

The QBO as driver of lower stratospheric ozone variability as quantified in the CCM SOCOLv3

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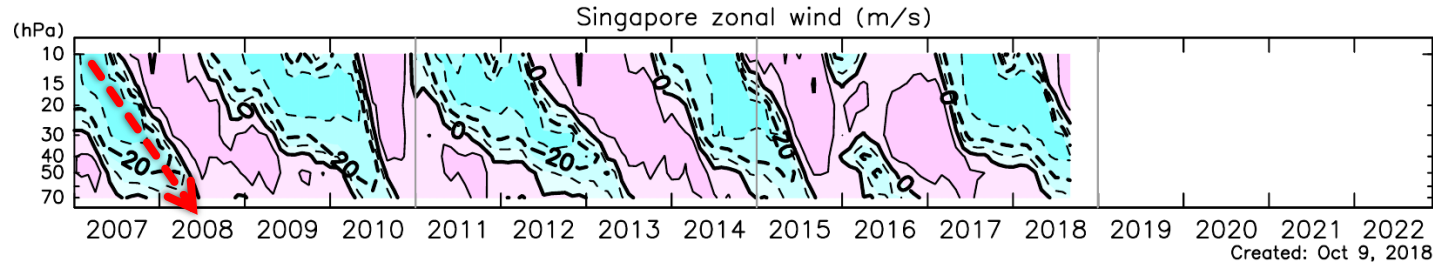
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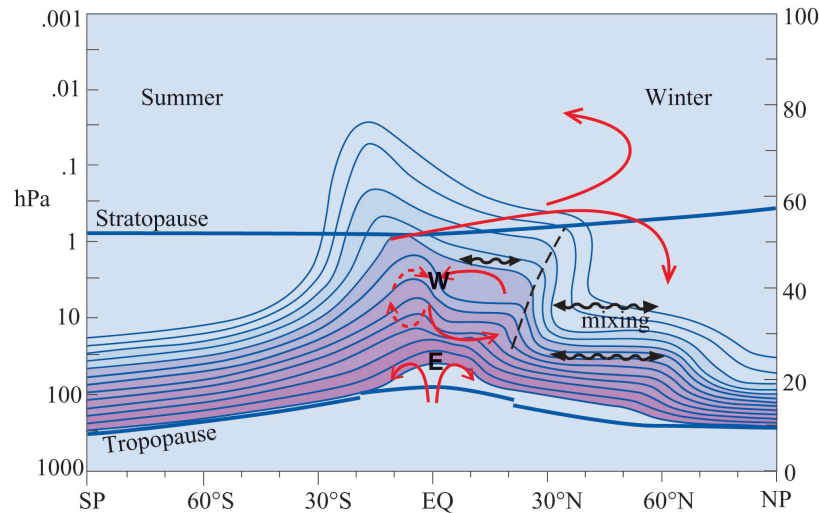
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Quasi-biennial oscillation

Change of zonal wind in equatorial lower stratosphere with period of 25 – 27 months.



<https://www.gfd-dennou.org/arch/eriko/QBO/>

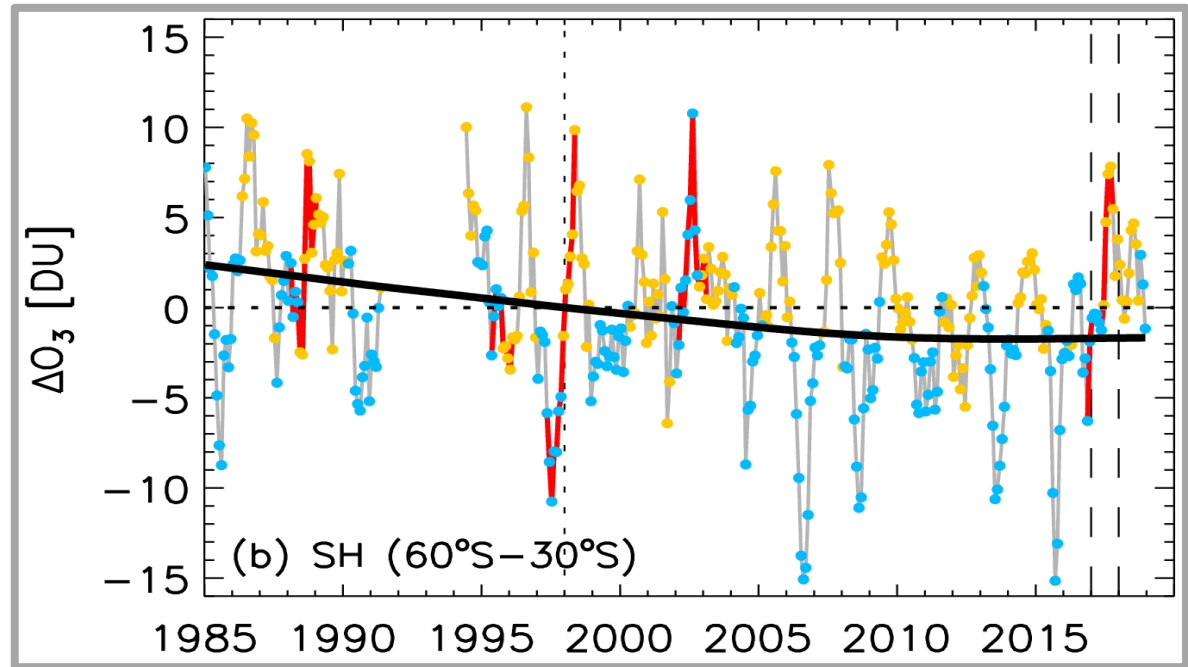


Temperature anomalies associated with vertical wind shear (thermal wind balance) induced secondary meridional circulation (red arrows), which affects tracer transport. Extratropical variability is seasonally synchronize and peaks during winter/spring.

QBO and lower stratospheric ozone

Lower stratospheric partial column ozone anomalies for the SH (60–30 S, 147–30 hPa). Coloured dots are plotted on each time series when the QBO at 30 hPa is either in an easterly (yellow) or westerly (blue) phase.

Ball et al. (2019)



QBO-E ●

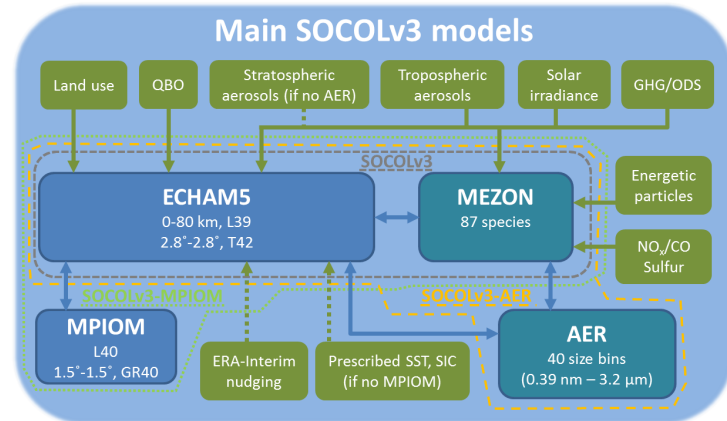
QBO-W ●

Goals & Methods

Goals: Improved understanding of QBO impact on lower stratospheric ozone variability and of the interaction between simulated stratospheric circulation and the QBO-induced secondary circulation in CCMs

Method:

- Chemistry-Climate Model SOCOLv3
- 20-member ensemble in **free-running mode**
- Simulations in **specified dynamics mode**:
 - Model dynamics relaxed to ERA-Interim
 - Troposphere-only vs. whole domain
 - QBO-nudging tests



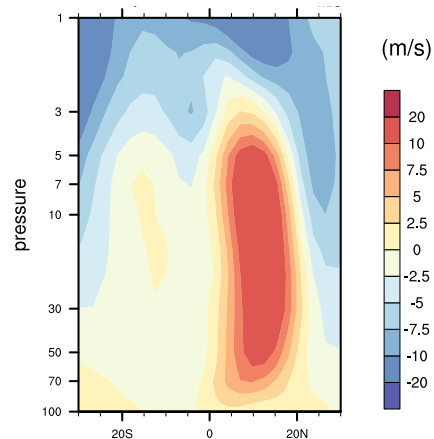
Model simulations

Exp	Resolution	Period	Set-up
FR_QBOa	T42L39	2005 – 2018	20-member ensemble in free-running mode, CCMI REF-C1 boundary conditions, QBO nudged (method A)
SD	T42L39	1980 – 2018	Specified dynamics simulations; nudging domain: surface – 0.01 hPa
SD_L90	T42L90	1980 – 2018	Specified dynamics simulations; nudging domain: surface – 0.01 hPa
SD_TP	T42L39	1980 – 2018	Specified dynamics simulations; nudging domain: nudging domain: 735 – 255 hPa full, 4 levels above/below transition; QBO nudged (method A)
SD_TP2	T42L39	1980 – 2018	Specified dynamics simulations; nudging domain: 735 – 455 hPa full, 4 levels above/below transition; QBO nudged (method A)
SD_TP2_QBOb	T42L39	1980 – 2018	Specified dynamics simulations; nudging domain: 735 – 455 hPa full, 4 levels above/below transition; QBO nudged (method B)
SD_TP2_QBOc	T42L39	1980 – 2018	Specified dynamics simulations; nudging domain: 735 – 455 hPa full, 4 levels above/below transition; QBO nudged (method C)
SD_O3nudge	T42L39	1980 – 2018	Specified dynamics simulations; nudging domain: surface – 0.01 hPa; Ozone above 10 hPa relaxed towards BASIC _{SG} observational composite

QBO nudging methods

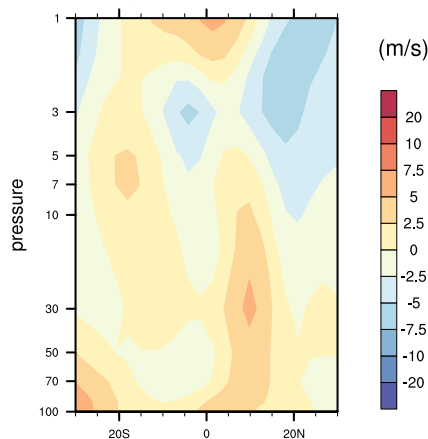
QBO-A:

- Relaxation to Singapore wind profile: $u = f(p)$
- Symmetric:
20N - 20S, 90 - 3 hPa.



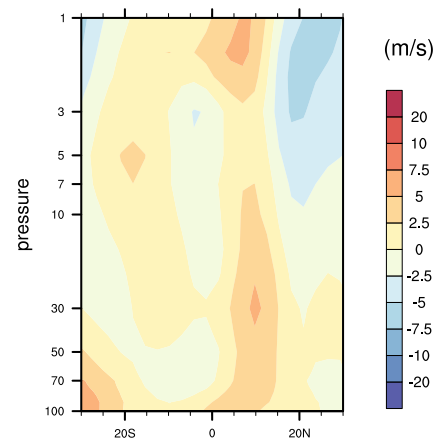
QBO-B:

- Relaxation to ERA-Interim zonal winds: $u = f(p, lat)$
- Non-symmetric:
20N - 20S, 90 - 3 hPa.



QBO-C:

- Analog as QBO-B, but extended up to 0.01 hPa

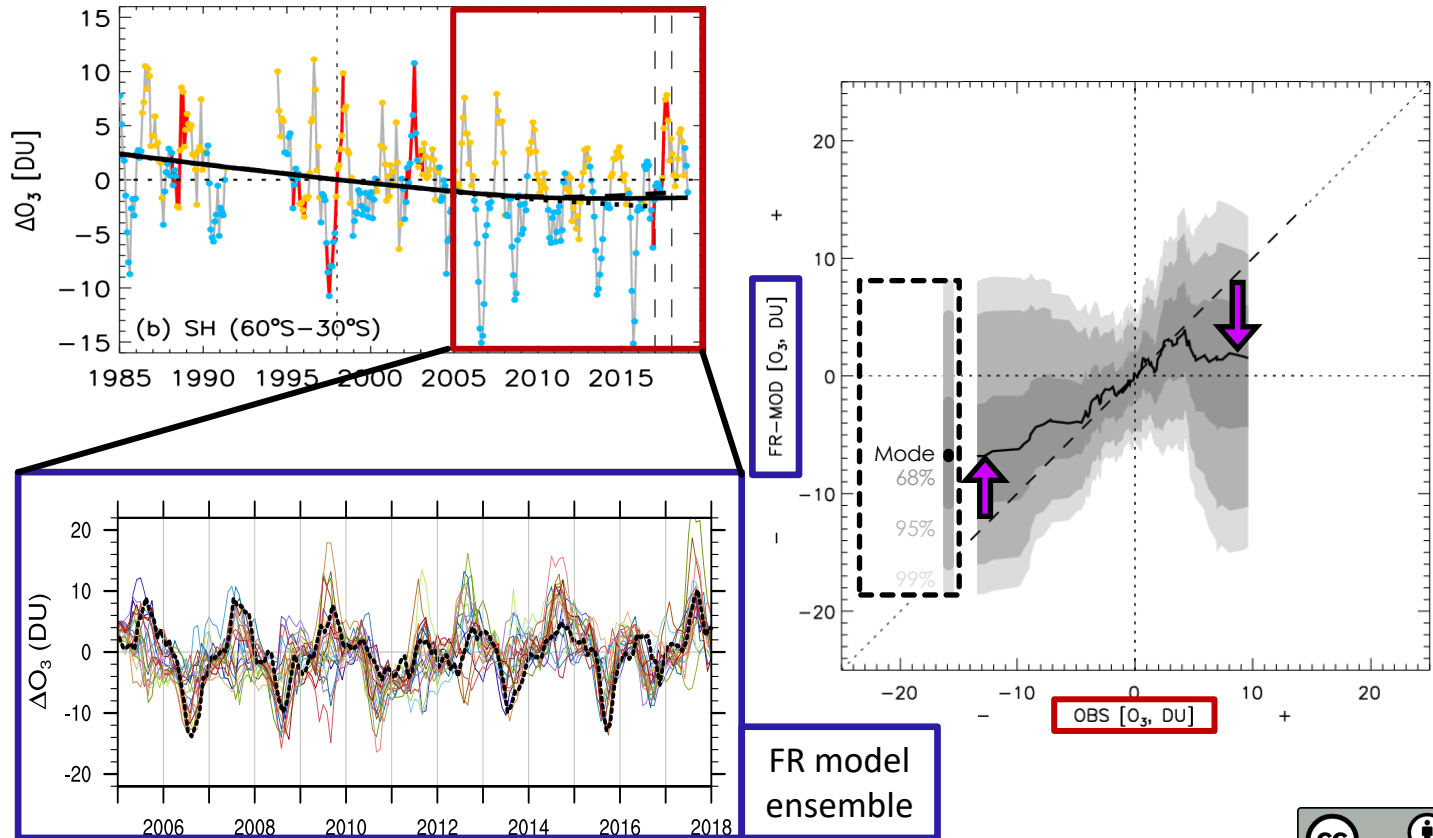


Zonal wind biases (wrt ERA-Interim) in SOCOL applying different QBO nudging for July.

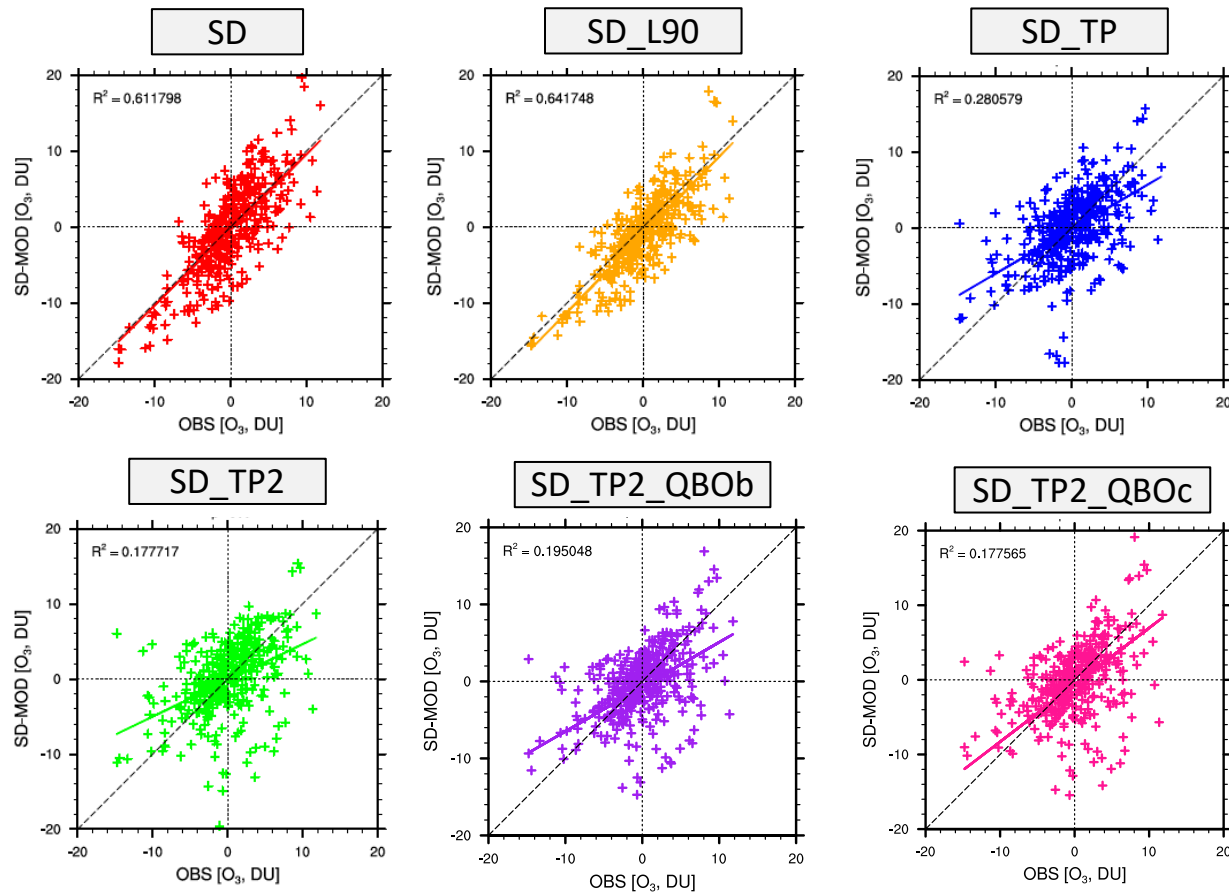
→ Hemispherically symmetric nudging (QBO-A) leads to erroneous patterns in the respective summer hemisphere, resulting in an unrealistic secondary meridional circulation with adverse effects on tracer transport!

SOCOL FR: O₃ variability 30S – 60S, 147 – 32 hPa

- 20-member ensemble in free-running mode, QBO nudged (QBO-A)
- No single best ensemble member
- Observed variability not reproduced



SOCOL SD: O₃ variability 30S – 60S, 147 – 32 hPa

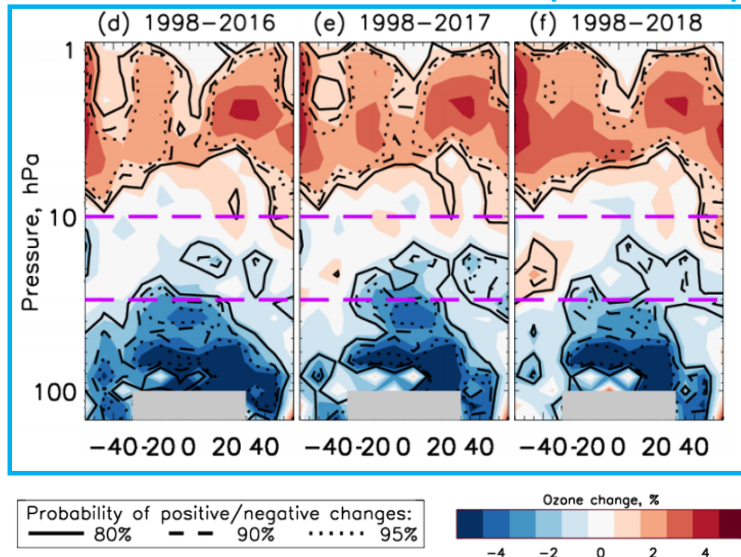


Ozone anomalies [DU] in SH lower stratosphere from SOCOL SD simulations (y-axis) vs. the BASIC_{SG} observational composite (x-axis, Ball et al., 2019) for 1985 to 2018 (Pinatubo period omitted).

- Only the fully nudged model simulations SD and SD_L90 show a good agreement with the observations.
- **Nudging of tropospheric dynamics and QBO not sufficient.**

LS O₃ trends

Observations (Ball et al., 2019)



- Topics: robust decrease
- Mid-lats: unclear, large QBO-effect

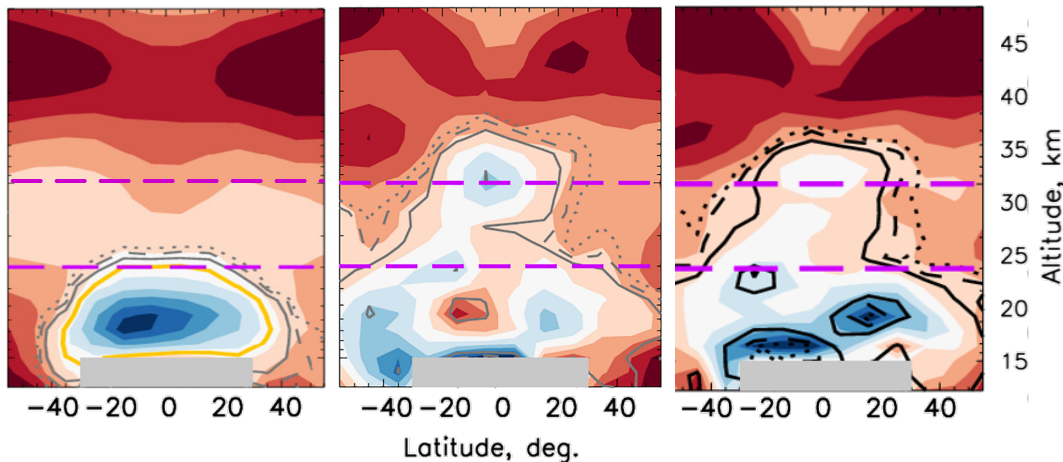
SOCOL

Specified dynamics

Free-running

L39

L90



- Neither FR, nor SD SOCOL (and other CCMs) accurately reproduce the long-term changes in LS
- Upper stratospheric ozone trends overestimated

Summary

- The QBO can drive large seasonal variability in extratropical LS ozone (10 – 20 %)
- SOCOL-FR (QBO nudged) only partly reproduce observed variability
- Specified dynamics:
 - Only fully nudged simulations capture observations
 - Nudging of tropospheric dynamics and QBO not sufficient
- Vertical model resolution does not affect results
- Neither specified dynamics, nor free-running models reproduce long-term trends in LS ozone
- Overestimated trends in upper stratosphere do not affect trends lower down
- Outlook: in-depth analysis of interactions between Brewer-Dobson-Circulation and QBO-phase in SOCOL

References

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