Seasonal mixed layer heat budget in coastal waters off Angola

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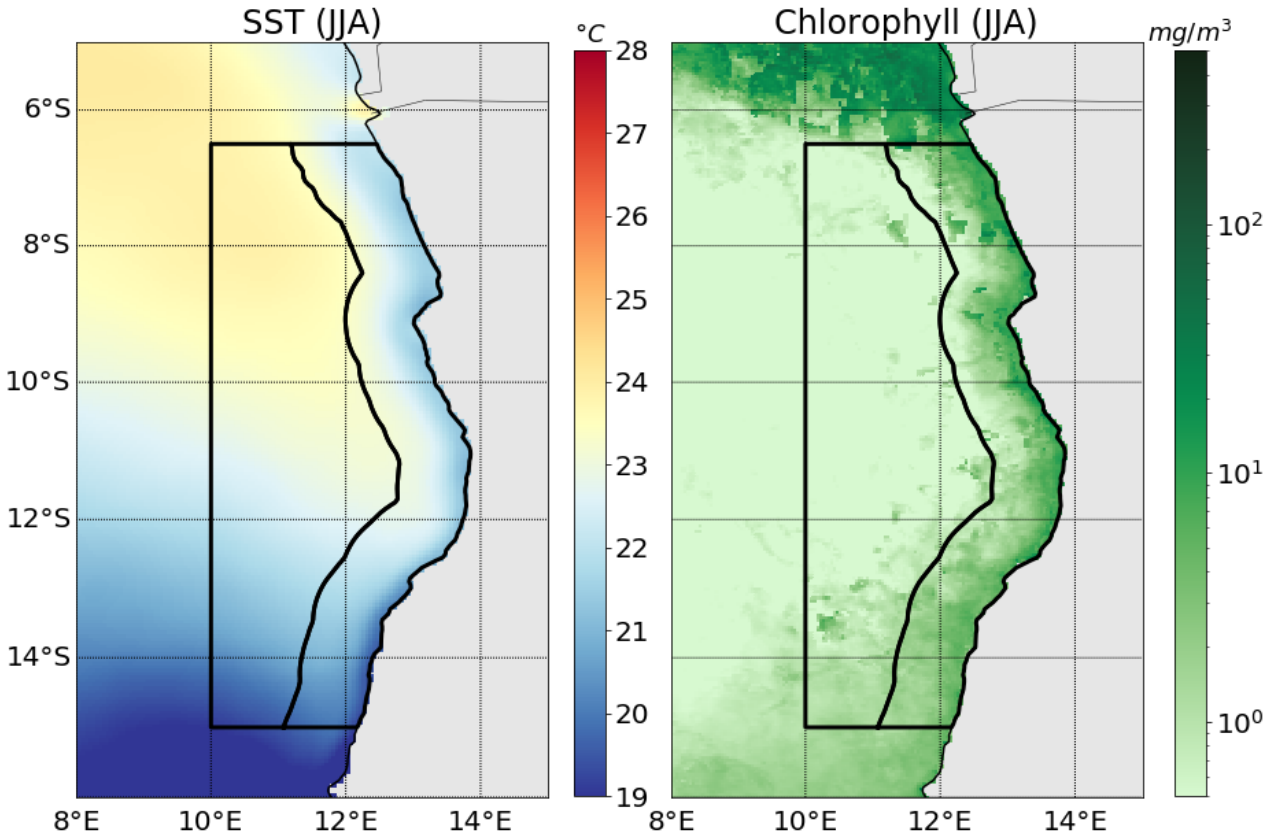
Motivation

- The Angolan shelf system is a highly productive ecosystem with pronounced seasonal variability.
- Productivity peaks in austral winter when seasonally prevailing upwelling favorable winds are weakest.
- We calculate the mixed layer heat budget to analyze atmospheric and oceanic causes for heat content variability.



OISTA sea surface temperature during June-August (left). Modis Chlorophyll concentration during June-August (right). Black lines mark the coastal and offshore box used for spatial averaging of the mixed layer heat budget terms.

Mixed layer heat budget

$$h\frac{\partial T}{\partial t} + h\left(\boldsymbol{v} \cdot \nabla T + \overline{\boldsymbol{v}' \cdot \nabla T'}\right) + \varepsilon = \frac{q_{net} - q_{-h}}{\rho c_p}$$

(a) (b) (c) (d)

Terms

a) Heat storage
b) Horizontal advection
c) Residuum consisting of errors and terms that are not considered
d) Net atmospheric heating & vertical turbulent diffusion at the base of the mixed layer

Variables:

h → ML depth
T → ML temperature
v → horizontal velocities
q_{net} → net surface heat flux
q_{-h} → neat heat loss through the base of the mixed layer
ρ → density
c_p → specific heat content
‘ → deviations from the mean

Data & Methods

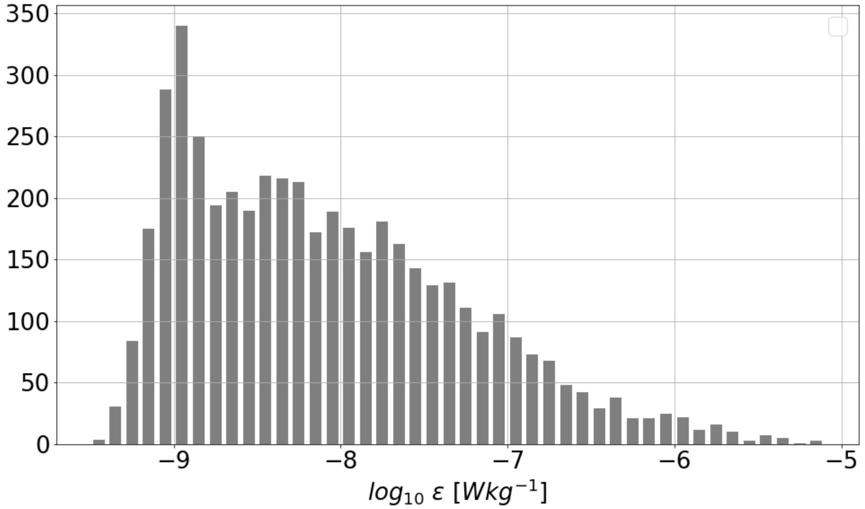
Variable	Dataset	Horizontal resolution	Temporal resolution
Temperature	OISTA SST (satellite)	1/20°x1/20°	Daily
Velocity	OSCAR (satellite)	1/3°x1/3°	5-day mean
Shortwave & longwave radiation	TROPFLUX (satellite)	1°x1°	monthly
Latent & sensible heat flux	MERRA2 (reanalysis)	0.625°x0.5°	monthly
Mixed layer depth	PREFCLIM	1/4°x1/4°	climatology
Diapycnal mixing	Calculated from ocean turbulence data	-	Data collected from cruises in 07-2013, 06-2018 & 09-2019

The data above is used to calculate the individual terms of the mixed layer budget. Afterwards the terms are spatially averaged over two boxes (see slide 2).

Note that the diapycnal mixing term is calculated from ocean turbulence data that were measured during 3 cruises in the region. Thus, estimation of this term is only available during 3 points in time.

Measuring diapycnal mixing

Cruise	Profiles
07-2013	212
06-2018	160
09-2019	56



Histogram of dissipation rates measured below the mixed layer.

Dissipation rates of turbulent kinetic energy is inferred from airfoil shear data. The dissipation rate for isotropic turbulence is given by:

$$\varepsilon = \nu\overline{\left(\frac{\partial u'_j}{\partial x_i}\right)^2} = 7.5\nu\overline{\left(\frac{\partial u}{\partial z}\right)^2}$$

(Hummels et al., 2013)

Eddy diffusivities for buoyancy can be parameterized as:

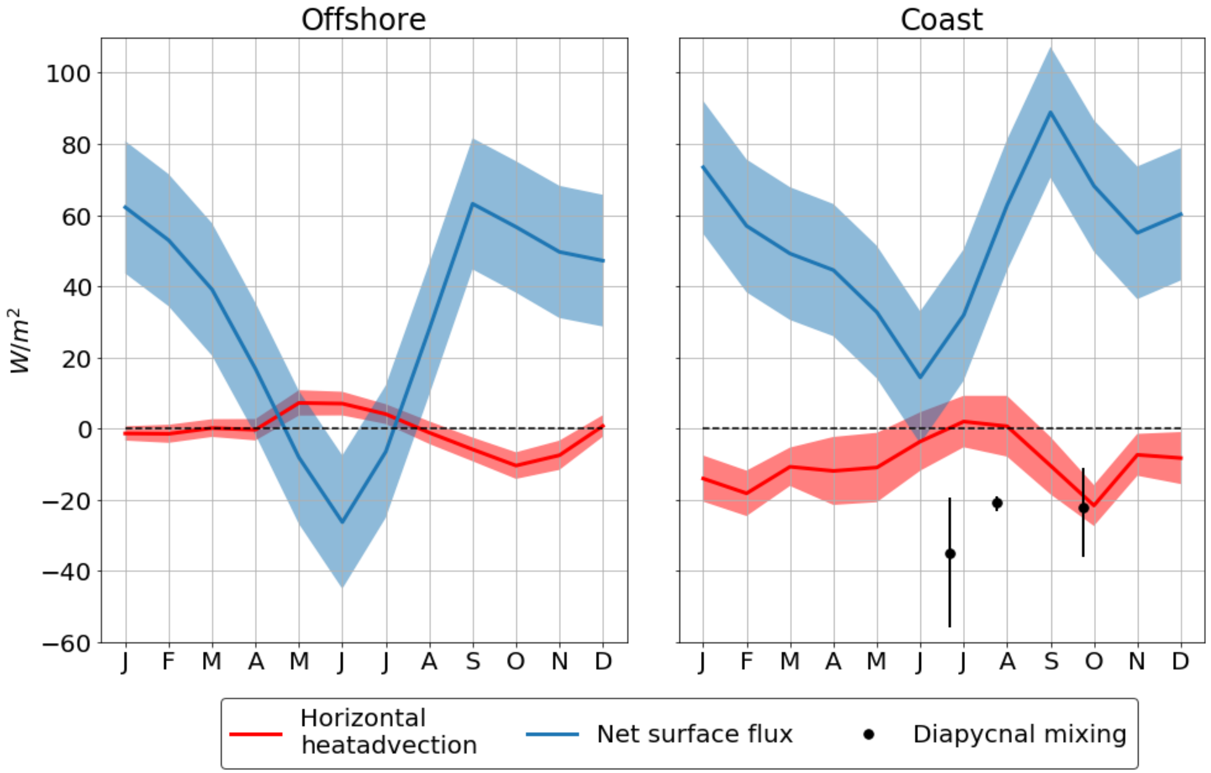
$$K_\rho = \Gamma\frac{\varepsilon}{N^2},\quad \Gamma = R_f/(1-R_f) \approx 0.2$$

(Osborn, 1980)

Turbulent heat flux: $\boxed{J_{heat} = -\rho c_p K_\rho \left(\frac{\partial\bar{\theta}}{\partial z}\right)}$ (Osborn and Cox, 1972)

Mixed layer heat budget

- The surface fluxes and the horizontal heat advection term are larger in the coastal box.
- The horizontal heat advection term is largest in both boxes in October. However, the term is small compared to the surface fluxes.
- The diapycnal mixing term is larger than the horizontal heat advection term.

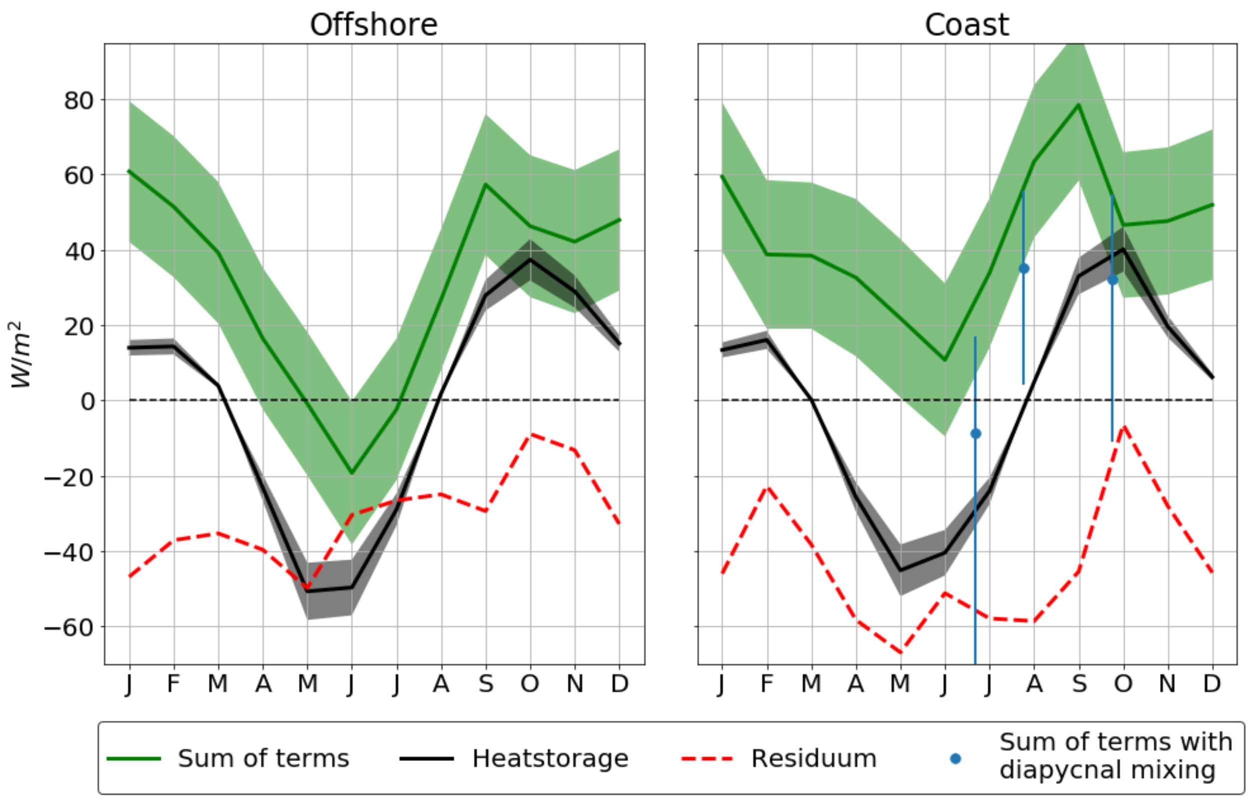


Mixed layer heat budget terms spatially averaged over the offshore box (left) and coastal box (right).

Mixed layer heat budget

- The mixed layer heat budget is not closed by only considering surface fluxes and horizontal heat advection.
- The residuum is about 20W/m^2 larger in the coastal box.
- Diapycnal mixing term is able to reduce the residuum considerably.

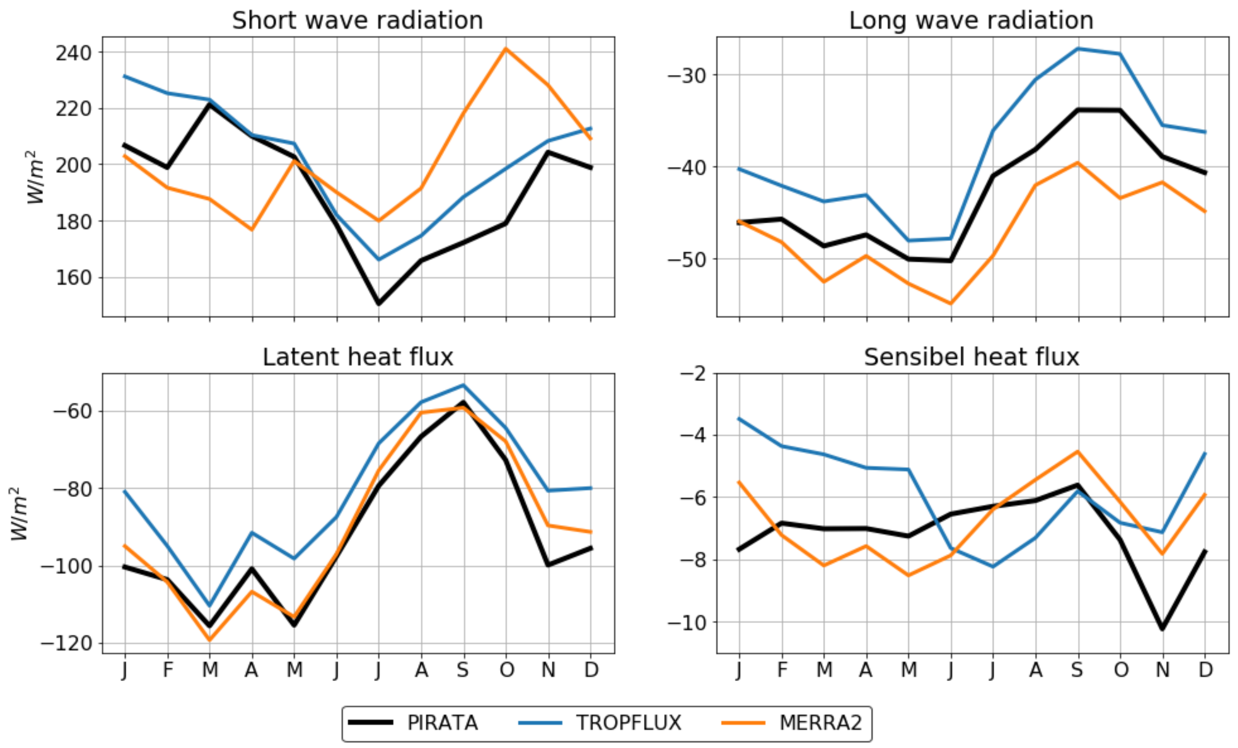
What are the reasons for the large residuum of the mixed layer heat budget?



Mixed layer heat budget spatially averaged over the offshore (left) and coastal (right) box.

Uncertainties in surface heat flux data

- Comparisons between different satellite, reanalysis and mooring data reveal striking differences in surface heat fluxes.
- These results underline the importance of understanding the surface heat fluxes in the coastal upwelling region off Angola. Uncertainties in the surface heat flux data greatly affect the discussion of the whole mixed layer heat budget and its residuum.



The seasonal cycle of surface heat fluxes at 6°S, 8°E measured by PIRATA mooring between 2013 and 2018 (black). And the seasonal cycle of TROPFLUX (blue) and MERRA2 (orange) at the same location and time period.

Summary & Outlook

- The seasonal mixed layer budget is not closed by considering only surface heat fluxes and horizontal advection terms.
- We show that the horizontal advection term is of minor importance for the overall budget.
- Considering diapycnal mixing from three cruises in coastal waters off Angola suggests that this term plays an important role in closing the budget.
- The analysis of surface heat fluxes from different data sources reveals large uncertainties.
- The residuum is considerably larger in the coastal box. One reason why could be that diapycnal mixing term is of greater importance here. However, also larger errors in the surface fluxes close to the coast could be a reason as well.

Our work underlines that still a lot is not understood concerning the surface signals in the upwelling region off Angola. Of particular importance is the role of diapycnal mixing and associated turbulence. Our future goal is to assess and understand the mechanisms leading to mixing at the shelf off Angola.

Thank you!

If you have questions or comments please feel free to contact me!

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References

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