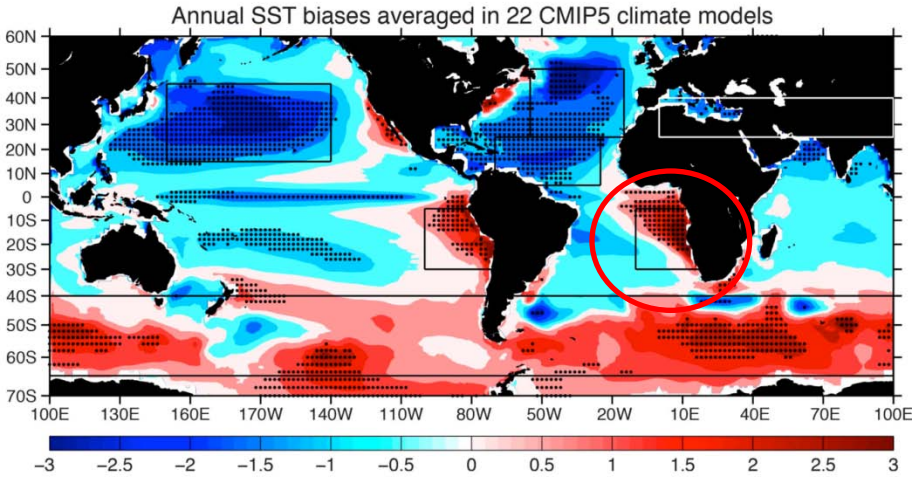
NSF funded project 0961545, June 2010-May 2015

OMWG meet, Jan. 2014

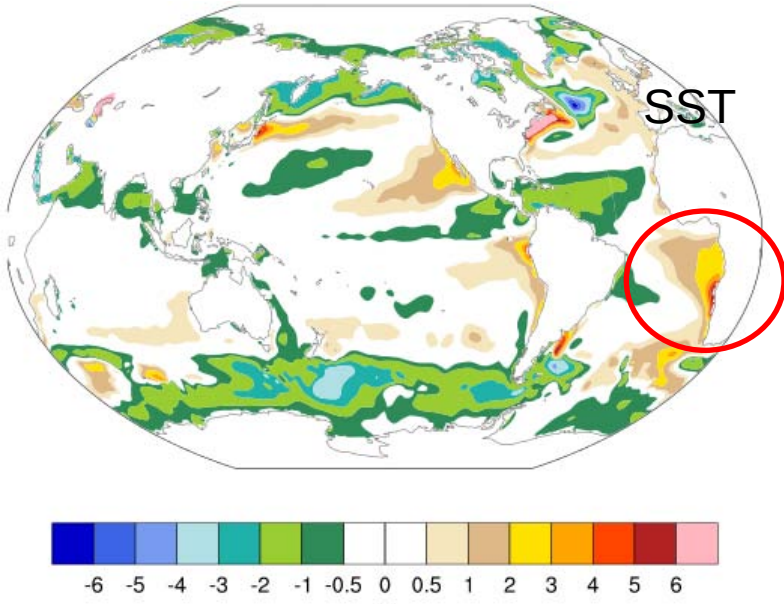
Tropical and South-east Atlantic biases

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

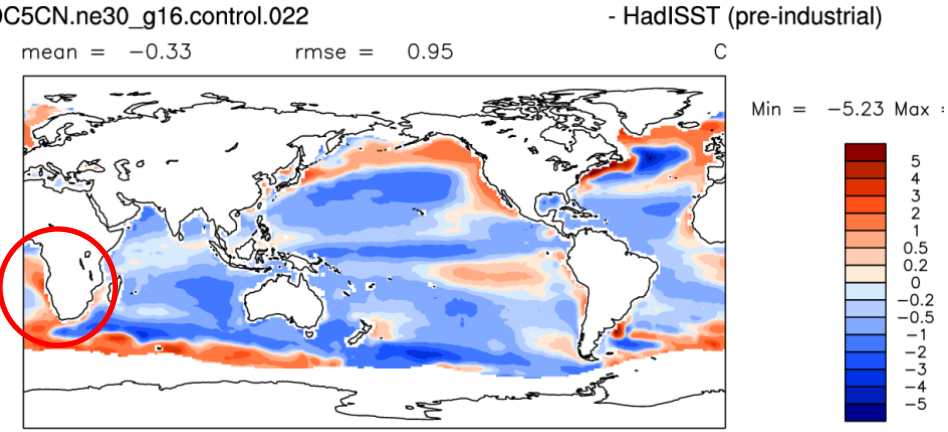
A common problem



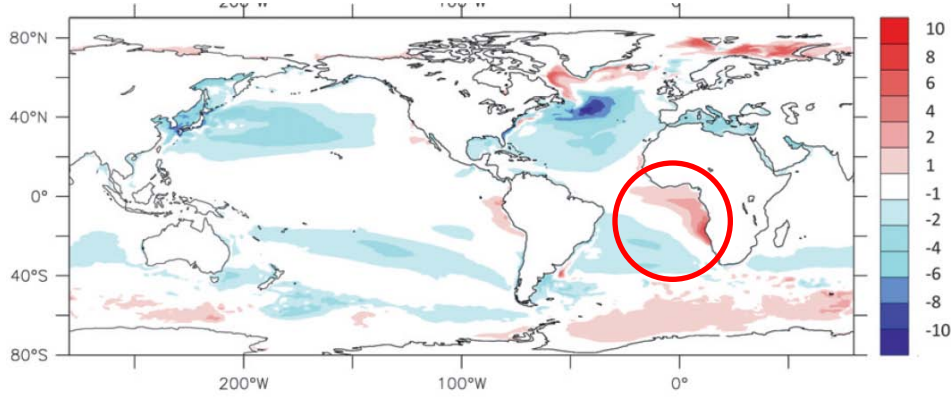
CMIP5 Multi-model mean (Provided by Roberto Mechoso, Matt Masarik). Long term, annual mean SST difference from observations.



CCSM4 1° model (from Gent et al. 2011). Long term, annual mean SST difference from Hurrell et al. 2008 observations.



CESM w CAM5 ne30.



Delworth et al 2012. CM2.5 RE REYNOLDS

- Leads to large precip biases (erroneous southern ITCZ in Atlantic)…
- Affects interannual variability in Atlantic…

Possible causes of warm bias

- Extra-tropical region (south-east Atlantic)
  - Inadequate cloud/radiation representation (e.g. Philander 1996, Wahl 2011, Medeiros et al. 2012)
  - Inaccurate winds (Gent et al. 2010) coastal and/or basin scale
  - Weak upwelling and/or currents (Large and Danabsoglu 2006, Grodsky et al. 2012, deSzoeke et al 2010)
- Equatorial Atlantic
  - Trade winds too weak or wrong sign (Chang et al 2007)
  - Related to convection biases over land in boreal spring (Richter and Xie 2008, Wahl et al 2011)
  - Affecting thermocline depth and SST in next season

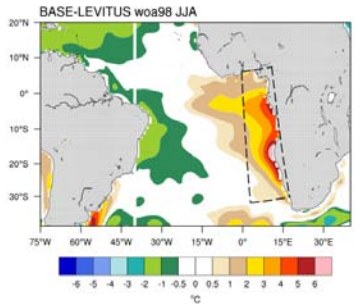
Overview

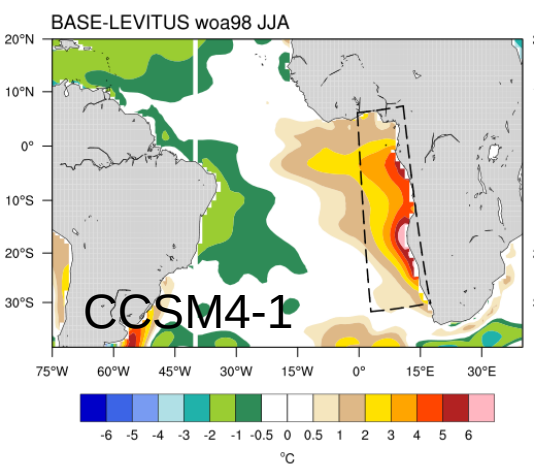
- Sensitivity of south-east Atlantic SST to ocean and/or atmosphere resolution.
  - Look at surface currents and vertical motion
- Teleconnections from south-east Atlantic to Equatorial Atlantic (& beyond?)
  - via ocean and ocean-atmosphere coupling
- Improvements in Equatorial winds on moving to high-res. CAM5
  - Seminar next week

Summary

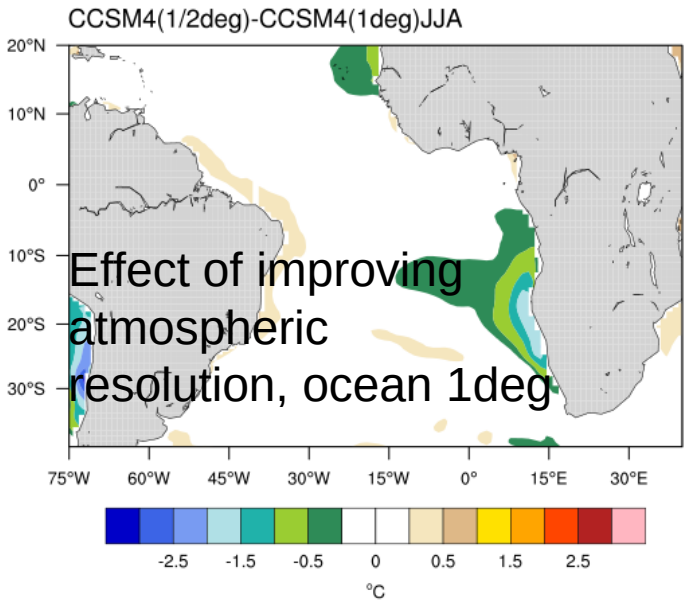
- In CCSM4, largest reduction of south-east Atlantic bias in going from 1deg CAM to 1/2deg CAM
  - Reverses surface currents and increases vertical velocity
  - Using high-res ROMS makes additional, smaller reduction of bias
  - ROMS currents strongly subject to wind stress curl
- Teleconnections from south-east Atlantic to Equatorial Atlantic
  - In NRCM and when restoring CCSM4 to obs. in S-E Atlantic.
  - Can reduces SST bias by more than ½
  - both ocean and ocean-atmosphere-ocean connections

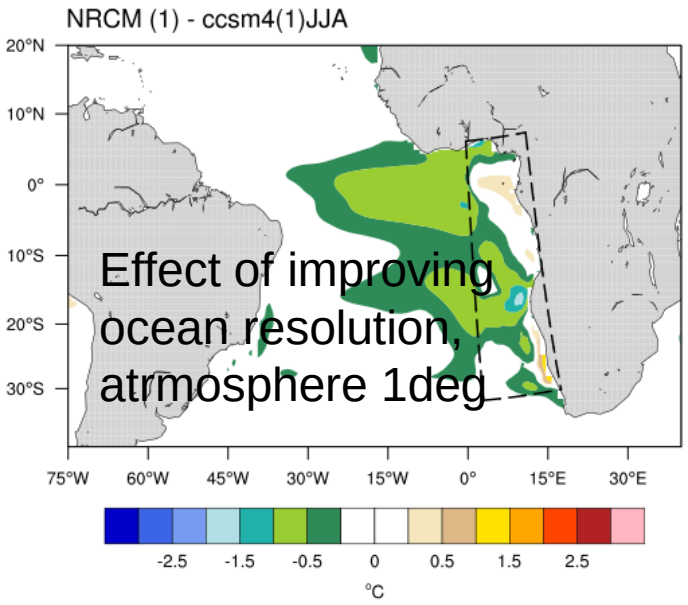
1. Sensitivity of S.E.Atlantic SST to ocean and/or atmosphere resolution.
   - CCSM4 with 1deg. Ocean/atmosphere (long 1850 baseline run). CCSM4-1
   - CCSM4 with 1/2deg. Atmosphere 1deg. Ocean (300+ years 1850 baseline run). Courtesy Christine Shields. CCSM4-0.5
   - NRCM-1 nested ROMS in CCSM4-1
   - NRCM-0.5 nested ROMS in CCSM4-0.5
   - CESM with 1/4deg atmosphere 1/10th deg ocean –different atmos physics (CAM5-SE). CESM-HI

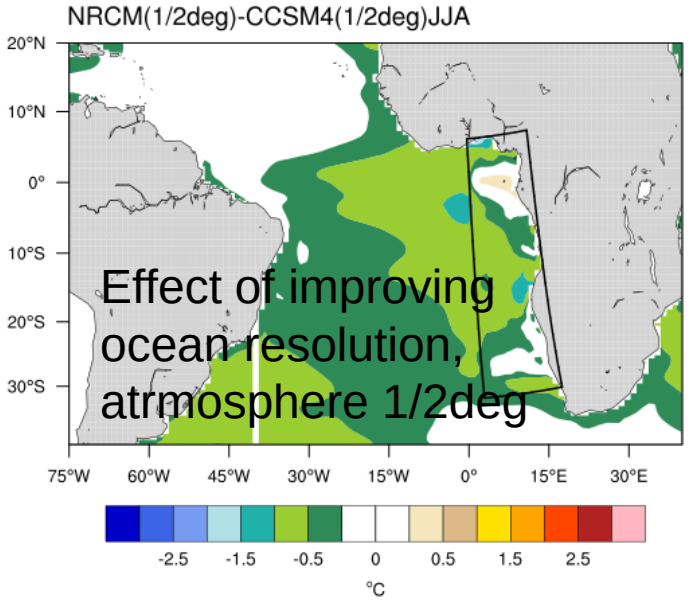


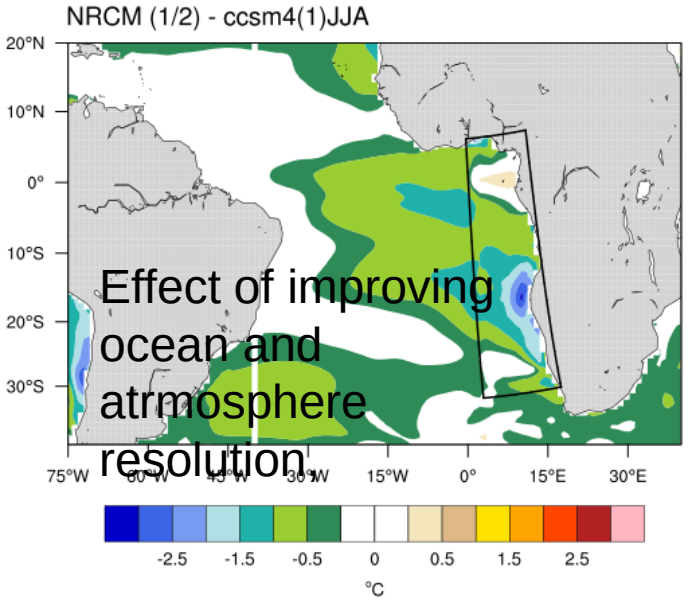


SST bias, CCSM4

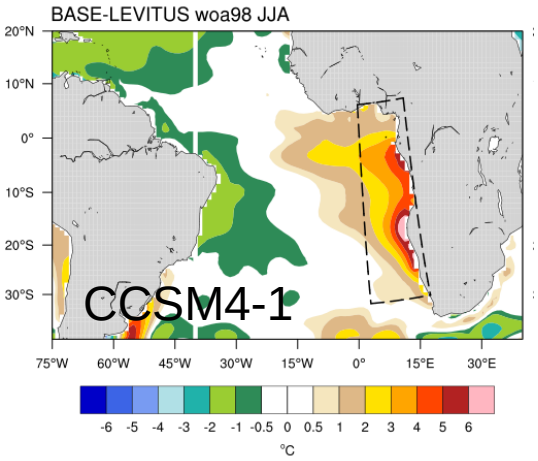


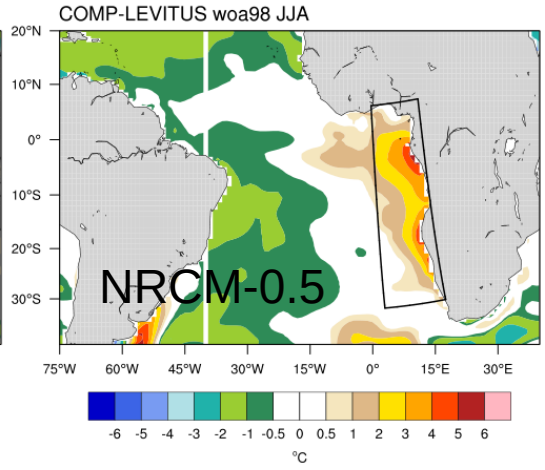




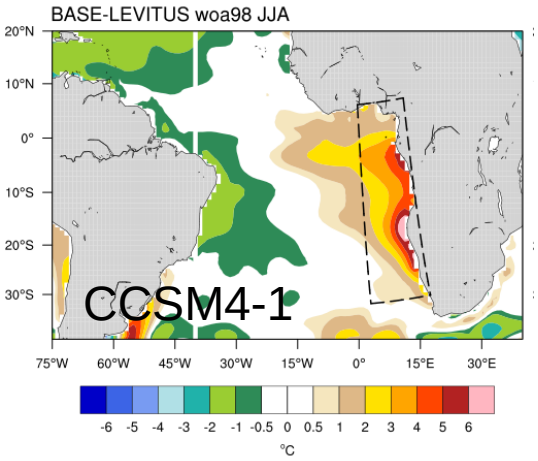


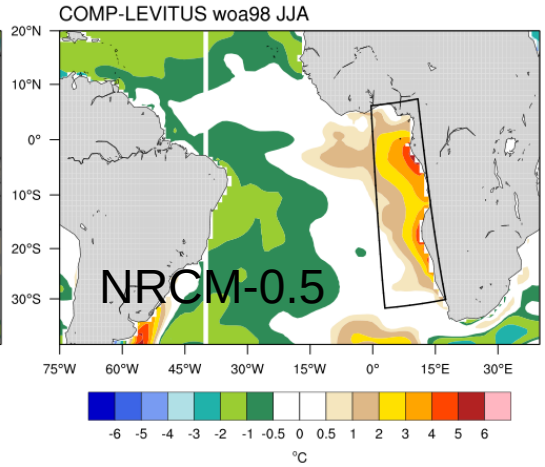
Intermodel differences in SST

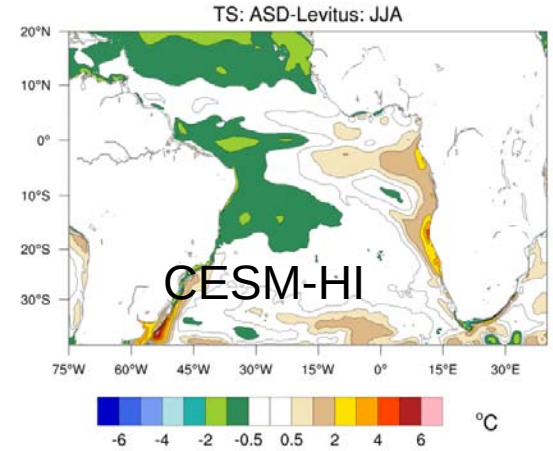

BASE-LEVITUS woa98 JJA
20°N
10°N
0°
10°S
20°S
30°S
CCSM4-1
75°W
60°W
45°W
30°W
15°W
0°
15°E
30°E
-6 -5 -4 -3 -2 -1 -0.5 0 0.5 1 2 3 4 5 6
°C


COMP-LEVITUS woa98 JJA
20°N
10°N
0°
10°S
20°S
30°S
NRCM-0.5
75°W
60°W
45°W
30°W
15°W
0°
15°E
30°E
-6 -5 -4 -3 -2 -1 -0.5 0 0.5 1 2 3 4 5 6
°C

SST bias


BASE-LEVITUS woa98 JJA
20°N
10°N
0°
10°S
20°S
30°S
CCSM4-1
75°W 60°W 45°W 30°W 15°W 0° 15°E 30°E
-6 -5 -4 -3 -2 -1 -0.5 0 0.5 1 2 3 4 5 6
°C


COMP-LEVITUS woa98 JJA
20°N
10°N
0°
10°S
20°S
30°S
NRCM-0.5
75°W 60°W 45°W 30°W 15°W 0° 15°E 30°E
-6 -5 -4 -3 -2 -1 -0.5 0 0.5 1 2 3 4 5 6
°C


TS: ASD-Levitus: JJA
20°N
10°N
0°
10°S
20°S
30°S
CESM-HI
75°W 60°W 45°W 30°W 15°W 0° 15°E 30°E
-6 -4 -2 -0.5 0.5 2 4 6
°C

Focus on south-east Atlantic

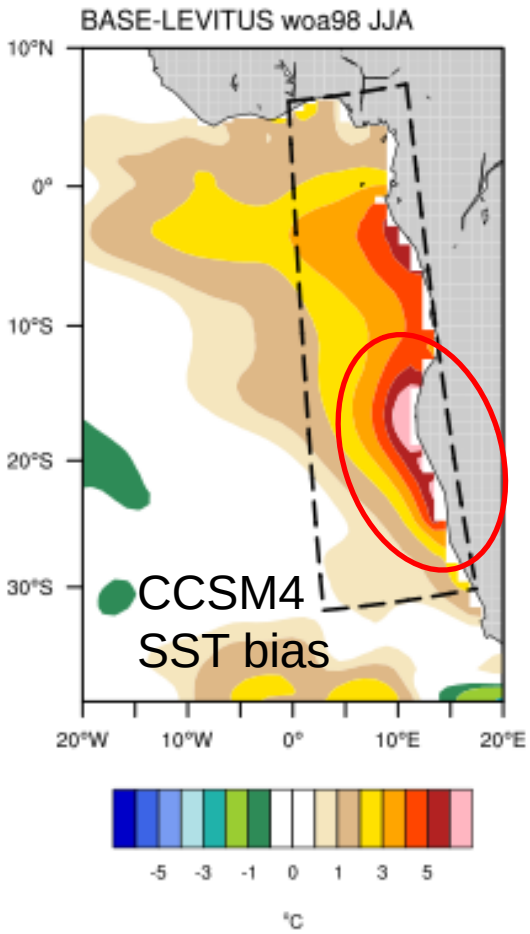
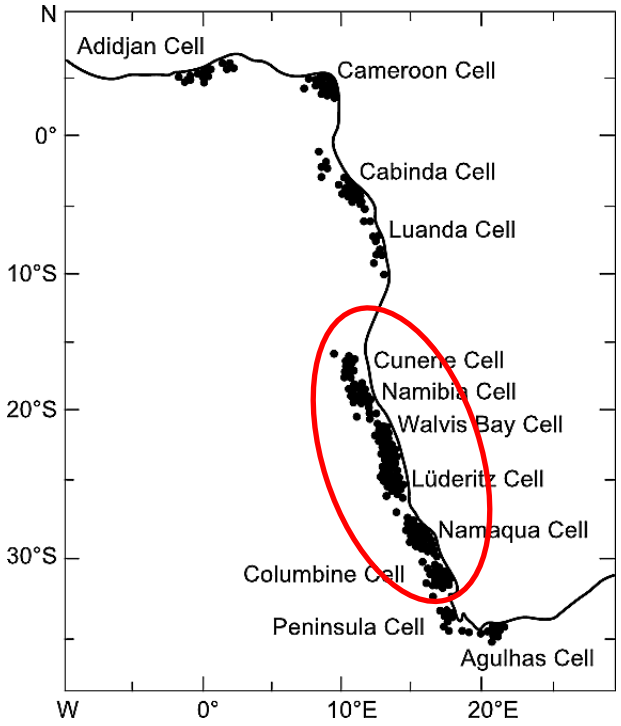


Figure 2. CCSM4 baseline SST biases relative to the: left) Hadley 1 SST dataset years 1982-2008 and: right) Levitus/WOA98 dataset, for summer (JJA). The ROMS domain is shown as a dashed line.



Distribution of the well-defined upwelling regions in the southeast Atlantic Ocean. Each dot represents the center of an upwelling event observed over a period of 156 weeks [after Lutjeharms and Meeuwis, 1987]. From Risien et al 2004., JGR.

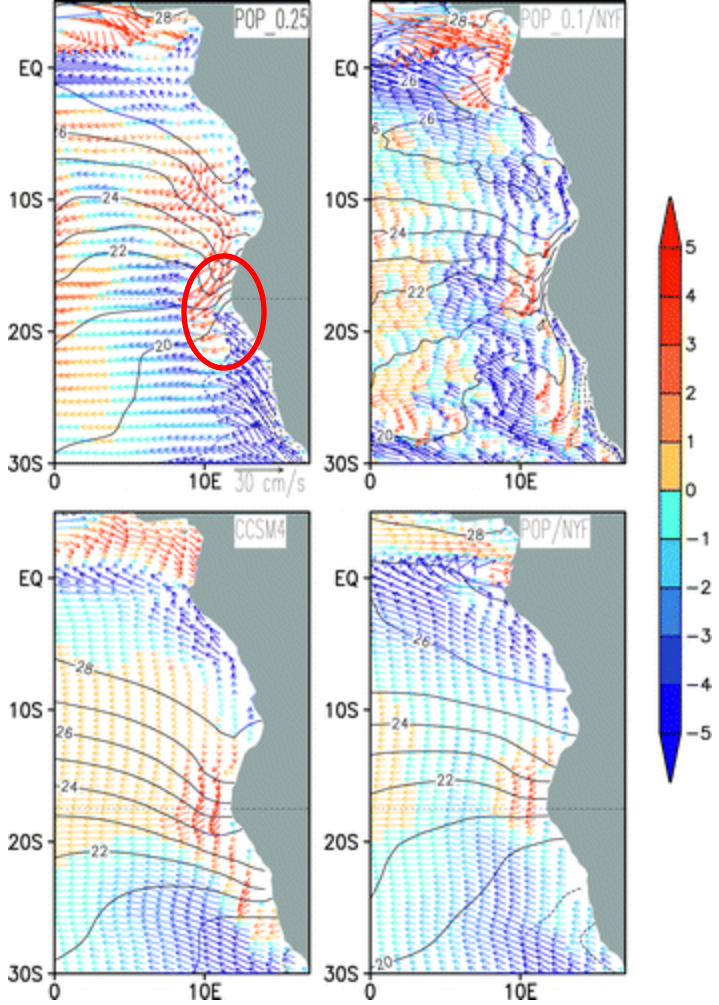


Fig. 9. Annual mean surface currents (arrows) and SST (contours, CINT = 1°C) in (a) POP_0.25, (b) POP_0.1/NYF, (c) CCSM4, and (d) POP/NYF. Northward (southward) currents are blue (red). Dashed line is SST below 20°C. Horizontal dashed line is the annual mean latitude of the AFB.

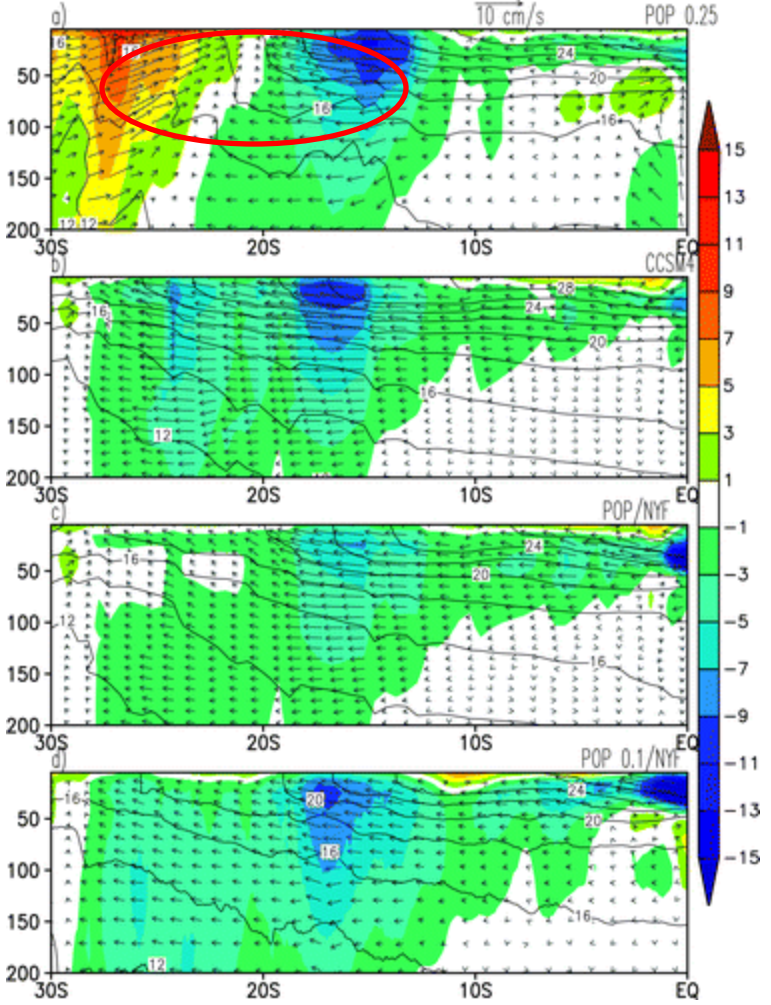
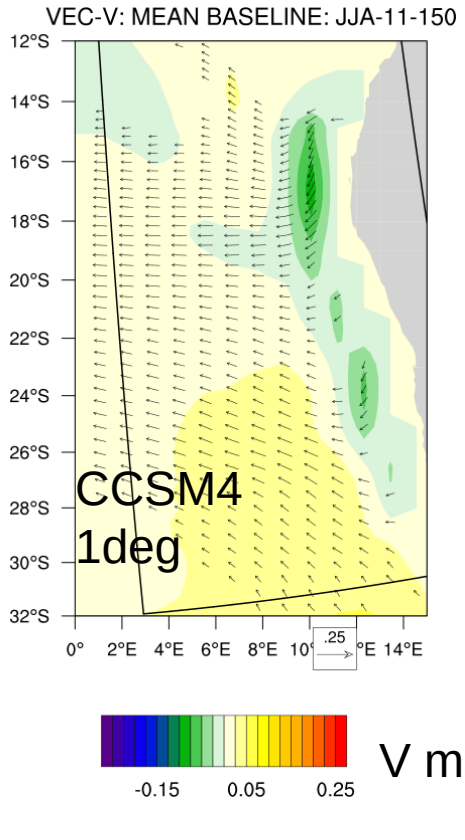
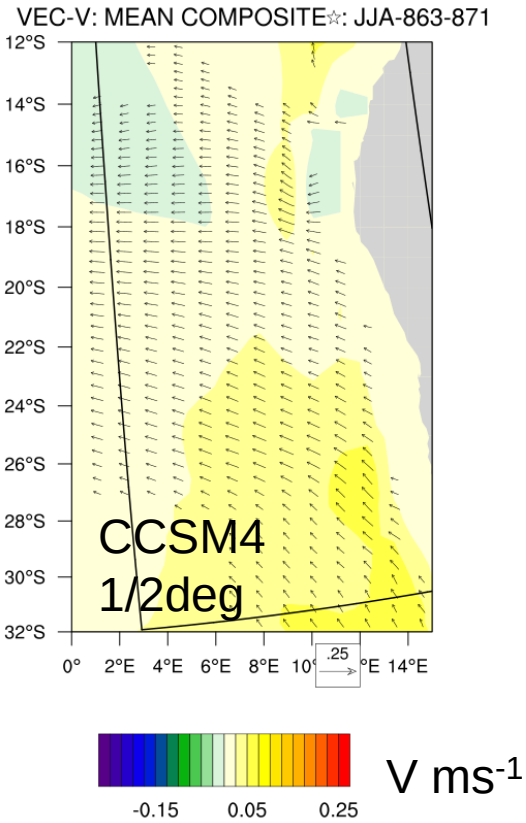


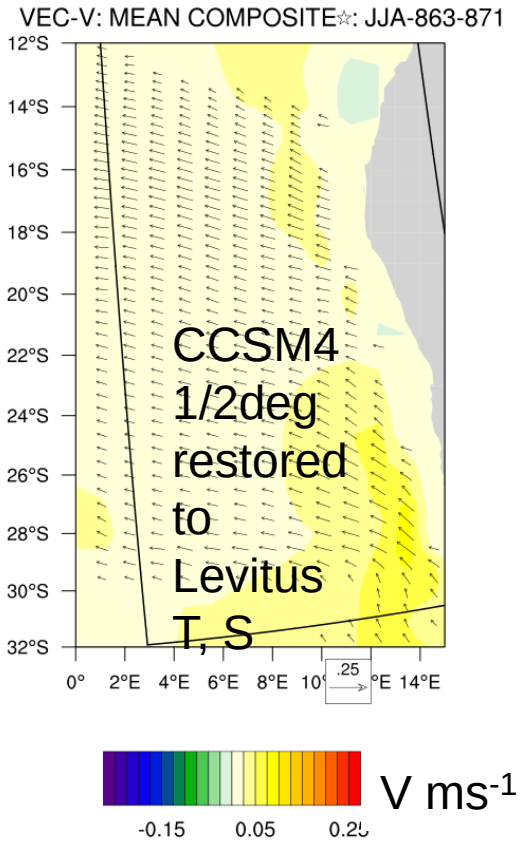
Fig. 10. Annual mean meridional currents (shading), water temperature (contours), and meridional and vertical currents (arrows) averaged 2° off the coast. See Table 1 for description of runs. Arrow scale represents meridional currents. Vertical currents are magnified. Annual mean latitude of the ABF is marked by dashed line.

Fig. 6. From Grodsky et al 2012 (JCLI, CCSM special collection). The authors believe that good representation of the Angola/Benguela currents and their confluence at Angola Front (circled) is important to reduce SST bias. POP 0.25 is, I believe, the SODA product.

Ocean surface currents



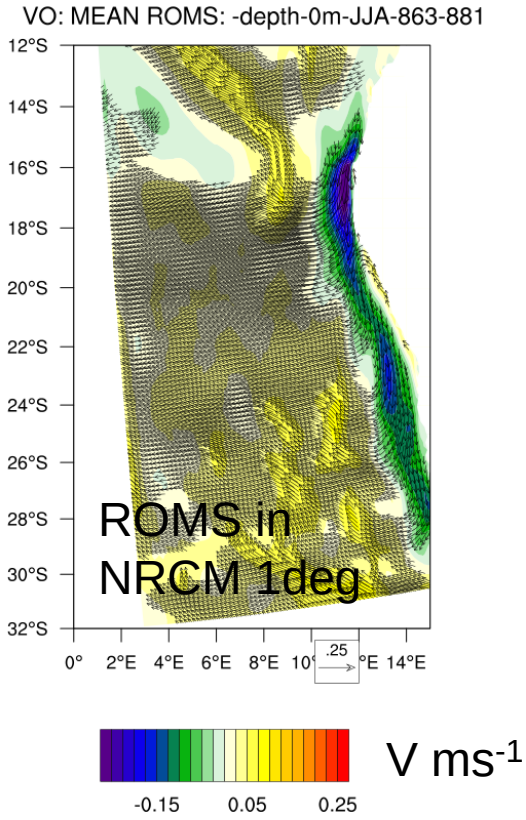


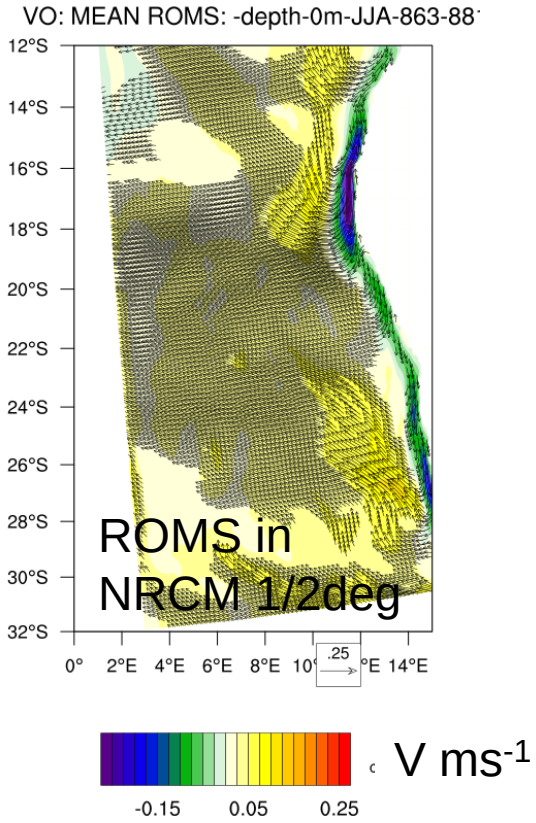


Vectors of climatological-mean surface current (JJA) overlaid on meridional current (V)

Using 1/2deg CAM reverses sign of flow off coast in S-E Atlantic.

Ocean surface currents

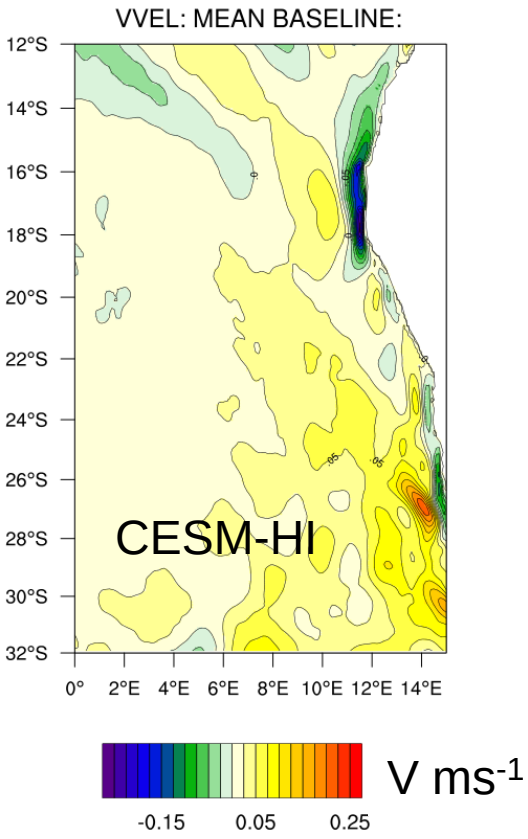




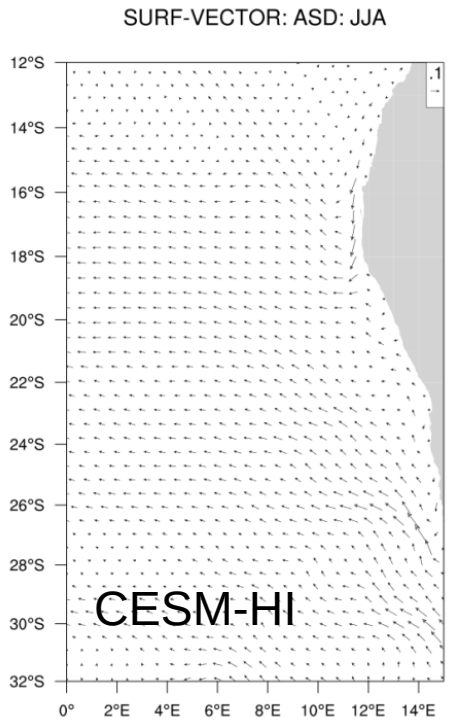
Vectors of climatological-mean surface current (JJA) overlaid on meridional current (V)

ROMS has strong southward current near coast, gets weaker with 1/2deg CAM.

Ocean surface currents



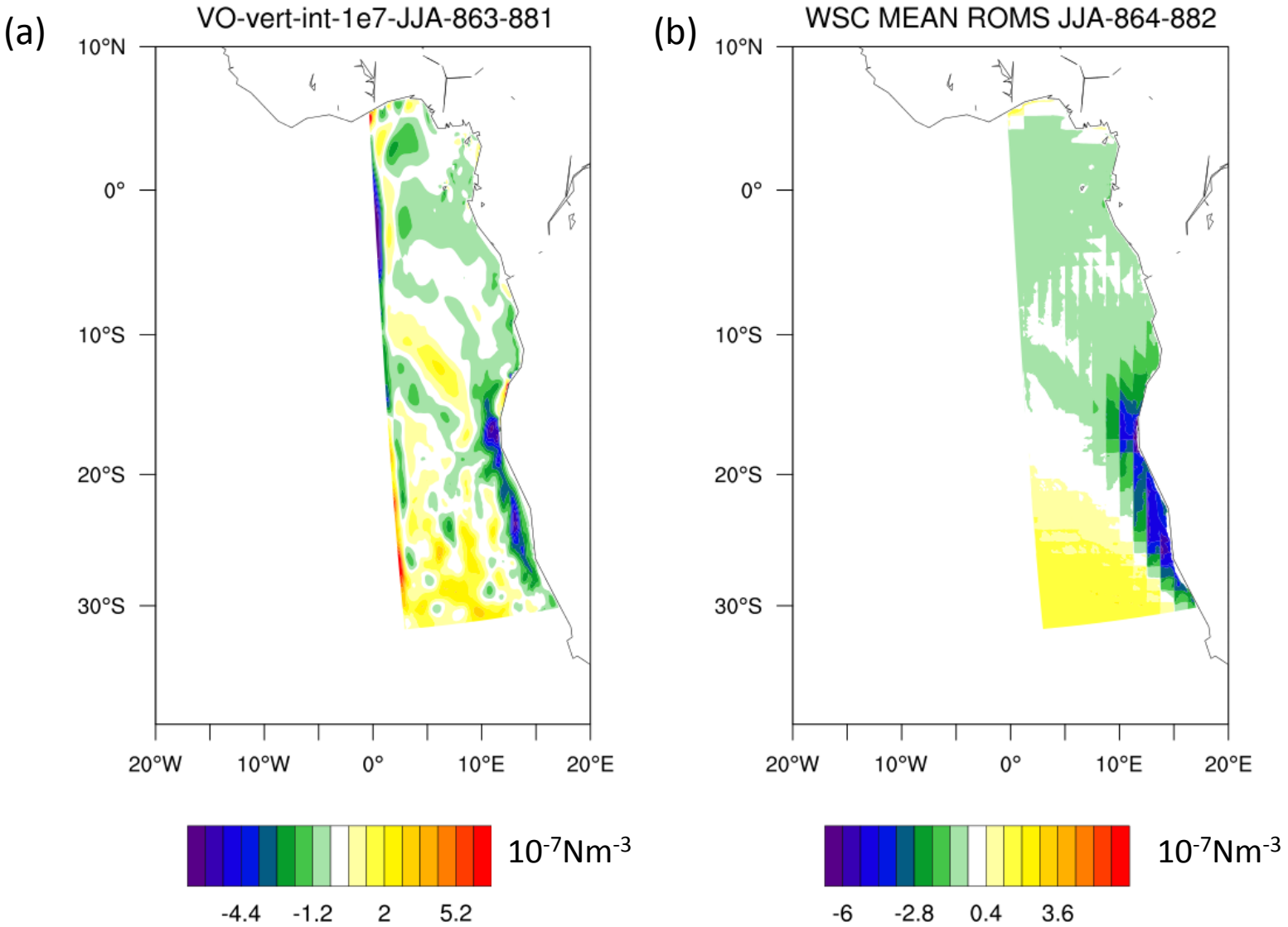
Climatological mean meridional current (V)



Vectors of climatological-mean surface current (JJA)

CESM-HI also has southward flow, not as strong or extensive as ROMS

Sverdrup balance (ROMS)

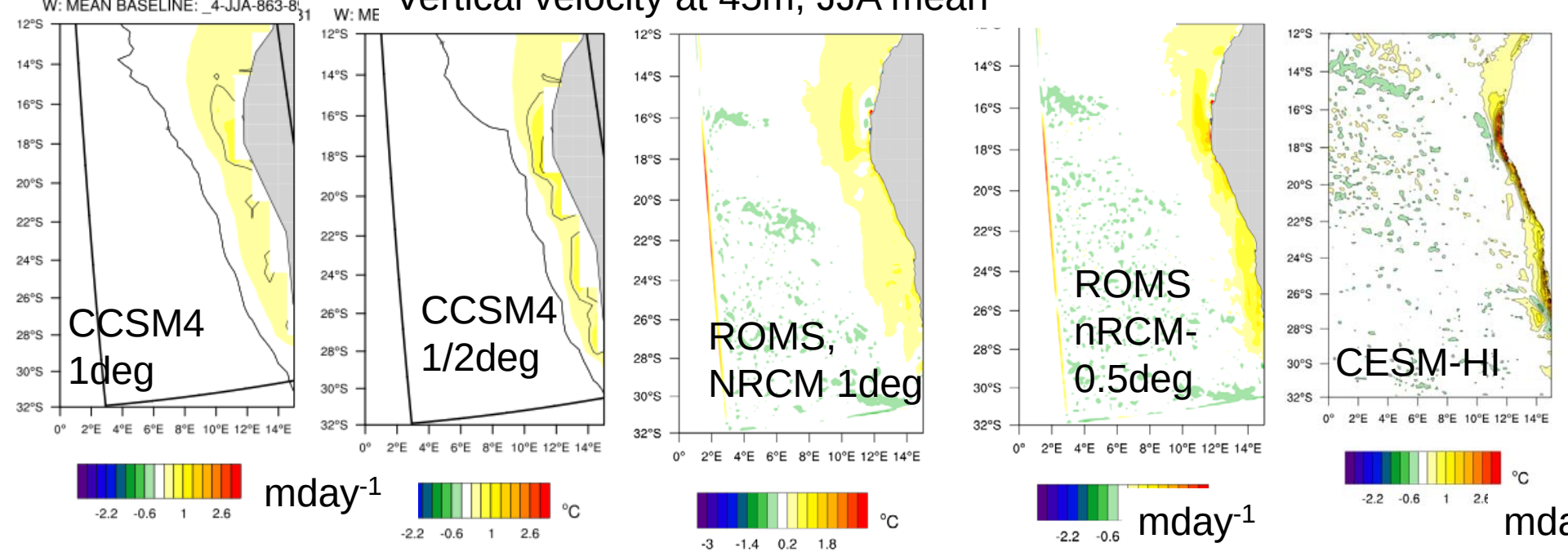


Terms of Sverdrup balance (1) from ROMS (Nrcm), 20 years of JJA average. A) LHS (~ vertical integral of meridional velocity) b) RHS: curl of wind stress. Color bar and units are same for both panels.

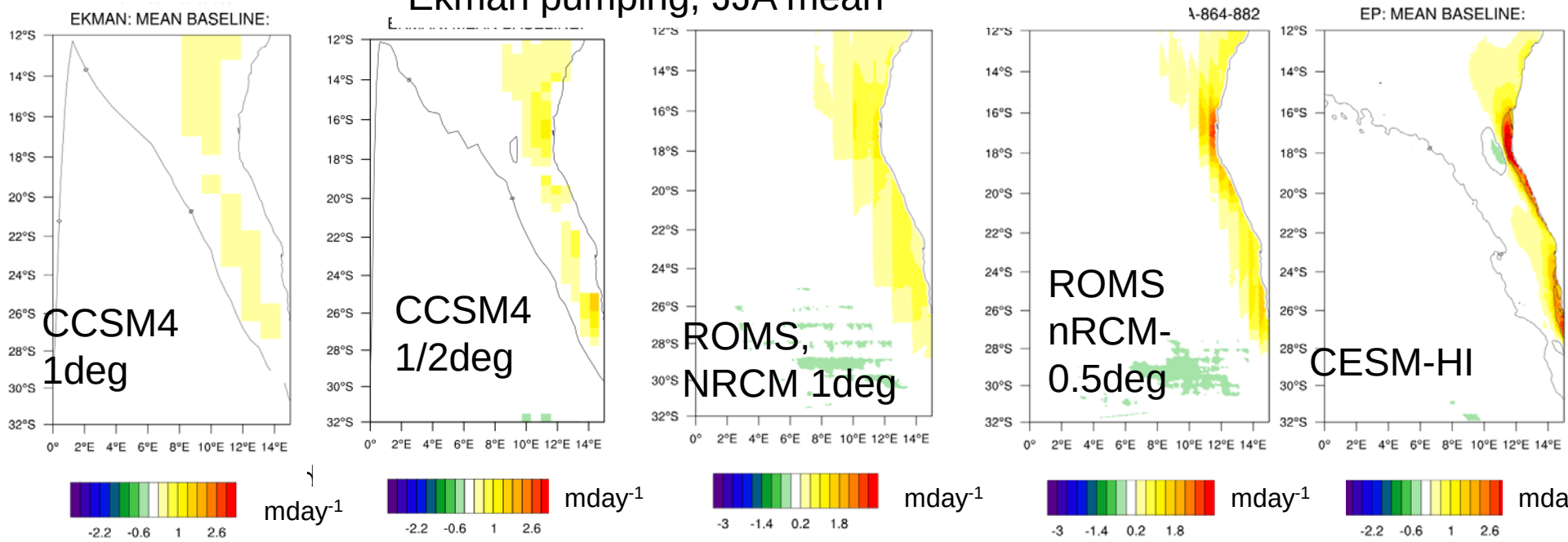
Ocean upwelling

Upwelling velocities increase as we go from CCSM4-1 to CCSM4-0.5 then to ROMS in NRCM. Maximum in CESM-HI.

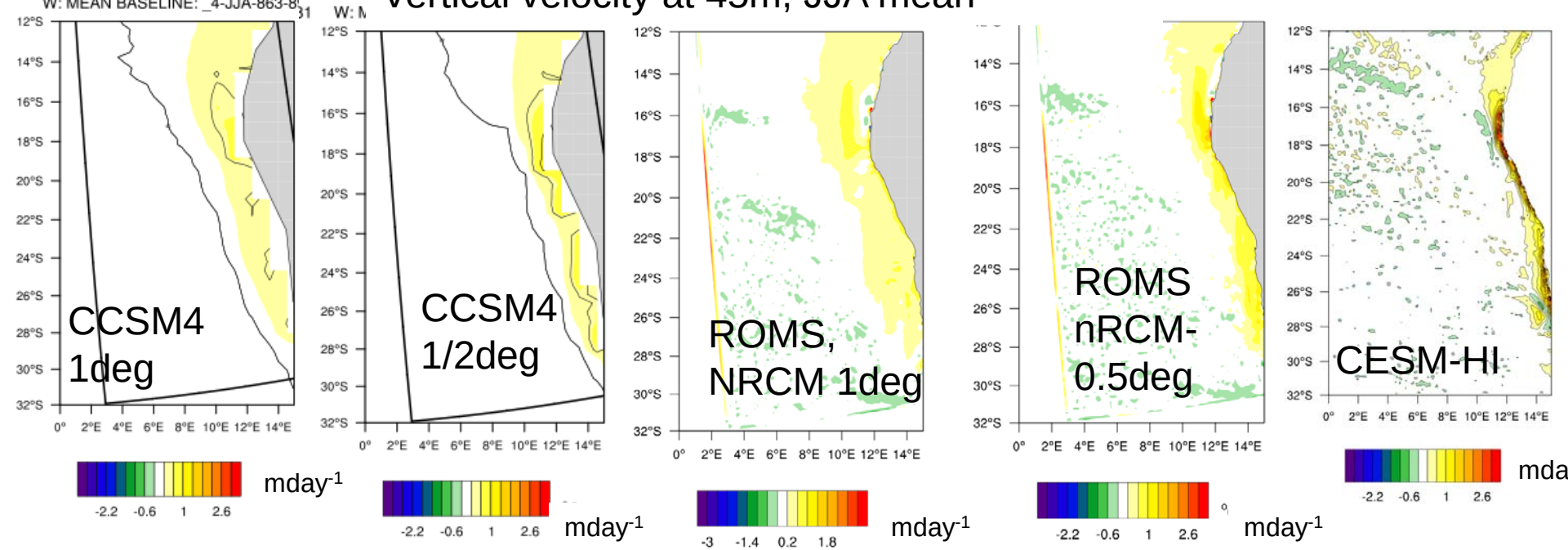
Vertical velocity at 45m, JJA mean



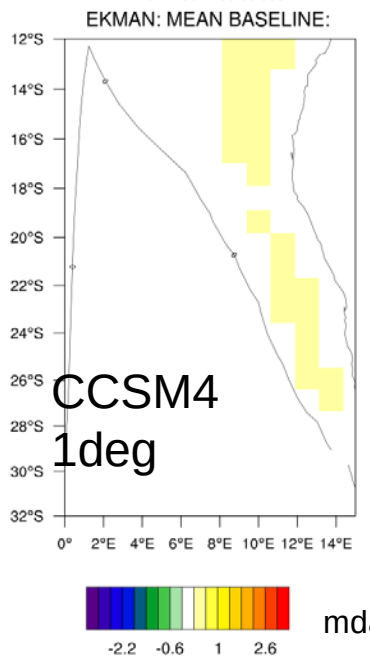
Ekman pumping, JJA mean



Vertical velocity at 45m, JJA mean

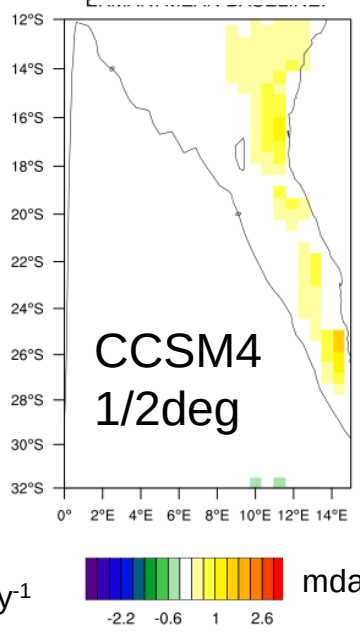


Ekman pumping, JJA mean



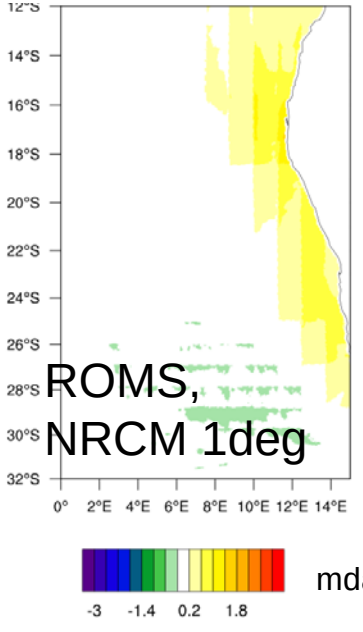
CCSM4 1deg

$mday^{-1}$



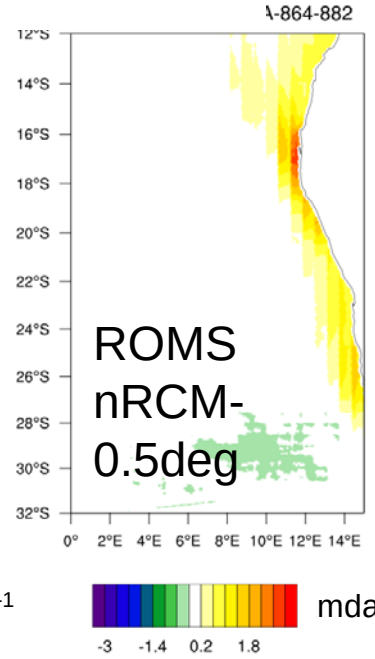
CCSM4 1/2deg

$mday^{-1}$



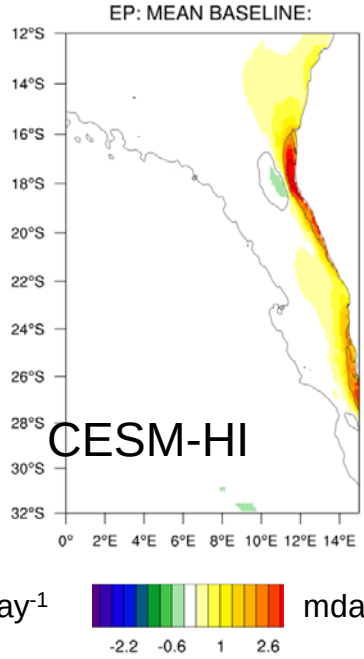
ROMS, NRCM 1deg

$mday^{-1}$



ROMS nRCM-0.5deg

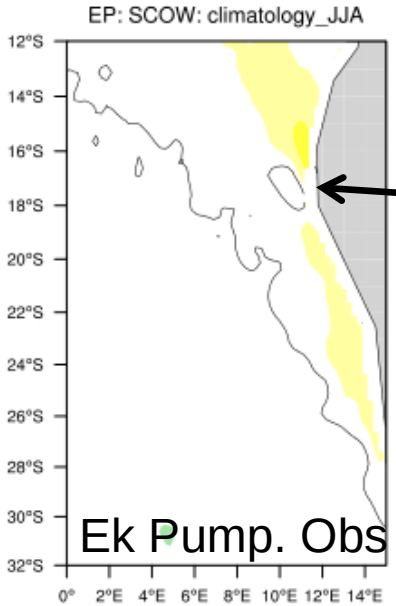
$mday^{-1}$



CESM-HI

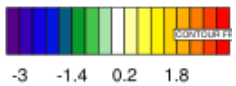
mda

QuiKSCAT climatology. Risien and Chelton 2008



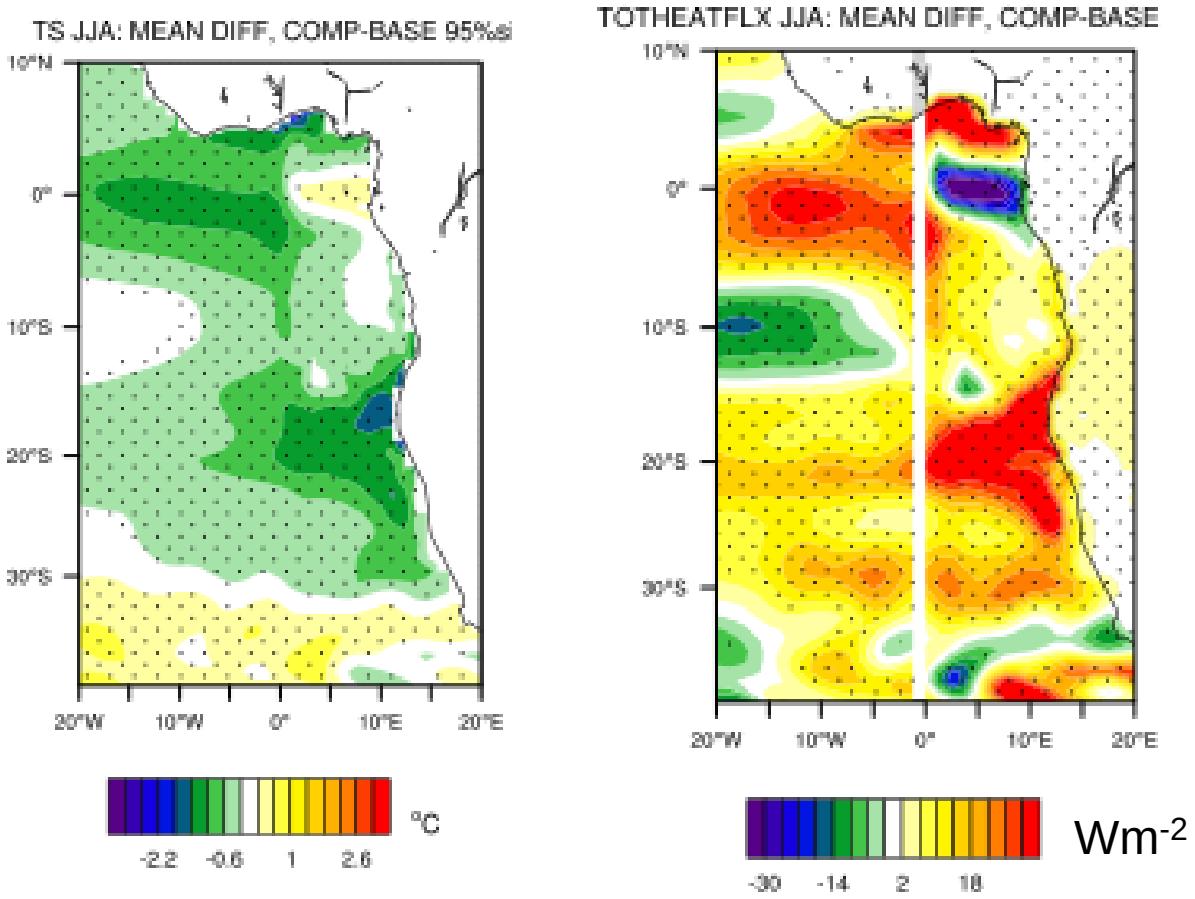
Ek Pump. Obs

No data within 50km of coast



$mday^{-1}$

Ocean-atmosphere feedback



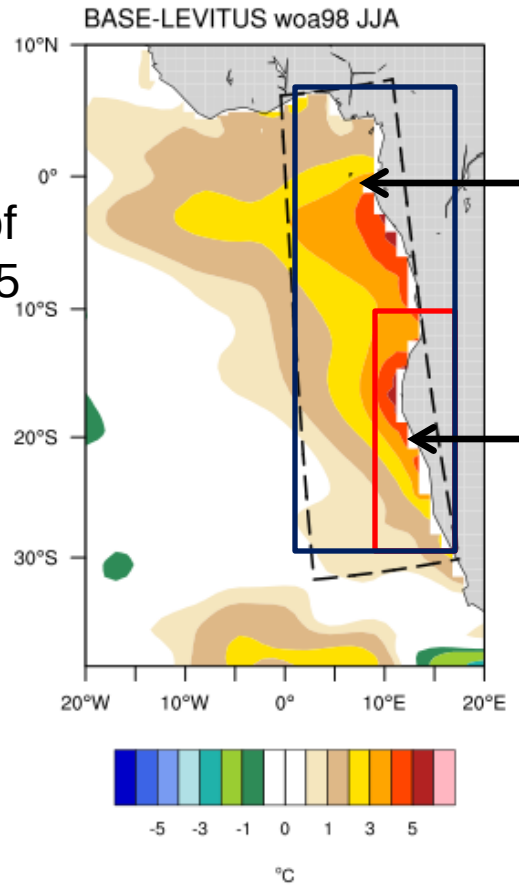
Left panel: SST difference, NRCM-1 minus CCSM4-1. Right panel: net surface heat flux difference, positive values imply warming of ocean.
(From an earlier version of NRCM-1.)

damping of SST signal.

2. Teleconnections from S.E.Atlantic to Equatorial Atlantic (& beyond?)

CCSM4-0.5 with T&S restoring in S. E. Atlantic
Looks at effect of correcting errors due to ocean processes, stratus, etc.

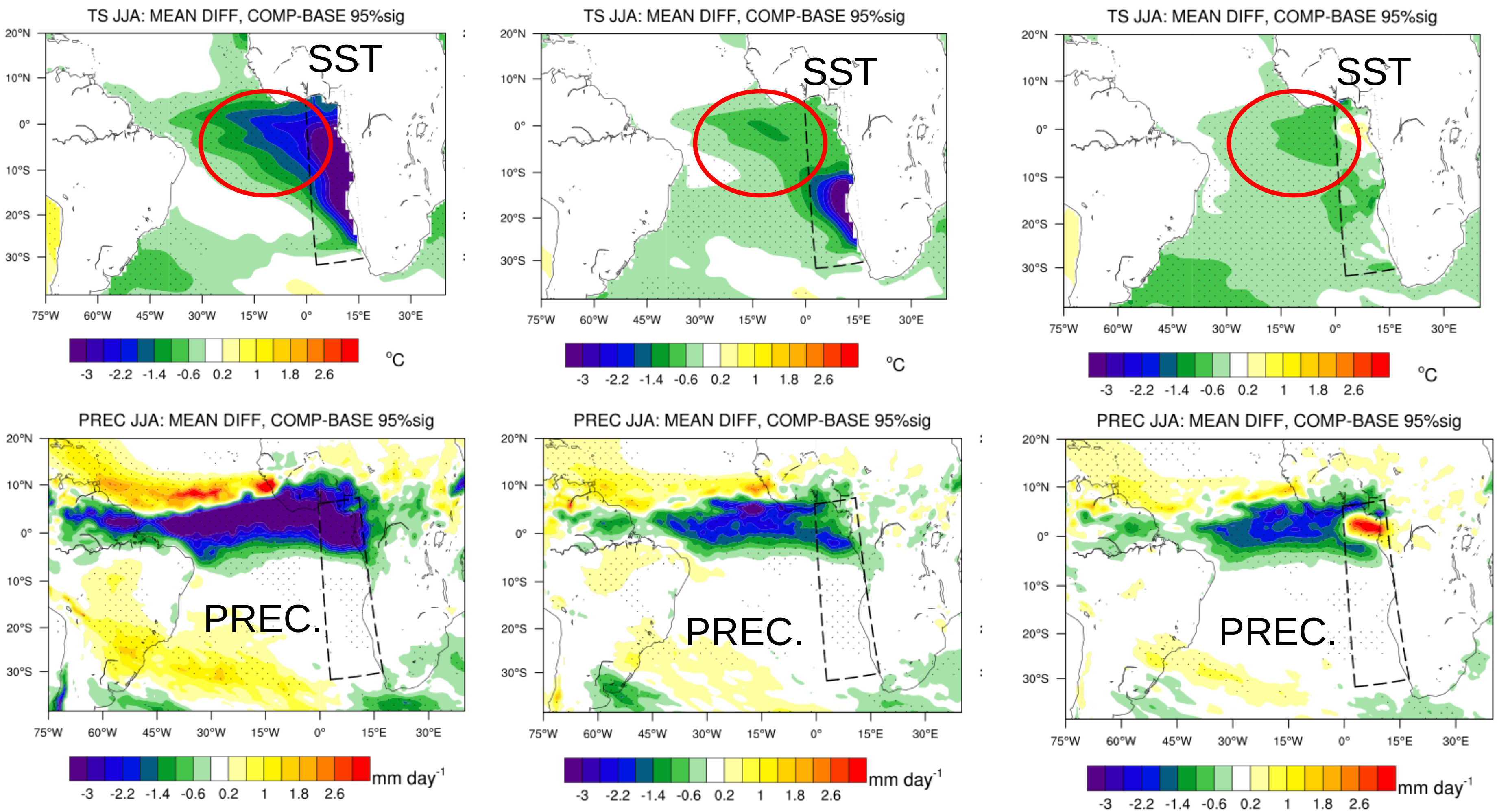
SST bias of CCSM4-0.5 (JJA)



Large domain to mimic ROMS domain and Large and Danabasoglu 2006

Small domain to isolate effect of South-east Atlantic

Effect of restoring



Large domain

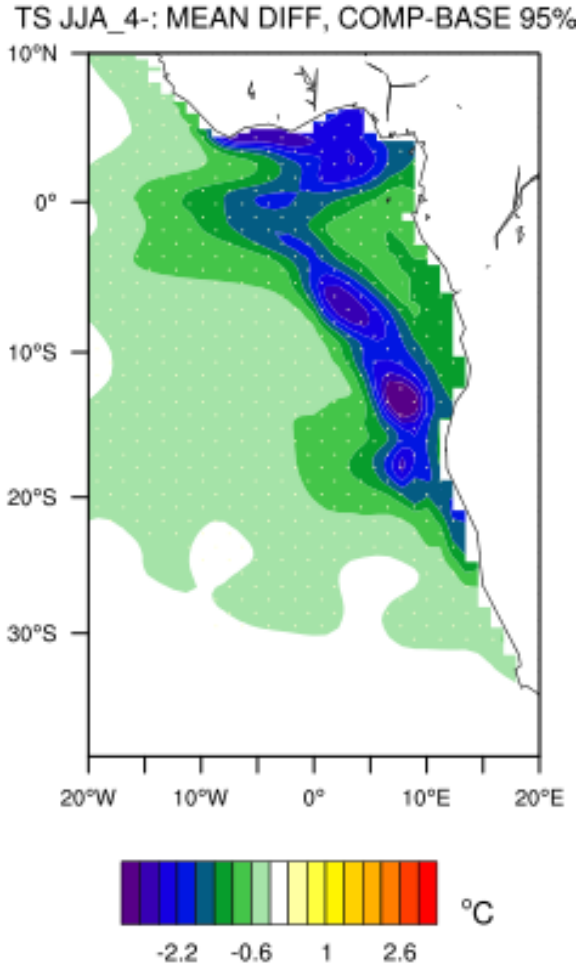
Small domain

NRCM-0.5 for comparison

Plots show differences from CCSM4-0.5 baseline, for JJA.

Original bias in circled region is 1degC to 3degC.

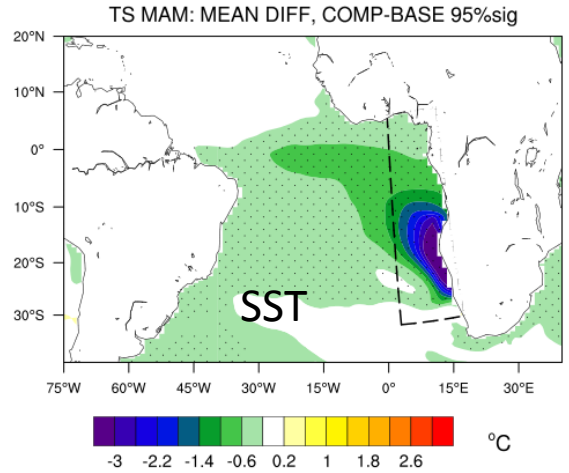
Ocean teleconnection

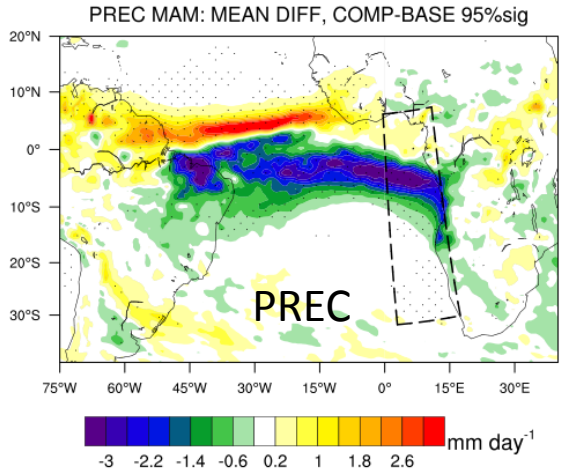


Ocean temperature difference at 45m between NRCM-1 and CCSM4-1

See also Large and Danabasoglu 2006

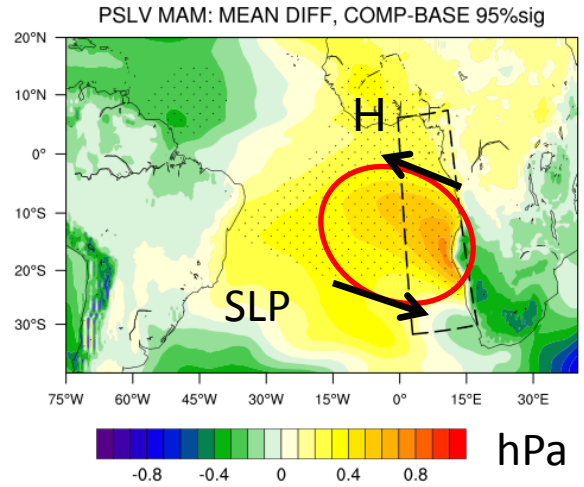
Atmos-ocean teleconnection

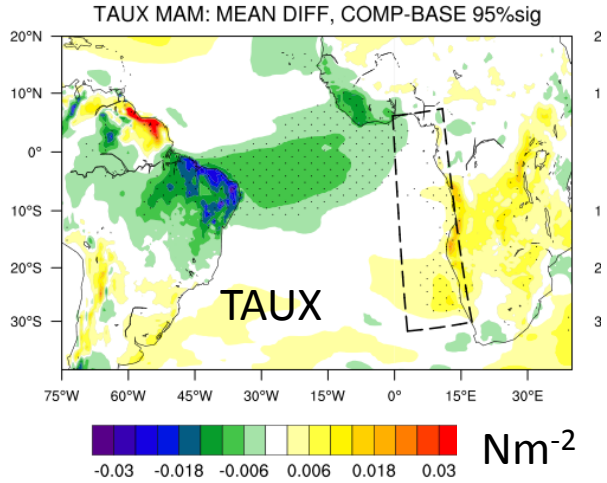


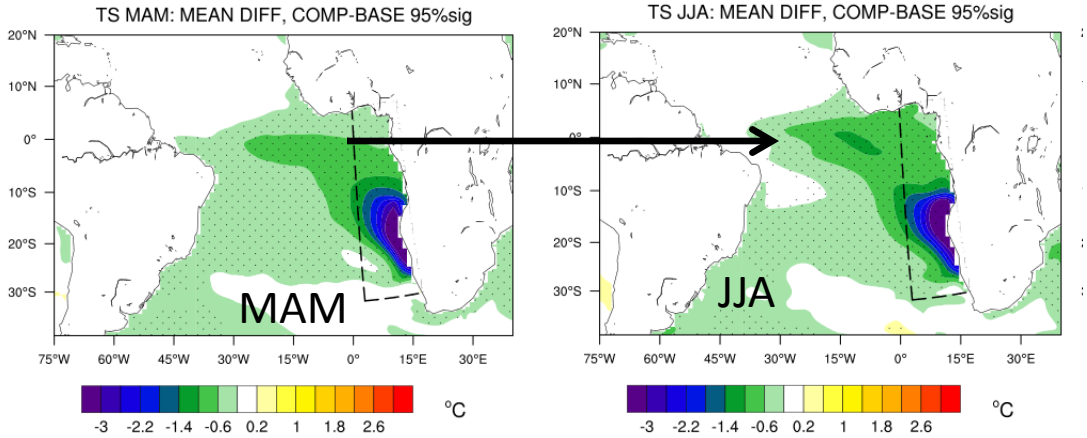


Small domain: response of sea level pressure, wind stress and precip. to restoring of T, S. Boreal spring MAM

Qualitatively similar process seen in Nrcm runs and large domain restoring run.







Panels at left: seasonal evolution of SST difference MAM to JJA

CCSM4 bias

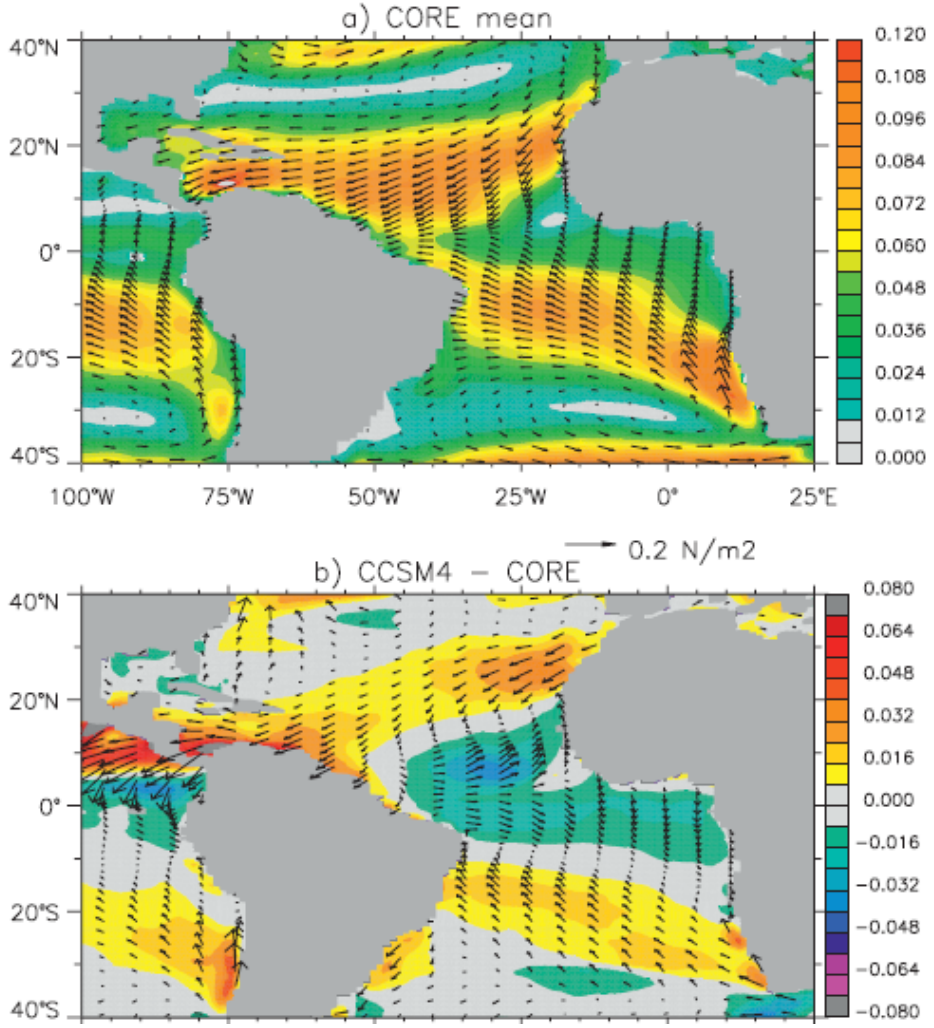


FIG. 1. (top) Total mean CORE-based wind stress derived for the period 1980–2005. Model- minus CORE-based difference for (middle) CCSM4 and (bottom) CCSM3. Period used for each model is explained in the text. Shading indicates wind stress magnitude, and vectors indicate the direction. Units are N m^{-2}.

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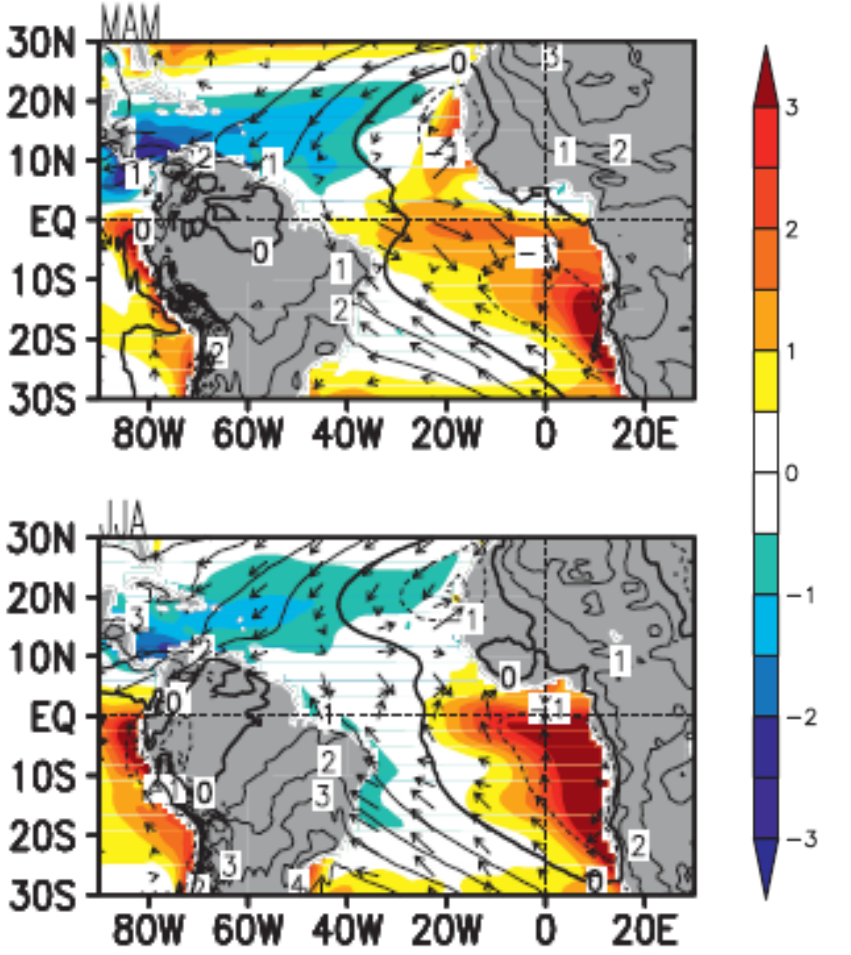

FIG. 4. Bias in SST (°C, shading) and MSLP (mbar, contours) during (top to bottom) four seasons. (left) CCSM4 data. (right) Data from two independent runs: SST is from a stand-alone ocean model forced by NYF (POP/NYF) and MSLP is from a stand-alone atmospheric model forced by observed SST (CAM4/AMIP). Arrows are the surface wind bias in (left) CCSM4 and (right) CAM4/AMIP.

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Way ahead

- Heat budgets in S.-E. Atlantic region to look at relative contributions of horizontal advection, upwelling, mixing & eddies to model-differences in SST
- More investigation of wind stress curl issue
  - Would ROMS do better if less curl?
  - Nudging CAM?
- Investigation of Teleconnections to Equator, perhaps in stand-alone ocean and atmosphere mode
- Effect of improvements in mean state on Atlantic variability
- Investigate behavior of CAM5 -1/4deg stand-alone, coupled to 1/10deg ocean and to 1deg ocean

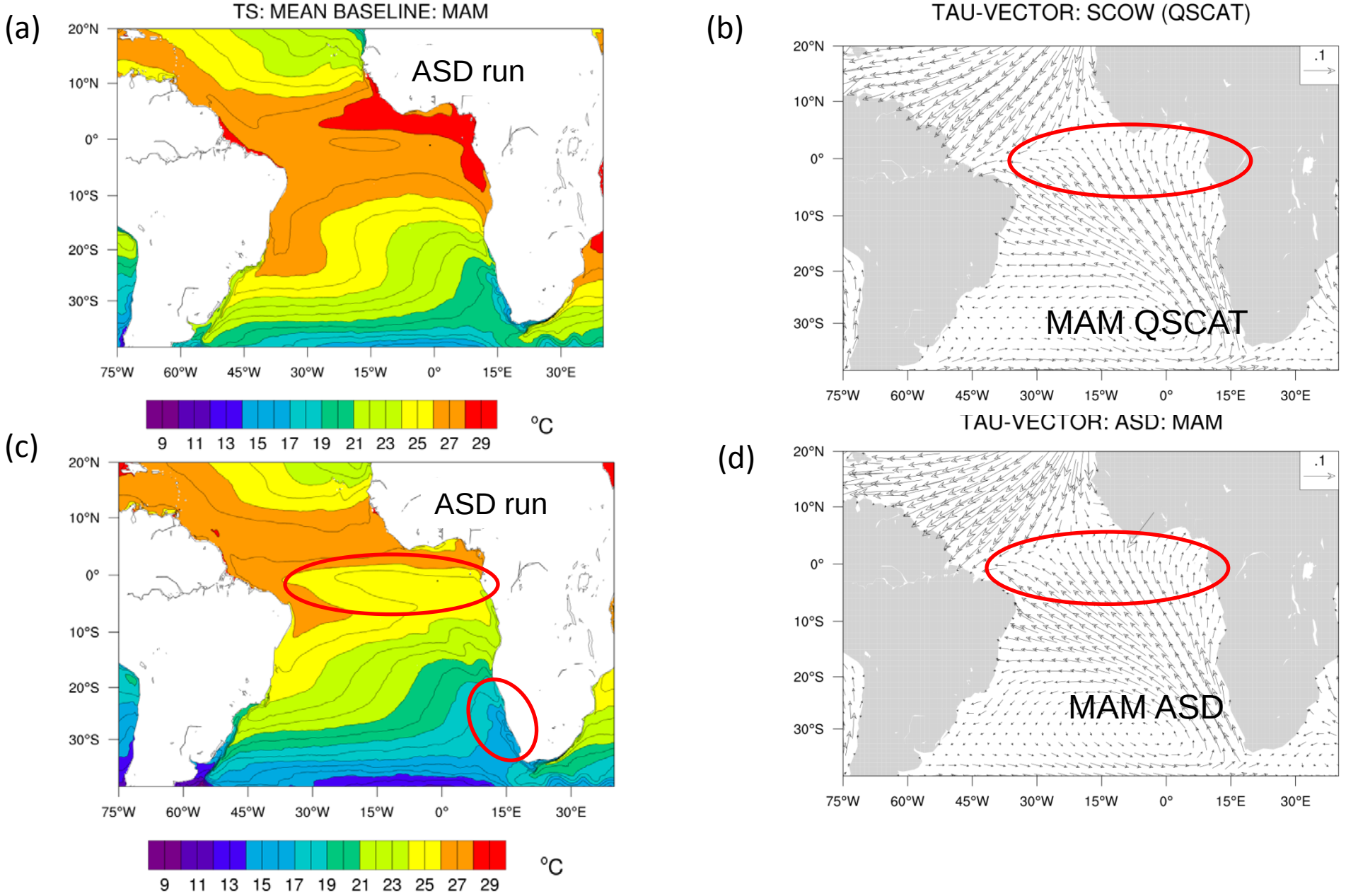

Fig. 10. Climatological Mean SST from ASD run (yr 1-42 of hybrid) in a) March-April-May (MAM) and c) JJA. Corresponding climatological mean wind stress vectors (Nm^{-2}) in MAM from b) QuikSCAT observations, Risien and Chelton 2008 and c) ASD run.

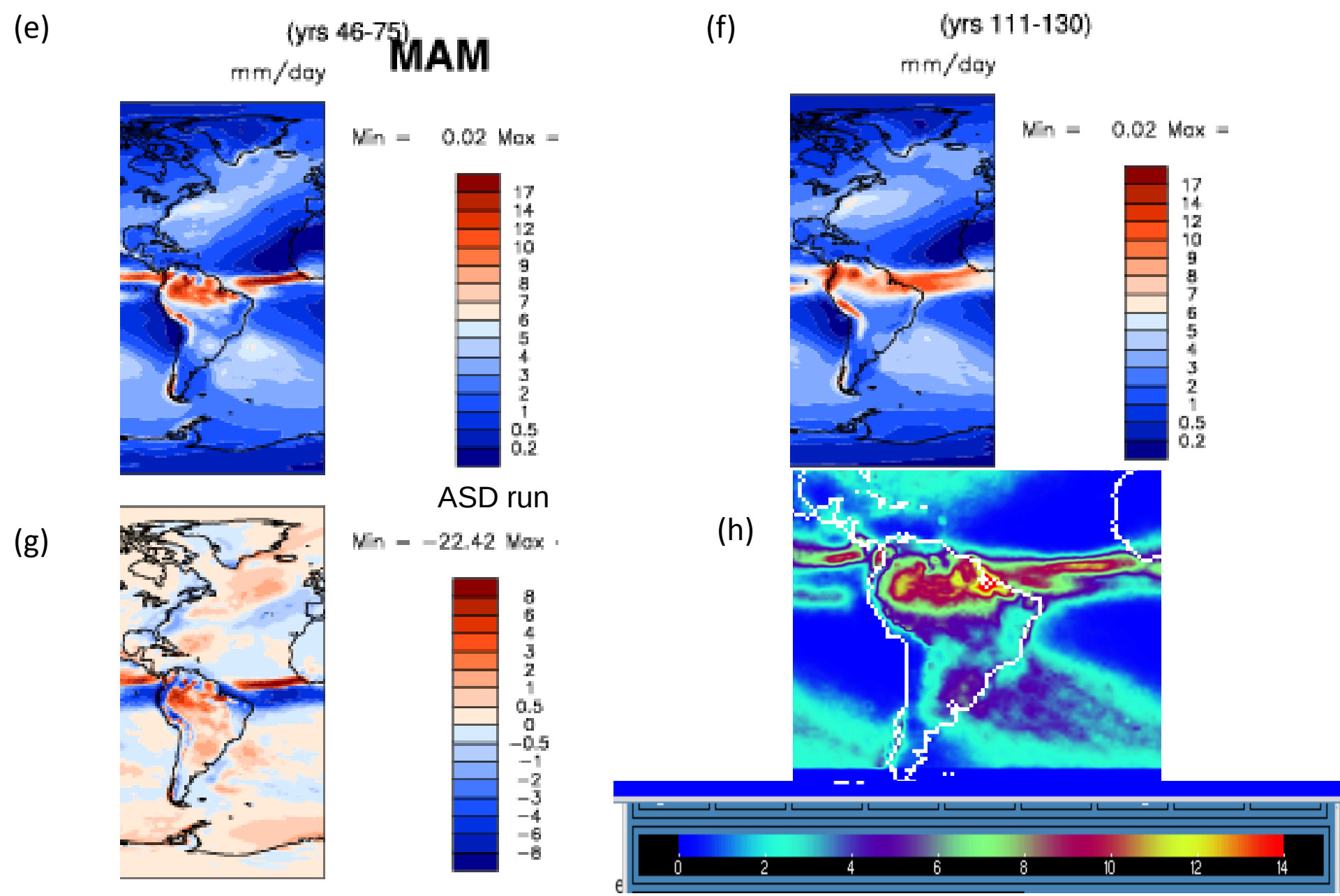

Fig. 10 continued. e,f) Climatological Precipitation in MAM for the e) ASD run and f) the 1850 CESM ne30 run. g) Difference in Climatological Precipitation in MAM between ASD run and CESM ne30 1850 run. h) MAM precipitation from the TRMM 3b42 product.