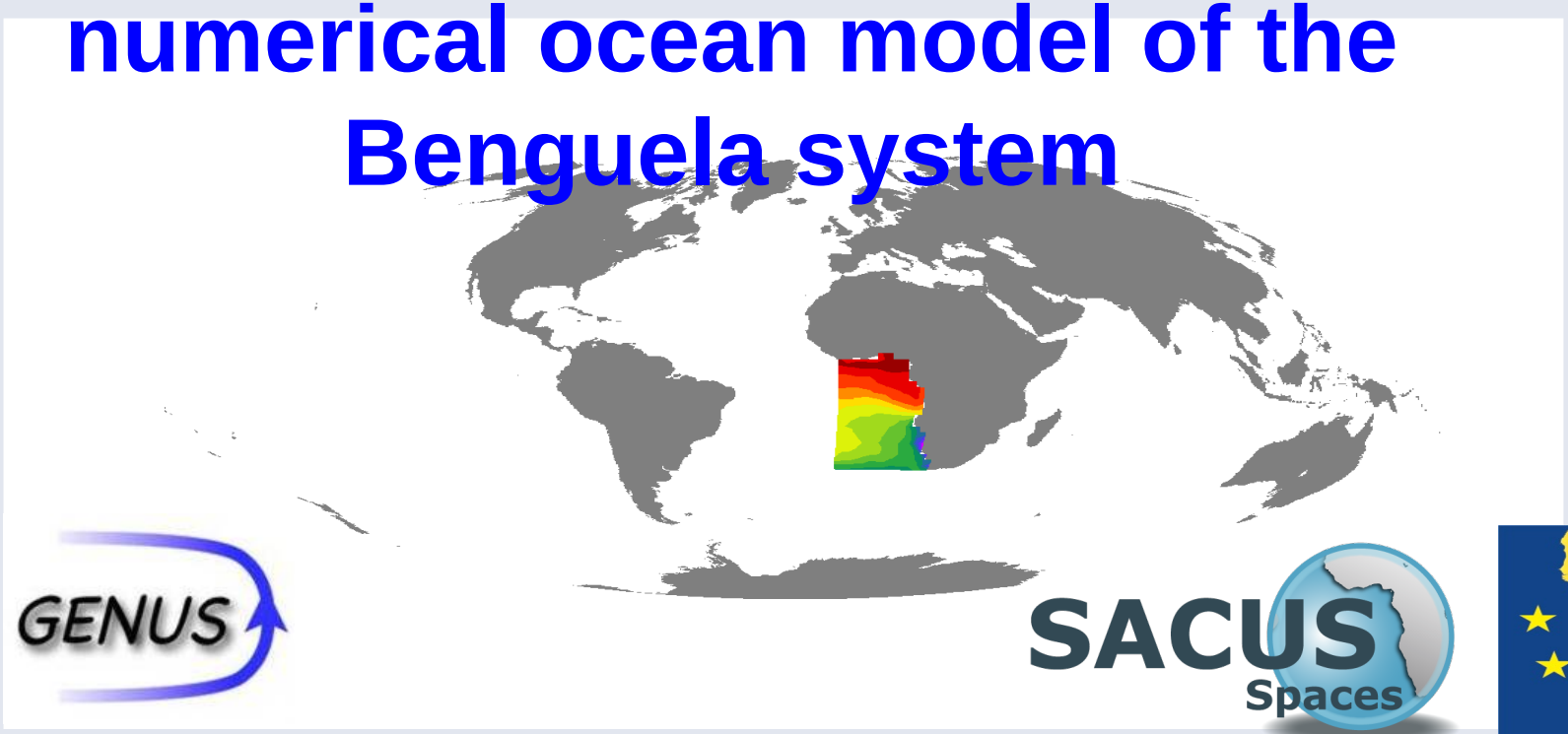
The relation of SST-bias and water mass distribution seen in a regional numerical ocean model of the Benguela system



Martin Schmidt
Leibniz-Institute for Baltic Sea Research
Rostock-Warnemünde, Germany

Contributions from: Tim Junker, Lydia Siegfried, Volker Mohrholz, Annethea Muller, Anja Van Der Plas ...

Method

Use **regional, “forced” models** to simulate the circulation in the Benguela upwelling system.

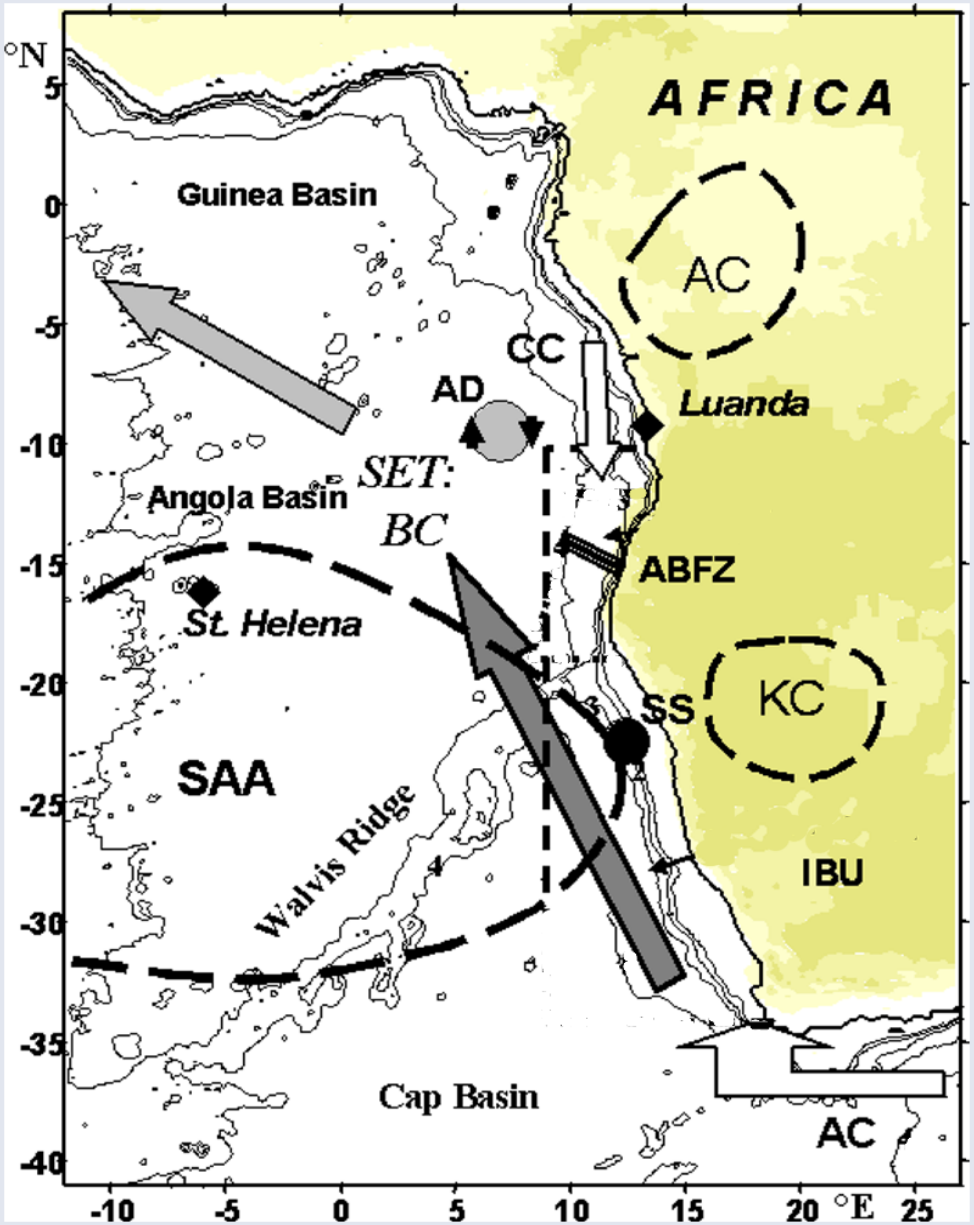
Use **realistic** drivers to allow comparison with **field data**

Validate models results of a regional model with focus on the SST-bias

Discuss:

- Flow pattern from **analytical** results
- SST bias
- Current pattern in relation to the wind forcing
- Salinity distribution

The circulation model



Atmospere circulation (Hagen et al. 2005)
SAA : South Atlantic Anticyclon
KC : Kalahari Cyclon
AC : Angola Cyclon

Circulation model →

MOM (8 km, 89 levels)

Atmospheric drivers →

- Forecast products:
  ECMWF, 6 hourly, 1/4 deg.
- Reanalysisc products:
  NCEP, 3 hourly, 1/8 deg.
- DRAKKAR forcing
- Scatterometer Products
  QuikSCAT/ASCAT, daily
  CCMP, 6 hourly

Open boundaries → ECCO

Numerical experiments

Available reanalysis data sets

- **NCEP Climate Forecast System Reanalysis (CFSR) 6-hourly Products, Jan. 1979 – Dec. 2010 (ds093.0)**
- **Era-Interim Reanalysis and Forecast 3 hourly, 1989 - …**
- **DRAKKAR forcing set DS5.2 (derived from ERA, observed flux data …)**

Available data sets for correction of wind fields

- **Scatterometer winds (QuikSCAT, ASCAT) daily composite from 3-days**
- **Cross-Calibrated Multi-Platform (CCMP) project 6 hourly wind data**

Numerical experiments

Sensitivity studies:

Replace wind fields from reanalysis/forecast products with scatterometer based winds

NCEP/ERA winds -> QuikSCAT/ASCAT winds

Replace downward solar radiation products with reduced radiation products

NCEP/ERA radiation -> Bodin-formula

Heat fluxes –one way coupling

escribe state variables, calculate fluxes. (Beljaars et al

$$Q^{surf} \approx Q^{short} + Q^{lat} + Q^{bot} + \left(4\sigma T_a^3 + C^{sens}\right)\left(T_a - T_s\right).$$

Keeps the ocean model close to T_a.

May change sign from Q^{bot}

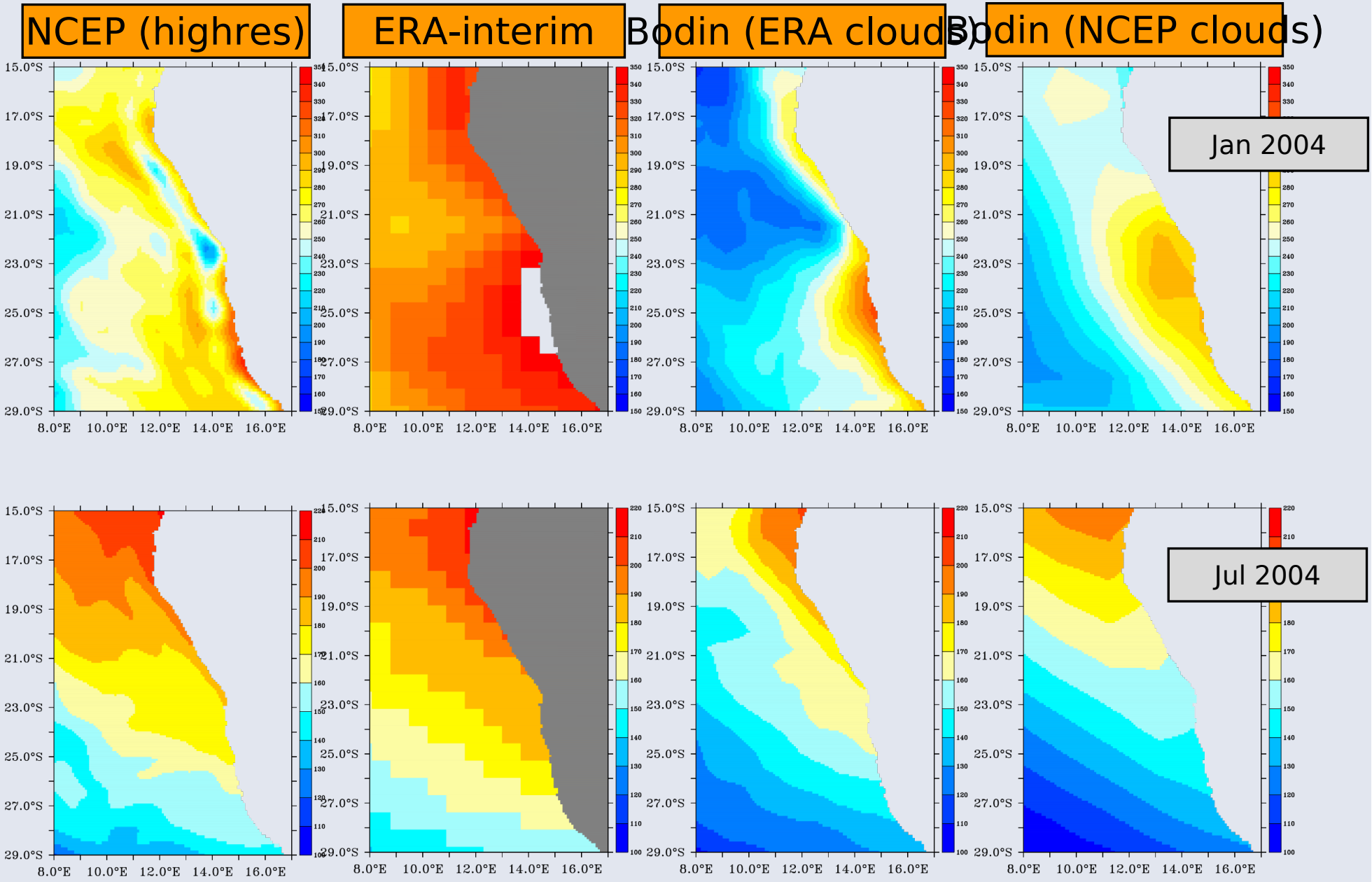
A steady state solution allways exists.

Inherit atmosphere model bias of T_a.

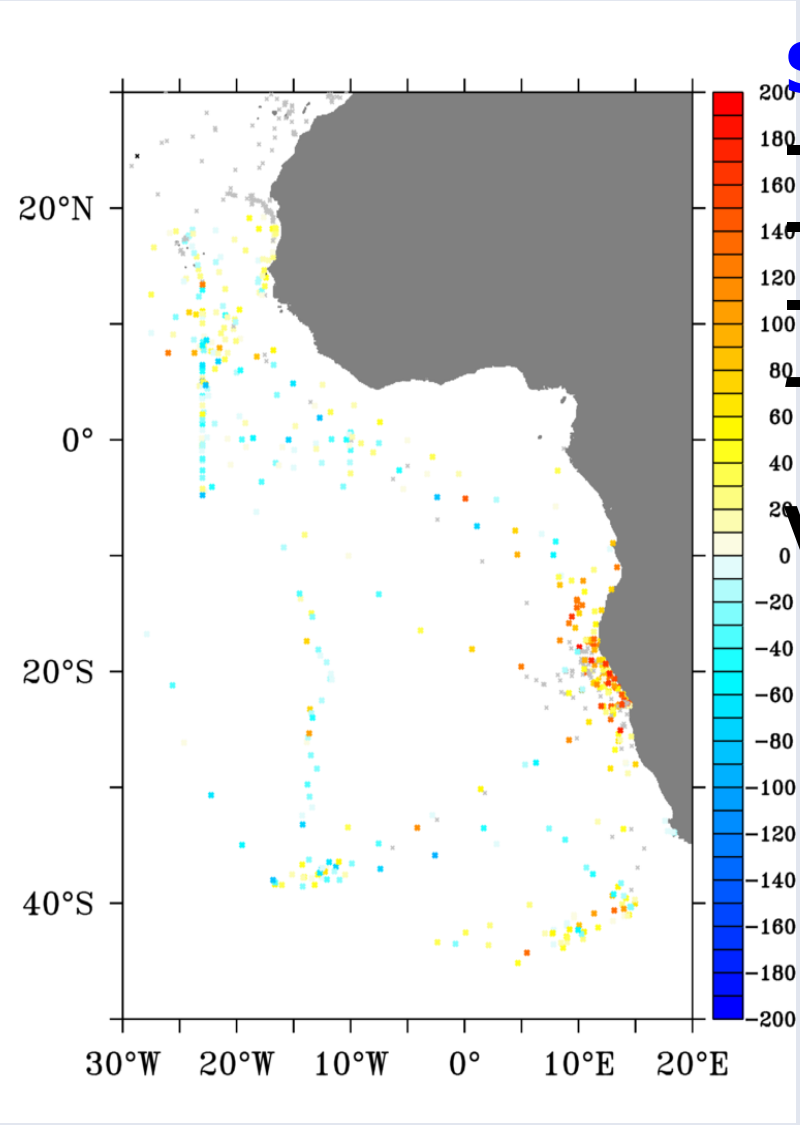
Steady state

shortwave (solar) radiation

Cape Town, August 2015



shortwave (solar) radiation



Ship weather station data

- **wind**
- **air temperature**
- **air pressure**
- ***downwelling radiation***

Virtual cruises in data sets

ECMWF daily shortwave radiadion vs daily shortwave radiadion measured with ships weather station on Maria S. Merian (2007 - 2013)

Summary:

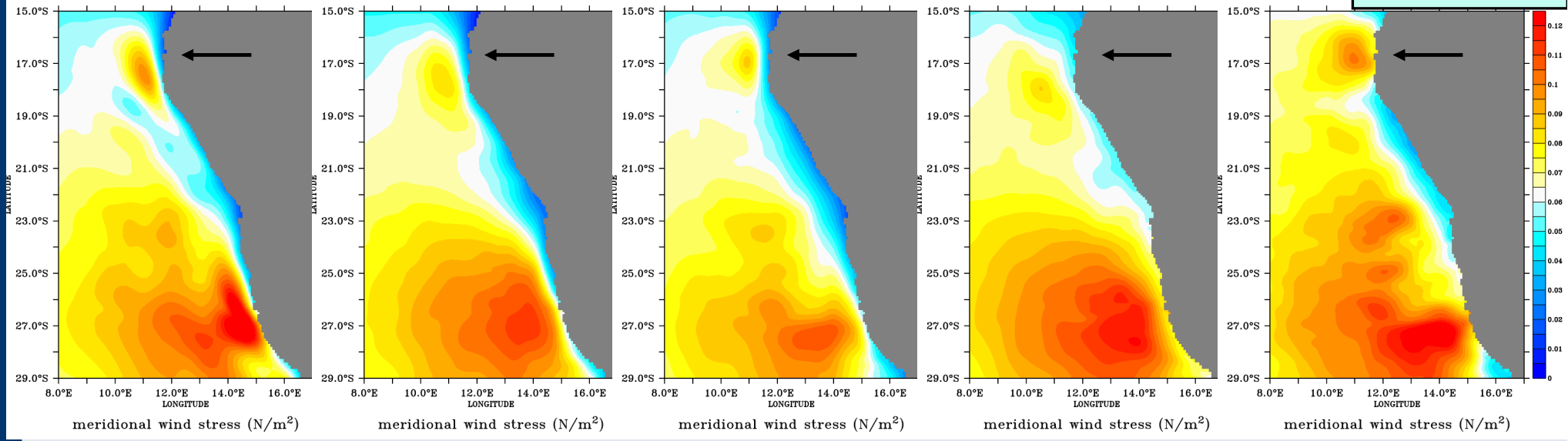
Used bulk formulas for heat flux components may be inconsistent with the forcing data set.

Solar radiation is over-estimated in NCEP reanalysis and ERA forecasts

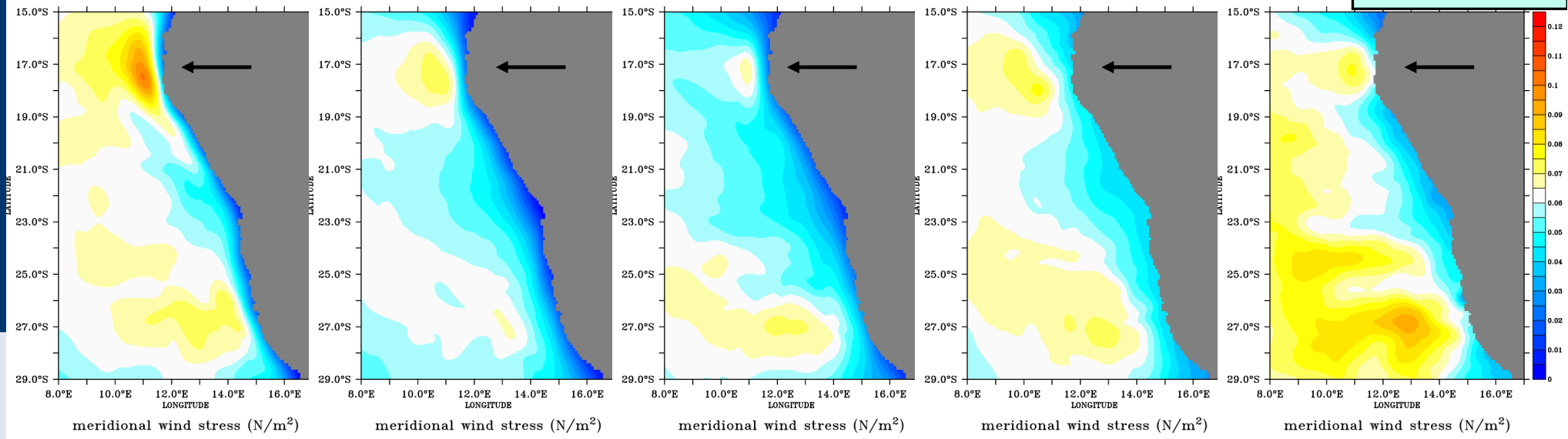
Typical wind stress pattern

NCEP(highres) | ERA(interim) | CCMP | DRAKKAR | QuikScat

Jan 2004

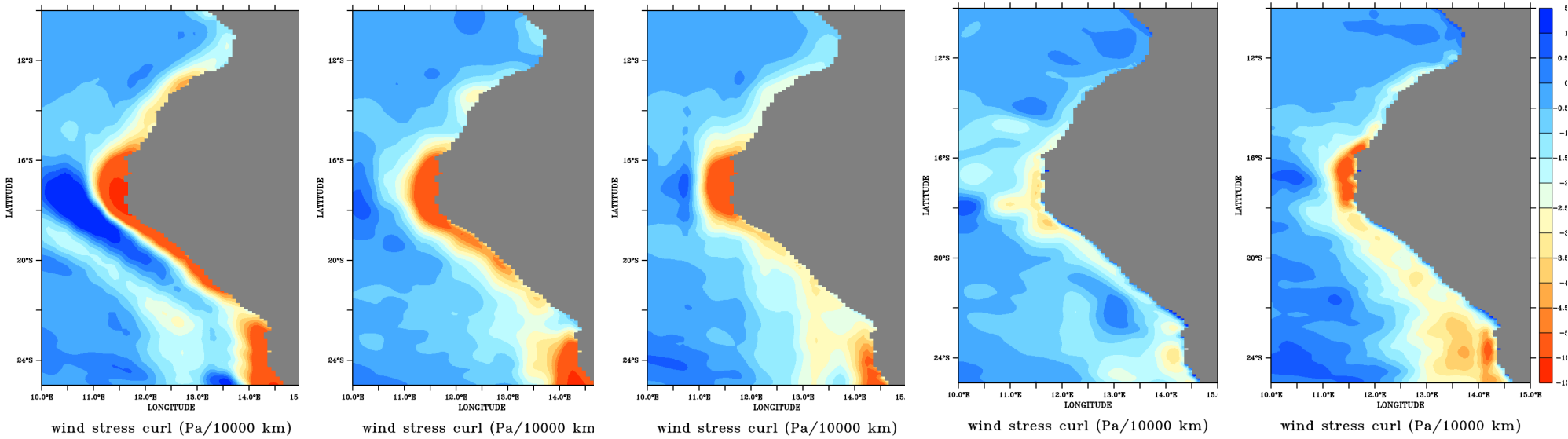


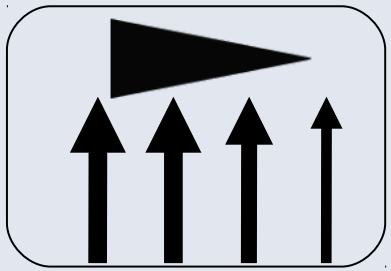
Jul 2004

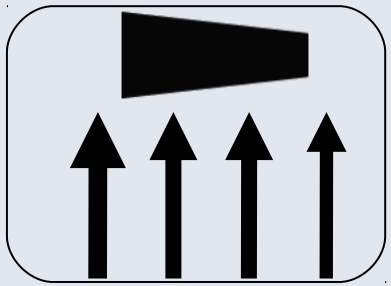


Typical wind stress pattern

NCEP(highres) | ERA(interim) | CCMP | DRAKKAR | QuikScat







Weak coastal winds:

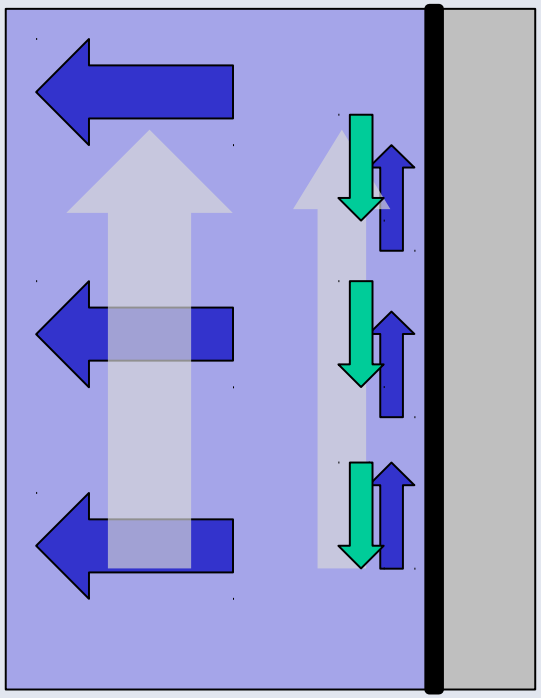
-> weak coastal upwelling

-> weak equator-ward coastal jet

-> enhanced wind stress curl

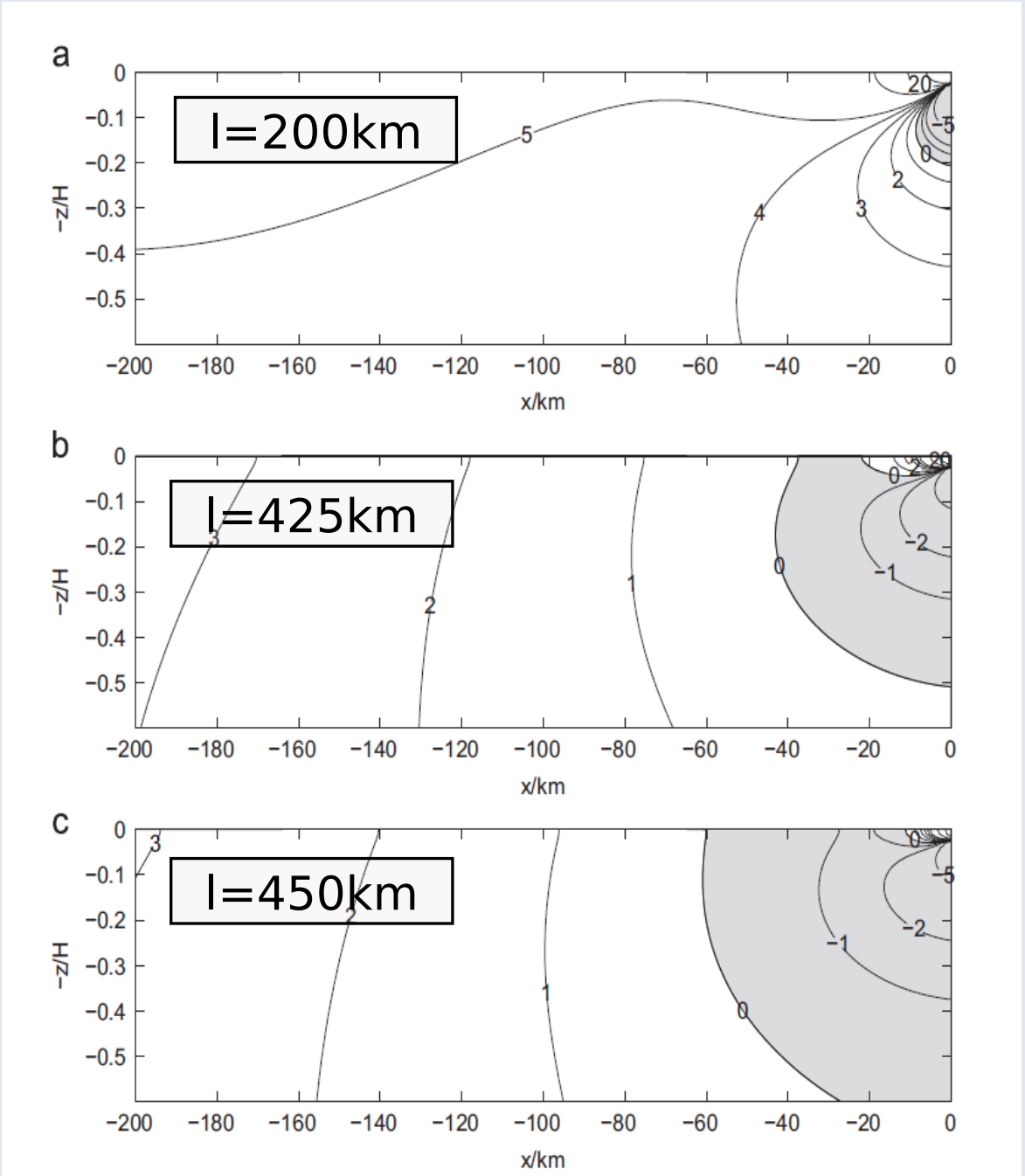
-> enhanced pole-ward Sverdrup flow

Meridional transport



Coastal jet and **under-current** for weak (a) to strong (c) wind stress curl near the coast.

For strong **cur**l the undercurrent penetrates to the surface.
(Fennel et al., 2012)



Meridional transport

$$\rho\beta v = curl\,\tau$$

$$poleward \leftrightarrow < 0$$

$$flow$$

Sverdrup balance?

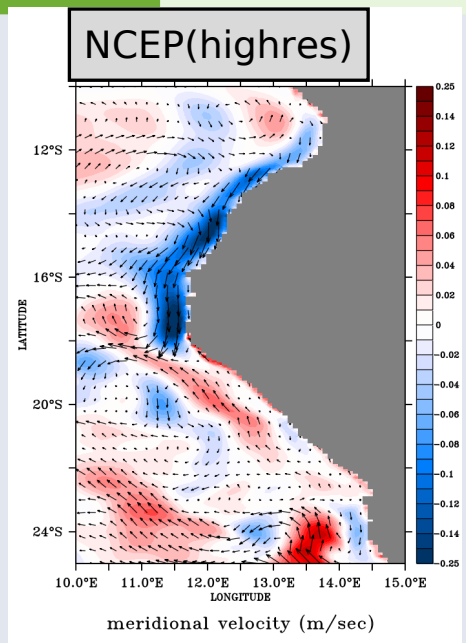
- Near the coast

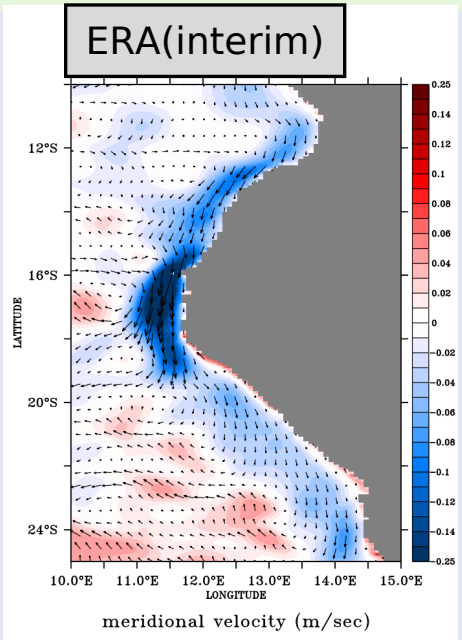
  ->Time scale weeks … months

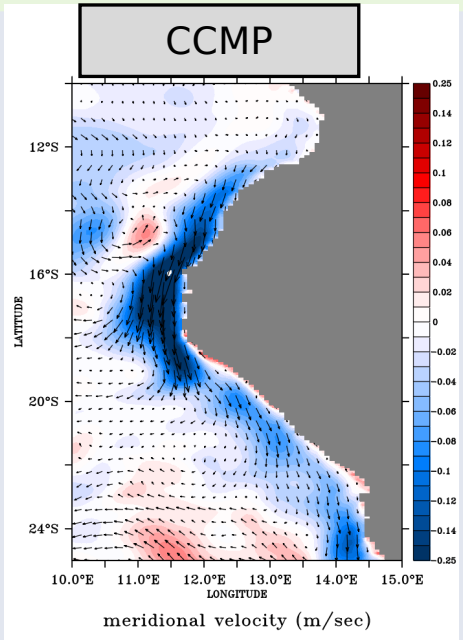
- Negative wind stress curl -> pole-ward flow

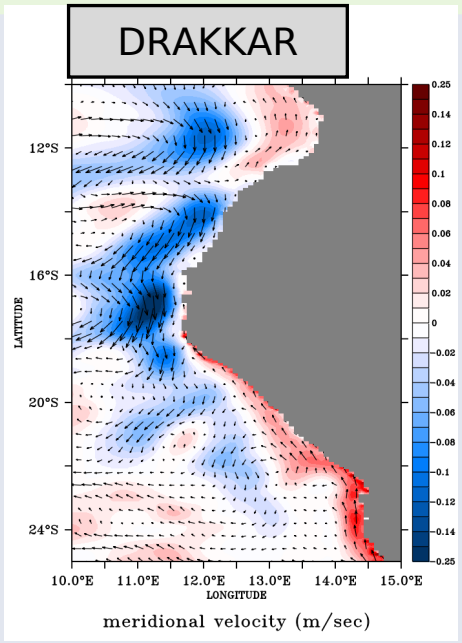
- Relation to f-plane theory?

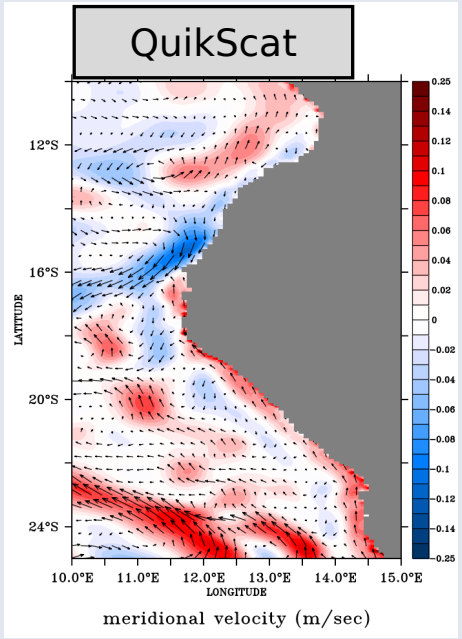
Meridional transport

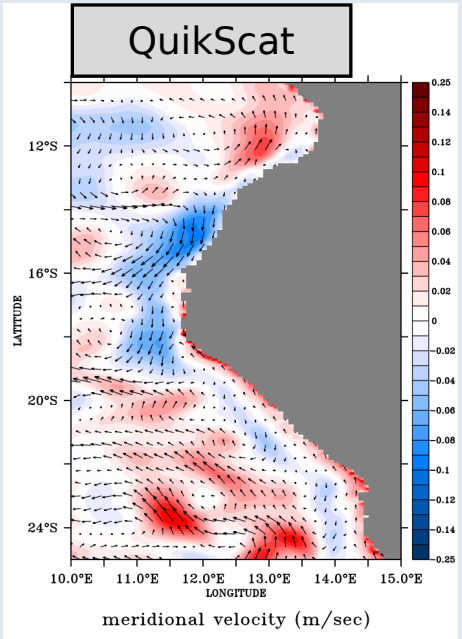






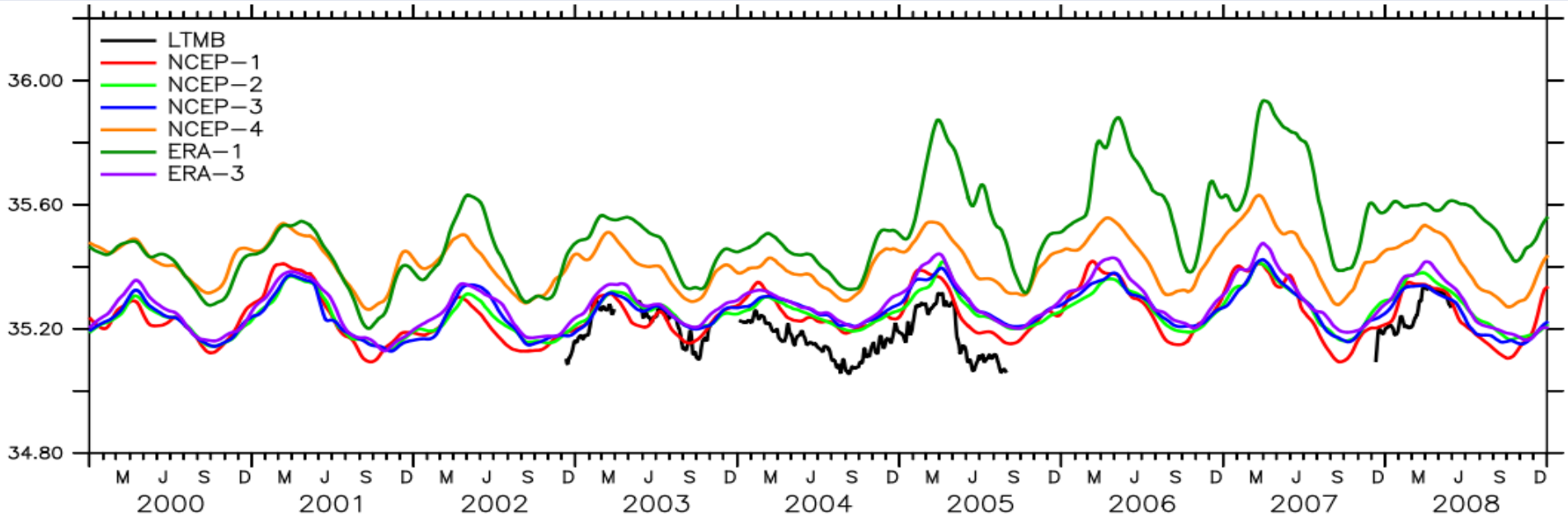




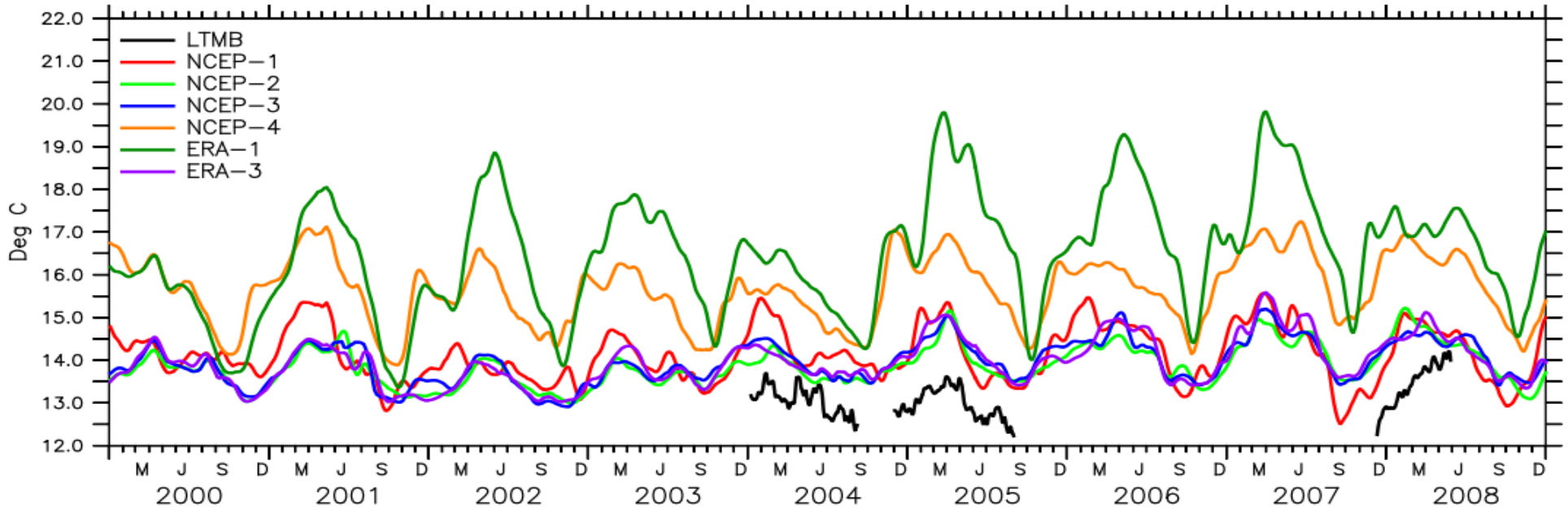


meridional currents in the upper 50 m, January 2004

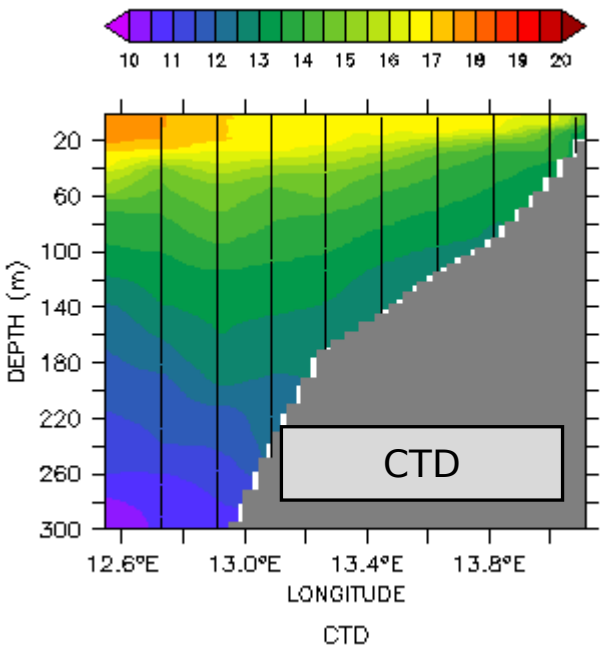
Meridional transport

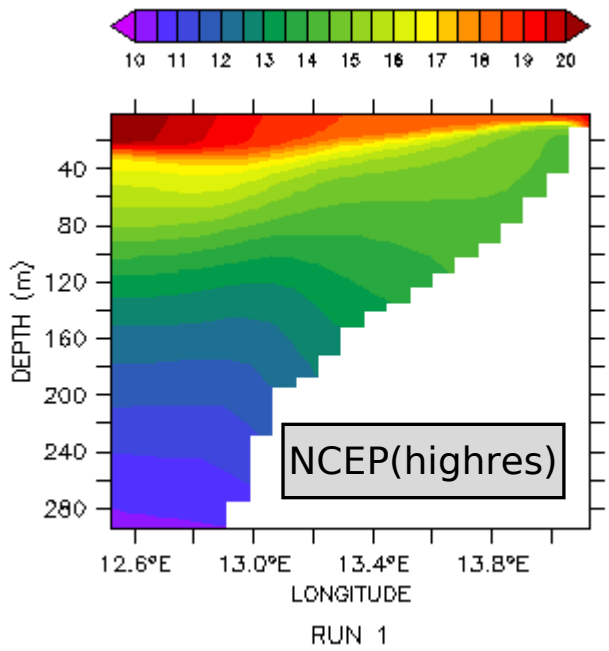


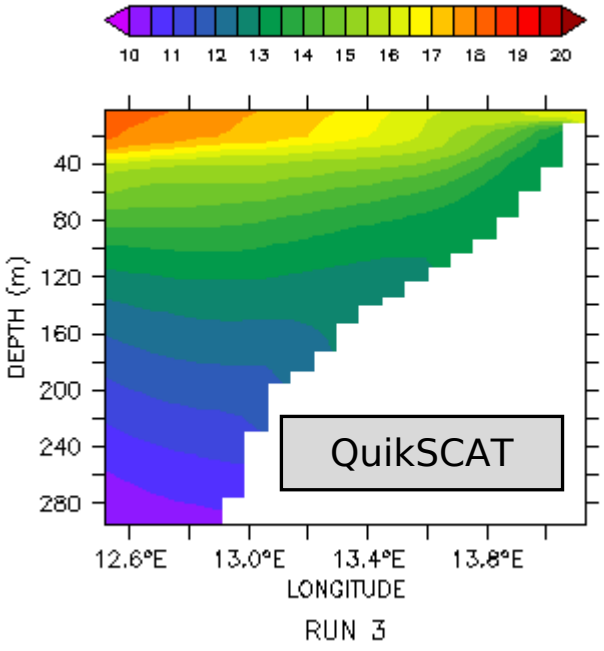
Ensemble salinity at LTMB, z = 63.5 m

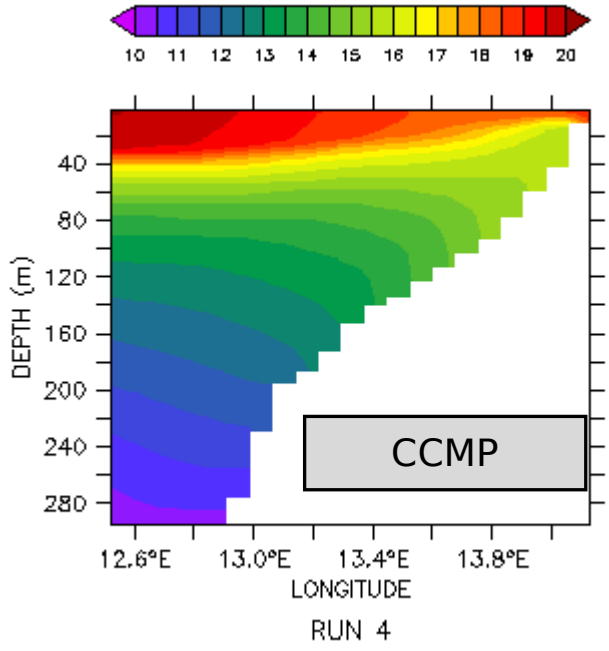


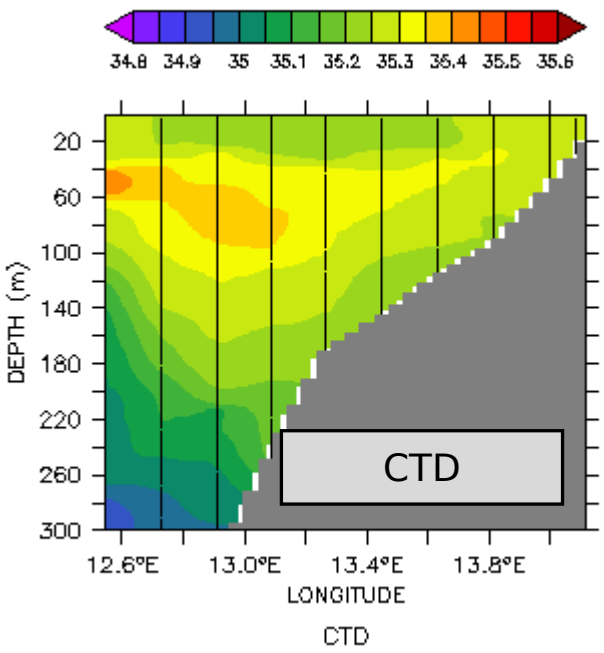
Ensemble temperature at LTMB, z = 43.5 m

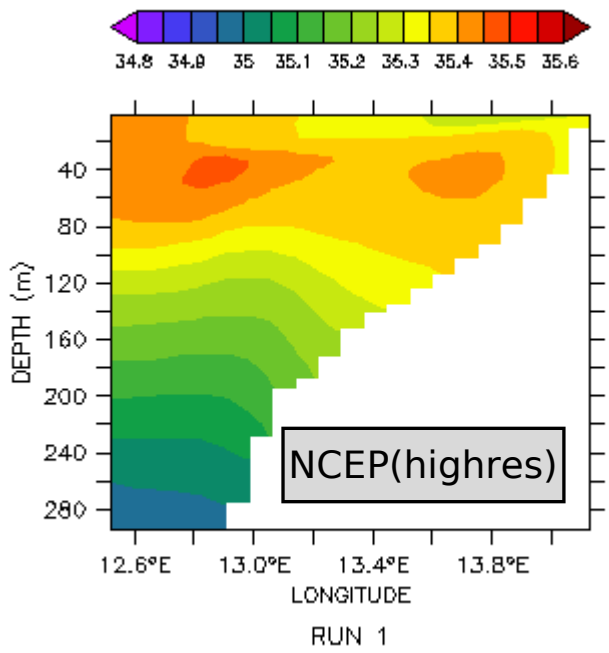

10 11 12 13 14 15 16 17 18 19 20
DEPTH (m)
20
60
100
140
180
220
260
300
12.6°E
13.0°E
13.4°E
13.8°E
LONGITUDE
CTD
CTD

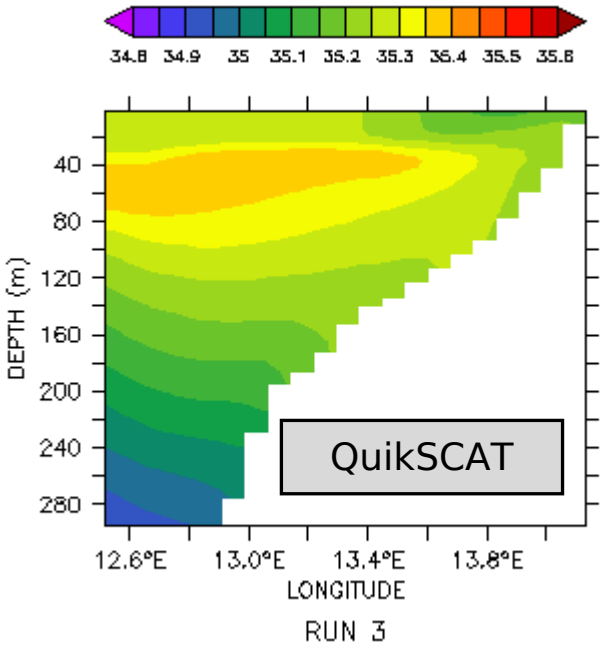

10 11 12 13 14 15 16 17 18 19 20
DEPTH (m)
40
80
120
160
200
240
280
12.6°E
13.0°E
13.4°E
13.8°E
LONGITUDE
NCEP(highres)
RUN 1

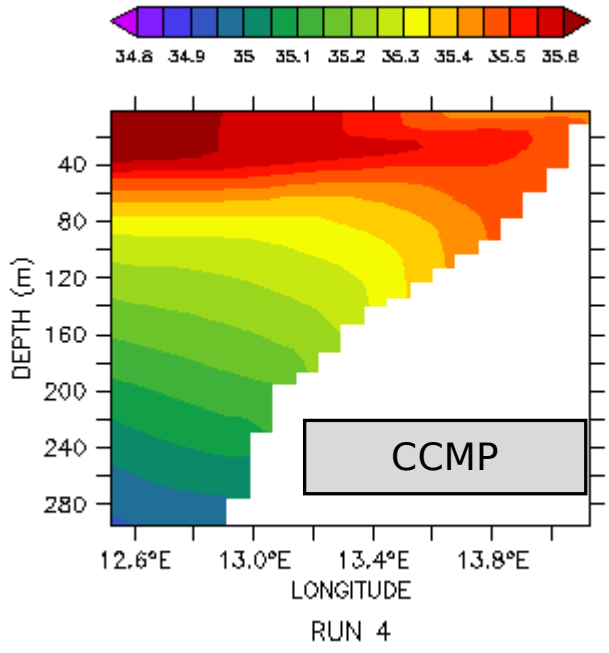

10 11 12 13 14 15 16 17 18 19 20
DEPTH (m)
40
80
120
160
200
240
280
12.6°E
13.0°E
13.4°E
13.8°E
LONGITUDE
QuikSCAT
RUN 3


10 11 12 13 14 15 16 17 18 19 20
DEPTH (m)
40
80
120
160
200
240
280
12.6°E
13.0°E
13.4°E
13.8°E
LONGITUDE
CCMP
RUN 4

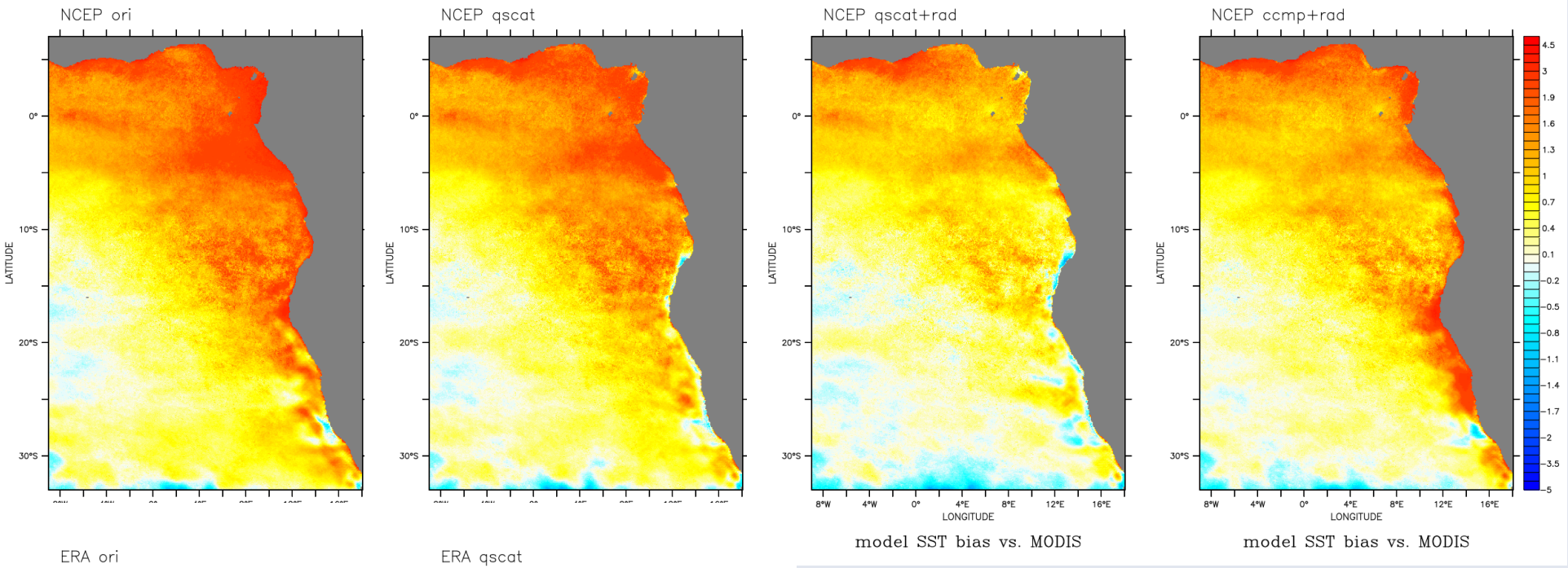

34.8 34.9 35 35.1 35.2 35.3 35.4 35.5 35.6
DEPTH (m)
20
60
100
140
180
220
260
300
CTD
12.6°E 13.0°E 13.4°E 13.8°E
LONGITUDE
CTD


34.8 34.9 35 35.1 35.2 35.3 35.4 35.5 35.6
DEPTH (m)
40
80
120
160
200
240
280
NCEP(highres)
12.6°E 13.0°E 13.4°E 13.8°E
LONGITUDE
RUN 1


34.8 34.9 35 35.1 35.2 35.3 35.4 35.5 35.6
DEPTH (m)
40
80
120
160
200
240
280
QuikSCAT
12.6°E 13.0°E 13.4°E 13.8°E
LONGITUDE
RUN 3


34.8 34.9 35 35.1 35.2 35.3 35.4 35.5 35.6
DEPTH (m)
40
80
120
160
200
240
280
CCMP
12.6°E 13.0°E 13.4°E 13.8°E
LONGITUDE
RUN 4

SST-bias (average 2004)



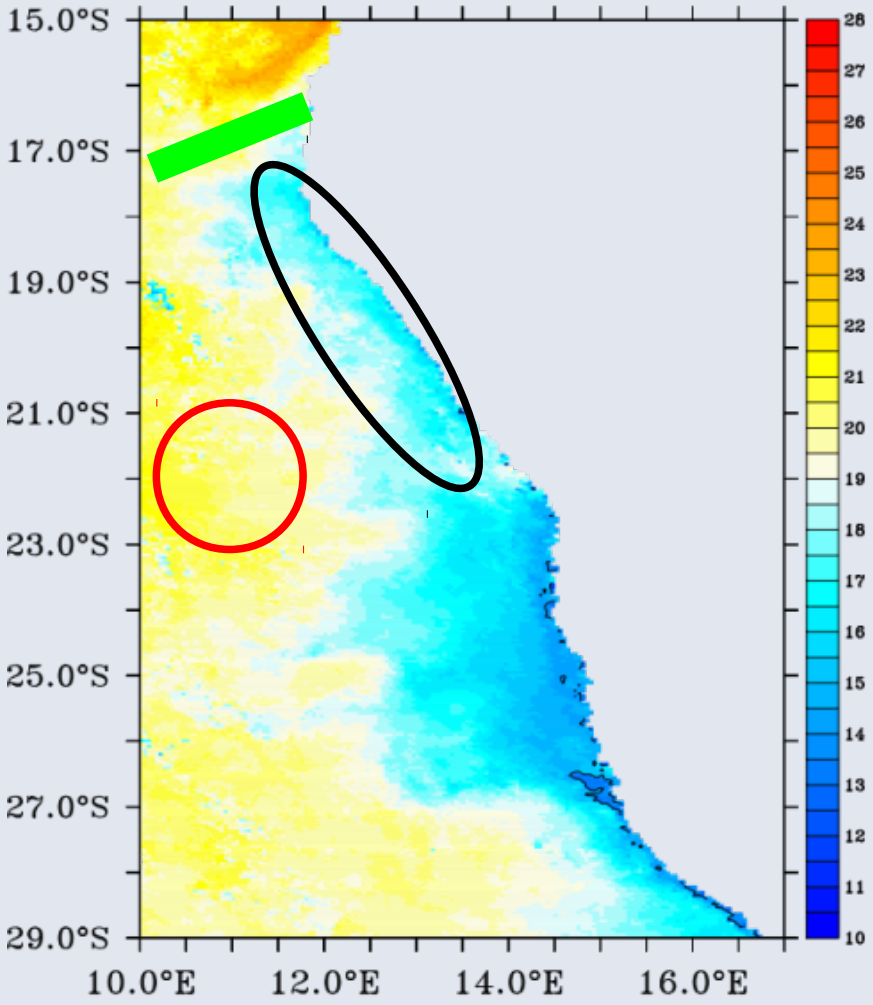
model SST bias vs. MODIS

model SST bias vs. MODIS

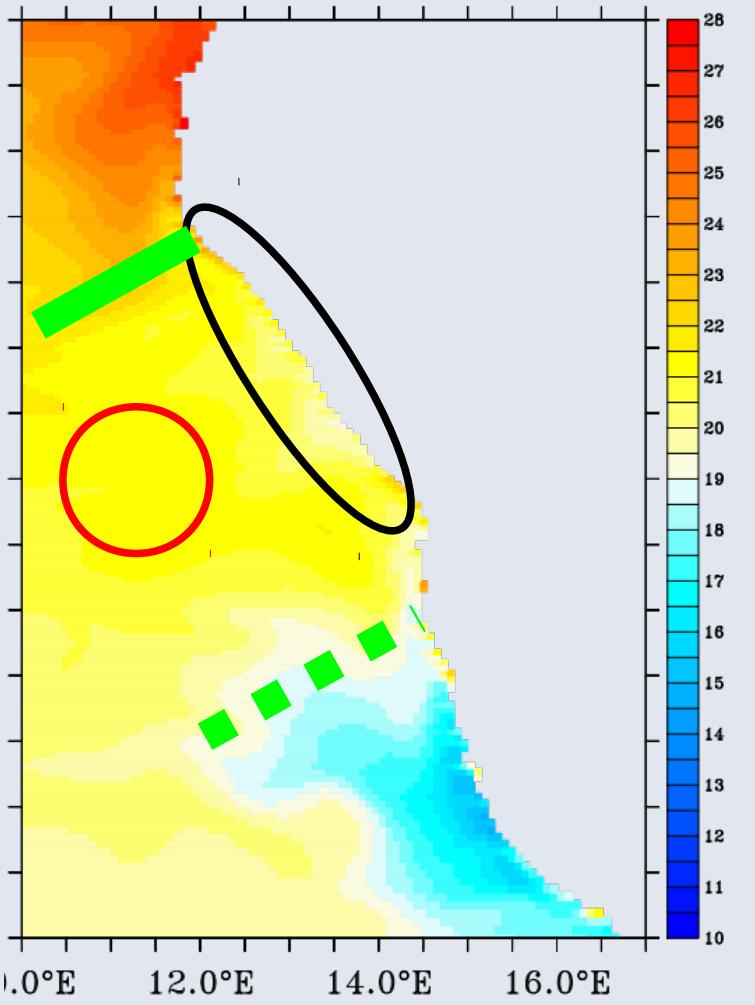
model SST bias vs. MODIS

model SST bias vs. MODIS

SST-bias contributions



MODIS - SST



Model - SST with inappropriate surface forcing

Conclusion

- **Surface fluxes** determine a positive SST bias

  Heat fluxes : large scale distribution
  Wind stress : coastal SST – gradients, upwelling strength

- **Standard flux products** may have a large bias.
  The coupling scheme stabilises the model.
  Radiation errors lead to a bias, no model drift.

- **Reanalysed winds** underestimate coastal meridional winds, especially in the upwelling cells (Kunene cell)

  low coastal upwelling : low vertical heat flux.
  enhanced wind stress curl : enhanced poleward transport
  -> poleward heat (and salt) transport

Open question: Do we see mainly an f-plane regime or a Sverdrup regime?

Outlook

- **Quantitative estimate of lateral heat fluxes**
- **Heat flux by upwelling and vertical mixing**
- **Mixed layer depth evaluation**
- **Influence of optical water properties**

....

Foto: T. Heene(2013)