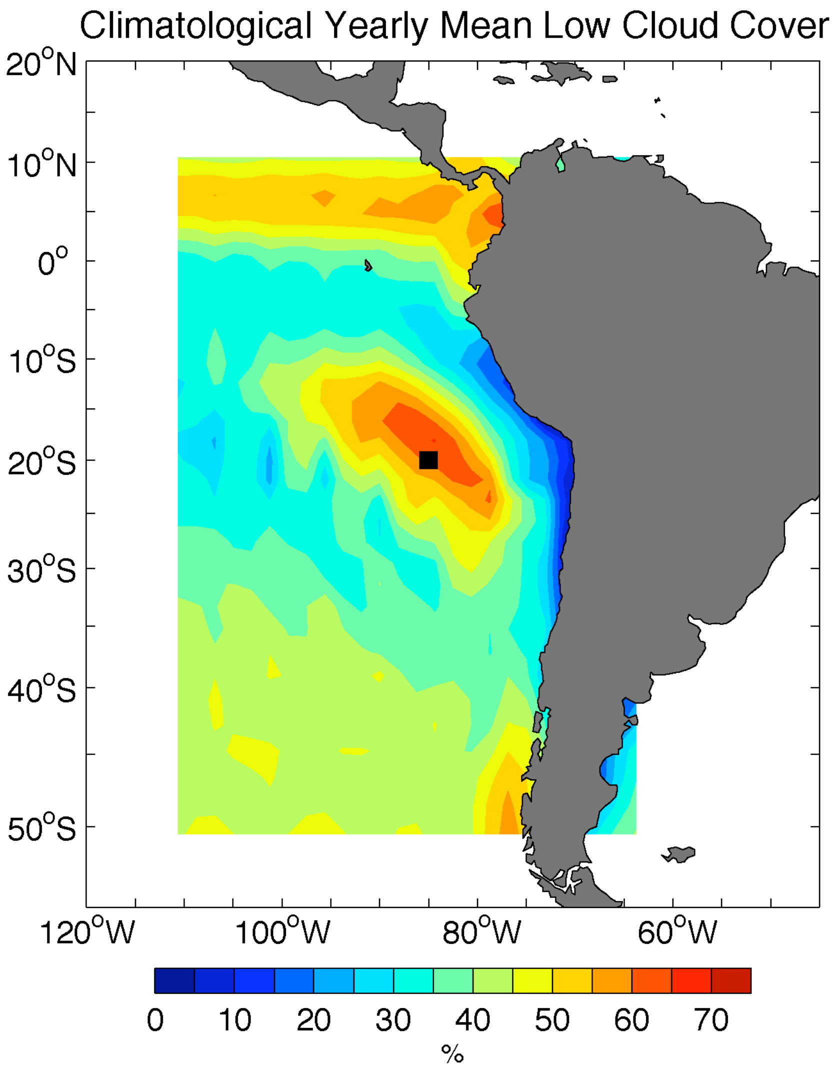
VOCALS - Ocean
Science and Implementation

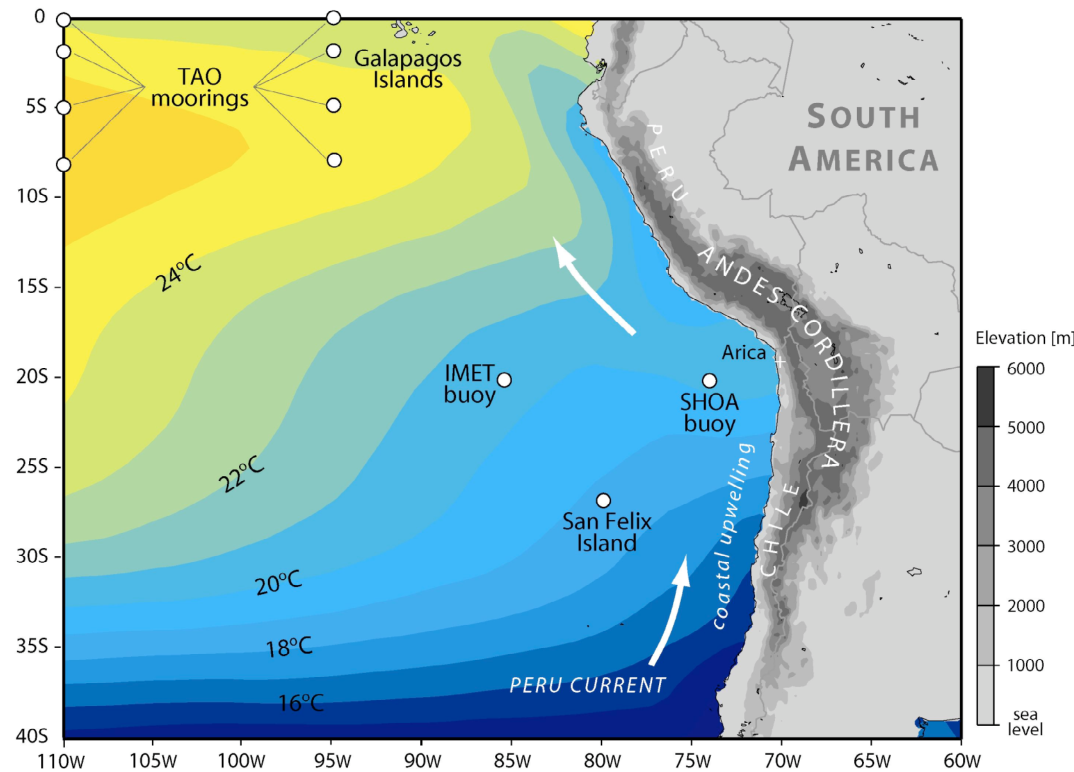
An eastern boundary

- model biases
- cloud cover
- ocean-atmosphere



The ocean setting - the Southeast Pacific (SEP)

- Persistent trade winds, coastal upwelling.
- Trade winds - directionally steady but vary in speed, with periods of low winds
- Low level of synoptic weather systems
- Peru/Chile Current flowing north and northwest.



The ocean setting

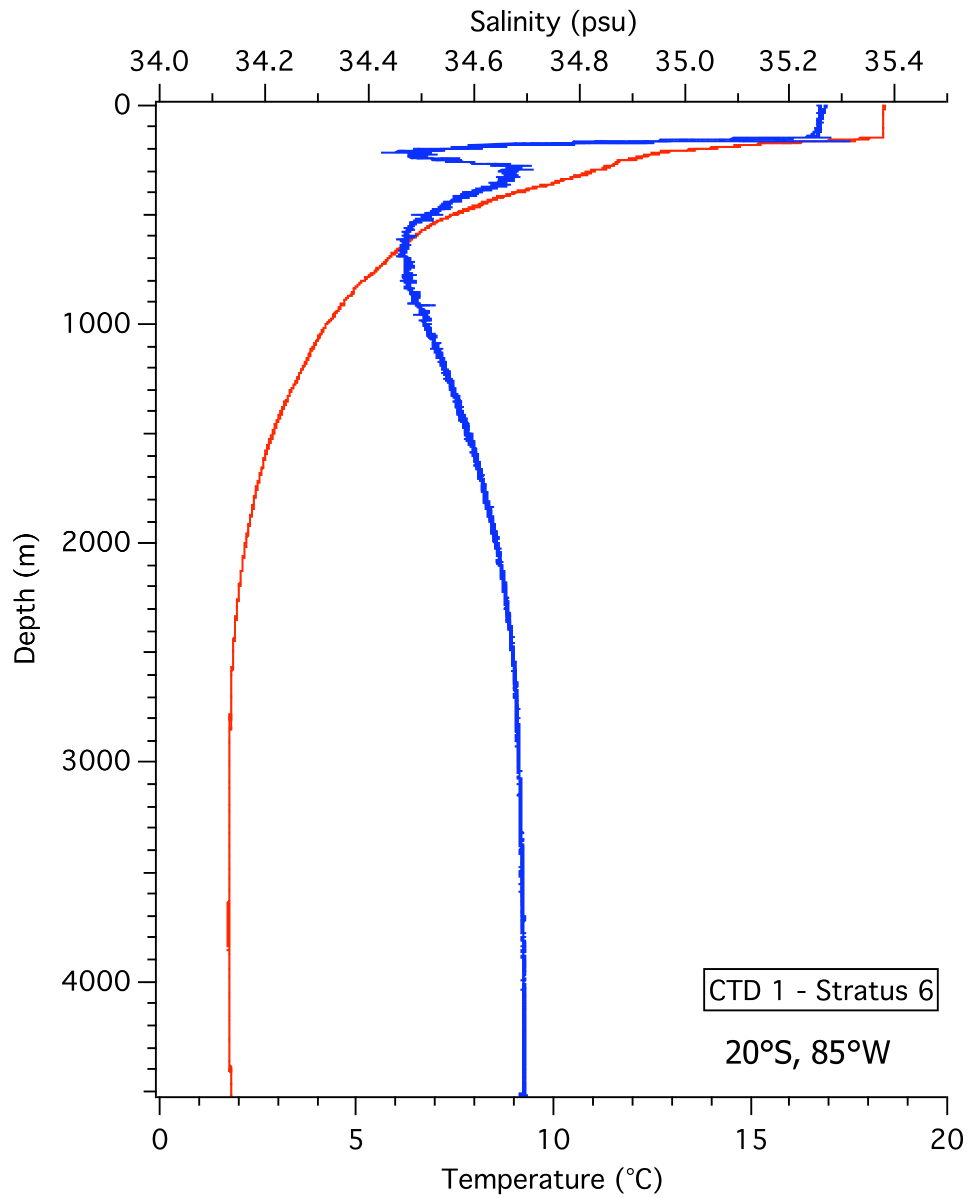
- A strongly evaporative, moderately warmed region producing temperate, salty surface water.

- Fresher water moving in below the surface layer.

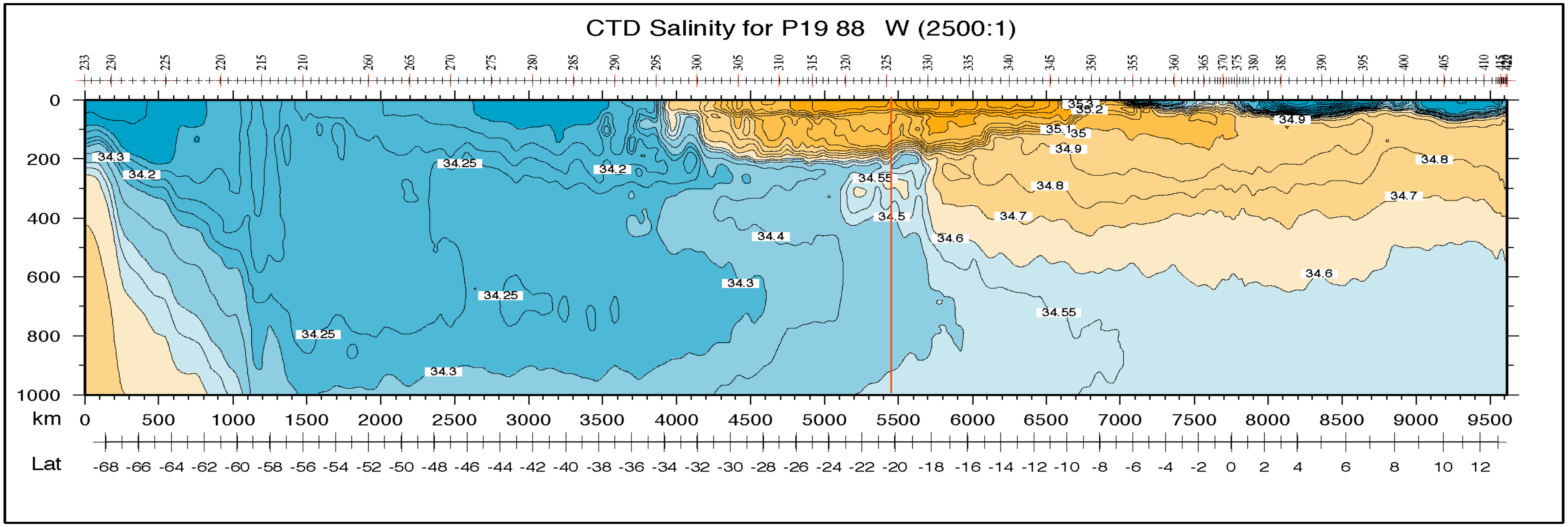
- Below that a more saline layer and a second salinity minimum.

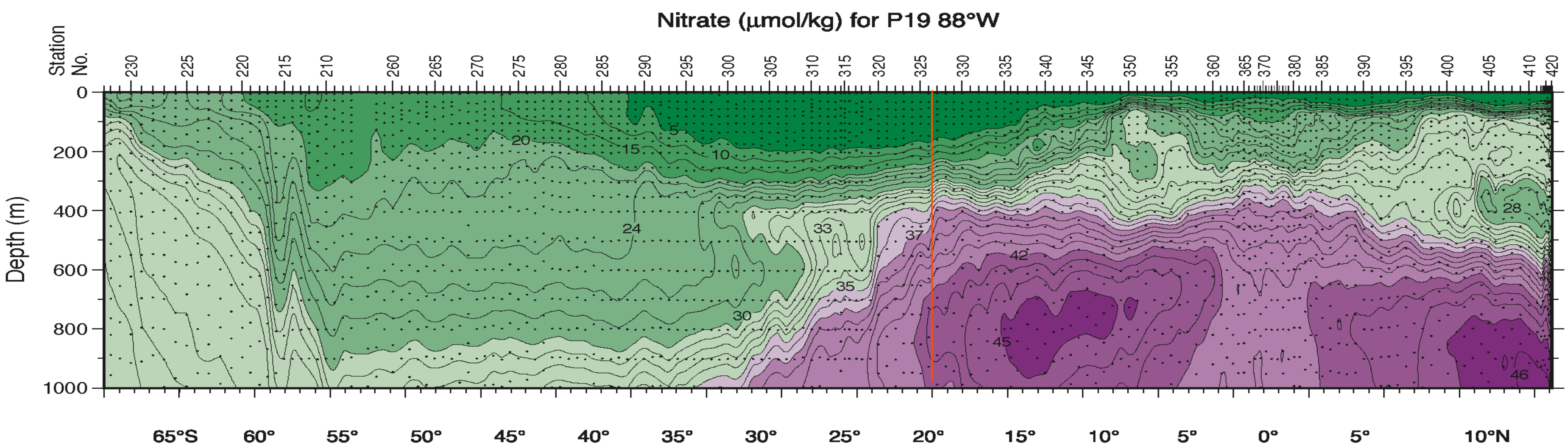
- VOCALS' goal of understanding controls on SST sets a focus on the surface layer

- VOCALS partners (Chile,Peru, France - PRIMO) interest is on the oxygen minimum layer below

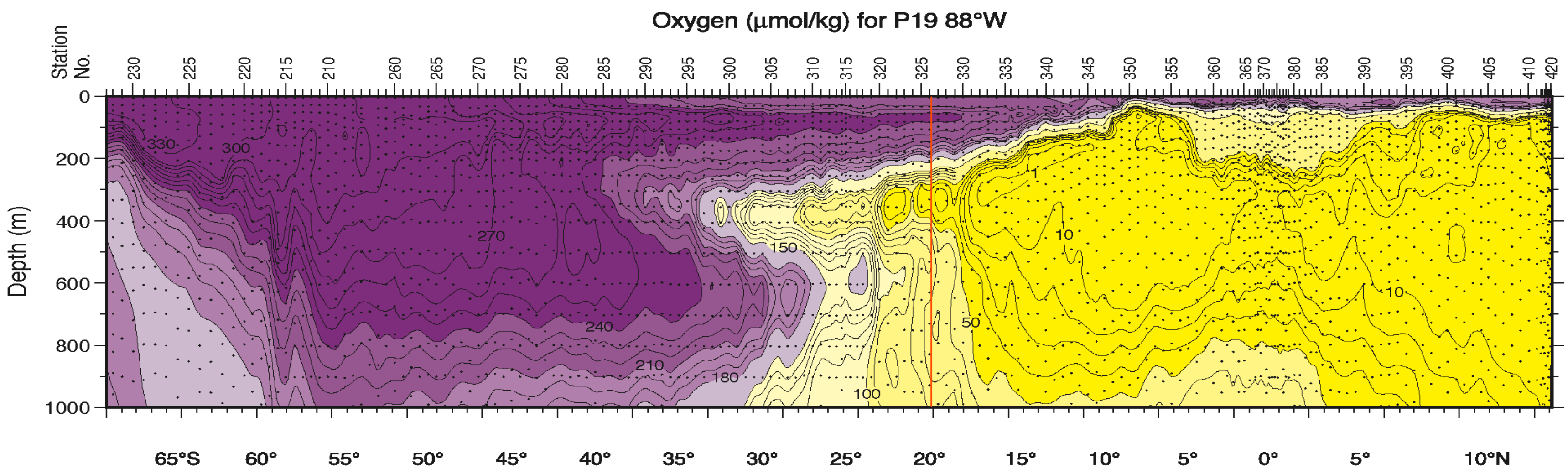


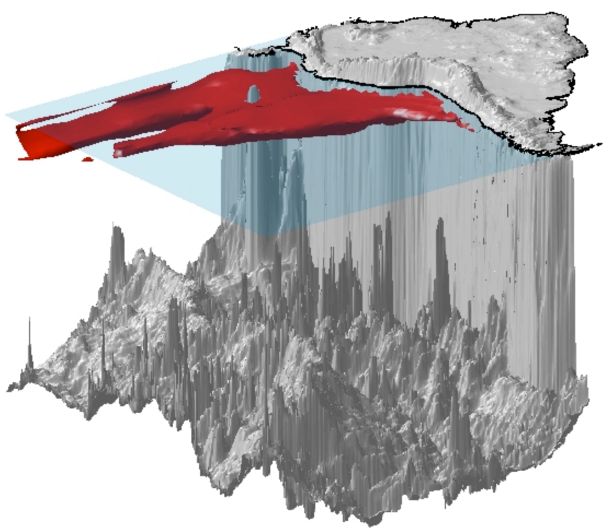
The ocean setting

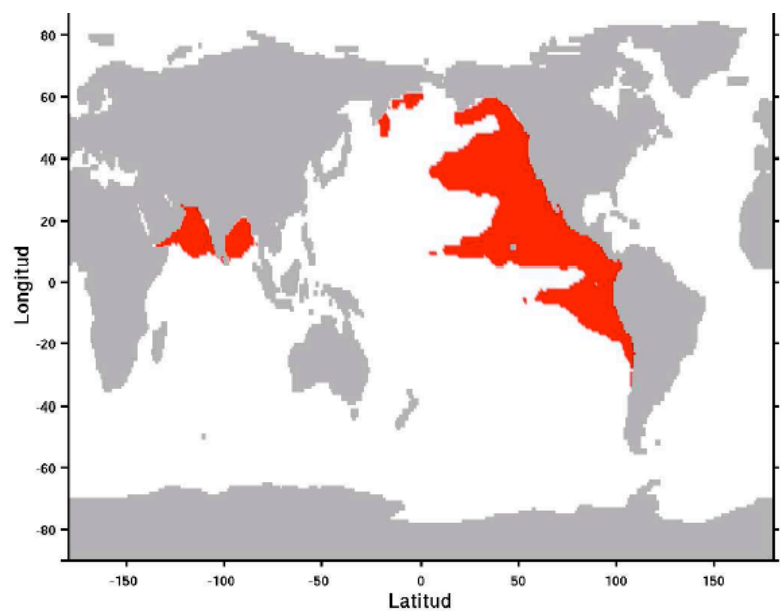




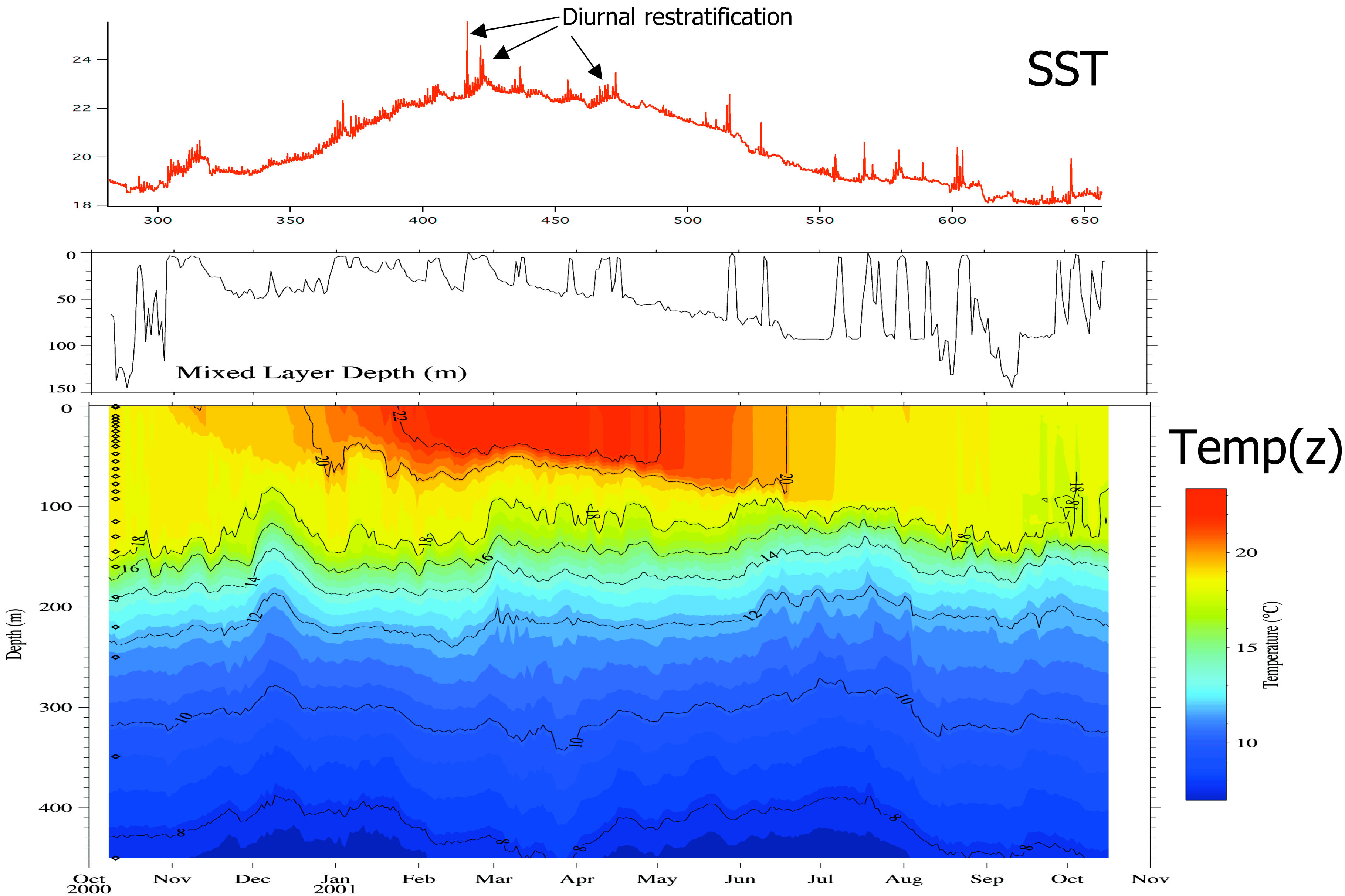
The ocean setting







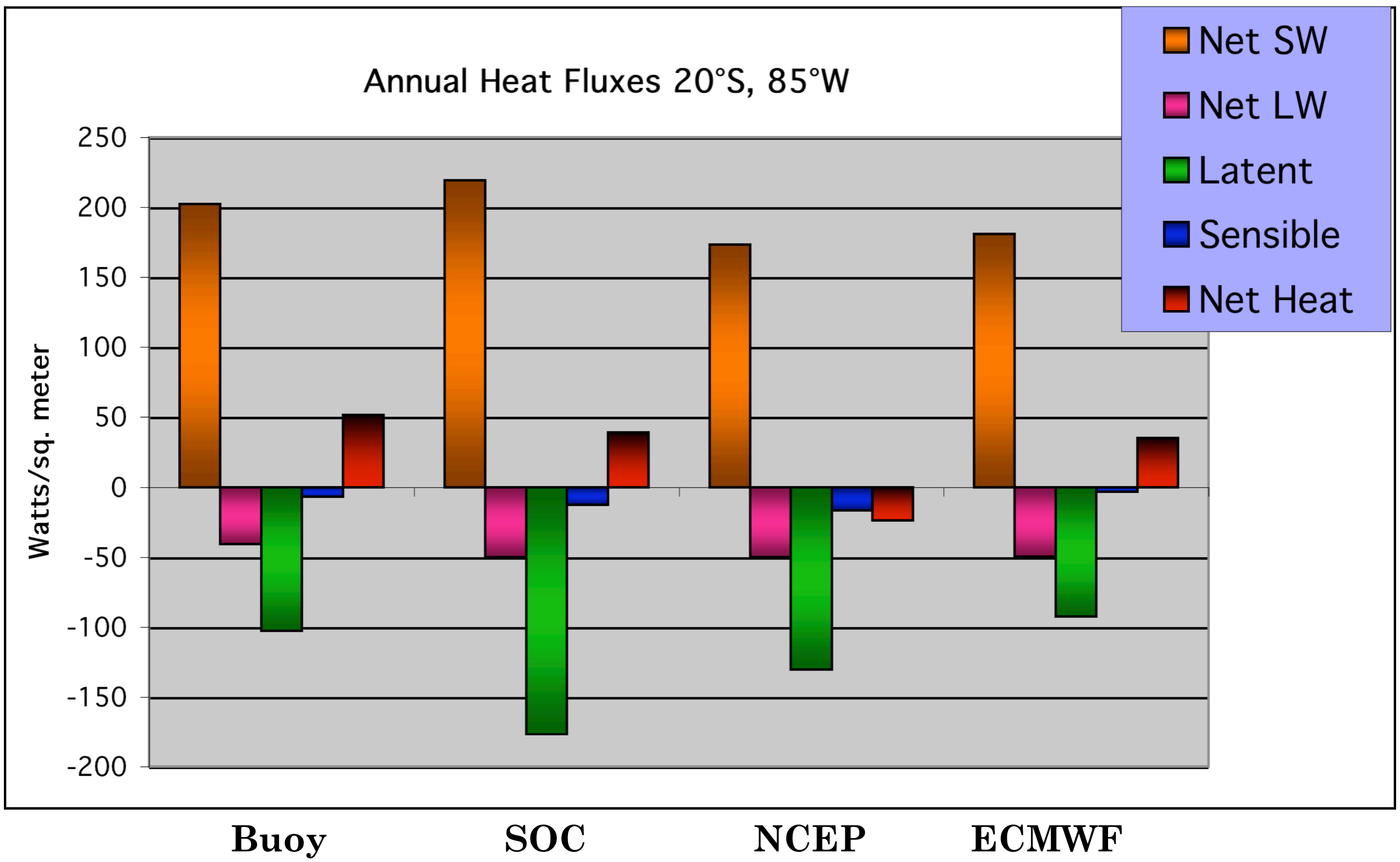
Annual cycle in the upper ocean under the stratus deck



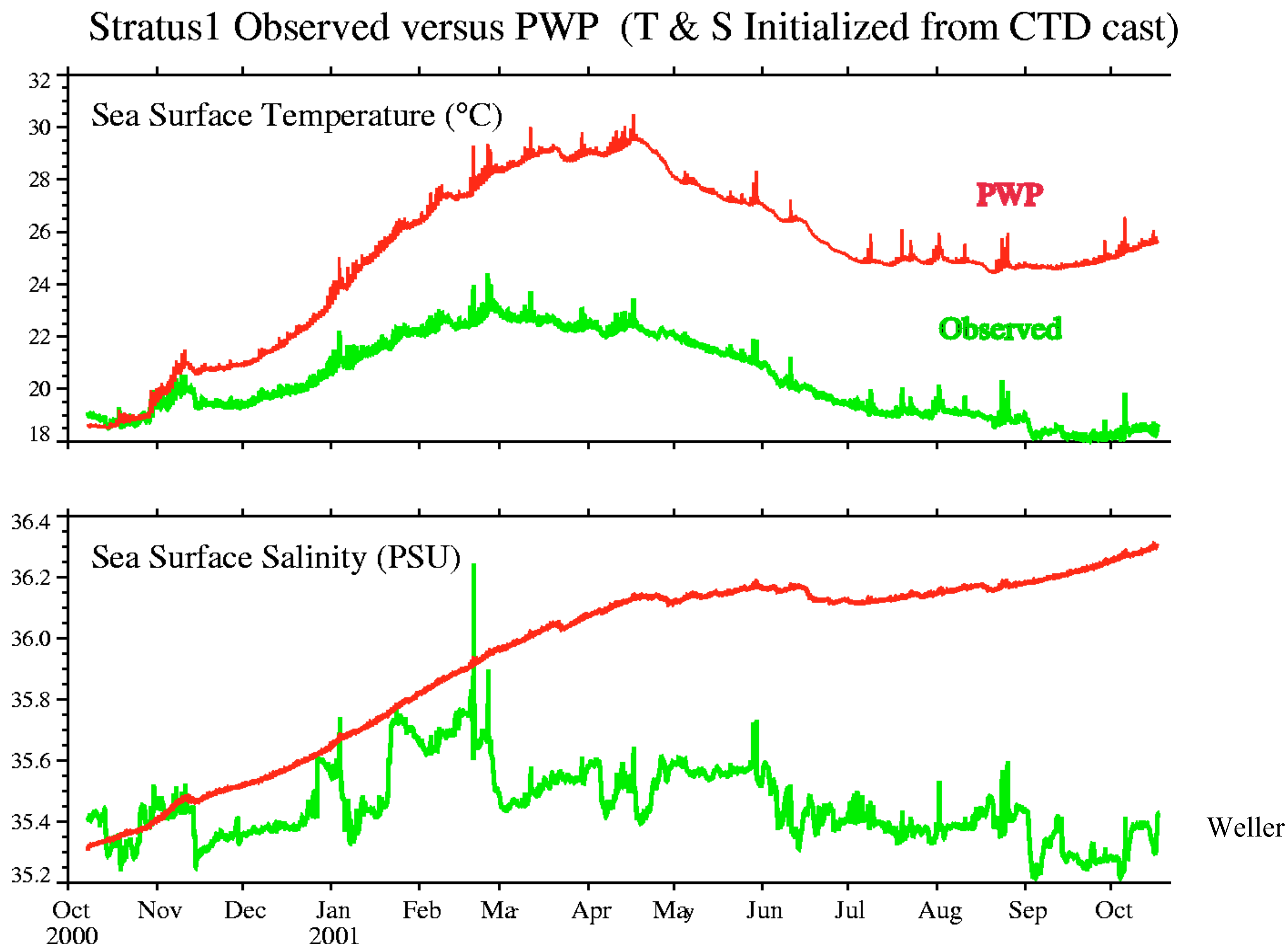
Pilot studies: To what extent are SST and upper ocean structure predictable from surface forcing alone?

Model-based surface fluxes are not accurate, for example, NCEP1 suggests a longer, cooler winter and little net heating of the ocean.

Annual net heat ranges from Buoy - more ocean gain than models, NCEP shows a loss
NCEP stress 30% stronger
Models: rain (.07 to .3 m yr^{-1}) Buoy: no rain to .03 m yr^{-1}

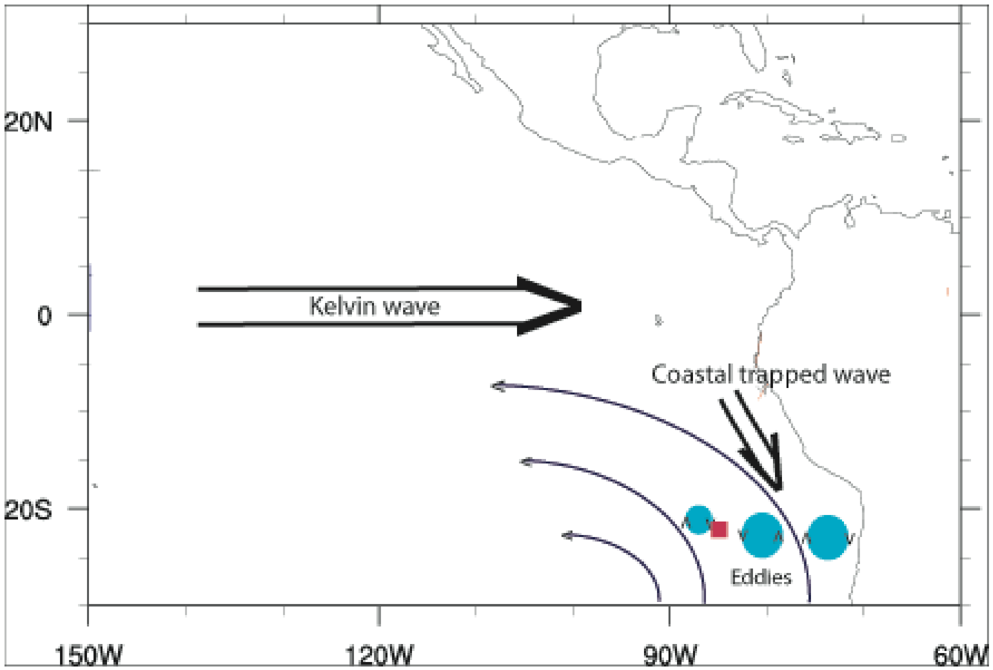


Surface forcing from buoy driving a one-dimensional ocean model (PWP) produces a surface layer that is too warm and too salty.



Additional cooling and freshening is needed. Possible mechanisms:
- Ekman (wind-driven surface layer) transport offshore of coastal water
- Open ocean downwelling/upwelling (Ekman pumping)
- Mixing with low saline water below
- Geostrophic currents (advection)
- Eddy processes, including
  - horizontal transport
  - enhanced vertical mixing

Remote as well as local forcing is possible, possible links to ENSO variability.
- Kelvin waves->coastal waves-> Rossby waves
- Displacement of S Pacific high pressure center

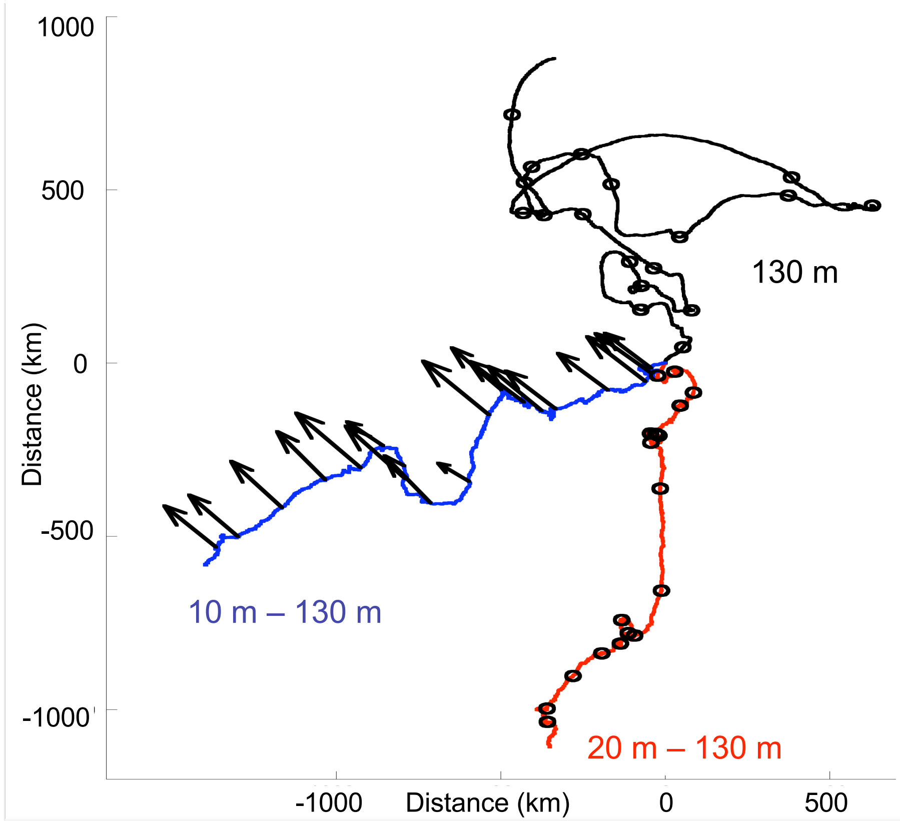


Integrated Heat Content Equation

$$\int_{0}^{1year}\left(\frac{Q_{net}}{C_P\rho_0}-\int_{z_0}^{0}\left(u\cdot\nabla T+w_E\frac{\partial T}{\partial z}+\frac{\partial\overline{u'T'}}{\partial x}+\frac{\partial\overline{v'T'}}{\partial y}\right)dz-\kappa_v\left.\frac{\partial T}{\partial z}\right|_{z=z_0}\right)dt\approx 0$$

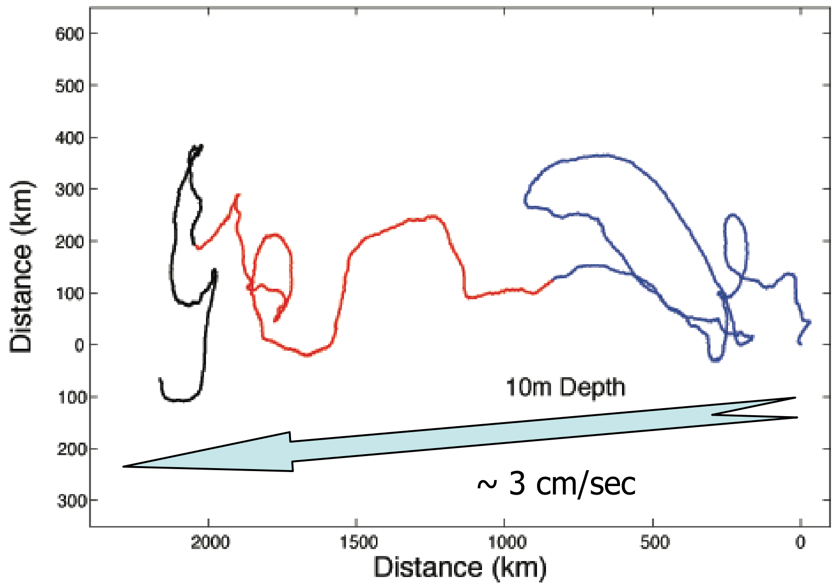
Surface Flux | Advection | Ekman Pumping | Eddy Flux Divergence | Vertical Diffusivity

Steady Trade Winds to the NW, wind-driven surface flow to the Southwest

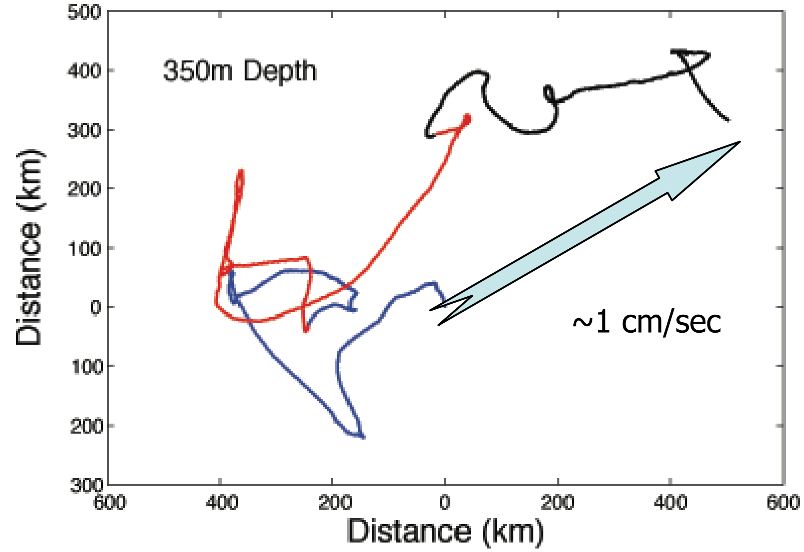


One-year displacements or progressive vector diagrams of velocities at 10 and 20 m relative to that at 130 m, as well as for the velocity at 130 m.

The surface water moves offshore under the influence of the wind.



3 year displacement at 10 m depth,
a mean of ~ 3 cm/sec

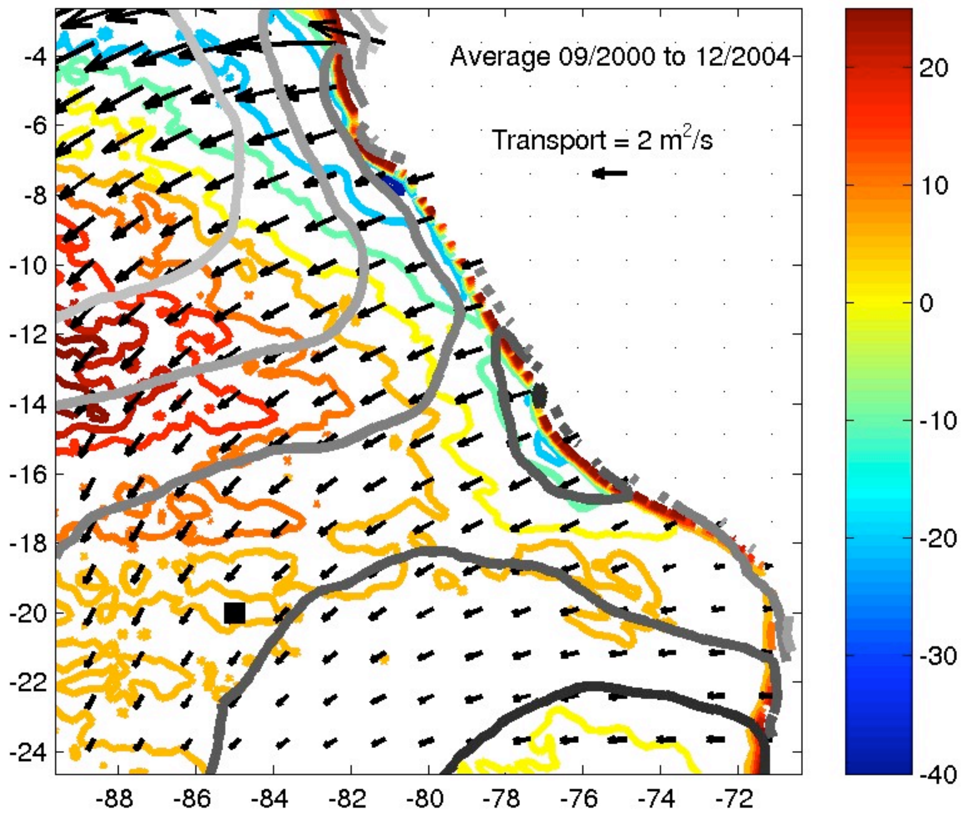


3 year displacement at 350 m depth,
a mean of ~ 1 cm/sec

In upper thermocline, 1-2 cm/sec annual mean
Flows to NW.

QuikScat winds and TMI SST fields used to estimate the advective component of heat flux due to Ekman transport across SST gradients. Calculation done for weekly fields and then combined to get an annual average. The steadiness of the winds implies that the mean of the high-frequency product is close to the product of the means.

Ekman Advection along SST gradients

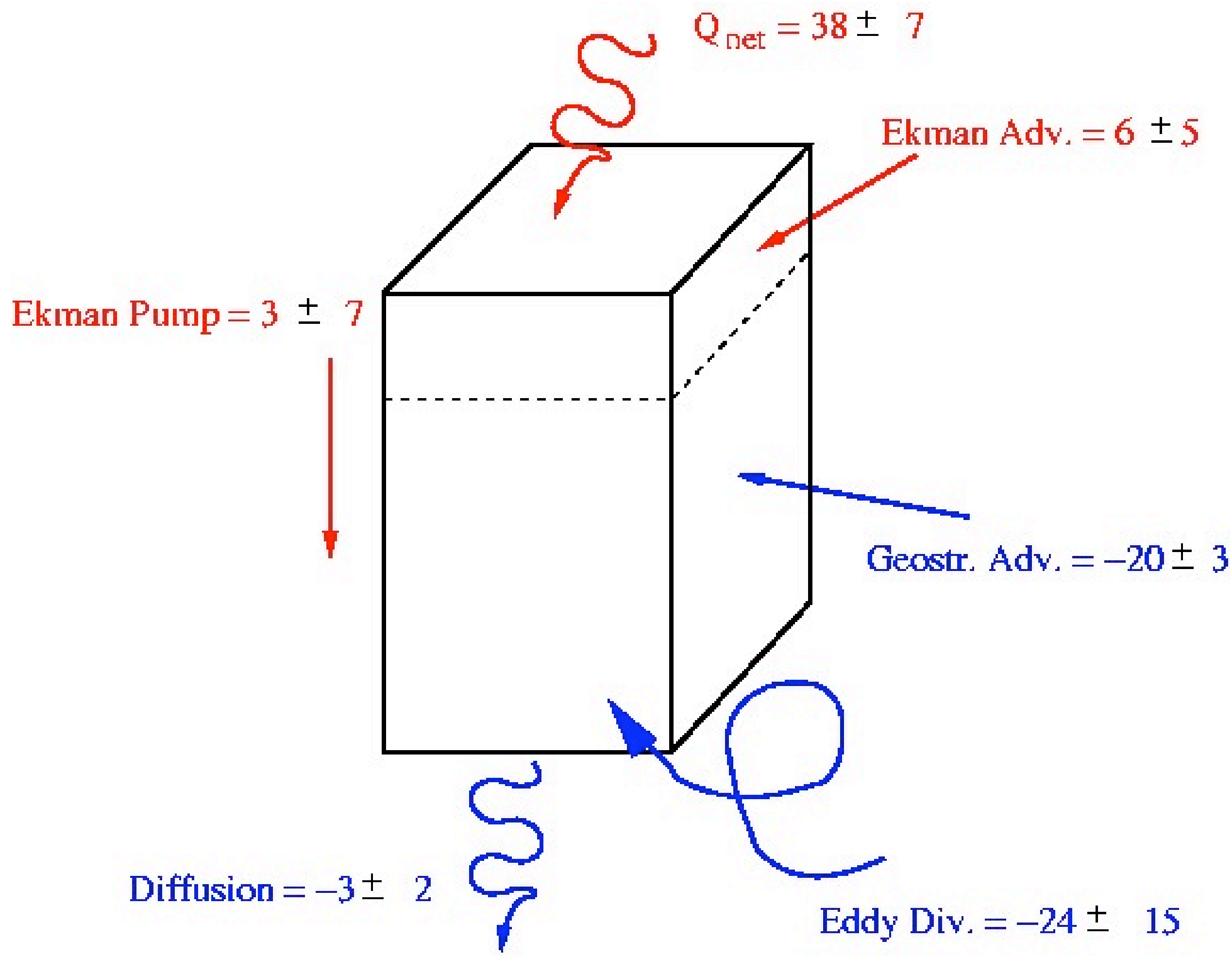


Color Contours: Annually averaged component of the heat flux due to advection by Ekman transport

Gray Contours: Annually averages SST

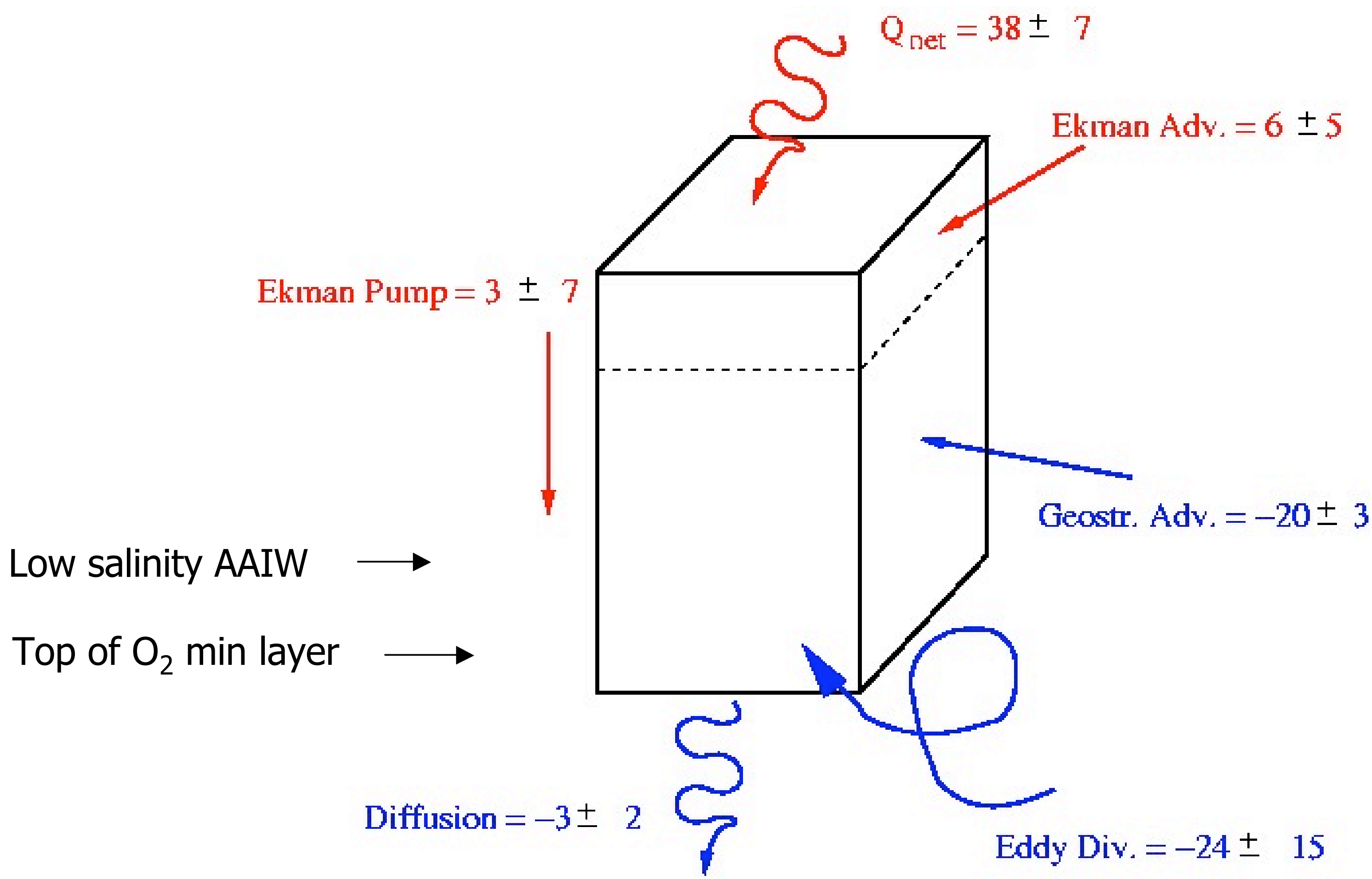
Arrows: Annually averaged Ekman transport

Ekman Advection = 6 +/- 5 W/m^2

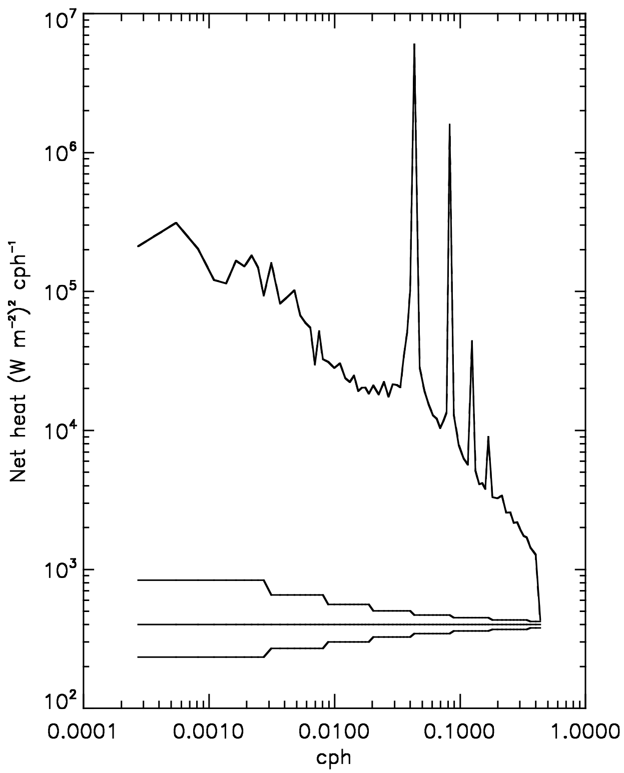


Best estimates of heat balance at Stratus mooring, 20°S, 85°W in a volume down to 250m.

Major terms: surface heating, geostrophic advection, eddy divergence.



Geostrophic advection from SW - heat, salt
Eddy flux from the coast - heat, salt, nutrients
Vertical mixing between upper thermocline and surface mixed layer
Vertical exchange between surface layer and oxygen minimum layer



Power spectrum of net heat flux.

Of concern: Diurnal variability in forcing and in response.

wind

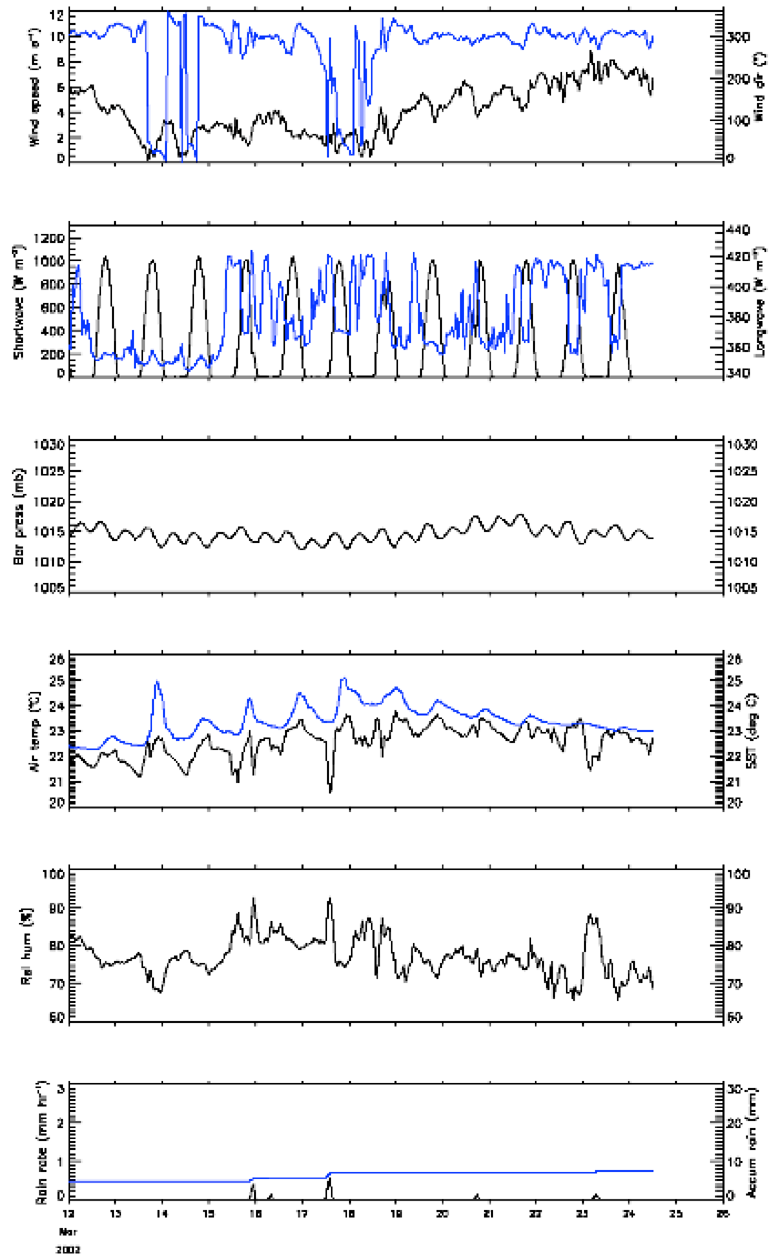
radiation

bar pres

SST
Air temp

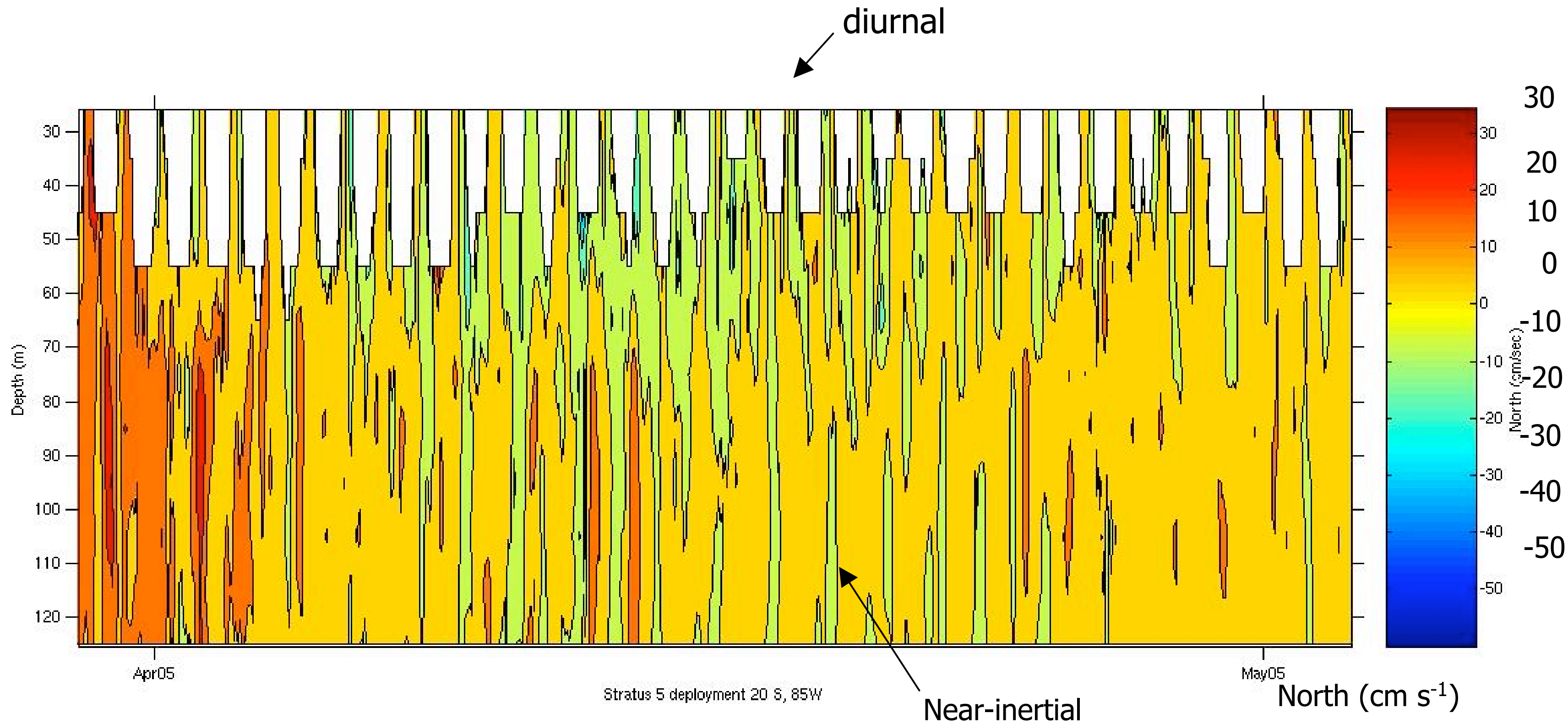
Rel hum

rain



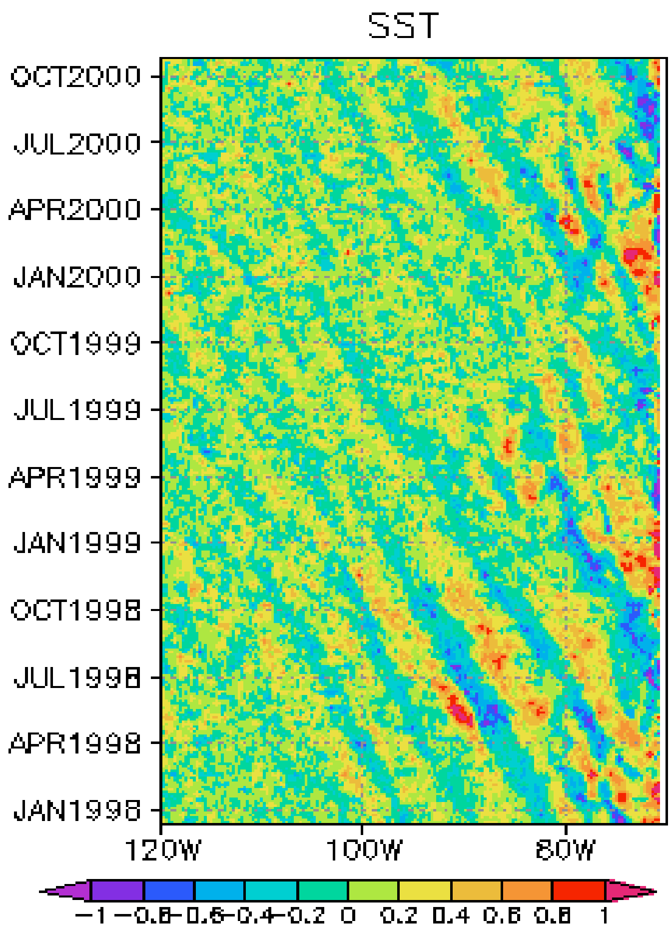
Low wind period - diurnal response

Of concern: diurnal and near-inertial ocean

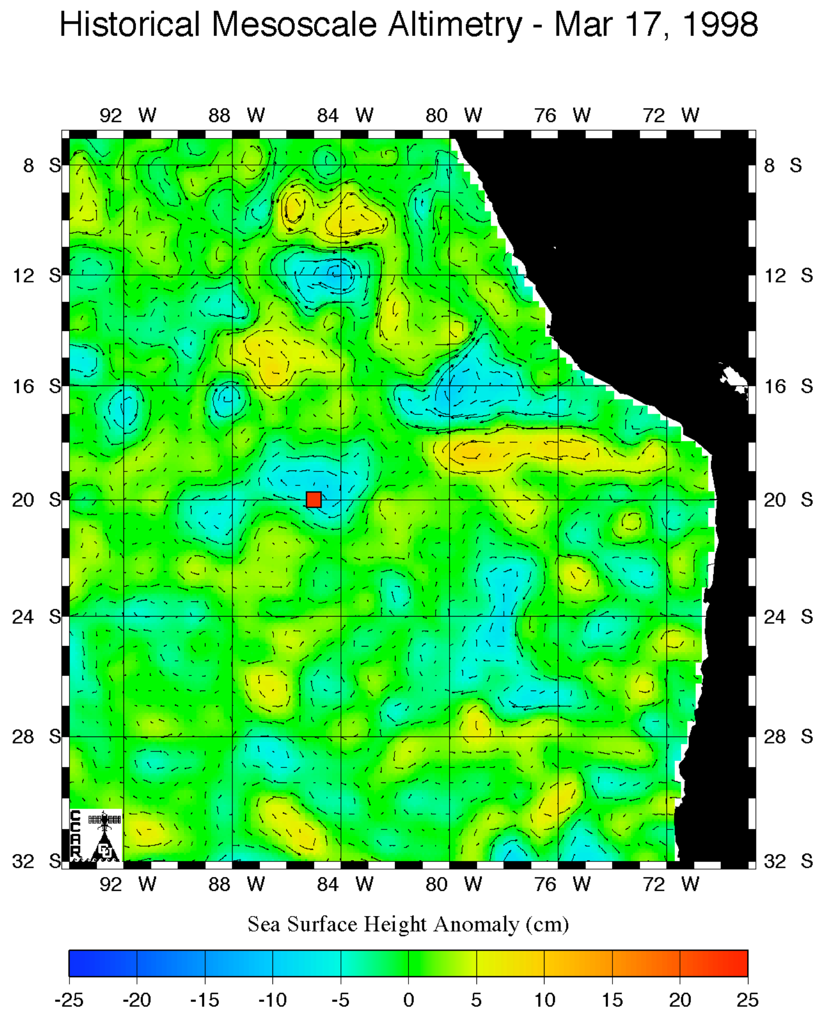


One month of upper ocean velocity (15 to 125 m) data at the Stratus mooring from an acoustic Doppler velocity profiler. Note at the surface, a diurnal (24 hour) cycle in the depth of the scattering layer modulates Doppler return. Below the surface layer, near-inertial (36 hour) oscillations are evident; these play a role in mixing.

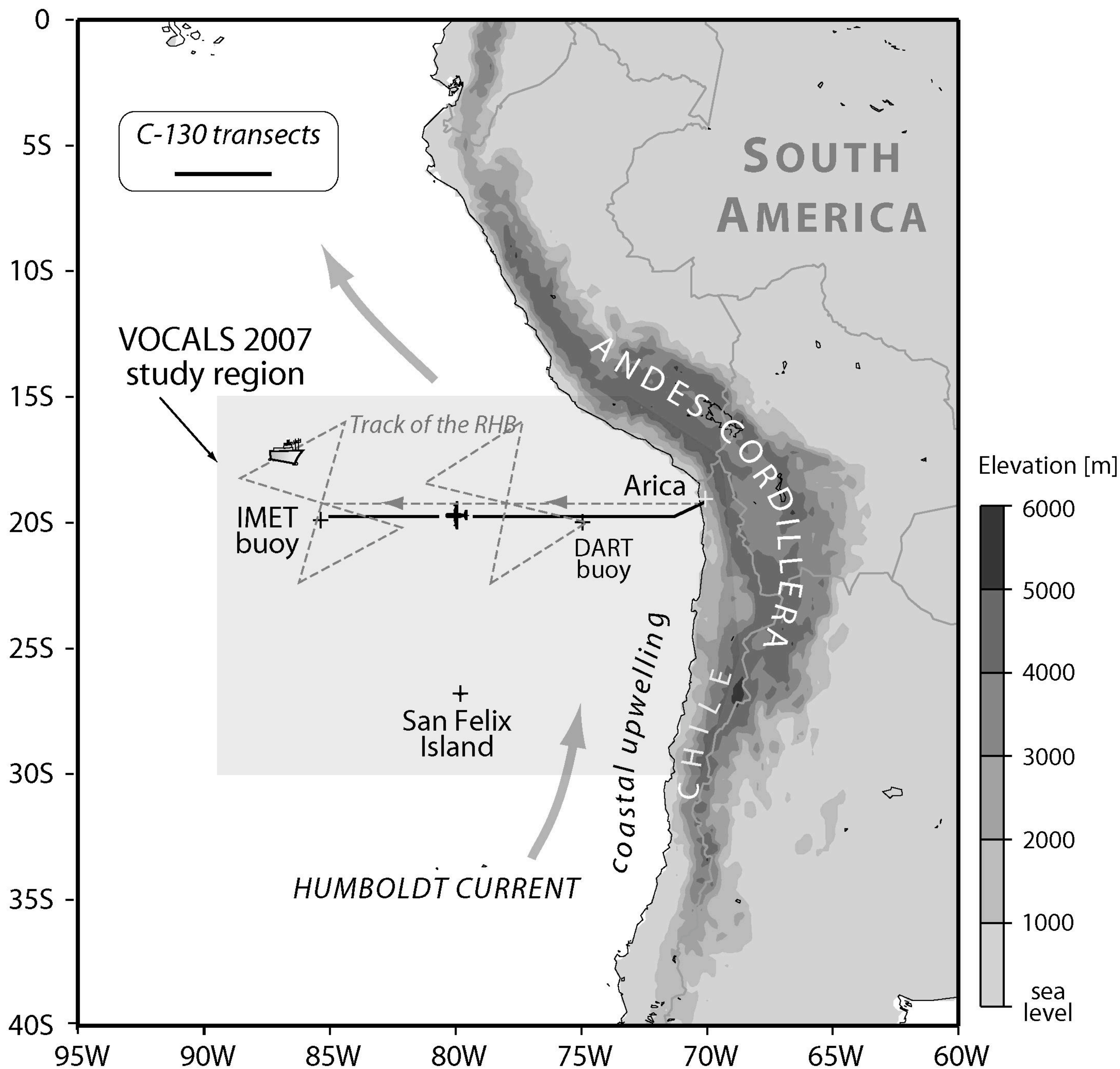
Altimetric satellites show westward propagating eddies are typical of the region.

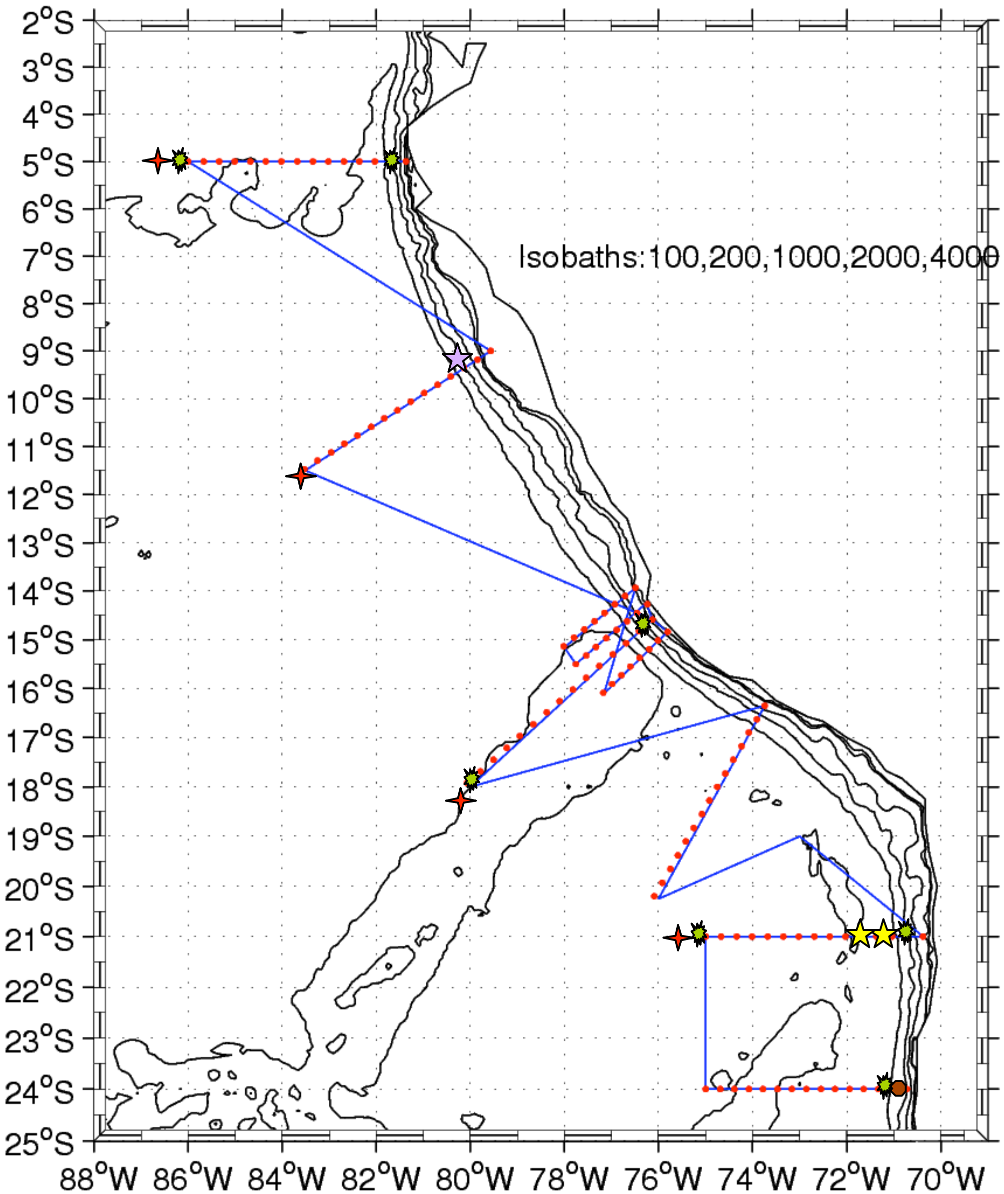


S-P Xie



Weller


C-130 transects
SOUTH AMERICA
VOCALS 2007 study region
Track of the RHB
ANDES CORDILLERA
Arica
IMET buoy
DART buoy
CHILE
coastal upwelling
San Felix Island
HUMBOLDT CURRENT
Elevation [m]
6000
5000
4000
3000
2000
1000
sea level
0
5S
10S
15S
20S
25S
30S
35S
40S
95W
90W
85W
80W
75W
70W
65W
60W



- 6 main sections, 250-300 nm
- 114 stations, 1000m or less
- 4 stations to the bottom
- 1 « radiator », 100 nm
- Total time: 37 days
- Including:
- 7 x 2-day BGC fixed stations
- 1 deep-core

- Existing moorings
- Future ADCP mooring (pos. to be defined)

VOCALS ocean implementation:

Regional scale, annual cycle:

- Argo float, surface drifter
- Lagrangian tracking of eddy by sea gliders
- Satellite
- Model comparisons

High time, high vertical resolution, time series at two contrasting sites with accurate surface fluxes:

- Stratus (20°S, 85°W) NOAA Climate Obs - ongoing
- Chilean Tsunami (DART) buoy (20°S, 75°W) - Oct 2006-Oct 2008 (turn around planned for Oct 2006)

Vertical mixing processes at Stratus and DART sites over diurnal and near-inertial cycles:

- Microstructure profiling for 6-10 days at each
- Near-surface profilers to resolve diurnal layer

VOCALS ocean implementation:

Mesocale sampling - the role of the eddies:

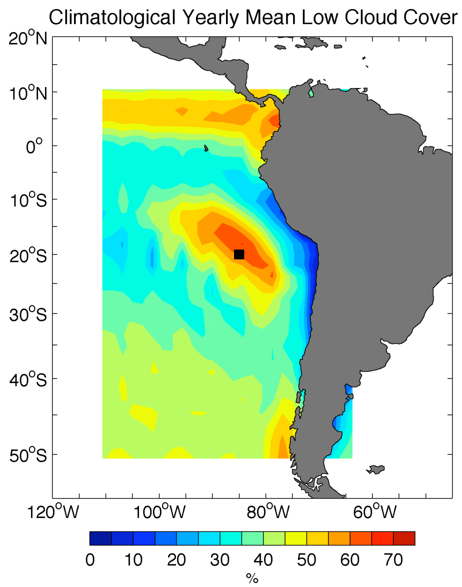
- SeaSoar surveys at Stratus, DART, coastal sites
- Sea glider deployment for one year
- XBT, ADCP sections

Partnering

- –Ongoing NOAA Climate Observation Program
- –SOLAS
- –PRIMO
- –Chilean coastal program

summary

- Coupled atmosphere-ocean models
  - Tested across regimes, coastal upwelling to open ocean, offshore weak downwelling, eddy-influenced
  - Tested at sites (Stratus buoy, DART) at different phases of diurnal subsidence wave, different aerosol regimes
  - Clear separation of surface layer from upper thermocline
- Surface fluxes at 3 sites (also San Felix)
- Coupled physics-biology ocean models
  - Ability to get surface layer, oxygen minimum layer
  - Ability to get offshore nutrient transport
  - DMS production, impacts on optical absorption



Surface fluxes and ocean structure and evolution: Addressing model (atmospheric, coupled atmosphere-ocean, coupled physics-biology) performance in a region spanning several regimes