Parte C: DOCUMENTO CIENTÍFICO. Máximo 20 páginas.

C.1. PROPUESTA CIENTÍFICA

- **Introduction and state-of-the-art**

The aim of this project (DANAE) is to increase current seasonal forecasting capabilities of winter surface climate in the North Atlantic-European region.

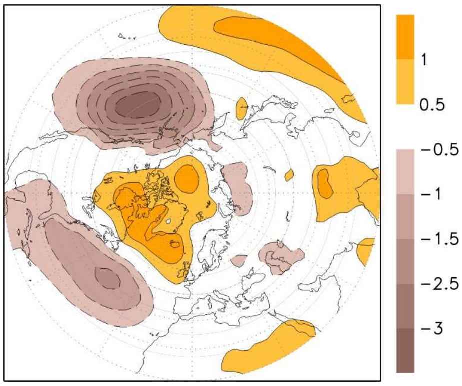
Given the chaotic nature of the climate system, one might question the feasibility of forecasting climate conditions months in advance. Yet, seasonal climate prediction is feasible because atmospheric variability on seasonal timescales is modulated by slowly-varying boundary conditions, such as snow cover, sea ice, or sea surface temperature (SST). This modulation is not noticeable in day-to-day weather conditions but becomes evident in seasonal averages, e.g. two/three-month mean (e.g. Shukla 1998). Seasonal climate prediction has progressed considerably in the last decade but the tropics remain the region where seasonal forecasts are most successful (e.g. Palmer et al. 2004; Weisheimer et al. 2009; see Doblas-Reyes et al. 2013 for review; Manzanas et al. 2014).

In most of the extratropics, and particularly for the North Atlantic-European (NAE) sector, the signals predicted by general circulation model (GCM)-based forecast systems are usually weak and barely add valuable information over a climatological forecast. Even so, previous studies have revealed signs of skill for particular European regions, periods, and variables (e.g. Doblas-Reyes et al. 2000; Frías et al. 2005). For instance, some traces of skill associated with El Niño-Southern Oscillation (ENSO) events have been reported in Spain (e.g. Sordo et al. 2008; Frías et al. 2010).

ENSO is the first mode of global climate variability on seasonal-to-interannual timescales. It can be characterized as a dipole in ocean heat content across the tropical Pacific, in which ocean-atmosphere coupled processes yield anomalous warm (El Niño) or cold (La Niña) events over the central-eastern equatorial Pacific in conjunction with a zonal pressure seesaw (the Southern Oscillation) between eastern and western regions of the tropical basin (e.g. Chang and Battisti 1998). The main reason for the attention ENSO receives is that it affects the weather/climate variability in large parts of the world (e.g. Trenberth et al. 1998; Alexander et al. 2002). Such remote effects of ENSO are called *teleconnections*. This project focuses on the *canonical ENSO* phenomenon, characterized by SST anomalies with an arrowhead shape shooting off the South American coastline, for which robust tropical-extratropical atmospheric teleconnections have been established (e.g. Trenberth et al. 1998; Alexander et al. 2002; Hoerling and Kumar 2002). A convenient measure of ENSO is the Niño3.4 index, defined as the anomaly of SST averaged over the region 5ºS-5ºN / 170ºW-120ºW; the strength of an ENSO teleconnecction is then defined as the linear regression coefficient of the field in question on Niño3.4 (e.g. Sterl et al. 2007; Yang and DelSole 2012).

ENSO is the most important source of predictability at seasonal timescales (e.g. Doblas-Reyes et al. 2013). The ENSO influence on the North Pacific-American (NPA) sector is well known: the atmospheric response displays a wavetrain structure arching northeastward, whose centres of action are organized in a so-called Tropical-Northern Hemisphere (TNH) pattern, which is distinct from the internally-generated Pacific-North America (PNA) pattern (e.g. Robertson and Ghil 1999; Alexander et al. 2002; Straus and Shukla 2002; DeWeaver and Nigam 2002; Nigam 2003; Bladé et al. 2008). The ENSO influence on the winter NAE atmospheric circulation has only recently been elucidated. The canonical ENSO signal takes place in mid/late-winter, namely January-to-March (JFM), not in the conventional winter season (December-to-February; DJF), and consists of a dipolar surface pressure anomaly that resembles the North Atlantic Oscillation (NAO). As reviewed by Brönnimann (2007), this *canonical ENSO-NAE teleconnection* has been stationary and robust over the past 300 years and is linear for El Niño and La Niña events. <u>DANAE will maximize North Atlantic atmospheric predictability emanating from ENSO and revisit prediction skill of European surface climate by using JFM as target season</u>.

To illustrate the ENSO-NAE teleconnection, the object of this proposal, the regression map of sea level pressure (SLP) anomalies onto the Niño3.4 index is shown in the figure below. The ENSO signal in the NAE region for El Niño conditions resembles a negative NAO phase and is accompanied by low (high) surface temperatures over northern Europe (southern Mediterranean), together with above-normal (below-normal) precipitation in central/southern (north-western) Europe (e.g. Brönnimann 2007; García-Serrano et al. 2011).



Regression map of mid/late-winter (JFM) SLP anomalies onto the winter (DJF) Niño3.4 SST index (hPa/std.dev). Data comes from the NCEP/NCAR atmospheric reanalysis and NOAA extended-reconstructed SST, respectively. Updated to 1948-2015, after Brönnimann (2007).

The underlying mechanisms of the ENSO-NAE teleconnection however, remain to be properly understood. Tropospheric and stratospheric pathways have been suggested to be at play in setting the canonical response but an unifying framework has been elusive to date.

With regards to tropospheric mechanisms, some modelling studies have suggested that transient-eddy activity in the North Atlantic basin generates an NAO-like signal in response to the downstream extension of the ENSO-forced wavetrain propagating across the NPA sector (e.g. Cassou and Terray 2001a, 2001b; Merkel and Latif 2002; Pohlmann and Latif 2005). However, no clear evidence has been found in observations supporting a link between ENSO and the NAO via this downstream effect (Brönnimann 2007). Some authors pointed to model biases as key to explain this apparent connection (Cassou and Terray 2001a, 2001b). An alternative and simpler view was proposed by García-Serrano et al. (2011), who interpreted the canonical dipole-like surface pattern over the NAE as resulting from the westward tilt with height of the Rossby wavetrain triggered remotely from the tropical Pacific. This westward tilt is a characteristic feature of quasi-barotropic teleconnection patterns (e.g. Hsu and Wallace 1985). García-Serrano et al. (2011) further discussed that the dynamics involved in the generation of the canonical ENSO-NAE signal are very different from the dynamics associated with the NAO, suggesting that the former should not be described as a NAO-like response. Their interpretation can explain the observed (Moron and Gouirand 2003; Brönnimann 2007; Fereday et al. 2008; Li and Lau 2012) and simulated (Gouirand et al. 2007) intra-seasonal variation of the ENSO impact on the NAE atmospheric circulation from early-winter (November-December; ND) to mid-winter (January-February; JF), since the ENSO-forced wavetrain is not completely established until January (Wang and Fu 2000; Bladé et al. 2008). The intra-seasonal timing in the development of the ENSO teleconnection in the NAE sector can be traced back to the NPA sector, in agreement with Livezey and Mo (1987) and Alexander et al. (2002), who also showed that the wavetrain response to ENSO is stronger in JF than in December. Bladé et al. (2008) used simple Rossby waveguide arguments to attribute the late timing of the canonical extratropical NPA response to changes in the mean-flow, as a result of which the sensitivity of the NPA circulation to tropical forcing in the central-eastern Pacific is stronger in JF than in ND (Newman and Sardeshmukh 1998). They also pointed out that the subtropical jet is strongest in January and thus represents a stronger vorticity source. DANAE will apply Rossby wave source (Sardeshmukh and Hoskins 1988) and ray-tracing (Hoskins and Ambrizzi 1993) diagnostics to gain insight into the dynamics of the ENSO wavetrain response over the NPA and its propagation to NAE; this will be performed upon both the observations and forecast systems.

The annual cycle thus appears to be necessary in any complete theory of low-frequency variability related to ENSO (Newman and Sardeshmukh 1998). For the NPA sector, Wang and Fu (2000) and Bladé et al. (2008) concluded that it would be more consistent to consider JFM as the winter season for analysing the ENSO influence on the extratropical circulation. Likewise, Fereday et al. (2008) emphasized that the ENSO-NAE teleconnection can be obscured in analysis based on the conventional DJF winter season. This effect might explain some of the deviations from linearity of the ENSO signal over NAE reported in several studies (e.g. Pozo-Vázquez et al. 2001, 2005). All these evidences suggest that an update of the ENSO-NAE link is necessary, especially in the context of the errors shown by current GCMs used in climate forecasting.

The timing of the wavetrain response to ENSO might also be fundamental when seeking an unifying framework of the ENSO-NAE teleconnection involving the stratosphere. It has been suggested both that ENSO has a strong and robust influence on the stratosphere (e.g. García-Herrera et al. 2006; Randel et al. 2009) and that ENSO-induced stratospheric changes may dominate the ENSO impact on the NAE region (e.g. Ortiz Beviá et al. 2010; Butler et al. 2014). It is worth noting that, consistent with the establishment of the ENSO-forced wavetrain in January, most studies assessing the seasonal evolution of the zonal-mean ENSO temperature and zonal wind anomalies in the stratosphere using observations, re-analysed data or model output, show that the ENSO signal begins with maximum amplitude in January and propagates downwards thereafter (Manzini et al. 2006; Cagnazzo and Manzini 2009; Ineson and Scaife 2009; Bell et al. 2009; Free and Seidel 2009). Although all these studies agree that the downward influence of the ENSO-induced stratospheric anomalies on the troposphere is strongest in late-winter (February-March; FM), they differ in the interpretation of this result. For some, the downward-propagating signal is responsible for the ENSO-NAE teleconnection (Ineson and Scaife 2009), while for others it simply helps the NAE SLP anomaly to persist into early-spring (March; Cagnazzo and Manzini 2009). Given the results of García-Serrano et al. (2011), according to which the ENSO-forced wavetrain alone can explain the dipole-like signature over NAE in JF, we speculate here that the *tropospheric pathway* dominates the ENSO-NAE relationship in mid-winter (JF), whereas the *stratospheric pathway* becomes dominant in late-winter (FM). <u>DANAE will clarify the time-dependent role of both pathways for the ENSO-NAE teleconnection</u>.

Concerning the dynamics involved in the stratospheric pathway, prior upward propagation of ENSO-induced waves from the troposphere into the stratosphere is obviously required (e.g. Manzini et al. 2006). There is evidence of a linear impact of ENSO on the tropical stratosphere (e.g. Randel et al. 2009): El Niño (La Niña) events are associated with a reinforcement (weakening) of the subtropical jet, which then becomes more (less) effective at channeling gravity wave upward propagation (de la Cámara et al. 2014), whose dissipation and drag in the lower stratosphere intensify (damp) the Brewer-Dobson (BD) circulation, thus enhancing (inhibiting) the upwelling through the tropical tropopause (Calvo et al. 2010; Ábalos et al. 2015). This subtropical wave-forcing primarily affects the 'shallow branch' of the BD circulation (Ábalos et al. 2014). <u>DANAE will assess for the first time the contribution of changes in the shallow-BD circulation to the timing of the stratospheric anomaly in January linked to the ENSO-NAE teleconnection</u>.

Concomitant with the ENSO signal in tropical upwelling in the lowermost stratosphere, there is also an ENSO modulation of the polar downwelling in the Arctic stratosphere, which also tends to be linear and is associated with anomalies in the zonal-mean temperature in the middle stratosphere (e.g. Randel et al. 2009; Calvo et al. 2010). These perturbations, in turn are intimately related to anomalies in the vortex strength (e.g. Manzini et al. 2006; Cagnazzo and Manzini 2009). However, there is no agreement on the effective wave-forcing of this ENSO signal. Some studies suggest that it arises from the interference of the ENSO-forced wavetrain with the climatological stationary wave located over the Aleutian region (e.g. Garfinkel and Hartmann 2008), but the actual injection of ENSO-related wave-activity into the stratosphere occurs at latitudes poleward of about 60ºN, i.e. father north (e.g. Taguchi and Hartmann 2006). The discrepancies could be due to the different data period considered in those studies; for example, Garfinkel and Hartmann (2008) computed observed composites over NDJF, probably mixing in various signals, whereas Taguchi and Hartmann (2006) performed sensitivity experiments under perpetual January conditions, more likely isolating the ENSO signal when it is maximum. Note that the target of our project is the mean seasonal stratospheric response to ENSO, which is approximately linear (e.g. Butler et al. 2014), rather than disturbances on short timescales (days and weeks) associated with sudden stratospheric warmings, which may be internally generated within the atmosphere (e.g. Manzini et al. 2006). Regardless of its origin, it is clear that the subpolar wave-forcing mainly affects the 'deep branch' of the BD circulation (Ábalos et al. 2014). DANAE will explore the interference of the ENSO-forced wavetrain with the climatological stationary wave at high latitudes over northern Canada-Alaska, which is where the ENSO signal penetrates deeper into the middle stratosphere (Garfinkel and Hartmann 2008), and the implications for the deep-BD circulation and the timing of the stratospheric anomaly in January linked to the ENSO-NAE teleconnection.

The comprehensive and systematic comparison that will be carried out in this project between the observed tropospheric/stratospheric dynamics linked to the canonical JFM ENSO-NAE signal and the teleconnection mechanisms simulated by state-of-the-art coupled models, apart from being unprecedented, could clarify the as-of-yet elusive unified view of this remote relationship.

Prospects for seasonal climate prediction are very encouraging, since improvements in understanding of the physical phenomena at seasonal-to-interannual timescales would translate into advances in operational forecasting systems. A recent example of this transfer is the predictability gained from Eurasian snow and Arctic sea-ice anomalies, which can be used to formulate skilful empirical (Brands et al. 2012; García-Serrano et al. 2015) and dynamical (Riddle et al 2013; Scaife et al. 2014) predictions. This exercise requires an appropriate assessment of the obtained skill for subsequent comparison with model improvements in terms of forecast quality (Frías et al. 2010). Ideally this assessment needs to be complemented with the identification of GCM biases, ultimately working towards their elimination. In the NAE region, winter is the season with the overall largest systematic errors in dynamical prediction systems, particularly for the pressure field, surface temperature and precipitation (e.g. Doblas-Reyes et al. 2010). The winter North Atlantic eddy-driven jet and stratospheric polar vortex are also biased, not only regarding the strength of the flow but also the location, as they are usually displaced southward compared to re-analysis (e.g. Maycock et al. 2011; Peings et al. 2012). Moreover, climate prediction handles the additional dimension of lead-time; when initialized with states close to the observations, models drift towards their preferred imperfect climatology, which implies systematic uncertainties and errors in the forecasts. DANAE will investigate the evolution of model biases and also point out elements that need to be corrected in seasonal forecast systems to better represent the ENSO teleconnection in the NAE region.

This project provides a suitable scenario for improving the predictability of the winter surface climate in the North Atlantic-European region and its simulation.

- **Objectives**

Following the identification of all the issues above, a set of objectives has been designed:

- To describe the key variables and dominant processes underlying the ENSO-NAE teleconnection.

- To assess the ability of current seasonal forecasts in capturing the ENSO-NAE teleconnection.

- To quantify the contribution of ENSO to grid-point prediction skill over the NAE region.

- To explore the link between model systematic errors and the success/lack of prediction skill over the NAE region.

- **Background of the Research Team / Other groups working in the topic**

In his PhD at UCM, the PI (Javier García-Serrano) developed a profound understanding of the atmospheric teleconnections associated with oceanic forcings, such as ENSO in the tropical Pacific, the Atlantic Niño in the tropical Atlantic, the Subtropical North Atlantic, or temperature anomalies in the Mediterranean Sea. Although the main focus was the influence of these teleconnections on the Euro-Atlantic climate variability, the training provided him with an insightful knowledge of the dynamical processes governing the remote impacts of SST anomalies. In particular, he developed an excellent background on tropical-extratropical atmospheric teleconnections, which usually comprise: (i) a heat-induced baroclinic response related to changes in deep tropical convection; (ii) a Rossby wave source resulting from the conversion of the heat-induced baroclinic response into barotropic anomalies; (iii) barotropic wave propagation to high latitudes, largely determined by the structure of the mean flow; and (iv) the interaction between the perturbations that propagate to the extratropics and midlatitude storm-tracks. One of the key conclusions derived from his thesis was that the seasonal cycle of the jetstreams determines to a large extent the propagation paths of Rossby wavetrains reaching the NAE region. After his Phd, he moved his scientific training from the diagnostic approach into a more prognostic approach. During his career as post-doctoral scientist, first as a hired researcher at IC3, then via his own funding at the University of Tokyo (AORI), and afterwards at LOCEAN-IPSL, he has analysed the most complete set of decadal climate predictions available to date, including the ENSEMBLES and CMIP5 multi-models, where he has acquired an in-depth knowledge of the primary skill measures to evaluate forecast quality of ensemble hindcasts. The main objectives of this research have been the Atlantic Multi-decadal Oscillation and the West African monsoon. In the last three years, he has started to assemble his two research interests, teleconnection dynamics and climate prediction, into a single research line. This work focuses on predictability of the winter NAO from Arctic sea-ice variability and ENSO-related predictability over the tropical Atlantic.

Ileana Bladé holds a Ph.D degree in Atmospheric Sciences from the University of Washington. During her doctoral thesis, which was supervised by Dr. Dennis Hartmann, she used a simple two-level general circulation model (the spectral model of Hendon and Hartmann 1985) to investigate the dynamics and thermodynamics of the Madden-Julian Oscillation, an important mode of tropical intraseasonal variability. She then spent an additional 4 years as a post-doctoral researcher at the Joint Institute for the Study of the Atmosphere and Oceans (JISAO), investigating low-frequency atmospheric variability as part of Dr. Mike Wallace's group. She returned to Barcelona to work at the Polytechnic University of Barcelona (1999); during that time she co-authored two important review papers, both of which have been highly cited (Alexander et al. 2002, Kushnir et al. 2002). In 2002 she obtained a Ramón and Cajal position at the University of Barcelona. She is now an associate professor ("professora agregada") in the department of Astronomy and Meteorology at the University of Barcelona (METEO-UB), where she has pursued her interest on midlatitude coupling, atmospheric low-frequency variability, climate change and ENSO teleconnections. As a result of her solid education, Ileana Bladé possesses a very strong theoretical background in atmospheric and climate dynamics. She has considerable experience diagnosing and interpreting the results from large numerical experiments with general circulation models (GCMs), including CMIP ensembles. Her most recent work, which has focused on the summer North Atlantic Oscillation (SNAO), has revealed an important bias of climate models in the Mediterranean region in that they fail to reproduce the strong positive influence of the SNAO on Mediterranean precipitation (Bladé et al. 2011, 2012).

The PI and Dr Bladé are joining forces in this proposal because of their common interest in exploring poorly understood aspects of the ENSO influence in the North Atlantic-European sector and questioning often-assumed views on ENSO teleconnections. They began to develop ideas for the current proposal following their 2011 paper which showed that, although the surface signature of ENSO in the North Atlantic exhibits a dipolar pattern reminiscent of the NAO, this teleconnection should not be interpreted in terms of the NAO but simply as the propagation of the ENSO-related Rossby wavetrain emanating from the tropical Pacific (García-Serrano et al. 2011). Since this wavetrain is not well-established until mid-winter, as convincly demonstrated in an earlier paper by Bladé et al. (2008), this result also explained the intra-seasonal fall-to-winter change in the ENSO teleconnection in the NAE sector. Many open questions remained, however, particularly whether a suitable Rossby ray-tracing analysis would be able to confirm the postulated source of the dipolar-like signal in the North Atlantic as well as the implications of this result for seasonal forecasting of surface climate in Europe.

At national level, several research groups work on ENSO teleconnections and/or ENSO-related impacts, among them:

- Dept. Geofísica y Meteorología (TROPA), UCM, Madrid; led by Belén Rodríguez-Fonseca [they have submitted a proposal to this call dealing with low-frequency modulation of the ENSO teleconnection to Europe in spring and autumn – TROVARTE project]
- Dept. Astrofísica y CC Atmósfera (STREAM), UCM, Madrid; led by Ricardo García-Herrera
- Santander Meteorology Group, UNICAN-CSIC, Santander; led by J.M. Gutiérrez
- Instituto Pirenaico de Ecología, CSIC, Zaragoza; led by Sergio M. Vicente-Serrano
- Dept. Física Aplicada, Universidad de Granada, Granada; led by Yolanda Castro-Díez
- Dept. Física, Universidad de Jaén, Jaén; led by A. David Pozo-Vázquez
- Dept. Física, Universidad de Alcalá, Alcalá de Henares; led by María José Ortiz Beviá
- Climate Dynamics and Impacts Unit (UDIC), IC3, Barcelona; led by Xavier Rodó
- Environmental Physics Laboratory, Universidad de Vigo, Orense; led by Luis Gimeno

At international level, many different research centres and university departments work on ENSO teleconnections and/or ENSO-related predictability; listed below are the most relevant ones for the project:

- Hadley Centre for Climate Change, Met Office, Exeter, UK; led by Adam A. Scaife
- Max-Planck-Institut für Meteorologie (MPI-M), Hamburg, Germany; led by Elisa Manzini
- Dept. of Meteorology, University of Reading, UK; led by Julia M. Slingo
- Helmholtz-Zentrum für Ozeanforschung (GEOMAR), Kiel, Germany; led by Mojif Latif
- Attribution and Predictability (ESRL/NOAA), Boulder, USA; led by Martin P. Hoerling
- Atmosphere-Ocean Processes (ESRL/NOAA), Boulder, USA; led by Michael A. Alexander
- Atmospheric Chemistry Division (NCAR), Boulder, USA; led by Bill J. Randel
- Dept. Atmospheric Sciences, University of Washington, USA; led by Dennis L. Hartmann
- Dept. Environmental Sciences, Columbia University, USA; led by Jeffrey Shaman
- Dept. of Earth and Planetary Sciences, Hardvard University, USA; led by Eli Tziperman
- Dept. of Meteorology, University of Maryland, USA; led by Sumant Nigam

- **Societal Challenges**

The goal of DANAE is twofold: on the one hand, to gain understanding in the mechanisms responsible for the predictability; and, on the other hand, to gain insight into the sources of prediction skill and point at the key elements/processes that need to be better represented in seasonal forecast systems. The systematic assessment of the atmospheric pathways proposed here may address the elusive unifying view of the canonical ENSO-NAE relationship in mid/late-winter. All in all, the results are expected to provide better scientific understanding of the research problem, whereby matching the premises of the challenge '*6.4.5. Reto en acción sobre el cambio climático y eficiencia en la utilización de recursos y materias primas*', and in particular those of the sub-items *I. Cambio Climático (i)* and *(viii)* dealing with '*investigación aplicada al desarrollo de las técnicas de análisis y modelización de datos*'. The results are also expected to contribute to the sub-item *II. Eficiencia en la utilización de recursos y materias primas (i)* '*previsión de sequías, avenidas y catástrofes naturales o de origen antrópico*'. Likewise, the objectives and expected outcomes of DANAE tightly follow the H2020 societal challenge '*Climate action, environment, resource efficiency and raw materials*', since the project is expected to increase European competitiveness in climate forecasting; this advance is assembled through the priority line '*Developing comprehensive and sustained global environmental observation and information systems*'. Lastly, the results of this project are also expected to contribute to the WCRP (WMO) Grand Challenge '*Understanding and predicting weather and climate extremes*'.

The outcomes of this project will be useful for the community as a benchmark for future generations of seasonal prediction systems; however, they may also provide valuable information for forecast providers and decision makers that use seasonal forecast products. Thereby, DANAE fits within the *Global Framework for Climate Services*, established by the WMO to ensure that climate information and predictions will be made available to decision makers enduring the increasing impacts of climate variability and change. DANAE aims at providing some guidance for the development of climate services based on climate predictions. In particular, the skilful prediction of the ENSO influence on the winter European climate may translate into actionable information for surface wind-based resources, namely wind power. Thereby, DANAE could facilitate strategic choices in the energy sector, this way addressing the challenge '*6.4.3. Reto en energía segura, eficiente y limpia*', with a marked emphasis on the priority *II. Energía Eólica*. The development and application of climate services will increase our knowledge of the ability to reliably predict climate variability in the European region on timescales ranging from a month to a season. This is a pre-requisite to provide support for technical, institutional and socio-economic innovation in the area of climate action. DANAE, thus, also addresses the H2020 societal challenge '*Climate action, environment, resource efficiency and raw materials*' via its specific objective '*protection and sustainable management of natural resources*'.

- **Methodology**

To achieve the objectives mentioned above, the following list of tasks has been considered:

Task 1.1. Revisit the ENSO-NAE teleconnection by using observations.

Javier García-Serrano (20%)	Tércio Ambrizzi
Ileana Bladé (60%)	Álvaro de la Cámara
Miguel Castrillo (20%)	Marta Ábalos

Regression maps of the observed Niño3.4 SST index onto different variables will be computed. Boreal winter (DJF) will be considered to construct the Niño3.4 index. Three consecutive monthly means (J, F, M) and their seasonal average (lag 1, JFM), together with two-month means (JF, FM), will be considered to compute the regression maps. This will characterise the linear teleconnections in the Northern Hemisphere in mid/late-winter. The fields to be analysed are monthly means of SST, SLP, 2m air-temperature, precipitation, velocity potential at 200-hPa (representative of the divergent circulation), streamfunction at 200-hPa (representative of the rotational circulation), and daily means of geopotential height, temperature and three-dimensional wind from 1000hPa to 1hPa. The two latter fields will be used to compute the Eliassen-Palm flux (e.g. Vallis 2006). Divergent and rotational components of the wind at 200-hPa will be derived from the velocity potential and streamfunction, respectively, in order to compute the Rossby wave source terms (Sardeshmukh and Hoskins 1988). Climatological zonal wind at 200-hPa will be used to perform Rossby wave ray-tracing, i.e. integration of the preferential energy propagation path (e.g. Hoskins and Ambrizzi 1993). To assess observational uncertainty, two datasets will be used both for SST (NOAA's ERSST; Met Office-Hadley Centre's HadSST) and atmospheric variables (ECMWF's ERA-interim and NOAA's MERRA re-analyses).

Task 1.2. Sensitivity experiments.

Javier García-Serrano (20%)	Rein Haarsma
Miguel Castrillo (80%)	Daniela Matei

Two sets of sensitivity experiments will be performed in this project to advance understanding of the dynamics involved in the ENSO-NAE teleconnection.

The first type of experiments will analyse the tropospheric pathway of the ENSO teleconnection to NAE mid-winter. The atmosphere model used will be SPEEDY (Simplified Parameterizations primitivE-Equation DYnamics), which is an intermediate complexity AGCM without stratosphere. It has a vertical resolution of seven layers and a triangular spectral truncation at total wavenumber 30 (T30L7; top level at 100hPa) The experimental set-up will be similar to the one used in Haarsma and Hazeleger (2007), namely control and perturbed transient-runs, in this case both consisting of a 200-member ensemble of 30-day integrations for the month of January. The initial conditions for the first of January will be obtained from a 200-year integration with climatological SSTs. The control transient-simulations use SST climatology as boundary condition. In the perturbed transient-simulations, a SST anomaly will be prescribed in the tropical Pacific with climatology elsewhere. To partially separate results from the model framework, and for ease of comparison, observational SSTs (ERSSTs) will be used to define the anomalous forcing fields, which correspond to the regression of ERSST January anomalies onto the Niño3.4 index in DJF (see Task 1.1); this will correspond to El Niño runs – multiplying the regression by -1 will set the forcing field for La Niña runs. The amplitude of the SST regression maps will be augmented to reach a maximum of 2.5ºC at the equator, similar to previous studies (Taguchi and Hartmann 2006), in order to compensate for the damping in surface heat fluxes which results from considering the ocean as an infinite reservoir of heat capacity (AGCM simulations).

The second type of experiments will investigate the role of the stratosphere in the ENSO-NAE teleconnection during late-winter. In this case, two state-of-the-art coupled climate models will be used, namely EC-EARTH and MPI-ESM. These two models are regularly employed for climate prediction (Du et al. 2012; Guemas et al. 2013 – EC-EARTH / Matei et al. 2012a, 2012b – MPI-ESM) and in particular for seasonal forecasting (Batté and Doblas-Reyes 2015 – EC-EARTH / Domeisen et al. 2015 – MPI-ESM; see Task 2.1). The sensitivity experiments performed in DANAE will use EC-EARTH at T255L91 resolution and MPI-ESM at T63L47 resolution, both with a top level at 0.01hPa. The experimental set-up will be common as well and coordinated, consisting of twin control and degraded-stratosphere runs, both 200-year long simulations with pre-industrial conditions in order to avoid effects of time-varying radiative forcings. The degraded-stratosphere runs will make use of a linear relaxation of the zonal-mean zonal winds above 10hPa toward the daily control climatology; this has the advantage of damping the variability of the vortex, and hence the stratospheric response to ENSO, but without strongly affecting the mean state (see Bell et al. 2009).

Task 2.1. Assessment of the prediction skill in JFM.

Javier García-Serrano (10%)
Javier Vegas (40%)
Post-doc (25%)

Daniela Matei
Marta Ábalos

The first step towards gaining insight into the NAE predictability is to assess current capabilities of the forecast systems in predicting regional anomalies. The project will analyse retrospective forecasts (hindcasts) from an unusually large number of operational dynamical forecast systems. These are part of EUROSIP (EUROpean Seasonal-to-Interannual Prediction; http://ecmwf.int/products/forecasts/seasonal/documentation/eurosip/) and NMME (North American Multi-Model Ensemble; http://www.cpc.ncep.noaa.gov/products/NMME/). These hindcasts represent the most comprehensive set of seasonal hindcasts to date; it is worth noting that no study so far has tackled the inter-comparison exercise of assessing their relative merits to forecast the ENSO-NAE teleconnection – this project will be pioneering. The study will also analyse hindcasts from the longest-to-date multi-model seasonal hindcast repository, provided by the European project ENSEMBLES (http://www.ensembles-eu.org/). This additional set of seasonal hindcasts will be used as reference for the performance of the EUROSIP and NMME forecast systems. The latter cover a relatively short period of around 30 years, 1981-2011 (in EUROSIP) or 1982-2011 (in NMME), whereas ENSEMBLES extends over 1960-2005. The ensemble size varies between forecast systems. Additionally, DANAE will evaluate two experimental seasonal prediction systems, based on EC-EARTH and MPI-ESM climate models. The former (EC-EARTH) is not implemented as an operational forecast system but the results of the forecast quality assessment could be used to guide changes in the ECMWF's operational forecast system (contributing to EUROSIP), as EC-EARTH is a coupled model derived from the ECMWF's model components: IFS for the atmosphere and NEMO for the ocean (see Du et al. 2012). The latter (MPI-ESM) is not yet operational but it is planned to be the German contribution to EUROSIP.

The target season in this task is mid/late-winter (JFM), when the ENSO influence is at the maximum over NAE; in addition to the seasonal average we will also consider mid-winter (JF) and late-winter (FM) separately. Two start dates will be used for verification, i.e. the initializations of November and August (of the previous year), which will allow us to analyse 2 and 5 months lead-time predictions for JFM (and JF) and 3-6 months lead-time for FM. In addition, the start date of February, providing lead-time zero for FM, will be used to assess the impact of stratospheric initial conditions on the reproducibility of the ENSO-NAE signal. SLP, 2m air-temperature and precipitation will be the target variables. To facilitate comparison with other tasks, the key measure of forecast quality will be the deterministic skill score anomaly correlation coefficient (ACC), although other deterministic/probabilistic scores will also be considered.

Task 2.2. Evaluation of the ENSO-driven prediction skill over the NAE region.

Javier García-Serrano (20%)	Daniela Matei
Javier Vegas (20%)	
Post-doc (20%)	

The second step to improve our understanding of the NAE predictability is to quantify the contribution of ENSO to regional prediction skill. The goal is to identify areas where the observed ENSO fluctuations (as characterised via the Niño3.4 index) are more representative of the simulated variability. To this aim, correlation maps between ensemble-mean hindcast anomalies and the observed Niño3.4 index will be performed. This diagnostic is complementary to the prediction skill assessment at grid-point level (Task 2.1). This approach, developed by the PI in the context of decadal climate prediction (García-Serrano et al. 2012, 2014), provides a simple, systematic procedure for quantitatively assessing performance in different forecast systems. The target seasons are again JFM, JF and FM. The diagnostic will be applied to the same three start dates as above (February, November, August; e.g. with 0, 3, 6 months lead-time for FM) and upon the multi-model ensembles and experimental forecast systems. El Niño/La Niña composites will also be considered to evaluate potential non-linearities or conditional skill.

Task 2.3. Analysis of the ENSO-NAE teleconnection in seasonal forecast systems.

Javier García-Serrano (10%)	Tércio Ambrizzi
Ileana Bladé (30%)	Rein Haarsma
Javier Vegas (20%)	Álvaro de la Cámara
Post-doc (25%)	Marta Ábalos

Regression and correlation maps of ensemble-mean hindcast anomalies, with similar atmospheric variables as in Task 1.1, will be performed onto the observed and predicted Niño3.4 SST index. The latter will illustrate how the ENSO-NAE teleconnection is simulated in the forecast systems, while the former will give information of how close the predicted dynamical processes are to the observed ones and will help to relate the NAE prediction skill (Tasks 2.1-2.2) with the models' accuracy in representing the ENSO atmospheric teleconnection. El Niño/La Niña composites will also be considered.

Task 2.4. Identification of model biases relevant for the ENSO-NAE teleconnection.

Javier García-Serrano (20%)	Daniela Matei
Ileana Bladé (10%)	Álvaro de la Cámara
Javier Vegas (20%)	
Post-doc (25%)	

To better understand the performance of different forecast systems, i.e. relative merits and deficiencies, their systematic errors in the course of the forecast time, from 2-month (JFM for the November start date) to 5-month lead-time (JFM for the August start date), plus additionally 0-month lead-time for FM (start date of February), will be evaluated. Different target variables will be analysed according to the results from previous tasks (e.g. SLP, zonal wind...). The purpose is to lay the foundation for reducing bias-related uncertainties and improving the simulation and prediction of the NAE winter surface climate in future seasonal hindcast/forecast experiments.

- **Implementation**

As envisaged from its conception, DANAE has been designed with the aim of tailoring the Research Team's background, the Work Team's expertise and the facilities at the host institution, in order to ensure its successful completion. The work plan reflects this idea, where the scientific program can be implemented from head-to-tail and in autonomy. The project is divided into three main work-packages (WPs): two for research (WPs 1-2) and one for management and dissemination (WP3). Further details follow below, including milestones (Ms) and deliverables (Ds); note that the expected date is indicated in terms of the corresponding project month, hereafter *pm*. The schedule of the tasks described above is presented in the following chronogram.

Project_Month		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
WP1	T1.1																		
	T1.2																		
WP2	T2.1																		
	T2.2																		
	T2.3																		
	T2.4																		
WP3	Comm		C1																
	Dissem						D1						D2						D3
	Explot										E1								
Milestone						M1	M2	M3					M4					M5	
Deliverable												D1.1							D2.1
Meeting																			
Visit														V1					

Project_Month		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
WP1	T1.1																		
	T1.2																		
WP2	T2.1																		
	T2.2																		
	T2.3																		
	T2.4																		
WP3	Comm					C2												C3	
	Dissem						D4						D5						D6
	Explot				E2												E3		
Milestone							M6										M7		
Deliverable									D1.2									D2.2	D3.1
Meeting																			
Visit						at MPI		V2								V3			

Note that no substantial weaknesses or risks have been identified, apart from occasional delays with the milestones/deliverables, since the members of the Research and Work Teams have ample competences in the field and all datasets to be analysed are freely available for research purposes. Even so, the project would rely on WP3 in the case of unexpected setbacks.

<u>Work-Packages description</u>

WP1. Teleconnection dynamics. This work-package aims to increase understanding of atmospheric processes key to the ENSO-NAE teleconnection, by means of analysing observational datasets for the target season and performing dedicated modelling experiments. It comprises Tasks 1.1-1.2 and will be monitored by M1,M3 and D1.1-D1.2.

WP2. Predictability. This work-package is devoted to assessing the skill current operational forecast systems have in the NAE region, the ENSO contribution and its underlying dynamics, and to evaluate models' systematic errors and investigate their influence on the forecast quality. It comprises Tasks 2.1-2.4 and will be monitored by M2,M5 and D2.1-D2.2.

WP3. Project management and dissemination of results. This work-package will ensure the appropriate management of the project and broadly disseminate the outputs throughout its duration. It will be feasible thanks to administrative support at the host institution (BSC) and the strong team "Earth Science Services" established at departmental level (BSC-ES): 1 group leader, 2 project manager, 5 climate services officers. WP3 will monitor the progress of the project, ensure timely preparation of scientific reports (Ms, Ds) and outreach activities (see Section C.2), facilitate communication among the Research and Work Team members' institutions (BSC, UB, USP, KNMI, MPI, LMD/NCAR), and organize the project meetings. The latter consist of three annual meetings to ensure that action items are under way, and will be hosted by BSC [M4, pm12; M7, pm34] and MPI [M6; pm24]. These project meetings are not intended to be internal symposiums but open conferences, in which researchers not directly involved in DANAE, e.g. from other groups in Spain (e.g. UCM, UNICAN), will be welcomed or even invited. Coincidental with the project meetings, 1-month visits of a Work Team member to BSC are scheduled to discuss results and plan additional analysis (V1-V3).

Under WP3, the project will also undertake a final report that, in addition to summarizing the scientific achievements, will identify priority research lines to enhance skill of the NAE climate variability by advancing the impact of model improvements on prediction and their potential to reduce uncertainties in operational forecasts (D3.1).

<u>List of milestones</u> (*tracking progress*)

- M1: Observational analysis performed [due date - pm05; dissemination level - participants].
- M2: Database for hindcast data established [due date - pm06; dissemination level - participants].
- M3: Boundary conditions and experimental protocol defined [due date – pm07; dissemination level - participants]
- M4: First project meeting [date - pm12; dissemination level - public].
- M5: Report on achievements and setbacks of the skill assessment, and strategy for hindcast validation of teleconnection dynamics established [due date - pm17; dissemination level - public].
- M6: Second project meeting [date - pm24; dissemination level - public].
- M7: Third project meeting [date – pm34; dissemination level - public].

<u>List of deliverables</u> (*tracking achievements*)

- D1.1: Assessment of the relevant processes in the ENSO-NAE teleconnection from observations [due date - pm11; dissemination level - public].
- D1.2: Analysis of the tropospheric and stratospheric pathways from sensitivity experiments [due date - pm26; dissemination level - public].
- D2.1: Assessment of the dynamical forecasting capabilities for NAE climate [due date - pm18; dissemination level - public].
- D2.2: Assessment of the dynamical forecasting capabilities to reproduce the observed teleconnection mechanisms [due date - pm35; dissemination level - public].
- D3.1: Final scientific report and recommendations [due date - pm36; dissemination level - public].

- **Technical resources**

[see requested budget for details]

The BSC has hosted outstanding high performance computing facilities since its inception in 2006. All the computational resources that the centre has are going to be available for DANAE to carry out the sensitivity experiments described in Task 1.2. Currently, BSC has the following supercomputing infrastructures:

- The MareNostrum III, a supercomputer based on Intel SandyBridge processors, iDataPlex Compute Racks, Linux Operating System and Infiniband interconnection. It has a total of 48896 cores, a peak computing power of 1017 TFlops.
- The MinoTauro supercomputer (3 TB ram, 182.9 Tflops peak), which combines traditional CPU cores with GPU accelerators is also hosted at the BSC facilities.

However, additional equipment is required for a successful implementation of the work plan. Due to the unusually large number of dynamical seasonal hindcasts that will be used in the project (Tasks 2.1-2.4), EUROSIP and NMME multi-models plus EC-EARTH and MPI-ESM, DANAE would need a particular infrastructure for the accomplishment of all post-processing; a fat node is the most suitable tool for handling this kind of data output, which involve two extra dimensions: ensemble-member and lead-time. On top of this, to allocate the seasonal hindcast files, the observational datasets (Task 1.1), the outputs from the sensitivity experiments, and all post-processed variables and diagnostics, the project would also require local storage; a suite of five disks of 4TB HDD each has been requested. Likewise, DANAE considers hiring a post-doc (see below) to complementarily deal with Tasks 2.1-2.4; hence, the project would additionally need a workstation (PC) to work in autonomy. Finally, and in order to facilitate an efficient execution/development of the activities in missions outside the host institution, e.g. attendance to meetings or the visit to MPI (Germany), DANAE would require a laptop with an UNIX-based OS.

- **Human resources**

The need of a post-doc for the optimal achievement of the tasks belonging to WP2 'Predictability' (Tasks 2.1-2.4) is justified by the enormous amount of diagnostics proposed to accomplish our goal of advancing knowledge of how current seasonal forecast systems represent the dynamics involved in the ENSO-NAE teleconnection. These diagnostics are all necessary to go beyond the forecast quality assessment (skill scores) and perform an appropriate evaluation of model dynamical mechanisms and systematic errors. The post-doc will help the scientists of the Research and Work Teams towards a better completion of these objectives. At the same time, he/she will benefit from the support of a dedicated Computer Engineer. The candidate should be a recent PhD graduate in Meteorology, Oceanography or Environmental Sciences, preferably with a good background in atmospheric dynamics and statistical analysis.

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C.2. IMPACTO ESPERADO DE LOS RESULTADOS

[see attached letters of support/interest]

This proposal presents the novelty of evaluating the ENSO-NAE teleconnection using an unprecedented set of dynamical seasonal hindcasts. The joint use of ENSEMBLES, EUROSIP and NMME multi-models will provide the most comprehensive assessment so far of the seasonal forecasting capabilities over the NAE region. This will also be the first study to explore the specific ability of these forecast systems to simulate the winter ENSO-NAE teleconnection. Together, this project could represent a major breakout at international level for the climate forecasting community, as attested to by prime institutions in Spain, Europe and USA.

The project also aims to investigate the influence of model systematic errors on the skill of the seasonal forecast systems. Some of the largest biases in state-of-the-art climate models are found in the NAE region in winter, and ongoing international initiatives, such as the FP7 SPECS project, are being carried out to understand the sources of those biases, as part of one of the WCRP challenges towards more reliable models. Our approach and outcomes will be of great interest to the climate modelling community, as indicated by the SPECS's project office.

This project is also committed both to expanding the basis for learning about climate forecasting and to applying the new knowledge to activities of scientific disclosure.

- Communication: DANAE could contribute substantial advances in seasonal climate prediction in the Euro-Atlantic sector. The project will prepare three leaflets for research centres producing operational forecasts (e.g. ECMWF, Météo-France); the first one will contain basic information about the premises and objectives (C1); the next two will distribute information about major achievements (C2-C3). The project will also contact the IRI (International Research Institute for Climate and Society) to schedule a general-purpose talk about extratropical prediction skill linked to ENSO given by the PI.

- Dissemination: The active presence of the Work Team members and scientists from the BSC-ES in different international committees will ensure the projection of DANAE's outcomes. The results will also be presented at top scientific meetings, such as those by the American Geophysical Union and/or European Geosciences Union. The project will produce periodic brochures (D1-D6) that will be made available via the BSC-ES's webpage. Lastly, the project intends to follow the European Commission's policy on open-access for research articles.

- Exploitation: The forecast quality assessment performed in DANAE could translate into actionable regional climate information, particularly for surface wind. Two private companies from the wind energy sector have already expressed their interest in the project's outcomes. The project will provide them with a yearly newsletter describing goals and applicability (E1-E3). As a first approach towards climate services, the project will contribute to the prototype development of wind power supply forecasts undertaken in the FP7 EUPORIAS and national RESILIENCE projects. DANAE will notably increase the capability of Spanish research groups in dynamical ensemble climate forecasting by encouraging visits to the BSC-ES and via the unique data repository and analysis tools that will be created. It is also hoped that the Agencia Española de Meteorología (AEMET) will be able to easily take over the technical development carried out in this project for specific operational applications.

C.3. CAPACIDAD FORMATIVA DEL EQUIPO SOLICITANTE

The project is structured in such a way as to offer a unique opportunity to strengthen and widen the competences of the PI (Dr García-Serrano), whereby he will have to build a bridge between his theoretical background in atmospheric dynamics and the practical requirements of climate prediction. Particularly effective in this regard will be the clear bottom-up nature of the proposed study and the high research level of the Research and Work Teams. The proposal represents a great opportunity for the PI to develop project management skills needed to become an accomplished and multidisciplinary researcher. By doing so, and by managing a scientific problem from end to end, he will create a stream of responsibilities associated with the outcomes of the project, an important part of the training of an independent researcher. Thus, the project will provide him with the final expertise needed to lead a research group as a junior scientist.

Since its goals are clearly stated, the methodology is precise and the technical support to undertake the research is considerable (see Research Team), DANAE is very adequate for the formation of young researchers. The ENSO influence on the remote NAE region has always brought the attention of the international scientific community, so that training young experts on this research area will reinforce the Spanish position in the global framework. The novel approach of exploring teleconnection dynamics for operational climate prediction will definitely increase the capability of the Spanish scientific community, and particularly the host institution (BSC-ES), on dynamical ensemble climate forecasting (see Section C.2). The background of the PI and Dr. Bladé provides a great opportunity for training new experts. The PhD student will also benefit from interacting with the Work Team as well as with the large amount of scientists visiting both BSC-ES and METEO-UB, who in some cases are considered world-class references in their field. Hence, this project provides a highly stimulating scenario for carrying out a PhD thesis. Its work plan would be similar to the one in DANAE but applied to other seasons, for which the ENSO signal has shown to be as strong as in winter: spring (Rodó et al. 1997; van Oldenborgh et al. 2000; Mariotti et al. 2002; Frías et al. 2010) or autumn (Mariotti et al. 2002, 2005; Shaman and Tziperman 2011).

BSC-ES has a long record of supervising PhD theses in the doctoral programme *Environmental Engineering* (UPC), with 8 dissertations completed during the last five years. BSC-ES has also ample experience in organising/hosting conferences and workshops. As for METEO-UB, it has demonstrated teaching capacity in that it has been offering professional degrees in Meteorology since 2000. Currently it runs the only professional master in meteorology offered in Spain, the *European Master of Meteorology*. Two of the department members also coordinate other masters, the UB *Master in Applied Climatology and Media* and the UB-UPC *Master in Renewable Energies and Energy Sustainability*. Dr Bladé herself has supervised 3 PhD theses: Antonio Barrera-Escoda (2008, UB) –"Evolution of hydrological extremes in Catalonia in the last 500 years and regional modelling" – Excellent Cum Laude; Vicent Altava Ortiz (2010, UB) – "Application of the analogue approach to heavy precipitation events in Catalonia", Excellent Cum Laude; and, Didac Fortuny Almiñana (2015, UB) – "Climate change and precipitation trends in the northern Mediterranean", Excellent by unanimity.

C.4. IMPLICACIONES ÉTICAS Y/O DE BIOSEGURIDAD

Not applicable.

María Dolores Frías
Santander Meteorology Group
http://www.meteo.unican.es
Department of Applied Mathematics and Computer Science
University of Cantabria
Santander, Spain
mariadolores.frias@unican.es

July 10, 2015

To Whom It May Concern,

I am writing this letter in support of the application of Dr. Javier García Serrano for the project proposal entitled *Dynamics And predictability of the ENSO teleconnection in the North Atlantic-European region.*

The Santander Meteorology Group, and myself as part of the group, have been working on seasonal forecasting in the last 15 years and participating in several European projects related to this issue. In our studies we have found some seasonal predictability over Europe associated with El Niño-Southern Oscillation (ENSO) as main source. However the skill of this kind of forecasts is still limited at these latitudes. Clearly, more research is required to better understand the ENSO influence on the European region and how the seasonal forecasting systems represent the dynamical mechanisms of this teleconnection. In this research topic, the proposal of Dr. García Serrano is consistent with the state of the art and fulfill the previous requirement. The study can contribute to improve the current seasonal forecasting capabilities over Europe.

Dr. García Serrano is a young researcher, but he has a strong background in the study of atmospheric teleconnections related to oceanic forcings and their influence on the European climate. I strongly believe that he will make the most out of this opportunity to further his research and encourage you to consider his application for financial support.

Sincerely,

M. Dolores Frías

Met Office
Hadley Centre

Professor Adam Scaife
Met Office
Exeter EX1 3PB
United Kingdom
Tel: +44 (0)1392 884056
adam.scaife@metoffice.gov.uk

6th July 2015

To Whom it may concern,

RE: DANAE Proposal

The project DANAE 'Dynamics and predictability of the ENSO teleconnection in the North Atlantic-European region' would contribute to improve our understanding of the mechanisms behind the links between the El Niñc Southern oscillation and European climate. ENSO itself is highly predictable and forms the cornerstone of seasonal forecasting while European seasonal climate has up until recently been difficult to predict. This project is therefore very timely in helping us to understand and increase the skill of current seasonal forecasting systems. The proposed analyses could also advance knowledge about climate predictability and long term change that it is known to be uncertain in the target region.

We would like to continue our collaboration with the applicant's group, and I'm personally confident in the ability of Javier Garcia-Serrano to undertake and achieve the proposed research. Therefore, we fully support this grant proposal.

Yours Sincerely,

A. Scaife.

Professor Adam Scaife

Head Monthly to Decadal Prediction, Met Office Hadley Centre

The International Research Institute for Climate and Society

goddard@iri.columbia.edu
Tel: +1-845-680-4430

17 July 2015

Re: "Dynamics And predictability of the ENSO teleconnection in the North Atlantic-European region" - DANAE

To whom it may concern,

The IRI is very supportive of the work proposed by Dr. García-Serrano of the Barcelona Supercomputing Center (BSC) under the DANAE project. The project aims to increase understanding of the dynamics how ENSO impacts the North Atlantic and European region – a region notoriously difficult to predict on seasonal timescales. Better understanding can lead to targeted model improvement and better use of existing state-of-the-art models for prediction.

We are interested to collaborate with Dr. Garcia-Serrano and his colleagues at BSC on this work, which would be greatly facilitated if this project were approved.

Sincerely,

Lisa Goddard

Director, International Research Institute for Climate & Society (IRI)
The Earth Institute, Columbia University

Madrid, July 10, 2015

To whom it may concern,

As coordinator of the Mediterranean Outlook Forum (MedCOF), it is my pleasure to write a letter expressing my interest and support for the proposal by Dr. García-Serrano titled "Dynamics And predictability of the ENSO teleconnection in the North Atlantic-European region (DANAE)". The proposal is very relevant to MedCOF activities and I am sure it will contribute to the improvement of our operational activities. In particular, MedCOF can highly benefit from the scientific results and outreach material produced by this project.

Launched following the Scoping Meeting in June 2013 at the State Meteorological Agency of Spain, MedCOF generates consensus seasonal forecasts for the Mediterranean region and Northern African region. The forum reflects the World Meteorological Organization's (WMO) desire to increase the availability of user-friendly climate service. Its purpose is to improve climate scientists' understanding of the information needs of different user groups and thus able to produce more usable and salient climate information. The forum stands for an opportunity to member countries to exchange information on the last and current knowledge of climate conditions. Besides, it promotes training and operational activities on seasonal timescales.

In conclusion, I fully support Dr. García-Serrano's proposal as MedCOF will clearly benefit from the project outcomes.

Sincerely,

Ernesto Rodríguez-Camino
MedCOF Coordinator

EnBW AG
Durlacher Allee 18
76131 Karlsruhe
Germany

July 16th, 2015

To whom it may concern,

This is a letter of support for the BSC-ES group in its next project-proposal within the national R&D&I plan. The proposed project *Dynamics and predictability of the ENSO teleconnection in the North Atlantic-European region* (DANAE), whose principal investigator is Dr Javier García-Serrano, shares a common root objective with us of continuously redefining the field of activity; BSC-ES aims to thoroughly characterize the seasonal prediction of the ENSO system and its related effects on the European weather, whereas EnBW AG is keen to better predict seasonal changes on the power & heat demand in Europe. In particular, the proposed research aligns well with the vision of our company which includes the expansion of renewable energies, the subsequent restructure of the power grid as a result, and the more accurate and cost-effective delivery of energy to our clients.

Thus, with this letter we communicate our sincere interest for this project.

In witness whereof I sign this letter,

Director of Analyses & Evaluations Fuels & Carbon
Ronny Bierhals

EnBW
EnBW
Energie Baden-Württemberg AG
Durlacher Allee 93
Karlsruhe

renewables

To whom it may concern,

This letter supports the research line that the *Earth Sciences* department of the *Barcelona Supercomputing Center* is going to undertake via the DANAE project (Dynamics and predictability of the El Niño-Southern Oscillation teleconnection in the North Atlantic-European region) under the supervision of Dr Javier García-Serrano. EPDR considers that the outcomes derived from DANAE could help to gain insight into the surface climate predictability of North Atlantic surrounding areas, and particularly of surface wind in the European continent, which would certainly increase the confidence in monthly-to-seasonal climate forecasts. Any added-value in climate information at local scale upon this time horizon could likewise translate into added-value in the environment, the renewable power sector, and eventually the economy.

It is considered that EDPR could greatly benefit from the DANAE project, namely to focus its efforts on capturing and developing opportunities and/or to complement existing platforms. Thus, we enthusiastically support this proposal.

Best regards,

Ignacio Láinez
Director of Energy Assessment Department
EDP Renewables Europe S.L.
Serrano Galvache, 56 - Edificio Encina C.P. 28033, Madrid (Spain)

Francisco J. Doblas-Reyes
ICREA Research Professor at
Institut Català de Ciències del Clima – IC3
Doctor Trueta 203, 08005, Barcelona, Spain
+34 935679977
francisco.doblas-reyes@ic3.cat

To whom it may concern,

This letter is to express my support to the *Programa Estatal de Investigación, Desarrollo e Innovación Orientada a los Retos de la Sociedad* proposal entitled 'Dynamics and predictability of the ENSO teleconnection in the North Atlantic-European region (DANAE)', submitted by Javier García-Serrano at the Earth Sciences department of the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) to the call opened by MINECO.

As coordinator of the Spanish MINECO-funded RESILIENCE and the FP7-funded SPECS projects, I foresee that the implementation of the DANAE proposal will contribute to improving the much-needed forecast quality of the Euro-Atlantic winter climate. This will facilitate our efforts to provide an enhanced communication protocol and services to satisfy the climate information needs of a wide range of public and private stakeholders with whom we are already working. Likewise, DANAE tackles challenging issues ranked as first priorities by several of the panels of the World Climate Research Program (WCRP), which offers a unique framework for the project outcomes. Besides, the host institution (BSC-CNS) offers a unique environment not only to carry out the research, but also to interact with our group and many others in Spain and in Europe who will appreciate this opportunity.

For all the above, I hope the project will be granted.

Yours sincerely,

IC3 Institut Català de Ciències del Clima

Francisco J. Doblas-Reyes

Met Office

EUPORIAS

Exeter, 13/07/2015

Dr. García-Serrano
Earth Sciences Department
Barcelona Supercomputing Center (BSC-CNS)
Jordi Girona 29 - 08034 Barcelona, Spain

Dear Dr. García-Serrano,

As scientific coordinator of the FP7 project EUPORIAS I am happy to provide my support for your proposal "Dynamics And predictability of the ENSO teleconnection in the North Atlantic-European region" DANAE

As you know EUPORIAS has been designed to understand and then address the needs of the European users in terms of climate services with a specific focus on seasonal and decadal time-scales.

EUPORIAS analysis of users' landscape in Europe demonstrated that with the exclusion of the energy sector very few people are using climate predictions to inform business-related decision and/or policies. One of the reasons for this is the relatively low skill this kind of predictions has over our continent.

Any initiative such as DANAE that aims to understand winter teleconnections between the ENSO region and Europe, reduce model systematic errors, and ultimately enhance climate prediction skill in the region should be enthusiastically supported by EUPORIAS and by the users 'community.

I wish you all success with your proposal and hope that we have the opportunity to cooperate in the future as we have done in the recent past.

Sincerely,

Carlo Buontempo

EUPORIAS Science coordinator
www.euporias.eu