Ubiquity and seasonality of deep submesoscales in the Southern Ocean revealed by elephant seals

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY | Centre d'Études Biologiques de Chizé

Lia Siegelman[1], Baptiste Picard[2], Christophe Guinet[2]

1. Scripps Institution of Oceanography, UC San Diego 2. Centre d'Etudes Biologiques de Chizé, France

Introduction

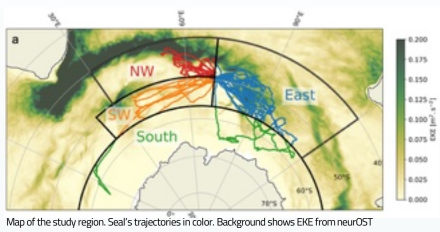
Submesoscale motions are thought to be principally confined within the ocean surface mixed layer.

Here, we challenge this paradigm thanks to our oceanographer friends the Southern Elephant Seals!

Elephant Seal Data

Indian sector of the Southern Ocean

- **7 years**: 2014-2020
- **133, 598 profiles**
- **All seasons**
- median horizontal resolution: **780m**
- Max depth: **999 m**



Map of the study region. Seal's trajectories in color. Background shows EKE from neurOST

Regional and seasonal statistics

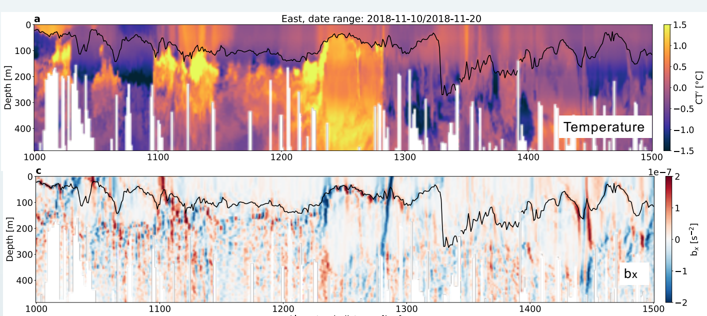
East	SW	NW	South
Years: 2014 2015 2016 2017 2018 2019 2020	Years: 2014 2015 2016 2017 2018 2019 2020	Years: 2014 2016 2017 2018 2019	Years: 2014 2015 2018 2020
# of East profiles: 58105/118121 - 49% of the total profiles	# of SW profiles: 24098/118121 - 20% of the total profiles	# of NW profiles: 18649/118121 - 16% of the total profiles	# of South profiles: 17269/118121 - 15% of the total profiles
djf (summer): 25438/58105 profiles - 44% of the East profiles	djf (summer): 11313/24098 profiles - 47% of the SW profiles	djf (summer): 6869/18649 profiles - 37% of the NW profiles	djf (summer): 1541/17269 profiles - 9% of the South profiles
mam (fall): 4088/58105 profiles - 7% of the East profiles	mam (fall): 3254/24098 profiles - 14% of the SW profiles	son (spring): 11780/18649 profiles - 63% of the NW profiles	mam (fall): 12418/17269 profiles - 72% of the South profiles
jja (winter): 5700/58105 profiles - 10% of the East profiles	son (spring): 9531/24098 profiles - 40% of the SW profiles		jja (winter): 3310/17269 profiles - 19% of the South profiles
son (spring): 22879/58105 profiles - 39% of the East profiles			

Altimetry Data

Novel product: **neurOST** (Martin et al. 2023)

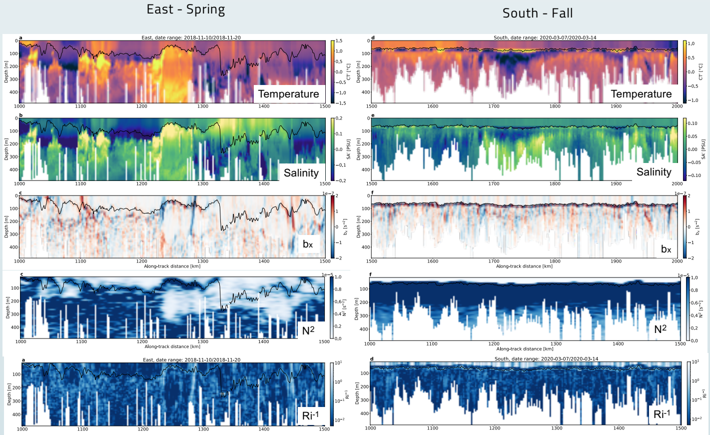
NeurOST Surface Geostrophic Currents analysis product from the University of Washington and JPL are mapped by a neural network trained with sparse Level 3 nadir altimetry observations (CMEMS, E.U. Copernicus Marine Service Information) and the MUR Level 4 gridded sea surface temperature product (PO.DAAC)

Example of vertical sections



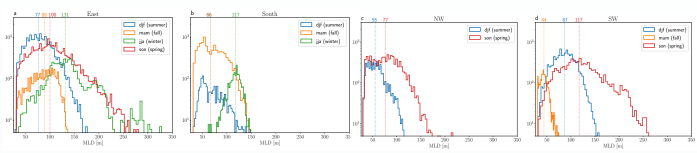
East - Spring

South - Fall



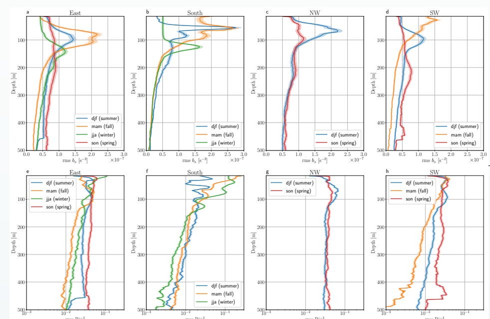
Ubiquity and Seasonality

Mixed Layer Depth Seasonality



- Deeper in winter and spring in all regions
- As deep as +300m

Lateral buoyancy gradients and Balanced inverse Richardson Number



bx

Within the ML
- Intensified in fall

Below the ML
- Intensified in spring
- Weaker in fall

Most intense at the base of the ML

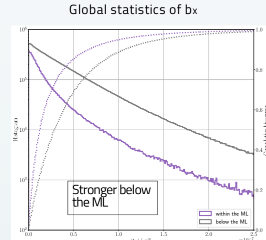
Ri^{-1}

Within the ML
- Unclear

Below the ML
- Intensified in spring
- Weaker in fall/winter

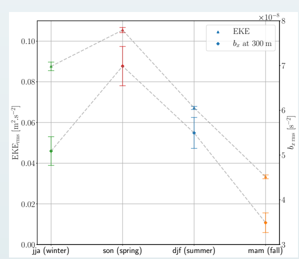
No signal at the base of the ML

Global statistics of bx



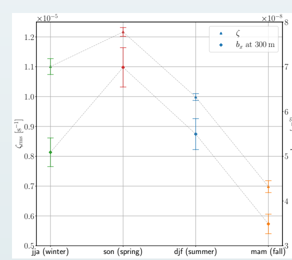
Mesoscale EKE and relative vorticity

Eddy Kinetic Energy



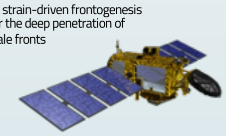
Lateral gradients of buoyancy at 300 m follow the same seasonality as EKE and relative vorticity in the East region

Relative vorticity



Hypothesis: strain-driven frontogenesis accounts for the deep penetration of submesoscale fronts

Deep submesoscales follow the seasonality of surface eddy kinetic energy derived from altimetry, suggesting they are generated by mesoscale eddies



References

Martin, S. A., Manucharyan, G. E., & Klein, P. (2023) Synthesizing sea surface temperature and satellite altimetry observations using deep learning improves the accuracy and resolution of gridded sea surface height anomalies. *Journal of Advances in Modeling Earth Systems*, *15*(5), e2022MS003589.

Siegelman, L., Picard, B., Guinet, C., (*in revision*) Ubiquity and seasonality of deep submesoscales in the Southern Ocean revealed by elephant seals. *Nature Geoscience*

Acknowledgements

We acknowledge support from NASA and CNES. We thank Fabien Roquet for maintaining and operating the MEOP database, as well as all the field participants in IPEV program 109, who have deployed and retrieved the tags mounted on Southern Elephant Seals on the remote Kerguelen Islands throughout the years, and who made this study possible.