Sea surface temperature and what we can (or cannot) learn from it

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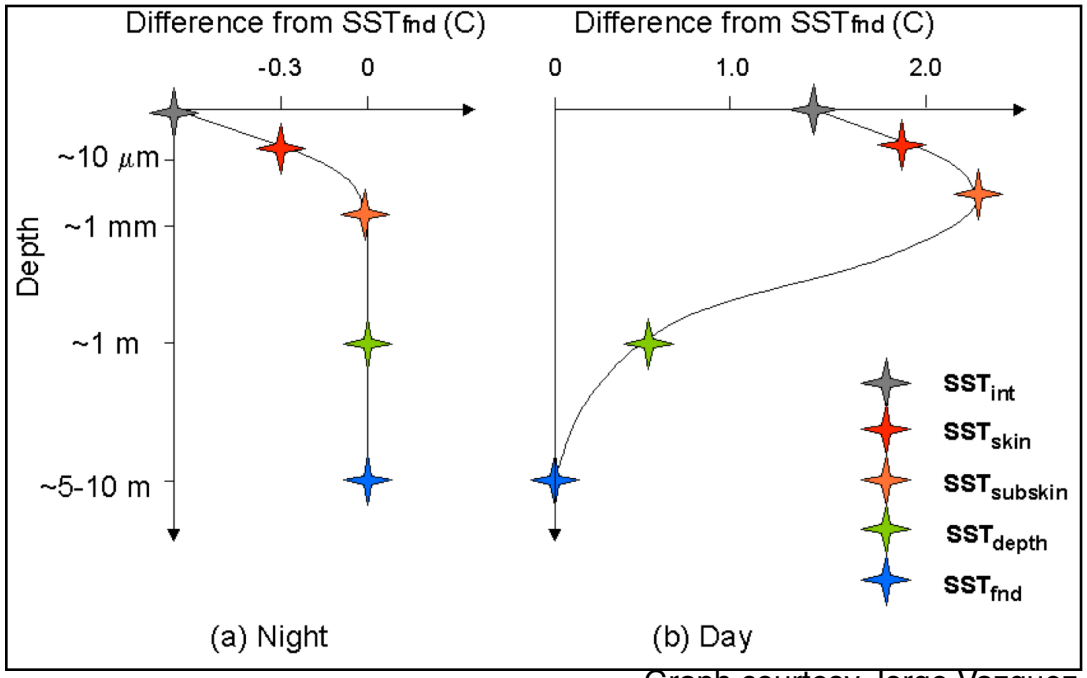
In cooperation with JPL
(Dimitris Menemenlis, Jorge Vazquez,
Ed Armstrong, and Dave Moroni)

- SST is the best observed oceanic quantity
- Satellite measurements have high quality, but there are several issues, e.g.:
  - What do different sensors actually measure?



Graph courtesy Jorge Vazquez

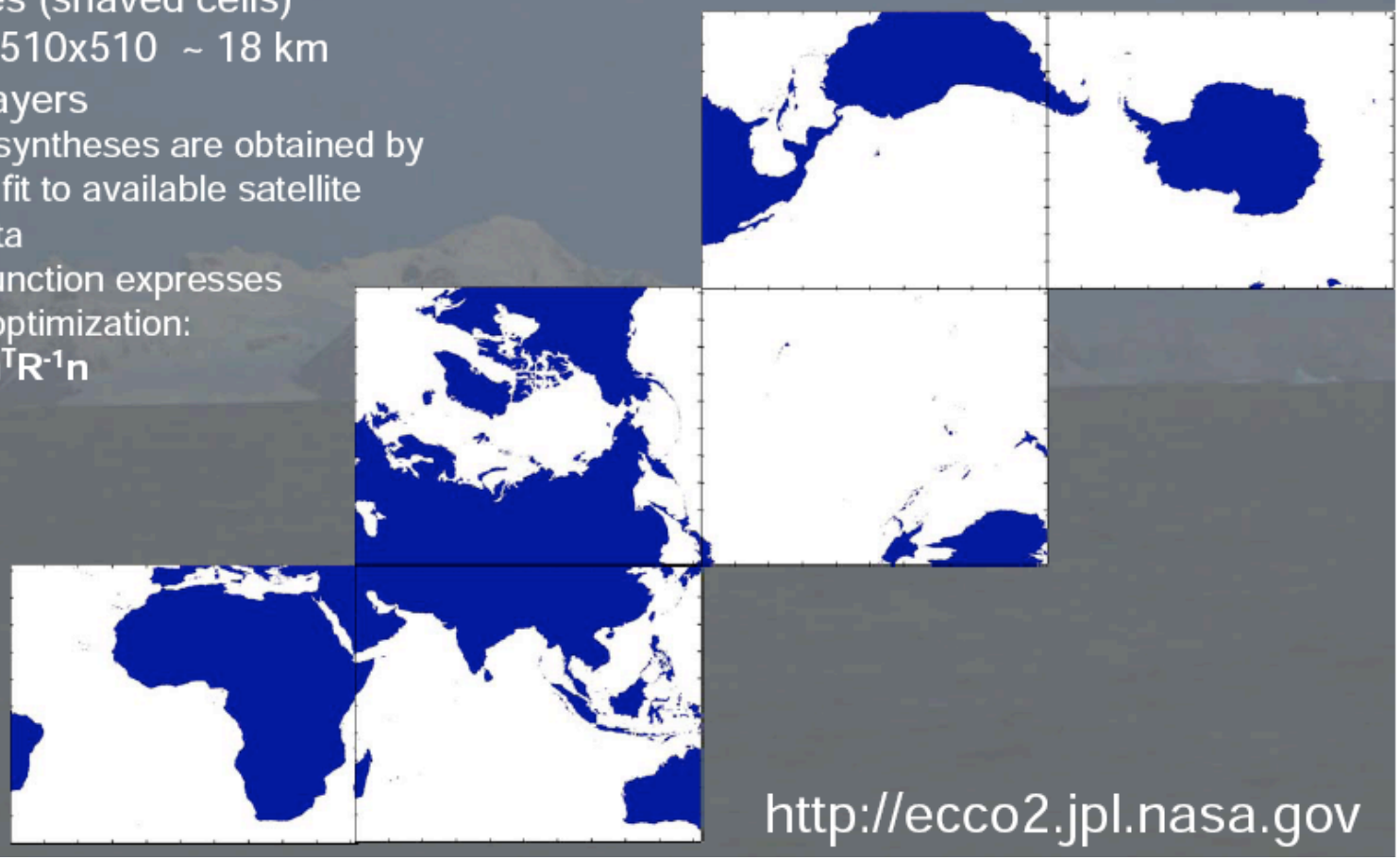
  - How does that compare to modeled SST?

Estimating the Circulation and Climate of the Ocean, Phase II: High Resolution Global-Ocean and Sea-Ice Data Synthesis

Model Set up:

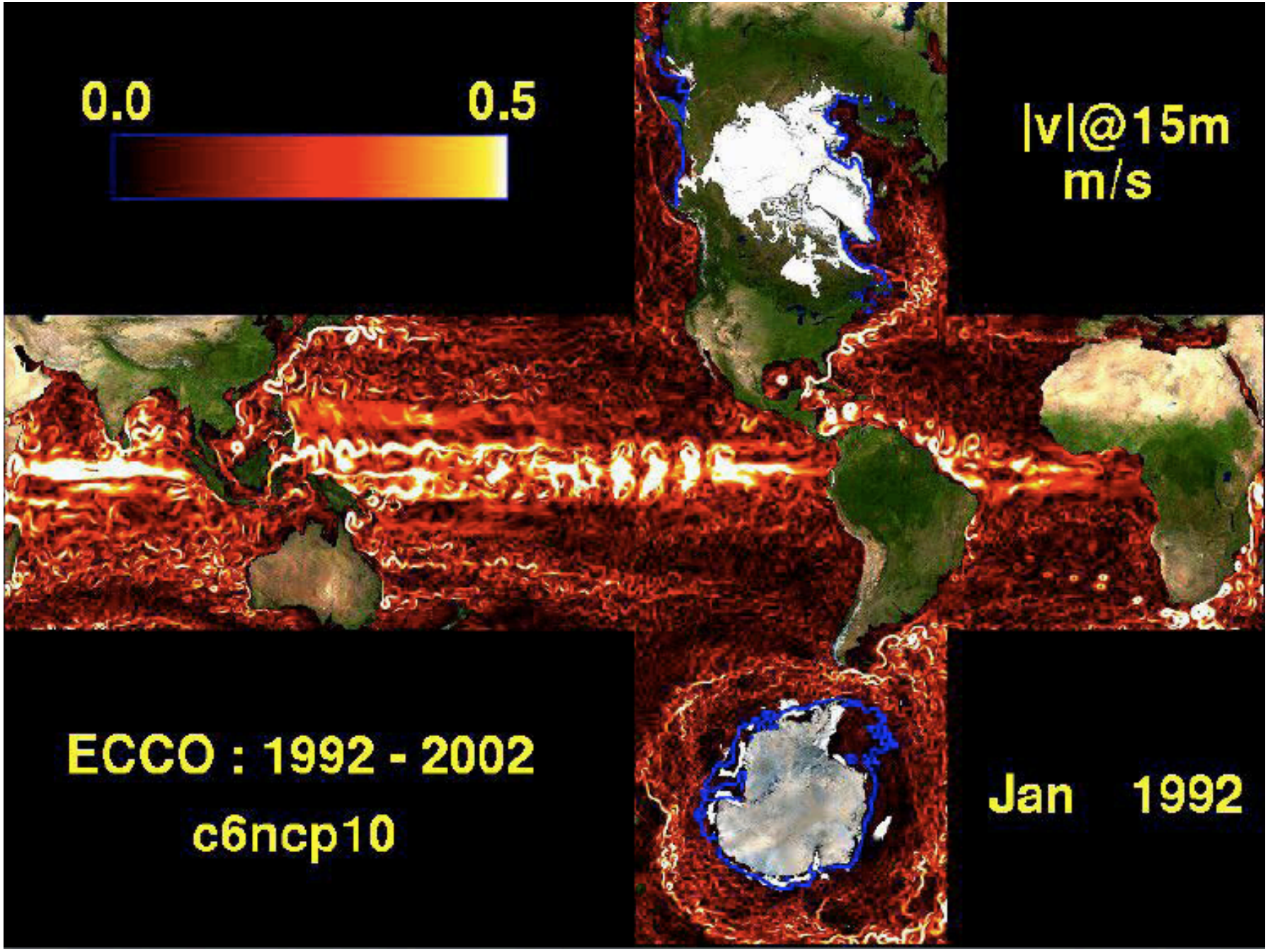
- Ocean model MITgcm
- z-coordinates (shaved cells)
- 6 `Faces` à 510x510 ~ 18 km
- 50 vertical layers
- ECCO2 data syntheses are obtained by least squares fit to available satellite and in-situ data
- An objective function expresses the extent of optimization:

$$J = u^T Q^{-1} u + n^T R^{-1} n$$



http://ecco2.jpl.nasa.gov

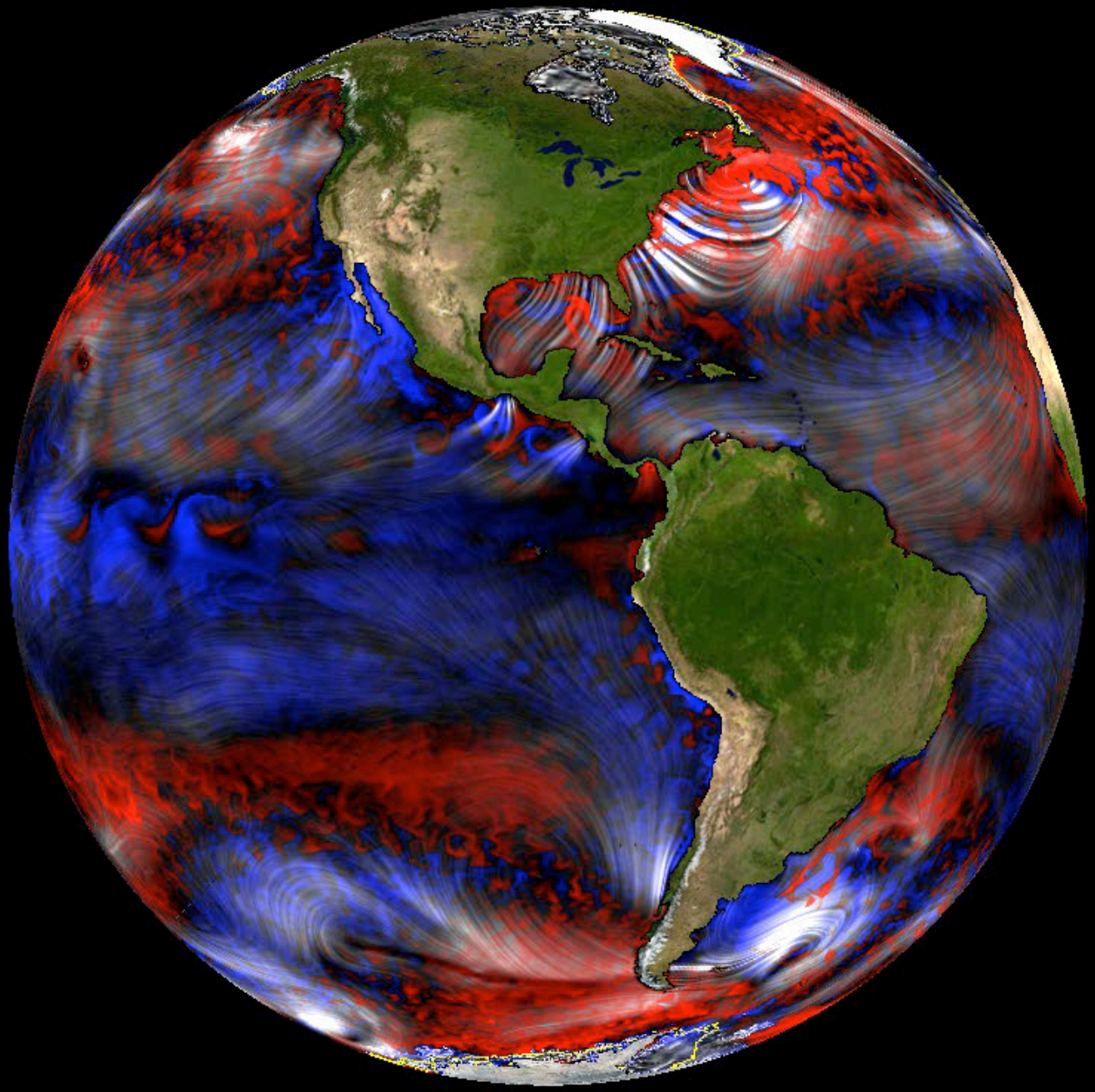
Slide courtesy Michael Schodlok



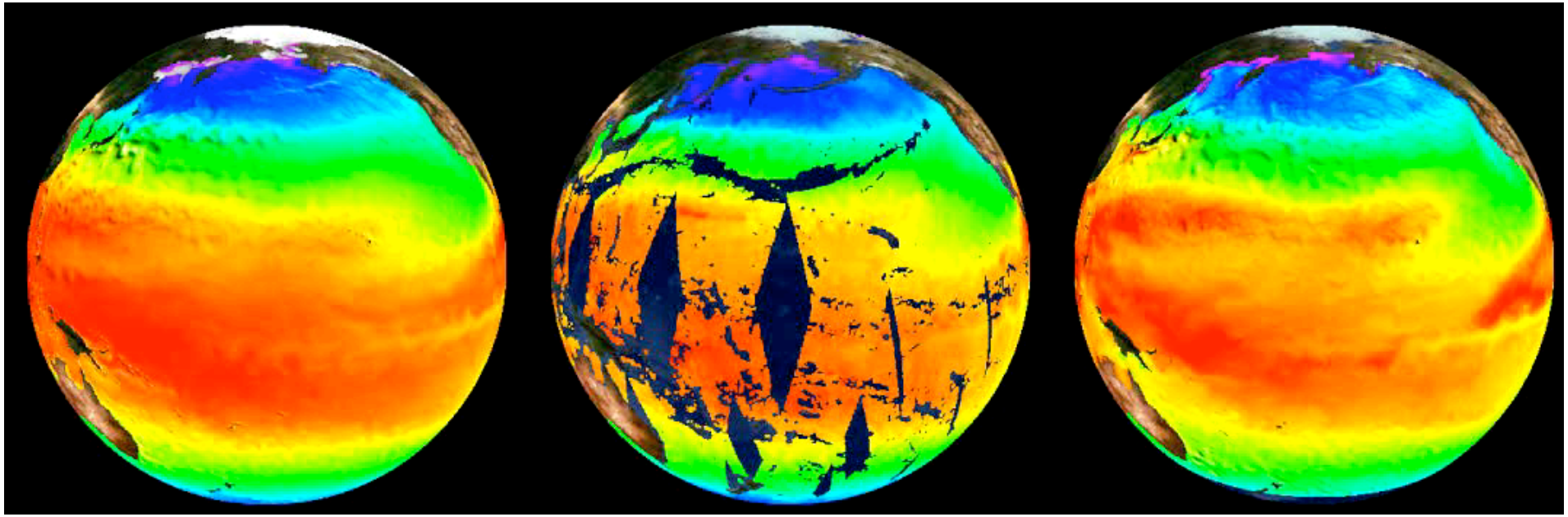
Slide courtesy Dimitris Menemenlis

- Can we use SST to get more information about other oceanic quantities?
  - Mixed layer heat budget
  - Mixed layer depth
  - Surface currents
  - Climate pattern
- What drives SST variability?

ECCO2
SST
TAU



SST variability in ECCO2 and beyond….



ECCO2 model | AVHRR-AMSRE satellite data | ROMS model

Mixed layer heat budget and SST

$$\frac{\partial T}{\partial t} = \frac{1}{h}\frac{Q}{\rho C_p} - \frac{1}{h}\frac{\partial h}{\partial t}\Delta T + \text{advection} + \text{diffusion}$$

<u>Project Questions:</u>

- Which processes dominate on which time scales?
- How do the components of this equation vary with location?
- Does resolution matter?
- How big are the associated errors?

Mixed layer heat budget and SST

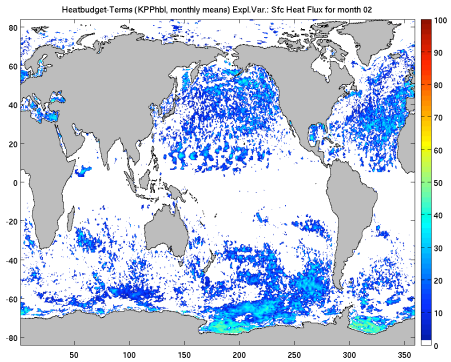
$$\frac{\partial T}{\partial t} = \frac{1}{h}\frac{Q}{\rho C_p} - \frac{1}{h}\frac{\partial h}{\partial t}\Delta T + \text{advection} + \text{diffusion}$$

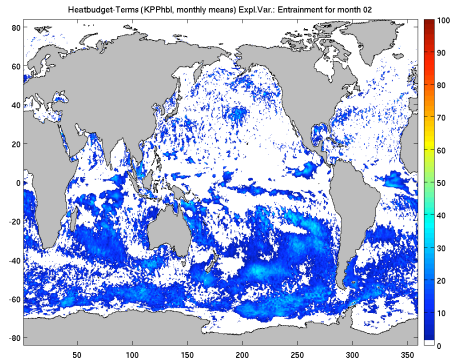
$$= \text{Heat} + \text{Entr} + \text{Resi}$$

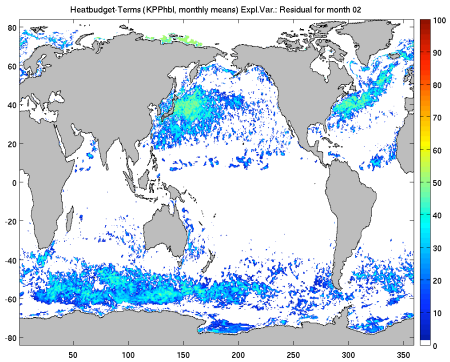
$$= Q + E + R$$

Srfc.heat flux | Entrainment | Residual

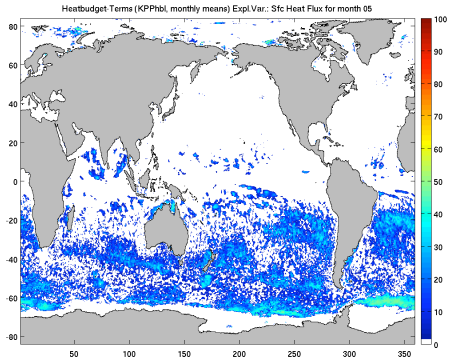
FEB

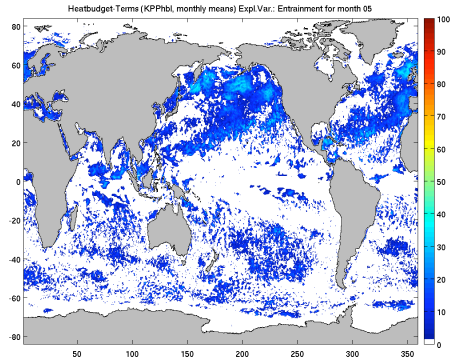


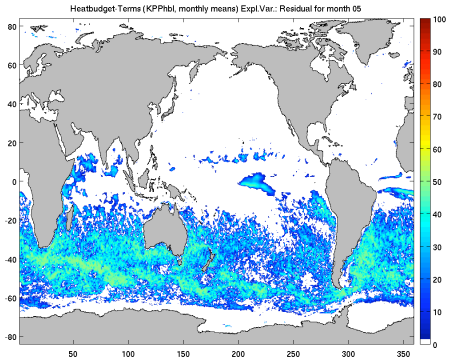




MAY





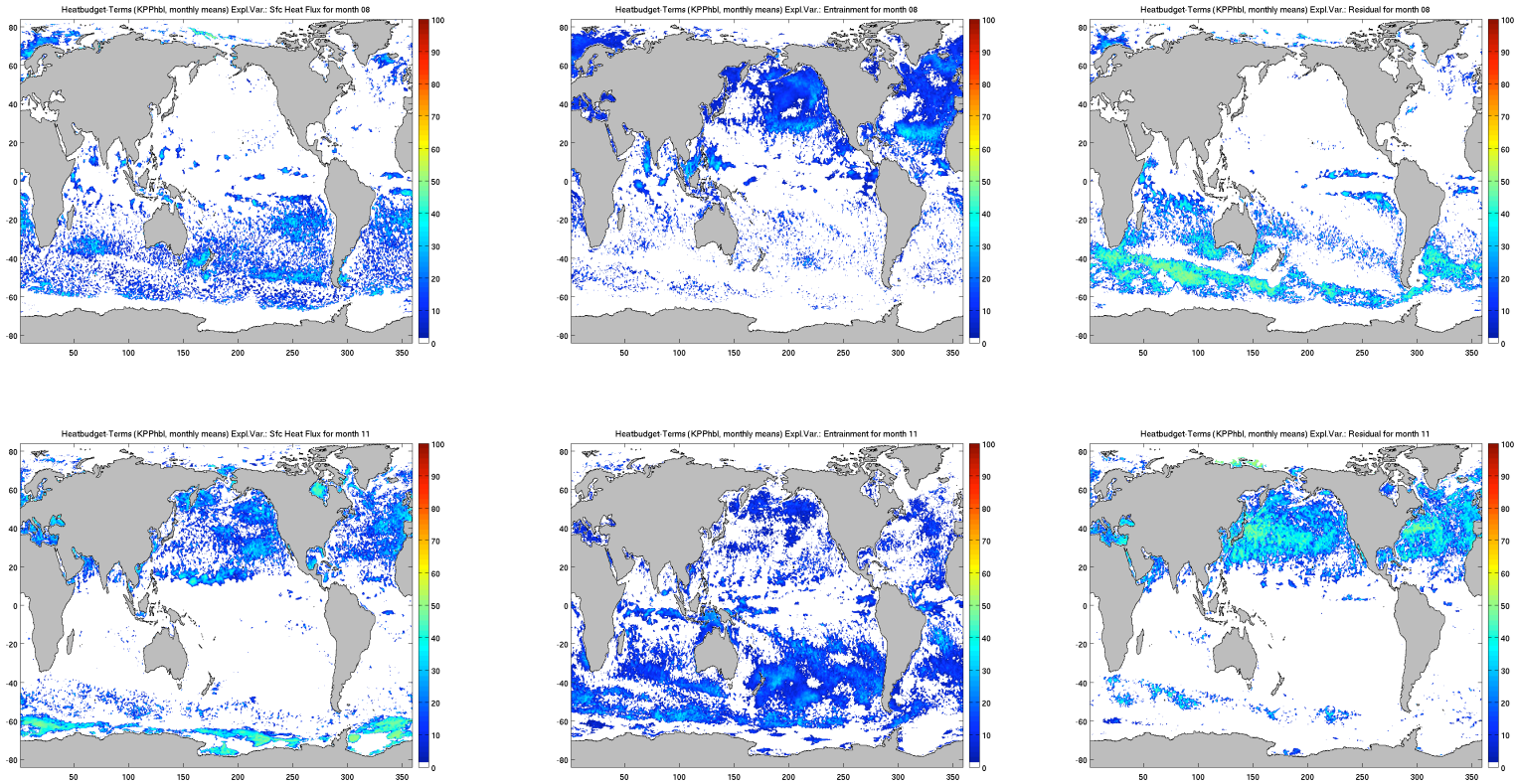


Explained variances, monthly data
Single months

Srfc.heat flux | Entrainment | Residual

AUG

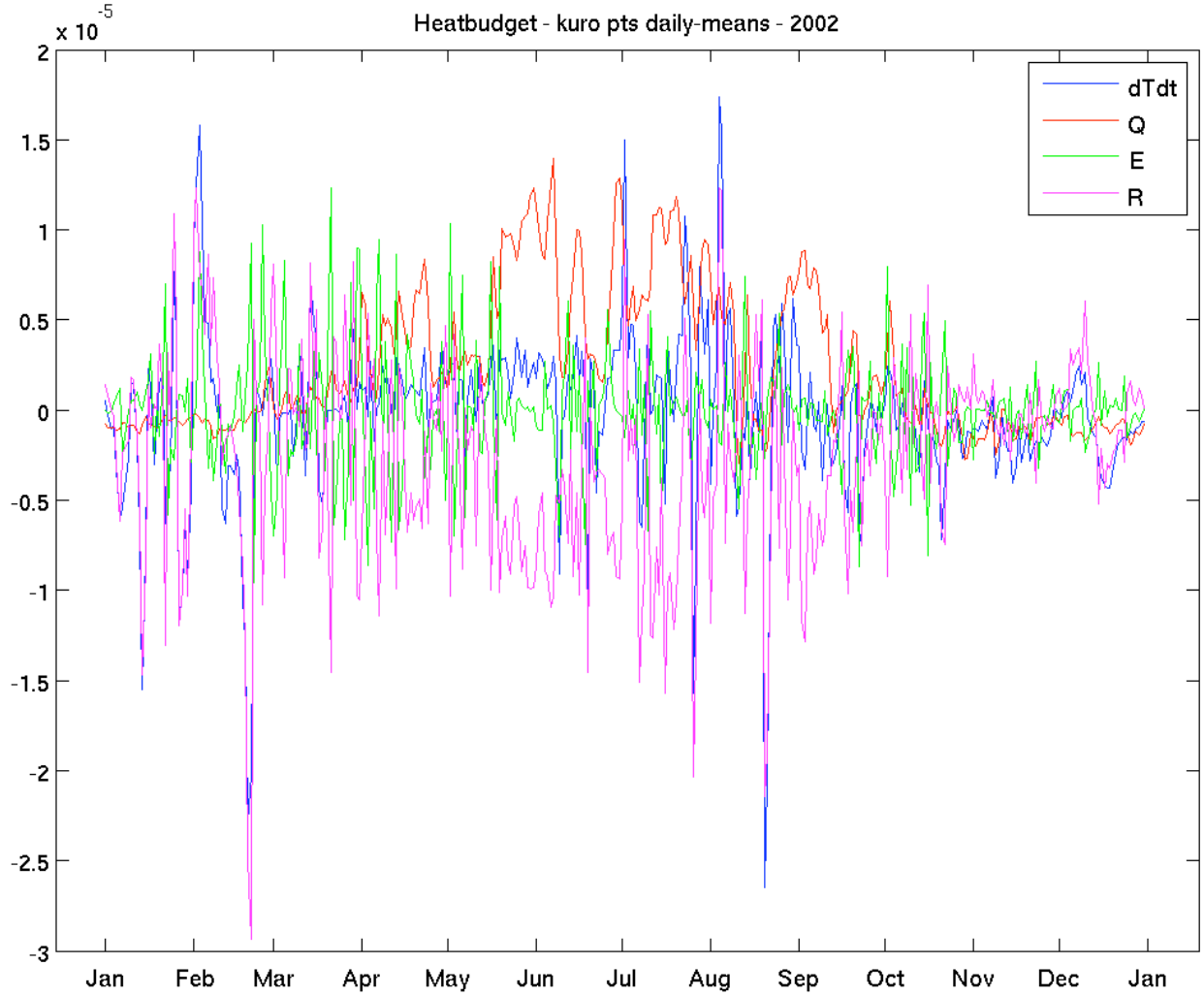
NOV



Explained variances, monthly data
Single months

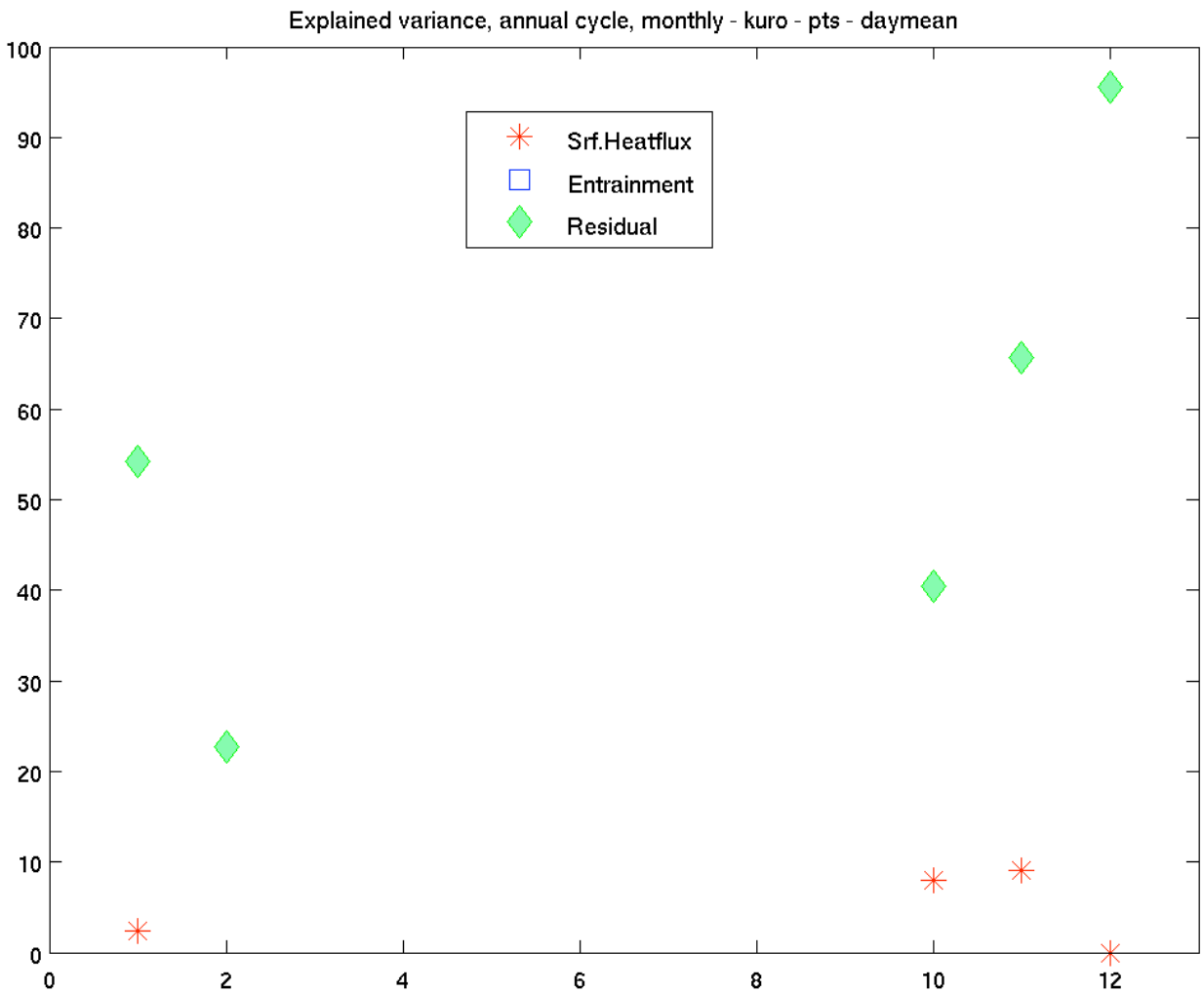
ECCO2 – heat budget – year 2002 – Kuroshio

Daily means single point



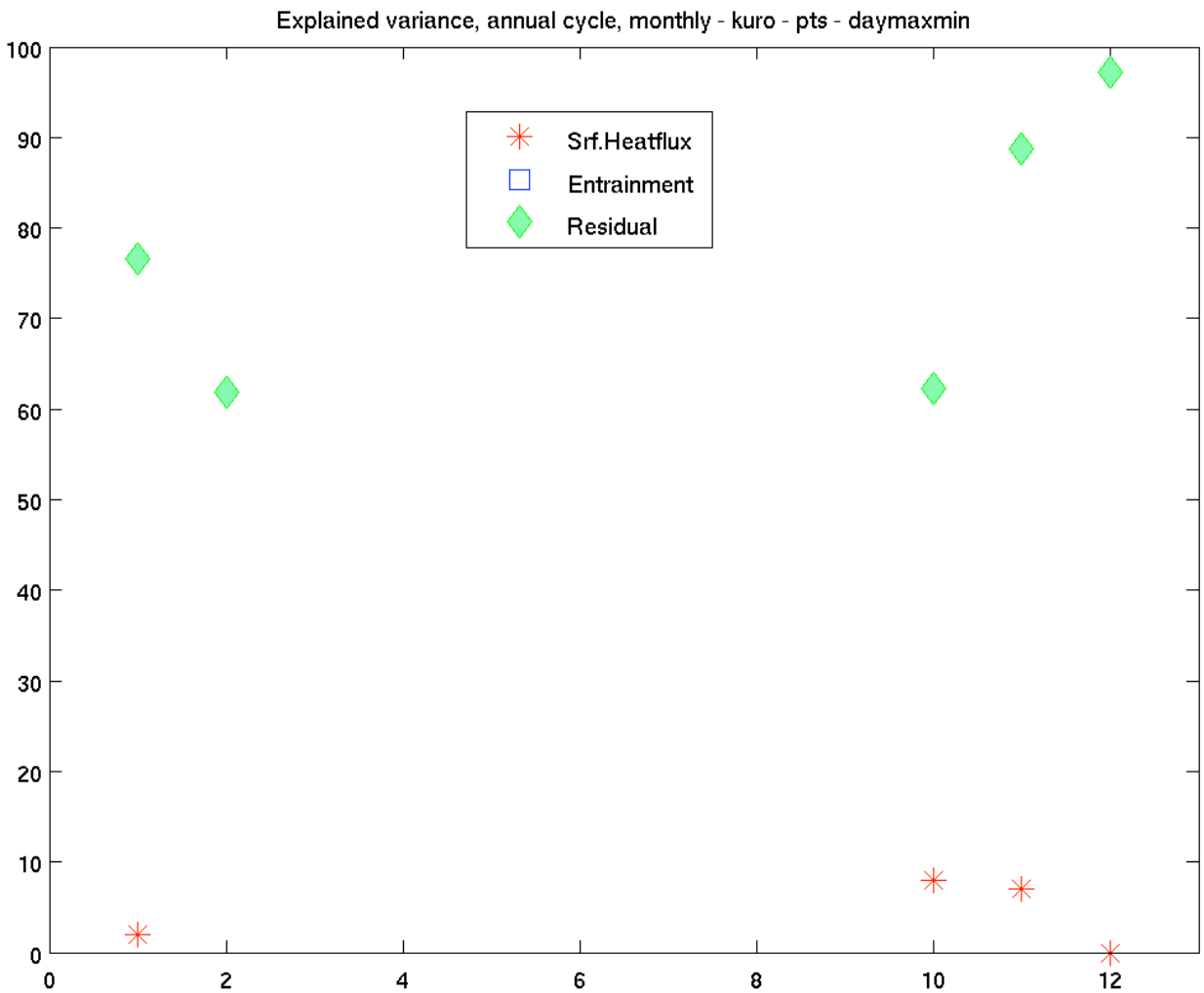
ECCO2 explained variance for single months Kuroshio

Daily means single point



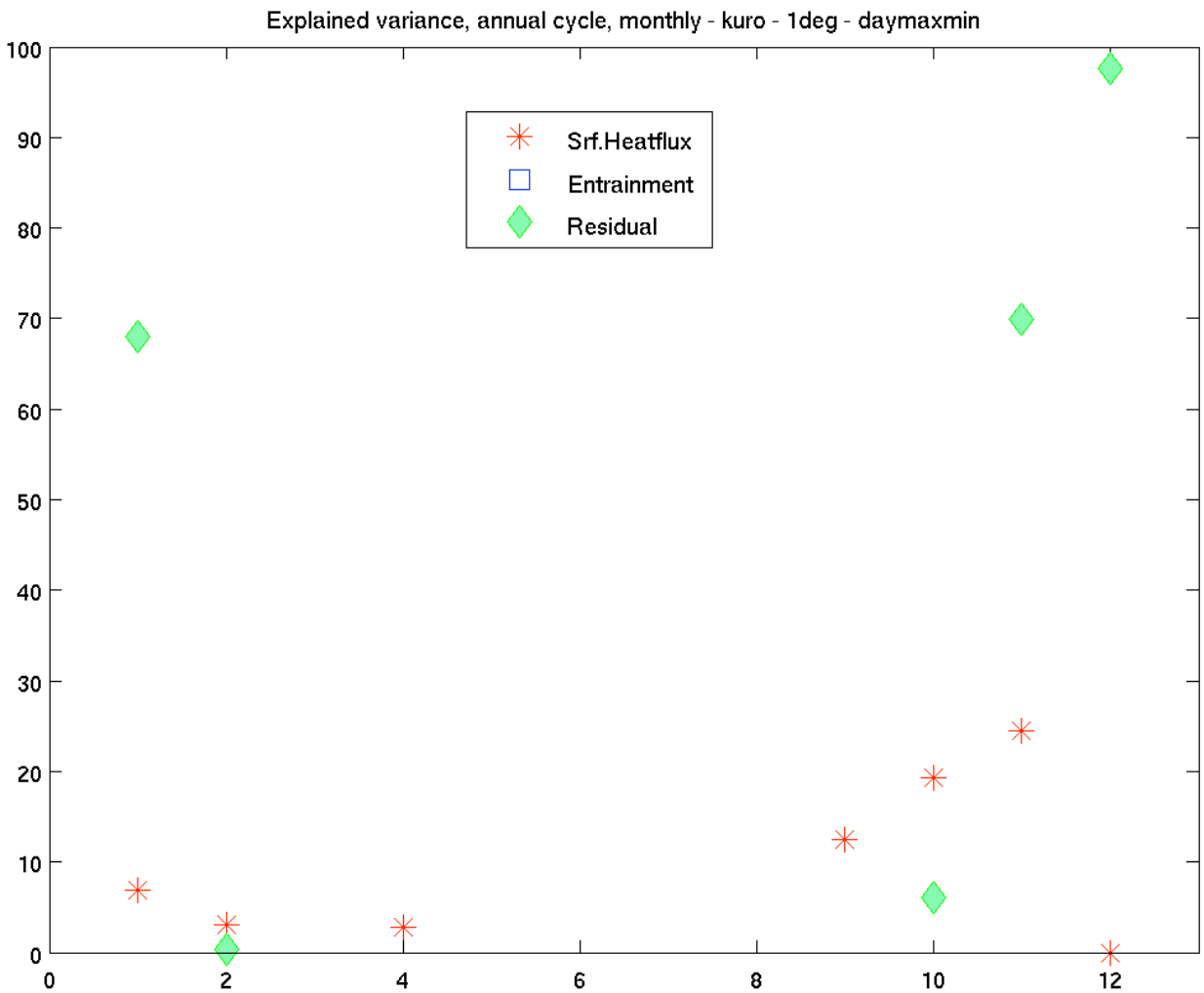
ECCO2 explained variance for single months Kuroshio

Daily extrema single point



ECCO2 explained variance for single months Kuroshio

Daily extrema 1 degree box



Mixed layer depth and SST

Can SST information be used to determine MLD?
When and where?

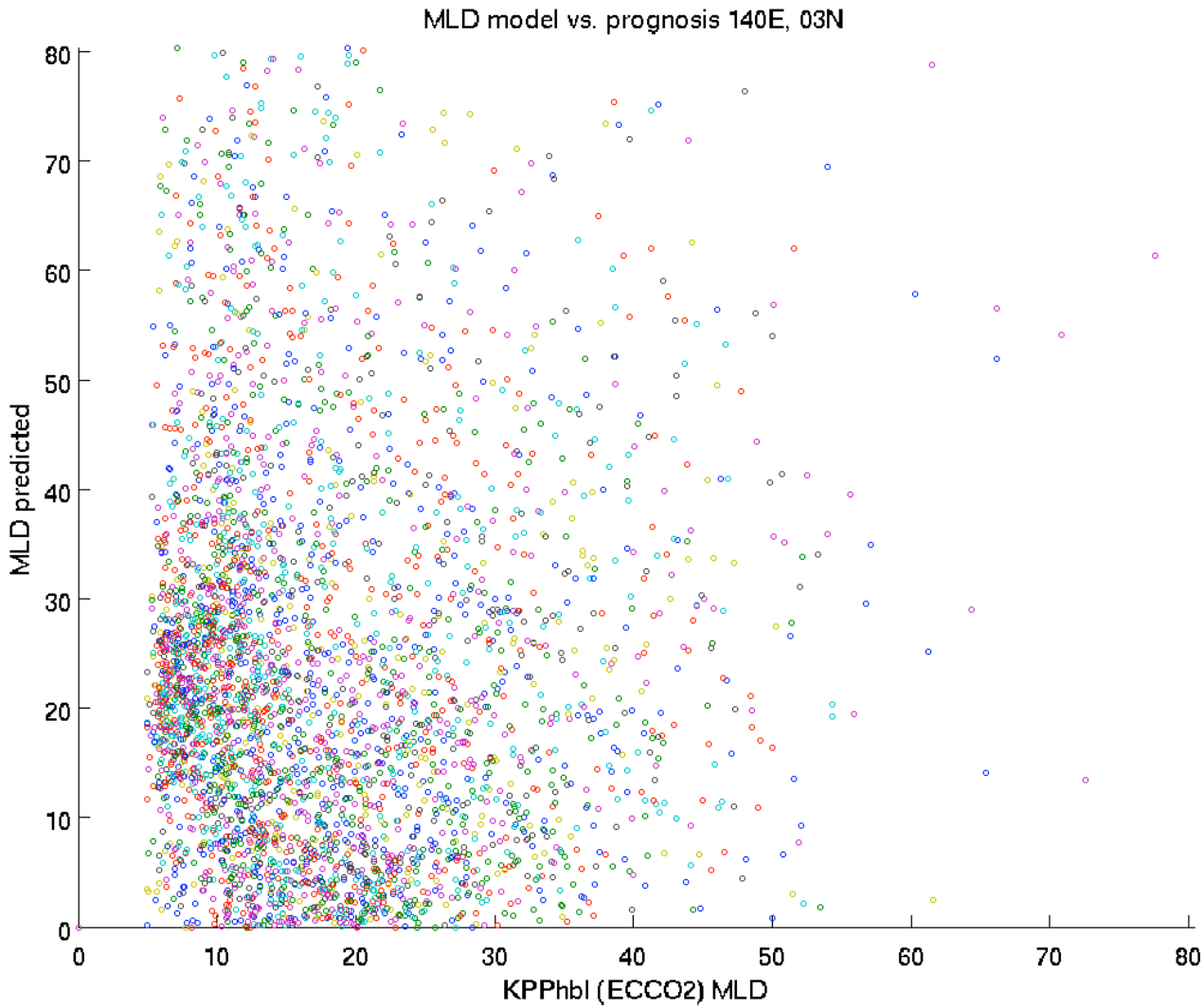
$$\frac{\partial T}{\partial t} = \frac{1}{h}\frac{Q}{\rho C_p} - \frac{1}{h}\frac{\partial h}{\partial t}\Delta T + \text{advection} + \text{diffusion}$$

Concentrating on surface heat flux:

$$\frac{\partial T}{\partial t} = \frac{1}{h}\frac{Q}{\rho C_p}.$$

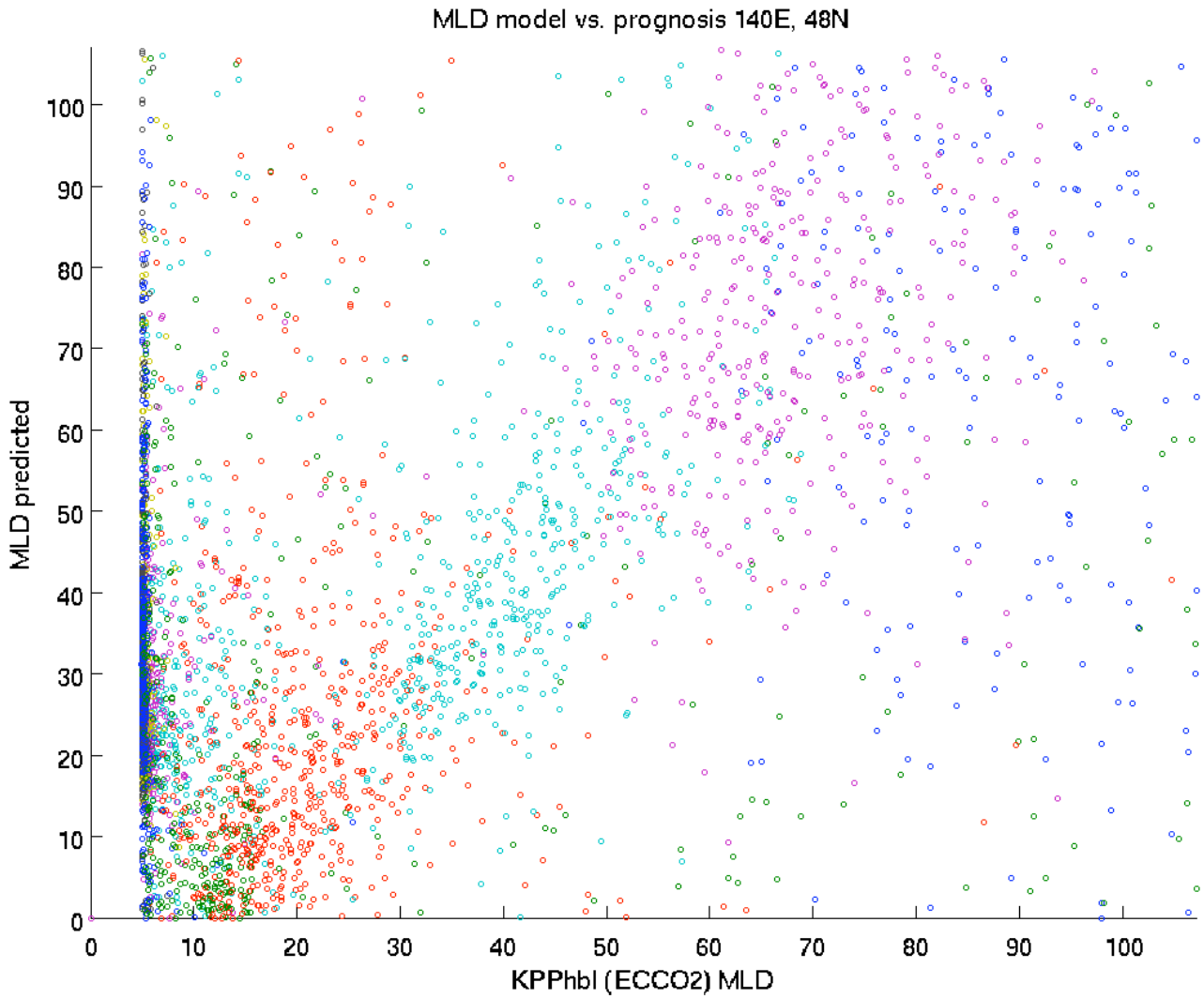
Solve for h….

MLD: model vs. SST-derived



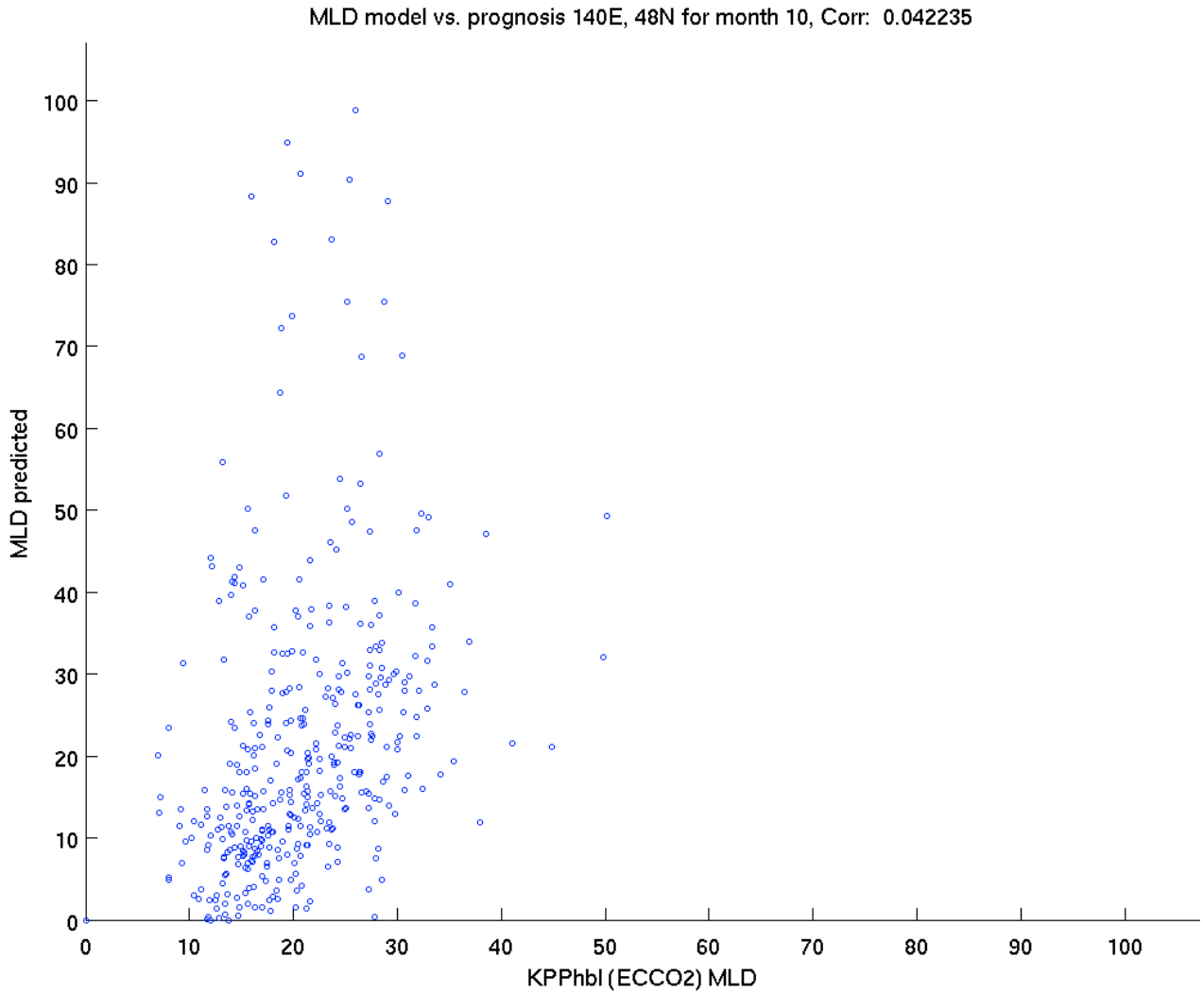
Equatorial Pacific

MLD: model vs. SST-derived



North Pacific

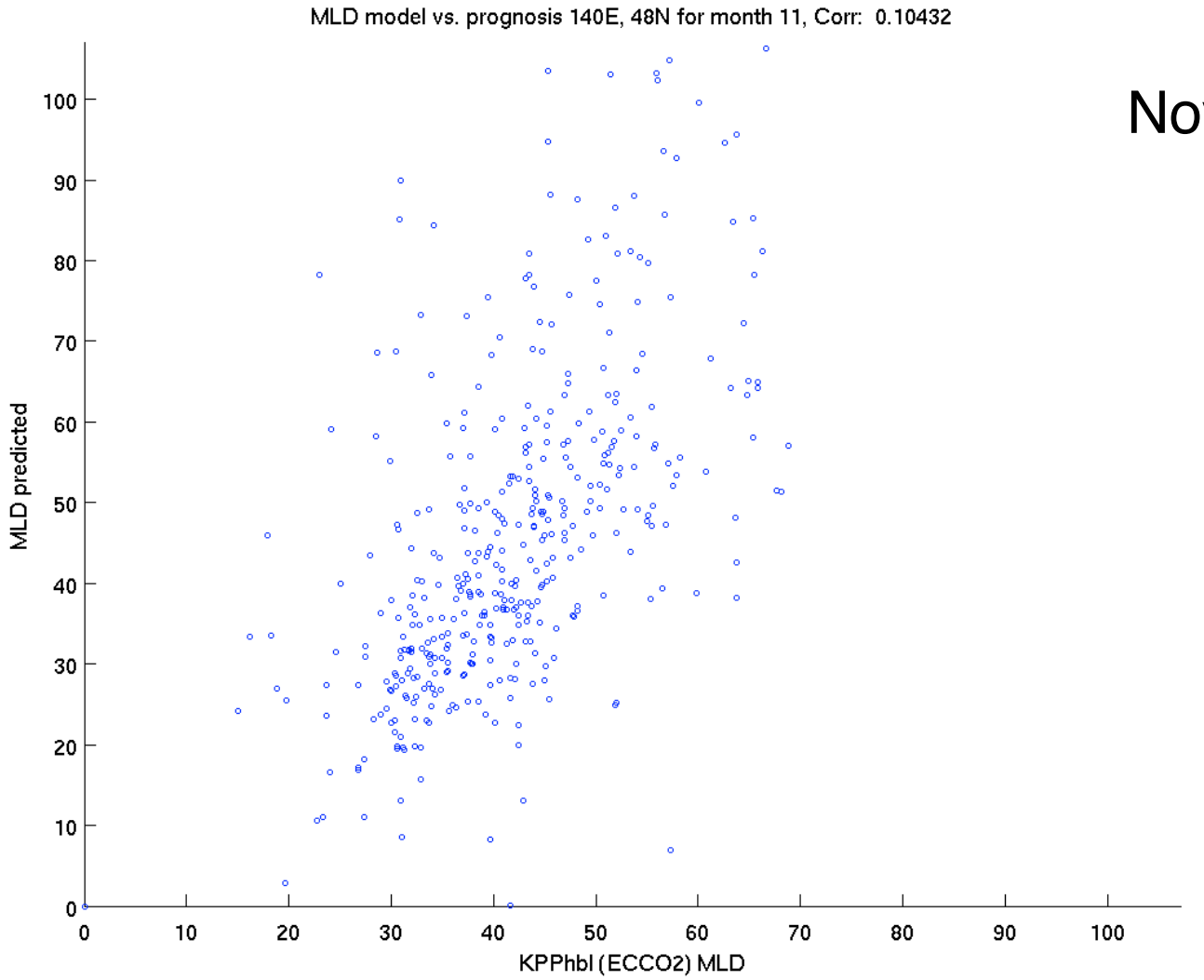
MLD: model vs. SST-derived



October

North Pacific

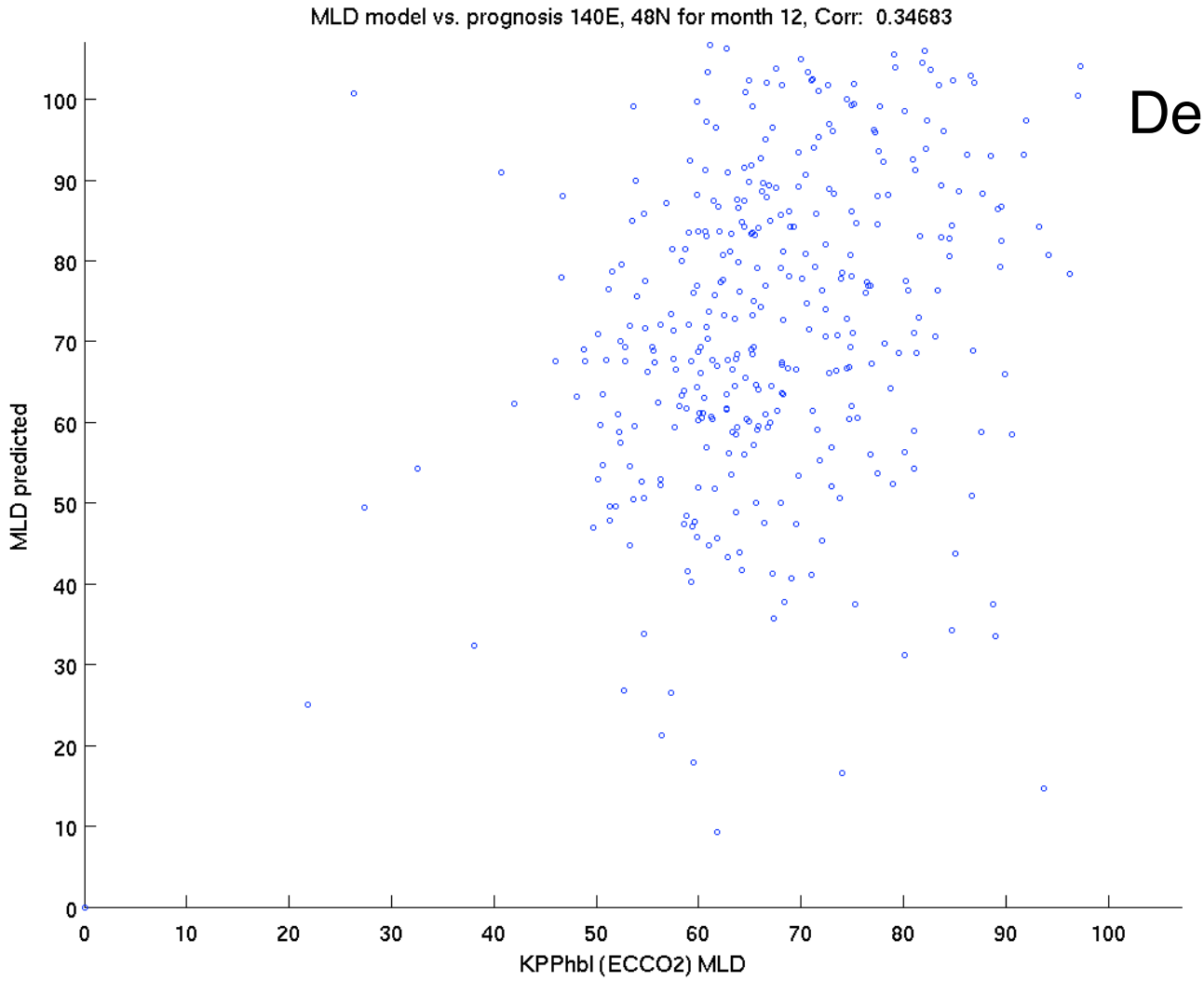
MLD: model vs. SST-derived



November

North Pacific

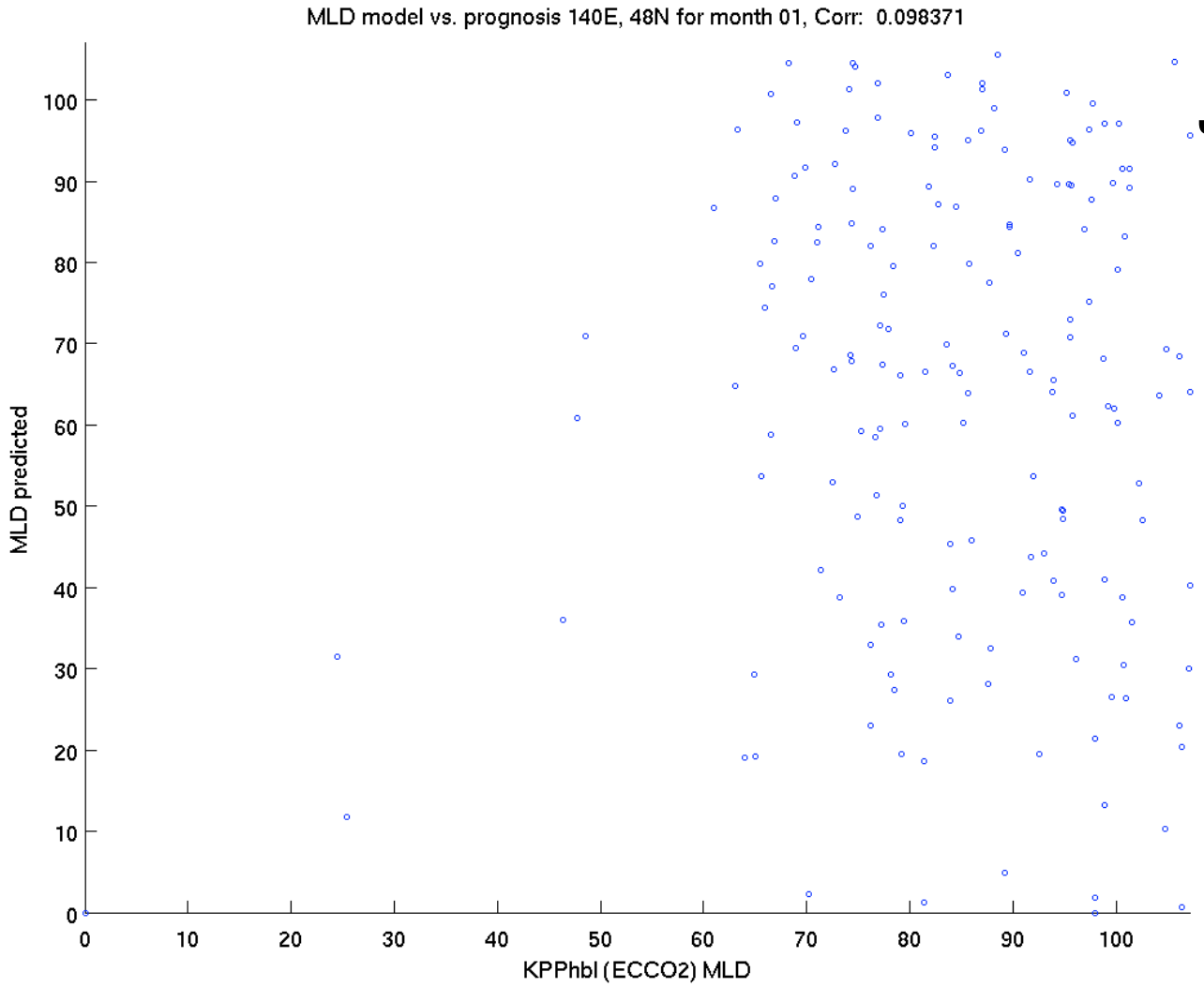
MLD: model vs. SST-derived



December

North Pacific

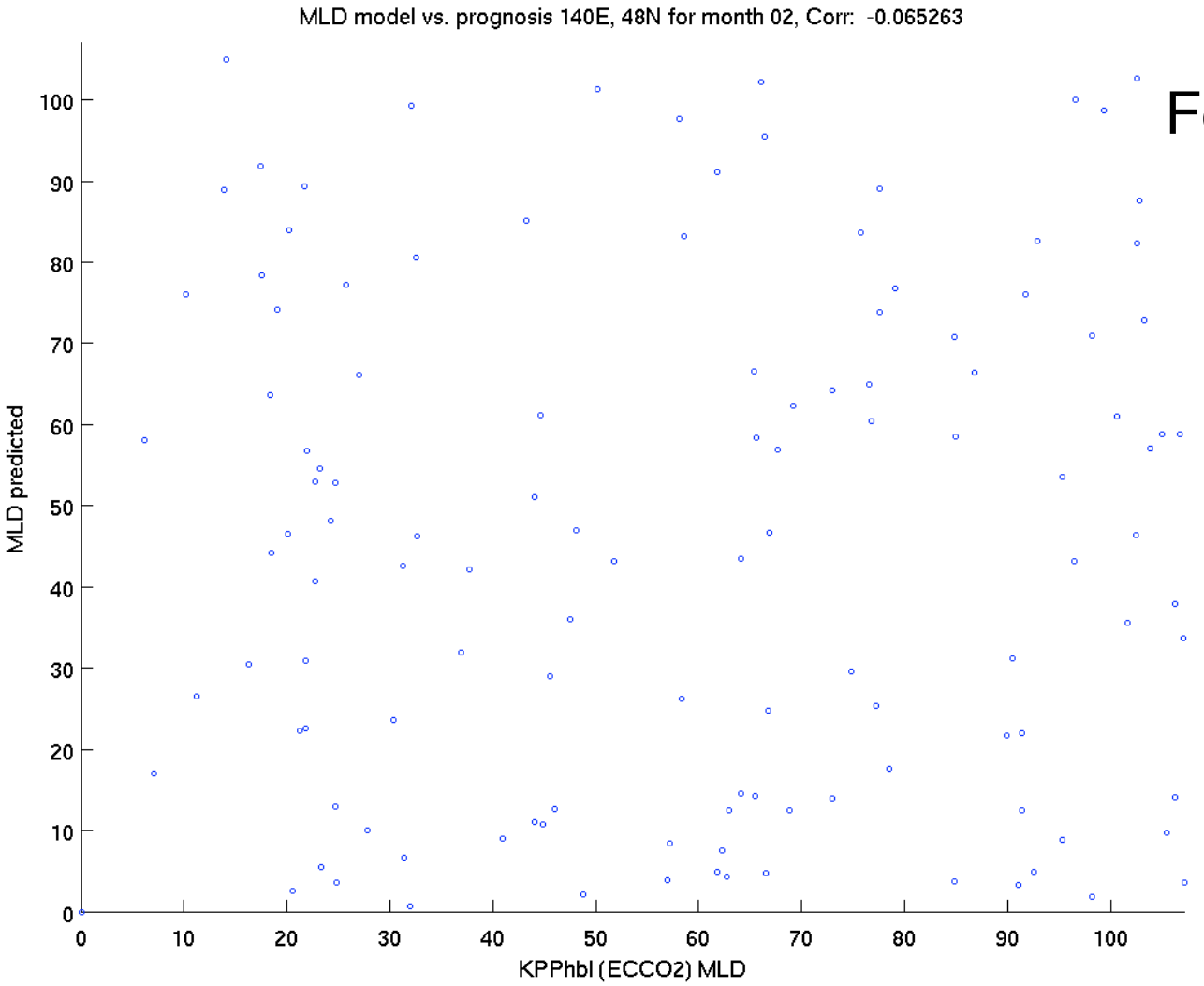
MLD: model vs. SST-derived



January

North Pacific

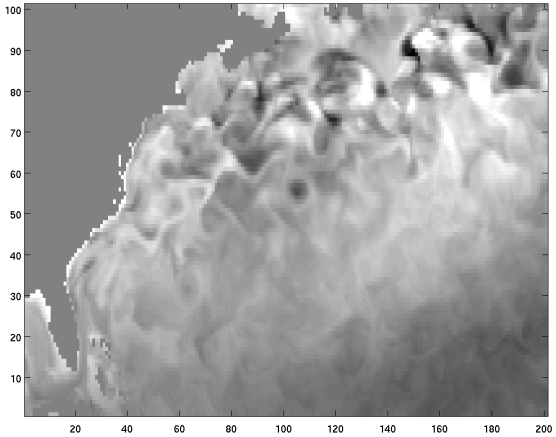
MLD: model vs. SST-derived



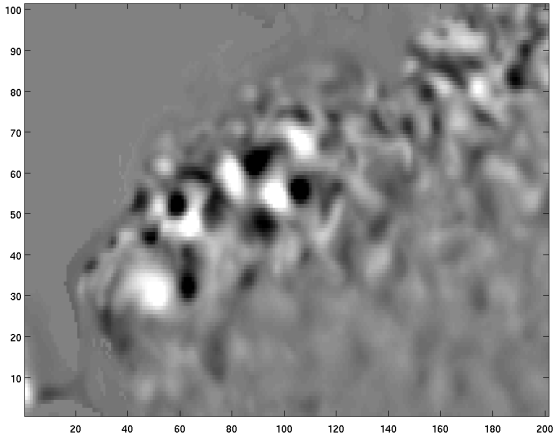
February

North Pacific

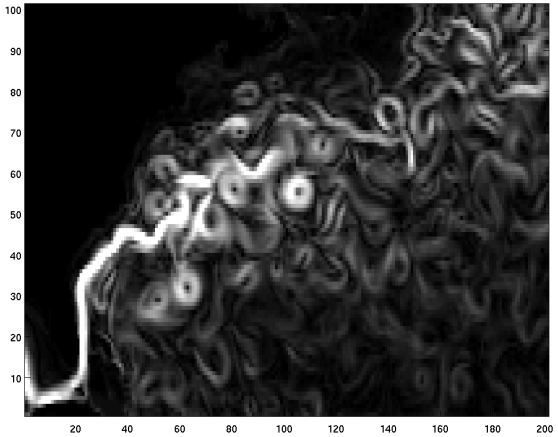
SST, Eddies, and Velocities



SST



SSH



current speed

ECCO2

SST and horizontal propagation of eddy variability

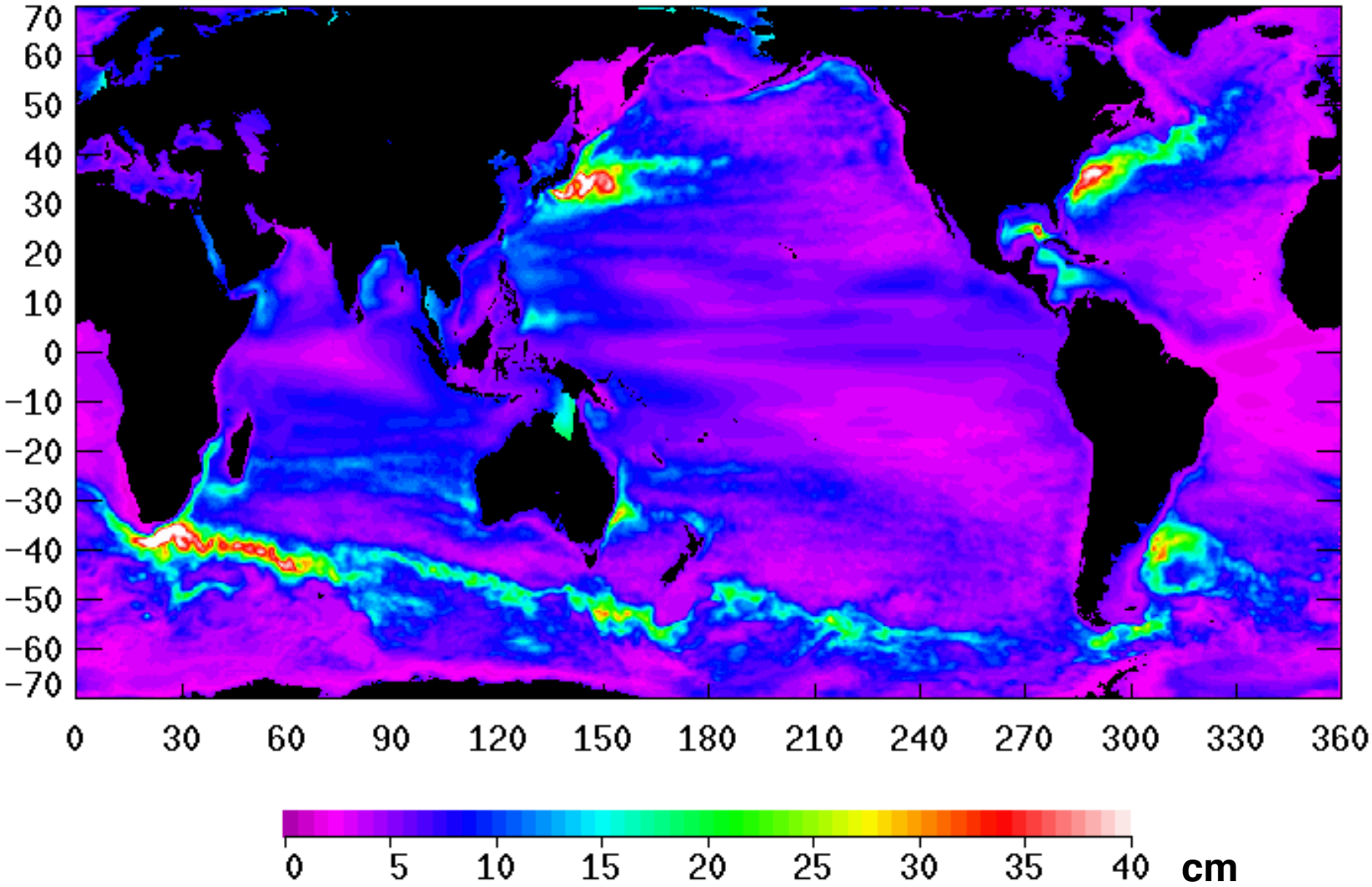
Maximum Cross Correlation Method

For each grid node location (x,y):

- Cross-correlations ($C_{x,y}$)
- SSH or SST time series (h)
- Time lag ΔT in multiples of 7 days
- Spatial lag Δx and Δy
- Overbar: time averaging

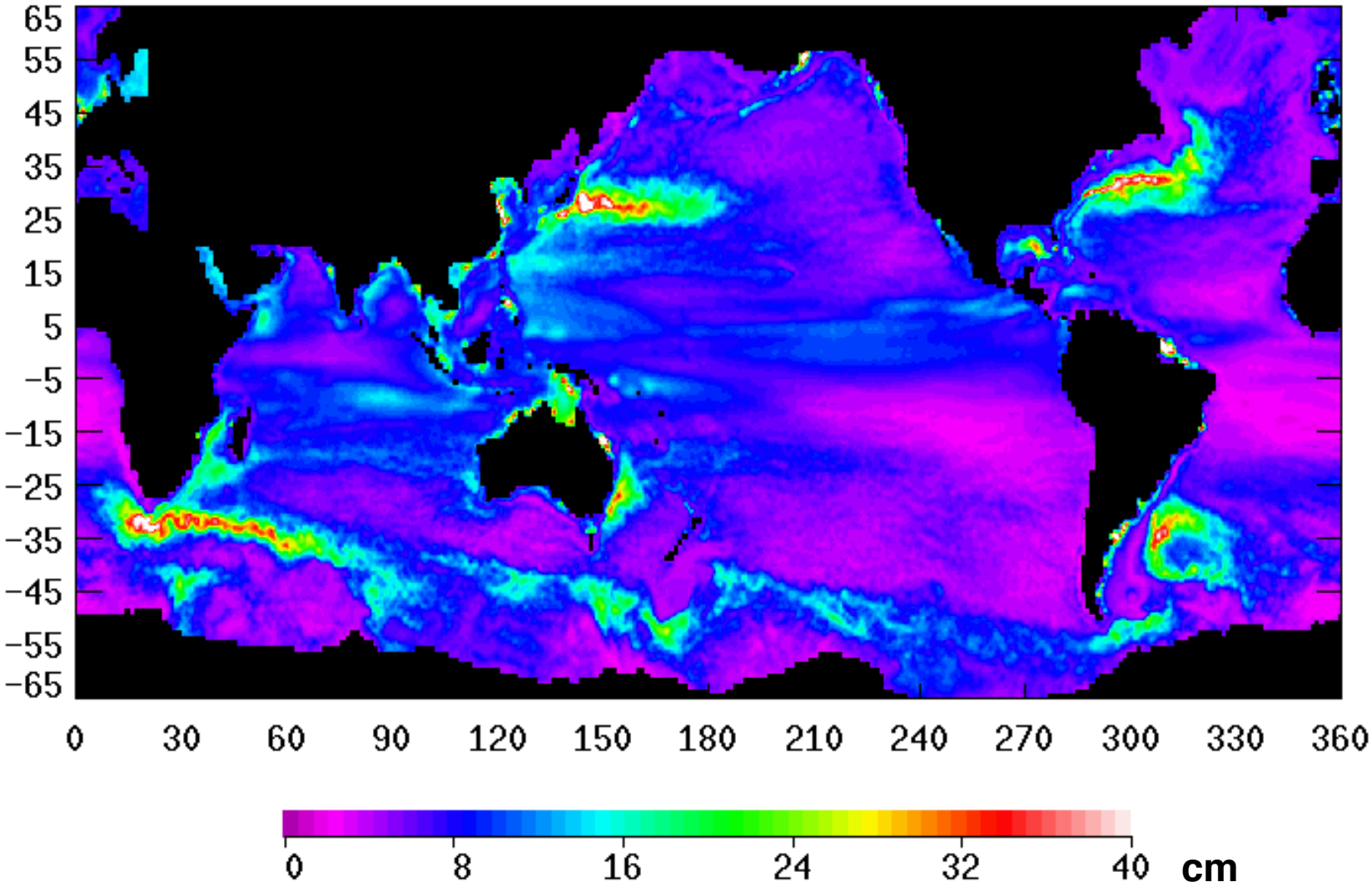
$$C_{x,y}(\Delta x, \Delta y, \Delta T) = \overline{h(x, y, t)h(x + \Delta x, y + \Delta y, t + \Delta T)}$$

ECCO-2 simulation of ocean eddy variability (ssh standard deviation)



Slide courtesy Lee-Lueng Fu

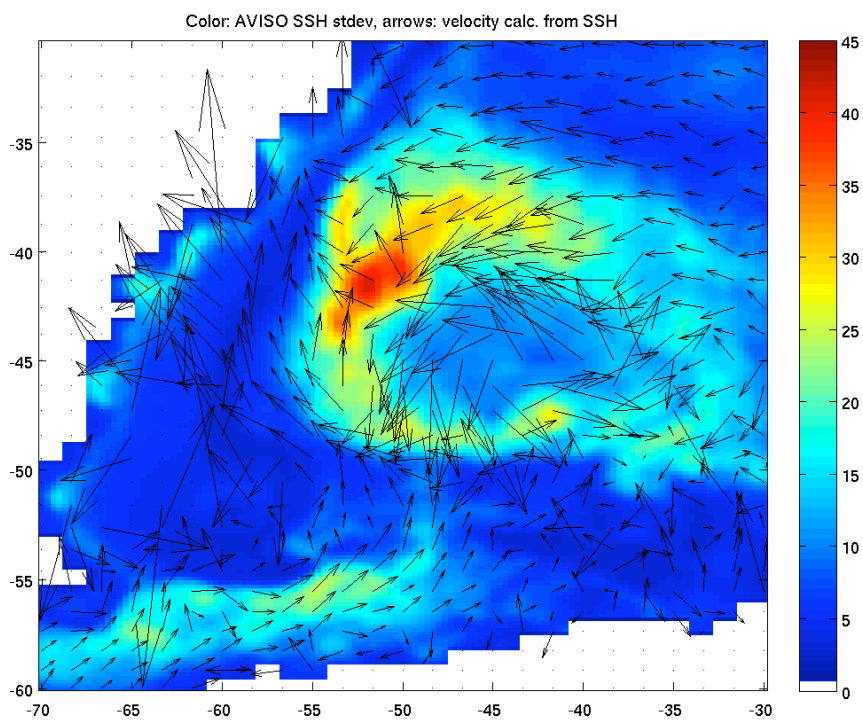
eddy variability (ssh standard deviation) from altimetry



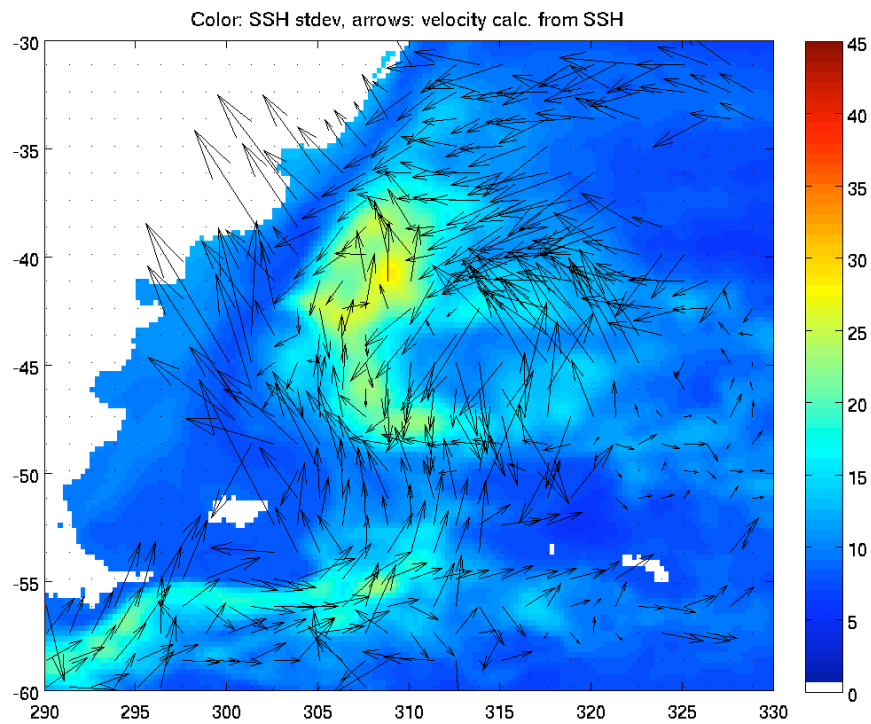
Slide courtesy Lee-Lueng Fu

SSH stdev and derived velocities – SW Atlantic

AVISO

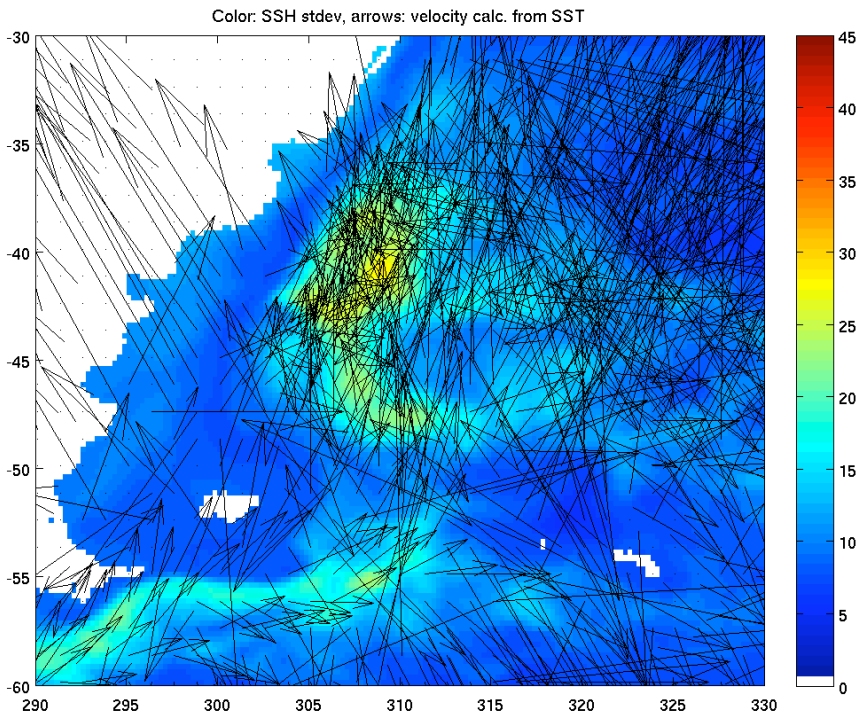


ECCO2 - SSH

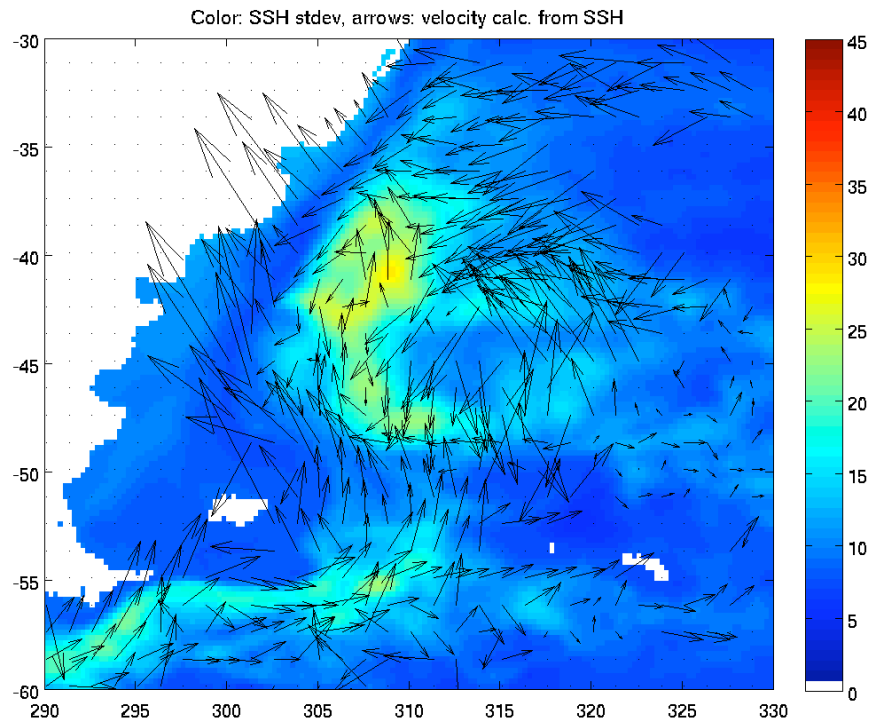


SSH stdev and derived velocities – SW Atlantic

ECCO2 – SST (w/o mean)

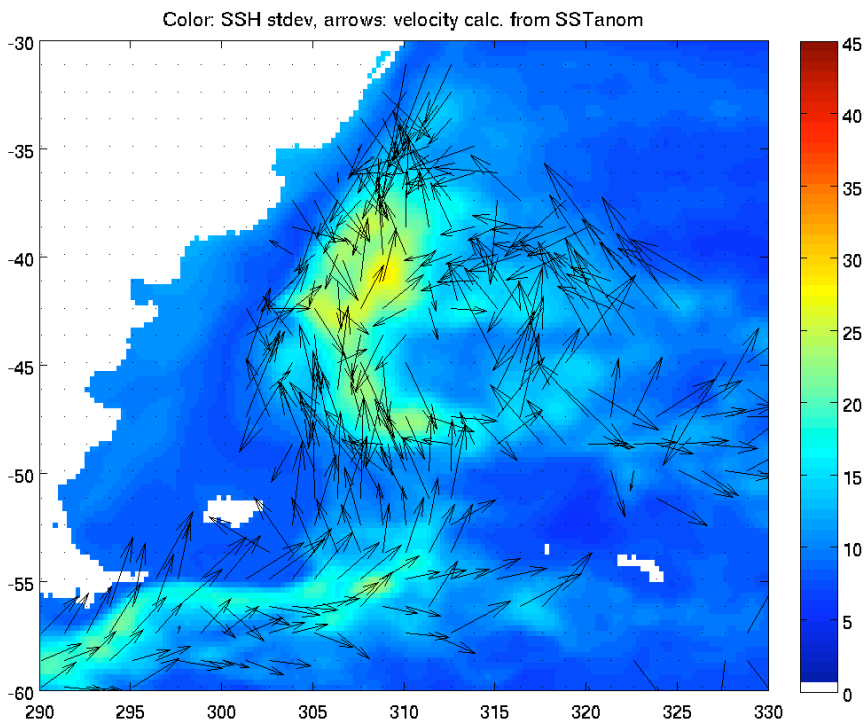


ECCO2 – SSH (w/o mean)

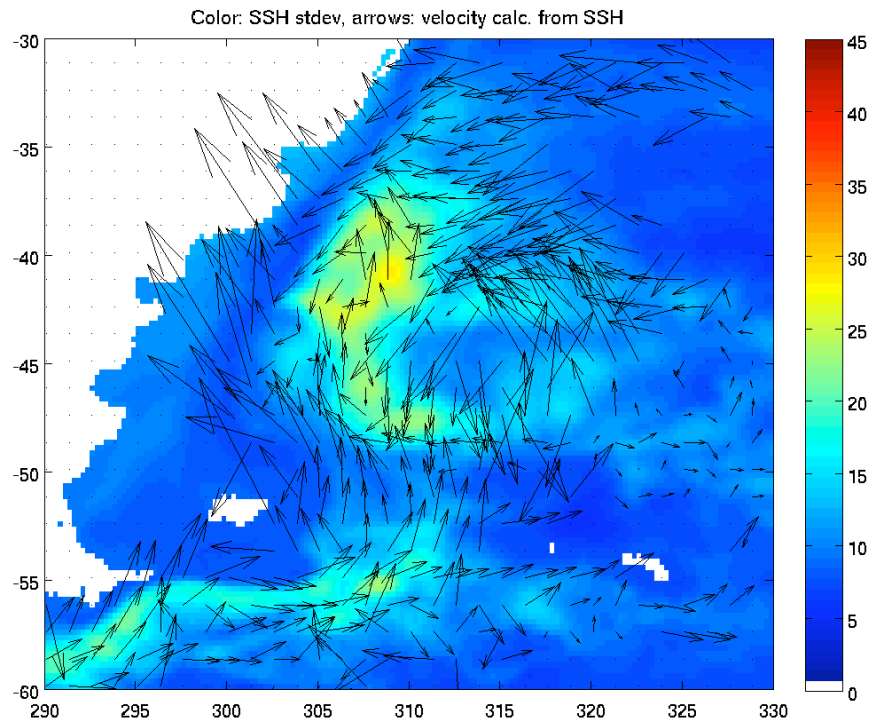


SSH stdev and derived velocities – SW Atlantic

ECCO2 – SST (w/o annual cycle)

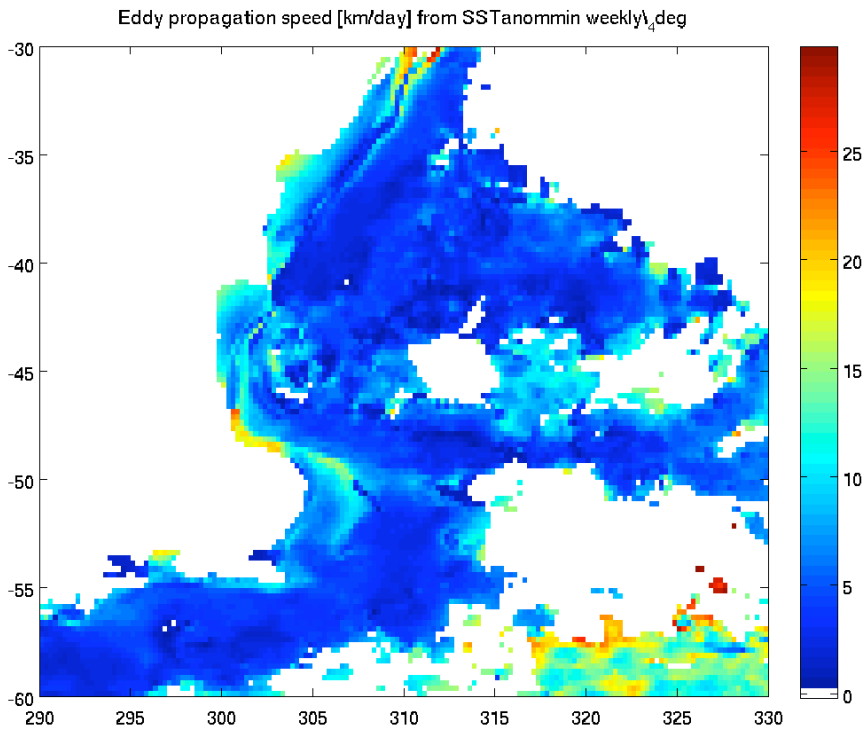


ECCO2 – SSH (w/o mean)

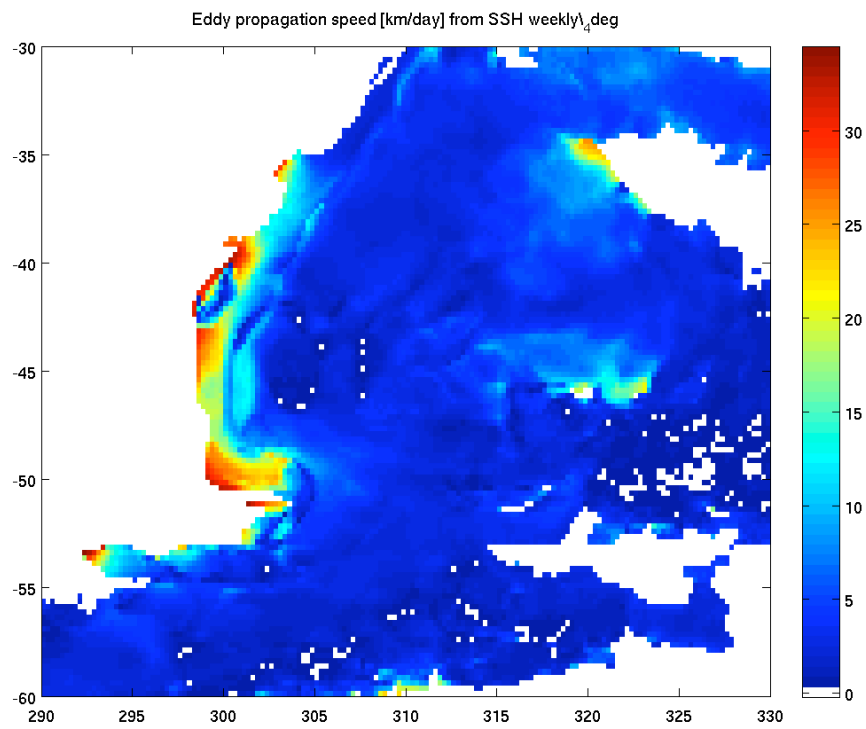


SST and SSH derived speeds – SW Atlantic

ECCO2 – SST
(w/o annual cycle)

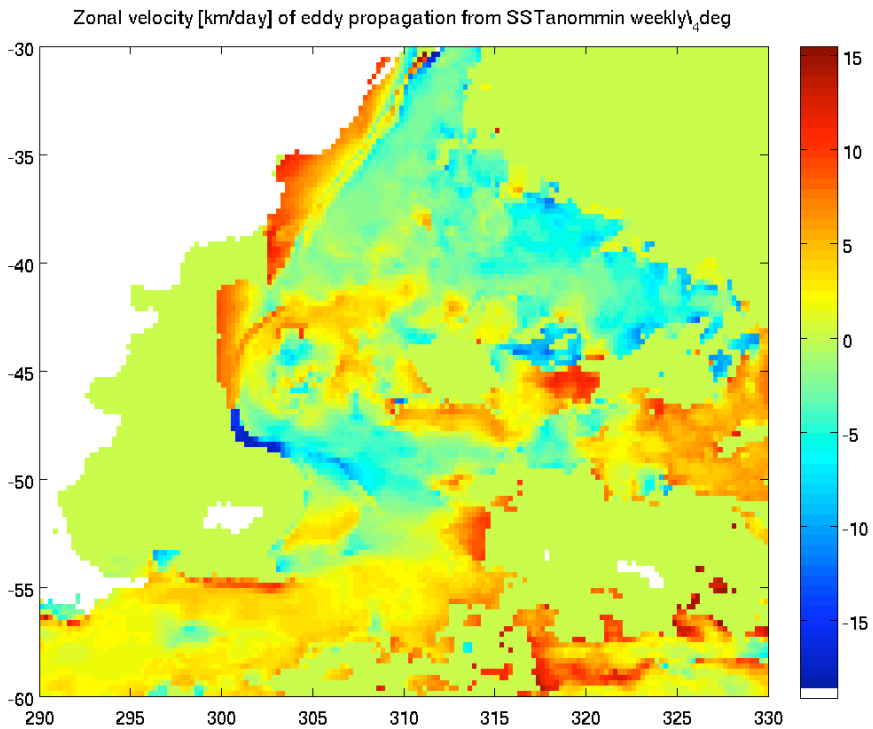


ECCO2 – SSH
(w/o mean)

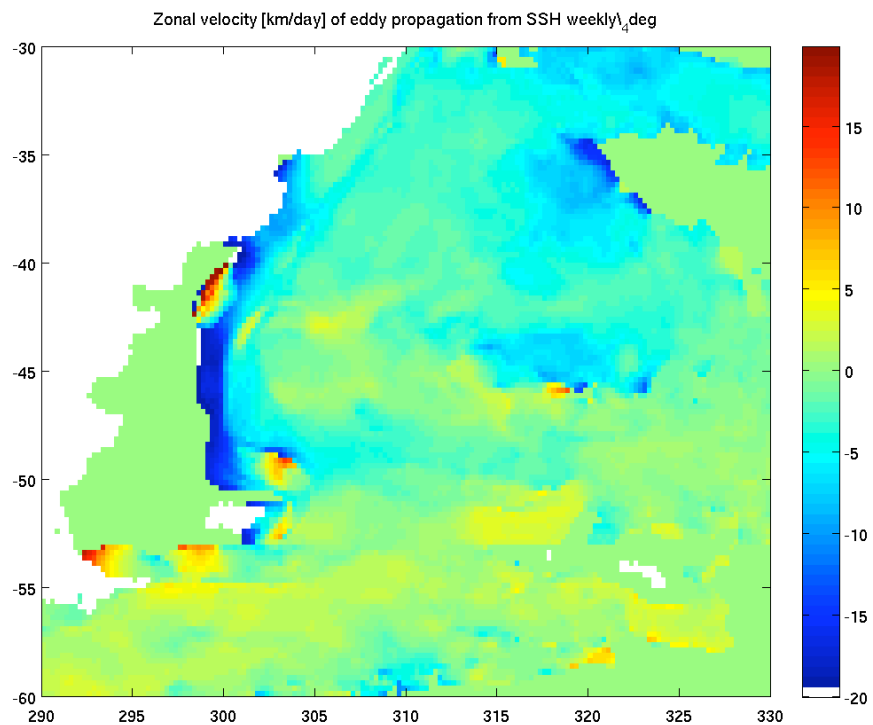


SST and SSH derived zonal velocity

ECCO2 – SST
(w/o annual cycle)

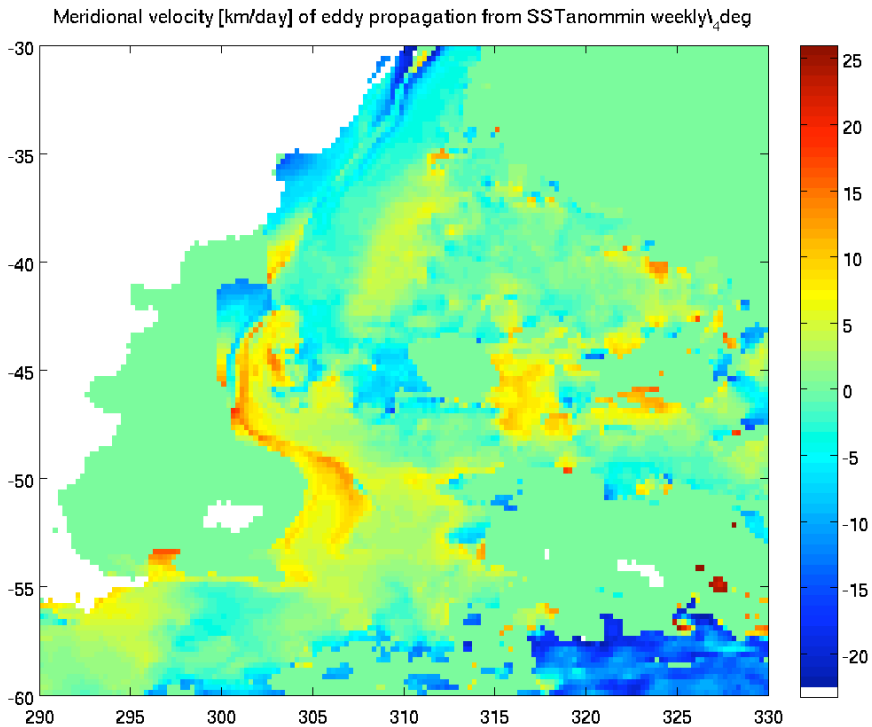


ECCO2 – SSH
(w/o mean)

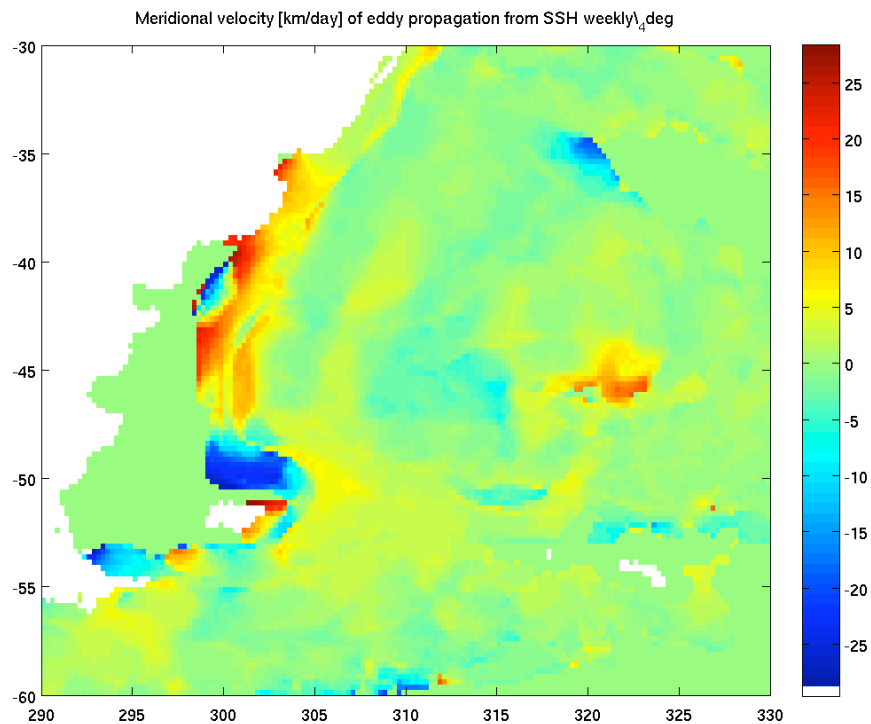


SST and SSH derived meridional velocity

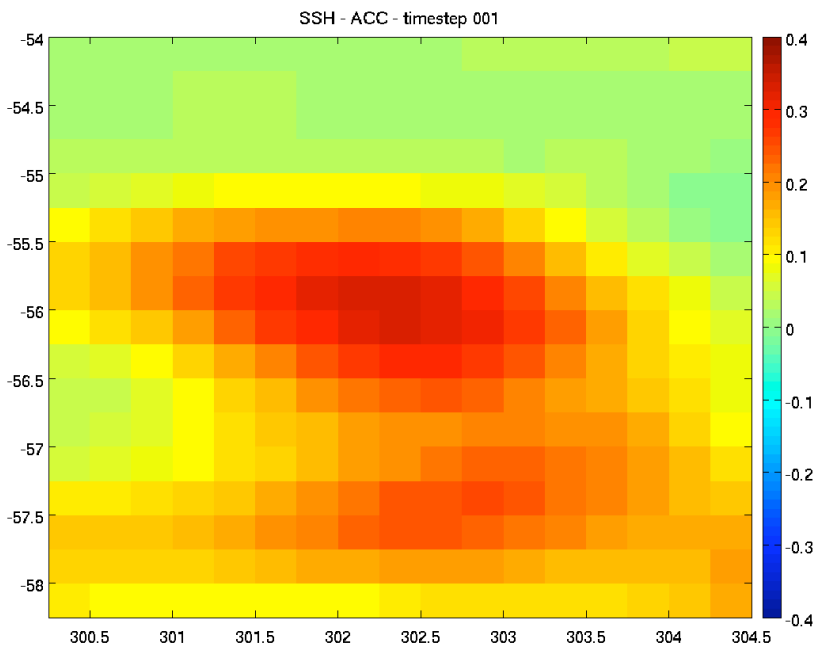
ECCO2 – SST
(w/o annual cycle)

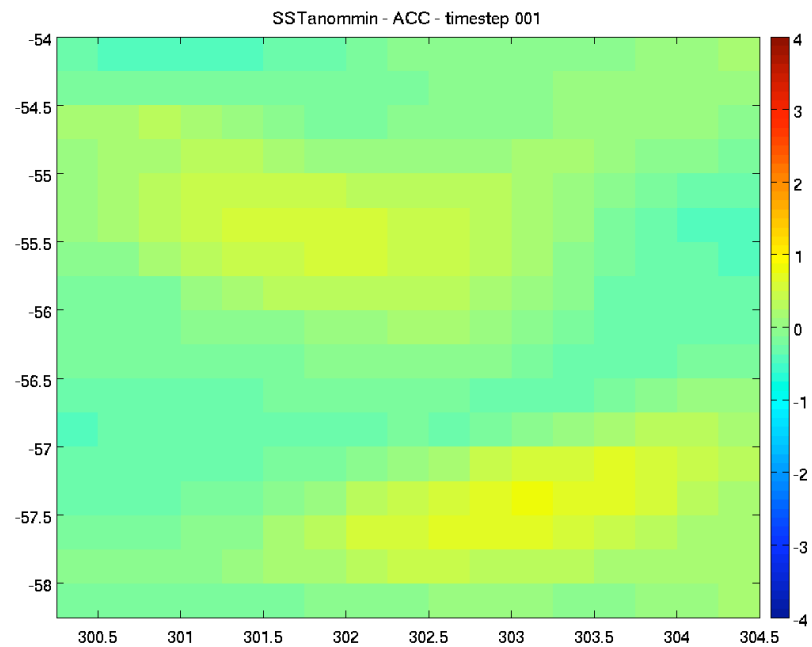


ECCO2 – SSH
(w/o mean)



ACC location:
SSH anomalies vs. SSTmin anomalies

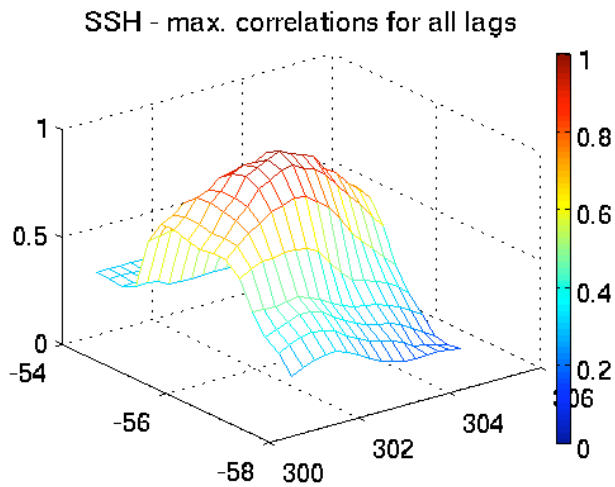


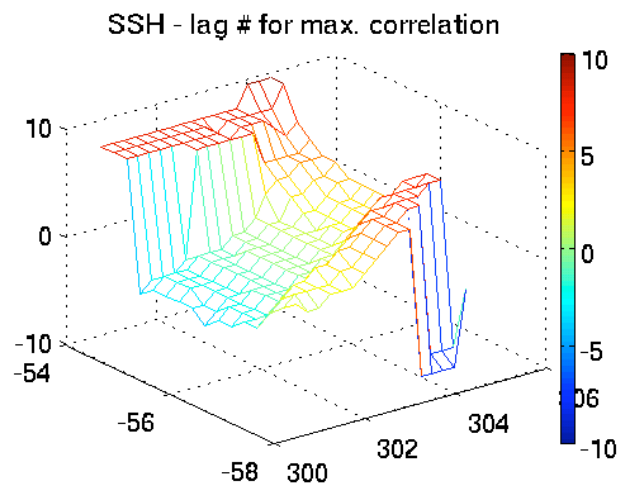


ACC location:

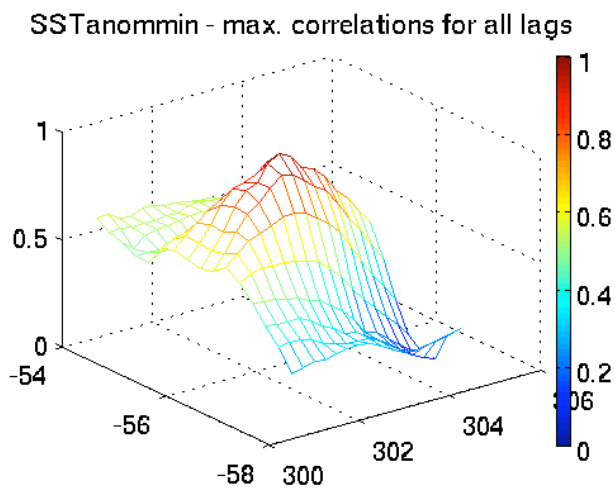
Max. corr. lag for max corr

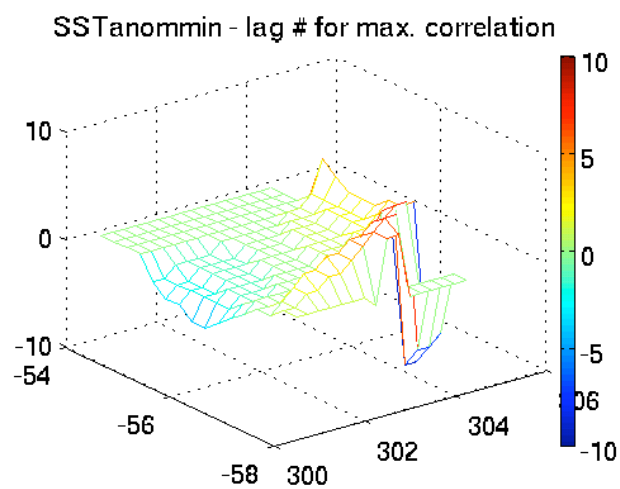
SSH



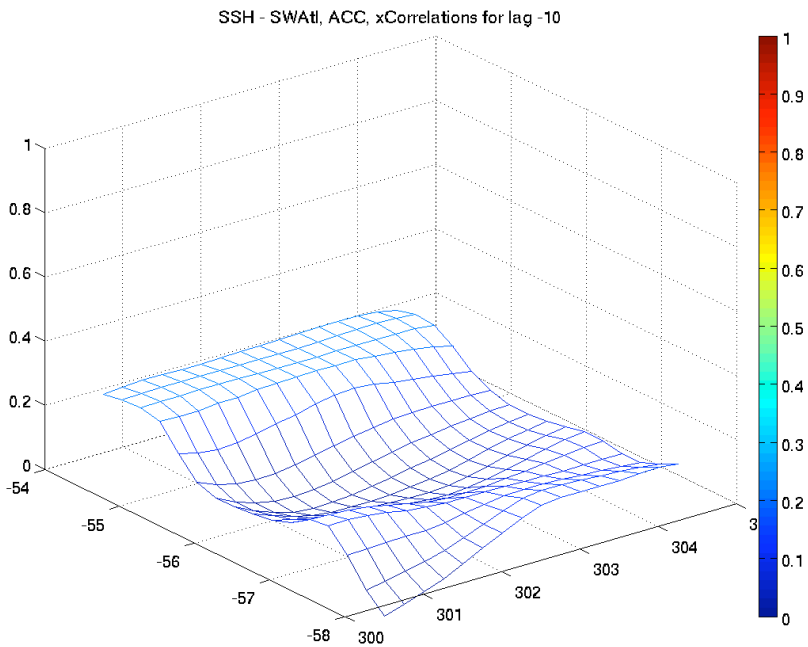


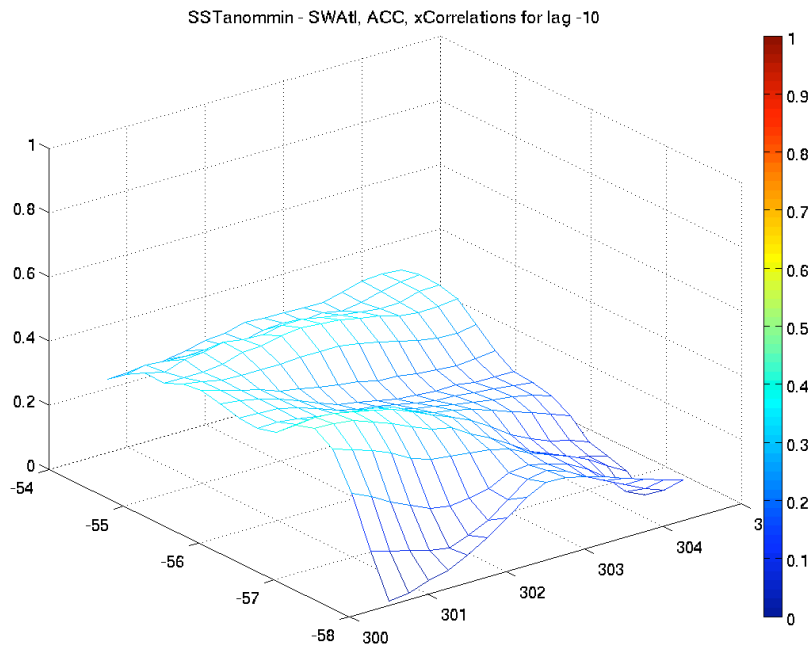
SST



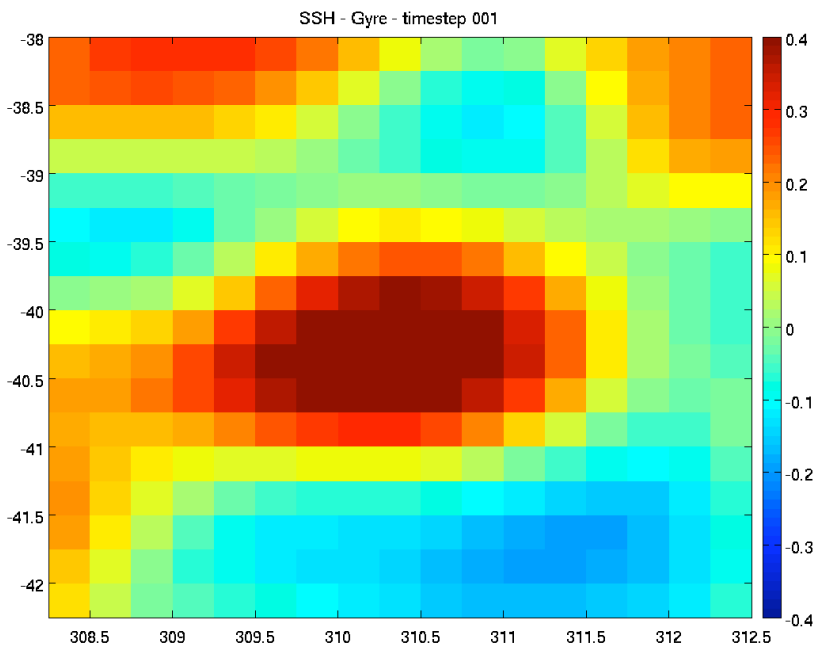


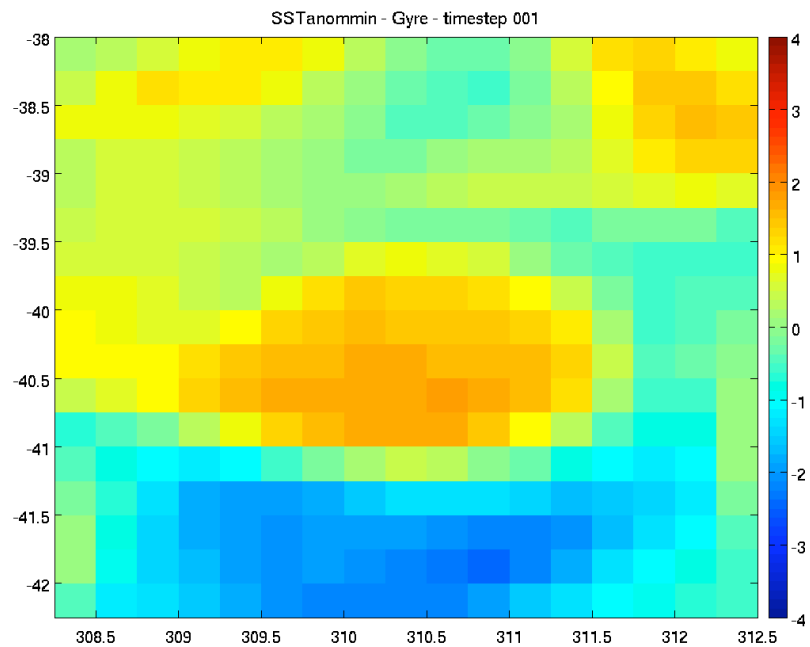
ACC location – xCorrelation time lags -10 to 10:
SSH anomalies vs. SSTmin anomalies





Gyre location:
SSH anomalies vs. SSTmin anomalies

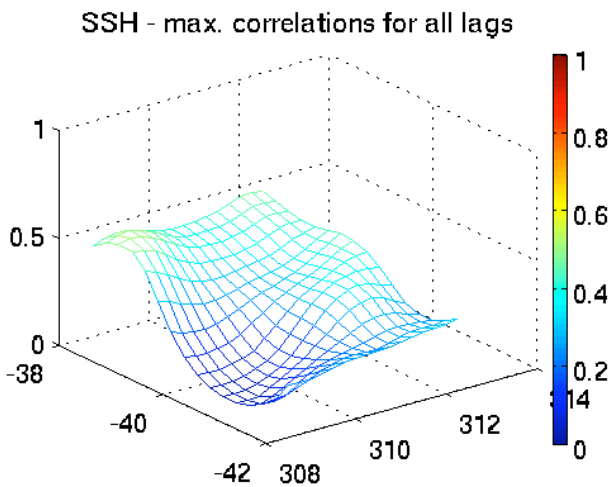


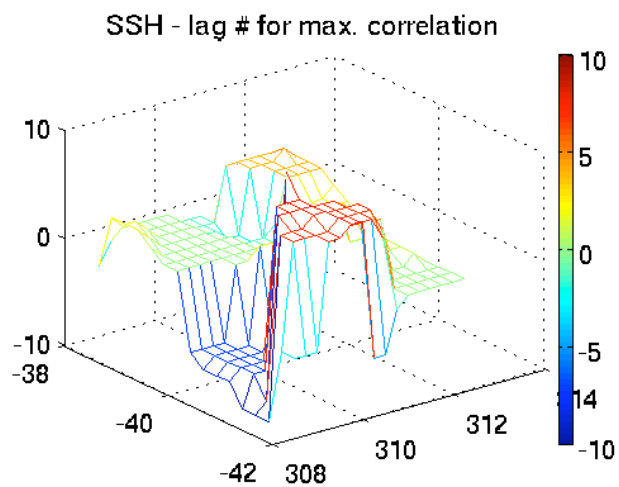


Gyre location:

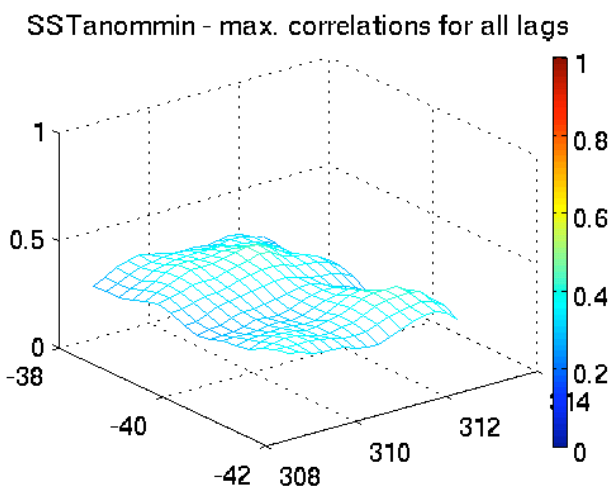
Max. corr. lag for max corr

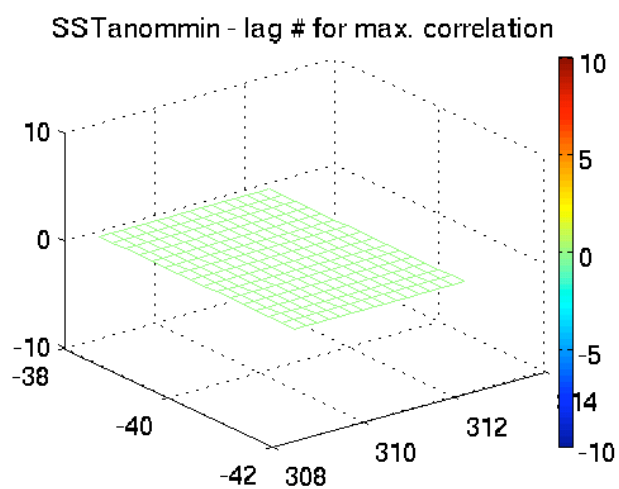
SSH



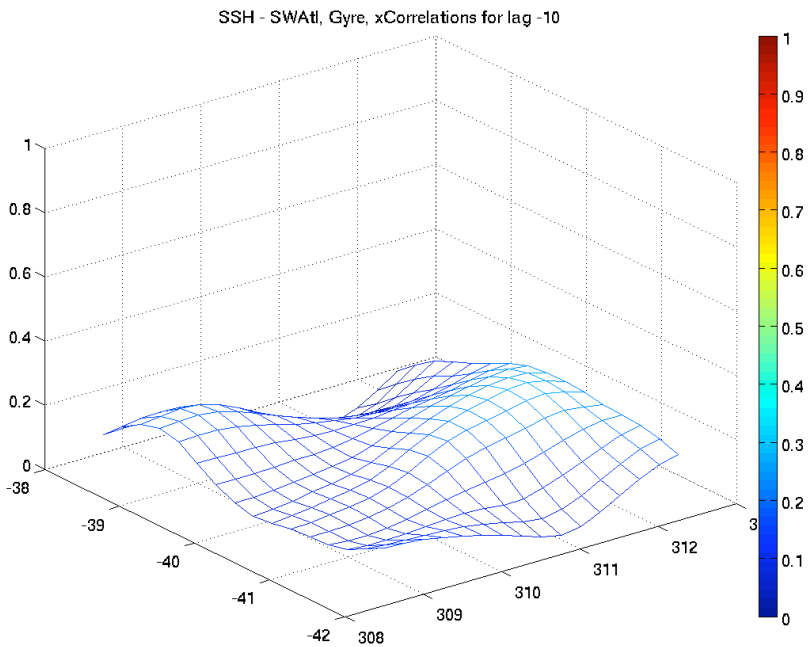


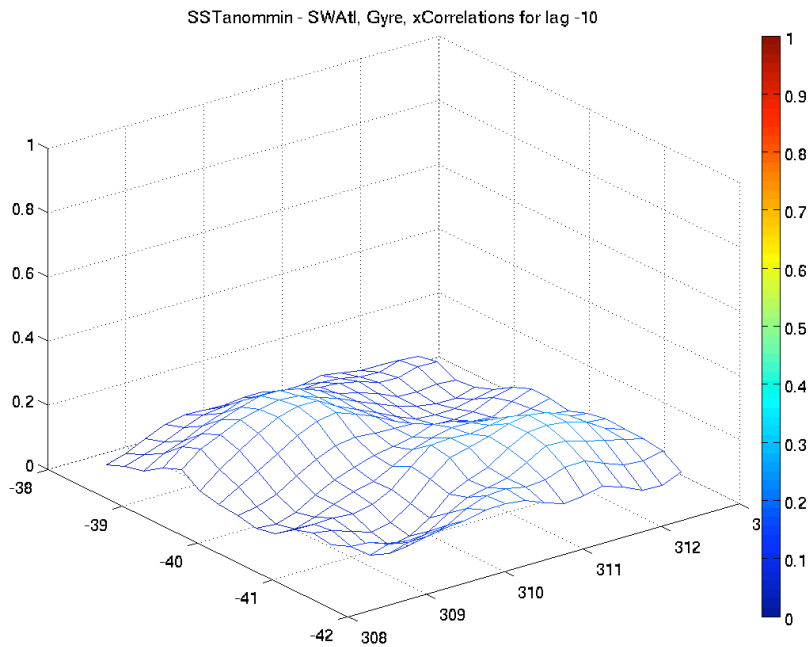
SST





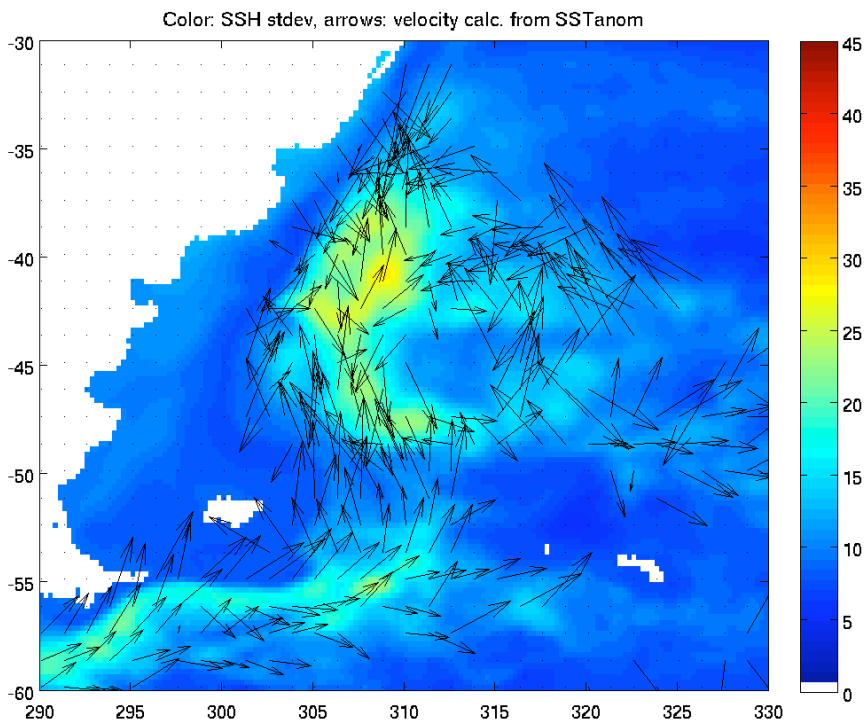
Gyre location – xCorrelation time lags -10 to 10:
SSH anomalies vs. SSTmin anomalies



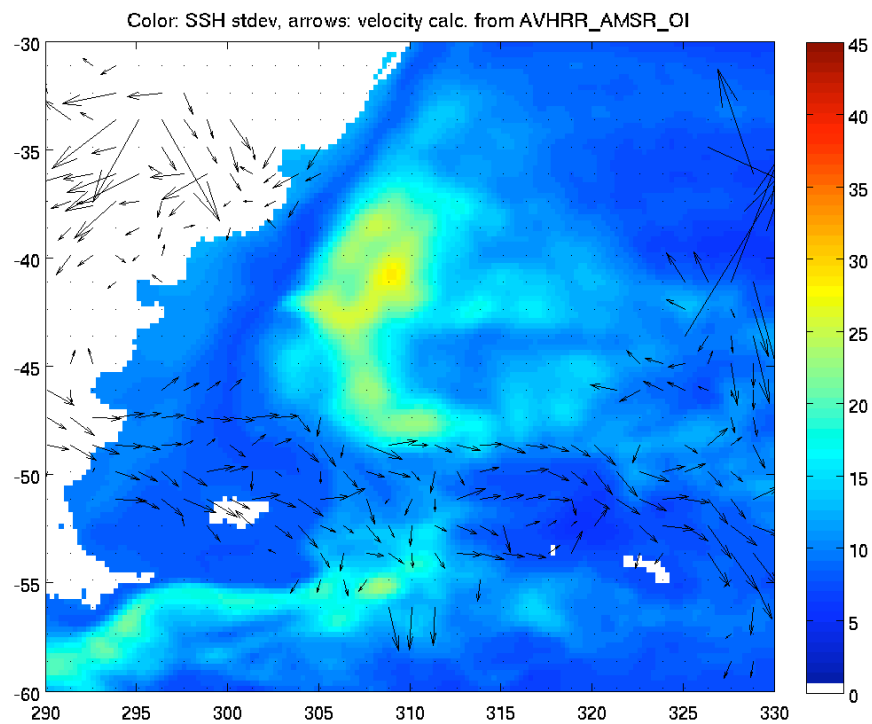


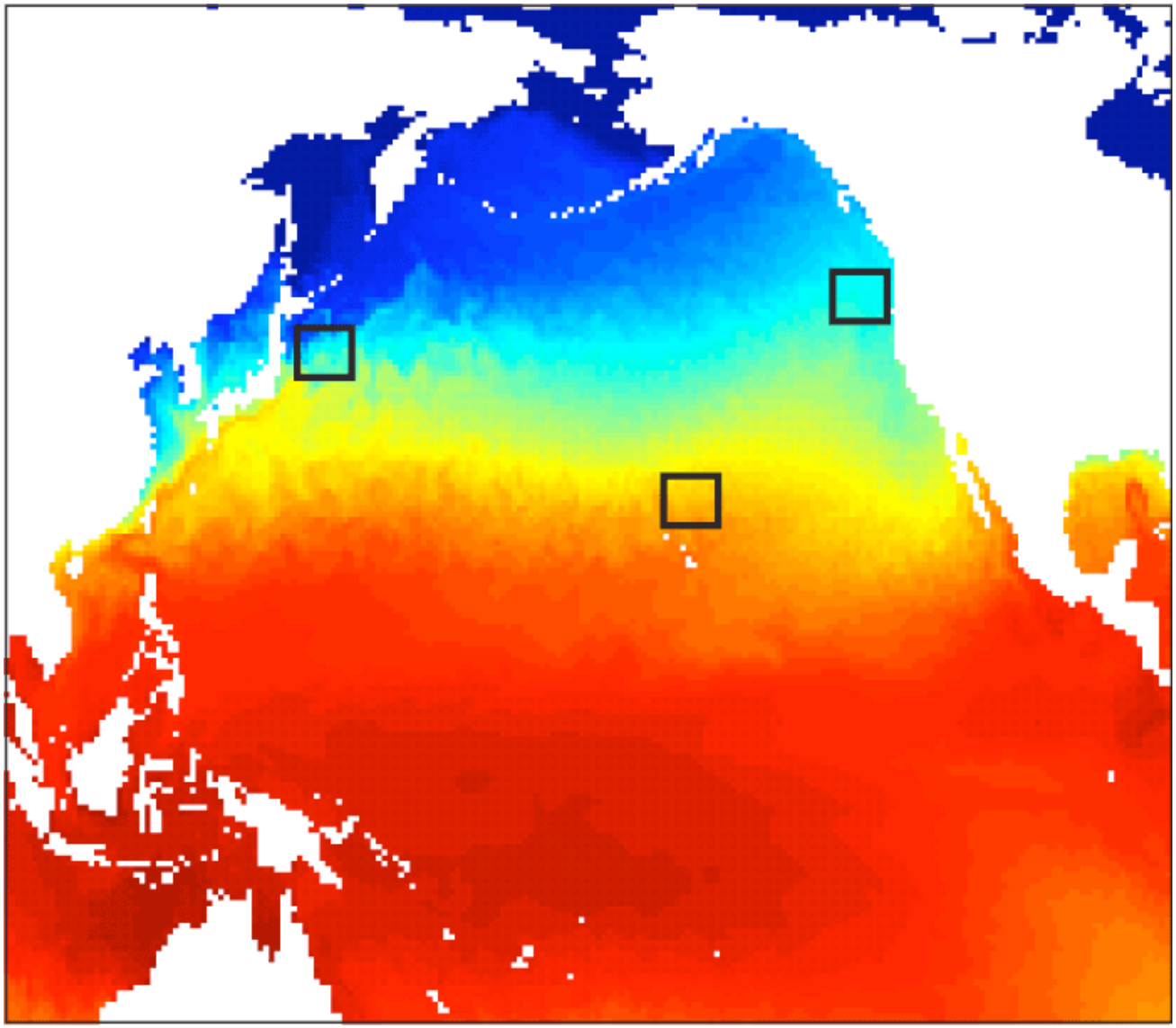
And satellite SST?????

ECCO2 – SST
(w/o annual cycle)



AVHRR AMSR OI
(Reynolds)



Summary

- Satellite SST provides us with a range of long-term high resolution data sets
- SST is controlled dynamically and thermo-dynamically
- There is a potential to use SST (under certain spatial and temporal conditions) as a proxy for other oceanic quantities.
  - This does not seem to work for mixed layer depth
  - Potential use for heat budget – needs probably additional information to be useful
  - Velocity: Possibly complementing altimeter data, for eddy propagation velocities