Update on NEMO 5 timestep-dependence experiments

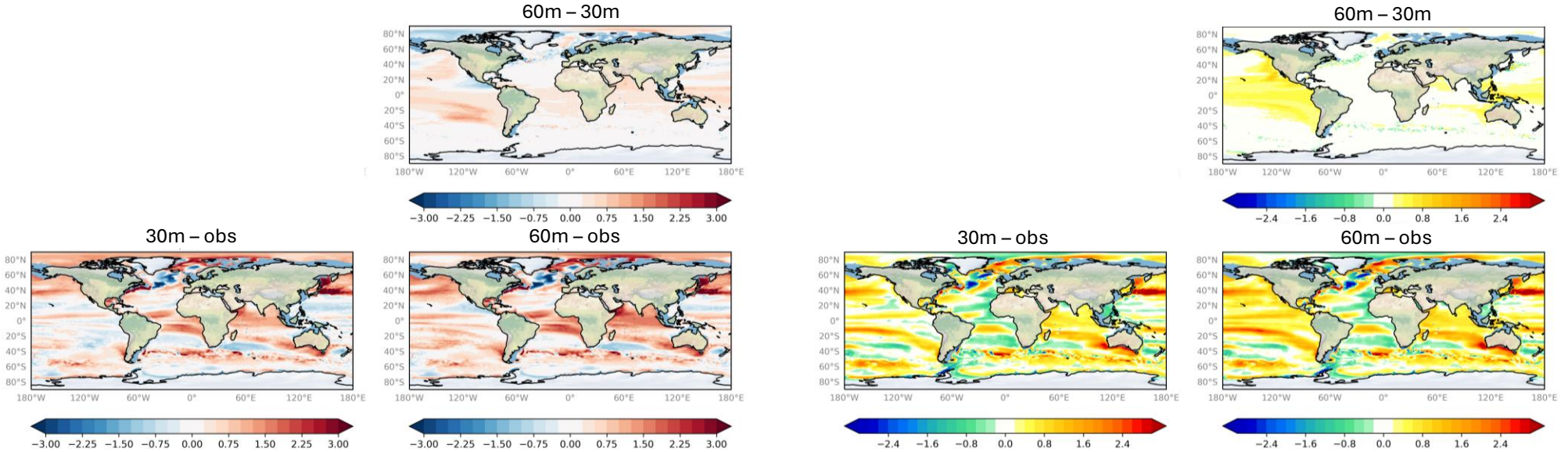
JMMP GO development meeting, 20th November 2025

Summary / reminder of the issue

GOSI10.beta.4 ORCA025 (y50-60)

"GOSI10-like" ORCA025 (y6-20)

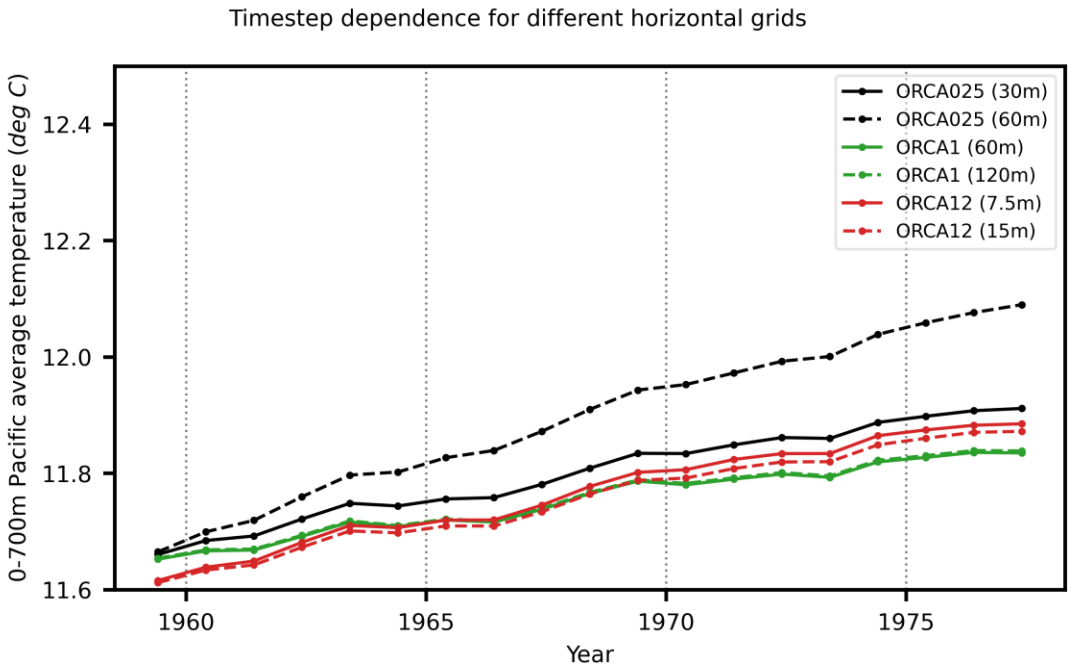
300m temperature



Zonal Pacific cross-section of temperature

- Increasing the timestep from 30m to 60m in ORCA025 RK3 configurations has a prominent subsurface warming response in the tropics
  - This specific response has been the initial focus of the analysis and the various experiments performed
- Caveat: most of the experiments to date use a "GOSI10-like" NEMO 5 configuration produced for a technical benchmark
  - Approximates GOSI10.beta.4 but does not have the GOSI code and associated scientific options, sea ice is initialised from SST
  - However, they are still able to reproduce the subsurface warming

Timestep impact at different resolutions

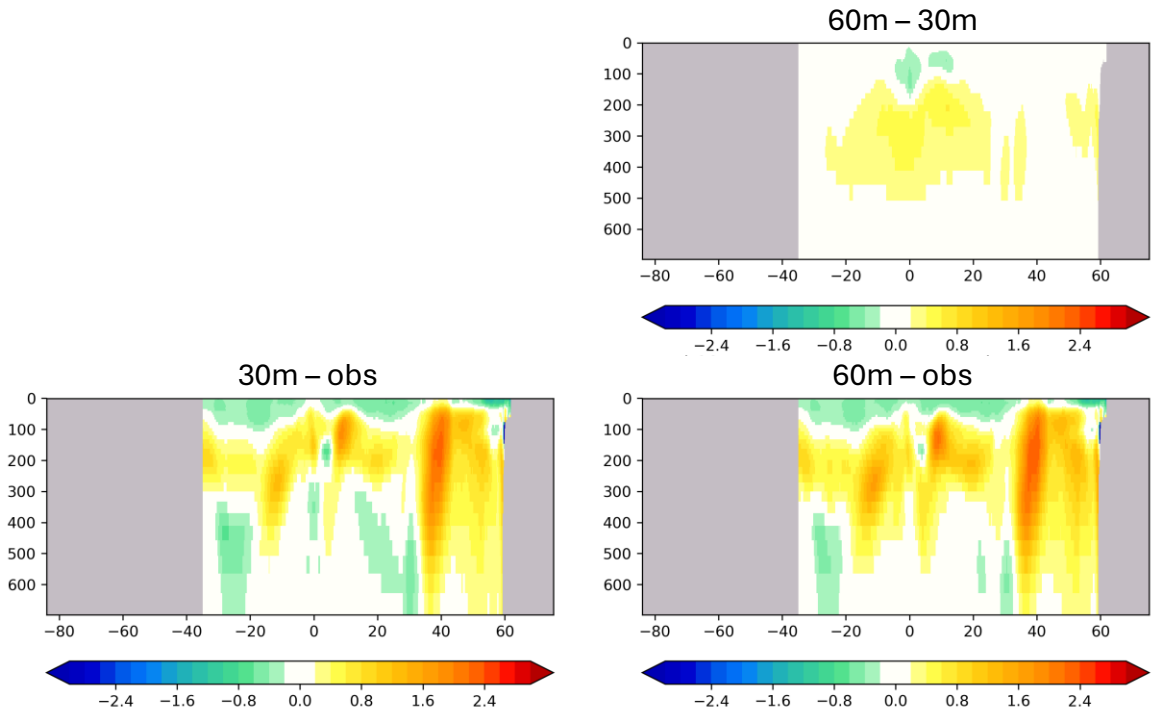


- RK3 allows the timestep to be doubled for ORCA1, ORCA025 and ORCA12 configurations
  - ORCA1 and ORCA12 were increased to 120m and 15m respectively- this seems to be the limit
  - Attempting to increase these further (to 180m and 20m respectively) caused the model to quickly crash

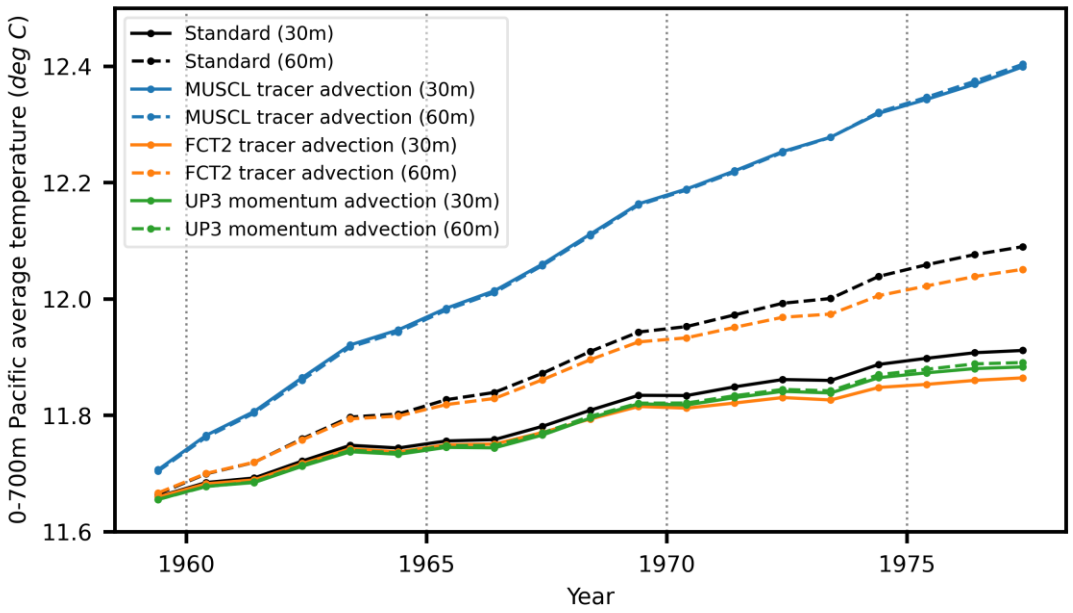
- The subsurface warming in the Pacific is absent from the ORCA1 and ORCA12 response

Impact of changing tracer advection: 4th order FCT → 2nd order FCT

Zonal Pacific cross-section of temperature for FCT2 experiments



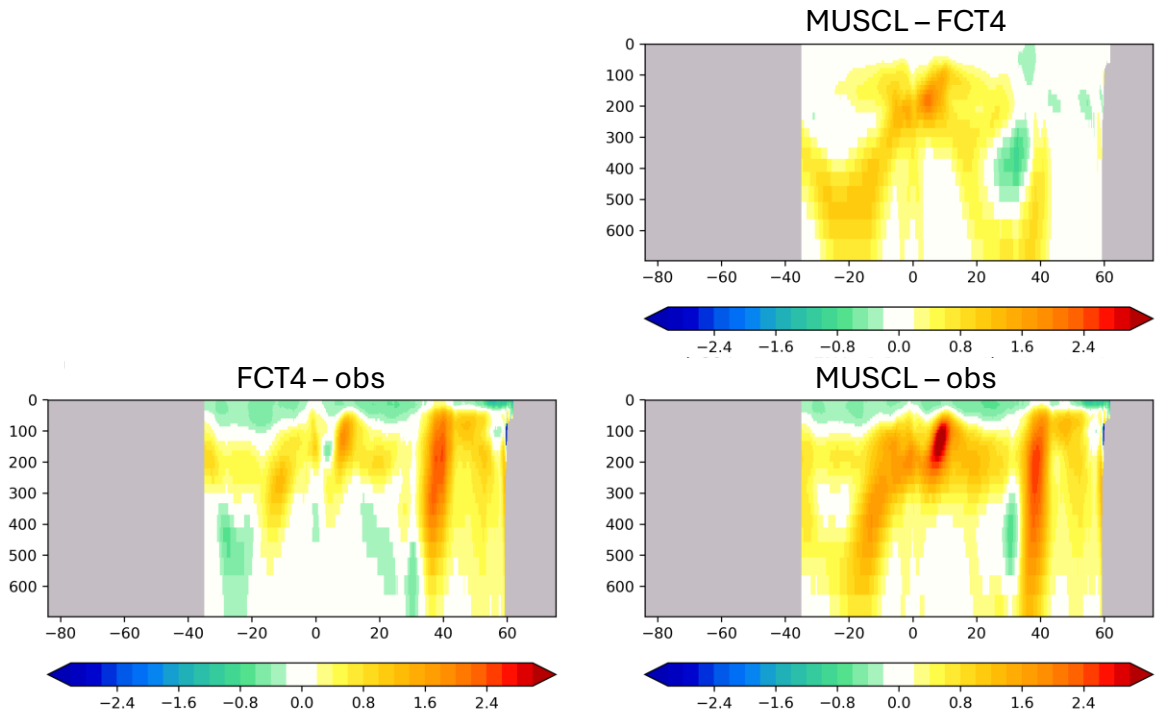
Timestep dependence for ORCA025 with different advection schemes

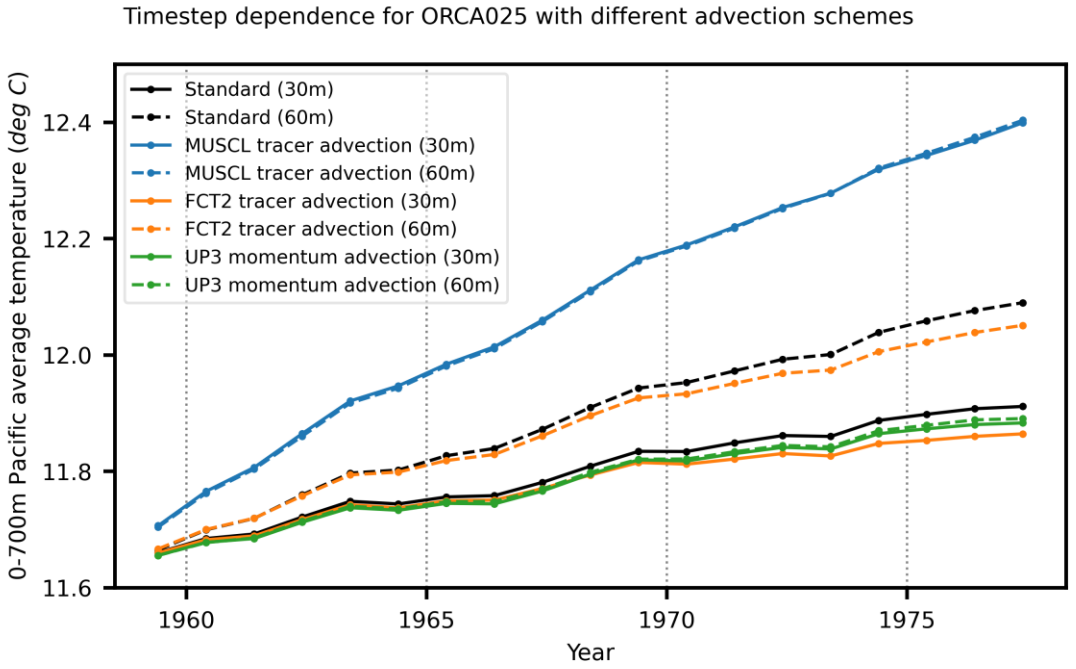


- Switching to the 2nd order FCT scheme (FCT2) has little impact on the warming response
  - Comment from Dave Storkey: “The frequency of triggering of the adaptive-implicit vertical advection with a 60min timestep seems pretty similar regardless of whether you use FCT2 or FCT4”
- Note that this doesn’t include Jerome’s !761 fixes for adaptive-implicit vertical advection in RK3
  - The CFL threshold for implicit/explicit partitioning of vertical velocity was hard-coded and should depend on advection scheme
  - We couldn’t run FCT4 stably with these fixes using a 60m timestep (this also happened for some other experiments)

Impact of changing tracer advection: 4th order FCT → MUSCL

Zonal Pacific cross-section of temperature for 30m timestep experiments

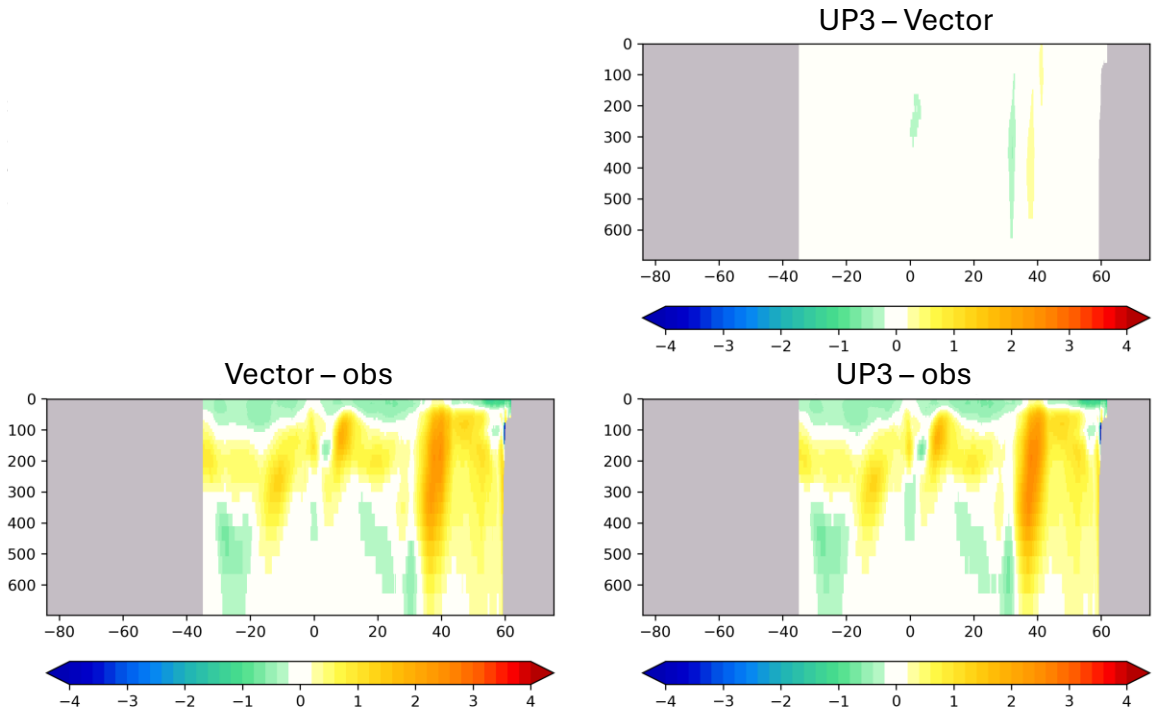


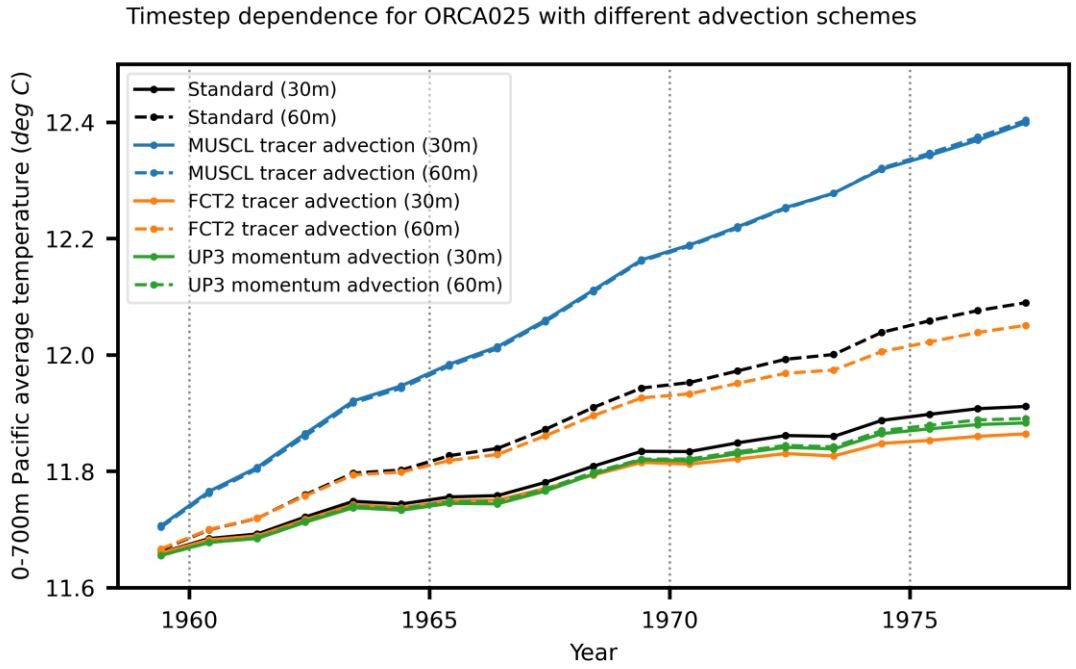


- Switching to MUSCL significantly reduces the warming response
  - But it is more diffusive than FCT (Lévy et al., 2001) and already much warmer in the Pacific
  - Subsurface biases are considerably worse compared to FCT

Impact of changing momentum advection: 2nd order centered vector form → UP3

Zonal Pacific cross-section of temperature for 30m timestep experiments

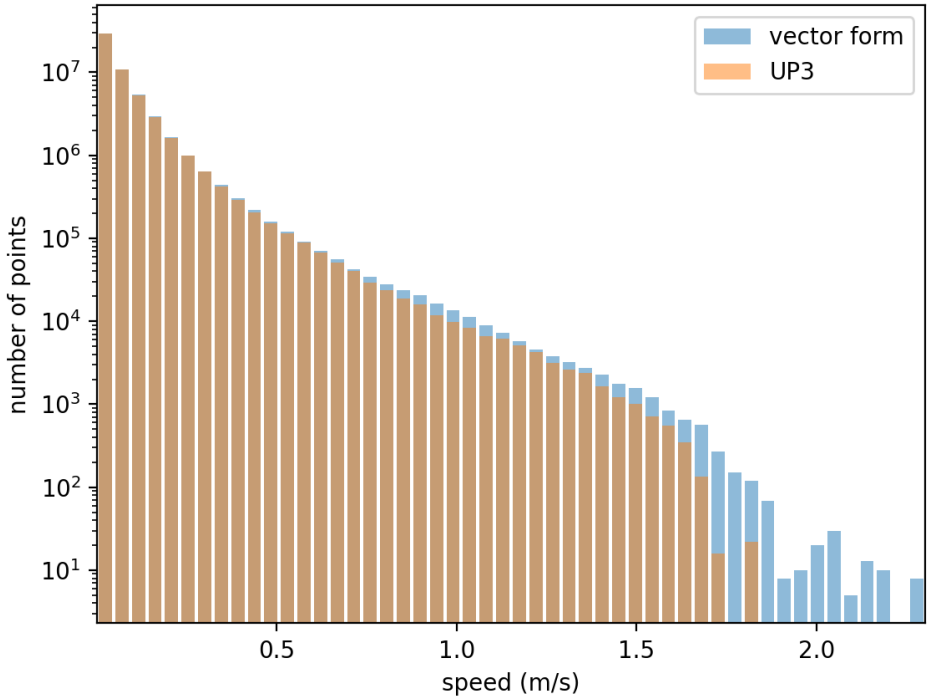




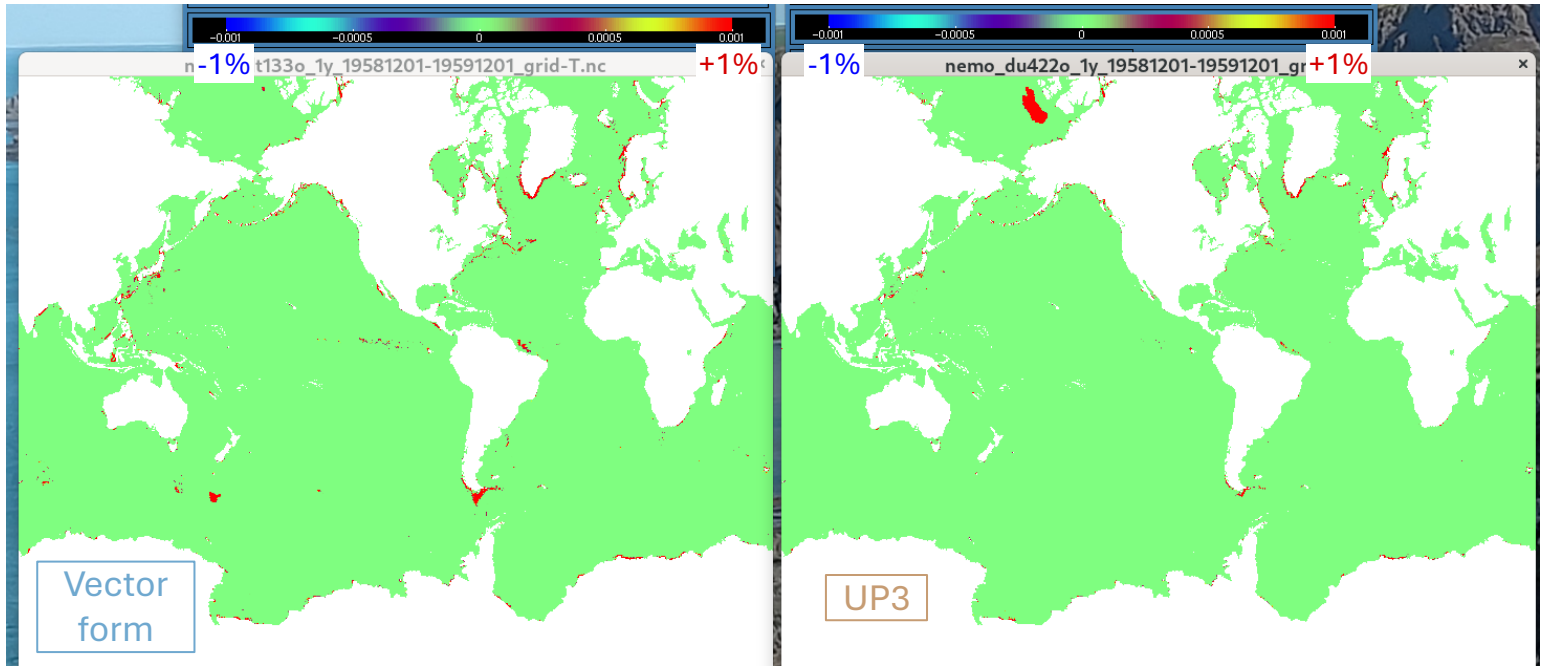
- Switching to UP3 also significantly reduces the warming response
  - Much less impact on temperature compared to MUSCL

Impact of changing momentum advection: 2nd order centered vector form → UP3

Histogram of instantaneous velocities- year 20 of 60m timestep experiments



Activity (% of timesteps) of adaptive-implicit vertical advection scheme- year 2 of 60m timestep experiments



Credit: Dave Storkey

- UP3 is an upwind scheme and has some implicit numerical diffusion
  - Left figure: there is some clipping of larger velocities- less likely to hit CFL limit
  - Right figure: the adaptive-implicit scheme is a bit less active (except in the Arctic), but still only O(1%) of the time

Larger version of the figure from the previous slide