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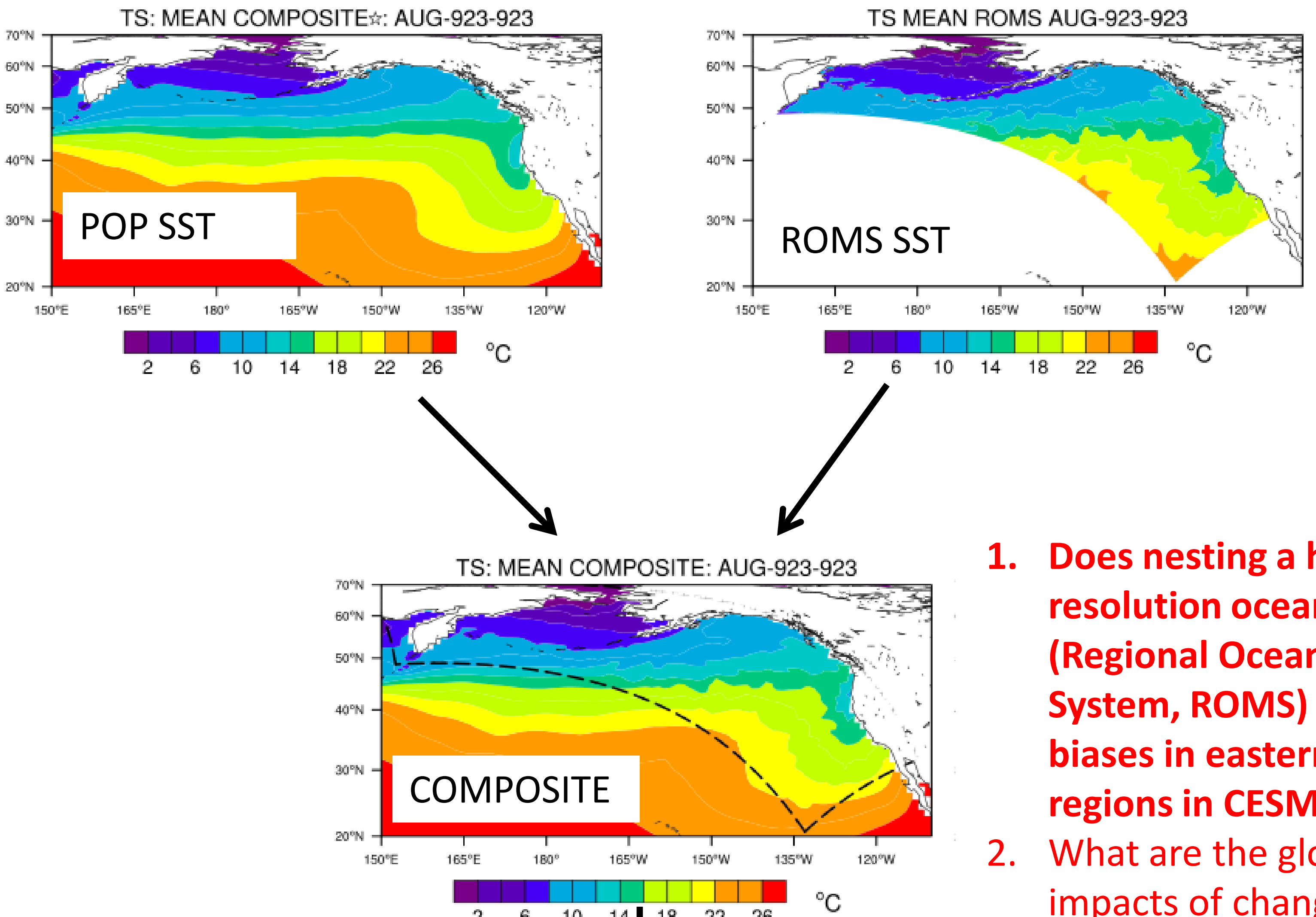
Nested Regional Climate model update and a heat budget in the California Current System

R. Justin Small (NCAR)
Enrique Curchitser (Rutgers)
Brian Kauffman (NCAR)
Kate Hedstrom (U. Alaska)
Bill Large, Jim Hurrell (NCAR)

Nested Regional Climate model (nRCM)

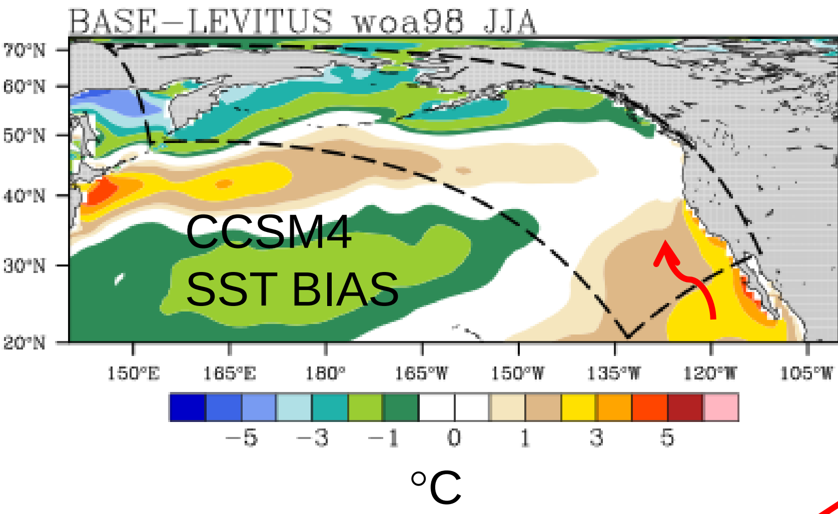


Monthly mean SST from August, year 60 of NEP integration.

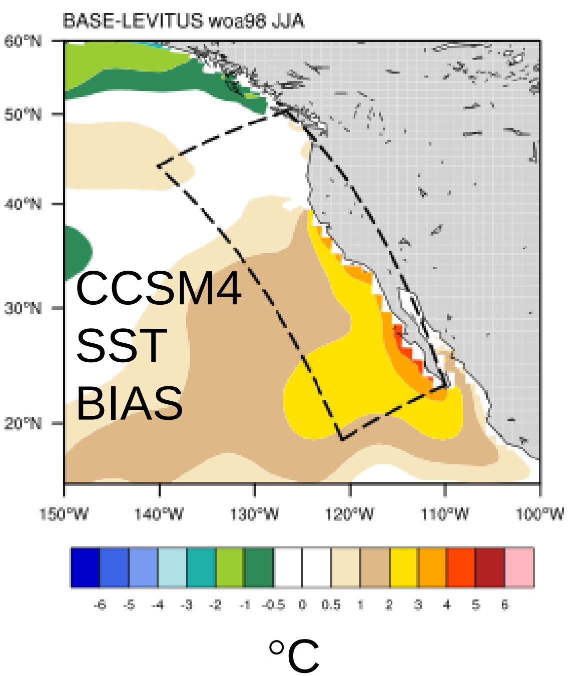
To CESM Coupler

1. **Does nesting a high resolution ocean model (Regional Ocean Modeling System, ROMS) reduce SST biases in eastern boundary regions in CESM?**
2. What are the global climate impacts of changes to SST in eastern boundary regions?

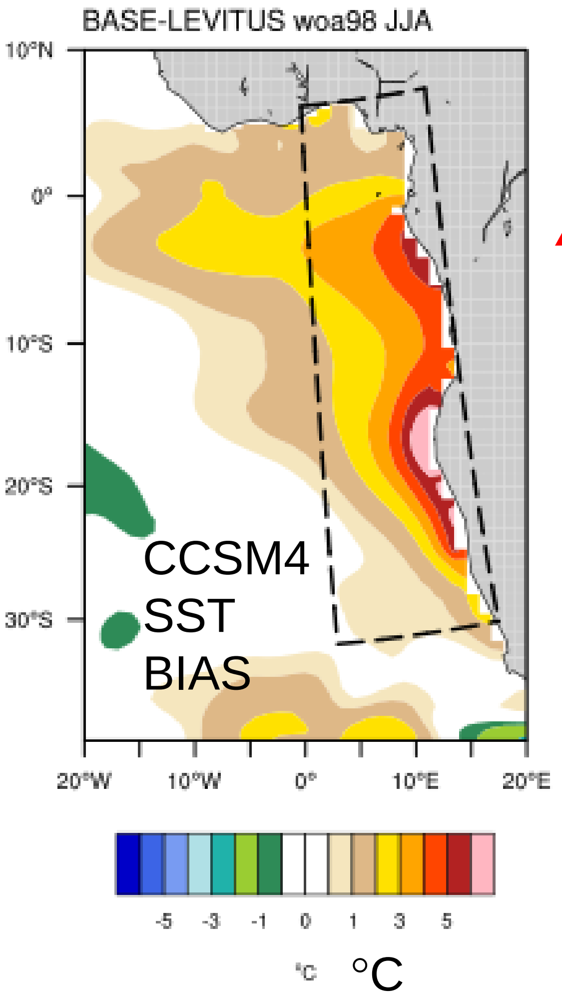
nRCM update and Status



- Changed ROMS domain location to focus on California Current System (CCS).
  - Old domain did not cover largest biases.
- Ran 150 year run for new CCS domain.
  - Employed surface temperature restoring of POP to ROMS



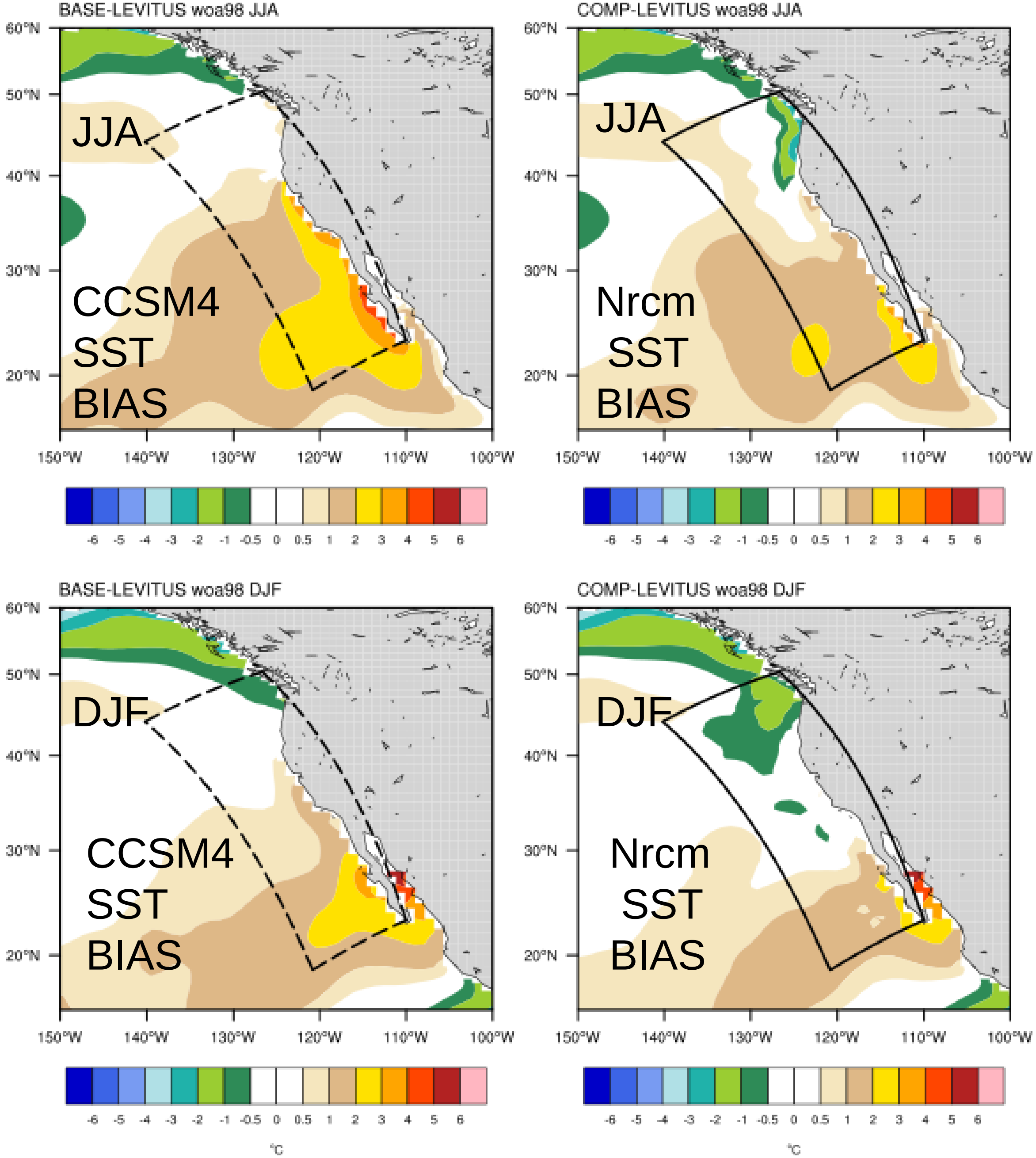
nRCM update and Status



- Set up domain for Benguela and Equatorial Atlantic upwelling system.
  - No restoring – 50 year run
- Employed 3D T&S restoring of POP to ROMS
  - 3D restoring – 20 year run continuing
- Now transitioning to Yellowstone
- Future plans
  - Pass run-off to ROMS (important for Congo etc.)
  - Mid-Atlantic Bight domain (Enrique's EASM project)
  - Scenario runs

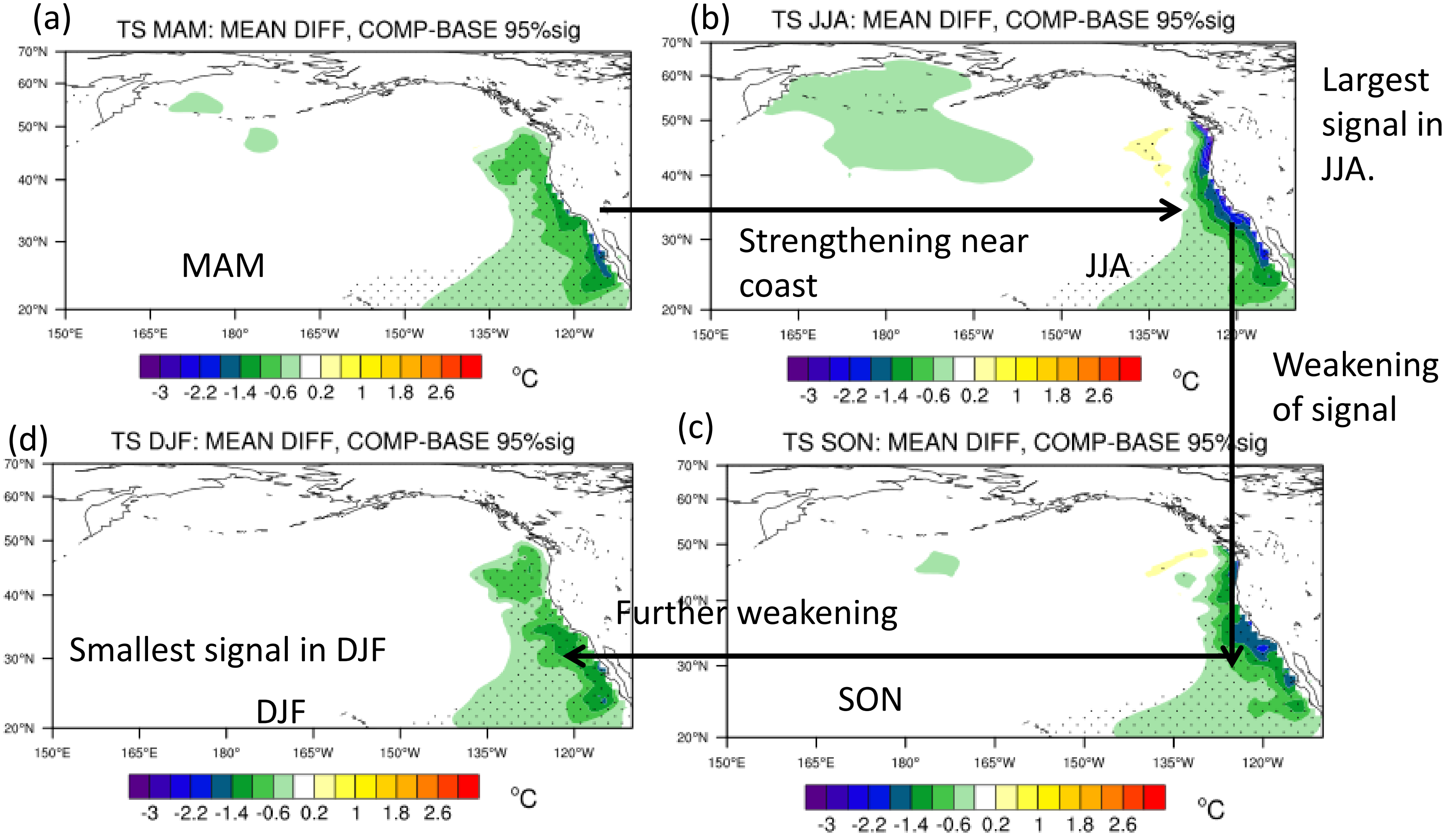
Results from CCS run and associated heat budget

Seasonal SST bias from CCS run



June-July-August (JJA) surface temperature bias (relative to Levitus/WOA98) for baseline CCSM4 run and Nrcm run.

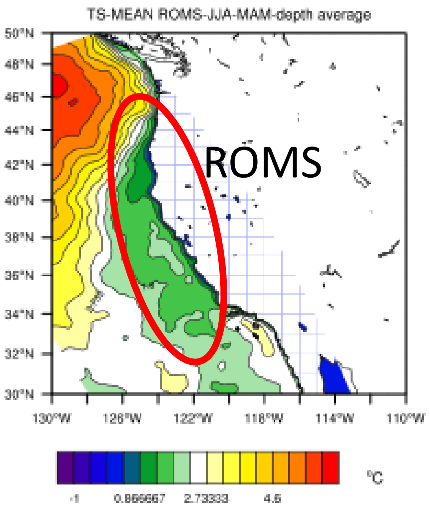
December-January-February (DJF) surface temperature bias (relative to Levitus/WOA98) for baseline CCSM4 run and Nrcm run.

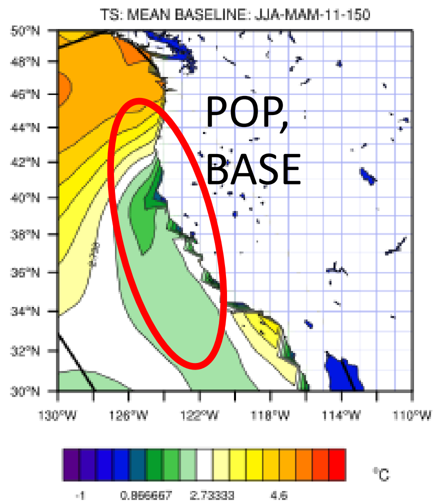


SST differences between seasonal averages of the Nrcm and the baseline run (called "the signal" here). Differences significant at 95% are stipled. Clockwise from top left: a) spring, MAM b) summer, JJA, c) fall, SON, d) winter DJF. Long-term time average from years 10-149 of nRCM run compared to years 873-1012 of baseline run. **What causes the difference between Nrcm and baseline CCSM4 run? Stratocumulus clouds? Horizontal or vertical advection in ocean? Differences in winds? Eddies?**

Strengthening of signal between MAM and JJA

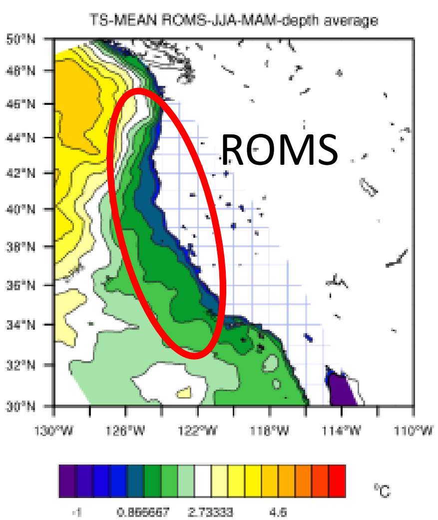
Temperature(JJA)- (MAM)15m average

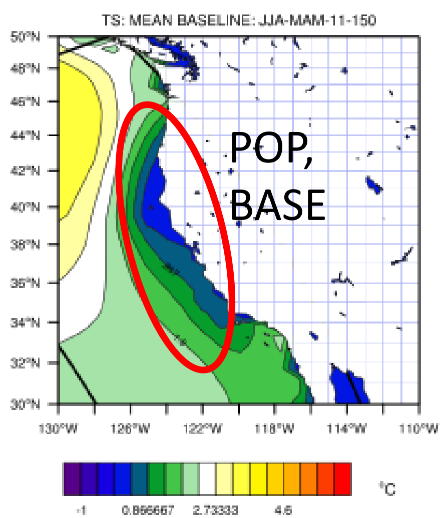




Temperature tendency between MAM and JJA more negative in ROMS along coast when averaged to 15m depth.

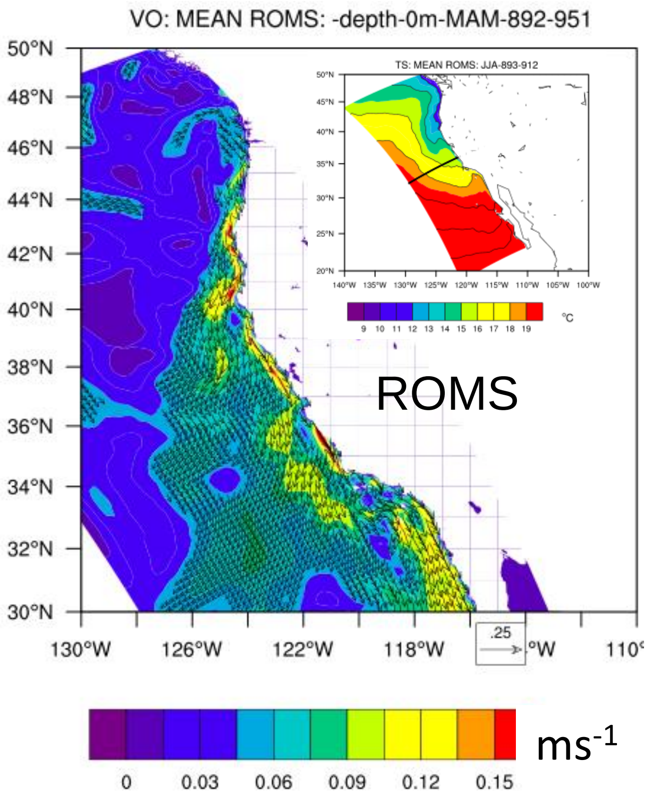
Temperature(JJA)- (MAM)50m average

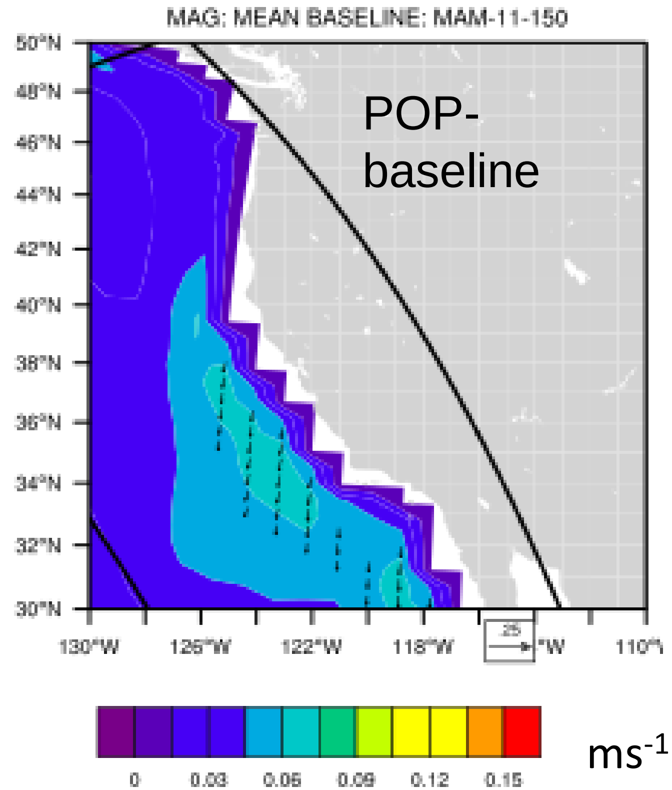


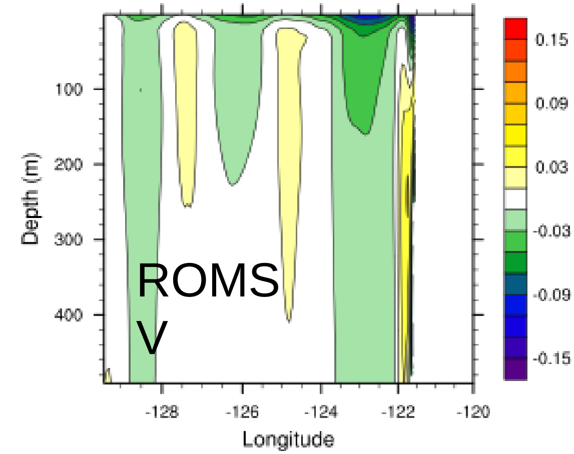


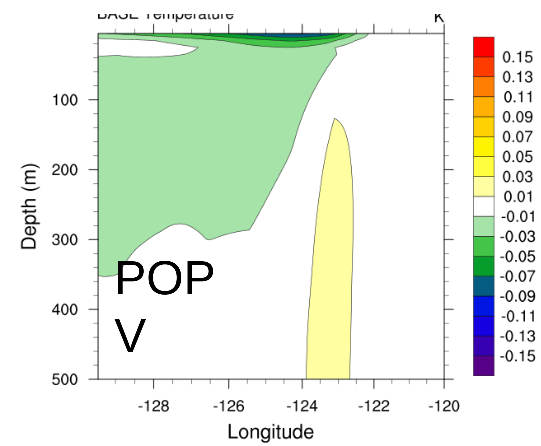
Temperature tendency between MAM and JJA more negative in POP along coast when averaged to 50m depth.

Surface Currents (MAM)







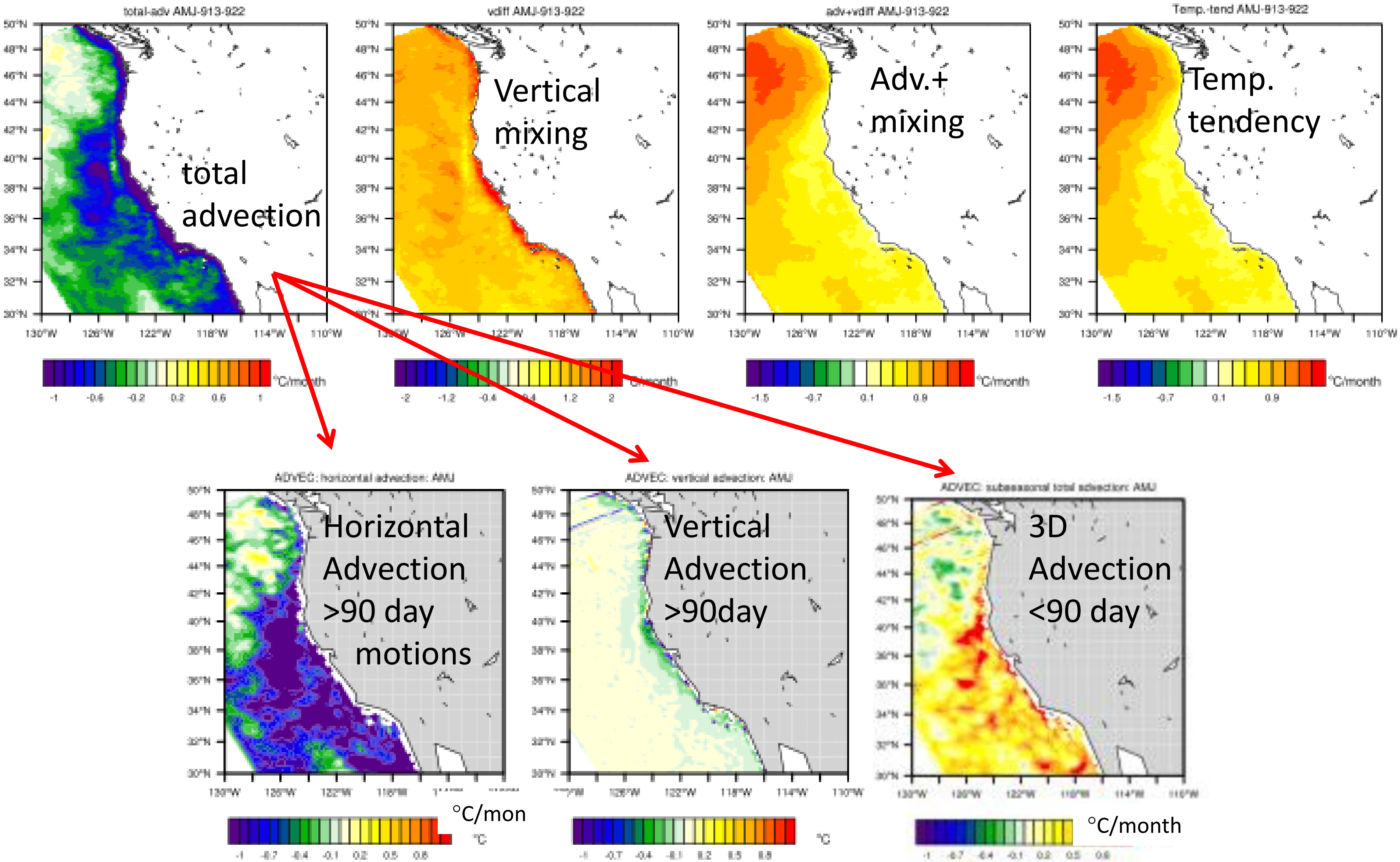


Left two panels: mean surface velocity vectors and their magnitude from ROMS and long baseline run, long term summer mean MAM. Scale arrow shows $0.25 ms^{-1}$. Only vectors greater than $0.05 ms^{-1}$ are shown.

Right panels: mean meridional (V) velocity along a section shown in inset at left.

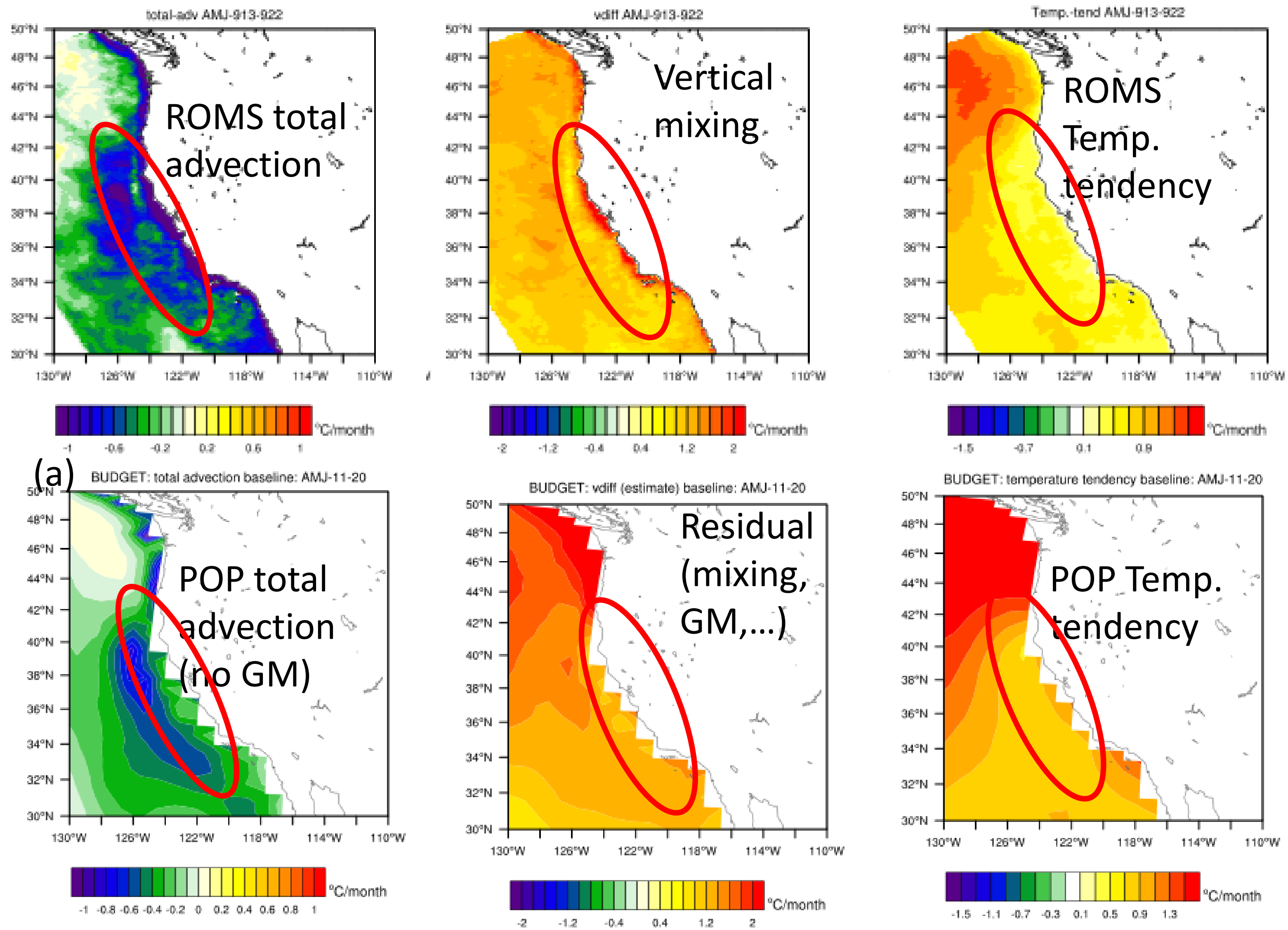
ROMS southward currents are stronger. In both ROMS and POP currents are surface intensified (Ekman).

ROMS heat budget in April-May-June (AMJ)



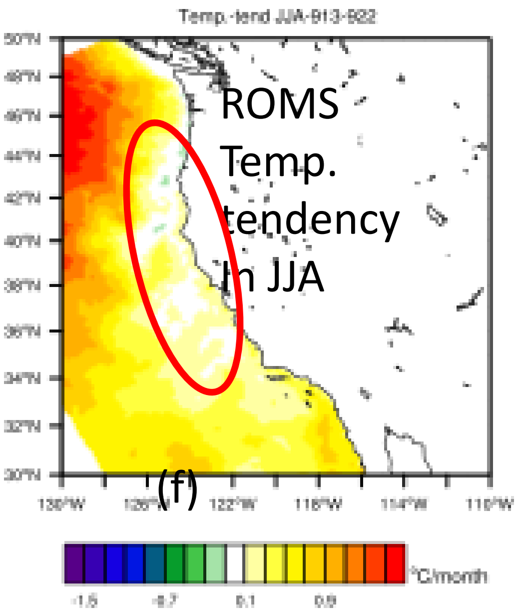
Heat budget in upper 15m from ROMS for AMJ. Terms are written as deg. C/month

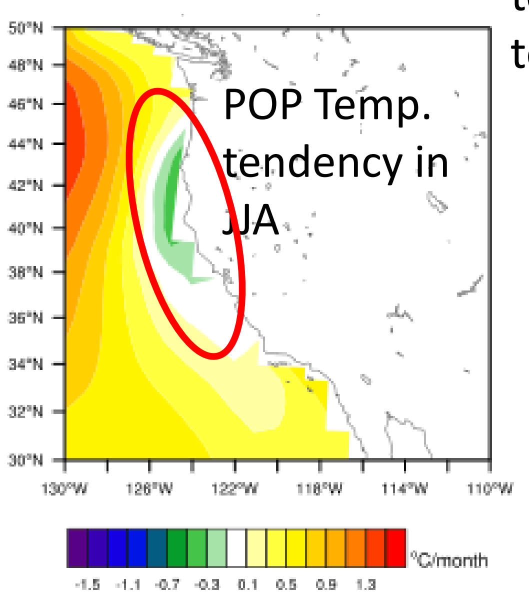
Comparison of ROMS vs POP heat budget in April-May-June (AMJ)



Heat budget vertically averaged over top 20m for POP and top 15m for ROMS for AMJ. Terms are written as deg. C/month. ROMS warms less near coast (right panels) because of strong advection (despite more surface heating near coast than POP).

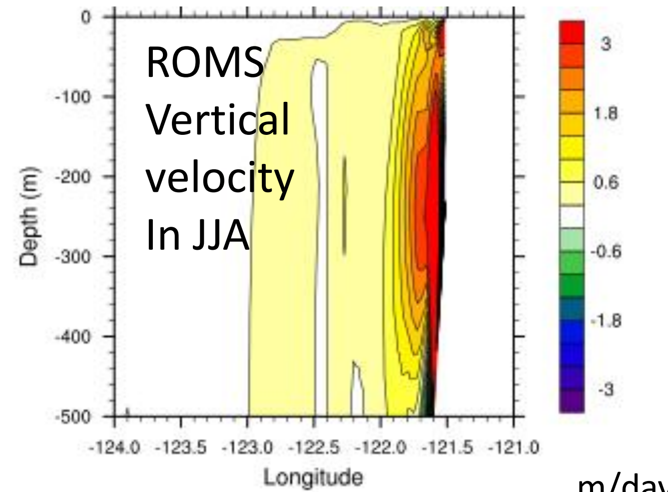
Heat budget **in upwelling season, JJA**

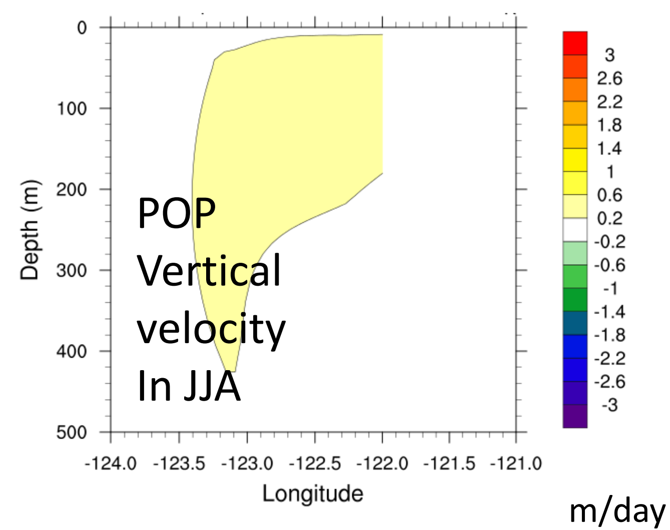




Left. Temperature tendencies in top 50m.

Right. Vertical velocities along section previously shown.





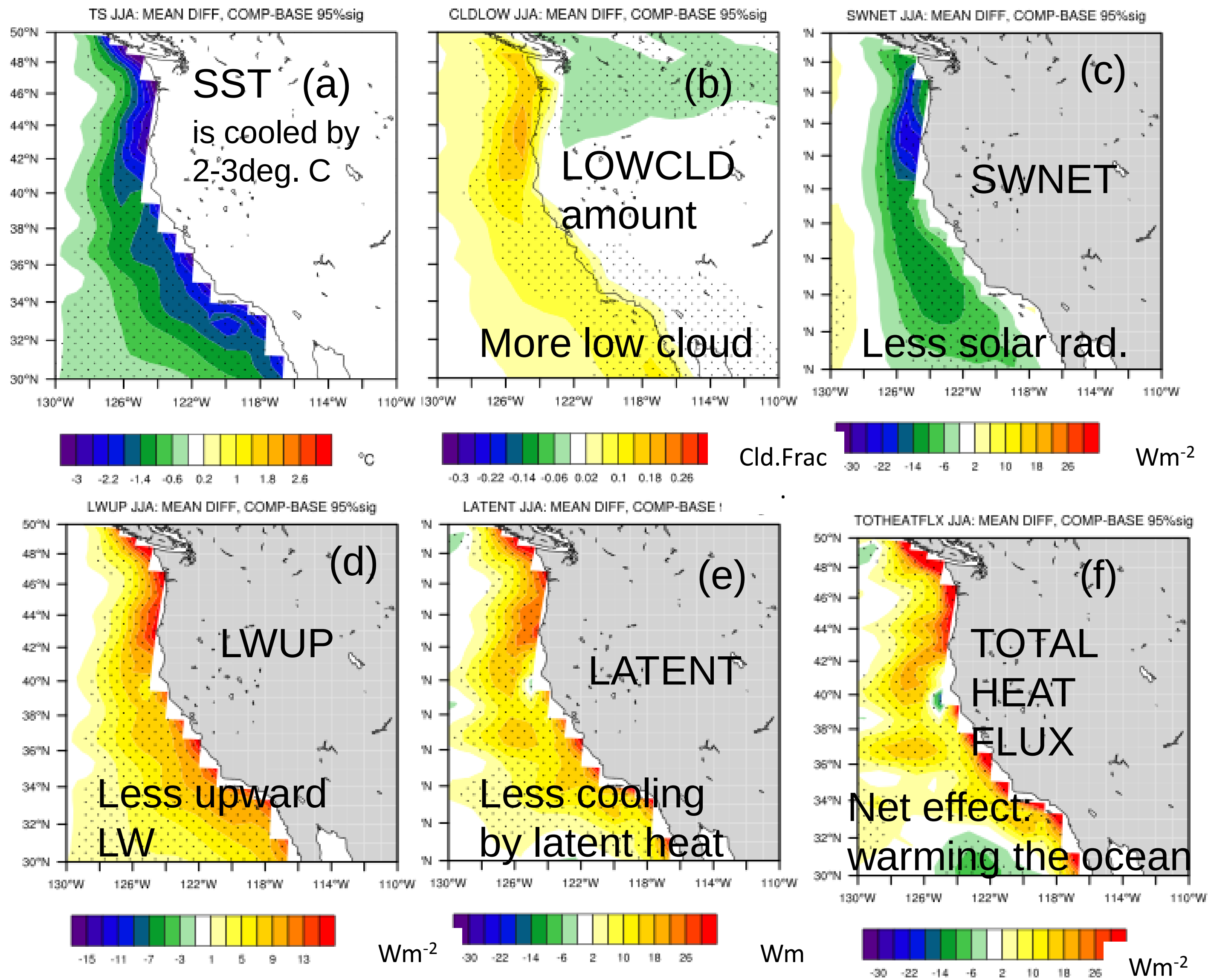
Why is POP cooling more near coast when ROMS has large upwelling velocities?

Heat budget in upwelling season, JJA

Why is POP cooling more near coast when ROMS has large upwelling velocities?

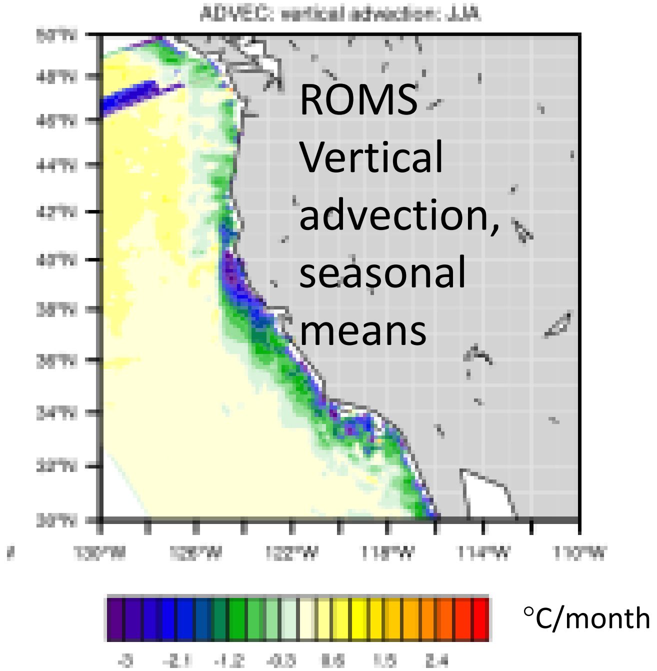
Reason 1. Total, net surface heat fluxes damp the existing cold SST anomaly in ROMS.

Although net short-wave on its own acts as a positive feedback on SST, it is counteracted by latent and long-wave-up. The long-wave down and sensible contributions are smaller.

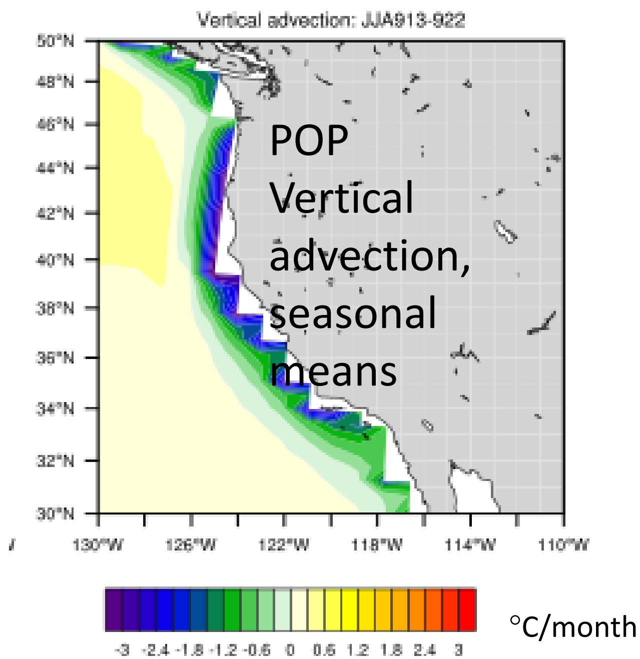


Differences between NRCM and baseline in JJA. a) SST, b) low cloud amount, c) net surface shortwave radiation, d) upwelling long wave, e) latent heat flux, and f) total surface heat flux. Convention is that positive is into the ocean.

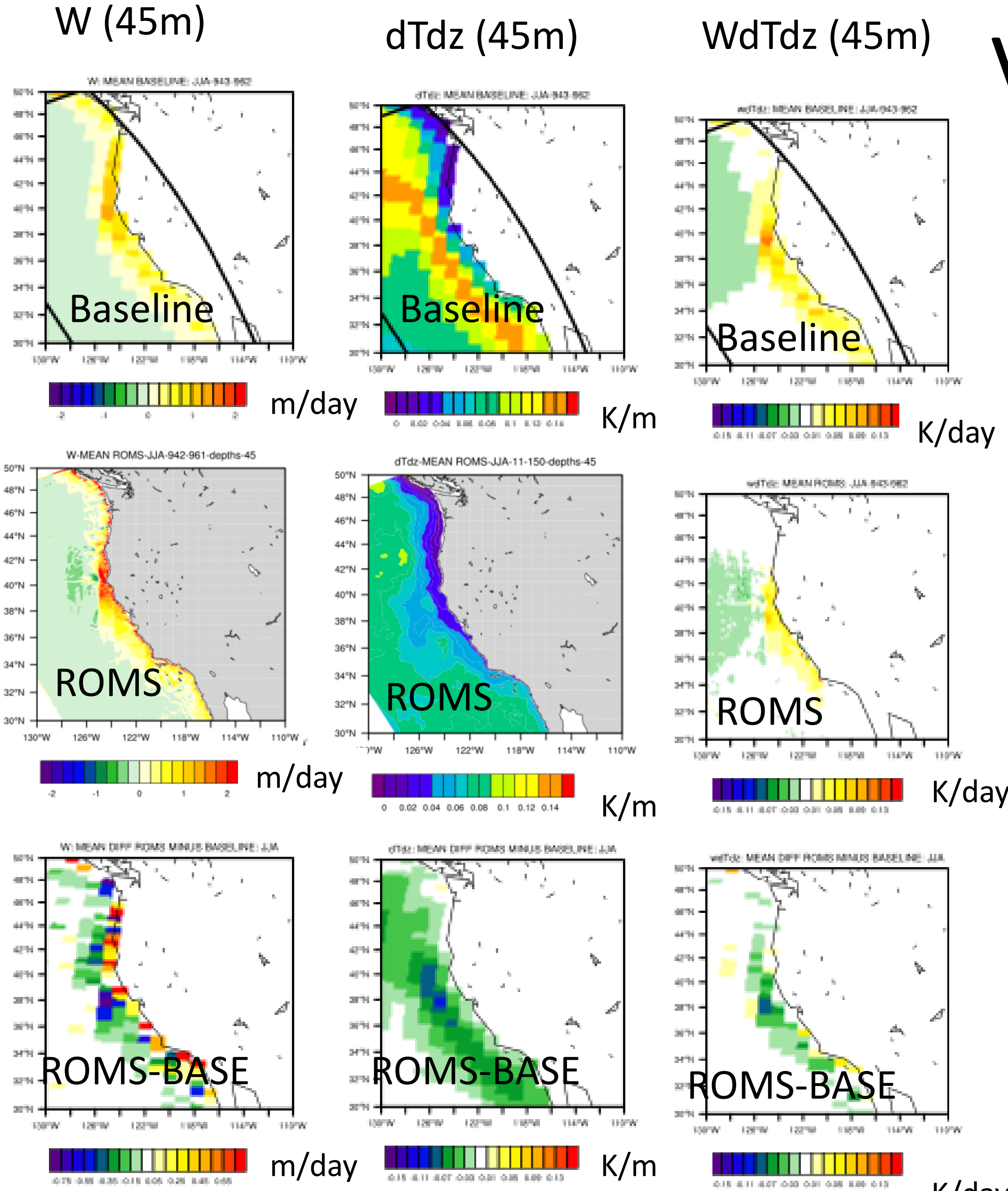
Why is POP cooling more near coast when ROMS has large upwelling velocities?



Reason 2. Vertical advection in POP (bottom panel) as large, or larger than, ROMS (top panel), in top 50m in JJA, despite larger vertical velocities.



Vertical advection decomposition



Plots show climatological means of W, dTdz and the product of these means i.e. <W>.<dTdz> where <> is climatological means.

Why is POP cooling more near coast when ROMS has large upwelling velocities?

Reason 2. Cooling of ROMS at surface before summer reduces stratification, and hence cooling by vertical advection is limited .

(i.e. ROMS has larger vertical velocities than POP, but POP has a larger stratification (dT/dz) and so WdTdz is slightly larger in POP.)

Summary of CCS heat budget

- Between MAM and JJA strong southward currents (CCS) in ROMS cool the near surface layers more than POP.
- ROMS becomes less stratified than POP
- In JJA, upwelling velocity is very strong in ROMS but now dT/dz is weak. Hence vertical advection is comparable to or weaker than POP.
- In JJA the surface heating is more in ROMS (negative feedback on SST). Combined with the slightly weaker advection in ROMS means POP cools more in JJA.
- Eddies typically warm the upper layers.

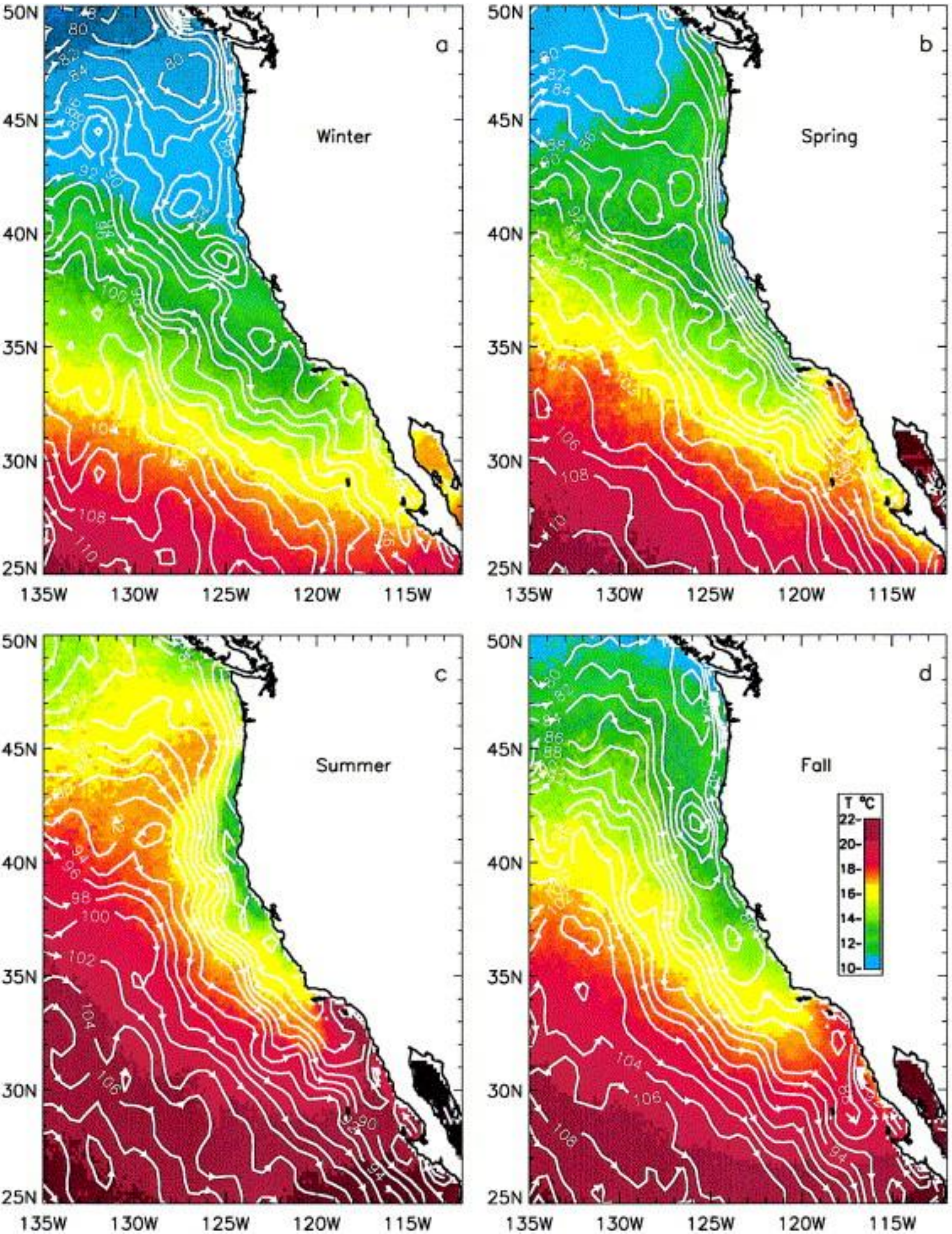


Fig. 4. Mean seasonal height fields from the California Current (three-month means) overlaid on mean seasonal SST fields from AVHRR satellite data, 1981 through 1986. Winter is January–March, etc. Contour intervals are 2 cm. Strub and James 2000.

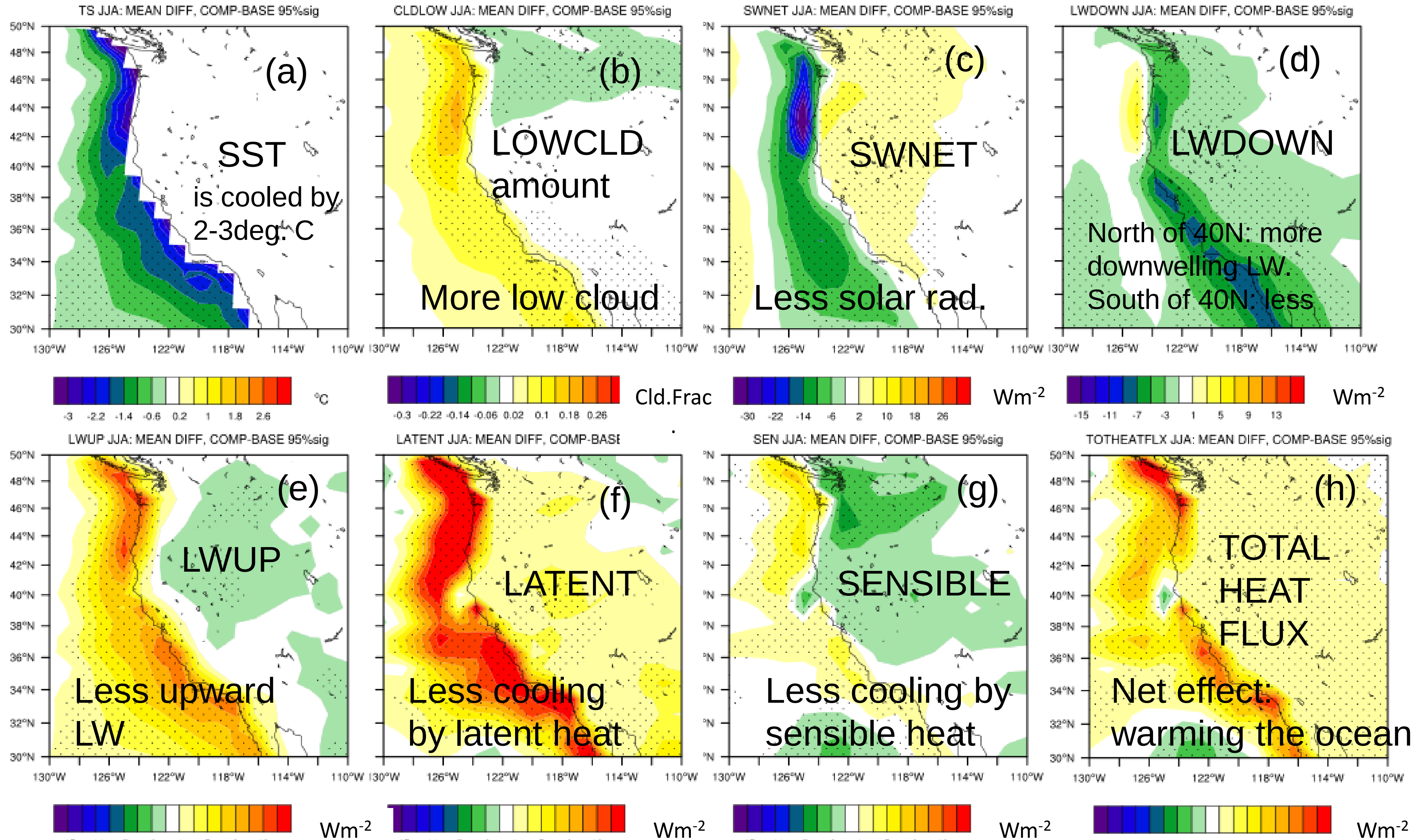
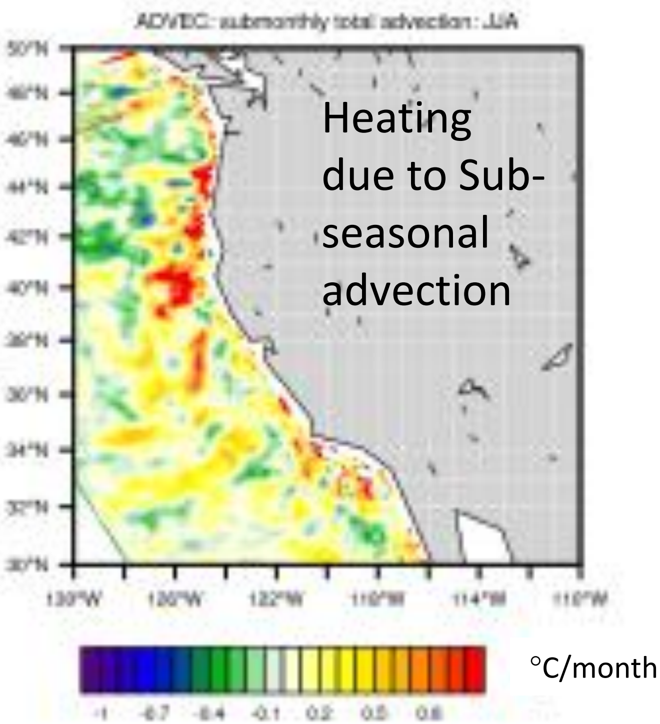


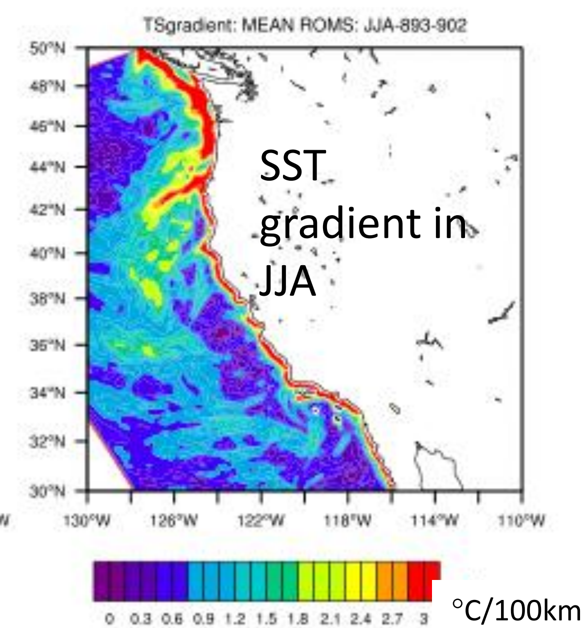
Fig. 4.4. Differences in a) SST, b) low cloud amount, c) net surface shortwave radiation, d) longwave downwelling radiation, e) upwelling long wave, f) latent heat flux, g) sensible heat flux and h) total surface heat flux. NRCM minus baseline, for long-term summer average (JJA). Convention is that positive is into the ocean.

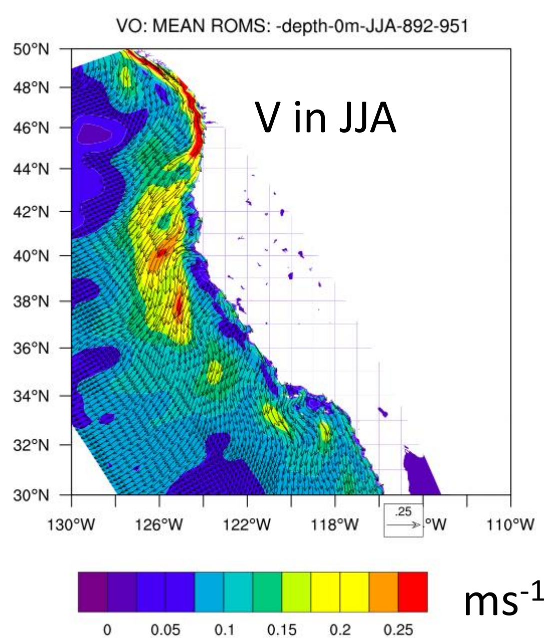
Years 10-129 (SST&fluxes), 80-99 (clouds). Positive fluxes warm the ocean.

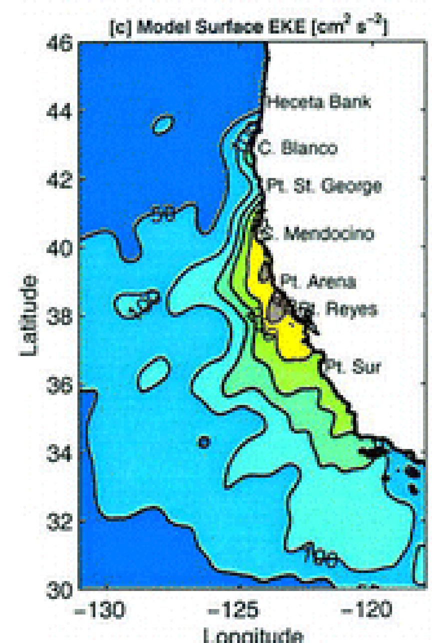
What about the role of eddies in the heat budget?

Eddy heat flux divergence in JJA (left) shows warming close to coast and in vicinity of strong currents and SST gradients.

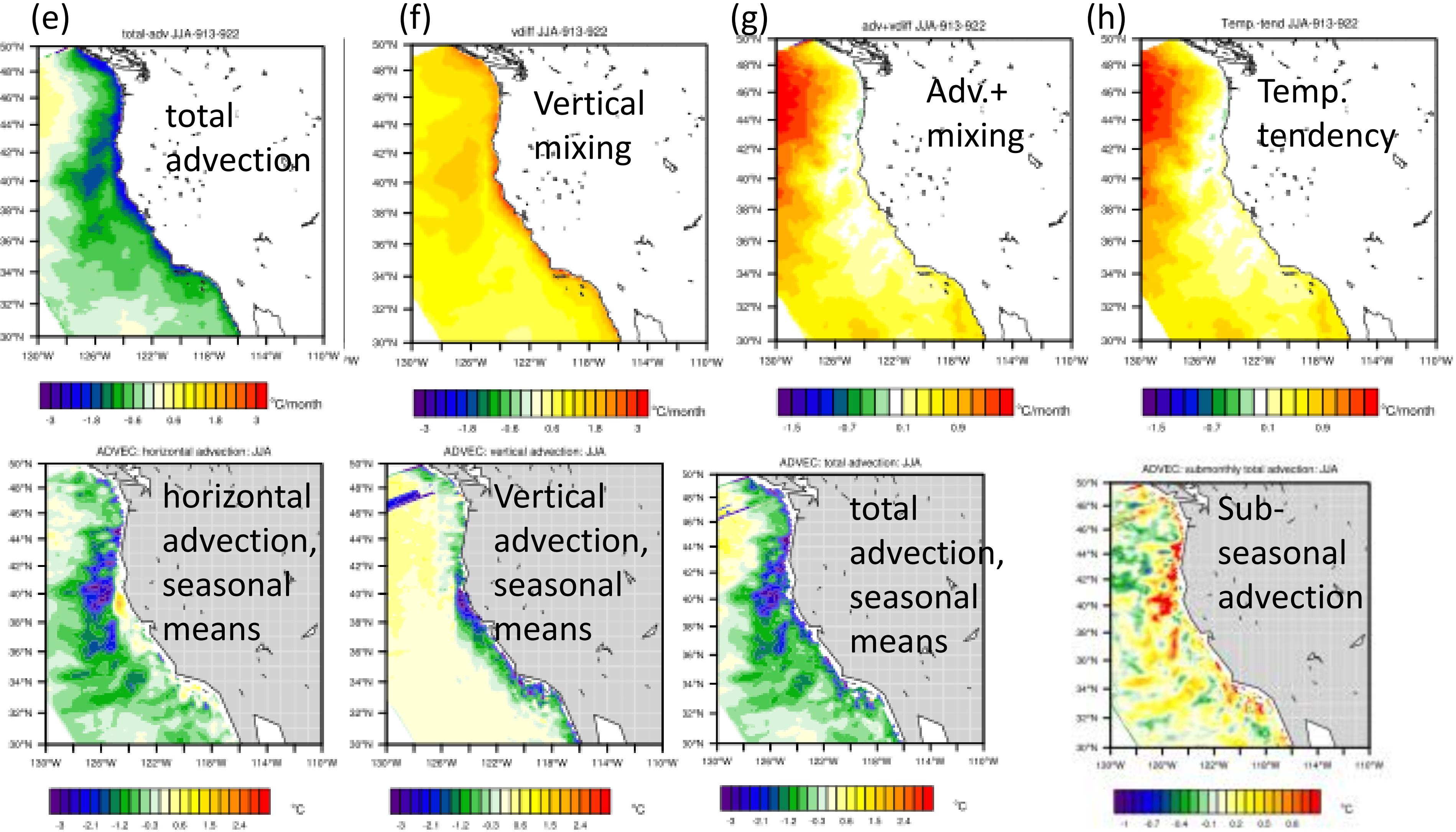








EKE from Marchesiello et al 2003.



Heat budget in upper layers from ROMS for JJA. Decomposition of advection into horizontal and vertical (seasonal means) and sub-seasonal advection. All are in deg. C per month.

Fig. . Heat budget in upper layers from ROMS (top panels) and POP (bottom panels) for JJA. Terms are written as deg. C/month and are vertically averaged over top 50m for ROMS. From left: total advection (horizontal+vertical), vertical mixing, advection plus mixing, and the total temperature tendency.