

REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: Germany

Principal Investigator¹: Univ.-Prof. Dr. Ulrike Langematz

Affiliation: Freie Universität Berlin

Address: Institut für Meteorologie
Carl-Heinrich-Becker-Weg 6-10
D-12165 Berlin
Germany

E-mail: ulrike.langematz@met.fu-berlin.de

Other researchers:

Anne Kubin, Markus Kunze, Janna Abalichin

Project Title: Ocean-Atmosphere Chemistry Climate Model Simulations for new WMO-SPARC-Chemistry Climate Model Initiative (CCMI)

If this is a continuation of an existing project, please state the computer project account assigned previously.	SP DEWMO3 (account 2012-2014)	
Starting year: <small>(Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)</small>	2015	
Would you accept support for 1 year only, if necessary?	YES <input checked="" type="checkbox"/>	NO <input type="checkbox"/>

Computer resources required for 2015-2017: <small>(The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.)</small>	2015	2016	2017
High Performance Computing Facility (units)	4.000.000	4.000.000	4.000.000
Data storage capacity (total archive volume) (gigabytes)	12.000	12.000	12.000

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):
30.06.2014

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Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Within this project Atmosphere-Ocean-Chemistry-Climate Model (AOCCM) simulations with the MA-ECHAM5/MESSy/MPIOM (EMAC-O) will be conducted as contribution to the new phase of the SPARC-CCMI initiative of WMO as well as to the research project "Quantification of Uncertainties of Solar Induced Climate Variability" (SOLIC) which is part of the German research programme "Role of the Middle Atmosphere in Climate" (ROMIC) funded by the German Federal Ministry of Education and Research.

The main focus will lie on the assessment of the interaction between climate change due to increasing greenhouse gas (GHG) concentrations and stratospheric chemistry. At present ozone recovery is expected to take place until mid-century (WMO, 2011; Eyring et al., 2010), so that column ozone reaches 1980 values in southern polar latitudes. This development is determined on the one hand by a decrease in ozone depleting substances (ODSs) and on the other hand by a decrease in stratospheric temperatures due to GHG concentrations in the atmosphere, which affects polar stratospheric cloud formation and heterogeneous ozone destruction.

So far most CCMs were not coupled to an ocean model. Therefore, it was necessary to prescribe sea surface temperatures and sea-ice conditions at the lower boundary. This was a limitation as it rendered the reaction of the ocean to any atmospheric changes impossible. It has been shown that, e.g., anomalies in the Southern Annular Mode have an impact on the southern circumpolar ocean circulation (Gupta and England, 2006) and on the extent of sea ice (Lefebvre and Goosse, 2008) with feedback on atmospheric climate variables. Sea ice loss at high northern latitudes is assumed to affect the atmospheric circulation and weather patterns through changes in the energy exchange between the ocean and the atmosphere (e.g., Francis et al, 2009).

For studies of the interaction between chemistry and climate it is of great importance to take into account interactions between radiation, dynamics and chemical composition of the atmosphere as well as interactions between the atmosphere and the oceans. Ozone is a major constituent in radiative processes and is also affected by dynamics and transport. Only CCMs can simulate the feedback of chemical processes on dynamics and transport of trace gases. The use of an ocean-coupled CCM opens the possibility for the full range of interactions between a high-top atmosphere and a deep-ocean model to occur.

Model and experimental Setup

We intend to use the MA-ECHAM5/MESSy/MPIOM (EMAC-O) AOCCM (Roeckner et al., 2003; Jöckel et al., 2005; Jöckel et al., 2006, Jungclaus et al., 2006), which is a modular system. Depending on the particular object of research EMAC-O allows for tailor-made configurations by switching on

and off respective sub-models for e.g. atmospheric chemistry, radiation, microphysical processes amongst others. Within this project a model version including a spectrally resolved radiation routine (Nissen et al., 2007, Kunze et al. 2014), the atmospheric chemistry module MECCA1 (Sander et al., 2005) and the interactive deep-ocean model MPIOM (Jungclaus et al., 2006) will be employed. The coupling of EMAC to the MPIOM ocean model has been performed at FUB. The new EMAC-O model has been implemented on the IBM high performance computer system at ECMWF, and is currently used for production. By the time of the special project start the model will be installed and tested on the new Cray high performance computer.

The experimental setup of the simulation will follow the recommendations by the SPARC CCM1 group for CCM simulations (Eyring et al., 2013).

The experiment to be carried out is a CCM1-REF-C2 simulation. It is designed as an internally consistent simulation from the past into the future. The objective with this simulation is to deliver best estimates of the future evolution of ozone and climate change. Greenhouse gas concentrations are prescribed following the RCP6.0 scenario and ODS abundances are taken from the A1 scenario of WMO 2011. Volcanic eruptions are considered in the past but not in the future. Solar variability is accounted for by prescribing daily total solar irradiance (TSI) and spectrally resolved irradiance (SSI) data which are repeated in the future. Moreover, the variability of auroral activity associated with the solar cycle is considered. The Quasi-Biennial Oscillation of the zonal wind in the lower stratosphere is included by nudging the model towards observed winds in the past which is continued in the future. In contrast to previous studies with the atmosphere-only CCM the sea surface temperatures and sea-ice will be modelled interactively in the AOCCM which allows for atmosphere-ocean interactions in response to the applied natural and anthropogenic forcings.

We will use the model in T42L39 resolution with a model top at 0.01 hPa. The ocean model is run in GR15L40 resolution. The simulation will span the period from 1960 to 2100 with ten years spin-up prior to 1960.

The results will be analysed to quantify the response of the ocean-atmosphere system to the 11-year solar forcing and its two possible mechanisms, i.e. the transfer from the upper to the lower stratosphere and to the troposphere (“top-down”, Kodera and Kuroda (2002)) and/or the direct total solar irradiance changes at the surface (“bottom-up”, Meehl et al. (2009)) as well as interactions of the solar forcing with the QBO. These analyses are part of a comparison with similar simulations where only SSI forcing (“bottom-up” effect suppressed) or TSI forcing (“top-down” mechanism suppressed) are used. From this comparison recommendations will ultimately be derived for upcoming IPCC simulations. Aspects of stratosphere-troposphere coupling, i.e. the effects of stratospheric perturbations on the troposphere including the surface climate, will also be the object of research.

The analysis will be done within the approved projects “ROMIC-SOLIC - Quantification of Uncertainties of Solar Induced Climate Variability”, “MiKlip-STRATO – The role of the stratosphere for decadal climate prediction”, and the approved DFG-Research unit “Stratospheric Change and its Role for Climate Prediction” (SHARP, FOR1095), coordinated by Ulrike Langematz. Subjects within SHARP are interactions between anthropogenically generated climate change and stratospheric dynamics, the future development of water vapour and the ozone layer as well as feedbacks of the stratosphere on climate and weather. Several institutions will jointly evaluate the model data for ROMIC-SOLIC, MiKlip-STRATO, and SHARP.

Ulrike Langematz, Univ.-Prof. Dr., is Professor at the Institut für Meteorologie of Freie Universität Berlin and head of the working group 'Atmospheric Dynamics'. Her scientific interests are in the fields of radiation, dynamics, and chemistry of the middle atmosphere with focus on stratospheric ozone, the interaction between stratospheric chemistry and climate change, and solar variability. She was/is PI in different national and European projects on climate change modelling (HGF-ENVISAT, EuroSPICE, SCOUT-O3), solar cycle modeling (BMBF-MESA, SOLICE and CAUSES-ProSECCO) and planetary modeling (HGF-Allianz 'Planetary Evolution'). She is coordinating the

DFG Research Unit SHARP. Ulrike Langematz is involved in the international climate modeling activity CCMI. She has been lead and co-author of several international assessments (e.g. the WMO Scientific Assessment of Ozone Depletion: 2006, 2010 and 2014).

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