Quantifying the uncertainty in climate response to stratospheric aerosol injection from gravity wave parametrizations in CESM2(WACCM)

(work in progress…)

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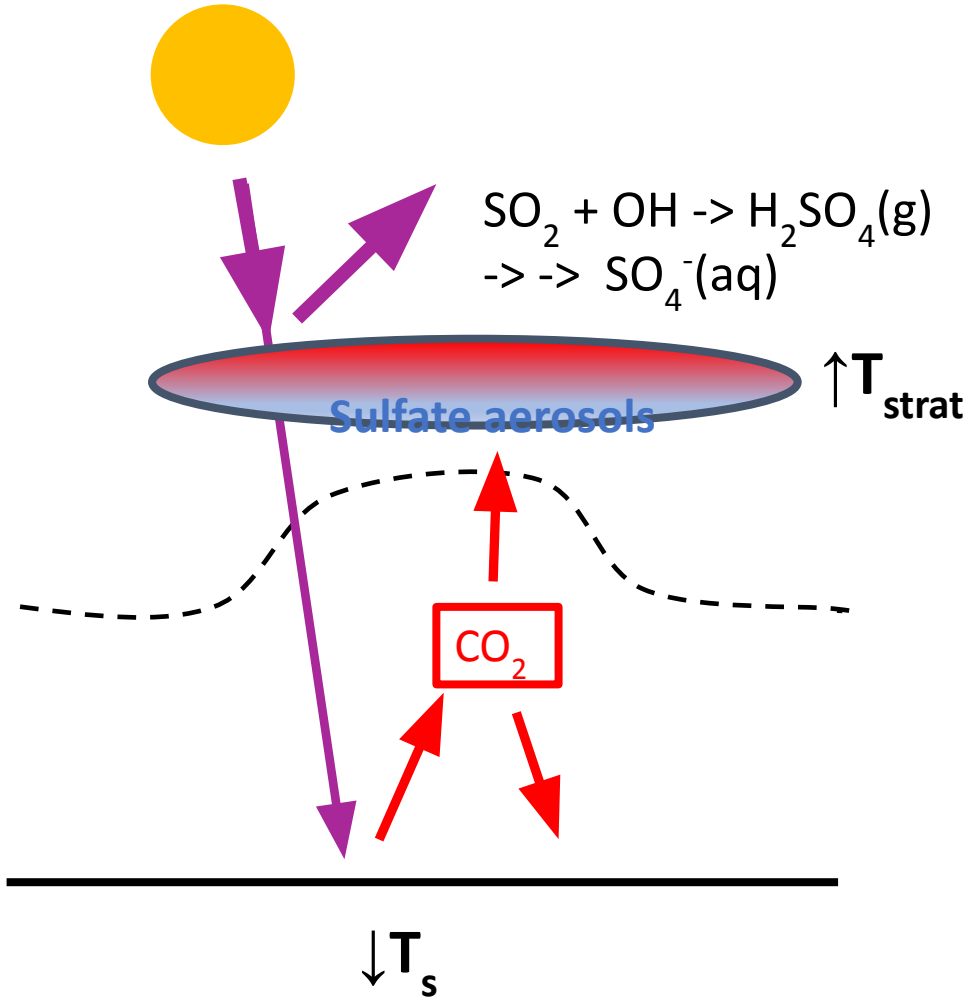
NCAR, 01 February 2023

Background – Stratospheric Aerosol Injection (SAI)



- Injection of sulfate aerosol precursors into the lower stratosphere => aerosols reflect solar radiation => ↓T_{trop}

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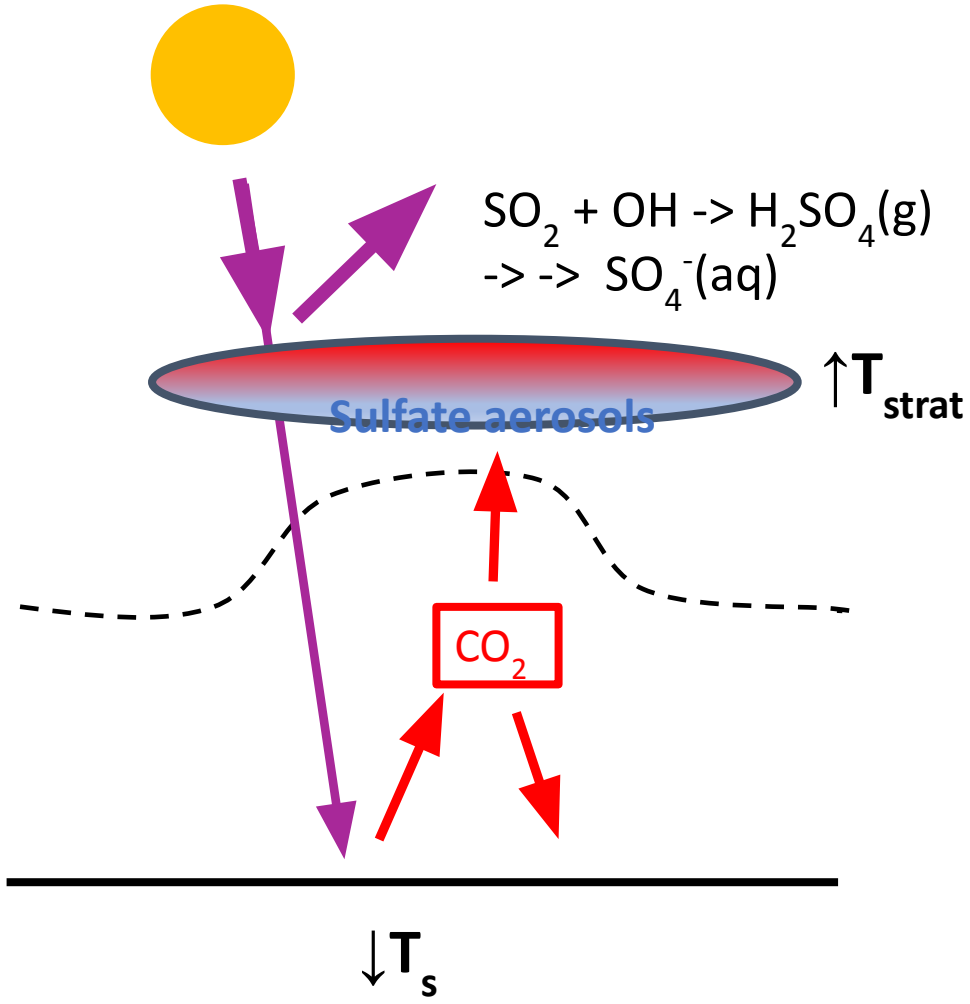

- Injection of sulfate aerosol precursors into the lower stratosphere => aerosols reflect solar radiation => ↓T_{trop}
- <u>Many uncertainties:</u>

- the efficiency of SO_2 to aerosol conversion, and its later removal

- transport of aerosols by the BDC+mixing

- efficiency of direct impact on radiative balance

- indirect impacts (many!)

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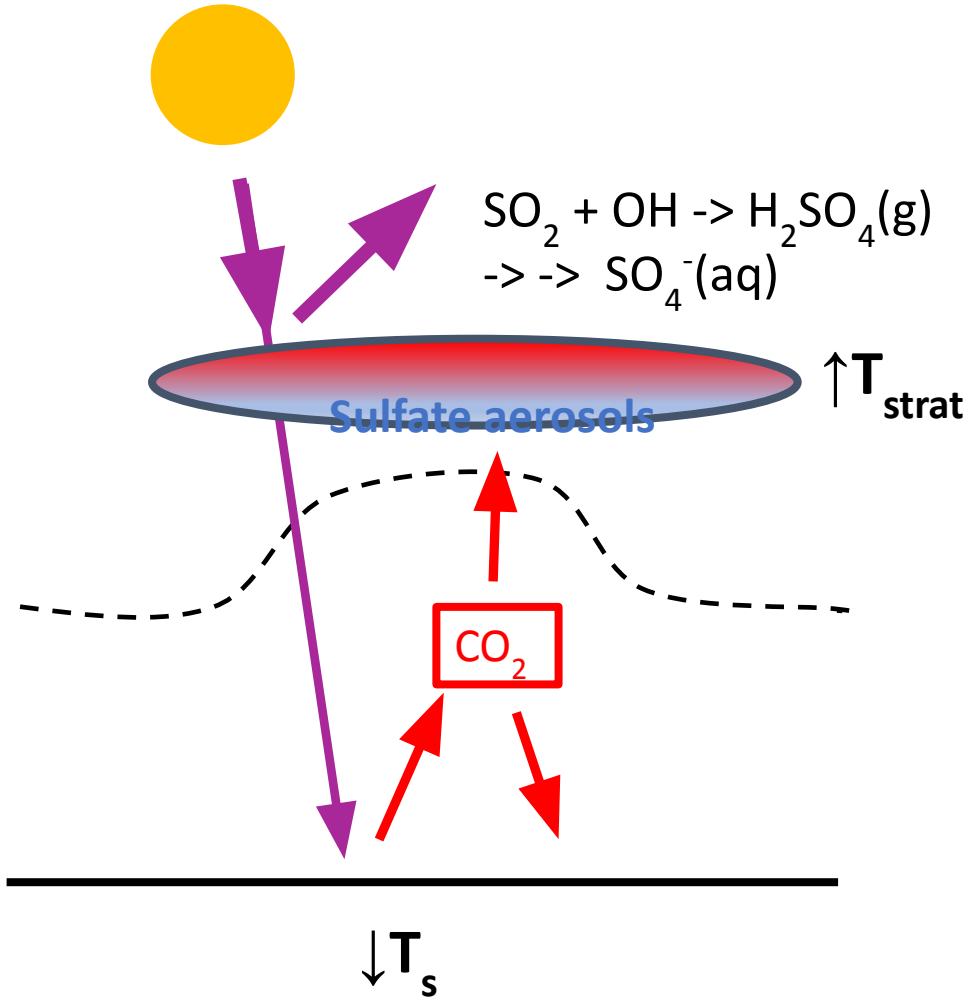

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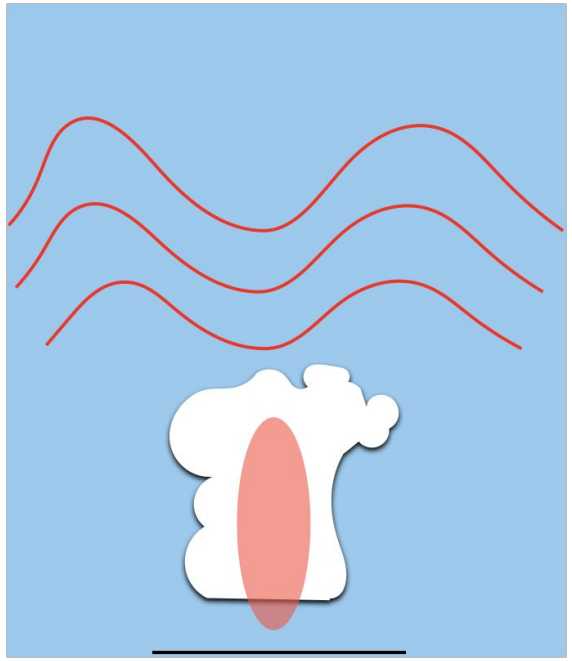
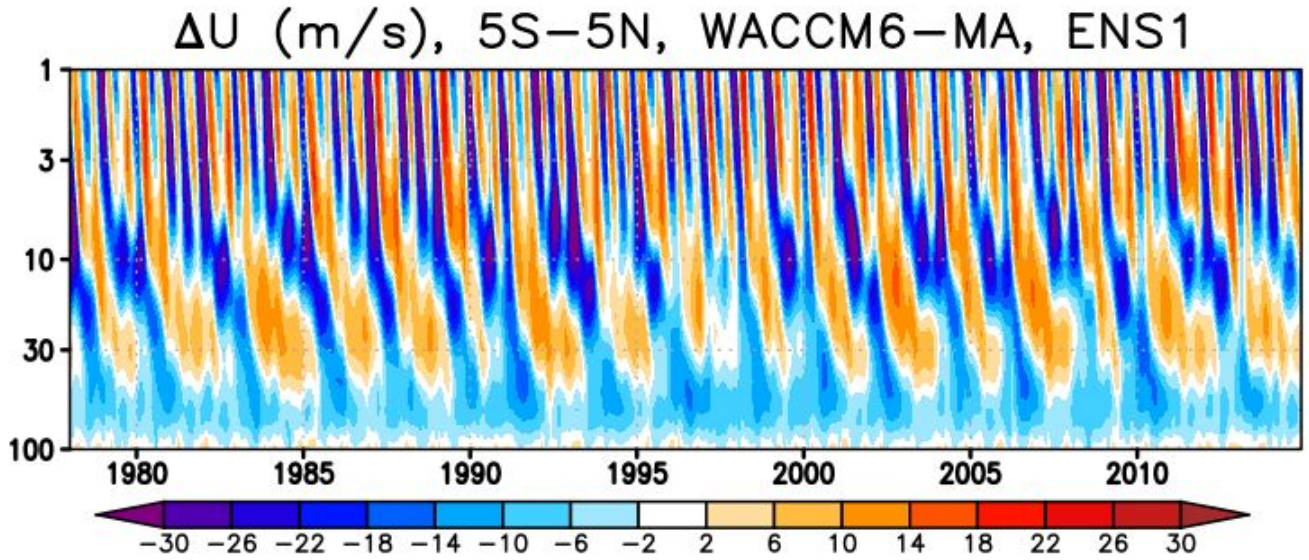
Part 1: Impacts of ***convective*** gravity wave drag parametrization

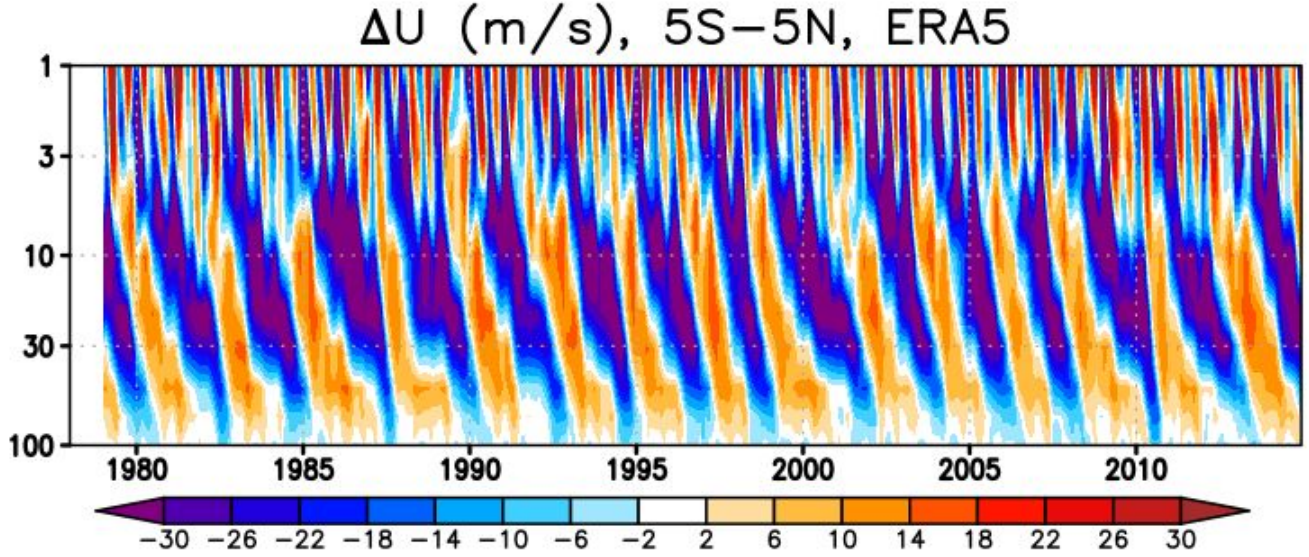


Current convective GW parametrization:

- following Beres et al. (2004)
- largely drives QBO in the L70 model
- wave phase speeds related to:
  - depth of convective heating region
  - maximum convective heating
  - zonal wind in heating region

=> QBO speeds up in warming climate as GW amplitude increases





Standard WACCM6-MA L70 version has QBO with too weak amplitude (esp. in lower stratosphere) and somewhat shorter period compared to ERA5

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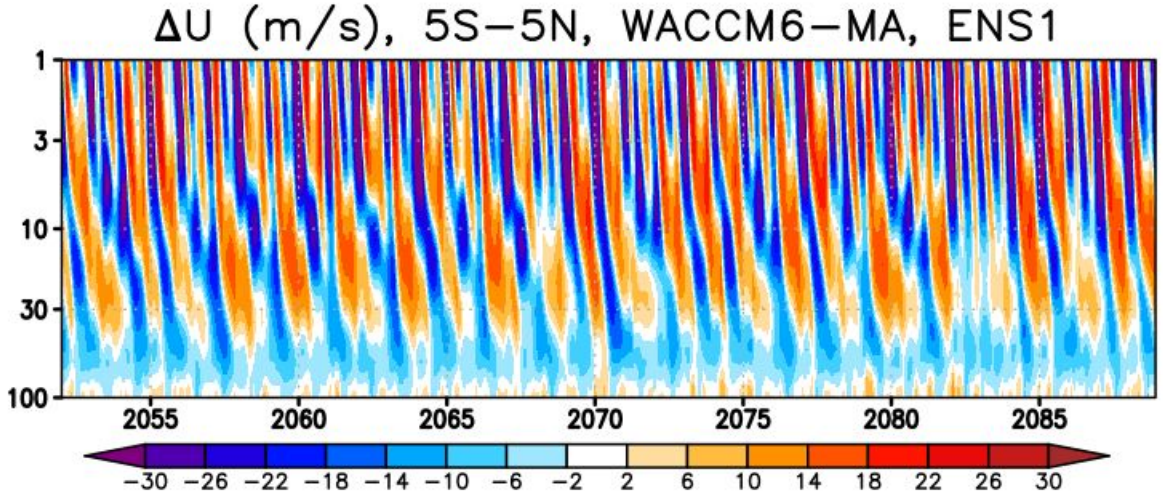

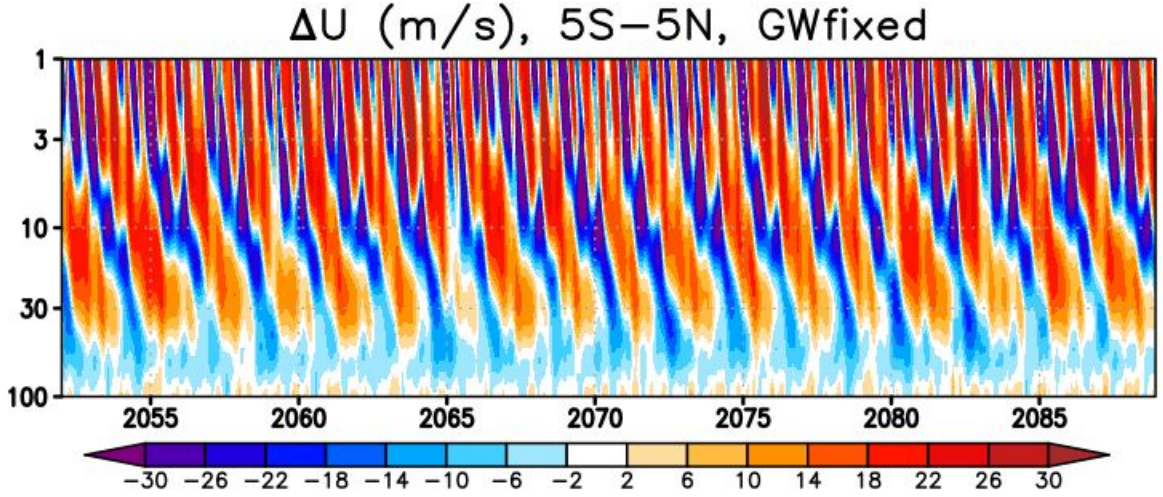

Here: Uncoupled convective GWs from convective heating ('GWfixed'):

- climatological heating area, heating depth, and heating amplitude
- get different amplitude and period of QBO, prevents QBO from speeding up as much

QBO Period:	**2020 – 2060**	**2060 - 2100**
SSP2-4.5 MA:	21.3 mo	16.7 mo
GWfixed:	27.9 mo	24.9 mo

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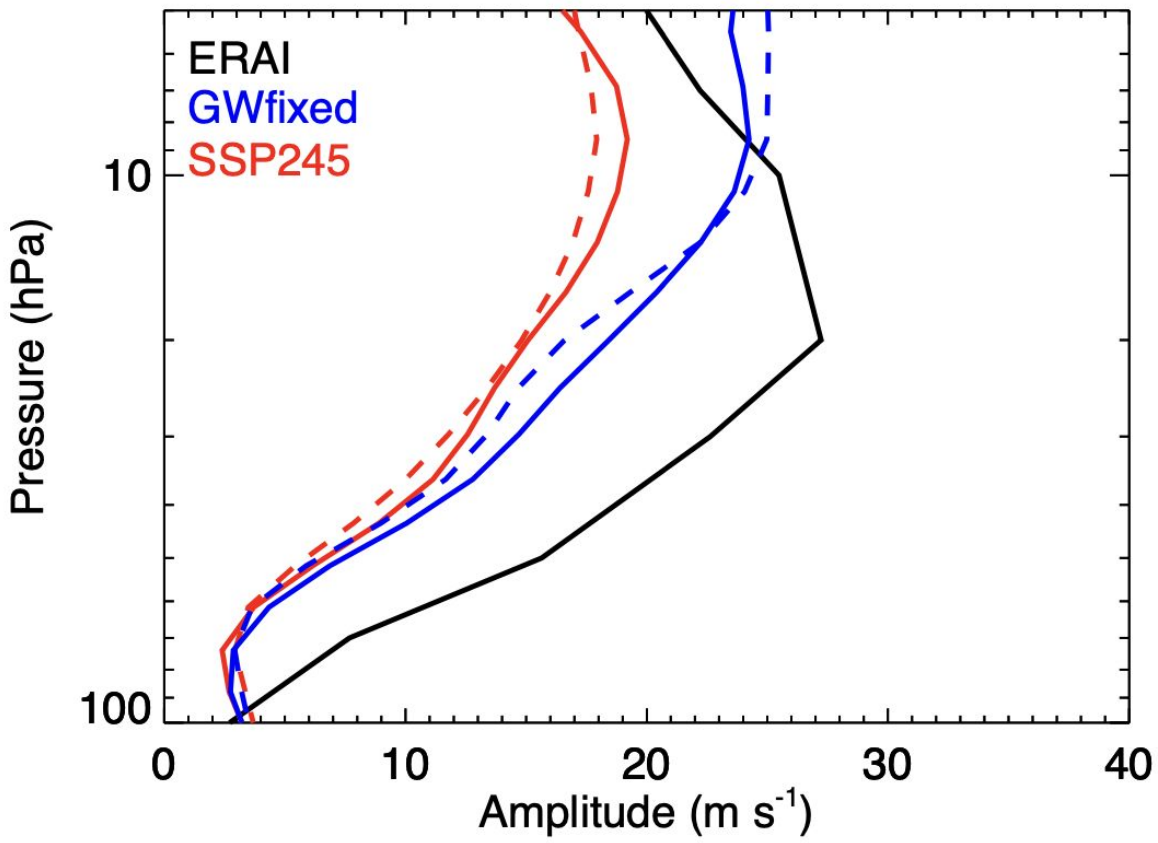

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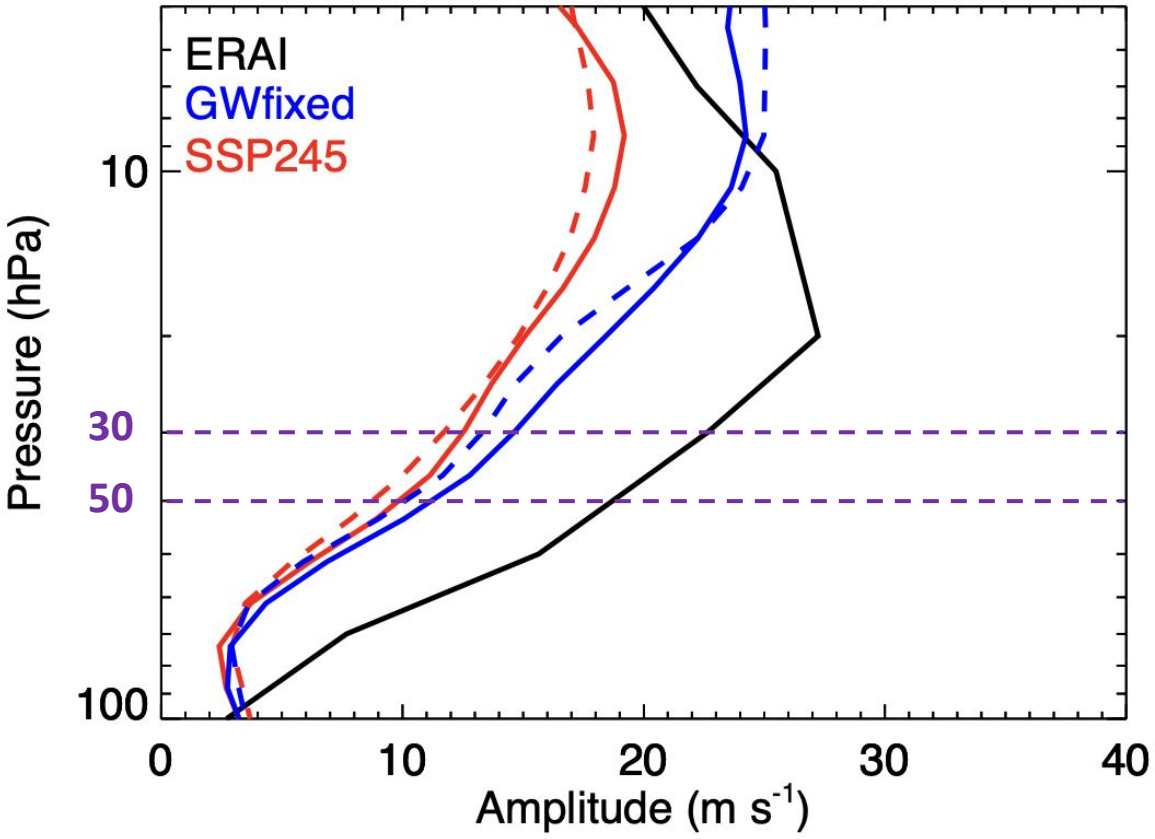

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-> GWfixed has stronger amplitude, but still mainly above 30 hPa

<u>CESM2(WACCM6-MA) SAI simulations:</u>

Constant 12 Tg-SO_2/yr injections over 2035-2069 at EQ and either:

- 22 km (~50 hPa, like ARISE-SAI) or
- 25 km (~30 hPa, like GLENS)

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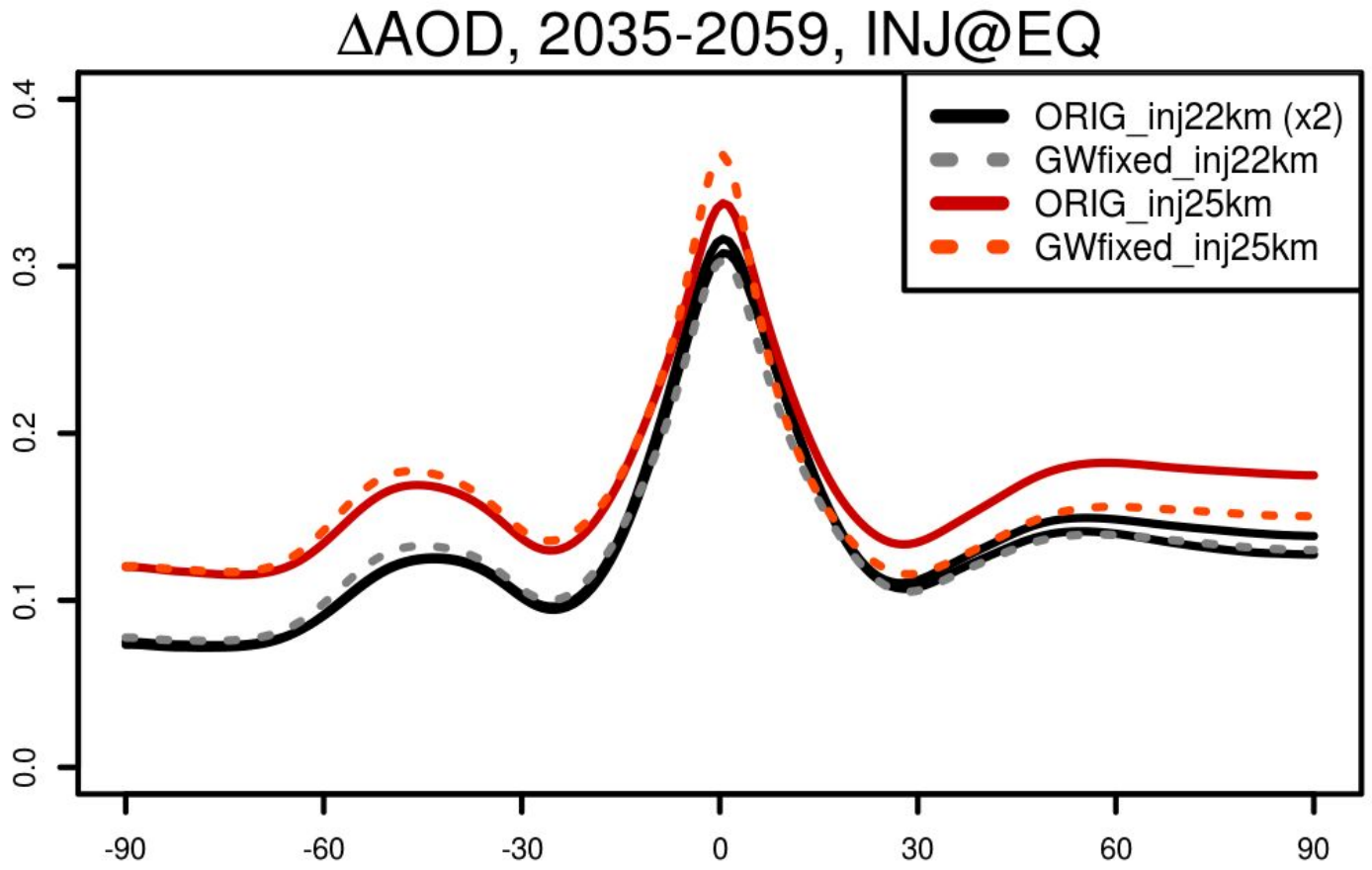

- Perturbing QBO has little impact on AOD for injections at 22 km in this model version
- For 25 km injections, GWfixed has higher AOD at equator and lower AOD in NH (~10%)

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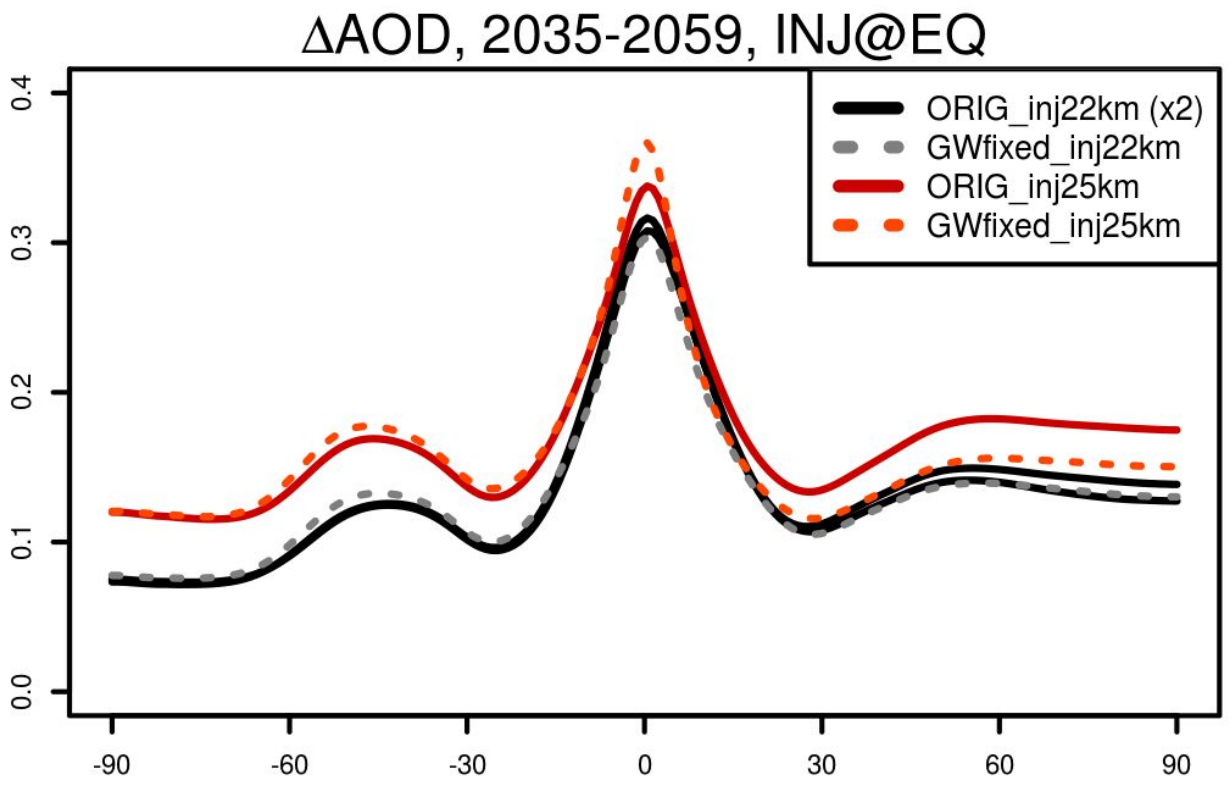

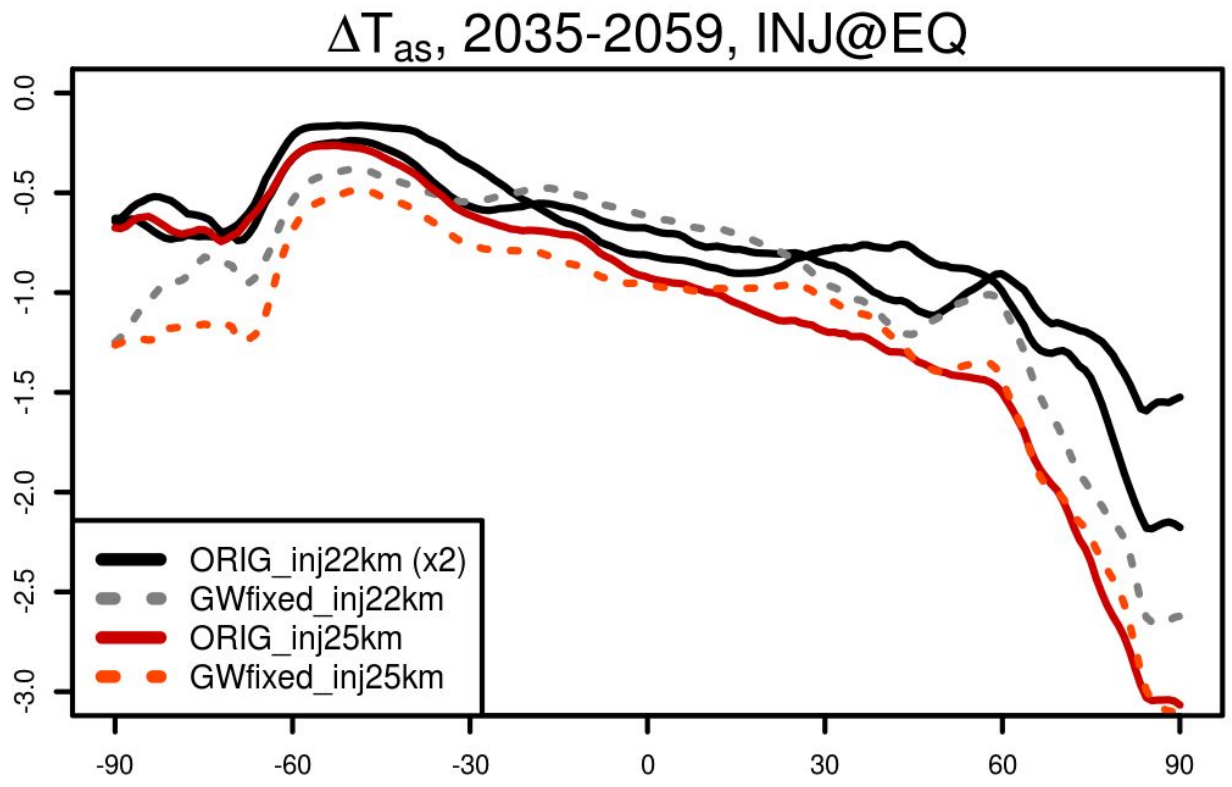

- No clear impacts on NH yearly mean T_{as} (except in the subtropics)
- But: lower T_{as} in the SH mid-/high latitudes (?)

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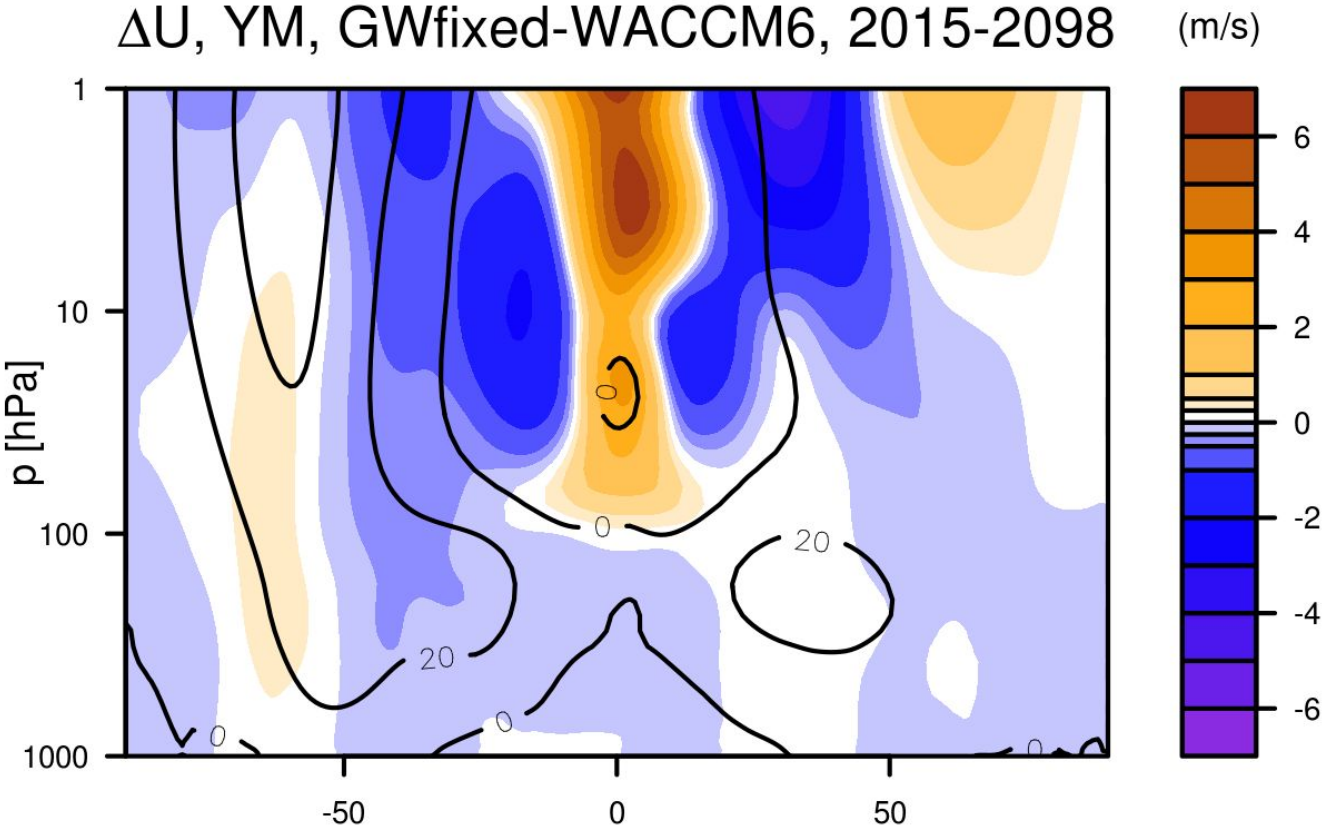


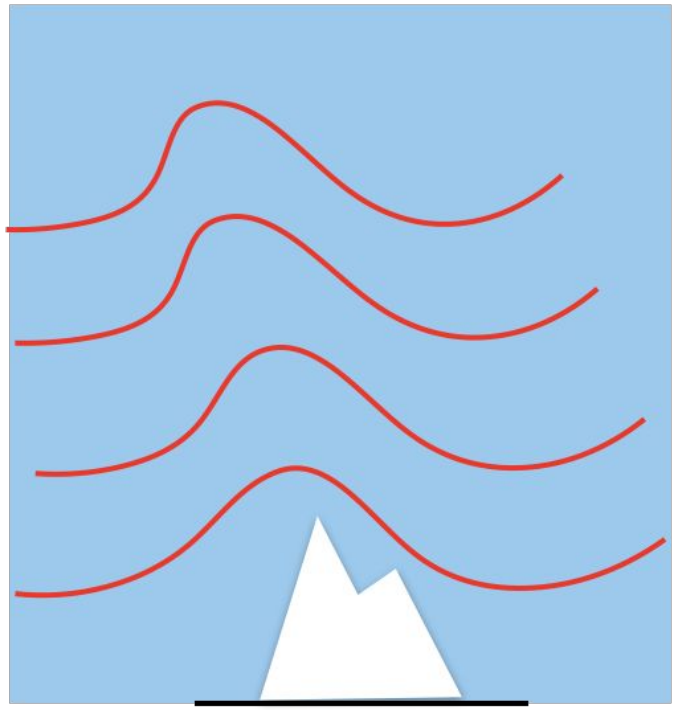
Different (stronger) climatological SH polar vortex in GWfixed

-> QBO teleconnection (~Holton Tan) ?

-> differences in GW flux outside of the tropics ?

-> does the anomaly get amplified under SAI ?

Part 2: impacts of ***orographic*** gravity wave drag parametrization



Orographic GW parametrization:

- new in CESM2
- following Scinocca and McFarlane (2000)
- controls primarily extratropical stratospheric circulation (U, BDC)

A number of tuneable parameters, including ‘effgw_rdg_beta’ and ‘effgw_rdg_beta_max’ that control the scheme’s efficiency

-> default = 1

-> here vary between 0.1 – 3.0

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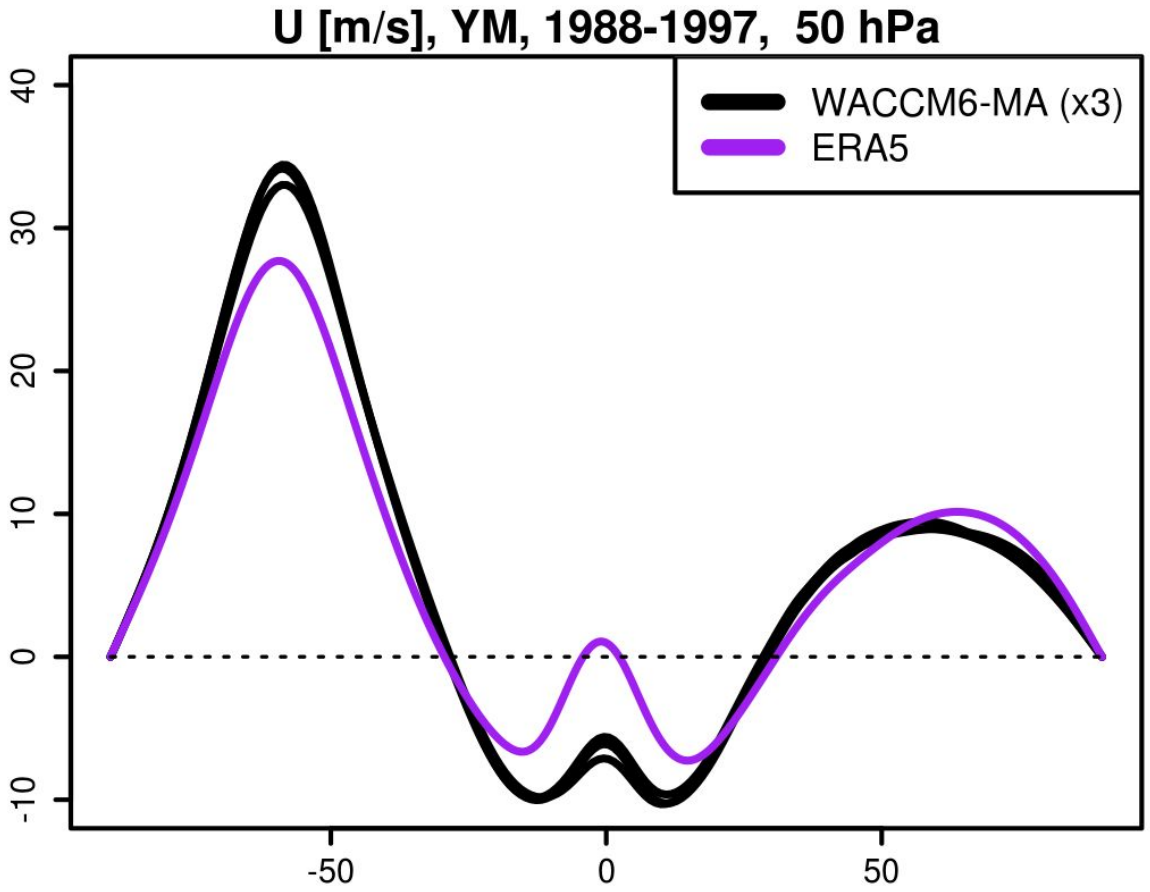

-> polar vortex too strong in CESM2 in SH and a bit too weak (in DJF) in NH

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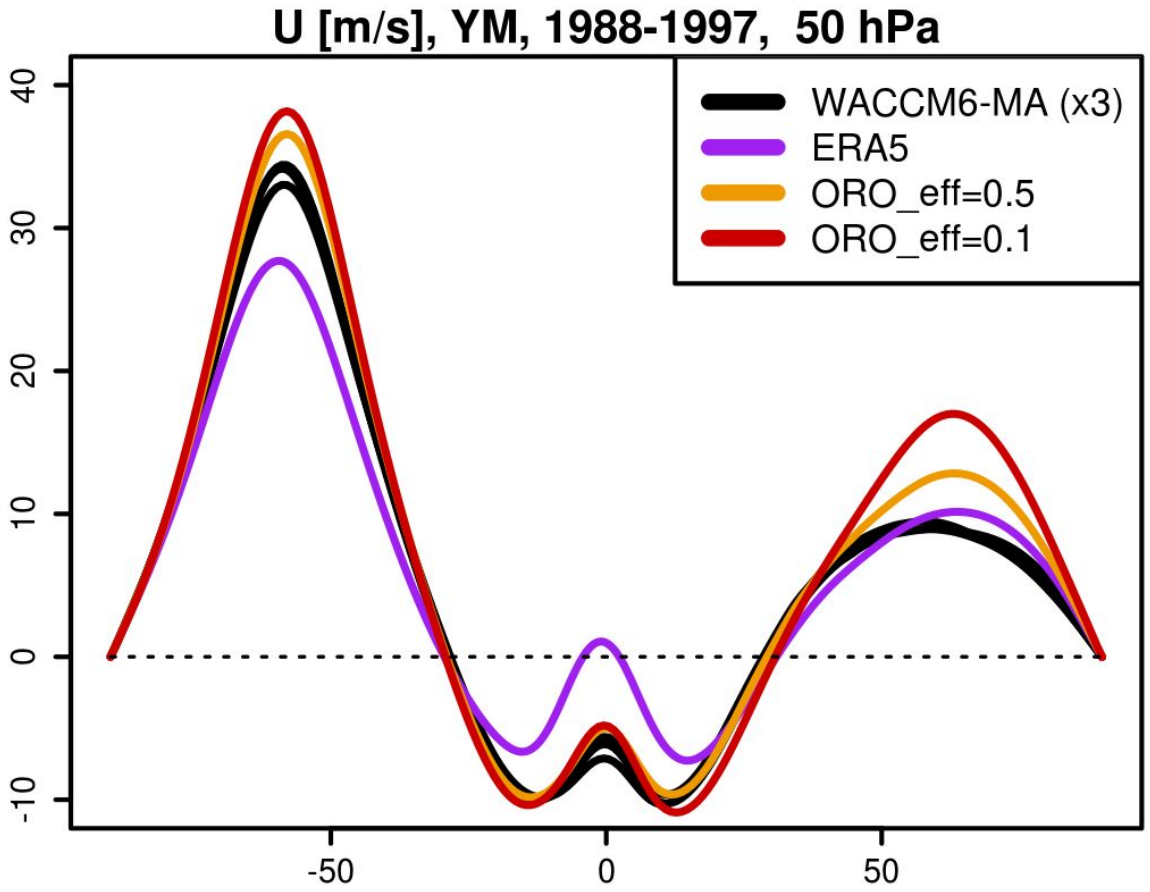

-> polar vortex too strong in CESM2 in SH and a bit too weak (in DJF) in NH

-> can modify the GW efficiency to make them stronger (= reduced GW drag)

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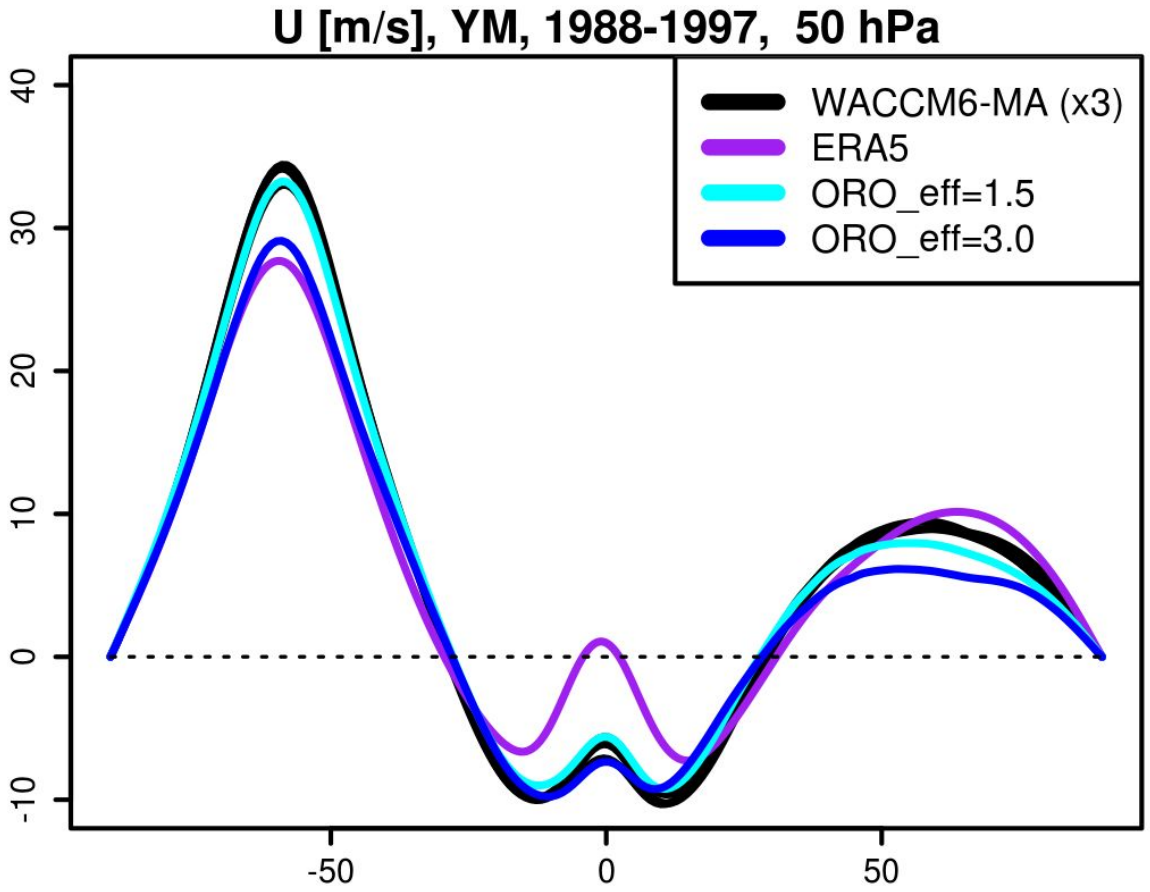

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-> can modify the GW efficiency to make them weaker (= increased GW drag)

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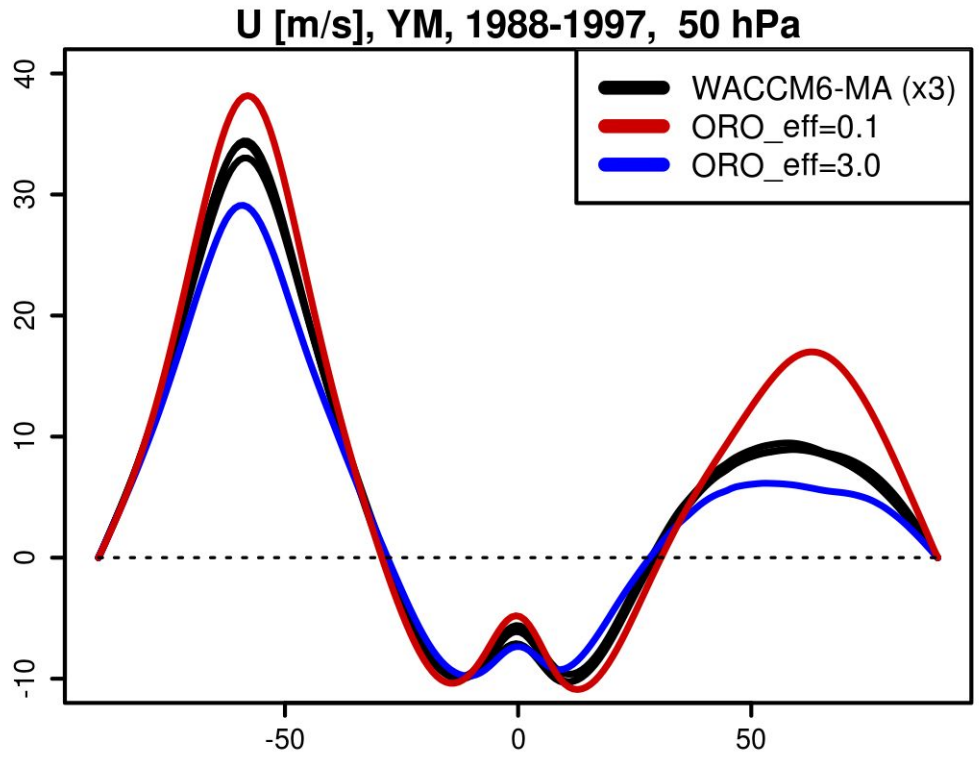

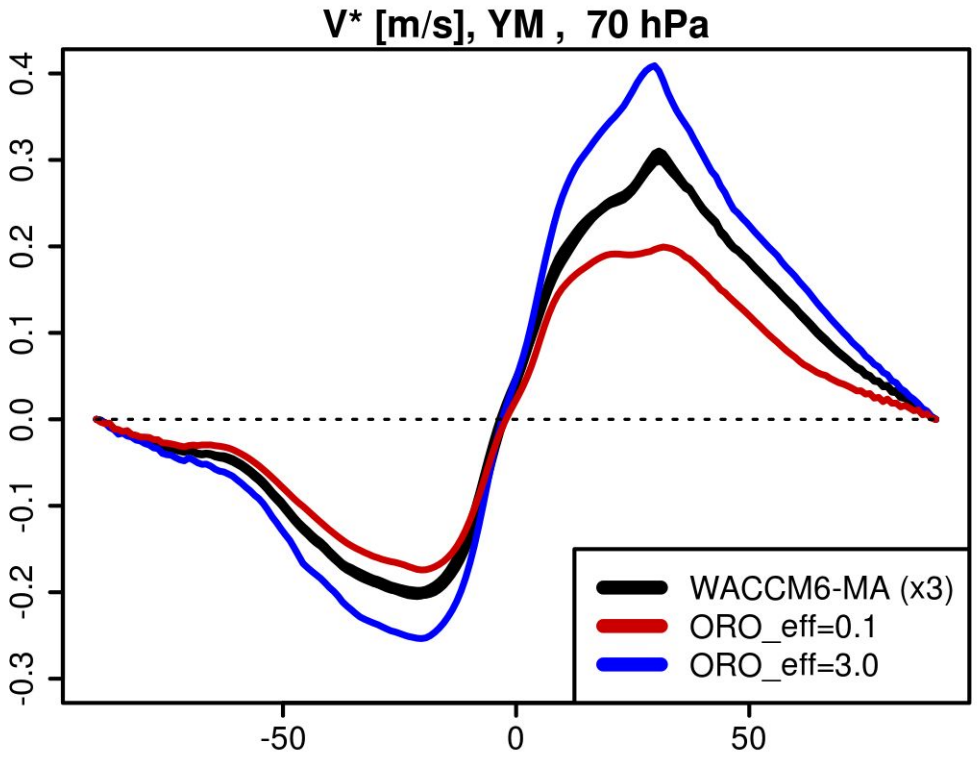

-> use two high- and low- end values of orographic GW drag

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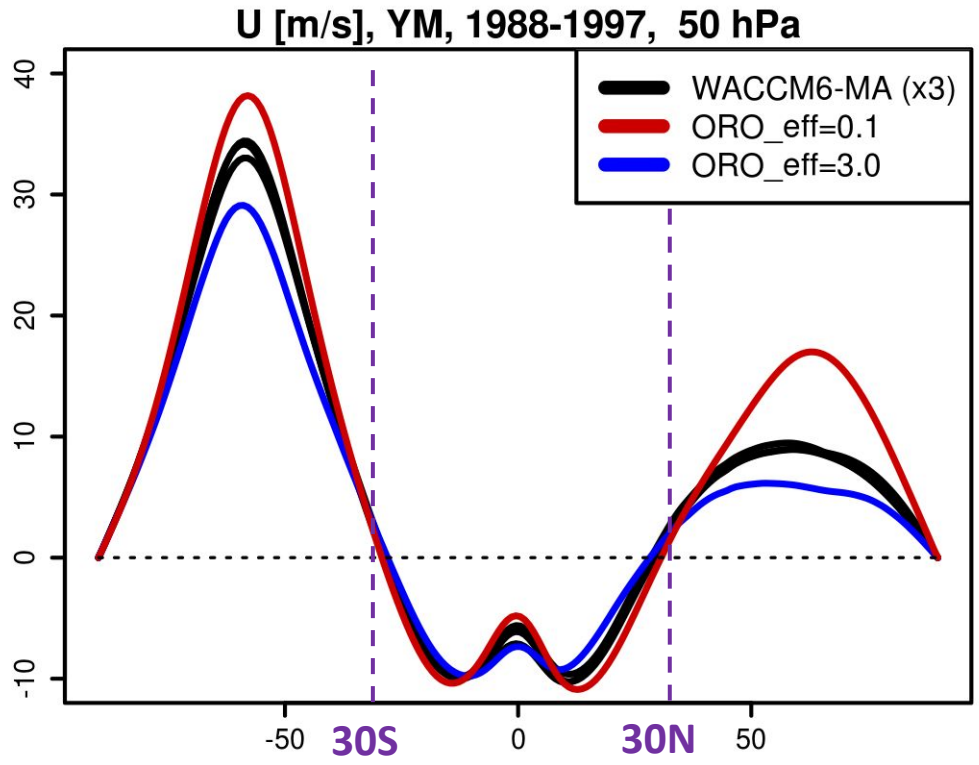

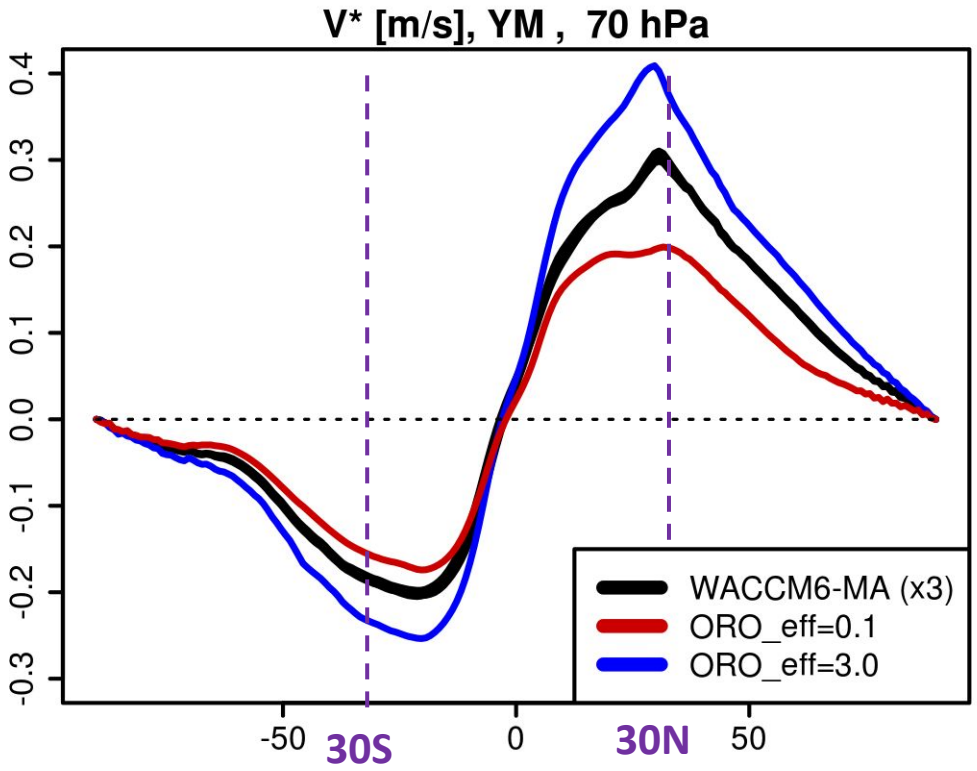

-> use two more extreme values of orographic GW drag

-> SAI simulations: constant 12 Tg-SO_2/yr injections at 22 km and either 30°N or 30°S

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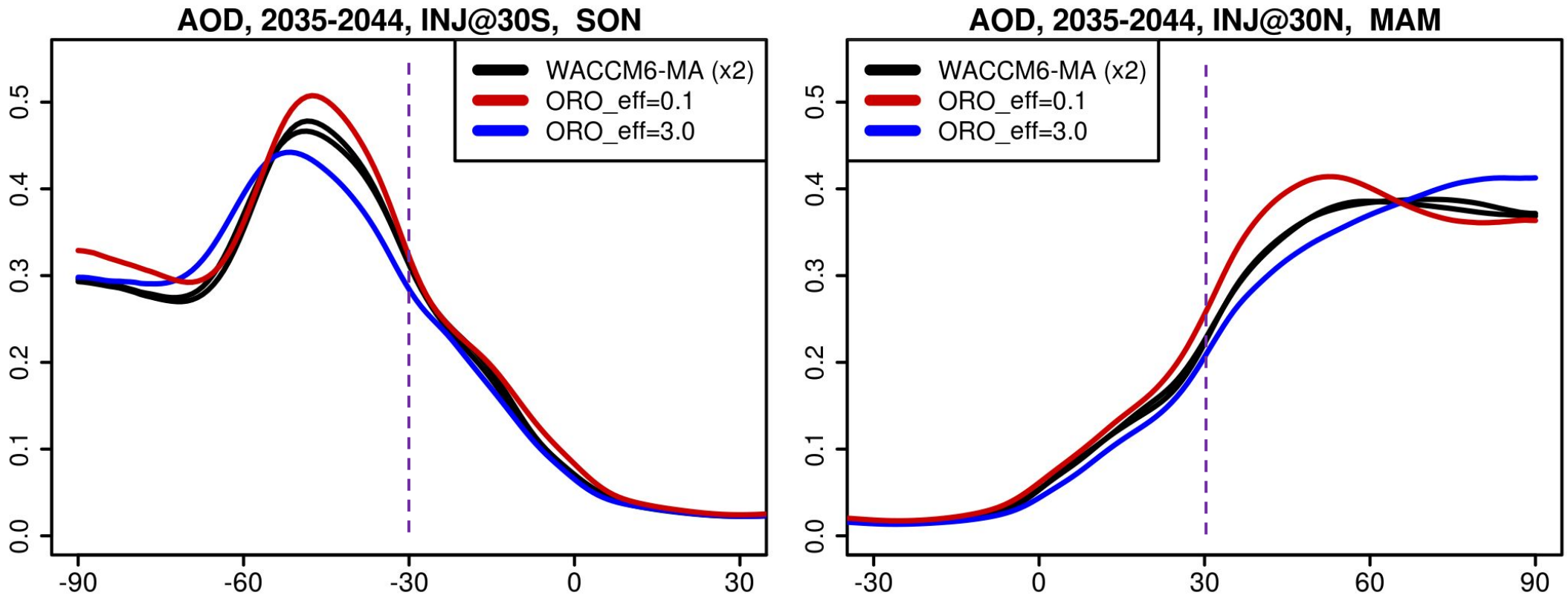

- Preliminary results from initial 10-years of simulations
- Larger differences between high and low OROGWD (~10%) in winter/spring

Part 2: impacts of ***orographic*** gravity wave drag parametrization

Outlook:

- Sensitivity for 15N/15S emissions?
- Only 10 years of data – longer simulations in pipeline
- Impacts on surface T response?
- Impacts on stratospheric O_3 response? (heterogenous chemistry + transport)?
- Impacts on the high latitude dynamical response?

Thank you for your attention!

And stay tuned for future updates ☺️

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