High-resolution Ocean-ice simulations forced by CORE vs JRA55: Eastern boundary upwelling

Sensitivity to ocean resolution

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NCAR
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Charles Stock, Steve Griffies
NOAA GFDL

Winds: CORE vs JRA-55-gogo

- CORE forcing
  - Winds based on NCEP/NCAR reanalysis,T62, ~1.8deg.
  - Large and Yeager 2004, 2009
  - wind speed & direction corrected towards QuikSCAT annual climatology
  - 6 hourly data
- JRA55v0.8 forcing (JRA-gogo)
  - Winds based on JRA55 reanalysis, TL319, ~0.56deg
  - Hiroyuki Tsujino et al. (2016, pers. comm.)
  - winds corrected towards QuikSCAT annual climatology
  - 3 hourly data

Summary of the adjustment method for v0.7

red: change from v0.3

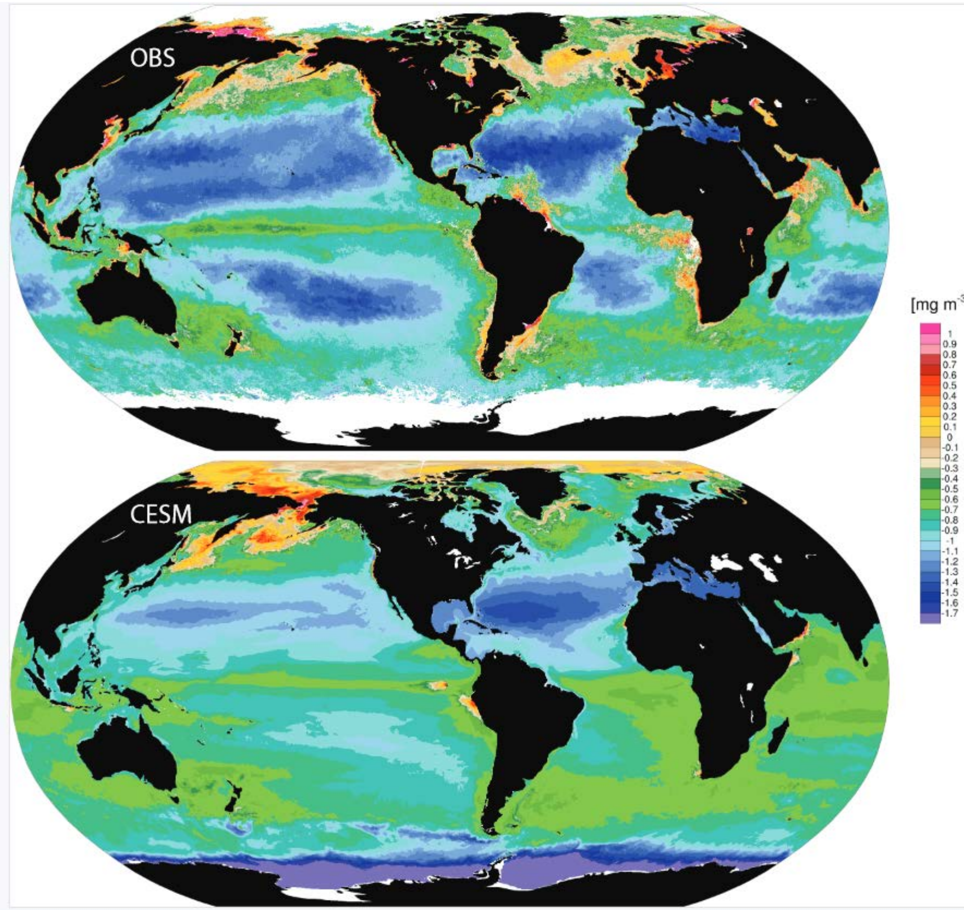
	reference data	availablity for deriving adj factor	time dependency	spatial dependency	How is the factor used
short wave	adjusted CERES	2000-2015	monthly	(x,y) & constant	multiply
long wave	adjusted CERES	2000-2015	monthly	(x,y) & constant	multiply
precipitation	CORE	1979-2009	monthly	(x,y) & constant	multiply
air temperature	JRA55-anl_surf& IABP-NPOLES	1958-2015 1979-1998 (over sea ice)	monthly	(x,y)	offset
specific humidity	JRA55-anl_surf&	1958-2015	monthly	(x,y)	multiply
wind speed	QuikSCAT* SSMI# JRA55-anl_surf&	1999-2009 1988-1998 (to fill data gap)	annual	(x,y)	multiply
wind angle	QuikSCAT* JRA55-anl_surf&	1999-2009 (to fill data gap)	annual	(x,y)	offset

(*) Remote Sensing Systems 0.25 x 0.25 data set version 4
(#) Remote Sensing Systems wind speed product version 7
(&) JRA55 anl_surf adjusted to ERA-Interim in the period 2002-2015

Courtesy Hiroyuki Tsujino (JMA).

Why do we care about the eastern boundary upwelling?

- Recent high-resolution ocean-biogeochemistry simulations with the Community Earth System Model show low chlorophyll productivity in the eastern boundaries (right: bottom) compared to observations (right, top). As the model was forced by CORE, one of the factors governing this bias might be the weak upwelling.
- Figure shows chlorophyll productivity on log10 scale
- courtesy Matt Long



Basic features of wind fields

- Provided by Fernando Gonzalez Taboada

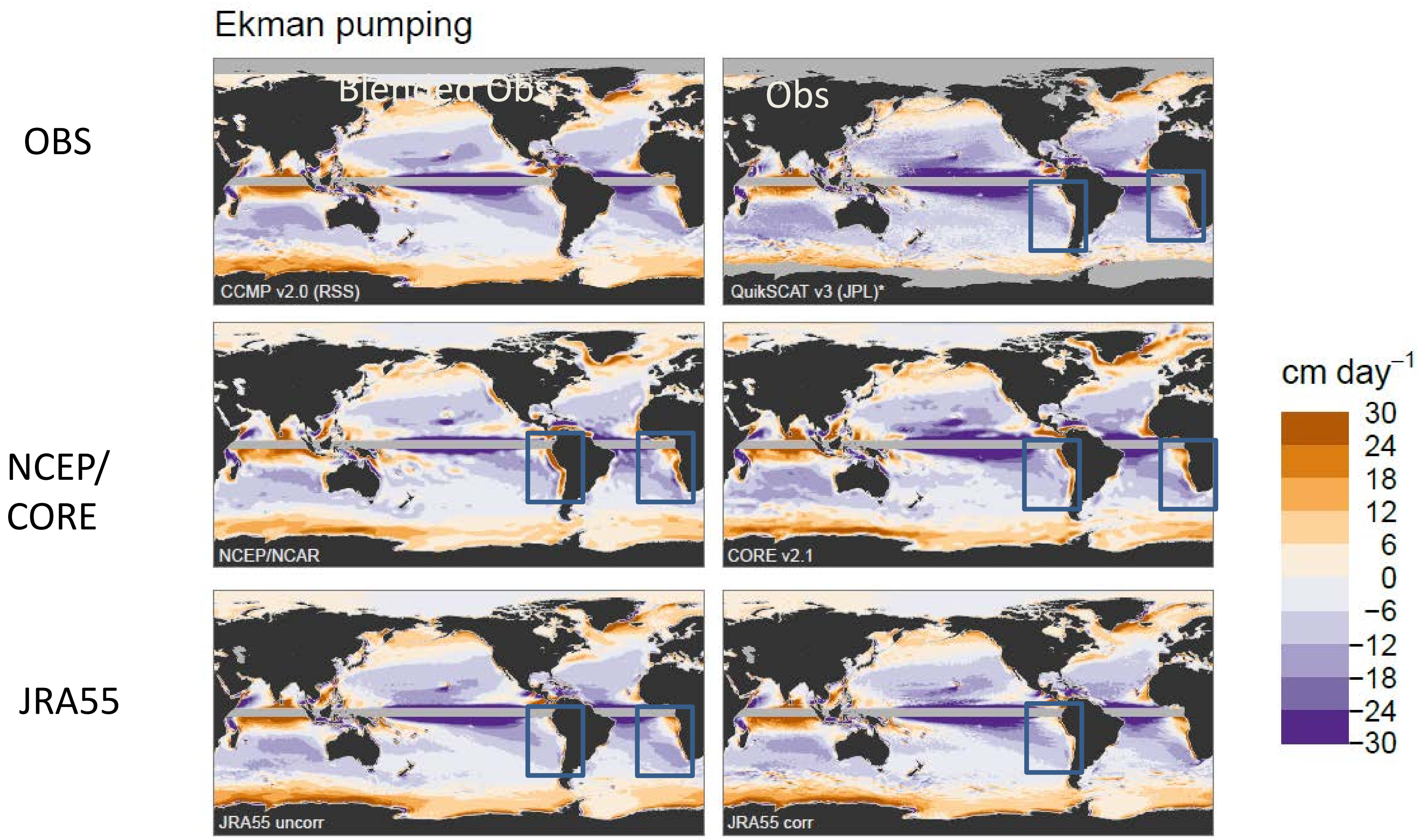
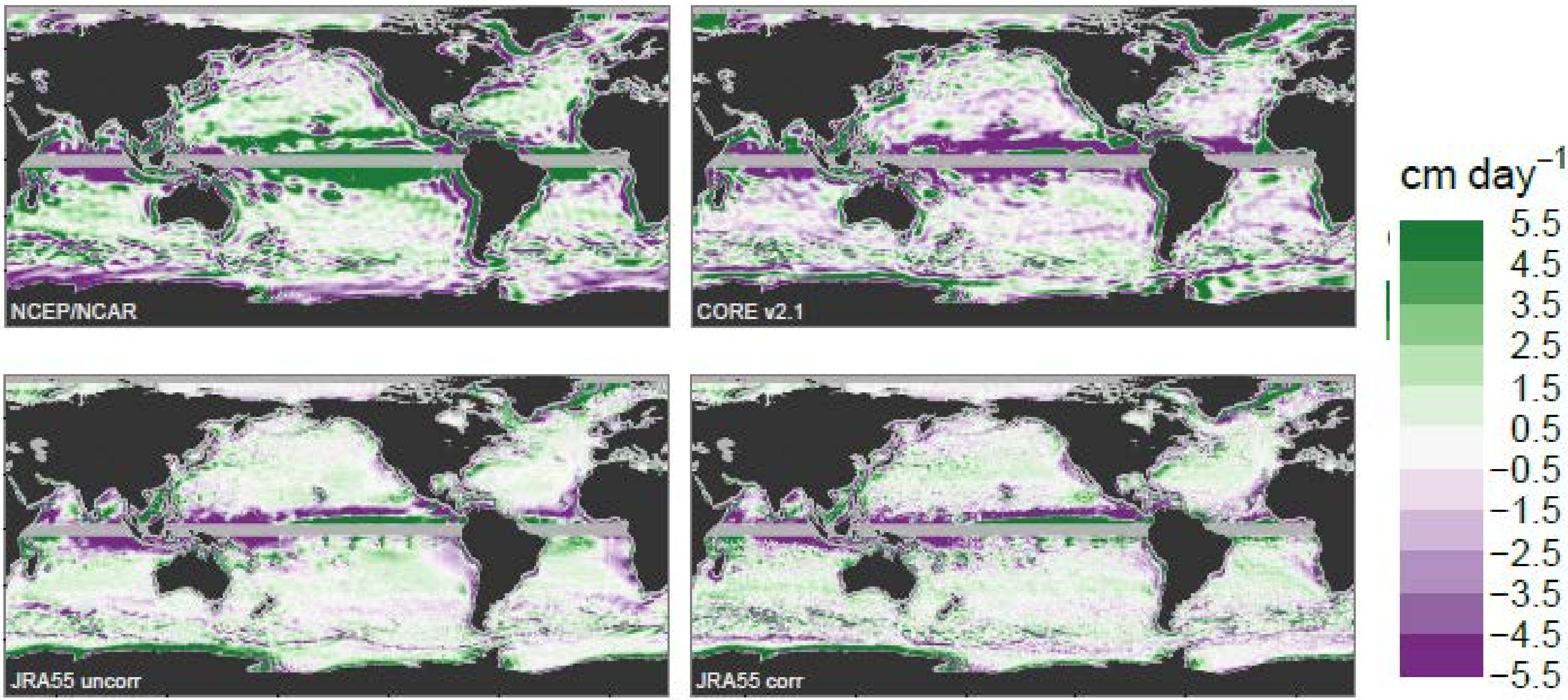


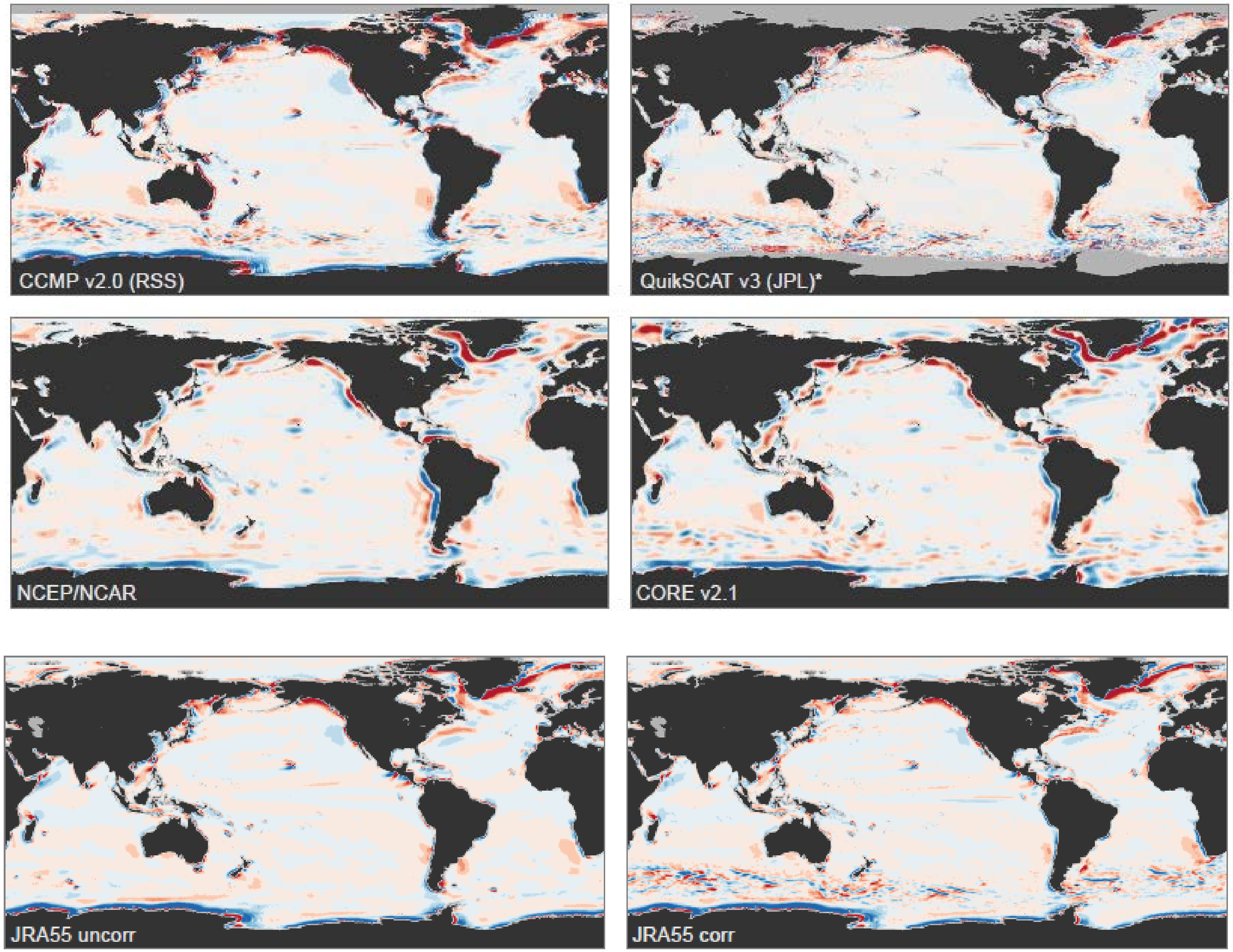
Fig. 2: Ekman pumping climatological maps for each of the observational and reanalysis products considered (see Table 1 for fu details). Same conventions as in Fig. 1.

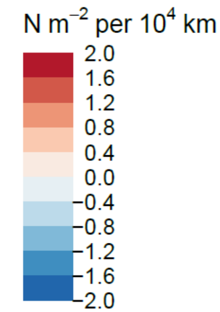
Upwelling-favorable Ekman pumping bands are too wide in CORE near eastern boundaries → associated wind stress curl leads to poleward flow by Sverdrup balance

Difference in Ekman pumping (w.r.t CCMP v2.0)



Wind stress curl (high pass filtered)





Small scale wind-stress-curl features seen in JRA55-gogo (and too lesser extent in CORE)

Fig. 5: Maps of small-scale persistent wind features based on high-pass filtered wind stress curl fields. The high-pass filter removes features associated to large scale gradients (larger than 30°in longitude and 10°in latitude, following Chelton *et al.* [2004]). Table 1 provides for further details about the original datasets. Climatologies were estimated for the period Sep 1999–Oct 2010 using monthly averaged wind stress curl fields. Grey areas indicate the lack of satellite retrievals for more than half of the averaging period for the observational products (*first row*).

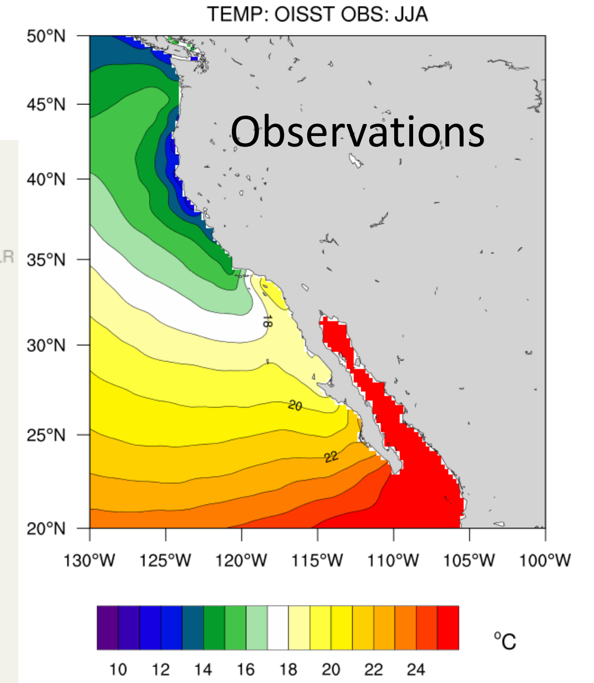
Experiments

- 1 degree POP
  - CORE Inter-annual-forcing . Data from first 50 year cycle.
  - JRA55 v7 inter-annual forcing . Data from first 50 year cycle.
  - Performed by Who Kim
- 0.1 degree POP
  - CORE inter-annual forcing performed by B. Johnson
  - JRA55 v8 inter-annual forcing (4 year run) performed by Fred Castruccio
- **All results are for JJA**
- CORE is 6 hour forcing: JRA is 3 hour
- Plots organized by upwelling system
- Following variables are compared:
  - SST
  - Meridional wind stress, TAUY
  - Surface meridional velocity
  - Vertical velocity at 50m
  - Net surface heat flux, SHF, positive means warming of ocean

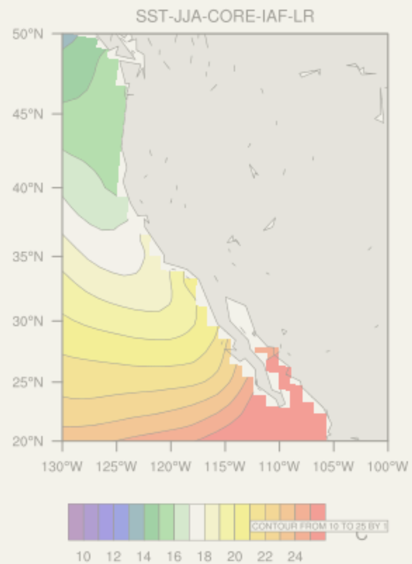
California Current

- An example of changes in upwelling when moving from CORE to JRA-55-gogo

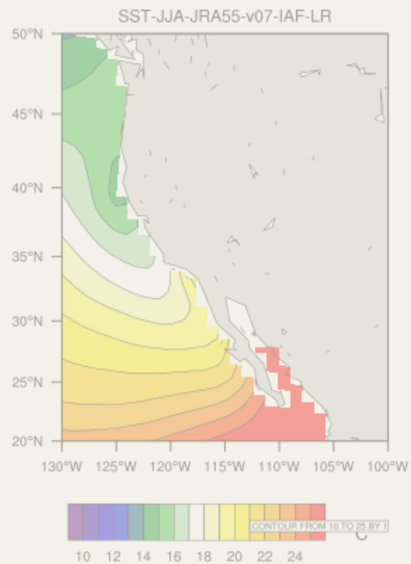
SST



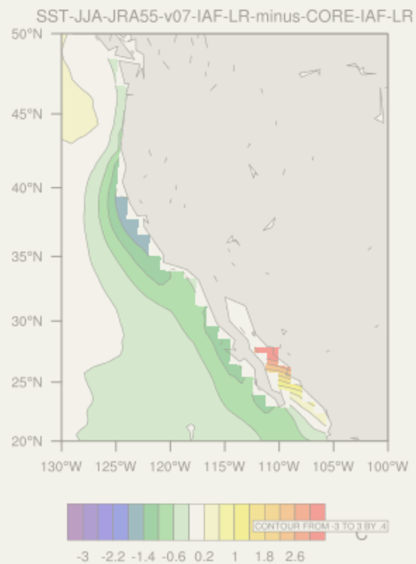
1 deg ocean: CORE



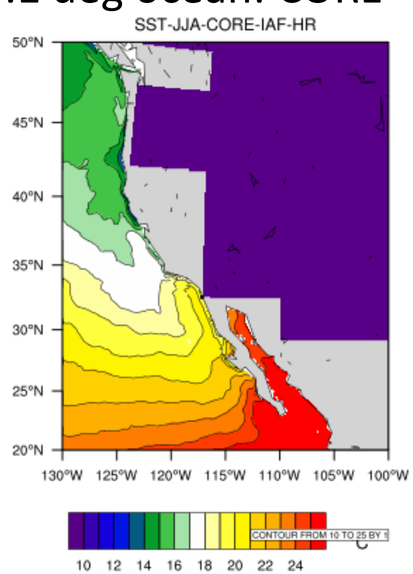
JRA



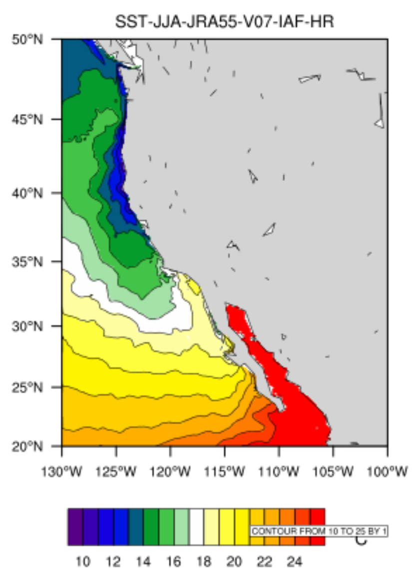
JRA-CORE



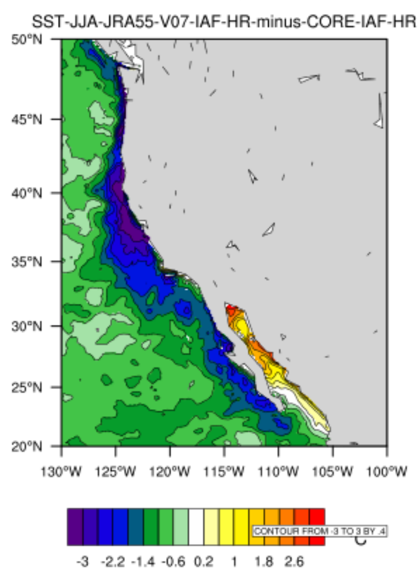
0.1 deg ocean: CORE



JRA

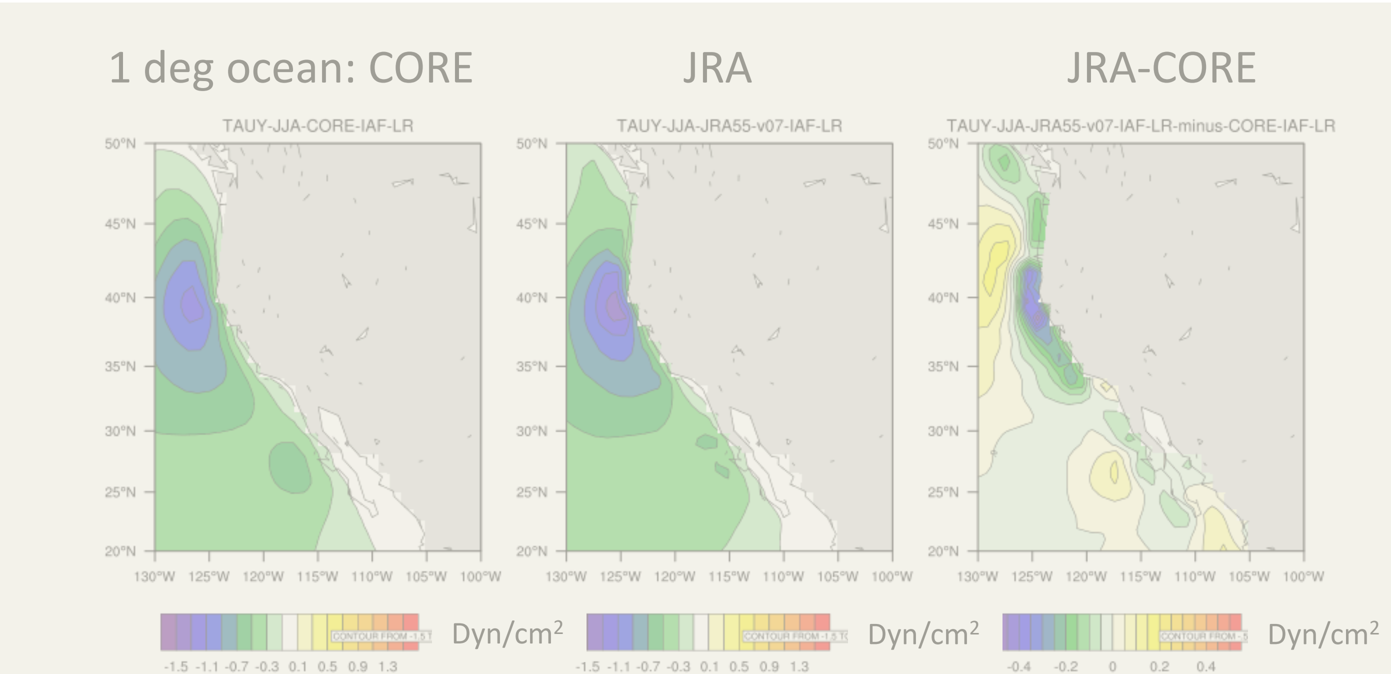


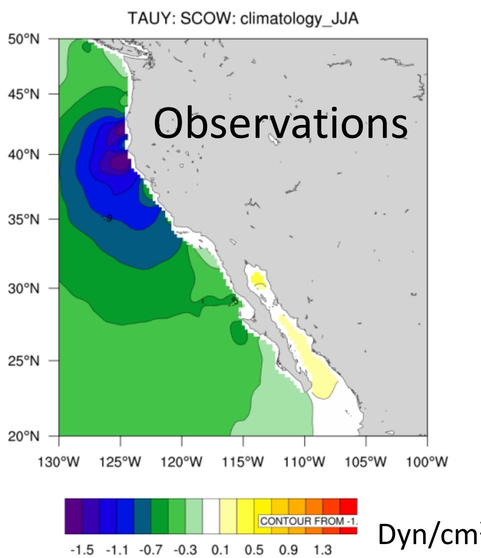
JRA-CORE



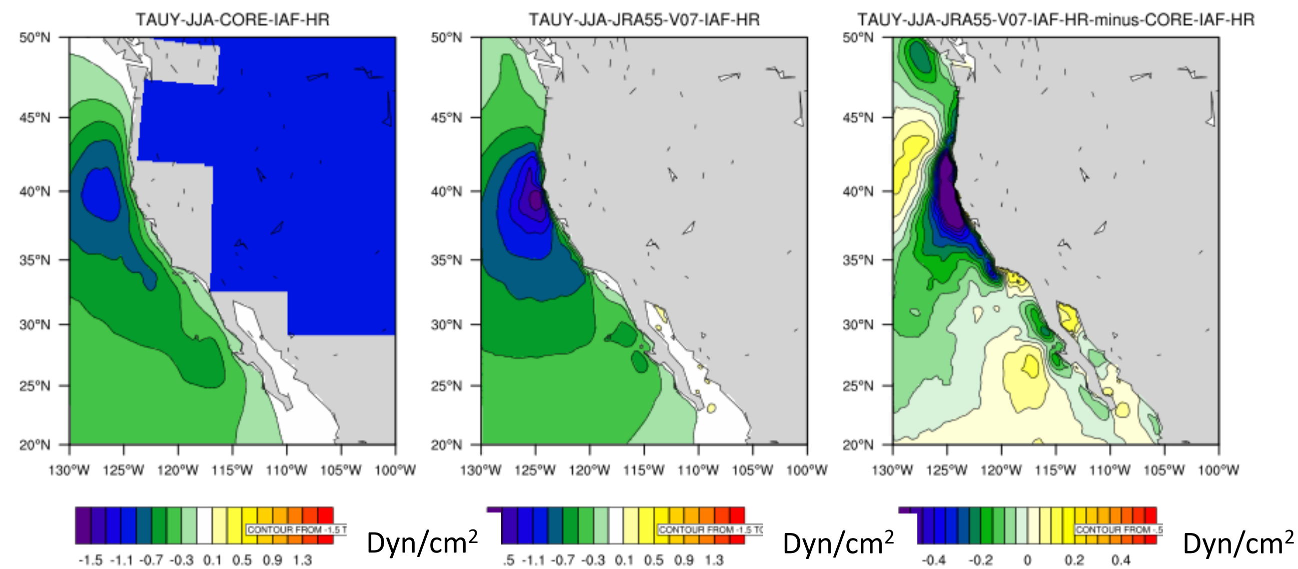
Much larger improvement to SST with JRA55 in 0.1deg ocean case (lower panel)

TAUY



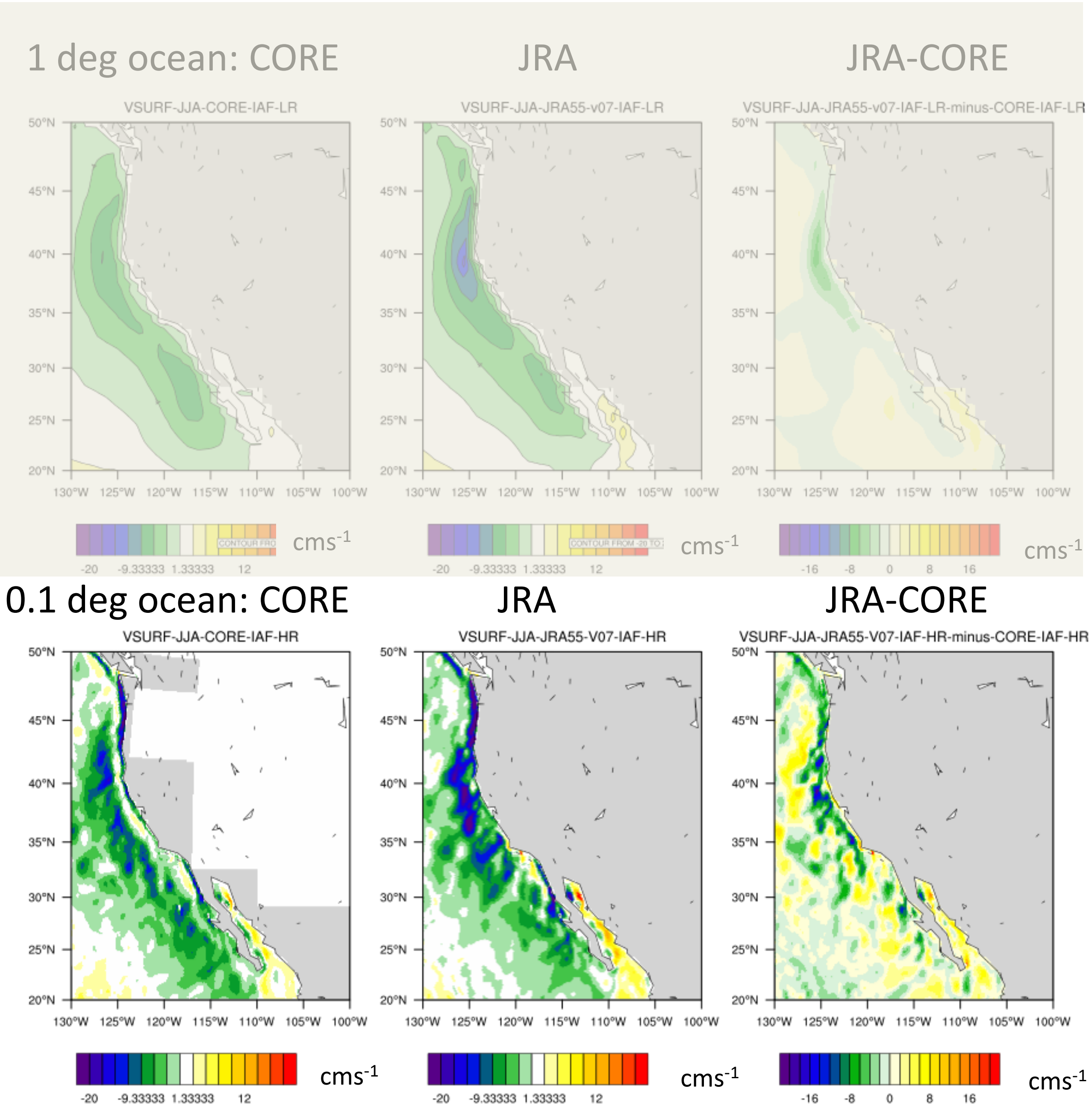


0.1 deg ocean: CORE | JRA | JRA-CORE



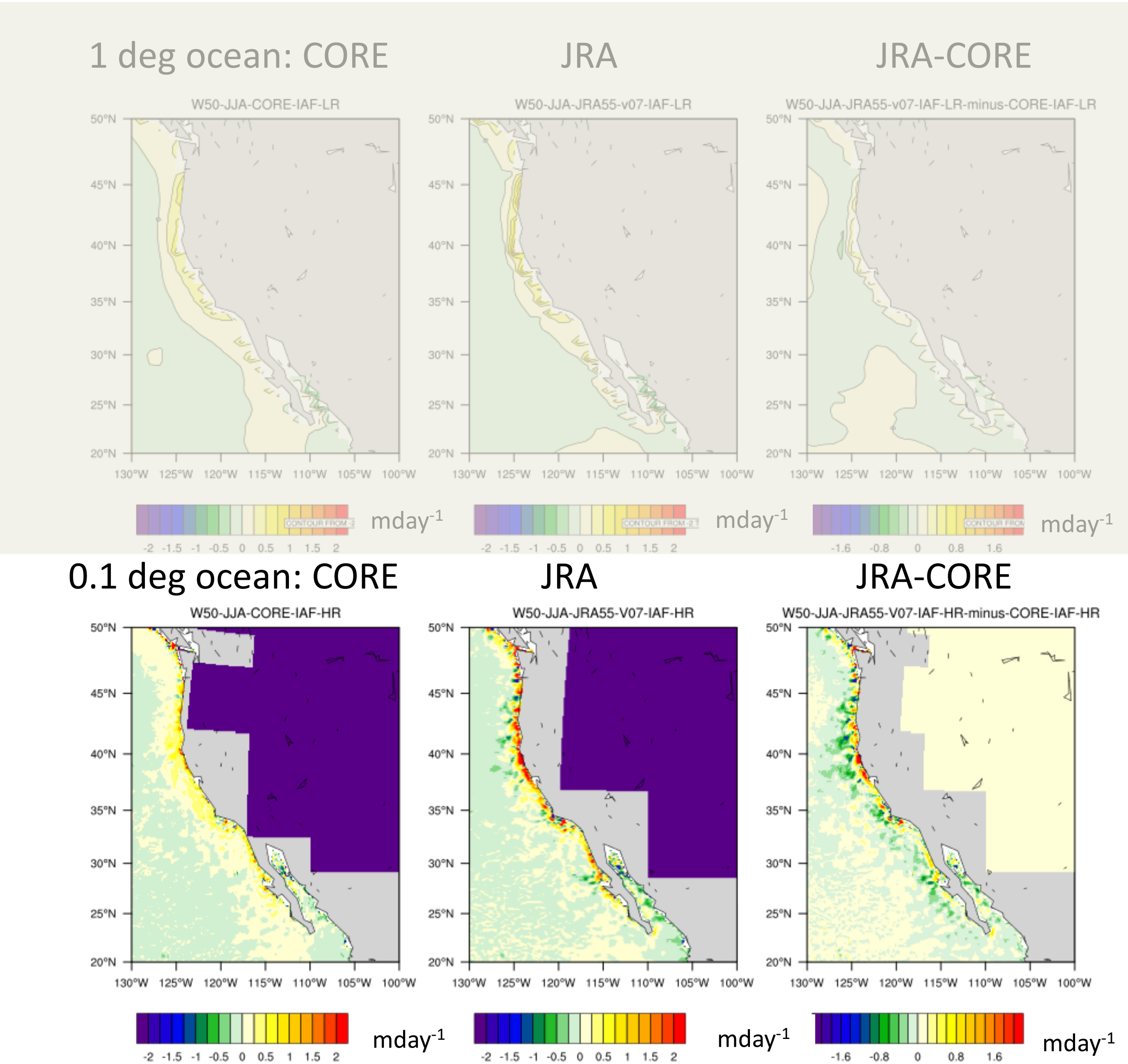
Units are dyn/cm^2. Note stronger wind stress (more negative TAUY) close to coast in JRA55.

Surface meridional current



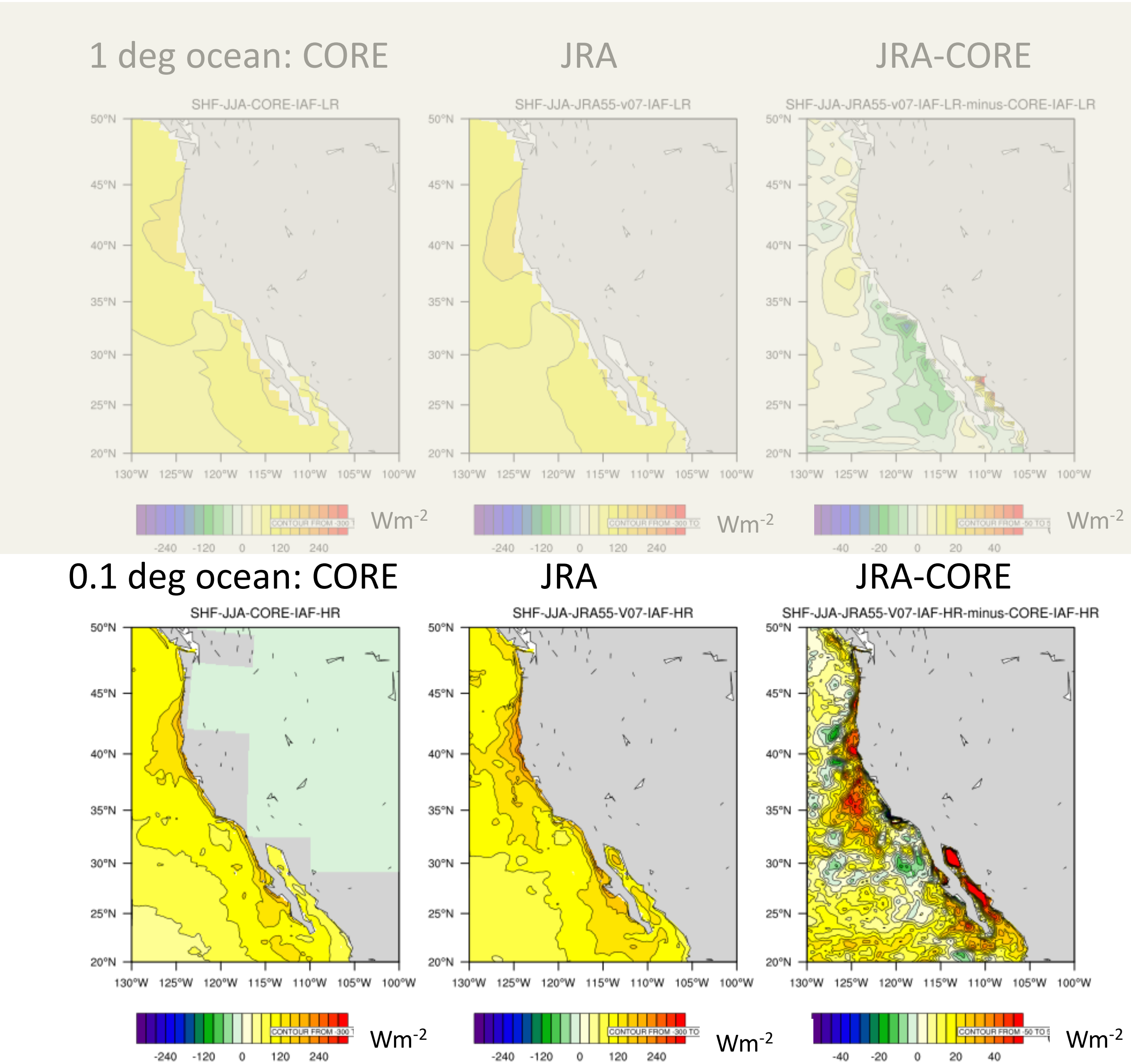
Units are cm/s. Note the generally stronger Equatorward currents close to coast in JRA55 forced. California Current is strongest in 0.1deg POP, JRA forced.

Vertical velocity at 50m



Units are m/day. Vertical velocities close to coast are stronger in JRA forced, and strongest in 0.1deg.

Net surface heat flux

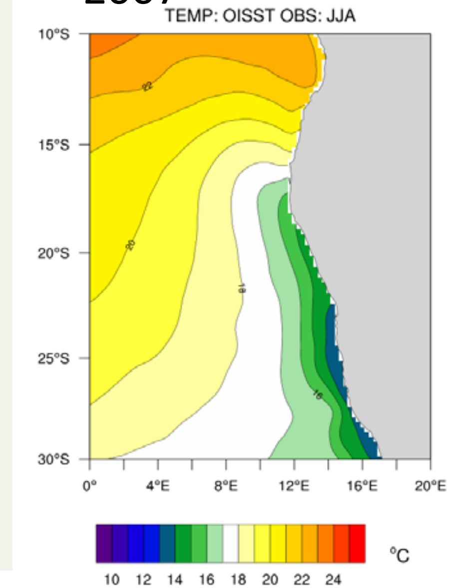


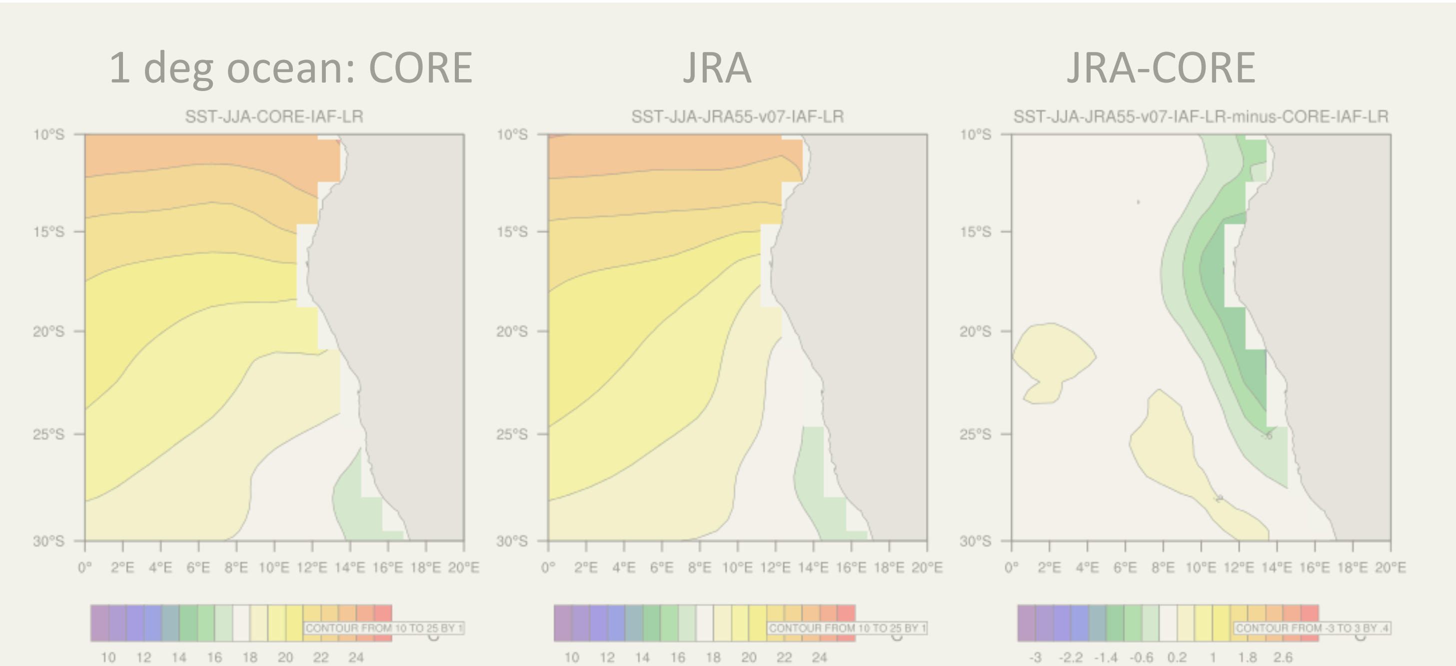
Units are W/m^2. Positive values warm the ocean. Surface fluxes give a mixed signal along the coast at 1deg., but at 0.1deg the cool SST in JRA is again strongly damped.

Benguela

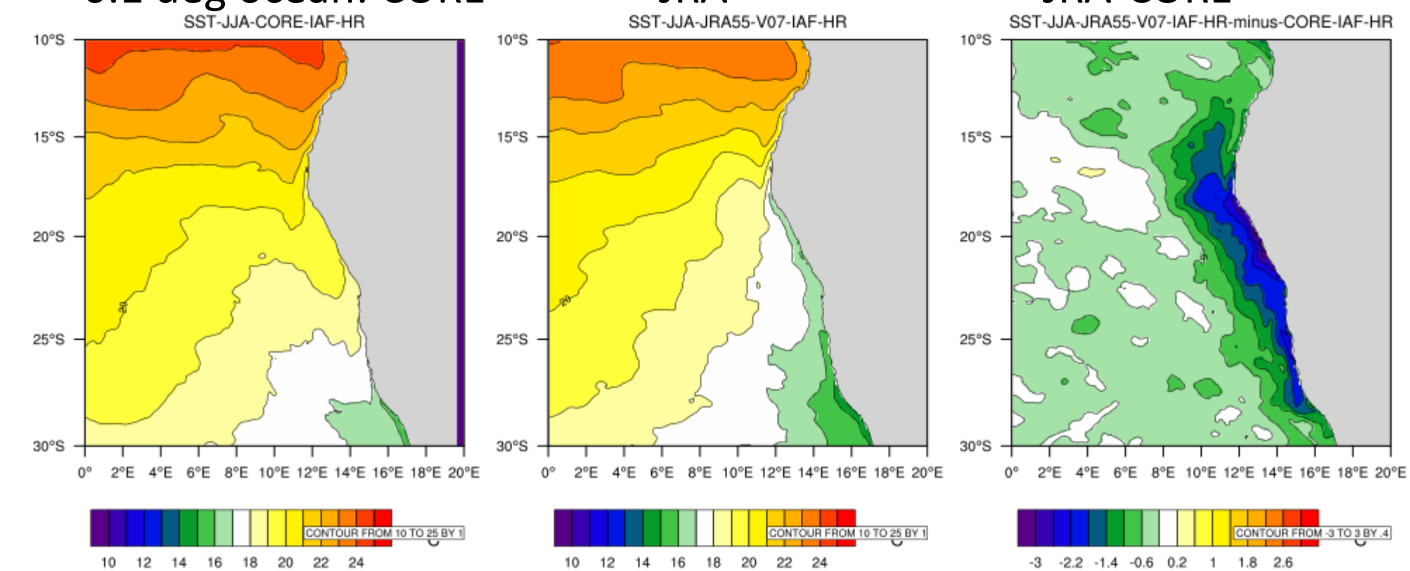
SST

OBS SST: REYNOLDS ET AL 2007





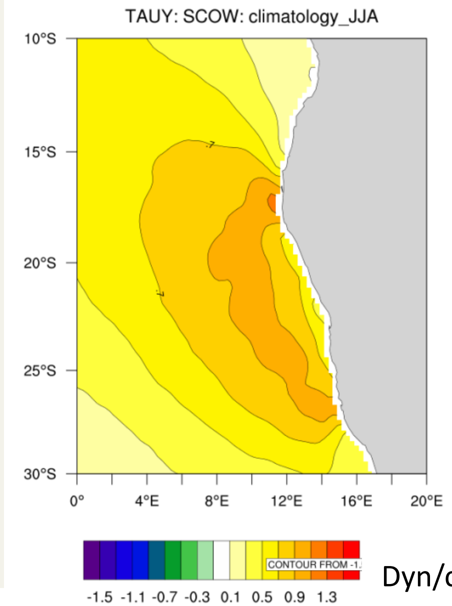
0.1 deg ocean: CORE — JRA — JRA-CORE



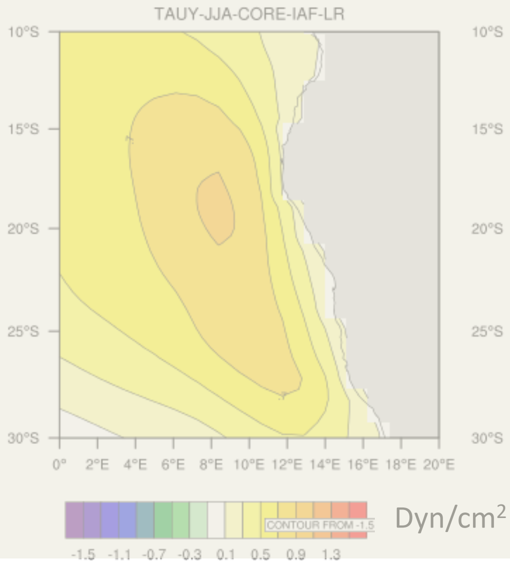
Much larger improvement to SST with JRA55 in 0.1deg ocean case (lower panel)

TAUY

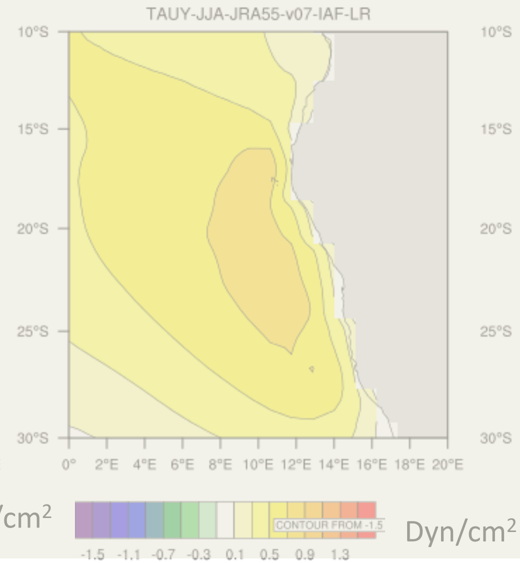
OBS TAUY: RISIEN & CHELTON 2008



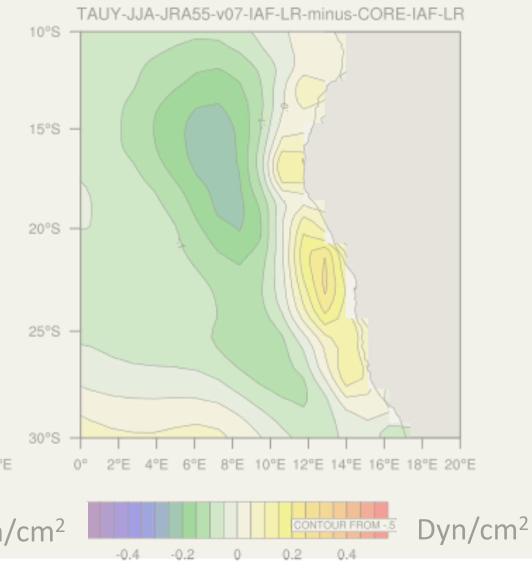
1 deg ocean: CORE



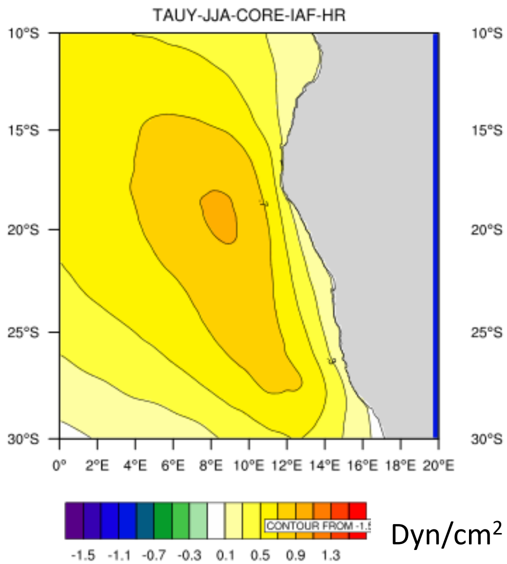
JRA



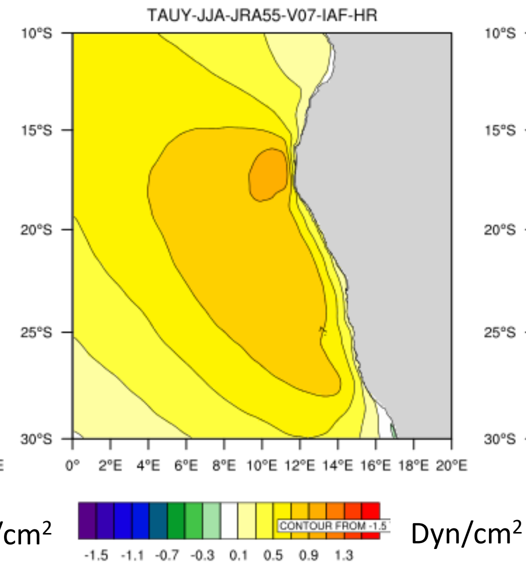
JRA-CORE



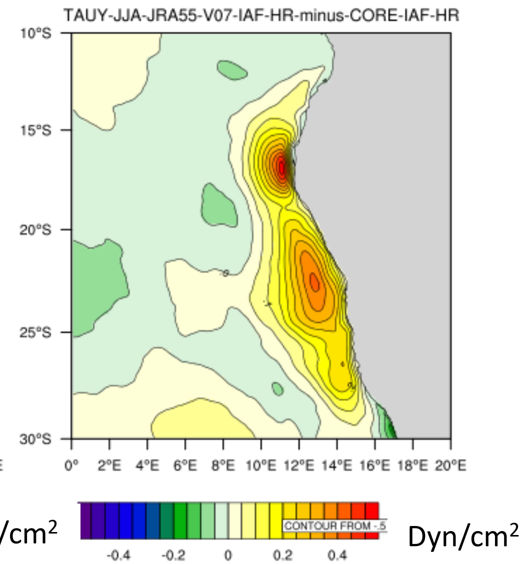
0.1 deg ocean: CORE



JRA

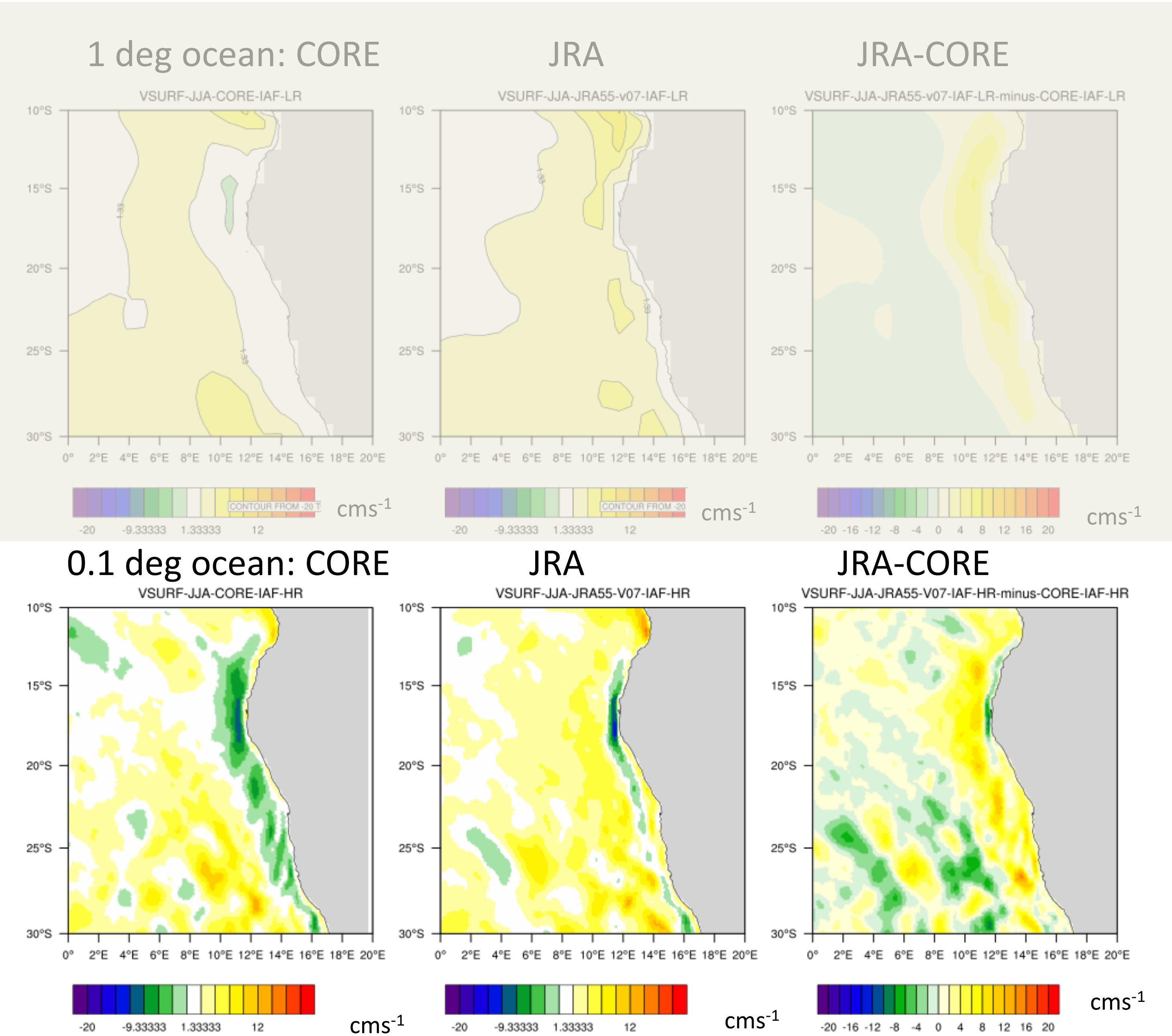


JRA-CORE



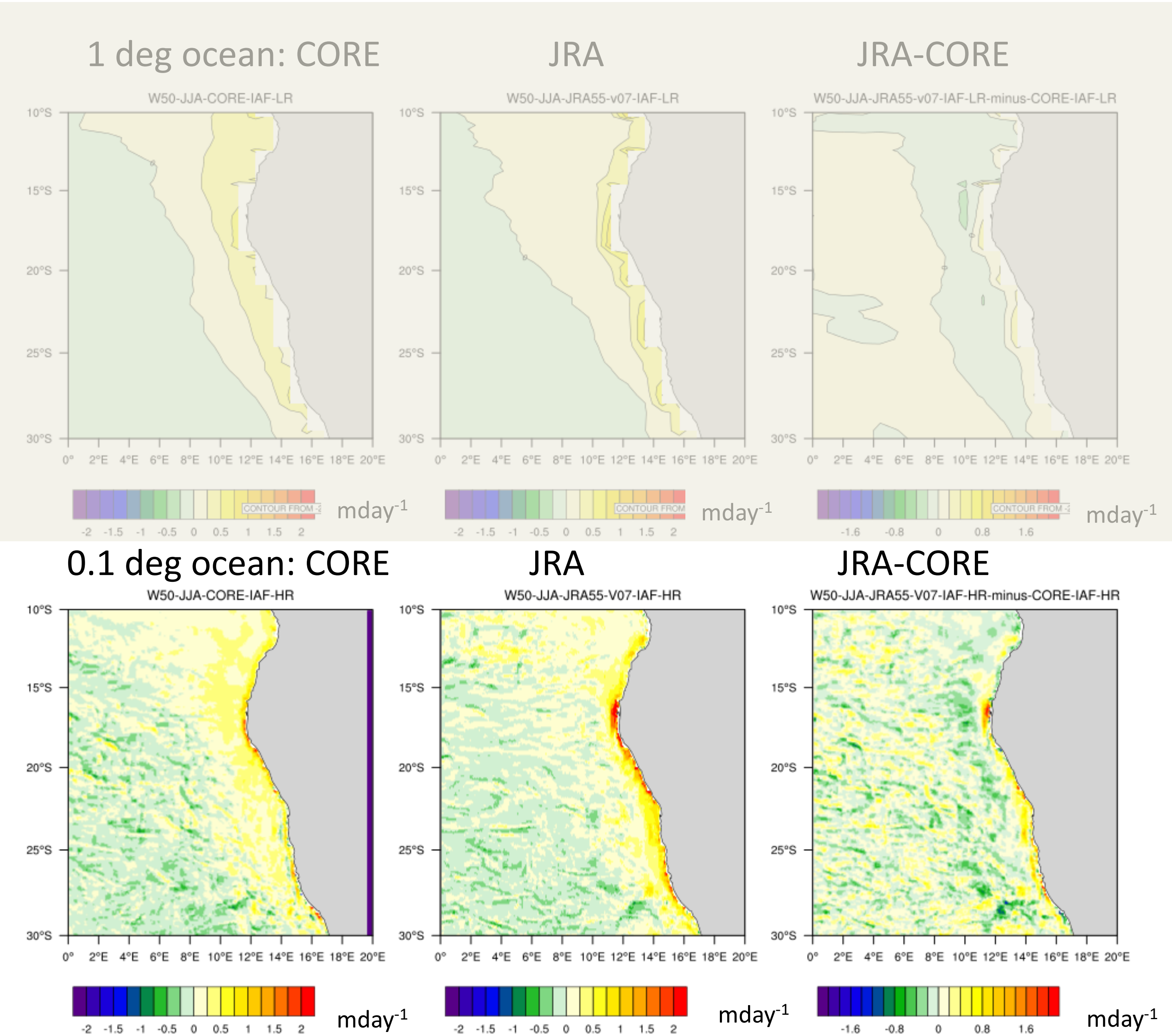
Units are dyn/cm^2. Contours every 0.2dyn/cm^2. Note stronger wind stress (more positive TAUY) close to coast in JRA55.

Surface meridional current



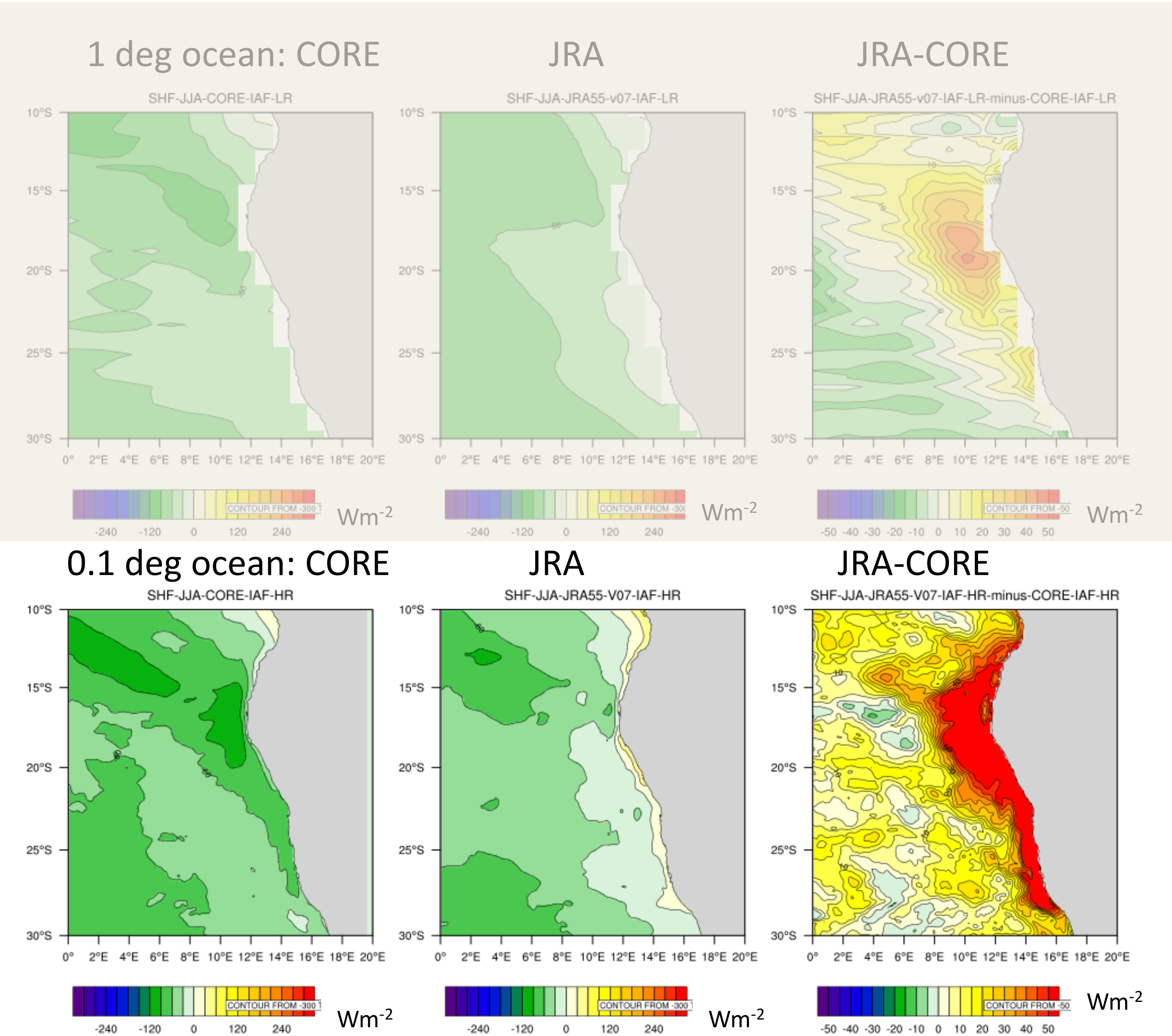
Units are cm/s. Note the generally stronger Equatorward currents close to coast in JRA55 forced. Also note strong poleward currents in 0.1deg CORE forced, already seen by Grodsky et al 2012.

Vertical velocity at 50m



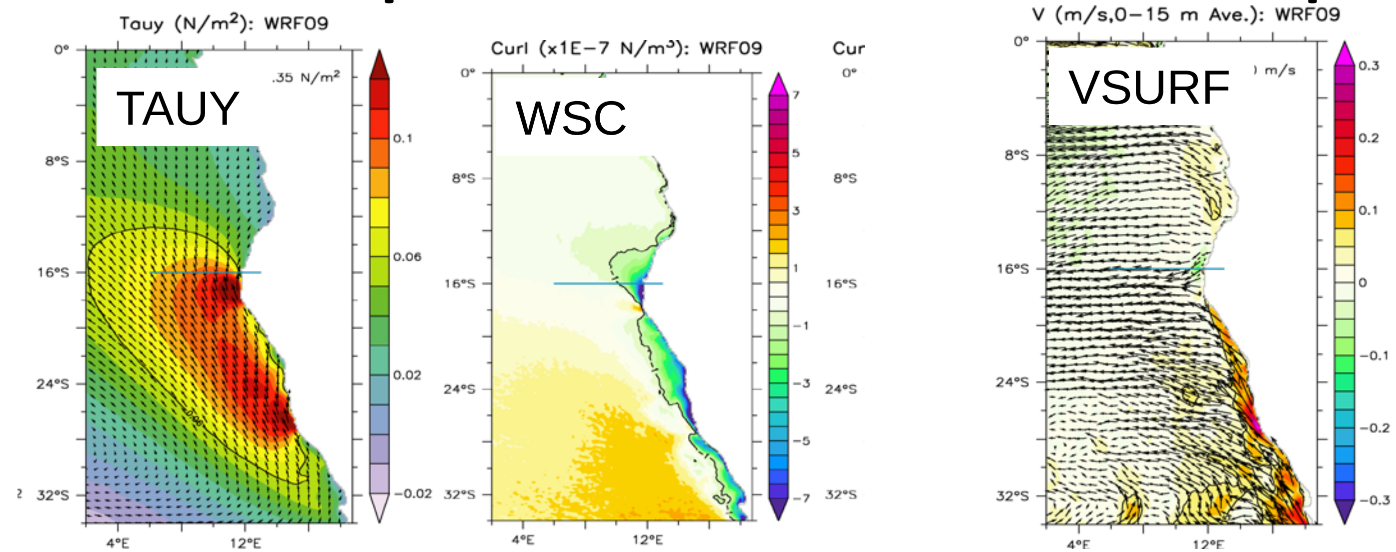
Units are m/day. Vertical velocities close to coast are stronger in JRA forced, and strongest in 0.1deg.

Net surface heat flux

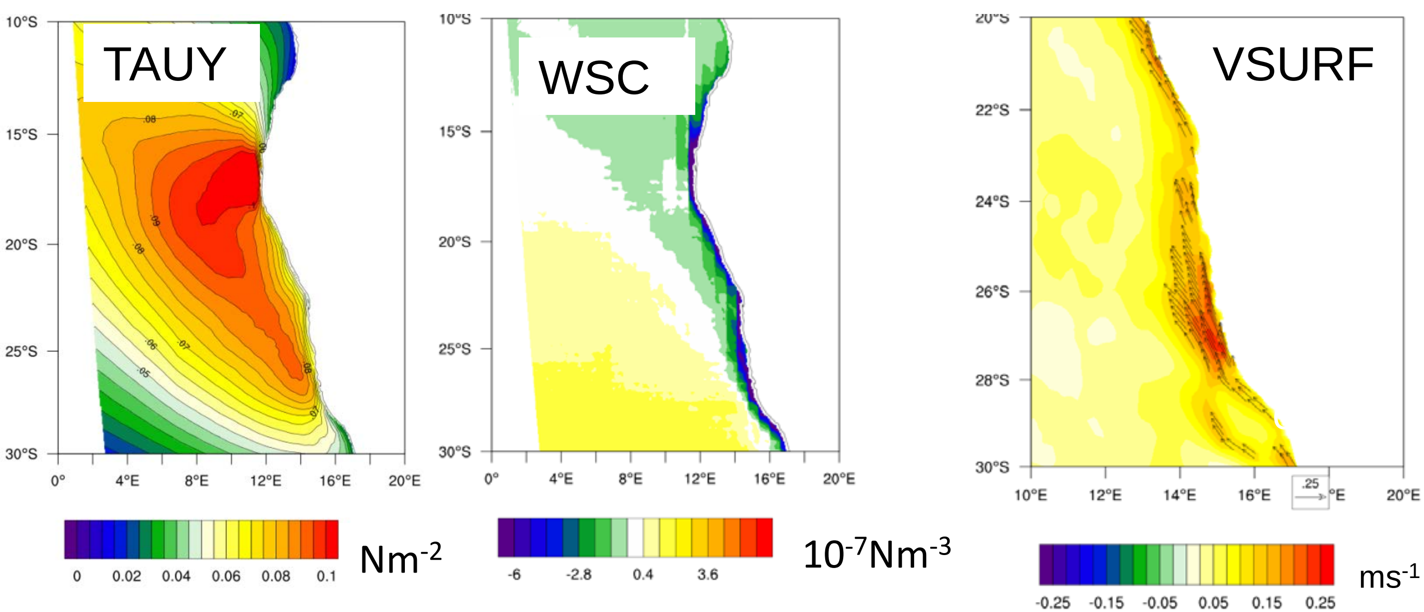


Units are W/m^2. Positive values warm the ocean. Note that the cooler coastal SST in JRA is being damped by surface fluxes, especially latent, and especially for 0.1deg.

Comparison with other experiments



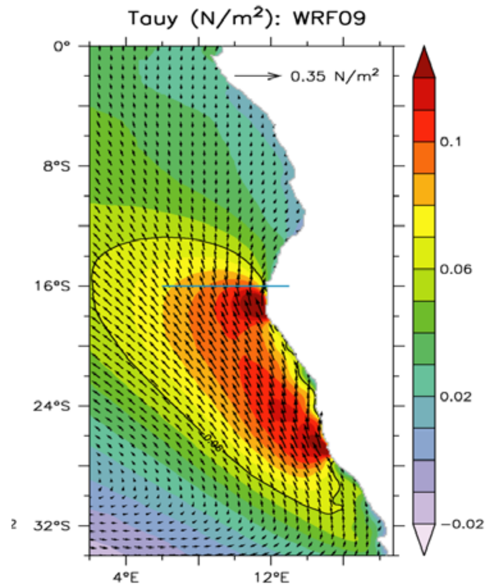
Kurian, Ping Chang, Christina Patricola et al. (2017, in prep.) ROMS forced by 9km WRF



Small, Curchitser, Kauffman, Hedstrom et al 2015, JCLI. ROMS embedded in CCSM4, wind core shifted ad-hoc.

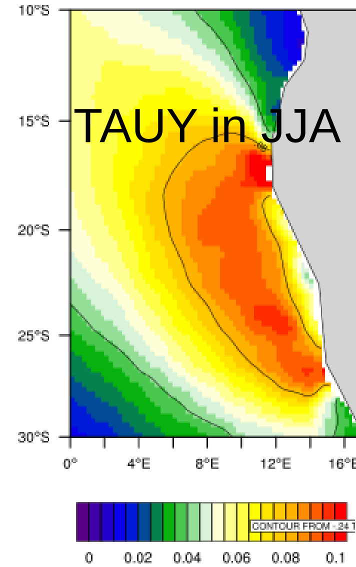
Both these experiments gave realistic coastal SST: very narrow wind drop-off is essential.

Interpolation near coast discussion (1)



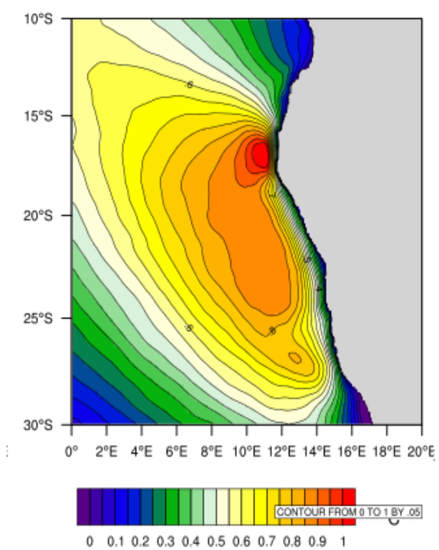
(c) QuiKSCAT

TAUY in JJA

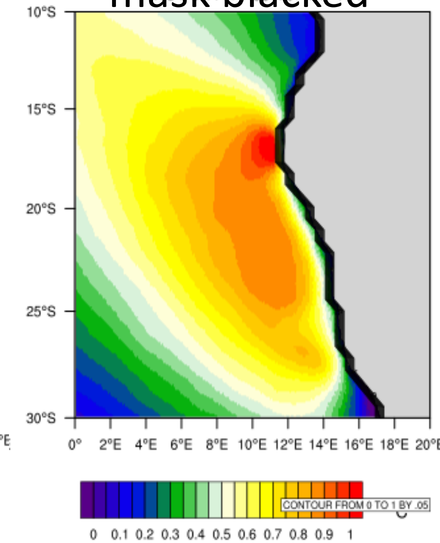


Nm^{-2}

JRA55-gogo



JRA55-land mask blacked

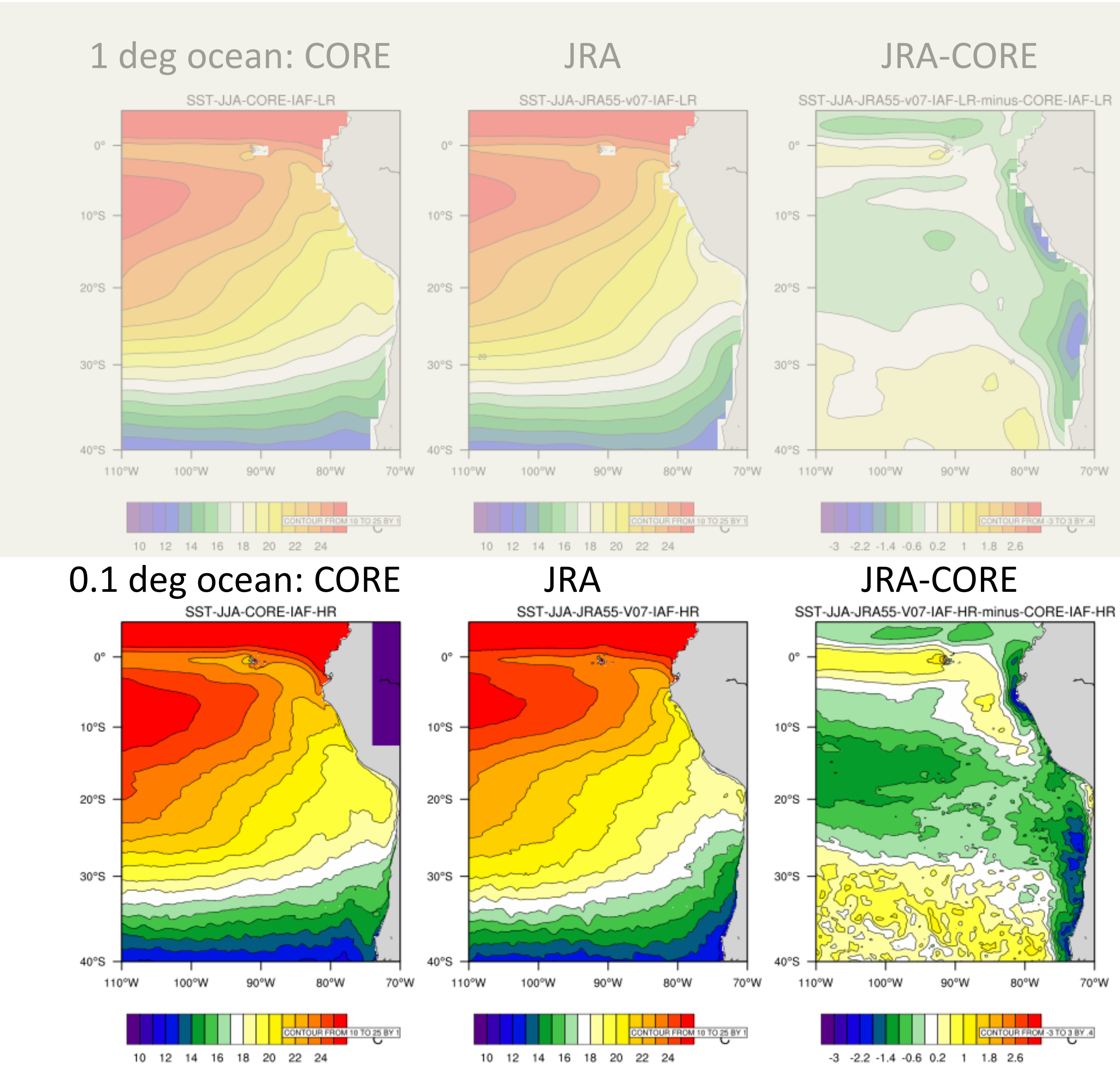


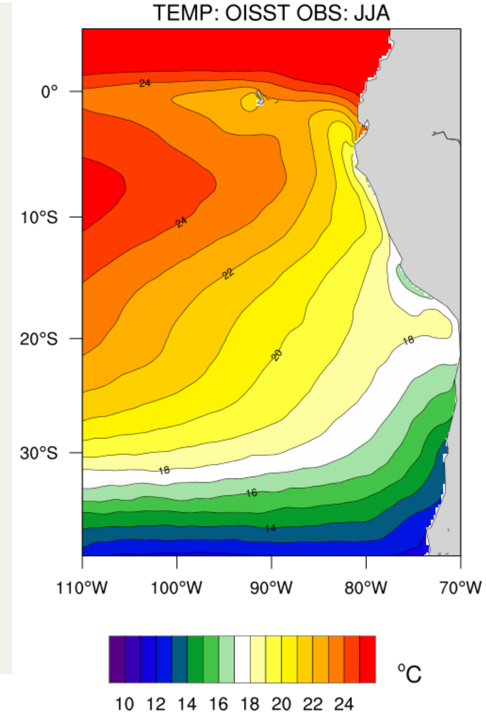
Interpolation near coast discussion (2)

- How to deal with ocean cells under atmosphere cells with some proportion of land
  - LANDFRAC>0
  - Typically biases wind speed low
- Kara et al. 2007
  - iterative filling of land-affected cells, using weighted averages of nearby land-free cells
- Pinardi et al.
  - iterative filling of land-affected cells
- Barnier et al
  - NEMO group “flooding” method
- Methods being tested by B. Kauffman

Peru-Chile

SST





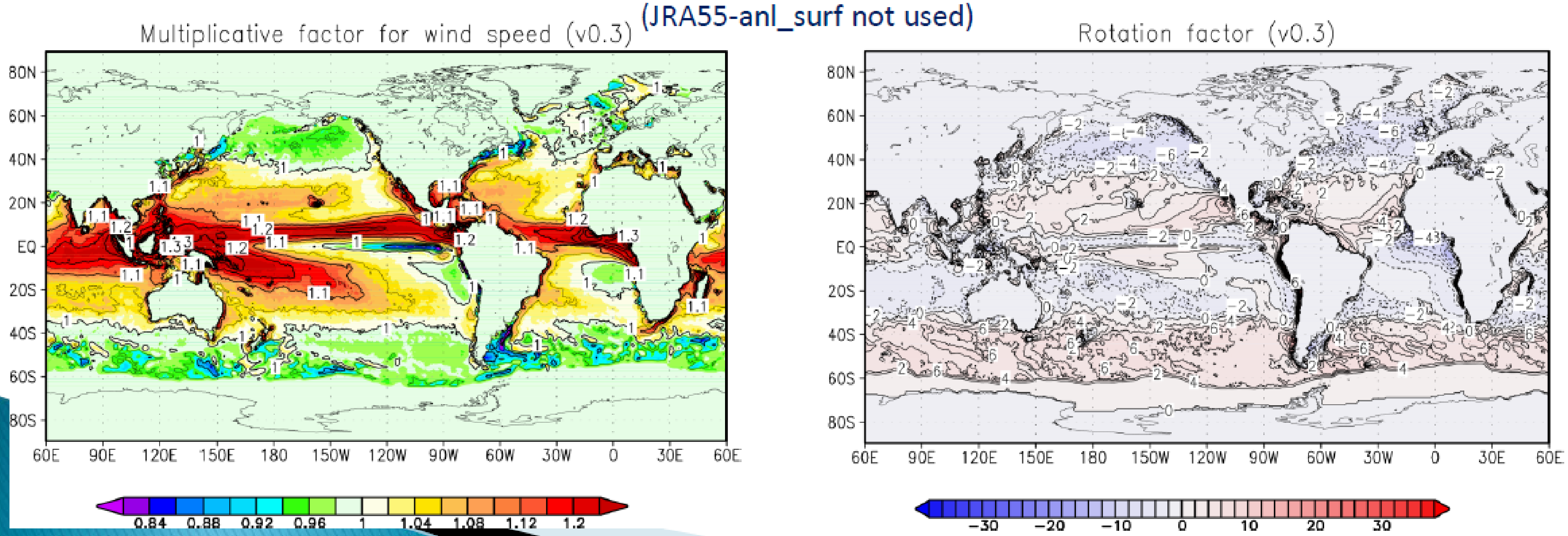
Note: SST difference in Peru-Chile is sensitive to years analyzed. Lots of inter-annual variability.

Summary

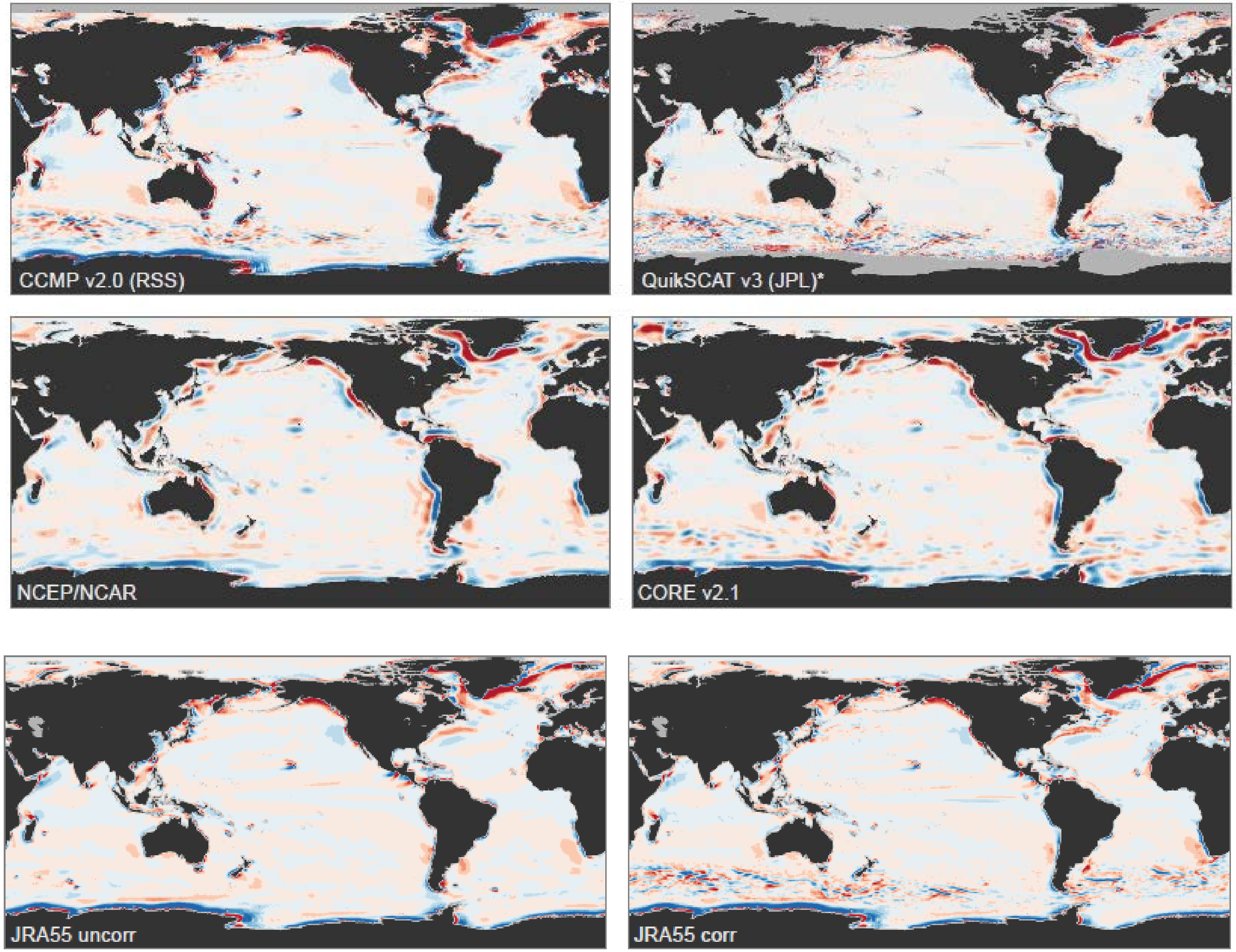
- JRA-55-gogo improves on coastal winds and Ekman pumping
- Coastal ocean flow more downwind “coastal ocean jet” – cold advection
- Upwelling more coastally confined
- Surface heat fluxes damp SST difference (except off Peru where changes to low level cloud also important)

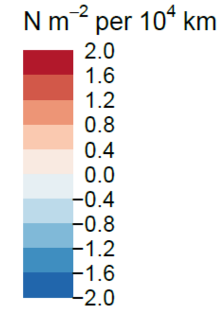
Discussion

v0.3 (annual mean of monthly factors)
(JRA55-anl_surf not used)



Wind stress curl (high pass filtered)





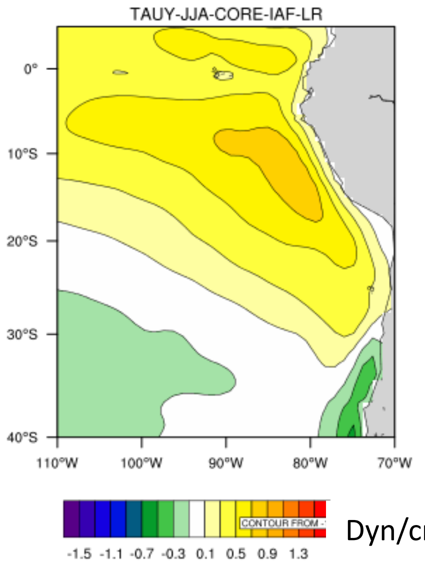
Small scale wind-stress-curl features seen in JRA55-gogo (and too lesser extent in CORE)

Fig. 5: Maps of small-scale persistent wind features based on high-pass filtered wind stress curl fields. The high-pass filter removes features associated to large scale gradients (larger than 30°in longitude and 10°in latitude, following Chelton *et al.* [2004]). Table 1 provides for further details about the original datasets. Climatologies were estimated for the period Sep 1999–Oct 2010 using monthly averaged wind stress curl fields. Grey areas indicate the lack of satellite retrievals for more than half of the averaging period for the observational products (*first row*).

Extra slides

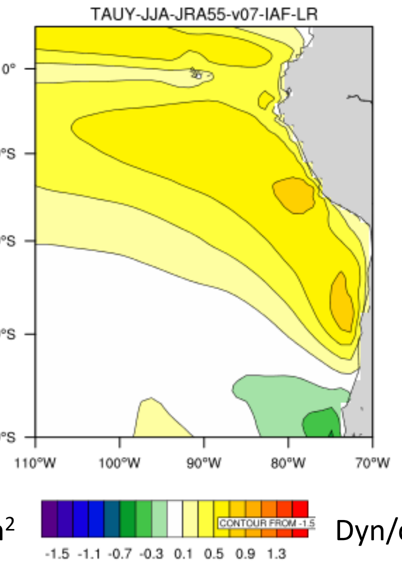
TAUY

1 deg ocean: CORE



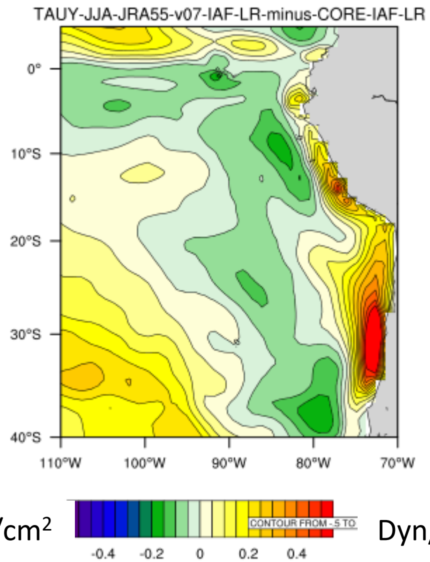
Dyn/cm^2

JRA

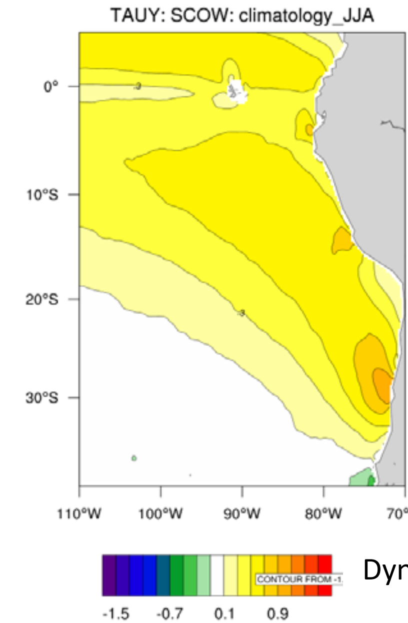


Dyn/cm^2

JRA-CORE

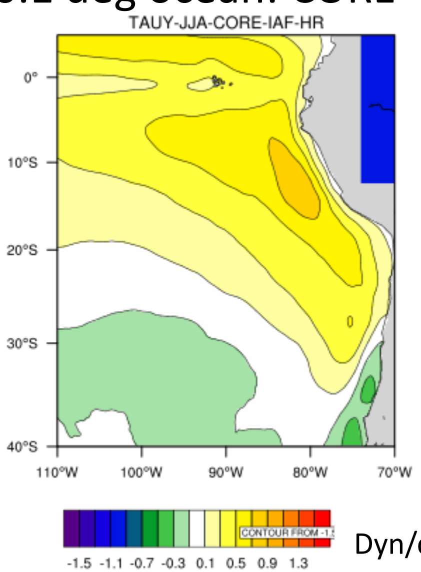


Dyn/cm^2



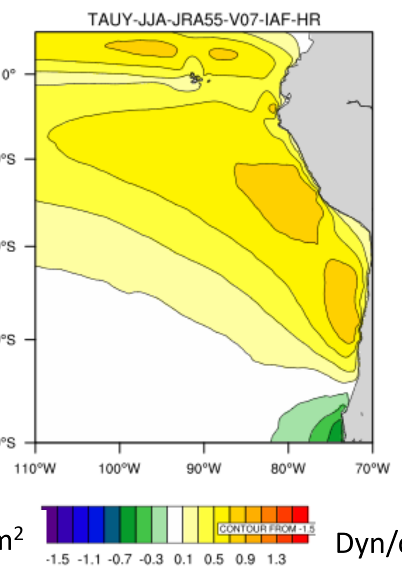
Dyn/cm

0.1 deg ocean: CORE



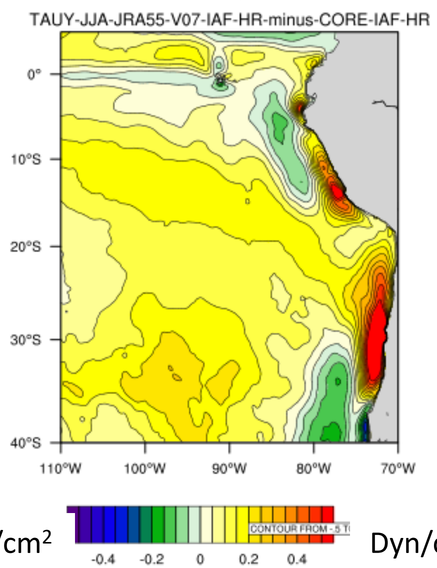
Dyn/cm^2

JRA



Dyn/cm^2

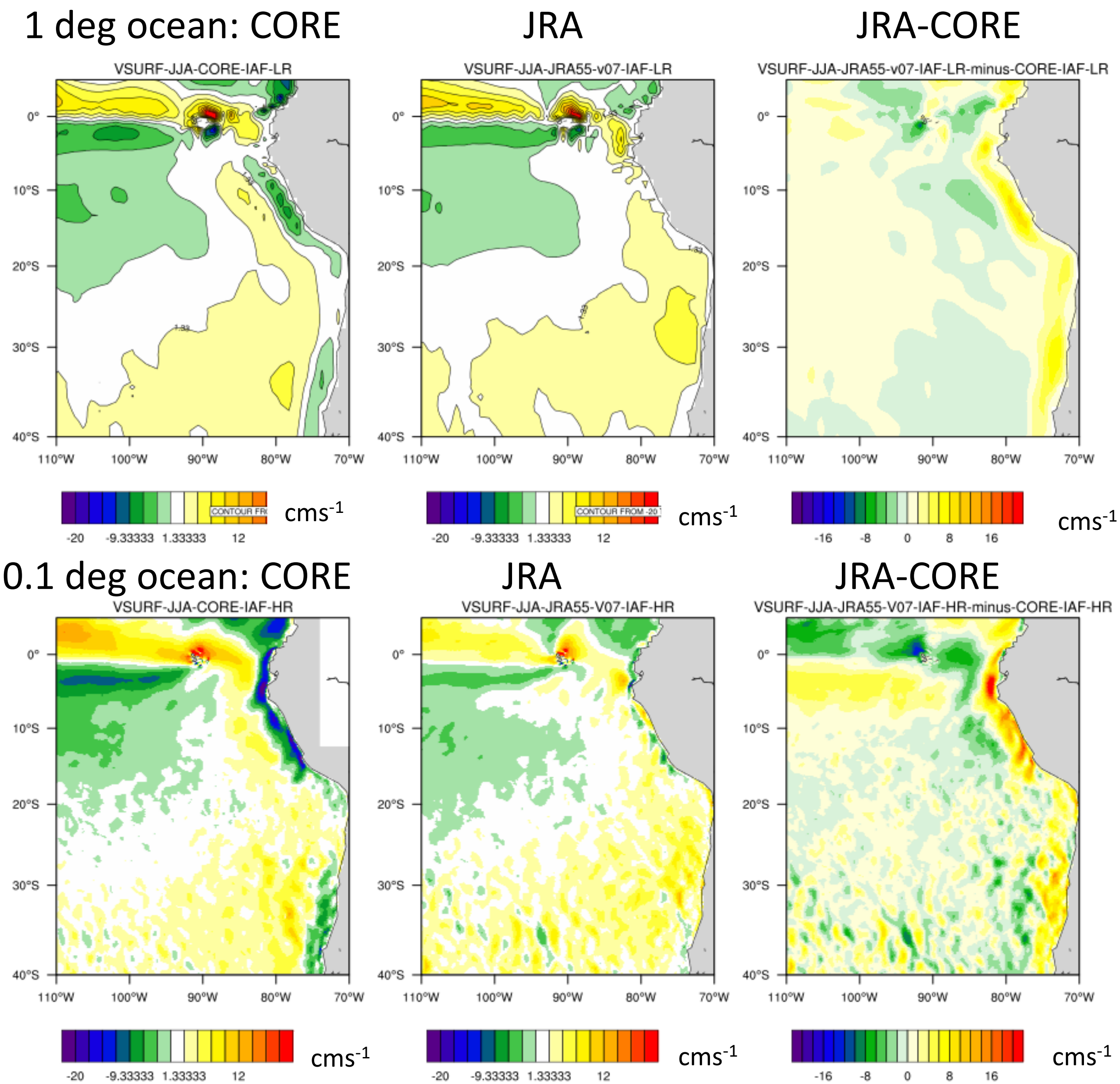
JRA-CORE



Dyn/cm^2

Units are dyn/cm^2. Note stronger wind stress (more positive TAUY) close to coast in JRA55.

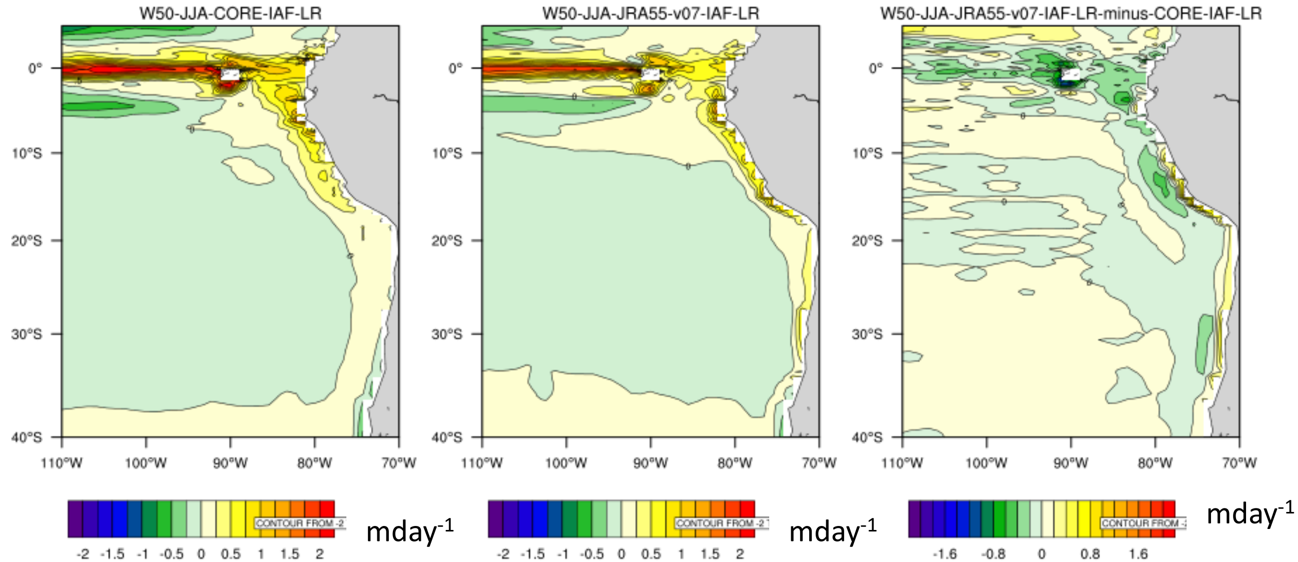
Surface meridional current



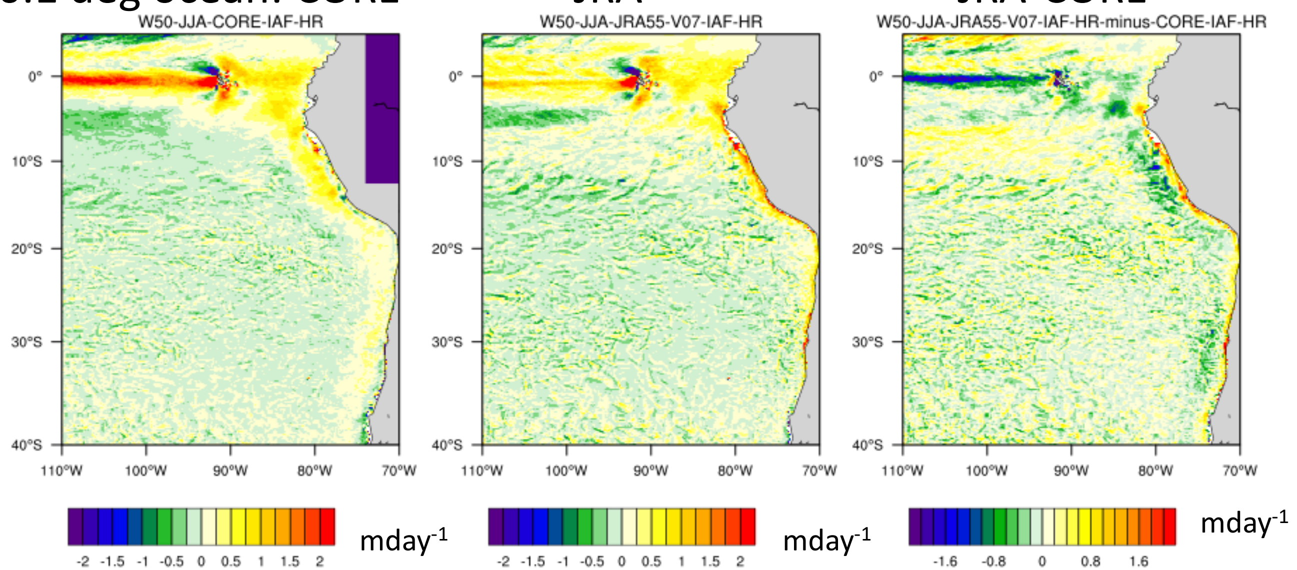
Units are cm/s. Note the generally stronger Equatorward currents close to coast in JRA55 forced. 1deg and 0.1deg CORE forced has Poleward currents close to coast.

Vertical velocity at 50m

1 deg ocean: CORE JRA JRA-CORE



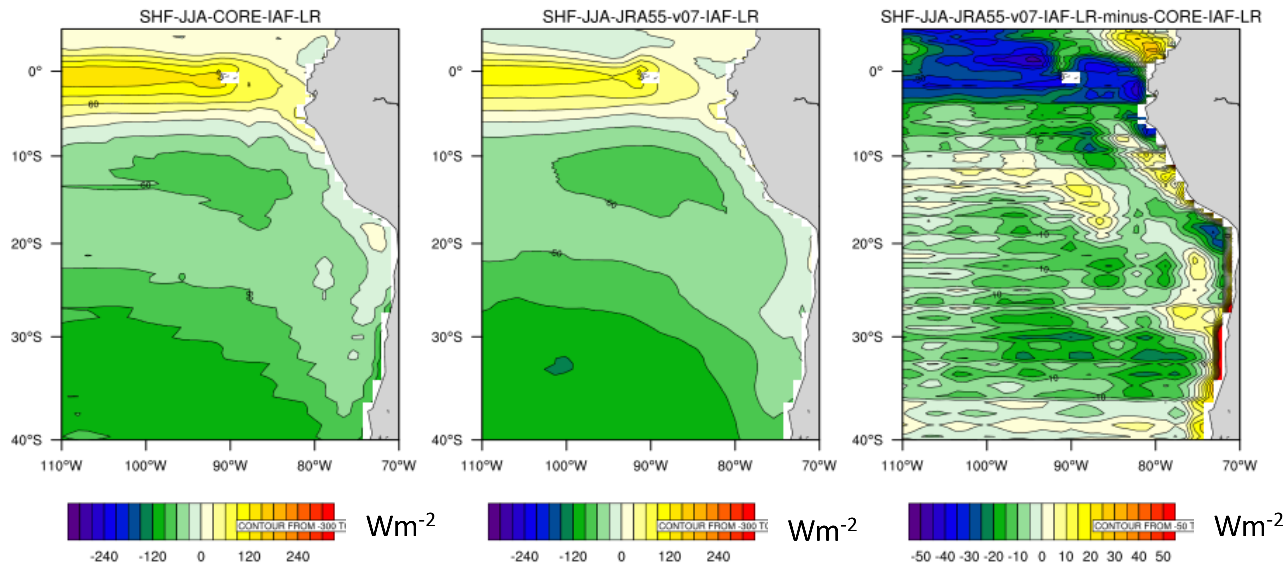
0.1 deg ocean: CORE JRA JRA-CORE



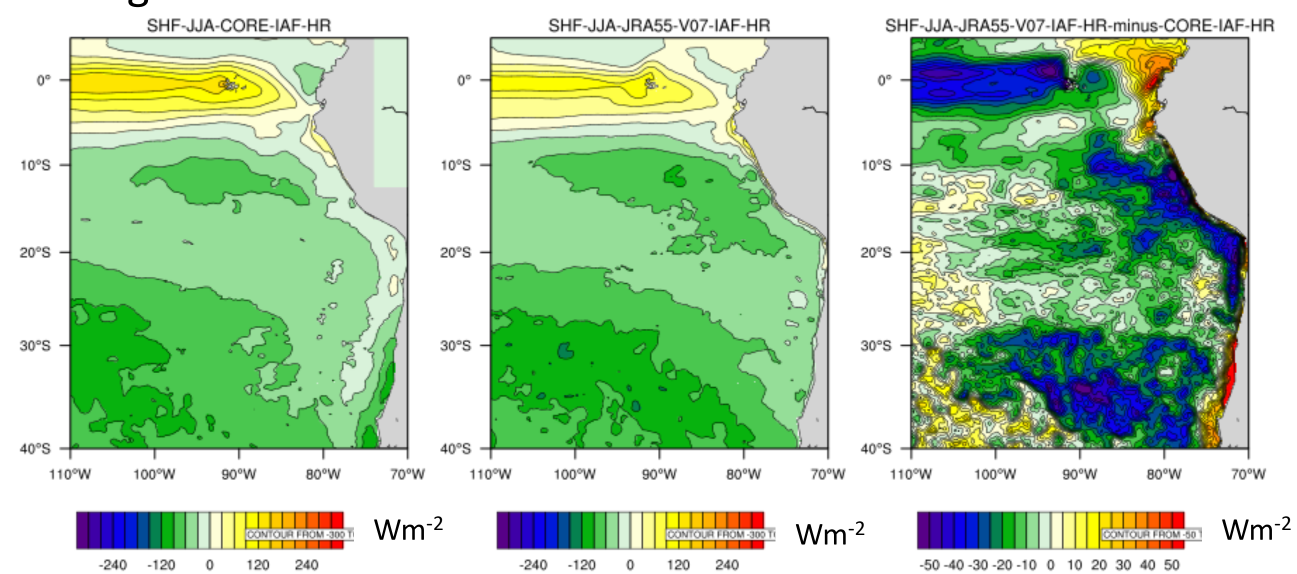
Units are m/day. Vertical velocities close to coast are generally stronger in JRA forced, and strongest in 0.1deg.

Net surface heat flux

1 deg ocean: CORE | JRA | JRA-CORE



0.1 deg ocean: CORE | JRA | JRA-CORE



Units are W/m^2. Positive values warm the ocean. Surface fluxes give a mixed signal along the coast with some patches of relative cooling (JRA-CORE) and some of warming.

Table 1: Wind reanalysis datasets included in the assessment. The table list first the reference satellite datasets then the original, «uncorrected» and adjusted versions of the reanalysis products used to drive ocean model experiments. Each row provides a short description of the data inputs, models and data assimilation methods used to generate each product. Spatial resolution is indicated as degrees of longitude × latitude (native model resolution detailed in the comments). The time extent corresponds to the data used in this study.Spatial extent is global for all datasets.

Dataset	Comments	References
QuikSCAT SeaWinds scatterometer (QuikSCAT v3, JPL)		
Nov 1997 – Nov 2009 [0.25°, ~24h]	Satellite mission that provides high resolution wind vectors measurements at the global scale (12.5 km). The JPL L2B v3 dataset relies on the geophysical model Ku-2011 [Ricciardulli & Wentz, 2011] and in novel gridding and correction algorithms [Fore *et al.*, 2014] to provide a root mean square error (rms) of 1 m s^{-1} and 17° with respect to buoy data (3.8 m s^{-1} under rain conditions).	[Liu *et al.*, 2010; Fore *et al.*, 2014], podaac.jpl.nasa.gov/QuikSCAT.
Cross-Calibrated Multi-Platform reanalysis (CCMP v2, RSS)		
Jul 1987 – present [0.25°, 6h]	Reanalysis product that uses variational analysis to combine microwave and scatterometer satellite winds with moored buoy measurements, using ERA-Interim reanalysis fields as an initial guess. With respect to the original version, the RSS v2 product incorporates state of the art versions of the algorithms used to retrieve satellite winds and extra platforms (AMSR2, GMI and ASCAT).	[Atlas *et al.*, 2011; Wentz *et al.*, 2015], www.remss.com/measurements/ccmp.
	....	
NCEP/NCAR Reanalysis 1 (NCEP)		
Jan 1948 – Dec 2013 [1.85 x 1.90°, 6h*]	Reference reanalysis product that uses 3D-Variational analysis to assimilate data into NCEP T62/28-level model (~100 km). Marine surface winds include voluntary observing ships and buoys.	Kalnay *et al.* [1996]; Kistler *et al.* [2001], rda.ucar.edu/datasets/ds090.0.
ECMWF Reanalysis Interim (ERAI)		
Jan 1979 – present [0.70°, 3h]	Reanalysis product that uses 4D-Variational analysis with the atmospheric Integrated Forecast System model (IFS Cy31r2, ~80 km). *In situ* marine wind measurements extended with microwave satellite wind speeds from SSM/I (since 1987) and scatterometer wind vectors from ERS-1 and 2 (1991–2011) and from QuikSCAT (1999–2009).	Dee *et al.* [2011], www.ecmwf.int.
Japanese 55-year Reanalysis (JRA-55)		
Jan 1958 – Feb 2015 [0.56 x 0.56°, 3h]	Reanalysis product that uses 4D-Variational analysis to assimilate atmospheric data into the Japanese Meteorological Agency Global Spectral Model (JMA GSM), with a 55 km nominal resolution (TL319). *In situ* surface pressure observations are complemented since 1979 with atmospheric motion vectors from geostationary satellites and since 1999 with scatterometer data from QuikSCAT (JPL v2) and ASCAT.	Kobayashi *et al.* [2015], internal report by H. Tsujino, jra.kishou.go.jp.
	....	
Coordinated Ocean-sea ice Reference Experiments (COREv2.1)		
Jan 1958 – Feb 2015 [0.56 x 0.56°, 3h]	Reanalysis product based largely on NCEP reanalysis [Kalnay *et al.*, 1996]; winds were adjusted to match mean wind speed and direction derived from a 0.5°version of QuikSCAT data based on the methods presented by Chin *et al.* [1998].	Large & Yeager [2009]; Griffies *et al.* [2009]; see also data1.gfdl.noaa.gov/nomads/forms/core/COREv2.html.
Drakkar forcing set (DFS v5.2)		
Jan 1958 – present [0.70°, 3h]	DFS is based on the ERA-Interim reanalysis (ERA-40 for data prior to 1979). Local wind component means were shifted to match mean wind speeds from QuikSCAT data (thresholded to a maximum increase of 15% and excluding locations poleward of 60° of latitude).	Brodeau *et al.* [2010]; see also www.drakkar-ocean.eu.
Adjusted Japanese 55-year Reanalysis (JRA-55corr)		
Jan 1958 – Feb 2015 [0.56 x 0.56°, 3h]	Adjusted version of JRA-55. Surface winds were adjusted to satellite climatological winds (SSM/I and QuikSCAT) using a spatially varying scale factor for wind speed and complex EOF analysis for wind direction.	Kobayashi *et al.* [2015], internal report by H. Tsujino, jra.kishou.go.jp.

*Uses 365 day, no leap years.

Shorten this Table for presentation (Justin)

Assessment of different wind reanalysis products

Reanalysis product	Corrected version	Resolution	
NCEP	CORE v2.1	1.85° x 1.90°	6h
ERA-Interim	DRAKKAR	0.70° x 0.70°	3h
JRA-55	JRA-55corr	0.56° x 0.56°	3h