REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: ……United Kingdom………………………………………..…

Principal Investigator[1]: ……Dr. Graham Mann ……………………………….…………

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Other researchers: ……Will Hewson, Tim Keslake, Martyn Chipperfield, Ken Carslaw
.……Sandip Dhomse, Matt Woodhouse, Helen McIntyre

Project Title:

…… Development and testing of a microphysical aerosol scheme in the IFS …………………………………………………….……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _GBWOOD_________________	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2015 (SPGBWOOD began in 2012 to initially run to end 2014.	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2015-2017: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.)		**2015**	**2016**	**2017**
High Performance Computing Facility	(units)	3,000,000	3,000,000	3,000,000
Data storage capacity (total archive volume)	(gigabytes)	15,000	30,000	45,000

*An electronic copy of this form **must be sent** via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

……15th August 2014………………

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

Principal Investigator: …Dr. Graham Mann………………………………………………

Project Title: …Development and testing of a microphysical aerosol scheme …

Extended abstract

1. Scientific Plan

A new aerosol module "GLOMAP-mode" has been implemented into the IFS to upgrade on the mass-based scheme developed initially and referred to here as IFS-LMD (Morcrette et al., 2009). The GLOMAP-mode aerosol microphysics scheme (e.g. Mann et al., 2010; Mann et al., 2012) simulates the evolution of the particle size distribution, with explicit sources and sinks of particle number (e.g. via nucleation and coagulation) as well as mass. The scheme tracks the same component masses as the original "IFS-LMD" scheme (sulphate, sea-salt, mineral dust and black and organic carbon) but calculates how their composition is distributed across the size range resolving internal mixtures and gas to particle transfer. Resolving these aerosol microphysical processes has been shown to improve the fidelity of simulated aerosol radiative forcings (Bellouin et al., 2013a) and also allows to provide improved aerosol boundary conditions to regional air quality models, many of which include similar aerosol microphysics schemes.

The first evaluation of IFS-GLOMAP, which took place at the end of MACC (December 2011, see http://www.ukca.ac.uk/wiki/images/4/45/D_G-AER_1.8_final_Dec22.pdf), focussed on simulated size-resolved particle number concentrations and of the mass of sulphate, sea-salt and black & organic carbon. As part of MACC-II, the RADAER module to diagnose aerosol optical properties from GLOMAP (http://www.ukca.ac.uk/wiki/images/d/dc/UKCA_RADAER.pdf) has been implemented into the IFS and a report evaluating IFS-GLOMAP AOD has been delivered. (http://www.ukca.ac.uk/wiki/images/7/73/MACCII_AER_DEL_D_62_3.pdf), May 2013) comparing to AERONET observations (based on a reference run b0zg from Jan to Dec 2003).

This run has now been upgraded to include DMS (missing from the original run and in the initial MACC aerosol re-analysis using IFS-LMD, Innes et al., 2013) and daily-mean AOD and aerosol fields from this run are being submitted to the AeroCom server. A description and evaluation paper for IFS-GLOMAP is in progress (Woodhouse et al. 2014).

The GLOMAP-mode scheme is also being applied to simulate stratospheric aerosol in a 80 km-top version of the HadGEM-UKCA model, based on a case study (Dhomse et al., 2014) around the Mount Pinatubo eruption, and we would like to carry out an IFS-GLOMAP Pinatubo case study and also simulate the 15-year transient stratospheric aerosol record from 1998-2013 to investigate the contribution of changes in SO2 from anthropogenic and the series of small volcanic eruptions to the observed increase in stratospheric aerosol over the period (e.g. Hofmann et al., 2009; Vernier et al., 2011). The aerosol radiative forcing from the increased stratospheric aerosol offset about a quarter of the anthropogenic greenhouse gas radiative forcing over the same period (Solomon et al., 2011), and may have contributed to the recent "hiatus" in observed global warming.

A forecast-cycling experiment with IFS-GLOMAP coupled to the C-IFS chemistry has been tested. This "C-IFS-GLOMAP" system then allows the sulphate and secondary organic aerosol production in GLOMAP to be driven by the oxidation predicted by the TM5 tropospheric chemistry that has become fully integrated into the IFS as part of MACC-II.

A paper comparing IFS-GLOMAP and C-IFS-GLOMAP simulated aerosol properties is planned, focussing on seasonal cycle of aerosol properties and a higher temporal resolution case study, with submission intended by the end of MACC-III (Hewson et al., 2015).

A PhD studentship investigating data assimilation of gas phase and aerosol observations into the IFS has already begun at Leeds (Tim Keslake, supervised by Martyn Chipperfield and Graham Mann at Leeds, ECMWF supervisor Johannes Flemming). The project examines the influence of biomass burning on atmospheric composition and will involve running C-IFS and C-IFS-GLOMAP simulations with emissions from the GFAS fire module developed during MACC and MACC-II (e.g. Remy and Kaiser, 2014) to drive simulations with and without aerosol/chemistry data assimilation. Evaluation of case studies against aircraft measurements from the SAMBBA field campaign have already begun and will be used more extensively through the project.

During MACC-III, the Aerosol Optical Depth data assimilation system developed during GEMS/MACC (Benedetti et al, 2009) will be fully coupled to C-IFS-GLOMAP enabling re-analyses of atmospheric composition enabling aerosol forcings to be derived consistently with the best estimate including both AOD assimilation, online atmospheric chemistry and interactive aerosol microphysics. We anticipate this new product to provide an aerosol forcings with unprecedented physical realism, improving on the products from MACC (Bellouin et al., 2013b) which were used to give reference aerosol forcings in the recent IPCC AR5 climate assessment report (Myhre et al., 2013)

A "nitrate-extended" version of GLOMAP-mode (Benduhn et al., 2014), which resolves the partitioning of gas phase nitric acid and ammonia into nitrate and ammonium components within each of the four soluble modes, will be transferred into the IFS and coupled to C-IFS during MACC-III. The extension to C-IFS-GLOMAP to also resolve changes in nitrate and ammonium aerosol will further improve predicting radiative forcings and enhance the information available to sophisticated regional air quality models, which will already include these extra components.

2. Justification of Computer Resources Requested

We now have two Leeds users able to run IFS-GLOMAP experiments (the MACC-II PDRA Will Hewson and Tim Keslake, a 1st year PhD student at Leeds) whereas previously there was only one.

Due to our needing to run scientific experiment over longer simulation periods, and due to the increase in users, in June we requested the current 500,000 SBU per year limit to be increased to 2,000,000 SBUs commensurate with the higher number of users and widening scope of the science.

The potential science areas briefly described above will require further increased CPU resources but will bring with them world-leading modelling capability with high-impact research papers very likely to result from the aerosol forcing and stratospheric aerosol research in particular.

3. Technical Characteristics of the Code to be Used.

For details we refer to the D62.3 and D62.5 MACC-II deliverable reports and description papers listed below along with the other references cited in the report.

Description papers

- Bellouin, N. (2011). Interaction of UKCA aerosols with radiation: UKCA RADAER. UKCA technical description. http://www.ukca.ac.uk/wiki/images/d/dc/UKCA_RADAER.pdf.
- Dhomse, S. S., K. M. Emmerson. G. W. Mann, N. Bellouin, K. S. Carslaw, M. P. Chipperfield, R. Hommel, N. L. Abraham, P. Telford, P. Braesicke, M. Dalvi, C. E. Johnson, F. O'Connor, O. Morgenstern, J. A. Pyle, T. Deshler, and J. M. Zawodny, Whole-atmosphere aerosol microphysics simulations of the Mt Pinatubo eruption with the UKCA composition-climate model, *Atmos. Chem. Phys. Discuss.*, 14, 2799–2855, 2014
- Mann, G.W., K.S. Carslaw, D.V. Spracklen, D.A. Ridley, P.T. Manktelow, M.P. Chipperfield, S.J. Pickering, and C.E. Johnson: Description and evaluation of GLOMAP-mode: a modal global aerosol microphysics model for the UKCA composition-climate model, Geosci. Model Dev., 3, 519-551, doi10.5194/gmd-3-519-2010.
- Mann, G. W., Carslaw, K. S., Ridley, D. A., Spracklen, D. V., Pringle, K. J., Merikanto, J., Korhonen, H., Schwarz, J. P., Lee, L. A., Manktelow, P. T., Woodhouse, M. T., Schmidt, A., Breider, T. J., Emmerson, K. M., Reddington, C. L., Chipperfield, M. P., and Pickering, S. J.: Intercomparison of modal and sectional aerosol microphysics representations within the same 3-D global chemical transport model, *Atmos. Chem. Phys.*, 12, 4449--4476, doi: 10.5194/acp-12-4449-2012, 2012.
- Remy, S. and Kaiser, J. W.: Daily global fire radiative power fields estimation from one or two MODIS instruments, Atmos. Chem. Phys. Discuss., 20805-20844, 2014.

Other papers referred to in this report

- Bellouin, N., Mann, G. W., Woodhouse, M. T., Johnson, C. E., Carslaw, K. S., and Dalvi, M.: Impact of the modal aerosol scheme GLOMAP-mode on aerosol forcing in the Hadley Centre Global Environmental Model, Atmos. Chem. Phys., 13, 3027-3044, doi:10.5194/acp-13-3027-2013, (2013a).

- Bellouin, N., Quaas, J., Morcrette, J.-J, and Boucher, O.: Estimates of aerosol radiative forcing from the MACC re-analysis, Atmos. Chem. Phys., 13, 2045–2062, (2013b).

- Benduhn, F., Carslaw, K.S., Pringle, K., Mann, G.W., Topping, D., McFiggans, G. et al: (2014) A Computationally Efficient Hybrid Solver of Inorganic Dissolution for Use in Global Models: I. Description, Validation and First Results., in prep., for submission to Geosci. Mod. Dev,

- Benedetti, A., Morcrette, J.-J., Boucher, O., Dethof, A., Engelen, R.J., Fisher, M., Flentje, H., Huneeus, N., Jones, L., Kaiser, J. W., Kinne, S., Mangold, A., Razinger, M., Simmons, A. J., and Suttie, M.: Aerosol analysis and forecast in the ECMWF integrated forecast system: 2. Data assimilation, J. Geophys. Res., 114, D13205, doi:10.1029/2008JD011115, (2009).
- Hewson W., Mann, G. W., Flemming, J., Woodhouse, M. T., Morcrette, J.-J., Macintyre, H., The influence of tropospheric chemistry on simulated aerosol properties in the IFS-GLOMAP aerosol forecasting and reanalysis system, in prep. For submission to Geosci. Mod. Dev. 2015

- Hofmann, D.J., Barnes, J. O'Neill, M., Trudeau, M. and Neely, R.: Increase in background stratospheric aerosol observed with lidar at Mauna Loa Observatory and Boulder, Colorado, *Geophys. Res. Lett.*, 36, doi:10.1029/2009GL039008, (2009).

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Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, (2013).

- Solomon, S., Daniel, J. S., Neely, R., Vernier, J.-P. Dutton, E. G and Thomason, L. W.: The Persistently Variable “Background” Stratospheric Aerosol Layer and Global Climate Change, Science, 333, 866-970, (2011).
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