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Supplementary Material

(The Influence of Freshwater Input on the Evolution of the 1995 Benguela Niño)

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EGU General Assembly

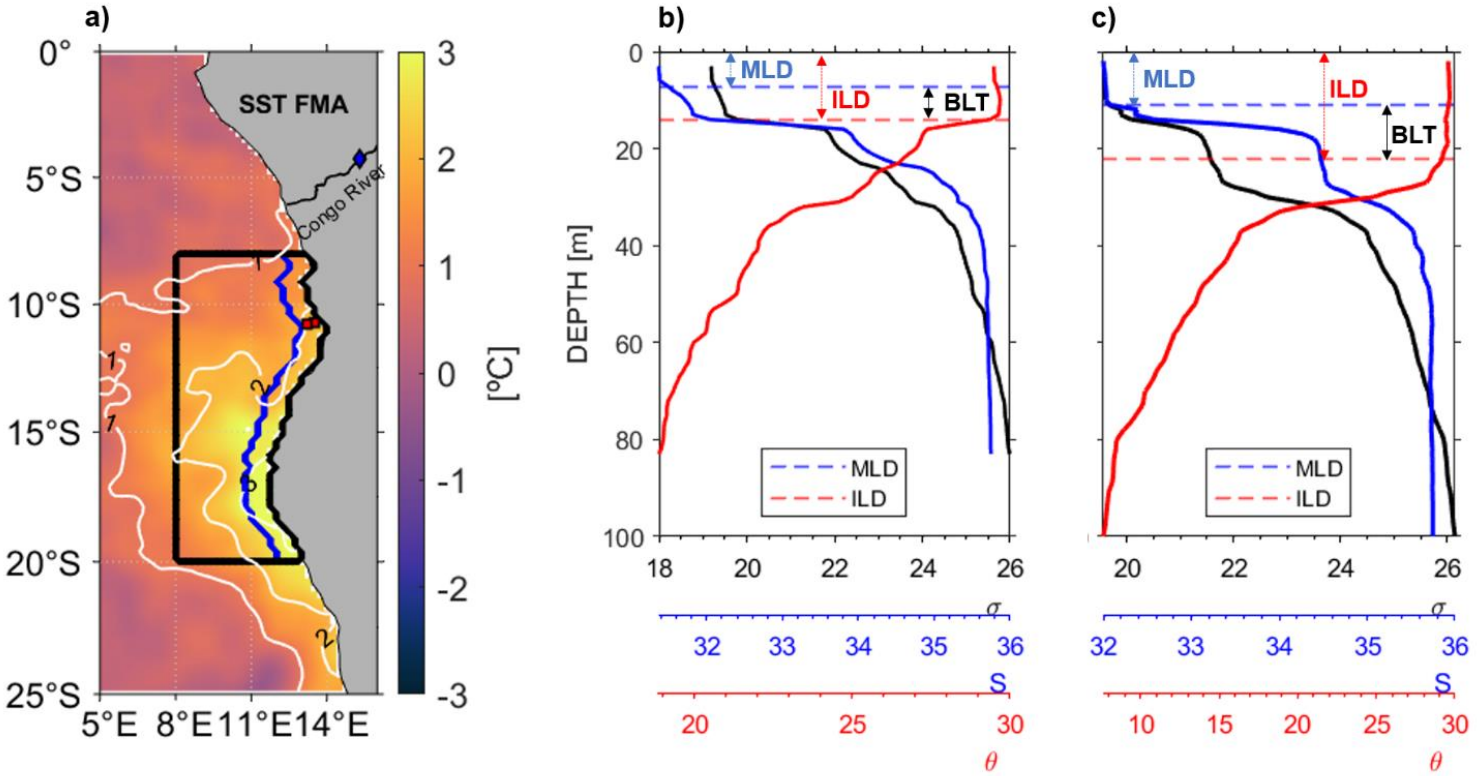
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

GEOMAR Helmholtz Centre for Ocean Research Kiel

KMS & GEOMAR FYORD FOSTER YOUNG OCEAN RESEARCHER DEVELOPMENT

Supp. Material

(Aroucha et al. 2024)



(a) Detrended monthly sea surface temperature (SST) anomalies from NOAA Optimum Interpolation SST for February-March-April 1995. White contours are anomaly isotherms 1°C apart from each other. Blue diamond represents Congo River Brazzaville station. Contours indicate ABA (8°S–20°S, 8°E to the coast, black) and coastal box 1 (8°S–20°S, 1° away from the coast, blue). Red squares indicate the location of conductivity-temperature-depth (CTD) profiles depicted in (b), (c). CTD profiles from Nansen Program (b) on 16 March 1995 at 10.74°S and 13.5°E and (c) on 27 March 1995 at 10.76°S and 13.2°E. Red, blue, and black solid lines in (b), (c) represent potential temperature (θ), salinity (S), and density (σ) profiles, respectively. MLD, mixed layer depth; ILD, isothermal layer depth; BLT, barrier layer thickness.

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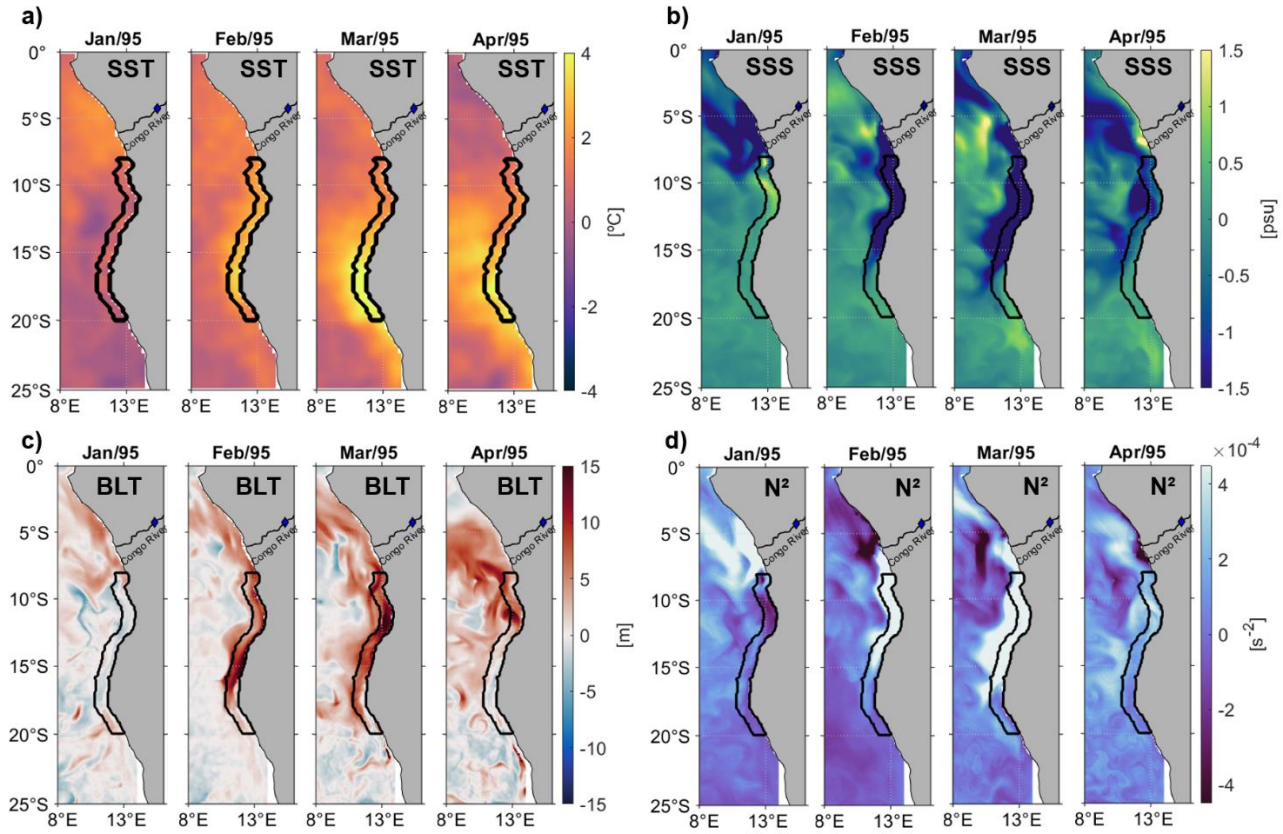
(Aroucha et al. 2024)



Detrended monthly anomalies from January–April 1995 for sea surface temperature (SST) (a), sea surface salinity (SSS) (b), Barrier Layer Thickness (BLT) (c), N2 (d). Black contours indicate coastal box 1 region (8°S–20°S, 1° away from coast). Blue diamond represents Congo River Brazzaville station. SST from NOAA Optimum Interpolation SST. SSS from Global Mercator Ocean Reanalysis product (GLORYS12), BLT and N2 calculated from GLORYS12 dataset.

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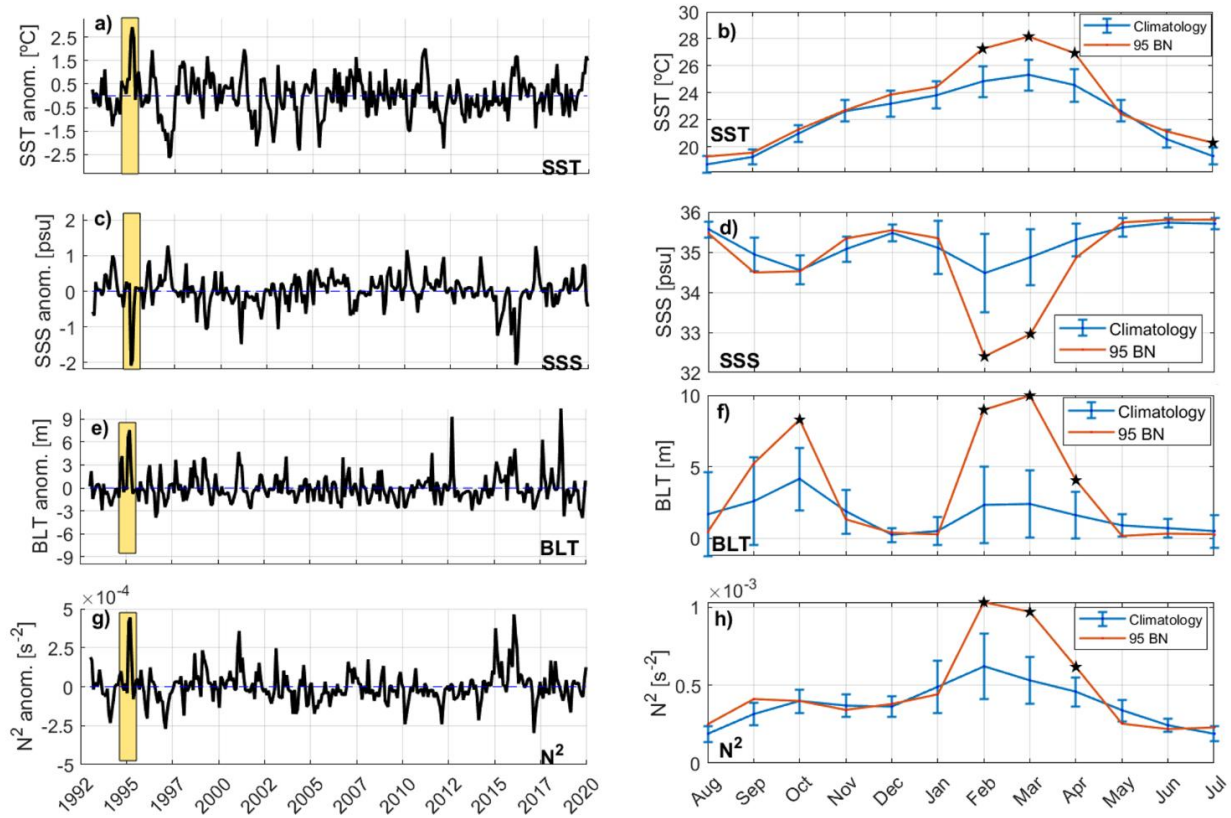
(Aroucha et al. 2024)



Detrended monthly anomalies of sea surface temperature (SST) (a), sea surface salinity (SSS) (c), Barrier Layer Thickness (BLT) (e) and N2 (g) averaged for coastal box 1 region (8°S–20°S, 1° away from coast) from 1993 to 2019. Yellow shading indicates the period from August 1994 to July 1995. (b) SST climatology (shown from August to July, in blue) calculated over 1993–2019 and monthly values (in red) from August 1994 to July 1995 averaged in the coastal box 1. Panels (d, f, h) same as panel (b) but for SSS, BLT, and N2, respectively. Intervals in panels (b, d, f, h) depict monthly standard deviation. SST from NOAA Optimum Interpolation SST. SSS from Global Mercator Ocean Reanalysis product (GLORYS12), BLT, and N2 calculated from GLORYS12 data set. Black stars in panels (b, d, f, and h) indicate significant differences from monthly climatologies of each respective month at a 90% confidence level according to the Student's t test.

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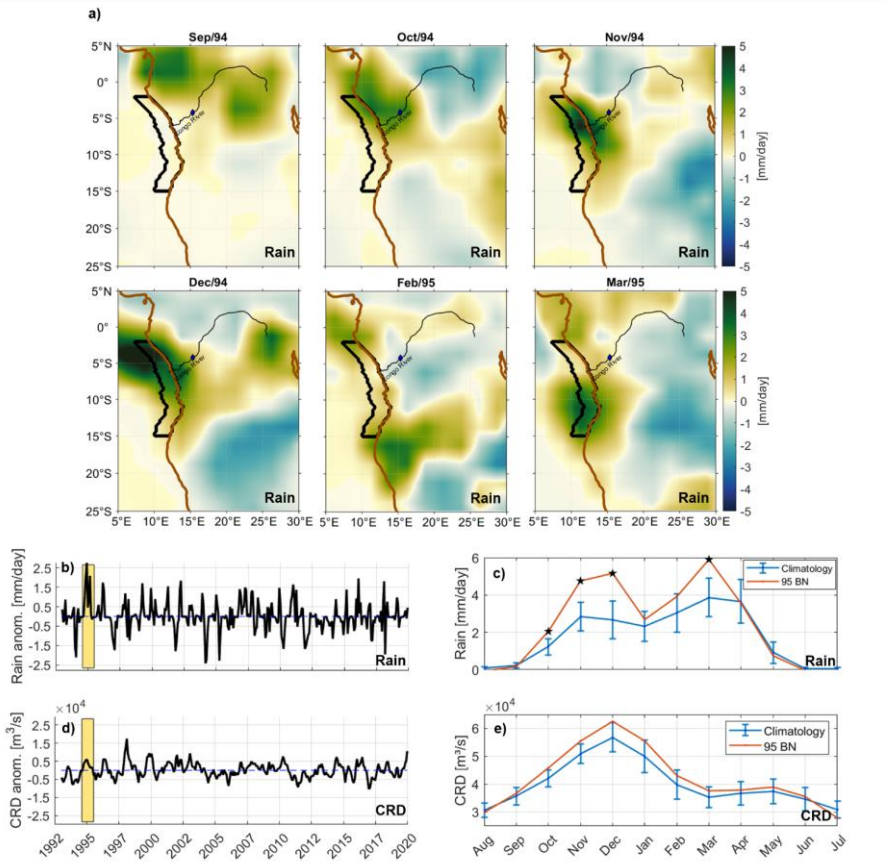
(Aroucha et al. 2024)



Detrended monthly anomalies from September 1994 to March 1995 for precipitation (a). Black thick contours indicate coastal box 2 region (2°S–15°S, 2° away from coast). Brown contour denotes coastline. Blue diamond represents Congo River Brazzaville station. Detrended monthly anomalies of precipitation averaged for coastal box 2 region (b) and Congo River discharge (d) from 1993 to 2019. Yellow shading indicates the period from August 1994 to July 1995. (c) Precipitation climatology (shown from August to July, in blue) calculated from 1993 to 2019 and monthly values (in red) from August 1994 to July 1995 averaged in the coastal box 2. Panel (e) same as panel (c) but for Congo River discharge. Intervals in Figures (c, e) depict monthly standard deviation. Black stars in panels (c) and (e) indicate significant differences from monthly climatologies of each respective month at a 90% confidence level according to the Student's t test.

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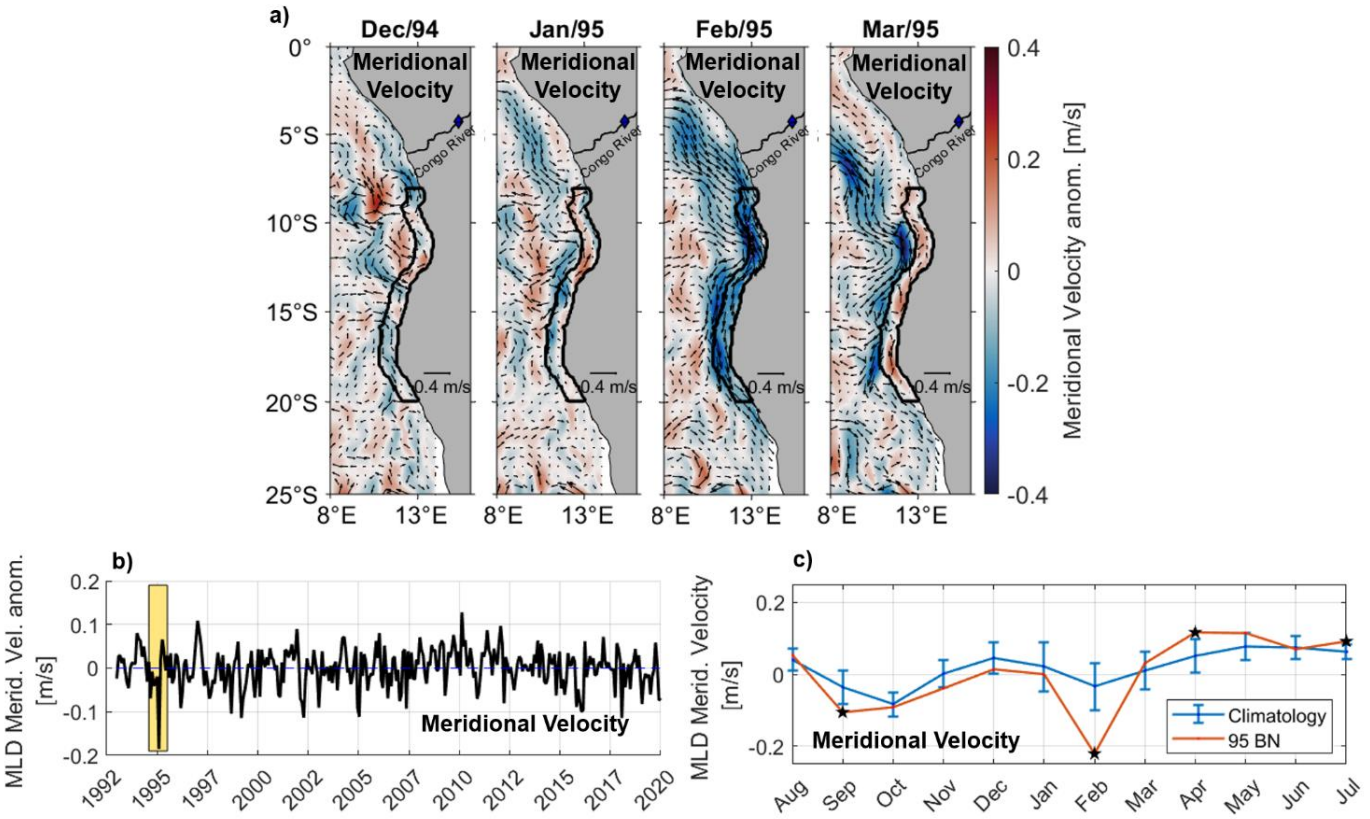
(Aroucha et al. 2024)



Detrended monthly anomalies from December 1994 to March 1995 for mixed layer meridional velocity (a). Arrows indicate the current anomaly direction. Black contours indicate coastal box 1 region. Blue diamond represents Congo River Brazzaville station. Detrended monthly anomalies of mixed layer meridional velocity averaged for coastal box 1 region from 1993 to 2019 (b). Yellow shading indicates the period from August 1994 to July 1995. Mixed layer meridional velocity climatology (shown from August to July, in blue) calculated from 1993 to 2019 and monthly values (in red) from August 1994 to July 1995 averaged in the coastal box 1 (c). Intervals in panel (c) depict monthly standard deviation. Black stars in panel (c) indicate significant differences from monthly climatologies of each respective month at a 90% confidence level according to the Student's t test.

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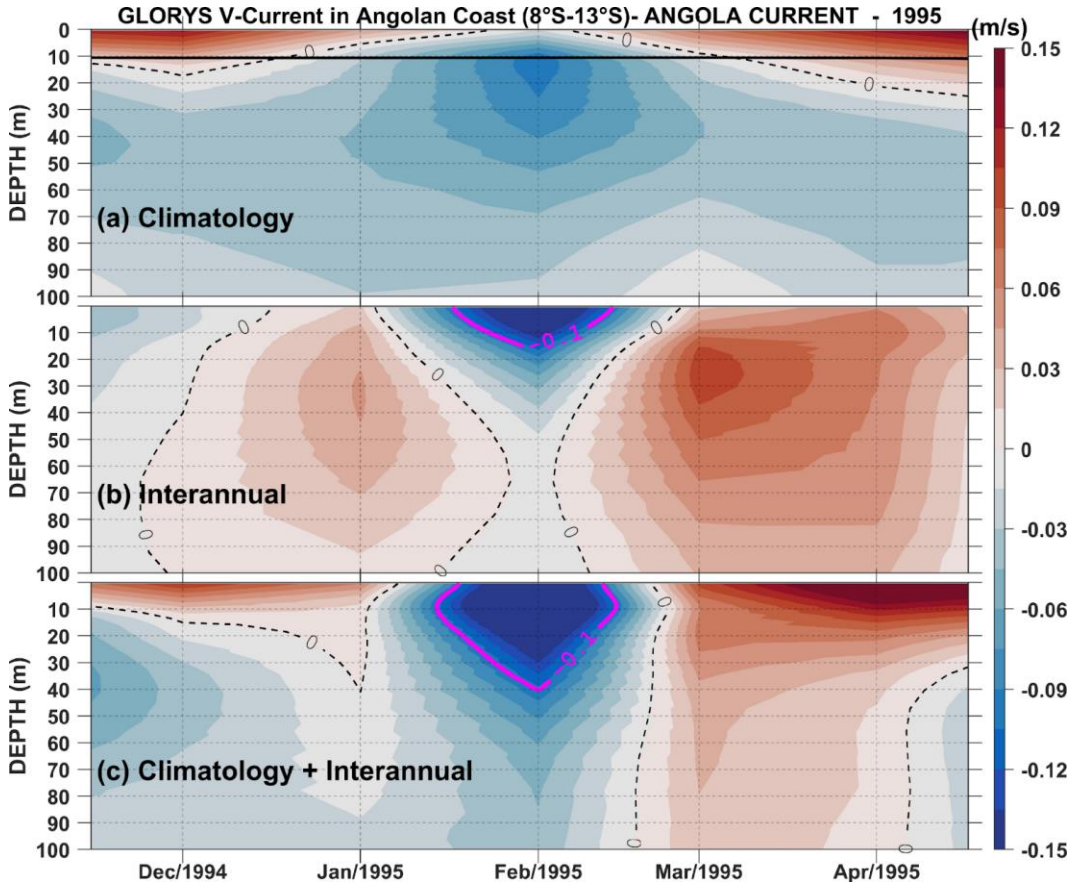
(Aroucha et al. 2024)



Depth-time Hovmöller diagram of climatology (calculated from 1993 to 2019, and shown between November and April) (a), monthly detrended anomalies (b), and absolute values (c) of coastal Angolan meridional current (v) averaged from 8°S to 13°S, 1° away from the coast (b, c) are shown from November 1994 to April 1995. The black line represents the density ocean mixed layer thickness obtained directly from Global Mercator Ocean Reanalysis product reanalysis, defined by sigma theta, and also averaged for the same area. Magenta contour depicts −0.1 m/s isoline.

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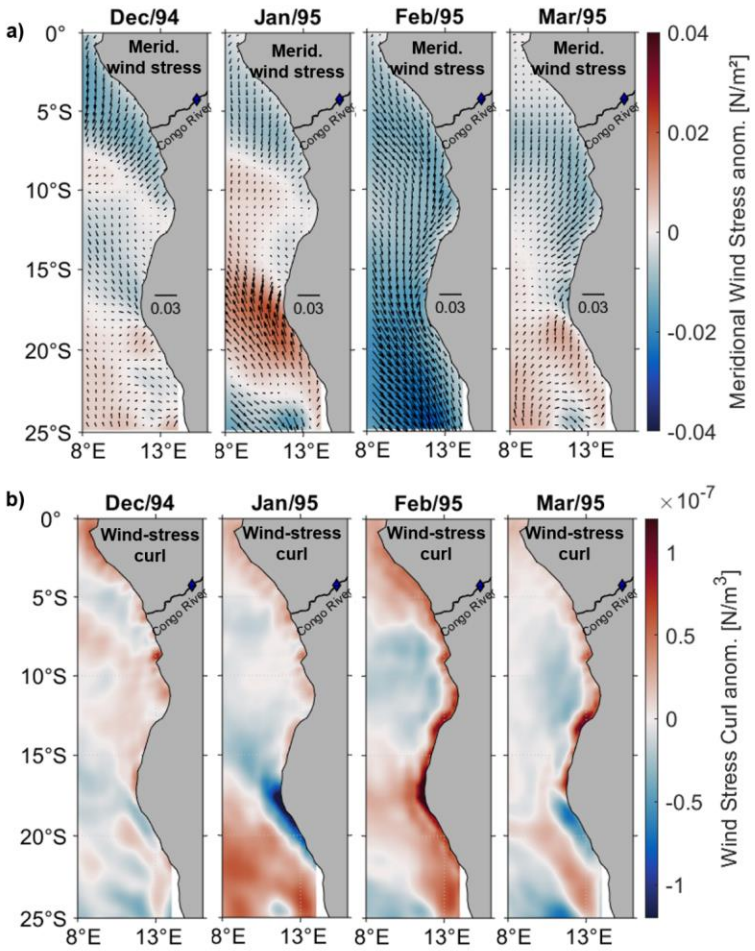
(Aroucha et al. 2024)



Detrended monthly meridional wind-stress anomalies (a) and wind-stress curl anomalies from December 1994 to March 1995 (b). Arrows indicate the direction of the wind stress anomaly. Blue diamond represents Congo River Brazzaville station. Positive values in panel (b) indicate weakening of the wind stress curl.

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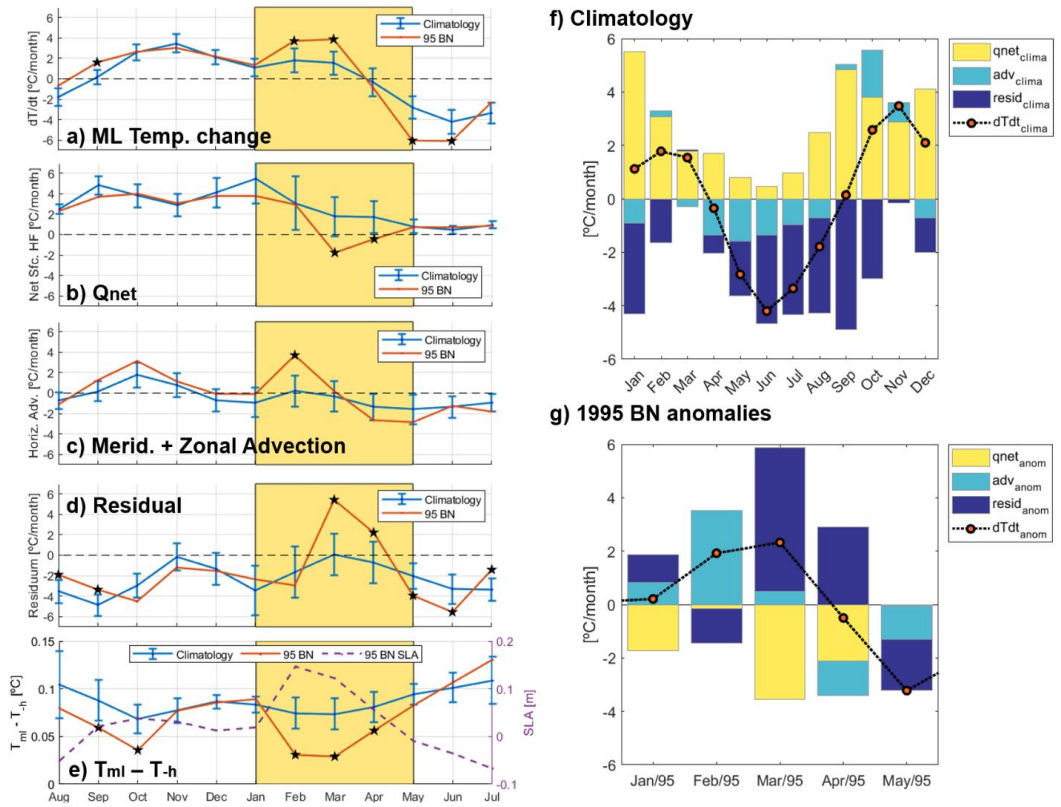
(Aroucha et al. 2024)

$$MLD\text{: } depth\ where\ \sigma_\Theta = \sigma_{rfd} + \Delta\sigma_\Theta$$

$$\Delta\sigma_\Theta = \sigma_\Theta(T_{rfd} - 0.2°C, S_{rfd}, P_0) - \sigma_\Theta(T_{rfd}, S_{rfd}, P_0)$$

$$\partial T/\partial t = -\boldsymbol{v}.\nabla T + qnet/\rho c_p h + \text{residual}$$

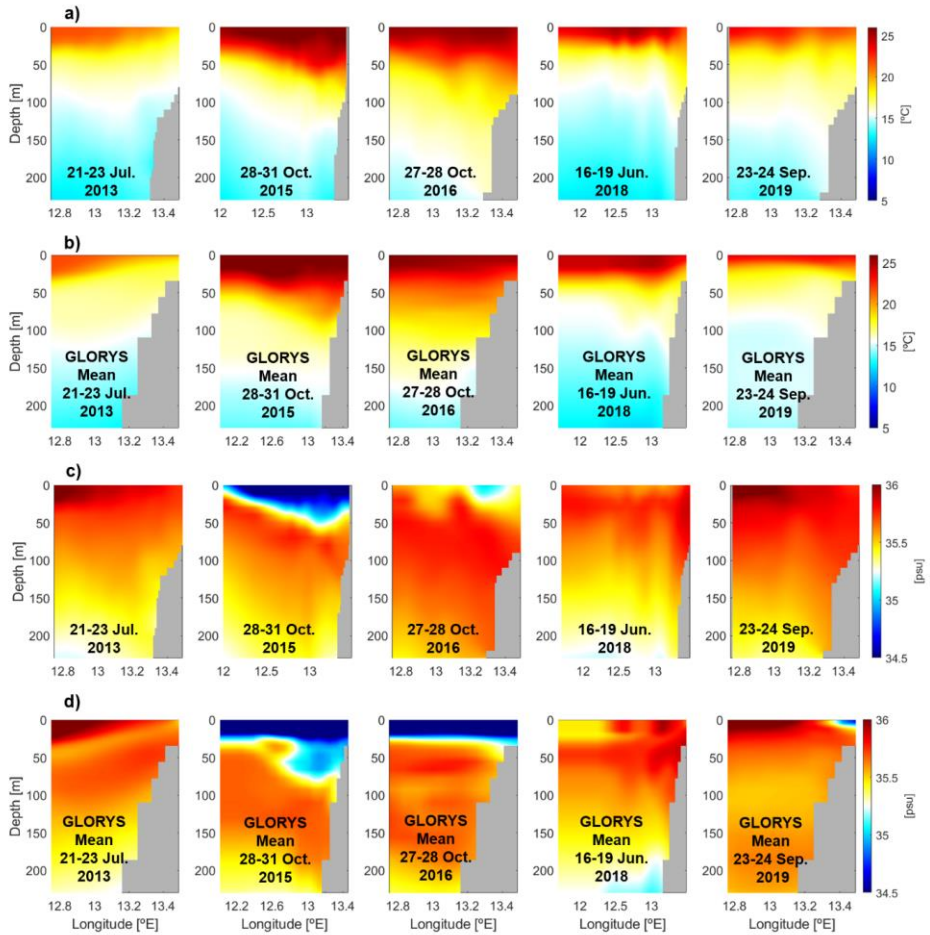
Average for coastal box 1 (8ºS – 20ºS, 1º off the coast)



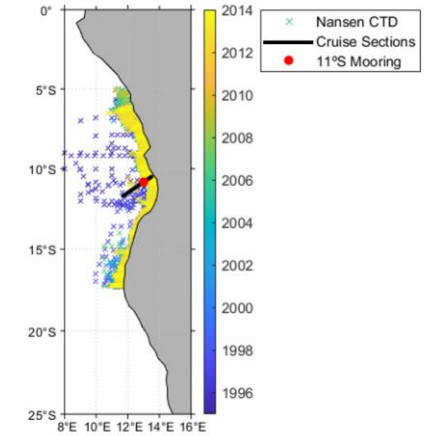
Monthly climatology (blue) of the terms from mixed layer heat budget equation averaged for coastal box 1 from 1993 to 2019 depicted from August to July for (a) temperature tendency; (b) net surface heat flux; (c) horizontal advection; (d) residual; (e) temperature gradient (i.e., difference between ML temperature and temperature at the base of ML) and Sea Level Anomaly (SLA) from GLORYS12 data set (purple dashed line). Intervals indicate monthly standard deviation. (a–e) In red are monthly values from August 1994 to July 1995 of the parameters mentioned above, respectively. (f) Climatological contribution of each calculated term for coastal box 1 mixed layer temperature between 1993 and 2019. (g) Detrended monthly anomalies of the terms from mixed layer heat budget equation averaged for coastal box 1 from November 1994 to May 1995 coastal box. Black stars in panels (a–e) indicate significant differences from monthly climatologies of each respective month at a 90% confidence level according to the Student's t test. Yellow shading in panels (a–e) indicates the period from January to May 1995.

Supp. Material

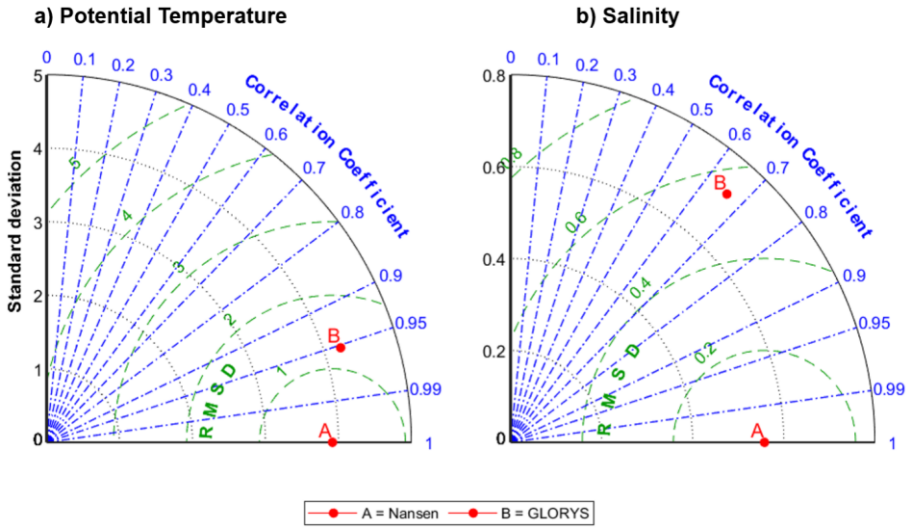
(Aroucha et al. 2024)



CTD sections from the 5 different cruises depicting temperature (a) and salinity (c) profiles, with their corresponding sections in interpolated GLORYS dataset for temperature (b) and salinity (d). GLORYS sections are taken as the average of the daily fields that match cruises sections dates.



Location of CTD profiles, Cruises Sections, and 11ºS mooring.



Taylor Diagram comparing reference as Nansen profiles (A) with GLORYS interpolated profiles (B) for Temperature (a) and Salinity (b) from 1995-2014.

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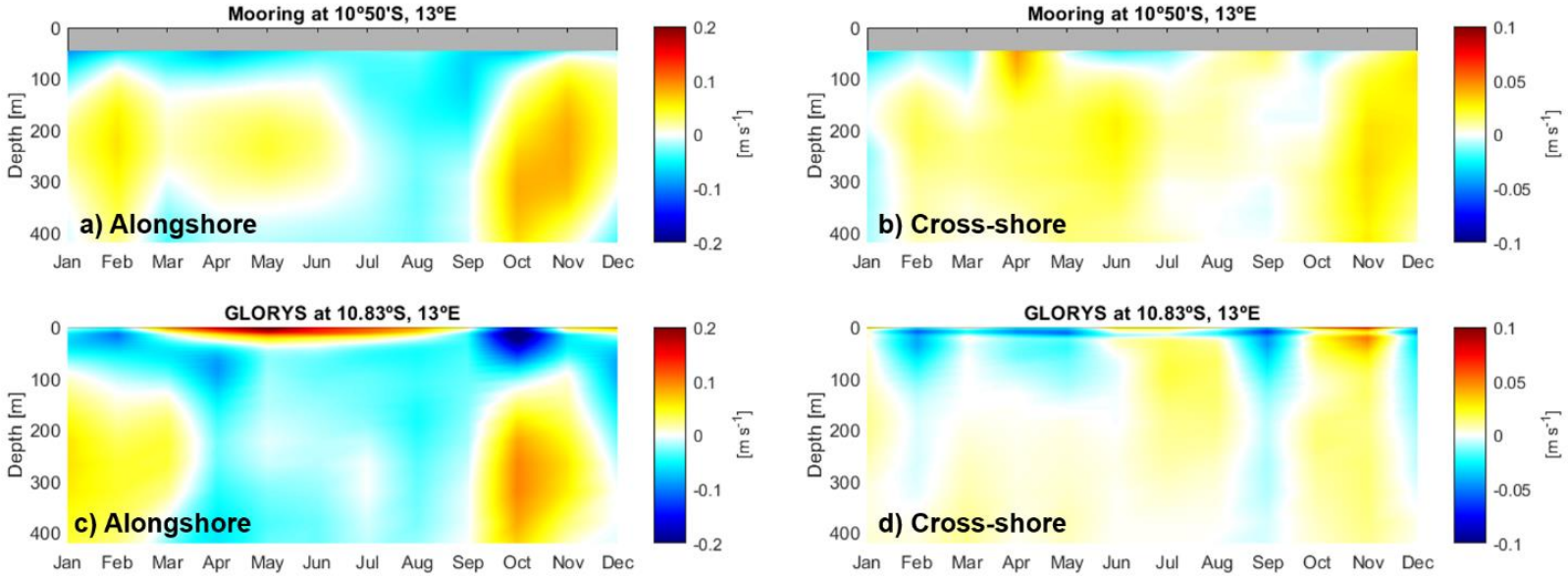
(Aroucha et al. 2024)



Alongshore (a, c) and Cross-shore (b, d) velocity climatology (rotated by -34º with respect to true north) recorded by the moored ADCP located at 10º50'S, 13º00'E (a, b) and the corresponding climatology taken from GLORYS dataset (c, d) at nearest grid position from mooring location and -34º rotation. Both climatologies were calculated over the period 2013 – 2019.

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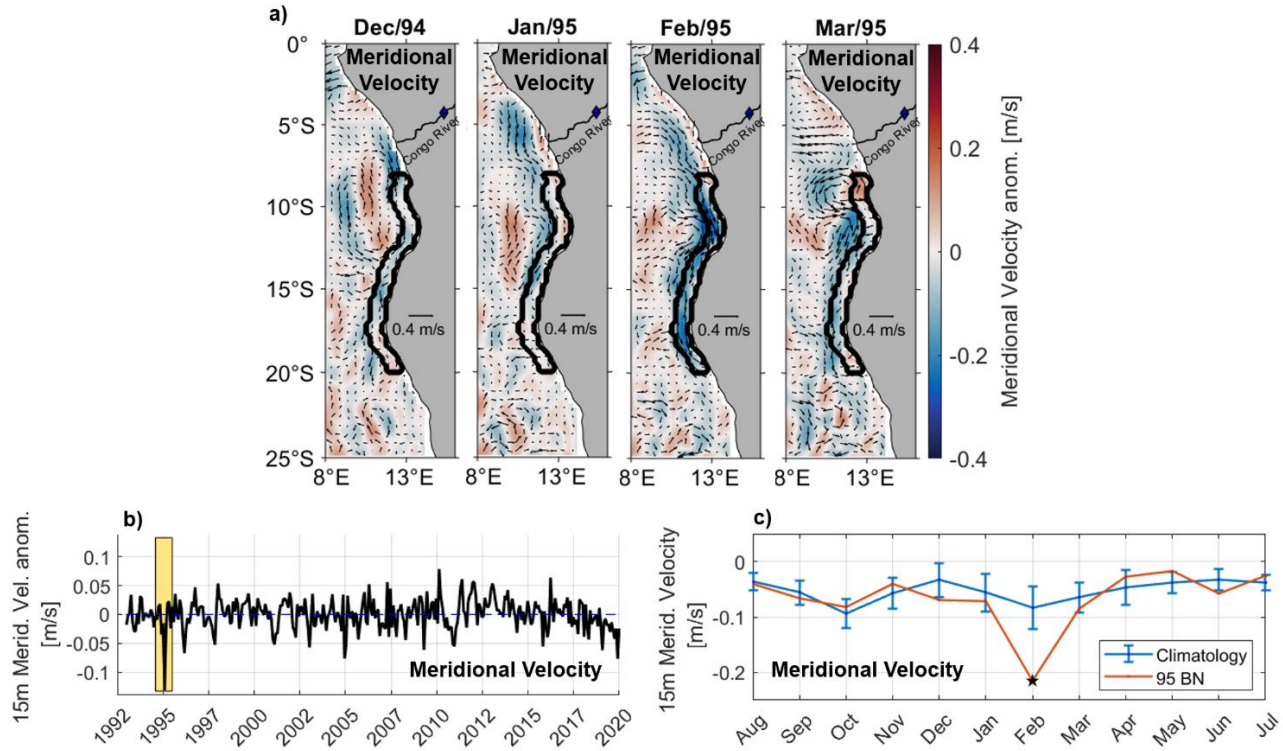
(Aroucha et al. 2024)



Detrended monthly anomalies from December 1994 to March 1995 for meridional velocity (a). Arrows indicate the current anomaly direction. Black contours indicate coastal box 1 region. Blue diamond represents Congo River Brazzaville station. Detrended monthly anomalies of meridional velocity averaged for coastal box 1 region from 1993-2019 (b). Yellow shading indicates the period from August 1994 to July 1995. Meridional velocity climatology (shown from August to July, in blue) calculated from 1993-2019 and monthly values (in red) from August 1994 to July 1995 averaged in the coastal box 1 (c). Intervals in Fig. (c) depict monthly standard deviation. Black stars in (c) indicate significant differences from monthly climatologies of each respective month at a 90% confidence level according to the Student's t test.

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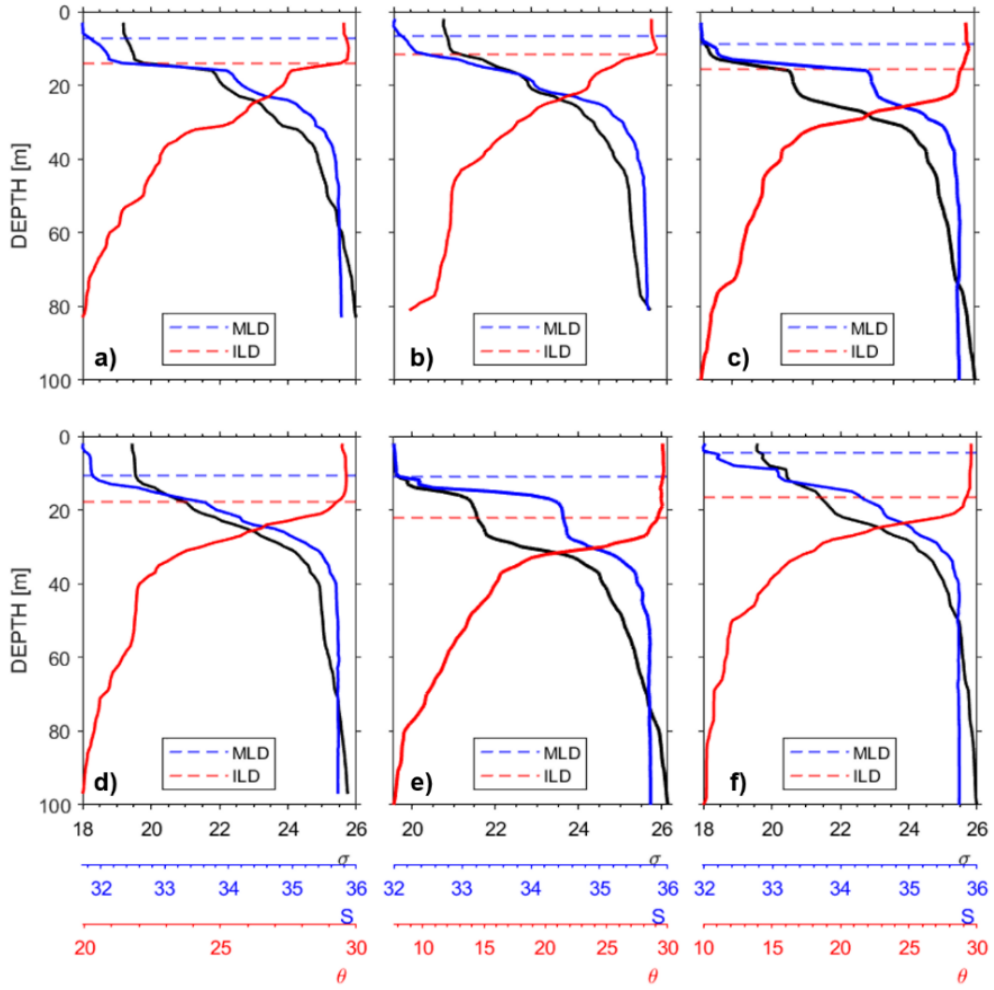

CTD profiles from Nansen Programme (a) on 16th March 1995 at 10.74ºS and 13.5ºE; (b) on 25th March 1995 at 11.48ºS, 13.51ºE; (c) on 25th March 1995 at 10.99ºS, 13.38ºE. (d-f) on 27th March 1995 at (d) 10.76ºS and 13.2ºE; (e) at 10.70ºS, 13.41ºE; (f) at 10.73ºS, 13.31ºE. Red, blue, and black solid lines in (b, c) represent potential temperature (θ), salinity (S), and density (σ) profiles, respectively. MLD = Mixed Layer Depth, ILD = Isothermal Layer Depth.

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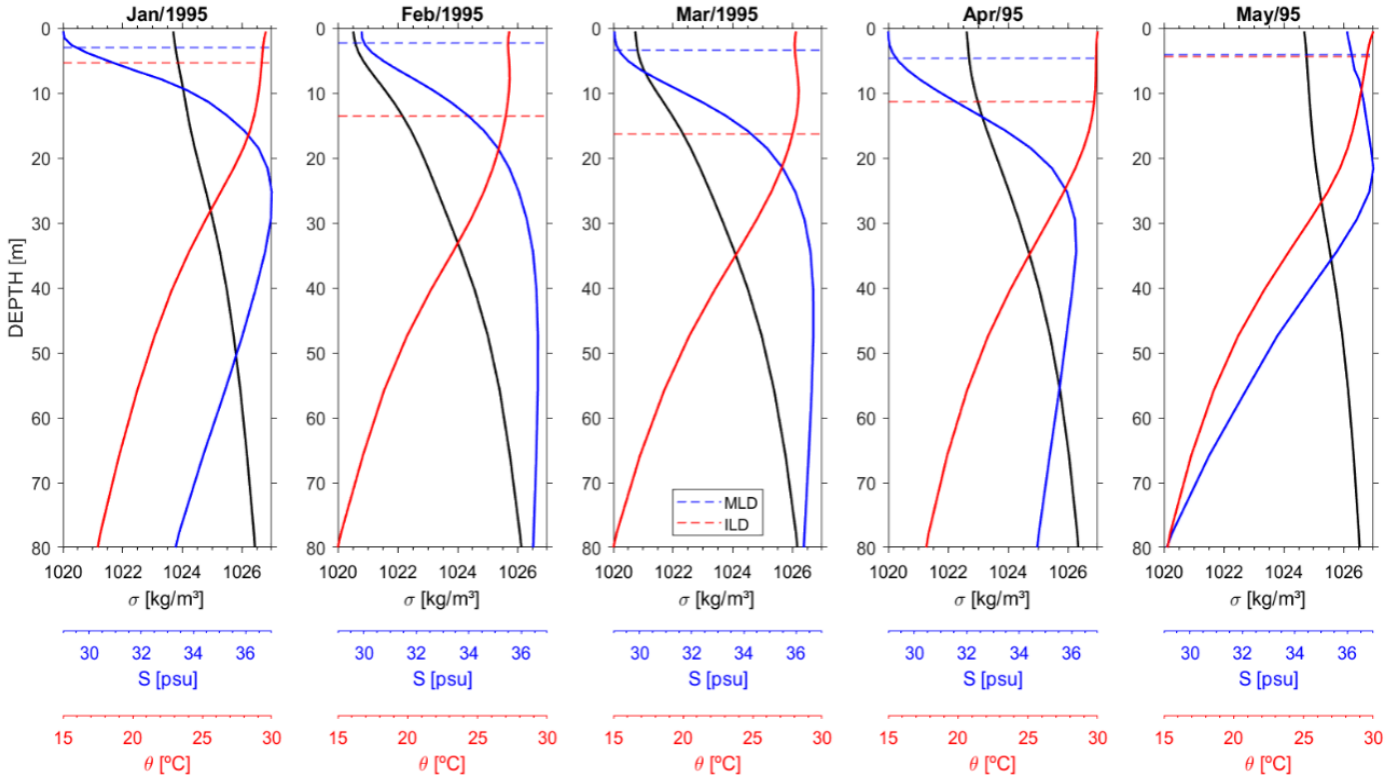
Coastal box averaged profiles



Monthly means of the temperature (red), salinity (blue), and density (black) profiles averaged for coastal box 1 region (8ºS – 20ºS, 1º away from coast) from the onset until the demise of the 1995 Benguela Niño. Data from GLORYS reanalysis.

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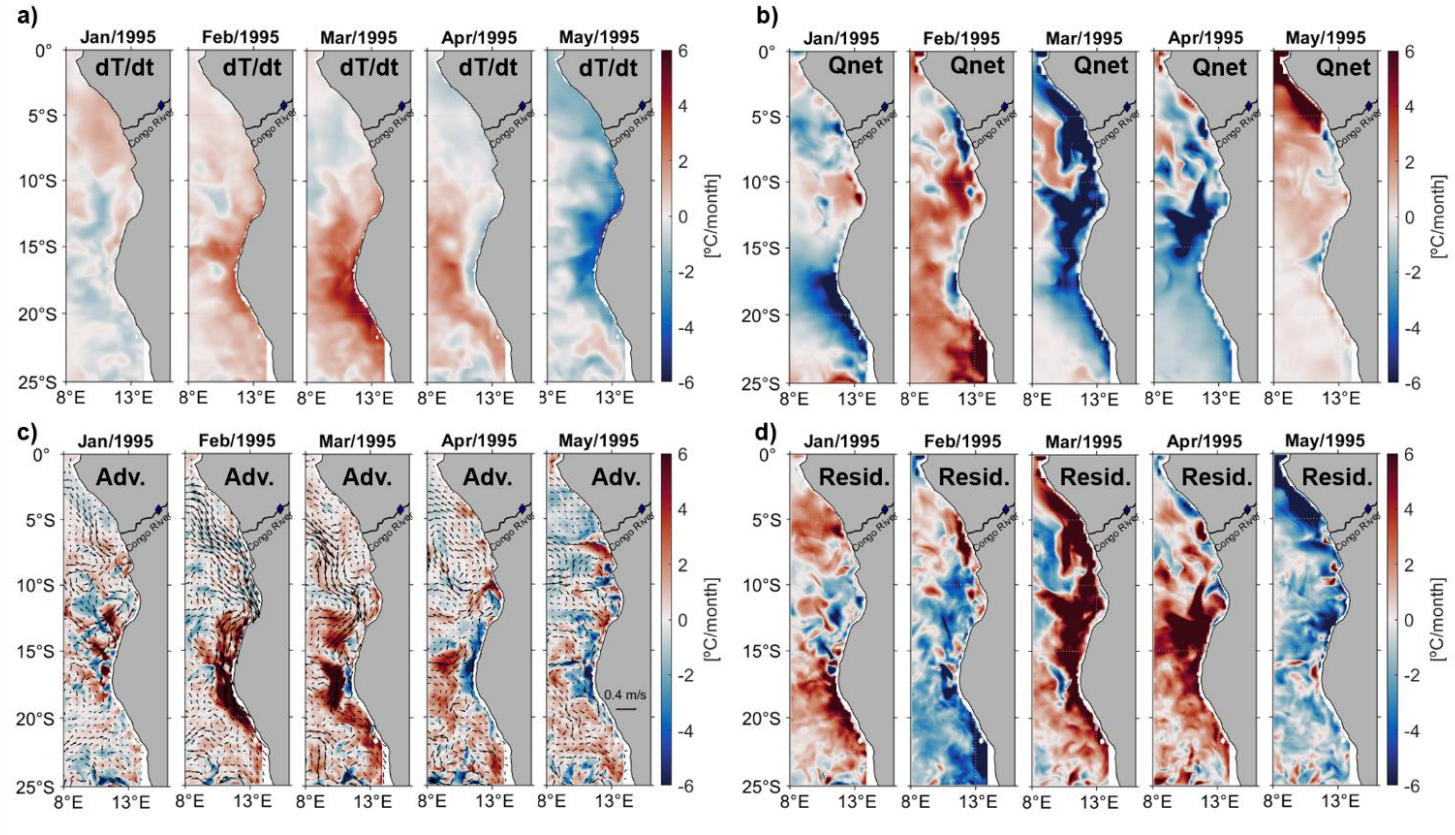
(Aroucha et al. 2024)

$$MLD\text{: } depth\ where\ \sigma_\Theta = \sigma_{rfd} + \Delta\sigma_\Theta$$
$$\Delta\sigma_\Theta = \sigma_\Theta(T_{rfd} - 0.2°C, S_{rfd}, P_0) - \sigma_\Theta(T_{rfd}, S_{rfd}, P_0)$$

$$\partial T/\partial t = -\boldsymbol{v}.\nabla T + qnet/\rho c_p h + \text{residual}$$



Detrended monthly anomalies from January to May 1995 for mixed layer heat budget terms. (a) temperature tendency, (b) net surface heat flux, (c) horizontal advection, (d) residual. Arrows in (c) indicate mixed layer currents anomaly. Blue diamond represents Congo River Brazzaville station. Anomalies are based on GLORYS12 and ERA5 datasets and calculated over the period 1993 – 2019.

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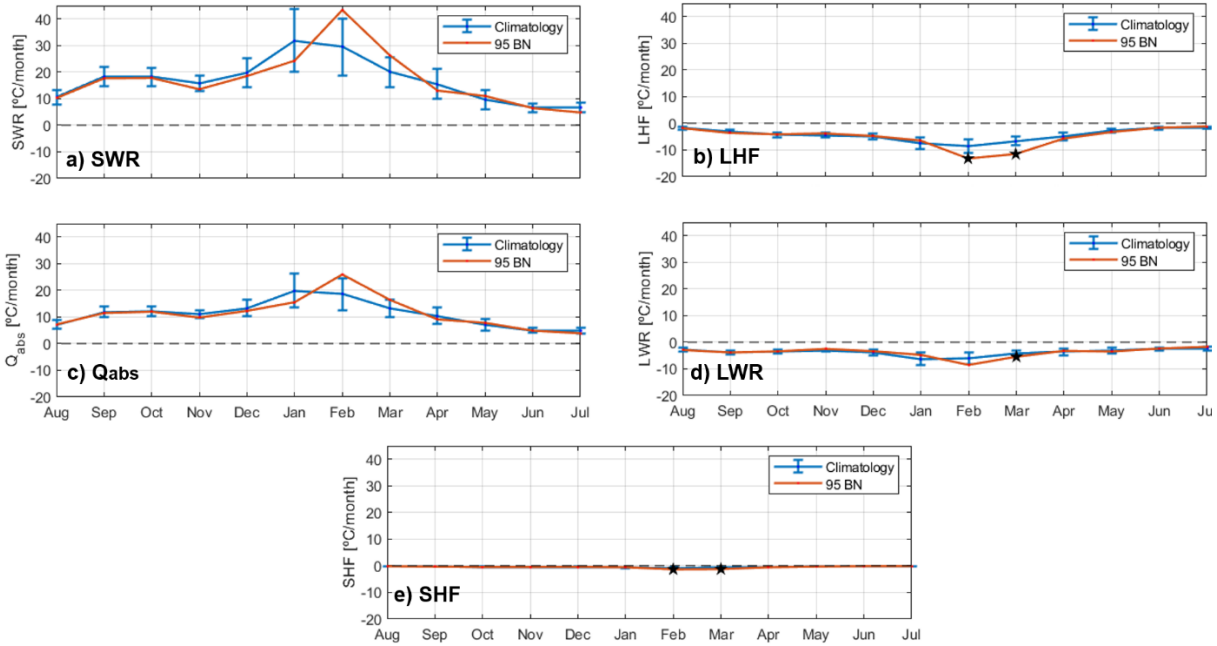
(Aroucha et al. 2024)

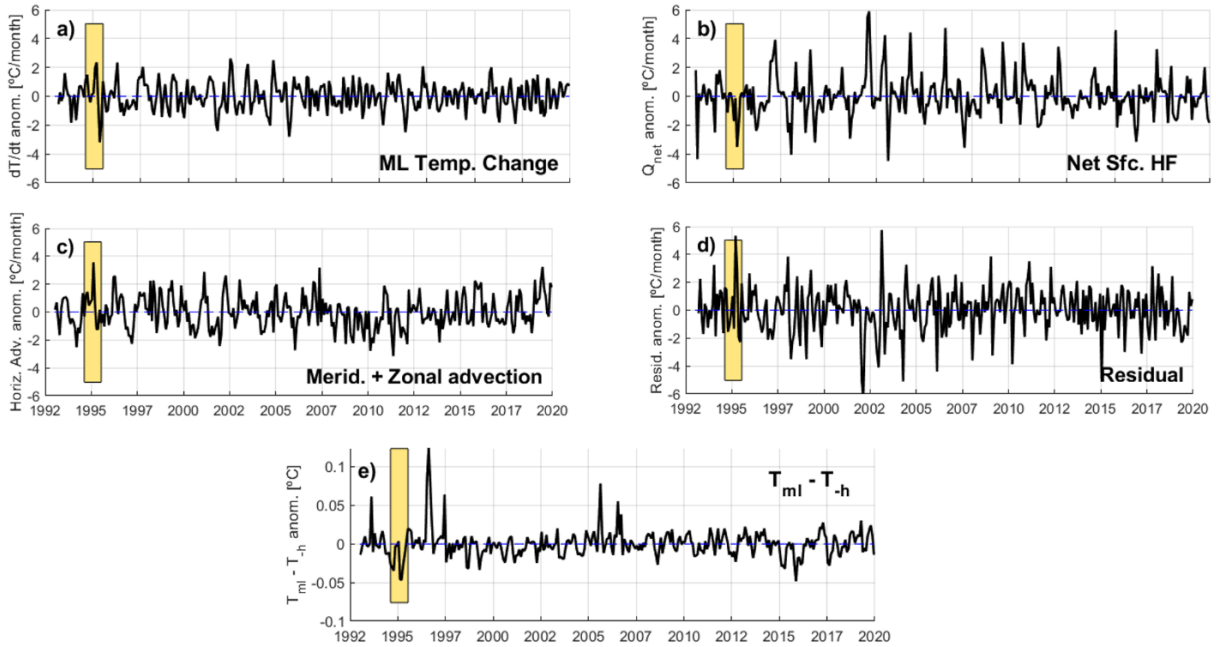
$$\partial T/\partial t = -\boldsymbol{v}.\nabla T + qnet/\rho c_p h + \text{residual}$$

$$qabs = SWR\,(1 - 0.47e\,\text{^}{-h}/15)$$

qnet = qabs + LHF + LWR + SHF



Monthly climatology (blue) of the terms from mixed layer heat budget equation averaged for coastal box 1 region (8ºS – 20ºS, 1º away from coast) from 1993-2019 depicted from August to July for a) Shortwave Radiation (SWR) b) Latent Heat Flux (LHF); c) SWR absorbed by the mixed layer (Qabs); d) Longwave Radiation (LWR); e) Sensible Heat Flux (SHF). Intervals indicate monthly standard deviation. a-e) In red are monthly values from August 1994 to July 1995 of the parameters mentioned above, respectively. Black stars indicate significant differences from monthly climatologies of each respective month at a 90% confidence level according to the Student's t test.



Detrended monthly anomalies (a - d) of the mixed layer heat budget equation terms averaged for coastal box 1 region (8ºS – 20ºS, 1º away from coast). Same for (e) but for mixed layer temperature vertical gradient. Anomalies are based on GLORYS12 and ERA5 datasets and calculated over the period 1993 – 2019.