SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2013/2014
Project Title:	"Chemistry Climate Model Simulations for WMO Ozone Assessment" and "Simulations with an Atmosphere-Ocean-Chemistry-Climate Model for the development of a decadal climate prediction system"
Computer Project Account:	SPDEWMO3
Principal Investigator(s):	Prof. Dr. Ulrike Langematz
Affiliation:	Institut für Meteorologie, Freie Universität Berlin
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	2012
Expected end date:	2014

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	1.650.000	1.650.000	11.250.000	4.149.010
Data storage capacity	(Gbytes)	9.000	9.000	24.000	24.000

Summary of project objectives

(10 lines max)

Within this project Atmosphere-Ocean-Chemistry-Climate Model (AOCCM) simulations with the MA-ECHAM5/MESSy/MPIOM (EMAC-MPIOM) will be conducted as contribution to the German research programme "Mittelfristige Klimaprognosen" (MiKlip). The main focus within this project lies on the assessment of the importance of stratospheric solar forcing, decadal stratospheric internal variability and the role of atmosphere-ocean interactions in view of the development of a mid-term, i.e. decadal, climate prediction model.

Furthermore the simulation will be analyzed in the projects SHARP and ISOLAA, both interested in the atmosphere-ocean interactions.

Summary of problems encountered (if any)

(20 lines max)

In September 2013 a transient simulation with the atmosphere-ocean-chemistry-climate-model EMAC-O spanning the period 1950 to 2100 following the IPCC RCP6.0 scenario was started. This simulation was completed in February 2014, but had to be restarted from the beginning due to two serious mistakes in the set-up of the experiment: A false treatment of the shortwave (SW) radiation resulted in the neglect of variations in the solar cycle. A second bug was detected in an input file for the treatment of photolysis rates of ozone (O_3) reactions, resulting in an amplified tropical O_3 cycle in the second part of the simulation (since 2008). Both mistakes seriously affect the proper operation of the chemistry module of EMAC-O and an accurate interpretation of the simulation in several topics. Hence, we applied for additional resources to complete the simulation before the shut-down of the IBM-AIX computer system in September 2014 which were approved in June 2014.

Summary of results of the current year (from July of previous year to June of current year)

As stated above in the "Summary of problems encountered" section, a transient simulation with the atmosphere-ocean-chemistry-climate-model EMAC-O spanning the period 1950 to 2100 following the IPCC RCP6.0 scenario was started. Although this simulation suffers from two serious mistakes, it can still be evaluated with respect to radiative forcing of the climate system and possible future changes in wintertime polar stratospheric variability within the DFG project SHARP-STC.

Radiative forcing

Since scientists know that climate will change they search for a way to quantify its strength and its consequences for human life. Thus, in 1990 the Intergovernmental Panel on Climate Change (IPCC) picked up the still existing idea of the radiative forcing in the First Assessment Report (Houghton et al. 1990). They describe the physical background and show the application of the method. Since then the concept has been frequently used to show the impact of human and natural emissions of climate active agents to the Earth's climate system.

Adjusted radiative forcing is defined as the net change in energy balance of the Earth system. It quantifies the energy imbalance that occurs when a perturbation is imposed. That means that a reference atmosphere is going to be perturbed for instance by a change of the mixing ratio of a climate active agent, like a greenhouse gas. It is expressed in W/m^2 and is mostly presented globally. By fixing the temperature in the troposphere the net flux change (short-wave plus long-wave radiation difference with respect to the reference atmosphere) is calculated by our global climate model EMAC (ECHAM/MESSy) with the submodel RAD. Mixing ratios of the climate active agents and the tropopause height are calculated interactively with the chemistry-climate-model EMAC in a transient simulation from 1960 to 2100 following the RCP6.0 scenario. The analysis of the adjusted and instantaneous radiative forcing is still in progress. Here, the first results are shown.

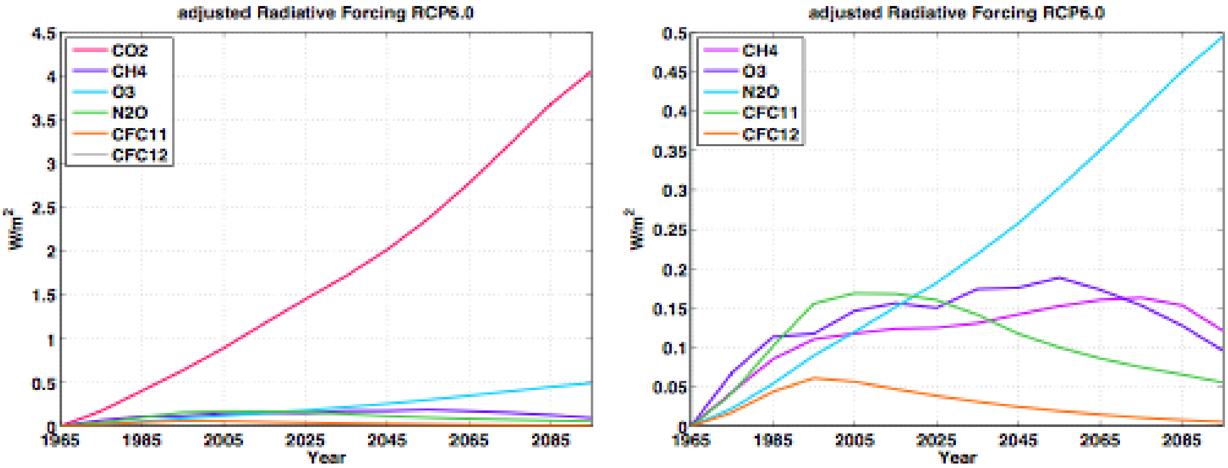

Figure 1: Left: Adjusted radiative forcing for the climate active agents CO_2, CH_4, O_3, N_2O, CFC-11 and CFC-12 from a transient simulation with EMAC following the RCP6.0 scenario. Right: the same as left but without CO_2

Figure 1 shows the adjusted radiative forcing for the climate active agents CO_2 (red), CH_4 (purple), O_3 (blue), N_2O (light blue), CFC-11 (green) and CFC-12 (orange) for the years 1975 to 2095. It is seen that the radiative forcing will grow in the future. The highest impact for climate change is given by CO_2 with up to 4 W/m^2 in 2095 followed by N_2O and CH_4 and ozone. Based on the Montreal Protocol the CFCs will lose influence on the climate system in the next decades and CFC-12 will almost disappear until 2095.

Figure 2 shows the adjusted radiative forcing plotted against the changing mixing ratios of the climate active agents in the troposphere. The colours denote the years from 1975 to 2095. For well mixed greenhouse gases, i.e. gases with a homogeneous distribution, there is a strong correlation between the changing mixing ratio in the troposphere and the resulting radiative forcing. Because of the inhomogeneous distribution of ozone in the atmosphere, it shows an interesting exception: In this special case the radiative forcing at the tropopause is mainly driven by the increase of ozone in the troposphere, but it has a second influencing component by a decrease of the mixing ratio in the tropical lower stratosphere.

These results will be presented at the SHARP Annual Meeting, 2-4 July 2014 in Heidelberg, Germany, as well as at the 4th EMAC Symposium, 14-16 July 2014 in Berlin, Germany (oral presentation by C. Gellhorn, U. Langematz, S. Meul, S. Oberländer, J. Abalichin and S. Dietmüller: “Past and Future: Radiative Forcing of climate active agents with the EMAC submodel RAD”)

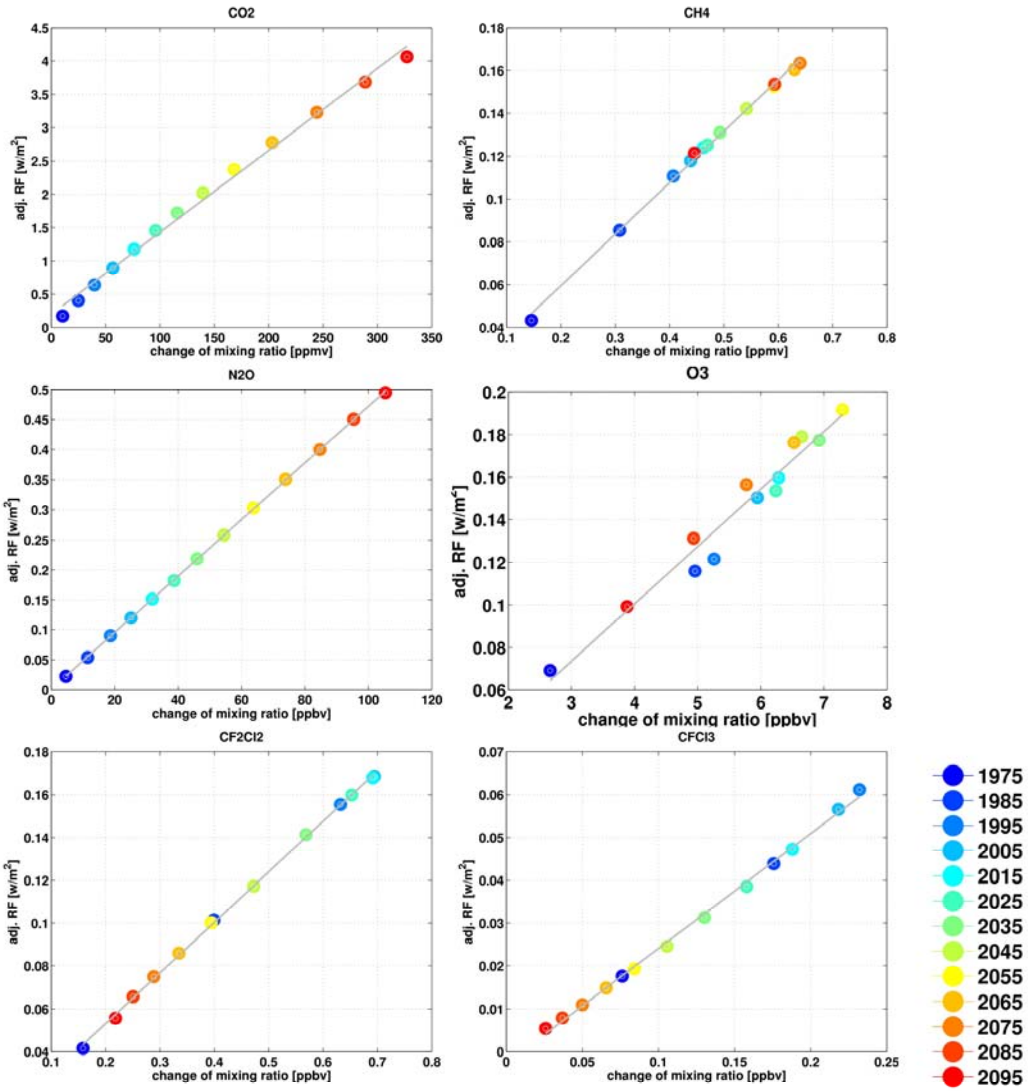

Figure 2: Adjusted radiative forcing plottet against the changes in mixing ratio from RCP6.0.

Future changes in wintertime polar stratospheric variability

Major stratospheric warmings (MSWs) are the most abrupt events of boreal wintertime polar stratospheric variability, whose influence extends down to the troposphere. Thus, the analysis of these phenomena and their possible variations in the future is also important for the future climate change projections of surface climate. In the framework of a Chemistry Climate Model Initiative (CCMI) project, an analysis of future changes of these phenomena has been carried out by means of transient runs of different CCMs under RCP6.0 future scenario, one of these CMMs being EMAC. All of these runs extend from 1960 to 2100 and include natural and anthropogenic forcings and natural variability following the specifications by the CCMI initiative (Eyring et al., 2013). Future changes in MSWs characteristics are assessed by comparing the last 40 winters of each run with the first 40 ones.

As a first step, variations in the frequency of these phenomena have been studied. The results indicate that although future MSWs show an increase in the mean frequency of these phenomena in most of the analysed CCMs, this increase is in general not statistically significant, except for NIWA-UKCA (Table 1). However, in the case of NIWA-UKCA, the statistically significant future change in the mean frequency of MSWs could be due to the unrealistically low frequency of these phenomena in the past period in comparison with observations (0.8 MSWs/decade in NIWA-UKCA vs. 6.0 MSWs/decade in ERA40).

As a second step, a possible change in the seasonality of MSWs has been examined. However, as the number of MSWs in some models is very low, we have rather focused on the intensity of the polar night. Thus, future changes in the daily climatology of the zonal-mean zonal wind at 10 hPa have been studied and based on this study, we have identified three groups of models (Figure 3). While some models (CCSRIES-MIROC3.2 & NIWA-UKCA) show a future weakening and an increased variability in the polar stratosphere in midwinter and a future strengthening in early winter (Figure 3, upper row), others (CNRM-CCM & EMAC) show just the opposite future signal in the seasonal march (Figure 3, middle row). Additionally, GEOS-CCM does not show any change in the intensity of the polar night jet (Figure 3, lower row).

Model	Past (MSWs/decace)	Future (MSWs/decade)
CCSRNIES-MIROC3.2	2.3	3.0
NIWA-UKCA	0.8	3.3
GEOS-CCM	1.8	1.8
CNRM-CCM	7.5	7.3
EMAC	6.8	7.3

Table 1: Mean frequency of MSWs per decade in the past (1960/61-1999/2000) and the future (2060/61-2099/2100) for each CCM.

A further analysis of the dynamical forcing has shown that models with similar changes in the polar night jet show similar changes in the tropospheric forcing and thus, for instance, models with a future weakening of the polar stratospheric winds in mid-winter have an associated future enhancement of the upward propagating wave activity in that winter sub-period. Moreover, those models have also a similar response of sea surface temperatures (SSTs) to global warming, with a predominant El Nino-like pattern in December-January. In contrast, the SST change pattern is different in the case of the models with a strengthening of the polar night jet in mid-winter or without any statistical change in that winter period and an associated reduced or unchanged tropospheric forcing, respectively. Thus, it seems that differences in the response of SSTs to global warming can be at least partly responsible for these differences in the future polar stratosphere among models.

Results have been presented at the CCMI Workshop 2014 in Lancaster (oral presentation “Future changes in wintertime stratospheric Arctic variability in CCMI models” by Blanca Ayarzagüena, Ulrike Langematz, Janna Abalichin, H. Akiyoshi, M. Michou, O. Morgenstern and L. Oman) and at the SHARP Annual Meeting in Heidelberg (oral presentation “Future changes in wintertime stratospheric Arctic variability in climate models” by Blanca Ayarzagüena, Ulrike Langematz, Janna Abalichin, H. Akiyoshi, M. Michou, O. Morgenstern and L. Oman).

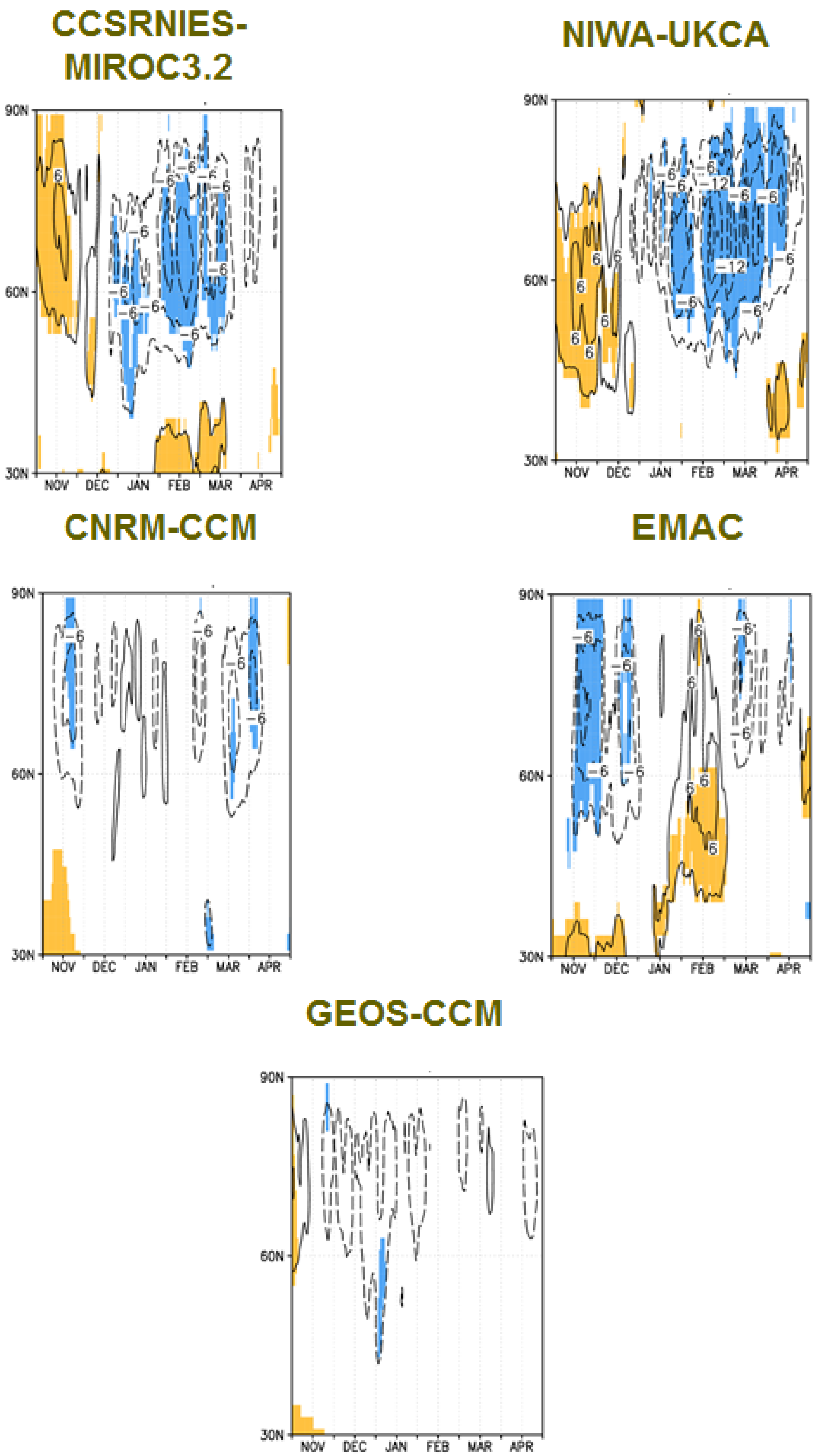

Figure 3: Differences future-minus-past of daily climatology of 10-hPa zonal-mean zonal wind from November to April in the Northern Hemisphere. Contour interval: 3 m s^{-1}. Yellow (blue) shadings correspond to positive (negative) statistically significant values at a 95% confidence level (two-tailed Student’s t-test).

References

Eyring, V. et al., 2013: Overview of IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) Community Simulations in Support of Upcoming Ozone and Climate Assessments, *SPARC Newsletter*, **40**, 48-66.

Intergovernmental Panel on Climate Change (IPCC): Houghton, J. T., Jenkins, G. J., & Ephraums, J. J. (1990). Climate Change. The IPCC Scientific Assessment by Working Group I. Cambridge University Press, Cambridge, Great Britain, New York, NY, USA and Melbourne, Austral

List of publications/reports from the project with complete references

Summary of plans for the continuation of the project

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Until the shut-down of the IBM system we will complete the ongoing simulations, i.e. a transient RCP6.0-run and a control simulation under boundary conditions representative for 1960. We will apply for a new special project in order to carry out transient simulations with the Atmosphere-Ocean-Chemistry-Climate Model EMAC-O. The planned simulations are contributions to a) the new German research programme “Role of the Middle Atmosphere in Climate” (ROMIC) project “Quantification of Uncertainties of SOLar Induced Climate variability” (SOLIC) and b) to the new phase of the SPARC-CCMI initiative of WMO. The main focus will lie on a) the assessment of the importance of stratospheric solar forcing, decadal stratospheric internal variability and the role of atmosphere-ocean interactions and b) the assessment of the interaction between climate change due to increasing greenhouse gas concentrations and stratospheric chemistry.