REQUEST FOR A SPECIAL PROJECT 2017–2019

MEMBER STATE: Finland

Principal Investigator[1]: Petteri Uotila

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Timo Vihma,
N.N. research assistant

Project Title:

Links between warming Arctic and climate extremes in northern Eurasia (LAWINE)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ___________________	
Starting year: (Each project will have a well-defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2017	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2017-2019: (To make changes to an existing project please submit an amended version of the original form.)		**2017**	**2018**	**2019**
High Performance Computing Facility	(SBU)	2,000,000	2,500,000	200,000
Accumulated data storage (total archive volume)[2]	(GB)	300	900	1000

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

……………………………………………

Continue overleaf

1The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

Principal Investigator: Prof. Petteri Uotila

Project Title: Links between warming Arctic and climate extremes in northern Eurasia (LAWINE)

Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (1,000,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Summary

We request computational resources to assist us in completing model simulations on the EC-Earth climate model to address the LAWINE scientific objectives (see below). In LAWINE; Prof. Uotila has been awarded a two-year H2020-MSCA-IF-2015 Fellowship commencing in 2017, where Uotila is the fellow and Prof. Vihma the host, to study climatic teleconnections in northern Eurasia. LAWINE tasks consist of atmospheric model simulations on the IFS model with surface temperature and soil moisture perturbations, and fully coupled climate EC-Earth model perturbation experiments. By using a hierarchy of model configurations with increasing complexity and resolution, we are able to quantify model responses in northern Eurasia to surface perturbations. These modelled responses will be compared to observational ones, and the physical mechanisms of linkages cam be identified. Information on how well state-of-the-science climate models simulate the northern Eurasian teleconnections is crucial for improving the model skill.

LAWINE scientific plan

Although an understanding of complex processes linking Arctic amplification with mid-latitude climate extremes is emerging, this understanding is incomplete and important issues remain unclear due to imperfect models and sparse observational records. Specifically, more research is needed:

1. to identify and better understand the processes linking Arctic warming with regional climate extremes outside the Arctic.
2. to identify and quantify other remote climate impacts (teleconnections).
3. to better understand causal linkages.
4. to better understand regional aspects related to Arctic warming and climate extremes.

Comparisons of observation and model-based diagnostics reveal important information on teleconnections and model skill in simulating them. In addition to available model output, we carry out model simulations under constant and variable forcing (such as constant greenhouse gas concentrations, volcanic emissions and solar irradiance) using different grid resolutions. In these simulations we perturb surface temperatures and soil moisture in the origin regions. In this way we can quantify model responses in northern Eurasia to perturbations as the complexity and resolution of model configurations increases. In atmosphere-only simulations we prescribe the surface temperature and/or soil moisture of the origin regions (an AMIP kind of approach), while in the coupled atmosphere-ocean simulations they are nudged towards desired values. This hierarchy of model configurations allows investigation on how model complexity affects teleconnection mechanisms in terms of atmospheric circulation and climate extremes.

As Arctic warming is occurring over decadal time scales, our analysis focus on inter-decadal trends (1979-2015). We hypothesise that also other remote regions which significantly impact the northern Eurasian climate, manifest their inter-decadal variability in ocean/land surface properties, such as temperature and soil moisture. We think this is a reasonable assumption due to the significant inter-annual to inter-decadal oceanic variability, often described by oscillations such as the ENSO, the Pacific Decadal Oscillation and the Atlantic Multidecadal Oscillation. Furthermore, it is plausible to assume that persistent barotropic and tropospheric changes in the atmosphere, such as the jet stream shifts, interact and modify the ocean surface properties. Our specific objectives are:

1. to identify remote regions that generate teleconnections affecting the occurrence, intensity and duration of extreme climate events in northern Eurasia.
2. to analyse how well state-of-the-science climate models simulate the identified associations.
3. to identify physical mechanisms of the teleconnections affecting the northern Eurasian climate extremes.

LAWINE WP1 focuses on to identify which remote regions are associated with the inter-decadal changes in the occurrence, intensity and duration of extreme climate events in northern Eurasia, and WP2 to assess how well state-of-science climate models simulate the teleconnections, identified in WP1, based on exisisting CMIP5 climate model simulations. Results from these two work packages support the modelling work, as described in the next two paragraphs, where physical mechanisms behind the identified teleconnections are determined.

In LAWINE one of our objectives is to find out the effects of regional perturbations of surface temperature and moisture on the climate in northern Eurasia in a climate model with constant forcing in its WP3. We determine teleconnection mechanisms affecting the northern Eurasian climate extremes by running idealised climate model perturbation experiments using both the atmospheric (the IFS model) and the atmosphere-ocean component (IFS-NEMO) of the EC-Earth climate model. These model simulations occur under constant forcing (such as constant greenhouse gas concentrations, volcanic emissions and solar irradiance) determined by the climate the 20th century protocol (http://www.iges.org/c20c/). Hence, models can be assumed to be in an undisturbed equilibrium state. We perturb surface temperatures and soil moisture of origin regions identified in WP1. The specific range of perturbations is extensive, but realistic in order to yield large responses in northern Eurasia. To address uncertainties, we aim to obtain an accurate probability distributions with a large ensemble size. After completing the equilibrium simulations, trend diagnostics are applied to the simulation output. These diagnostics results are compared with each other and with observational based results of WP1 and climate model results of WP2. In this way we obtain information on the modelled regional response in northern Eurasia to the changes in remote surface forcing. Atmosphere-only simulations are compared with the coupled simulations to determine the importance of atmosphere-ocean exchange processes, large-scale atmospheric circulation modes and the sensitivity of responses in northern Eurasia to surface perturbations in the remote regions. By comparing the model responses with the perturbation strength we obtain information on how sensitive models are for perturbations and how this affects their internal variability over inter-decadal scales and their representation of climate extremes in northern Eurasia in particular. Based on the perturbation simulations we will write and publish a peer-reviewed publication on the role of regional perturbations in idealised model simulations and affecting northern Eurasian climate

Another LAWINE objective is to find out effects of regional perturbations of surface temperature and moisture on the climate in northern Eurasia in a climate model with observed historical forcing. For this, we We carry out climate model perturbation experiments under a historical forcing as defined in the CMIP6 protocol. FMI is committed to do CMIP6 EC-Earth simulations starting in 2016 and we collaborate with that activity. From these transient model simulations we determine teleconnection mechanisms affecting the northern Eurasian climate extremes by again applying the trend diagnostics. Results from the diagnostics are compared with model simulations carried out in WP3. As in WP3, we isolate the responses due to regional and dynamical factors such as atmosphere-ocean feedbacks, soil moisture, atmospheric circulation versus oceanic processes and the role of model internal variability. With WP3 results, responses in model equilibrium and responses in transient state are compared which enables the attribution of the change in the frequency, intensity and duration of climate extremes in northern Eurasia. Based on these we will write and publish a peer-reviewed publication on the role of regional perturbations in affecting northern Eurasian climate using historical forcing.

We are committed to an Open Science continuum (open publications, accessible computer codes, input data linked to codes and methods, etc.). This ensures full reproducibility of scientific results and benefits the academic research and enterprises, and improves opportunities to maintain the scientific self-correction. Furthermore, the analysis software will be released freely available for academic use.

We have three specific main dissemination targets in the research space: the EC-Earth consortium, the Copernicus services, and CMIP climate modelling community. The dissemination will take place by direct contacts, workshops and short-term visits. We share infra-structure with the EC-Earth consortium and their developers and users directly benefit of the new knowledge created in this project. The EC-Earth components, such as its atmospheric and ocean modelling tools, are in a central role in the Copernicus services which are provided to the European national environmental services, enterprises, and general public by ECMWF. Lastly, the new findings and diagnostics tools of this project are of great interest for the CMIP community.

Justification of the resources requested and the technical characteristics of the code

In LAWINE, many model simulations will be carried out on the FMI Cray XC-30 supercomputer, but due to expected high level of usage by other projects, we would much appreciate if granted additional resources on the ECMWF HPC facility. Moreover, a significant amount of the EC-Earth input data, such as initial conditions, is shared on the ECMWF storage space. A direct access to these data would also make the collaboration within the EC-Earth modelling consortium seamless. Resources on the HPC facility help us in sharing our model output with partners and analysts.

We would like to carry out the AMIP type perturbation simulations on the FMI supercomputer, but the fully coupled EC-Earth simulations on the ECMWF HPC facility due to its more powerful computational resources compared to the FMI ones. These coupled simulations will follow the climate of the 20th century protocol (www.iges.org/c20c/) with a constant forcing. These equilibrium simulations are associated with an extensive range of surface perturbations and a large ensemble size (20 members, 10 model years each matching the length of 1979-2015 observational data), which are required to address uncertainties related to climatic variability. According to the information on EC-Earth development wiki (https://dev.ec-earth.org/projects/ecearth3/wiki/CPU_performance_and_scaling_on_cca-intel), a 10-day simulation on hyperthread=1 configuration with 3G/core requested memory takes 3 minutes 40 seconds and use 358 SBUs on 288 ncores. Accordingly, one ensemble member uses 470,000 SBUs and we request to generate 10 members on the ECMWF HPC facility. If this is deemed to be too large, we request to generate 2 members only which would keep our SBU allocation below 1,000,000.

For detailed scientific information, the 10-page LAWINE research plan is available from (https://www.dropbox.com/s/sbrvvaw7aagpaqo/FMI-LAWINE_research_plan.pdf). Also, we assume that the assessment panel is relatively familiar with the EC-Earth code and its technical characteristics as it is routinely used on the ECMWF HPC facility, but if any more information is needed please do not hesitate to contact Petteri Uotila (petteri.uotila@fmi.fi).