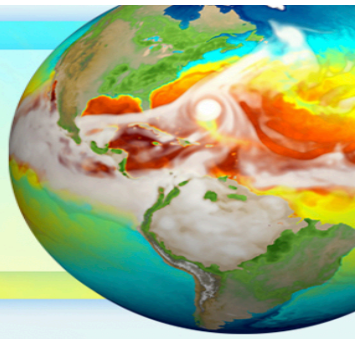

Analysis of eastern subtropical North Pacific SST bias in the E3SM

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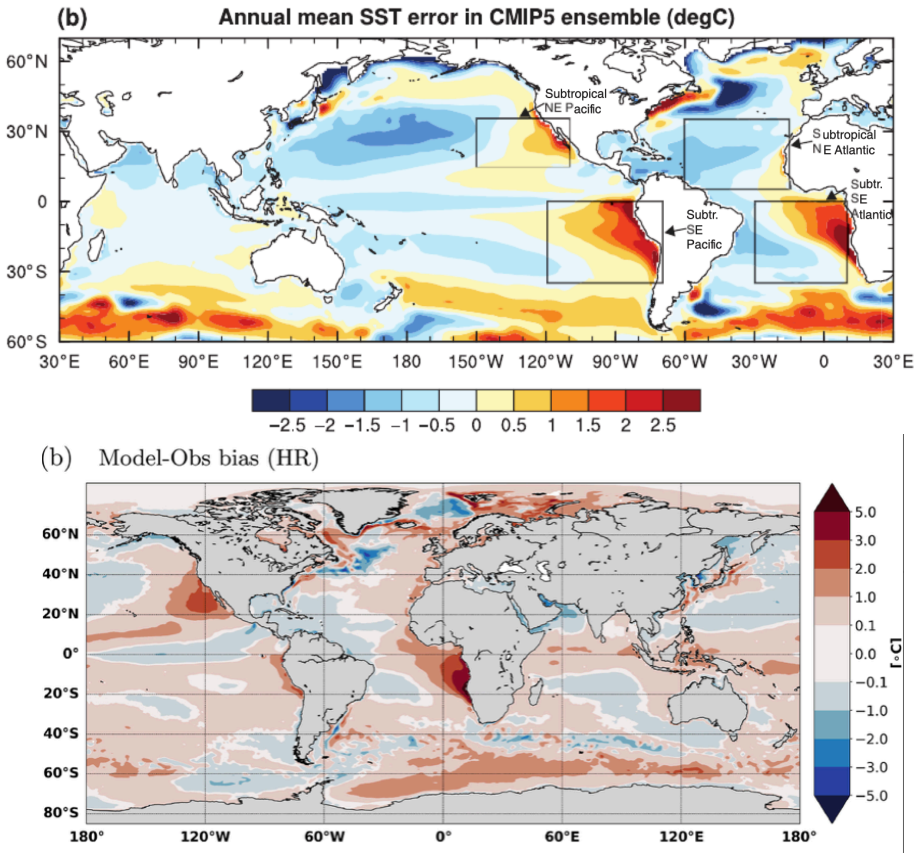
E3SM Energy Exascale Earth System Model

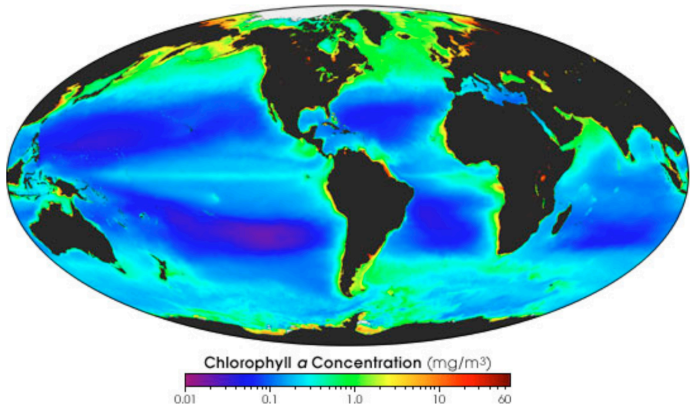
U.S. DEPARTMENT OF ENERGY

Coupled climate model SST biases



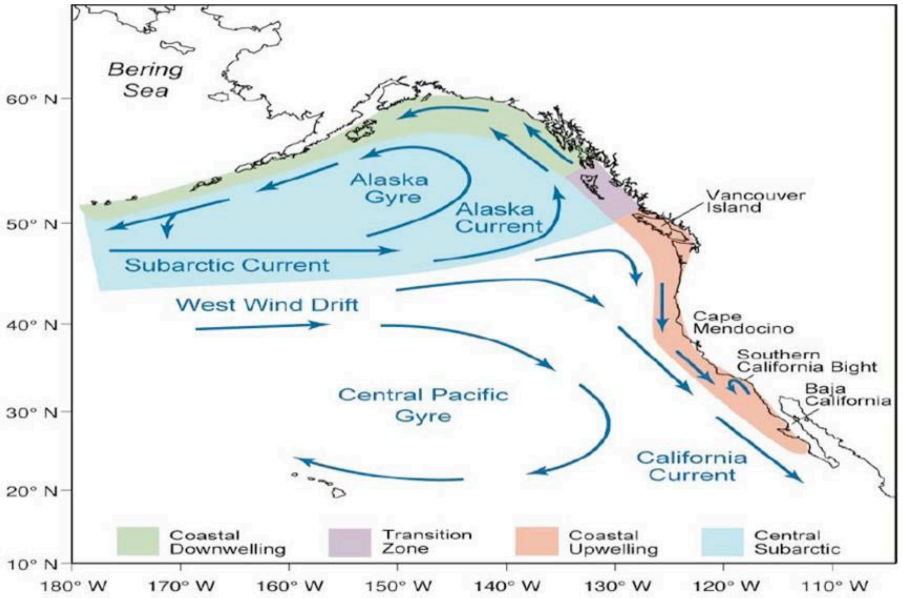
Source: Richter (2015) and Caldwell et al. (2019)

- SST biases in the global subtropical eastern boundary regions are a persistent feature of coupled climate models.
- These issues have persisted in E3SM-HR.
- These regions tend to be high in biological productivity.

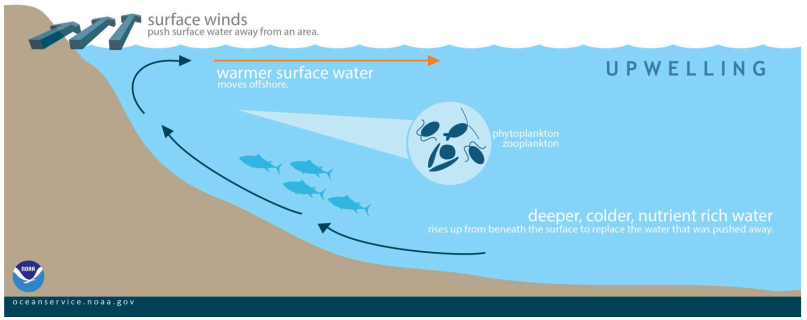


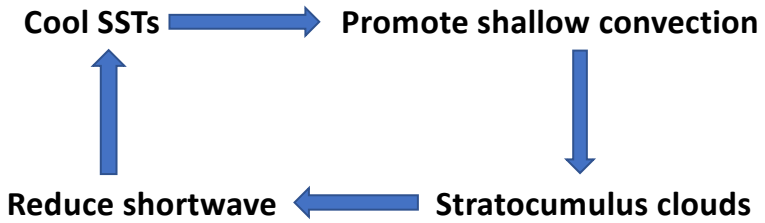
Source: NASA

Air-sea coupled processes in the region



Source: baynature.org





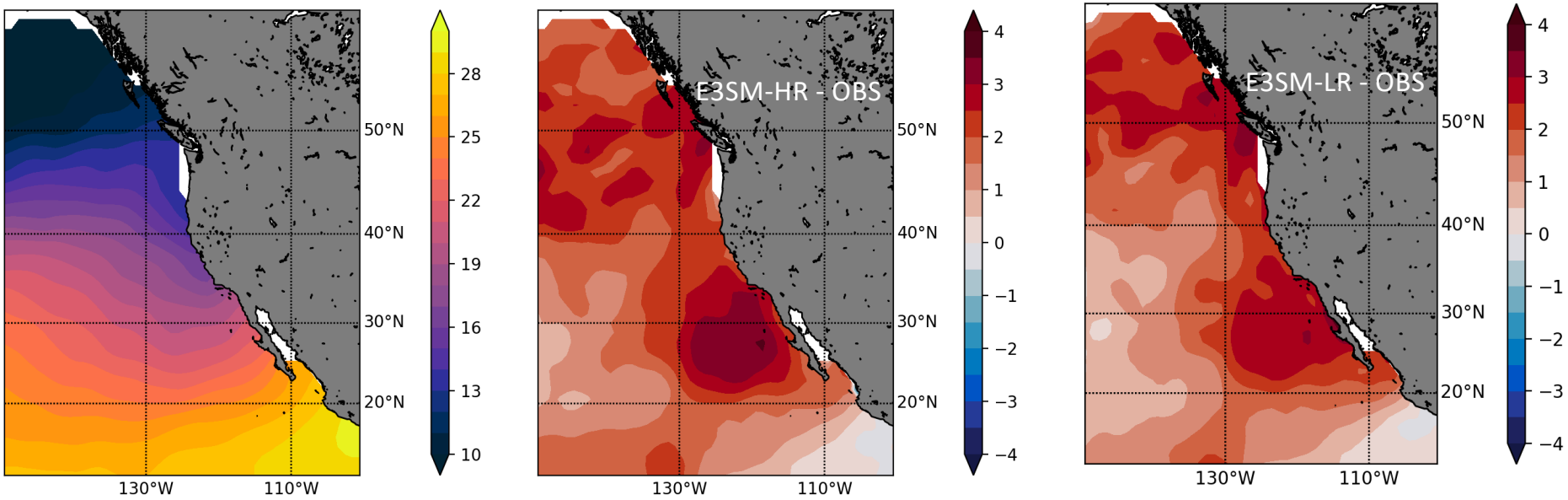
Data and Simulations

- Temperature and Salinity based on Argo (http://www.argo.ucsd.edu/Argo_data_and.html)
- OSCAR surface ocean currents from NASA-JPL (https://podaac.jpl.nasa.gov/dataset/OSCAR_L4_OC_third-deg)
- OAFlux surface ocean fluxes from WHOI (http://oaflux.whoi.edu)
- Ocean surface wind stress from ECMWF (https://www.ecmwf.int/en/research/climate-reanalysis/ocean-reanalysis)

- 30 years of output from E3SM-HR (Model uses constant 1950s forcing based on the HighResMIP protocol)

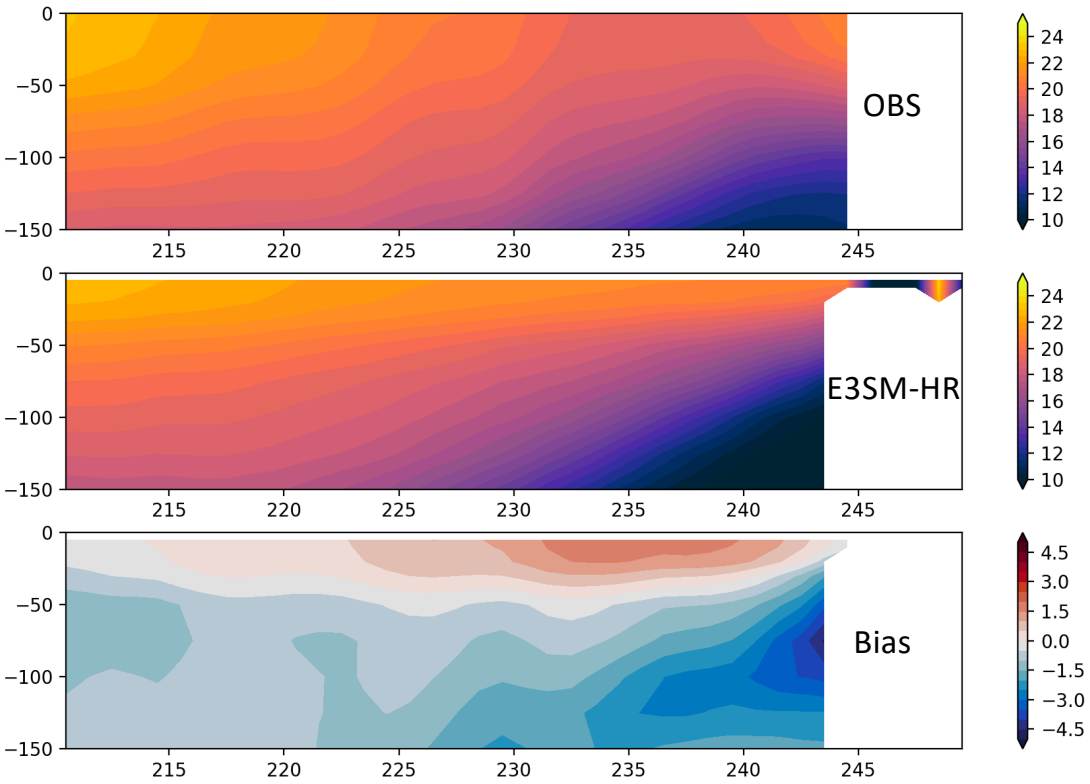
- 30 years of output from E3SM-LR (Historical run – H1).

SST bias



- There is a warm bias in much of the eastern North Pacific.
- Main location (~ 120W, 28N): Off Baja California, exceeding 3 C.
- The spatial pattern of annual mean SST bias in the subtropical Northeast Pacific is similar at both resolutions. However, the magnitude of the bias is weaker in E3SM-LR (H1 run: 1985-2014) compared to E3SM-HR

Temperature bias along 28N transect



- In both observations and model, the water gets colder as we move closer to the coast.
- Unlike observations, in the model, water from the sub-surface is less able to reach the surface near the eastern boundary.
- What is the role of surface winds?

Mixed layer heat budget

$$\frac{\partial T_{ml}}{\partial t} + V_H . \nabla T_{ml} + \frac{\Delta T}{h} W_e + \frac{[K_z \frac{\partial T}{\partial z}]_{-h}}{h} = \frac{Q_o - Q_{-h}}{\rho C_p h}$$

Time Tend.	Hor. Adv.	Entr. ML base	Vert. Mix.	Surf. Flux.

$$\Delta T = T_{ml} - T_{-h}$$

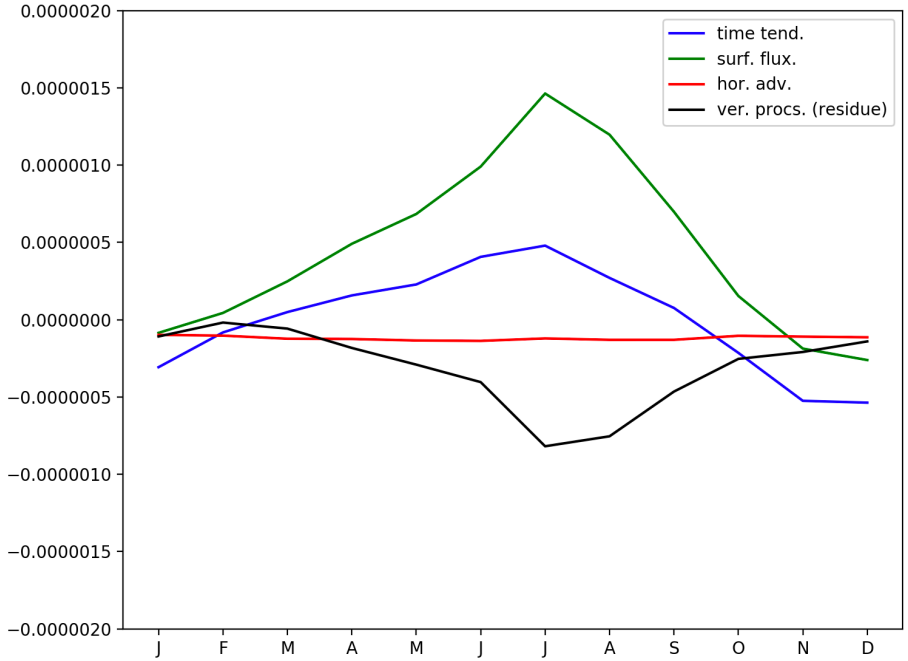
$$W_e = \frac{\partial h}{\partial t} + \nabla_H (h.V_H)$$

$$Q_o = Q_{SW} + Q_{LW} + Q_{LH} + Q_{SH}$$

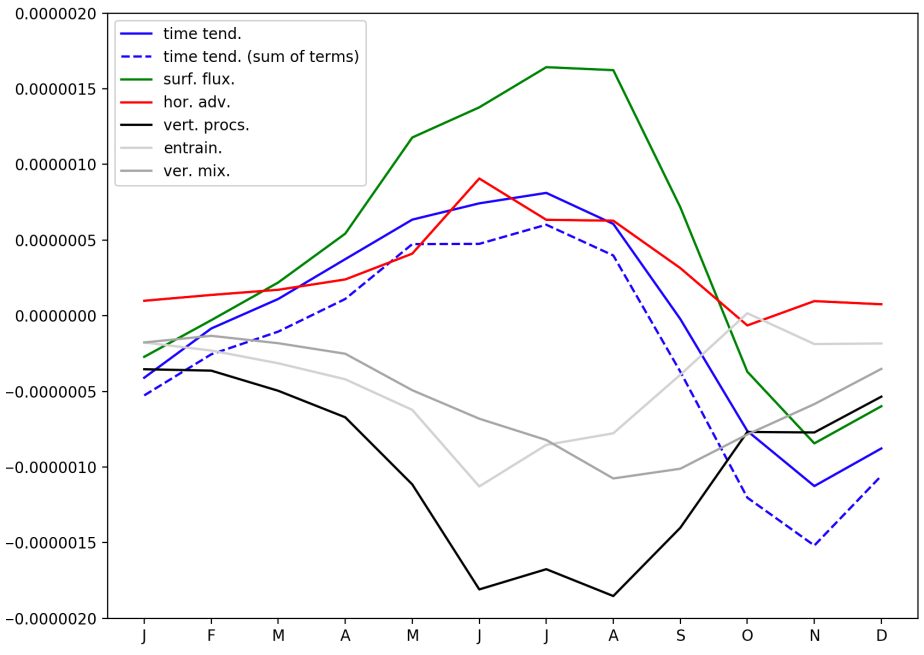
We assume an albedo of 6% for reflection of surface shortwave flux

Penetration of shortwave flux at ML base is based on Jerlov Type II scheme

ML heat budget: Observations



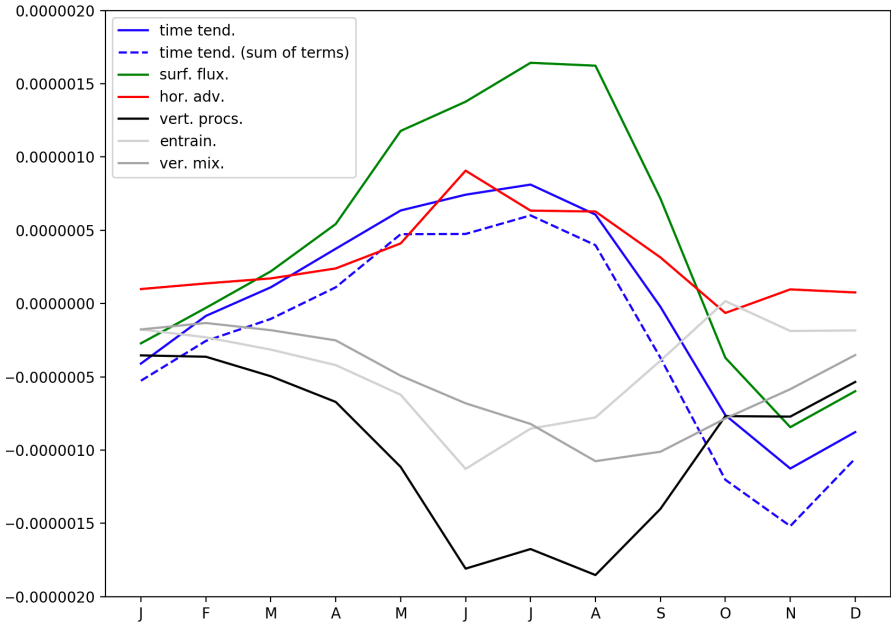
ML heat budget: E3SM-HR



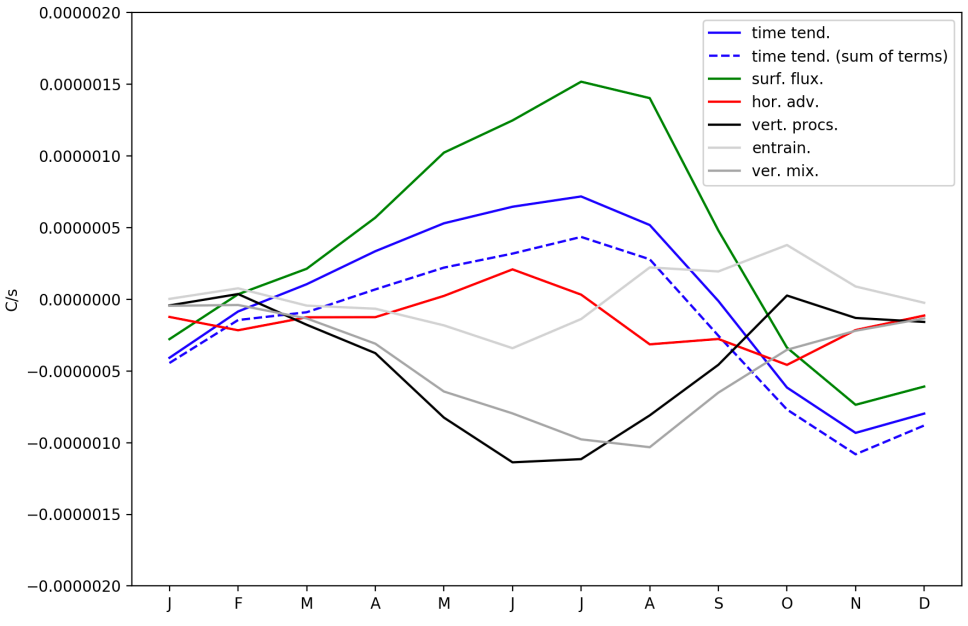
- The ML heat budget from the model is nearly closed.
- Horizontal advection has almost no contribution in observations, but positive contribution in the model.
- Tendency from surface fluxes is higher despite a low bias, possibly due to shallower ML.
- Contribution of entrainment and mixing is larger in the model.

Note: All terms averaged over 125W-115W, 25N-30N

ML Heat budget: E3SM-HR



ML Heat budget: E3SM-LR



- Compared to E3SM-LR, the net surface heat flux and horizontal advective flux cause more warming in E3SM-HR
- While vertical mixing is similar in both E3SM-LR and E3SM-HR, the vertical advective flux cools the mixed layer more in E3SM-HR.

Summary

- An analysis of subtropical eastern North Pacific SST bias in the fully-coupled E3SM model was performed.
- The warm bias is persistent in E3SM-LR and doesn't improve with resolution (E3SM-HR).
- A mixed layer heat budget analysis indicates that errors in surface fluxes and horizontal advection may be responsible.
- Stand-alone MPAS-O simulations at standard and high-resolutions will be used to isolate the relative contributions of the ocean and atmosphere to the bias.