NSF funded project 0961545, June 2010-May 2015

Nested Regional Climate Model (nRCM) update

The effect of embedding ROMS in a coastal upwelling zone in CCSM4

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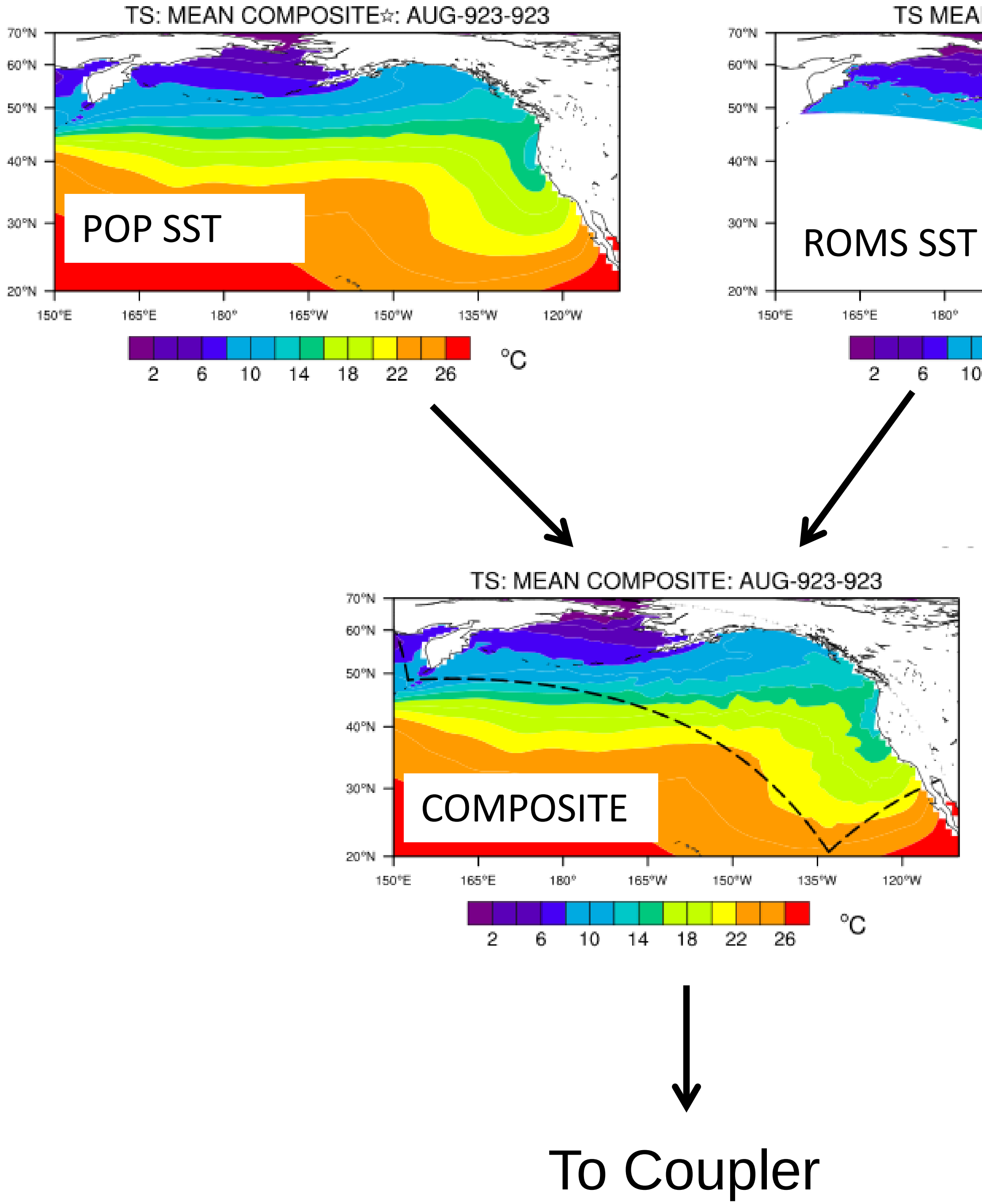
Summary

- Our old results suggested strong cooling in upwelling zones induced by including ROMS
- A bug was found which was making stress too strong
  - Bug fixed and fluxes in ROMS now exactly aligned with those in CCSM4 coupler
  - New results very different with a hint of warming due to ROMS
- Upwelling velocity in ROMS follows Ekman pumping expectation and is comparable to POP



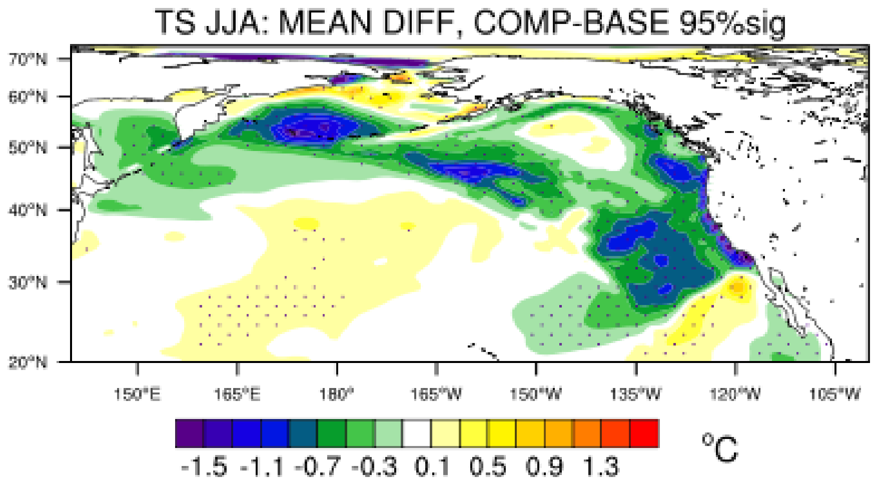
Monthly mean SST from August, year 60 of integration.

Nrcm Atmosphere-Ocean Components

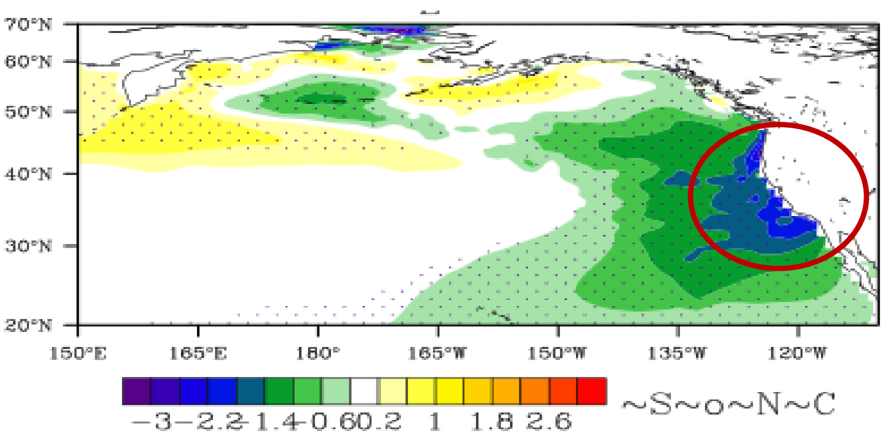
- **Ocean**
  - POP2 - ~1deg., 60 levels
  - ROMS ~10km, 42 stretched sigma levels
- **Atmosphere** CAM 4, 1deg. FV, 26 levels

Previous Nrcm results

The SST difference of Nrcm from the corresponding long baseline CCSM run, for summer (June, July, August). Based on 100 years of more model data.



First version (2010), CCSM3.



New version (summer 2011). CCSM4. Fixed error in rotation of stress vector. Restored POP SST to ROMS SST.

However…

Problem found

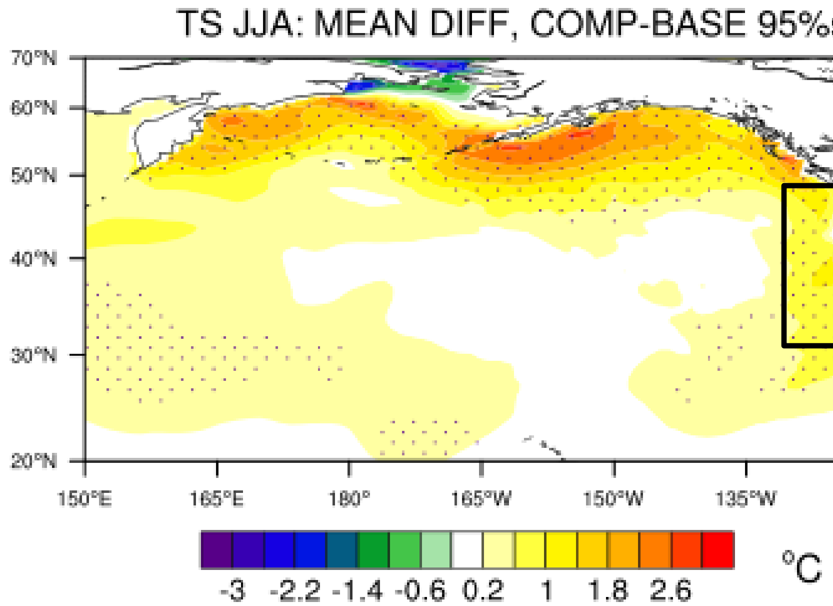
- ROMS thought CAM lowest level winds, temperature and humidity were at 10m…
- …not at the real lowest model level, ~50m
- Caused big changes in stress (factor of two) and smaller changes in surface heat flux (~15Wm^{-2})

Problem fixed

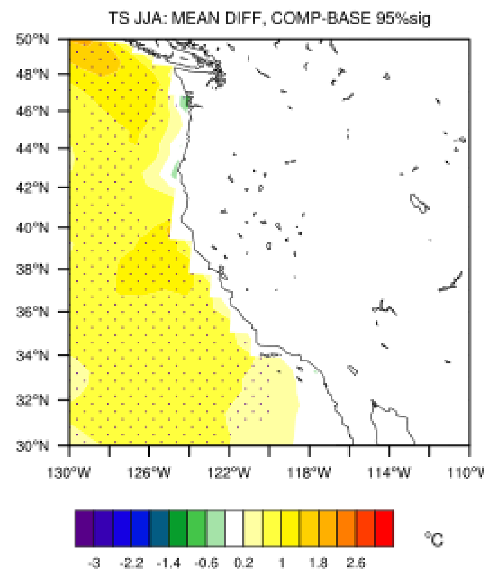
- Also, replaced Fairall et al (1996) flux algorithm with CESM (Large and Yeager) algorithm in ROMS
- **… so air-sea fluxes are now totally consistent between ROMS and CESM**


However…

New run: SST difference after 30 years



Very different solution!



What has changed?

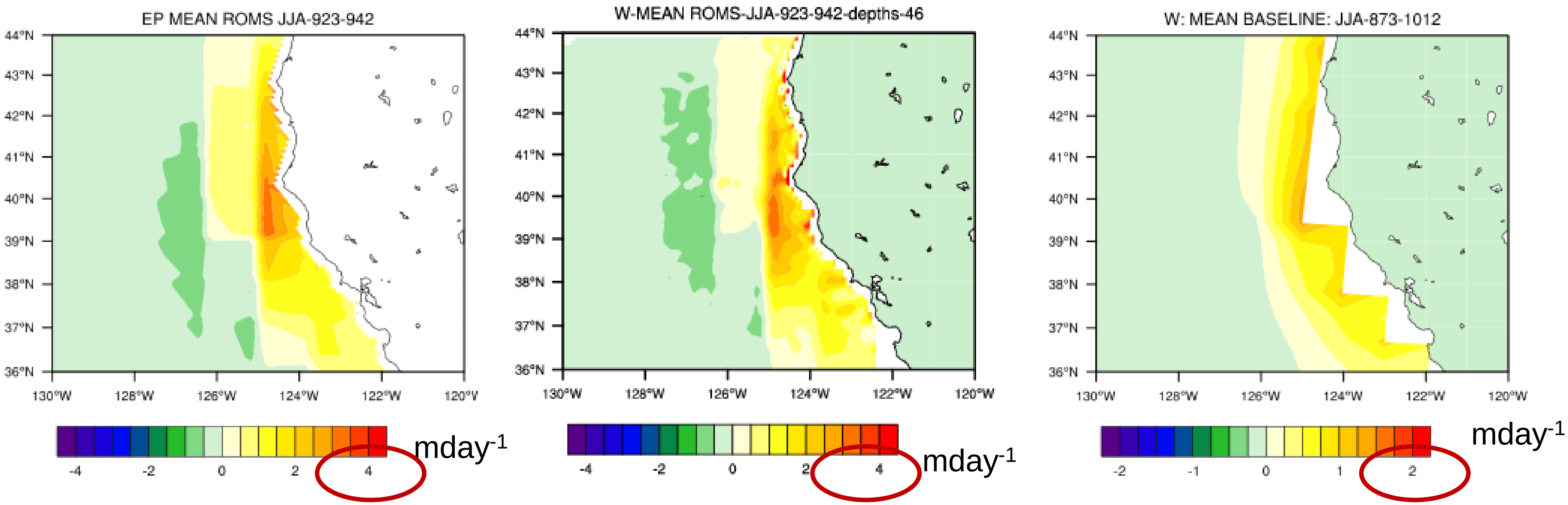
- (One aspect)

Ekman pumping and ROMS w

Ekman pumping seen by ROMS

ROMS vertical velocity at 41-45m depth

POP vertical velocity at 45m.

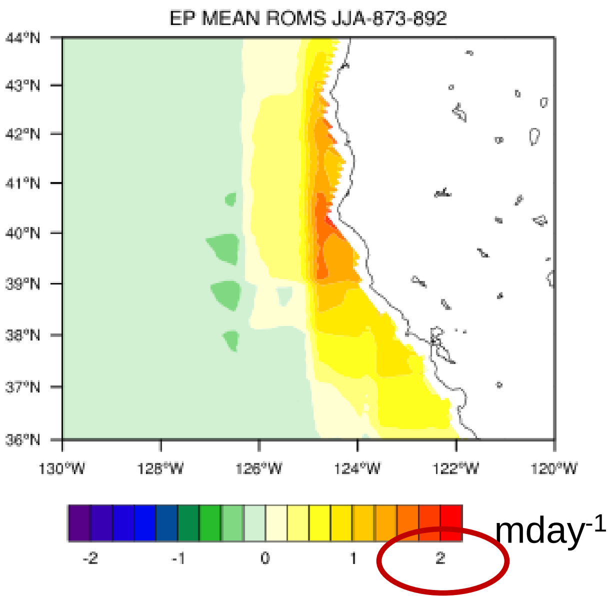


Old run. ROMS upwelling velocities twice as large as in POP of standard CESM – because Ekman pumping is too large.

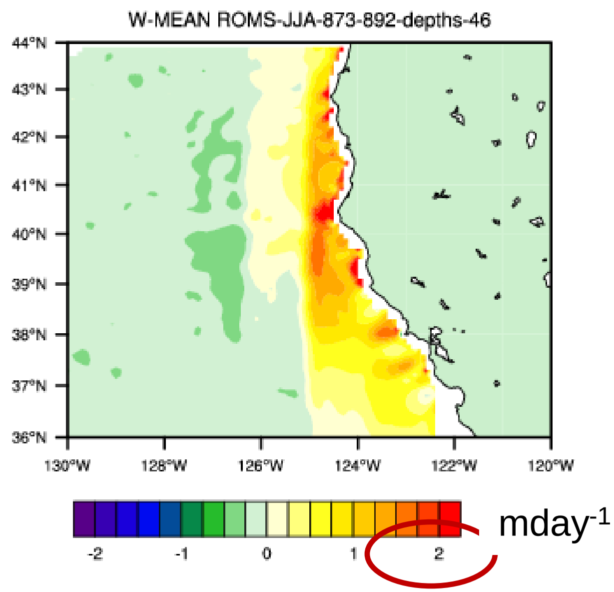
Hypothesis: The differences in vertical advection term dominate the mixed layer heat budget and the SST differences.

Ekman pumping and ROMS w

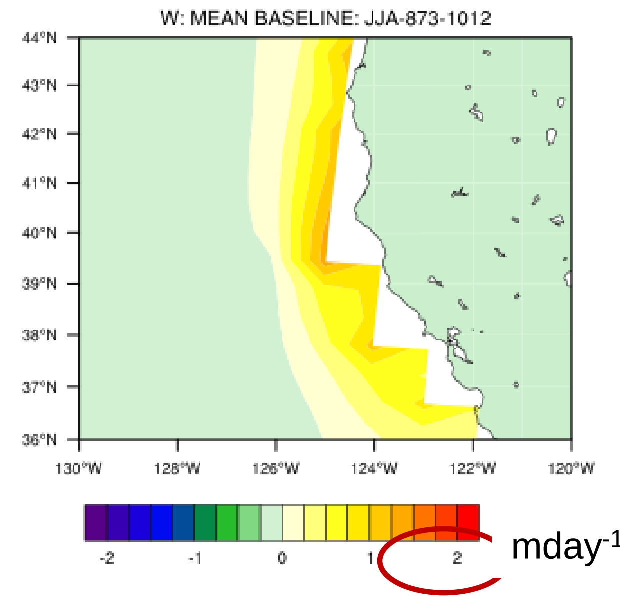
Ekman pumping



ROMS vertical velocity at 41-45m depth



POP vertical velocity at 45m.



New run. ROMS upwelling velocities comparable to POP of standard CESM – as Ekman pumping is the same.

Hypothesis: As ROMS upwelling is not much greater than POP's, other terms than vertical advection may be dominating the difference between the Nrcm SST and the standard CCSM

Some other ideas for future

Atmospheric Resolution

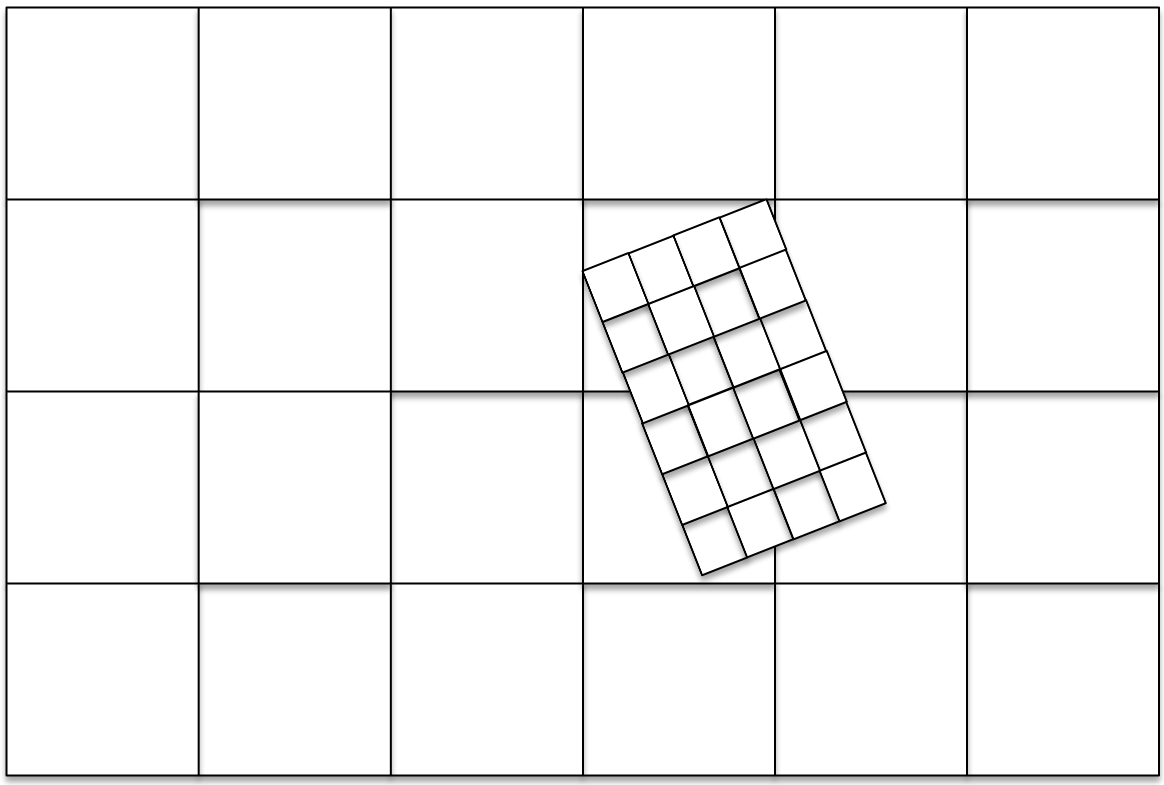
- Present system has atmospheric grid comparable to POP
  - ROMS sees essentially the same wind forcing as POP (just interpolated)

A next step would be to use a higher atmospheric resolution, between that of POP and ROMS

- E.g. 1/4deg.
- ROMS will see more fine structure of winds
- Fine structure of ROMS can feedback to atmosphere
- See also Gent et al 2010 and McClean et al 2011 for results with 1/4deg atmosphere

Special flux grid in coupler

High resolution regional grid replaces part of global ocean domain
Eg. Roms grid overlaying pop grid
E.g. MPAS



Better 2-way ocean interaction

WRF

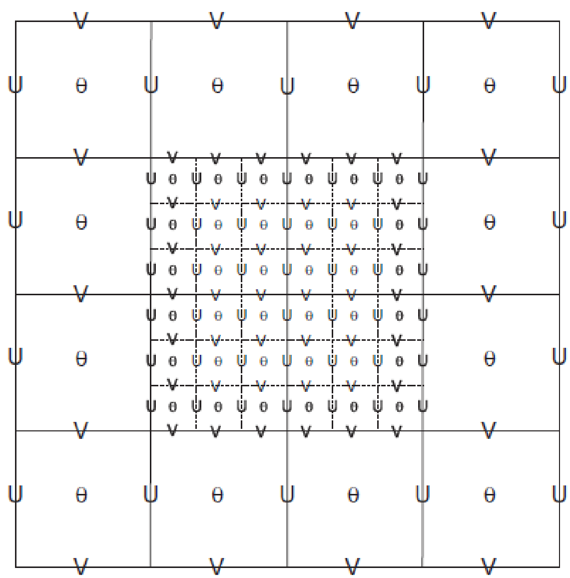
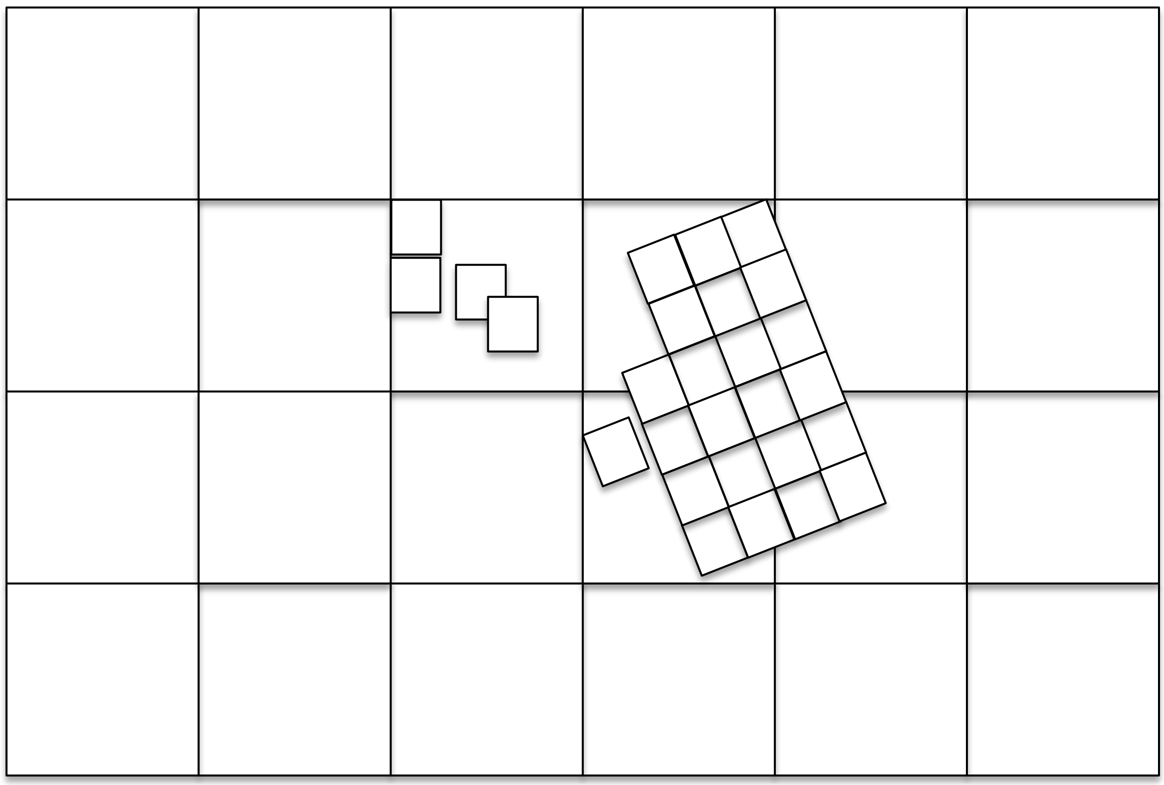
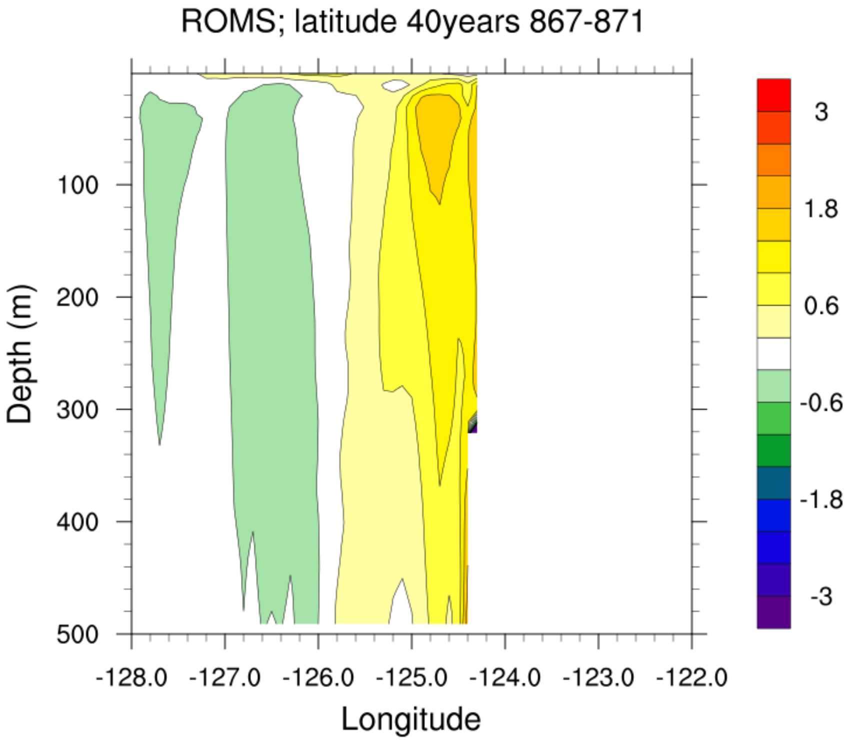
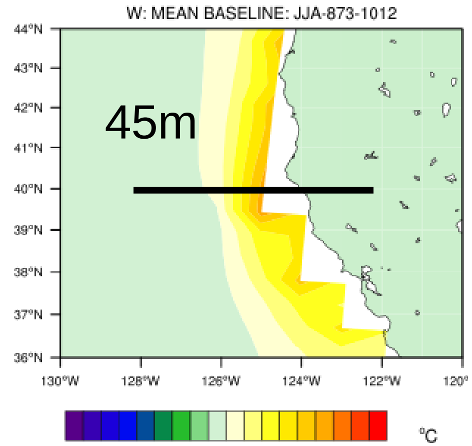


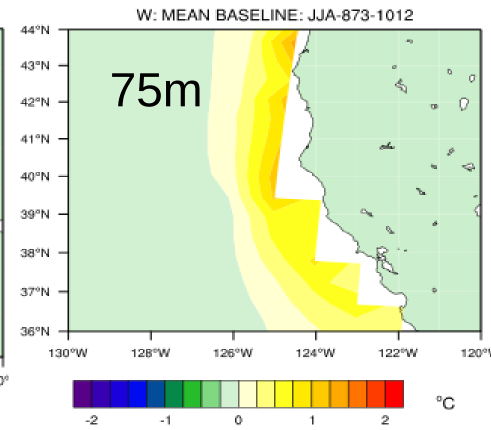
Figure 7.3: Arakawa-C grid staggering for a portion of a parent domain and an imbedded nest domain with a 3:1 grid size ratio. The solid lines denote coarse grid cell boundaries, and the dashed lines are the boundaries for each fine grid cell. The horizontal components of velocity ("U" and "V") are defined along the normal cell face, and the thermodynamic variables ("θ") are defined at the center of the grid cell (each square). The bold typeface variables along the interface between the coarse and the fine grid define the locations where the specified lateral boundaries for the nest are in effect.

Can we do similar for ROMS and POP ?
(but problems with B grid to C grid mismatch
+ Z level to sigma)

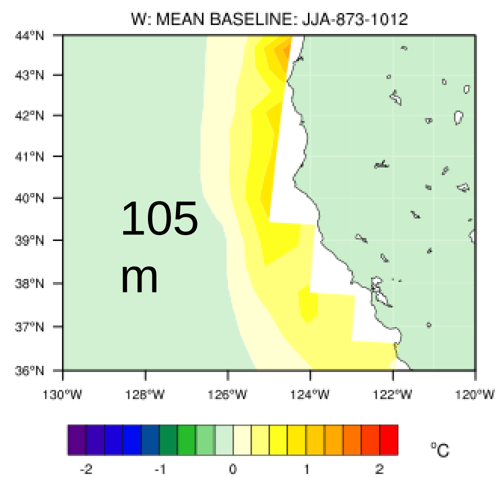


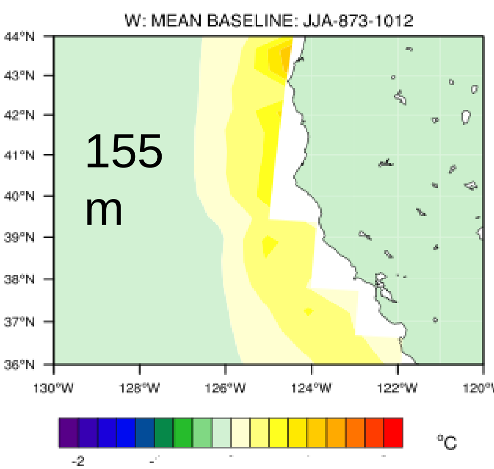


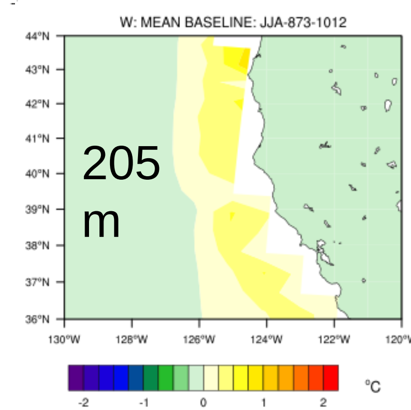




Vertical structure of upwelling velocity, m/day.



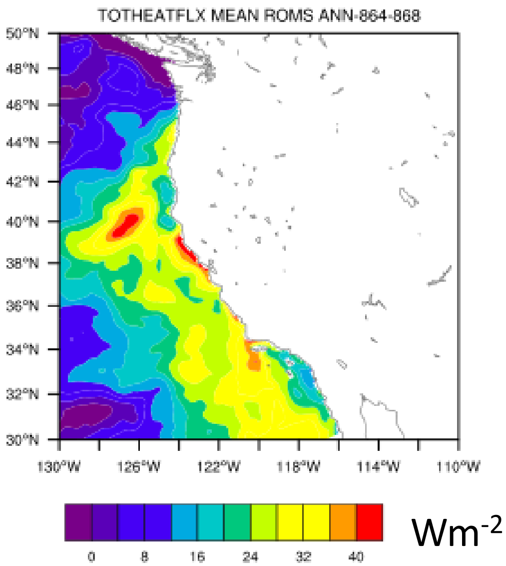


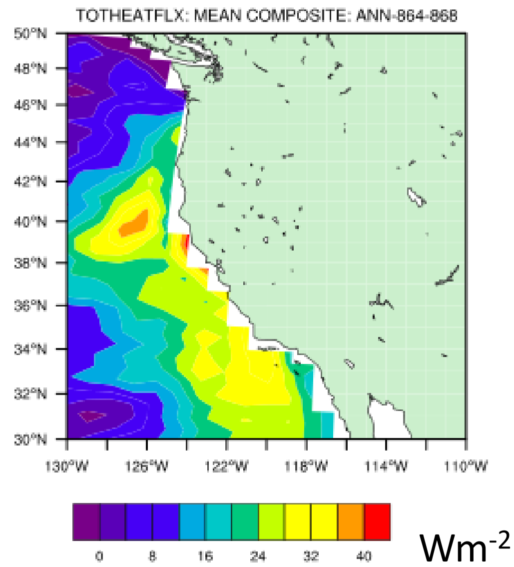


Left: ROMS at 40deg, N
Right: POP at various depths

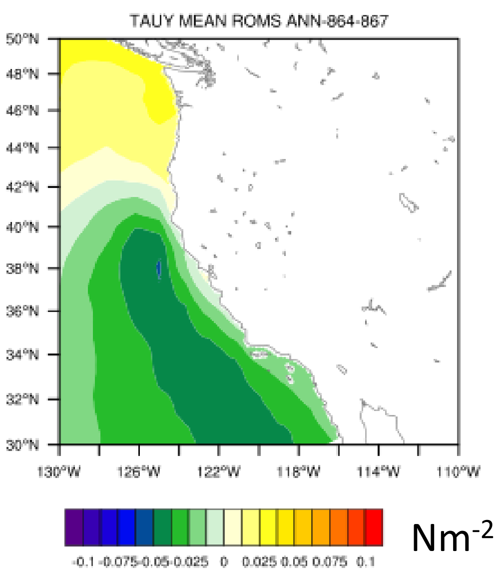
NEW CASE 07

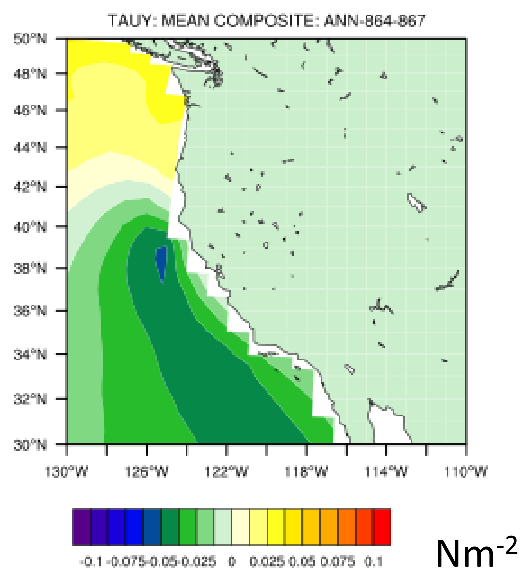
ROMS | COMPOSITE





Left: Net total surface heat flux, annual mean , 5 years.

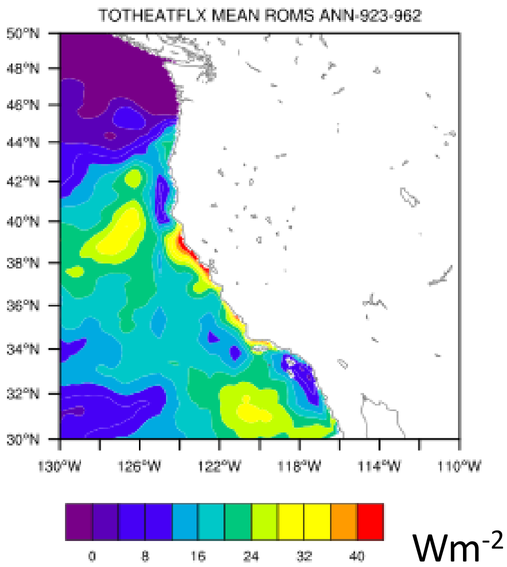


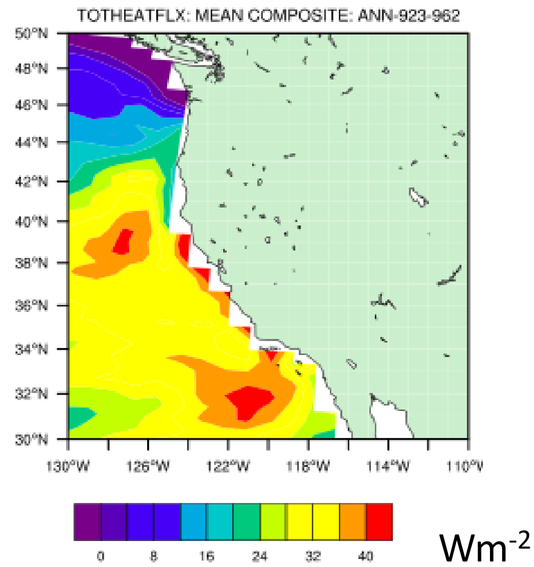


Left: Meridional surface stress, annual mean, 4 years.

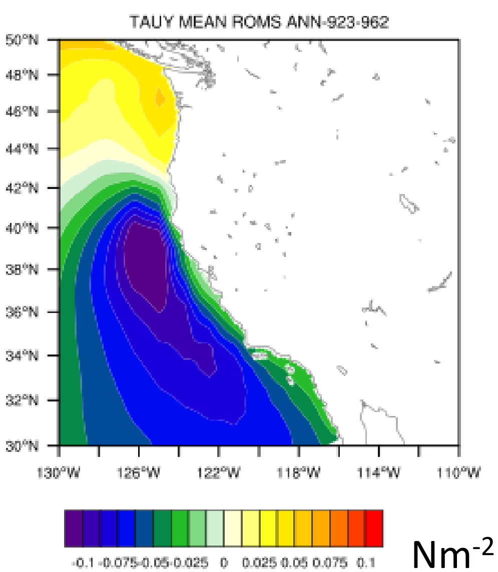
OLD CASE 04

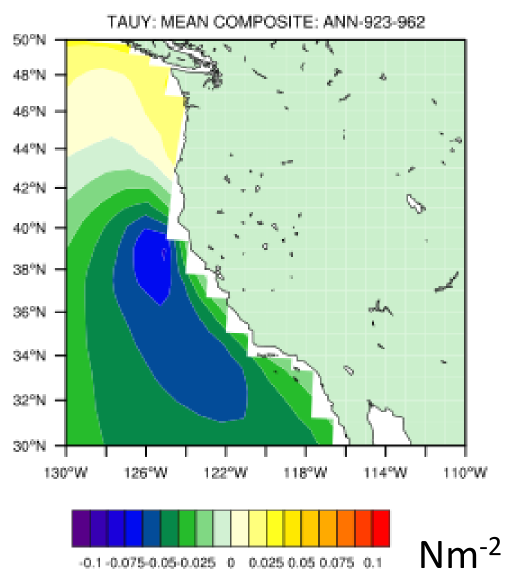
ROMS | COMPOSITE





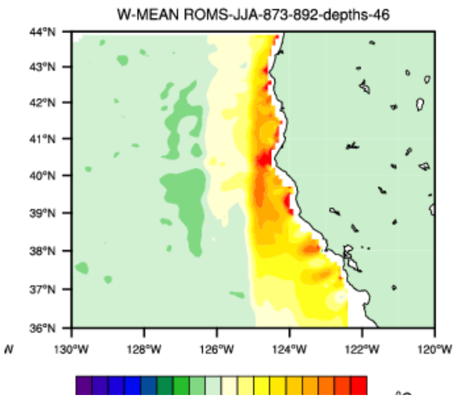
Left: Net total surface heat flux, annual mean , 40 years. Positive values denote warming of ocean.



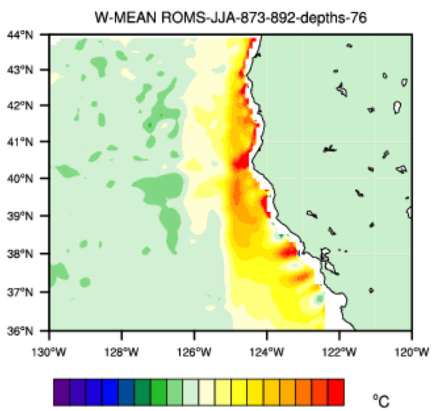


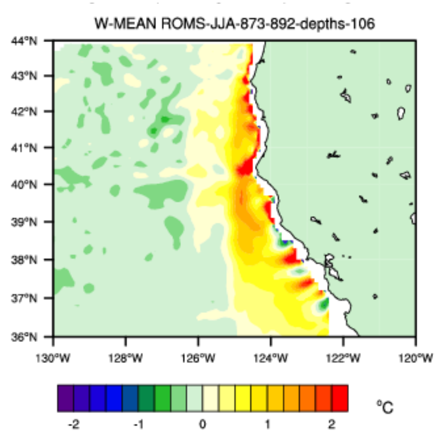
Left: Meridional surface stress, annual mean, 40 years.

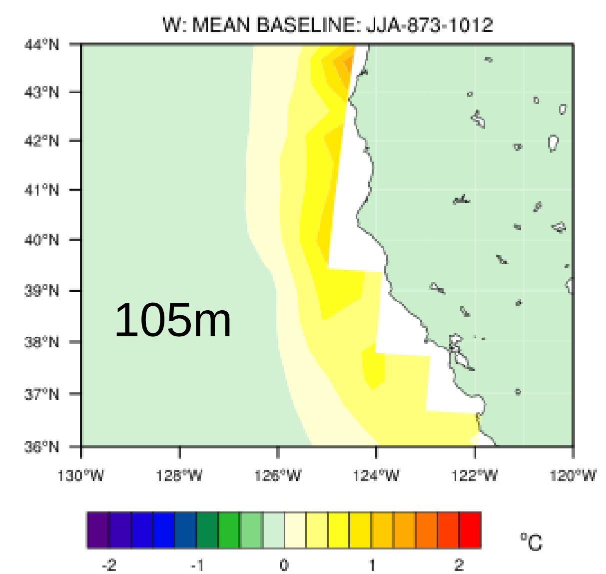
Vertical structure



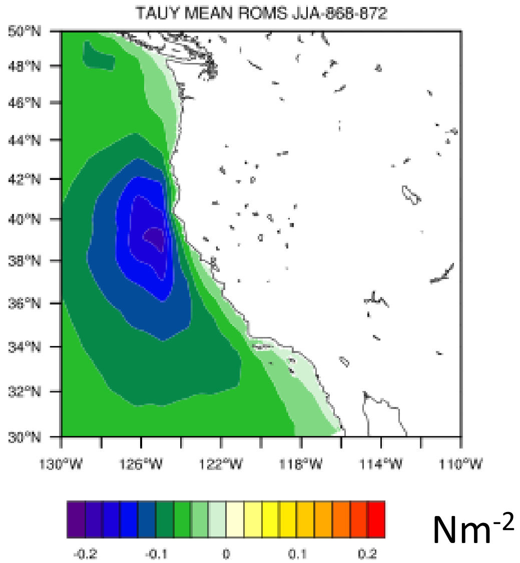
45m

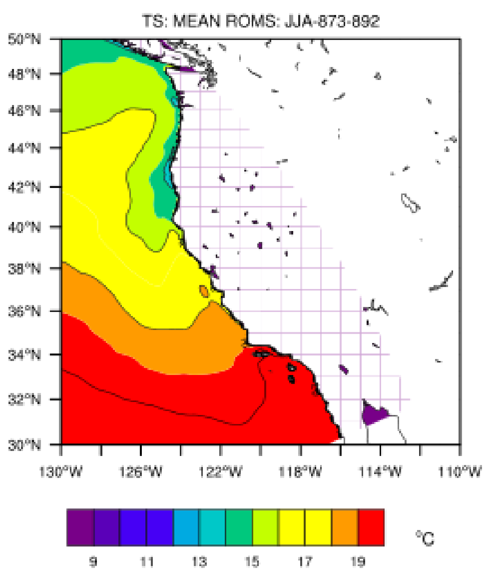


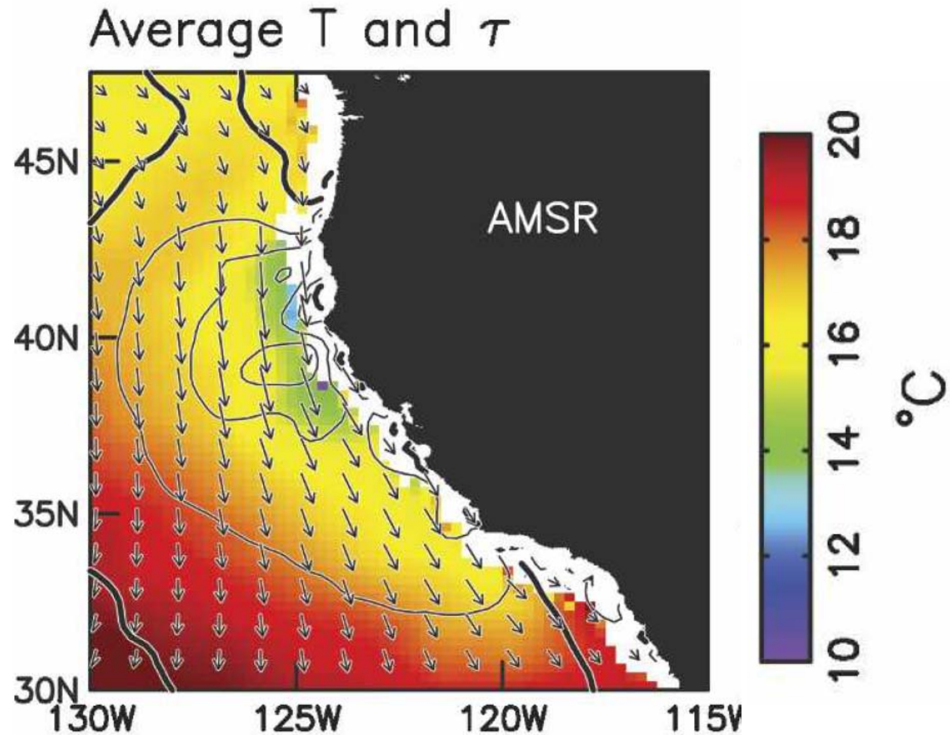




Chelton et al.







Summertime (June to September) average of wind stress vectors and magnitude (contours), and SST (color). From QuikSACT and AMSR-E satellite data. Contour intervals for wind stress are $0.03Nm^{-2}$, heavy contour is $0.06Nm^{-2}$. Maximum stress is around $0.15Nm^{-2}$.