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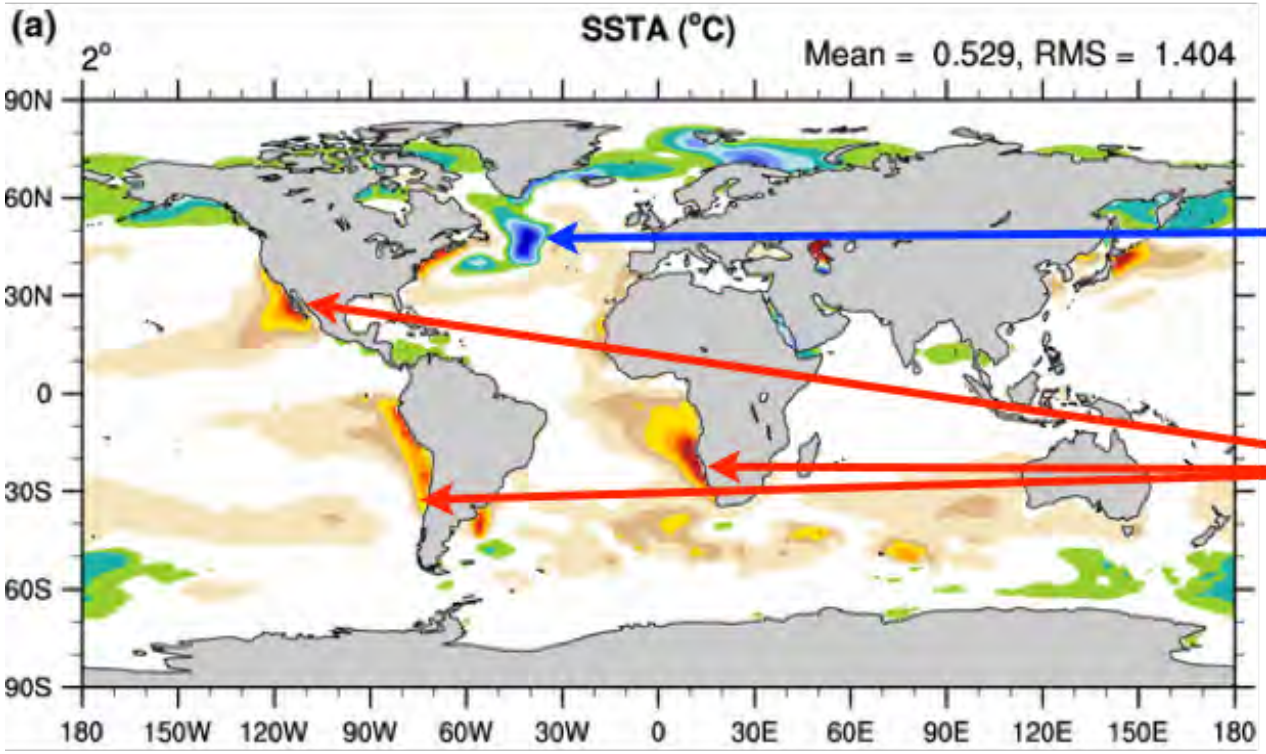
Regional and global ramifications of eastern boundary upwelling

Enrique Curchitser
Department of Environmental Sciences

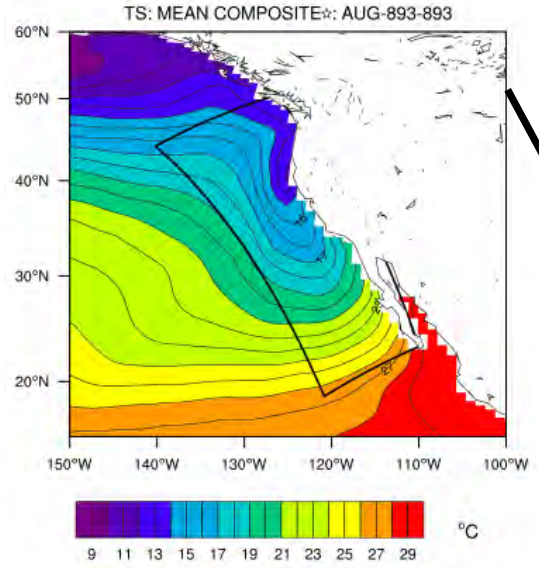
In collaboration with:

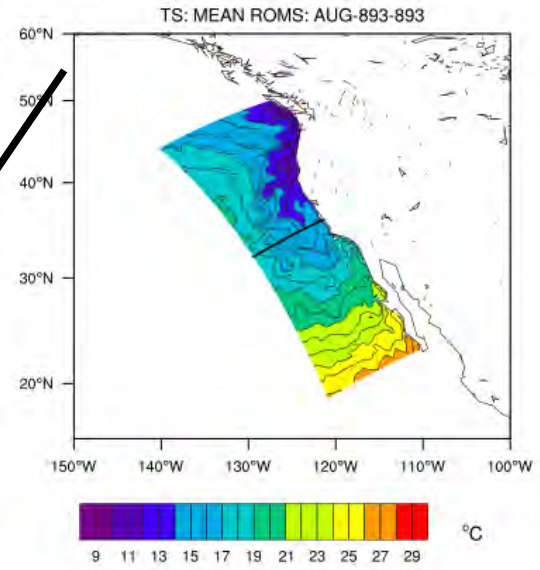
Justin Small, Bill Large, Kate Hedstrom, Mike Alexander, Jerome Fiechter

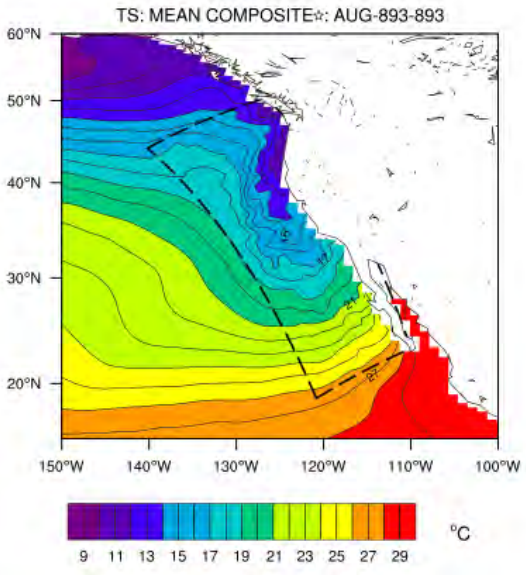
Motivation: Climate model biases in coastal regions



The method: Embedding a high-resolution ocean (ROMS) within a climate model (NCAR-CESM)



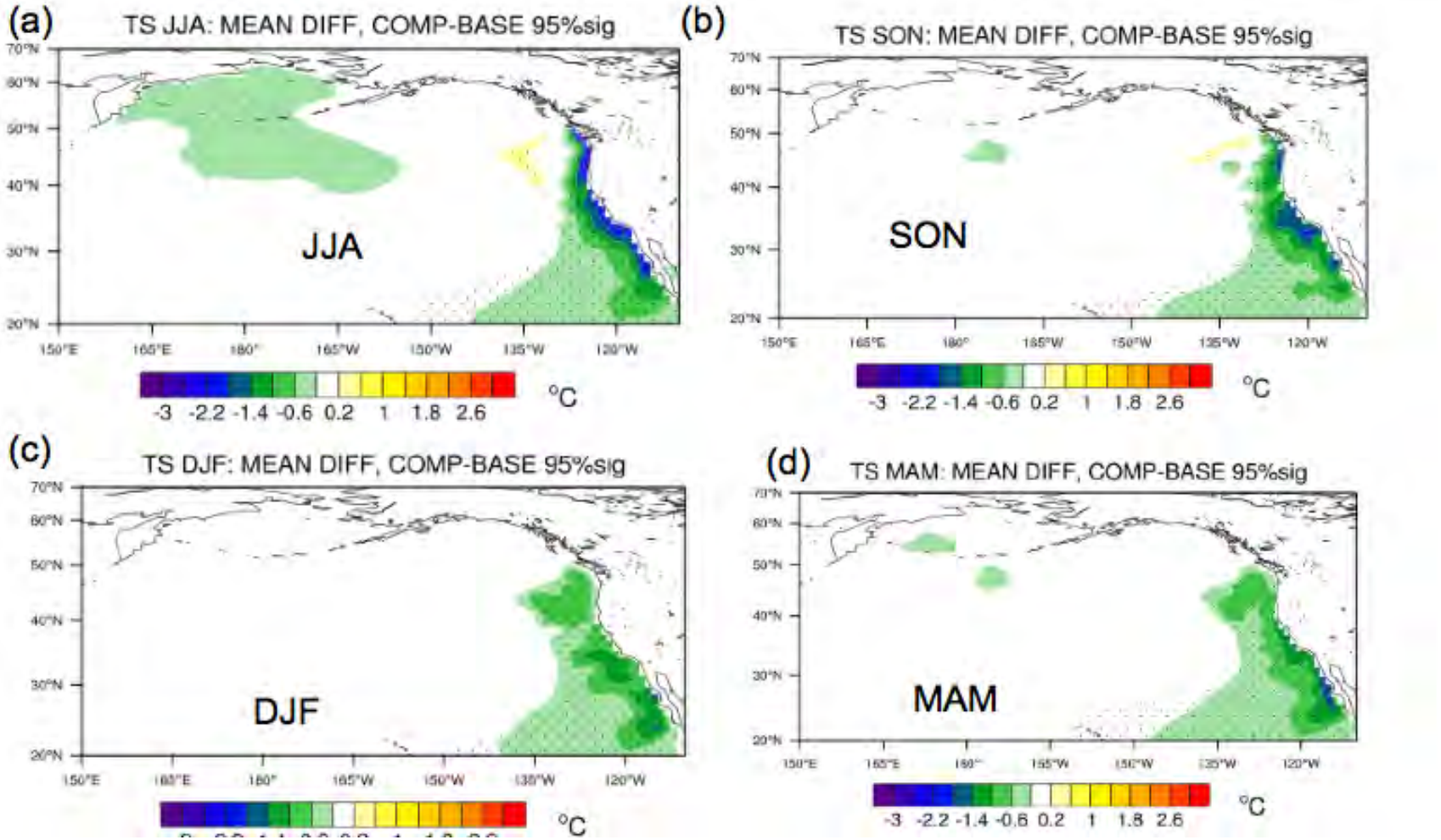




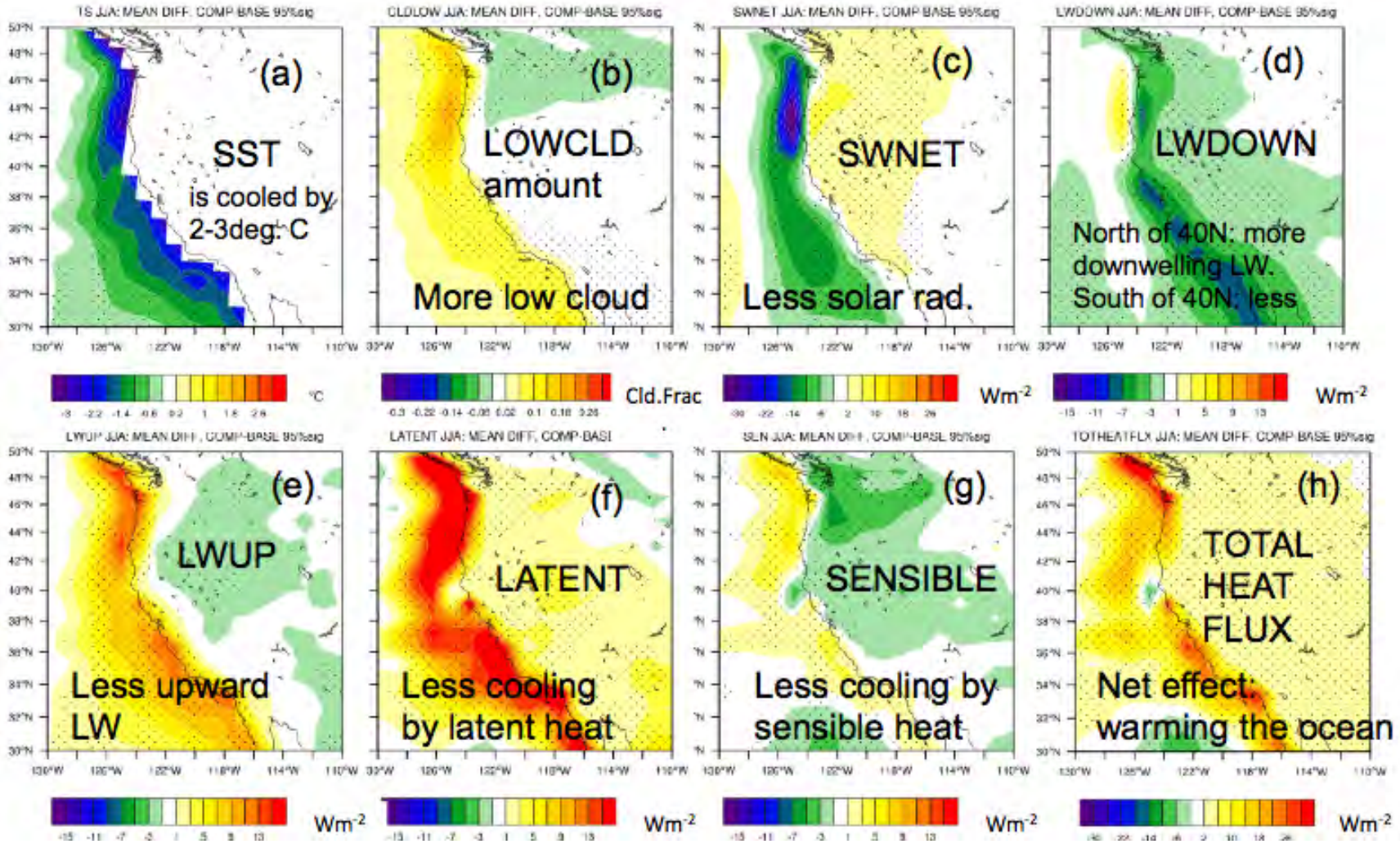
Numerical experiments

- Baseline: 150 year run of CESM, branched from 1870 control run.
- Composite: 150 year run of CESM-ROMS, same initial conditions.
- Ocean:
  - POP ~1-degree, 40 Z-levels
  - ROMS 7 km, 50 stretched sigma levels
- Atmosphere: CAM 4 1-degree
- Land: CLM 3
- Sea ice: CICE
- Analysis: 140 years of monthly means.
- Statistics: T-test for means, F-test for variability.

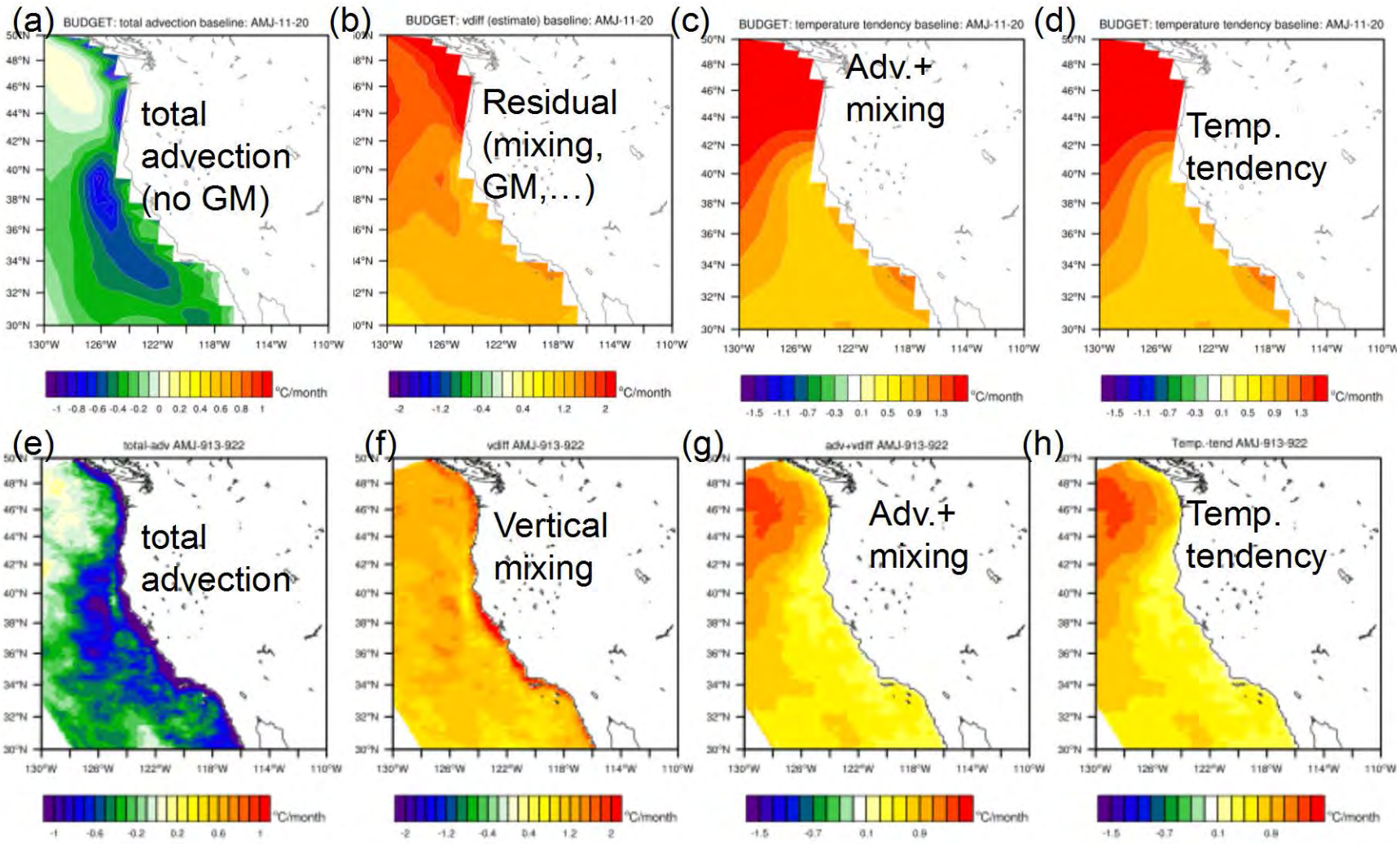
California Current: Local SST response



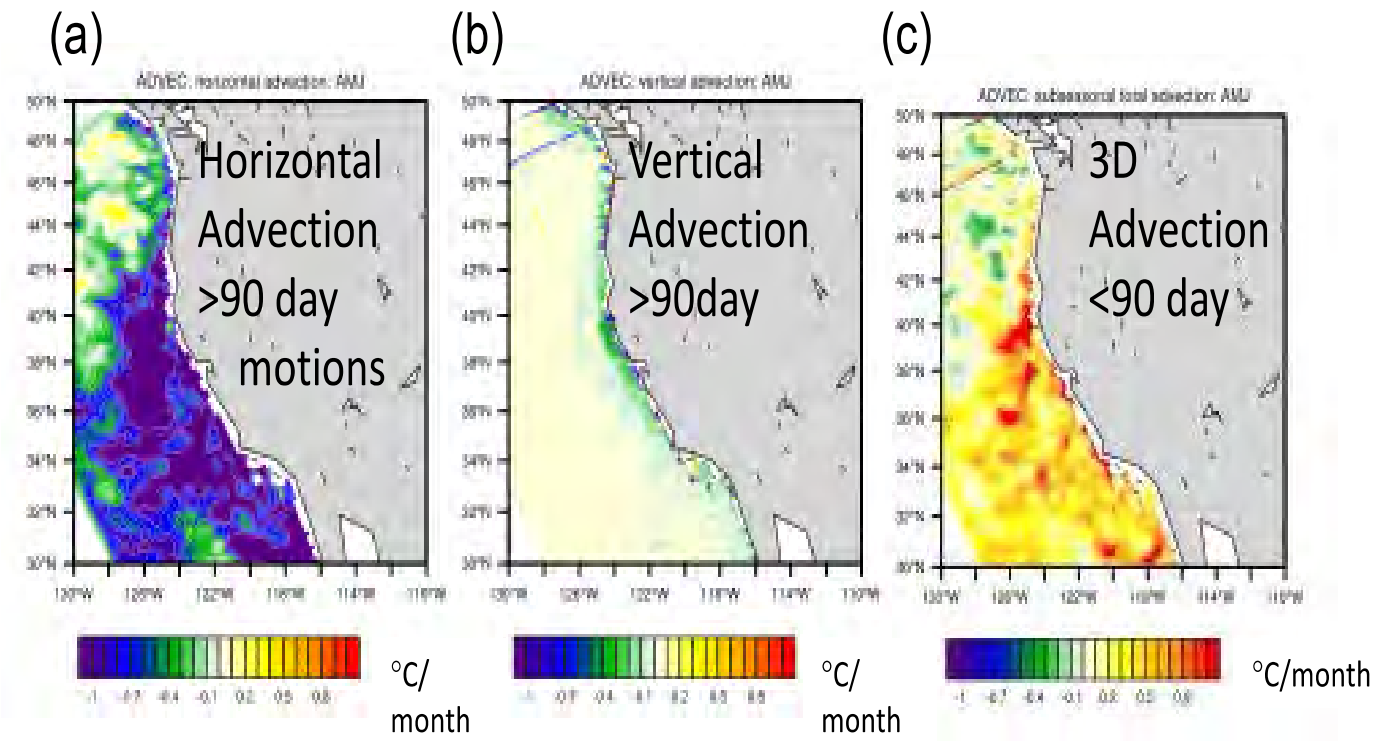
California Current: Surface fluxes



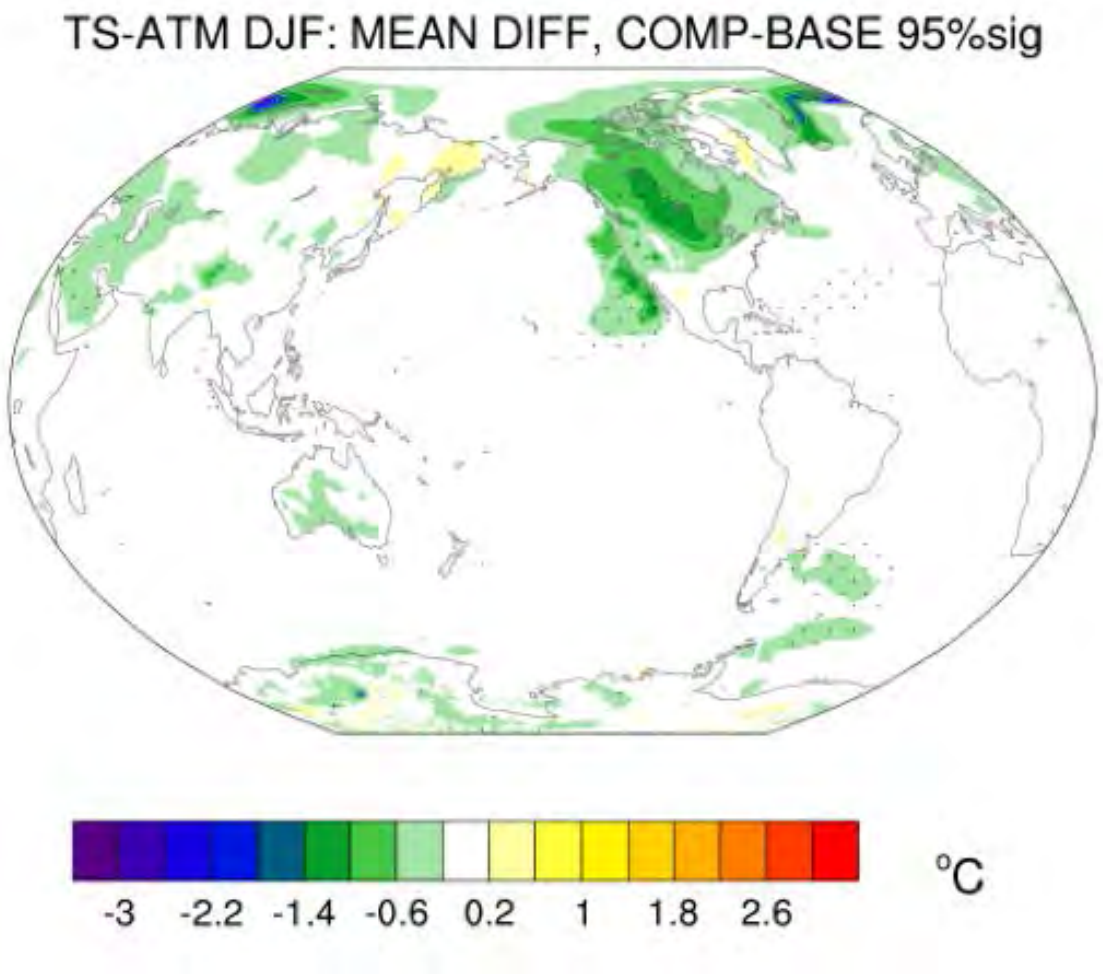
California Current: Heat budget



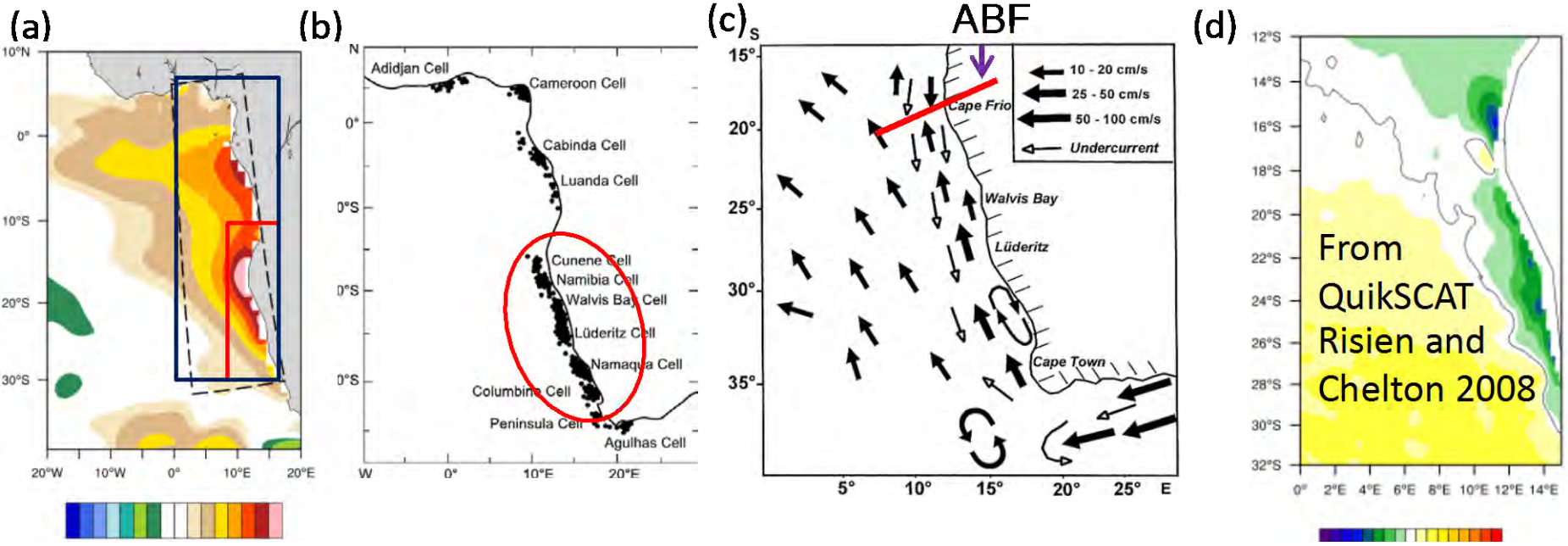
Decomposition of advection term



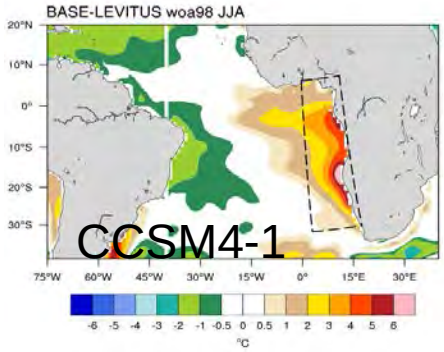
Global response: Surface temperature



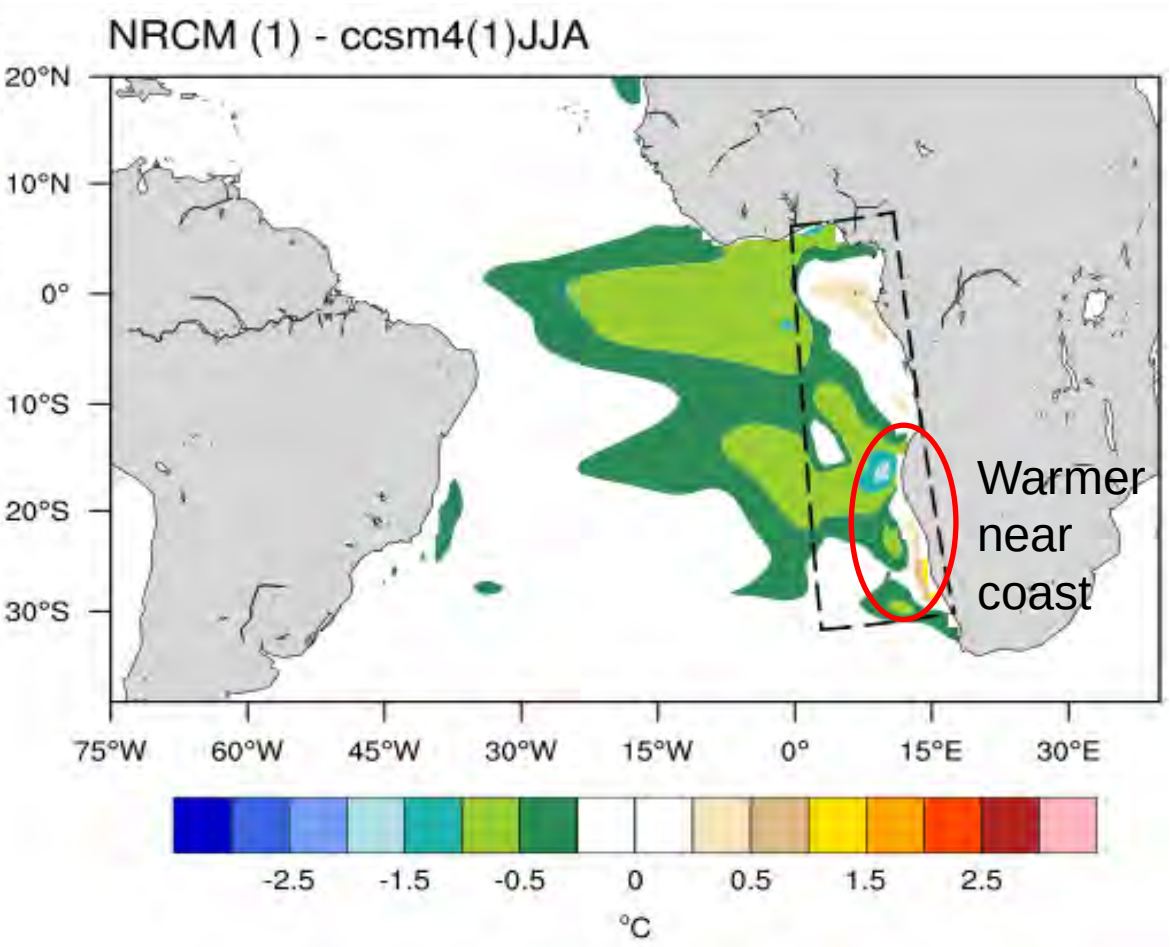
Benguela Current



Benguela Current

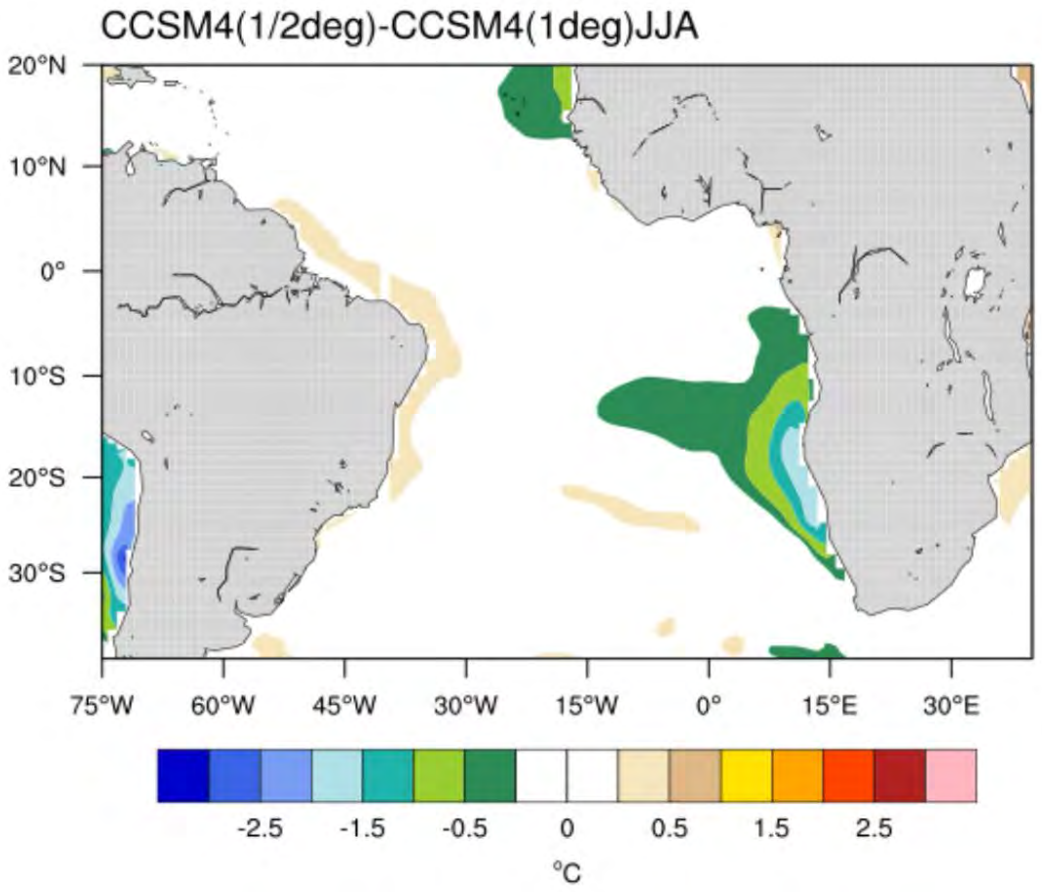


SST bias, CCSM4

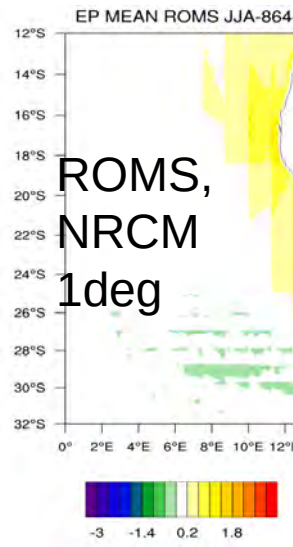


Nested RCM SST minus CCSM4 baseline, JJA

Role of atmospheric model resolution

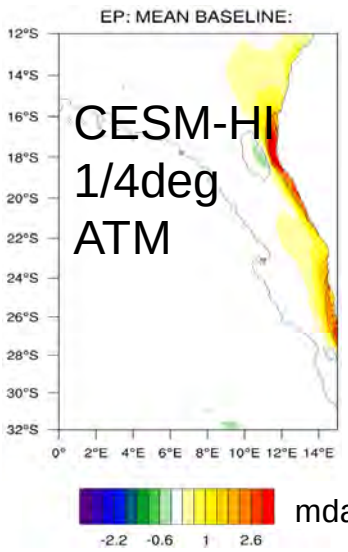


Wind stress curl at coast



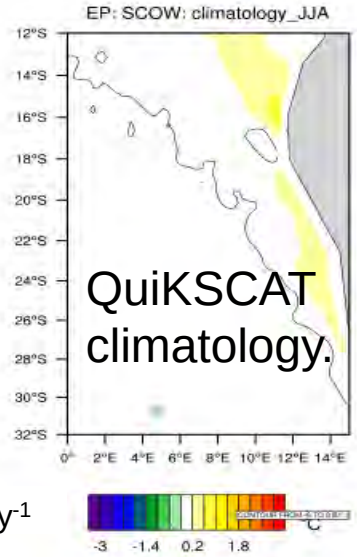
ROMS, NRCM 1deg

mday^{-1}



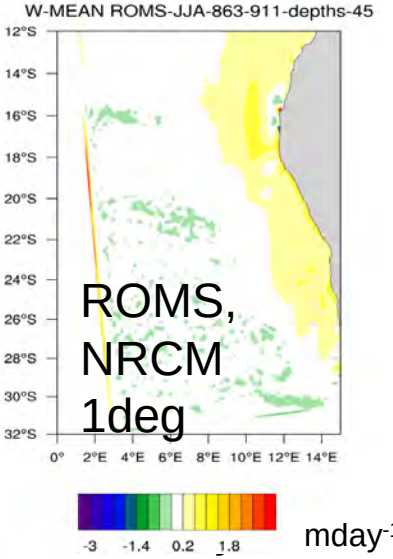
CESM-HI 1/4deg ATM

mday^{-1}



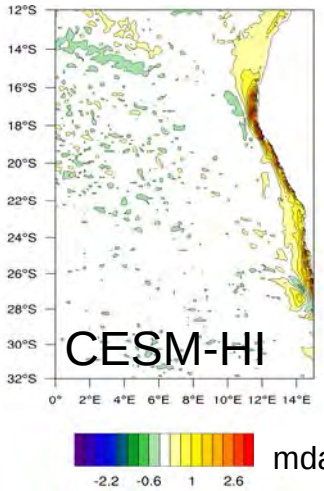
QuiKSCAT climatology.

mday^{-1}



ROMS, NRCM 1deg

mday^{-1}



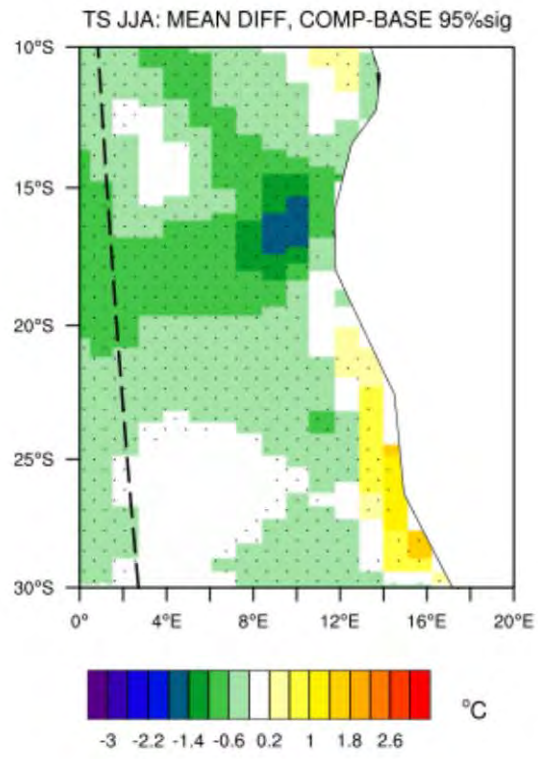
CESM-HI

mday^{-1}

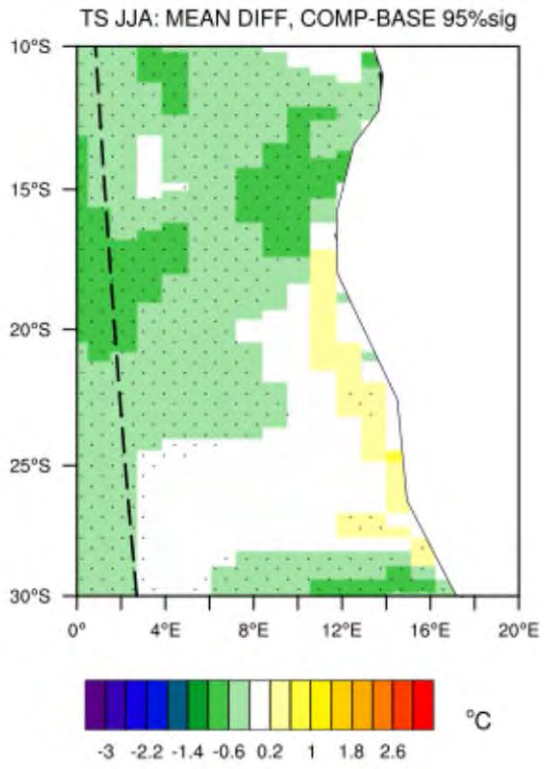
Vertical velocity at 45m, JJA average

Shifted winds experiments

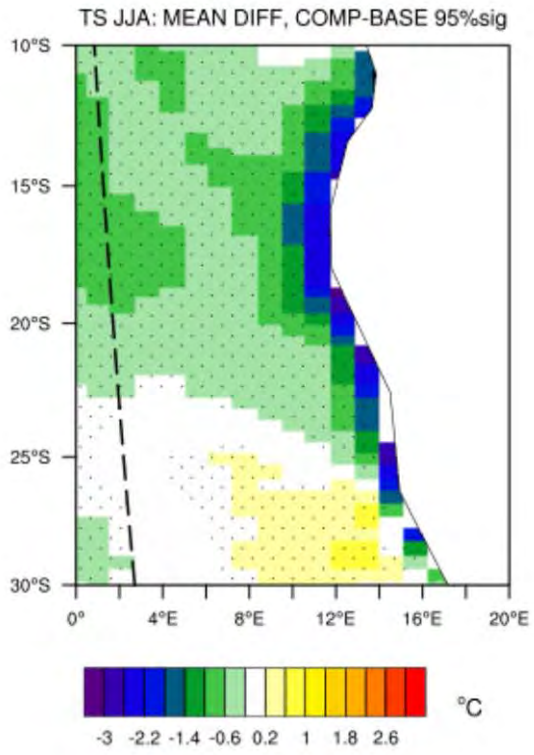
(a)



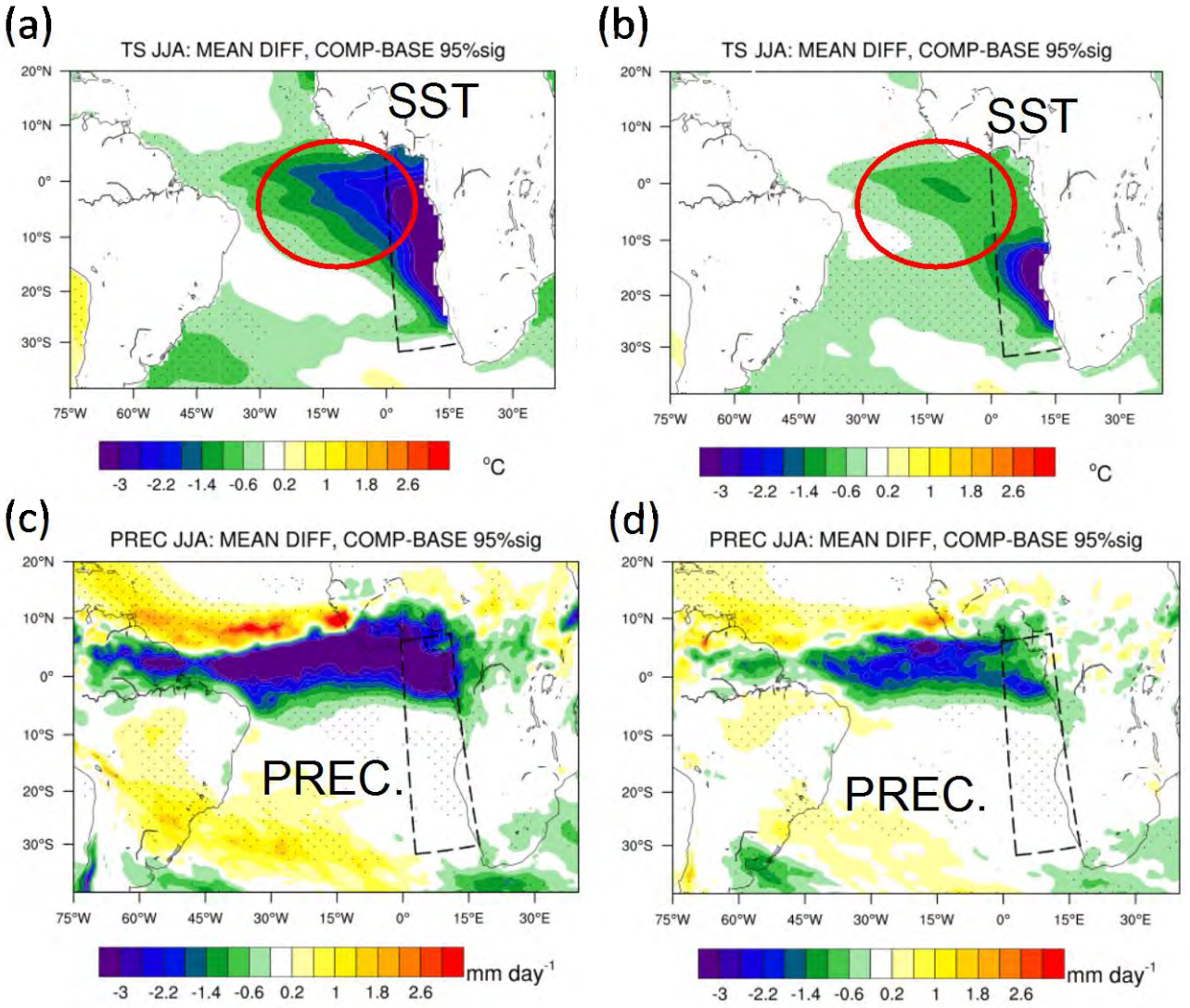
(b)

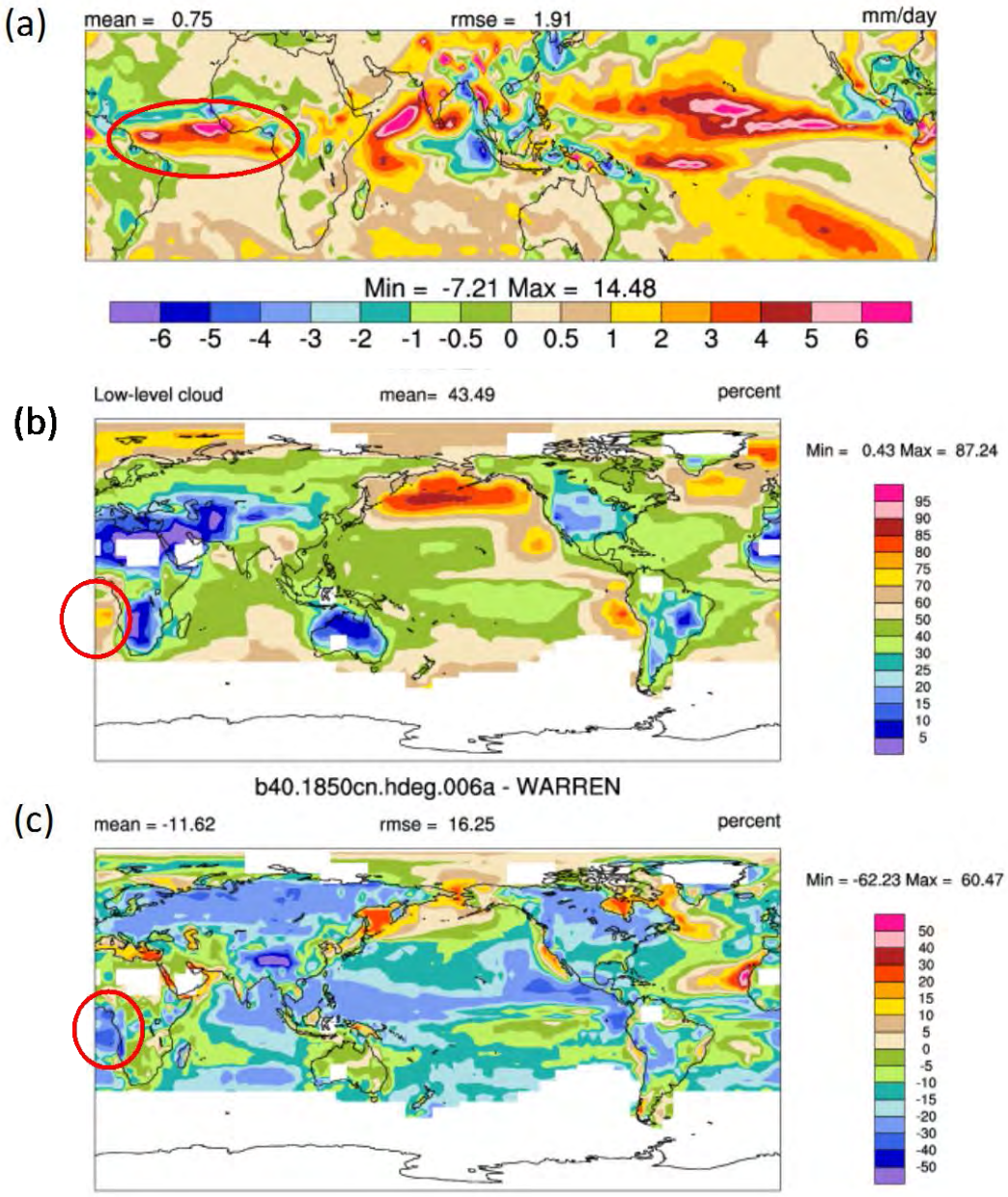


(c)

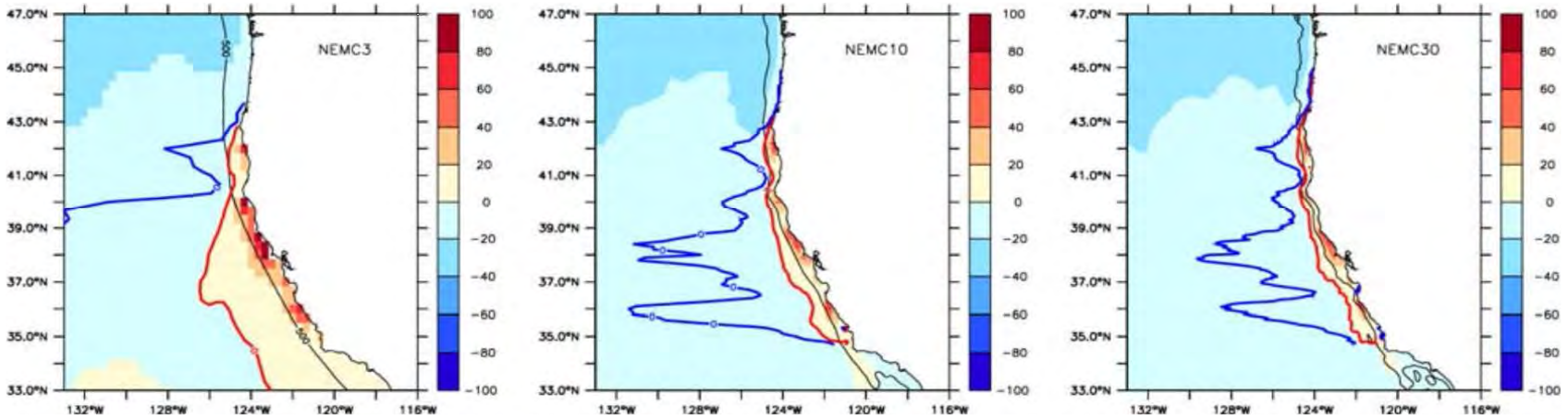


Restoring experiments




(a)
mean = 0.75
rmse = 1.91
mm/day
Min = -7.21 Max = 14.48
-6 -5 -4 -3 -2 -1 -0.5 0 0.5 1 2 3 4 5 6
(b)
Low-level cloud
mean= 43.49
percent
Min = 0.43 Max = 87.24
95 90 85 80 75 70 60 50 40 30 25 20 15 10 5
b40.1850cn.hdeg.006a - WARREN
(c)
mean = -11.62
rmse = 16.25
percent
Min = -62.23 Max = 60.47
50 40 30 20 15 10 5 0 -5 -10 -15 -20 -30 -40 -50

Back to CCS. Biogeochemical considerations: It's both the atmosphere and ocean resolutions!



Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1002/2013GB004683

Key Points:
- Outgassing intensification linked to coastal topographic features
- Near-shore outgassing balanced by offshore absorption
- Carbon fluxes most sensitive to horizontal resolution for 35-40N

Air-sea CO_2 fluxes in the California Current: Impacts of model resolution and coastal topography

Jerome Fiechter[1], Enrique N. Curchitser[2], Christopher A. Edwards[3], Fei Chai[4], Nicole L. Goebel[3], and Francisco P. Chavez[5]

[1]Institute of Marine Sciences, University of California, Santa Cruz, California, USA, [2]Institute of Marine and Coastal Sciences, State University of N. J. Rutgers, New Brunswick, New Jersey, USA, [3]Ocean Sciences Department, University of California, Santa Cruz, California, USA, [4]School of Marine SciencesUniversity of Maine, Orono, Maine, USA, [5]Monterey Bay Aquarium Research Institute, Moss Landing, California, USA

Coupled Physical-Biogeochemical Model

Ocean Circulation Model

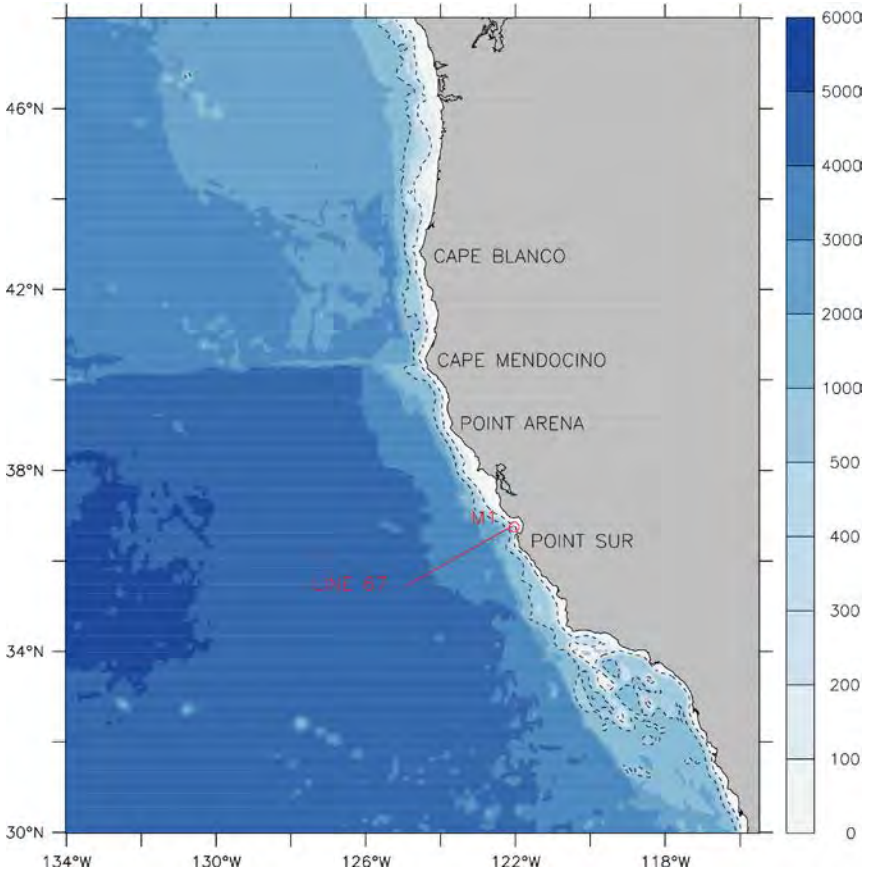
- ROMS
- Resolution: 1/3°, 1/10°, 1/30°
- 42 vertical levels
- BC/IC: SODA, monthly
- Surface: COAMPS, daily

Biogeochemical Model

- NEMURO (3N, 2P, 3Z, 3D)
- DIC, Alkalinity, Ca Carbonate (Hauri et al., 2013)
- OCMIP air-sea CO_2 exchange
- NEMURO BC/IC: WOA, monthly
- Carbon BC/IC: GLODAP, annual

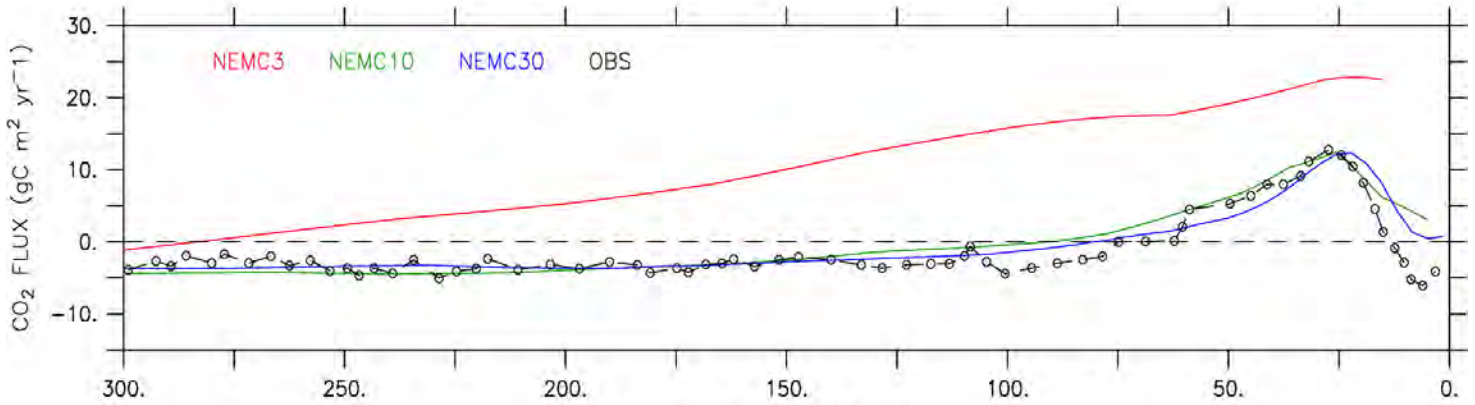
Run duration

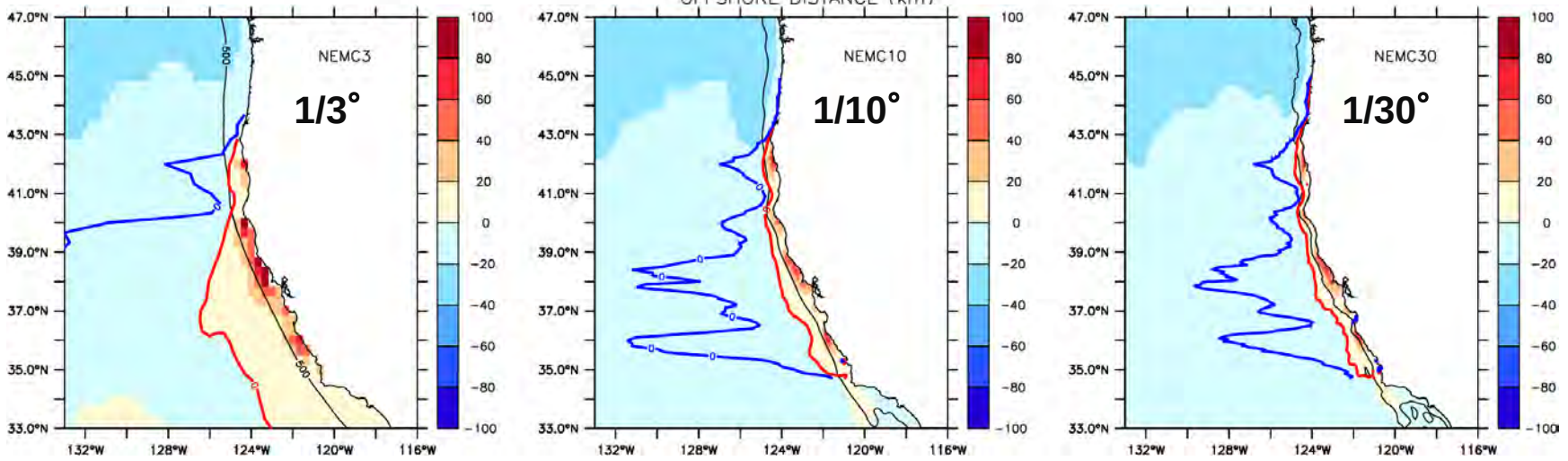
- 7 years (1999-2005)



Model domain and bottom topography (m)

Air-Sea Flux: Impact of Horizontal Model Resolution

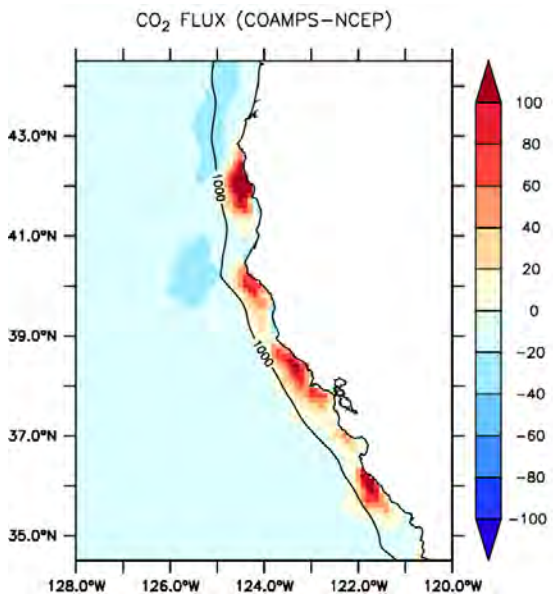


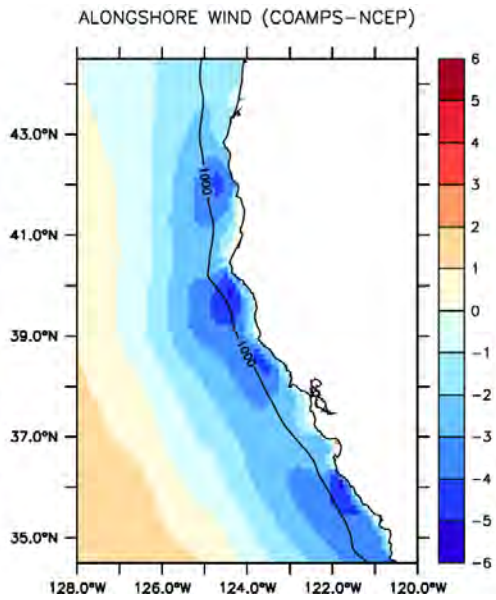


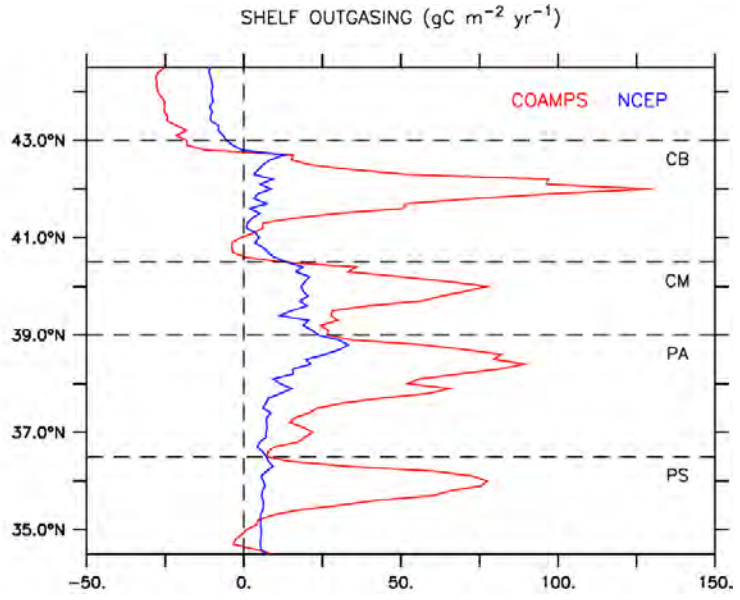
Red Line: Outgassing Region Blue Line: Equilibrium Region

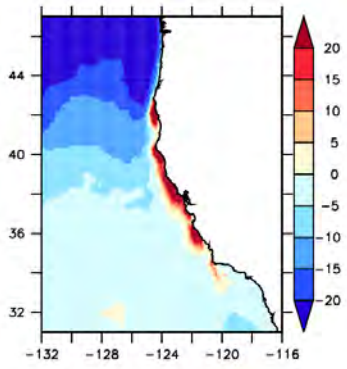
1/3° solution grossly overestimates near-shore outgassing

Impact of Surface Atmospheric Forcing on Air-Sea Flux

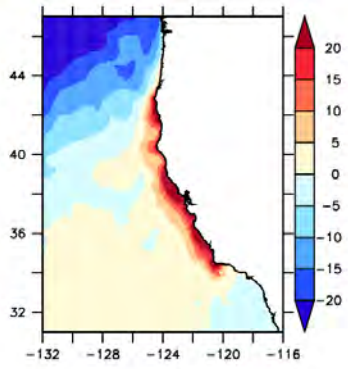




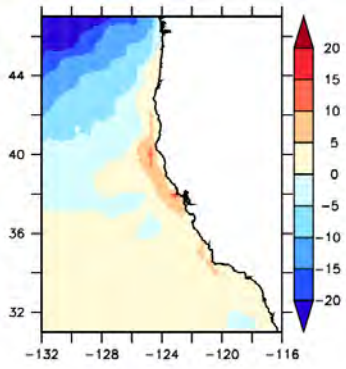




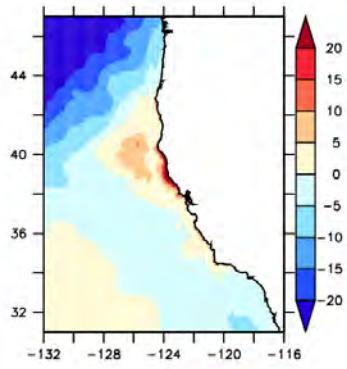
COAMPS



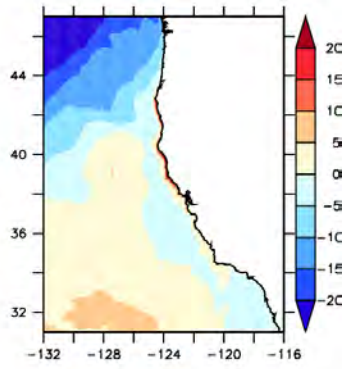
CCMP



MERRA

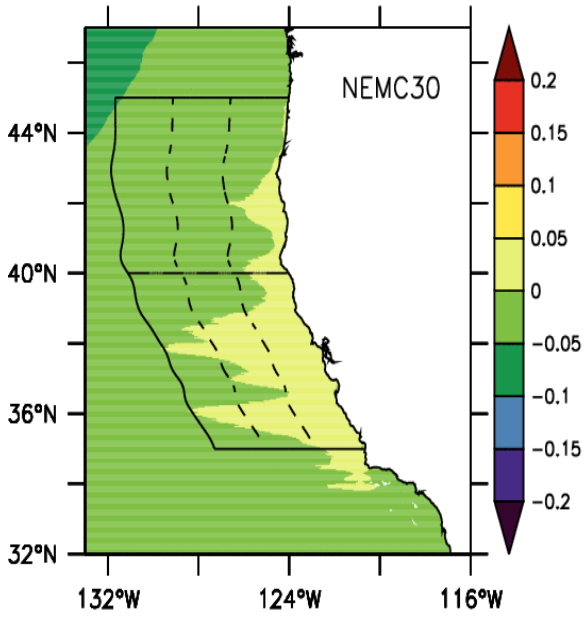


CORE2



NCEP

Net Air-Sea Carbon Exchange in CCS

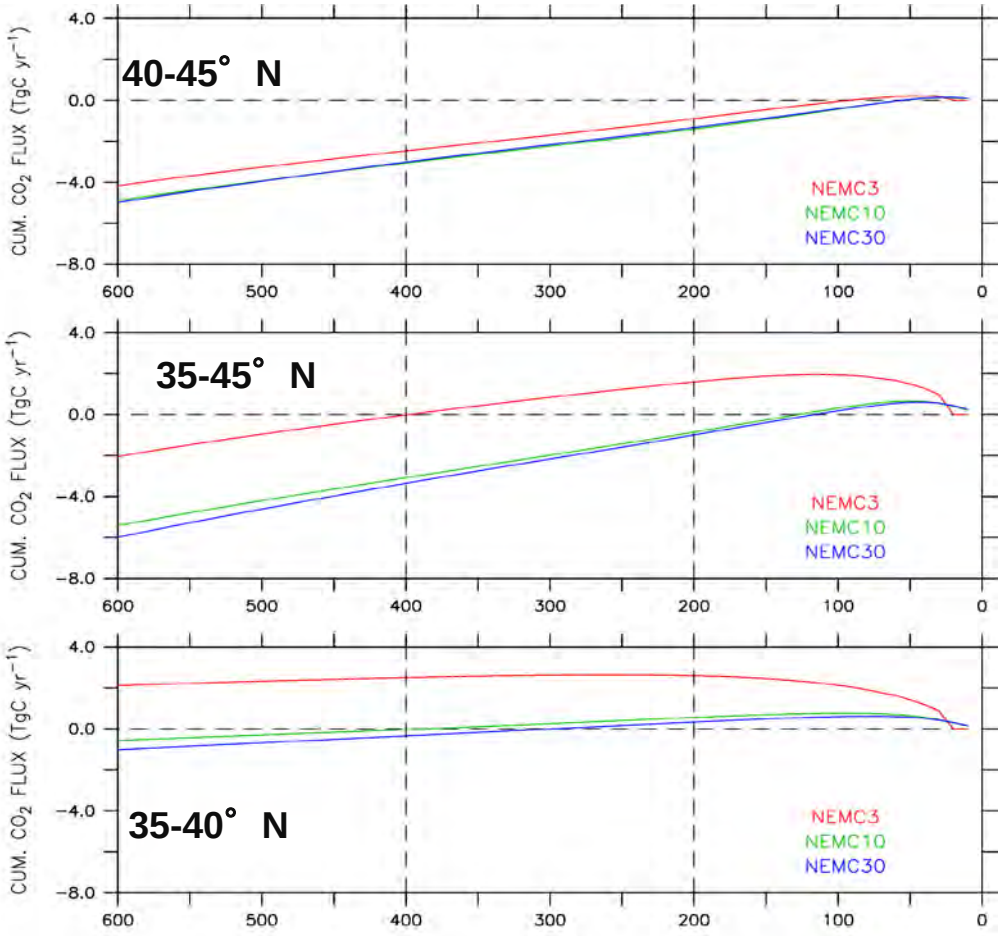


For 35-45° N out to 600 km

1/3° : ~2.0 TgC/yr

1/10° : ~5.4 TgC/yr

1/30° : ~6.0 TgC/yr



At 600km offshore, CCS is net CO_2 sink of ~6.0 TgC/yr

Net sink contribution: 20% SoCCS and 80% NoCCS

Summary

- Upwelling is a coupled phenomena with multiple scales interacting.
  - Air-sea feedbacks modulate the response
  - Clouds and coastal atmospheric conditions are significant
  - Feedbacks can extend well beyond upwelling region
- Dynamics of upwelling can be different in the different regions *and* within a region.
- Ocean dynamics are important and resolution is not the only “fix”.
- BGC considerations can be different than purely physical modeling needs.

Multi-scale atmosphere