20th Met Office Scientific Advisory Committee Meeting (11-13th November 2015)

Chairman's Report

Response by the Chief Scientist

Preamble

The 20th meeting of MOSAC took place concurrently with the annual meeting of the Hadley Centre's Scientific Review Group (SRG). Approximately 70% of the MOSAC meeting time was dedicated to joint plenary sessions with the SRG.

The Chief Executive opened the meeting and welcomed both Committees. MOSAC was happy to underscore his remarks concerning the centrality of the Office's research to its current and future well-being. The Committee congratulated Dale Barker on his appointment as the new Head of 'Weather Science', and it welcomed two new members - Pedro Viterbo (Director of the Department of Meteorology and Geophysics at Portugal's Institute for the Ocean and Atmosphere) and Ian Renfrew (Professor in the School of Environmental Sciences at the University of East Anglia). Further it is pertinent to note that a non-Executive Member of the Met Office Board and the Chairman of the PWSCG attended as observers.

At the meeting the Chief Scientist summarized the major advances in the Office's research capabilities and achievements, the four Deputy Directors overviewed recent developments and on-going activities in their specific domains, and the Chief Meteorologist set out briefly some of the current challenges confronting operational forecasting. In addition a further 18 presentations were given that focused on specific aspects of the Office's research and collaborative activities.

1. Overview, Major Achievements and Some Highlights.

The overall impression is that there has been significant progress in the Office's long-standing programmes, and in addition some distinctively innovative new initiatives have emerged during the year. The research effort remains firmly customer-orientated in its focus, its profile reflects commendable foresight, and its scientific quality remains of the highest calibre. During the year the Office exploited opportunities to retain, and in some respects enhance, its position as one of the world's leading institutions for weather and climate research and operational weather forecasting.

The high quality of the Office's research and its notable standing in the scientific community is attested by updated bibliographic statistics of its publication and citation records. These standard metrics, nowadays often referred to by funding agencies and the media, casts the Office in a very favourable light and permits a comparison of its standing relative to other similar organizations. These results make the Office an attractive first port of call for individuals, and national and international organizations seeking high quality research partnership.

Another indicator of the Met Office's scientific standing is its forecast performance and capabilities as an operational Weather Service. In the international league table for global forecast skill it has retained its second place ranking (to ECMWF) with the Japanese Meteorological Agency emerging as a significant competitor. In the realm of regional forecasting its suite of deterministic and ensemble regional forecast models for the UK together with its plans for acquiring novel

observational data sets, developing accompanying scale-relevant assimilation schemes, and pursuit of broader environmental prediction objectives places it arguably at the forefront in the development of appropriate, high quality and timely regional forecasts. The recent evolution of the regional model's forecast skill relative to that of the global model is commented upon later.

Recent noteworthy achievements include implanting the ENDGAME into the operational regional model, and completing the first phase of the HPC installation ahead of schedule. These two key successes could not have been achieved without the dedication of highly skilled science and IT staff whose expertise is invaluable to the Office's core activities and its future effectiveness. Also the maturing Applied Science and Scientific Consultancy Division has consolidated and extended its activities, and MOSAC appreciated the detailed information it provided on its modus operandi, its range of activities, and its strategy for assuring the integrity of its science. These responses are witness to the Division's keen awareness of, and sensitivity to, the issues previously raised by MOSAC.

The Committee also noted several striking new research highlights, and three are referred to here. First, results presented from a coupled atmosphere-ocean model undertaken with a 1/12 degree ocean component demonstrate that it can replicate fine-scaled features of the ocean circulation and remove some long-standing biases in coupled climate models. The results could well promote a paradigm shift in the field. Second, research performed with the high resolution 'London / Fog Model' was a delightful exemplar of a user-orientated and hypothesis-driven study. It yielded additional physical insight, formed a basis for the development of a new forecasting tool, and provided information for improving the parameterization of the existing coarser grid model. Consideration could be given to assessing the model's efficacy in a (pseudo-) operational setting over an extended period. Third, the effort launched on 'Post-Processing and Forecast Verification" as it pertains to mesoscale ensemble forecasts is novel in conception, and the results point to its potential. It could evolve to become a cornerstone of the Office's future activity in this area, and MOSAC encourages its further development and the strengthening of its underlying theoretical basis.

We welcome MOSAC's comments on these ground-breaking developments which demonstrate that we remain at the cutting edge of research. We believe that this is important for the Met Office if it is to retain its world-leading position in weather and climate services in the coming years.

With regard to post-processing, we are seeking to invest significantly in the development of a new streamlined and probability-based post-processing system to provide consistent gridded and site forecasts as part of the wider Met Office Transformation and Efficiency programme, which we are driving forward, corporately, over the next five years. This system will be based on the software infrastructure developed for Best-Gridded Data and the HPC Decoupler (that separates forecasting system upgrades from downstream products and services); it will be developed in parallel with existing systems, which will continue to support operations during the development of this new system.

We hope to make significant progress this year in defining the new system and would be happy to provide an update at the next meeting of MOSAC, covering the wider aspects of our post-processing and verification strategy in the context of Transformation and Efficiency programme.

2. Core Activities.

(a) HPC and the Dynamical Core

A key activity during the last twelve months was the technical work associated with Phase 1a of the new HPC's installation. MOSAC congratulates the Office on completing this demanding task ahead of schedule. It notes that the commendable performance level achieved in the benchmarking exercise, and that the "Research: Operations" ratio is likely to improve in subsequent phases. It also notes the ramifications resulting from the distribution of the different processors between the various IT halls.

We are pleased to report that Phase 1b has also been implemented ahead of schedule and we are making good progress in weighing up the options for Phase 1c which will be housed in the new IT Hall on the Exeter Science Park. We will report on progress at the next meeting of MOSAC.

It is also gratifying to learn that Gung-Ho, another associated IT-related activity, LFRic, are proceeding smoothly without encountering major technical obstacles, and that ENDGame has been successfully incorporated into the regional models.

We are pleased that MOSAC recognizes the good progress being made with Gung-Ho and LFRic, and will be happy to provide further updates in future meetings. As well as the LFRic project (which is developing the core next generation model), we have constituted an over-arching exascale programme board whose role is to oversee and prioritize all aspects of work required for future computer architectures. We are also engaging closely with the parallel activities at ECMWF.

(b) Model Development

During the year the Office made several advances in global and regional modeling, and recorded accompanying modest improvements in forecast performance. Roadmaps were also presented of the goals set for the coming years.

For the global model, MOSAC noted with approval the incorporation of a stochastic physics package into the Global Atmosphere (GA) configuration and the carefully conducted assessments of the model's performance in the tropics. It noted the progress made in reducing the bias in the humidity at the tropical tropopause, and sought clarification of the treatment at the air-land interface. The Committee recognizes that impact of increased vertical resolution will need to be carefully evaluated given the complexity of physics-dynamics interaction in the vertical and the resolution-dependency of some physical parameterization schemes. With respect to the simulations undertaken with a 1/12 degree ocean model coupled to a 25km atmosphere model, the Committee pondered what the result would be of coupling the ocean component with an atmospheric component run with an even higher resolution than that used hitherto.

For the regional (UK) scale, MOSAC noted approvingly the careful assessments being undertaken of the impact of model developments such as those arising from higher horizontal and vertical resolution, and stochastic boundary layer perturbations (see also the overarching remark in Section 2e below). It also welcomes the improvements in the representation of both gravity waves and stratocumulus, and applauds the on-going effort being devoted to examining the model treatment of fog-related physics, the diurnal cycle, and specific aspects of convection. The Committee was also reassured that other regional-focused activities - the UK Environmental Prediction Prototype and NAME - continued to evolve satisfactorily, and that a fleet of data assimilation upgrades were foreseen in the next two years.

MOSAC also drew attention to the potential benefits for short-range detailed forecasts for coastal areas of the on-going ocean and marine-related model developments for example the introduction of a storm surge capability for NEMO and wave-models designed to simulate sea states close to shore (Wave Watch 3).

(c) Use of Satellite Data & Field Campaigns Programmes

The Office's exploitation of satellite data for forecasting purposes is world class, and this year's progress report adds further substance to this assertion. MOSAC noted with approval that:- the amount and type of data being successfully assimilated continues to grow; a major advance has been achieved in the technique to adjust for biases; there is likely to be an accompanying improvement in operational global forecasts next year from the better use of the data. The Committee notes with interest that significant positive impact is expected from the improved incorporation of cloud motion winds.

Acknowledging that there is much current interest in the impact of sea-ice changes upon the prediction of global seasonal circulation patterns, MOSAC pondered what the impact of introducing better satellite-derived sea-ice data or more regular updates of that data would have upon shorter time forecasts. In addition the Committee wishes to underline that an imperative for rapid-cycle regional forecasts will be the increased use and hourly assimilation of satellite (when appropriate) and radar and Mode-S retrieved data, and welcomes plans to accomplish this task.

A fundamental part of the Office's research portfolio has been, and is, its active engagement in the design and execution of field experiments. MOSAC complements it on the Lidar-related results emerging from the campaign in Oklahoma. Likewise it endorses the Office's planned engagement in forthcoming FAAM field campaigns and its proposed involvement in NAWDEX.

We welcome MOSAC's support for our plans to extend our exploitation of satellite data and our continuing involvement in field experiments. We regard the latter as fundamental to our future progress in model development. It is with regret that we note that the bid to NERC for funding the UK's participation in NAWDEX has not been successful. We will continue to engage in field experiments whenever possible, working with our national and international partners.

(d) Climate Dynamics & Seasonal Forecasting

Research on seasonal prediction has been a major element of the Office's activities in recent years, and in 2014 a new framework was established for research on the inter-related themes of climate dynamics and seasonal prediction. In light of this development there were three main components to this year's presentation.

First, information was provided on a suite of dynamically-based diagnostic tools now being utilized to address issues at the core of climate dynamics research. MOSAC warmly welcomes this eminently desirable development. Concomitantly it urges that cognizance be taken of the limitations of each deployed tool (- the relaxation tool can be sensitive to the value and spatial distribution of the relaxation factor; the 'divergent-flow' formulation adopted for the Rossby wave-source is geared predominantly to account for tropical sources; and the ray-tracing tool although instructive and illuminating assumes no wave-mean flow interaction that might be crucial in establishing seasonal anomaly patterns).

We note these important limitations and sensitivities of these newly developed diagnostic and modeling tools to the details of their formulation. We will test the validity of our parameter choices wherever possible while bearing in mind the limitations as we use them in our analyses and model experiments.

Second, an update was provided on further research undertaken to underpin previous results on the skill in predicting a seasonal NAO-based metric. The update lends further credence to the earlier results, and also provides a tantalizing hint of good seasonal skill in predicting some tropical rainfall features.

On the basis of these results MOSAC reiterates that the progress achieved in this field over recent years is world leading, and has the potential to open new vistas both for further research and application. Notwithstanding MOSAC continues to strongly caution the Office not to over-stress the utility of its seasonal forecasting capability. This caution stems from:- recognizing the possible dependence of the NAO-based skill to the amplitude / sign of the realized NAO; noting that the currently prevailing skill level could evolve in response to future decadal-scale changes in the realized NAO index; and recalling that a winter of extreme events over the UK can, and has, accompanied seasons with a weak NAO signal. In a similar vein MOSAC acknowledges that the Office's forecast for the 2014/2015 Winter for the UK and the extra-tropical Eastern Atlantic was most creditable, but it also notes that this success was not evident in other/ neighbouring areas of the Northern Hemisphere.

We thank the committee for their encouragement and will continue to monitor the real time forecast performance in future winters, as well as continuing to investigate the skill of retrospective predictions.

Third an indication was provided of some potential applications of reliable seasonal forecasts, and this is clearly an activity that should continue apace.

We continue to develop seasonal forecast applications, carefully highlighting the uncertainties, but also taking advantage of demonstrated winter skill with various users in collaboration with applied science.

(e) Two Generic Remarks

(i) The new HPC will provide a massive increase in the Office's computing capability and an opportunity to radically refine and improve the suite of forecast models. Thus it will be desirable that MOSAC strives on an on-going basis to

- monitor the extent to which the new model constellation will conform to the pre-established 'Business Case' foci highlighted in the 'HPC Update' presentation, and
- encourage the Office to underpin and justify its strategy for the evolving new model constellation with scientifically well-founded and rigorously tested assessments of key modeling and forecasting issues (- a list of such issues is provided in the Appendix).

The new HPC is indeed a huge opportunity; a priority for us will be to ensure that it is optimally used. We look forward to providing MOSAC with updates on our progress, and to continuing to receive their feedback and guidance around it.

(ii) The Office assesses the skill of the regional model's forecast, and also its value relative to that of the global model in terms of a weighted Business Performance Measure (BPM). The latter

relative measure has narrowed conspicuously during the last year. MOSAC does not view this 'narrowing of the gap' as an incipient show-stopper for regional models, but recognizes with the Office that contributory factors might include improvements in the global model accruing from its earlier incorporation of ENDGame and the comparative insensitivity of the BPM to important finer-scaled features of the regional model's forecast. The Committee recommends that over a period of time detailed consideration be given to developing a refined BPM that is underpinned by a well-founded rationale. In this context MOSAC also encourages consideration a probabilistic skill measure(s) to reflect the value of an ensemble of regional forecasts.

We agree that the existing BPM does not adequately capture the value of regional models. A new probabilistic framework for verification of convective scale models and ensembles based on neighbourhood methods has been developed, and trials have demonstrated clear benefit of (a) regional models over global, and (b) ensemble over deterministic. This method is now being used in model trials and is also being trialed in real-time to better understand its sensitivity to model changes with a view to implementing a new BPM in coming years, probably focusing on ensemble performance.

3. Initiatives and Challenges.

(a) Atmospheric Convection

The overview presentation on this theme outlined plans to develop convective schemes able to span the range of space-time scales corresponding to the Office's own suite of models. This is truly a 'Grand Challenge', and MOSAC notes approvingly the researchers' desire to reexamine the fundamentals of the representation of convection in models, appreciates the expose provided of the limitations of the schemes currently being deployed by the Office and the international community, and applauds the Office's determination to be guided and constrained by observations.

The Committee recognizes the essentially preliminary and exploratory nature of much of the current research, and looks forward both to its maturing and to the forthcoming joint Met Office-NERC programme on the theme. In this context MOSAC notes that it would be helpful to compare the evolving concepts with those prevailing elsewhere (e.g. the Aladin limited area consortium's efforts to develop schemes unifying convection across the scales, and the US super-parameterization approach).

The Met Office fully recognises that sharing ideas, understanding and progress world-wide will be vital to this challenge. To this end, the joint NERC-Met Office convection programme plans to seek much wider engagement, initially by inviting experts from the parametrization community to our plenary meetings; later on there will be the potential to host visiting scientists to work alongside us. The UK convection programme was publicised at the recent conference in Berlin on 'High definition clouds and precipitation for advancing climate prediction'. This was attended both by members of the Aladin and from the US super-parametrization communities, and substantial interest has already been expressed. We look forward to some interesting debates in the coming years!

(b) Observational Strategy

An update was provided on the 'Observational Strategy' that was introduced last year. It was demonstrated that a promising preliminary analysis had been undertaken of the potential of mode-S data based upon the effective collection of an enormous amount of aircraft data deriving from a

very modest investment. Attention was drawn to further opportunistic sources of hopefully accessible and inexpensive asynoptic data for ingesting into regional models (e.g. data from cars). MOSAC continues to view the acquisition and deployment of such data as integral to the effective utilization of the foreseen rapid cycle regional forecasts. However it also stresses that this component should be accompanied by and coupled to advances in convective-scale data assimilation.

The Office's decision to build its own network of weather radars is notable. MOSAC recognizes that this will enable it to exercise control on the design and specification of the instrument and to tailor the overall system to more effectively exploit the garnered data for the high-resolution regional forecasting purposes. Again there will be accompanying data assimilation challenges.

Direct assimilation of advanced radar data (radial velocity, reflectivity, refractivity, etc) is seen as a key driver for development of an advanced km-scale data assimilation capability (see below). Our MetOffice@Reading Data Assimilation (DA) group continues to work with the University of Reading and other collaborators in this challenging area, most notably under the NERC Flooding For Intense Rainfall (FFIR) activity.

(c) Data Assimilation for the Convective / Meso β-scale (smaller than synoptic scale systems but larger than microscale and storm-scale cumulus systems)

To the present, data assimilation on the convective, meso β-scale is comparatively unchartered territory. The Met Office's primary target in this area as been articulated as achieving a shift from 3D-Var to 4D-Var. Beyond this a glimpse of the challenges lying ahead was also provided in the presentation on 'Convective-scale ensemble data assimilation'. MOSAC regarded this as a promising exploratory study indicative of research being pursued by the Office. It anticipates an update on this theme in the coming years.

The short-term priority for the UKV data assimilation is the implementation of hourly cycling 4D-Var, following its successful demonstration during the London 2012 Olympic Games. Delivery of the UK-wide system is expected in late 2016 following further tests on the expanded UKV domain. Once implemented, coupling between 4D-Var and the MOGREPS-UK ensemble will be explored to supplement the preliminary EnKF (Ensemble Kalman Filter) work, to help decide the longer-term km-scale DA strategy.

Initial steps to develop a tropical, km-scale DA capability have also been taken, with the implementation of a test 3D-Var system in Singapore (the SINGV project, see below). As noted at MOSAC, we continue to invest significant resources in the exploitation of high-resolution satellite data in both UKV and SINGV applications. We would be happy to provide an update on our strategy, plans and latest results for convective-scale DA to MOSAC as required.

(d) Air Quality & Climate Change

The presentation on 'Emerging issues of air quality and climate change' drew attention to the range of air quality issues associated with climate change and the consequent implications for both short-term forecasting of air quality and the integration of air quality into consideration of climate change itself. Attention was also drawn to the Office's significant modeling capabilities in this field. MOSAC acknowledges that the theme is one of growing national and international concern offering

significant potential benefit for a range of users. It recognizes and endorses the need for additional support to effectively pursue research in this area, but in view of its complex multi-faceted nature and the constraints upon resources it suggests that the Office's activities be formulated in the context of its development of the UK Environmental Prediction prototype and complementary national and international partnerships.

We appreciate MOSAC's comments and agree that this is an area of growing importance. We also agree that additional support is vital to effectively pursue research and application in this area. UKEP has a role and composition within it and ultimately air quality have always been part of our plans. However, we view this as a longer term ambition since the current focus of UKEP is primarily around coupling the atmosphere, land hydrology and coastal ocean systems.

Our current air quality activities include, for example, UK forecasting, European forecasting, regional and global climate modelling. These configurations are reasonably well aligned though currently not yet with UKEP. Also developments and challenges in UK air quality are also not currently associated directly with coupling complexities or feedbacks.

Therefore, our current view is that there is no efficiency to be gained from linking with UKEP at this point. Our air quality plans are already fully integrated with the UM, and composition developments are also linked through UKCA and Glomap activities. Better coordination, planning and execution are certainly possible and needed, as is additional resource; we continue to seek every opportunity to advance these with our partners.

(e) Tropical Regional Modelling.

In past years MOSAC has had a series of presentations on the status of the Office's capability in modelling tropical weather and climate. This year one presentation overviewed the real-time tropical regional forecasting conducted by the Office in collaboration with UM partners. Attention was drawn to the range of such collaborations, and detailed information provided on the SINGV project (with the Meteorological Service of Singapore) concerned with forecasting of precipitation in the Singapore area and the PAGASA project (with the Philippine National Met Service) on tropical cyclone forecasting for the Philippines. MOSAC notes with approval the fostering of these collaborative research activities because UM partners had previously indicated their desire to engage in such ventures.

The SINGV project confronts the convective-scale UM with tropical observations, and the Committee applauds the research underway to:- improve the forecast precipitation patterns and the representation of the diurnal cycle, and examine the sensitivity to stochastic temperature perturbations and model configuration. It notes that SINGV currently operates at 1.5 km horizontal resolution with the ENDGame dynamical core but without a data assimilation scheme. Several of the scientific challenges confronting this project, such as the development of an effective tropical assimilation scheme, are also confronting other institutions, and MOSAC endorses the workshop being planned for February. In passing the Committee also notes that the project enables a comparison to be made of the UM's performance with a different (*sic.* WRF) model. A 'fair' inter-comparison of the forecast performance of different regional models is difficult to achieve, but nevertheless such a comparison, could prove to be revealing and instructive particularly if they operate with the same lateral boundary conditions.

An initial SINGV 3DVar capability has been implemented in Singapore in early 2016, with encouraging preliminary results in the representation of convective rainfall in the nowcasting range

via latent heat nudging of local rainfall data. Work is also underway to address a number of fundamental modeling issues (conservation, 'blobbiness' of convective storms) seen in tropical simulations. The February workshop noted above has been held in Singapore and attracted a large number of participants. It highlighted these as issues for a variety of UM partners; hence this will be a fruitful focus for collaboration in coming years.

In the framework of PAGASA simulations were performed for all the named storms for the 2013 west Pacific tropical cyclone season, but the results are coloured somewhat by the use of a model with a 'gray zone' horizontal grid of 4.4km. Another short presentation overviewed the customer-orientated work currently underway designed to help build up the resilience of the Philippines to weather and climate extremes, and explored how tropical cyclone-related hazards might evolve in response to climate change. MOSAC recognizes that the need for such applied research will assume greater prominence within the international community in the coming years.

4. International Collaborative Activities and Knowledge Integration.

Two presentations highlighted different aspects of the Met Office's engagement in European-level (EC) collaborative activities. One presentation set out the rationale for engaging in European partnerships and listed the range of opportunities before focusing on issues related to Horizon 2020 and Copernicus Climate Change Services (C3S). MOSAC encourages the Office to participate fully in the latter activities, and endorses its rationale for participation. Indeed the Met Office's expertise can contribute substantially to the success of the C3S. However the Committee also recognizes the tension that can arise both from the 'research' versus 'provision of services' split in the funding of Horizon 2020 and C3S. The second presentation covered the Office's engagement within the 'Copernicus Marine Environment Monitoring Service' (CMEMS) venture, and illustrated that the synergy between the venture's goals and the Met Office's own core activities was beneficial and providing added-value.

MOSAC also noted with approval the update on the Newton-funded Climate Science for Service (CSSP) initiative with China, including the development of the five Work Packages. These Packages complement the Office's own activities and are of benefit to both parties. Moreover the CSSP initiative can help foster partnership with the UK and Chinese academic communities.

The Office's presentation of its engagement in 'Knowledge Integration' served admirably to indicate the function and scope of this activity. The quality of the material it makes available on the web is widely recognized. MOSAC noted with approval the work being undertaken ahead of the COP 21, and recognized that the response to the recently organized event to communicate "The 'record' for global temperature in 2015?" had been picked up by numerous media organizations. The Committee welcomed the compilation of the "State of the UK Climate: 2014" document, endorses the Office's aim to make this an annual publication, and urges it to ensure its wide dissemination or publication, perhaps an abridged form, in a journal.

The State of the UK Climate report is expected to undergo evolution through its earliest editions as we receive feedback from the wider community. The UKCP18 project is one mechanism through which we are working to understand user requirements. In addition we will explore alternative publication models such as journal publication or via the UK statistical system, with the latter building on a previous project working with the Office for National Statistics looking at the use of climate statistics across the Government Statistics Service.

5. Further Remarks

The Committee wishes to thank the administrative staff for ensuring the smooth conduct of the meeting and the very thorough compilation of the Office's publication and citation records. This year the latter enabled a comparison of the Met Office with some other similar national and international institutions that are either operationally-orientated or purely research-focused.

In addition MOSAC particularly wishes to thank the speakers for their papers and presentations. The papers reflected the care and attention invested by the staff in their preparation. (A welcome addition would be the provision of an Annex setting out concisely the main content of the various model adjustments - PS36, PS37, etc.). The presentations themselves were a testimony to the enthusiasm and commitment of the presenters. The spirit of openness with which they highlighted the current challenges and problems in their area was refreshing, and it helped encourage discourse and facilitated MOSAC's ability to assess the research and to proffer advice. Likewise the Committee welcomed the attendance of an increased number of Met Office personnel at the meeting and their constructive participation in the discussions.

In accord with its duties, MOSAC reviewed the Office's response to the requests, comments and queries that it had raised in last year's report. It concluded that the combination of written responses, the subsequent actions plus the content of this year's presentations addressed directly and appropriately the various points that had been raised by the Committee. In the context of the recent publication of the *"Met Office Science Strategy: 2016-2021. Delivering science with impact"* and noting that MOSAC's ToR includes the requirement *'to review aspects of the Met Office strategy ….'*, the Committee had anticipated being asked to comment on the document ahead of its publication and therefore it sought to clarify its role in the process of formulating the strategy.

MOSAC is correct that they should have been engaged in reviewing the strategy during its development and we apologise for omitting to do so. Although the overall structure and research directions had been presented at the previous meeting, MOSAC should have had the opportunity to comment. We were pleased that MOSAC was nevertheless happy with the document.

MOSAC applauds the stream of novel and creative initiatives being adopted and pursued vigorously by the Office, but concedes that it is sometimes difficult to assess whether the resources being devoted to each initiative will suffice to ensure its success. Thus it would be helpful to routinely receive some indication of the manpower likely to be assigned to an initiative and a 'ball-park' indication of the time-scale set for it to come to fruition.

We will encourage presenters in future meetings to assist the committee in this regard by giving a broad indication of the scale and timelines of significant initiatives.

Finally MOSAC welcomed two innovative features in this year's programme. First was the series of four presentations devoted to highly specific topical or research-led discoveries given by comparatively less-senior scientists, and the second was the opportunity for a structured but comparatively informal exchange with the Strategic Heads. The former provided the Committee with a detailed description of particular research areas, and the latter prompted a dialogue that was fruitful and beneficial to both parties. MOSAC invites the Office to propose a format for future meetings that builds upon these innovations whilst still enabling the Committee to retain an overall view of the Office's research portfolio.

We agree with MOSAC that this year's meeting benefited from the involvement of our younger scientists and the increased opportunities for discussions with the Strategic Heads. We are already

planning to extend these activities, for example by including an evening buffet at the Met Office, with a poster session that will facilitate more opportunities to interact with our younger scientists across the breadth of our research.

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 has featured in previous MOSAC reports and is 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?*