REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: …… Israel, Germany ……..…

Principal Investigator[1]: …… Pavel Khain[1] ……..……

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(1) Israel Meteorological Service (IMS)
(2) Deutscher Wetterdienst (DWD)
(3) Israel Oceanographic and Limnological Research (IOLR)

Project Title:

Coupled climate simulations using the ICON model

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ……	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for project year:		**2024**	**2025**	**2026**
High Performance Computing Facility	[SBU]	304M	303M	303M
Accumulated data storage (total archive volume)[2]	[GB]	630,000	630,000	630,000

EWC resources required for project year:		**2024**	**2025**	**2026**
Number of vCPUs	[#]	0	0	0
Total memory	[GB]	0	0	0
Storage	[GB]	0	0	0
Number of vGPUs[3]	[#]	0	0	0

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 annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. 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 etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

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Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 5,000,000 SBU should be more detailed (3-5 pages).

Scientific plan

In the framework of ICON-Seamless, Deutscher Wetterdienst (DWD) and the Max Planck Institute for Meteorology are developing a new earth system model (ESM) based on the atmospheric Icosahedral non-hydrostatic (ICON) model in the version which is also used for numerical weather prediction (ICON-NWP). A major step was the coupling of ICON-NWP to the ocean model ICON-O. The global configuration will be used for climate predictions and could also be the new ESM for climate projections performed for the upcoming seventh phase of the Coupled Model Intercomparison Project (CMIP). Beyond that, ICON-Seamless is a starting point for the ESM for weather scales, including ocean and coupled data assimilation. Coupled simulations over a long time period (1000 years at least) will have to be conducted at the computing facilities of ECMWF for a proper spin-up of the ocean.

For most users of climate data, the resolution of the global CMIP models is still too coarse. Therefore, the national weather services are obliged to perform a downscaling of CMIP simulations using regional climate models. The ICON model in climate limited-area mode (ICON-CLM) has been developed within the Climate Limited-area Modelling (CLM) community. The first recommended version for the European domain at a horizontal resolution of about 12 km is available and the CMIP6 downscaling with ICON-CLM will start at the end of 2023. Beyond that, coupled simulations will be necessary to provide consistent estimations of the future sea-level rise in combination with atmospheric parameters under the influence of climate change, e.g. for the investigation of storm surges. As ICON-O, the ocean component of ICON-Seamless, is not available in limited-area mode, an alternative ocean model – NEMO – will be used for the regional coupled simulations.

However, the setup of the coupling and the method of adapting the atmospheric land-sea mask to the one of the ocean model were adopted from ICON-Seamless.

The Middle East region is defined in climate change as a hot spot and therefore the importance of a reliable climate model for this sensitive region. An assessment of future climatic trends and the frequency of extreme events serve as a basis for national strategic plans in the Eastern Mediterranean, including in Israel and neighbouring countries. The problem is that these estimates are based on coarse-resolution climate models that require significant corrections that include statistical downscaling, which questions their reliability.

In recent years, the Israeli Meteorological Service, in cooperation with the CLM community and especially with researchers from DWD and Helmholtz-Zentrum Hereon (Germany), and in cooperation with The Cyprus Institute, conduct a comprehensive study that includes the calibration of ICON over South-East Europe and the Mediterranean, with a focus on the convection-permitting resolution over the East Mediterranean. Following the decisive influence of the Mediterranean Sea in this region, as part of the study, a working environment is being established that enables the running of the ICON model coupled with the NEMO ocean model and the HD rivers model. A requirement for a coupled model is also supported by the CORDEX-MED Steering Committee.

The scientific plan is divided into three parts:

1. Performing climate simulations for the years 1950-2100 using the ICON model at a resolution of 12 km over the Mediterranean region and at a resolution of 2.5 km over the East Mediterranean (Figure 1). The climate run will be carried out with boundary conditions from EC-Earth3-Veg GCM and using the SSP3-7.0 climate scenario (CO2 emissions double by 2100). To the best of our knowledge, this will be the first long-term run worldwide with a convection-permitting resolution to be performed over the East Mediterranean.
2. Performing a 1000-year global simulation with ICON-Seamless with a horizontal resolution of about 80 km in the atmosphere and 40 km in the ocean. The period of 1000 years is aimed at a proper spin-up of the ocean.
3. Performing several research simulations on past periods of the ICON/NEMO coupled system with the aim of calibrating and adapting it to future coupled climate runs, both for the Mediterranean setup (Figure 1) and the European one (Figure 2). Special attention will be given to the comparison between

the coupled and the uncoupled historical simulations, in order to evaluate the added value of coupling over the Mediterranean.

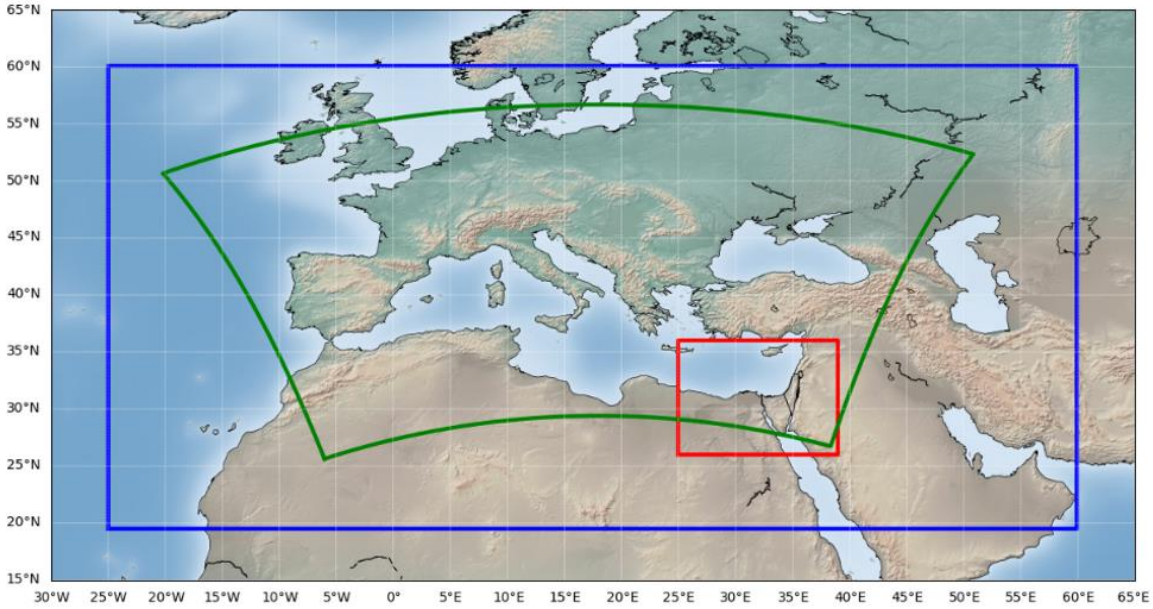

Figure 1. Simulation domains of the ICON model over the Mediterranean region. The model resolution in the "Large domain" (blue) containing the CORDEX-MED domain (green), will be 12 km. The model resolution of the "Small domain" over East Mediterranean (red) will be 2.5 km.

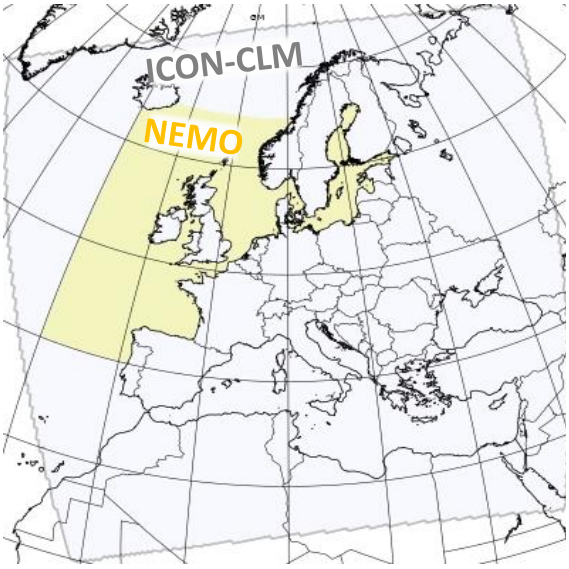

Figure 2. EURO-CORDEX domain (light grey) at about 12 km horizontal resolution and NEMO domain (yellow) at a horizontal resolution of about 2 km, used for the coupled ICON-CLM simulations for Europe.

Justification of the computer resources requested

Requirements for part 1:

We plan to perform an 85-year simulation with the scenario SSP3-7.0 using EC-Earth3-Veg GCM. First, a historical run will be performed using ERA5 as boundary conditions and then a historical run will be performed with EC-Earth3-Veg GCM for the period 1950-2014. Second, a climate simulation will be performed for the period 2015-2100. The total simulations length will be 2X65+85=215 years.

Each simulation will include the Large and Small domains (Figure 1). 1-year test simulations were already performed on ATOS@ECMWF HPC allowing us to estimate precisely the needed computer resources. 150-year simulation over the Large domain (Figure 1) on ATOS@ECMWF HPC using 700 CPUs takes about 150 days and requires 75 MSBUs and 720 TB of storage. 150-year simulation over the Small domain (Figure 1) on ATOS@ECMWF HPC using 2000 CPUs takes about 200 days and requires 260 MSBUs and 90 TB of storage (much less than for the Large domain since no data is saved for further nesting). Hence, 215 years of climate simulations described above require **480** MSBU and 1160 TB of storage.

Requirements for part 2:

1000 years simulation of the global ICON-Seamless simulation with a horizontal resolution of about 80 km in the atmosphere and 40 km in the ocean requires about **30** MSBUs and about 50 TB of storage.

Requirements for part 3:

For tuning purposes, we plan to perform 4 coupled ICON/NEMO historical runs for the period 1950-2020 on the Large Mediterranean and the European domains, driven by ERA5. Our estimation is that a 70-year coupled simulation over the Large domain on ATOS@ECMWF HPC using about 1000 CPUs will require about 50 MSBU and 84 TB of storage (no data is saved for further nesting). Since the number of cells is similar (225,000 for the Large Mediterranean domain and about 200,000 for the European domain), the same holds for the European domain. Hence, 8 coupled historical simulations described here require about **400** MSBU and 670 TB of storage.

Therefore, the total requirement for the project is 480+30+400=**910 MSBU** and 1890 TB of storage. After analyzing the results of each simulation, the data stored on the ECFS will be thinned, preventing its accumulation. Therefore the storage request is **630 TB per year**.

Technical characteristics of the code to be used

The atmospheric model ICON-CLM 2.6.5 (https://code.mpimet.mpg.de/projects/iconpublic), which includes the land scheme Terra (Schulz, J.-P. and G. Vogel, 2020), will run in the framework of the SPICE package (https://hereon-coast.atlassian.net/wiki/spaces/SPICE/overview) version 2.1. The model run was successfully tested on ATOS@ECMWF HPC.

ICON-Seamless is a particular configuration of the operational ICON-NWP model and it is compiled together with ICON-O into one binary. It was tested on ATOS@ECMWF HPC. At the resolutions of 80 km and 40 km for the atmosphere and the ocean, respectively, it reaches about 50 SYPD.

Coupler: OASIS (https://oasis.cerfacs.fr/) is the software interface to couple existing ocean and atmosphere numerical GCMs. Version: OASIS3-MCT_5.0.

Ocean model: NEMO (https://www.nemo-ocean.eu/) is the modelling framework for research activities and forecasting services in ocean and climate sciences, developed in a sustainable way by a European consortium. Version: NEMO-MED v3.6. / NEMO-GCOAST based on the official NEMO v4.2.

Input-Output effective software: XIOS version 2.5.

The Hydrological Discharge Model: HD (https://zenodo.org/record/7890682) is a river runoff component for offline and coupled model applications. Version: HD-5.2.0.