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	July 2016 – June 2017
Project Title:	The role of coupled ocean/atmosphere interactions in the tropics for seasonal and decadal prediction
Computer Project Account:	spdegrea
Principal Investigator(s):	Prof. Dr. Richard J. Greatbatch (GEOMAR), Dr. Felicitas Hansen (GEOMAR), Dr. Gereon Gollan (GEOMAR), Prof. Dr. Thomas Jung (AWI), Prof. Dr. Katja Matthes (GEOMAR), Dr. Sebastian Wahl (GEOMAR), Ole Wulff (GEOMAR)
Affiliation:	GEOMAR Helmholtz Centre for Ocean Research Kiel
Name of ECMWF scientist(s) collaborating to the project (if applicable)	N/A
Start date of the project:	January 1 2015
Expected end date:	December 31 2017

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)	11.950.000	1.781.929	9.240.000	353.604
Data storage capacity	(Gbytes)	41.628	Not known	29.400	Not known

Summary of project objectives
(10 lines max)
To determine factors that are important for seasonal and decadal predictions in the mid-latitudes, especially over Europe. Of particular interest are influences from the tropics and the stratosphere. But we are also interested in how the mid-latitudes influence the tropics and whether a positive feedback can sometimes exist between anomalies in the tropics and anomalies in the mid-latitudes, a possible example being during the winter of 1962/63.

Summary of problems encountered (if any)
(20 lines max)

1) As noted in the progress reported submitted in June 2016, Dr. Hansen was on leave until the end of 2016 and returned in January 2017. Some of the experiments which had originally been planned for 2016, namely seasonal forecast experiments using the coupled ocean-atmosphere model, had therefore been shifted to 2017 as also stated in the amended “Request for a special Project” submitted together with last year’s report.
2) In some of our seasonal forecast experiments, namely atmosphere-only experiments using relaxation towards ERA40 in the extratropical troposphere between 1959 and 2001, some of the dynamic variables showed unrealistic behaviour. The origin of this needs further investigation. A consequence is that we decided not to do some of the experiments using extratropical relaxation.
3) Instead of performing our own set of control (i.e. without relaxation) seasonal forecast experiments with the coupled ocean-atmosphere model Cy40R1 and Cy41R1 (i.e. simple hindcasts for the ERA-Interim period), we have arranged to use the existing experiment sets containing 51 ensemble members for boreal winter hindcasts and 25 ensemble members for boreal summer hindcasts (Cy41R1 only) from Antje Weisheimer (ECMWF/University of Oxford).

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

Our existing set of experiments using a relaxation technique (e.g. Jung et al., 2010; Greatbatch et al., 2012) has been further extended during the last year. By applying relaxation towards reanalysis data like ERA40 or ERA-Interim throughout the course of a seasonal forecast in some parts of the atmosphere, these regions can be assumed to be perfectly forecast, and hence their importance for seasonal prediction can be analysed. The experiments described below all use ERA-Interim for the relaxation (see Hansen et al, 2017, for the details):

CLIM-NO: Atmosphere-only, no relaxation is used and climatological sea surface temperature and sea-ice (SSTSI) is used at the lower boundary. Experiments are initialised around November 1 for boreal winter and around May 1 for boreal summer realisations.

OBS-NO: As CLIM-NO but using realistic, time varying SSTSI at the lower boundary.

CLIM-TROPICS: As CLIM-NO but using relaxation in the Tropics.

OBS-TROPICS: As CLIM-TROPICS but including realistically varying SSTSI at the lower boundary.

CLIM-STRAT: As CLIM-NO but including relaxation in the extratropical stratosphere.

OBS-STRAT: As OBS-NO but including relaxation in the extratropical stratosphere.

CLIM-EXTRATROP: As CLIM-NO but including relaxation in the extratropical troposphere.

CPL-TROPICS: Coupled model experiments using relaxation in the Tropics and initialised as for seasonal forecasts.

CPL-STRAT: As CPL-TROPICS but using relaxation in the extratropical stratosphere instead of relaxation in the Tropics.

One of the past year's foci has been on performing seasonal forecast relaxation experiments with the coupled ocean-atmosphere model. Comparing these with the existing seasonal forecast experiments using the atmosphere-only model allows us to investigate the role of ocean-atmosphere coupling for seasonal prediction. As we report in Hansen et al. (2017), extratropical atmosphere-ocean coupling seems to be important for the seasonal prediction of extreme events in the stratosphere in Northern Hemisphere (NH) winter, so-called Stratospheric Sudden Warmings (SSWs). A complication is a strong bias in the stratospheric polar night jet in the coupled model. This seems to be associated with a drift in the modelled sea surface temperatures (SSTs) resembling the well-known North Atlantic cold bias (Keeley et al., 2012; Drews et al., 2015) and an underestimation of blockings in the North Atlantic/Europe sector (Gollan et al., 2015b). After statistically removing the bias, the occurrence of a SSW in a given winter is predicted with a success rate of 70% in a coupled model experiment using relaxation in the tropical atmosphere. This is a better performance than is found in the atmosphere-only experiments, even those that include relaxation in the Tropics. In the same manuscript, we are able to confirm an influence of SSWs on the troposphere by showing a shift of the index of the North Atlantic Oscillation (NAO) towards lower values in combination with SSW occurrence. Further, by comparing several seasonal forecast experiments using relaxation towards ERA-Interim in different regions of the atmosphere, we highlight the importance of the stratosphere for seasonal prediction of the NAO (see Figure 1). Nevertheless, the skill for predicting the NAO does not rely on the occurrence of SSWs in our experiments. This result differs from the experience with other seasonal forecast systems, e.g., the UK Met Office seasonal forecast system (Scaife et al., 2016) or a seasonal forecast system based on the Canadian Middle Atmosphere model (Sigmond et al., 2013).

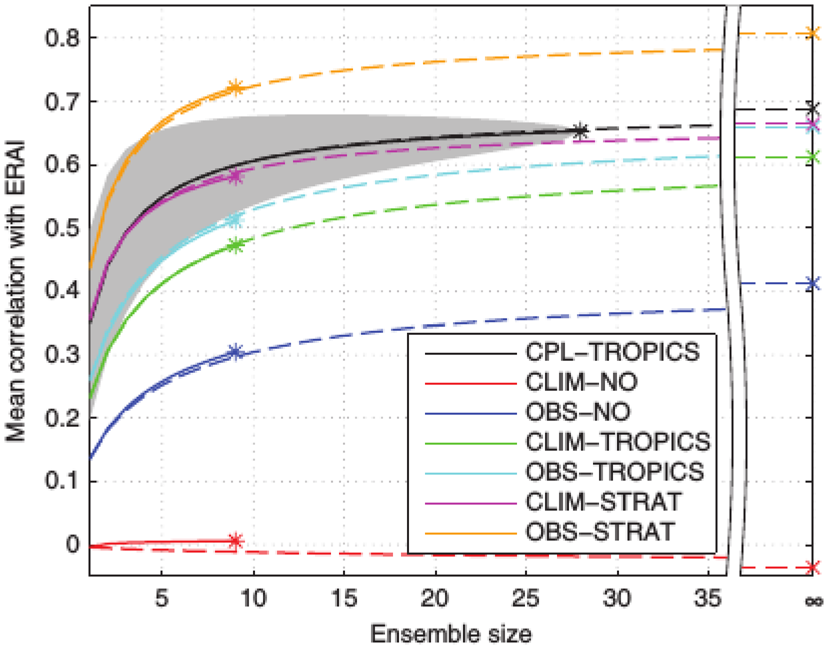

Figure 1: NAO correlation between relaxation experiments and ERA-Interim as a function of ensemble size. Solid curves: average of correlations between all possible ensemble mean combinations created from the existing nine (CPL-TROPICS: 28) ensemble members for each ensemble size (1:9, 1:28 for CPL-TROPICS) and ERA-Interim; asterisks indicate the correlation value for the full ensemble; the grey area indicates the range of 90% of all correlations between possible ensemble combinations in CPL-TROPICS. Dashed curves: theoretical estimate of the variation of NAO correlation with ensemble size following Murphy (1990); crosses indicate the asymptotes of the theoretical estimates for an infinite-sized ensemble. From Hansen et al. (2017).

Another focus of last year has been on analysing the seasonal forecast experiments for NH summer. In particular, we wanted to know which factors influence the variability in this season, a topic that has received little attention until now. Analysis on this has mainly been done by Ole Wulff within the framework of his thesis to obtain the Master of Science degree at the Christian-Albrechts University in Kiel. It is found that two modes have the most impact on the NH summer surface climate, namely the summer NAO (SNAO) and the summer East Atlantic (SEA) mode. Regarding the predictability of these modes, no skill improvement could be found from any of the perfectly forecast regions in the relaxation experiments for the SNAO. Even though previous studies have suggested an influence from Atlantic Multi-decadal Variability (Sutton and Hodson, 2005) we are unable to find a significant influence from specifying SSTSI. For the SEA, analysis of reanalysis data suggests that the Tropics might be a source of potential predictability, in such a way that diabatic heating anomalies in the tropical Pacific and the Caribbean, driven by anomalous SSTs, alter the upper tropospheric divergence. This acts as a source for Rossby waves in the eastern North Pacific which can propagate downstream in the jet stream wave guide. This behaviour is reproduced in our experiment with specified, realistically varying SSTSI. On the other hand, while our experiments that include tropical relaxation quite accurately reproduce the diabatic forcing in the Tropics, they fail in predicting SEA variability (see Figure 2). This suggests that the relaxation interferes with the wave refraction process in the North Atlantic jet; however, further analysis, maybe in form of further relaxation experiments using a narrower relaxation zone in the Tropics, are needed to clarify this point. We are currently writing up our work on the SEA for publication.

Some ongoing work focusses on the question of how SSWs are initiated, which is still not fully understood. From analysis of SSWs in our relaxation experiments it seems that some SSWs are predicted correctly only in the tropical relaxation experiments, while others are predicted correctly only in the NH extratropical relaxation experiment (relaxation towards ERA-Interim in the troposphere and not the experiment mentioned above in the “Problems” section). Using composite analysis we investigate the conditions prior to, during and after the “tropical” and the “extratropical” events.

Another aspect of ongoing work deals with the seasonal prediction of extratropical winter wind storms related to intense extratropical cyclones. Similar to the analysis done for the NAO in Hansen et al. (2017), we investigate which factors or which regions could enhance predictive skill of these events which, due to their large destructive potential, are of great socio-economic interest.

Preliminary results suggest an influence from the stratosphere again, especially over northern Europe and the British Isles.

Finally, we have continued our work on mid-latitude blocking and, in particular, influences on blocking from the Tropics, including ENSO and the MJO, extending the work of Gollan et al. (2015b) and using a 2-D blocking index instead of the 1-D blocking index used there. To infer influence from the Tropics, we use the CLIM-TROPICS experiment, where the Tropics are relaxed towards ERA-Interim. This work is currently under review (Gollan, G., and Greatbatch, R.J., “The relationship between northern hemisphere winter blocking and tropical modes of variability”, submitted to Journal of Climate).

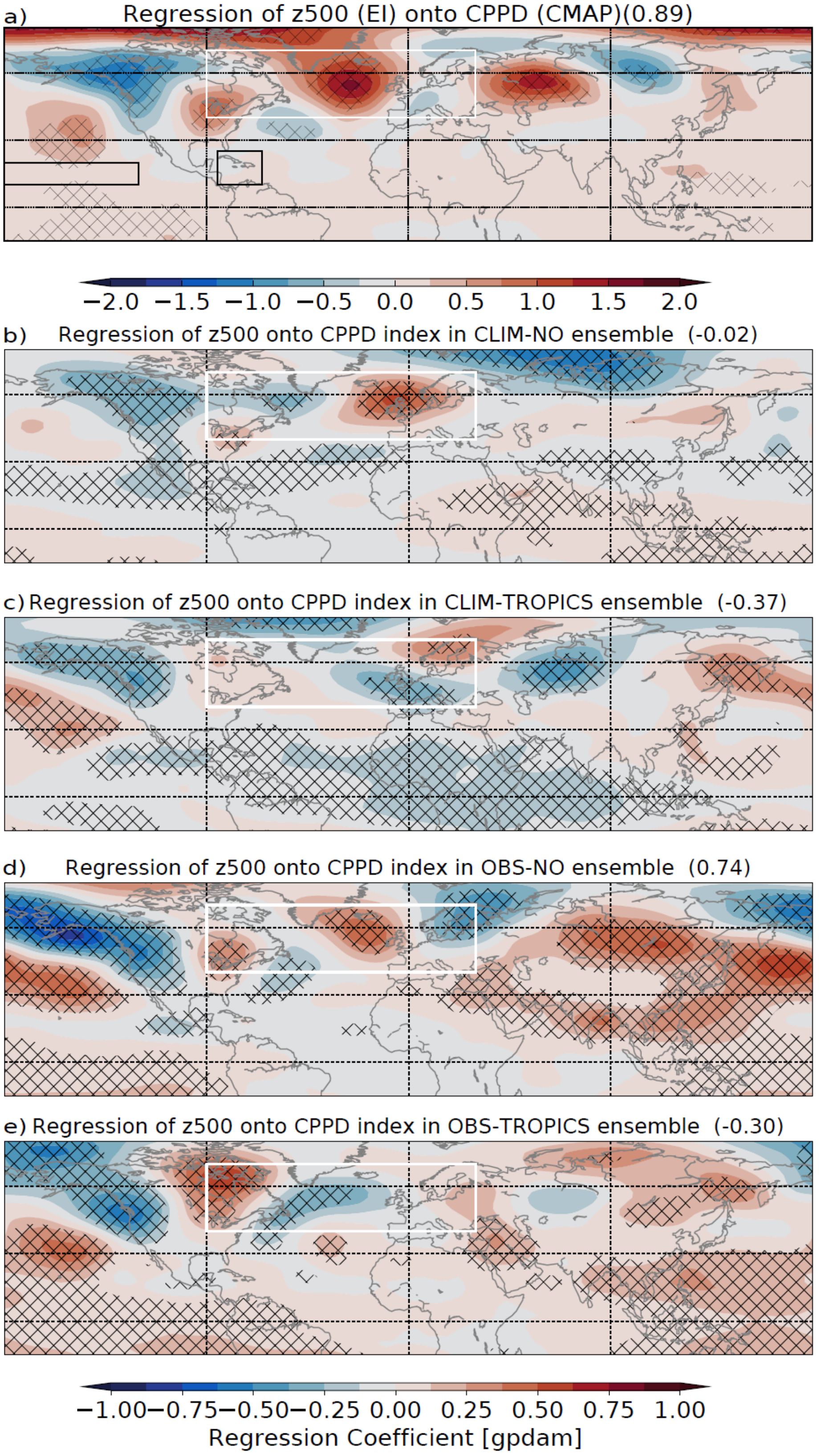

Figure 2: Regression of June/July/August (JJA) geopotential height at 500hPa (Z500) on the Caribbean-Pacific precipitation dipole (CPPD) index for ERA-Interim and in the different model experiments, noting that the individual ensemble members are used for the regression in the case of the model experiments. Here the CPPD index is the difference in JJA mean precipitation for the box in the Caribbean Sea minus the box in the tropical North Pacific shown in panel (a). The numbers in brackets are the pattern correlation with the SEA pattern which is the second EOF of JJA mean Z500 inside the white box. Note that the experiments that include relaxation in the Tropics (CLIM-TROPICS and OBS-TROPICS) completely fail to capture the centre of action to the west of the British Isles seen in (a), whereas this feature is quite well reproduced in OBS-NO, the experiment that does not include relaxation but includes realistically varying SSTSI. Interestingly, this feature is also found in CLIM-NO that also does not include relaxation, although it is displaced eastwards in this experiment. Comparing CLIM-NO with OBS-NO suggests a role for North Atlantic SSTSI in the dynamics of the SEA.

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List of publications/reports from the project with complete references

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Hansen, F., Greatbatch, R. J., Gollan, G., Jung, T. and Weisheimer, A., 2017, Remote control of NAO predictability via the stratosphere, Q.J.R. Meteor. Soc., 143 (703), 706-719, 10.1002/qj.2958.

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Summary of plans for the continuation of the project

Until the end of the project in December 2017, we shall perform the remaining extratropical relaxation experiments with the coupled model. Some computing time will be used for short test runs to see whether or not we can do multi-year forecasts rather than forecasts restricted to a single season, using again the relaxation technique in some parts of the atmosphere if possible. If we are successful with this, we will apply for another special project next year.

Ongoing work will be continued.