Met Office (UK)
2. The Climate Modelling and Global Change team from the Centre Européen de Recherches et de Formation Avancée en Calcul Scientifique (France)
3. The Department of Meteorology of the Reading University (UK)
4. The Canadian Centre for Climate Modelling and Analysis of Environment Canada (Canada)
5. The Max Planck for Meteorology (Germany)
6. The National Center for Atmospheric Research (USA)

The project will become the Spanish contribution to the DCPP components A and B, which will precede and play an important role in the preparation of the Intergovernmental Panel on Climate Change (IPCC) next assessment report, in which the PI has been involved from its early stages. It will also contribute to the "Decadal climate variability and predictability" foci of the World Climate Research Programme core project CLIVAR (Climate and Ocean Variability Predictability and Change), where the PI is also a panel member.

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2. La hipótesis de partida y los objetivos generales perseguidos, así como la adecuación del proyecto a la Estrategia Española de Ciencia y Tecnología y de Innovación y, en su caso, a Horizonte 2020 (H2020) o a cualquier otra estrategia nacional o internacional de I+D+i. Si la memoria se presenta a la convocatoria de RETOS, deberá identificarse el reto cuyo estudio se pretende abordar y la relevancia social o económica prevista.
2. Starting hypothesis and general objectives, as well as the project fit to the Estrategia Española de Ciencia y Tecnología y de Innovación and, if applicable, Horizon 2020 (H2020) or any other national or international R&D&I strategy. If the application is submitted to the RETOS call, the challenge that is expected to be addressed and its socio-economic relevance should be identified.

With the relentless pace of the anthropogenic climate change, there is still a substantial amount of variability around the quasi-monotonic growth in temperature and the associated long-term changes in circulation. Decadal climate prediction is a tool that addresses the challenge of simulating these climate variations on time scales that range between a couple of years and one decade by taking advantage of both estimates of the slow changes in atmospheric composition, natural forcings of the Earth's surface radiation and the ability to predict some aspects of the climate internal variability. These predictions have received the attention of several socioeconomic sectors that require information about their potential benefits in a context where they need to manage assets in near-term time scales while at the same time adapt to climate change. The Earth Sciences Department of the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) is, to the best of our knowledge, the only Spanish institution with the capability to develop a climate forecast system to address this challenge, a system that can be compared to the handful of systems that are being developed around the world while it provides a flagship national contribution to the upcoming Decadal Climate Prediction Project (DCPP) of the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6). The general objectives of CLINSA are:

1. Build a reliable and skillful decadal forecast system that can contribute to the components A (hindcasts) and B (real-time exchange) of the DCPP
2. Investigate the main characteristics of the predicted climate, comparing it with the DCPP multi-model and uncovering the main sources of predictability
3. Illustrate in a climate services context the potential benefits of decadal prediction for the crop yield and energy sectors

These objectives are aligned with those of the recently finished FP7 SPECS and EUPORIAS projects in which the applying team played a key role in the development of climate services based on climate forecast systems, the H2020 "European coordination of climate services activities, 2nd part" (Climateurope) coordinating and support action project that aims at monitoring through a range of activities the developments in climate services and their requirements in terms of climate modelling and observation, and the QA4Seas Copernicus Climate Change Service that will develop a multi-model quality assurance system for seasonal climate forecasts, among many other projects described in section B in which the team is involved.

The implementation of CLINSA will give an extraordinary visibility to national activities and investments in the framework of CMIP6, which is expected to be the basis of the next assessment report of the Intergovernmental Panel for Climate Change. At the same time, it will nicely position our country at the centre of the World Climate Research Project Grand Challenge on Near-Term Climate Prediction, which is expected to promote the development of real-time decadal climate forecast systems. The PI is a member of the panel that is establishing such grand challenge and has already been involved in the early phases of the preparations for the next IPCC report representing precisely the interests of the climate prediction community.

The development and application of climate services are pre-requisites to provide support for technological, institutional and socio-economic innovation in the area of climate action and addresses the challenge "Reto en Acción sobre Cambio Climático y Eficiencia en la Utilización de Recursos y Materias Primas". CLINSA addresses the challenge by developing a decadal forecast system targeting specific user requirements for the next decade. This project is also fully in line with the objectives from the Scientific and Technological Spanish strategy of "generating cutting-edge knowledge", and with the priority axis of "knowledge transfer". The experiments that will be carried out in the project will also contribute to the establishment of an enhanced expertise in climate modelling and data analytics in our country, aspects that are still incipient in the Spanish climate research system.

3. Los objetivos específicos, enumerándolos brevemente, con claridad, precisión y de manera realista (acorde con la duración prevista del proyecto). En los proyectos con dos investigadores principales, deberá indicarse expresamente de qué objetivos específicos se hará responsable cada uno de ellos.
3. Specific objectives, listing them briefly with clarity, precision and in a realistic manner (according to the project duration). In projects with two PIs, the specific objectives of which each one of them will take responsibility should be precisely indicated.

To develop the three objectives listed in the previous section, the research team of the CLINSA project will address the following specific objectives:

1. to develop a decadal forecast system that ensures that there is a Spanish contribution to the decadal prediction component of CMIP6, sampling all known sources of uncertainty [M1-M18]
2. to survey the crop yield and energy sectors to determine their main interests in the climate information produced for the near term [M1-M12]
3. to analyse the mechanisms behind the successful decadal climate predictions and single out the mechanisms that could be responsible for systematic failures by confronting the simulations to a range of innovative observational data sources that include uncertainty estimates [M7-M30]
4. to establish a data dissemination system according to international standards providing public access to the simulations in almost real time [M12-M18]
5. to implement a prototype climate service on the BSC-CNS climate user interface platform that illustrates the potential benefits of the decadal climate predictions for the selected sectors based on the best possible climate information accessible during the project and a two-way interaction with a selection of actors of these communities [M1-M36].

4. El detalle de la metodología propuesta, incluyendo la viabilidad metodológica de las tareas. Si fuera necesario, también se incluirá una evaluación crítica de las posibles dificultades de un objetivo específico y un plan de contingencia para resolverlas.
4. The details of the proposed methodology, including the methodological feasibility of the tasks. Should it be required, a critical evaluation of the potential difficulties of a specific objective and a contingency plan to solve them should also be included.

The five specific objectives listed above will be tackled through a series of tasks organised around three different work packages (WP) that are detailed in the following paragraphs.

<u>WP1: Development of the decadal forecast system (M1-M18)</u>

Participants: Francisco Doblas Reyes 40%
Pierre-Antoine Bretonnière 50% (0.5 EDP in the project)
Raúl Marcos 20%
Postdoc 30%

The decadal forecast system will be based on the EC-Earth3.2 climate model, in particular the configuration that will be used for the CMIP6 experiment. The expertise developed by the team in the last five years to perform climate prediction experiments with previous versions of this model will be the basis of the activity in this WP. However, EC-Earth3.2 is a completely new model, which is still being tuned, with higher resolution than previous versions, and with the possibility of being configured at much higher resolutions, as it is done in the EU-funded PRIMAVERA project. The decadal forecast system will use initial conditions from ERA40 (before 1979) and ERA-interim (after 1979) ECMWF atmospheric reanalysis for the land and the atmosphere, while the ocean ones will be from the NEMOVAR-ORAS4 and ORAS5 ECMWF ocean reanalysis, and the sea-ice initial conditions will come from an in-house sea ice reanalysis system developed as part of the MINECO-funded PICA-ICE project (CGL2012-31987).

The contribution to the components A and B of DCPP implies the performance of decadal forecasts initialised every year over the period 1960 to 2016, with a forecast horizon of up to ten years and using ten-member ensembles. These simulations will be used to calibrate (i.e. for the bias adjustment process), verify and analyse the dynamical characteristics of the climate predictions in WP2. Radiative forcings estimated from observations will be used until 2015 and a scenario afterwards, following the CMIP6 protocol.

Finally, to assess the role of the initialisation of the predictions it has been decided in the DCPP protocol to compare the hindcasts with a similar ensemble of historical simulations. An ensemble of ten-member historical simulations will be also run with EC-Earth3.2 started from randomly chosen restarts taken from the pre-industrial control simulation required in the CMIP6 standard protocol (DECK experiments). They will be extended beyond 2015 with the scenario that will be finally selected as standard by the DCPP panel using the exact same external radiative forcings as used for the climate predictions. In these experiments the internal variability will not be in phase with the observed one and, hence, the only skill can only come from the changing natural and anthropogenic forcings.

A set of preliminary analyses will be performed while the experiments are running on the supercomputer to diagnose if there are problems with the simulations and reduce the risk of wasting computing time. These diagnostics include the global mean surface temperature, the Atlantic meridional overturning circulation, the Atlantic multidecadal oscillation index, a set of sea-ice indices (thickness and extent), and the El Niño-Southern Oscillation index, which will be computed online while the model runs and continuously compared to an observational reference.

The computing time required for all these simulations will be requested to the Red Española de Supercomputación with a multi-period activity and to the PrACE programme. Should these resources prove insufficient, resource applications will be submitted to the INCITE and ECMWF special project programmes, where the team has already often been successful in the past. If these options risk of introducing delays in the hindcast production, the team still has the possibility of using internal BSC-CNS resources on the Marenostrum4 supercomputer. At the same time, the forecast system will be ready to be delivered to the partners that might be interested in its operational use (AEMET or ECMWF).

The output from these experiments will be shared with the community as soon as a quality-control process has been concluded. An Earth System Grid Federation data node will be installed at the BSC-CNS with more than 100 TB of net disk space. This will allow distributing the data using the international standards that the team has contributed to create in the framework of the EU-funded SPECS project. This is a very important activity to give visibility to the activities of the CLINSA project. The data will be encoded in NetCDF using the CMOR3 convention with the extensions created at the BSC-CNS for DCPP to appropriately describe climate predictions.

The tasks of this WP are
T1.1: Implementation of the CMIP6 EC-Earth3.2 model in the relevant platforms
T1.2: Adaptation of the EC-Earth3.2 model as a forecast system, initialization and ensemble generation
T1.3: DCPP experiments, hindcasts, forecasts and continuous simulations
T1.4: Implementation of the data dissemination system

Deliverables: D1.1 [M18] EC-Earth3.2 decadal forecast system ready to be shared with partners
Milestones: M1.1 [M6] Ensemble of historical simulations and projections performed
M1.2 [M12] Data dissemination system publicly available
M1.3 [M18] Full set of retrospective climate predictions performed

<u>WP2: Characteristics of the predicted climate and main sources of predictability (M7 - M36)</u>

Participants: Francisco Doblas Reyes 30%
Raúl Marcos 60%
Eleftheria Exarchou 50% (0.5 EDP in the project)
Verónica Torralba 50%
Postdoc 50%

The comprehensive assessment of the multifaceted aspects of forecast quality assessment of the decadal climate predictions and the sources of predictability requires the gathering of a complete and heterogeneous ensemble of datasets. Observational and reanalysis data need to be collected over, at least, the period 1960-present to create a reference dataset over the recent past. This database will rely on the most reputable global atmosphere and ocean reanalyses like ERA-Interim, ERA5, JRA55, and the families of ORA and GLORYS ocean reanalyses. Longer reanalyses as the most recent version of NOAA's XXth Century Reanalysis will also be collected as soon as they become available. Observational datasets will include the new CCI datasets from ESA, as well as more traditional gridded datasets like ERSST, HadEX, HadCRUT4 and EOBS. The use of different observational references takes into account the large observational uncertainties affecting the variables at the global scale. In terms of climate simulated data, apart from the access to the decadal prediction, historical and control simulations performed with EC-Earth3.2 for CMIP6, the analyses will require access to similar experiments performed with the handful of systems contributing to at least the component A of DCPP, plus those systems that are run quasi-operationally such as MiKlip (Germany). The access to these datasets has already been guaranteed to the team by its collaborators. The main set of variables will include monthly means of geopotential height and winds in the troposphere and lower stratosphere, surface variables like precipitation, heat fluxes and temperature, ocean velocities, temperature and salinity and the main sea-ice variables (concentration and thickness). Whenever possible, these datasets will be reduced to indices, as in the case of the Atlantic meridional overturning circulation (AMOC) that can be characterized with a few variables. Some variables will be required at higher frequency for the analysis of extremes and intraseasonal variability (temperature and mean sea level pressure). The datasets will be kept updated regularly as is required with quasi-operational systems. It is expected that the hindcasts and forecasts will require substantial resources in terms of disk space and an appropriate organisation as described in WP1, which are aspects regularly considered in the Department's organisation, where curation and governance are regularly taken into account and reviewed. The full database (observations, indices and illustrative products) will be made available upon request to all the scientists funded under this call or under other related calls opened by the Ministerio de Economía, Industria y Competitividad, provided those scientists explicitly accept the corresponding terms of reference of the different data providers. However, redistribution of data will be discouraged.

A set of analyses will be performed on both the decadal climate predictions and the control simulations to understand the mechanisms behind decadal predictability, with a particular focus on ocean processes. Heat budgets will be performed in each main basin, separating the tropical, mid-latitudes and high latitudes regions and the ocean mixed layer, the upper ocean (down to 500 m) below the mixed layer, the intermediate ocean (500 m to1 km) and the deep ocean (below 1 km). The ocean dynamics and the role of coupling with the atmosphere will be studied to extract potential mechanisms responsible for the internal variability of the system using the control simulations, in which the external forcings are constant. In particular, changes in the strength of the ocean gyres, overturning circulation and the main currents in each ocean basin will be diagnosed as well as associated changes in the surface large-scale atmospheric circulation, ocean convective activity and atmospheric meridional cells in the simulations. The main spatial and temporal features of the main modes of multiannual variability, such as the Interdecadal Pacific Oscillation (IPO) and the Atlantic Multidecadal Variability (AMV) will be described. The conclusions will be validated against observational data whenever these references exist and are robust. The main modes of variability will be estimated using both empirical orthogonal functions and weather types, with a special emphasis on the North Atlantic Oscillation and the Pacific North American index. Their teleconnections to the near-surface European temperature, precipitation and wind speed will be estimated to frame the possibility of producing hybrid decadal predictions that merge empirical knowledge with the outcome of the simulations. Other aspects of the intraseasonal atmospheric variability such as the weather regime occurrence and the storm tracks will be also considered. The characterisation of these variability measures using several observational sources will provide uncertainty estimates for all those diagnostics, which is an aspect not readily available to the climate research and services communities.

Hindcasts spanning several years such as those planned in component A are needed to estimate the systematic error, drift and initial shock, evaluate the multifaceted forecast quality and perform exercises of calibration and combination of the different forecast systems, which makes this exercise particularly costly given the complexity of the experiments used and the sample ensemble size considered. The different aspects of the systematic error of the predictions in terms of mean climate and variability as a function of the forecast time will be identified and documented to interpret the forecast quality assessment and guide the calibration process in WP3. The intention is to gain confidence on the quality of the simulations by identifying the relevant phenomena that the systems should reproduce, and those that they do not and contribute to degrade the initial-condition information, and to use this information to interpret the forecast quality estimates.

An important aspect of this WP is the forecast quality assessment of the predictions, where the simultaneous predicted and observed values are compared. This is a fundamental step in climate prediction because it assesses whether or not the forecast systems lead to an improved forecast with respect to a standard, which is usually the climatology, a simple persistence forecast or the robust empirical system developed in Suckling et al. (2016), which will be used as the main reference. Due to the high dimensionality of forecast verification, multiple verification measures will be used. The correlation and root mean square error of the ensemble mean, the Brier skill score, along with its decomposition in reliability and resolution, and the continuous ranked probability skill score are the forecast quality measures chosen. This selection includes measures of accuracy, discrimination and reliability, all highly relevant to users of climate predictions, keeping the number of diagnostics limited to reach meaningful conclusions. Attention will also be given to the prediction of extreme events, both of an intraseasonal (e.g. frequency of daily rare events) or interannual (e.g. heat waves) character. These measures will be interpreted in the light of the few truly independent events observed for these time scales, which require an individual analysis of those events (for instance, the recent sea surface temperature transition in the North Atlantic) and estimates of the uncertainty of these measures. The sampling uncertainty in the verification measures will be quantified using both confidence intervals and p values, where bootstrap methods will be implemented taking into account the serial correlation of the variables (block bootstrapping). This activity will be linked to the development of the quality control system for climate predictions in the QA4Seas Copernicus contract funded by ECMWF.

These analyses will be performed using generalised functions coded with the R language or in python, as well as through the use of packages such as ESMValTool that the research team contributes to develop. The software developed will be made publicly available through the GIT repository of the Department, while the use of community packages allows benefiting from the important effort carried out in preparation of CMIP6. All these tasks will take into account the special character of the climate predictions, where the characteristics of the simulations evolve with the forecast time as a result of the forecast drift.

The information generated in this WP will feed the UIP to illustrate the merits and difficulties of the forecast systems to simulate the actual climate and its variability.

The tasks of this WP are
T2.1: Collection of the most comprehensive set of observational and simulated data
T2.2: Assessment of the mechanisms responsible for the decadal predictability
T2.3: Process-based forecast quality assessment

Deliverables: D2.1 [M36] Forecast quality assessment of the decadal predictions and its process-based interpretation in the light of predictability estimates

Milestones: M2.1 [M12] Status of the observational and simulated datasets available
M2.2 [M24] Assessment of climate processes responsible for the internal variability and the representation of the forced component

WP3: Climate service development (M1-M36)

Participants: Francisco Doblas Reyes 30%
Andrea Manrique 100%
Verónica Torralba 50%
Raúl Marcos 20%
Postdoc 20%

The climate service based on the decadal climate predictions will be a main outcome of the CLINSA project. CLINSA will create a solid link between climate and application research by co-designing a climate service to use reliable predictions at decadal time scales. This service will be co-produced with the supporting institutions, some of whom are already collaborating with BSC-CNS in the context of ongoing European projects. The information provided will be based on state-of-the-art, calibrated decadal predictions of relevant variables (temperature, precipitation, wind, frequency of extreme events, etc.), tailored visually to the users' needs and including a full assessment of the prediction uncertainty, its skill and reliability.

Due to the novelty of this information, the project will try to reach out a maximum number of potential users of decadal climate predictions. Several activities have been planned to achieve this objective, always within a climate-services framework. Among the first ones considered there is the design of a user survey. The first objective of the surveys is to identify the specific user needs, such as their spatial and temporal regions of interest, variables and relevant indices and thresholds. The result of the survey will allow designing a plan to co-develop user-tailored decision-support materials and tools to be applied to key decision-making processes. The surveys will be designed and tested to favour the co-production and evaluate the efficiency of the communication of the climate predictions. They will cover aspects like key "communication modes" of the predictions, such as their visualisation, value assessment and interpretation, by which the usefulness and usability of the scientific information, support materials and tools are determined. The surveys will be complemented by interviews, which will be conducted at the end of the project with the users that followed most closely the climate service development to assess the usefulness of the prototype climate service to their practices and extract the main lessons.

Presentations for specific user communities will be prepared using the outcome of the survey and made publicly available from the Department's UIP, a web portal that collects all the information about the services developed in the Department. The efficiency of the communication of all the information provided in the UIP will be tested with the supporting institutions to ensure that they are understandable and usable. The UIP will be developed with a link to complementary international initiatives (both generic, like the Climate Services Partnership, and sector specific) to ensure the visibility of the effort. The material prepared will be presented at international professional events, such as the European Wind Energy Association annual meeting, which allows to expand the user basis in a much more cost-effective way than with the organisation of generic workshops. Due to their inherently uncertain nature, probabilistic climate predictions are poorly understood, and therefore underutilised by users of climate information. The presentations will address this type of issues. The experience collected during these interactions will be used to prepare the script of two videos, which will be shot professionally. The videos will reflect in one of them the bases of decadal forecasting and in the other the challenges associated with the application of the resulting information, illustrated with success and failure cases. The need to consider the different sources of uncertainty will be part of the backbone of these videos. In parallel, a series of fact sheets will be produced at quasi-regular intervals (every nine months in principle), with simple illustrations of decadal forecasts, including the challenges of their production, the unavoidable verification, the sources of predictability, examples of past predictions compared to a range of observations and even a real-time prediction building on the annual decadal prediction outlook planned by the Grand Challenge on Near-Term Climate Prediction. The fact sheet series will target a more general audience, including in some cases the general public. It is the first time such a range of tools will be set up and for this reason, both English and Spanish versions will be created.

The interaction with the users will include illustrations of past forecasts in a commented comparison with the available observations. They will be the basis for the prototypes that will be built collaboratively. The evolution of the prototypes, made available through the Department's UIP, will be discussed regularly with the supporting institutions, either by teleconference or during presential meetings. In the last phase of the project a real-time forecast will be discussed with the these institutions, focusing mainly on the robust signals for which the forecast confidence is beyond a threshold set by the users. The prototypes in the

UIP will allow exchanging and integrating ideas and procedures between research, policy and the industry. The results are expected to provide better scientific understanding and guidance enabling the users concerned to frame strategic choices concerning cost-effective management.

Past experience suggests that some users require a single source of information, which leads to the need to find optimal ways to combine the multiple data sources that will be available to the CLINSA team, namely the EC-Earth3.2 decadal predictions, the DCPP multi-model and the empirical predictions. While the team has a vast experience in the combination of seasonal forecasts, very little has been done at the BSC-CNS and elsewhere to test its merit in a decadal prediction context. Other users require the climate data to be representative of small spatial scales, some times even corresponding to specific locations, as usually happens with wind farms. The CLINSA team will assess the challenges associated with statistical downscaling of the decadal predictions, estimating the losses of information that might occur in the prototypes having this kind of requirements. In any case, all systems will require a calibration of the decadal predictions to be usable given the pervasive presence of a wide range of systematic errors. Different methods of bias adjusment and forecast calibration will be implemented and the improvements achieved discussed with the users to ellaborate a guide of best practices.

To avoid the risk of having to deal with complex intellectual property rights issues, all the software produced will be distributed under a GPL license in the Department's GIT repository, which allows redistribution and commercial use, while the hindcasts and forecasts performed with EC-Earth will be freely disseminated following the plan described in WP1 along with a disclaimer that specifies that commercial use is particularly encouraged.

The tasks of this WP are
T3.1: Interaction with the users, surveys and periodic feedback collection
T3.2: Preparation of the dissemination material
T3.3: Development of the user prototypes and implementation in the user interface platform
T3.4: Illustration of the relative merits of the calibration, combination and downscaling of the decadal predictions

Deliverables: D3.1 [M30] Best practices for the combination, downscaling and calibration of the decadal predictions
D3.2 [M30] Multimedia to introduce decadal climate prediction
D3.3 [M36] Delivery of the prototype climate service for the agro-management and wind-energy sectors with documented user feedback
Milestones: M3.1 [M6] Outcome of the first user survey and recommendations for post-processing of the decadal predictions
M3.2 [M12] First fact sheet
M3.3 [M24] Illustration of the merits of the combination, downscaling and calibration of the decadal predictions

5. La descripción de los medios materiales, infraestructuras y equipamientos singulares a disposición del proyecto que permitan abordar la metodología propuesta.
5. Description of the material means, infrastructures and singular equipment available to the project that will allow undertaking the proposed methodology

The CLINSA project will be carried out by members of the Earth Sciences Department of the BSC-CNS. The Department undertakes research in environmental modelling and forecasting, with a special focus on global climate and atmospheric composition modelling. An important and innovative aspect of the Department's activities consists in the identification of the needs for the development of climate services that respond to well-identified needs from specific users and according to the recommendations recently formulated by the European Commission in its roadmap.

The Department has been a pioneer in the field, participating in the first European projects aimed at addressing the problems associated with co-development of climate information, such as the FP7 CLIM-RUN project. More specifically, the Department undertakes research for the development and assessment of dynamical and statistical methods for the prediction of global and regional climate on time scales ranging from a few weeks to several years. Sources of predictability and processes at the origin of model error play a major role in the assessment. The formulation of the predictions includes the development and implementation of techniques to statistically downscale, calibrate and combine dynamical ensembles and simple statistical forecasts to satisfy specific user needs. The software engineers work on high performance computing (HPC) over different platforms. They have a highly qualified technical expertise to deal with complex parallelized codes such as the ones that will be used within this proposal. Besides, the Department members work with freely available software developing post-processing and diagnostic tools that are openly shared under GNU licenses with the rest of the community, strengthening the efficiency and impact of the work developed. They also maintain a common data repository competitive with what is available in the leading climate research institutions to ensure that the research carried out makes use of the latest, highest quality observational datasets. Thanks to the host infrastructures (detailed below) and unique human resources (with a ratio of one technician for every two researchers), the Department offers an ideal environment to perform global experiments with state-of-art seasonal-to-decadal ensemble climate forecast system.

HPC and storage: Marenostrum is a 12 PFlop supercomputer that gives service to the Spanish research community through the Red Española de Supercomputación (RES) and European researches through the Commission's initiative PrACE. The machine is also used by the BSC-CNS departments for their research. They are entitled to the use of 4% of the machine. The Department has also regular access to other supercomputers in Europe and the USA through competitive calls of the ECMWF Special Project, PrACE and INCITE programmes. The use of this heterogeneous ecosystem of platforms benefits from the large investment the Department has made on a technical capability to increase the portability of the EC-Earth model. The storage is based on a multi-platform solution that includes a NAS with 0.7 PB of disk and the "archive" system of the BSC-CNS in which the Department has an allocation of 0.9 PB. Both systems are accessed seamlessly by the users through a THREDDS server that takes advantage of the unified approach for the storage of both observations and simulations, an approach that substantially increases productivity. The systems are also accessible as separate filesystems for specific uses. The local storage hosts at this stage a unique set of global climate simulations performed by the members of the Department as well as by climate research and operational centres around the world. The storage has attached a number of dedicated computing nodes with increased memory (more than 8 GB per core) as well as to heterogeneous nodes (IBM Power 8) to allow for a speedy post-processing and analysis of all these simulations. These nodes are accessible through ssh and can be used through schedulers that have been fine tuned for the kind of work carried out at the Department.

Desktops: All scientists have desktops with multi-core processors that are available through the local network and share exactly the same software stack and modules, offering a seamless environment to perform in a reproducible way all sorts of diagnostics that do not require the large memory available in the fat nodes.

Communication and outreach: The BSC-CNS counts on a communication and technology transfer team that allows reaching out to external actors from both public and private sectors. There is also a communication group in the Department that ensures that some of the outreach targets the weather, climate and air quality sectors. This is expressed via the services platform in which the department makes publicly available its operational products and scientific results of interest for a range of sectors. The communication team ensures that any relevant finding performed at the BSC-CNS is disseminated in a timely manner, a service that the CLINSA team will use regularly to engage not only with the users identified at the time of writing the proposal, but also to expand the number of users of the climate service that will be developed. The BSC-CNS also takes advantage of an exceptional set of meeting rooms available to the BSC-CNS staff that allows organising meetings with stakeholders, other scientists (in the form of workshops and conferences) and the public in general, as well as series of webinars. For instance, the department has organised four international workshops and conferences in the last two years.

6. Un cronograma claro y preciso de las fases e hitos previstos en relación con los objetivos planteados en la propuesta.
6. A clear and precise Gantt chart of the phases and milestones proposed as they are related to the objectives considered in the proposal.

The tasks described above are summarised in the following Gantt diagram.

Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
T1.1																																				
T1.2																		D1.1																		
T1.3						M1.1												M1.3																		
T1.4																		M1.2																		
T2.1												M2.1																								
T2.2																								M2.2												
T2.3																																				D2.1
T3.1						M3.1																														
T3.2												M3.2																		D3.2						
T3.3																																				D3.3
T3.4																								M3.3						D3.1						

7. Si se solicita ayuda para la contratación de personal, justificación de su necesidad y descripción de las tareas que vaya a desarrollar.
7. If requested, justification of the need to hire personnel and description of the tasks to be performed.

Postdoc (36 PM): The post-doctoral researcher requested will be in charge of the monitoring of the decadal prediction experiments performed in WP1 and involved in their analysis according to the tasks described in WP2. He/she will be leading the comparison of the decadal predictions and historical simulations to assess the role of the initialisation, interacting closely with the members of the Department that will develop the QA4Seas multi-model verification system to extend it to decadal time scales. The researcher will be also involved in the analysis of the sources of predictability, with a special focus on those active in the North Atlantic basin. He/she will be also encouraged to learn how to set up and perform climate prediction experiments. Finally, the researcher will interact with those team members involved in WP3, contributing to the development of the illustration material required for an efficient interaction with the users. Although the research team can address many of these activities, it is fundamental to be able to hire a person that can devote all his/her time to ensure the appropriate link between WPs 2 and 3 to provide in a timely manner the climate information identified in the surveys while being able to explore the forecast quality and dynamical characteristics of the decadal climate predictions. At the same time, this person will benefit from the vast experience accumulated in the Department, helping to train the new generation of climate services scientists that the society is urgently demanding.

C.2. IMPACTO ESPERADO DE LOS RESULTADOS

1. Descripción del impacto científico-técnico social y/o económico que se espera de los resultados del proyecto, tanto a nivel nacional como internacional.
1. Scientific-technical and/or economic impact expected from the project results, both at the national and international level.

The CLINSA project will be a key Spanish contribution to the international coordinated Decadal Climate Prediction Project, which is part of the Coupled Model Intercomparison Phase 6 (CMIP6). It will also contribute to the "Decadal climate variability and predictability" research foci of CLIVAR, both initiatives closely monitored by the PI as he is part of both scientific panels. At the same time, the project will contribute to the Climate Services Partnership (CSP), illustrating the possibilities that decadal climate prediction offers to users and fostering their application in those regions and for those variables where it can offer skillful and reliable information. Also from a climate services perspective, the CLINSA illustrative material will be exchanged with the people responsible of the Global Framework for Climate Services (GFCS) exemplars (mainly in energy and food security) at the World Meteorological Organisation (WMO) and with those in charge of the evolution of the

Copernicus Climate Change Service, both having requested repeatedly this kind of material to decide about the role that decadal climate predictions could play in a more operational (real time) context.

In contrast with the use of weather information, few tools are in place to minimise climate-related risks. This implies that users are constantly operating in reactive mode whereby risks have to be dealt with, likely at high costs. By assessing the likelihood of climate risks and their impact on the energy network several weeks or months in advance, some decisions can be modified in time to adapt operational strategies, avoid possible financial penalties and increase the resilience of the systems as a whole. This suggests that the climate simulations that CLINSA will provide for the next decade could raise substantial socio-economic interests among the range of applications selected. This has been already the case at the time of writing the proposal. The European Commission's Joint Research Centre and the Codorniu wine company have expressed their intention to access action-oriented climate information in interannual and decadal time scales to better plan their operations and management. EDPR, Nnergix S.L. and Taiko Meteorologia are expecting to work with the CLINSA scientists to assess the potential benefits that decadal climate prediction might offer to them with respect to the business-as-usual approach of considering that future near-term climate will be similar to today's average climate. All these institutions made clear that it is currently impossible for them to access this kind of information. The interest of these institutions in our investigations may be representative of the issues that their communities have to face, both in Spain and worldwide, and help demonstrate what climate services can do for them. In addition, compared to climate-change projections, the shorter, near-term operational time scale of the decadal climate predictions is expected to be useful to design adaptation and mitigation strategies.

2. El plan de difusión e internacionalización en su caso de los resultados.
2. Plan for the dissemination and internationalisation of the results.

The prototype climate service will be the main outcome of the CLINSA project. CLINSA will create a solid link between climate and application research by co-designing a climate service to use reliable predictions at decadal time scales. This service will be co-produced with the supporting institutions, some of whom are already collaborating with the Earth Sciences Department of the BSC-CNS in the context of ongoing European projects and private contracts. The information provided will be based on state-of-the-art, calibrated decadal predictions of relevant variables (temperature, precipitation, wind, frequency of extreme events, etc.), tailored visually to the users' needs and including a full assessment of the prediction uncertainty, its skill and reliability. Due to the novelty of this information, the project will try to reach out a maximum number of potential users of decadal climate predictions. Several activities have been planned to reach this objective, always within a climate-services framework. Presentations for specific user communities will be prepared and made publicly available from the Department's User Interface Platform (UIP), a web portal that collects all the information about the services developed in the Department. The efficiency of the communication of all the information provided in the UIP will be tried and tested with the supporting institutions to ensure that they are understandable and usable. The UIP will be developed with a link to complementary international initiatives to ensure the visibility of the effort.

The material prepared will be presented presentially at international professional events, such as the European Wind Energy Association annual meeting, which allows to expand the user basis in a much more cost-effective way than with the organisation of generic workshops. The experience collected during these interactions will be used to prepare the script of two videos, which will be shot professionally, reflecting in one of them the bases of decadal forecasting and in the other the challenges associated with the application of the resulting information, illustrated with success and failure cases. The need to consider the different sources of uncertainty will be part of the backbone of these videos. It is expected that these videos will be a unique tool for the interaction with users well beyond CLINSA as there is nothing similar available worldwide. In parallel, a series of fact sheets will be produced at quasi-regular intervals (three to four during the project duration), with simple illustrations of decadal forecasts, including the challenges of their production, the unavoidable verification, the sources of predictability, examples of past predictions compared to a range of observations and even a real-time prediction. The fact sheet series will target a more general audience, including in some of them the general public. It is the first time such a set of tools will be set up and for this reason, both English and Spanish versions will be created.

At least five manuscripts will be submitted to international peer-review journals. This is without prejudice to the participation in other publications led by scientists from collaborating climate research institutions where some CLINSA results might feature, which we consider an important added value of this project. The results will be presented in a number of conferences that include the European Geophysical Union annual meeting and a number of workshops and events in climate modelling, prediction and services that will be announced in the next three years, in particular in events of the World Climate Research Programme in which the PI is regularly involved.

All the deliverables and milestones due in CLINSA will be made available from the Department's wiki site in the form of technical memoranda. They will be publicly available unless the funding agency explicitly decides the contrary. This way we will ensure that the scientific outcome of the project is available to the community well before they are published in peer-review journals, while ensuring a full traceability of the project activities.

3. Si se considera que puede haber transferencia de resultados, se deberán identificar los resultados potencialmente transferibles y detallar el plan previsto para la transferencia de los mismos.
3. In case of the possibility of result transfer, the results potentially transferable should be identified and the plan for its transfer be detailed.

Any result with potential socioeconomic use will be shared with the supporting institutions. These results will include illustrations of past forecasts in a commented comparison with the available observations. They will be the basis for the prototypes that will be built collaboratively. The evolution of the prototypes, made available through the Department's UIP, will be discussed regularly with the supporting institutions, either by teleconference or during presential meetings. In the last phase of the project a real-time forecast will be discussed with the these institutions, focusing mainly on the robust signals for which the forecast confidence is beyond a threshold set by the users. The prototype in the UIP will allow exchanging and integrating ideas and procedures between research, policy and the industry. The results are expected to provide better scientific understanding and guidance enabling the users concerned to frame strategic choices concerning cost-effective management.

As the system developed in this project might be used in an operational context, its evolution and the potential transfer to an institution with operational activities will be regularly discussed with both the Agencia Española de Meteorología (AEMET) and the European Centre for Medium-range Weather Forecasts (ECMWF), including the people responsible for the Copernicus Climate Change Service who already requested first-hand information about the aspects included in this proposal. The deliverables and milestones will be notified to them by email. AEMET leads the Mediterranean Regional Climate Outlook Forum (MedCOF), in which the PI participates as a collaborator. The MedCOF offers an ideal framework to explore the response of nearby operational climate centres to the developing decadal climate predictions and the climate services that will be based upon them. The CLINSA team will be at the disposal of AEMET to provide this information, following the collaborative spirit that has been created in the last few years between AEMET and BSC-CNS. Participation in other regional climate outlook fora will be considered upon request, an aspect that will be discussed during the lifetime of the project with the WMO group coordinating the fora.

C.3. CAPACIDAD FORMATIVA DEL EQUIPO SOLICITANTE

1. Plan de formación previsto en el contexto del proyecto solicitado.

1. Training plan in the context of the proposal.

While there have been many studies focused on climate prediction at seasonal time scales, there are fewer devoted to the ability to predict the climate variations on time scales of up to 10 years. This conclusion can be extended to the number of doctoral theses centred in this problem. We request with CLINSA support for a PhD proposal that covers aspects that have up to now received little attention, and hence have a potential to produce innovative research, and that focus on the sources of decadal predictability at interannual to decadal time scales in the North Atlantic basin. The North Atlantic variability arises from both the internal variability of the climate system and from the external radiative forcings (Meehl et al., 2011). A number of mechanisms for the predictability of the North Atlantic dynamics in those time scales have been suggested (Cassou et al., 2007; Persechino et al., 2012) that suggest a predictability limit between 5 and 20 years, depending on the model and the part of the basin considered (Msadek et al., 2010). However, how this predictability is manifested as actual skill in initialised simulations is still a major open question, especially because the skill over the North Atlantic has strong spatial variations between the existing forecast systems (García-Serrano et al., 2015). Besides, there is little consensus about the mechanisms behind this predictability, which cast doubts on the actual meaning of the predictability limit. The PhD project proposed therefore aims at furthering our understanding of the mechanisms driving the interannual to decadal variability, the predictability and the skill of the North Atlantic variability and at extending the robust skill found over the ocean to the land surfaces surrounding the North Atlantic. This will be achieved throug three main activities:

1. To assess the robustness of previously published mechanisms to explain the interannual variability and predictability of the North Atlantic climate using the most recent observational datasets and experiments performed with EC-Earth.
2. To assess to which extent those mechanisms and the teleconnections between the North Atlantic Ocean variability are captured by the EC-Earth simulations in both historical and present-day control simulations.
3. To assess the ability of EC-Earth to predict the North Atlantic climate on interannual and decadal time scales with a focus on selected major events over the ocean (e.g. warm shift in the 1990s) and over land (warm European summers in the last 15 years).

These analyses will contribute to WPs 1 and 2 of the CLINSA project.

The PhD advisor will be Prof Doblas Reyes, who is an expert in climate prediction and the development of climate services. He has so far succesfully supervised 3 PhD students until June 2017 and has solid experience in mentoring MsC and PhD students. He is currently the supervisor of two more PhD students, while as director of the Earth Sciences Department he supervises the practices of the PhD directors of the Department's eight PhD students. As a result, an internal policy has been created that describes the rights of and expectations from PhD students, while it creates the figure of the mentor, whose role is to act as a mediator in case of conflict between the student and the director/s.

Besides the participation in PhD theses, the team is involved in the implementation of two Marie Curie grants (executed by Drs Etienne Tourigny and Raffaelle Bernardello). The Marie Curie grants have an important training component, although at the postdoctoral level, which is also regulated in the Department to ensure that their work is monitored and that the grantees receive adequate support and feedback.

References

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Meehl, G.A., J.M. Arblaster, J.Y. Fasullo, A. Hu and K.E. Trenberth, 2011. Model-based evidence of deep-ocean heat uptake during surface-temperature hiatus periods. Nature Climate Chan., 1, 360-364.

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2. Relación de tesis realizadas o en curso (últimos 10 años) con indicación del nombre del doctorando, el título de tesis y la fecha de obtención del grado de doctor o de la fecha prevista de lectura de tesis.

2. List of PhD theses performed or under preparation (last 10 years) including the name of the PhD, the title and the date when the degree was awarded or the date foreseen for the thesis defense.

Although the Department of Earth Sciences of the Barcelona Supercomputing Centre-Centro Nacional de Supercomputación (BSC-CNS) has hosted a large number of PhD students, the team involved in the project has participated in the mentoring of four PhD students:

1. Danila Volpi (January 2011-March 2015) has defended her PhD entitled “Benefits and drawbacks of different initialization techniques in global dynamical climate predictions” on 27 March 2015 at the University of Reading. Francisco Doblas Reyes was her PhD advisor.
2. Luis Ricardo Lage Rodrigues (January 2010-January 2016) has defended his PhD entitled “Improvement of seasonal climate prediction over the Mediterranean region”. His obtention of a permanent position in Brazil in spring 2014 delayed the writing and defense of his PhD. Francisco Doblas Reyes was his PhD advisor.
3. Verónica Torralba Fernández (October 2013-present) is currently carrying out her PhD on climate services for the renewable energy sector and follows the PhD programme at the Universidad Completense de Madrid.
4. Oriol Tintó (June 2015-present) is currently working on his PhD on the computational efficiency of climate models and the implementation of solutions to speed up the simulations typical of global climate experiments. He follows the PhD programme at the Universitat Autonoma de Barcelona.

3. Breve descripción del desarrollo científico o profesional de los doctores egresados del equipo de investigación.

3. Brief description of the scientific or professional development of the scientists awarded with a PhD members of the research team.

1. Danila Volpi currently has three articles published and three under review. She is currently working as a research scientist in Météofrance (Toulouse, France) after a brief experience in the private sector where she worked for a climate consultancy company.
2. Luis Ricardo Lage Rodrigues currently has a permanent position as a research assistant at the Center for Earth System Sciences (CCST) from the Brazilian National Institute for Space Research (INPE) on the validation of climate models. He is first author of two papers and co-author of three more.

C.4. IMPLICACIONES ÉTICAS Y/O DE BIOSEGURIDAD

It does not apply.