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Improved QBO teleconnection due to reduced model circulation biases

Alexey Yu. Karpechko[1] , Nicholas Tyrrell[1] and Sebastian Rast[2]
[1]FMI, Helsinki, Finland; [2] MPI-Meteorology, Hamburg, Germany (alexey.karpechko@fmi.fi)

Abstract

The Quasi-Biennial Oscillation (QBO) in equatorial stratospheric zonal winds correlates with extratropical zonal circulation (QBO teleconnection). The westerly QBO phase is normally associated with a stronger stratospheric polar vortex and positive phase of the Arctic Oscillation in the Northern Hemisphere in mid-winter. This teleconnection can potentially be used to improve seasonal forecasts. Here, the sensitivity of the QBO teleconnection to biases in model circulation is explored in an atmosphere-only model ECHAM6-T63L95 with an internally generated QBO. We contrast simulations by an original, biased model, and a model version in which biases are artificially reduced. To reduce model biases, we first run the model with its winds and surface pressure nudged towards observations. Second, the annually repeated nudging tendencies from the first step are added to winds and surface pressure in an otherwise freely running model. This two-step procedure allows the model to freely develop variability and can be thought of as implementation of a parameterization scheme that artificially corrects biases arising from unresolved processes. Each ECHAM experiment is run for 100 years. We find that while an original model has only marginal QBO teleconnection to extratropical stratosphere, the bias-corrected model has strong QBO teleconnection similar to that seen in observations. Further tests show that reducing biases only in the stratosphere is not enough to improve teleconnections.

1. Zonal mean

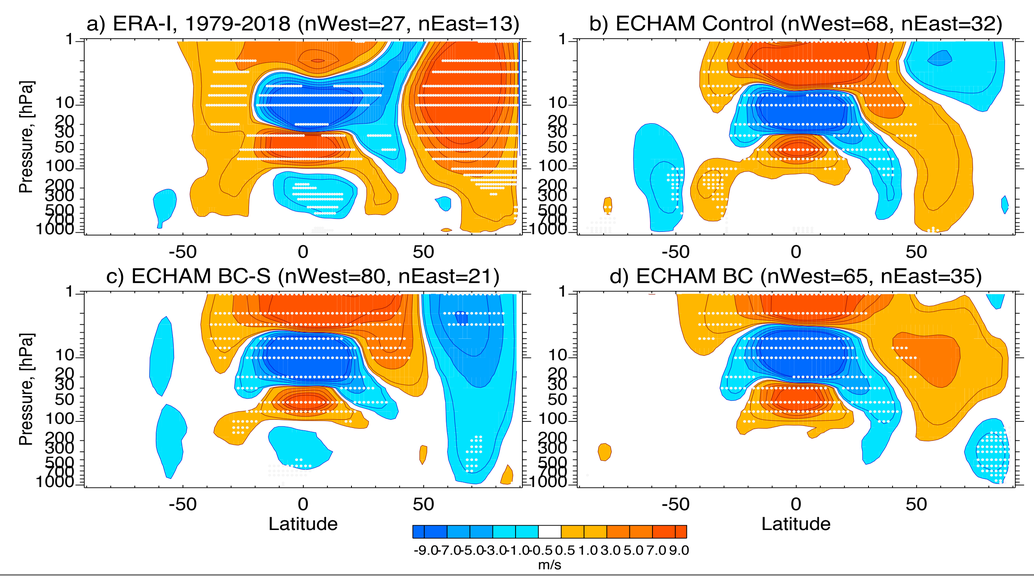

Fig.1: *Difference in January zonal mean zonal (U) winds between QBO-W and QBO-E in* ***(a)*** *ERA-I and* ***(b-d)*** *ECHAM versions.* ***(b)*** *Original biased model* ***(control)****;* ***(c)*** *model with bias-correcting tendencies applied globally to winds but only above 100 hPa* ***(BC-S)****;* ***(d)*** *model with bias-correcting tendencies applied globally to winds and surface pressure* ***(BC)****. White dots mark significant differences (p=0.05).*

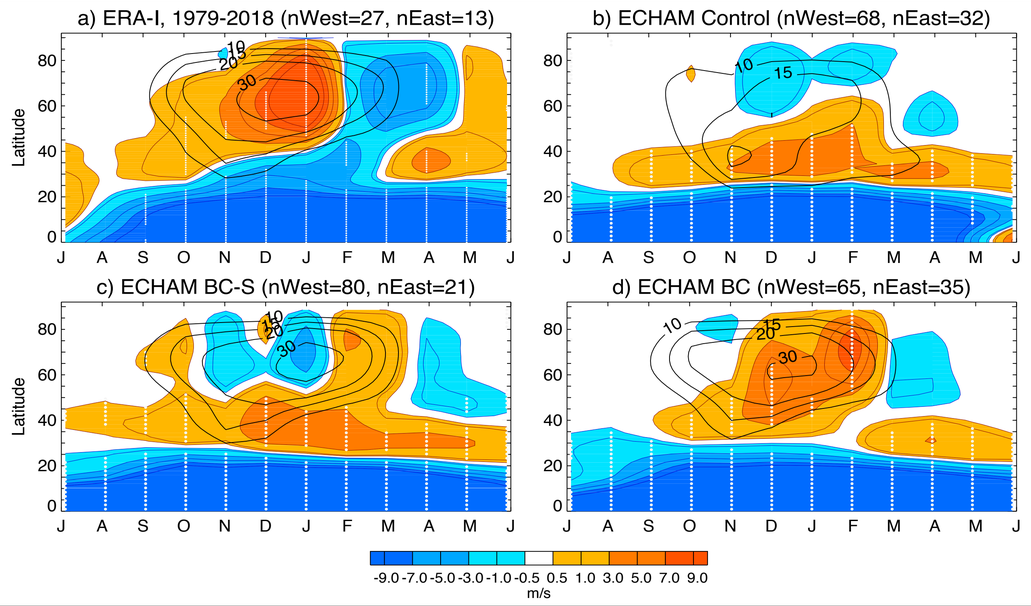

Fig.2: *Difference in 10-hPa monthly zonal mean zonal winds between QBO-W and QBO-E in* ***(a)*** *ERA-I,* ***(b)*** *Control,* ***(c)*** *BC-S and* ***(d)*** *BC ECHAM runs. Contours mark climatological winds. White dots mark significant differences (p=0.05).*

2. Waves

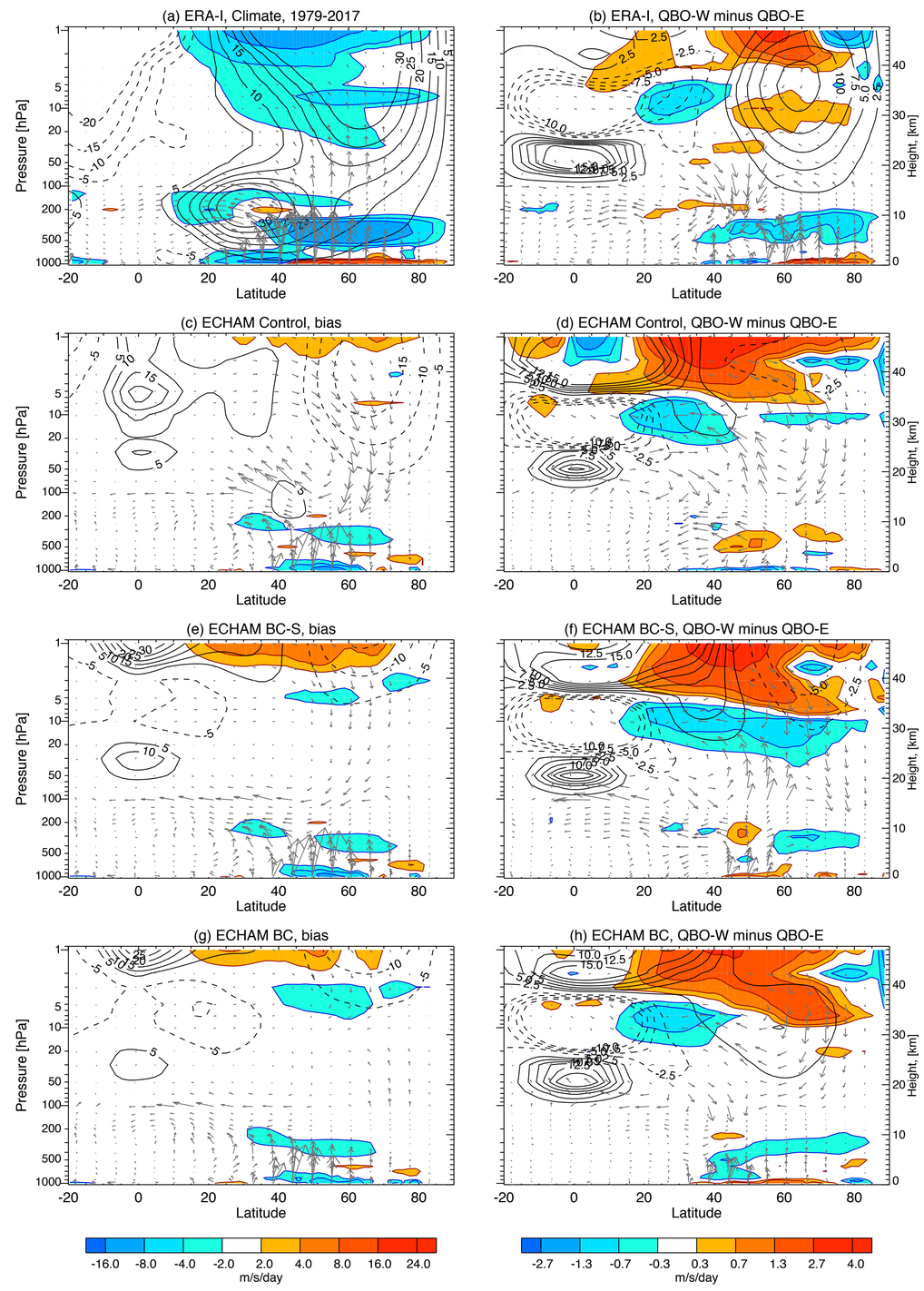

Fig.3: *(**a**) ERA-I December-January mean U-winds (contours), Eliassen-Palm (EP) fluxes (arrows) and their divergency (shadings);* ***(b)*** *ERA-I December-January mean differences in U-winds and EP-fluxes between QBO-W and QBO-E;* ***(c,e,g)*** *Biases in December-January mean U-winds and EP-fluxes with respect to ERA-I in* ***(c)*** *Control,* ***(e)*** *BC-S and* ***(g)*** *BC;* ***(d,f,h)*** *December-January mean differences in U-winds and EP-fluxes between QBO-W and QBO-E in* ***(d)*** *Control,* ***(f)*** *BC-S,* ***(h)*** *BC.*

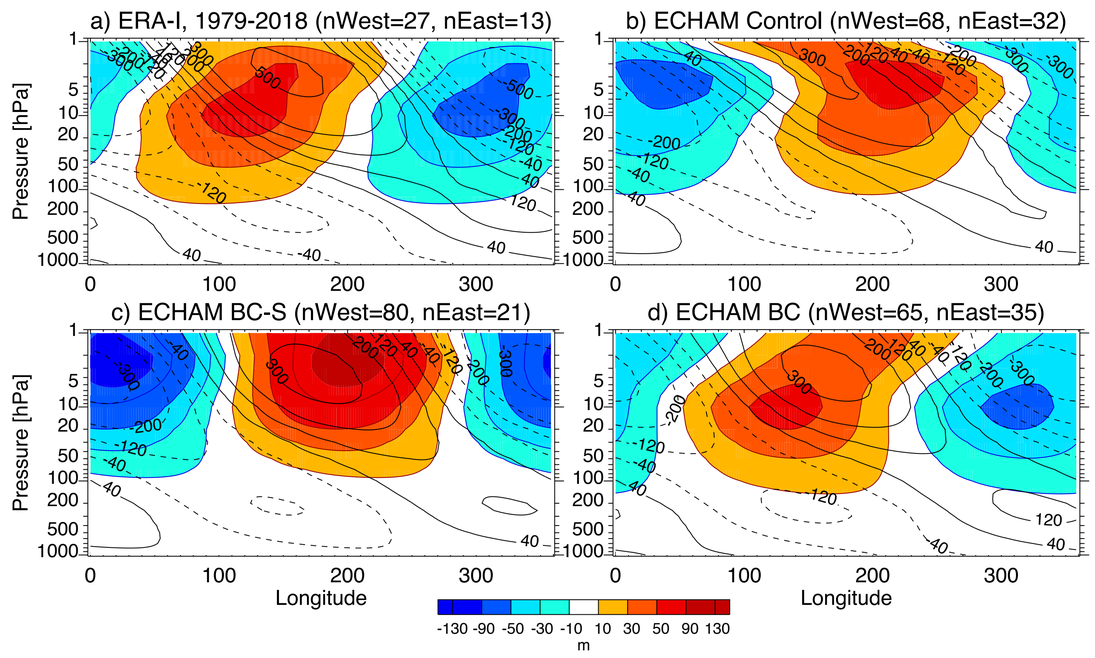

Fig.4: *Difference between QBO-W and QBO-E in December-January mean wavenumber 1 geopotential height (40°N-60°N) in* ***(a)*** *ERA-I,* ***(b)*** *Control,* ***(c)*** *BC-S and* ***(d)*** *BC ECHAM runs. Contours mark climatological wavenumber 1 magnitudes.*

Key findings

1) Northern hemisphere extratropical zonal wind response to QBO is greatly improved by reducing biases in tropospheric and stratospheric circulation (***Figs. 1-2***)
2) In bias-corrected run (BC), stronger stratospheric winds in QBO-W are related to downward anomalous EP-flux in extratropical lower stratosphere (***Fig. 3***) and out-of-phase anomalous wavenumber 1 in the stratosphere (***Fig. 4***), as observed in ERA-I.
3) At the same time, reducing biases only in the stratospheric circulation (BC-S) is not enough to get realistic QBO teleconnection in zonal winds (***Fig. 1-2***) and in the planetary waves (***Fig. 3-4***)
4) A possible reason for sensitivity of the teleconnection to tropospheric biases maybe the magnitude of the *tropospheric* wavenumber 1 (***Fig.4***). While the magnitude is realistic in the BC run, it is underestimated by factor 1.5-2 in Control and BC-S runs. Unrealistically small tropospheric wave forcing maybe less sensitive to QBO-induced changes in wave transmittance properties of the equatorial stratosphere, leading to weak teleconnections in biased models.