SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Coupled HCLIM-NEMO regional downscaling simulations for Ireland phase1: Historical comparison with atmosphere only
Computer Project Account:	spieodea
Start Year - End Year :	2024-2024
Principal Investigator(s)	Enda O'Dea
Affiliation/Address:	Met Éireann, Glasnevin Hill, Dublin 9, Ireland
Other Researchers (Name/Affiliation):	Tido Semmler, Met Éireann

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The primary objective of this one-year Special Project was to develop and test a coupled regional climate modelling system for Ireland, integrating the HARMONIE-Climate (HCLIM) atmospheric model with the NEMO ocean model via the OASIS3-MCT coupler. The project aimed to establish a functioning coupled system, with a specific focus on debugging and identifying key challenges in the coupling process. The initial goal was to achieve a stable, coupled configuration and perform short demonstrator runs to assess the system's viability for future, longer-term climate simulations, rather than to produce a comprehensive scientific evaluation in this initial phase.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

1. **Coupling Instability:** Significant effort was required to get the HCLIM-NEMO coupled system to run stably. Numerous issues related to the interaction and data exchange between the two models via OASIS3-MCT had to be investigated and resolved.
2. **Anomalous Sea Surface Temperatures and Shortwave Radiation:** A key challenge was the appearance of unphysical, sharp spikes in Sea Surface Temperature (SST) close to the coast in the coupled runs. Initial investigation focused on NEMO, but detailed analysis revealed the root cause to be anomalous radiation fluxes from HCLIM when using the LMEB scheme. This, in turn, was traced to an incorrect passing of arguments within the HCLIM/SURFEX subroutines. While the fundamental code error has since been rectified, identifying and diagnosing this complex, cross-component issue was a major focus of the project period.

Due to these debugging challenges, the project's focus remained on achieving a functional system, which limited the ability to perform long-term simulations.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The administrative process for the Special Project application and reporting was straightforward. The support from ECMWF was helpful in addressing technical queries related to the Atos.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

The initial work focused on the significant technical challenge of working towards a one-month demonstrator run. This preparatory phase was a substantial project in itself, involving getting the AMM15 (NEMO at 1.5km resolution) configuration to run on ECMWF's Atos HPCF, synchronizing NEMO versions to ensure compatibility with the HCLIM coupled system, and dealing with numerous unforeseen configuration issues.

While this initial one-month run eventually succeeded in completing, it revealed numerous issues that required a more focused diagnostic approach. Consequently, the strategy shifted to performing very short runs of a single day. This allowed for an in-depth analysis of the data from both NEMO and HCLIM, examining relevant coupling variables at the single timestep level. This detailed work was instrumental in uncovering sharp, anomalous spikes in SST near the coast. Initially, it was suspected that the problem lay with how NEMO was handling the coupled fields. However, further analysis demonstrated that the issue stemmed from the shortwave radiation being passed from HCLIM. This was later confirmed to be a specific problem when using the LMEB (Multi Energy Balance) scheme in HCLIM.

Identifying and documenting this major anomaly and tracing its origin from the ocean model's symptoms (SST) back to the atmospheric model's physics (radiation scheme), was a key scientific outcome of this project.

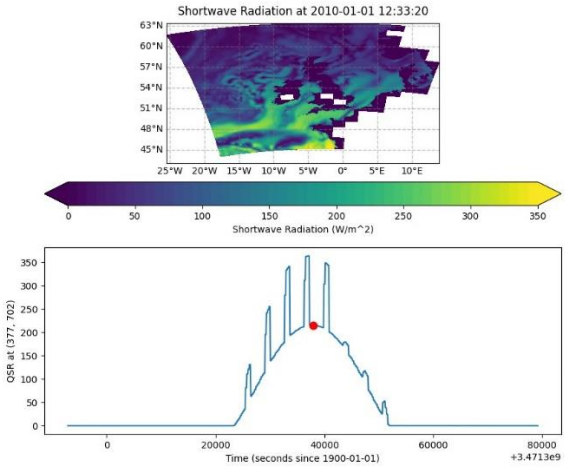

Figure 1 Top Panel: Shortwave radiation as seen in NEMO at an instant in time near the coast with no deviations from the expected curve. Bottom Panel: A time series at a near coast point with large jumps in shortwave radiation.

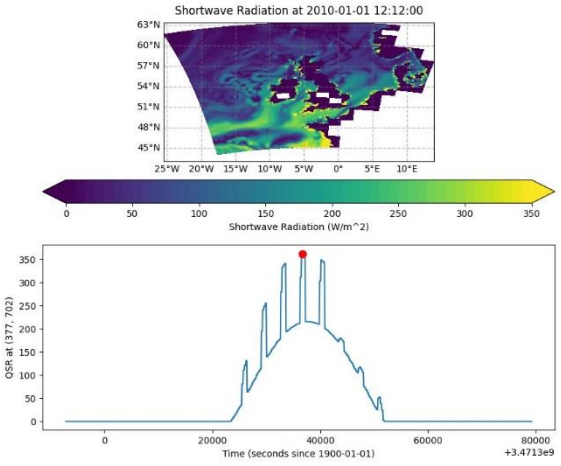

Figure 2: Top Panel: Shortwave radiation as seen in NEMO at an instant in time near the coast with large deviations from the expected curve. Bottom Panel: A times series at a near coast point with large jumps in shortwave radiation.

The focus on short, intensive diagnostic runs meant that the project itself used a relatively small fraction of the total computational allocation, approximately 2.1 million SBU. By late 2024, it became clear that a large surplus would remain. To ensure these valuable resources were put to good use, the remaining ~27 million SBU were transferred to a colleague, Tido Semmler (Met Éireann), for his research. This brought the total utilization for the special project to over 29 million SBU, very close to the full 30 million SBU allocation. The work conducted by Tido Semmler is summarized as follows:

The extra units helped to do sensitivity tests with Greenland separated into 7 Mouginot regions when routing the runoff into the surrounding sea areas. In the baseline version, Greenland is just considered as one region and the runoff equally distributed into the sea areas around Greenland. The separation into 7 Mouginot regions is a first step towards a more realistic distribution of the Greenland freshwater into the surrounding seas, resulting in more freshwater coming into the area south of Greenland and less in the north and east. Especially the Labrador Sea but to some extent also the Nordic Seas were getting stronger stratified compared to the baseline simulation.

As this was an initial, one-year investigatory project, the primary goal was to establish a working system and identify challenges, rather than to produce peer-reviewed publications. The project has successfully laid the groundwork for future, more in-depth research with the coupled model.

List of publications/reports from the project with complete references

As this was a one-year, investigatory project focused on technical development and debugging, no peer-reviewed publications have been produced at this stage

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

The work initiated in this Special Project is being continued using National SBU units. The immediate focus is on resolving the remaining issues in the coupled system. Now that the SST and shortwave radiation anomaly is understood and fixed, further debugging work continues with a number of other issues that have been highlighted as part of the original intensive investigations. Once all coupling issues have been resolved, the plan is to conduct longer-term simulations to evaluate the performance of the coupled model in downscaling climate information for the Irish region. This could be the subject of a future Special Project application.