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Upwelling and regional response to embedding ROMS in CCSM3 at an eastern boundary

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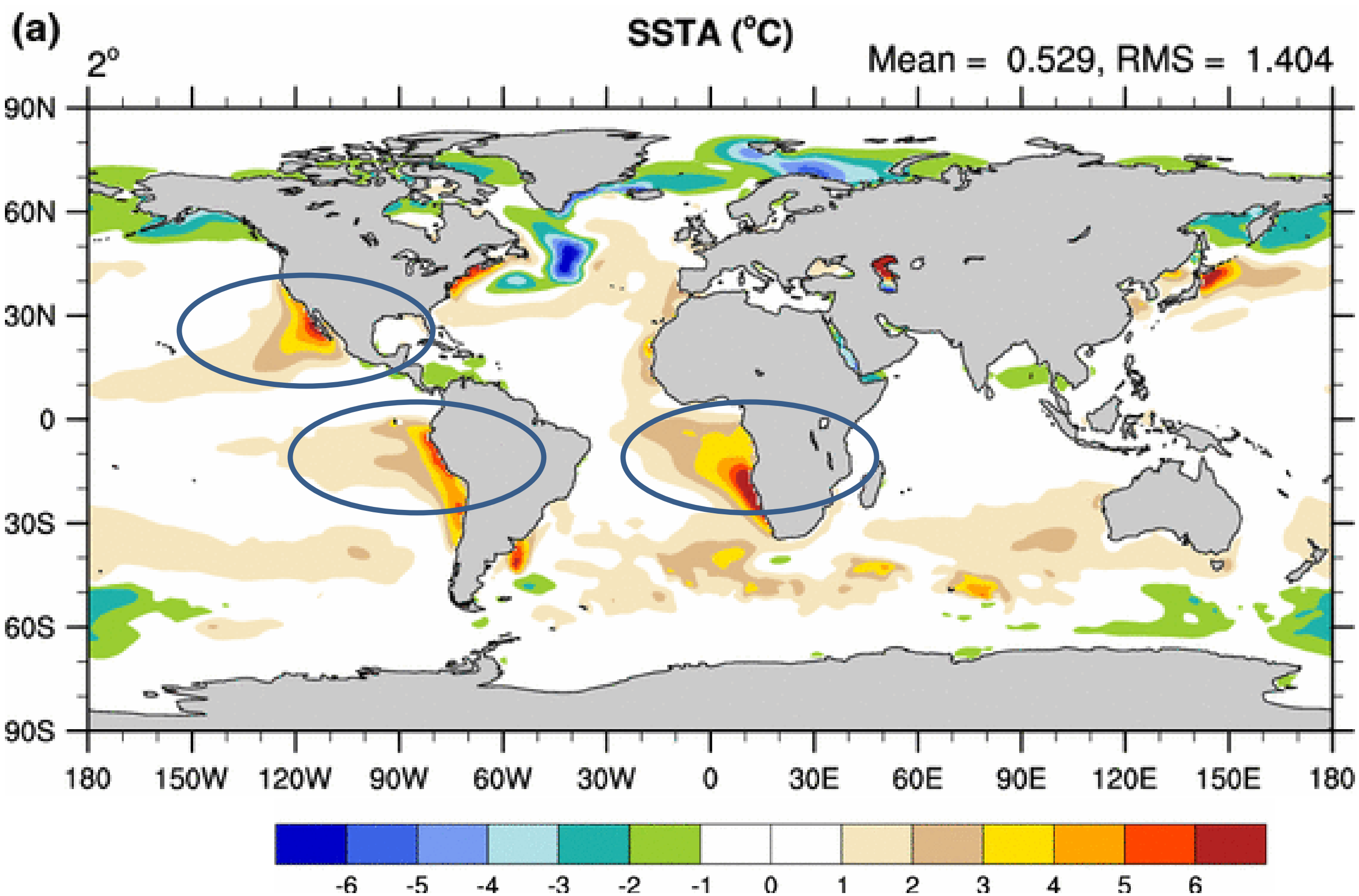
Thanks also to Markus Jochum, Mike Alexander,
Jon Wolfe (ex NCAR), Zack Powell and Frank Bryan, others

Warm SST bias problem

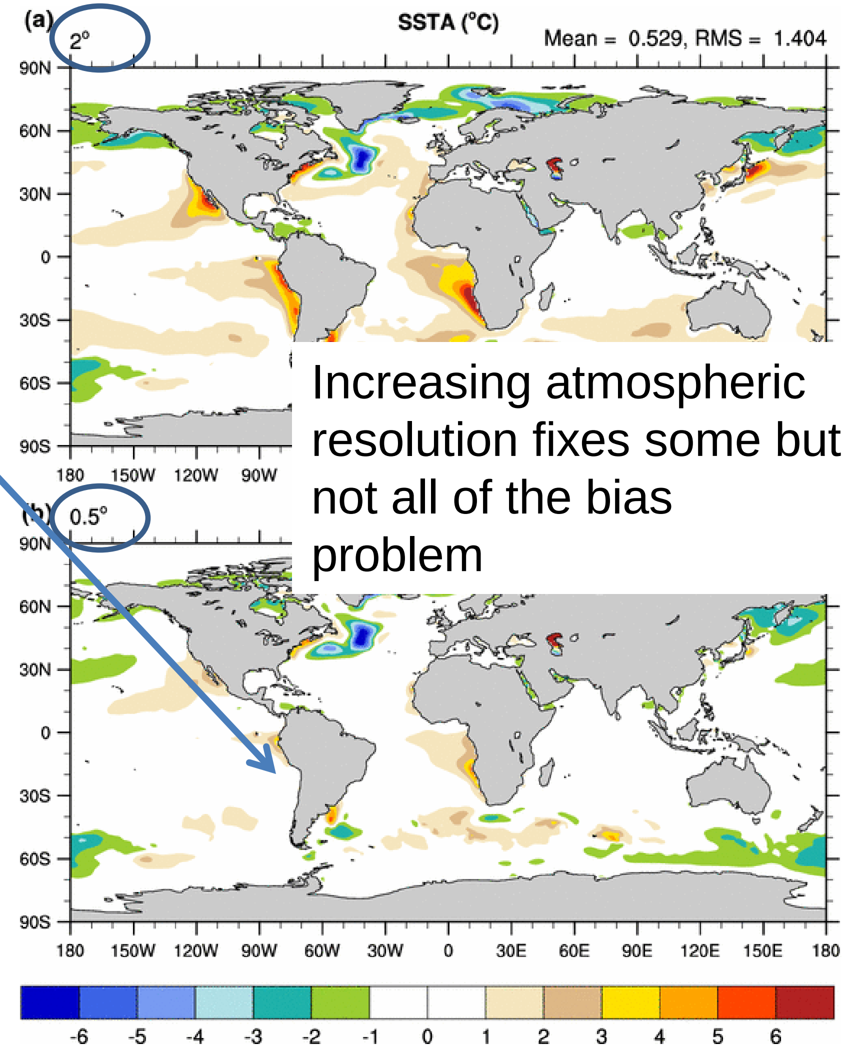


CCSM3.5 finite volume atmosphere

Differences in SST, CCSM minus WOA98 observations

Approaches to address the problem

- Higher resolution in atmosphere – better upwelling-favorable winds (Gent et al 2010)
- Improvements to boundary layer physics (Park & Bretherton 2009), cloud-radiation interaction
- Improved resolution in ocean – better upwelling



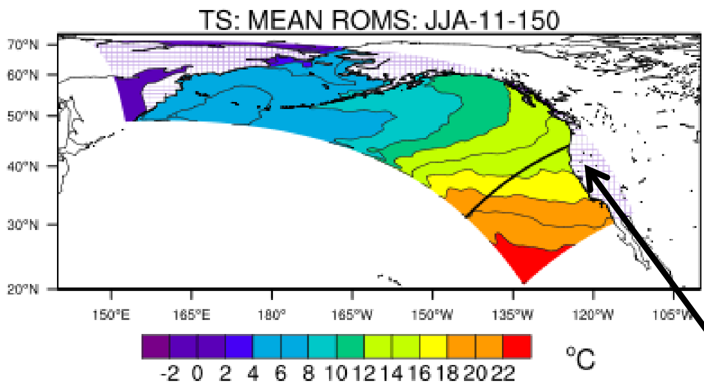
Increasing atmospheric resolution fixes some but not all of the bias problem

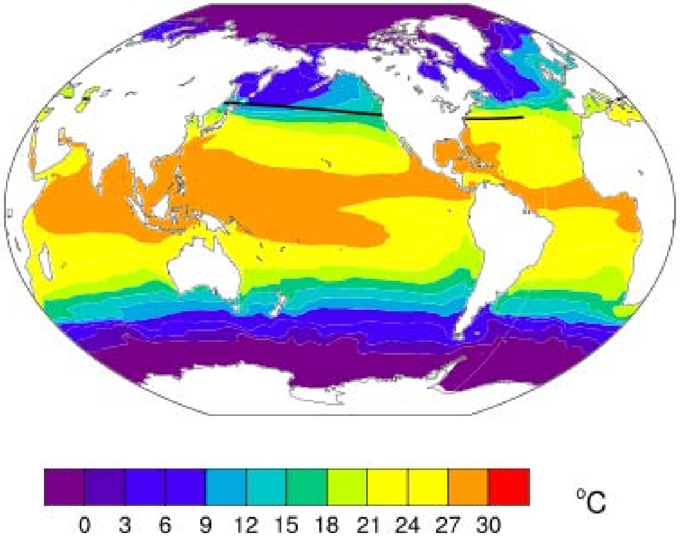
CCSM3.5 finite volume atmosphere

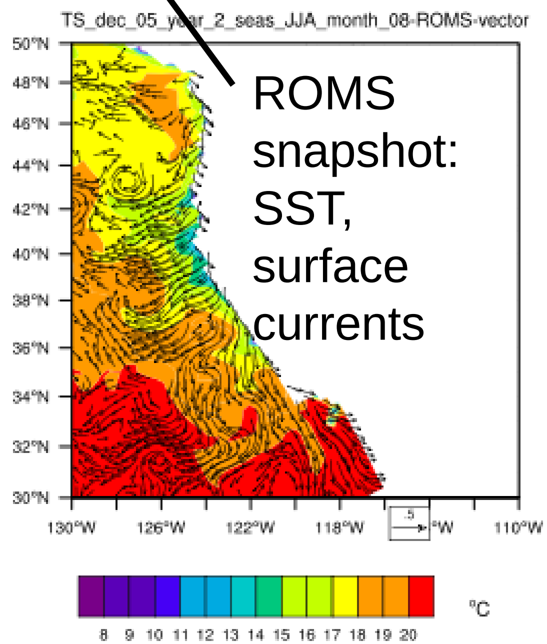
Approach: What if ocean resolution improved in these areas?

- Use a **nested, regional** model.
  - Allows for use of a different models –physics, grid designed for use in coastal regions.
  - Alternative to unstructured grids (Ringler et al., this workshop).
- Increase resolution at eastern boundaries to better resolve upwelling, coastal currents, and mesoscale fronts, eddies and filaments.
- Regional Oceanic Modeling System (ROMS: Haidvogel et al. 2000, Shchepetkin and McWilliams 2005)

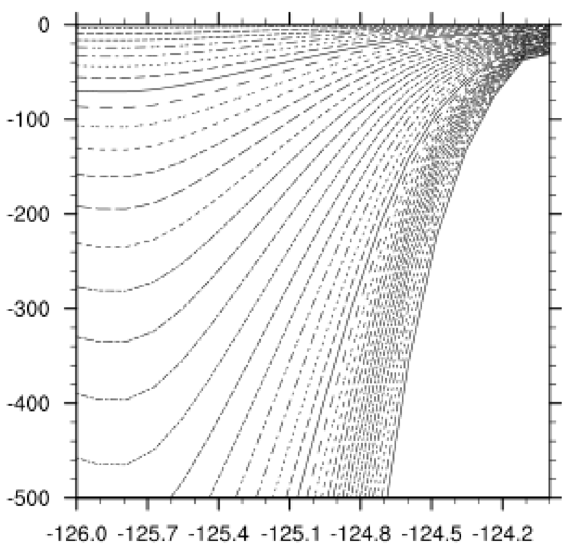
Ocean Model Grids

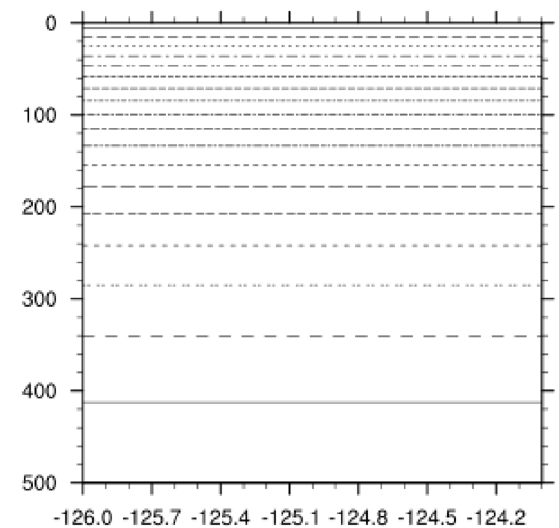






ROMS snapshot: SST, surface currents



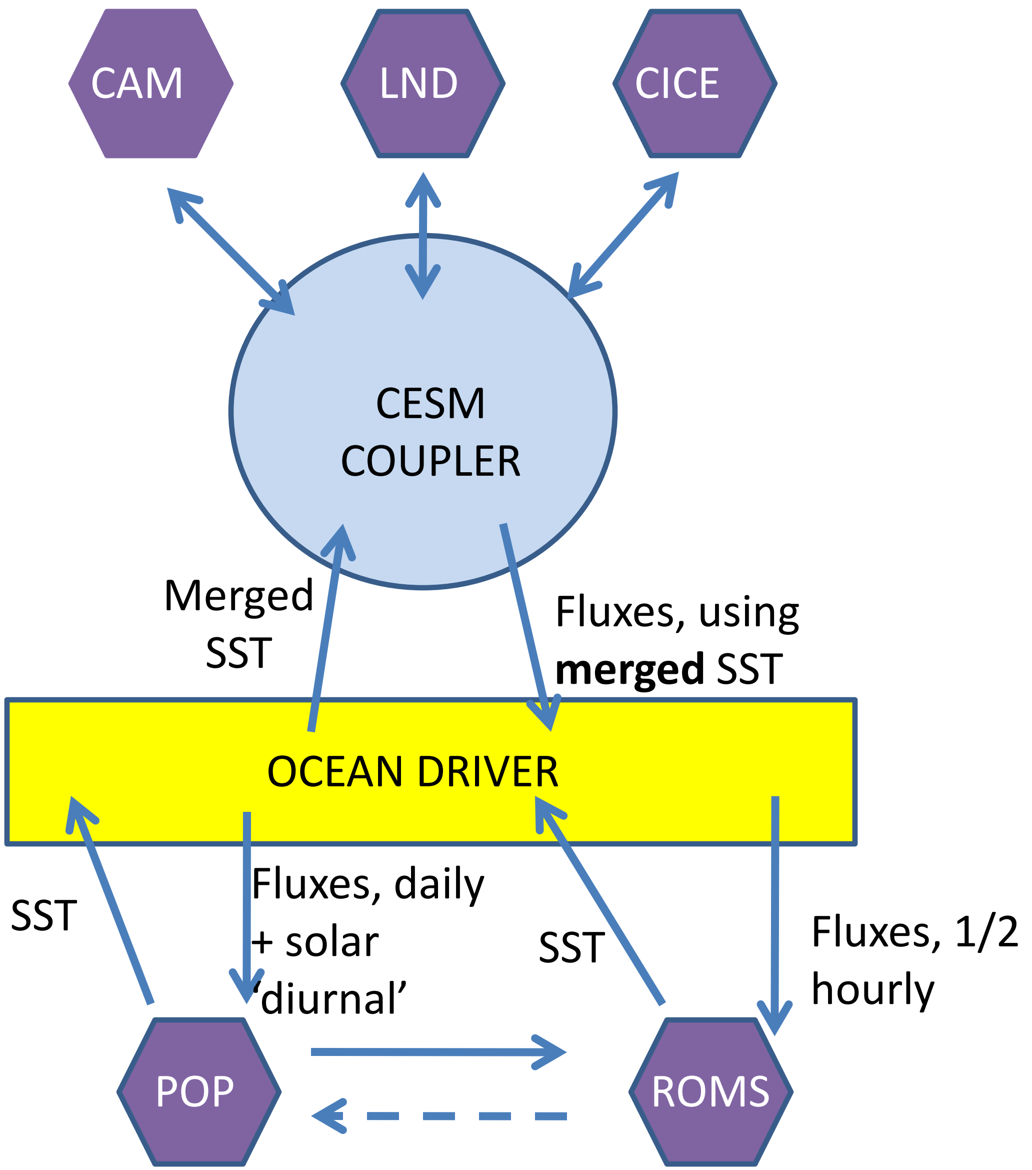


ROMS

Horizontal: ROMS is ~0.1degree vs POP ~ nominal 1degree.

POP

nested Regional Climate Model (nRCM)



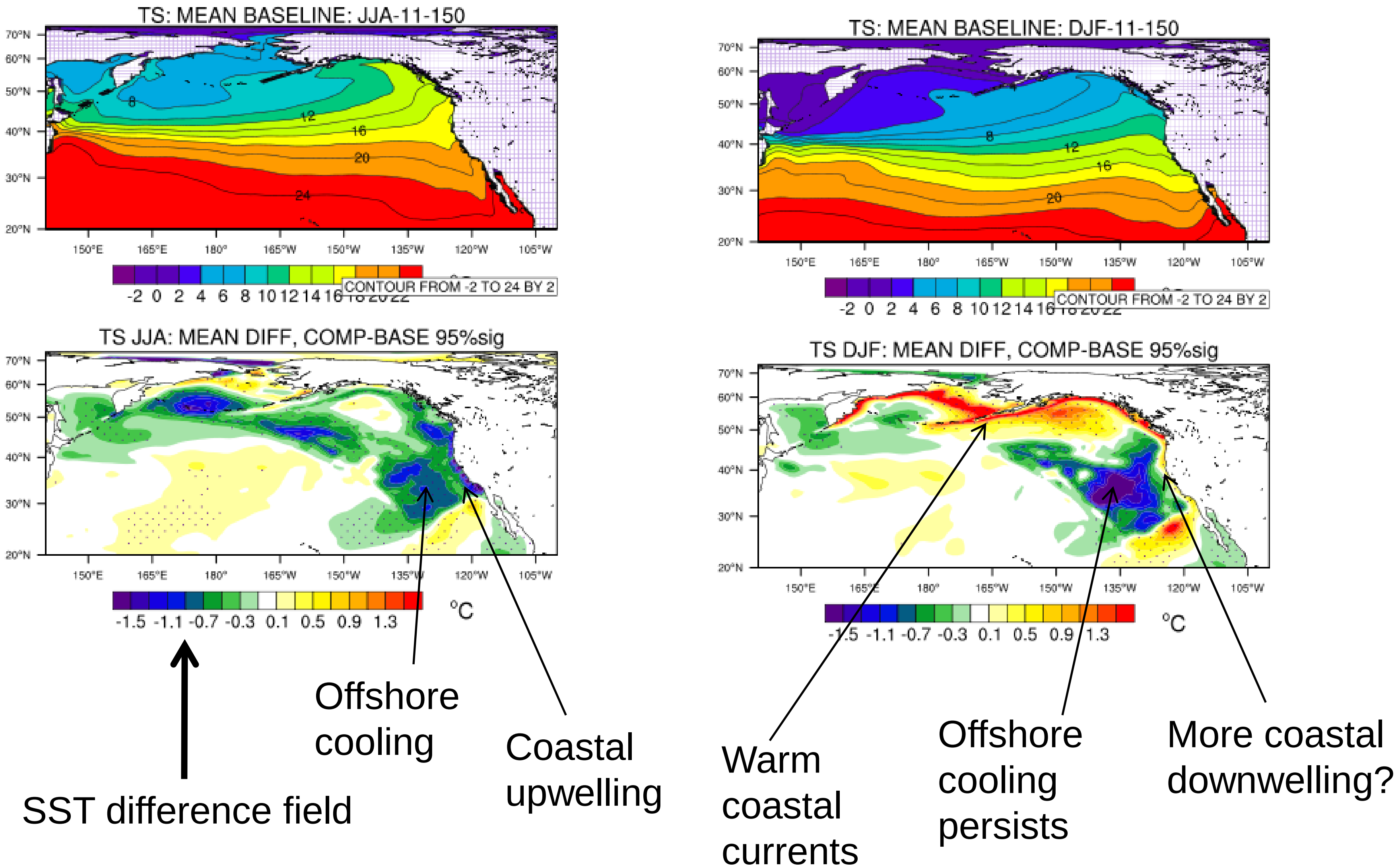
CCSM3 Experiments

- **Baseline**: 150 year run of CCSM3.1, T85, g1v4, branched from 1870 control run.
- **Composite (NRCM)**: 150 year run of CCSM3.1-ROMS, same initial conditions.
- Ocean
  - POP - ~1degree, 40 levels
  - ROMS ~10km, 42 stretched sigma levels
- Atmosphere CAM 3.3 – T85, 26 levels
- Land-CLM 3
- Sea ice-CSIM 5
- Data analysed- 140 years of monthly mean fields everywhere except ROMS – one snapshot per month

North Pacific SST

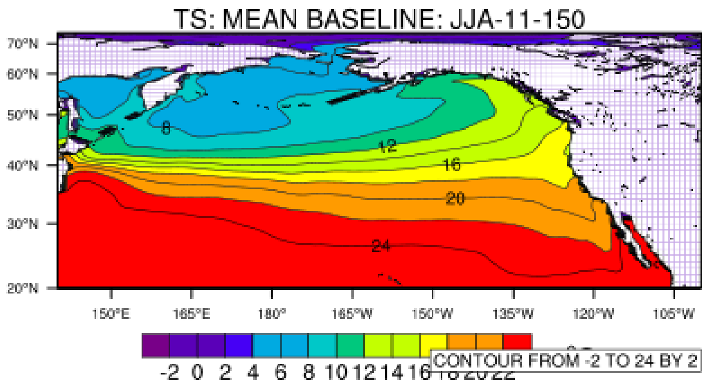
summer

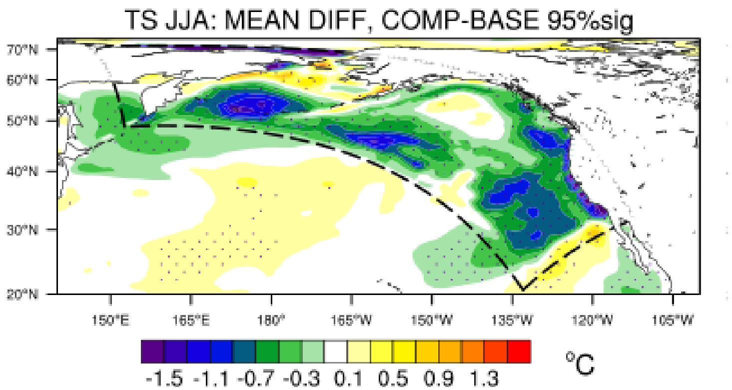
winter



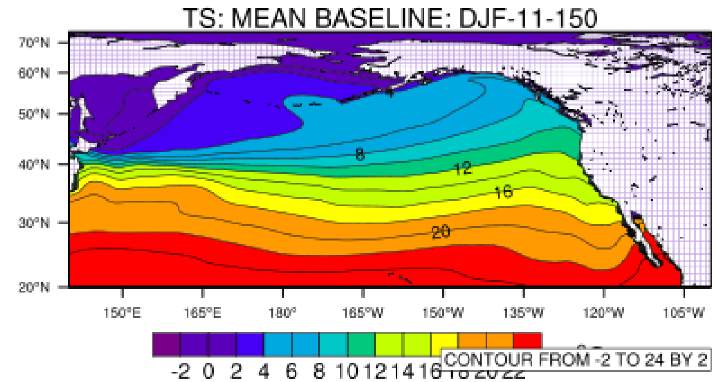
North Pacific SST

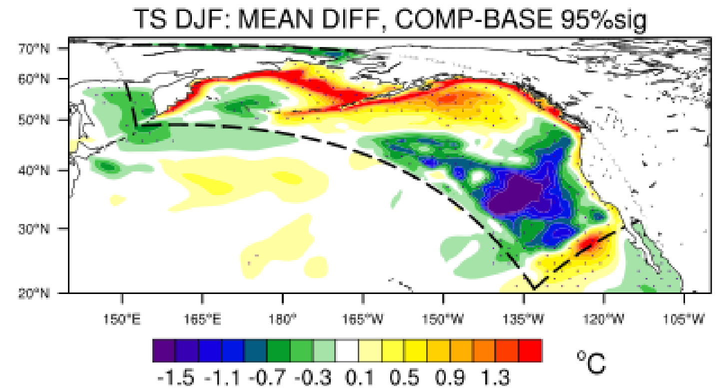
summer





winter





SST difference field

Offshore cooling

Coastal upwelling

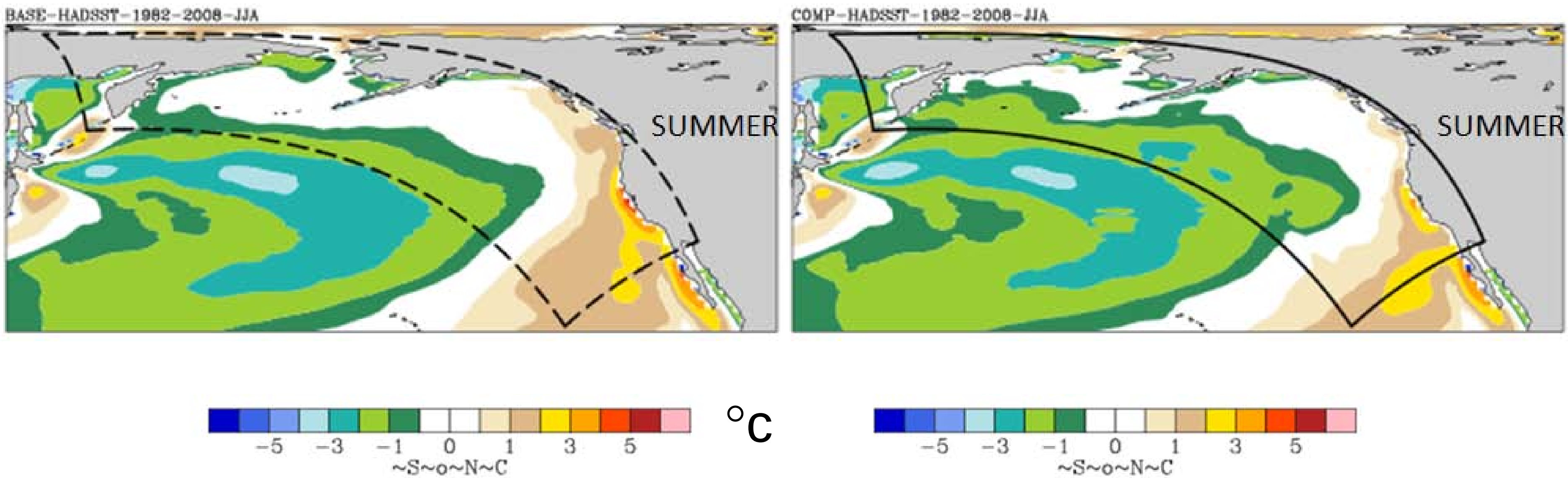
Warm coastal currents

Offshore cooling persists

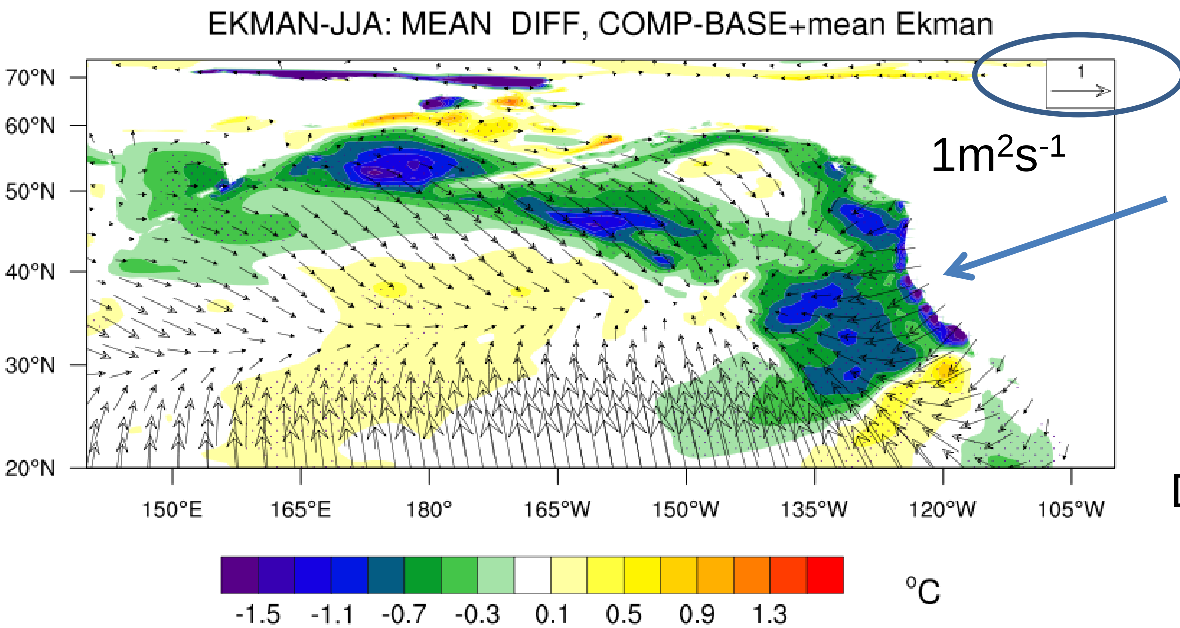
More coastal downwelling?

Seasonal SST Bias

relative to HadSST 1982-2008

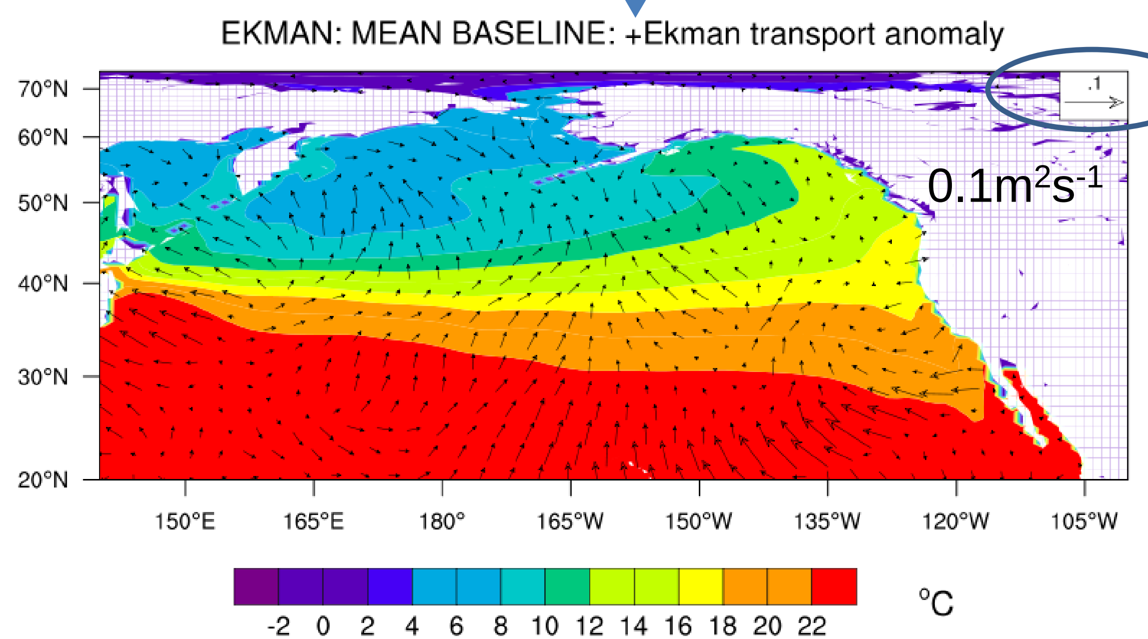


Ekman transport



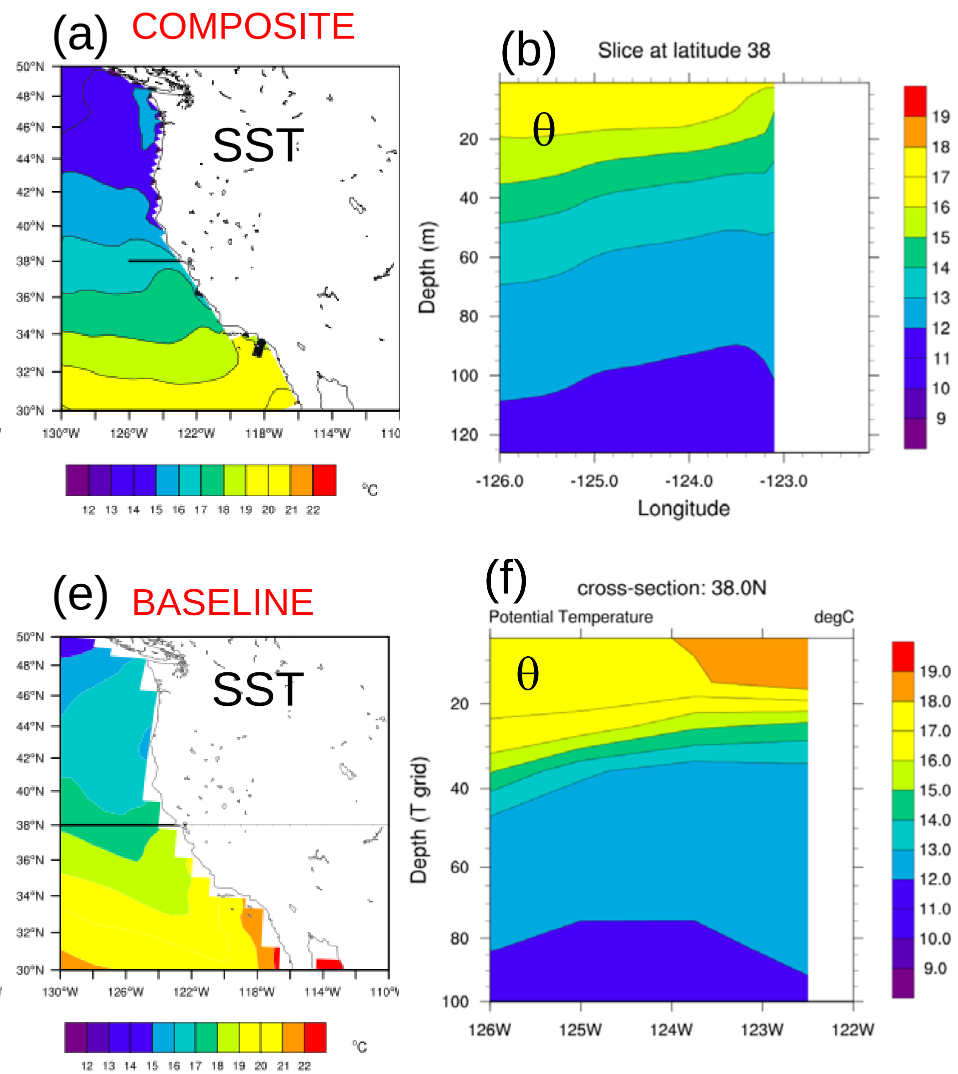
Mean Ekman transport (vectors only)

Differences in Ekman transport



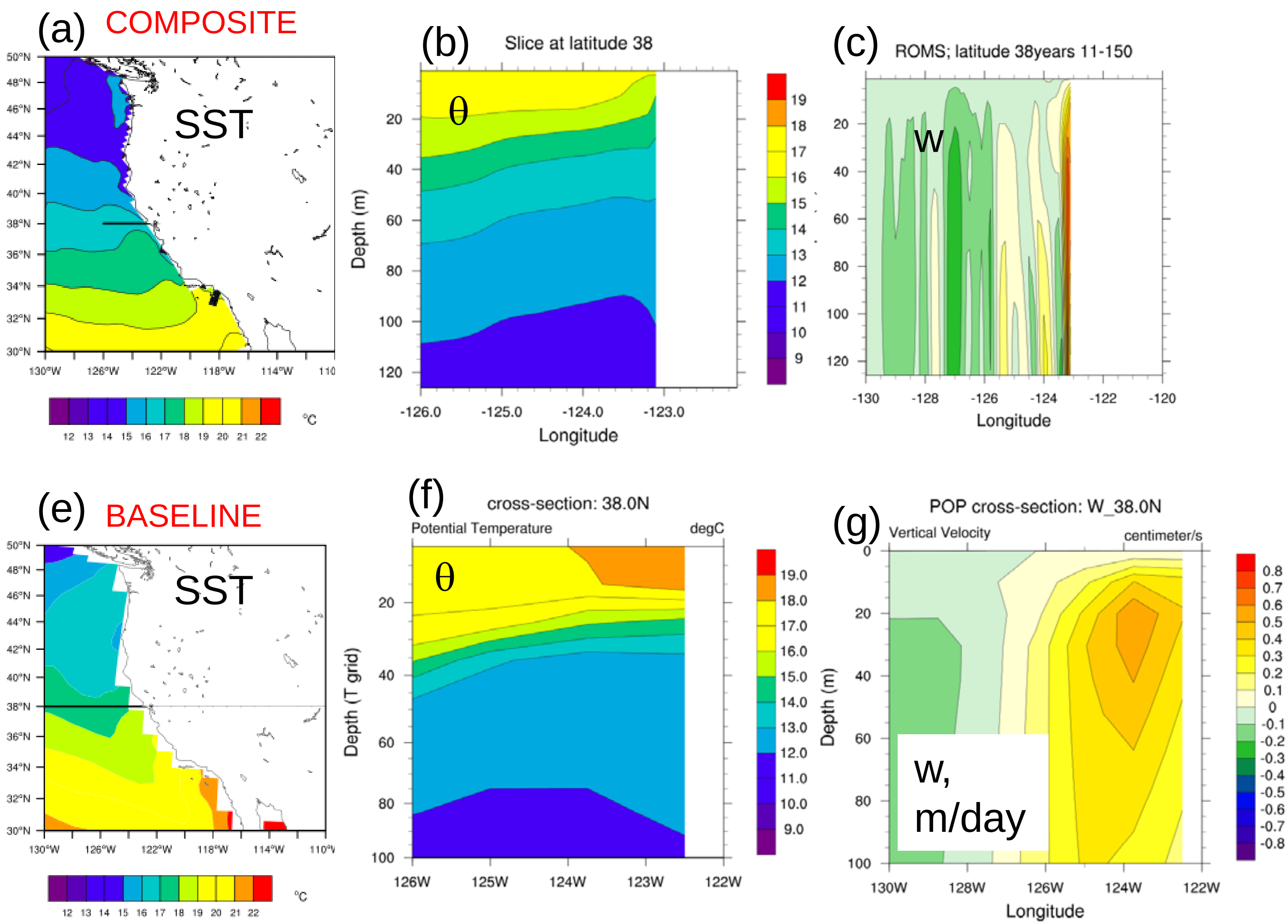
Likewise, changes to coastal wind stress magnitude and to wind stress curl are small
–
Wind Forcing on ocean is similar for both runs

Upwelling



Temperature and vertical velocity sections from Top) ROMS component of composite model and Bottom) POP component of baseline run. a,e) Surface temperature map, mean JJA from 140 years; b, f) potential temperature vs depth along the line (38°N) ; c, d, g) vertical velocity (m/s) at 38 °N;

Upwelling



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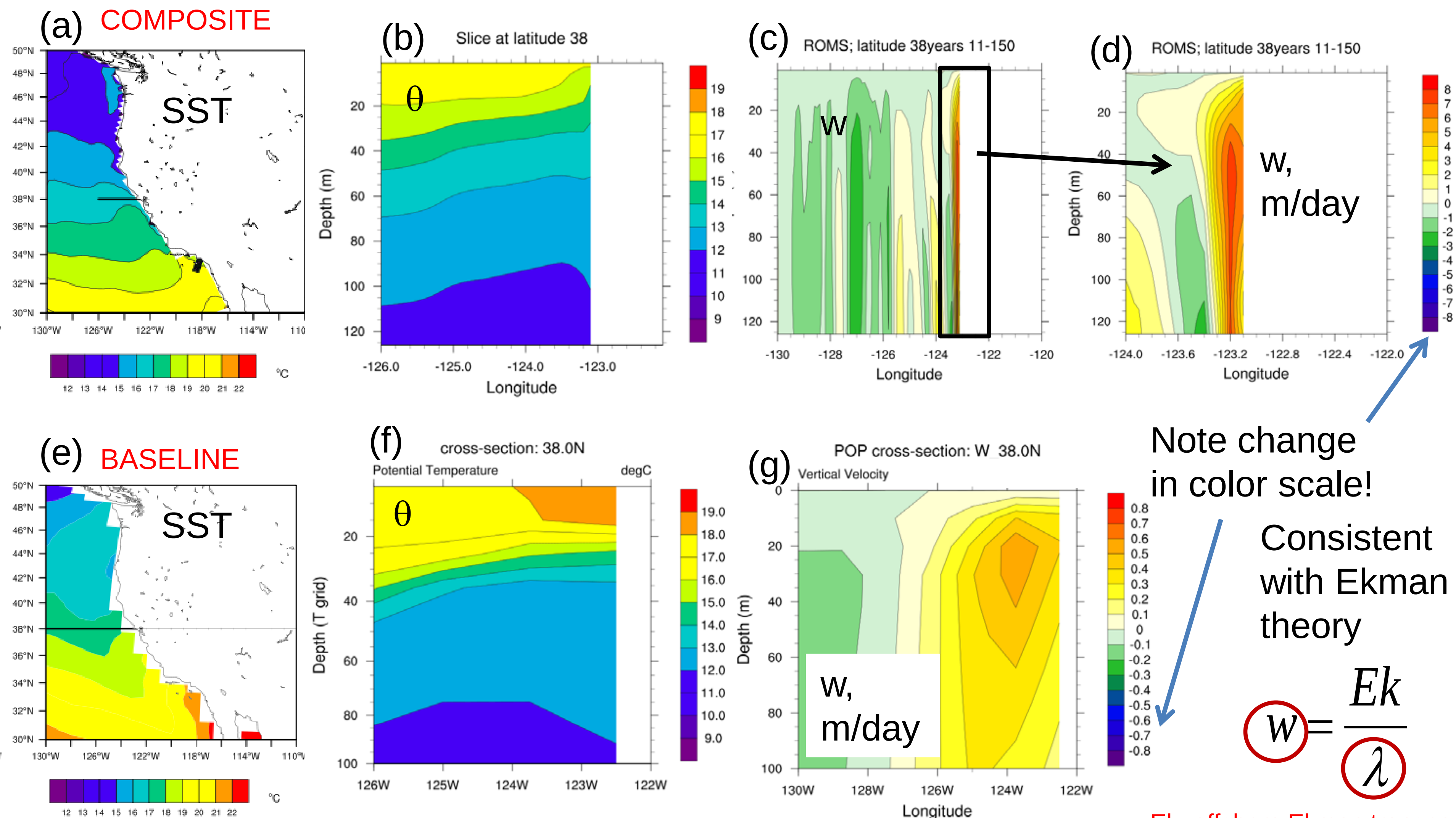
Upwelling

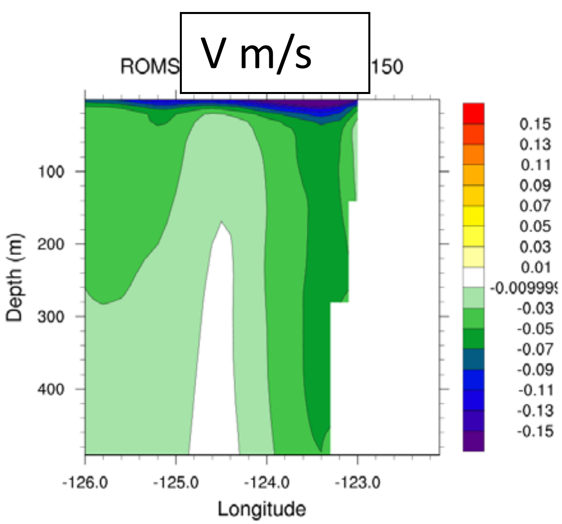


Ek- offshore Ekman transport
w – Ekman vertical velocity
λ- length scale

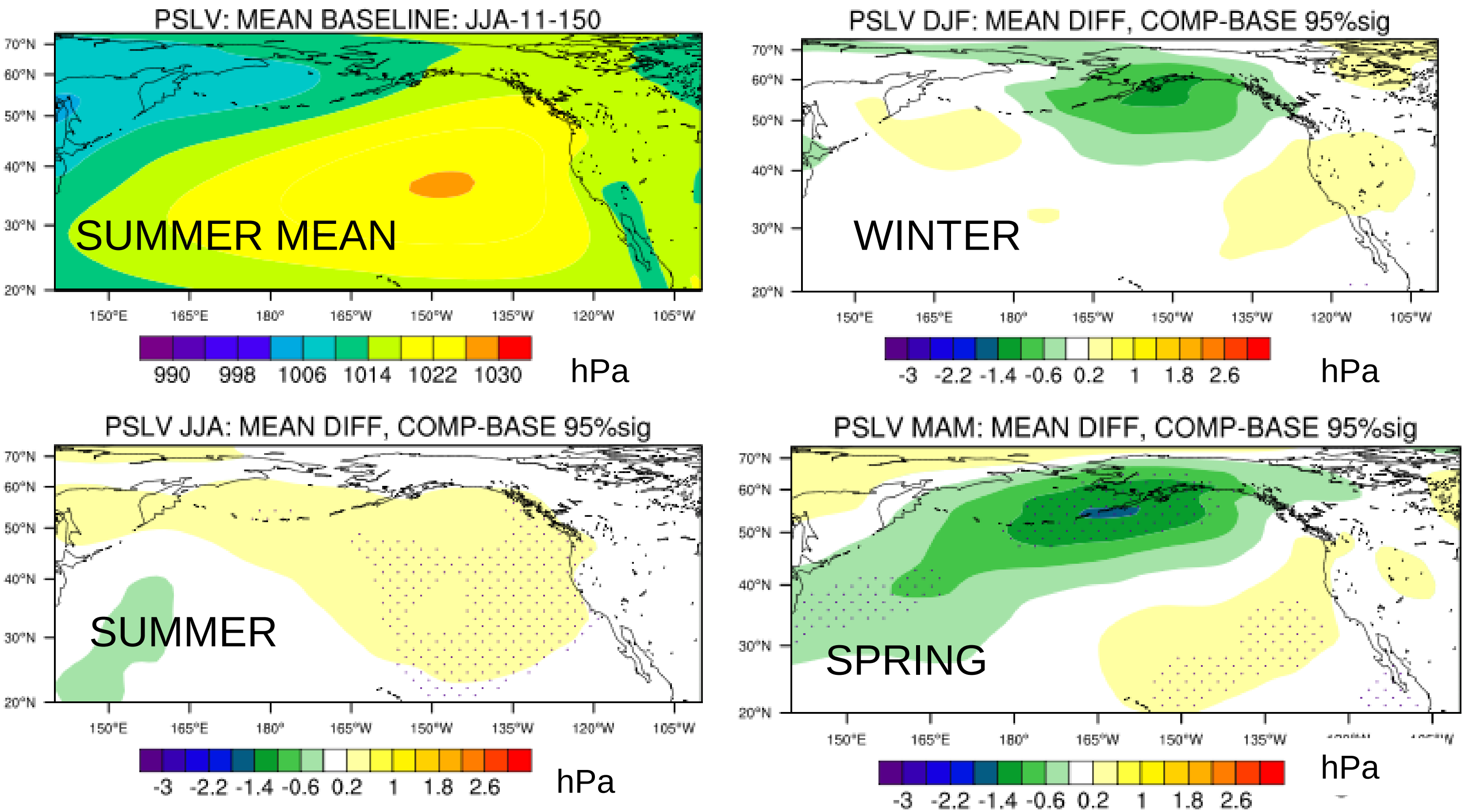
Temperature and vertical velocity sections from Top) ROMS component of composite model and Bottom) POP component of baseline run. a,e) Surface temperature map, mean JJA from 140 years; b, f) potential temperature vs depth along the line (38°N) ; c, d, g) vertical velocity (m/s) at 38 °N;

Upwelling (observations)

- Upwelling is confined to 10-20km off coast (Huyer 1983, Huyer et al 2005)
- Comparable to baroclinic radius of deformation
- Upwelling velocities of several m/day observed
- Coastal surface current has similar width, 10-20cm/s (Barth et al 2000)



Sea level pressure and difference



SUMMER –statistically significant enhancement of seasonal high

WINTER–low pressure enhanced in Gulf of Alaska, but not statistically significant **SPRING** – significant response

Prototype 2-way ocean interaction:

Nudge POP SST to ROMS SST with 10 day timescale

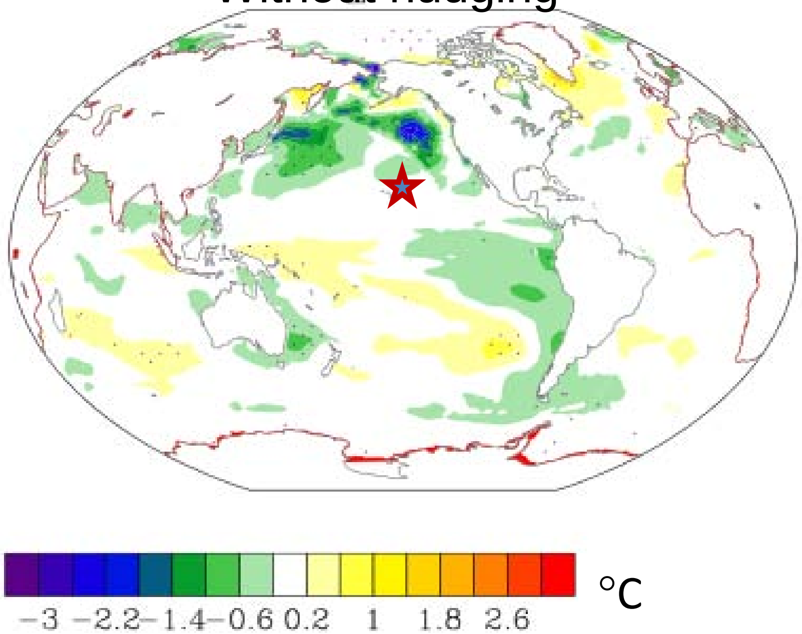
& Port code to CESM

★ Spreading due to air-sea interaction only

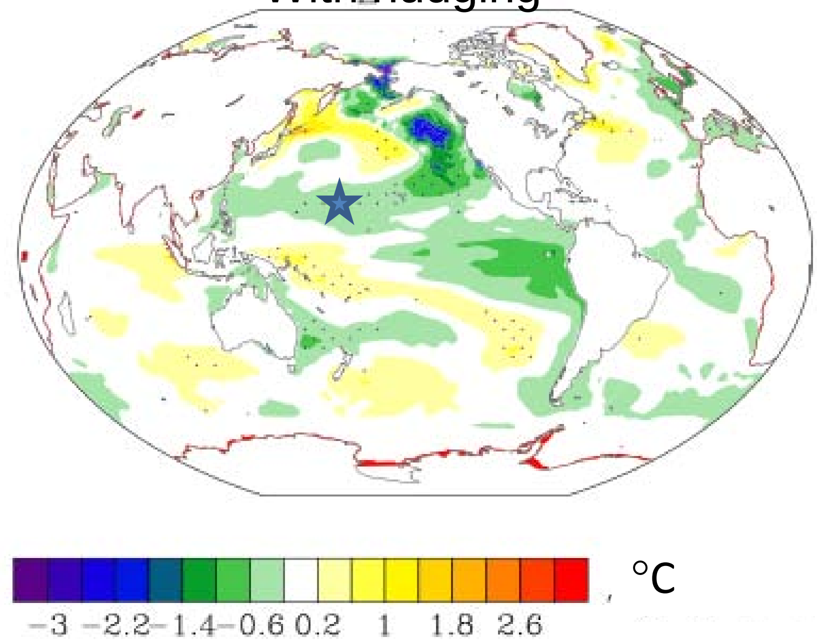
★ Spreading due to *oceanic advection and* air-sea interaction

Without nudging

JJA



With nudging



Difference maps: Merged ROMS-POP SST in composite run, minus SST from baseline run.

Results from first 10 years only.

Prototype 2-way ocean interaction:

Nudge POP SST to ROMS SST with 10 day timescale

★ Spreading due to *oceanic advection and* air-sea interaction

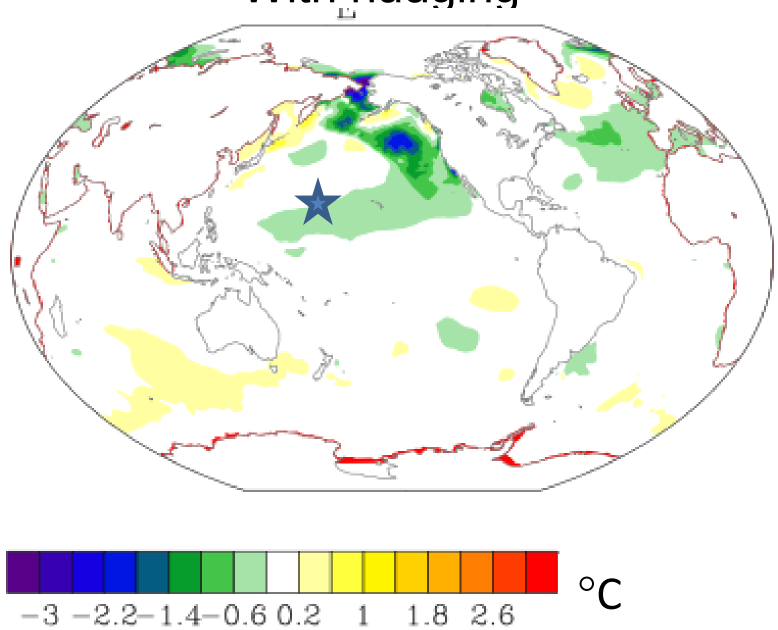
Without nudging

JJA

20 years

°C

With nudging



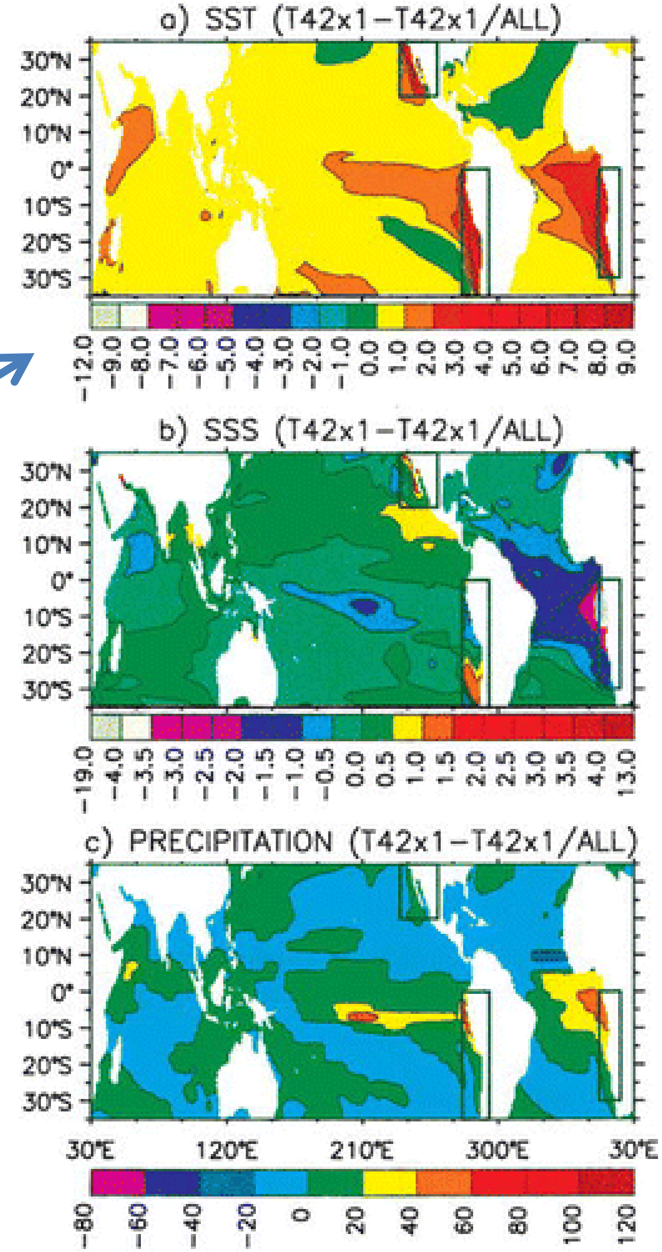
°C

Difference maps: Merged ROMS-POP SST in composite run, minus SST from baseline run.

Results from 20 years.

Way ahead

- Further test 2-way ocean boundary conditions
  - 3D nudging
  - Other methods?
- Look at other eastern boundary regions
- *and western boundaries (new NSF grant)*
- Add bio-geochemistry and couple between ROMS and POP



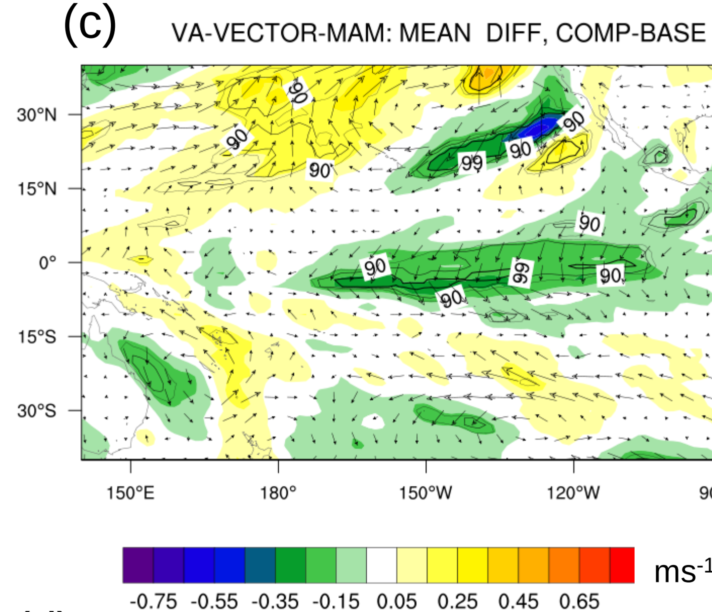
Large and Danabasoglu 1996

Extra Slides

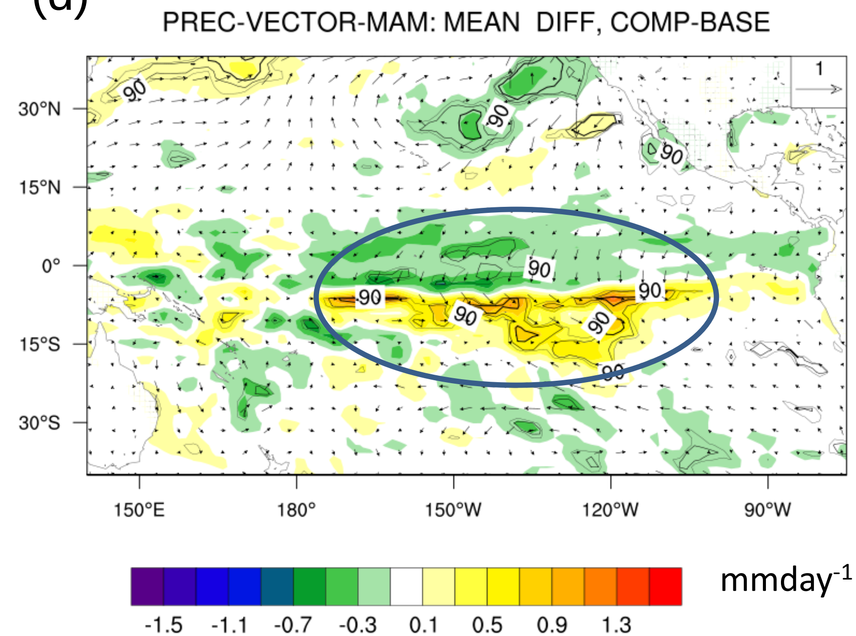
Boreal Spring

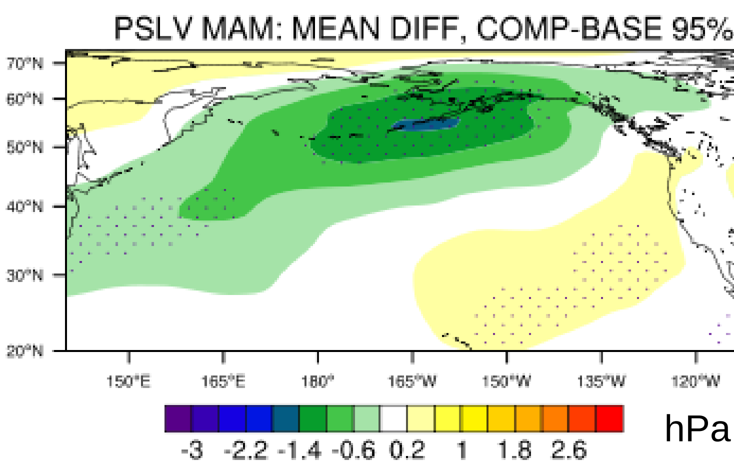
In Boreal Spring (MAM) there is a statistically significant North Pacific low response. Also, a southward shift of the ITCZ associated with anomalous southward winds away from high pressure regions.

(c)

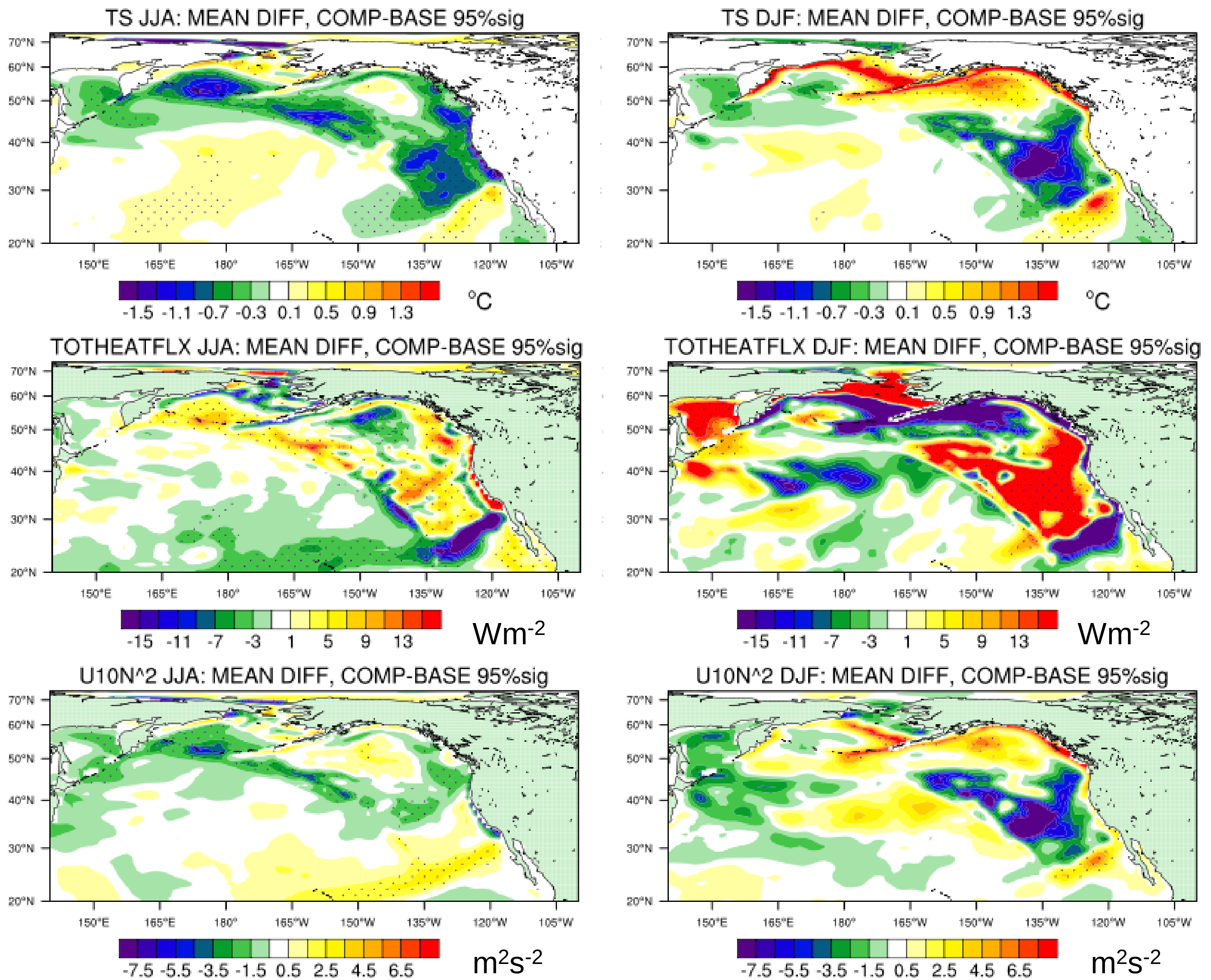


(d)



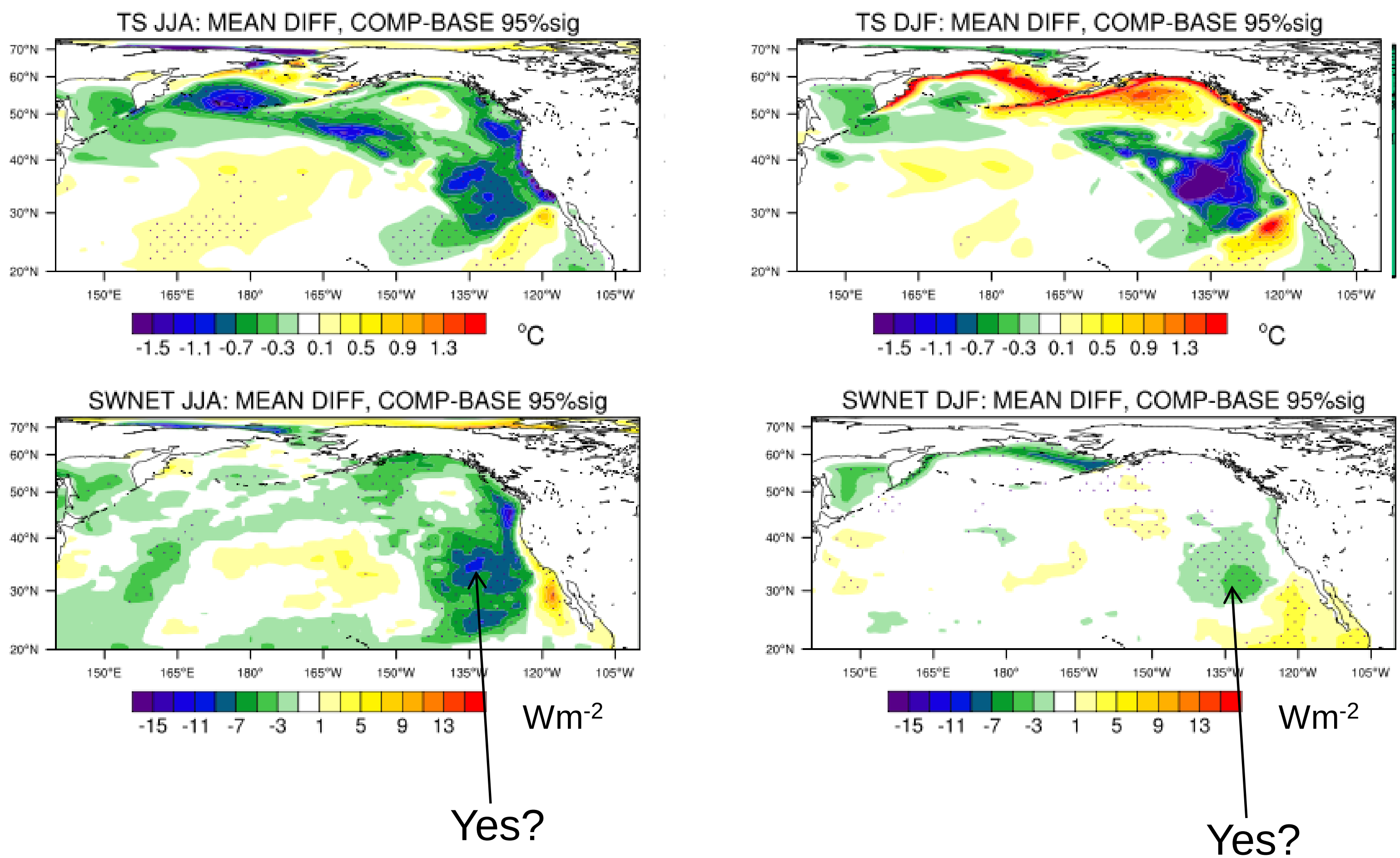


Changes in wind stress (+heat flux)



SUMMER **WINTER**

Net shortwave flux (any increase of stratus clouds when SST cools?)

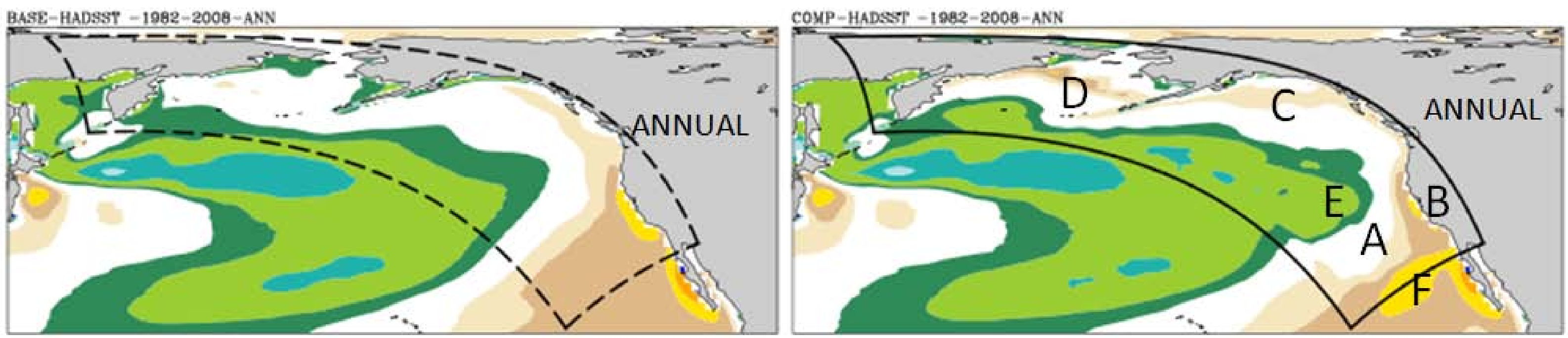


SUMMER

WINTER

Annual Mean SST Bias

relative to HadSST 1982-2008



BASELINE 140yrs

COMPOSITE 140yrs

But Levitus & HadSST not ideal for coastal zone (resolution).

Seasonal SST Bias

relative to HadSST 1982-2008