SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	The role of the polar regions in weather and seasonal prediction
Computer Project Account:	Spdejun2
Start Year - End Year :	2013-2014
Principal Investigator(s)	Thomas Jung
Affiliation/Address:	Alfred-Wegener-Institute for Polar and Marine Research (AWI), Bussestrasse 24, 27570 Bremerhaven, Germany
Other Researchers (Name/Affiliation):	Soumia Serrar (AWI) and Tido Semmler (AWI)

The following should cover the entire project duration.

Summary of project objectives
(10 lines max)

The aim of this project is to determine how medium-range and seasonal prediction in the mid-latitudes and especially over Europe will benefit from improved predictions in polar regions. To this end relaxation experiments will be carried out with the ECMWF model (atmosphere-only) in which the development of forecast error in the polar regions is suppressed during the course of the integration by relaxing the model toward reanalysis fields over the Arctic and Antarctic. Differences in forecast skill with and without relaxation will highlight those areas, which will benefit from improved prediction capabilities in the polar regions.

Summary of problems encountered
(If you encountered any problems of a more technical nature, please describe them here.)

No major problems encountered. Porting the code to the new supercomputer took some time.

Experience with the Special Project framework
(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The administrative aspects are very good.

Summary of results
(This section should comprise up to 10 pages and can be replaced by a short summary plus an existing scientific report on the project.)

1. Medium-range and subseasonal experiments (Part I)

To study the impact of both Arctic and Antarctic relaxation towards reanalysis data on the quality of mid-latitude forecasts, two large sets of forecasts were produced with the IFS model cycle 38r1: one set of control integrations (CTL) without relaxation, and one set in which the troposphere is relaxed to ERA-Interim data north of 75 N and south of 75 S (R75). The difference between CTL and R75 is evaluated in terms of forecast skill in the Arctic and in the Northern mid-latitudes as well as in the Antarctic and in the Southern mid-latitudes. The relaxation over the Southern Hemisphere is assumed to have no influence on the Northern Hemisphere and vice versa. This is a reasonable assumption given that a forecast length of 14 days is hardly long enough for possible signals to cross hemispheres.

Arctic influence

The reduction of the root mean square error (RMSE) in different parts of the Northern mid-latitudes due to relaxing the Arctic atmosphere toward ERA-Interim can be inferred from Fig. 1. For the mid-latitudes as a whole (between 40 and 60 N) the reduction of RMSE amounts to approximately 5% of the RMSE in the control integration after 5 days into the forecast (Fig. 1a) with little evidence for a strong seasonality. However, there are marked regional differences (Fig. 1b-d). By far the strongest improvement can be seen for Asia with up to 15% (10%) error reduction in autumn and winter (summer). For North America and Europe, the error reduction is comparable to that for the entire Northern mid-latitudes although more uncertainty is evident due to the smaller domain size and hence larger sampling variability.

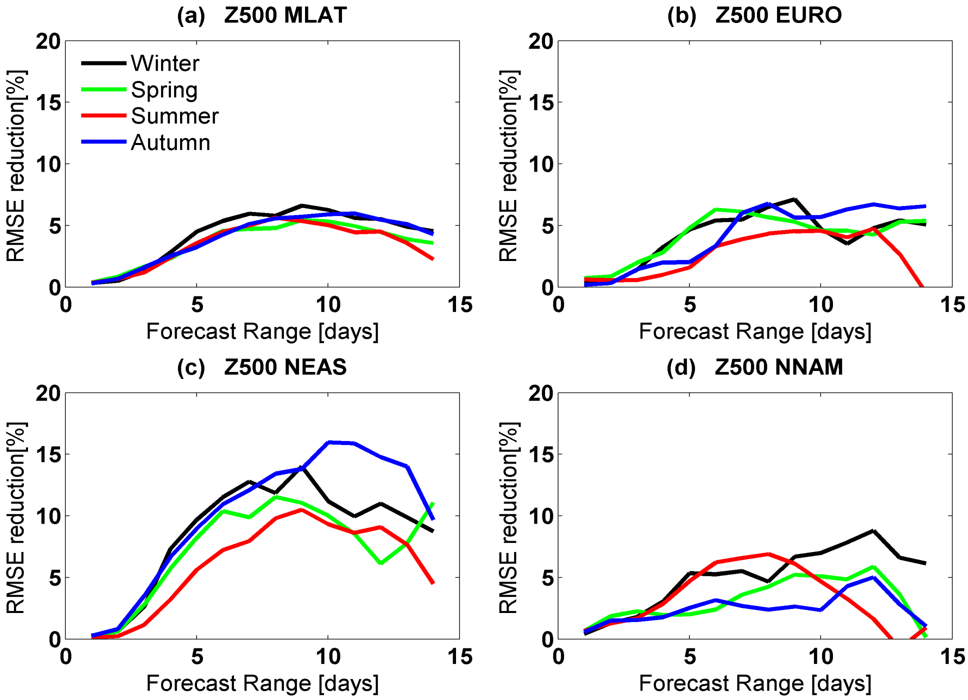

Fig. 1: RMSE reduction (%) of 500hPa geopotential height forecasts due to the relaxation as a function of forecast lead time in days and dependent on the season: (a) averaged over the whole Northern mid-latitudes between 40 N and 60 N (MLAT), (b) averaged over Europe (40 N to 60 N, 20 W to 40 E, EURO), (c) averaged over Northern Asia (40 N to 60 N, 60 E to 120 E, NEAS), (d) averaged over Northern North America (40 N to 60 N, 130 W to 70 W, NNAM)

Fig. 2 provides a comprehensive picture of the geographical distribution of the error reduction for the different seasons. We considered two forecast ranges: Averaging over forecast lead times of 4-7 days, when it is still influenced by the initial conditions and error growth has not saturated yet; and averaging from 8-14 days when the initial conditions play a minor role and the error reduction is approximately constant apart from random fluctuations.

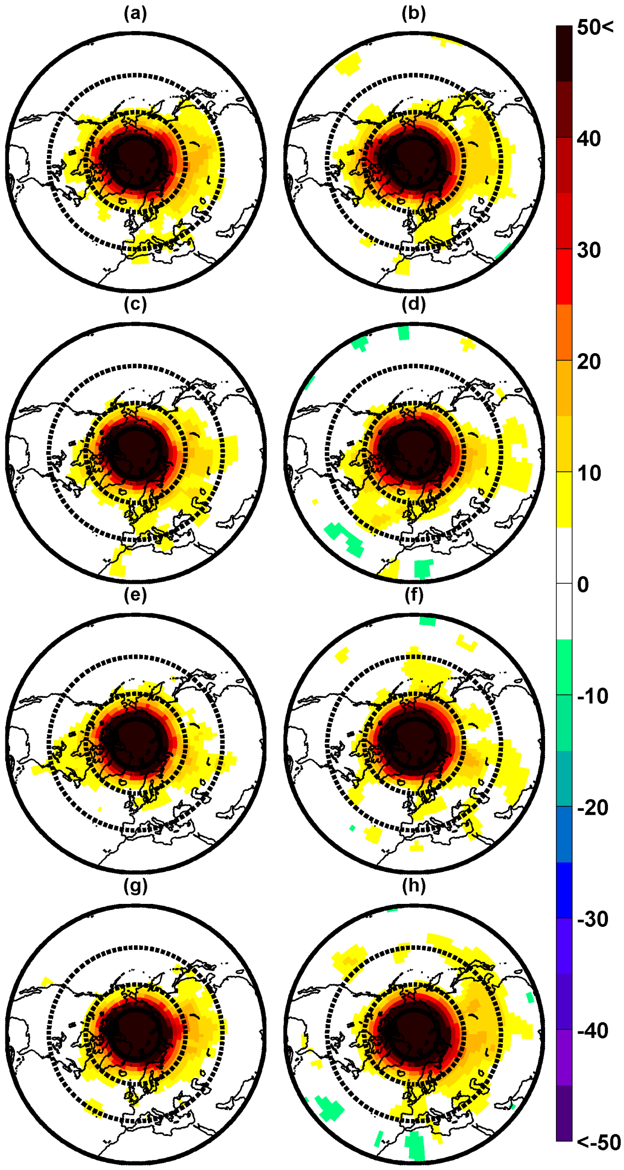

Fig. 2: RMSE reduction (%) of the 500 hPa geopotential height forecasts for the Northern Hemisphere north of 20 N due to the relaxation dependent on the season: (a) winter averaged over forecast lead times 4 to 7 days, (b) winter averaged over forecast lead times 8 to 14 days, (c) and (d) as (a) and (b) but spring, (e) and (f) summer, and (g) and (h) autumn. The dashed lines indicate the Northern mid-latitude region from 40 N to 60 N.

Fig. 2 shows that RMSE reduction due to Arctic relaxation shows some strong regional dependency. Perhaps the most striking feature is the relatively strong Arctic influence over the continents, especially over Asia, compared to the oceans. This can be explained by the climatological troughs over the east coasts of northern Asia and northern North America, leading to transport of Arctic air into northern Asia and Canada. A possible explanation for a lesser impact over the oceans lies in the fact that the North Atlantic and North Pacific regions are primarily determined by mid-latitude dynamics due to the relatively low-latitude location of the main storm formation regions over the Gulf Stream and Kuroshio regions.

The Arctic signal propagates southward relatively quickly over Asia. During the second week, for example, RMSE reduction is evident as far south as 20 - 40 N, although the picture becomes somewhat noisy as we go towards longer forecast lead time. Over Europe and North America only in winter and spring consistent improvements between 5 and 10% are evident for days 4 to 7 and days 8 to 14. During the other seasons, the Arctic impact appears to be smaller and the results are less conclusive in terms of error reduction. The west coasts of North America and Europe, which are marked by maritime climate, show a rather small influence from the Arctic, consistent with the lesser influence over the oceans.

After having established the existence of preferred pathways along which the Arctic influences mid-latitude weather, it is worth asking whether the strength of this linkage is flow-dependent. It turns out that the link is strongest when anomalous northerly flow from the Kara Sea brings air of Arctic origin towards mid-latitudes; this is especially true during boreal winter. The anomalous circulation also helps to reduce the zonality of the flow which weakens the upstream influence from the North Atlantic which is more strongly determined by mid-latitude dynamics.

The character of the flow-dependence for Europe and North America, that is, anomalous northerly flow associated with cold air outbreaks into the considered region increases the linkage, is comparable to that over Asia, at least during winter and spring. Similarly like for northern Asia, the anomaly pattern reduces the zonality of the flow and weakens the North Atlantic influence.

Antarctic influence

Fig. 3 depicts the reduction of the RMSE due to the relaxation in the Southern mid-latitudes between 40 and 60 S. Strongest improvements are achieved for winter, followed by autumn and spring, while the improvements are only weak in summer. The error reduction grows during the first week and remains between around 2 and 5% during the second week. This is to be expected as during the first few days there is still a considerable forecast skill and therefore the relaxation does not impact the forecasts as much as for longer forecast lead times. Compared to the Northern Hemisphere, the error reduction is weaker.

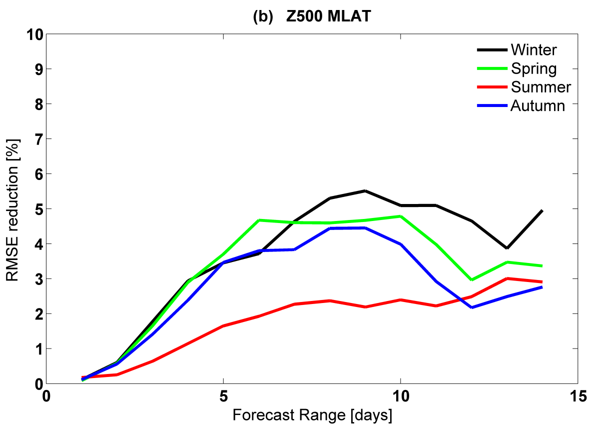

Fig. 3: Z500 RMSE reduction (%) of the average of relaxed forecasts compared to the average of control forecasts.

Regarding the spatial distribution (Fig. 4), there is a tendency towards stronger improved forecasts over the South Atlantic and southern South America. For days 4 to 7 the error reduction is still quite restricted to the vicinity of the relaxation area, especially for summer. While for days 8 to 14 in winter and spring the signal spreads out more into the mid-latitudes and partly beyond, in summer and autumn the perfect knowledge of the Antarctic atmosphere does not have any important impact on the forecast quality in the mid-latitudes. In winter and spring larger areas of improved forecasts can be seen. Compared to the Northern Hemisphere, the regional distribution of error reductions is rather homogeneous. This makes sense given that there are hardly any land masses in the Southern mid-latitudes. Also the generally weaker influence of the relaxation in the Southern compared to the Northern Hemisphere could be related to the lack of land masses.

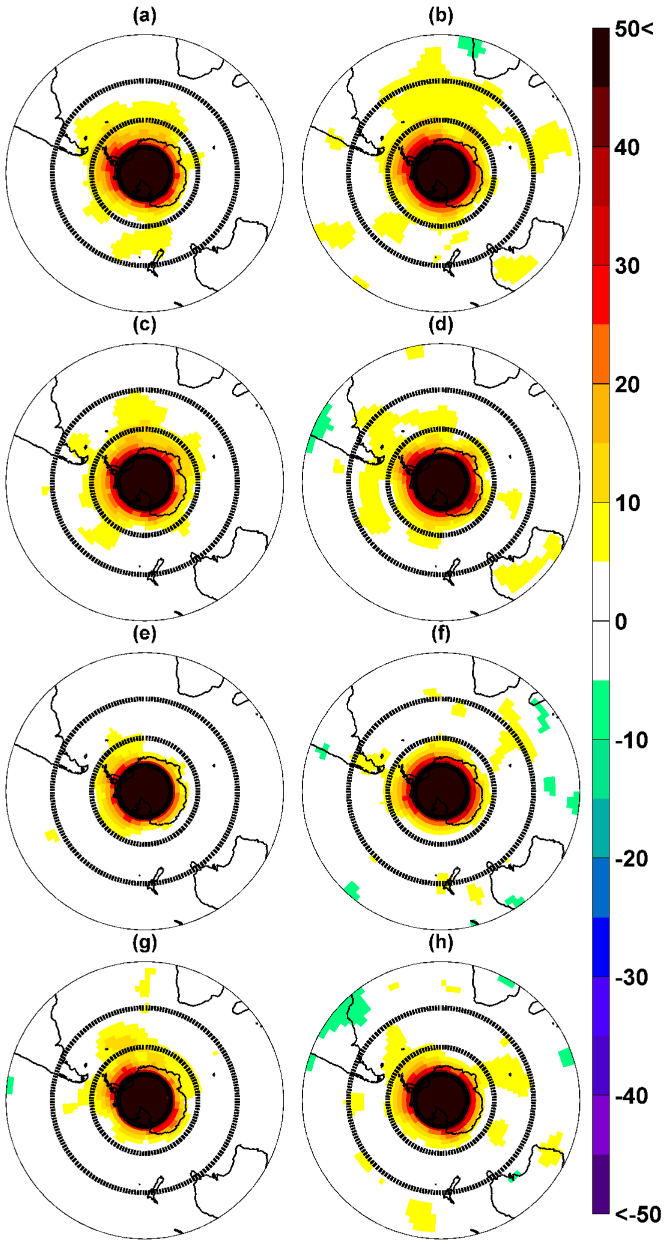

Fig. 4: Z500 RMSE reduction (%) due to relaxation south of 75 S in winter (JJA) averaged over (a) days 4-7, (b) days 8-14. (c) and (d) as (a) and (b) but for spring (SON), (e) and (f) for summer (DJF), and (g) and (h) for autumn (MAM). The dashed circles indicate the southern mid-latitudes between 40 S and 60 S.

The only land mass in the southern mid-latitudes between 40 and 60 S where an improvement of weather forecasts is most relevant is the southern tip of South America. At the same time in this region as well as downstream of it, i.e. over the South Atlantic, forecasts tend to be slightly more improved compared to other mid-latitude regions. Fig. 5 shows that forecasts are especially improved over southern South America and surroundings in all seasons but summer if there is an anomalous southerly flow from Antarctica into the target area. This makes sense as in such situations there is an anomalous transport of air masses from the relaxation area to southern South America and the benefit of the perfect knowledge over Antarctica can be felt. In summer there are only weak anomalies of the order of 20 m. It should be noted that there is another land mass even beyond 40 S, namely Australia, which seems to be affected by Antarctica, but only in winter and spring and only weakly. This could be a coincidence and can be regarded as noise given that in similar latitudes there are patches of RMSE increases which can not be physically explained. Indeed, the composite analysis of exceptionally improved weather forecasts for Australia compared to neutral forecasts for that area does not show any significant flow anomaly pattern.

It can be concluded that the influence of improved weather forecasts in the polar regions on the quality of mid-latitude weather forecasts or more generally the influence of the poles on the mid-latitudes is most pronounced in continental areas. This holds especially in situations with anomalous flow from the polar regions into continental target areas as well as in situations with a weakened westerly flow.

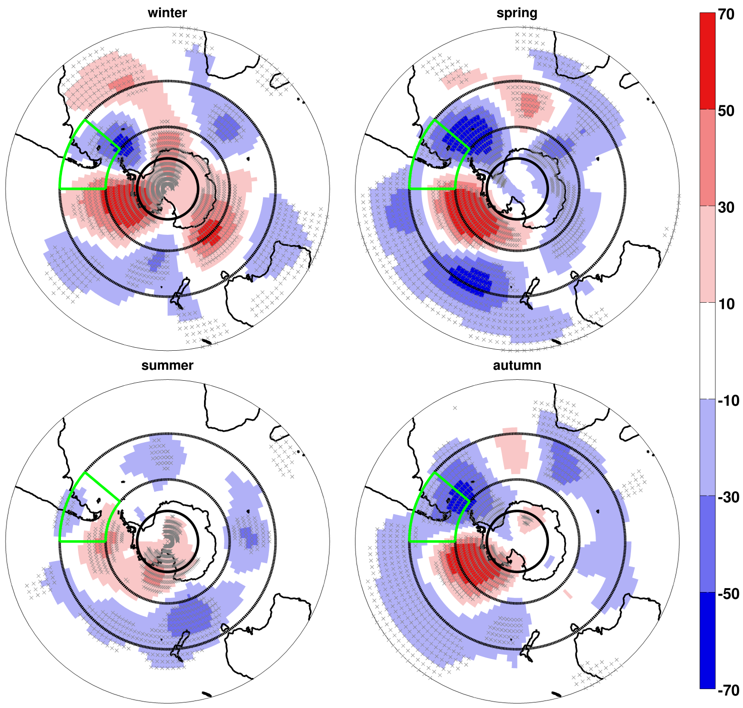

Fig. 5: Difference between Z500 composites (m) of exceptionally improved minus neutral forecasts over southern South America (40 S - 60 S, 90 W - 40 W) for forecast days 1-7 for each season. Areas marked with crosses are significant at the 95% level according to a Wilcoxon test. The inner black circle indicates the relaxation area, the outer black circles the southern mid-latitudes between 40 S and 60 S and the green box the target area: southern South America.

2. Seasonal experiments (Part II)

In order to investigate atmospheric teleconnections on longer time scales, seasonal simulations with the IFS (T255-L60, uncoupled) for winters and summers of the period 1979-2013 and 1980-2014, respectively, have been carried with and without relaxation of the atmosphere towards ERA-Interim data. The majority of the experiments has been carried out in December 2014; they have been finished in January 2015 using resources from the partner special project spdegrea. In the following, preliminary results from the experiments will be presented.

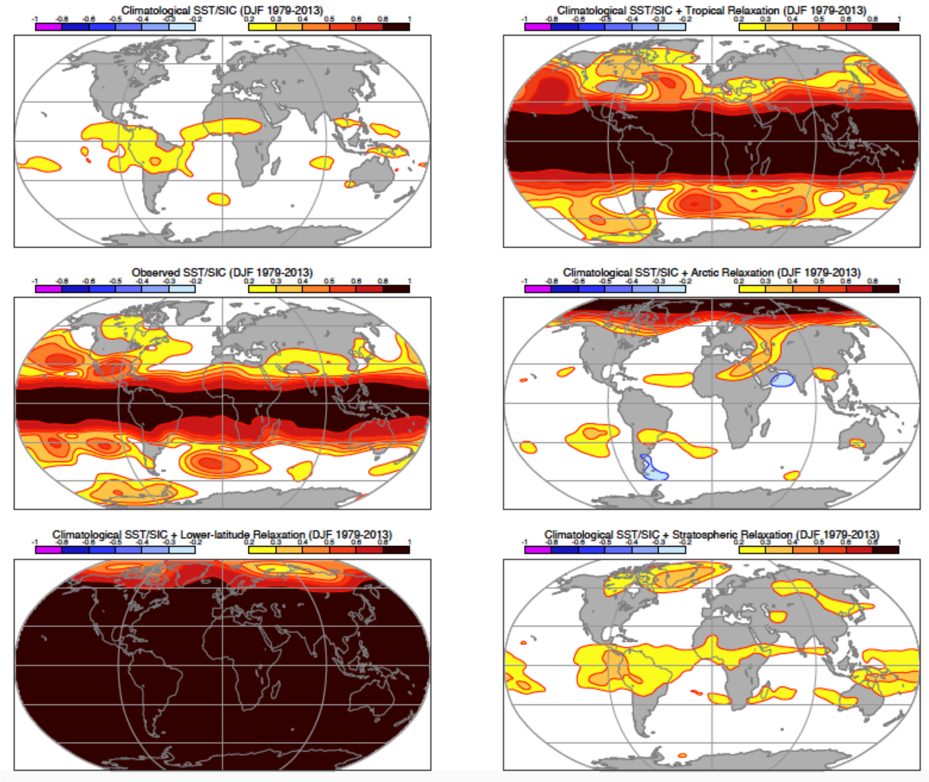

Fig. 6: Correlation coefficients for seasonal averaged (December through February) observed and simulated 500 hPa geoptential height fields. Correlations are based on a comparison of all 9 individual ensemble members with reanalysis fields for the period 1979-2013.

The impact of prescribing the lower boundary conditions (SST and sea ice concentration, SIC) and relaxing the atmosphere in certain parts on the evolution of seasonally averaged fields can be inferred from Fig. 6. Seasonal integrations with climatological lower boundary conditions show that the initial conditions are mostly „forgotten" after more than one month into the simuation. By prescribing observed lower boundary conditions, some of the observed variability can be captured; and this variability is mostly associated with the tropical processes and their teleconnections. The correlation map for the experiment with tropical relaxation looks very similar. The magnitude of the correlations, however, is larger.

Consistent with the results of Jung et al. (2014), Arctic relaxation has some influence on Z500 variability over continental regions of the Northern Hemisphere; over the North Atlantic and North Pacific Ocean the Arctic influence is relatively weak, with a mid-latitude influence on the Arctic dominating (Fig. 6). The correlation pattern for the experiment with Arctic relaxation shown high correlations in the northern centre of action of the NAO. However, given the lack of significant correlations in the Azores regions suggest that the NAO is actually not determined by prescribing the Arctic atmosphere. A similar argument holds for stratospheric experiments, where the tropospheric response shows a monopole in the northern centre of action of the NAO.

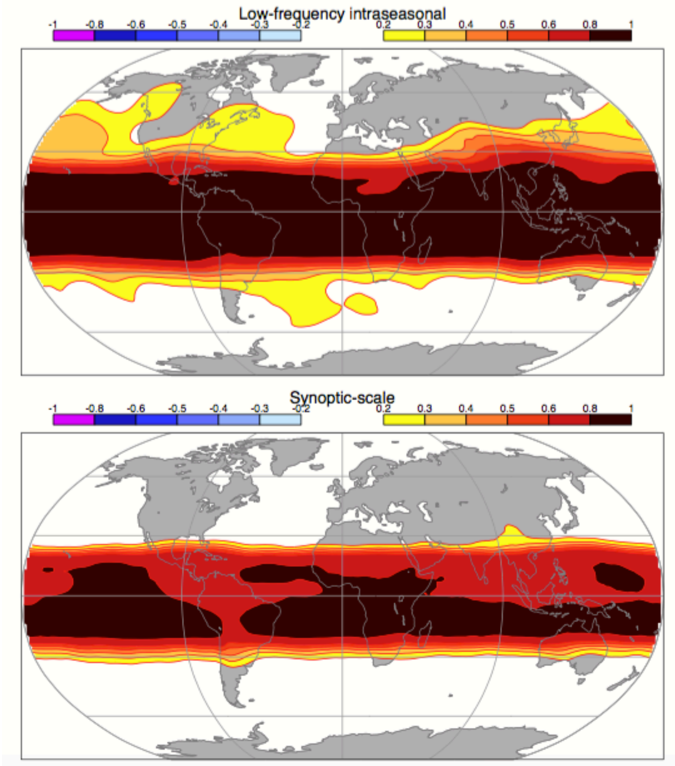

Fig. 7: Correlation coefficients for filtered daily observed and simulated (tropical relaxation) 500 hPa geoptential height fields. The upper panel shows results for lowpass-filtered (i.e. low-frequency intraseasonal variabilits) and the lower panel for highpass-filtered fields (i.e. synoptic-scale variability). Correlations are based on a comparison of all 9 individual ensemble members with reanalysis fields for the period 1979-2013.

It is instructive to consider, how much of the intraseasonal Z500 variability is driven from the relaxation regions. Preliminary results for the experiment with tropical relaxation are shown in Fig. 7. Evidently, synoptical-scale variability in the extratropical is soley determined by extratropical dynamics. For the low-frequency intraseasonal variability a larger tropical impact emerges. However, correlations are quite small, even in regions where tropical-extratropical teleconnections are known to occur. Our results highlight the importance of extratropical atmospheric dynamics when it comes to simulating and predicting intreasonal tropospheric variability.

References:

Jung, T., M. Kasper, T. Semmler and S. Serrar, 2014: Arctic influence on subseasonal mid-latitude prediction. Geophys. Res. Lett., 41, 3676–3680, doi:10.1002/2014GL059961.

List of publications/reports from the project with complete references

One paper has been submitted and two more are in preparation.

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

This project has been very strongly connected to spdegrea, and some of the work will continue in this framework. Another request for a special project will be submitted, in which the atmosphere will be relaxed towards climatological mean fields.