Simulations of the Quasi-Biennial Oscillation for 1980-2014 using the 2° version of the Whole Atmosphere Community Climate Model

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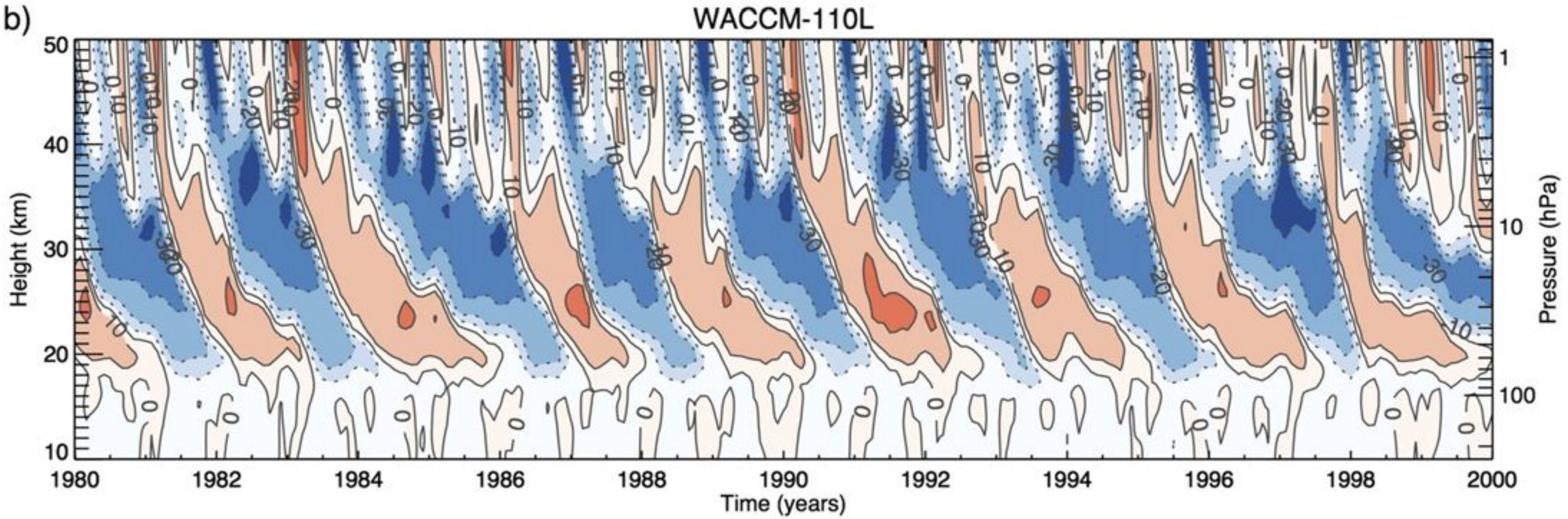
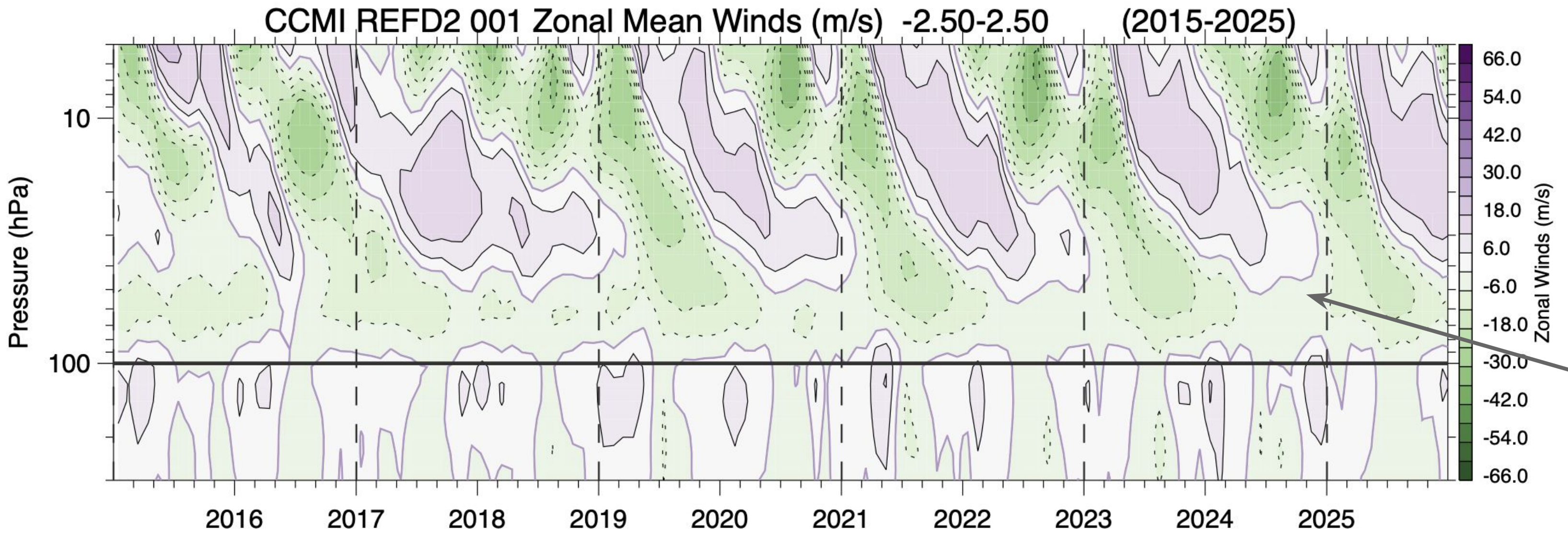


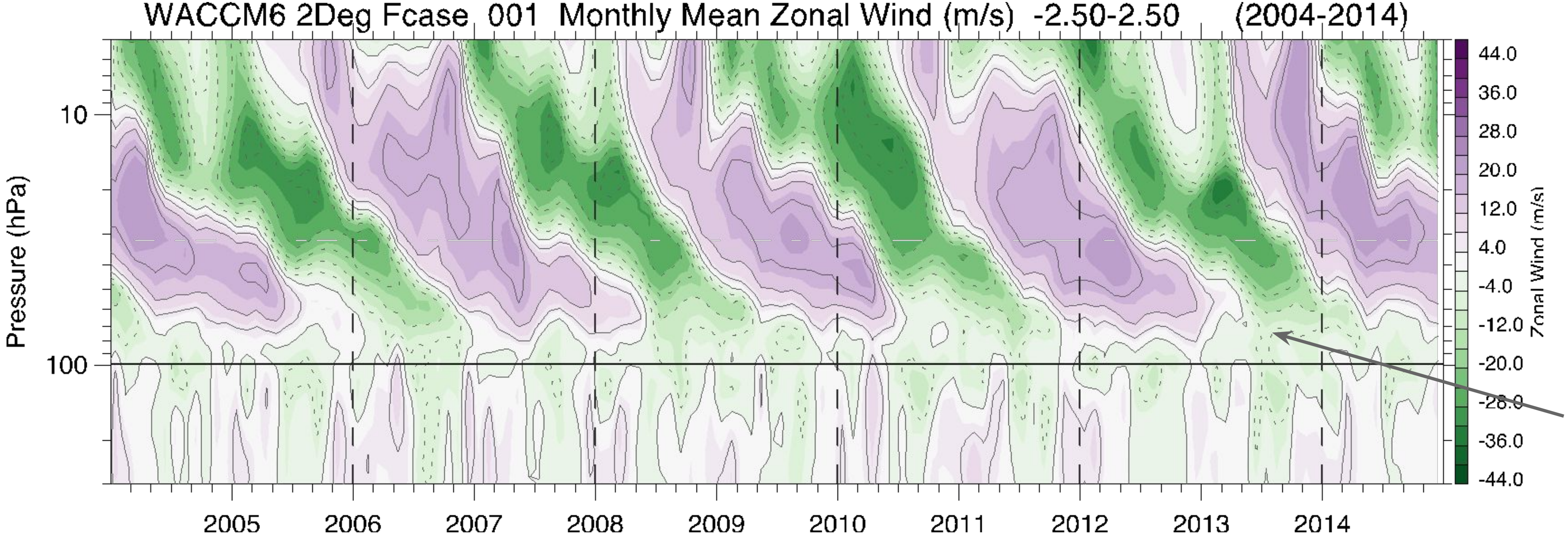
WACCM-110L, 1°
(0.95°×1.25°)

Successful simulation of the QBO: adequate horizontal and <u>vertical resolution</u>, a realistic simulation of tropical convection and a means of describing the effects of mesoscale gravity waves [Garcia and Richter, 2019].



WACCM-70L, 1°
(0.95°×1.25°)

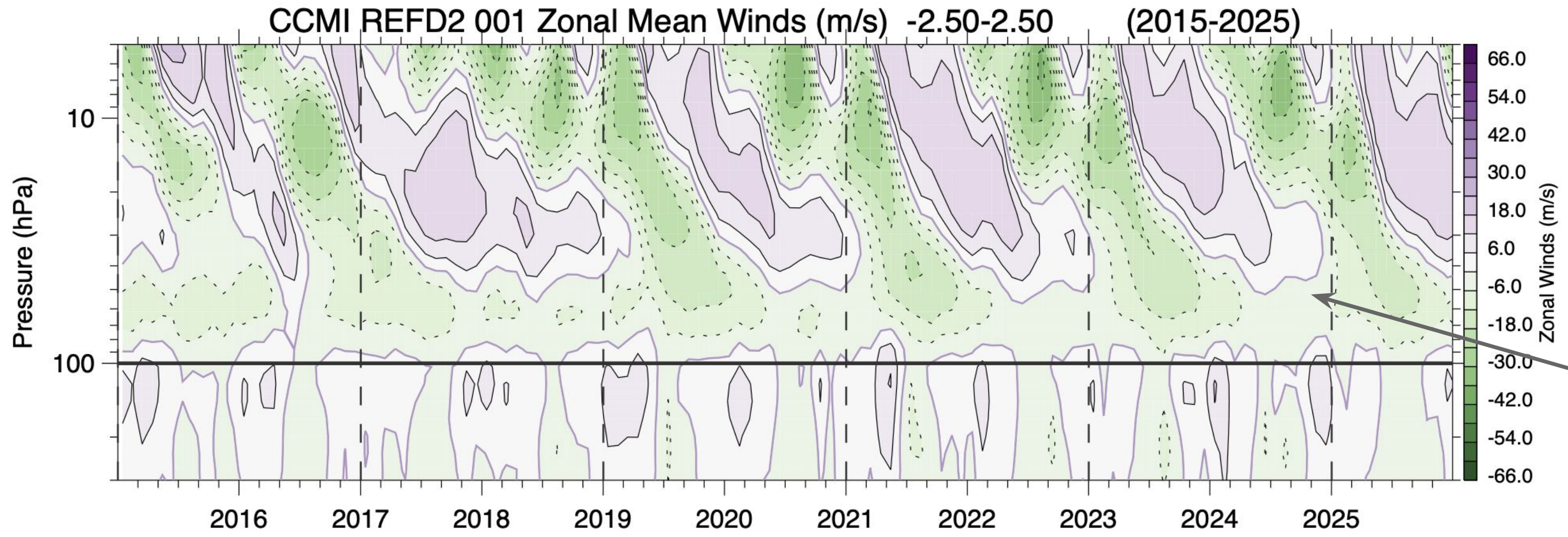
The QBO westerly does not come down to lower altitudes.



WACCM-110L, 2°
(0.95°×1.25°)

Reasonable QBO

Middle Atmosphere Chemistry, Data Ocean (obs), Interactive QBO



WACCM-70L, 1°
(0.95°×1.25°)

The QBO westerly does not come down to lower altitudes.

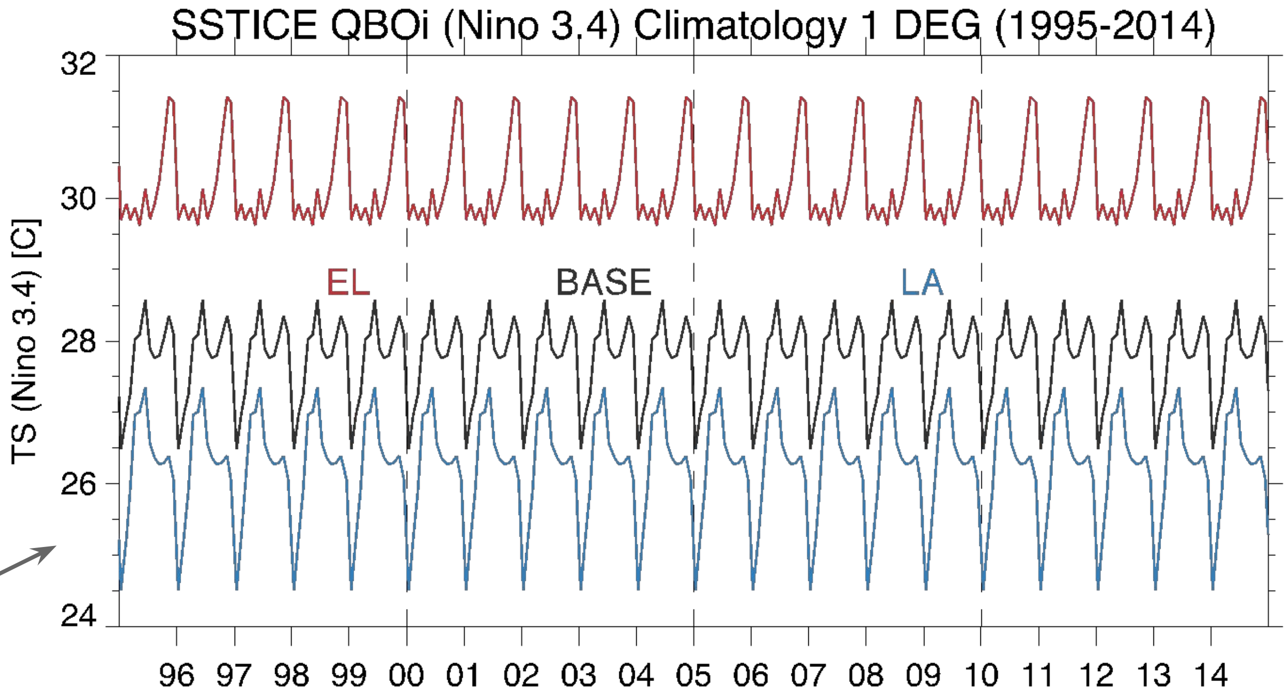
Key Points

High vertical resolution - A broad spectrum of atmospheric waves is necessary to generate the QBO in the model. Vertical resolution is sufficient enough to resolve waves with vertical wave lengths of 2.8 km or longer [Giorgetta et al., 2002].

Lower costs - The robust features of the QBO in the 2° configuration of WACCM6 are promising for further studies under various climate scenarios at the lower costs afforded by 2° resolution.

Potential modulation of the QBO by perpetual El Niño and La Niña conditions is examined by conducting model simulations with the composites of sea surface temperature anomalies constructed for **QBOi ENSO-QBO** experiment.

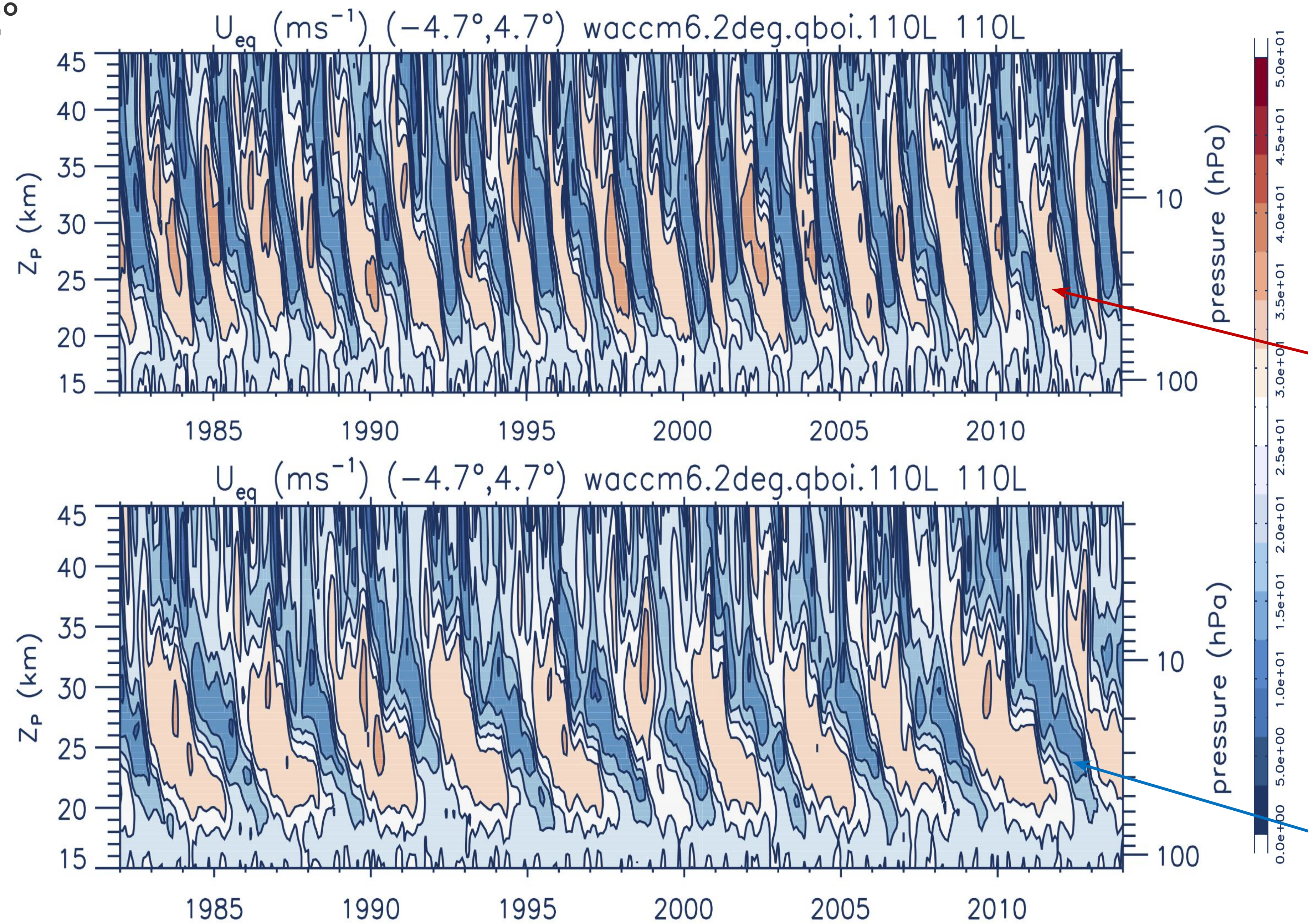
SST input



WACCM 6 - 2° (1982-2014)

Perpetual EL

Perpetual LA

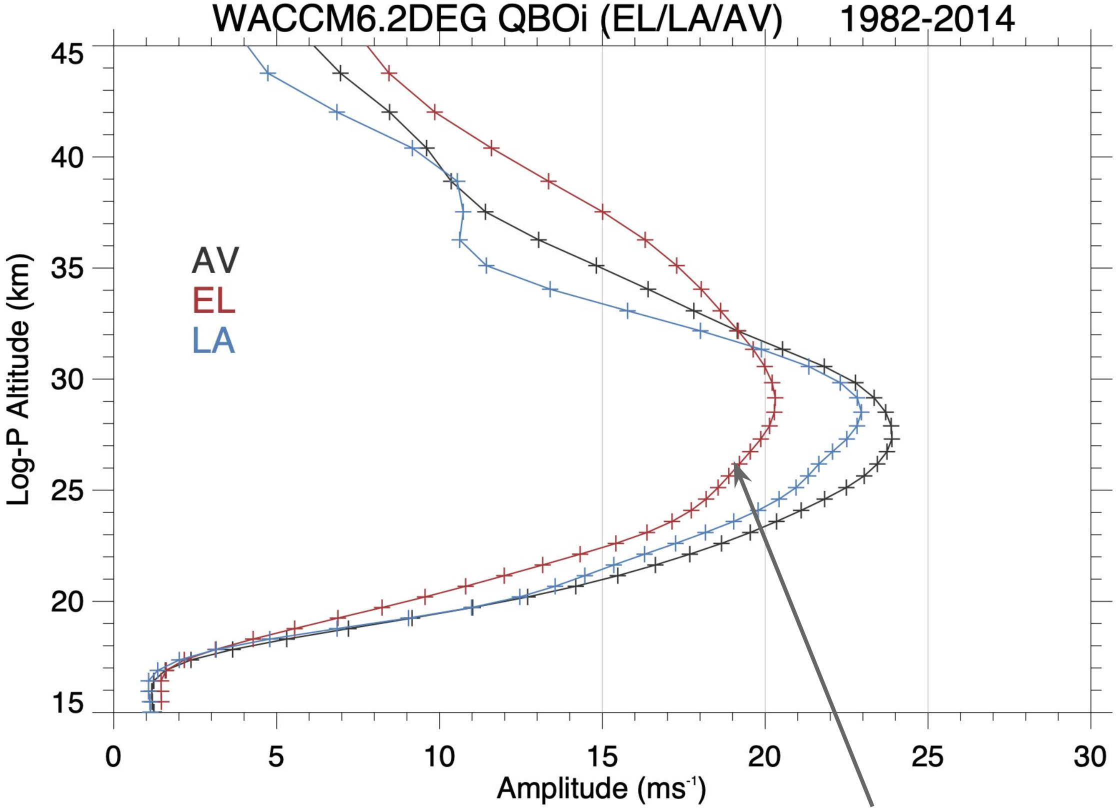


Shorter QBO Period

Longer QBO Period

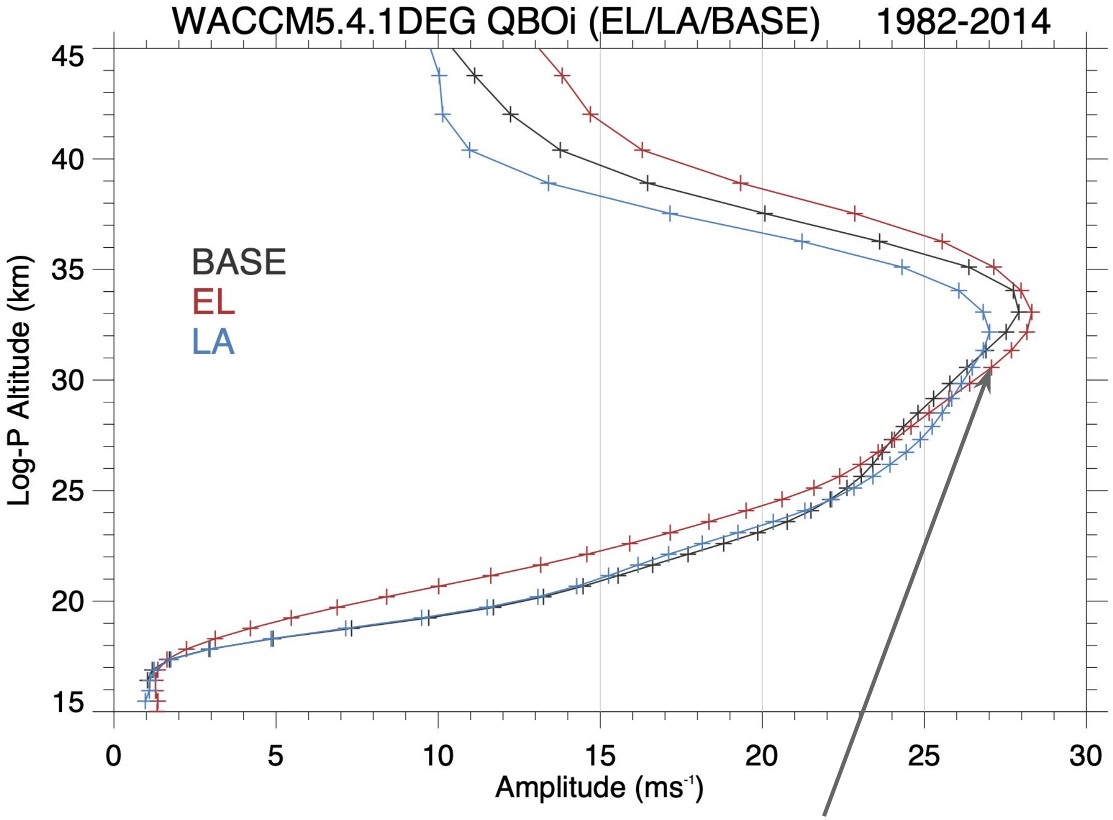
QBO Amplitudes

WACCM6 – 2°



EL- QBO amplitudes weaker

WACCM5.4 – 1°

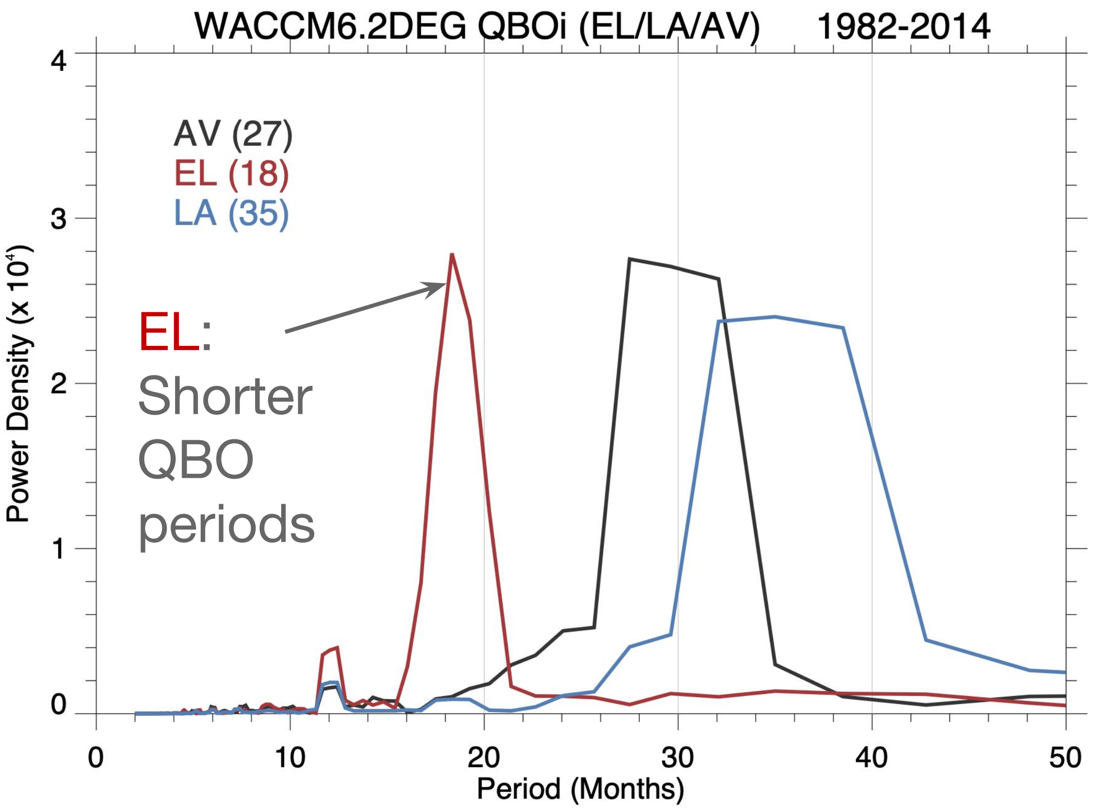


EL- QBO amplitudes stronger above 28 km and weaker below.

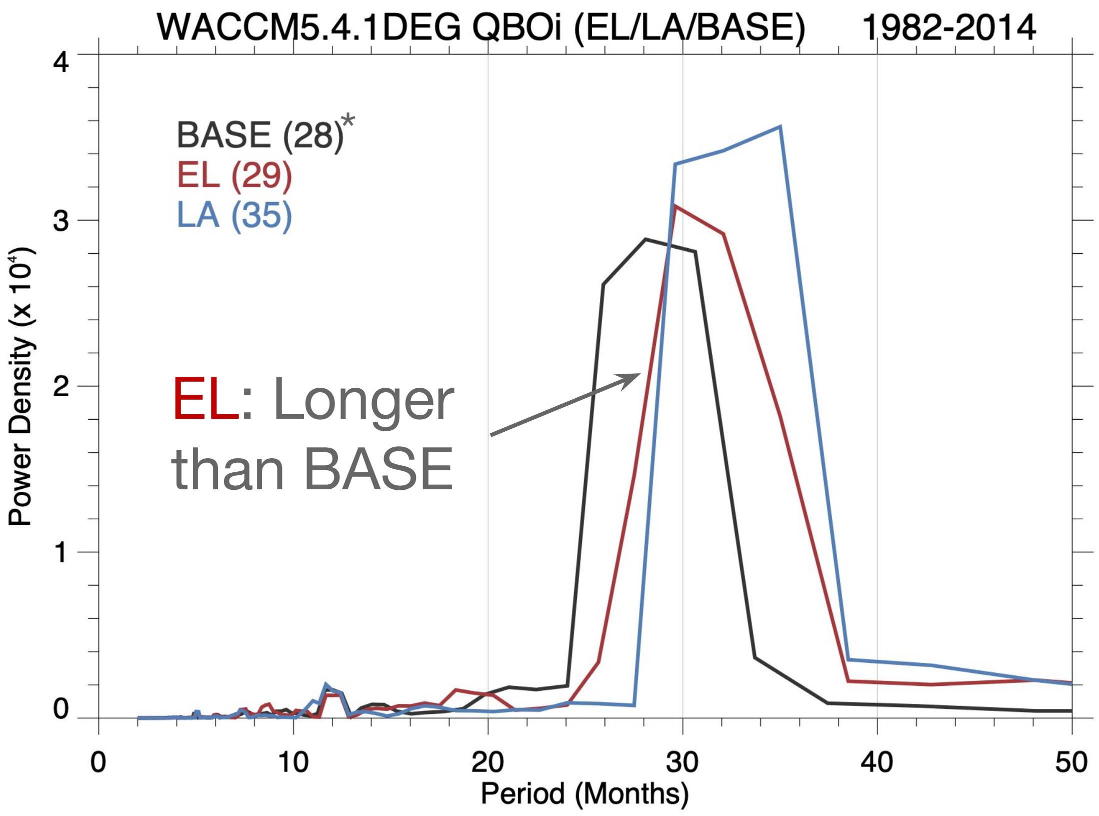
QBO Periods

EL/AV/LA

WACCM6 – 2°



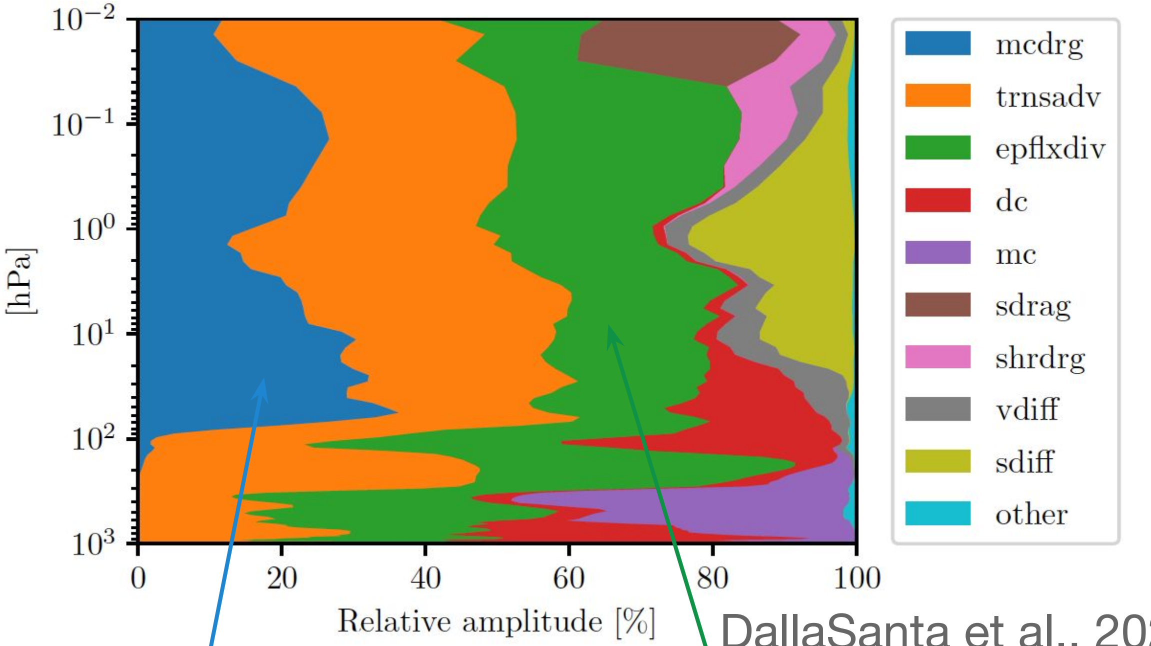
WACCM5.4 – 1°



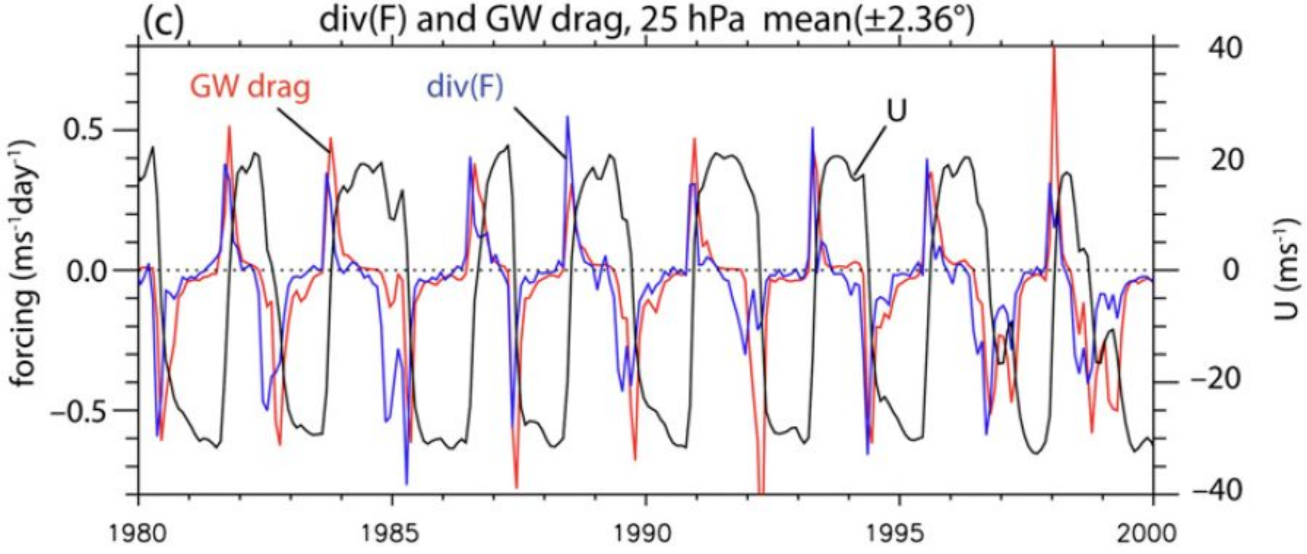
Warmer troposphere -> Shorter QBO periods are expected.
QBOi-ENSO models -> Shorter/longer/no change in QBO periods have shown.

What drives the QBO?

Zonal-mean zonal wind tendencies



DallaSanta et al., 2021



Garcia and Richter, 2019

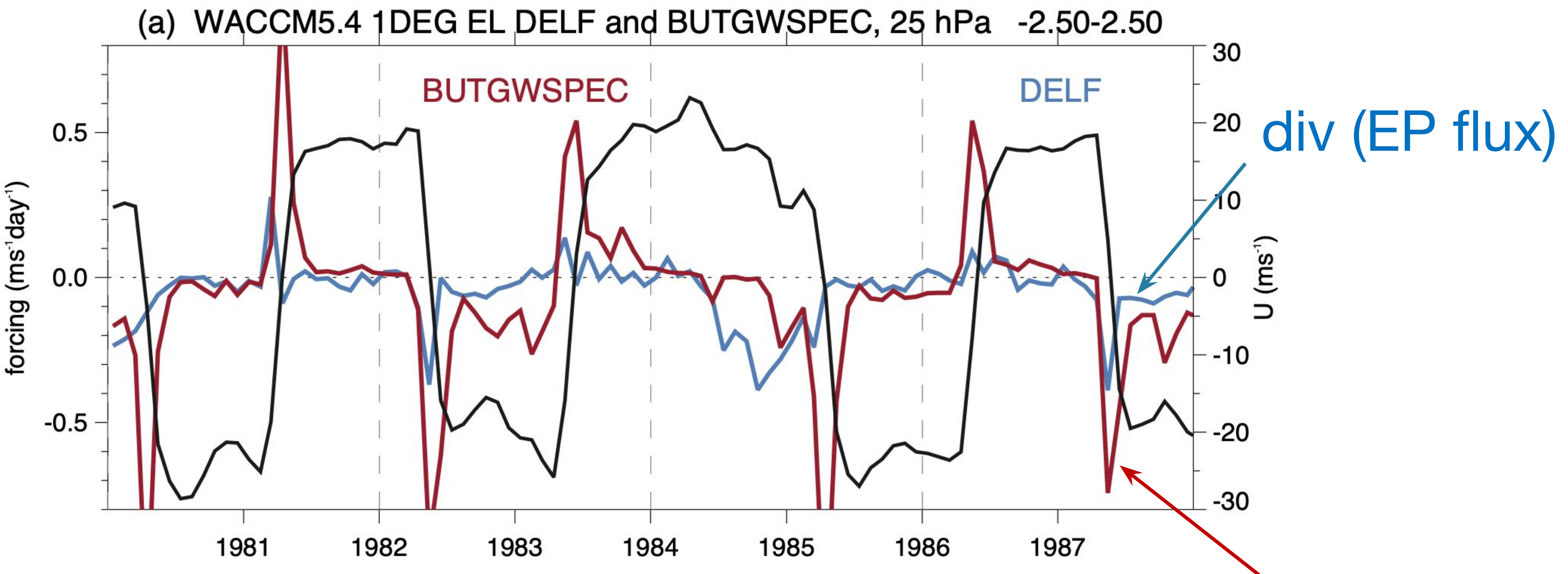
moist convective wave drag

Div (EP flux)

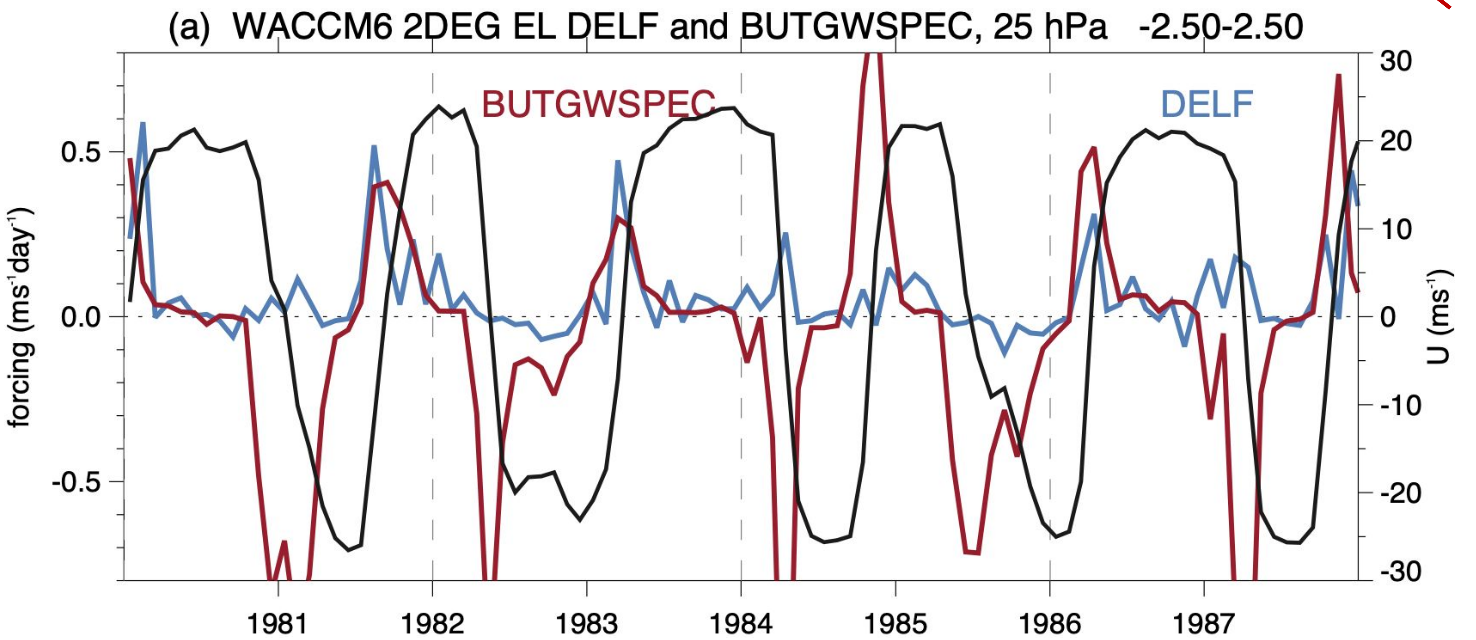
Contributions to the zonal-mean acceleration from the EP flux div. & parameterized GW drag are of comparable magnitude in the near-equatorial average.

25 hPa Lat: 2.5S-2.5N

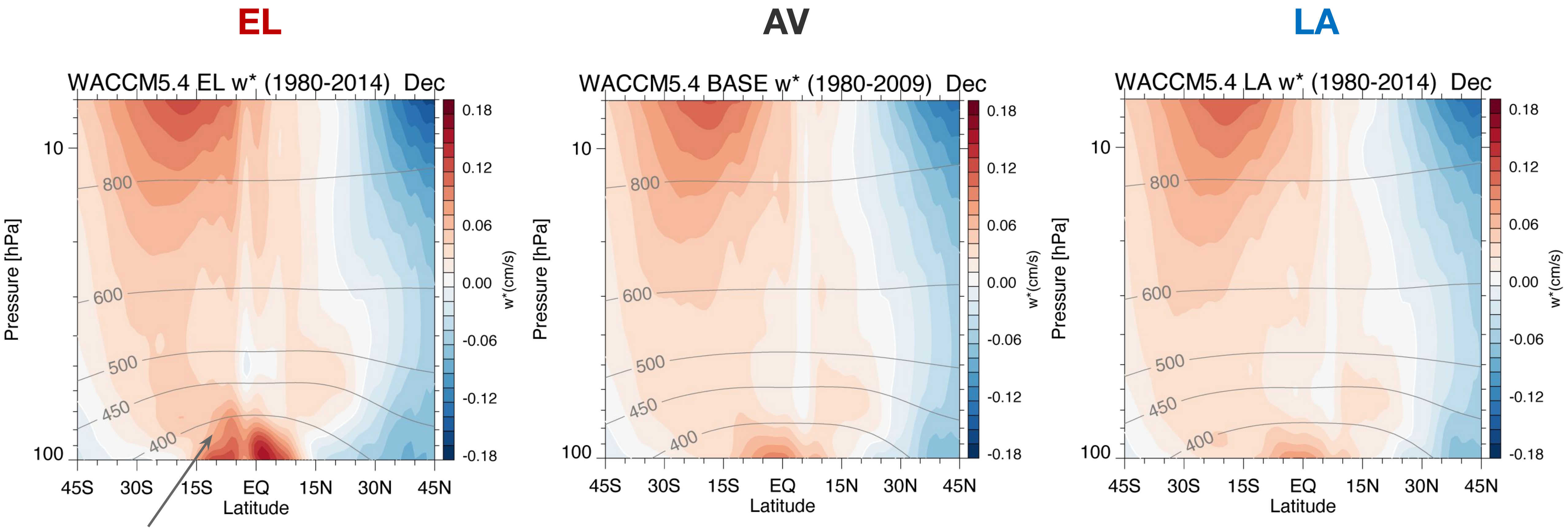
WACCM 5.4 - 1°
EL



WACCM 6 - 2°
EL



WACCM 5.4 - 1° $\bar{w}^*$ - Dec climatology (1980-2014)



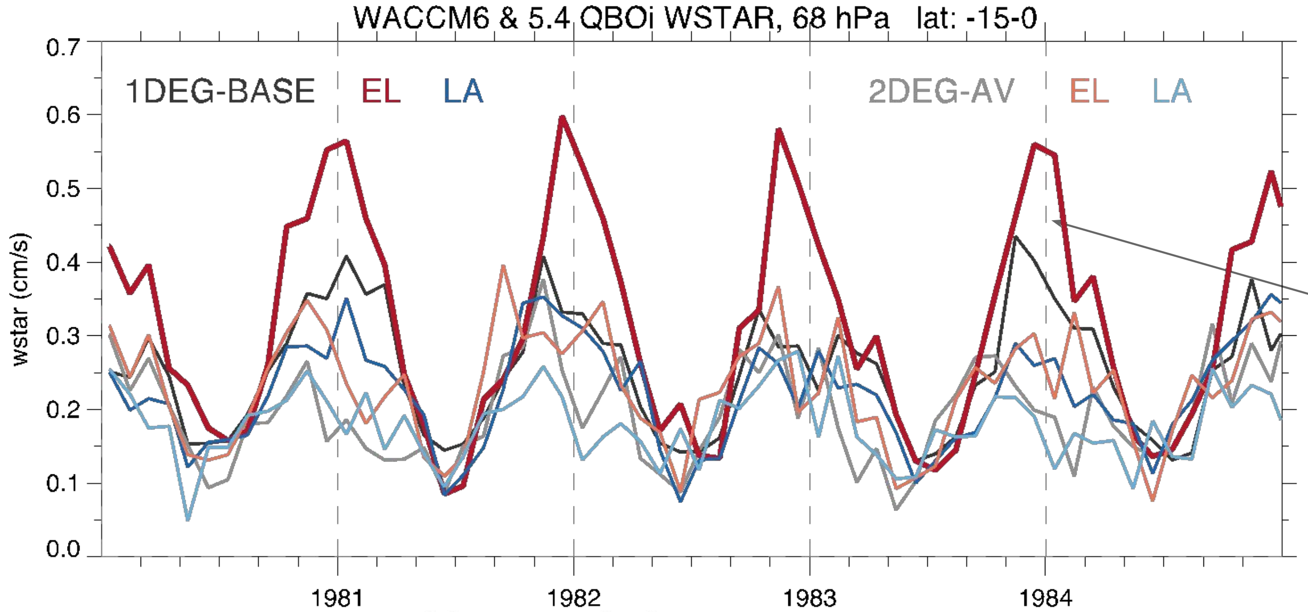
Stronger upwelling

Response to ENSO: enhanced upwelling + cooling in the tropical lower stratosphere – due to resolved wave drag in the SH subtropics [Simpson et al., 2011].

68 hPa

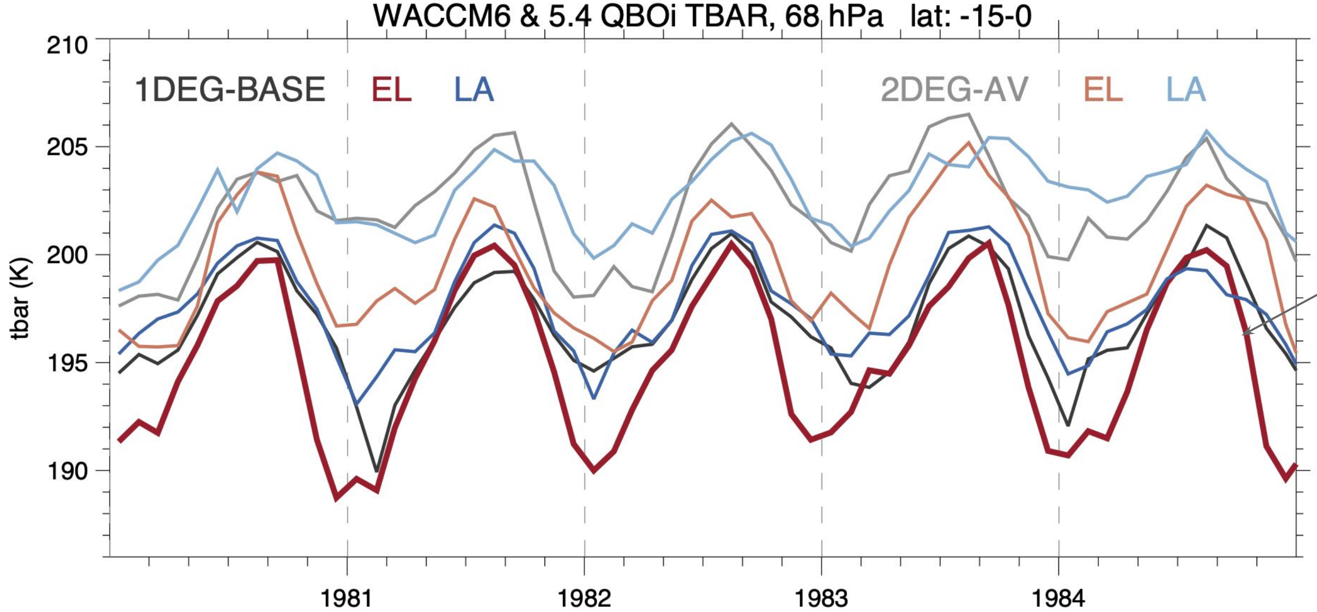
15S-0

$\overline{w}^*$



Strongest upwelling in 1°-EL case in the lower stratosphere.

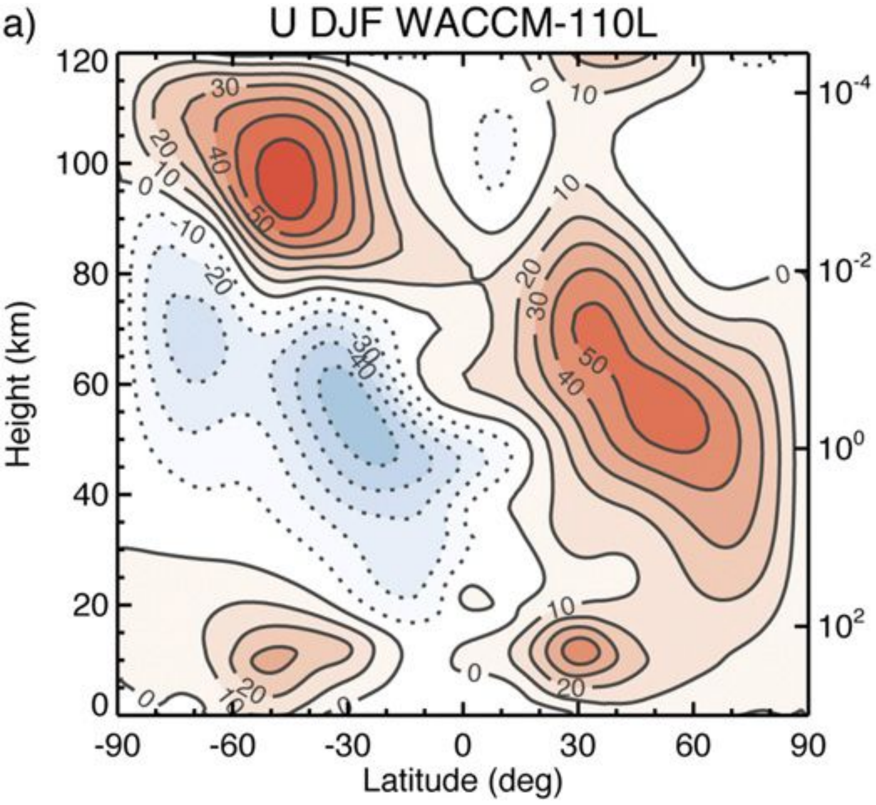
$\overline{T}$



Coldest temperature in 1°-EL case in the lower stratosphere.

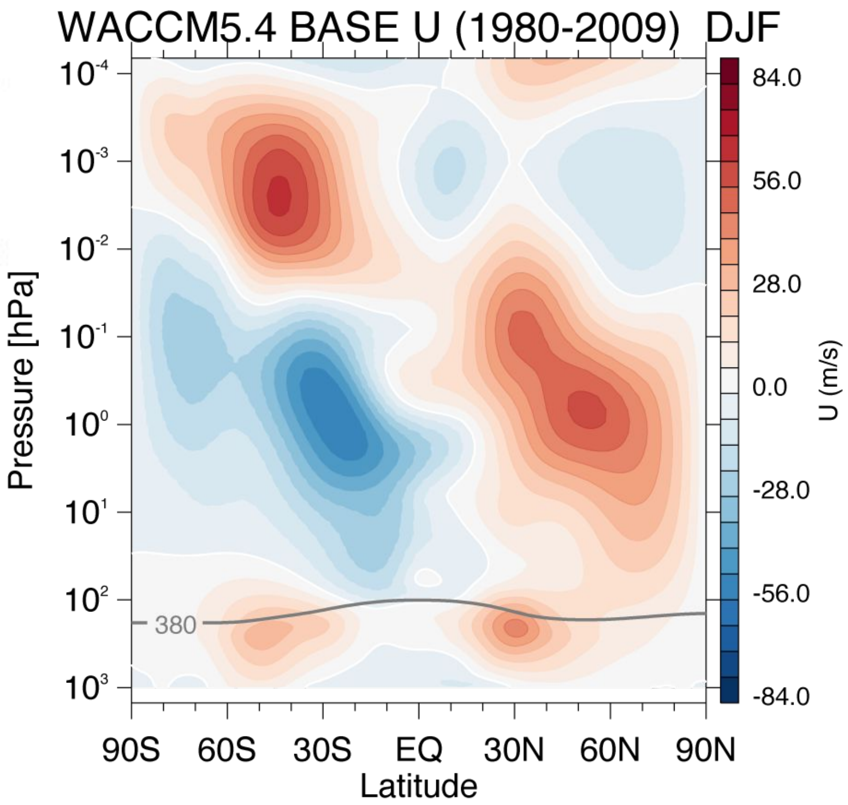
The ascent is comparable but opposite in sign to the rate of QBO shear-zone descent [Dunkerton, 1997].

Zonal-Mean Zonal Wind - DJF Climatology

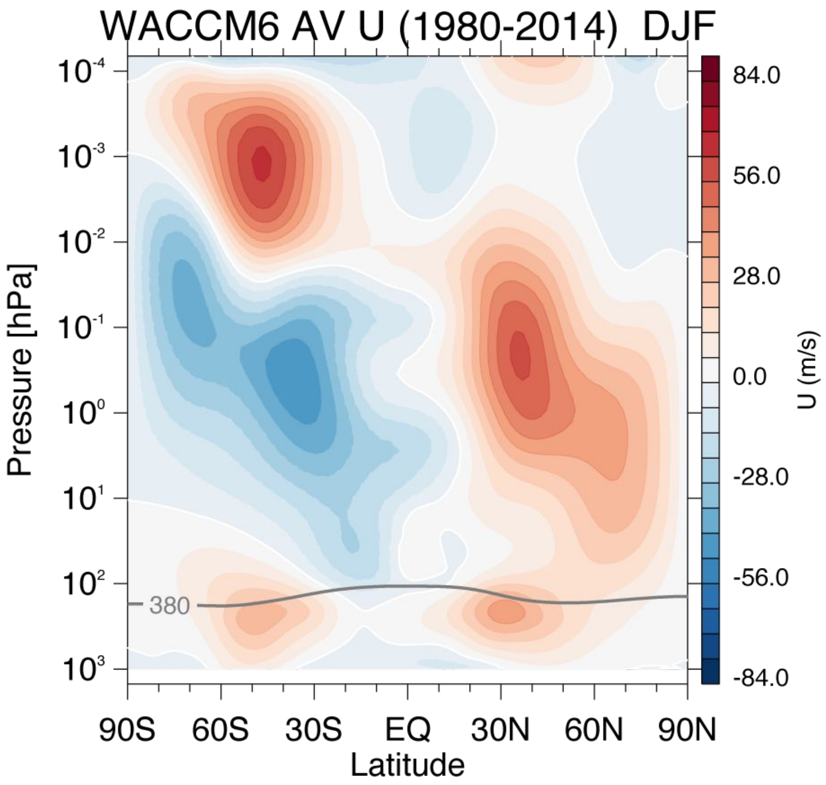


Garcia & Richter, 2019

WACCM 5.4 - 1° BASE

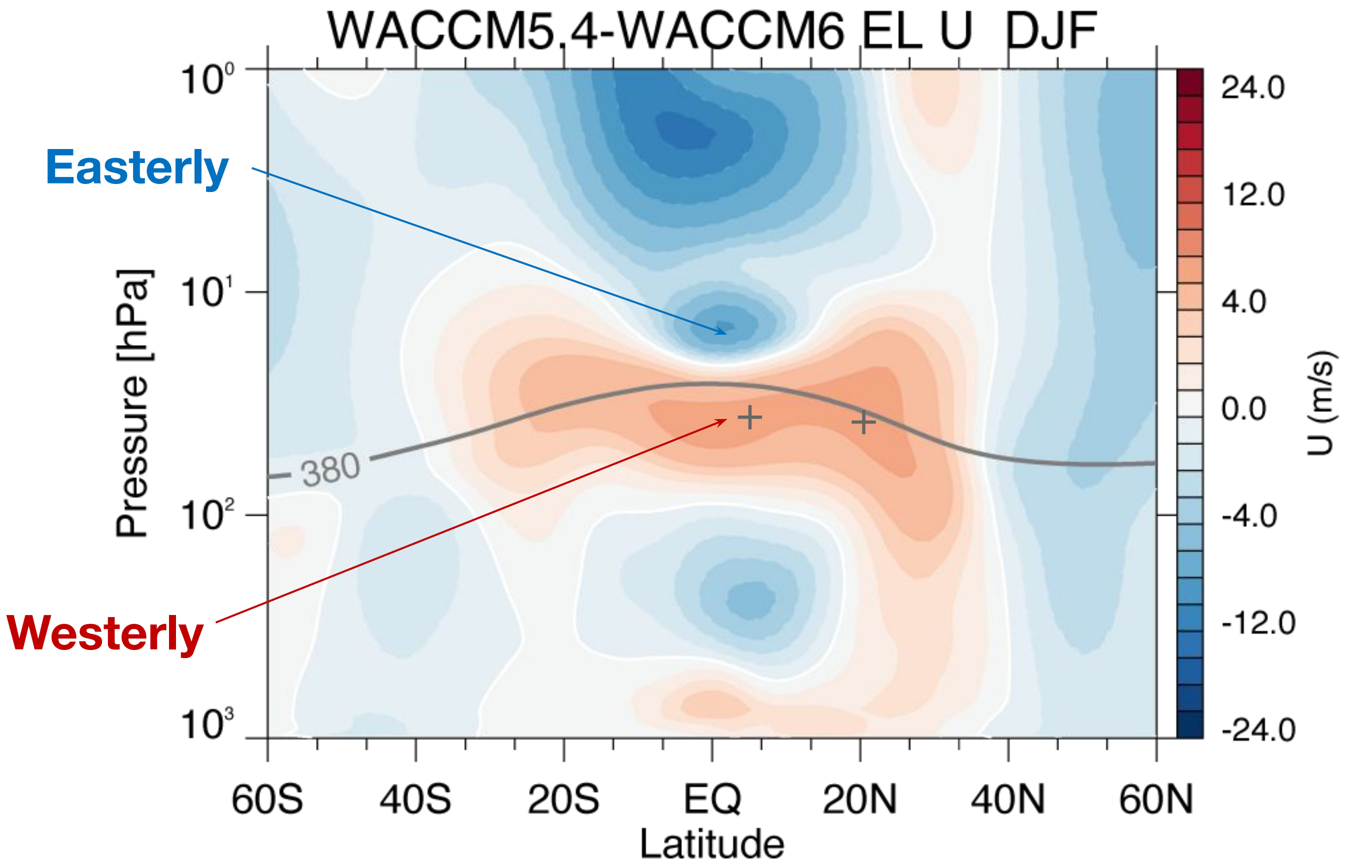


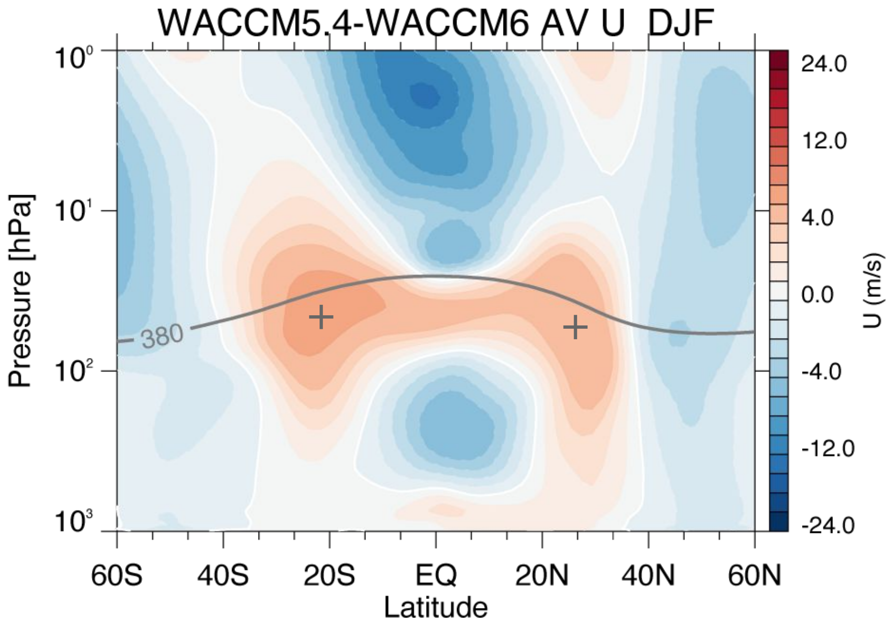
WACCM 6 - 2° AV



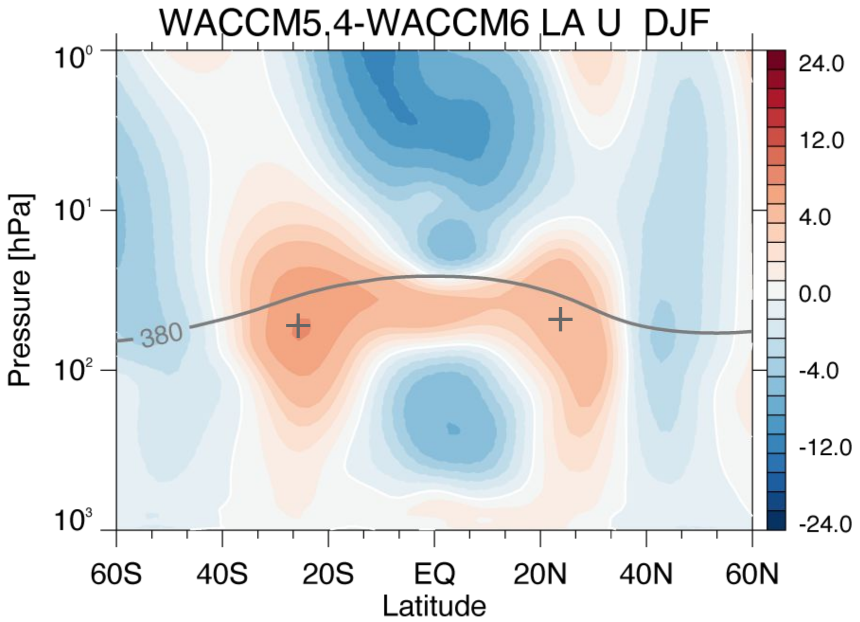
DJF Zonal Wind Differences (1°- 2°)

EL





AV



LA

Larger differences in the tropics for EL case.

Summary

- We successfully simulated the QBO with coarse horizontal (2°) and high vertical resolution (110L) configuration of WACCM6 with the Middle Atmosphere chemistry for 1980-2014.

- A modulation of the QBO by ENSO was investigated. Under perpetual El-Niño condition, QBO periods decreased in 2° (~18 months) but increased in 1° (~29 months) configurations. The QBO periods increase for the perpetual La-Niña condition for both the configurations.

- The most significant differences in the 1°, perpetual El-Niño condition are the increased upwelling, cooler temperature and stronger zonal winds in the tropical lower stratosphere.

- Better understanding of the resolution dependency of the QBO in the model is critical for the reliable prediction of the future climate.

QBO periods *vs*. Tropical Upwelling ($\overline{w}^*$)

Extra Slide

- Kawatani et al. (2011) used a model without parametrized non-orographic GWs and found that the effect of enhanced mean tropical upwelling in a warming climate overwhelms the counteracting influence from strengthened wave fluxes. Consequently, the amplitude of the QBO becomes smaller, especially in the lower stratosphere and the period becomes longer.

-A relationship between an increase in GW momentum flux and shortened QBO period (keeping all other factors the same) in the present-day climate has been shown before (*e.g.*, Geller et al., 2016a; 2016b).

-In the other models in which the period either remained unchanged or lengthened, the changes in the GW momentum fluxes at 100 hPa were much smaller.

The QBO period reduction in the warming climate simulation resulted from both the prescribed increase of wave sources and a simulated decrease in the tropical upwelling…[Richter et al., 2020]

During warm ENSO conditions there is enhanced upwelling in the tropical lower stratosphere, which is accompanied by cooler temperatures and up to a 15% decrease in ozone for a typical strength of El Niño [Simpson et al., 2011]

The ascent is comparable but opposite in sign to the rate of QBO shear-zone descent [Dunkerton, 1997].