

## **18<sup>th</sup> Met Office Scientific Advisory Committee Meeting (13-15<sup>th</sup> November 2013)**

### **Chairman's Report**

#### **1. Introduction**

The 18<sup>th</sup> meeting of MOSAC took place concurrently with the annual meeting of the Hadley Centre's Scientific Review Group (SRG). In line with the Met Office's overarching seamless approach to the science of weather and climate significantly more than 50% of the MOSAC meeting time was dedicated to joint plenary sessions with the SRG.

The Chief Executive opened the meeting and welcomed both committees. The Chief Scientist provided an overview of the science and an update on progress, and during the meeting the four Deputy Directors made presentations that addressed on-going activities in their specific domains. In particular both Committees welcomed Doug Johnson, Head of the new "Applied Science and Scientific Consulting" Directorate, and he outlined the proposed function and form of his Directorate. MOSAC also received presentations from a further 16 members of staff including a brief account of the background to the forecasting of the St. Jude Storm of the 28<sup>th</sup> October. Other members of the Met Office together with individuals associated with Met Office Science Partnership initiatives attended the meeting and participated in the open discussions.

Met Office activities and achievements during the year have served to consolidate and enhance its reputation as a world-leading organization undertaking research across the wide swath of weather and climate. Some of the notable activities and achievements include solid and significant progress in the realm of model development and in the conduct of regional deterministic and probabilistic forecasts, maintaining its second position (to ECMWF) in global forecasting skill, demonstrating retrospectively seasonal forecast skill in predicting the phase of the NAO with a model operating at comparatively high spatial resolution. In addition MOSAC commends and encourages the pioneering emphasis being placed on risk-based forecasting based on probabilistic guidance that is being undertaken on a broad range of time scales by deploying both global and regional domains. It also compliments the Met Office for highlighting in an effective way (- ahead of the publication of the IPCC's Fifth Assessment Report) the contribution of the Pacific Decadal Oscillation to global surface temperature change, and for contributing substantially and saliently to the latter Report. Likewise it notes approvingly the Office's highly commendable number of peer-reviewed publications during the year. Indeed the citation record accompanying the Office's publications is indicative of an organization that has a very high standing within the international science community.

The anticipated approval of a new HPC facility with a major increase in supercomputing capability plus the very recent securement for the continuation of the deployment of the NERC/Met Office Facility for Airborne Atmospheric Measurements (FAAM) constitute two developments that will impact substantially upon the Met Office's future operational and R & D activities. MOSAC noted that detailed and careful planning will be required to ensure their effective exploitation, and looks forward to receiving in due course a detailed description how these resources will be utilized in the coming years.

**The procurement of our next supercomputer will indeed facilitate major changes in our operational forecasting capabilities and in our research plans. We expect to update MOSAC next year on the details of how we plan to exploit this new capability.**

#### **2. On-Going Core Science Issues.**

##### ***(a) Foundational Studies.***

MOSAC welcomed the considerable progress made in tackling a range of important core science issues. It is particularly gratifying to note that the substantial effort devoted to ENDGame is now paying-off. Its successful implementation on the global scale is evidenced not only in better efficiency but also by the increased flow variability (sic. level of eddy kinetic energy) and by the improvement that accrues in various forecast metrics from better accuracy and scalability. In the high resolution UKV model the pay-off has been shown to enable representation of one class of lee-waves and reduce the occurrence of spurious grid-point storms. It is to be expected that further work on mass conservation and on vertical advection at the tropopause will help improve/remedy current shortcomings. In tandem with the final phase of ENDGame, MOSAC recognizes that there is also progress in the development of the next generation model (GungHo & LFRic). It is bold both to start such a code from scratch and to embark upon the development a new model whilst maintaining the existing one. Advanced planning of resources dedicated to each code is required, and MOSAC expects that it will be reviewed from time to time.

We are pleased, too, that ENDGame is a success because it means that our current model will continue to be fit for purpose for the next upgrade of the supercomputer and therefore gives us the resource and the time to develop the next generation model from scratch. MOSAC is right that LFRic will be a major programme for us and we will need to dedicate substantial resources to it. Building on the success of the collaboration with NERC on the Gung-Ho project we hope that this will continue in LFRic as part of the Joint Weather and Climate Research Programme (JWCRP).

MOSAC applauds the effort being devoted to tackling a range of further fundamental model representations and biases. It notes that the use of comparatively high resolution climate models means that these models can now represent much better the dynamics of significant weather phenomena and hence they need to be evaluated accordingly. Likewise the use of regional, very high resolution, cloud-permitting models is generating a range of new challenges linked for example with model initialization, ensemble selection, and cloud instigation and representation.

Many of the latter challenges are most evident in the tropics. In this context the Committee notes the considerable progress reported at the meeting in the representation and forecasting of tropical phenomena, but recognizes that there remains scope for further substantial improvement. Therefore it suggests that the Met Office consider organizing a Workshop on the theme of tropical phenomena and prediction to flesh out the underlying problems and to help develop a roadmap to guide future research.

We agree with MOSAC's focus on the Tropics and we will provide a paper on progress in this area next year. We would welcome a MOSAC's advice on this topic. We also expect that the planned workshop on stochastic parametrization (see below) to be an important contribution to our thinking and we will consider whether another workshop would be desirable. In addition, tropical processes and phenomena are a growing area of collaboration with our partners in Australia, at the Centre for Australian Weather and Climate Research (CAWCR) and the Australian Research Council's Centre of Excellence for Climate System Science.

MOSAC, noting that the Met Office's was exploring various approaches to stochastic parameterization, encourages the Office to consider holding a workshop on this theme to bring together the relevant weather and climate communities engaged in this field. In the field of "classical" parameterization, MOSAC would welcome further clarification of the strategy being adopted to capture the model evolution of cloud and microphysical processes in relation to the issues of "single" and "two-moment" parameterization schemes and the representation of aerosols.

With Tim Palmer's leadership from Oxford University, one of our Met Office Academic Partnership universities, we are hosting a workshop on the theme of stochastic parametrization in March, bringing together UK academia and Met Office scientists. The aim is to gain a greater

understanding of how we should develop these approaches to represent model uncertainty more completely and also in the context of building better parametrizations of sub-gridscale processes, particularly tropical convection. The latter relates to some of the issues noted above with respect to tropical processes and prediction.

MOSAC welcomes the observation-based research geared to examining the value of satellite data for evaluating land surface temperature. It affirms the Office's move toward formulating an appropriate observational strategy for and a forecasting procedure to predict the formation, maintenance and disappearance of fog. It welcomes the recent securement for the continuation of the FAAM aircraft's deployment, and anticipates that the Office will develop a coherent plan for its effective exploitation.

***(b) NWP Models and Prediction.***

Diverse and substantial advances have been achieved during the year in the realms of numerical modeling, ocean forecasting, use of satellite data, and in data assimilation and ensemble forecasting.

On the global scale the Met Office has maintained its second ranking (- to the ECMWF). Moreover its planned operation in 2014 of a global ENDGame system at 17km with retuned physics will more than retain the Met Office's standing in global NWP activities. Likewise the demonstration of seasonal skill in predicting the NAO with a model operating at comparatively high resolution opens up exciting new basic and applied science vistas for the Office. There remain issues related to the relatively low signal-to-noise ratio, although the robustness of estimates of this ratio may be sensitive to sample size which is currently rather small being based on just 20 start dates.

The recent advances in seasonal forecasting with the high resolution climate model has been extremely encouraging and the culmination of a lot of research and development. Although the hindcast sample size of 20 (noting that we use 42 members for the actual forecast) is not as large as some centres use, we believe that the flexibility this gives us in terms of being able to update the system as and when the model improves more than outweigh those limitations. As MOSAC notes there are some interesting questions still to be resolved, such as the relatively low signal-to-noise ratio which is a feature of all systems at present. We have done some interesting work on looking at the sensitivity to ensemble size, and although there is no doubt that a larger hindcast set would increase the correlation skill even further, it is likely that there are more fundamental issues around the strength of the signal that need to be explored.

At the regional scale the value of the UKV deterministic model and the MOGREPS-UK ensemble model is now firmly established. Particularly noteworthy is the distinctly better performance of the UKV relative to that of the global model for weather-sensitive indices - a difference that attests to the current value of the limited area forecasting and furthermore hints that there will be continued benefit for a considerable future time-span. Likewise the St Jude Storm provided a valuable demonstration of the MOGREPS-UK's real-time capability. It is to be anticipated that the planned combination of the UKV deterministic model and the MOGREPS-UK ensemble model into a unified forecasting suite will deliver a distinctive and high quality forecast package.

Several possibilities for improving key characteristics of the UK systems were mentioned both last year and this year and these include increased vertical resolution, domain extension, increased ensemble size. MOSAC therefore anticipates being updated on how the efficacy of these various possibilities has been assessed and the strategy adopted for their implementation. In effect the operational use of the MOGREPS-UK serves to further highlight the range of fundamental issues associated with the preparation, verification and public dissemination of

ensemble/probabilistic forecasts (see Appendix), and addressing these issues in a systematic fashion will remain an on-going challenge.

MOSAC has noted correctly the major science challenges related to the future development of the UKV and the MOGREPS-UK system. Unlike our global model systems, the UKV model is still very 'young' in terms of how to verify it, initialize the ensemble and assess the impact of model improvements on performance scores. The fact that our Business Performance Measure (BPM) related to UKV model performance is unlikely to be met this year, despite our outstanding global and local forecast services being better than ever, demonstrates the need for new methods of verifying the UKV.

Nevertheless, although we have improved some aspects of the boundary layer and hence fog and low cloud prediction, we recognize that there needs to be a greater focus on UKV model improvements in the future; this may include higher vertical resolution. It is fair to say that post the Olympics we focused primarily on implementing the MOGREPS-UK system, which is proving invaluable to forecasters.

We will report to MOSAC next year on progress in this challenging area.

The Met Office, along with other European institutions, has been engaged in producing European Regional Reanalysis data sets that build upon and utilize the ECMWF's ERA data. The framework for, configuration of, and some results from, the Met Office Reanalysis study using the 4km UM were presented at the meeting, and demonstrate that the quality of the newly acquired data set is now becoming apparent. MOSAC urges the Office both to consider further refinement of the approach and to exploit the potential of the new data set for understanding regional weather and climate, for assessing the performance of forecast models, and for its value to the Applied Science Directorate. MOSAC also recognizes that the technical setup established at ECMWF to test the impact of using global boundary conditions to drive a high resolution limited area model can be used for model combinations other than the UM-UKV pair. Also planning for new observations to support high-resolution regional forecasts is considered by MOSAC to be a fundamentally critical activity over the next decade.

The development of 4km regional reanalyses for Europe has been a major achievement of the past year and one that is already demonstrating significant advantages over global reanalyses with respect to surface variables, such as rainfall. This activity will be a major plank of our plans to deliver climate services and we are actively seeking further opportunities to exploit the dataset and to produce similar products for other parts of the world. We have already secured funding to develop a regional reanalysis for India. We note the comments on using other global boundary conditions but do not have the resources to pursue this. It is also our view that consistency in the physics and numerics between the global driving model and the regional model has significant advantages.

We agree strongly with MOSAC's comments regarding the observational base for high-resolution regional models and expect this to be a major component of the next Science Strategy. It is vital that the observations for initialising and especially for evaluating the UKV performance keep pace with the increasing resolution and complexity. This will require innovation in observing platforms and the observing network, along with exploitation of opportunities arising from other 3<sup>rd</sup> party measurements. We would propose that Observations R&D presents to MOSAC next year on its latest thinking in this area.

Re-analysis is also a feature of R&D in ocean forecasting. This feature, along with current progress and planned work in higher resolution limited area models, in data assimilation allied to coupling with NWP configurations, is highly commendable. In relation to the use of satellite data, MOSAC welcomes the implementation of tools to assess the relative value of different data sets

upon forecast performance, and the major increase (- up by 50%) in the effective use of satellite-derived data.

### **3. Recent Initiatives & New Strategies.**

#### **(a) “Applied Science and Scientific Consulting” Directorate.**

MOSAC noted that the formation of this new Directorate is imaginative and distinctive. It has the potential to strengthen and broaden the two-way link between the Office’s core science and the customer, and the Committee viewed the establishment of Scientific Consultancy component as enterprising and far-sighted. It also recognized that, with the appointment of Doug Johnson, the Met Office has secured an individual to serve as Head who brings a wealth of experience and commitment to translating basic science to customer needs.

To be effective MOSAC believes that the Directorate must be accepted as an integral component of the organization’s science activities, and that it should both feed from and prompt developments in the other Directorates. In effect a key challenge will be to enable the two-way interchange of scientists and it therefore endorses its placement at the core of the Office’s science structure located between the Weather and the Climate Science Directorates and alongside Foundation Science. A further challenge will be defining the customer categories of the Directorate. For example a strategy will need to be developed to deal with customers whose needs require significant and on-going R&D, and MOSAC will be eager to learn how the Directorate responds to this challenge. Likewise, in addition to the benefits that will accrue from broadening the business links, the Committee invites the Met Office to capture examples of how the Directorate influences developments in other Directorates and to develop appropriate metric(s) that would reflect this feedback.

We welcome MOSAC’s endorsement of the new Directorate and agree with their assessment of the importance both of the location of the Directorate in Science and of demonstrating its value to Met Office business. We are actively pursuing processes to encourage the two-way exchange of scientists and hope to report on some successes next year. Likewise, because the Met Office has invested substantially in the new Directorate, we are putting in place metrics to demonstrate value and effectiveness. Because this is an innovative development and potentially high risk we agree that MOSAC should receive a progress report and its next meeting.

#### **(b) Major new model-based projects and strategies**

A stream of major new model-based developments and strategies were outlined at the meeting.

The Earth System Model (UKESM) is joint Met Office/NERC project designed to provide the UK science community with a world-leading model of this genre and to serve as a major feature of the UK’s contribution to CMIP6. The Committee underlined the timeliness of this development and was pleased with the recent appointment of a very suitably experienced individual, Dr. Colin Jones, to head this inter-organizational project. It acknowledged that solid progress has already been achieved during the last year and recognized the flexibility of the model in terms of resolution, but noted with some concern that for some purposes the model’s efficiency would hinge upon being able to develop an ‘effective’ degradation of the resolution so as to incorporate certain key processes. Further the Committee stressed that, although many of the model’s major components are already in existence, nevertheless their integration into the model and the subsequent testing and evaluation of the system would remain a demanding task.

We note MOSAC’s concern about the development of a lower resolution version of the model, but we feel strongly that we should develop and test the new ESM at the higher resolution

commensurate with our new baseline physical climate model, HadGEM3H. There are sound scientific reasons to do this although this has not necessarily been the strategy for ESM development in the past. Our view is that we will be in a stronger position with this approach to judge the validity of a lower resolution model in terms of the scientific use to which it will be put. We note that there will be a workshop this year with UK academia to understand the needs for a lower resolution version.

MOSAC viewed the strategies set out for 'Regional Environmental Prediction', 'Aerosol Modeling across the Timescales' and 'Atmospheric Dispersion and Air Quality Modeling' as being preliminary, but timely and ambitious. It noted that the first two of these initiatives were highly dependent upon interaction and collaboration with other UK communities (- NERC and MOAP), and that although some basic modeling components were already in existence their effective merging and testing would constitute a major undertaking. For each of these projects there are major challenges to develop the models so that they are routinely ready to rapidly deliver relevant information.

In light of the broad scientific scope and the major scale of these modeling tasks, MOSAC urges that a step-wise approach be adopted in their implementation (- as exemplified by the proposal for a Prototype Project in the strategy for Regional Environmental Prediction). Such an approach would help underpin the foundations of the strategies and demonstrate (or not) the potential for impact.

We are grateful for MOSAC's endorsement of these bold and innovative plans and accept there are some major challenges ahead, which require us to be realistic in our planning and the level of resource available. In particular we see the UK Environment Prediction System as a long-term part of our strategy and expect it to be a major collaborative programme with NERC through the JWCRP. In the coming year we will be discussing with our NERC partners how best to resource this for the long-term.

Moreover the Committee was of the opinion that a careful assessment be undertaken of the requisite and available resources and in effect of the feasibility of the projects, and that this assessment be tensioned against the need to ensure that these initiatives would not unduly detract from or disrupt the Met Office's other core science activities. Resource distribution has traditionally been documented in yearly issues of the detailed four-year plan, but the document is not provided routinely to the Committee.

The detailed 4-year plan can be made available again if MOSAC would like that although it probably has more information in it than is necessary. Alternatively we would be happy to provide MOSAC with a summary of planned deployment of resources in each strategic area and in our major new programmes, such as UKESM, LFRic and UKEPS, if that would be helpful.

#### **4. Collaborative and Partnership Activities.**

It was noted with approval that the Met Office continues to invest in and expand its collaborative activities by engaging in long-term Science Partnerships with national and international organizations. At the meeting particular attention was drawn to the Met Office Academic Partnership (MOAP) scheme that involves collaboration with a select number of Higher Education Institutes in the UK and to the growing partnership with the Met Service Singapore (MSS).

The Committee recognizes the advantages to be gained by effective and synergetic partnership to support partners in the realm of technical and software development and in undertaking forecast assessment and model improvement. It also encourages the Office to consider engaging more fully with UM partners in the joint pursuit of fundamental scientific issues.

In this context MOSAC notes the increased international collaborations with Australia and Korea and the benefits they could accrue for all partners, and in particular progress on tropical and regional high resolution forecasting is strongly encouraged.

We welcome MOSAC's endorsement of our progress in consolidating the joint interests in sustaining and developing the UM infrastructure with our national and international UM users and agree completely that we should grow our joint activities in fundamental science issues. Each year we hold a workshop for UM users and it is very pleasing that as the partnership has matured we are increasingly focusing on the scientific aspects of the model and fundamental issues. For example, we are working actively with our Australian partners on tropical convection. It might be appropriate for MOSAC to hear from one of our international UM partners about science developments at next year's meeting.

MOSAC also welcomed the growth in scope and depth of MOAP activities. An aspect of such partnerships that merits further consideration is the evaluation and attribution of the contribution of the University partners. This need arises because the demonstration of "impact" is now an integral component of the periodic assessment of Higher Education Institutes in the UK.

In the context of partnerships the Committee wishes to underscore the desirability that the Met Office seeks to optimize the benefits accruing from collaborative activities by engaging with the "best players in the field" irrespective of their affiliation. It is to be expected that the nature of such activities would exhibit significant case-to case variability, but nevertheless the Office might wish to consider articulating its views on and the possible framework for these more ad hoc activities.

These comments are well-made and we are acutely aware that whilst the MOAP is an important vehicle for both us and the partner universities for working with students, integrating our research and demonstrating its value, it is essential that we always work with the best, and we actively encourage our scientists to form collaborations where they see fit. Similarly we will continue to ensure fairness in terms of support for students across the range of universities we work with. The statistics on the number of academic institutes with which we publish is testament to the effectiveness of the 'bottom up' approach to collaboration, which we continue to promote very strongly.

One area of partnership activity not emphasized to MOSAC was that of European collaboration, particularly in the area of cooperation in model development. MOSAC notes approvingly that the Met Office is engaged in a number of European research projects, both within the EU framework as well as with European space agencies. In addition the Met Office collaborates with the ECMWF in a number of research areas. MOSAC would welcome a well articulated coherent strategy for future European partnerships, with a special emphasis on the new EU research framework in the areas of weather and climate science.

We would be happy to provide MOSAC with a structured summary of our research activities in Europe and how these relate to our strategy for European partnerships.

## **5. Further Remarks**

It is a pleasure to record the Committee's appreciation of the administrative staff's arrangements for the smooth conduct of the meeting, and the scientific staff's detailed position papers. The preparation of the latter was undoubtedly time consuming but the Committee regarded them as appropriate in scope and they provide very helpful overviews of the various topics.

To facilitate MOSAC's dialogue at the meeting with the presenters and with senior members of staff and the broader community, it stresses that the presentations at the meeting

should aim to summarize succinctly the material in the position papers and to highlight issues deemed to be worthy of detailed discussion.

We agree completely with this guidance and will endeavor to keep the presentations much shorter and less complex next year so that we can ensure time for discussion around the key issues.

In line with its role and responsibility, MOSAC reviewed and were satisfied with the response to its report for 2012. Further it appreciated that the agenda for this year's meeting both reflected the Committee's previous requests and provided a platform to overview issues of significant contemporary interest.

Finally MOSAC, conscious of its Terms of Reference and the Met Office's seamless approach to weather and climate science, regards the holding of concurrent MOSAC and SRG meetings to be justified in terms of the science and to be efficient in terms of the Office's preparatory work, and it welcomes the significant time allotted to plenary sessions.

## **APPENDIX**

### ***Key Issues for Ensemble Forecasting.***

An operational weather service is confronted with a range of enduring scientific challenges that can serve as a prompter for research and as a helpful benchmark for monitoring progress. A partial list of such challenges that relate to ensemble forecasting featured in the MOSAC report for 2012, and it has been reproduced, rephrased and supplemented below.

- *What should be the balance between resolution, domain size and ensemble size?*
- *How should the different ensemble members be generated?*
- *What is the relative importance of the observation-based initial state uncertainty and model representation error?*
- *How should the nesting in the larger-scale model be performed?*
- *How should the results be diagnosed for use by forecasters, and is extensive hindcasting required to calibrate the system?*
- *How should the very high resolution probabilistic forecasts be evaluated?*
- *How should probabilistic forecasts be communicated to the general populace?*

It is proposed to reproduce this list annually albeit with some modifications.

We welcome this summary and will ensure that in the preparations for the next MOSAC that we address these points and consider what progress has been made.