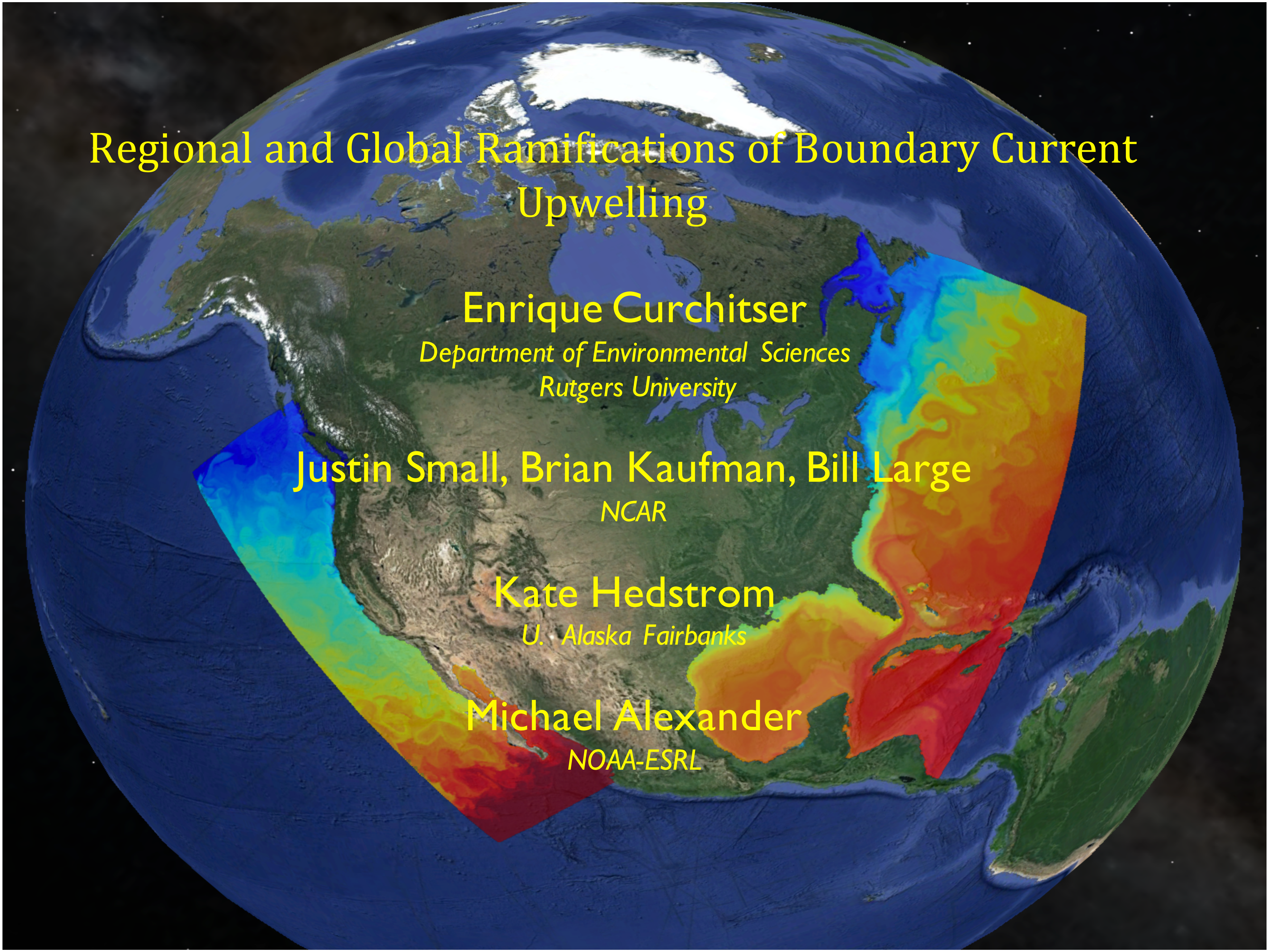

Regional and Global Ramifications of Boundary Current Upwelling

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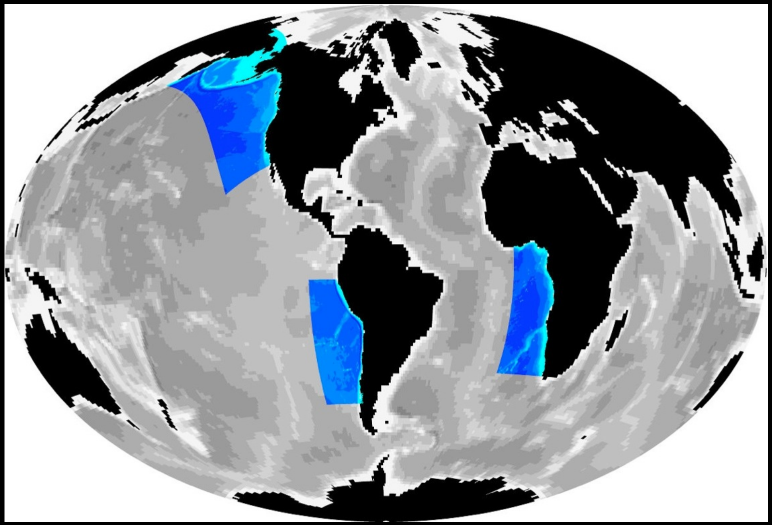
Outline

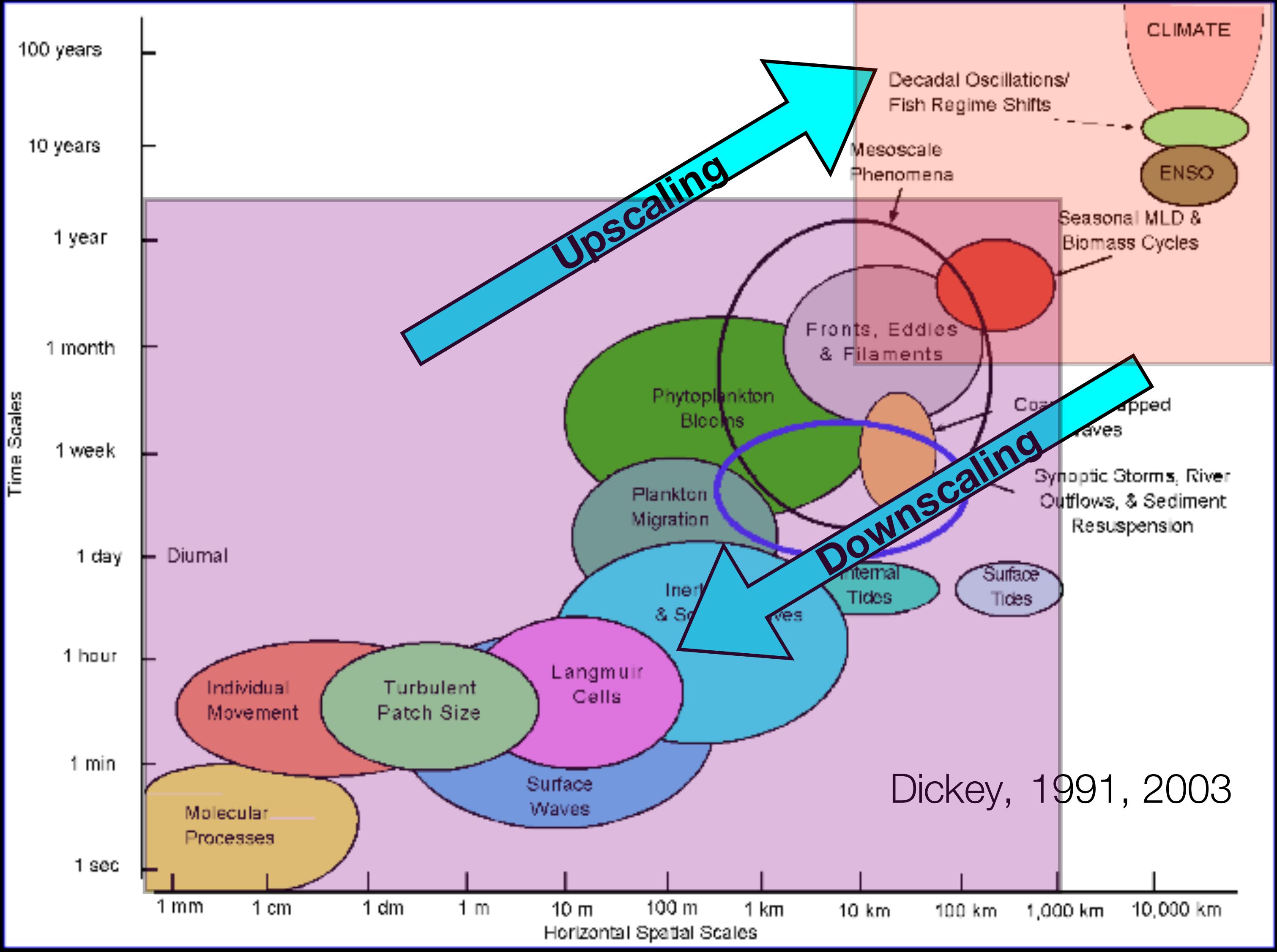
- Background and motivation
- Methods: A global climate model with a multi-scale ocean
- Implementations:
  - The California Current System
  - The Benguela Current
- Summary remarks



Why do we want to “downscale”?

- Regional impacts:
  - Improved predictions of changes in statistics of regional climate, especially extreme events, are required to assess impacts and adaptation
  - Need to improve representation of weather and climate link
- Climate model biases:
  - Working hypothesis is that the internal dynamics of the system are more accurately represented at higher resolution
- Ecosystems:
  - What resolution is needed beyond physics-only considerations?

Why do we need regional models?
Temporal and spatial scales of ocean phenomena

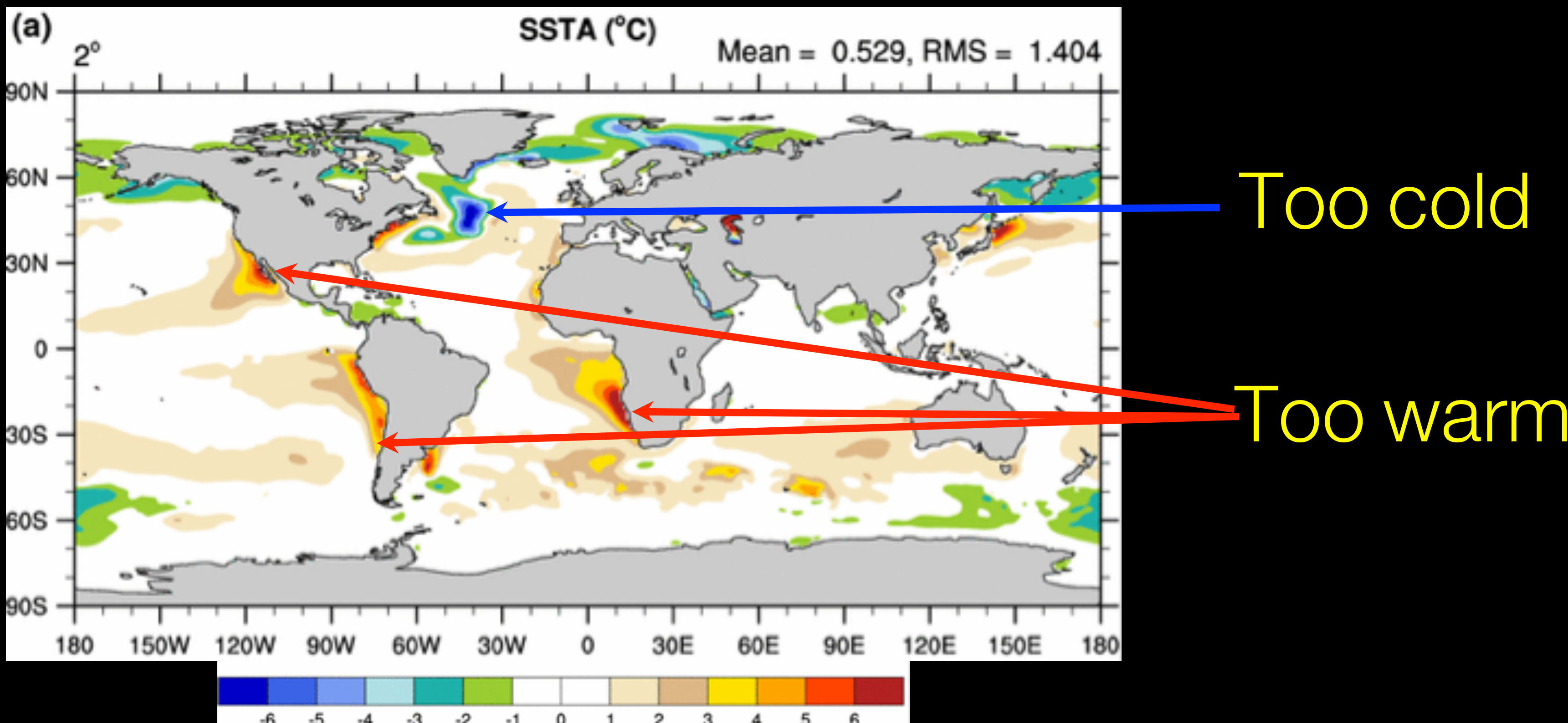


Dickey, 1991, 2003

Climate model biases

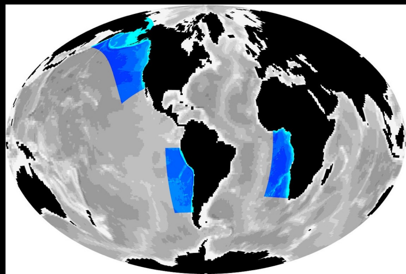
(Model minus Observations of mean SST)

(CCSM 3.5 - WOA98)

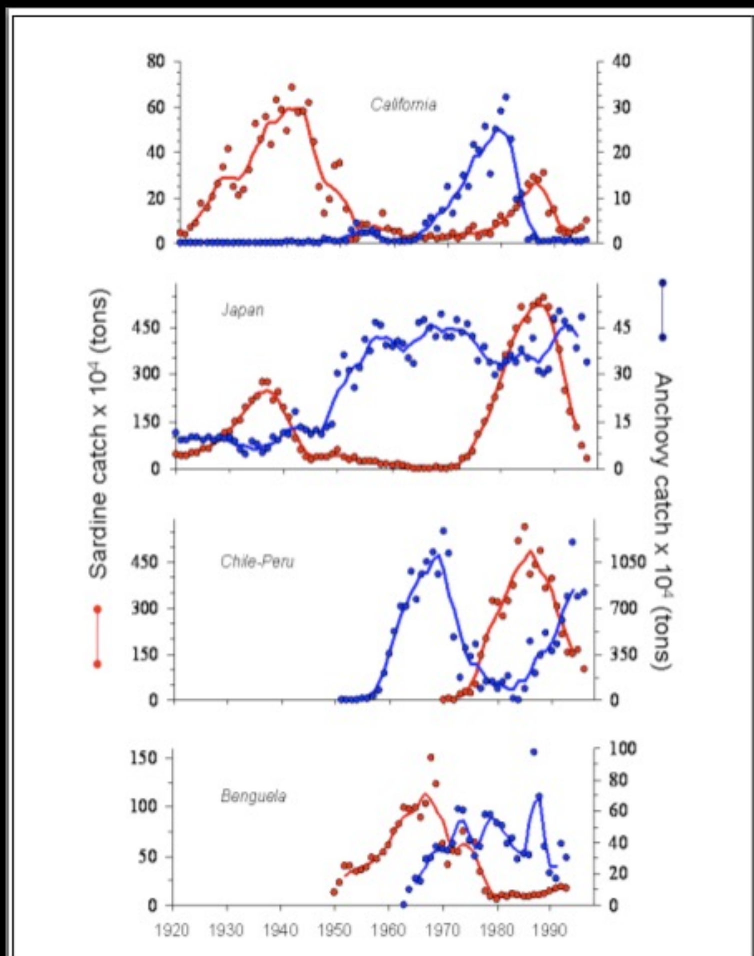


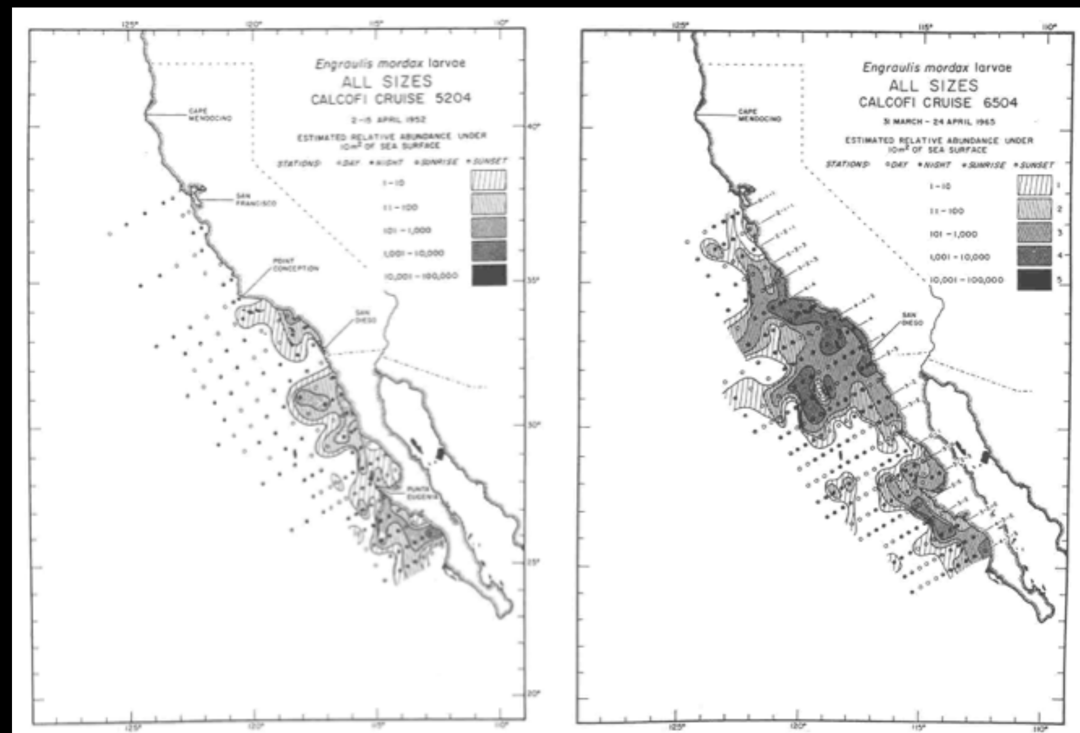
"Models still show significant errors … The ultimate source of most is that many important small-scale processes are not represented explicitly in models …"

Randal et al., 2007.



Ecosystems: Sardine and Anchovy Temporal and Spatial Variability

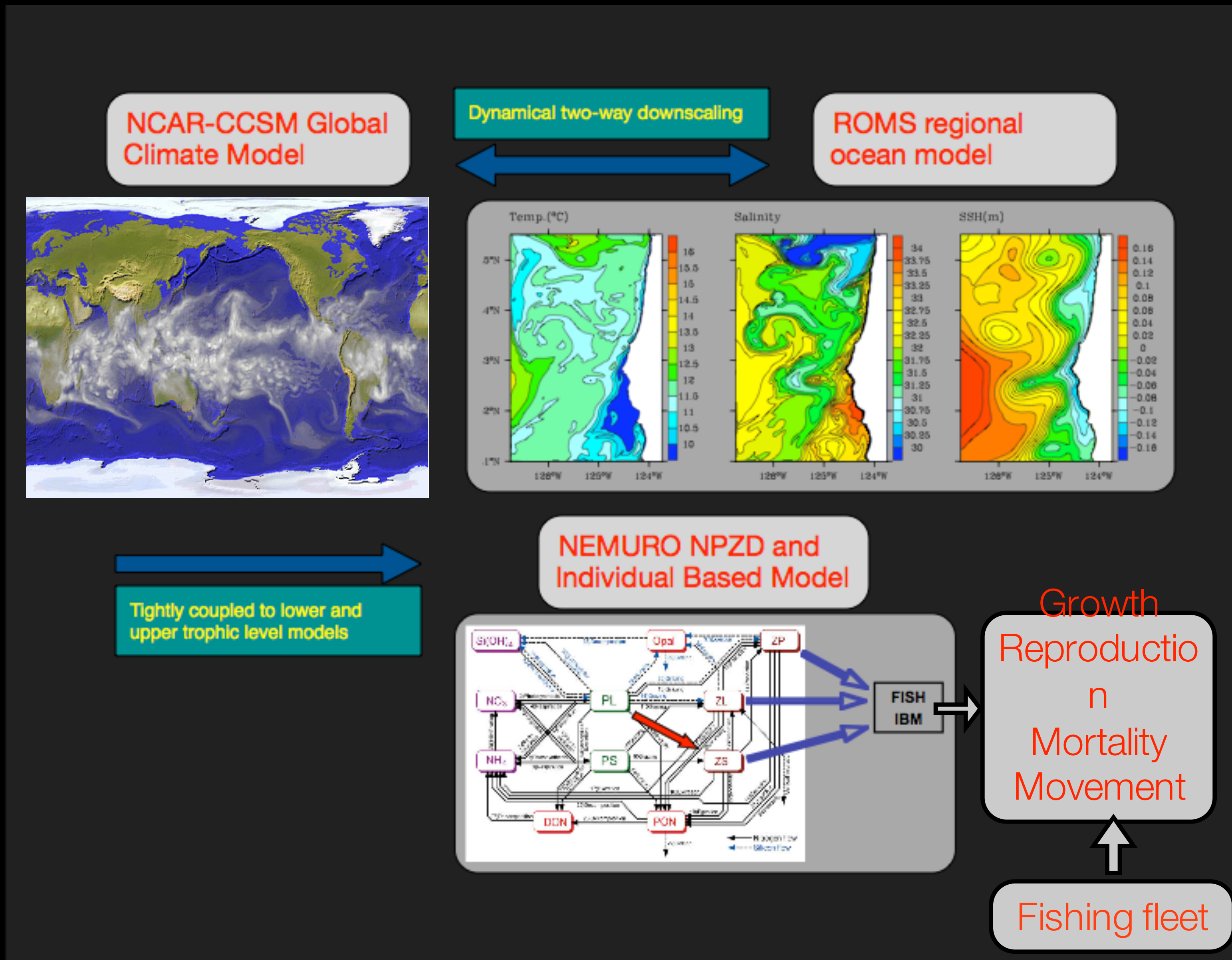




McCall, 1990

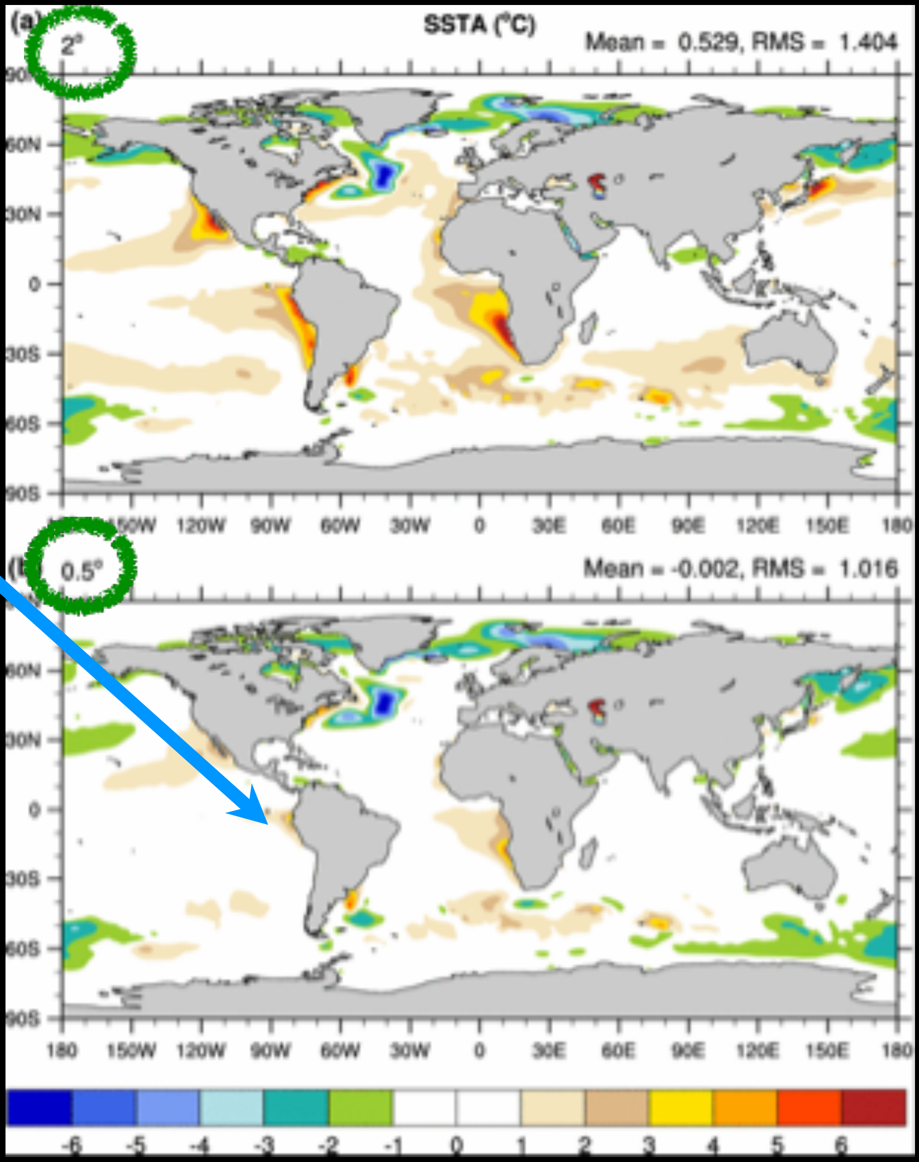
Time series of sardine (red) and anchovy (blue) landings since the 1920's. Data from Schwartzlose et al. (1999).

Our approach: Tightly coupled climate-to-fishers model

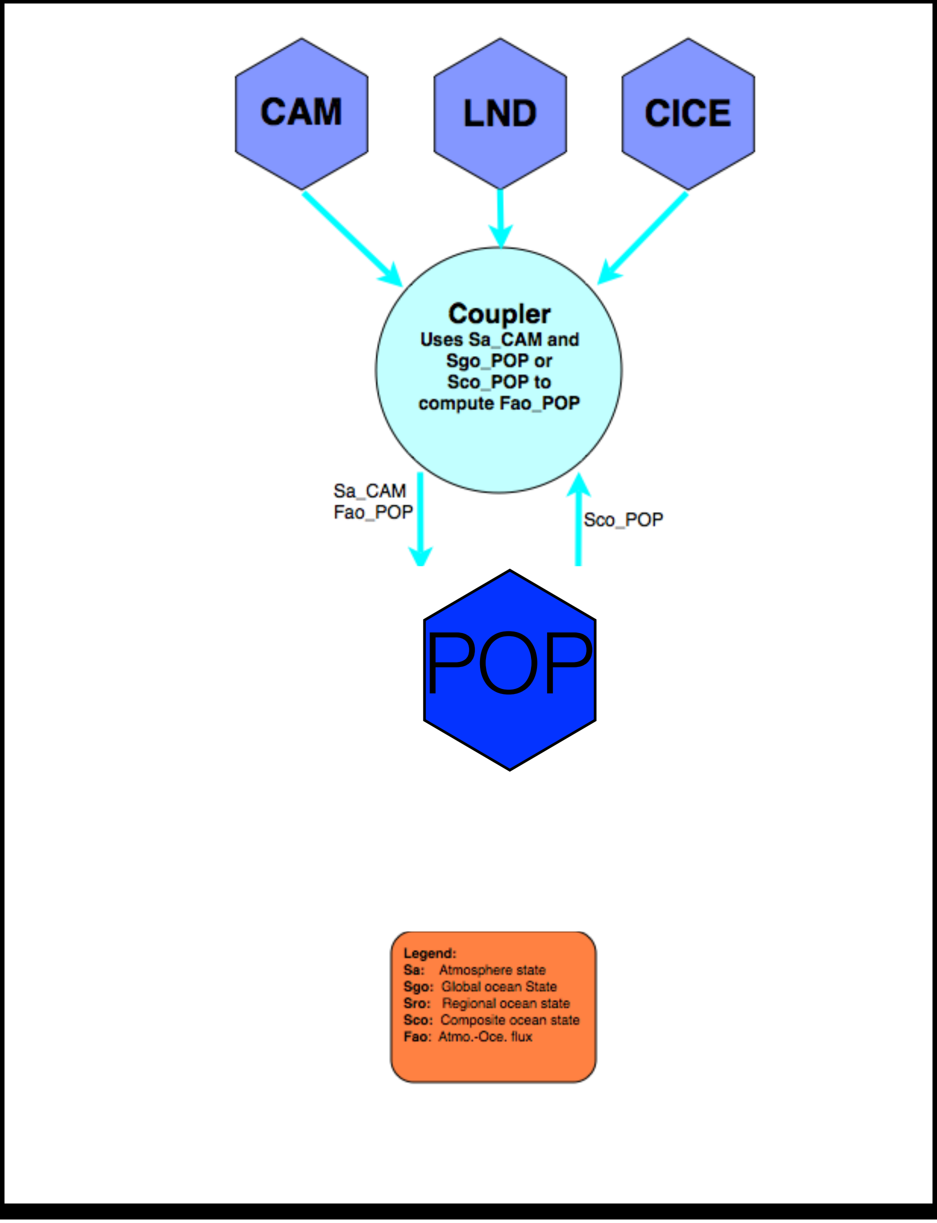


Aside: Approaches to address the bias problem

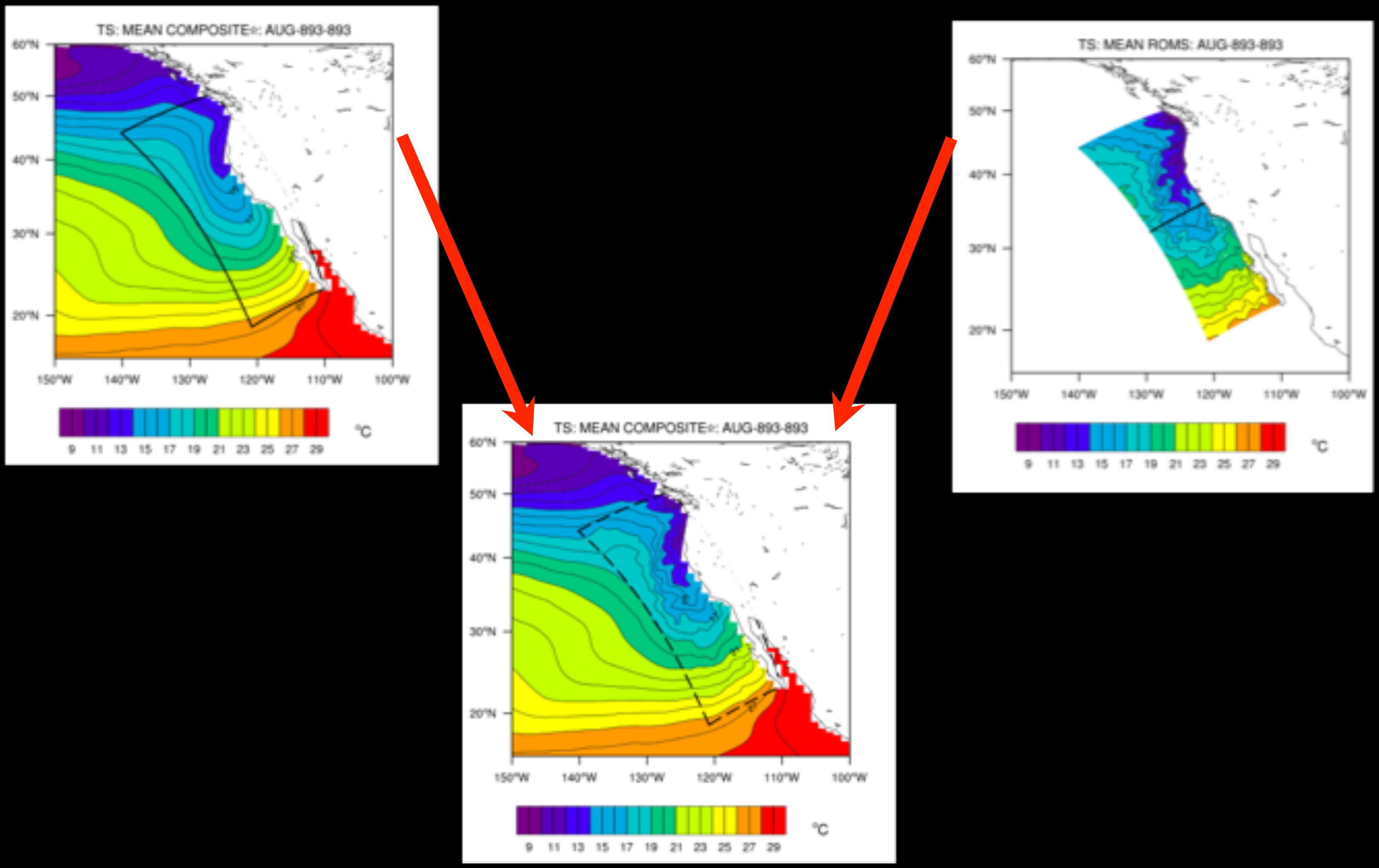
- Higher resolution in the atmosphere--better upwelling favorable winds (Gent et al., 2010)
- Improvements to boundary layer physics (Park and Bretherton, 2009)
- Improved resolution and physics in ocean--better upwelling (Curchitser et al. 2011; Curchitser et al. In prep., Small et al., 2015)



Methods: NCAR-CESM



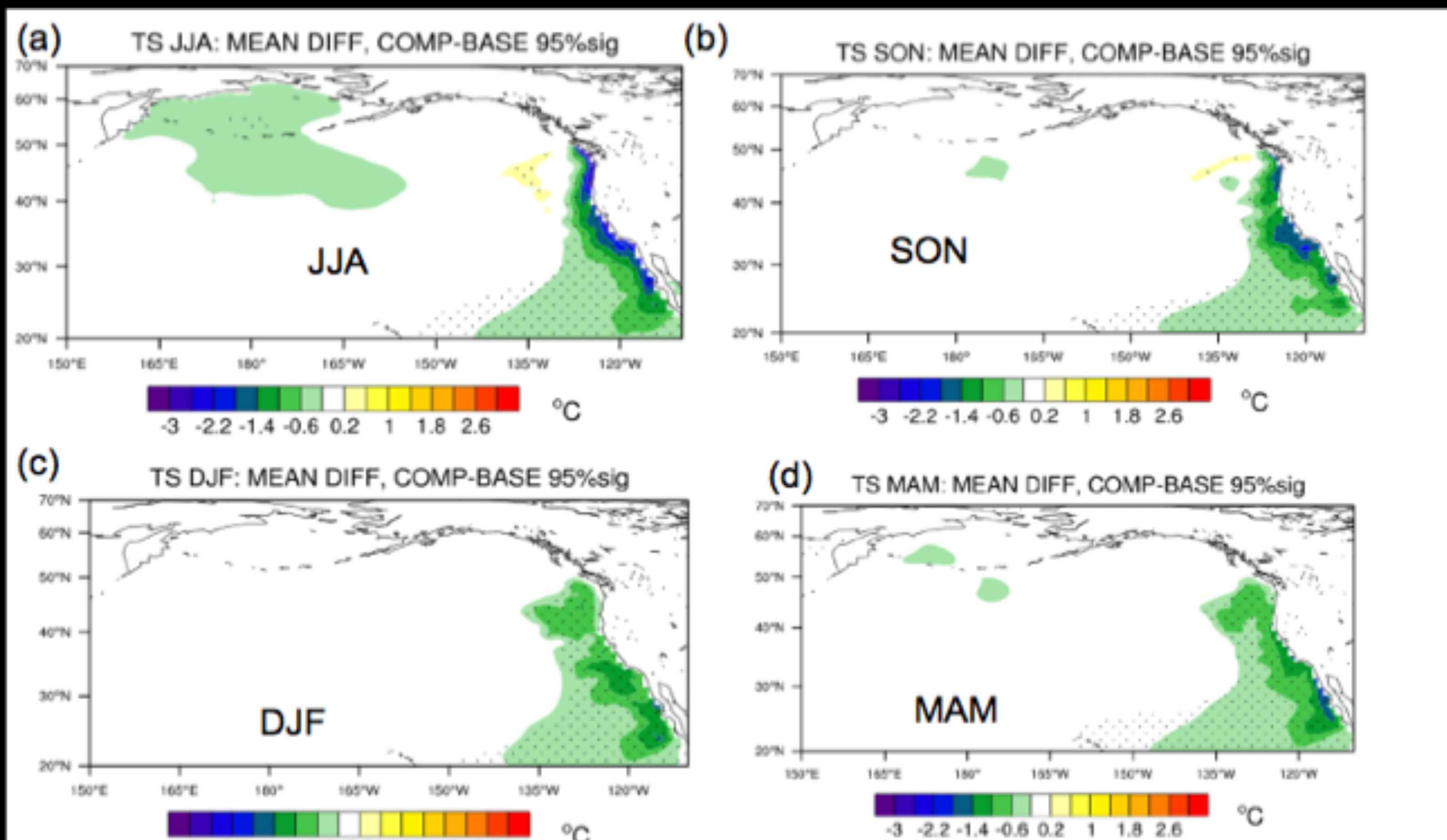
Methods: Embedding a high-resolution ocean (ROMS) within NCAR-CESM



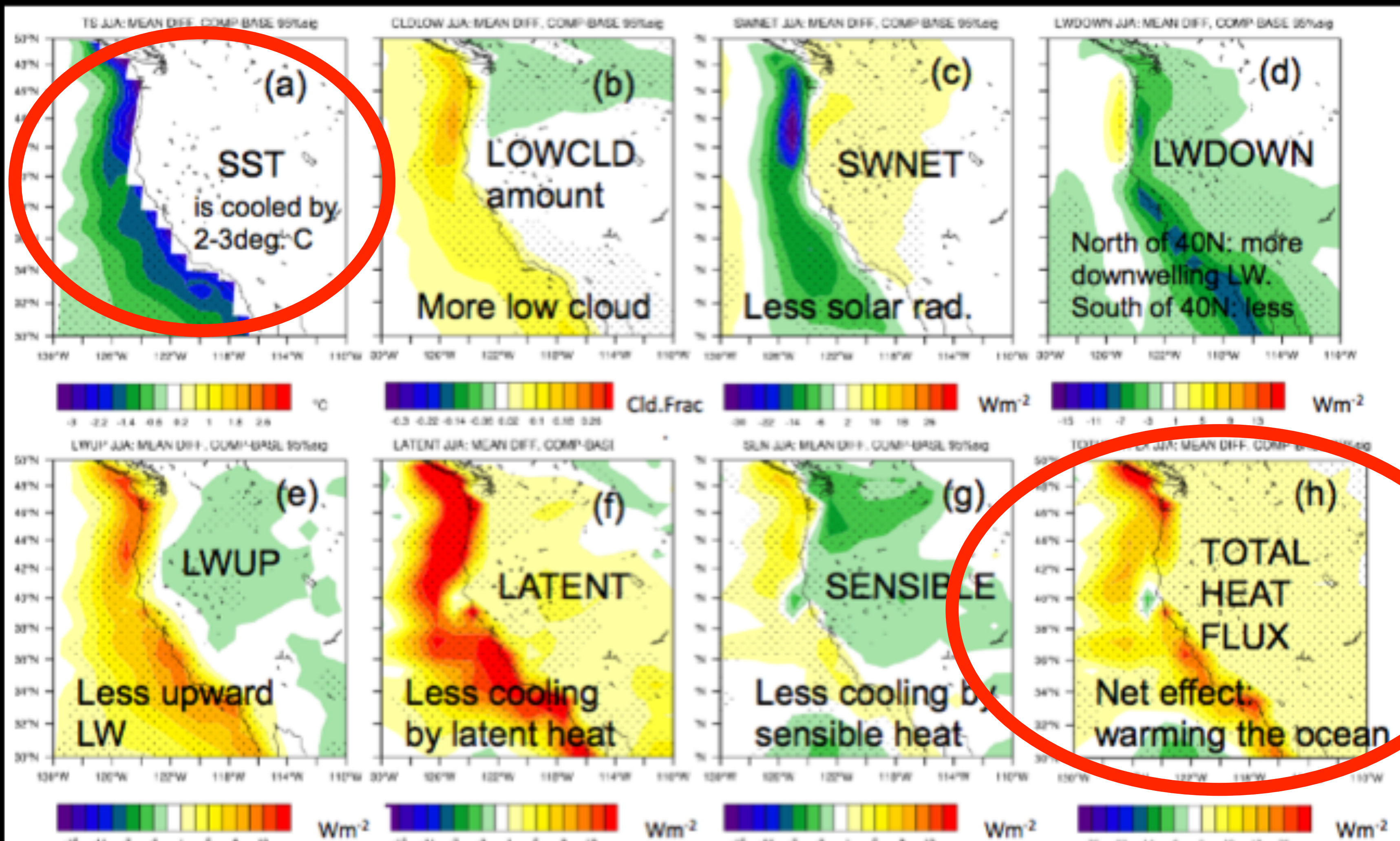
Numerical experiments (typical)

- Baseline: 150 year run of CESM1, branched from 1870 control run.
- Composite: 150 year run of CESM1-ROMS, same initial conditions.
- Ocean:
  - POP ~1-degree, 40 Z-levels
  - ROMS 7 km, 50 stretched sigma levels
- Atmosphere: CAM-5 1^{o}, 0.5^{o}
- Land: CLM 3
- Sea ice: CICE
- Analysis: 140 years of monthly means.
- Statistics: T-test for means, F-test for variability

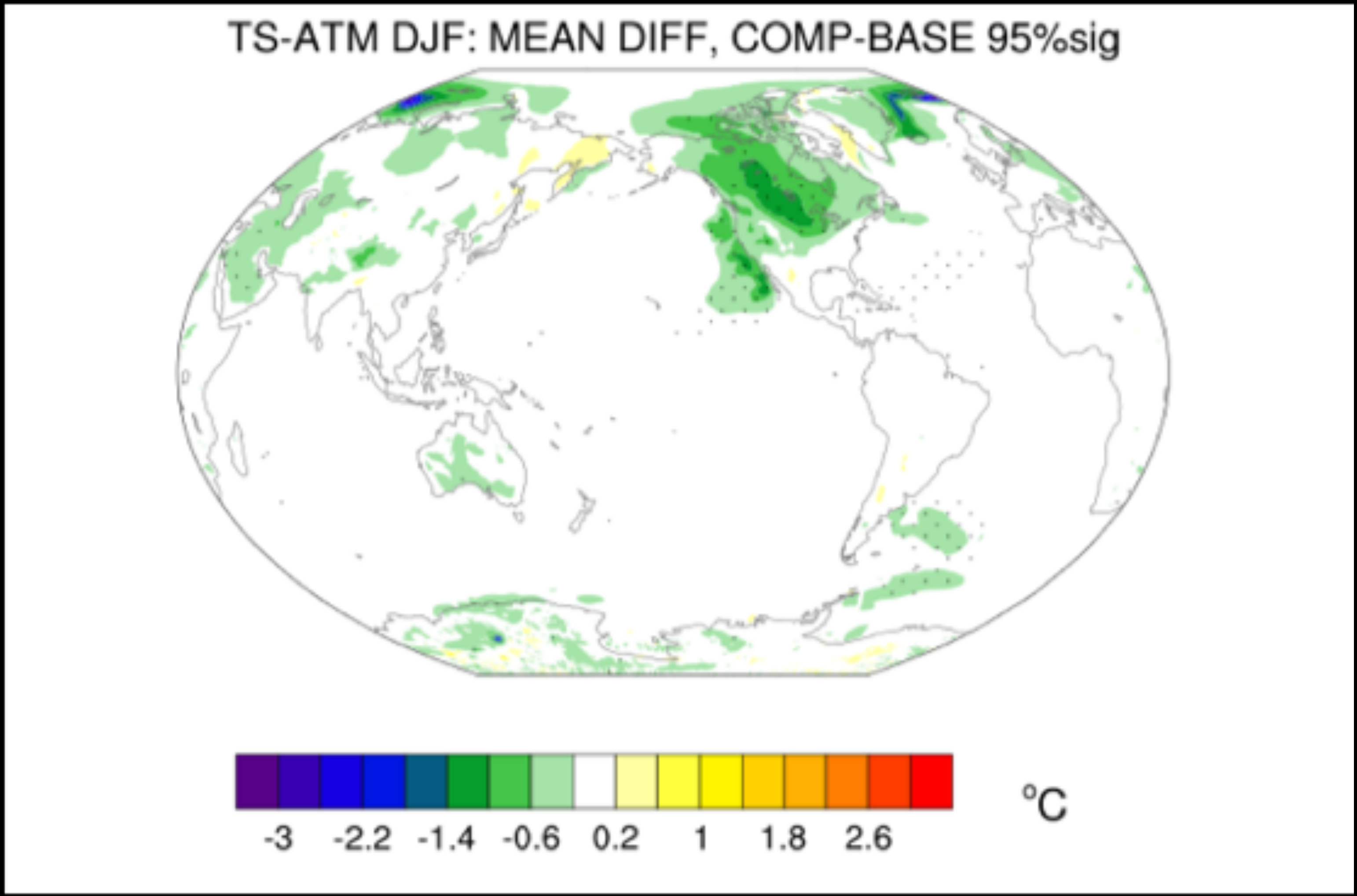
California Current: Local SST response



California Current: Surface fluxes



Global response: Surface air temperature



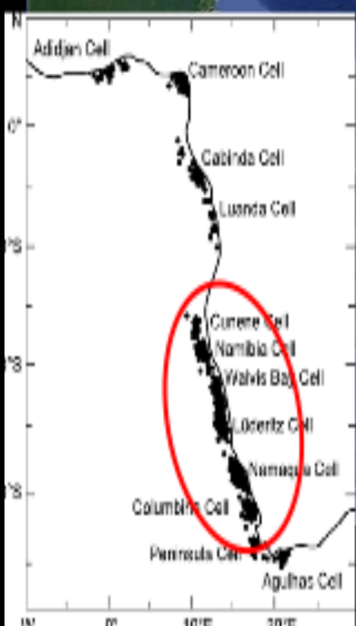
The Benguela Current System

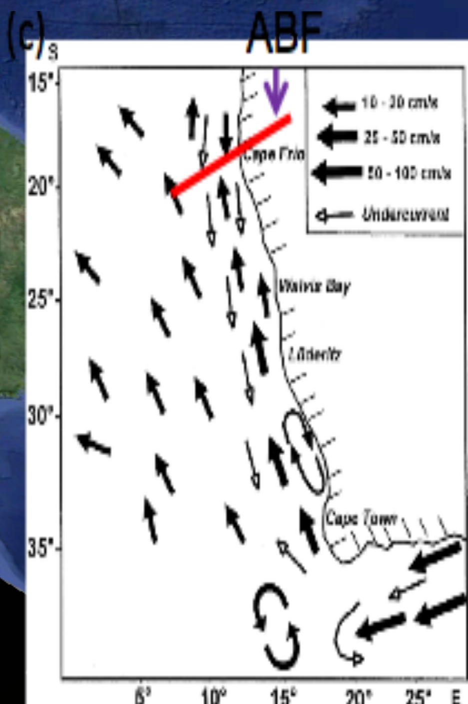
THE BENGUELA UPWELLING SYSTEM:

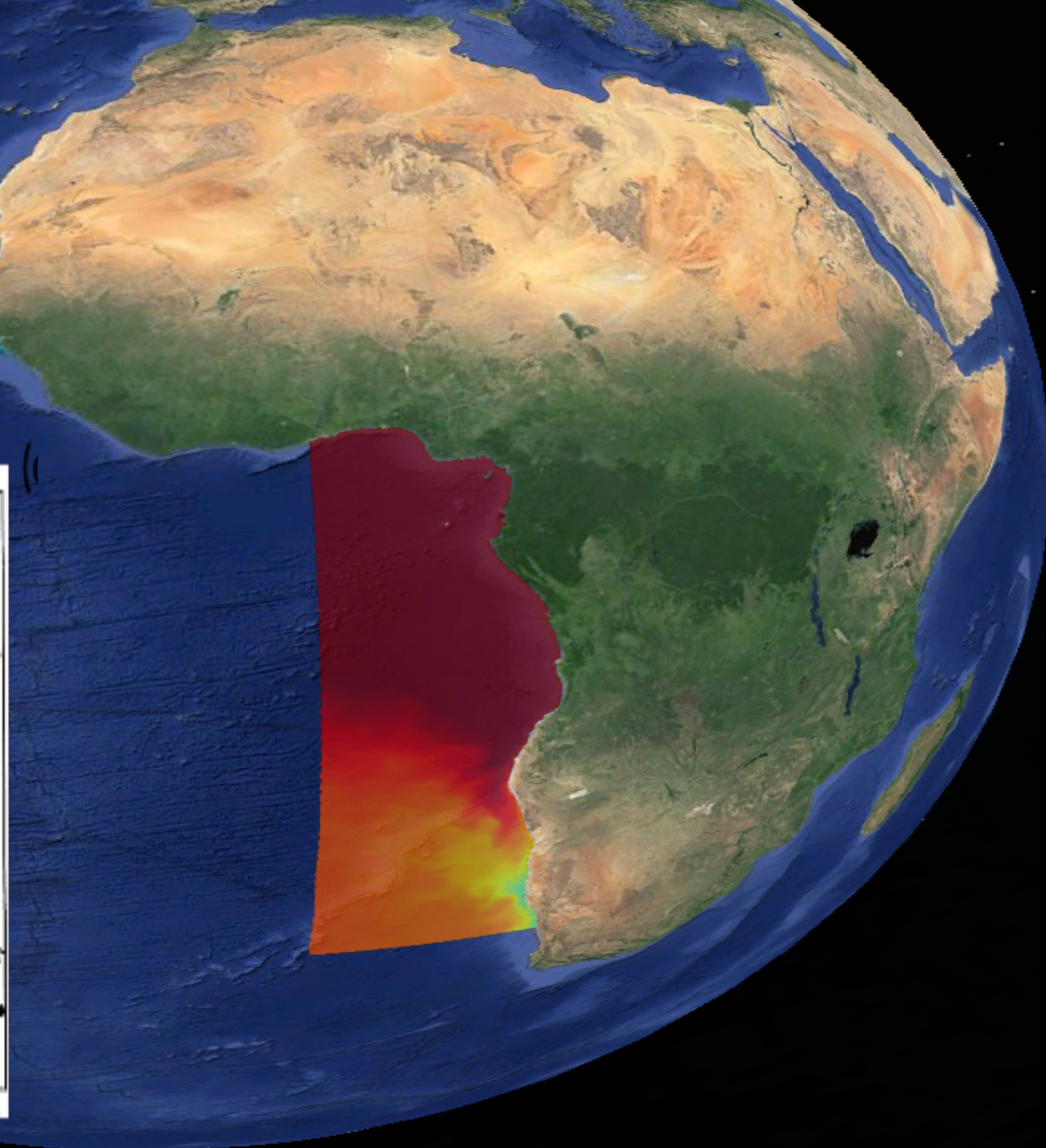
QUANTIFYING THE SENSITIVITY TO RESOLUTION AND COASTAL WIND REPRESENTATION IN A GLOBAL CLIMATE MODEL

R. Justin Small[1], Enrique Curchitser[2], Katherine Hedstrom[3],

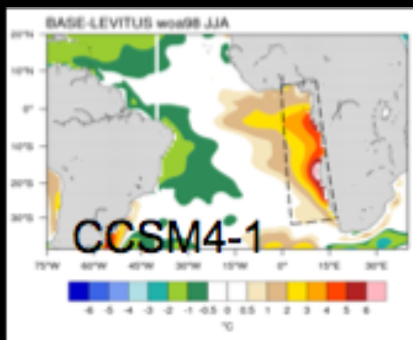
Brian Kauffman[1], William G. Large[1]



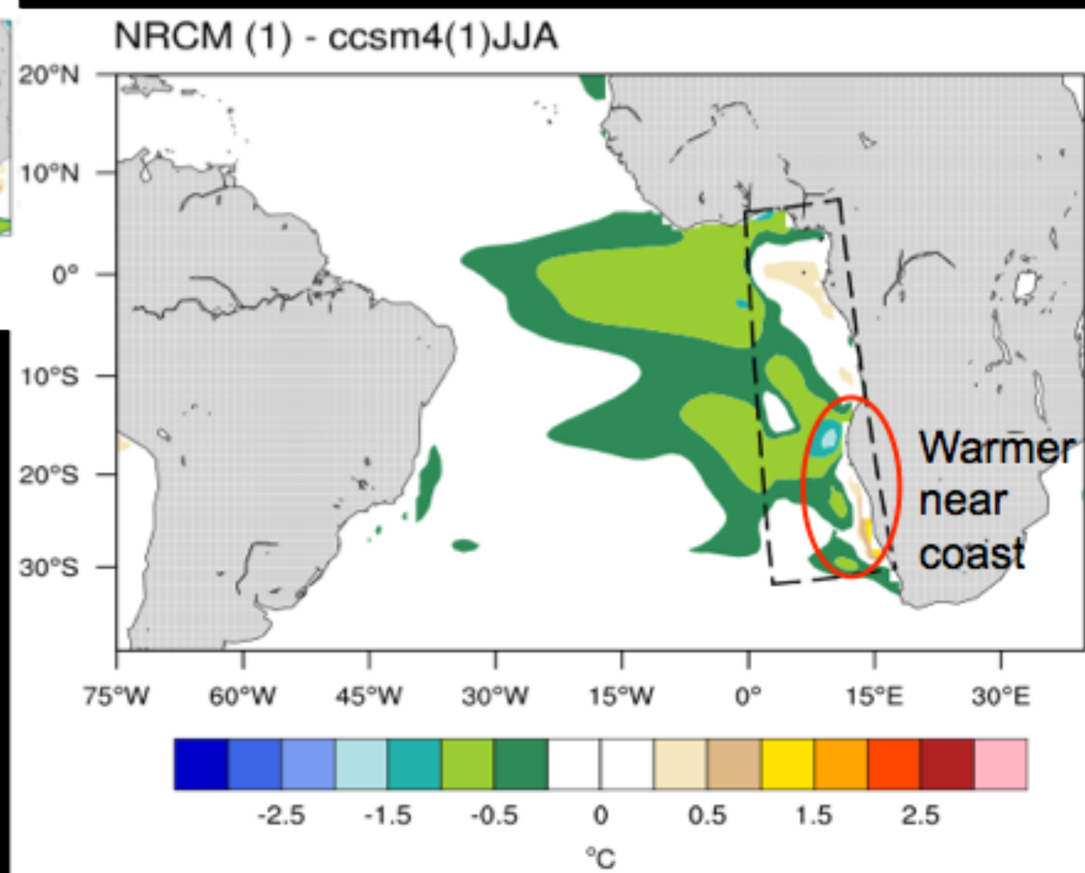




The Benguela Current System

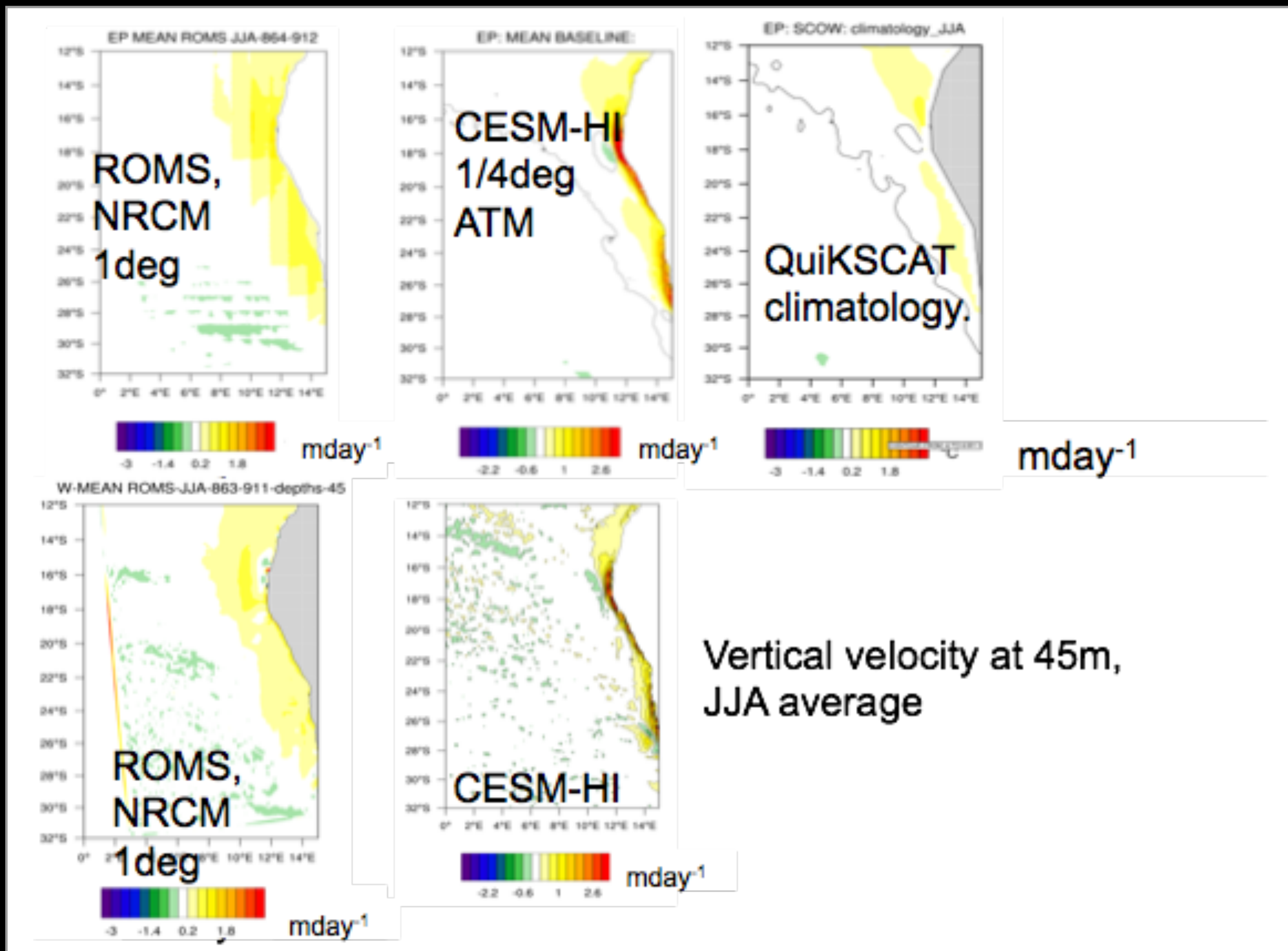


SST bias, CCSM4



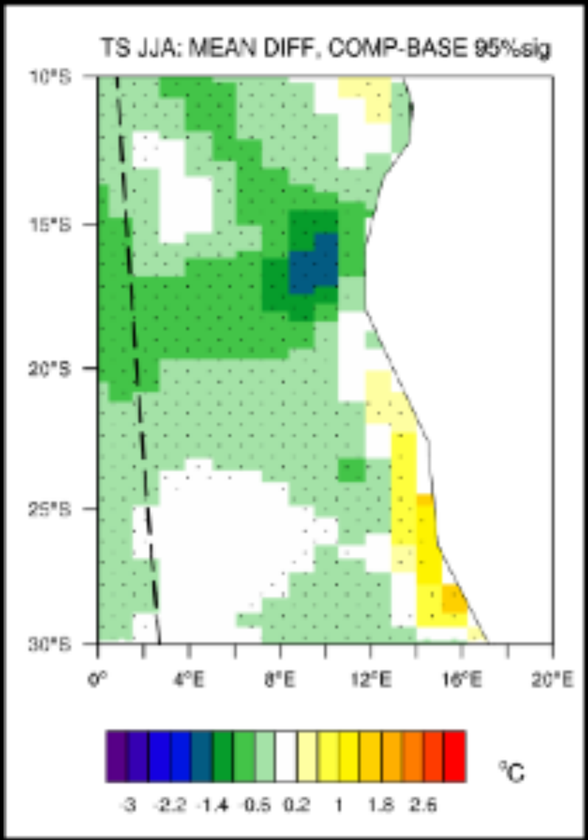
Nested RCM SST minus CCSM4 baseline, JJA

The Benguela Current System

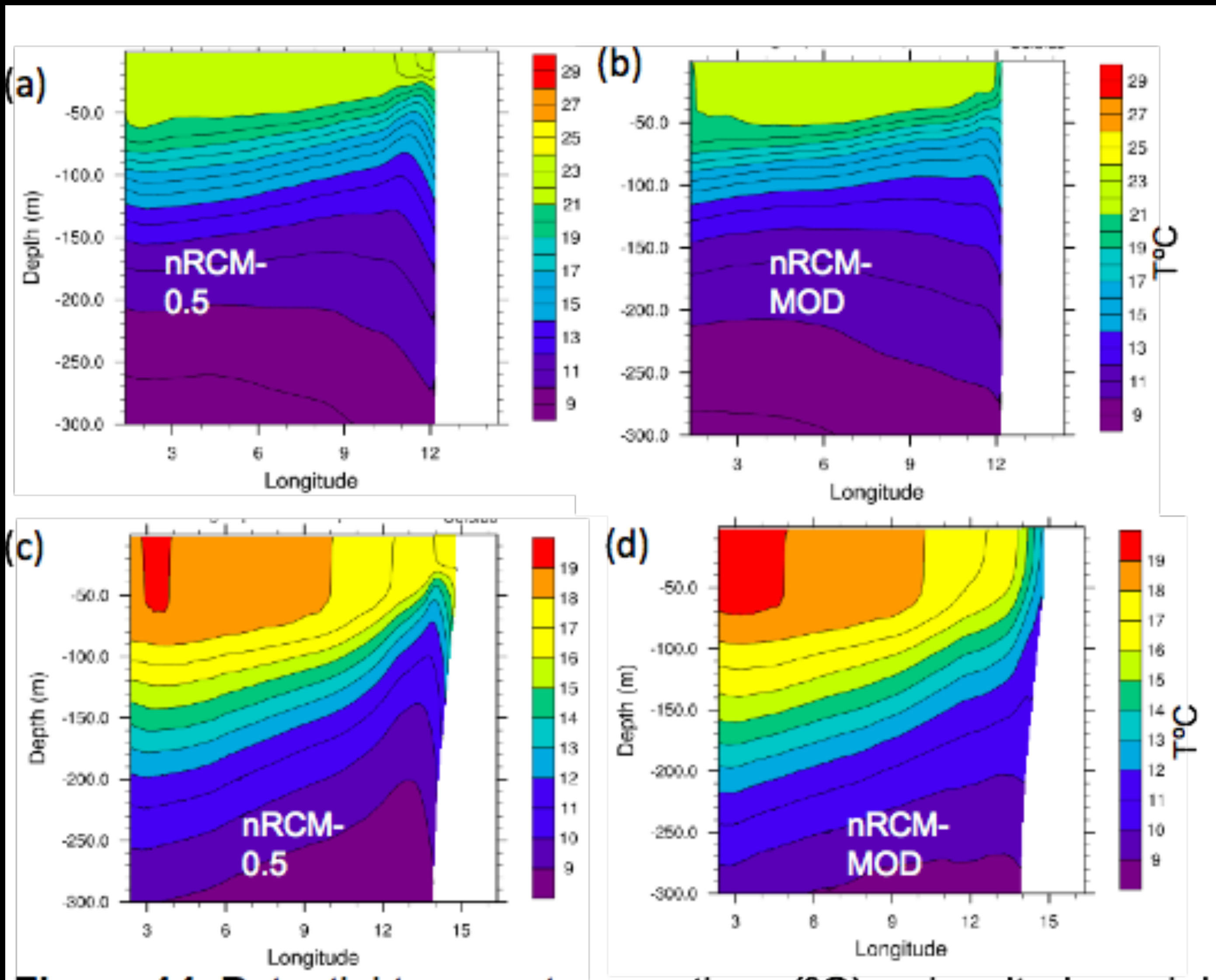


The Benguela Current System: Shifted winds experiment

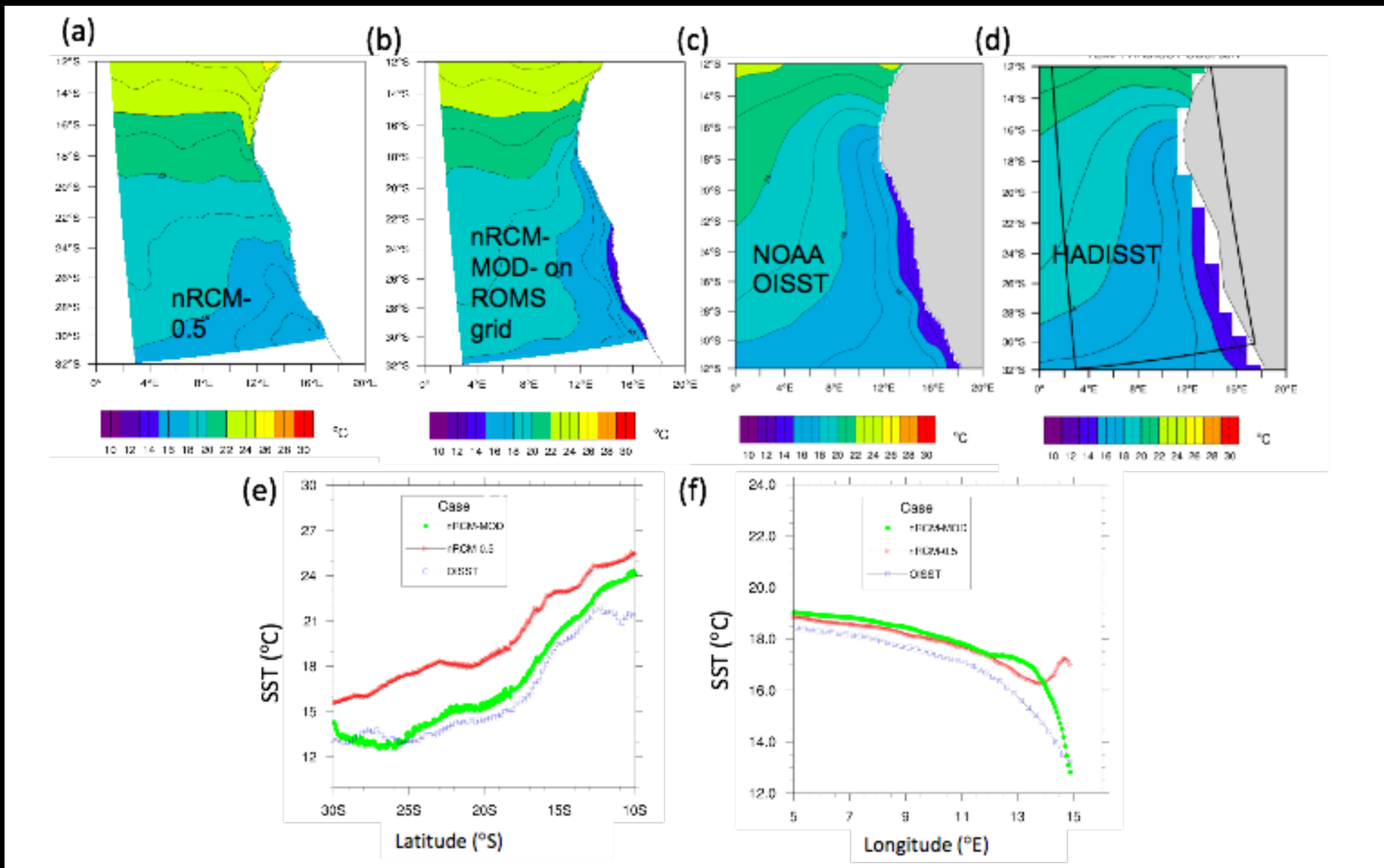
NRCM-1°



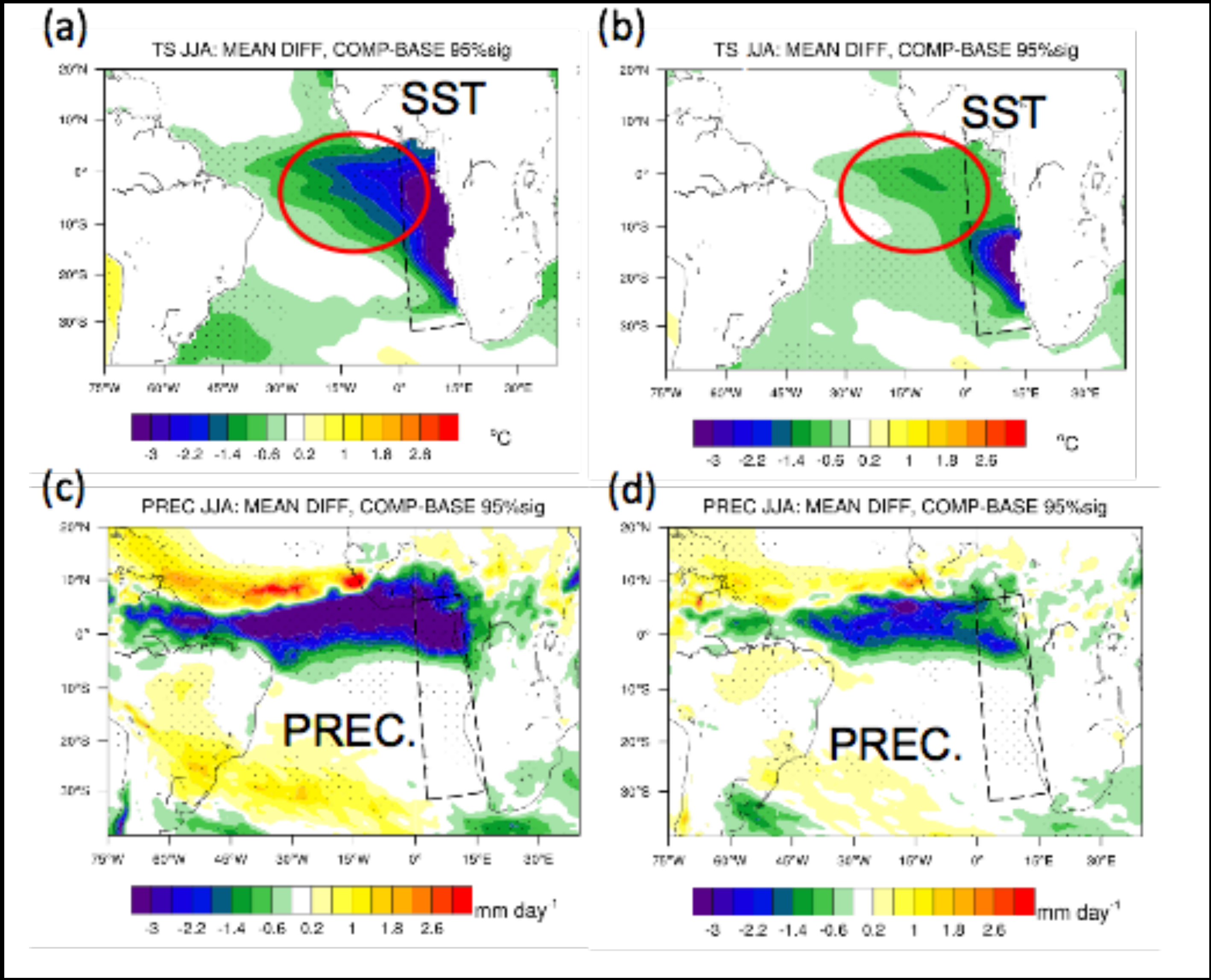
Temperature cross sections



Benguela: Comparing to observations



The Benguela Current System: Remote effects — Restoring Experiments



Back to the California Current: Biogeochemical considerations


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]

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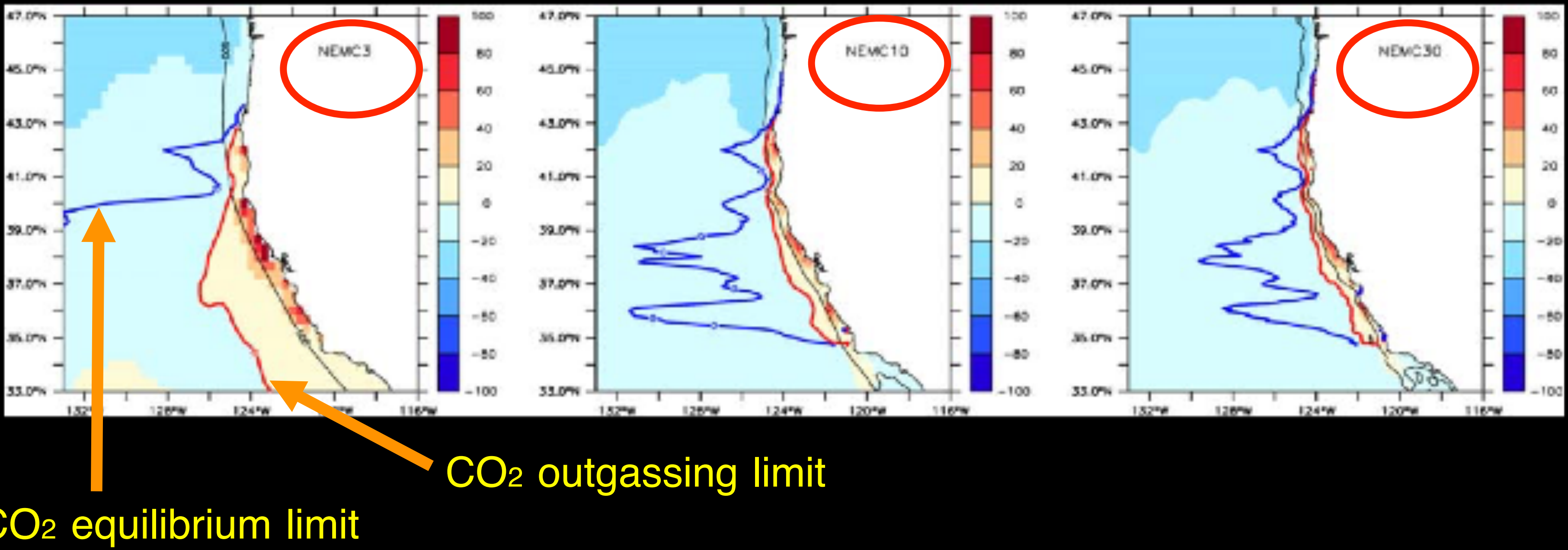

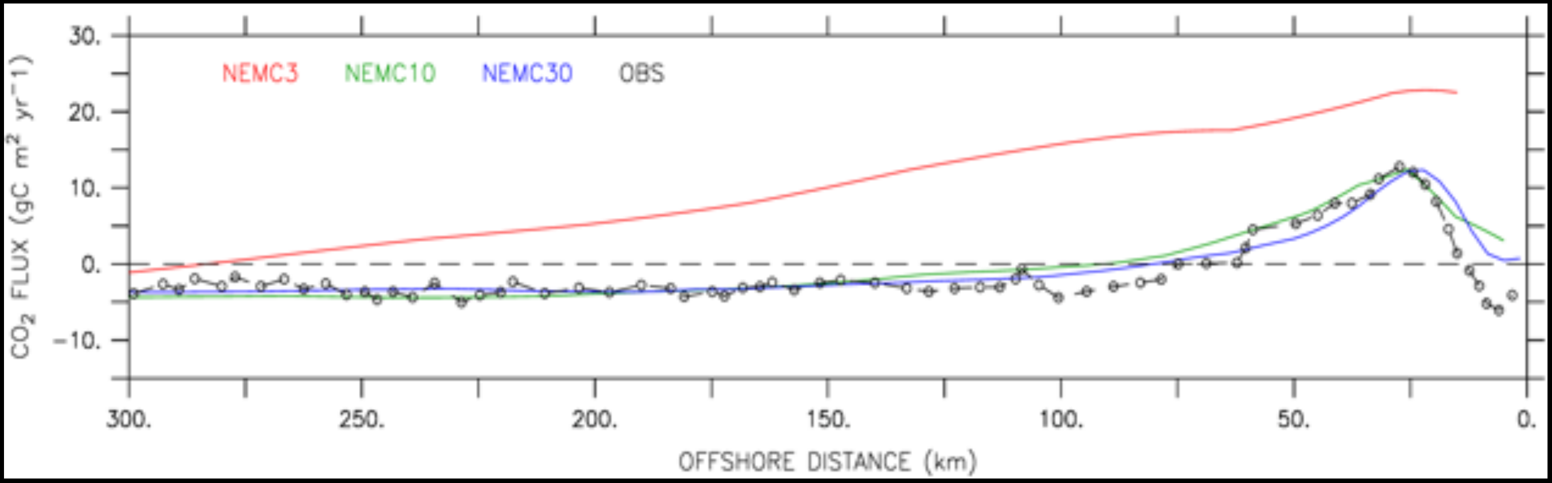

Final remarks

- Upwelling is a coupled phenomena with multiple scales interacting
    - Air-sea feedbacks modulate the response
    - Clouds and coastal atmospheric conditions are important
    - Feedbacks can extend well beyond upwelling region
- Dynamics of upwelling are different in the various regions (*and* within a region)
- Ocean dynamics are important and resolution is not the only "fix"
- Nesting permits isolating impacts of a given region
- Ongoing work: Western boundary currents, ensemble projections
- Don't wait for global high-resolution!