National Oceanography Centre

SOLSTICE

Marine Physics and Ocean Climate
Satellite Oceanography

Interannual monsoon wind variability over the south tropical Indian Ocean drives East African small pelagic fisheries

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1. Context & Questions

- In coastal East Africa (Tanzania and Kenya, **Fig. 1a**) lives of millions of people are highly dependent on living marine resources for economic stability and food security.

- The small pelagic fisheries represent a pillar for food security and a main source of income and livelihood support in these least developed countries (*Taylor et al.,* 2019) of the **W**estern **I**ndian **O**cean (**WIO**).

- What are the key large-scale environmental drivers of the small pelagic fisheries in coastal East Africa**?**

- Specifically, how does the monsoonal variability, known to dominate the ocean dynamics of the area (*Schott et al.,* 2009, **Fig. 1b**) affects the productivity of East African waters ?

- Is it via upwelling ? mixing? advection by the surface currents?

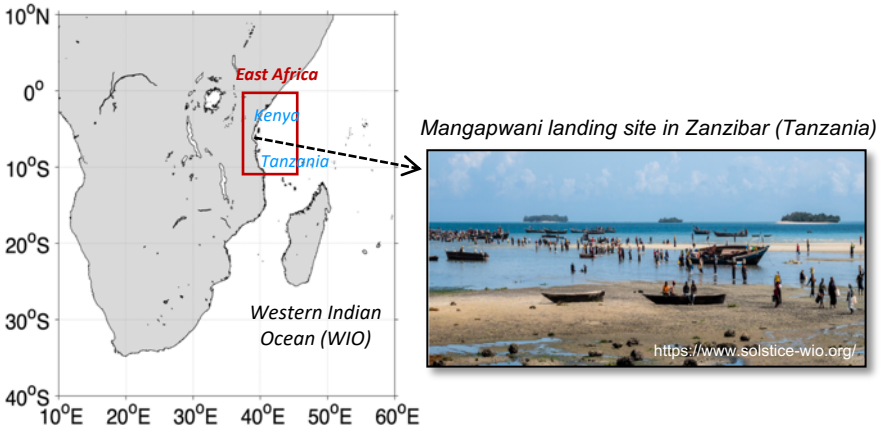

Fig 1a. (left) *Study area.* ***(right)*** *Example of a landing site in Tanzania (East Africa).*

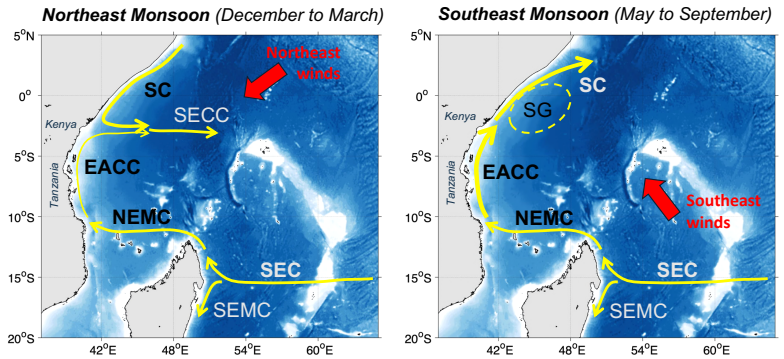

Fig 1b. *Schematic of Monsoonal surface currents and winds over the WIO. Main surface features from left to right:* ***SC****: Somali Current,* ***EACC****: East African Coastal Current,* ***NEMC****: North East Madagascar Current,* ***SEMC****: South Equatorial Counter Current,* ***SEC****: South Equatorial Current.*

2. Methods

- Satellite and field observations are used together with ocean modelling.

Remote sensing

+

Field data

+

Modelling

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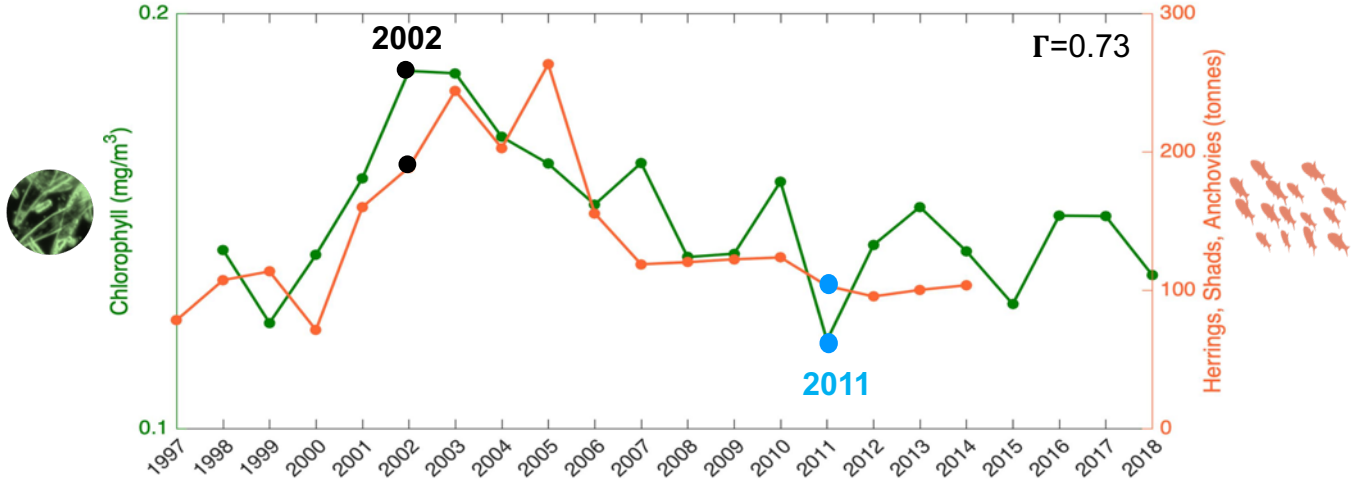
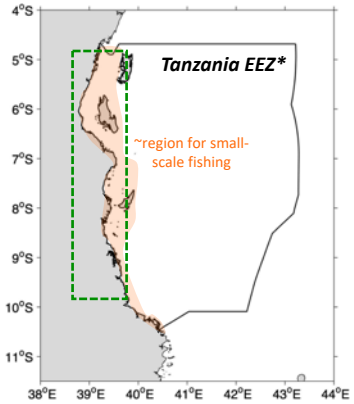
3. Results

- The annual variations in phytoplankton biomass (Chlorophyll-a, Chl-a) and fisheries yield are strongly associated **(Fig. 2)**. Two extremes are revealed : 2002 and 2011 as years of extreme peaks and drops in both Chl-a and catches, respectively.





*EEZ: Exclusive Economic Zone

Fig 2. (left) *Timeseries of Chl-a and small pelagic fisheries pure catches (landings) over Tanzanian waters from 1998 to 2018 and 1997 to 2018 respectively. The correlation coefficient between both variables is equal to 0.73 at 95% confidence level.* ***(right)*** *Approximate region for small-scale fishing within the Tanzanian EEZ.*

- There are 2 annual maxima associated with 2 peaks of monsoonal periods, with higher *Chl-a* during the Southeast monsoon than the Northeast monsoon. The Southeast monsoon *Chl-a* maxima (enhanced phytoplankton biomass) are most of the times greater than that of the Northeast monsoon (**Fig. 3**).

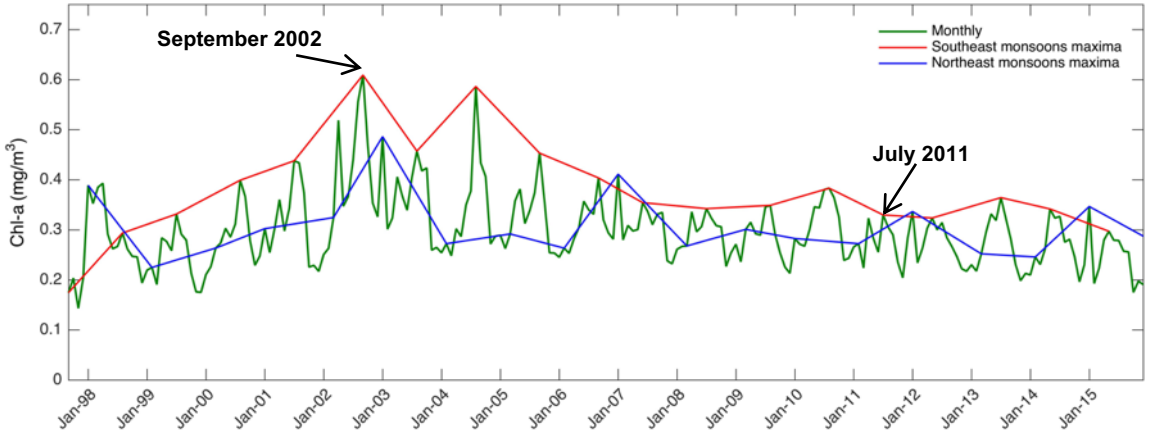


Fig 3. *Monthly timeseries of Chl-a from 1998 to 2018 over the coastal waters of Tanzania as indicated by the green box in Fig2. The Southeast monsoons maxima are highlighted in red and those of the Northeast monsoons in blue.*

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3. Results

- While enhanced phytoplankton biomass (*Chl-a*)during the Northeast monsoon is triggered by wind-driven upwelling **(Fig 4a, top)**, during the Southeast monsoon, it is driven by 2 current induced mechanisms (**Fig 4a, bottom**): coastal "dynamic uplift" upwelling (**Fig 4b**); and westward advection of nutrients (**Fig 4c**).

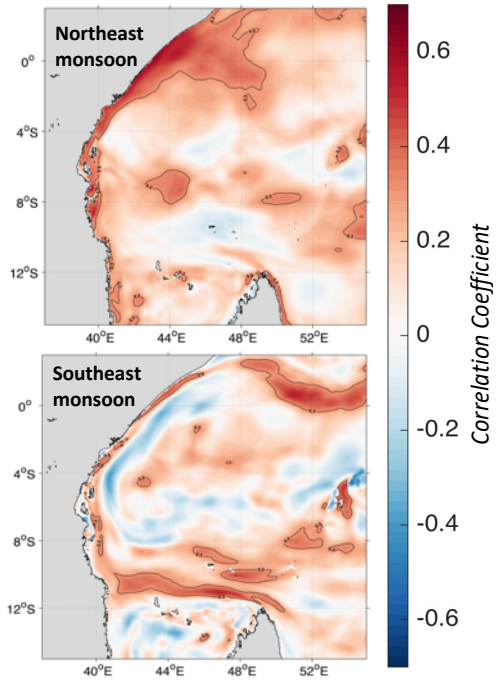

Fig 4a. (top) *Correlations between Chl-a and Wind Speed anomalies during the Northeast Monsoons of 20 years show a strong Chl-a response to the Northeast winds.* ***(bottom)*** *Correlations between Chl-a and Current Speed anomalies during the Southeast Monsoons of 20 years show a strong response along the path of the EACC and NEMC currents.*

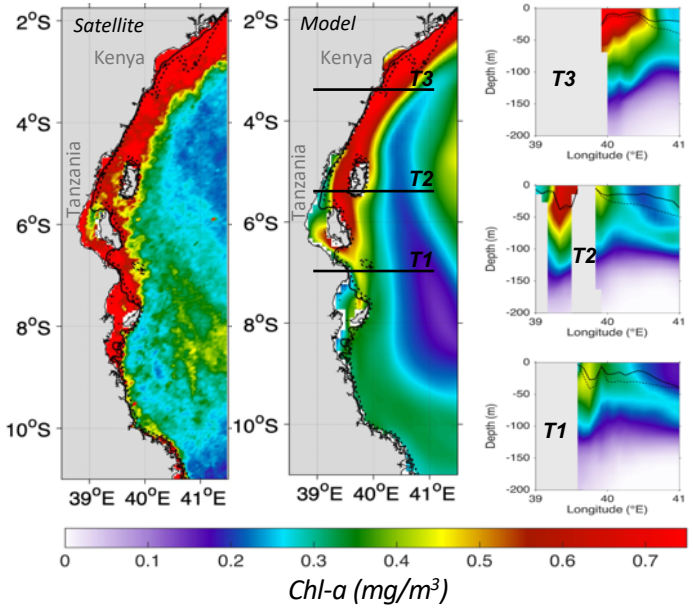

Fig 4b. *An example of dynamic uplift upwelling manifestation along the Tanzanian and Kenyan coast during the Southeast monsoon of 2002. Its surface signature is shown in the* ***(left)*** *satellite and* ***(middle)*** *modelled surface Chl-a.* ***(right)*** *Its subsurface signature can be seen in the Chl-a subsection crossing the East African coast. The Mixed layer depth in 2002 (solid line) is shallower than the climatology (dashed line). Note that Coherent Temperature and nutrients manifestation with the increased Chl-a are also detected (unshown) and that this upwelling occurs every Southeast monsoon with an intensity that varies interannually.*

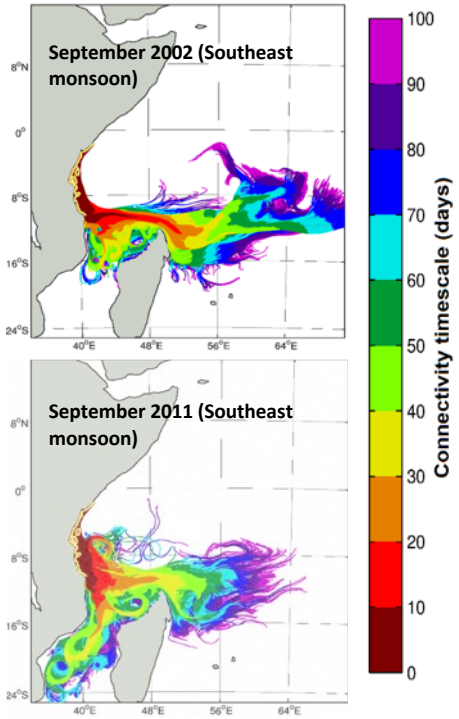

Fig 4c. *Trajectories of virtual particles backtracked from coastal East Africa (light yellow dots) during Southeast monsoons of* ***(top)*** *2002 and* ***(bottom)*** *2011, back to their upstream sources in the surface Indian Ocean up to 100 days prior. Note that in 2002 the particles along the NEMC path have reached faster the East African coast compared to 2011.*

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3. Results

- Interannually, an extreme increase (decrease) in chlorophyll concentrations is induced by strengthened (weakened) surface currents, which occur during anomalously "strong" ("weak") Southeast monsoon years (**Fig 4a, bottom**).

- The strength of surface currents (EACC and NEMC) controls that of the *Chl-a* during Southeast monsoons. The latter depends on the large-scale change in the wind fields, *Schott & McCreary, 2001*)!

- The Southeast monsoons of 2002 and 2011, which showed extreme *Chl-a* values, have experienced extreme changes in the large-scale winds of the south tropical Indian Ocean (**Fig 5**). In almost mirror like patterns, 2002 had stronger than normal winds (**Fig 5**) leading stronger currents and in turn enhanced nutrients advection and dynamic uplift upwelling (Figs. 2, 3, 4). Vice versa for 2011.

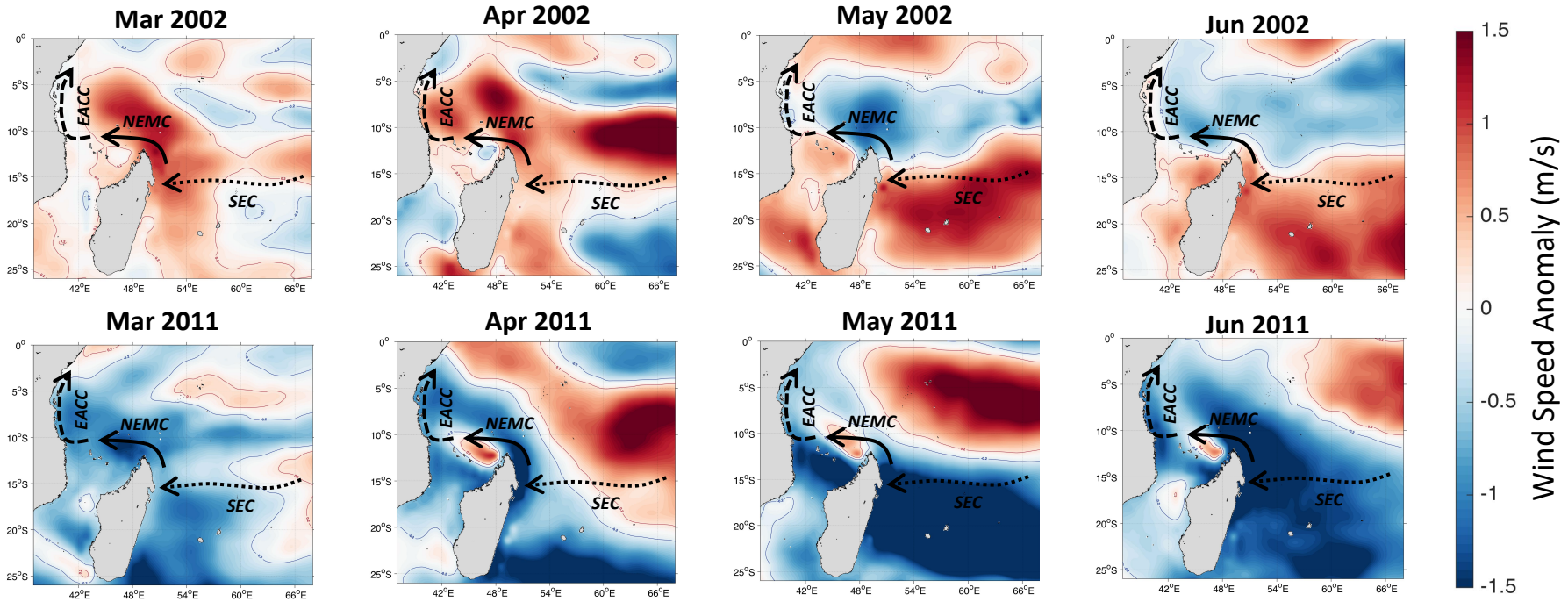

Fig 5. *Wind speed anomalies over the south tropical Indian Ocean WIO from March to June in* ***(top)*** *2002 and* **(bottom)** *2011. Schematics of the* ***EACC****: East African Coastal Current,* ***NEMC****: North East Madagascar Current and* ***SEC****: South Equatorial Current are shown.*

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4. Conclusions

- The Southeast monsoon wind strength over the south tropical Indian Ocean is the main driver of year-to-year variability, for years where the effects of El Niño / La Niña are weak.
- The interannual changes in the monsoon can dominate the biological response along the East African coast and emerge as the main climate variability mode.
- Such changes have important implications on the regional economy as it is highly dependent on fisheries.

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