# REQUEST FOR A SPECIAL PROJECT 2017–2019


**MEMBER STATE:** ………Denmark….……………………………………………...…

**Principal Investigator[1]:** ………Jens Hesselbjerg Christensen……………………………..……

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**Other researchers:**

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**Project Title:** ……Non-linear climate response to volcanic forcing …………..……

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| | | |
|---|---|---|
| If this is a continuation of an existing project, please state the computer project account assigned previously. | **SP** _________________ | |
| Starting year:<br>(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:**<br>(To make changes to an existing project please submit an amended version of the original form.) | | **2017** | **2018** | **2019** |
|---|---|---|---|---|
| High Performance Computing Facility | (SBU) | 2,250,000 | 2,250,000 | |
| Accumulated data storage (total archive volume)[2] | (GB) | 3000 | 5000 | |

***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):

…………30 June 2016………………


*Continue overleaf*


[1] The 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.

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**Project Title:** ……… Non-linear climate response to volcanic forcing ……

# 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.*

**Non-linear climate response to volcanic forcing**

During the past decades anthropogenic impacts on climate have been studied in great detail and future climate scenarios have been developed for planning purposes. The impact of volcanism in a future warming climate has, however, not been investigated. In the present project we will investigate the impact of volcanism in the past and predict impacts of future eruptions in a warming climate.

Explosive volcanic eruptions influence the climate of the Earth by injecting aerosols into the stratosphere, which reflect sunlight and cools the lower atmosphere and surface of the Earth. The climate impact of such eruptions can be severe and global in scale and through recorded history there are examples causing disruption to societies, including famines. The last such major eruption happened in 1815 (Tambora, Indonesia).

During the last 200 years we have not had any major volcanic eruption on the scale of those seen further back in time. Hence little is known about the influence of how location and timing (month/season) of eruptions can influence the global and regional climate and how the climatic impact depends on the initial climate state. Furthermore, the impact of volcanic eruptions in a future greenhouse-gas warmed climate is poorly constrained.

During the coming years, it is proposed to use Greenland and Antarctic ice core measurements to construct a more complete mapping of volcanic eruptions and polar climate during the past 12,000 years and selected periods within the Glacial. To take advantage of these developments, we will make comprehensive ensemble modeling using EC-Earth using ice core derived volcanic forcing estimates, hypothesizing that the magnitude and duration of volcanically caused climate change depends not only on the size of an eruption but also on the initial climate state. This will potentially bring our basic understanding of volcanic activities well beyond state-of-the-art and the knowledge will improve risk assessment of volcanic eruptions in the future climate.


**Left: Photo of the Eyjafjallajökull eruption, April 2010 (by Jens Hesselbjerg Christensen). This eruption was just 1/100 times smaller the size of the 1815 Tambora eruption. Right: Lancaster Sands, painting by J.M.W. Turner from the "year without a summer" in 1816 following the Tambora eruption. Note the reddish colors due to ash in the stratosphere and the hardship apparent in the painting. Famine was widespread due to crop failures in the cold summer weather.**

## Volcanic forcing vs. model initial conditions

We will combine the interplay between the climate components during volcanism-induced changes and interpret these using the fully coupled EC-Earth model.

While atmospheric and oceanic states are all represented along with aerosol transport, some processes in each of these components are still poorly resolved in models. In particular, there is a need to better represent transport and deposition of volcanic emissions. However, even with state-of-the-art models (e.g. EC-Earth) we can study if/when volcanic eruptions can trigger shifts in the climate system and performing Monte-Carlo simulations with probabilistic determined combinations and strengths of eruptions as deduced from ice core records, for glaciation (e.g. Dansgaard-Oeschger events; Baldini et al., 2015) and present day climates (e.g. El Niño cycles; Lehner et al., 2016). As part of a subsequent analysis, we will be able to demonstrate how volcanic forcing impacts temperature patterns, and associated seasonality and snow accumulation on ice sheets, and how this depends on the initial state of the climate system. We have identified a number of possible initial climate states that may or may not respond differently to volcanic forcing. These include but are not limited to, D-O events, ENSO phases, the pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO) and states of the Atlantic Multi-decadal Oscillation (AMO).

Advances of our experiment over previous ones (e.g., Baldini et al. 2015, Lehner et al. 2016) are exploring the role of the timing as well as strength of volcanic eruptions, ii) we run at much finer horizontal resolution (T159 vs. T21/T42) and iii) our focus is for very different climatological stages (glacial as well as Holocene).

## Requested HPC resources

The requested HPC resources in the following are based on our Eemian experiments with EC-Earth under the special project SPDKLANG (Pedersen et al. 2016a,b). We have not yet set up the latest version of the EC-Earth model in the low-resolution paleoclimatic configuration. Moreover, the latest upgrade of the HPC to Broadwell nodes will also influence the resource usage. Here, we base our estimates on our runs with the EC-Earth v.3.1 at T159 (1 deg ocean) on the CCA cluster where we spent about 4500 SBUs per model year.

Initially the model needs to be spun up to the changed boundary conditions describing either glaciation or the Holocene. We will, however be able to use conditions from other simulations as initial states, including nudged states of e.g. sea-ice coverage. Subsequently, the model will run in ensemble mode (~10 members) for ~15 years (portraying near term climate change), extending two members to ~100 years as the main experiment (probing longer term change) if clear different pathways are identified in some of the ensemble members. As a minimum, we wish to probe two different volcanic scenarios for one Holocene and one glaciated case. All in all, this amounts to about 1000 model years corresponding to an estimated usage of 4,500,000 SBUs.

Each model year produces just under 10 GB per year with the level of output we have taken for the Eemian experiments. With more aggressive clean-up (e.g. some ensemble members will not be analysed in details), we estimate a use of a total of 5 TB of storage needs.

| **2 year project 2017-18** | |
|---|---|
| Sum of model years: | 1,000 years |
| Billing units pr. model year: | 4,500 units |
| Total billing units: | 4,500,000 units |
| Storage pr. model year: | 2-10 GB |
| Total storage: | 5 TB |

## References

Baldini et al.: Was millennial scale climate change during the Last Glacial triggered by explosive volcanism?, Scientific Reports 5, 2015.

Lehner, F., et al.: The importance of ENSO phase during volcanic eruptions for detection and attribution. Geophysical Research Letters 43.6, 2851-2858, 2016

Pedersen, R. A., P. L. Langen, and B. M. Vinther, The last interglacial climate – comparing direct and indirect impacts of insolation changes, In review, Climate Dynamics, 2016a.

Pedersen, R. A., P. L. Langen, and B. M. Vinther, Greenland warming during the last interglacial: the relative importance of insolation and oceanic changes, Climate of the Past Discussions, pp. 1–20, doi:10.5194/cp-2016-48, 2016b.