Horizon 2020

Call: H2020-MSCA-IF-2017

(Marie Skłodowska-Curie Individual Fellowships)

Topic: MSCA-IF-2017

Type of action: MSCA-IF-EF-RI

(Reintegration panel)

Proposal number: 797961

Proposal acronym: PROTECT

Deadline Id: H2020-MSCA-IF-2017

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How to fill in the forms?

The administrative forms must be filled in for each proposal using the templates available in the submission system. Some data fields in the administrative forms are pre-filled based on the previous steps in the submission wizard.

Proposal ID **797961** *Acronym* **PROTECT**

1 - General information

Topic	MSCA-IF-2017
Call Identifier	H2020-MSCA-IF-2017
Type of Action	MSCA-IF-EF-RI
Deadline Id	H2020-MSCA-IF-2017

Acronym	PROTECT
Proposal title	Propagation of atmospheric ROssby waves - connection to prEdictability of Climate exTremes

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months	24
Scientific Area	ENV

Please select up to 5 descriptors (and at least 3) that best characterise the subject of your proposal, in descending order of relevance.

Descriptor 1	*Meteorology, atmospheric physics and dynamics*
Descriptor 2	*Climatology and climate change*
Descriptor 3	*Natural hazards*
Free keywords	*Atmospheric Rossby waves, Rossby refractive index, seasonal predictability, climate extreme events, climate model data, re-analysis data*

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Abstract

Extreme weather events, such as heatwaves, droughts and flooding, have a devastating impact on humanity, causing increased mortality and suffering, as well as economic losses. Skillful predictions of such events, with sufficient lead-time for adaptation procedures can provide huge benefits to humankind. Recent extreme events, including the severe European and Russian heatwaves, have been found to be associated with particular atmospheric wave dynamics, specifically the propagation of Rossby waves along atmospheric waveguides. Our proposed research will explore the seasonal predictability of extreme events through a lens of atmospheric waveguides and Rossby wave propagation. We will answer four key research questions:
I. What is the predictability of dominant modes of variability in waveguide geometry?
II. How does the frequency of extreme events as a function of location relate to waveguide geometry in both observations and forecast systems?
III. How do the results from I and II combine to provide predictability on the likelihood of extreme events?
IV. How does model resolution impact Rossby wave propagation and the relationship to extreme events?
Both re-analysis (observational) data, and seasonal forecast model data will be used. We will calculate the Rossby refractive index and analyze its spatial and temporal variability, quantifying the predictability in waveguide geometry. Extreme events (heatwaves, cold snaps, droughts and blocking events) will be identified in the datasets, with lag-lead regression and composites revealing the connections to the waveguide geometry. We will create empirical models to predict the frequency of extreme events, evaluate their reliability, and compare to these to existing dynamical forecasts. Our goal is to harness the increased understanding of climate extremes that atmospheric dynamics can bring, to help improve the predictability of extreme events, reducing their human and societal impacts.

Remaining characters 35

Has this proposal (or a very similar one) been submitted to a Horizon 2020 Marie Skłodowska-Curie Individual Fellowship call, with the same supervisor and future host institution (and partner organization for Global Fellowships)? ○ Yes ◉ No

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Declarations

1) The applicant (future beneficiary) declares to have the explicit consent of all partner organisations (if applicable) on their participation and on the content of this proposal.	☒
2) The information contained in this proposal is correct and complete.	☒
3) This proposal complies with ethical principles (including the highest standards of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity — and including, in particular, avoiding fabrication, falsification, plagiarism or other research misconduct).	☒

4) The applicant (future beneficiary) hereby declares:

- it is fully eligible in accordance with the criteria set out in the specific call for proposals; and	☒
- it has the financial and operational capacity to carry out the proposed action.	☒

The applicant (future beneficiary) is only responsible for the correctness of the information relating to his/her own organisation. Where the proposal to be retained for EU funding, the applicant (future beneficiary) will be required to present a formal declaration in this respect.

According to Article 131 of the Financial Regulation of 25 October 2012 on the financial rules applicable to the general budget of the Union (Official Journal L 298 of 26.10.2012, p. 1) and Article 145 of its Rules of Application (Official Journal L 362, 31.12.2012, p.1) applicants found guilty of misrepresentation may be subject to administrative and financial penalties under certain conditions.

Personal data protection
The assessment of your grant application will involve the collection and processing of personal data (such as your name, address and CV), which will be performed pursuant to Regulation (EC) No 45/2001 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data. Unless indicated otherwise, your replies to the questions in this form and any personal data requested are required to assess your grant application in accordance with the specifications of the call for proposals and will be processed solely for that purpose. Details concerning the purposes and means of the processing of your personal data as well as information on how to exercise your rights are available in the privacy statement. Applicants may lodge a complaint about the processing of their personal data with the European Data Protection Supervisor at any time.

Your personal data may be registered in the Early Detection and Exclusion system of the European Commission (EDES), the new system established by the Commission to reinforce the protection of the Union's financial interests and to ensure sound financial management, in accordance with the provisions of articles 105a and 108 of the revised EU Financial Regulation (FR) (Regulation (EU, EURATOM) 2015/1929 of the European Parliament and of the Council of 28 October 2015 amending Regulation (EU, EURATOM) No 966/2012) and articles 143 - 144 of the corresponding Rules of Application (RAP) (COMMISSION DELEGATED REGULATION (EU) 2015/2462 of 30 October 2015 amending Delegated Regulation (EU) No 1268/2012) for more information see the Privacy statement for the EDES Database).

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List of participants

#	Participant Legal Name	Country
1	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION	Spain

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2 - Administrative data of participating organisations

Future Host Institution

PIC	***Legal name***
999655520	*BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION*

Short name: BSC

Address of the organisation

Street Calle Jordi Girona 31

Town BARCELONA

Postcode 08034

Country Spain

Webpage www.bsc.es

Legal Status of your organisation

Research and Innovation legal statuses

Public body ..... yes
Non-profit ..... yes
International organisation ..... no
International organisation of European interest ..... no
Secondary or Higher education establishment ..... no
Research organisation ..... yes
Small and Medium-sized Enterprises (SMEs) ..... no
Academic Sector ..... yes

Legal person ..... yes

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Department(s) carrying out the proposed work

Department 1

Department name: Earth Sciences ☐ not applicable

☐ Same as organisation address

Street: Jordi Girona, 29

Town: Barcelona

Postcode: 08034

Country: Spain

If the location of the Department carrying out the proposed work is not the same as the location of the Host Institute, please note that although the proposal submission system calculates the budget of the project based on the location of the Host Institute, the budget of the project for the grant agreement will be calculated by using the country coefficient of the location of the Department carrying out the proposed work.

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Researcher

The name and e-mail of the Researcher and Supervisor are read-only in the administrative form, only additional details can be edited here. To give access rights and contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Last Name*	WHITE	Last Name at Birth	White
First Name(s)*	Rachel	Gender*	○ Male ◉ Female
Title	Dr.	Country of residence*	United States
Nationality*	United Kingdom	Nationality 2	
Date of Birth (DD/MM/YYYY)	31/07/1986	Country of Birth*	United Kingdom
		Place of Birth	Beverley

Contact address

Current organisation name	University of Washington
Current Department/Faculty/Institute/ Laboratory name	Department of Atmospheric Sciences

☐ Same as organisation address

Street	3920 Okanogan Lane		
Postcode/Cedex*	98195	Town*	Seattle
Phone	+12066123323	Country*	United States
Phone2 / Mobile	*+xxx xxxxxxxxx*		
E-Mail*	rachel.white@cantab.net		

ORCID ID	0000-0002-3650-3019		
Researcher ID			*The maximum length of the identifier is 11 characters (ZZZ-9999-2010) and the minimum length is 9 characters (A-1001-2010).*
Other ID	*Please enter the type of ID here*	*Please enter the identifier number here*	

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Qualifications

University Degree giving access to PhD	Date of award (DD/MM/YYYY)	01/07/2008
Doctorate	Start date (DD/MM/YYYY)	01/01/2009
Doctorate	Date of (expected) award (DD/MM/YYYY)	01/07/2012
Full time research experience	Number of months	110

(Measured from the date when a researcher obtained the degree entitling him/her to embark on a doctorate, either in the country in which the degree was obtained or in the country in which the researcher is recruited, even if a doctorate was never started or envisaged.)

Place of activity/place of residence (previous 5 years - most recent one first)

Indicate the period(s) and the country/countries in which you have legally resided and/or had your main activity (work, studies, etc) during the last 5 years up until the deadline for the submission of the proposal. Please fill in this section without gaps, until the call deadline (14/09/2017).

Period from	Period to	Duration (days)	Country
12/01/2015	14/09/2017	977	United States
01/01/2009	11/01/2015	2202	United Kingdom
	Total	3179	

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Supervisor

The name and e-mail of the Researcher and Supervisor are read-only in the administrative form, only additional details can be edited here. To give access rights and contact details of contact persons, please go back to Step 4 of the submission wizard and save the changes.

Title: Dr. Sex: ○ Male ◉ Female

First name*: **Virginie** Last name*: **Guemas**

E-Mail*: **virginie.guemas@bsc.es**

Position in org.: Head of the Climate Prediction Group

Department: Earth Sciences

☐ Same as organisation address

Street: Jordi Girona, 29

Town: Barcelona Post code: 08034

Country: Spain

Website:

Phone: +34 934137679 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Other contact persons

First Name	Last Name	E-mail	Phone
Louis-Philippe	Caron	louis-philippe.caron@bsc.es	+34 934137644
Dorota	Chmielewska	dorota.chmielewska@bsc.es	+34 934134082

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3 - Budget

Is the Researcher eligible for family allowance? ○ Yes ◉ No

Participant Number	Organisation Short Name	Country	Country Coefficient	Number of Months	Researcher Unit Cost			Institutional Unit Cost		Total
					Living Allowance	Mobility Allowance	Family Allowance	Research, training and networking costs	Management and Overheads	
1	BSC	ES	0,976	24	108921,60	14400,00	0,00	19200,00	15600,00	158121,60
Total				24	108921,60	14400,00	0,00	19200,00	15600,00	158121,60

Partner Organisation from Third Country does not sign the Grant Agreement, does not recruit the researcher and does not directly claim costs from the action. The entire EC contribution is transmitted to the Host organisation located in Members States or Associated Countries.

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4 - Ethics issues table

1. HUMAN EMBRYOS/FOETUSES		Page
Does your research involve Human Embryonic Stem Cells (hESCs)?	○ Yes ◉ No	
Does your research involve the use of human embryos?	○ Yes ◉ No	
Does your research involve the use of human foetal tissues / cells?	○ Yes ◉ No	
2. HUMANS		**Page**
Does your research involve human participants?	○ Yes ◉ No	
Does your research involve physical interventions on the study participants?	○ Yes ◉ No	
3. HUMAN CELLS / TISSUES		**Page**
Does your research involve human cells or tissues (other than from Human Embryos/ Foetuses, i.e. section 1)?	○ Yes ◉ No	
4. PERSONAL DATA		**Page**
Does your research involve personal data collection and/or processing?	○ Yes ◉ No	
Does your research involve further processing of previously collected personal data (secondary use)?	○ Yes ◉ No	
5. ANIMALS		**Page**
Does your research involve animals?	○ Yes ◉ No	
6. THIRD COUNTRIES		**Page**
In case non-EU countries are involved, do the research related activities undertaken in these countries raise potential ethics issues?	○ Yes ◉ No	
Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	○ Yes ◉ No	
Do you plan to import any material - including personal data - from non-EU countries into the EU?	○ Yes ◉ No	
Do you plan to export any material - including personal data - from the EU to non-EU countries?	○ Yes ◉ No	
In case your research involves low and/or lower middle income countries, are any benefits-sharing actions planned?	○ Yes ◉ No	
Could the situation in the country put the individuals taking part in the research at risk?	○ Yes ◉ No	

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7. ENVIRONMENT & HEALTH and SAFETY		Page
Does your research involve the use of elements that may cause harm to the environment, to animals or plants?	○ Yes ◉ No	
Does your research deal with endangered fauna and/or flora and/or protected areas?	○ Yes ◉ No	
Does your research involve the use of elements that may cause harm to humans, including research staff?	○ Yes ◉ No	
8. DUAL USE		**Page**
Does your research involve dual-use items in the sense of Regulation 428/2009, or other items for which an authorisation is required?	○ Yes ◉ No	
9. EXCLUSIVE FOCUS ON CIVIL APPLICATIONS		**Page**
Could your research raise concerns regarding the exclusive focus on civil applications?	○ Yes ◉ No	
10. MISUSE		**Page**
Does your research have the potential for misuse of research results?	○ Yes ◉ No	
11. OTHER ETHICS ISSUES		**Page**
Are there any other ethics issues that should be taken into consideration? Please specify	○ Yes ◉ No	

I confirm that I have taken into account all ethics issues described above and that, if any ethics issues apply, I will complete the ethics self-assessment and attach the required documents. ☒

How to Complete your Ethics Self-Assessment

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5 - Call specific questions

Eligibility Researcher (future fellow)

1. Were you in the last 5 years in military service? ○ Yes ◉ No

2. Are you a national of a Member State or Associated Country? ◉ Yes ○ No

Country: United Kingdom

Other Questions

1. For communication purposes only, the European Commission REA asks for permission to publish the name of the researcher (future fellow) should the proposal be retained for funding. Does the researcher (future fellow) give this permission? ◉ Yes ○ No

2. Some national and regional public research funding authorities run schemes to fund MSCA applicants that score highly in the MSCA evaluation but which cannot be funded by the MSCA due to their limited budget. In case this proposal could not be selected for funding by the MSCA, do the researcher and supervisor consent to the European Commission disclosing to such authorities the results of its evaluation (score and ranking range) together with their names and contact details, non-confidential proposal title and abstract, proposal acronym, and host organisation? ◉ Yes ○ No

3. Is there a secondment in Member States or Associated Countries envisaged in Part B of this proposal? ◉ Yes ○ No

In which sector is the secondment in Member States / Associated Countries foreseen?

☒ Academic ☐ Non Academic

Do you already know the organisation to which this secondment will be? ◉ Yes ○ No

Name: University of Stockholm

Country: Sweden

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Extended Open Research Data Pilot in Horizon 2020

If selected, applicants will by default participate in the Pilot on Open Research Data in Horizon 2020[1] , which aims to improve and maximise access to and re-use of research data generated by actions.

However, participation in the Pilot is flexible in the sense that it does not mean that all research data needs to be open. After the action has started, participants will formulate a Data Management Plan (DMP), which should address the relevant aspects of making data FAIR – findable, accessible, interoperable and re-usable, including what data the project will generate, whether and how it will be made accessible for verification and re-use, and how it will be curated and preserved. Through this DMP projects can define certain datasets to remain closed according to the principle "as open as possible, as closed as necessary". A Data Management Plan does not have to be submitted at the proposal stage.

Furthermore, applicants also have the possibility to opt out of this Pilot completely at any stage (before or after the grant signature). In this case, applicants must indicate a reason for this choice (see options below).

Please note that participation in this Pilot does not constitute part of the evaluation process. Proposals will not be penalised for opting out.

We wish to opt out of the Pilot on Open Research Data in Horizon 2020.	○ Yes	◉ No

Further guidance on open access and research data management is available on the participant portal: http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/open-access-dissemination_en.htm and in general annex L of the Work Programme.

[1] *According to article 43.2 of Regulation (EU) No 1290/2013 of the European Parliament and of the Council, of 11 December 2013, laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" and repealing Regulation (EC) No 1906/2006.*

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MARIE SKŁODOWSKA-CURIE ACTIONS

Individual Fellowships (IF)
Call: H2020-MSCA-IF-2017

PART B

Propagation of ROssby waves – connecTion to prEdictability of Climate exTremes
"PROTECT"

This proposal is to be evaluated as:

[EF-RI]

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List of Participating Organisations

Participating organisations	Legal Entity Short Name	Academic (tick)	Non-academic (tick)	Country	Dept./ Division / Laboratory	Supervisor	Role of Partner Organisation
Beneficiary							
Barcelona Supercomputing Center - Centro Nacional De Supercomputacion	BSC	√		Spain	Climate Prediction Group, Earth Sciences Department	Dr. Virginie Guemas	
Partner Organisation							
Stockholm University		√		Sweden	Department of Meteorology	Prof. Rodrigo Caballero	Hosting secondment

No inter-relationships exist between the participating organisation(s), individuals and other entities/persons.

1. Excellence

1.1 Quality and credibility of the research action

1.1.1 Introduction, state-of-the-art, specific objectives and overview of the action

Extreme weather events, such as heatwaves, droughts and flooding, have a devastating impact on society, causing increased mortality and suffering, as well as economic losses. The death toll associated with the European heatwave of 2003 is estimated to exceed 70,000[1], while the 2010 Russian heatwave killed ~55,000 people, caused an annual yield drop of 25%, and resulted in ~US$15 billion in economic losses[2]. Skilful predictions of such events with sufficient lead-time for adaptation procedures can provide huge benefits to our society. Some recent extreme events, including the severe European and Russian heatwaves, were associated with particular atmospheric wave dynamics, specifically the propagation of Rossby waves along atmospheric waveguides[3,4]. Our proposed research will explore the seasonal predictability of extreme events through a lens of atmospheric waveguides and Rossby wave propagation. Our goal is to harness the increased understanding of climate extremes that atmospheric dynamics can bring, to help improve the predictability of extreme events, reducing their human and societal impacts.

a. Extreme Events

This research will study the connection between extreme events and large-scale, slowly-varying (>5 day) background flow, focussing on slowly-moving events with lifetimes of at least several days: heatwaves, cold snaps, droughts and blocking highs. Shorter lived events may be more influenced by local conditions and advection of weather systems.

Heat waves (cold snaps) are consecutive days or nights with consistent extremely high (low) temperatures, while droughts are extended periods of time with reduced rainfall and/or increased evaporation. A blocking high is a region of anomalously high pressure that becomes stationary for days to weeks[5]. Blocking events have been found concurrent with many heatwaves[6], extreme temperatures, and heavy precipitation events[7], including the rain events that led to the catastrophic 2010 Pakistan floods[8]. The causes of blocking events are not yet well understood[9].

b. Rossby wave theory and the Rossby refractive index

Rossby waves are large-scale north-south undulations in eastward flowing air, made possible because we live on a spherical, rotating, planet. Figure 1 shows Rossby waves with two different pathways, the first with extensive meridional propagation, and the second zonally confined within a waveguide (figure from White et al. 2017a[10]). Colours show atmospheric streamfunction: flow is clockwise (anti-cyclonic in the Northern Hemisphere) around positive values, and anti-clockwise around negative values. Arrows show a form of wave-activity flux[11], indicative of wave propagation.

In the 1980-90s, Hoskins, Karoly and Ambrizzi produced a series of pioneering research papers, considering Rossby wave propagation analogous to optical ray theory. A

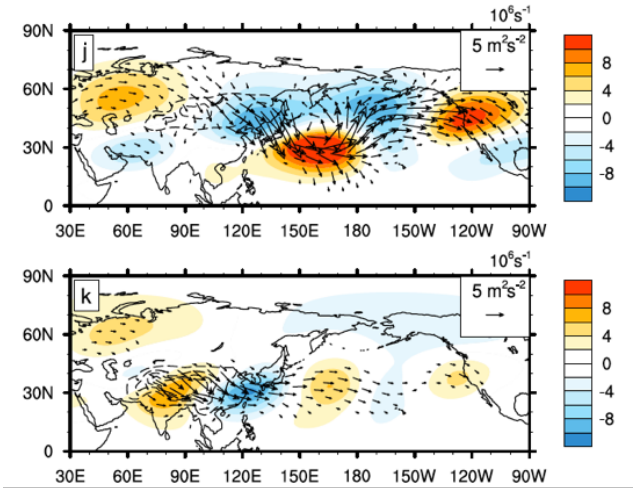


Figure 1. Streamfunction (colours) and wave activity fluxes (arrows) for Rossby waves forced by the Mongolia mountains (top panel), and the Tibetan plateau (bottom panel).

1 Robine, J.-M. et al., 2008: Death toll exceeded 70,000 in Europe during the summer of 2003. C. R. Biol. 331, 171–178.1.
2 Barriopedro, D., Fischer, E. M., Luterbacher, J., Trigo, R. M. & García-Herrera, R., 2011: The Hot Summer of 2010: Redrawing the Temperature Record Map of Europe. Science 332, 220–224.
3 Hoskins, B., Woollings, T., 2015: Persistent Extratropical Regimes and Climate Extremes. Curr. Cli. Chg Rep. 1, 115–124. doi:10.1007/s40641-015-0020-8
4 Petoukhov, V., Petri, S., Rahmstorf, S., Coumou, D., Kornhuber, K., Schellnhuber, H.J., 2016: Role of quasiresonant planetary wave dynamics in recent boreal spring-to-autumn extreme events. Proc. Natl. Acad. Sci. 113, 6862–6867. doi:10.1073/pnas.1606300113
5 Barnes, E. A., Slingo, J. & Woollings, T., 2012: A methodology for the comparison of blocking climatologies across indices, models and climate scenarios. *Clim Dyn* 38, 2467–2481
6 Horton, R. M., Mankin, J. S., Lesk, C., Coffel, E. & Raymond, C., 2016: A Review of Recent Advances in Research on Extreme Heat Events. *Curr Clim Change Rep* 2, 242–259
7 Carrera, M. L., Higgins, R. W. & Kousky, V. E., 2004: Downstream Weather Impacts Associated with Atmospheric Blocking over the Northeast Pacific. *J. Climate* 17, 4823–4839
8 Lau, W. K. M. & Kim, K.-M., 2011: The 2010 Pakistan Flood and Russian Heat Wave: Teleconnection of Hydrometeorological Extremes. *J. Hyd.* 13
9 Barnes, E. A., Slingo, J. & Woollings, T., 2012: A methodology for the comparison of blocking climatologies across indices, models and climate scenarios. *Clim Dyn* 38, 2467–2481
10 White, R.H., Battisti, D.S., Roe, G.H., 2017: Mongolian Mountains Matter Most: Impacts of the Latitude and Height of Asian Orography on Pacific Wintertime Atmospheric Circulation. J. Clim. 30, 4065–4082. doi:10.1175/JCLI-D-16-0401.1
11 Takaya, K. & Nakamura, H. A., 2001: Formulation of a Phase-Independent Wave-Activity Flux for Stationary and Migratory Quasigeostrophic Eddies on a Zonally Varying Basic Flow. *J. Atmos. Sci.* 58, 608–627

'refractive index' was developed, giving expected refraction of Rossby waves as they propagate through the atmosphere[12].

Rossby waves are refracted towards regions of high refractive index; a local maximum can therefore act as a waveguide[13]. Regions of low or negative refractive index are restrictive to Rossby wave propagation: zonally elongated regions of low refractive index can thus reduce Rossby meridional propagation. In figures 2 and 3 we display the refractive index as an equivalent stationary wavenumber (K_S)[14], at 200mb.

c. Extreme events and Rossby waves

Recent work has linked extreme events, particularly temperature extremes, to unusual Rossby wave patterns[15,16], amplified Rossby wave patterns[17], and Arctic sea ice loss[18]. These relatively disparate physical states can all affect the background refractive index, and hence preferred Rossby wave propagation.

One avenue of recent research has focused on the association of Rossby wave 'quasi-resonant amplification' (QRA) with extreme weather events[19,20]. QRA occurs when synoptic-scale propagating Rossby waves constructively interfere with quasi-stationary Rossby waves from land-sea contrasts and orography. Strong mid-latitude waveguides can provide the conditions necessary for QRA, and thus for these extreme events to occur.

If blocking events are connected with quasi-stationary waves, as the literature suggests, they may be affected by K_S. Blocking over the Alaskan region occurs more frequently during La Niña years than El Niño[21], and our preliminary work finds corresponding differences in waveguide geometry. Figure 2 shows composites of K_S during 9 strong El Niño winters (top panel) and 6 strong La Niña winters (bottom panel) as defined by the NOAA ESRL. We hypothesise that the strong gradient in K_S near the north-east Pacific (boxed region), present in El Niño winters and absent during La Niña, may aid in refracting slowly propagating Rossby waves southwards away from the north-east Pacific region, reducing the frequency of blocking.

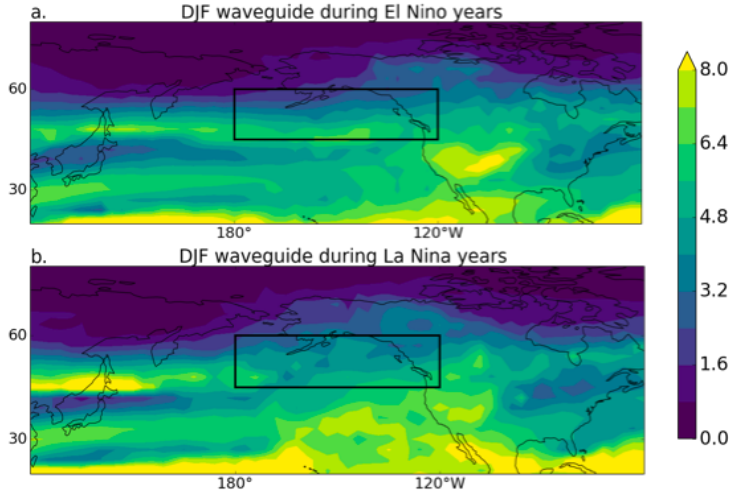


Figure 2. The Rossby refractive index in DJF for El Niño (a) and La Niña (b) years from ERA-interim re-analysis data.

d. Rossby waveguide variability and predictability

The seasonal cycle in waveguide strength impacts the propagation of Rossby waves[22]. Preliminary research by Dr. White (as yet unpublished) also finds inter-annual variability in the width and strength of the waveguide: figure 3 demonstrates this variability, showing two winter seasons with markedly different waveguide geometry. The approximate extent of the tropical waveguide (local maximum in K_S) is marked by a black box, with inter-annual variation in zonal extent, and the extent of imaginary refractive index (shaded white) north of this waveguide. We hypothesize that such differences in waveguide geometry can lead to different propagation pathways for slowly moving Rossby waves, which may lead to changes in the probability of climate extremes downstream. We use the term waveguide geometry to refer to all aspects of the distribution of K_S that impact propagation pathways, including regions of imaginary K_S.

12 Hoskins, B.J., Karoly, D.J., 1981: The Steady Linear Response of a Spherical Atmosphere to Thermal and Orographic Forcing. J. Atmospheric Sci. 38, 1179–1196. doi:10.1175/1520-0469(1981)038<1179:TSLROA>2.0.CO;2

13 Hoskins, B. J. & Ambrizzi, T., 1993: Rossby Wave Propagation on a Realistic Longitudinally Varying Flow. *J. Atmos. Sci.* 50, 1661–1671

14 Karoly, D. J. & Hoskins, B. J., 1982: Three Dimensional Propagation of Planetary Waves. *J. of the Meteo. Soc. of Japan. Ser. II* 60, 109–123

15 Mann, M.E., Rahmstorf, S., Kornhuber, K., Steinman, B.A., Miller, S.K., Coumou, D., 2017: Influence of Anthropogenic Climate Change on Planetary Wave Resonance and Extreme Weather Events. Sci. Rep. 7, 45242. doi:10.1038/srep45242

16 Petoukhov, V., Rahmstorf, S., Petri, S. & Schellnhuber, H. J., 2013: Quasiresonant amplification of planetary waves and recent Northern Hemisphere weather extremes. *PNAS* 110, 5336–5341

17 Screen, J. A. & Simmonds, I., 2014: Amplified mid-latitude planetary waves favour particular regional weather extremes. *Nature Clim. Change* 4, 704–709.

18 Tang, Q., Zhang, X., Yang, X. & Francis, J. A., 2013: Cold winter extremes in northern continents linked to Arctic sea ice loss. *Environ. Res. Lett.* 8, 14036.

19 Petoukhov, V. et al., 2013: Quasiresonant amplification of planetary waves and recent Northern Hemisphere weather extremes. *See 16.*

20 Coumou, D., Petoukhov, V., Rahmstorf, S., Petri, S., Schellnhuber, H.J., 2014: Quasi-resonant circulation regimes and hemispheric synchronization of extreme weather in boreal summer. Proc. Natl. Acad. Sci. 111, 12331–12336. doi:10.1073/pnas.1412797111

21 Renwick, J.A., Wallace, J.M., 1996: Relationships between North Pacific Wintertime Blocking, El Niño, and the PNA Pattern. Mon. Weather Rev. 124, 2071–2076. doi:10.1175/1520-0493(1996)124<2071:RBNPWB>2.0.CO;2

22 White, et al. 2017: Mongolian Mountains Matter Most. *See 10.*

Preliminary work confirms that we can expect some predictability in waveguide geometry. We studied persistence of zonal winds, from which the refractive index is calculated. For the region 25-40N, 180-240E we regress mean Dec-Jan zonal wind against that for Feb-Mar. With an r^2 value of 0.37 ($p < 0.01$), there is relatively good predictability for such a simple, single variable, model. We hypothesize that this predictability in zonal wind will lead to predictability in waveguide geometry.

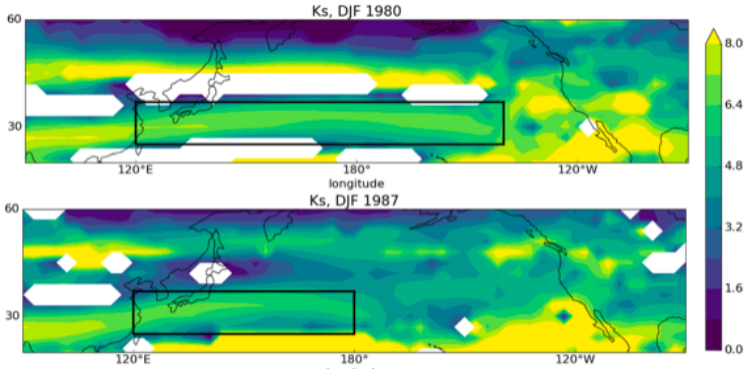


Figure 3. Refractive index in two different boreal winters, demonstrating inter-annual variability in the Pacific waveguide. An approximate extent of the waveguide over the Pacific Ocean is highlighted with a black box.

State-of-the-art

This project combines the state-of-the-art climate prediction capabilities of the BSC with the expertise of the applicant in Rossby wave refraction[23, 24]. While not new in concept, with the Rossby refractive index dating back over 35 years[25], when combined with output data from the latest climate forecast systems, this approach is producing exciting new insights into the behaviour and predictability of our atmosphere. Few studies have explored Rossby wave propagation in a seasonal forecasting perspective; those that do, focus on forecasting Rossby waves source locations, assuming constant background propagation conditions[26]. The novel aspect of this proposal is that we look at the seasonal predictability associated with the propagation pathways. We will also employ a new method to study the persistence of the refractive index based on a dynamical systems approach, and a state-of-the-art feature tracking algorithm to study the propagation of features related to extreme events.

Specific objectives

The over-arching goal of this project is to establish the impact of waveguide geometry on the seasonal climate predictability of extreme event frequency. This goal will be achieved through four narrower scientific questions:

I. What is the predictability of waveguide geometry?
II. How does the frequency of extreme events relate to waveguide geometry?
III. How do the results from I and II combine to provide predictability on the likelihood of extreme events?
IV. How does model resolution impact Rossby wave propagation and the relationship to extreme events?

Overview

We study extreme events from a perspective of Rossby wave refraction, aiming to improve the predictability of such events, with immediate implications for human society. This research takes a multi-faceted approach to attain the objectives outlined above. The experienced researcher, Dr. White, will perform analysis on re-analysis data and pre-existing ensembles of climate model simulations, run feature-tracking algorithms, and, depending on results obtained, may perform targeted general circulation model experiments. The initial focus of this research will be on the Pacific waveguide, as this is where the strongest atmospheric waveguides form. Depending on results and time available, this may be extended to Atlantic waveguides.

1.1.2 Research methodology and approach

In this section we detail the research to be conducted under each of the objectives defined in section 1.1.1.

I. Predictability of waveguide variability (months 1-12, inclusive)

To study the predictability and persistence of waveguide geometry, we will use rotated Empirical Orthogonal Function (REOF) analysis[27] and a recent method based on a dynamical systems approach[28]. The REOF analysis will produce one-dimensional indices that characterize aspects of the waveguide geometry, while the patterns will show the strongest modes of variability, which we will analyse based on known variability, including variability of jet strength, zonal jet extension/retraction, latitudinal shifts, or separation/colocation of the eddy-driven and sub-tropical

23 White, et al., 2017: Mongolian Mountains Matter Most. *See 10.*
24 White et al., 2017: Orographic impacts on boreal winter stratospheric circulation: Mongolian mountains matter most. *Submitted to GRL.*
25 Hoskins, B.J., Karoly, D.J., 1981. The Steady Linear Response of a Spherical Atmosphere to Thermal and Orographic Forcing. J. Atmospheric Sci. 38, 1179–1196. doi:10.1175/1520-0469(1981)038<1179:TSLROA>2.0.CO;2.
26 Scaife, A. A. et al., 2017: Tropical rainfall, Rossby waves and regional winter climate predictions. Q.J.R. Meteorol. Soc. 143, 1–11.
27 Richman, M. B., 1986: Rotation of principal components. J. Cli. 6, 293–335.
28 Messori, G., Caballero, R. & Faranda, D., 2017: A dynamical systems approach to studying midlatitude weather extremes. *GRL.* 44, 2017GL072879.

jets[29]. The principal components (PCs) of the REOF analysis provide the time evolution of the identified modes of variability. These timeseries will be analysed using autocorrelation and Fourier spectral analysis to search for persistence and oscillatory variability, providing a quantification of the predictability of waveguide geometry. During the secondment to the University of Stockholm Dr. White will analyse K_S using a new method based on dynamical systems analysis[30]; this will identify states (spatial distributions) of K_S that are associated with high predictability.

As we wish to study the background flow on which waves are travelling, and not the waves themselves, we will Lanczos filter raw data with a low-pass (e.g. > 5 days) filter. All data will be re-gridded onto a regular 2° latitude by 2° longitude grid prior to analysis, and de-trended to remove long-term trends. To include regions of imaginary K_S we will perform analysis on K_S^2, or use REOF analysis for complex numbers.

The analysis described above will be performed on ERA-5 re-analysis[31] and NASA-MERRA re-analysis data. We will exploit the seasonal prediction database available at the BSC through their access to the EUROSIP[32] and NMME[33] project data, the SPECS project, as well as the numerous seasonal forecasts produced by BSC using the EC-Earth model. We will evaluate the ability of these models to provide accurate seasonal predictions of waveguide geometry by comparison of individual hindcast seasonal predictions of waveguide indices to observed values. Dependency on forecast time, season of initialization, and the forecast system will be explored.

II. Waveguide geometry and frequency of extreme events (months 7 – 20)

Using the waveguide geometry indices defined during the research for section I, we will study relationships between waveguide geometry and the frequency and intensity of heatwaves, cold snaps, droughts, and blocking events. As with objective I, this will be explored in both observational re-analysis data, and in seasonal prediction databases. A 3-month secondment to the University of Stockholm (approximately months 7-9) will allow the applicant to collaborate with Prof. Caballero and colleagues on extremes and large-scale circulation patterns.

We use a climatological definition of extreme temperature events: occurrence of temperatures above (or below) a given threshold percentile. We will use thresholds between 95-99% (1-5%) to determine the robustness of results to this parameter. Heatwaves and cold snaps will be defined as times when the given threshold is exceeded for at least 3 days[34]. Droughts will be identified based on the Standardized Precipitation Evapotranspiration Index[35]. We expect waveguide geometry to affect broad patterns of extreme events, not grid-box scale frequency; as such we will use clustering analysis[36] to define larger regions over which to average extreme event frequency.

For each type of extreme we will produce event frequency maps for individual months and seasons. A blocking detection algorithm will be used to produce maps of blocking frequency[37]. We will investigate whether particular waveguide geometries alter the probability of extreme events in different regions by regressing the waveguide indices onto these frequency maps. Lead-lag correlations will indicate causality. We will also create composite refractive index maps for seasons/months with extremes events or high blocking frequency, relative to time periods with no extremes, or low blocking frequency. For waveguide indices or patterns strongly associated with extreme events, we will analyze case studies of particular events. Results from this section may be used to identify waveguide indices most connected with the probability of extreme events. We will also use the results from the dynamical systems analysis in section I to study the probability of extreme events associated with patterns of refractive index that show high predictability. Using composite analysis of extreme events in the weeks/months following the occurrence of such K_S patterns, this will provide an alternative perspective on extreme events predictability.

Event-tracking software will track the evolution of geopotential height and potential vorticity anomalies. We will identify anomalies associated with extreme events, allowing us to study the propagation path of the anomaly (or anomalies) prior to the event, and make a comparison with theoretical pathways predicted by waveguide geometry.

III. Predictability of extremes from waveguide geometry (months 13-24)

Using our results on waveguide geometry predictability, and the impact of waveguide geometry on the frequency of extreme events, we will build empirical forecast systems for each type of extreme event studied. These systems will

29 Eichelberger, S. J. & Hartmann, D. L., 2007: Zonal Jet Structure and the Leading Mode of Variability. *J. Cli.* 20, 5149–5163.
30 Messori, G., Caballero, R. & Faranda, D., 2017: A dynamical systems approach to studying midlatitude weather extremes. *See 28.*
31 http://climate.copernicus.eu/products/climate-reanalysis
32 https://www.ecmwf.int/en/forecasts/documentation-and-support/long-range/seasonal-forecast-documentation/eurosip-user-guide/multi-model
33 Kirtman, B. P. et al., 2013: The North American Multimodel Ensemble: Phase-1 Seasonal-to-Interannual Prediction; Phase-2 toward Developing Intraseasonal Prediction. *Bull. Amer. Meteor. Soc.* 95, 585–601.
34 Huth, R., Kyselý, J. & Pokorná, L., 2000: A GCM Simulation of Heat Waves, Dry Spells, and Their Relationships to Circulation. *Climatic Chg* 46, 29–60.
35 Turco, M. et al., 2017: On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. *Scientific Reports* 7, 81.
36 Fučkar, N.S., V. Guemas, N.C. Johnson, F. Massonnet and F.J. Doblas-Reyes (2016). Clusters of interannual sea ice variability in the northern hemisphere. *Climate Dynamics,* 47, 1527-1543, doi:10.1007/s00382-015-2917-2.
37 Dunn-Sigouin, E. & Son, S.-W., 2013: Northern Hemisphere blocking frequency and duration in the CMIP5 models. *J.G.R. Atmos.* 118, 1179–1188.

be compared to the wealth of data from dynamical forecast systems available at the BSC, enabling us to determine whether these dynamical models have skill exceeding the empirical model. Using ensembles, and different forecast lead times, we will attempt to diagnose the source of any identified skill. We will examine whether models that have greater skill at modelling waveguide geometry are more successful at forecasting extremes at the seasonal timescale.

Having identified waveguide geometries associated with extreme events, we will calculate the frequency at which such waveguide geometries occurs, and the probability of extreme events given such a waveguide geometry. This is an important aspect for seasonal forecasting: if all extremes events for a particular location are associated with a particular waveguide index value, but that index occurs frequently without a corresponding extreme event, then it does not provide much predictive value. Reliability diagrams will be employed as a measure of this forecast skill[38].

IV. Impact of model resolution (months 19-24)

To further understand the predictive skill of dynamical models, we will exploit the high-resolution datasets available at the BSC to explore the impact of model spatial resolution on the relationships between waveguide geometry and extreme events. We will repeat all analysis on output at both standard (100-150km) and high (40-80km) resolution from several climate models taking part in the PRIMAVERA project[39,40], including the BSC's EC-Earth model, as well as on simulations carried out with EC-Earth at a ground-breaking resolution (10-15km globally). Comparison of results from the different resolutions will be interpreted relative to differences in mean state.

1.1.3 Originality and innovative aspects of the research program.

This research will be the first time the seasonal prediction capability of Rossby propagation pathways will be explored. Combined with the proposed new research on links to high-impact weather events, this project may provide new extreme event prediction capacity. The proposed research will be the first to study preferred propagation pathways based on many aspects of waveguide geometry, not just waveguides. The results of objective I will provide the scientific community with an innovative set of indices describing observed variability in the Rossby refractive index, and thus providing information on preferred propagation pathways of Rossby waves.

This project will involve an original use of the wealth of seasonal forecasting data available at the BSC, including forecast simulations of ground-breaking resolution performed by the BSC. These data will be exploited to provide statistically significant results for extreme events which, by definition, occur infrequently. We will employ an event-tracking algorithm in a novel manner to study the development of extreme events, and use a new dynamical systems-based method of studying predictability, applying this approach to the Rossby refractive index for the first time.

1.1.4 Interdisciplinary aspects

This project will combine the expertise of the applicant in atmospheric dynamics, with that of the host group on extreme events, climate prediction and seasonal forecasting, combining these disciplines. This will not only further our knowledge of what causes extreme events, with the intent to improve forecasts of extreme event probabilities, but will also allow Dr. White to learn about extreme events and seasonal predictability, expanding her expertise in new directions. The potential exists for inter-disciplinary collaborations between this project and end-users of extreme event seasonal forecasts, including disaster relief agencies, and agricultural and insurance companies; this will be dependent on the results obtained. The Earth Systems Service Group at the BSC interacts with end-users to develop applications for seasonal forecast data; their expertise will be harnessed for this project, if applicable.

1.1.5 Career possibilities and collaborations

Having trained in atmospheric dynamics during her post-doctoral position at the University of Washington, Dr. White would use this fellowship to fully establish herself as an expert in the field of Rossby wave propagation, with a unique focus on the impacts on extreme events. This fellowship would help Dr. White position herself as a leader of the novel field of the seasonal forecasting of Rossby waveguide geometry and its impacts on high-impact weather events. This will provide a clear path forward for a research career in a field grounded in atmospheric dynamics, but with immediate and obvious application to human society.

This project would provide new collaborative opportunities between the BSC and University of Washington, where Dr. White has established professional relationships, and between Dr. White, the BSC, and the University of Stockholm, where Dr. White will travel for secondment. Dr. White will have access to new networks of collaborators from the researchers at the BSC, increasing her international visibility in this field, enhancing her future career

38 Hartmann, H. C., Pagano, T. C., Sorooshian, S. & Bales, R., 2002: Confidence Builders: Evaluating Seasonal Climate Forecasts from User Perspectives. *Bull. Amer. Meteor. Soc.* 83, 683–698

39 https://www.primavera-h2020.eu/modelling/#modelling-status

40 Haarsma, R. J. et al., 2016: High Resolution Model Intercomparison Project (HighResMIP v1.0) for CMIP6. *Geosci. Model Dev.* 9, 4185–4208

possibilities, and providing access to many opportunities for future collaborations. A short visit to Dr. Dim Coumou and his group at Vrije Universiteit Amsterdam will provide further opportunities for training and new collaborations.

1.2 Quality and appropriateness of the training and of the two way transfer of knowledge between the researcher and the host

This project will combine the expertise of Dr. White on Rossby wave dynamics, with the expertise on seasonal predictability and extreme events available at the Barcelona Supercomputing Center. Dr. White's recent work has produced major advances in our understanding of how mountains influence atmospheric circulation in both the troposphere and stratosphere, through her focus on Rossby wave dynamics and the influence of the Rossby refractive index. She will share her knowledge, experience, and analysis code with the Earth Sciences group at the BSC through seminars and code-sharing repositories. The BSC is a Severo Ochoa Center of Excellence, and the Director of the Earth Sciences department, Francisco Doblas-Reyes, is a World-leading expert in seasonal forecasting. Through collaborations with members of the Climate Prediction Group, and wider Earth Sciences Department, Dr. White will gain expertise in the study of extreme events, seasonal prediction and the analysis of large model ensembles.

Dr. White will take a 3-month secondment (months 10-12) at The Department of Meteorology at Stockholm University, hosted by Prof. Rodrigo Caballero. Prof. Caballero is an expert in atmospheric dynamics, and his group has been researching the relationship between Rossby wave patterns and extreme events[41, 42]. Dr. White will also collaborate with and learn from Ass. Prof. Abdel Hannachi, an expert in statistical methods for the study of atmospheric dynamics. From this secondment Dr. White will increase her knowledge of atmospheric dynamics, extreme events, and learn new statistical methods for analyzing climate data from a dynamics perspective. A short visit to the Vrije Universiteit Amsterdam will provide opportunities for additional training on extreme events.

Dr. White will benefit from the strong internal programmes developed at the BSC to guide the professional and personal development of all their research staff. The backbone of the BSC's career guidance, training and supervision programme is the centre's Personal Development Programme. At the start of the project, Dr. White will be guided in the creation of a personalised development plan, including annual objectives and a two-year training plan. Individual objectives, based on the applicant's own perceived needs and on those identified by the supervisor, will be agreed at the beginning of each year, revised in the middle of the year and evaluated at the end of the year. Many of these training needs are satisfied by various programmes run by the centre; for specific needs which cannot be met this way, external training is organised.

BSC uses a web-tool to manage researchers' Professional Development, facilitating the annual setting of objectives, their evaluation, and the monitoring of career development plans, as well as supporting the identification of the individual training needs. The resulting Professional Development Plan is aligned with the EU Principles for Innovative Training. Fellows will be expected to follow training courses, attend seminars and participate in other activities to develop both functional and research skills, including Time Management, Team Management, Leadership, Knowledge Transfer, Technical competences and Outreach skills. Dr. White will work towards BSC's Diploma of Excellence in Research Skills**,** a unique internal accreditation program applicable to all researchers.

BSC is a hosting partner of the Partnership for Advanced Computing in Europe (PRACE) which provides a distributed supercomputing infrastructure to all European scientists and is one of the designated PRACE Advanced Training Centres. The applicant already has some high performance computing (HPC) experience, and will be able to extend this knowledge by entering the curriculum at an appropriate level.

The annual BSC program includes around 14 training courses to enable the European research community to utilize the computational infrastructure available through PRACE. The fellow will benefit from hands-on sessions and communication with internationally renowned instructors. Of particular relevance to Dr. White's current and future research, she will be trained in effective parallelization, performance analyses, programming of novel architectures, big data analytics, and effective code-sharing practices.

1.3 Quality of the supervision and of the integration in the team/institution

The applicant will carry out her proposal within the Climate Prediction Group (CPG) of the Earth Sciences Department at the Barcelona Supercomputing Center. Her primary supervisor will be Dr Virginie Guemas, the head of the CPG. Dr. Guemas is an expert on seasonal to decadal climate prediction and a Ramon y Cajal fellow (national grant with 2% success). She was awarded the 2010 Adrien Gaussail PhD prize, granted every two years to a scientific

41 Harnik, N., Messori, G., Caballero, R. & Feldstein, S. B., 2016: The Circumglobal North American wave pattern and its relation to cold events in eastern North America. *GRL*. 43, 2016GL070760.

42 Messori, G., R. Caballero and M. Gaetani, 2016: On cold spells in North America and storminess in Europe. *GRL*, 43, 6620-6628

PhD. She is member of the WCRP (World Climate Research Program), CLIVAR (Climate and Ocean Variability, Predictability, and Change) and SSG (Scientific Steering Group). She has participated in 17 national and international research projects. Currently, she is Principal Investigator of eight European projects, one national project and one Copernicus project. She contributed to the IPCC (Fifth Assessment Report). She is author of 46 articles on climate modelling and predictions in international peer-reviewed journals, with nine in high-impact journals. She has supervised three PhD students and seventeen post-doctoral scientists, including two Marie Skłodowska-Curie Individual Fellows.

Dr. White will also be supervised by Dr. Louis-Philippe Caron, co-leader of the CPG. Dr Caron is an expert on seasonal to decadal forecasting of hurricane activity, a Juan de la Cierva fellow (national grant with 10% success), and a member of the seasonal Tropical Cyclone Prediction Panel of the Working Group on Tropical Meteorology Research (WGTMR) of the WMO. He has participated in seven national and international projects and is currently the PI of one national project and one Copernicus project. He is the author of 14 articles on hurricane activity and climate modeling in international peer-reviewed journals, including one in a high-impact journal (as first author). He currently supervises one PhD student, and co-supervises the CPG, which includes a dozen post-doctoral fellows. He collaborates with the private sector, in particular the insurance industry, to transfer knowledge from academia to applications; he manages a website translating real-time seasonal hurricane predictions into actionable information.

BSC will facilitate the integration of the fellow by providing access to a personal workstation, laptop, BSC's High Performance Computing facilities, the library, conference rooms and to services (e.g. internal trainings and seminars, language classes, health insurance, entry permits). BSC is an ideal institution for hosting the fellow, as it has made a Declaration of Endorsement to the principles of the "European Charter for Researchers" and "The Code of Conduct for the recruitment of researchers" and was awarded with the "HR Excellence in research" logo. The fellow will fully benefit from participating in the various projects that BSC is involved in and will be exposed to many networking opportunities. By focusing on improving current long-term forecasting capabilities, this proposal is fully in line with BSC's key interests, and those of the Climate Prediction Group in particular. Finally, given the large potential for application of this project, the fellow will closely interact with members of the Earth System Services group of the same department. This will further facilitate the candidate's integration within the host organization.

1.4 Capacity of the researcher to reach or re-enforce a position of professional maturity/independence

Dr. White has demonstrated her ability to learn and grow professionally during her post-doctoral position at the University of Washington (UW), through her publication of research papers in a field relatively distinct from her previous research; teaching several undergraduate lecture courses, including a course with 150 students, and a new undergraduate research course on Research in Weather and Climate, which she designed and developed herself; and leading the development and writing of successful funding proposals. Dr. White has previously demonstrated her capacity for independent research through the publication of a single author paper on regional ocean modelling. She received a two-year post-doctoral fellowship from the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the UW, giving her the opportunity to train in atmospheric dynamics and pursue her own research agenda.

In collaboration with Profs. Dargan Frierson and Cecilia Bitz at the University of Washington, Dr. White recently led a successful proposal submitted to the National Science Foundation, U.S., for approximately USD$500,000. During the proposal development, she worked closely with a graduate student, providing research supervision and both professional and personal mentorship. Dr. White is also helping supervise undergraduate students through individual research projects, in collaboration with faculty at the University of Washington. This fellowship would provide Dr. White with the opportunity to increase her international profile and network in the field of atmospheric dynamics, extend her expertise into the field of seasonal predictability and extreme events, gain additional training in leadership and supervision, and learn grant-management skills; combined with her current research independence, teaching, and supervision experience, this will place her in an excellent position to build, develop, and run an independent research group at the end of this fellowship.

2. Impact

2.1 Enhancing the potential and future career prospects of the researcher

This fellowship would allow Dr. White to progress from a relative newcomer in atmospheric dynamics, to an expert at the forefront of a new field combining Rossby waveguide geometry, extreme events, and seasonal predictability. With this research, Dr. White will lay the groundwork for an extended future research programme on the impacts of Rossby waveguide geometry on extreme events, including study of the impacts of anthropogenic climate change on extreme events, further analysis of the ability of climate models to accurately simulate extreme event probability,

and extending the evaluation of predictability to longer timescales. Dr. White maintains a research website, which provides free access to datasets produced by her research; hands-on training will be provided by the BSC on improving the 'visibility' and quality of this website. As part of her training, Dr. White will be involved in the supervision of PhD and Master's students at the BSC (some affiliated with other institutions), learning the skills required to supervise students independently. Dr. White will benefit from participating in some of the on-going projects at the BSC related to this research, observing the management, logistics, and leadership of both small, local projects, and international, multi-institution projects.

With the presentation of this work at international conferences (e.g. European Geophysical Union Annual Meeting) and in high-impact journals (e.g. Geophysical Research Letters, Journal of Climate, QJRMS), and the networking opportunities provided by the participation of the BSC CPG in multiple international projects, Dr. White will increase her international presence in the fields of Rossby wave dynamics and extreme event predictability. The leadership, professional, and personal skills that Dr. White will develop at the BSC, combined with the increased research expertise and enhanced international research presence she will gain, will put her in an excellent position to apply for independent research grants, and build her own research group by the end of this fellowship.

2.2 Quality of the proposed measures to exploit and disseminate the action results

The results of this research will be disseminated to multiple audiences: the scientific community, end users of climate forecast data, and to the public. In order to disseminate the results to a wide scientific community, five peer-reviewed publications are planned in international journals, of high-impact if the results allow it (see deliverables in section 3.1). Project results will be disseminated in high-level international conferences in the fields of atmospheric dynamics (e.g. AMS Conference on Atmospheric and Oceanic Fluid Dynamics), extreme events and predictability, and at inter-disciplinary conferences (e.g. the European Geophysical Union Annual Meeting). This will also provide Dr. White with networking opportunities, potential new collaborations, and will raise her international profile.

A potential benefit of this project is a more advanced warning signal of extreme events, with the possibility to increase reaction time to prepare adequate response measures. The socio-economic impacts of extremes (e.g. damages to health and/or food supply), and their potential predictability, imply the need to communicate their risk to relevant authorities in order to benefit society. Within the BSC, the Earth Sciences Services group has developed close contacts with end users of climate predictions, such as wind energy, agriculture, and insurance. Their products are derived from the work performed by the BSC CPG, in which Dr. White will carry out her project. This in-house expertise of a complete workflow, from the production of climate prediction to its application and dissemination to various socio-economic sectors, can be exploited to develop services in the seasonal prediction of extreme events, based on the results of this project. The fellow will make use of the contacts Dr. Caron has within the insurance industry to disseminate her results within that sector. The insurance industry is keen to incorporate information that would allow them to better estimate and react to upcoming risk from extreme events.

The applicant has already started to share her research code publicly on GitHub, and all code produced during this fellowship will be added to her account (www.github.com/rhwhite), with strong documentation to allow other researchers to take full advantage of this product.

2.3 Quality of the proposed measures to communicate the action activities to different target audiences

One of the priorities of the fellowship will be to seek public engagement through the active and effective communication of results to non-specialized audiences and to students. Dr. White will have the support of the BSC communications department and the Earth System Services Group of ES-BSC for the following planned activities:

- Inclusion of the project information, progress and results in several dissemination activities of BSC, including: website, presentations, leaflets, brochures, videos.
- Participation in MareNostrum open day events, aimed at high school, graduate students, and general public.
- Academic cooperation with the Grupo de Análisis de Situaciones Meteorológi (Uni. Barcelona)

The applicant maintains a personal website, with details of research projects, and links to data produced by these projects (http://www.atmos.washington.edu/~rachel/research.html). Support from BSC will help her improve this website, to disseminate results to both research scientists and the public. Dr. White enjoys scientific outreach work, and has held outreach events on climate science topics in numerous bookstores, pubs, and a correctional institution in Washington State. She will continue to actively seek opportunities to hold such events, either locally, e.g. Barcelona's Pint of Science events, or further afield in Europe. Dr. White is currently developing a 'Climate Questions: On Air' video series in collaboration with the Outreach Department at the University of Washington, and Cascadia Climate Action. Members of the public submit questions on climate science, and Dr. White will create a video, to be shared on YouTube, in which she answers the question while performing aerial circus. The goal is to

constrain the answer to be simple, and to provide a novelty factor that may engage audiences who would not watch conventional videos on climate science. During this Fellowship, Dr. White will continue this outreach project.

3. *Implementation*

3.1 Coherence and effectiveness of the work plan

We assign one work package (WP) for each of the four specific research objectives defined in section 1.1.1. See section 1.1.2 for more detail on research methodologies.

WP1: Predictability and variability of waveguide geometry

- Task 1.1: Update literature review; assess re-analysis and climate model data present at the BSC; download any additional data required
- Task 1.2: Research on waveguide geometry indices, their variability and predictability (objective I)
- Deliverable 1.1: Personal career development plan
- Deliverable 1.2: Research paper on Variability and Predictability in Rossby Waveguides geometry
- Dissemination 1.1: Make code to calculate waveguide geometry indices publicly available
- Dissemination 1.2: Conference presentation on Variability and Predictability in Rossby Waveguide geometry
- Milestone 1.1: Complete logistics for secondment
- Milestone 1.2: Selection of indices describing waveguide geometry: allows WP2 to commence.

WP2: Extreme events and waveguide geometry

- Task 2.1: Research on extreme events and waveguide geometry (objective II)
- Secondment (S) to University of Stockholm, and short visit (SV) to Vrije Universiteit Amsterdam
- Deliverable 2.1: Empirical forecast model for extreme events
- Deliverable 2.2: Research paper on Rossby waves pathways and extreme temperature events
- Deliverable 2.3: Research paper on Rossby waves pathways and blocking events
- Dissemination 2.1: Conference presentation on Rossby waves pathways and extreme events
- Milestone 2.1: Complete logistics for short visit

WP3: Extreme event predictability from waveguide geometry

- Task 3.1: Research on extreme event predictability (objective III)
- Milestone 3.1: Determine whether results can provide additional predictive skill that would be useful to end-users of seasonal climate prediction data. If so, initiate dissemination 3.2.
- Deliverable 3.1: Research paper on Predictability of extreme events using Rossby propagation pathways
- Dissemination 3.1: Conference presentation on Predictability of extreme events from Rossby wave propagation
- Dissemination 3.2: Contact end-users for predictive skill of extremes from this project, and disseminate results.

WP4: Impacts of model resolution

- Task 4.1: Research on the impact of model resolution on Rossby propagation and extreme events (objective IV)
- Deliverable 4.1: Research paper on Improving seasonal forecasts of Rossby wave propagation: model resolution

Communication: communication to the public will be on-going throughout this research project (see section 2.3)

Training 1: Training on effective coding, and BSC infrastructure during the first 2 months.

Training 2: All other training will be on-going throughout the fellowship, based on availability of seminars/courses.

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP1																								
WP2																								
WP3																								
WP4																								
Deliverables	1.1									1.2					2.1		2.2		2.3			3.1		4.1
Milestones				1.1			1.2			2.1										3.1				
Short visit/ Secondment							S	S	S				SV	SV										
Dissemination						1.1		1.2					2.1					3.1				3.2		
Training																								
Communication																								

3.2 Appropriateness of the allocation of tasks and resources

The scientific knowledge of Dr. White in Rossby wave dynamics makes her the ideal researcher to implement this project, while the resources of the BSC will complement her training in the areas of seasonal climate prediction and extreme events. Her secondment to the University of Stockholm will provide training in a new dynamical systems approach to assessing predictability, and in the connection of climate extremes to large-scale flow, complementing

both WP1 and WP2 respectively. The BSC's experience and expertise in project planning and resource management will be fully available to assist the candidate during the implementation of the action.

The planning of the project in terms of person-months has been carefully thought out: while WP1 is not expected to be research intensive, 12 months allows for a 'ramp-up' period, during which Dr. White will be learning the systems and infrastructure at the BSC. WP2 is anticipated to be the most research intensive period, as it includes the secondment and short visit, the formulation and testing of empirical forecast models, and production and evaluation of reliability diagrams. WP4 has been allocated the least amount of time: all code in WPs 1-3 will be written to be independent of the data resolution, and thus WP4 will require little new analysis code to be produced. The last 2-3 months of each WP is expected to be dedicated to writing and submitting research papers, as per the deliverables.

3.3 Appropriateness of the management structure and procedures, including risk management

A Project Manager will support the researcher in all legal, financial and administrative arrangements, and work with the Education, Human Resources and Communications departments for training arrangements and dissemination and outreach activities. In April 2015, BSC was awarded the badge of Human Resources Excellence in Research (HRS4R). The BSC has implemented measures to foster research careers and strengthen internal training, based on the principles of the European Charter for Researchers and on the Code of Conduct for Recruitment. Finances of the project will be managed according to MSC funding rules and will follow established processes in the centre. The applicant will share progress and results with the supervisors and scientific staff on a regular basis, through reports and presentations. This will allow the evaluation of progress against the work plan and Career Development Plan, identify any potential risks, and provide opportunities for any necessary assistance in a timely and periodic manner.

The potential research risks identified at this stage are summarised in the table below. Likelihood is judged from results in the literature, and from preliminary research.

Risk	WP	Likelihood	Contingency measure
REOF analysis doesn't produce well-separated, waveguide indices.	1	low	Explore other definitions for waveguide indices, based on theoretical understanding of expected variability, and expected influence on extreme events.
Relationships between waveguide indices and extreme events identified in reanalysis data are not statistically significant.	2	medium	Reduce thresholds for extremes (include more events) and/or exploit model output to obtain more data. Compare model results to observations: establish if correlations seen in models are representative of those observed.
Little to no relationship found between waveguide geometry and extreme events.	2	low	Consider other aspects of the background flow using lead-lag composites (upper level wind fields, stationary wave patterns) and/or study connection between refractive index and seasonal mean conditions, and intra-seasonal variability.
Little or no seasonal predictability found in waveguide indices associated with extreme events.	3	very low	Use alternative time periods for predictability: shorter (weeks), or longer (decadal, from, for example, the Pacific Decadal Oscillation).

3.4 Appropriateness of the institutional environment (infrastructure)

The infrastructure and computational resources (desktops, laptops, super-computing facilities, data availability, and computational storage space) available at the BSC is more than sufficient for attaining the project objectives. Dr. White already has extensive experience in computational analysis, and the BSC has a highly skilled and well trained team of technicians able to provide advice and support on using the available high performance computing infrastructure. Within the Earth Sciences Department the Computation Earth Sciences group provides strong support to researchers, developing tools to automate the running, post-processing and basic analysis of climate prediction experiments, and to efficiently manage the computing resources. Much of the data Dr. White will require for this project is already downloaded and available locally at the BSC; support is available to easily obtain any data not currently available. The BSC has extensive experience in hosting fellows and researchers, described in more detail in section 1.3. The combination of outstanding available supercomputing facilities, high quality user support and experience in hosting fellows will provide the candidate with a very strong basis of scientific infrastructure to be successful in this research project.

4. *CV of the Experienced Researcher*

PUBLICATIONS (PEER-REVIEWED)

White, R.H., Battisti, D., Sheshadri, A., 2017, Orographic impacts on boreal winter stratospheric circulation: Mongolian mountains matter most. Submitted to GRL

White, R.H., Battisti, D., and Skok, G., 2017, Global precipitation events tracked in time and space in gridded observational data, *GRL,* DOI: 10.1002/2017GL074011

White, R.H., Battisti, D., and Roe, G., 2017, Mongolian Mountains Matter Most: impacts of the latitude and height of Asian orography on the Winter Pacific Jet Stream, *J. Clim,* DOI: 10.1175/JCLI-D-16-0401.1

M.A. Stiller-Reeve, C. Heuze, W. T. Ball, R. H. White et al., 2016 Improving together: better science writing through peer learning, *Hydrology and Earth System Sciences,* DOI: 10.5194/hess-20-2965-2016

White, R.H., 2015, Using multiple passive tracers to identify the importance of the North Brazil undercurrent for Atlantic Cold Tongue variability, *Quarterly Journal of the Royal Meteorological Society*, *published online,* DOI: 10.1002/qj.2536

White, R.H. and Toumi, R., 2014: River Flow and Ocean Temperatures: The Congo River, *Journal of Geophysical Research - Oceans*, 119, 2501–2517, DOI: 10.1002/2014JC009836, *4 citations*

White, R.H. and Toumi, R., 2013: The limitations of bias correcting regional climate model inputs, *Geophys. Res. Lett., 40*, 2907-2912, DOI: 10.1002/grl.50612, *31 citations*

White, R. and Toumi, R., 2012: A Tightly Bound Soil-Water scheme within an atmosphere-land-surface model, Journal of Hydrology, *Journal of Hydrology 452/453*, 51-63, DOI: 10.1016/j.jhydrol.2012.05.028, *2 citations*

INVITED PRESENTATIONS

Exploring Tropical precipitation from an event-based perspective, *University of Washington*, *USA*, Nov 2016.

How ocean circulation connects extra-tropical mountains to tropical weather, *University of Otago*, *New Zealand,* Oct 2016.

The impact of latitude on mountain-jet-stream interactions, *University of Reading, UK,* June 2015.

The impact of mountain latitude and geometry on the Pacific Jet stream and storm track, *Imperial College London, UK,* June 2015.

Improving WRF Regional Climate Simulations; Precipitation and Runoff, *University of Washington*, *USA,* Apr 2014.

Freshwater river plumes and Ocean Temperatures, *NOC, Liverpool, UK,* September 2013.

The extent of the Congo River influence, *Institut Català de Ciències del Clima (IC3), Barcelona, Spain,* July 2013.

The influence of Congo Basin Precipitation on Atlantic SSTs, *NOC, Southampton, UK,* May 2013.

CONFERENCE AND WORKSHOP PRESENTATIONS

Orography and SSWs: Which Mountains Matter Most? *AMS 19th Conference on Middle Atmosphere, Portland, U.S. June 2017, oral presentation.*

Mongolian Mountains Matter Most: The Impacts of Asian Orography on Downstream Atmospheric Circulation and Variability, *AMS 21st Conference on Atmospheric and Oceanic Fluid Dynamics, Portland, U.S. June 2017, poster presentation.*

Topographic impacts on jet streams and storm tracks: Mongolian mountains matter, *EGU 2015, poster presentation.*

A new method for studying water mass origins on basin scales: using multiple passive tracers to study Atlantic Cold Tongue variability, *EGU 2015, poster presentation.*

Storm Tracks and Orography: The interaction of responses from different mountain ranges, *Latsis Symposium 2014, oral presentation.*

Modelling runoff in semi-arid climate: the importance of a tightly-bound-water scheme, *Africa Climate Conference 2013, 15-18 Oct 2013, Arusha, Tanzania, poster presentation.*

Freshwater river plumes and ocean temperatures, *Challenger Society for Marine Science Ocean Modelling Group Meeting, 9 September 2013, Imperial College London, UK, oral presentation.*

The impact of the Congo plume, *Challenger Society for Marine Science Ocean Modelling Group Meeting, 7 September 2012, University of East Anglia, UK, oral presentation.*

A tightly bound water soil physics scheme for the NOAH land surface model, *Sixth ICTP Workshop on the Theory and Use of Regional Climate Models, 7 – 18 May 2012, ICTP, Trieste, Italy, oral presentation.*

The impact of soil moisture on the regional climate of the Olifants basin in South Africa, *EGU General Assembly 2011, 3–8 April 2011, Vienna, Austria. EGU2011-850, poster presentation.*

PRIZES, AWARDS AND SCHOLARSHIPS

IOP Environmental Group Essay Competition 2014, winner.
Shell and Institute of Physics Award for the Very Early Career Woman Physicist of the Year, 2013 shortlisted finalist.
Imperial College GSEPS research symposium poster competition, 2011, 2nd prize winner.
BP Rosemary Murray Scholarships 2006; 2007; 2008.

FUNDING RECEIVED

NSF Climate and large-scale dynamics; Lead author/research scientist, 2017 – 2020: *Hemispheric energy balance and tropical precipitation shifts: the impacts of forcing location*, USD 594,498.
XSEDE start-up allocation; PI, 2015: *Tropical deforestation and the Madden-Julian Oscillation,* 50,000 Service Units, 500GB space.
XSEDE Research Request; Contributor, 2015: *Applying a computationally accelerated super-parameterized climate model to understand dynamics of drought, land-atmosphere feedback, and the Madden-Julian Oscillation.* 920,000 Service Units.
JISAO Post-doctoral fellowship (UW), 2014-2016: *Jets, Stationary Waves and Storm Tracks; the interaction of orographic and oceanic forcings. 2 year post-doc funding* ~USD200,000.
Royal Society International Exchange Grant, 2014 (3 months): GBP 1940

SUPERVISING, MENTORING AND TEACHING

Graduate and Undergraduate Students:
Currently **co-mentoring two undergraduates** in Atmospheric Sciences research projects.
Co-mentor to a Masters student for 1 year at University of Washington in 2016-2017.
Outreach Postgraduate Ambassador with the Imperial College, including e-mentoring of high school students.

Classes taught (as primary lecturer):
Global Warming: Understanding the Issues (Spring 2017; ~160 students), lecturer, University of Washington.
Research in Weather and Climate (Spring 2017; 7 students), lecturer for a new course-based undergraduate research experience, including design and development of curriculum. University of Washington, Bothell.
Introduction to Climate Science (Winter 2016-2017, Spring 2017; ~30 students), University of Washington, Bothell
Physics Mechanics laboratory classes (Winter 2016-2017, 48 students), lecturer, University of Washington, Bothell.
Undergraduate physics labs (2012-2014; ~20 students), supervisor for structured projects on planetary boundary layer wind turbulence and scattering of solar radiation, Imperial College London.

Education and Qualifications:
CELTA qualification in Teaching English as a Second Language awarded by the University of Cambridge, 2013.
Courses attended: Advancing Learning Through Evidence-Based STEM Teaching, edX.org online course, 2016; Introduction to Teaching and Learning for Postdocs, Imperial College PDC, 2012.

OUTREACH

Public lectures/Radio interviews:
Going to Extremes: Is it climate change or just bad weather? April 2017, Ravenna Third Place Books
Salmon in a time of Global Warming, March 2017, public talk at Peddler Brewing Company and radio interview with KBCS radio (http://kbcs.fm/2017/03/27/salmon-and-climate-change-in-the-northwest)
The Life of Carbon, Nov 2016, University House, Seattle;
A Price on Carbon for a Warming Planet, Sep 2016, Climate on Tap at Naked City Taproom;
Climate Change and Us, Sep 2016, Washington Corrections Center for Women;
Going to Extremes: Is it climate change or just bad weather? Sep 2016, Peddler Brewing Company;
Ask a Climate Scientist, March 2016, Seattle Central College Conversations on Social Issues;

Climate Change 101, Jan 2016, Ada's Technical Books;
Ask a Climate Scientist, Nov 2015, Sustaining all Life fundraiser.

As part of the UW Atmospheric Sciences Outreach team:

Presentations on weather, the climate of the Pacific Northwest, and climate change for school children of various age groups. Participation in school science fairs with atmospheric-physics demonstrations.

USA Science Festival Volunteer, Washington D.C. April 2016: Co-hosted a stand on weather and climate.

Other public engagement:

Project leader for a presentation on 'Building a Climate model', using the 'Science on a Sphere' at the Science Museum, London. Co-presenter in a 'Global Temperature Change' presentation for the same.

NON-PEER-REVIEWED PUBLICATIONS

White, R.H. 2014: A changing climate, should Britain worry now? *Winning essay of the IOP Environmental Physics Group Essay competition.*

White, R. H., 2014: Africa's Climate Challenges, *ClimateSnack.com.*

White, R. H., 2013: To rain or not to rain: Precipitation in a changing climate, *ClimateSnack.com.*

Ball, W., Craske, J., Czaja, A., Ingram, J., Messori, G., Mouradian, S., Sheldon, L., Tull, J., White, R., and Zhang, F., 2012: Ocean Day 2012, *An Institute Event Overview Report from the Grantham Institute for Climate Change*, Grantham Institute for Climate Change, Imperial College London, UK.

REVIEWER FOR SCIENTIFIC JOURNALS

Journal of Climate
Climate Dynamics
Journal of Geophysical Research - Atmospheres
Journal of Geophysical Research - Oceans

LEADERSHIP AND TEAM SKILLS

Chair and founder of the low-frequency variability discussion group within the Atmospheric Sciences Department at University of Washington, 2016-present
Explore Search and Rescue Team Member for King County, Washington State
Group Liaison Officer, 2014 for ClimateSnack outreach and communication project (climatesnack.com)
Co-chair of Atmospheric Group Seminar at Imperial College, 2009-10.

DYNAMICAL MODEL EXPERIENCE

CESM, NCAR/UCAR global atmosphere and ocean model. Significant experience running on local and national super-computers (Yellowstone), including extensive modification of input boundary conditions for sensitivity experiments.

SPCAM, Super-parameterized version of the NCAR Community Atmosphere Model (CAM). Added a mixed-layer slab ocean; running on national supercomputers (Stampede).

ECHAM, MPI global atmosphere model. Experience running on local super-computer.

HiRAM, GFDL high-resolution global atmosphere model. Experience running on local and national super-computers (Yellowstone)

WRF, NCAR/UCAR regional atmosphere model. Significant experience running on local super-computers, including the modification of input boundary conditions, and the modification of parameterisation code.

ROMS, regional ocean model. Significant experience running on local super-computer.

COMPUTATIONAL SKILLS

Programming: Strong ability in **Python**, **Fortran, IDL**, **NCL**, **NCO**, **CDO** and **Matlab.** Good basic understanding of **Java.**

Version control: Working knowledge of **Git** and **GitHub** for individual and collaborative projects

High Performance computing: Experience running climate models on super-computers, using **up to 512 CPUs**. Knowledge of multiple-core set-up optimisation for climate models.

Operating Systems: Highly proficient with **Linux**, including **bash and csh scripting.** Good working knowledge of **Windows, MS Office,** including excellent working knowledge of **Word** and **Excel,** including **Excel macros.**

EMPLOYMENT

March 2017 – present **Part-time Lecturer, University of Washington**, USA
Global warming: Understanding the Issues

April 2016 – present **Part-time Lecturer, University of Washington, Bothell,** USA
Undergraduate classes: Introduction to Climate Science, Physics mechanics lab.

Jan 2017 – present **Post-doctoral Research Fellow, Department of Atmospheric Sciences, University of Washington,** USA
Research on the influence on the atmospheric refractive index on atmospheric circulation and variability. Study of the influence of localized heating patterns on cross-equatorial heat fluxes in the atmosphere and ocean using coupled general circulation models.

Jan 2015 – Jan2017 **Post-doctoral Research Fellow, JISAO, University of Washington,** USA
Conducting research using general circulation models to study global atmosphere and ocean circulations. Including work to study the influence of topography on atmospheric circulation and storm tracks, and on the forcing of the AMOC. Other projects include the study of tropical deforestation effects in global models.

April 2012 – Nov 2014 **Research Associate, Imperial College London,** London, UK
Working with a regional ocean model (ROMS) and a regional atmospheric model (WRF) to study climate processes, with an African focus. Including the Congo River impact on ocean temperatures, and deforesting the Congo rainforest.

March – May 2014 **Visiting Scientist, University of Washington**, Seattle, USA
Collaborating with Prof. David Battisti to study the sensitivity of the Northern Hemisphere storm tracks to topography and the interaction of responses from different mountain ranges.

2010 **Scientific Consultant with Imperial Consultants for The Science Museum, London: Climate Science Exhibition (4 weeks part time)**
Summarised scientific literature on potential climate change impacts for non-specialists, for a new exhibition at The Science Museum, London

2007 **Research Internship at the Met Office, Hadley Centre (12 weeks)**
Work completed within the Climate Extremes team looking at the potential impact of future drought on global crop growth.

EDUCATION

2009 – 2012 **Imperial College London,** London, SW7 2AZ
PhD awarded July 2012
Physics Department, Space and Atmospheric Physics Group
Study of the impact of climate change on rainfall and water availability using the WRF regional forecasting model. Exploration of correcting general circulation model inputs for regional climate model simulations. Investigation into the mechanisms of water storage and evaporation, and implementation of new soil physics to a regional land surface model.

2004 - 2008 **University of Cambridge,** New Hall, Cambridge, CB3 0DF
BA (I) and MSci (I), Experimental and Theoretical Physics, awarded July 2008
Research project studying the vertical transport of atmospheric pollutants by deep convection, using a cloud resolving model to analyse observational measurements.

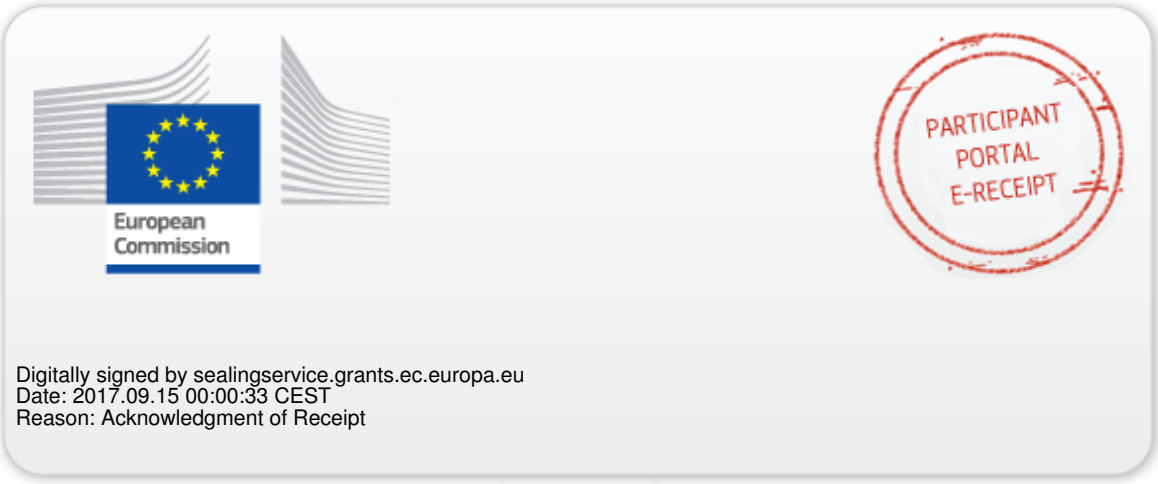
5. *Capacity of the Participating Organisations*

Beneficiary: BARCELONA SUPERCOMUTING CENTER - CENTRO NACIONAL DE SUPERCOMUTACIÓN	
General Description	The **Barcelona Supercomputing Center – Centro Nacional de Supercomputación (BSC-CNS*)*** combines unique high performance computing facilities and in-house research departments on computer, life, and Earth sciences, and computational applications, counting more than 400 researchers and students from more than 42 different countries. BSC-CNS has been accredited as one of the first eight Severo Ochoa Centers of Excellence. This award is given by the Spanish Government as recognition for leading research centers in Spain that are internationally well known institutions in their respective areas. Established in 2006, **the Earth Sciences Department** (ESD) of the BSC, worked on atmospheric composition modelling. The designation of Professor Francisco J. Doblas-Reyes as Director of the ESD in 2014 initiated the merging of the Climate Forecast Unit of the Institut Català de Ciències del Clima (IC3-CFU), which he was leading and in a short time that became a main European actor in the development of climate predictions and climate services. The newly merged department is structured around four groups, with more than 60 employees, including technical and support staff. Dr. Rachel White will be carrying out her project within the **Climate Prediction Group** (CPG), led by **Virginie Guemas and Louis-Philippe Caron**. The CPG aims at developing a climate forecast system based on the EC-Earth model and performs regular assessments of the characteristics of this forecast system compared to all other operational and quasi-operational systems available in the world. The CPG is a highly productive scientific group, producing over 100 peer-reviewed articles in the past 5 years, including 13 in high-impact journals (see https://earth.bsc.es/wiki/doku.php?id=publications:publications for a complete list of the publications of the Earth Sciences department). This group participates currently in ten European projects, four national projects and three Copernicus projects. Of special interest for this Marie Skłodowska-Curie fellowship, are the European H2020 IMPREX (2015-2019) project, which focuses on seasonal prediction of heavy precipitation events and droughts with tight relations with end users at the local scale in Europe, and the ERA4CS MEDSCOPE project (2017-2020), co-coordinated by Virginie Guemas, and which focuses on understanding sources of predictability including for extreme hydrometeorological events, improving forecast quality assessment methodologies and developing climate services.BSC is one of the world leaders in the development of climate prediction applicability and climate services. These objectives rely on expanding the understanding of the climate predictability mechanisms through tailored and comprehensive forecast quality assessment, on the development of the EC-Earth climate forecast system through the testing of new model parameterisations/components as well as the development of innovative initialization strategies.
Role and Profile of key persons (supervisor)	**Dr Virginie Guemas** is an expert on seasonal to decadal climate prediction, head of the climate prediction group and a Ramon y Cajal fellow (national grant with 2% success). She was awarded the 2010 Adrien Gaussail PhD prize, granted every two years to a scientific PhD. She is member of the WCRP (World Climate Research Program) CLIVAR (Climate and Ocean Variability, Predictability, and Change) SSG (Scientific Steering Group). She has participated in 17 national and international research projects. Currently, she is Principal Investigator (PI) of eight European projects, one national project and one Copernicus project. She contributed to the IPCC (Fifth Assessment Report). She is author of 46 articles on climate modelling and predictions in international peer-reviewed journals, among which nine in high-impact journals. She has supervised three PhD students and seventeen post-doctoral scientists, including two Marie Skłodowska-Curie Individual Fellows.
Key Research Facilities, Infrastructure and Equipment	BSC hosts and manages a range of HPC systems, including MareNostrum 4, with 148,176 cores and 13.7 Pflops capacity. Additionally, BSC manages Minotauro, a Sandy Bridge cluster with NVIDIA GPUs, providing more than 100 TFlops.
Independent research premises?	Yes. All key research facilities, infrastructure, and equipment will be available for the fellow.
Previous Involvement in Research and Training Programmes	BSC has coordinated and participated in more than 150 projects including 43 individual grants and fellowships; 9 EU-FP6 projects 38 EU-FP7 and 73 national projects (e.g. IS-ENES, APPRAISAL, FIELD_AC, PRACE 1IP, PRACE 2iP, Mont-Blanc, ScalaLife, OPTIMIS, PELE, RISC) and many private contracts. BSC also participated in the MC ITN project (SCALUS: FP7-PEOPLE-ITN-2008-238808) and three Marie Curie IEFs (EEPPIBM: FP7-PEOPLE-2012-IEF-327899, MatComPhys: FP7-PEOPLE-2011-IEF-302320 and MDRAF: FP7-PEOPLE-2013-IEF-622662).
Current involvement in Research and Training Programmes	Collaborations with universities: BSC closely collaborates with Universidad Politècnica de Catalunya (UPC) including a joint Master degree in Environmental Engineering. Excellence Programs and Networks: Severo Ochoa Excellence Programme (Research seminars series); RES training sessions; NVIDIA CUDA/GPU excellence center (PUMPS summer school); PRACE Advanced Training Center; HiPEAC (ACACES summer school, Computing system weeks and HiPEAC conferences) and H2020-EINFRA-Centers of Excellence for computing applications. Research Fellowships: BSC is currently awarded with 6 early-stage postdocs (4 Juan de la Cierva and 2 Beatriu de Pinós), 12 seniors (5 Ramón y Cajal, 3 I3 and 6 ICREA) and is supporting 4 MSCA ITN and 5 MSCA-IF. Noteworthy, three of these MSCA-IF are currently conducted at BSC-ES (NeTNPPAO, ACRoNNim, SPFireSD), which will host the proposal on hand. In addition, BSC is the main beneficiary of a MSCA COFUND program for postdoc fellows, which foresees the implementation of a training programme (STARS; H2020-MSCA-COFUND-754433). Projects: Total of 111 ongoing projects are funded by the European Commission (FP7, Horizon 2020, Copernicus, COST Action): e.g. Euroserver, DEEP, PRIMAVERA, EUDAT, PRACE 3IP; 37 at BSC-ES (4 EU-FP7, 21 EU-H2020, 12 EU-Other) and 8 National Projects.
Relevant Publications and/or research/innovation products	*Massonnet F, et al, 2017: Using climate models to estimate the quality of global observational data sets, Science, doi: 10.1126/science.aaf6369* *Doblas-Reyes F.J., et al., 2013: Initialized near-term regional climate change prediction, Nature Communications, doi:10.1038/ncomms2704* *Guemas V., et al., 2013 : Retrospective prediction of the global warming slowdown in the past decade, Nature Climate Change, doi:10.1038/nclimate1863* *Guemas V., et al., 2014 : Dependencies in Statistical Hypothesis Tests for Climate Time Series, Bull. Amer. Meteor. Soc., 95 (11), 1666-1667.* *Guemas V. et al., 2013: September 2012 Arctic sea ice minimum : Discriminating between sea ice memory, the August 2012 extreme storm and prevailing warm conditions, Bull. Amer. Meteor. Soc., 94 (9), S20-S22.*

Partner Organisation: UNIVERSITY OF STOCKHOLM	
General description	The Department of Meteorology at Stockholm University (http://www.misu.su.se) is an internationally leading institution with around 40 researchers and 25 PhD students engaged in large-scale atmospheric dynamics, cloud and boundary layer processes, upper-atmosphere physics and dynamics, atmospheric chemistry and physical oceanography. They enjoy strong links with the Bolin Centre for Climate Research (http://www.bolin.su.se), a cross-disciplinary centre bringing together all departments within Stockholm University engaged in climate science.
Key Persons and Expertise (supervisor)	The primary host will be Prof. Rodrigo Caballero (http://climdyn.misu.su.se), who has broad expertise in atmospheric and climate dynamics. His research group (currently 3 phd students and 3 postdocs) explores the role of atmospheric dynamics at all scales (from planetary scales down to cloud scales) in shaping the climate of past, present and future climates. Other relevant members of the department are Dr. Gabriele Messori, a research associate working on the interaction between Rossby waves, storm tracks and extreme events and Assoc. Prof. Abdel Hannachi, with expertise in statistical methods for the study of atmospheric dynamics.
Key Research facilities, infrastructure and equipment	The department has an active visitors programme (http://www.misu.su.se/imi) and is well equipped to host visiting scholars, with dedicated visitor office space and computer workstations. We have access to national-level supercomputing facilities for work with general circulation models and an in-house scientific programmer who can provide help and guidance in using such models.
Previous and Current Involvement in Research and Training Programmes	The department participates in SeSe (http://sese.nu), a training network for PhD students across the Nordic countries in computational science, including climate modelling. We also participate in the Bolin Centre Climate Research School, which provides training for PhD students in climate science as well as a yearly summer school.
Relevant Publications and/or research/innovation product	Messori, G., R. Caballero and M. Gaetani, 2016: On cold spells in North America and storminess in Europe. Geophys. Res. Lett., 43, 6620-6628. Löfverström, M., R. Caballero, J. Nilsson and G. Messori, 2016: Stationary wave reflection as a mechanism for zonalizing the Atlantic winter jet at the LGM. J. Atmos. Sci., 73, 3329-3342. Hannachi, A., D. M. Straus, C. L. E. Franzke, S. Corti, T. Woollings 2017: Low-frequency nonlinearity and regime behavior in the Northern Hemisphere extratropical atmosphere, Rev. Geophys., 55 ,199–234,

6. ***Ethical Issues***

No ethical issues were flagged in the Ethics Issues Table, and thus the proposal meets the EU and national legal and ethics requirements.



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