Role Of the MIddle Atmosphere in a changing Climate (ROMIC-II): Joint project: The Quasi-Biennial Oscillation in a Changing Climate (QUBICC)

Abstract

The quasi-biennial oscillation (QBO) is the dominating mode of variability in the tropical stratosphere and known to modulate the circulation in the troposphere and in the extra-tropical atmosphere over a broad altitudinal range. As changes of the QBO are expected for a future warmer climate, due to changes in the tropical weather and the related atmospheric wave fields, which drive the QBO directly and indirectly, also QBO effects on the tropospheric climate are expected to change. The overarching goal of the proposed research is therefore to develop a better understanding of (1) the responses of the tropical gravity waves (GWs) and other tropical wave modes, (2) the QBO, which is driven by tropical waves, and (3) the QBO signal in the tropical deep convection to a changing climate. The main tools to be developed and used are new deep-convection resolving versions of the ICON model for new baseline simulations of the QBO, improved GW parameterizations, and satellite observations of tropical waves and winds. The simulations will be validated by the observations, and the GW parameterizations will be calibrated against the deep convection resolving simulations. The related research will include the following goals, which are to be realised at the MPI-M in strong cooperation with the project partners:

- **New baseline simulations of the QBO in deep convection resolving models**
  A new version of the ICON general circulation model will be developed that excludes parameterizations of deep convection and GW drag, so that the two leading causes of uncertainty in the QBO forcing are avoided. These uncertainties currently impede any reliable statement on the response of the QBO to a changing climate. The development will include idealized small domain model setups for process studies and a realistic full domain setup for a comparison of the simulated and observed QBO in present conditions. These baseline simulations will be used to quantify in detail the forcing mechanism of the QBO.

- **Future changes in GWs, the QBO and deep convection**
  Here the new model setup will be employed for current and future climate conditions in order to develop a better understanding of the changes in (1) the wave field that forces the QBO, (2) the QBO itself, and (3) the QBO modulation of the deep convection. For this purpose, deep-convection resolving QBO simulations will be analyzed for idealized current and future climate conditions on small domains. Properties of the excited GWs and tropical wave modes will be validated against observations. The idealized climate modifications will include the effects of the tropospheric warming that will be most important for the convectively triggered waves that can drive the QBO, as well as the effects of composition changes on the radiative wave damping that is important for the wave meanflow interaction.

- **Comparison of observed and simulated QBO**
  We will compare the observed wave fields and momentum fluxes, and the observed QBO structure with the simulated wave field and the QBO in initialized seasonal simulations with start dates in periods with either SABER or Aeolus observations. The simulations will extend over six months to one year. The initial states will be chosen for different QBO phases. The skill in these simple hindcasts will be assessed both for the convection resolving setup and the lower resolution setup with parameterized GW sources and drag.

Among the QBO effects, the modulation of tropical deep convection is particularly intriguing, with only little research so far. We want to investigate (4) the mechanism of this modulation, and (5) how it may change in the future. The main focus of this sub-project in QUBICC is to understand the

modulation of the QBO on the tropical deep convection through idealized experiments using ICON-A.