Research Scientist: High-Resolution Global Climate Modelling

Further Details

This post is part of the long-term NCAS (JWCRP) Programme in High Resolution Climate Modelling (HRCM). The team comprises a core staff of five scientists at NCAS in Reading, three scientists at the MO Hadley Centre in Exeter and one dedicated scientist from the NCAS Computational Modelling Support (CMS), also based in Reading. NCAS-Climate comprises approximately 50 scientists at Reading, and provides a core-strategic programme and national capability in modelling and understanding the climate system.

HRCM has existed since 2004 and has involved international collaboration since its inception, e.g. at the Earth Simulator Centre in Yokohama, within the US CLIVAR Hurricane Working Group, and with the US CLIVAR Dynamics Panel. Further, it is supported by additional research grants that sustain strong collaborative research across Europe (e.g. the 19-institution Horizon 2020 PRIMAVERA, led by HRCM scientists), Asia (China, Philippines), and the UK, involving an additional sixteen post-doctoral scientists at Reading.

Main duties of the post

The post-holder will contribute to designing and executing major experimental "campaigns" such as those undertaken under PRACE-UPSCALE, and currently undertaken for the HighResMIP protocol, part of CMIP6. Further, the post-holder will assist in further developing our hierarchy of high-resolution global climate models, with the aim of constructing and exploiting an atmospheric GCM with a horizontal resolution of ~5km, thus beginning to resolve convective systems in the so-called atmospheric "Grey Zone". The project PIs have already developed a 10km AGCM and possess all necessary experience and tools for this next step. The scientific questions to be tackled with this new tool are discussed later in this document, under *Rationale and purpose of the NCAS HRCM programme*.

The post-holder will also be responsible for performing sensitivity experiments and process-based analyses using tools such as feature tracking (TRACK, Hodges 2007) and diagnostics contained in ESMValTool (Eyring) and the Met Office Auto-Assess suite, as well as metrics developed as part of the PRIMAVERA project. It is expected that these investigations will results in high-impact peer-reviewed publications.

The post-holder will also assist the PIs in planning and submitting proposals for large HPC resources to a number of supercomputing centres worldwide, to complement the national resources (petascale resource are available on both NERC and MO HPC platforms) that are available to the project on a regular basis.

HRCM is required to deliver periodic reports and scientific software to project partners and to the wider NERC community. The post-holder will also be expected to contribute strongly to these deliverables.

The NCAS (JWCRP) Programme in High Resolution Climate Modelling (HRCM)

Rationale and purpose of the NCAS HRCM programme

Confidence in the output of climate models is directly related to their fidelity in simulating relevant processes. A fundamental feature of both the atmosphere and ocean is the existence of two-way interactions across scales that range from planetary to molecular. Whilst it is not possible computationally to resolve the full range of scales explicitly, climate modellers must continue to push the frontiers of what is possible in order to assess the impact of unresolved scales on key issues in climate science such as climate sensitivity and high impact events. This research is not only of fundamental scientific importance but is also essential to address user needs, for example in relation to: early warning of high impact events; quantitative risk assessment for adaptation, mitigation, resilience and investment planning.

Hence:

> *The purpose of the NCAS HRCM programme is to play a leading role internationally in advancing the scientific and technical frontiers in global high resolution modelling, and to advance the application of this science to address societal needs.*

Specific priorities are:

- Science excellence generating high impact publications
- International leadership in simulation and analysis capability (e.g. HighResMIP)
- Building impact through partnerships

Main science question: what is the role of multi-scale interaction in the climate system?

Subsidiary science questions:

- Is climate sensitivity influenced by convective organisation?
- Is credible simulation of weather and climate extremes, and their change, dependent on resolving convective organisation?
- What model resolution is sufficient to simulate convective organisation, as well as the upscale energy cascade that affects large-scale global climate and impacts?
- To what extent is mid-latitude weather governed by processes in the tropics, via global teleconnections, and/or by mid-latitude air-sea interactions?
- Are weather and climate extremes sensitive to particular configurations of the tropical oceans?
- Are ocean-atmosphere feedbacks involved in triggering the main modes of large-scale oceanic variability?
- Are large scale transports of heat and (fresh)water in the coupled climate system credibly simulated and sensitive to atmosphere/ocean resolution?

HRCM: current activities

The **prime foci** of HRCM activities for the next few years are HighResMIP (one of the new CMIP6 protocols) and the EU Horizon 2020 PRIMAVERA programme. The main objective of PRIMAVERA/HighResMIP is to understand the role of scale interactions, and underpinning processes, in the climate system; we ask whether a more realistic representation of these processes leads to more trustworthy climate simulation and projection. See the HRCM website for further details on our current activities.

The strategy in relation to **model development** relies on exploiting the current capabilities of the Unified Model, with the EndGAME dynamical core in the atmosphere and the NEMO model in the ocean.

Current HRCM capability enables production of:

- Centennial global coupled simulations, in ensemble mode, with 25km in the atmosphere, 1/4^{o} in the ocean
- Decadal-scale global coupled simulation, in single member mode, with 25km in the atmosphere, 1/12^{o} in the ocean
- Multi-year global simulation, in atmosphere-only mode, with ~10km in the atmosphere

Capability developed in the context of PRIMAVERA/HighResMIP (2015-2019)

- Centennial-scale global coupled simulations, in ensemble mode, with 25km in the atmosphere, 1/12^{o} in the ocean
- Decadal scale global simulation, in atmosphere-only mode, with ~10km in the atmosphere

Post-PRIMAVERA (after 2019) capability, to be developed, required to retain world-leading status:

- Decadal-scale global ensemble simulation, in atmosphere-only mode, with ~5km in the atmosphere

The strategy in relation to **model analysis** builds upon current expertise in process-based analysis, but expands to multi-model and multi-process, with particular focus on:

1. Systematic model error and the role of missing processes
2. Storms: tracking, morphology, interactions with the large scale environment, including teleconnections and their long-term variability
3. Air-sea interactions and storm tracks
4. Waves, jets, boundary currents and eddy-mean flow interactions
5. Persistent features (blocking, atmospheric rivers, drought)
6. Convective organisation and propagation
7. Parallelisation and scalability of process-based analyses on advanced HPC
8. Analysis-driven design of targeted experiments to test scientific hypotheses, e.g., model sensitivity to parameter changes or boundary conditions, or forcing

Figure 1 illustrates the existence of two individual phases, leading from current activities to implementing our long-term strategy. Phase 1 (left, green) exploits the current generation of models for advanced process-based analysis and delivers contributions to the IPCC, as well as supporting industrial and OD partners in understanding and exploiting our scientific outputs. Phase 2 (right, blue) explores emerging capabilities in climate modelling, in order to develop new expertise and enable HRCM to remain at the forefront of climate simulation worldwide; this will happen by strengthening/initiating national and international partnerships.

The strategy in relation to **impact** focusses on weather processes in the climate system, as they are responsible for very substantial damage, and are perceived as the main agents of risk by a number of industrial partners. Among the target phenomena are: hurricanes and typhoons; wind storms; persistent features such as atmospheric blocks.

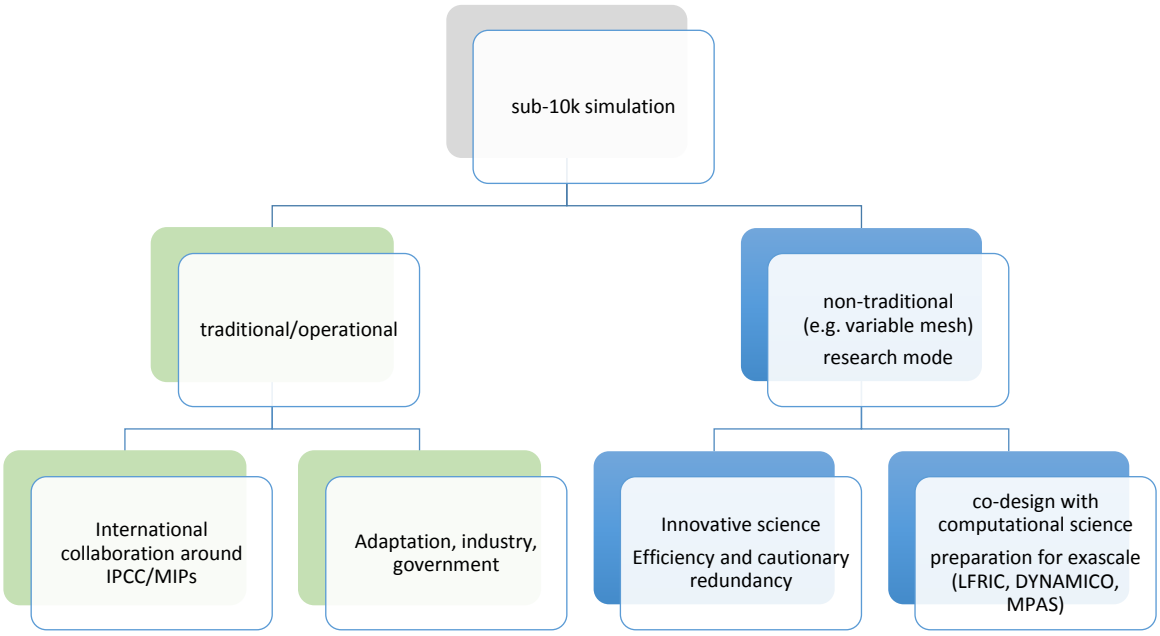

Figure 1: two phases of the path to cloud-system-resolving simulation.

HRCM: future outlook

Looking **further ahead**, preparations must be made for the transition to a new generation of models, e.g. LFRIC in the UK, MPAS in the USA, DYNAMICO in France, or ICON in Germany, as well as upcoming international programmes, such as EPECC. These programmes will operate models at 1-5km, thus resolving atmospheric convection (albeit not individual clouds) and will be ready to exploit the power of exascale HPC.

HRCM infrastructure

Our global modelling team, with over 30 core members (permanent staff), offers a range of talents, from scientific to technical, including HPC, data handling, data transmission, curation and dissemination of metadata.

The new Met Office supercomputer (xcs) is a CRAY-XC40 with a peak performance of 16PFlops; the NERC supercomputer, Archer, also offers Petascale resources; the Archer successor, which will arrive within the next two years, will match the current capabilities of the supercomputer at the Met Office. The project PIs have a strong track record of winning HPC resources worldwide and rapidly deploying to a number of international centres in order to exploit exceptional supercomputing resources.

The JASMIN-CEDA service provides data access via a portal and data analysis via multi-core servers (3'000 cores) and full user support. CEDA-JASMIN has reserved capacity for up to 5PB of data (Vidale already holds 1PB, of which 480TB are UPSCALE data). The analysis team comprises O(100) European scientists and ~20 teams in the USA, Japan, China, Brazil.

NCAS Computational Modelling Services

The Dept of Meteorology hosts NCAS-CMS, comprising a team of computational scientists supporting and developing Climate, NWP, and Earth-System modelling infrastructure through the provision of services (workflow, HPC, and data), development of model simulation and data analysis codes, delivery of training and technical support.

The group manages resources for in excess of 300 users on a variety of HPC platforms including Archer and xcs and several regional clusters. Our expertise covers UM workflow management systems; UM installation, porting and optimisation; data manipulation and transfer. We are heavily invested in CF-Python (python implementation of the CF data model) and own several software tools highly regarded and used word wide. CMS has close working relationships with HPC vendors, service providers, and resource allocation bodies, placing us in a privileged position to understand

Work environment

The post-holder will be part of the Tropical Climate and High-Resolution Climate Modelling research groups within the National Centre for Atmospheric Science's Climate Directorate (NCAS-Climate), based within the Department of Meteorology at the University of Reading. NCAS-Climate comprises approximately 50 scientists at Reading, and provides a core-strategic programme and national capability in modelling and understanding the climate system. The Department of Meteorology is a thriving centre for atmospheric and ocean science with around 200 research and academic staff and 80 research students. In the most recent Research Excellence Framework results (REF 2014), 86% of our research was graded as world leading or internationally excellent.

The post-holder will develop strong collaborations with scientists at the Met Office and internationally. The post-holder will make regular visits to the Met Office and annual visits to international conferences.

The University aspires to be an "Employer of Choice" and recognises that success is not simply determined by a competitive suite of terms and conditions of service, but by fostering a working environment that protects the physical and mental well-being of its staff. Full details of the University's Health and Well-being policy are available through the HR website. The University is committed to work-life balance and supportive of flexible working arrangements, and the School's website gives examples of excellent practices in respect of flexible work as well as for maternity/parental leave within the School. The University supports its staff in many other ways:

- its Centre for Quality Support and Development,
- its excellent Nursery facilities,
- its SportsPark,
- its membership of Childcare+.

Athena SWAN Silver Award

The School of Mathematical and Physical Sciences was awarded an Athena SWAN Silver award in 2010, renewed in 2014, in recognition of its good employment practices in relation to women working in science, engineering and technology (SET). Please follow the link for more information.

Stonewall DIVERSITY CHAMPION

The University is a Stonewall Diversity Champion and is participating in Stonewall's 2015 Workplace Equality Index.