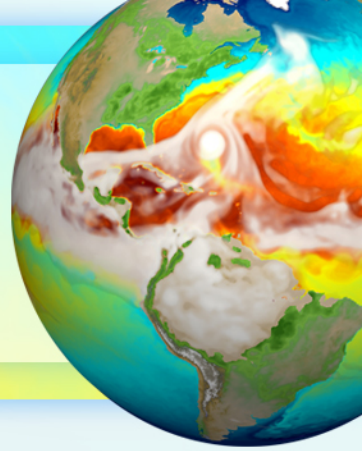


QBO Changes in E3SM

Jadwiga (Yaga) Richter

Jack Chen, Qi Tang, Shaocheng Xie, Phil Rasch

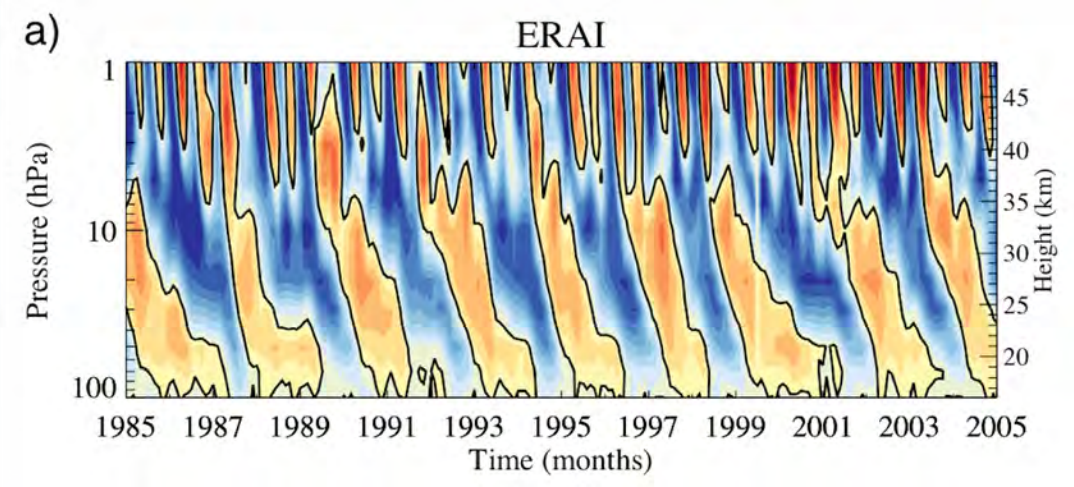
9/19/2019

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



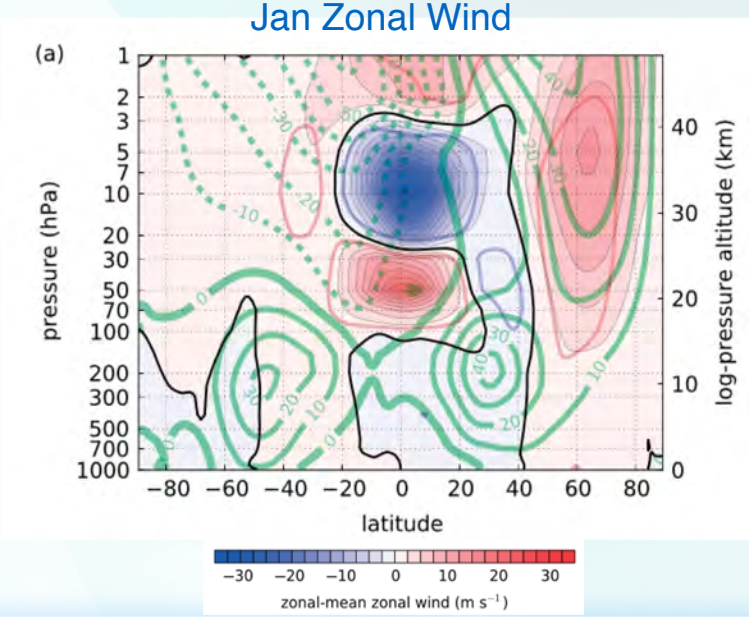
Mean Period: 28 months

- Oscillation also in temperature, ozone, & tropopause height

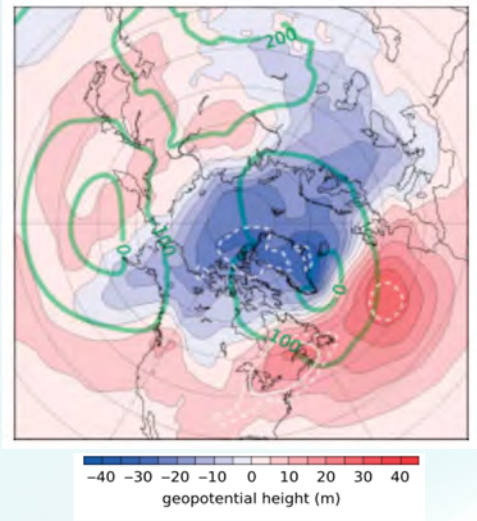
Why is QBO important?

- 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



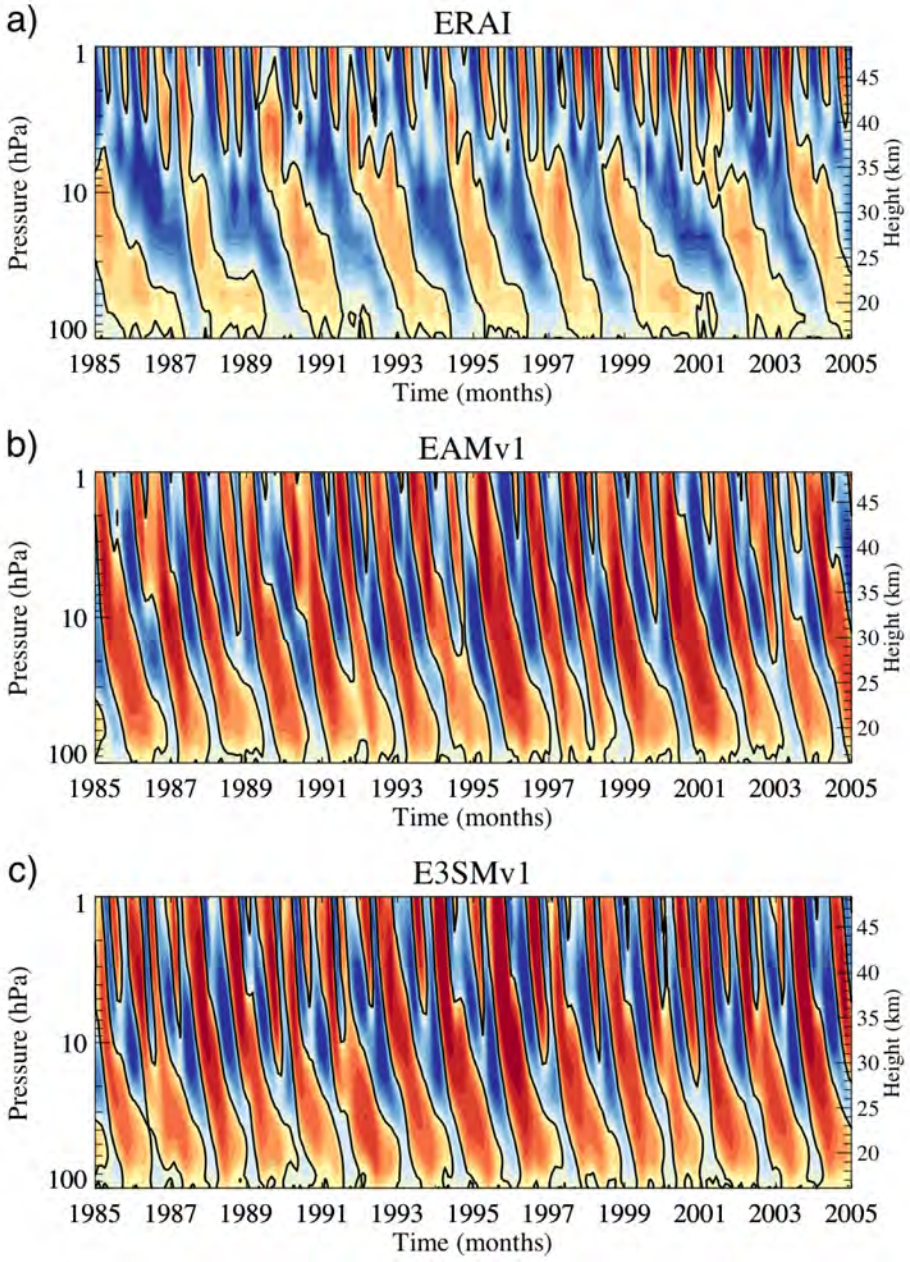
QBO W – QBO E
1000 hPa Geopotential height



+NAO

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

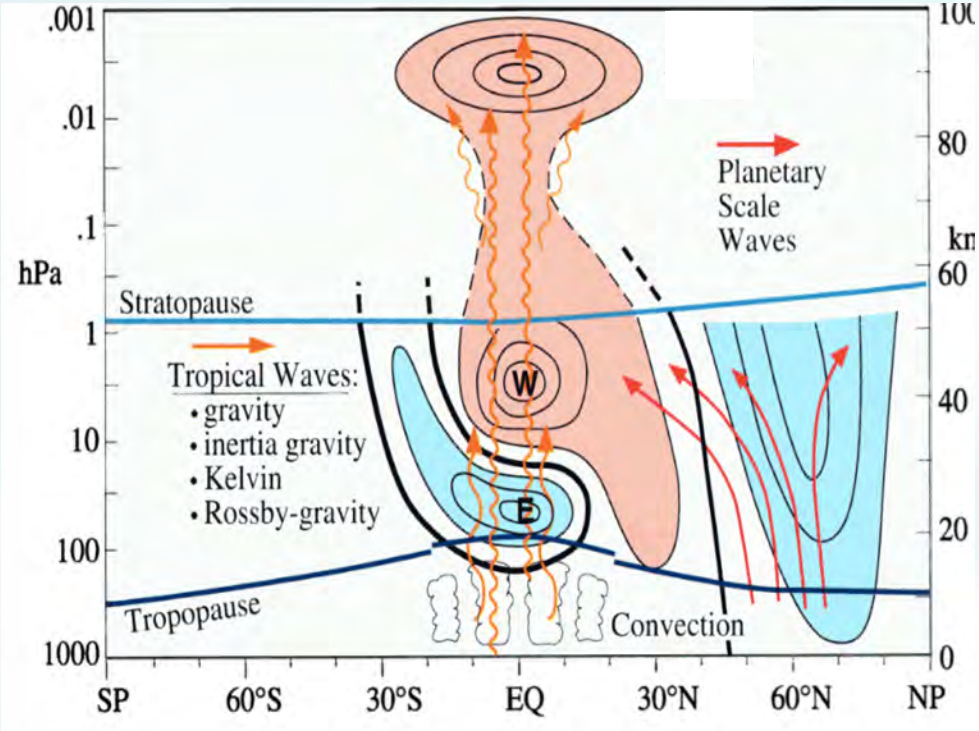
What's needed to model the QBO?

1) Kelvin & Rossby-gravity waves
   Often underrepresented

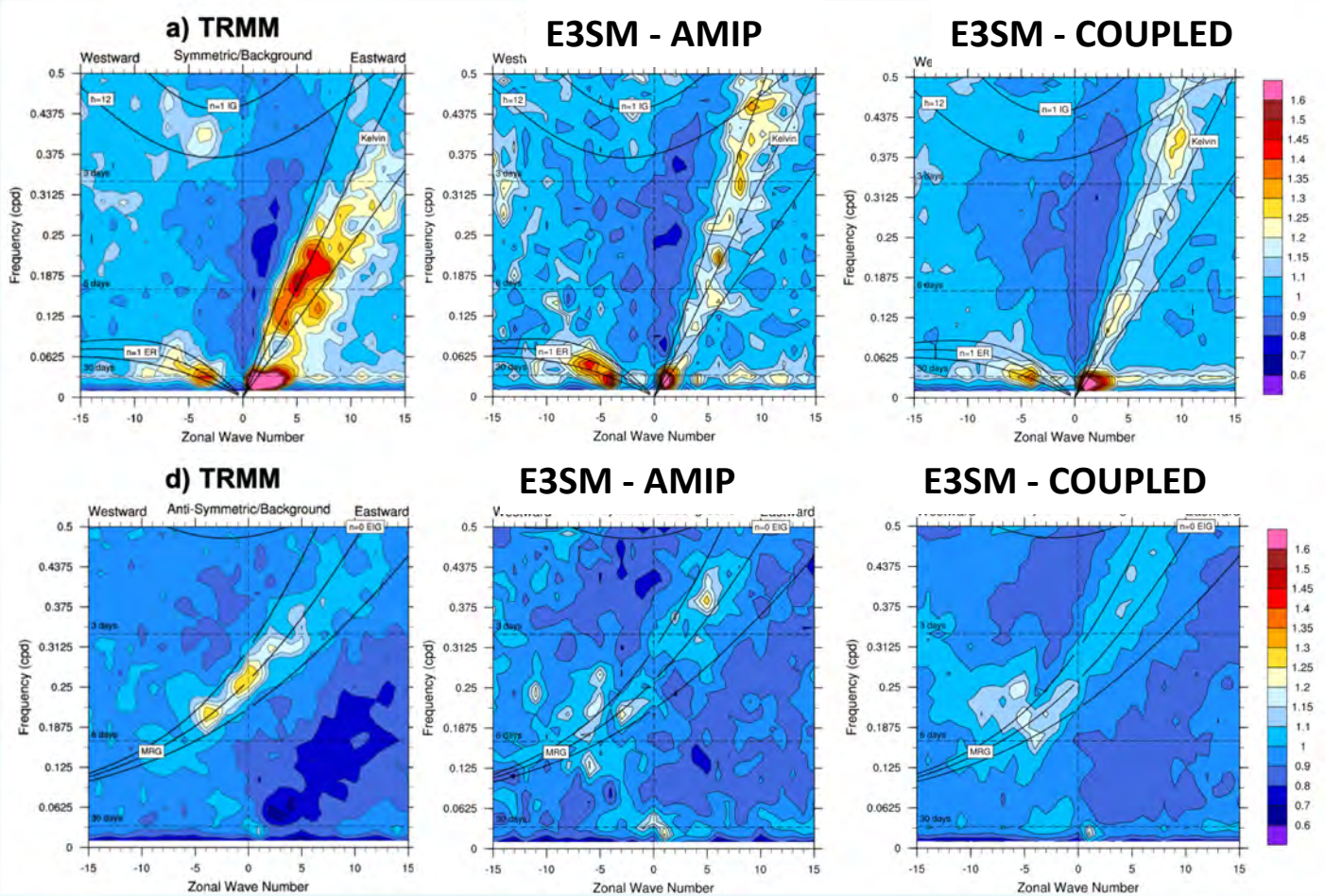
2) Small-scale gravity waves
   (~ 10's to 100s km)
   Mostly parameterized

3) Vertical resolution
   Often inadequate

4) Dynamical core
   Sometimes overly diffusive



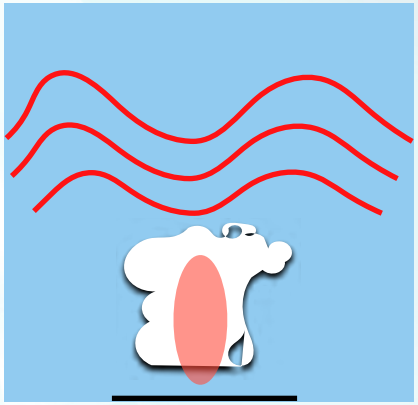
Resolved waves in E3SM



Largely underrepresented

GW Parameterization

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



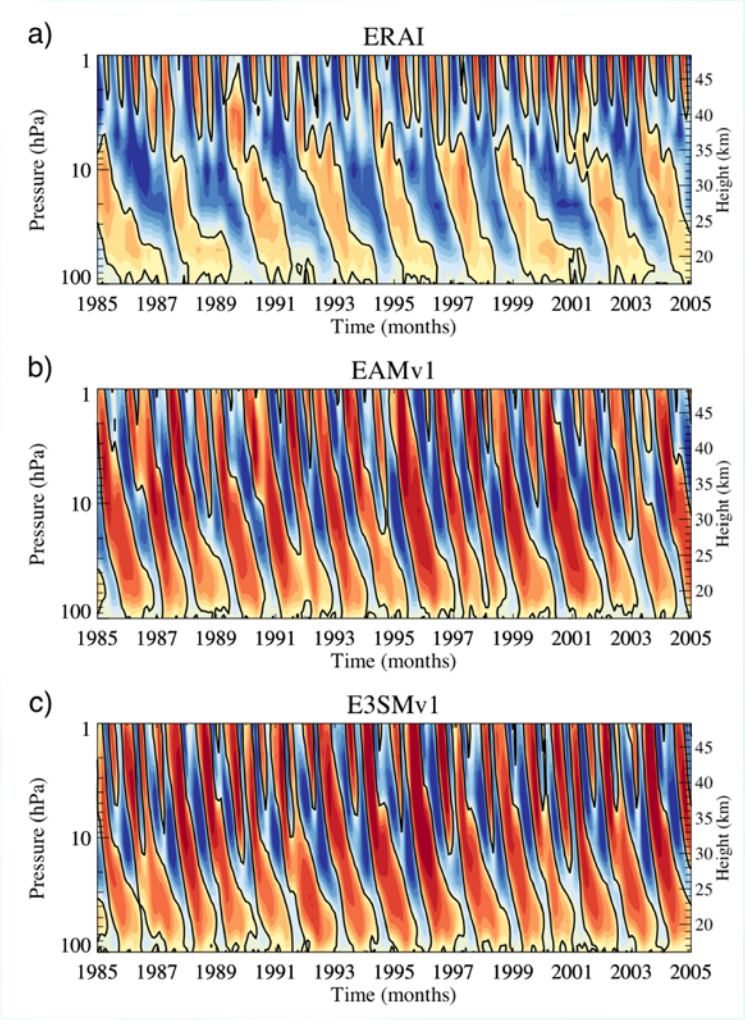
- Based on linear theory of wave generation by thermal forcing
- 40 waves with $-100 < c < 100$ m/s
- Dominant phase speed related to **h** (depth of heating)
- Wave Amplitude $\propto Q^2$ (Q = heating rate from Zhang and McFarlane scheme)
- Wave spectrum impacted by wind in heating

Tunable parameters:

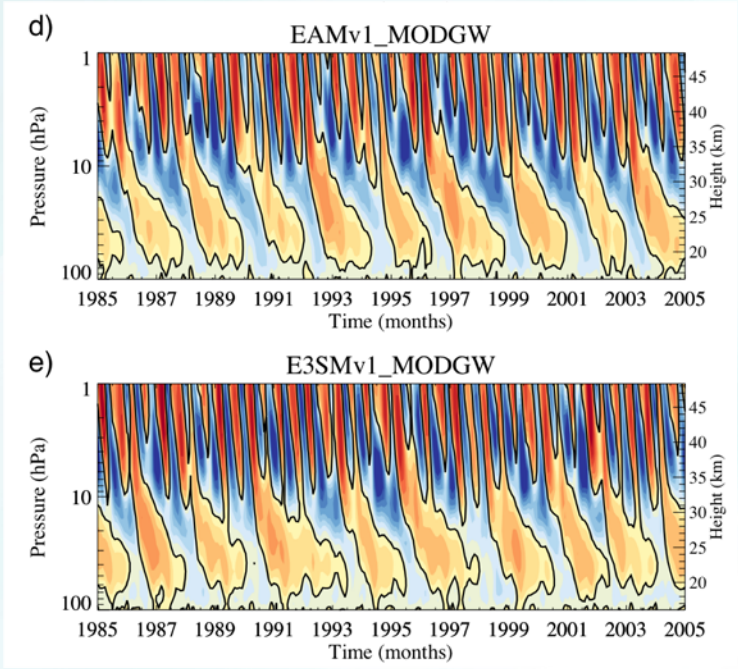
CF: conversion factor from grid cell avg to that representative of heating cell; Default: 20 (5%)

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

New vs Old QBO



QBO with GW parameter changes

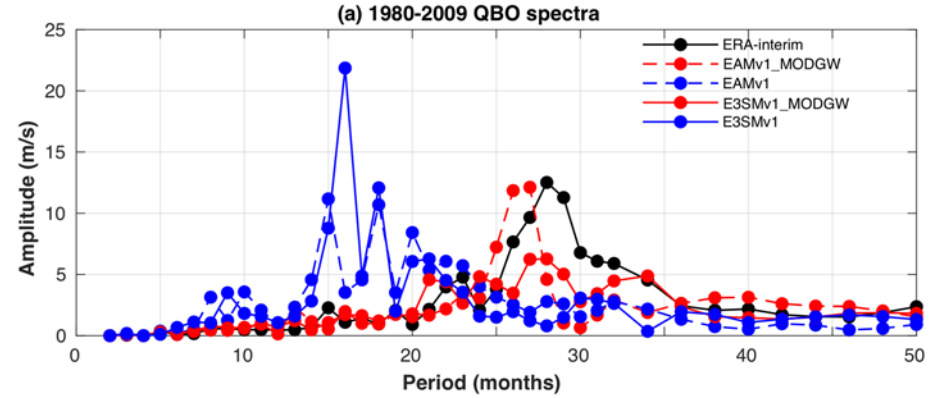


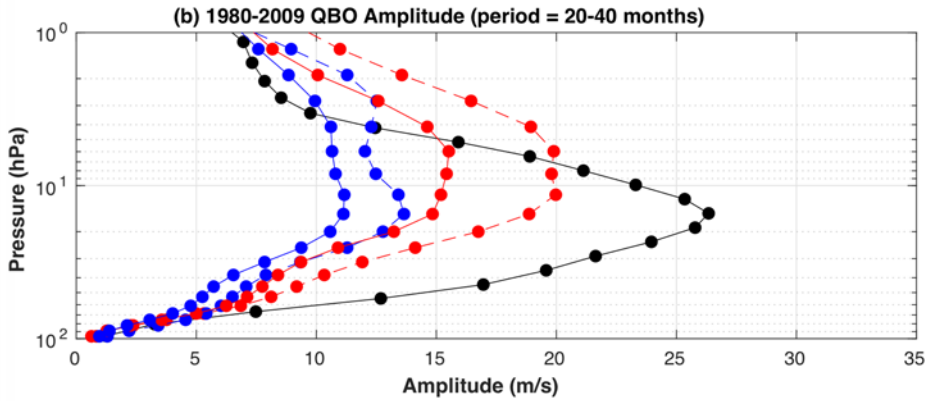
E3SMv1: CF = 20; Eff = 0.4

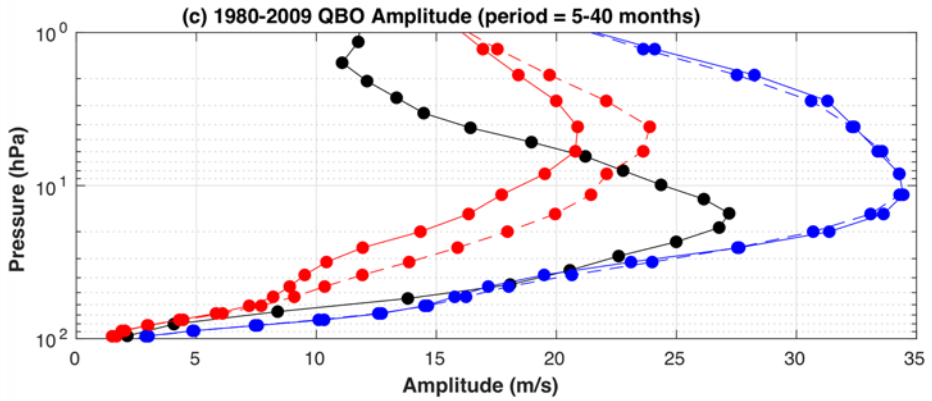
MOD: CF = 12.5; Eff = 0.35

Power Spectrum and Amplitude

Avg QBO Period:
ERAI: 28 months
E3SMv1: 18 months
E3SMv1_MOD: 26 months

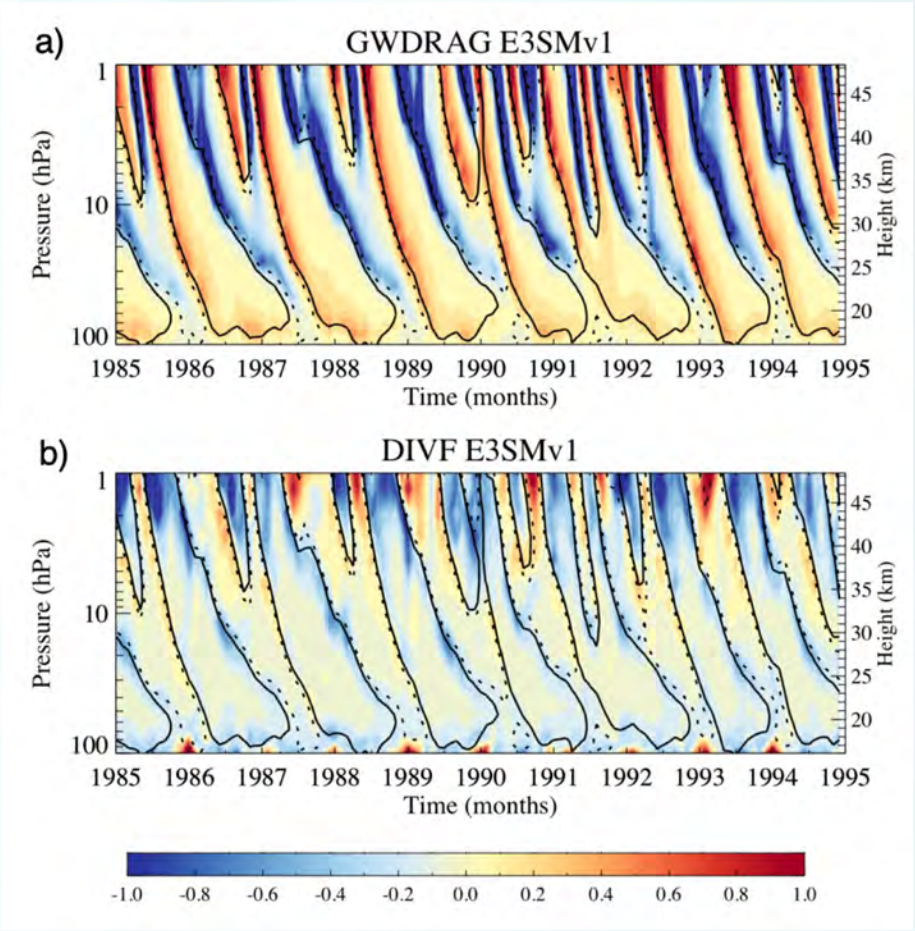




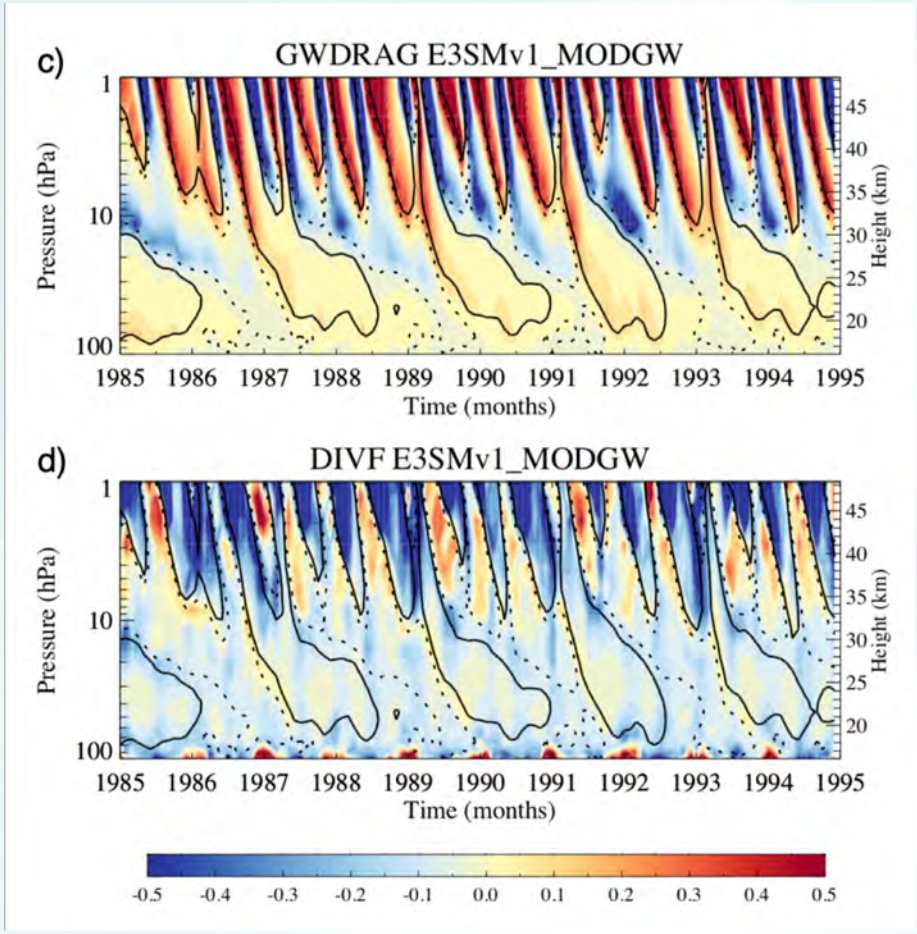


E3SM Energy Exascale Earth System Model

QBO Driving

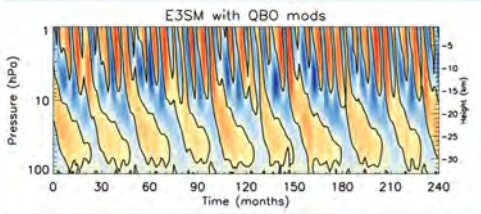


m/s/day



m/s/day

QBO: E3SM vs Other Models (mostly high top)

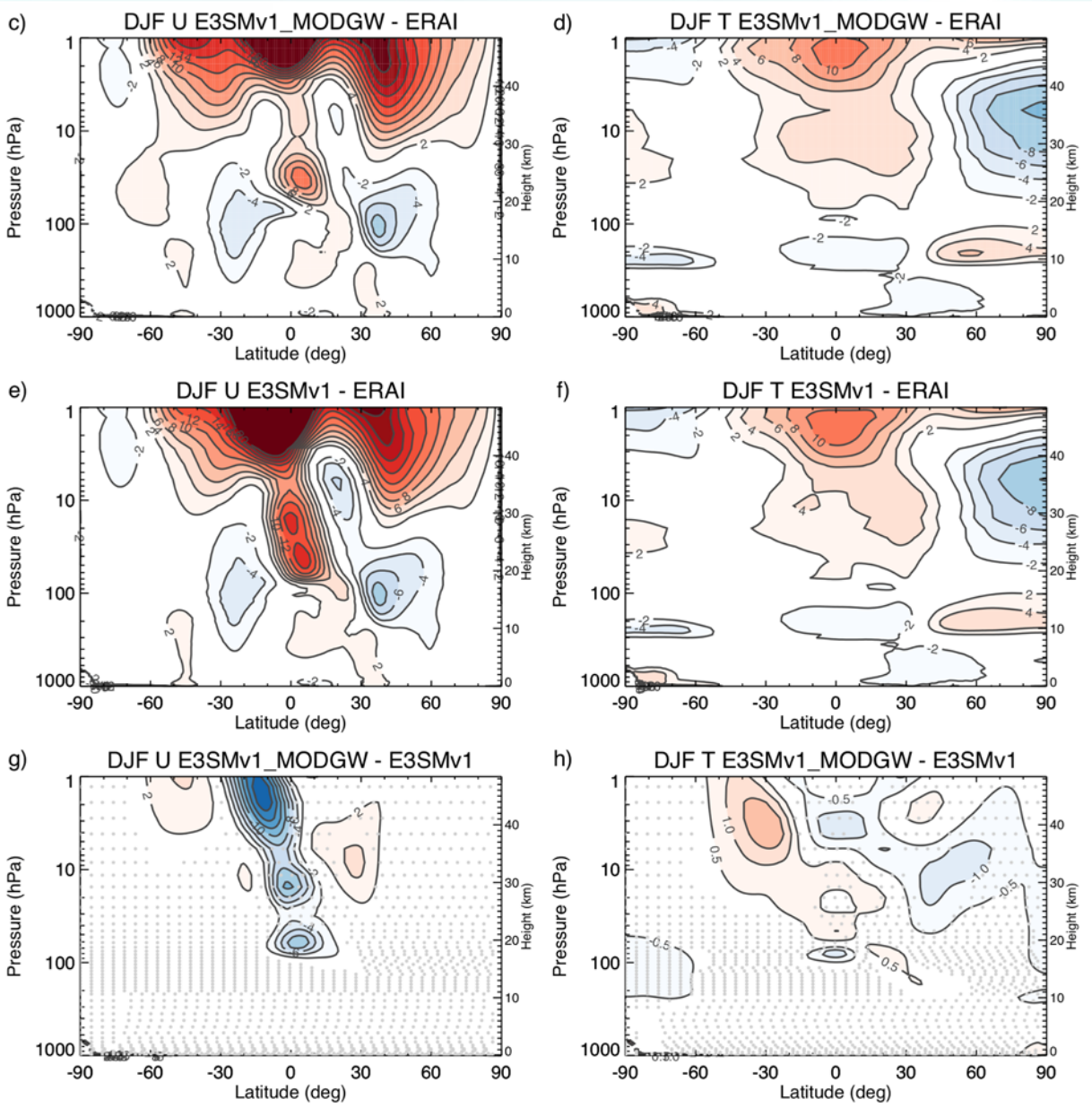


Left: QBOs in QBOi models and ERAi (Bushell et al. 2019, in review)

U.S. DEPARTMENT OF ENERGY

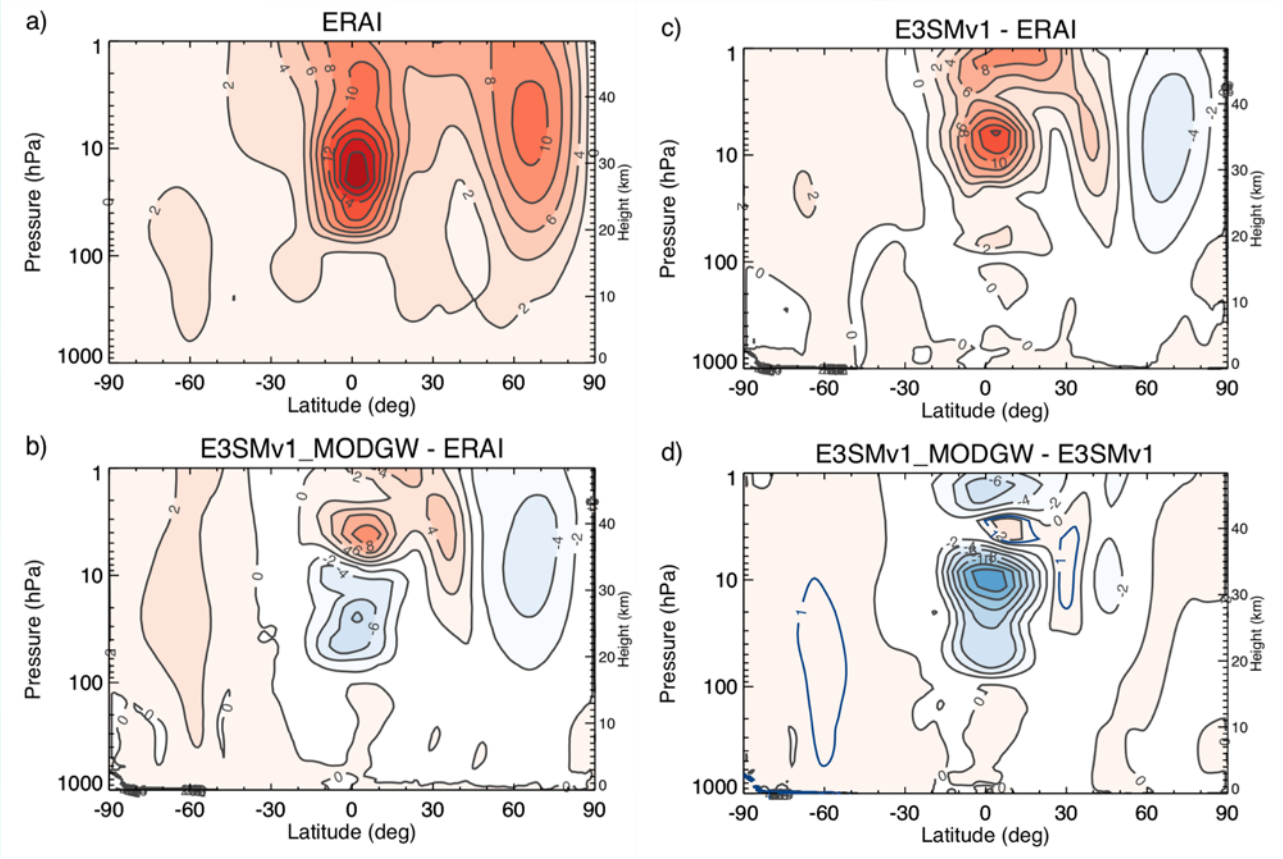
Stratospheric U & T Changes DJF

1980 – 2009 DJF Avg



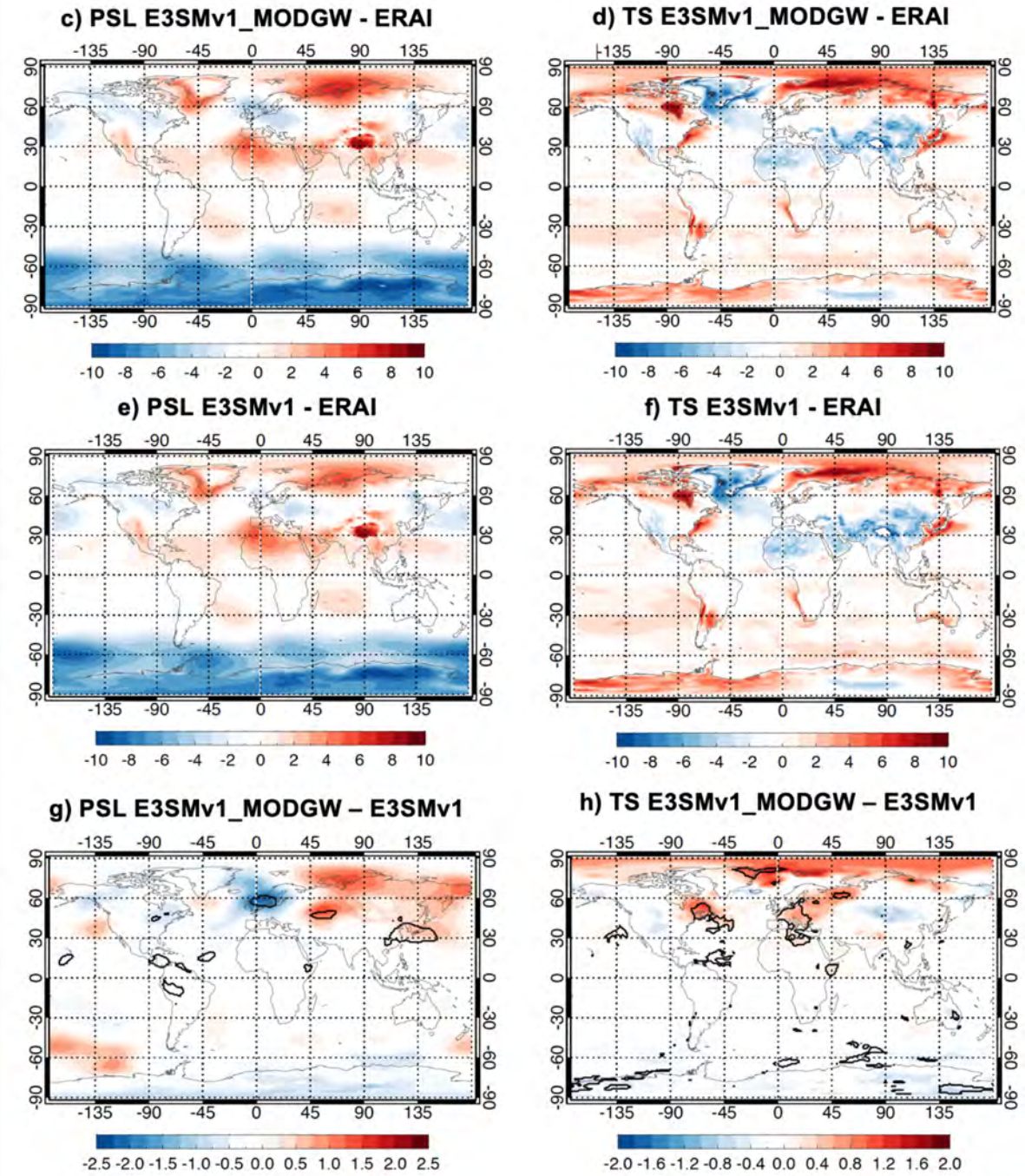
E3SM Energy Exascale Earth System Model

U Variability



DJF Standard deviation of U

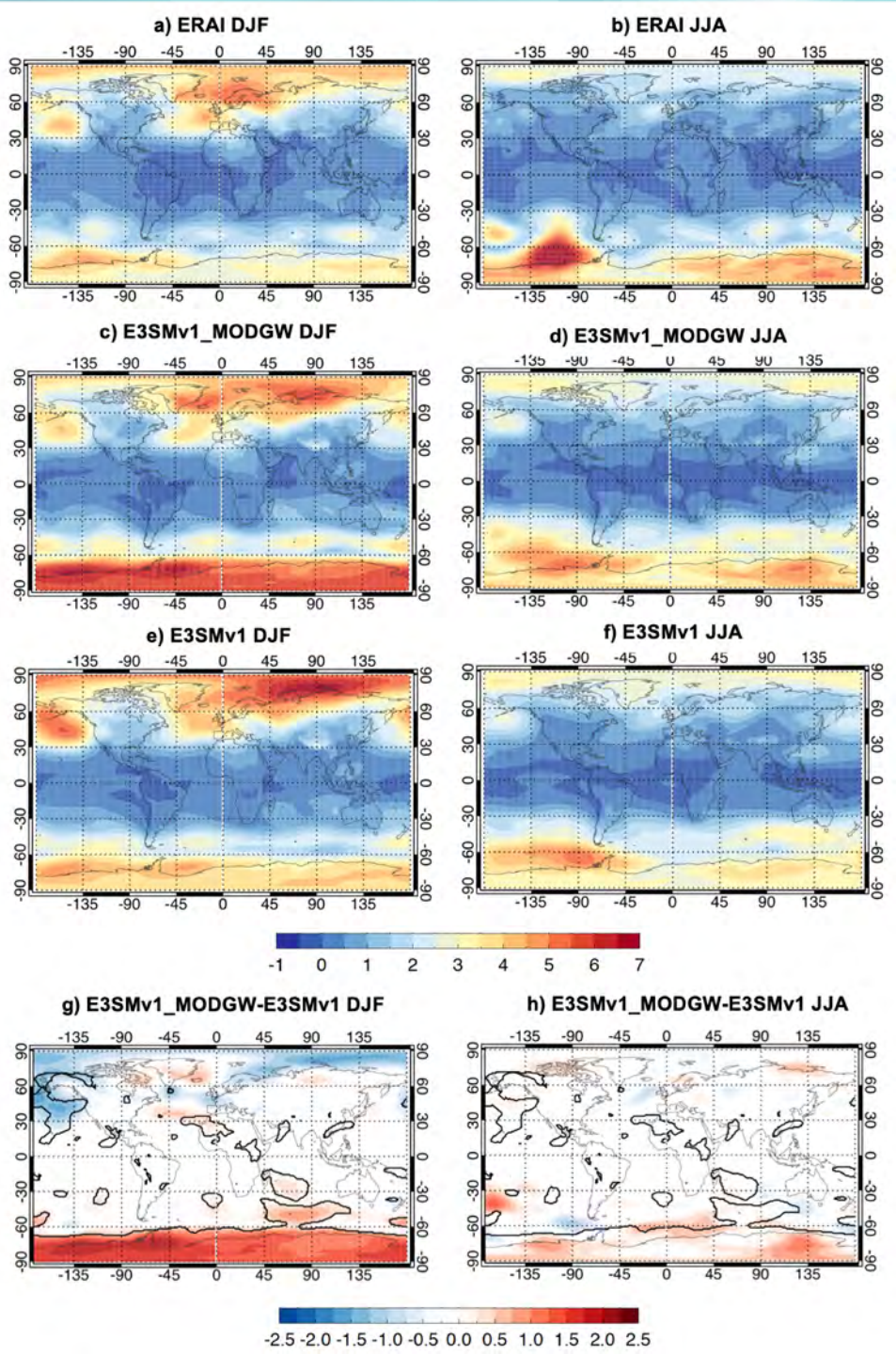
Surface Changes:



Black Contour:
Sig at 95% level

E3SM Energy Exascale Earth System Model

Surface Changes: Variability

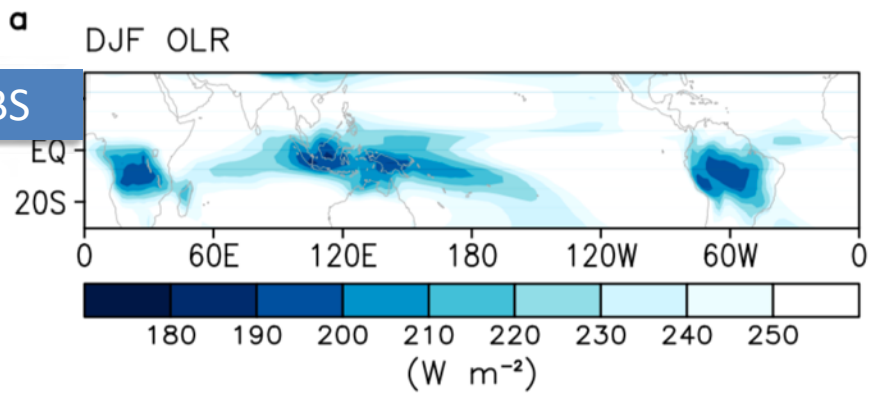


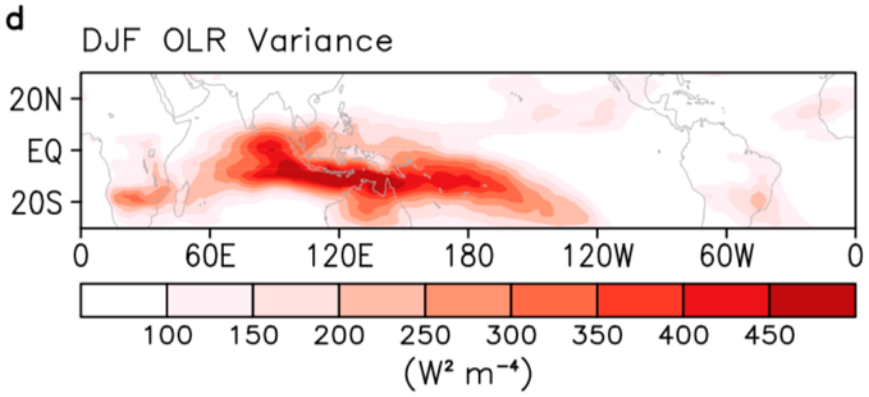
Black Contour:
Sig at 95% level

E3SM Energy Exascale Earth System Model

QBO Impacts on the MJO: OBS

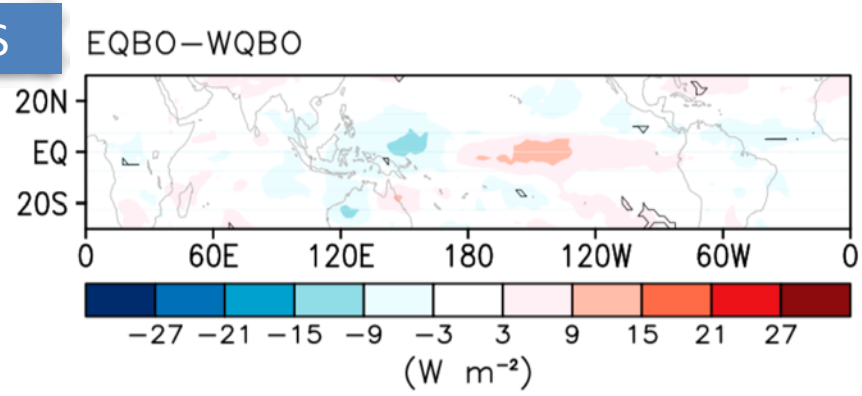
OBS

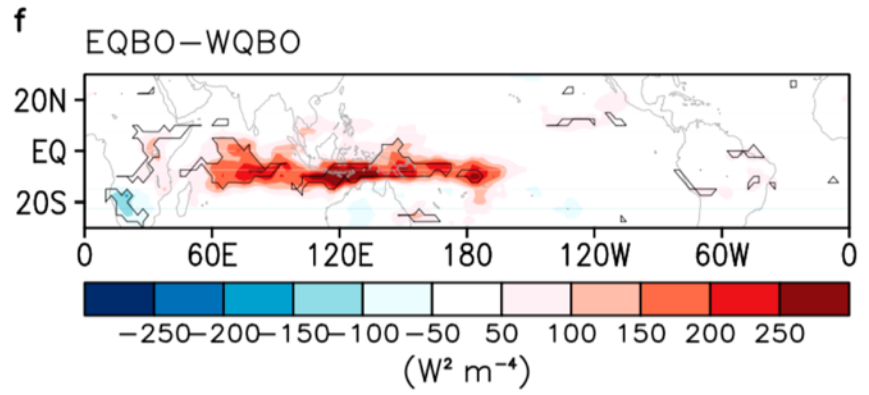




Son et al. 2017

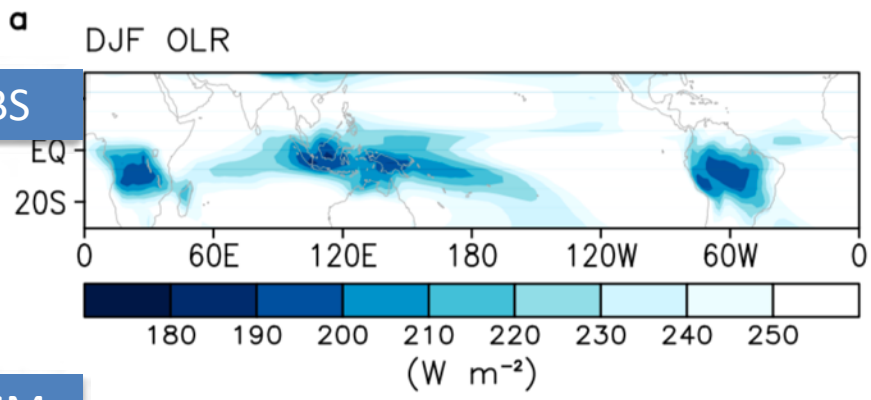
OBS

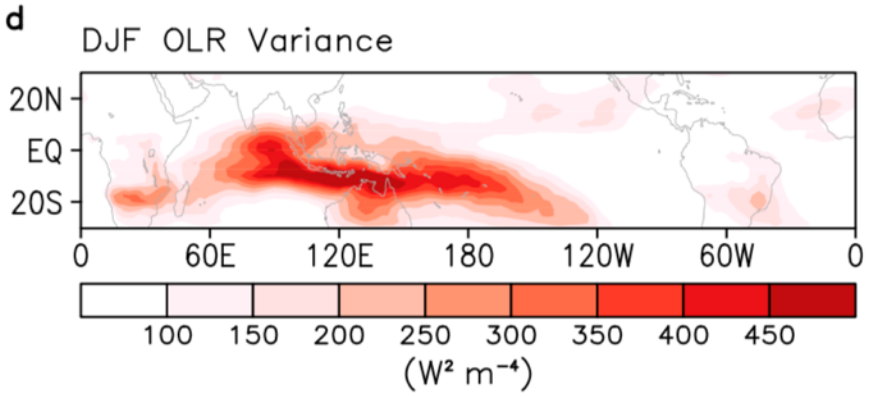




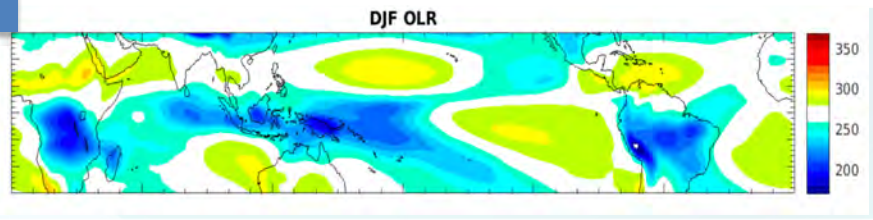
QBO Impacts on the MJO: OBS

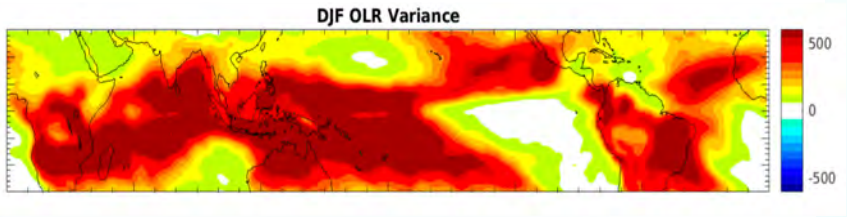
OBS



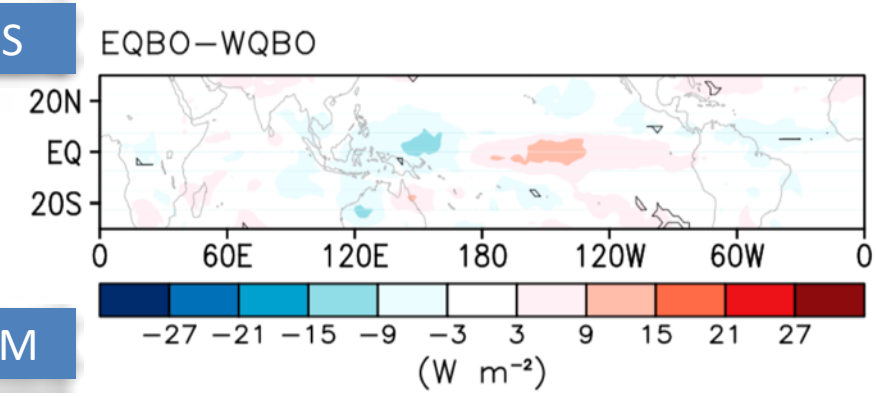


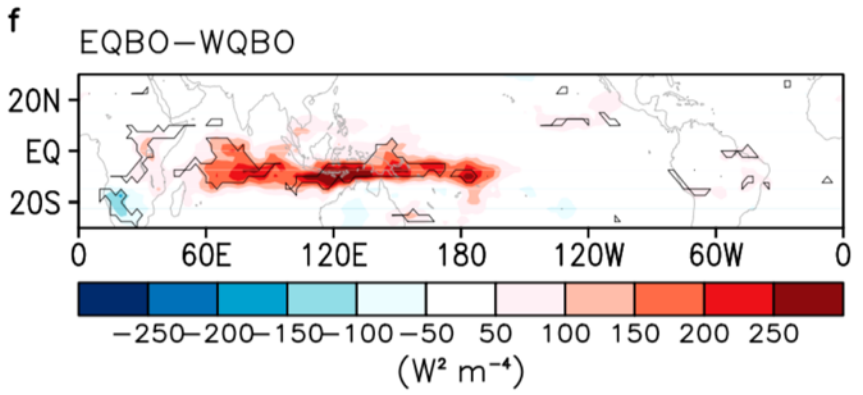
E3SM



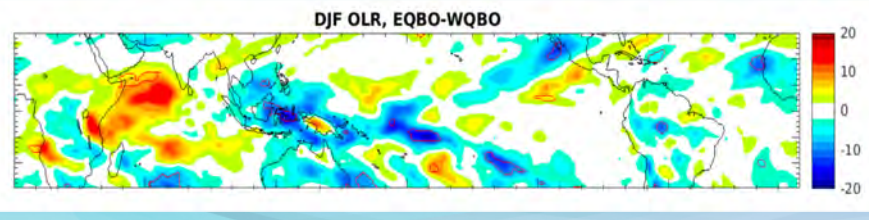


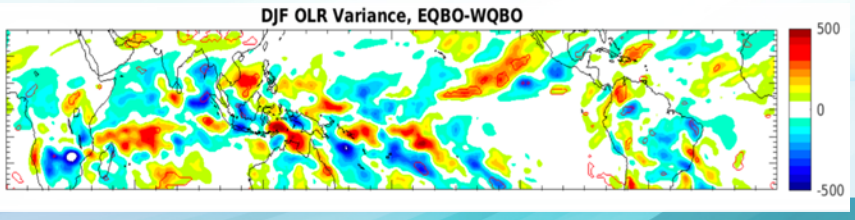
OBS





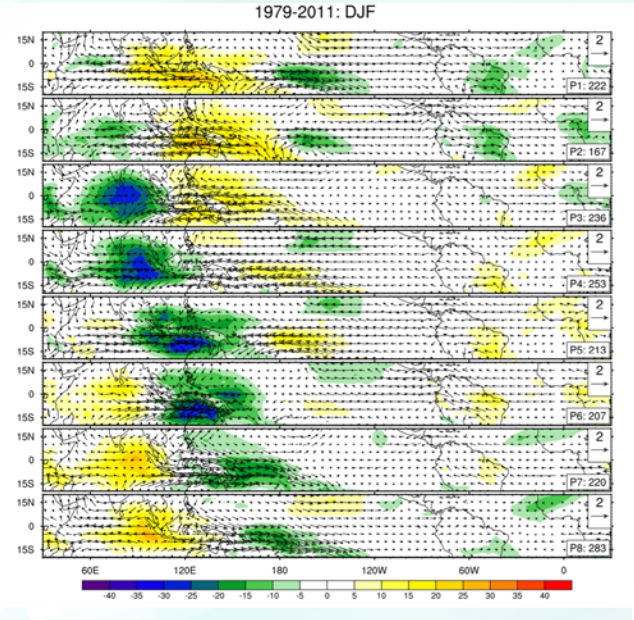
E3SM



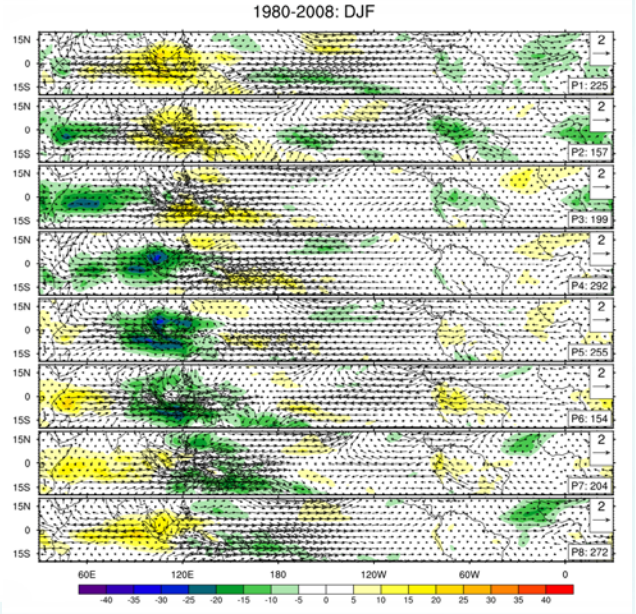


MJO Propagation

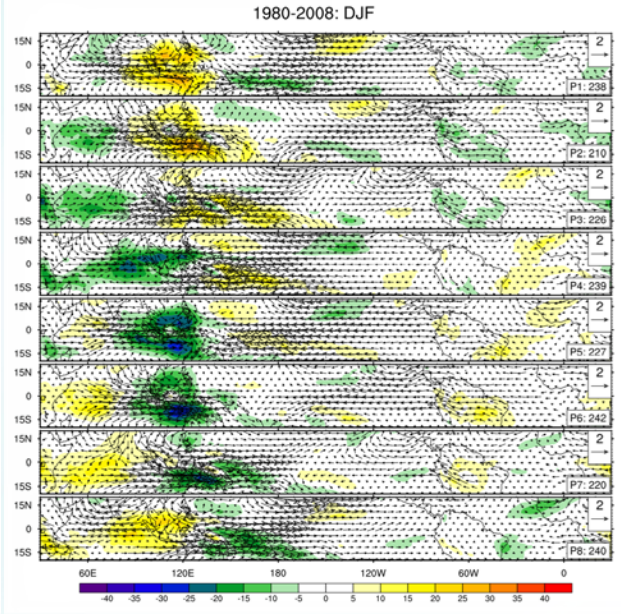
OBS



E3SMv1



MOD GW



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