Next Generation Ocean Dynamical Core Roadmap Project: Executive Summary

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The National Oceanography Centre (NOC) was commissioned by NERC in December 2010 to explore the evolution of physical ocean modelling in the UK over the next 5-15 years. This proceeded through an extensive investigation of the state of the art in ocean modelling and the expected evolution of high performance computers, on which these models run. It also included a wide-ranging consultation with UK and international stakeholders. This involved the key groups of: the research community (such as Universities and Research Centres), the operational community (such as the Met Office) and the assessment community (such as CEFAS and Marine Scotland). Through this process three key challenges in physical ocean modelling were identified:

1. The need to join up the modelling of open ocean and shelf /coastal seas, and so improve the representation of shelf seas in global models.
2. The need to improve mixing in ocean models, by both reducing spurious numerical mixing and improving the representation of turbulent mixing by small scale processes. Both are crucial issues in global climate and regional models alike.
3. The need to maintain and improve the efficiency of the models on evolving computational architectures.

All three are urgent in their own way, the first two to maintain the UK's standing as a scientific leader in ocean modelling. The third is unavoidable and must be addressed. It arises because increases in computer resource now occur primarily through more parallelism (e.g. more cores per chip). Not addressing this issue will mean that with each computer upgrade the models will become increasingly inefficient and expensive to use, and the capability to do science at best stays still, if not decreases, rather than increasing to exploit the growing resource. This issue can be addressed by further optimising the model codes, but this is such an invasive procedure that it will eventually be akin to a complete rewrite of the codes. Moreover, currently the computer science and ocean science aspects of the code are mixed together. This optimisation then risks making a model which cannot be developed by an ocean scientist without their having a high degree of computer science expertise. Hence a new approach is needed that clearly separates these two aspects. In order to address these three issues we propose two complementary ways forward:

1. The incremental evolution of the NEMO ocean model (see http://www.nemo-ocean.eu/), without a radical change in its scientific approach, but with a significant change in its software engineering approach. The scientific focus here would be on the vertical coordinates and subgrid-scale physics. This would primarily address points 2 and 3 above, but would lack the true multi-scale approach to address 1 in an optimal way. Noting that the full solution to point 3 would require a complete re-write of the model code.
2. The development of a new ocean model drawing on the atmospheric modelling effort in the joint NERC-Met Office GungHo project, which is currently developing a new atmospheric dynamical core. This would have both computational and scientific advantages, and address all three challenges. The atmosphere and ocean share very similar fundamental fluid dynamics, but differ in some important respects (e.g. the presence of the coastline and large changes in depths of the ocean). This option gains substantial added value from joining up with the atmospheric community, but requires further investigation to identify the details of the best approach that could align with the atmospheric model, and would need a proof of concept stage to engage with the international oceanographic community.

Ideally both options would be taken forward within the existing NEMO collaboration, including bringing in new partners, but it is evident that this is more straightforward for option 1. Further details of both these options can be found in the 'Summary and Recommendations' and 'Final Report' documents.