

QBO Changes in E3SM

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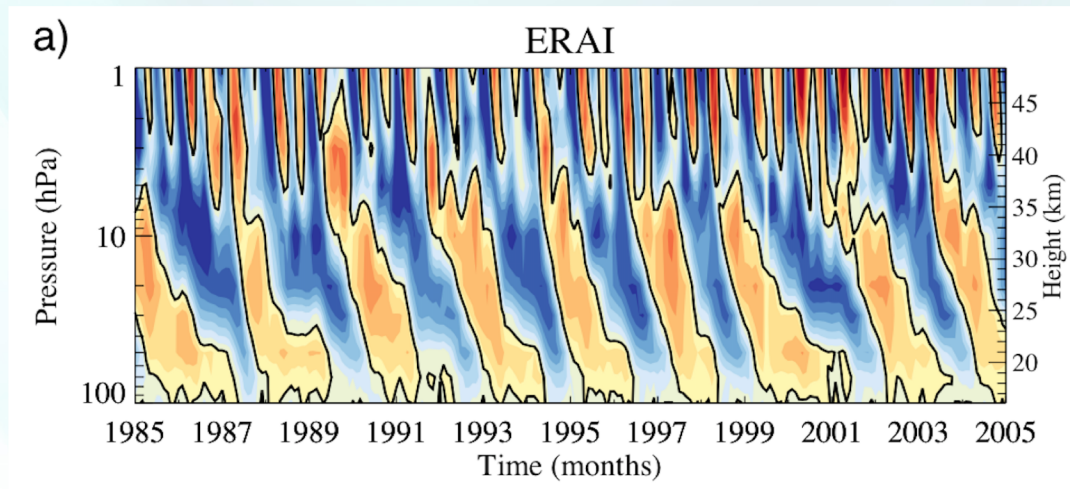
9/19/2019

Overview

- Introduction
- QBO in E3SM
- GW parameterization
- Results of GW tunings
- Impacts
- Future work

Introduction

- QBO: Alternating easterly and westerly shear zones near the equator



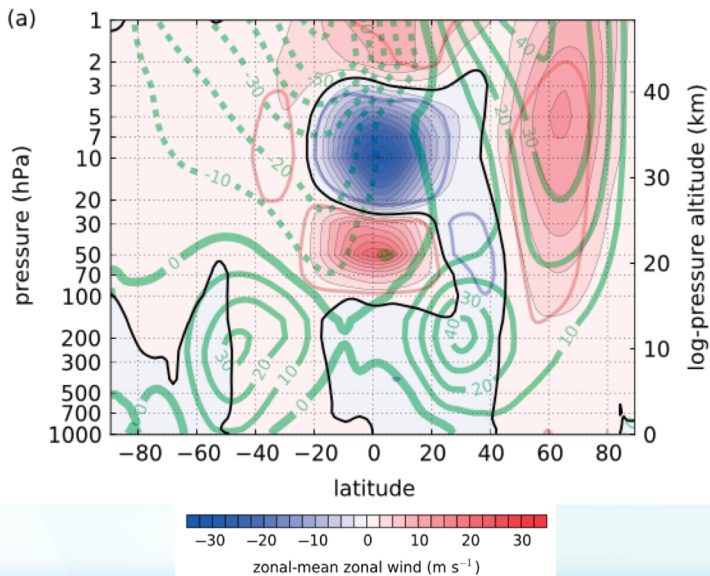
Mean Period: 28 months

- Oscillation also in temperature, ozone, & tropopause height

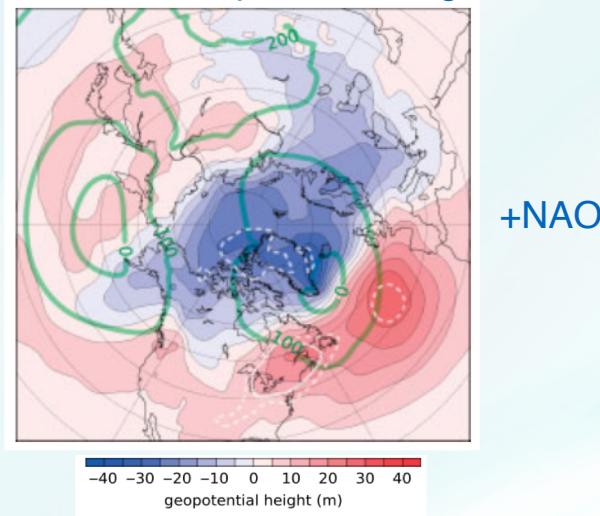
Why is QBO important?

- Influences residual circulation, temperature & chemical transport
- Effects the strength of the polar vortex & NAO
- Strong observational evidence of QBO influence on MJO

QBO W – QBO E
Jan Zonal Wind

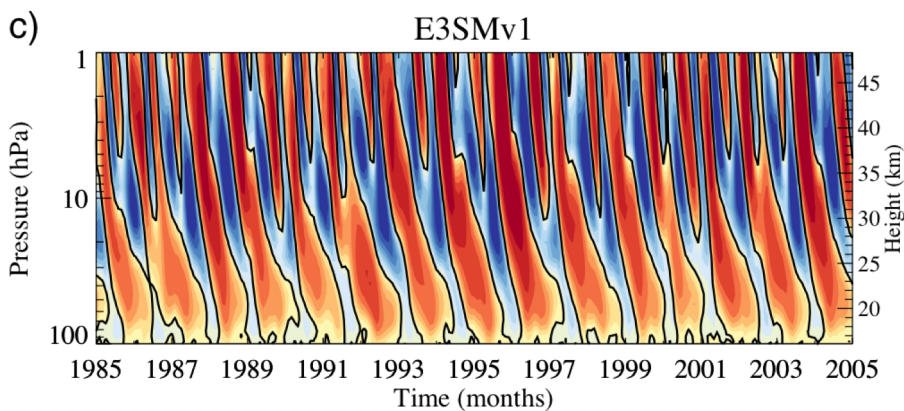
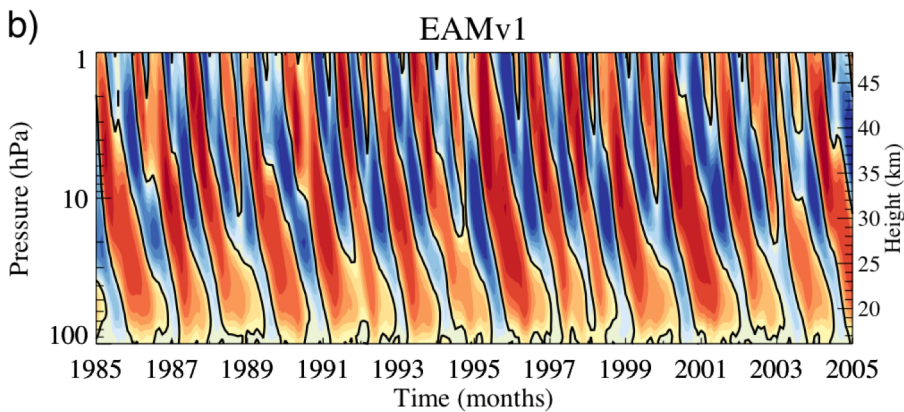
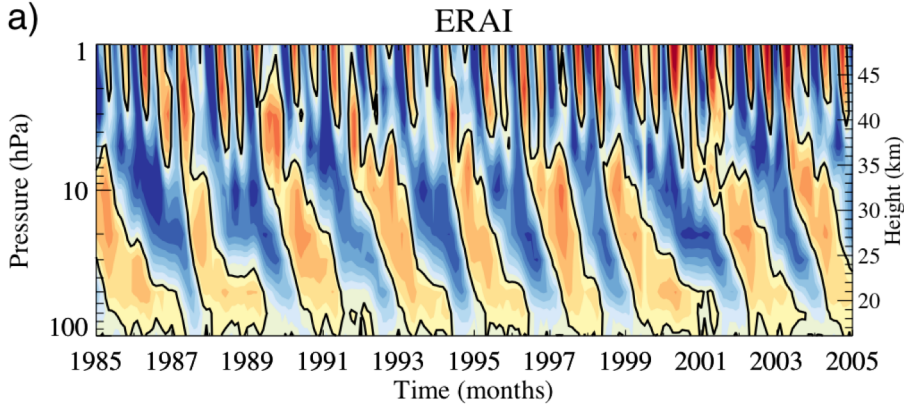


QBO W – QBO E
1000 hPa Geopotential height



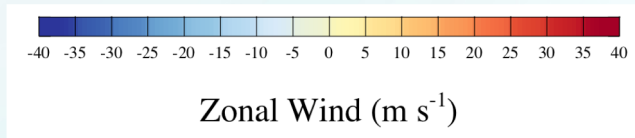
Figures from Anstey & Shepherd (2014)

QBO E3SM v1: U: 5S to 5N (zonal mean)



Avg Period: ERAI: **28** months
EAMv1/E3SMv1: **~18** months

Amplitude: Much too strong in E3SMv1



What's needed to model the QBO?

1) Kelvin & Rossby-gravity waves

Often underrepresented

2) Small-scale gravity waves

(~ 10's to 100s km)

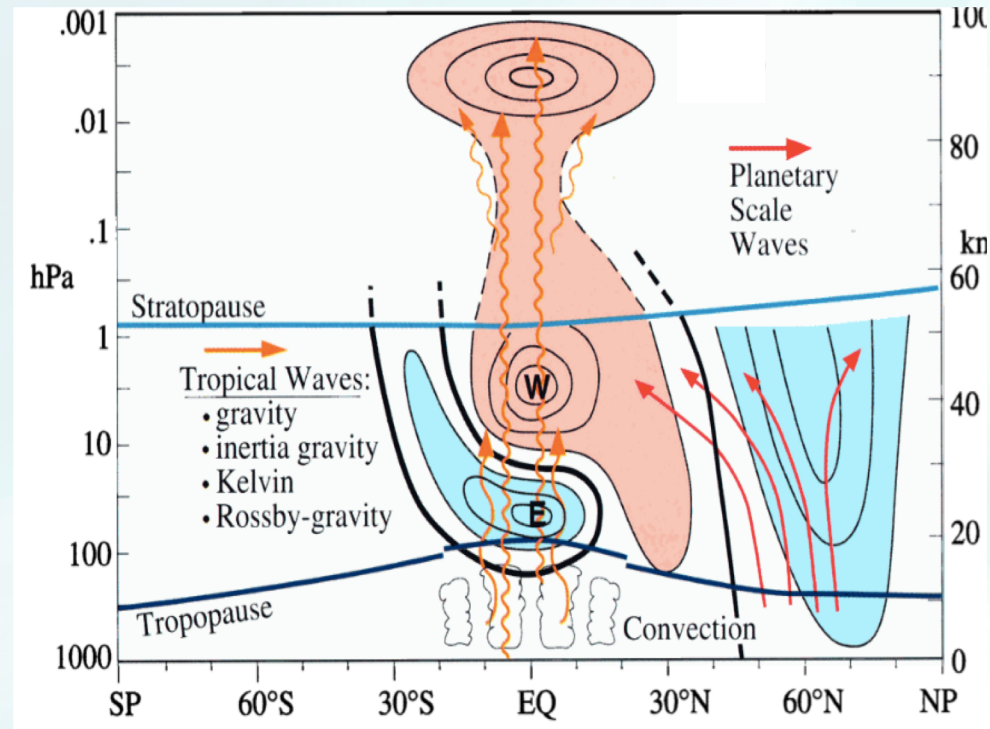
Mostly parameterized

3) Vertical resolution

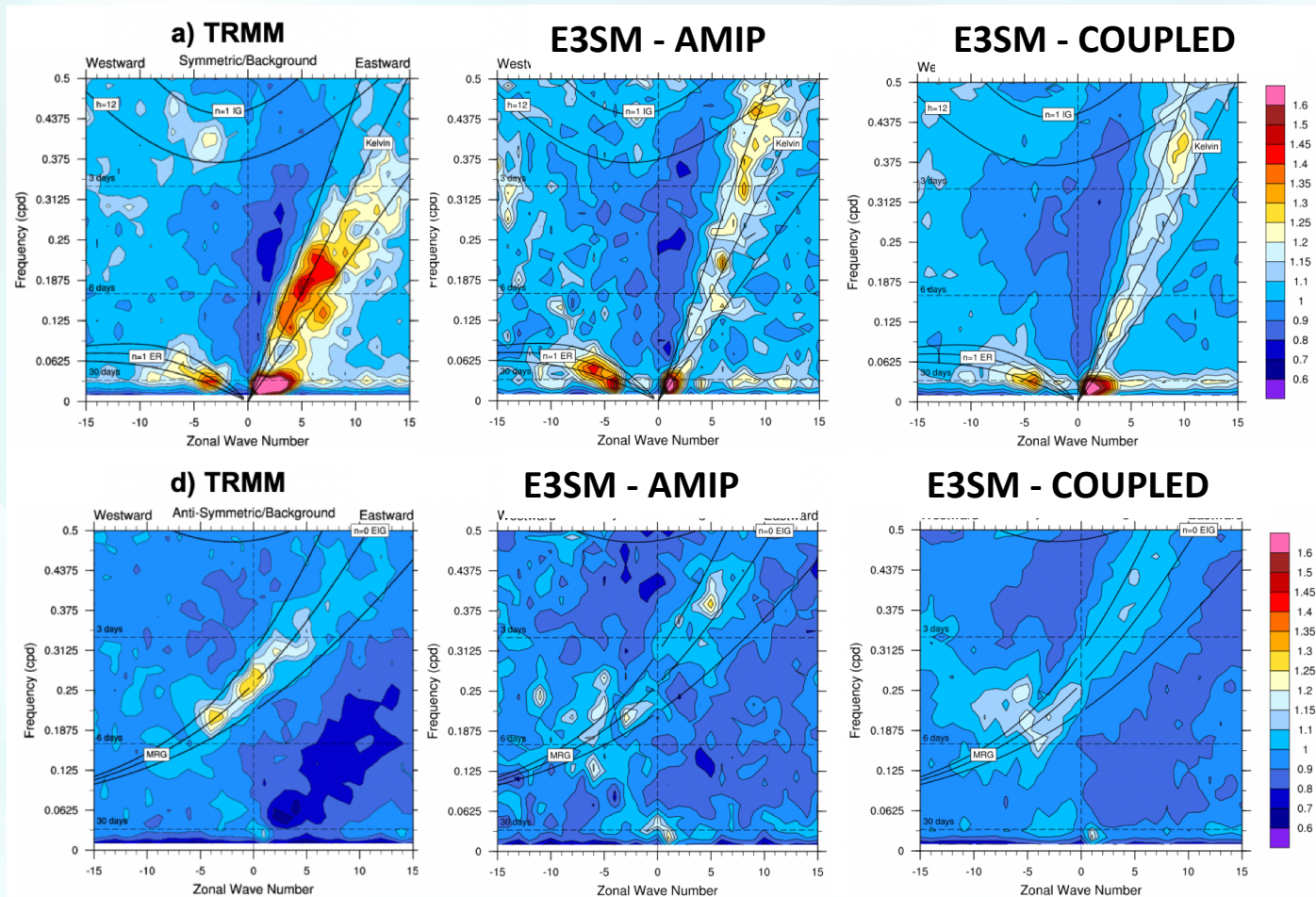
Often inadequate

4) Dynamical core

Sometimes overly diffusive



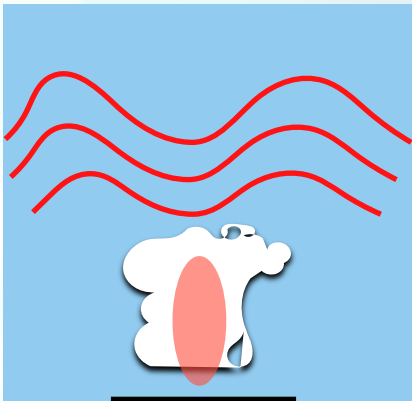
Resolved waves in E3SM



Largely underrepresented

GW Parameterization

- Lindzen (1981) GW propagation parameterization
- Two non-orographic sources: fronts and convection
- Convective Source spectrum parameterization: Beres et al. (2004)



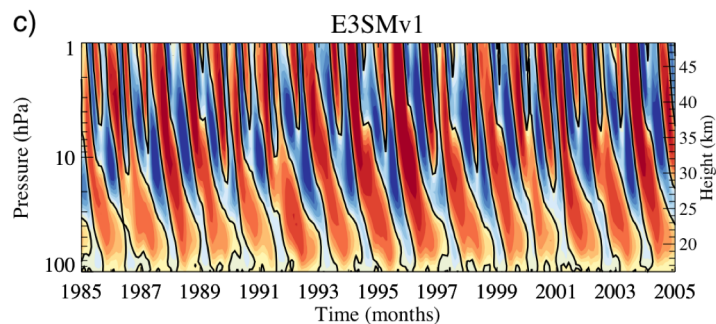
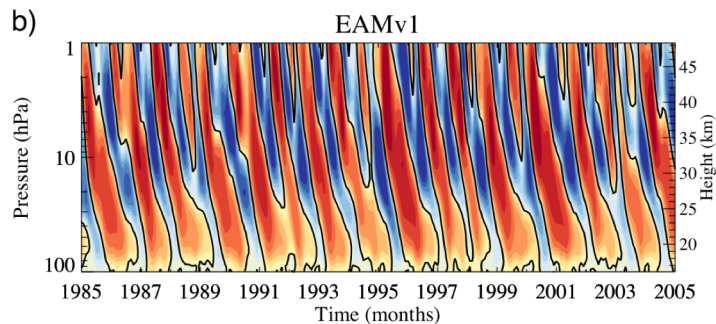
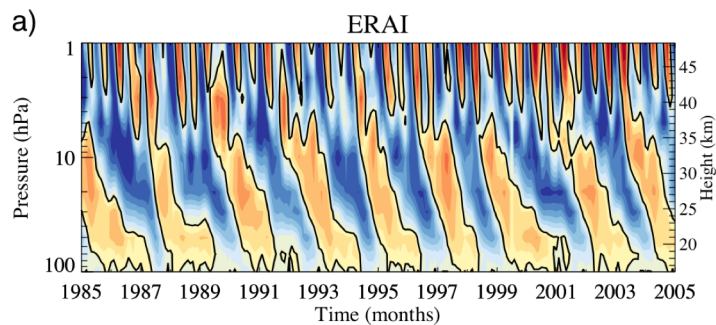
- Based on linear theory of wave generation by thermal forcing
- 40 waves with $-100 < c < 100$ m/s
- Dominant phase speed related to h (depth of heating)
- Wave Amplitude $\propto Q^2$ (Q = heating rate from Zhang and McFarlane scheme)
- Wave spectrum impacted by wind in heating

Tunable parameters:

CF: conversion factor from grid cell avg to that representative of heating cell; Default: 20 (5%)

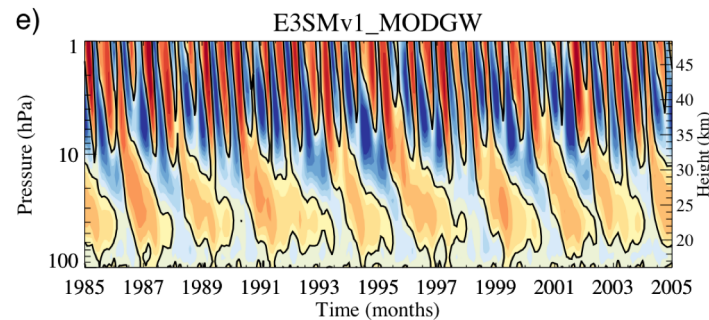
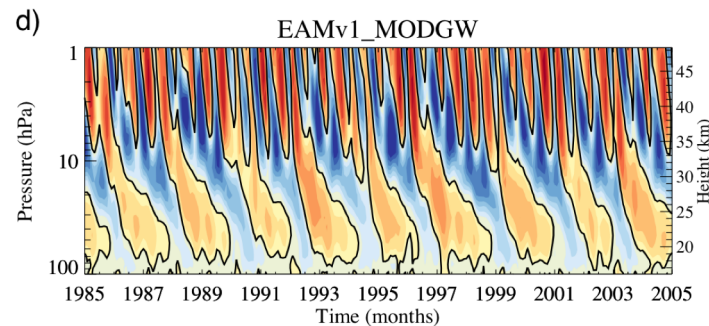
Efficiency: How efficiently is convection generating GWs?
Default: 0.4

New vs Old QBO



E3SMv1: CF = 20; Eff = 0.4

**QBO with GW
parameter changes**



MOD: CF = 12.5; Eff = 0.35

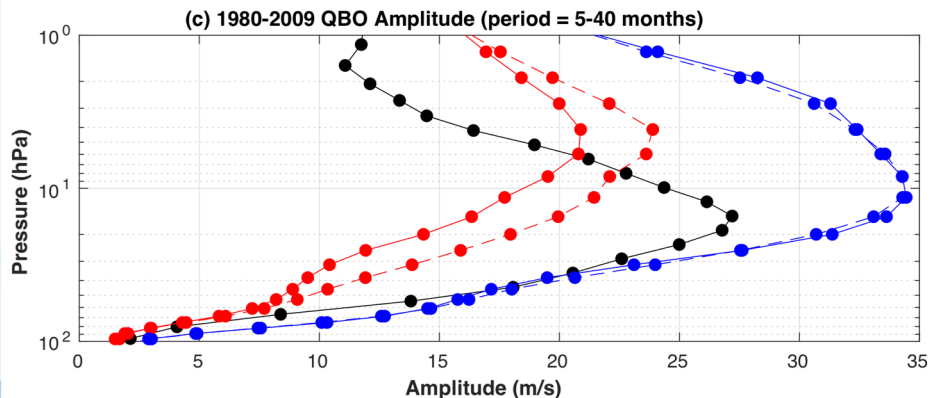
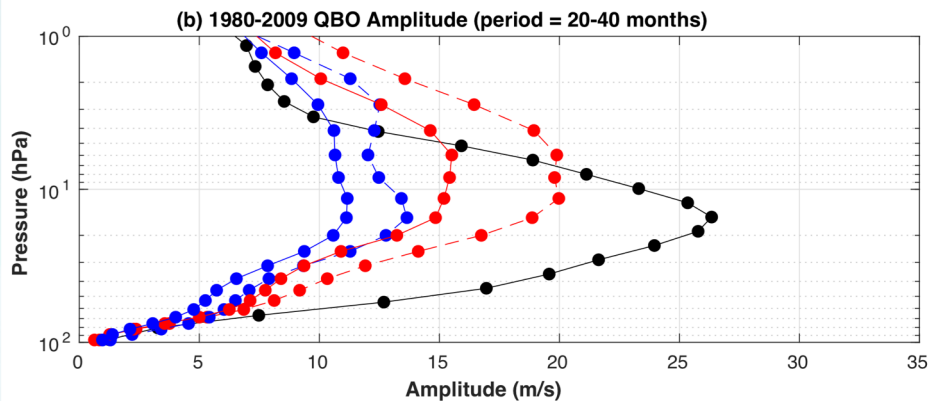
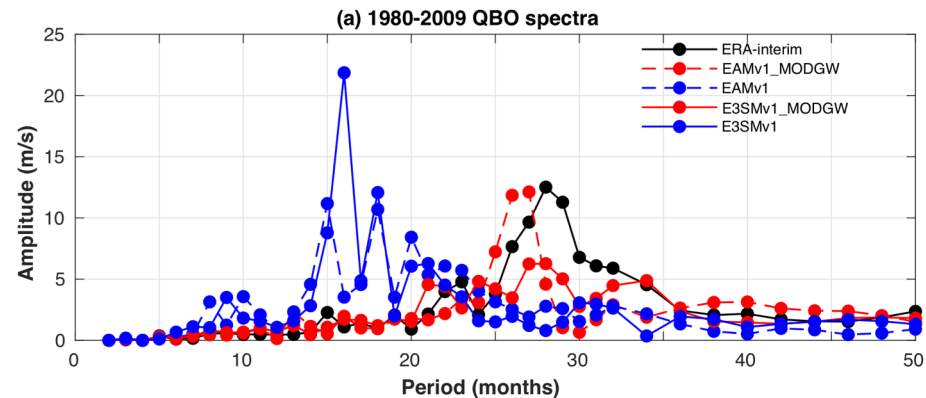
Power Spectrum and Amplitude

Avg QBO Period:

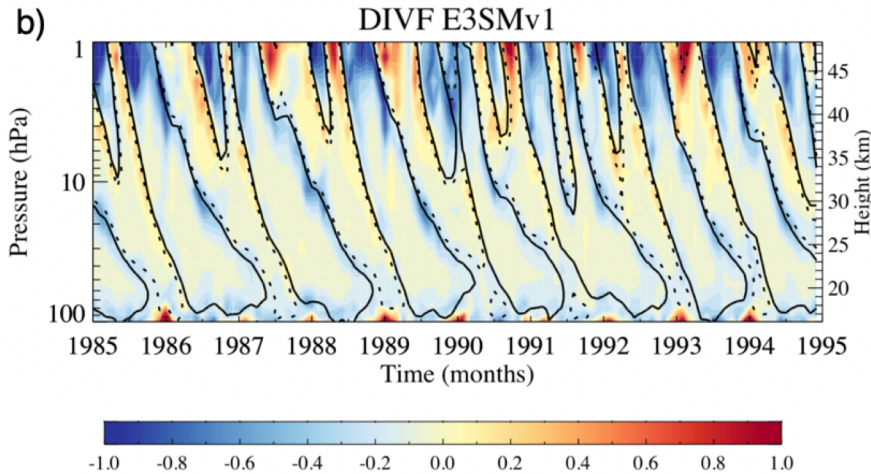
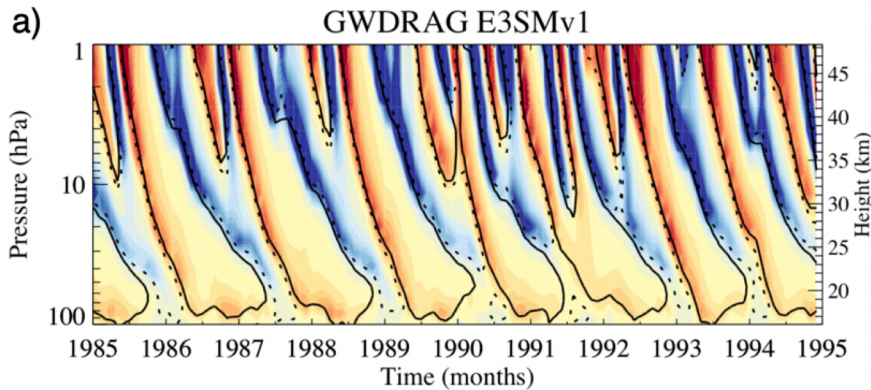
ERA-Interim: 28 months

E3SMv1: 18 months

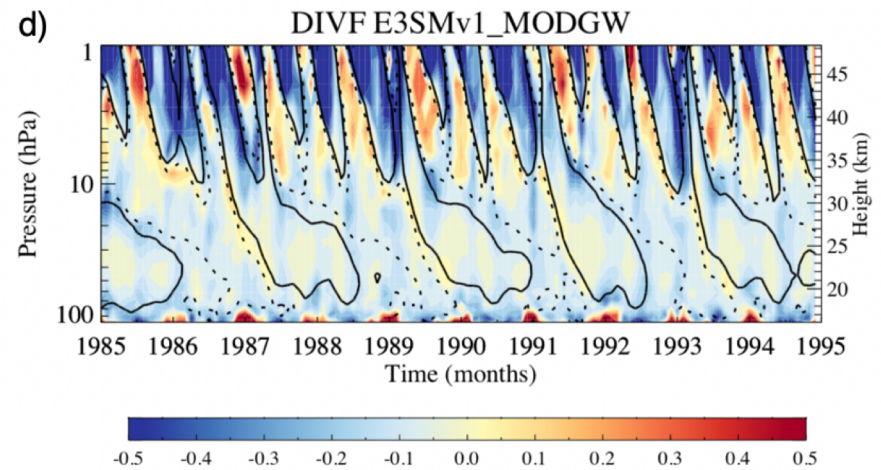
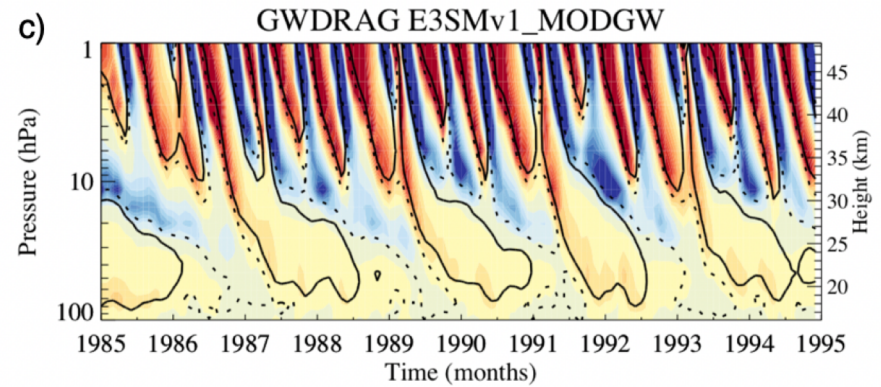
E3SMv1_MOD: 26 months



QBO Driving

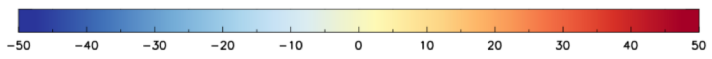
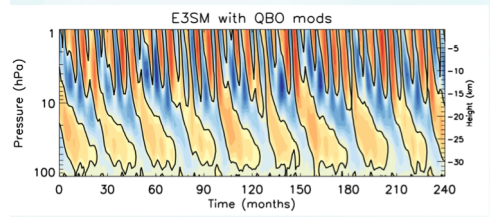
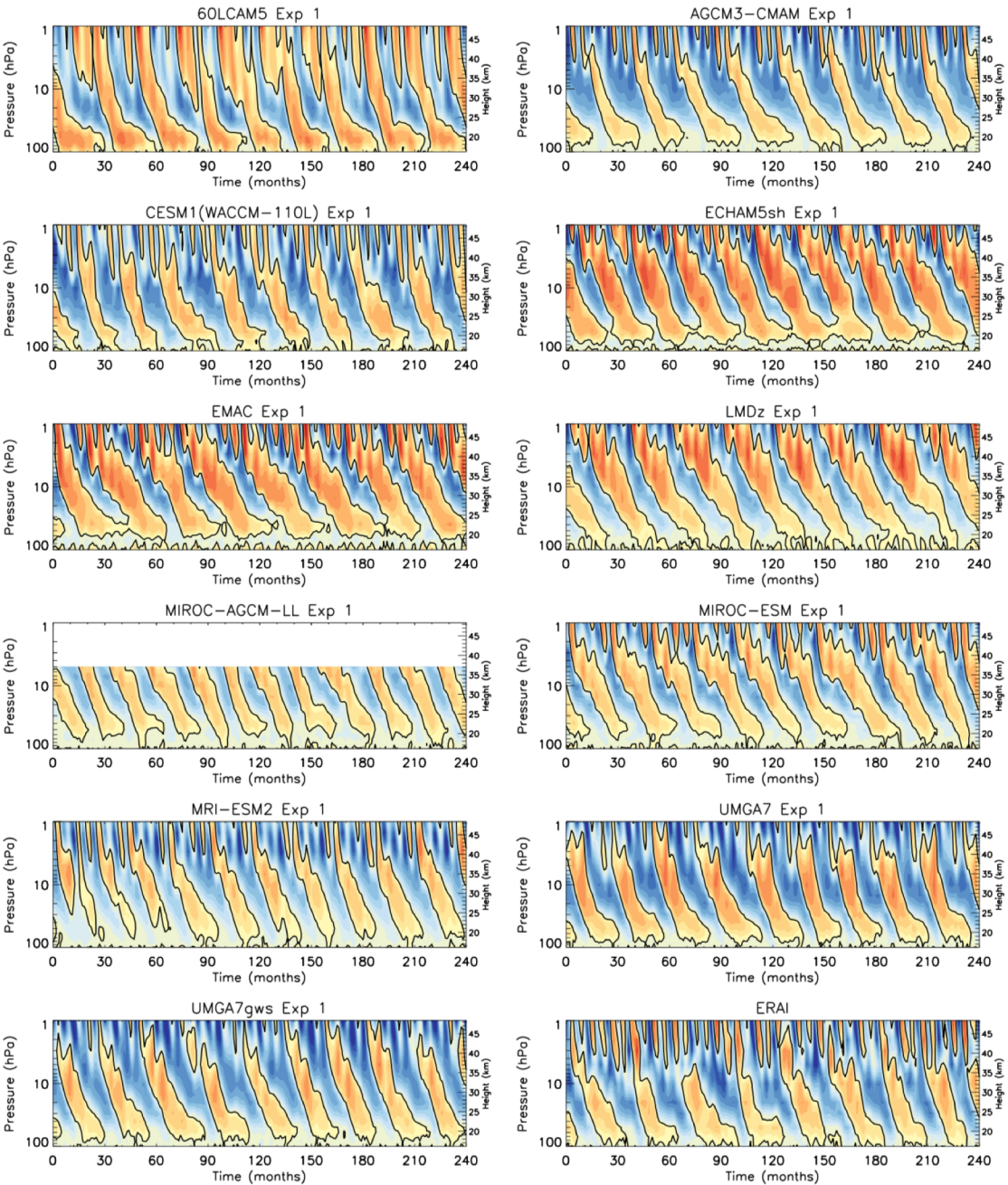


m/s/day



m/s/day

QBO: E3SM vs Other Models (mostly high top)

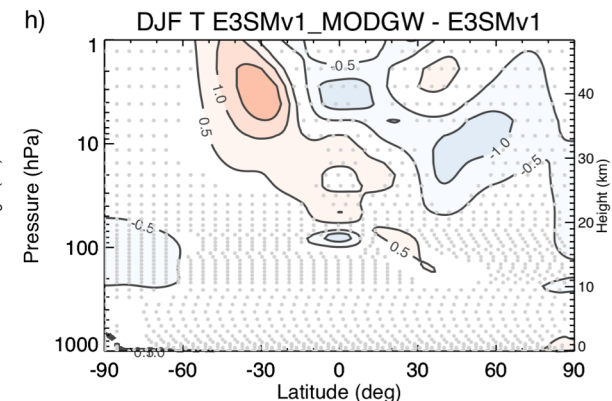
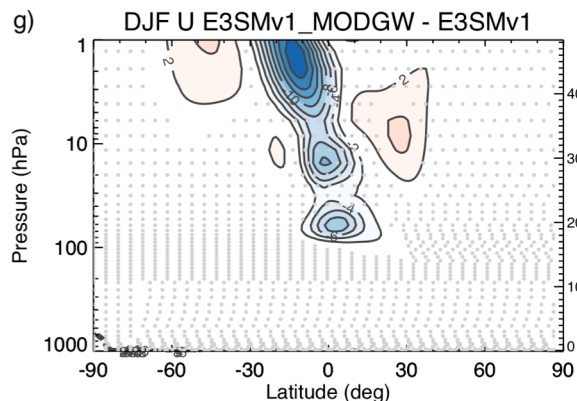
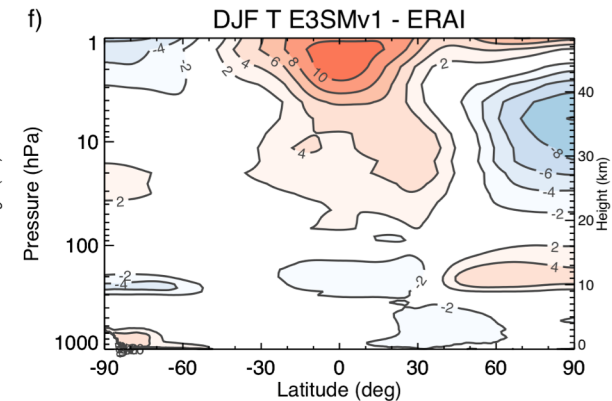
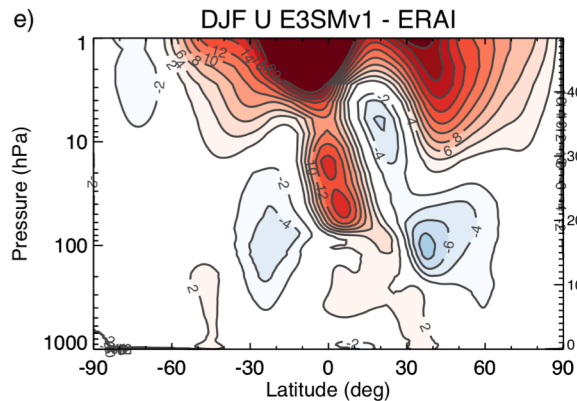
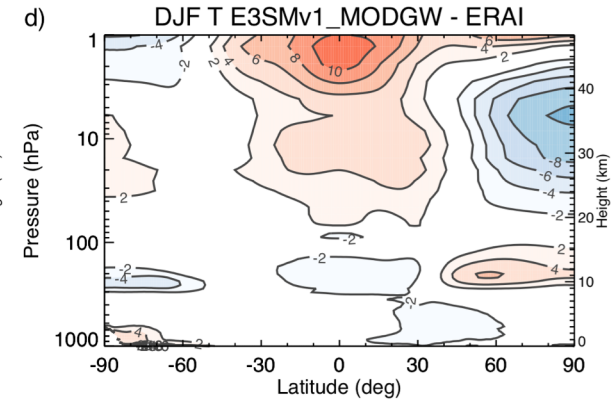
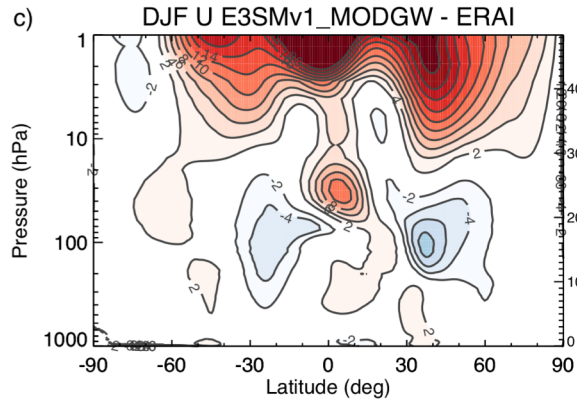


Zonal wind (m s^{-1})

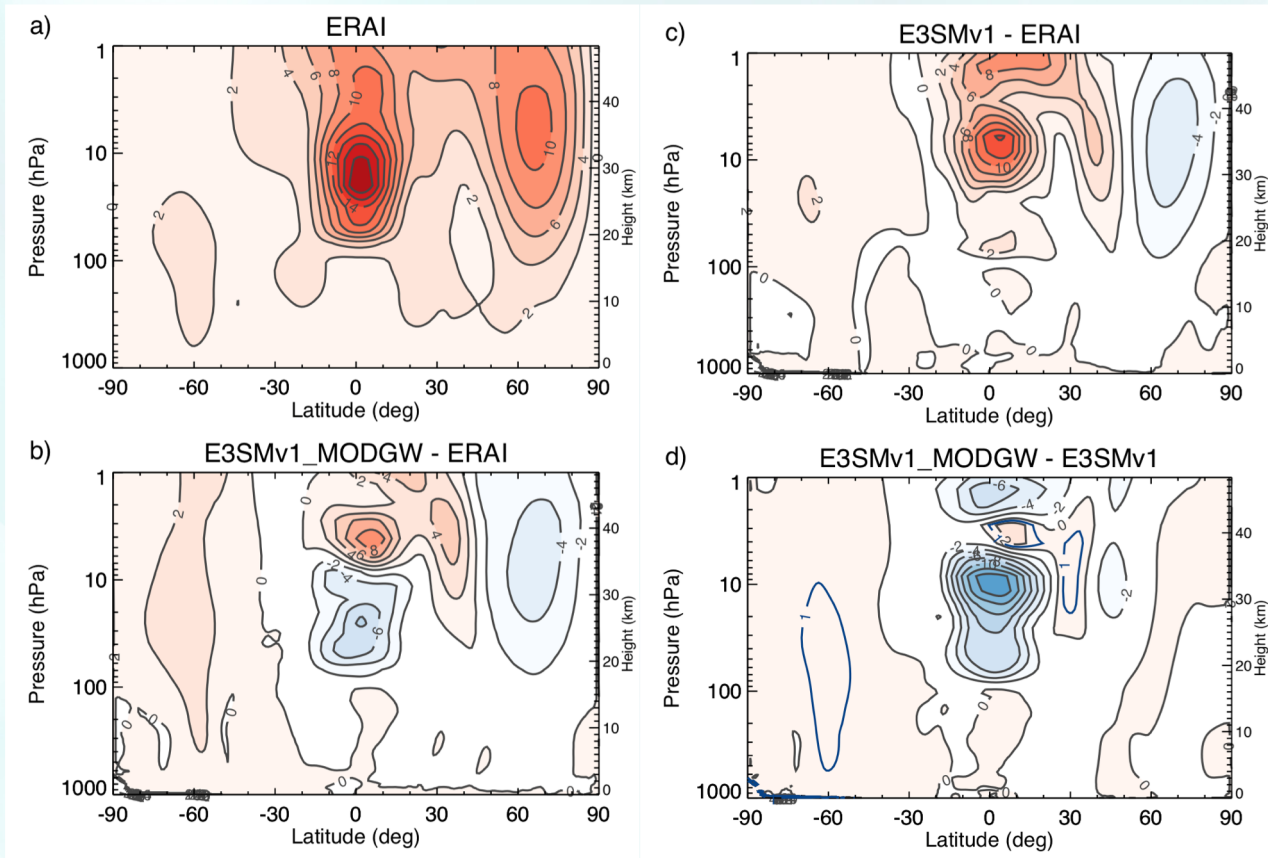
Left: QBOs in QBOi models and ERAI (Bushell et al. 2019, in review)

Stratospheric U & T Changes DJF

1980 – 2009 DJF Avg



U Variability

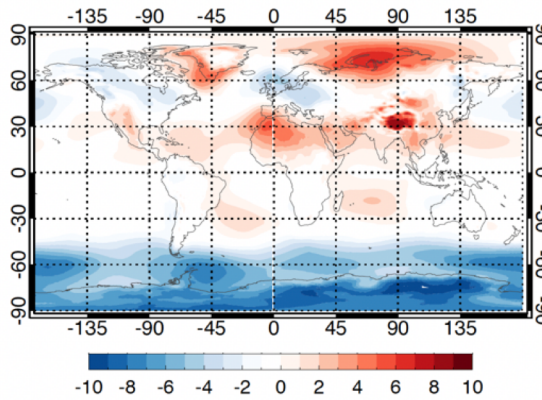


DJF Standard deviation of U

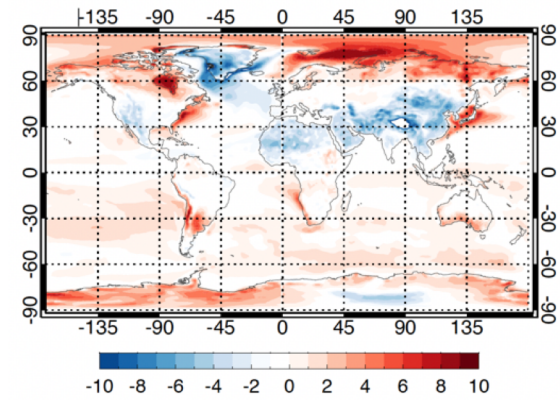
Surface Changes:

Black Contour:
Sig at 95% level

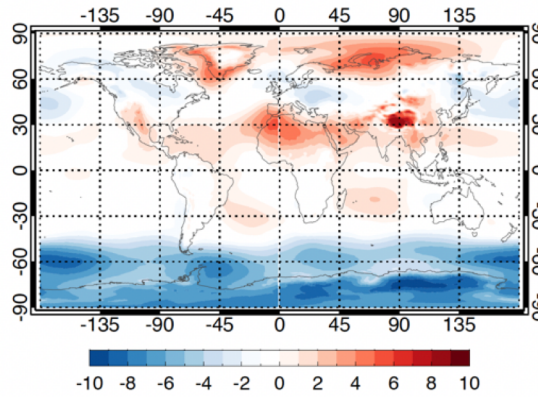
c) PSL E3SMv1_MODGW - ERAI



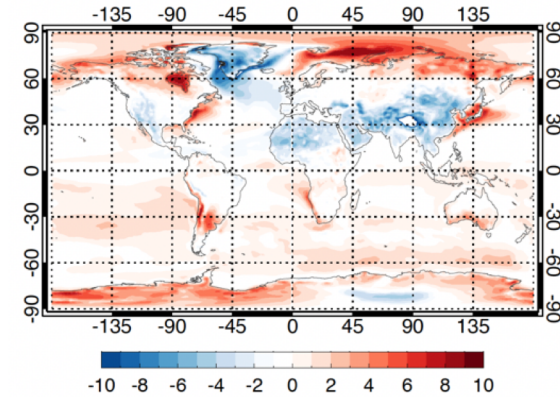
d) TS E3SMv1_MODGW - ERAI



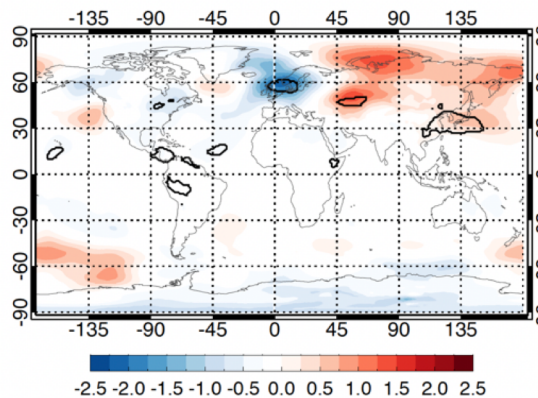
e) PSL E3SMv1 - ERAI



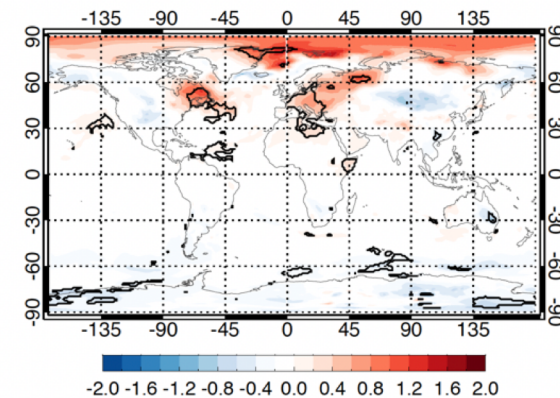
f) TS E3SMv1 - ERAI



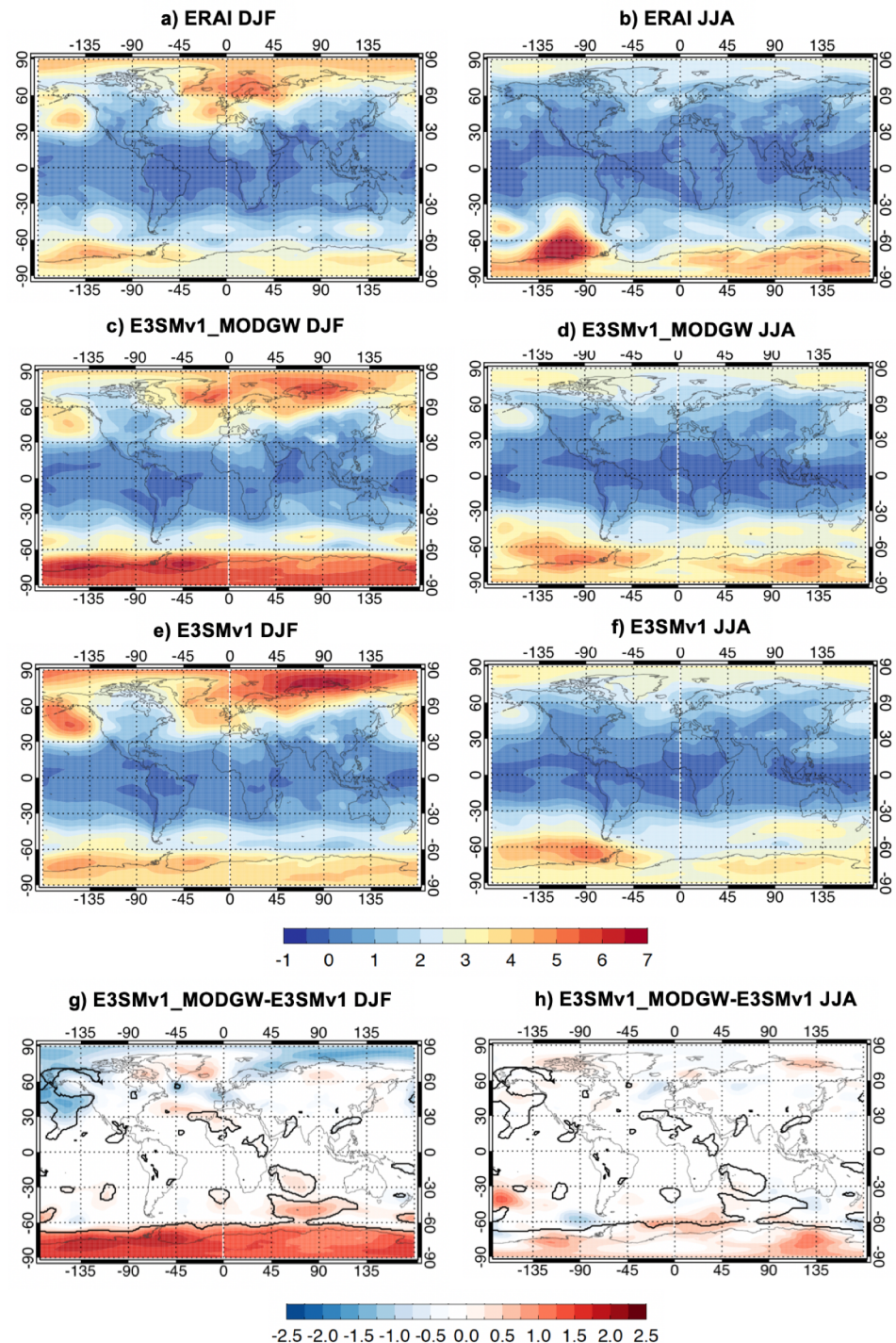
g) PSL E3SMv1_MODGW - E3SMv1



h) TS E3SMv1_MODGW - E3SMv1



Surface Changes: Variability

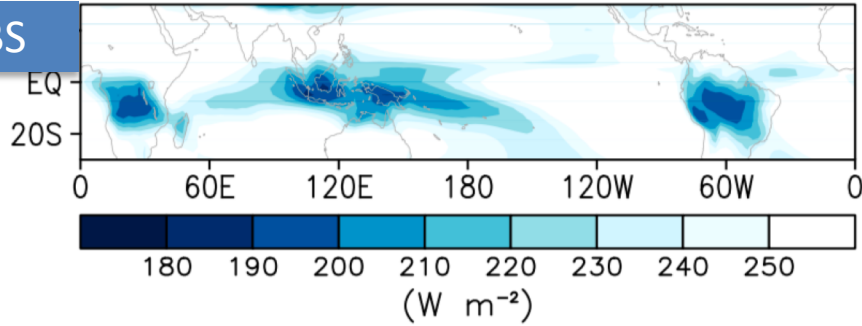


Black Contour:
Sig at 95% level

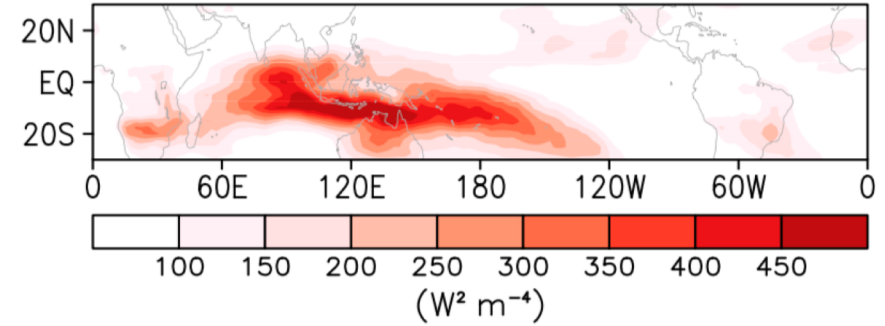
QBO Impacts on the MJO: OBS

a DJF OLR

OBS



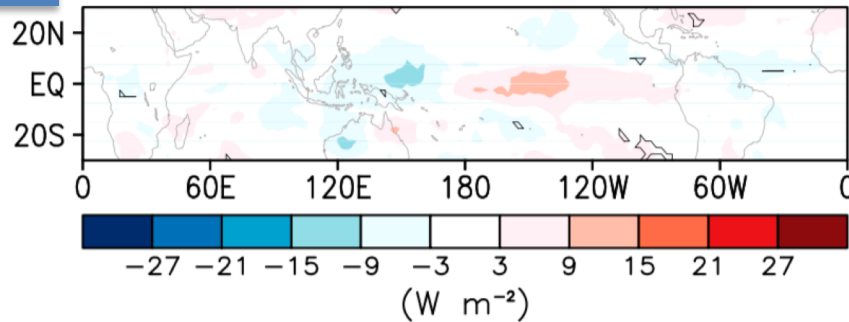
d DJF OLR Variance



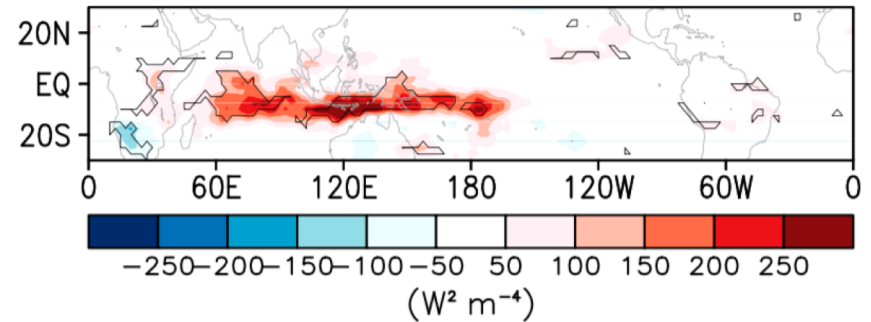
Son et al. 2017

OBS

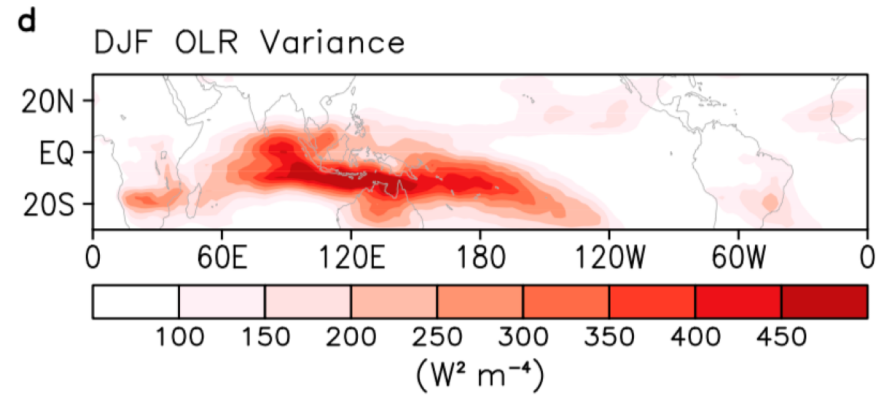
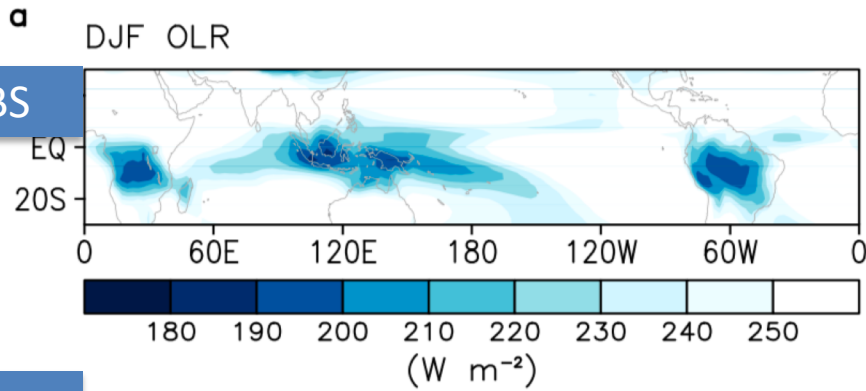
EQBO-WQBO



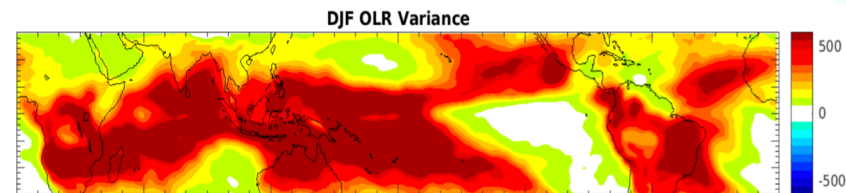
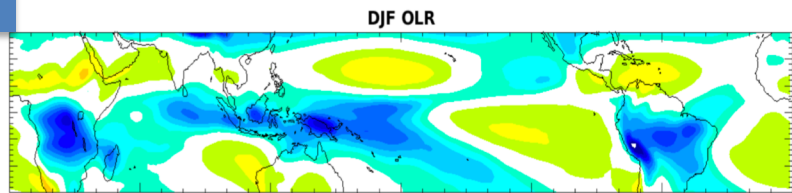
f EQBO-WQBO



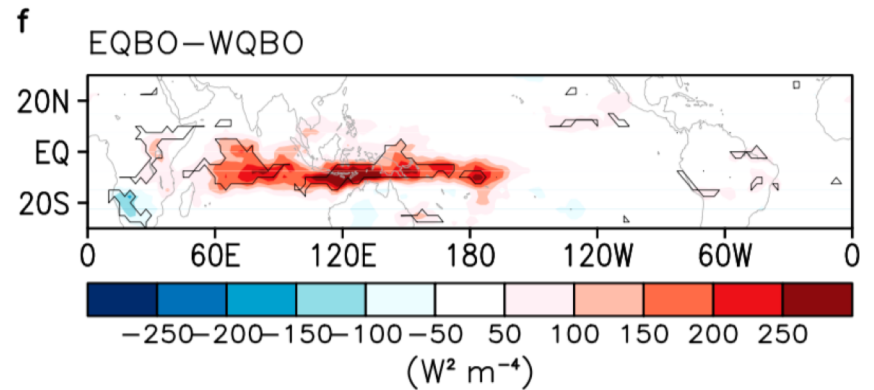
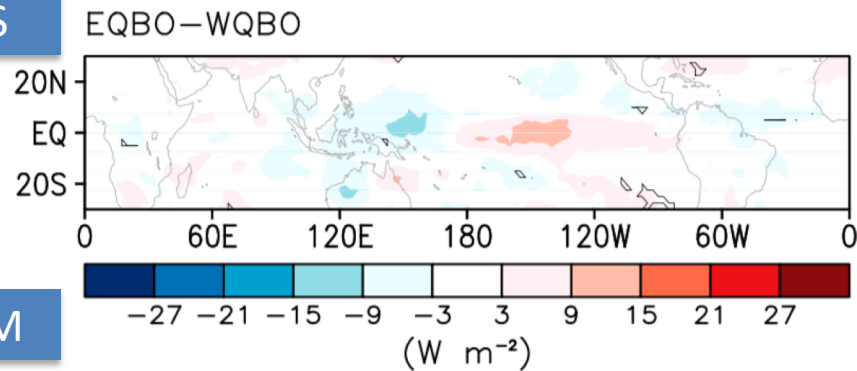
QBO Impacts on the MJO: OBS



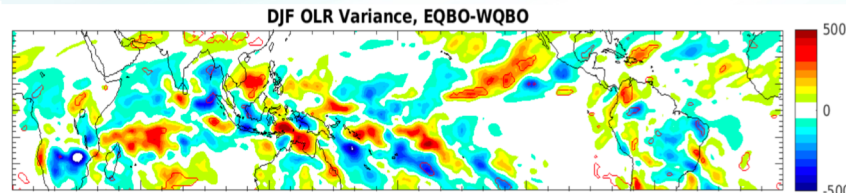
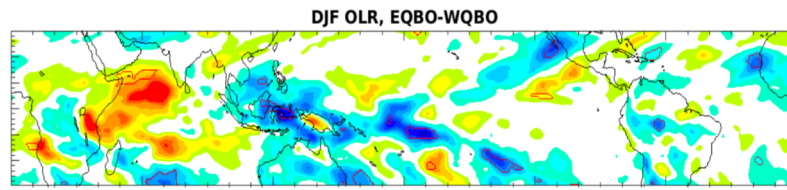
E3SM



OBS



E3SM



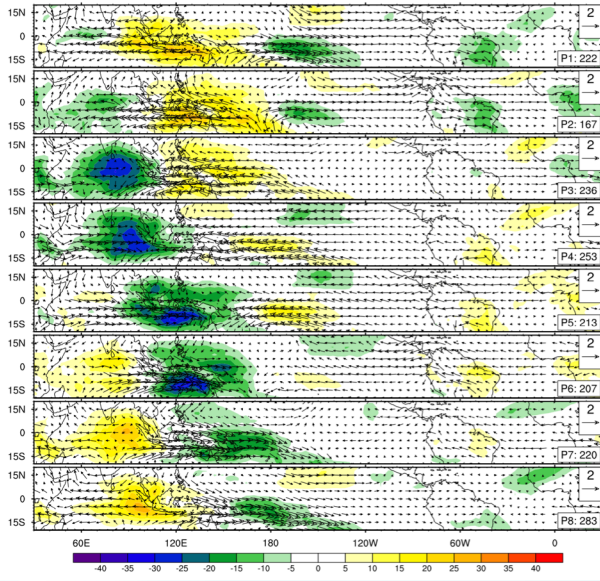
MJO Propagation

OBS

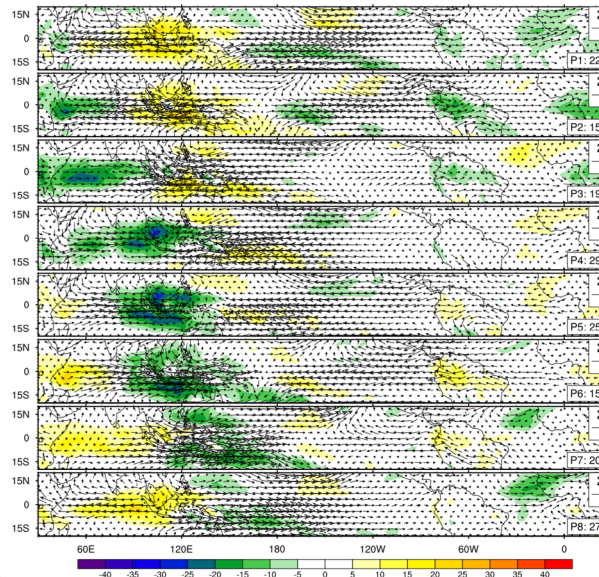
E3SMv1

MOD GW

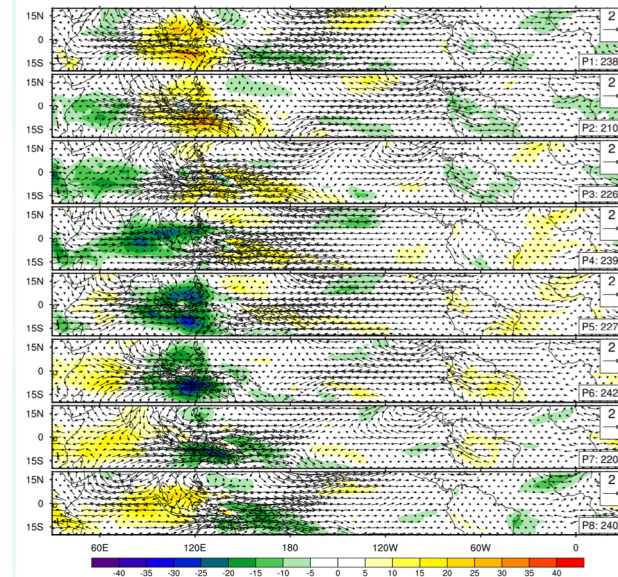
1979-2011: DJF



1980-2008: DJF



1980-2008: DJF



Stronger MJO in phase 5-6 in MOD GW (but might not be statistically significant)

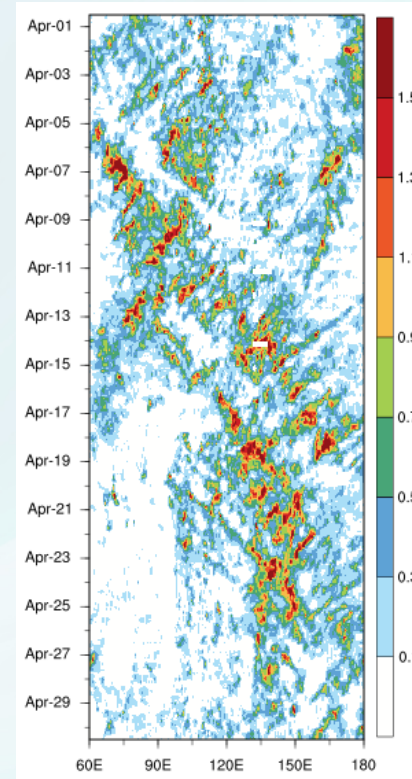
Summary & Future Work

- We improved the representation of the QBO in E3SMv1
 - QBO Period & overall amplitude are now much closer to observations
 - Easterly QBO phase still deficient
 - Kelvin & RG waves underrepresented
 - Modest changes to mean/variability of overall simulation
- Richter et. (2019) in press
- Will monitor changes to QBO as convection parameterization changes occur
 - Looking at effects of QBO on MJO, but:
 - MJO not quite right: period too long; Variance too high & doesn't propagate properly

Future Work

- Improvement of momentum transport in convection
- Verification of in-cloud momentum transport
- Additional of mesoscale convective momentum transport

TRMM



WRF

