MINISTERIO
DE ECONOMÍA, INDUSTRIA
Y COMPETITIVIDAD

AGENCIA ESTATAL DE INVESTIGACIÓN

AYUDAS RAMÓN Y CAJAL

MEMORIA DE LA TRAYECTORIA INVESTIGADORA Y LA LÍNEA DE INVESTIGACIÓN PRINCIPAL QUE HA DESARROLLADO (*SUMMARY OF THE RESEARCH CAREER OF THE CANDIDATE AND THE MAIN RESEARCH LINE THAT SHE/HE HAS CARRIED OUT)*

Esta memoria debe rellenarse preferiblemente en inglés - *Summary to be completed preferably in English*

INVESTIGADOR SOLICITANTE / *RESEARCHER APPLICANT*: Javier García-Serrano

IDENTIFICADORES DEL INVESTIGADOR / RESEARCHERS NUMBERS: **RESEARCHER ID:** I-5058-2015
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PALABRAS CLAVE / *KEY WORDS:* climate variability and predictability, air-sea interaction, atmospheric teleconnections, forecast skill

RESUMEN (aprox. 300 palabras) / SUMARY (approx. 300 words):

Teleconnection Dynamics for Climate Prediction

During his scientific career, Dr. García-Serrano has worked upon the fundamental initiative of exploring teleconnection dynamics for climate prediction. He has recently been able to tackle this aim with autonomy thanks to an EU-funded H2020 Marie Skłodowska-Curie Action, *DPETNA – Dynamics and predictability of the ENSO teleconnection to the tropical North Atlantic*, and a national project funded by the Spanish Ministry of Economy and Competitiveness, *DANAE – Dynamics and predictability of the ENSO teleconnection in the North Atlantic-European region*, which is allowing him to build his own research team at the Barcelona Supercomputing Center (BSC). Obtaining these grants is a reflection of the candidate's solid and coherent career during his postdoctoral stage, thoroughly building a bridge between his theoretical background in atmospheric dynamics and the practical requirements of climate forecasting. He is currently leading the *Atlantic Variability and Predictability* research line at BSC. He is also convening the session '*Towards better understanding mid-latitude atmospheric teleconnections*' at the annual meetings of the European Meteorological Society.

The applicant is an enthusiastic and ambitious researcher with a proven ability to obtain funding to support his scientific objectives, e.g. for stays abroad (4 months in UK and 3 months in Netherlands during his PhD; 9 months in Japan and 6 months in France during his postdoctoral stage) or to host foreign researchers (BSC Severo Ochoa Mobility Programme). He has supervised a Master Thesis and is supervising a PhD Thesis.

Summary of achievements: author of 32 articles, 29 published - 3 under review, all in journals ranked in the first quartile (including high-impact journals, 1 in Nature Communications and 2 in Bulletin of the American Meteorological Society); 502 total citations / H-index 12; 6 non peer-reviewed publications (e.g. CLIVAR Exchanges, WGNE-Blue Book); 3 book chapters (e.g. CLIVAR-Spain, TICCC-Catalonia); 23 oral contributions as first author (4 invited); participation in 5 European projects (FP6 AMMA, FP7 QWeCI and NACLIM, H2020 PRIMAVERA and APPLICATE), 8 national projects (MULCLIVAR, PICA-ICE, DEVIAJE, TRACS, MOVAC, TROVA, AVACOA, REN2002-03424), and in-kind contribution to 2 Belmont Forum/JPI Climate projects (InterDec and GOTHAM, thanks to the applicant's MINECO project *DANAE*); active collaboration with 11 international institutions; presence in the media; invited lecturer at workshops, university seminars and summer schools; co-author of the open-source 'S2Dverification' R-package; *contributing author to the IPCC 5th Assessment Report*.

Note. ENSO: El Niño-Southern Oscillation

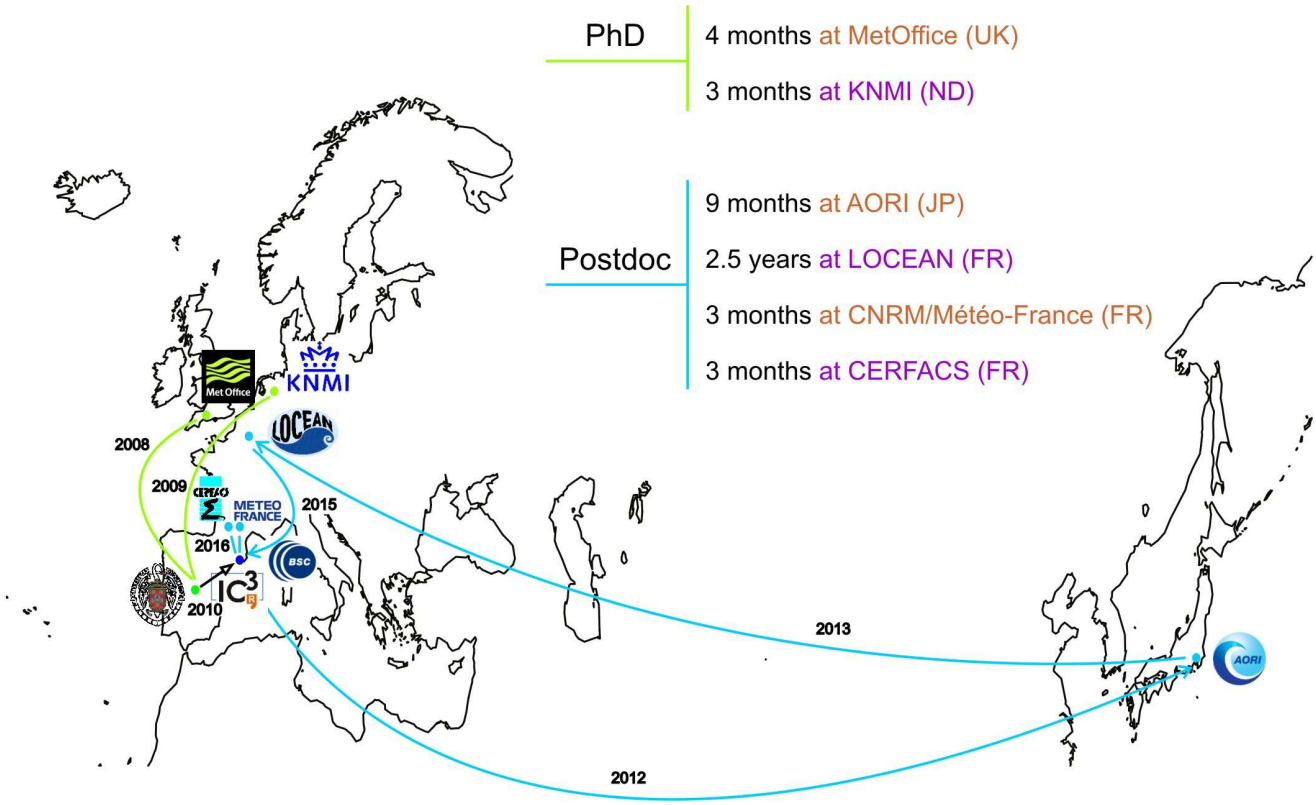
DESTACAR HASTA UN MÁXIMO DE LAS CINCO APORTACIONES MÁS RELEVANTES ENTRE LAS RECOGIDAS EN EL CURRÍCULUM VITAE

Highlight a maximum of 5 relevant achievements from the ones included in the CV

The five most **relevant achievements** and their **associated milestones** are listed below:

1. Marie Skłodowska-Curie Action (H2020-funded MSCA-IF-EF 655339) '*Dynamics and predictability of the ENSO teleconnection to the tropical North Atlantic - DPETNA*' / **Fund-raising capability**. Obtaining this grant has allowed the candidate to return to Spain with independence and autonomy after his postdoctoral stay in Japan (AORI - University of Tokyo; 9 months) and his postdoc in Paris (LOCEAN - Université Pierre et Marie Curie; 29 months); it has also been the confirmation of his aptitude to get funding in order to accomplish his research objectives, which dates back to his PhD stage when he got external fellowships to complete two separate stays abroad: at MetOffice-Hadley Centre (UK, via the European Science Foundation-MedCLIVAR in 2008; 4 months), and at KNMI (Royal Netherlands Meteorological Institute, via the Spanish Ministry of Education in 2009; 3 months). He also got competitive funding for his postdoctoral stay at AORI (9 months) thanks to a private grant from the CANON Foundation in Europe. The MSCA-IF-EF has included two secondments in Toulouse during 2016: at CNRM/Météo-France (Mar-May), and at CERFACS (Jun-Aug). Below is a diagram illustrating his mobility, both national and international, during his scientific career.

The aim of *DPETNA* is to advance understanding of the simulation and prediction of tropical North Atlantic (TNA) sea surface temperature (SST) at seasonal time scales. It addresses the observed delay of about one season of the ENSO-TNA teleconnection (peaking in boreal spring) with respect to mature ENSO conditions (peaking in boreal winter), which is still an unresolved scientific question. A new tropical teleconnection mechanism has been proposed to explain the lagged relationship. The first observational results are currently under review (García-Serrano et al. 2017a), while a model-based work is in preparation (García-Serrano et al. 2017b).



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2. Principal Investigator of **MINECO-RETOS project** (CGL2015-68342-R) '*Dynamics and predictability of the ENSO teleconnection in the North Atlantic-European region - DANAE*' / **Independence - Leadership capability**. The total allocated budget for *DANAE* is 146.410€, where the granted direct costs represent 88% of the requested ones. Due to its highly-ranked evaluation, *DANAE* was additionally assigned a FPI scholarship / BES-2016-076431; the associated PhD student (Bianca Mezzina, Italy) is already working at BSC under *DANAE*. Dr. García-Serrano is currently conducting the selection process for a young postdoctoral researcher to join the project. *DPETNA* and (in particular) *DANAE* are helping the applicant to strengthen and widen competences, such as project management skills. At BSC, he is also leading the *Atlantic Variability and Predictability* research line (https://www.bsc.es/research-development/research-areas/climate-prediction/atlantic-variability-and-predictability), which involves four other postdocs.

Through *DANAE*, the candidate is pursuing the projection of his research interest (*Teleconnection Dynamics for Climate Prediction*) at international level. Firstly, as envisaged from its conception, the project relies on an international environment – the Work Team includes a large number of external collaborators: R. J. Haarsma (KNMI, Netherlands), D. Matei (MPI-M, Germany), T. Ambrizzi (USP, Brazil), A. de la Cámara and M. Ábalos (NCAR, USA). Secondly, obtaining the project has allowed expanding the collaboration as in-kind contribution to two Belmont Forum/JPI-Climate projects: '*The potential of seasonal-to-decadal-scale inter-regional linkages to advance climate predictions - InterDec*' (PI D. Matei, MPI-M, Germany), and '*Globally observed teleconnections and their role and representation in hierarchies of atmospheric models - GOTHAM*' (PIs L. Gray/S. Osprey, U. Oxford, UK). With the latter, BSC is also contributing to QBOi (Towards Improving the Quasi-Biennial Oscillation in global climate models), initiative of SPARC (Stratosphere-troposphere Processes And their Role in Climate) – a core project of the World Climate Research Programme (WCRP). Additionally, obtaining *DANAE* has allowed the candidate to potentially enlarge the funding for his investigation of ENSO and its teleconnection in the Euro-Atlantic sector, thanks to a JPI-Climate/ERA4CS (European Research Area for Climate Services) proposal, with co-funding applicability: '*Mediterranean services chain based on climate predictions - MEDSCOPE*'. Below is a table summarizing the European projects where he is/has been involved during his postdoctoral stage.

Project title	Funding source	Period	Role of the applicant
SIDIS	ERC - Starting Grant 2016	2018-2021 (pending)	PI (1,146.570€ requested)
MEDSCOPE	JPI-Climate/ERA4CS 2016	2017/18-2019/20 (pending)	co-PI and Task leader (T2.2 'Teleconnections with low-latitudes')
InterDec	Belmont Forum/JPI-Climate	2016-2020	In-kind contribution
GOTHAM	Belmont Forum/JPI-Climate	2016-2020	In-kind contribution
APPLICATE	EU-H2020 (BG10)	11/2016-10/2020	Contributing researcher (WP3 'Atmospheric and oceanic linkages')
PRIMAVERA	EU-H2020 (SC5)	11/2015-10/2019	Contributing researcher (WP5 'Drivers of variability and change in European climate')
NACLIM	EU-FP7	01/2013-05/2015 at LOCEAN (Paris)	Hired researcher (WP1.2 'Predictability of the atmosphere related to the ocean's surface state')
QWeCI	EU-FP7	06/2010-02/2012 at IC3 (Barcelona)	Hired researcher (WP3.2 'Seamless decadal predictions and projections')

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3. Article in **Nature Communications** - F. J. Doblas-Reyes, I. Andreu-Burillo, Y. Chikamoto, *J. García-Serrano*, V. Guemas, M. Kimoto, T. Mochizuki, L. R. L. Rodrigues, G. J. van Oldenborgh (2013): Initialized near-term regional climate change prediction. *Nature Comms.* 4:1715, doi:10.1038.ncomms2704 [76 citations] / **High-impact visibility**. During his period as a postdoctoral researcher working on the pioneering field of decadal climate prediction, first hired at IC3 (Barcelona) and then via his own funding at the University of Tokyo – AORI (private grant from the CANON Foundation in Europe), the candidate was very productive, publishing 11 papers in major journals which contributed to internationalizing his research activity. The effort culminated in the publication of a collaborative work in *Nature Communications*, which e.g. showed for the first time that multi-annual predictions of land-surface precipitation in the Northern Hemisphere have skill.

4. Contributing Author to the **Intergovernmental Panel on Climate Change** (IPCC) 5th Assessment Report (AR5) / **International recognition**. All his exhaustive work carried out during 2010-2013 on illustrating and discussing the forecast quality of decadal climate predictions led the applicant to be part of the contributing authors to Chapter 11 "Near-term Climate Change: Projections and Predictability" of the most recent IPCC assessment report – *Climate Change 2013: The Physical Science Basis*. The recognition of his scientific work so far has also been reflected in three other book chapters (Rodríguez-Fonseca, Rodríguez-Puebla et al. 2010; Rodrigues et al. 2012; Calbó et al. 2016) and in two review papers (Doblas-Reyes et al. 2013b *WIREs-Climate Change* [49 citations]; Rodríguez-Fonseca et al. 2015 *Journal of Climate* [12 citations]).

5. Article in **Climate Dynamics** - *J. García-Serrano* and F. J. Doblas-Reyes (2012): On the assessment of near-surface global temperature and Atlantic multi-decadal variability in the ENSEMBLES decadal hindcast. *Clim. Dyn.* 39:2025-2040 [30 citations; strong impact in the field] / **Independence – Leading research**. This study was the first of a series of manuscripts that resulted from leading the IC3's research line on forecast skill of the Atlantic multi-decadal oscillation (AMO), or Atlantic multi-decadal variability (AMV), in decadal climate prediction. It discussed for the first time the effect of the hindcast start-date frequency and the length of the forecast average in the AMO skill, in addition to some methodological aspects of the forecast verification such as the bias correction. It also evidenced AMO skill beyond the radiatively-forced global-warming signal, thus opening the possibility of forecasting low-frequency climate variability related to the AMO (e.g. García-Serrano et al. 2013a *Decadal prediction of the dominant West African monsoon rainfall modes, J. Geophys. Res. - Atm. 118:5260-5279*; Guemas et al. 2014 *Prospects for decadal climate prediction in the Mediterranean region, Q. J. R. Meteorol. Soc. doi:10.1002/qj.2379*). The work continued in García-Serrano et al. 2012 (*Understanding Atlantic multi-decadal variability prediction skill, Geophys. Res. Lett. 39:L18708* [11 citations]) and García-Serrano et al. 2014 (*Added-value from initialization in predictions of Atlantic multi-decadal variability, Clim. Dyn. doi:10.1007/s00382-014-2370-7* [8 citations]).

During his scientific career the candidate has demonstrated the ability to perform independent research. During his PhD years, he led the strengthening of his research group (TROPA at UCM, Madrid) in atmospheric dynamics. The applicant confirmed his ability soon after completing his PhD, when he moved from the diagnostic approach of climate variability to the prognostic approach of climate forecasting. At IC3 he led the research line dealing with AMO forecast skill in decadal climate prediction. More recently, at LOCEAN (Paris), the candidate showed broad capabilities to develop and lead, both technically and by pursuing a theoretical level of understanding, the tasks undertaken by his institution within the EU-FP7 NACLIM project ('*North Atlantic Climate: predictability of the climate in the North Atlantic-European sector related to North Atlantic/Arctic Ocean sea surface temperature and sea ice variability and change*'). This involvement is reflected in three published papers: García-Serrano et al. 2015 (*On the predictability of the winter Euro-Atlantic climate: lagged influence of autumn Arctic sea-ice, J. Clim. 28:5195-5216*); García-Serrano and Frankignoul 2015 (*On the feedback of the winter NAO-driven sea ice anomalies. Clim. Dyn. doi:10.1007/s00382-015-2922-5*); and García-Serrano et al. 2016 (*Multi-model assessment of linkages between eastern Arctic sea-ice variability and the Euro-Atlantic atmospheric circulation, Clim. Dyn. doi:10.1007/s00382-016-3454-3*). The investigation has focused on the ground-breaking topic of teleconnections between Arctic sea-ice changes and European climate. Now at BSC, he is successfully carrying over this topic in two EU-H2020 projects, PRIMAVERA ('*Process-based climate simulation: advances in high-resolution modelling and European climate risk assessment*') and APPLICATE ('*Advanced prediction in polar regions and beyond: modelling, observing system and linkages associated with a changing Arctic climate*').

DESARROLLAR LA TRAYECTORIA INVESTIGADORA ASÍ COMO LA LÍNEA DE INVESTIGACIÓN PRINCIPAL QUE HA DESARROLLADO.

Extended detail of the research career of the candidate and the main research line that he/she has carried out.

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Teleconnection Dynamics for Climate Prediction

During his scientific career, the candidate has worked upon the fundamental initiative of exploring teleconnection dynamics for climate prediction.

During his PhD, the candidate developed a profound understanding of the atmospheric dynamics 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 a deep knowledge of the dynamical processes governing the remote impacts of SST anomalies. In particular, he developed an excellent background on tropical-extratropical atmospheric teleconnections (e.g. García-Serrano et al. 2008, 2011a,b), which usually comprise different steps: (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 path of Rossby wavetrains reaching the North Atlantic-European region in response to the different oceanic forcings. Thus, where the jetstream is weak the Rossby wave propagation tends to follow an arching pattern (meridional propagation); while in regions where the jetstream is intense the Rossby wavetrains tend to be meridionally confined (zonal propagation) and project onto a circumglobal pattern (Fig. A).

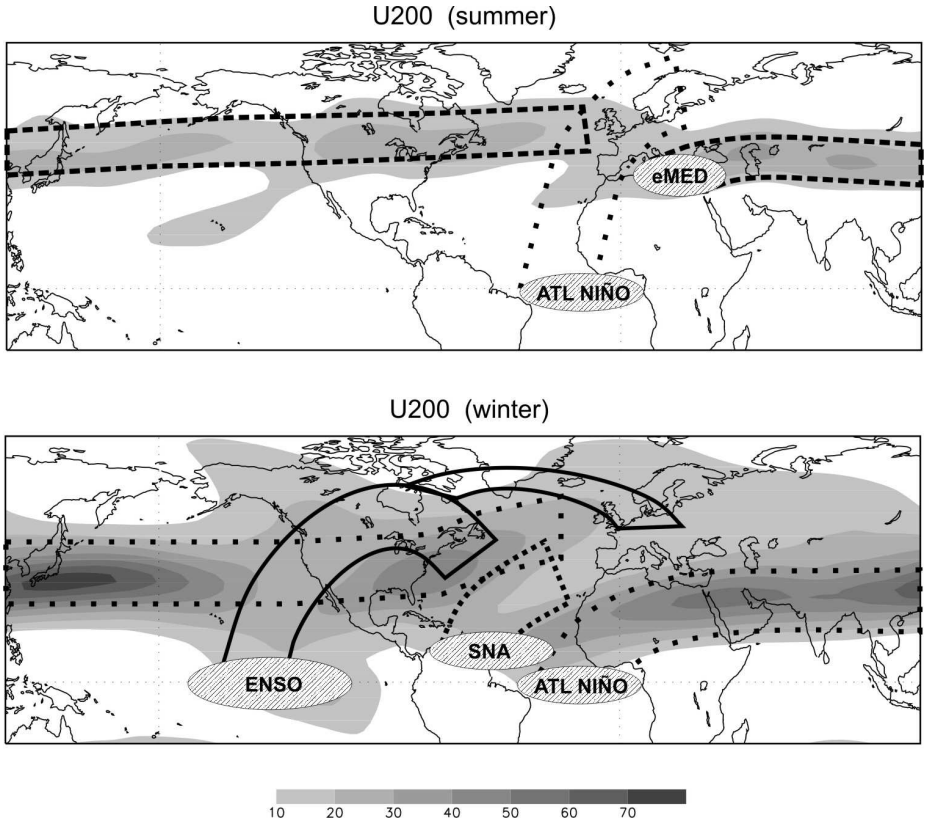

Fig. A: Schematic diagram summarizing the Rossby wavetrain propagations associated with the Atlantic Niño (ATL NIÑO), the Subtropical North Atlantic (SNA), the eastern Mediterranean basin (eMED), and the ENSO phenomenon; shading represents the westerly jetstreams during summer (July) and winter (January) by means of zonal wind climatology at 200hPa (m/s).

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The work carried out on the tropical Atlantic variability modes led the candidate and his research group at UCM (TROPA) to develop a new statistical methodology to capture the time-evolving covariability between the tropical Atlantic SST and tropical Atlantic precipitation, which could be viewed as a proxy for deep convection. This innovative methodology was named extended-maximum covariance analysis (EMCA) and was employed separately to describe time-varying predictor (Polo et al. 2008) and time-varying predictand fields. The latter was the focus of García-Serrano et al. (2008); the main findings of this study are summarized next. The first EMCA mode involves SST anomalies related to the Atlantic Niño and its atmospheric response shows variations of the Atlantic Hadley cell, displacements of the Atlantic Walker cell and the excitation of Rossby waves that are trapped in the North African-Asian jet. The second EMCA mode is associated with the summer horseshoe and winter tripole SST patterns, and thus with the winter North Atlantic Oscillation (NAO); the related atmospheric circulation anomalies include direct thermal forcing (altering the local Hadley cell) and a wave-like response from the Caribbean region.

On the other hand, in García-Serrano et al. (2011b), the upper-tropospheric North Atlantic-European streamfunction field was analysed for late-winter (Jan-Feb). The choice of the streamfunction field was motivated by the evidence that it represents the primary variable for the analysis of Rossby wave propagation, as it is most succinctly described in terms of rotational (non-divergent) barotropic theory. The main difference between the streamfunction and geopotential norms is that the former tends to emphasize lower latitude variability. This is particularly helpful for detecting variability forced from the tropics, such as that associated with ENSO, and indeed the application of this norm allowed to obtain some novel results. The first mode of upper-level streamfunction describes the remote ENSO influence; this is in contrast with most previous regional studies based on geopotential or sea level pressure, in which the NAO tends to be more prominent. The first pattern corresponds to the tail of the Tropical/Northern Hemisphere (TNH) wavetrain emanating from the tropical Pacific and yields a surface dipolar structure in the North Atlantic that is reminiscent of the NAO; however, this response should not be described as a NAO-like pattern, because of the different underlying dynamics. The second mode of upper-level streamfunction corresponds to the NAO and it is mainly associated with internal variability, through meridional shifts of the storm-tracks and the eddy-driven jet.

After his PhD, the candidate shifted his interest towards climate prediction. During the last few years, the climate forecasting community has undertaken the challenge of providing actionable information on multi-annual time scales. This new field of decadal climate prediction was recognized as a major part of the Coupled Model Intercomparison Project phase 5 (CMIP5) experimental design, whose setup is based on the decadal hindcasts performed in ENSEMBLES, the first coordinated experiment ever to explore the feasibility of decadal prediction. The relevance of making available trustworthy information with a lead time of several years is recognized as a key planning horizon and is also a central component of WMO's Global Framework on Climate Services. <u>During his first three years as postdoctoral researcher, first as a hired researcher at IC3 and then via his own funding at the University of Tokyo (AORI), the candidate analysed the most complete set of decadal climate predictions available to date, including the ENSEMBLES multi-model, the UK Met Office Decadal Prediction System (DePreSys) and the CMIP5 experiments</u>. These decadal integrations aim at identifying evidence of regional multi-year prediction skill beyond the slow and relatively predictable warming of the planet, thus opening the possibility of forecasting low-frequency climate variability. The main objectives of his research were the AMO/AMV (García-Serrano and Doblas-Reyes 2012; García-Serrano et al. 2012, 2014; Guemas et al. 2014), for which several climate impacts in the North Atlantic surrounding regions have been documented, and the West African monsoon (WAM; García-Serrano et al. 2013a, 2014), for which improved forecasts would be of great help to local economies that largely depend on agriculture.

In García-Serrano et al. (2012, 2014), initialized and uninitialized decadal hindcasts were used to assess the key source regions of skill for the AMO-related SST in the North Atlantic basin. A targeted procedure for quantitatively evaluating performance in different forecast systems was developed, complementing other pioneering initiatives that establish a common verification framework for decadal prediction. The results showed an important role of the varying radiative forcing in the AMO-related prediction skill over the Labrador and Irminger convection regions, whereas the largest impact of the initialization was an improvement in the AMO-related skill over the area where the Atlantic subpolar gyre operates (Fig. B). Initialization also reduced the inter-model spread when estimating the level of AMO skill, thus reducing its uncertainty.

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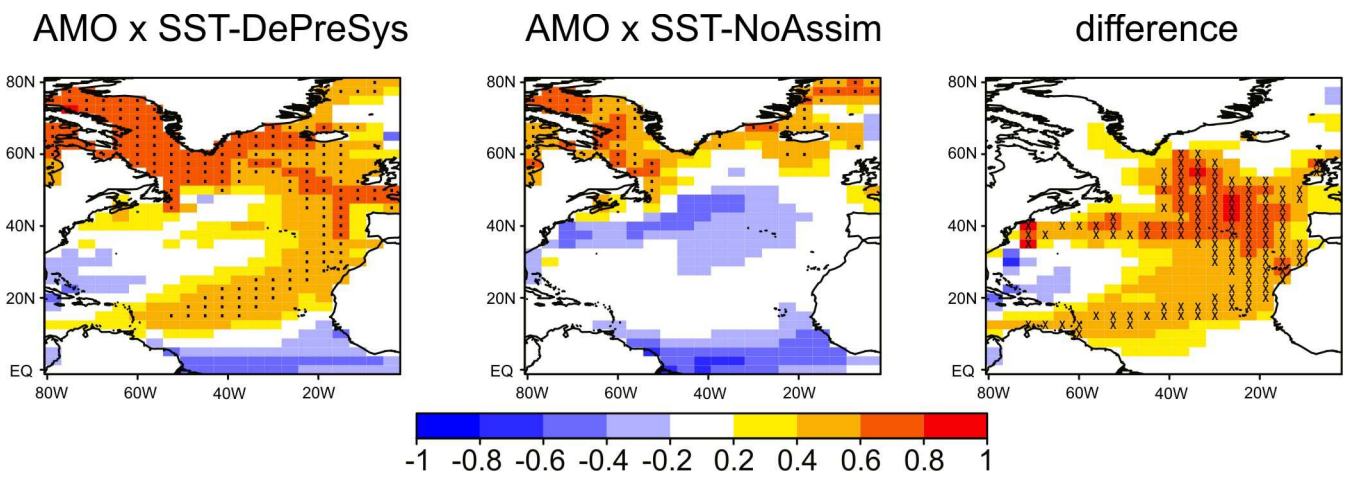

Fig. B: Correlation maps between the ensemble-mean detrended decadal hindcast SST anomalies in (left) DePreSys and (middle) NoAssim and the observed AMO index for the forecast average 2-5 years; (right) difference between the correlation maps in DePreSys and NoAssim. Statistically significant areas at 95% for correlation coefficients (left and middle) are indicated with dots; areas with crosses (right) show regions where the correlation difference is larger than 0.5. *Adapted from García-Serrano et al. (2012)*.

García-Serrano et al. (2013a) offered for the first time the validation of decadal prediction systems for the WAM variability. The ENSEMBLES multi-model and DePreSys decadal hindcasts were used to assess multi-year prediction skill for the dominant WAM rainfall modes. The results showed that while in the observations global warming has an important role, in the forecast systems the Atlantic Ocean is the main player. The Atlantic Niño represents the leading forcing for the simulated Guinean precipitation. SST anomalies associated with the simulated Sahelian precipitation project onto the AMO, whose subtropical branch showed consistency across the forecast systems. No significant skill was found, however, to predict these WAM rainfall modes, although the Sahelian pattern presented systematic positive correlation scores and lower root mean square errors along the whole forecast range. This was reflected in a tendency to reproduce the Sahel dry period around the 1980s. The good performance across the models in simulating the relationship between the leading rainfall modes and the surrounding SST implied encouraging prospects for future decadal forecasting initiatives (Rodríguez-Fonseca et al. 2015).

Due to the novelty of the findings in García-Serrano et al. (2013a), the work received support and publicising by the American Geophysical Union through the Research Spotlight "Can West African monsoon rainfall be predicted on decadal time scales?" in *EOS, Transactions American Geophysical Union*, vol. 94, no. 29, page 260 (2013).

The expertise acquired by the candidate in the novel framework of decadal climate prediction does not reside solely in understanding multi-year prediction skill of the AMO and WAM regimes but extends far above and beyond. He has also insightfully worked on evaluating forecast quality of the Indian Ocean SST (Guemas et al. 2013), the inter-decadal Pacific oscillation (IPO; Doblas-Reyes et al. 2013a; Mignot et al. 2015), climate variability in the Mediterranean region (Guemas et al. 2014), and global-mean surface temperature (García-Serrano and Doblas-Reyes et al. 2012), which is a proxy for long-term externally-forced trends. Likewise, he has brought his expertise in climate forecasting to wider scopes, namely exploring strategies for ensemble generation (Du et al. 2012), applicability to climate-related infectious diseases (Rodó et al. 2013), and dependence of the climate prediction skill on spatio-temporal scales (Volpi et al. 2013).

All this exhaustive work carried out during his first stage as postdoctoral researcher on illustrating and discussing the forecast quality of decadal climate predictions led the candidate to be part of the contributing authors to Chapter 11 "Near-term Climate Change: Projections and Predictability" of the 5th IPCC Assessment Report (AR5) - *Climate Change 2013: The Physical Science Basis*.

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At LOCEAN (under the FP7 NACLIM project) and, back in Spain, at BSC (thanks to his H2020 MSCA-IF-EF), the candidate has assembled his two research interests, teleconnection dynamics and climate prediction, into a single research line.

The work undertaken by the candidate under the NACLIM project focused on the predictability of the NAO associated with Arctic sea-ice variability (García-Serrano et al. 2015, 2016) and on the feedback of the NAO-driven sea-ice anomalies to the atmosphere (García-Serrano and Frankignoul 2015). García-Serrano et al. (2015) developed for the first time empirical predictions of interannual variability of the winter NAO and European surface climate based on Arctic sea-ice concentration (SIC). It was shown that November sea-ice anomalies over the Barents-Kara Seas could provide skill for winter sea level pressure, surface air-temperature and precipitation over the Euro-Atlantic sector (Fig. C-right). The related atmospheric circulation shows a wave-like anomaly crossing Eurasia in November that appears to impact vertical wave propagation and thereby the stratospheric polar vortex strength (Fig. C-left); the signal subsequently descends to the troposphere and triggers a positive transient-eddy feedback over the North Atlantic that helps to maintain the tropospheric anomaly into winter. These results emphasize the importance of incorporating Arctic sea-ice variability in seasonal prediction systems.

As example of the relevance of this achievement the European Commission contacted him for an interview in *HORIZON – The EU Research and Innovation Magazine* - to comment on the role played by Arctic sea-ice changes in European winter climate anomalies (http://horizon-magazine.eu/article/european-temperatures-likely-fall-due-arctic-vortex-us-thaws_en.html).

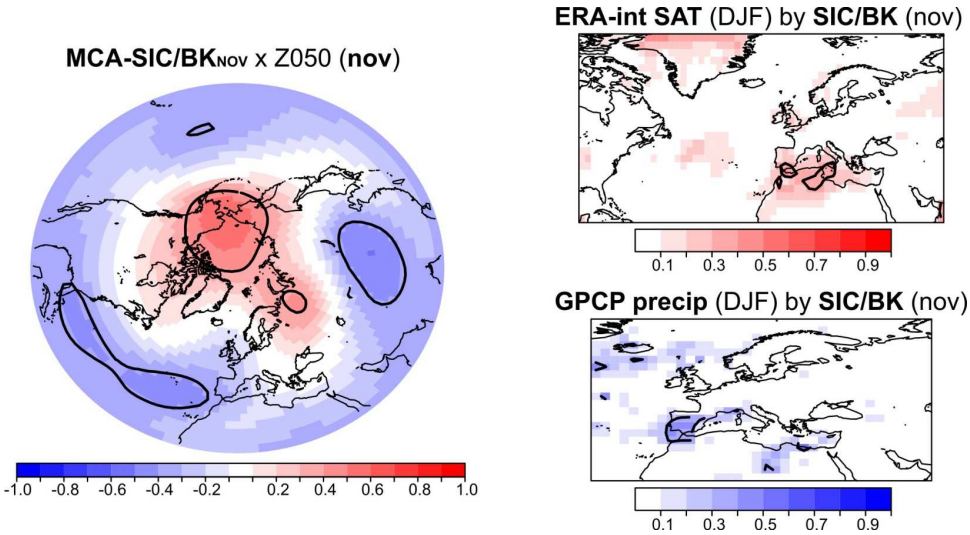

Fig. C: (left) Correlation map of detrended geopotential height anomalies at 50hPa with the November Arctic sea-ice predictor. (right) Cross-validated correlation skill of winter surface air-temperature (top) and precipitation (bottom) using the November Arctic sea-ice predictor. Statistically significant areas at 95% are contoured. *Adapted from García-Serrano et al. (2015).*

The key role of the candidate in NACLIM has allowed him to author the project's multi-model assessment. In García-Serrano et al. (2016) a set of integrations from CMIP5 have been used to explore if current state-of-the-art climate models are able to simulate previously reported linkages between SIC anomalies over the eastern Arctic (Greenland-Barents-Kara Seas) and lagged atmospheric circulation anomalies that project on the NAO. The underlying question is to know if there could be a detectable influence of sea-ice, statistically different from noise, on NAO-like variability in the coupled system by overcoming the sampling limitation of the observational record. The successful reproducibility of the linkages suggests that there is a detectable influence in nature as well, which could be beneficial for enhancing climate forecasting capabilities. Already at BSC, he has continued this topic by assessing recent changes in the Arctic (Fuckar et al. 2016) and its potential consequences at lower latitudes (Bellprat et al. 2016).

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The ongoing MSCA-IF-EF project carried out by the candidate at BSC, *DPETNA - Dynamics and predictability of the ENSO teleconnection to the tropical North Atlantic*, tries to address the gap in the understanding of the ENSO-TNA lagged relationship, i.e. a delay of about one season between the remote teleconnection (peaking in boreal spring) and mature ENSO conditions (peaking in boreal winter). A new tropical teleconnection mechanism has been proposed and tested in observational and re-analysis data, which could shed light on the origin of the ENSO-related surface winds that trigger the oceanic response over the TNA region (García-Serrano et al. 2017a). The project also undertakes the novelty of evaluating the ENSO-TNA teleconnection using an unprecedented set of dynamical seasonal hindcasts; the joint use of EUROSIP and NMME multi-models represents the most comprehensive evaluation so far of the seasonal forecasting capabilities over the tropical Atlantic. Likewise, it is worth highlighting that no previous assessment has examined the ability of these forecast systems to specifically simulate the ENSO-TNA teleconnection. Together, *DPETNA* offers a prime opportunity for making substantial progress in seasonal-to-interannual predictions in the tropical Atlantic sector (García-Serrano et al. 2017b).

A major step towards reinforcing his research line (*Teleconnection Dynamics for Climate Prediction*) at BSC and start building up a research team has been achieved as a result of obtaining a project from the MINECO-RETOS, *DANAE - Dynamics and predictability of the ENSO teleconnection in the North Atlantic-European region* (CGL2015-68342-R). Its aim is to dissect the influence of ENSO in this sector and diagnose the ability of forecast systems to reproduce it. The most up-to-date set of seasonal hindcasts, including EUROSIP and NMME multi-models plus two experimental prediction systems based on EC-EARTH and MPI-ESM, will be used to assess the skill of the ENSO teleconnection in mid/late-winter (e.g. García-Serrano et al. 2011b). The total allocated budget for *DANAE* is 146.410€, where the granted direct costs represent 88% of the requested ones. Due to its highly-ranked evaluation, *DANAE* was additionally assigned a FPI scholarship / BES-2016-076431; the associated PhD student (Bianca Mezzina, Italy) is already working at BSC under *DANAE*. Dr. García-Serrano is currently conducting the selection process for a young postdoctoral researcher to join the project.

Thanks also to *DANAE*, the applicant is pursuing the projection of his research line at international level. Firstly, as envisaged from its conception, the project relies on an international environment – the Work Team includes a large number of external collaborators: R. J. Haarsma (KNMI, Netherlands), D. Matei (MPI-M, Germany), T. Ambrizzi (USP, Brazil), A. de la Cámara and M. Ábalos (NCAR, USA). Secondly, obtaining the project has allowed expanding the collaboration as in-kind contribution to two Belmont Forum/JPI-Climate projects: '*The potential of seasonal-to-decadal-scale inter-regional linkages to advance climate predictions - InterDec*' (PI D. Matei, MPI-M, Germany), and '*Globally observed teleconnections and their role and representation in hierarchies of atmospheric models - GOTHAM*' (PIs L. Gray/S. Osprey, U. Oxford, UK). With the latter, BSC is also contributing to QBOi (Towards Improving the Quasi-Biennial Oscillation in global climate models; http://users.ox.ac.uk/~astr0092/Papers.html), initiative of SPARC (Stratosphere-troposphere Processes And their Role in Climate) – a core project of the World Climate Research Programme (WCRP). Additionally, obtaining *DANAE* has allowed the candidate to potentially enlarge the funding for the investigation of ENSO and its teleconnection in the Euro-Atlantic sector, thanks to a JPI-Climate/ERA4CS proposal which requires co-funding for applicability: '*Mediterranean services chain based on climate predictions - MEDSCOPE*' (see table in Relevant Achievement **2**).

It is now, when the candidate has reached a certain professional maturity, that he can effectively guide his research towards pioneering activities which could represent a major breakthrough at European level. The aim of his planned investigation is to make a comprehensive dynamical study of the influence of troposphere-stratosphere interaction on winter Euro-Atlantic climate, with emphasis on improving forecasting capabilities on seasonal time scales. This is the subject of a submitted proposal for an ERC Starting Grant (ERC-STG-2017-759575). The project '*Understanding stratospheric influence on tropospheric dynamics for improving North Atlantic-European seasonal forecasts - SIDIS*' will perform targeted seasonal hindcast experiments with and without stratospheric variability by nudging the stratosphere to climatology, and evaluate the effect of adding a non-orographic gravity wave parameterization to troposphere-stratosphere coupling processes in EC-EARTH (e.g. QBO, Brewer-Dobson circulation). The completion of this investigation could lead to worldwide cutting-edge results and would certainly contribute to the overall competitiveness and excellence of Spain in the field of climate prediction.

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Below is a diagram summarizing the conception of his research line – *Teleconnection Dynamics for Climate Prediction*; it also shows the institutions where the applicant has been developing his scientific objectives, including those where he has carried out short stays thanks to his fund-raising capability (see Relevant Achievement **1**).

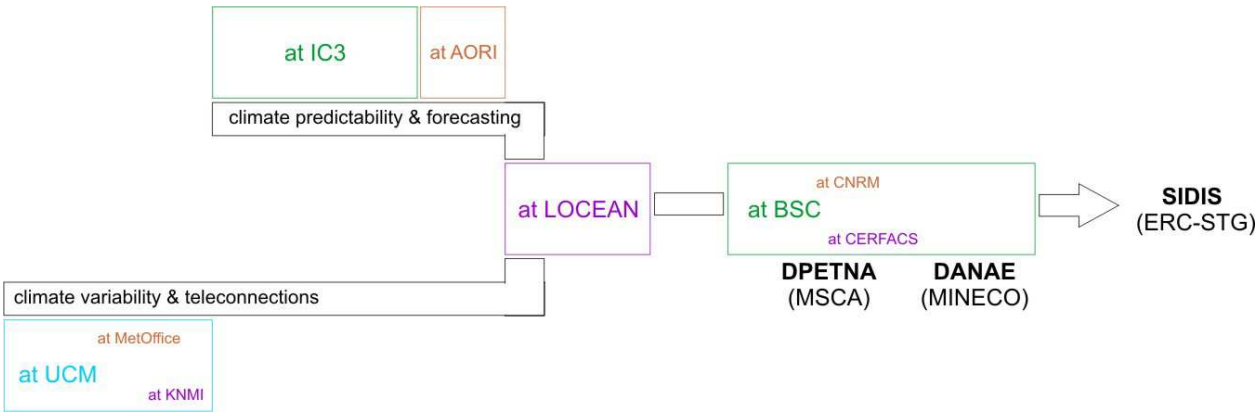

Fig. D: Conception of the research line.

The candidate has worked in several leading institutions and in all cases has interacted successfully with the new scientific environment, demonstrating both team-player skills and leadership, as well as initiative and critical thinking. His curriculum vitae clearly shows how these interactions have been extremely fruitful and have always resulted in publications in major journals [see below and CVN]. Moreover, as a result of those experiences, the candidate has created a rich network of national and international collaborations which he continues to maintain. At national level he is in close collaboration with UB (Ileana Bladé) and UCM (Belén Rodríguez-Fonseca). He also collaborates actively with 11 international institutions: KNMI (Rein Haarsma; Netherlands), LOCEAN (Claude Frankignoul, Juliette Mignot; France), CNRM/Météo-France (Hervé Douville; France), CERFACS (Christophe Cassou, Emilia Sanchez-Gomez; France), UniRes/BCCR (Martin King; Norway), NERSC/BCCR (Yongqi Gao; Norway), MPI-M (Daniela Matei; Germany), GEOMAR (Wonsun Park; Germany), NCAR (Álvaro de la Cámara, Marta Ábalos; USA), USP (Tércio Ambrizzi; Brasil), CIMA/UBA (Ramiro Saurral; Argentina).

Note that three recent publications do not involve either the PhD advisor or postdoc advisors:

- García-Serrano J., R. J. Haarsma (2016): Non-annular, hemispheric signature of the winter North Atlantic Oscillation. *Climate Dynamics*, doi:10.1007/s00382-016-3292-3 [99 downloads].
- King M. P., J. García-Serrano (2016): Potential ocean-atmosphere preconditioning of late-autumn Barents-Kara sea ice concentration anomaly. *Tellus A*, 68, 28580, doi:10.3402/tellusa.v68.28580 [110 downloads].
- Mignot J., J. García-Serrano, D. Swingedouw, A. Germe, S. Nguyen, P. Ortega, E. Guilyardi, S. Ray (2015): Decadal prediction skill in the ocean with surface nudging in the IPSL-CM5A-LR climate model. *Climate Dynamics*, doi:10.1007/s00382-015-2898-1 [264 downloads].

The candidate has fully demonstrated his proficiency and capability to deal successfully with a wide range of scientific challenges, achieving with quality all the required steps to pursue his career development. The fact that he has already revealed a high degree of responsibility guarantees the accurate implementation of future research. Consequently, this Ramón y Cajal application, if granted, will provide him with the final expertise needed to become a completely independent researcher able to lead a research team.

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Apart from the research activities summarised above, the applicant has also been committed during his career to activities of scientific disclosure, communication and education. Below there is a summary of this involvement:

- Member of the *BSC Outreach Group*. Barcelona, Spain: June 2016 - present.

- (Invited) Seminar '*Decadal climate prediction: experience and perspectives*' and teacher of "Workshop on decadal climate prediction and its application". Center for Climate and Resilience Research (CR2)/Universidad de Chile, Santiago, Chile: 09-13 January 2017; https://www.youtube.com/watch?v=d4UYcyKq70s&t=158s

- Participant/Speaker in the "48h Open House Barcelona" – La Capilla-MareNostrum. Barcelona, Spain: 24 October 2016.

- Convener of the session '*Towards better understanding mid-latitude atmospheric teleconnections*' (ASI6/UC8) at the 16th EMS Annual Meeting, Trieste, Italy: 12-16 September 2016; http://meetingorganizer.copernicus.org/EMS2016/session/22365

- Speaker '*Coming from abroad; success?*' in H2020-funded outreach activity EURAXESS – RESEARCHERS IN MOTION. Barcelona, Spain: 05 November 2015; http://ec.europa.eu/euraxess/.

- (Invited) Lecture on '*Drivers/empirical predictors of mid-latitude seasonal forecasts*', in the "First MedCOF Training Workshop on Seasonal Forecasting". WMO, hosted by AEMET, Madrid, Spain: 26-30 October 2015; http://medcof.aemet.es/index.php/events/training1.

- (Invited) Speaker '*Predictability of the Euro-Atlantic climate from Arctic sea ice variability*', in the WCRP "Workshop on understanding, modelling and predicting weather and climate extremes". Oslo, Norway: 05-07 October 2015.

- Organising Committee of the WWRP/WCRP "International workshop on polar-lower latitude linkages and their role in weather and climate prediction". Barcelona, Spain: 10-12 December 2014; http://www.polarprediction.net/linkages.

- (Invited) Lecture on '*Climate Variability in the Mediterranean*', in the summer course "The Mediterranean Sea. An ocean of resources and a global change scenario". University of Barcelona International Summer School (UBISS), Barcelona, Spain: 18-22 July 2011.

- Co-convener of the session '*Tropical Climate Variability and Teleconnections: past, present and future*' in the climate disciplinary sessions at the EGU General Assembly, Vienna, Austria; 2010-2011-2012.

- Contributor to "S2Dverification (R-package)", set of open-access tools to assess performance of climate models through the computation of typical prediction skill scores. CFU-IC3 (Climate Forecasting Unit - Institut Català de Ciències del Clima) + Earth Sciences Dept. (BSC); started in 2012: https://cran.r-project.org/web/packages/s2dverification/index.html.

- Participation in teaching innovation projects: "Virtual Workshop on Meteorology and Climate", UCM, Madrid, Spain: http://meteolab.fis.ucm.es.

- Teacher Assistant of the course '*Elements of Geophysics Fluids Dynamics*' in charge of Dr. C. R. Mechoso (Depart. of Atmospheric Sciences, UCLA, California, USA). Dept. of Geophysics and Meteorology, UCM, Madrid, Spain; 2006.

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