Response of the QBO to Abrupt Increases in CO_2 Using Three Atmospheric Chemistry Configurations

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Experiments

- Using the GISS "Middle Atmosphere" Climate model E2.2 *(Rind, Orbe, et al. 2020)*, we explore the response of the QBO to abrupt changes in CO_2, and the role of ozone feedbacks:

  NINT: fixed ozone, only CO_2 evolves

  LINOZ: ozone evolves following the linearized scheme of *McLinden et al. [2000]*

  OMA: all trace gases and aerosols evolve interactively

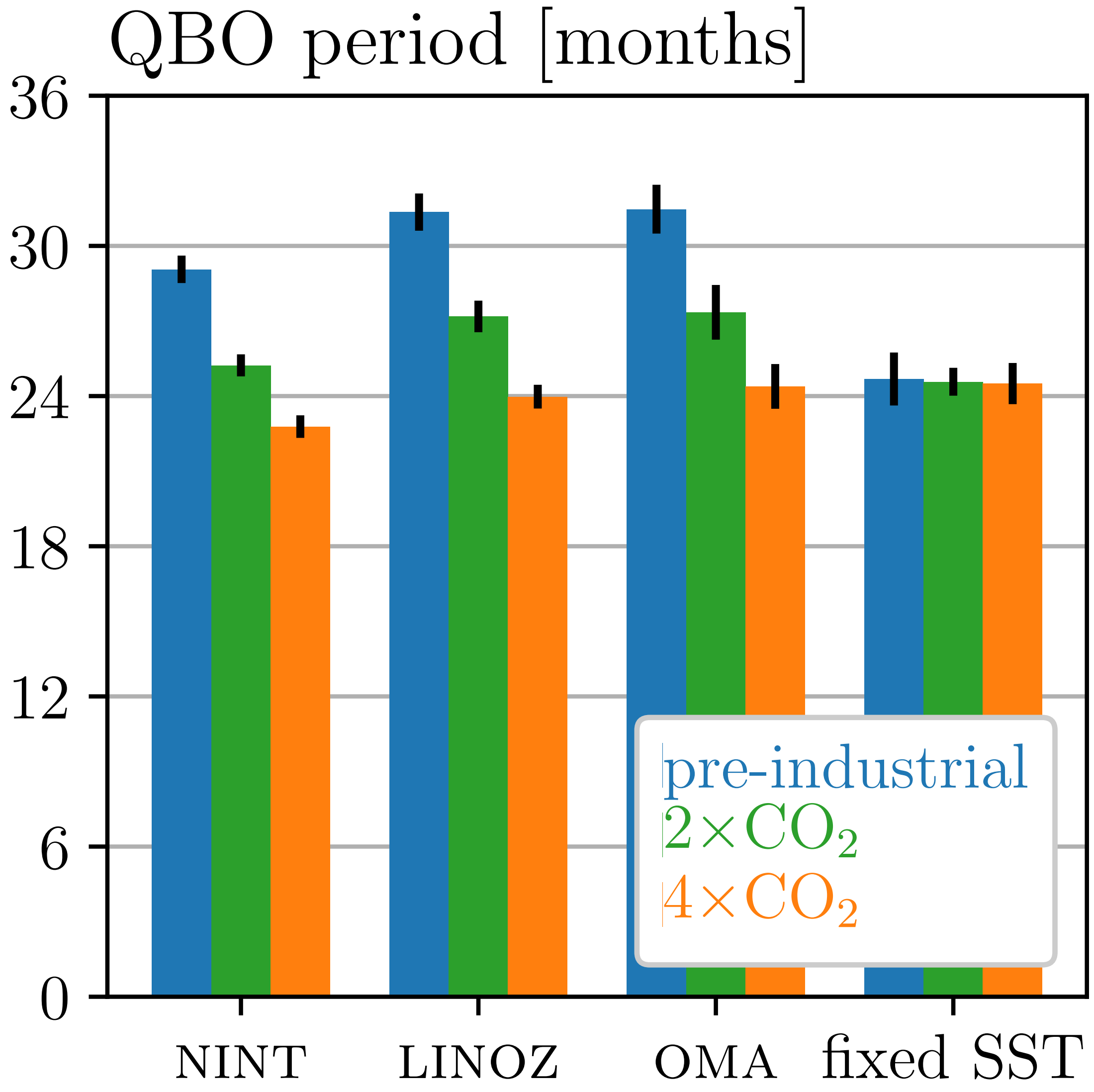
  Fixed SST: As in NINT, but with SSTs prescribed from a pre-industrial control (PiControl)

- For all configurations the results from the PiControl, $2xCO_2$ and $4xCO_2$ experiments are shown.

- QBO period and amplitude are evaluated using EOF analysis *(cf. Wallace et al. 1993)*

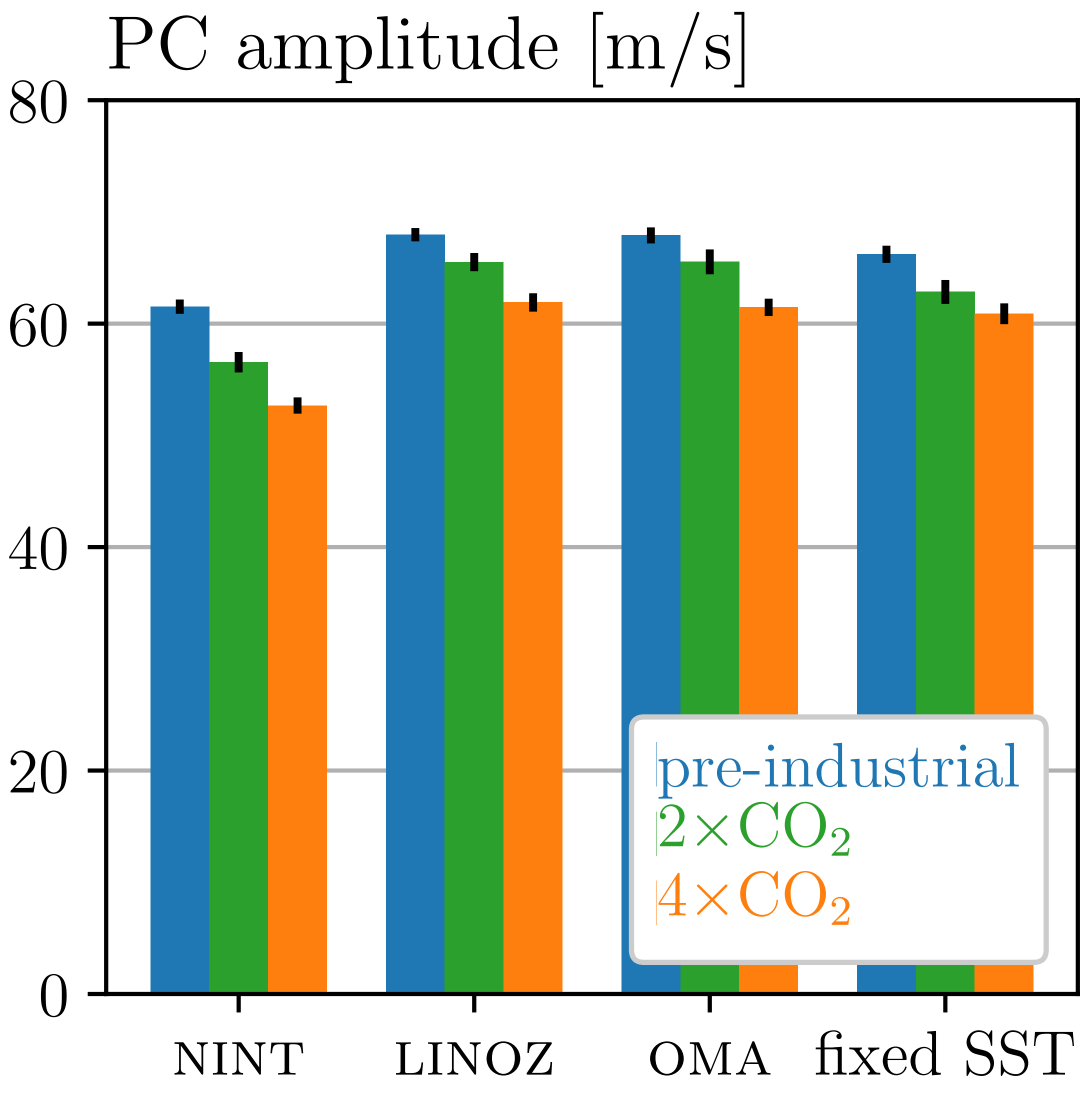
1. QBO period

- Mixed results from the multi-model QBOi study *(Richter et al. 2020).*
- Here in the NASA GISS model, in which non-orographic gravity wave drag is explicitly tethered to convection (and shear), CO_2 decreases the QBO period.
- Changes in ozone increase the control period *(cf. Butchart et al. 2003)*, but not its response to CO_2. Additional chemistry does not appear to modulate the period response.
- The period does not change in fixed SST runs, pointing to the role of changes in momentum fluxes due to (parameterized) convection.



2. QBO amplitude

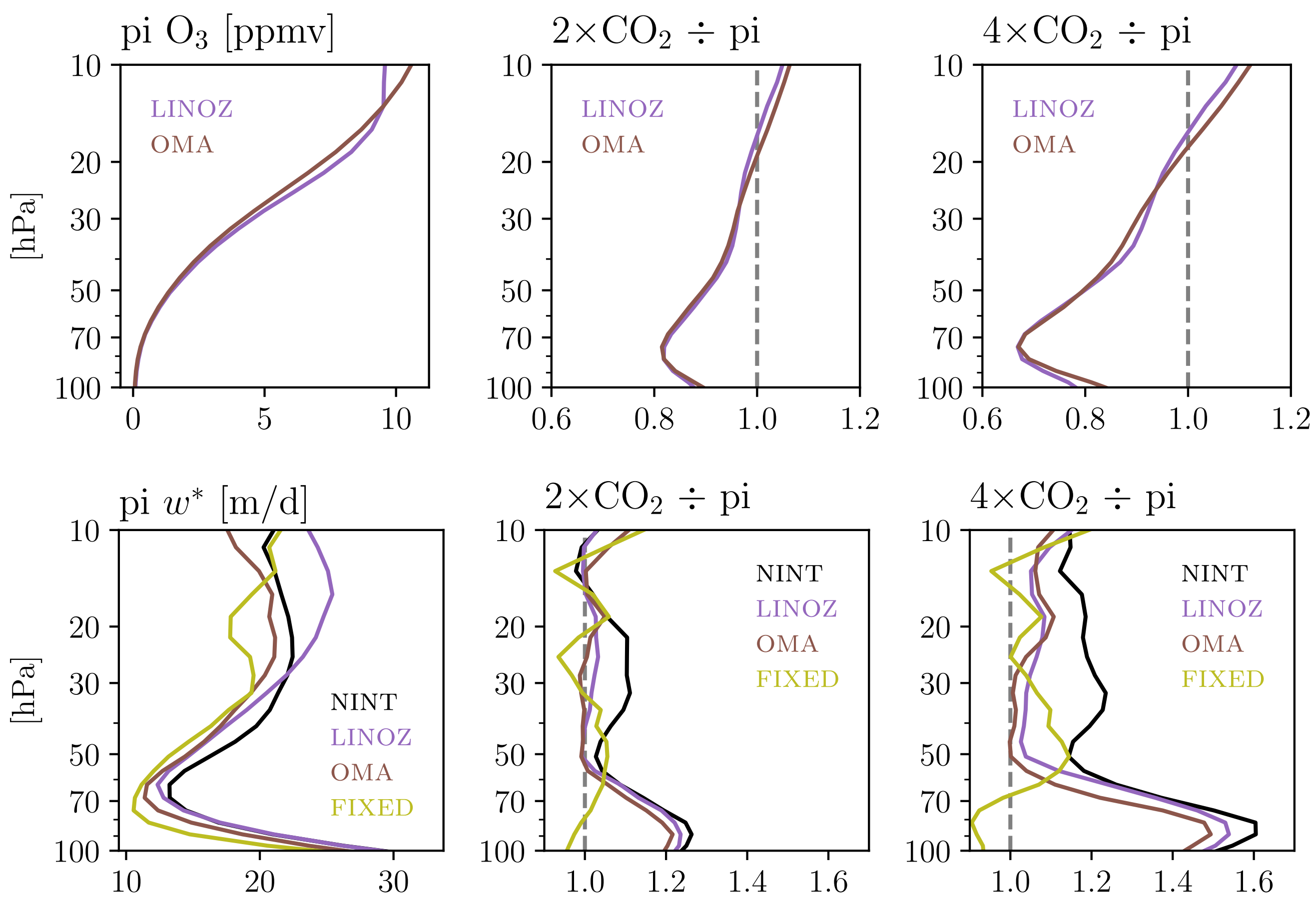
- In the GISS model, CO_2 also weakens QBO amplitude, particularly for the easterly phase.
- This is consistent with most studies *(Kawatani & Hamilton 2013, Richter et al. 2020)*, and with increases in lower stratospheric upwelling.
- Interactive ozone increases amplitude *(cf. Butchart et al. 2013)* and seems to temper the amplitude response to CO_2. Both ozone changes and the basic state appear to play a role in this.



3. Role of Ozone Changes

- Ozone feedbacks impact (weaken) the upwelling response.
- Enhanced upwelling with increased CO_2 is associated with QBO amplitude weakening, and an out-of-phase momentum forcing.
- Very good agreement between linearized ozone (LINOZ) and full chemistry (OMA) schemes, which offers significant computational savings.

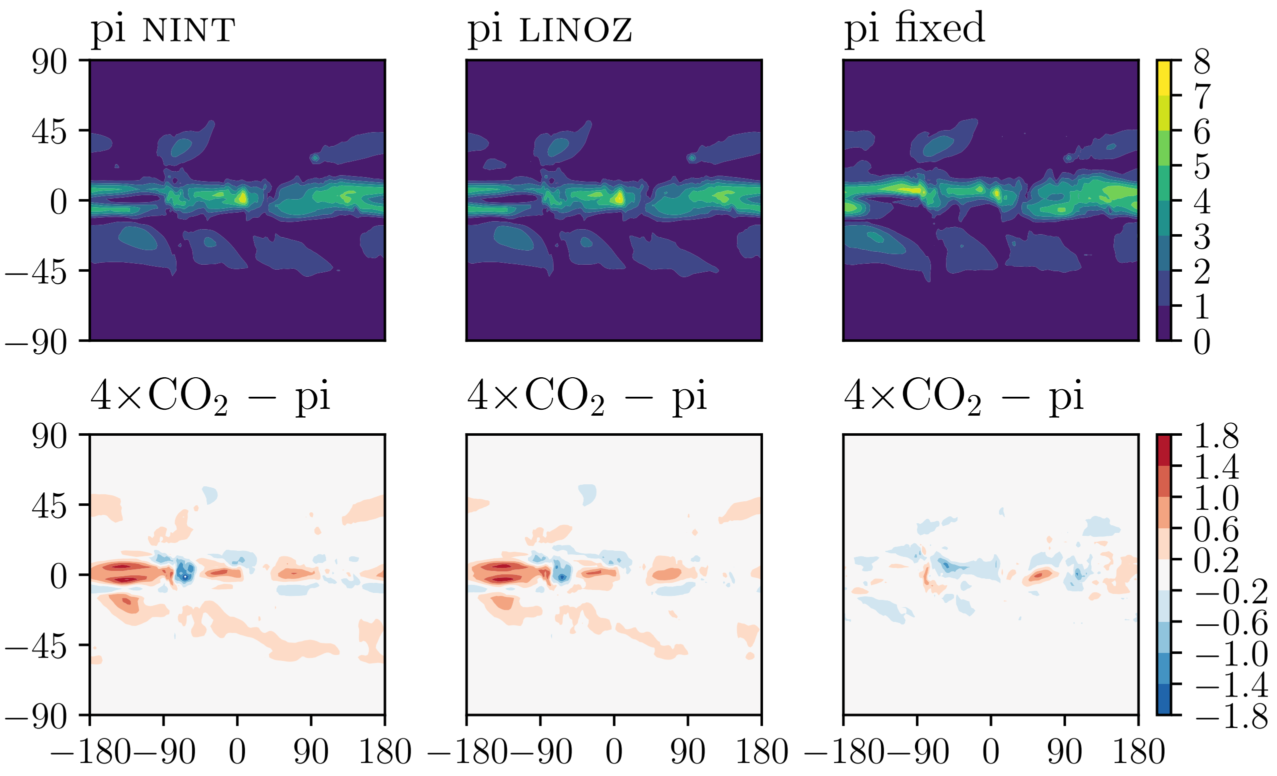
Tropical average from 5ºS to 5ºN



4. Momentum Flux Changes

- Parameterized convective momentum flux (MF) changes appear to be linked to changes in QBO period (in-phase momentum forcing).
- Very similar response in NINT and LINOZ integrations (OMA not shown).
- Fixed SST integrations exhibit minimal momentum flux changes, concomitant with minimal QBO period response.

Momentum Flux (MF) due to (Parameterized) Convection



*Note that the non-orographic gravity wave drag forcing associated with convection is parameterized in Model E2.2 as $F = (\text{constant})\rho_0 k(\text{MF}^2)^2 N_0 \vec{V}/|\vec{V}|$