Project: **1146**

Project title: **Long-term trends in relation to the QBO**

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Report period: **2020-01-01 to 2020-12-31**

Report (27.10.2020)

Previous results have shown that long-term changes in both the stratosphere and the troposphere are much stronger during the westerly (QBO-West) than the easterly (QBO-East) phase of the tropical Quasibiennial Oscillation, as derived from reanalysis data (ERA-Interim) and the CMIP5 simulations with the Earth-System model MPI-ESM-MR including greenhouse gas emission (GHG) scenarios up to 2100 (Gabriel, 2019; the model data were kindly provided by MPI-Met Hamburg). The aim of the project is to investigate the processes controlling these changes based on additional sensitivity simulations with the MPI-ESM-MR (two with the RCP4.5 and two with the RCP8.5 scenario), where the change in radiative forcing is specified either to high-latitudes or up to mid-latitudes to extract the GHG-induced changes related either in the polar vortex or in the westerlies and mid-latitude planetary waves. Overall, the project works should be finished within about two years (2020/2021), inclusively publication.

Because of a delay in the research works, the simulations were not carried out during the first 10 months of the project period but have to be carried out during the second year of the project period (a request for computer resources is applied). However, as a preliminary work, additional analysis of reanalysis and existing model data have been carried out, providing a useful tool to analyse the planned simulations. An example is giving in the following.

The results of Gabriel (2019) have particularly shown a pronounced long-term change in the mid-winter stratospheric three-dimensional (3D) residual wind w_{res}, which is a reliable proxy of the 3D stratospheric mass circulation (w_{res} was calculated following Sato et al., 2013). This change is embedded in the long-term change of the stationary waves usually developing in the stratosphere during winter (preferably zonal wave number two during QBO-West and wave one during QBO-East). For orientation, Figure 1 shows the time mean pattern of w_{res} for QBO-West at the 10hPa-level under current climate conditions and its long-term change Δw_{res}, indicating a decrease of the wave-like pattern between North America and Europe as well as an increase in amplitude and eastward shift in phase of the downwelling branch over Asia.

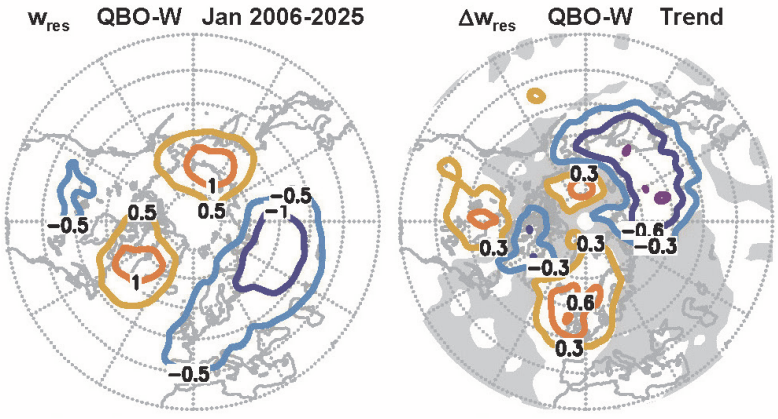

Figure 1: January-mean vertical residual wind w_{res} (isolines in 0.5 cms^{-1}, zero-line not shown) at 10 hPa for January 2006-2025 during the westerly phase of the QBO, and long-term change Δw_{res} over the total time period 2006-2100 (isolines in 0.3 cms^{-1}per 95 years), derived from the RCP45 simulation including the moderate CO_2-scenario; shaded areas: changes are not significant at the 95%-significance level (these plots are adopted from Gabriel, 2019, Figure 14).

One idea of the project is that the strength and position of the downwelling within the polar low might induce a tendency towards blocking surface high anomalies below this area, as suggested by basic meteorology. As a first guess, this relation can be illustrated by the temporal correlation

between the January-mean patterns of w_{res} and a specific surface pressure p_s averaged over a middle-east European region (20°-50°E, 40°-60°N). Figures 2 and 3 show examples of these correlation patterns, i.e., for a cross-section of w_{res} at 60°E for current climate conditions derived from ERA-Interim and the RCP45 simulation (Figure 2), and for w_{res} at 10hPa for the first and second half of the 21st century derived from the RCP45 simulation (Figure 3).

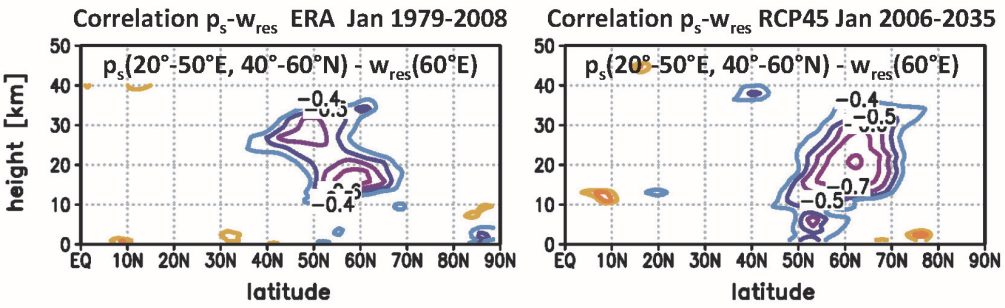

Figure 2: Temporal correlation between January means of a surface pressure p_s averaged over (20-50°E,40-60°N) and the vertical residual wind w_{res} at 60°E (isoline distance is 0.1), derived from (left) ERA-Interim 1979-2008 and (right) the first 30 years of the RCP45 simulation.

Figure 2 shows that, for current climate conditions, the variability of p_s over Eastern Europe is well correlated with the variability of the pronounced downwelling in the area of the polar low, which might indicate the assumed top-down forcing of blocking surface high anomalies. For QBO-West, the correlation patterns between p_s and w_{res} at 10hPa (Figure 3) indicate a long-term change of this relationship following the eastward shift of the maximum downwelling shown in Figure 1, i.e., a related eastward shift of the top-down forcing effect towards Eastern Asia.

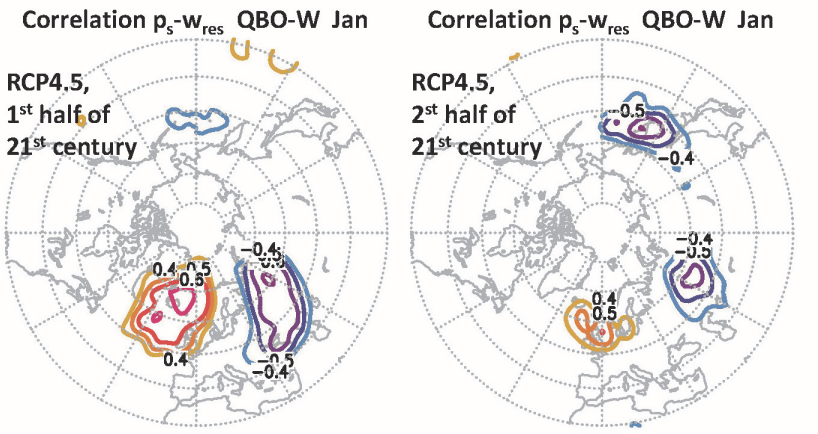

Figure 3: Temporal correlation between January means of a surface pressure p_s averaged over (20-50°E,40-60°N) and the vertical residual wind w_{res} at 10hPa during the westerly phase of the QBO (isoline distance is 0.1), derived from (left) the first and (right) the second half of the RCP45 simulation..

Overall, the eastward shift of the downwelling towards Eastern Asia may impose a corresponding eastward shift in the top-down forcing of surface high anomalies, i.e. a decrease in anticyclonic blocking events over North-Eastern Europe which could contribute to long-term changes in the circulation patterns related to the North-Atlantic oscillation (NAO). The ongoing project work will further elucidate the interactions between the changes in the stationary wave patterns, the downwelling embedded in the area of the polar vortex and the related top-down forcing effects.

References

Gabriel, A., (2019), Long-term changes in the northern midwinter middle atmosphere in relation to the Quasi-Biennal Oscillation, *J. Geophys. Res.*, 124, 13914-13942, doi:10.1029/2019JD030679.

Sato, K., T. Kinoshita and K. Okamoto (2013), A New Method to Estimate Three-Dimensional Residual-Mean Circulation in the Middle Atmosphere and Its Application to Gravity Wave–Resolving General Circulation Model Data. *J. Atmos. Sci.*, 70, 3756–3779.