Resolving Weather in CAM-SE (hydrostatic)

What can we do **now** with what we **have**?

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CGD Climate & Global Dynamics a laboratory of NCAR

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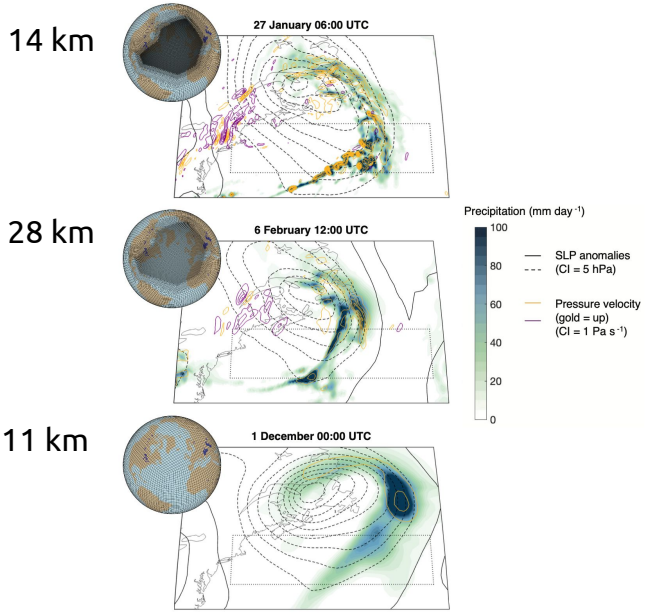
Resolving weather fronts increases the large-scale circulation response to Gulf Stream SST anomalies in variable-resolution CESM2 simulations

Robert C. J. Wills[1,2], Adam R. Herrington[2], Isla R. Simpson[2], David S. Battisti[3]



Prior work on variable-resolution CAM-SE; this talk focuses on **global** high/ultra-high resolution in CAM-SE-CSLAM.

- ❏ ne120pg3 (28 km)
- ❏ ne240pg3 (14 km)
- ❏ ne480pg3 (7 km)

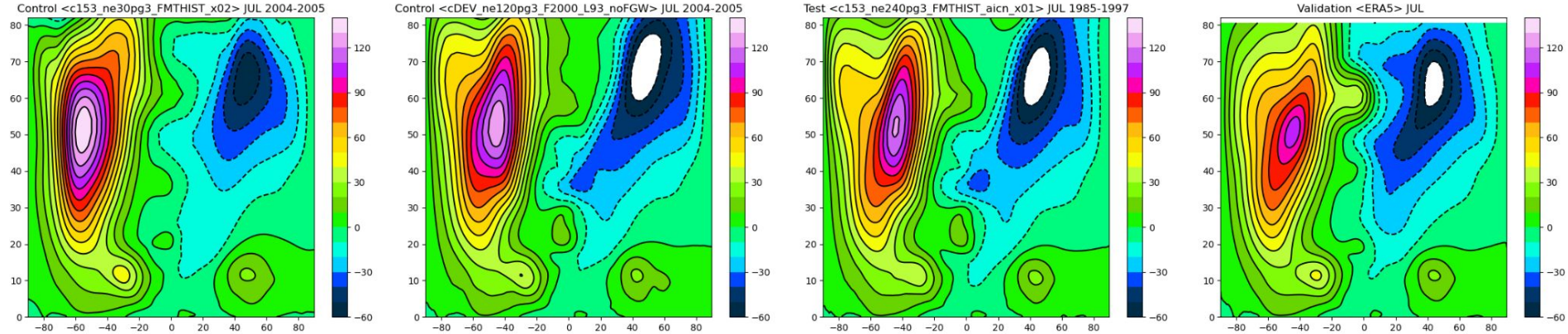
Hitting limits in software & hardware (as in MPAS 3.75 km; see Earthworks, SIMA talks)

- ❏ This is expected, CESM was not developed for ultra hi-res.
- ❏ CESM brings complexity, e.g., we resolve the stratosphere in this talk.

Resolution impact on stratospheric circulation

SH polar night vortex (July) in ne120 and ne240 is better, but still too strong and long-lived. Note continuing improvement with resolution.

ne30(~110km) ne120(~27km) ne240(~14km) ERA5



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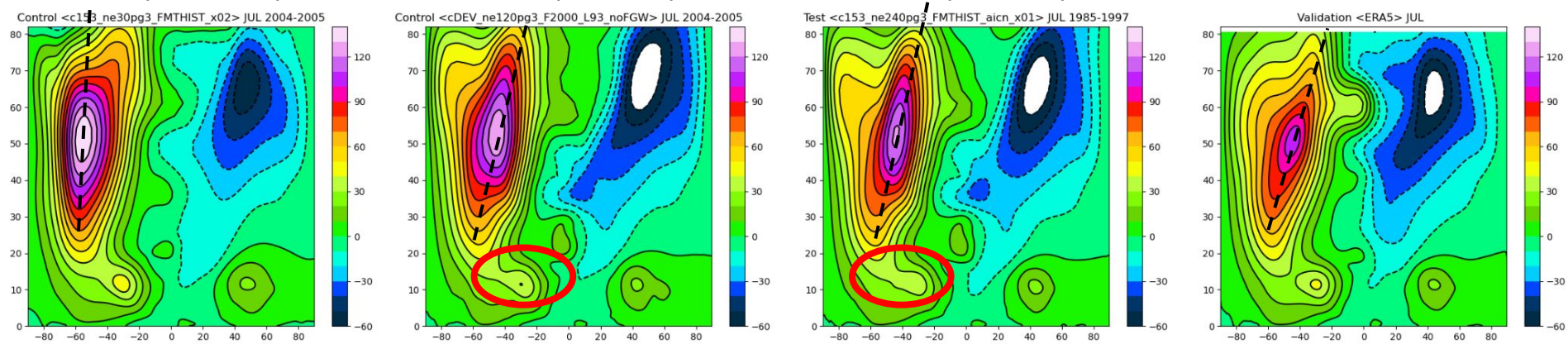
Resolution impact on stratospheric circulation

Equatorward tilt of SH polar night vortex begins to appear. Nice to see. Implications for general circulation not clear.

ne30(~110km) ne120(~27km) ne240(~14km) ERA5

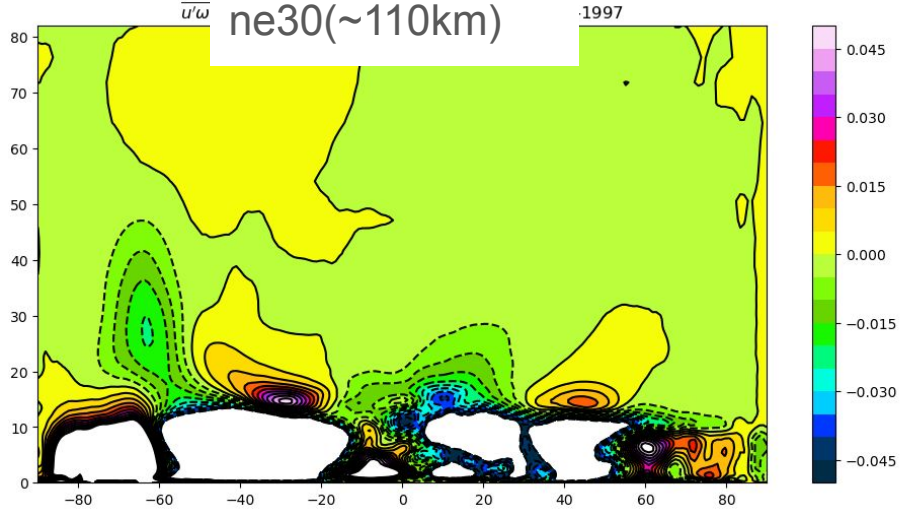


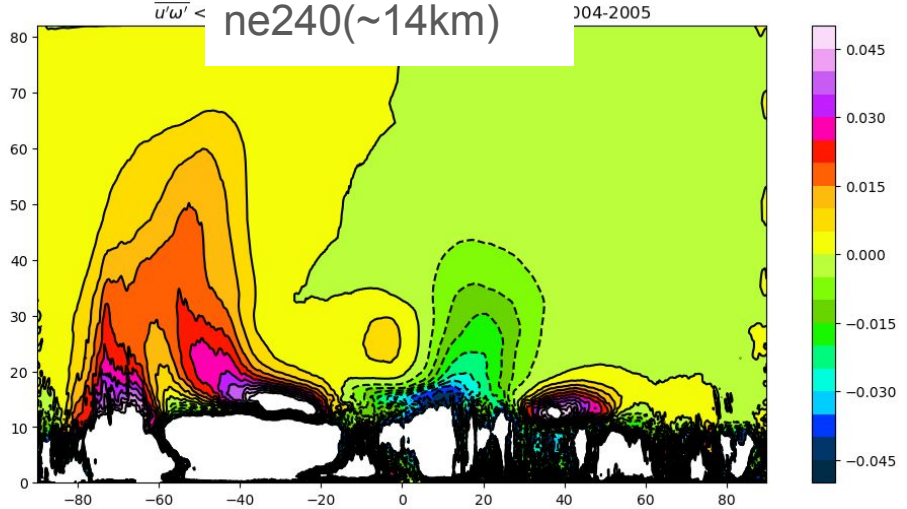
Worrisome weakening of trop. Jet. Retuning of orographic GWP may be needed

Resolution impact on stratospheric circulation

$\overline{u'\omega'}$: Resolved zonal-mean vertical flux of zonal momentum (July)

+ve indicates tendency to *decelerate* westerly winds





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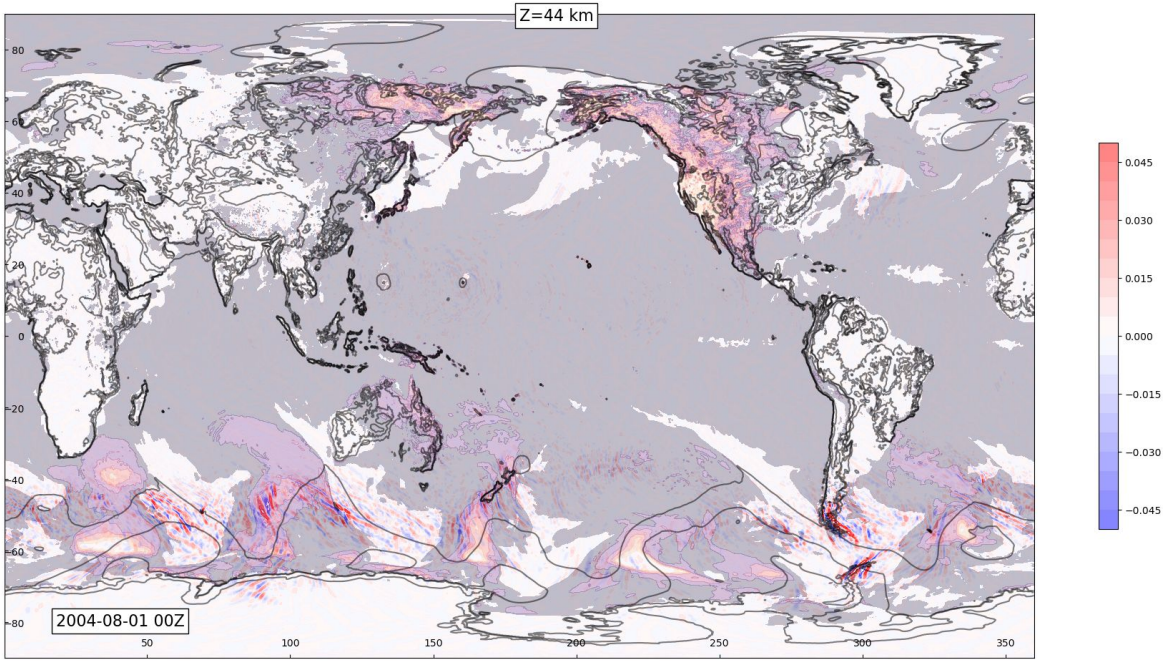
Resolution impact on stratospheric circulation



Animation Fields:

- Bright blue-red: ***omega' at Z=44km***
- Background pink-orange: ***surface sensible heat flux***
- Black contours: ***surface pressure***

Note bursts of activity in omega'(44km) over southern ocean:

- Forcing mechanism is unclear. Possible connections to SHFLX, lower trop vorticity
- Timing and spacing seems "front like"
- Low phase speeds ~15 ms^{-1}

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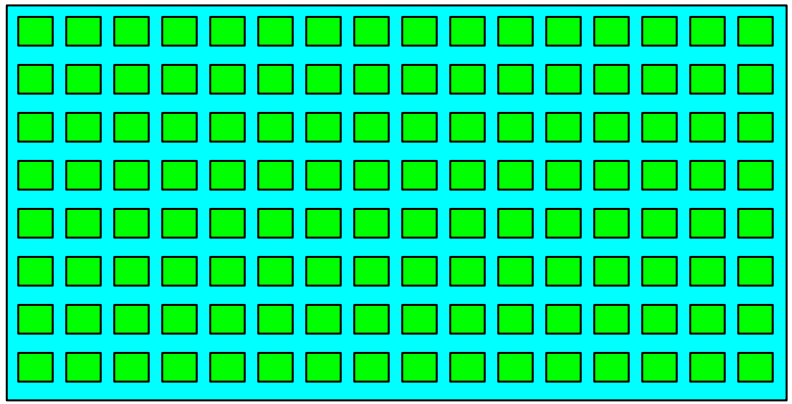
Issues at ne480pg3:

- ❏ SE dycore grid init (large grids)
- ❏ ESMF calls in cesm init (high core counts)
- ❏ Optimize CAM restart file / write times (large grids)

CTSM5.2: generate ultra-hi resolution land bc's with ease

Derecho compute node:
256 GB memory / 128 AMD Milan CPUs



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CTSM5.2: generate ultra-hi resolution land bc's with ease

Throughput - ne480pg3 on 900 nodes

- ❏ 12M grid columns, 93 vertical levels
- ❏ 45 minute init. (on 64/128 tasks per node)
- ❏ 1.0 hours per simulated day (1.5 for hi i/o)

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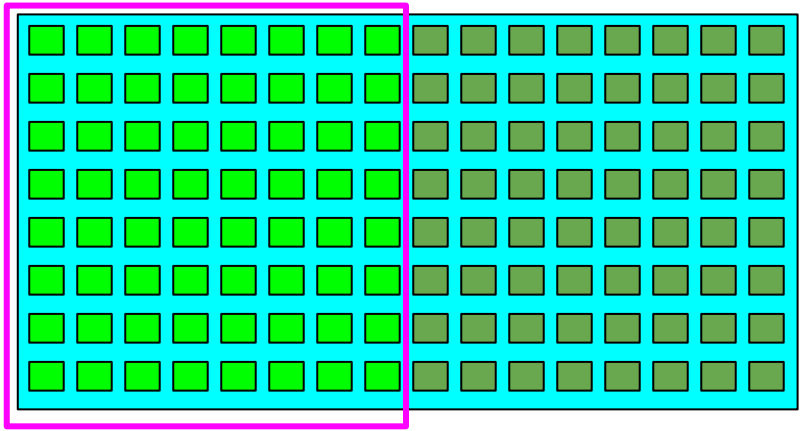

SE grid init. workaround: **under-subscribe 64/128**

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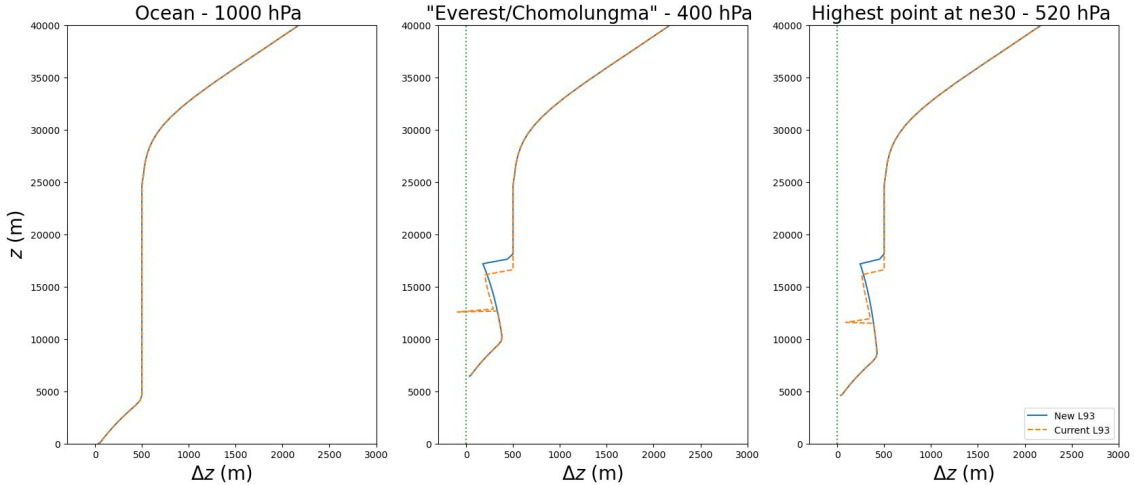
ne480pg3 reveals bug in mid-top configuration

Layer thickness in L93 grid as a function of height over different surface pressures:

Hybrid vertical coordinates:

$$p(x, y, \eta) = A(\eta)p_0 + B(\eta)p_s(x, y)$$

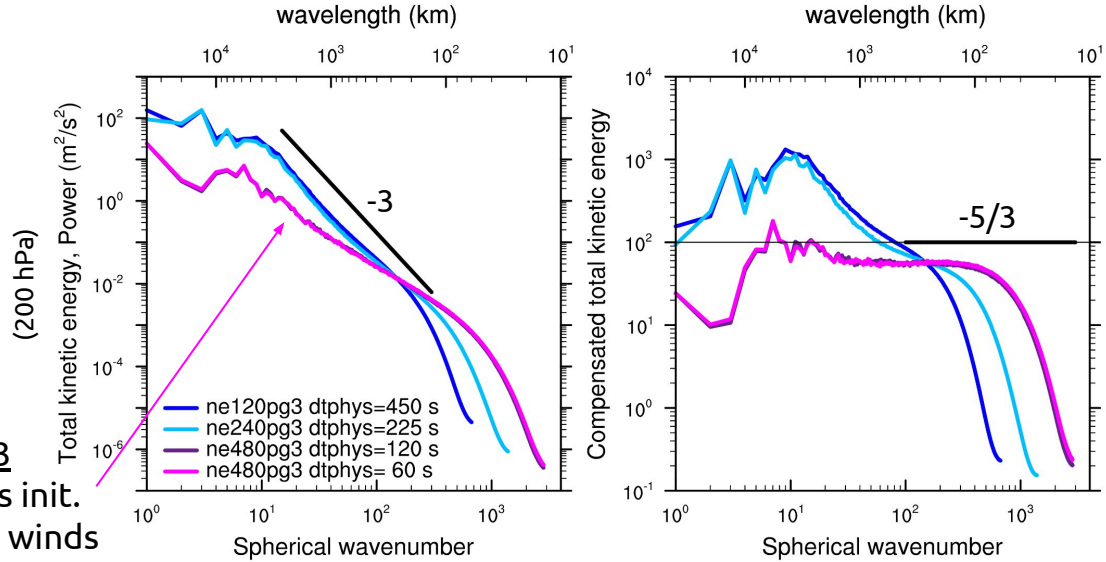


L93 has problematic hybrid coefficients, resulting in a negative layer thickness for the highest elevation grid points (~400 hPa), which is never attained in our 1˚ workhorse configuration (ne30pg3).

ne480pg3 and the hydrostatic limit

Scale analysis indicates non-hydro req'd for length scales **O(10 km)** and less (k→m).

- For a **5*dx** effective resolution, non-hydro req'd at **dx=2 km**
- Yang et al. 2017, Liu et al. 2022 – non-hydro dynamics matter at dx~25 km

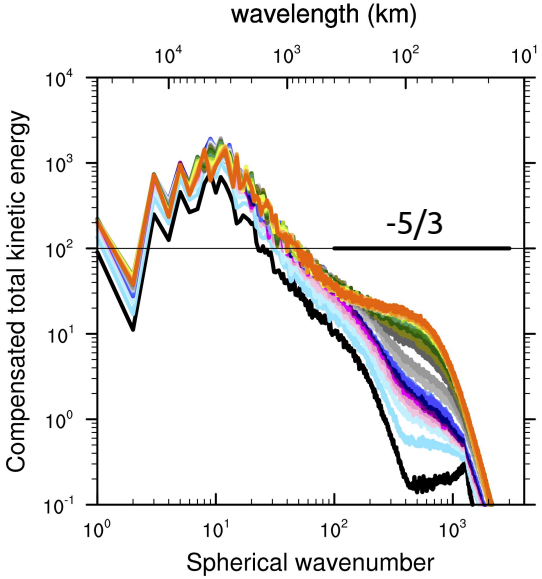


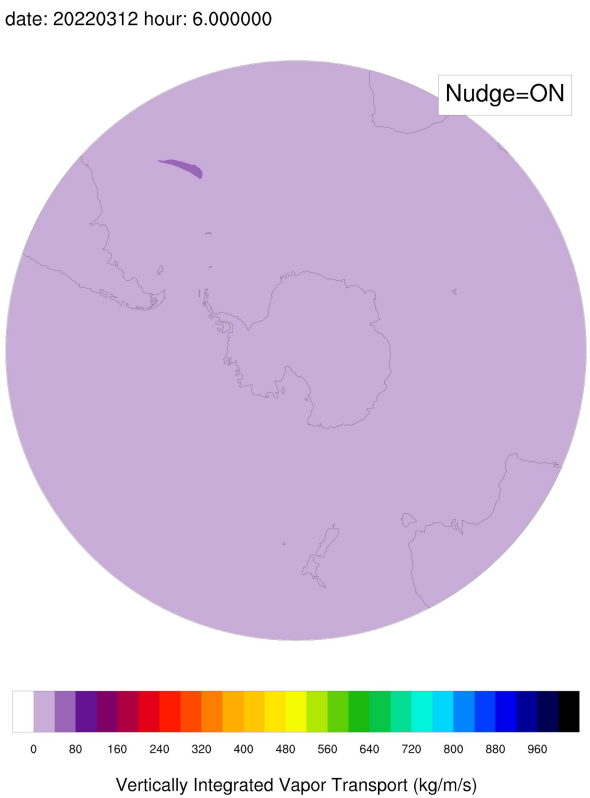
ne480pg3
5 day runs init.
with zero winds

Initializing ultra-high res

ERA5 model level data (137 levels)

- ATM - nudge CAM to ERA5 for 2 days prior to init.
- LND - nudge CAM to ERA5 for 3 mnths prior to init. at coarser resolution (e.g., ne120pg3)





Initializing the March 2022 Atmospheric River (Wille et al. 2024) in ne480pg3.

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Questions?

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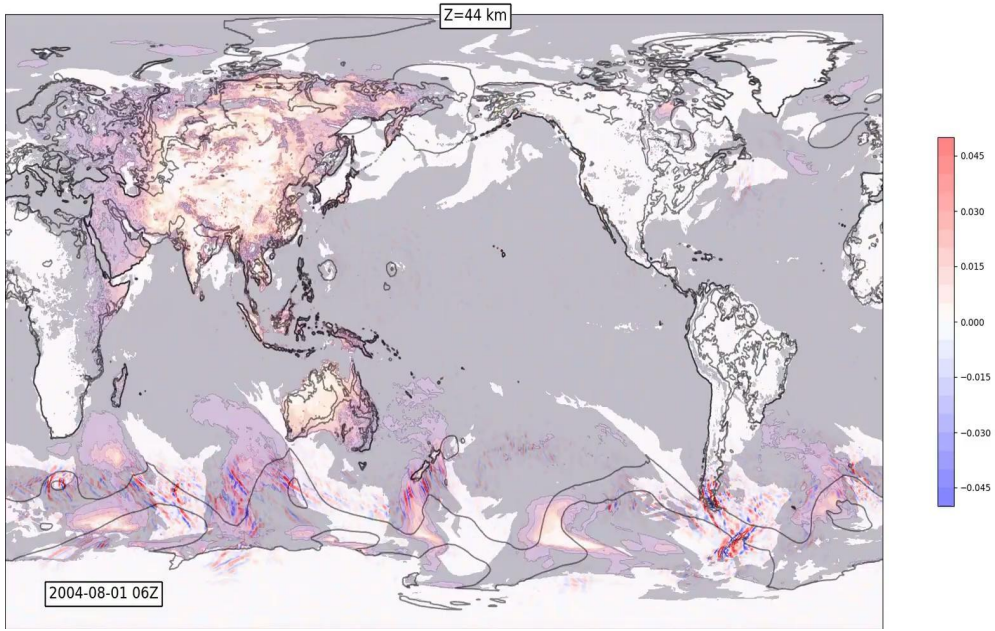
Resolution impact on stratospheric circulation



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