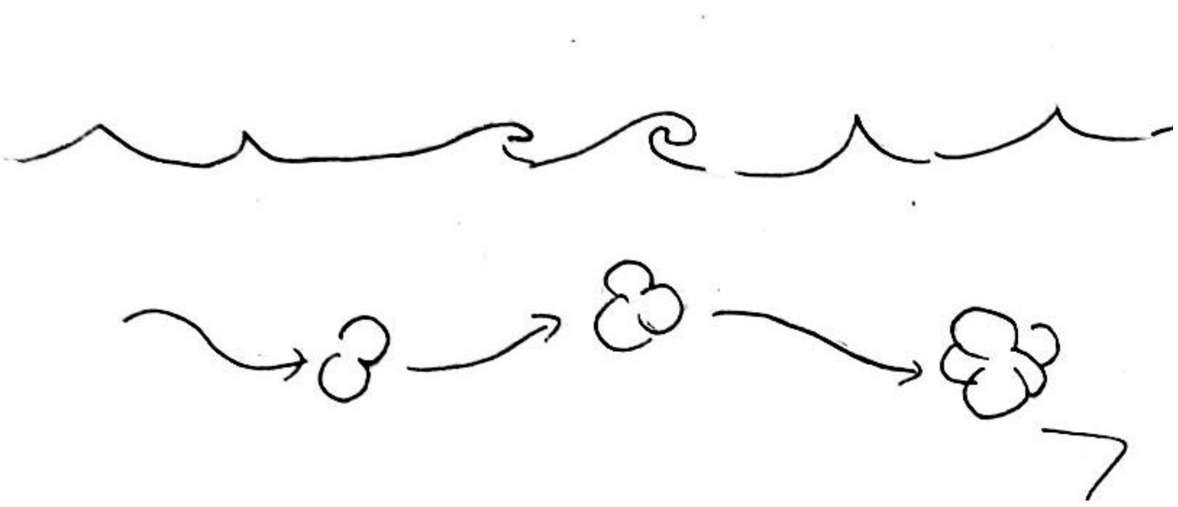
Transport of planktic foraminifera by ocean currents



Investigating ocean currents in the Uruguayan Margin

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Summary slide

Scope of the problem

The shells of planktic foraminifera can be found in sediment cores and are used widely to study oceanic circulation and past oceanic conditions

- Due to transport by ocean currents, shells found in the sediment do not reflect oceanic conditions at the sediment core location.
- We expected that at sites located in regions with strong or shifting currents the effect of transport on foraminifera should be taken into consideration

Approach

The Uruguayan Margin in the Argentine basin was chosen as a case study site. We used a high resolution ocean general circulation model to simulate the pathways of virtual particles resembling planktic foraminifera, through Lagrangain ocean analysis. The ocean water temperatures along the trajectory were used to compute the 'temperature signal' reflected by a particle.

Conclusions

We compared the distribution of modelled temperature signals of advected particles with water temperature distributions locally above a sediment core and found:

The mean of the advected and local temperature distributions are very similar, but there is an offset between the tails of the local and advected temperature distributions.

- The mean temperature of an assemblage in a sediment sample will likely not have been affected much by transportation.
- When measuring single specimen within a sediment sample and aiming to reconstruct e.g. seasonal temperature extremes, transportation SHOULD be taken into account, since these extreme temperature values belong to species transported from locations with water temperatures significantly different from the temperatures occurring above the core site.

Introduction

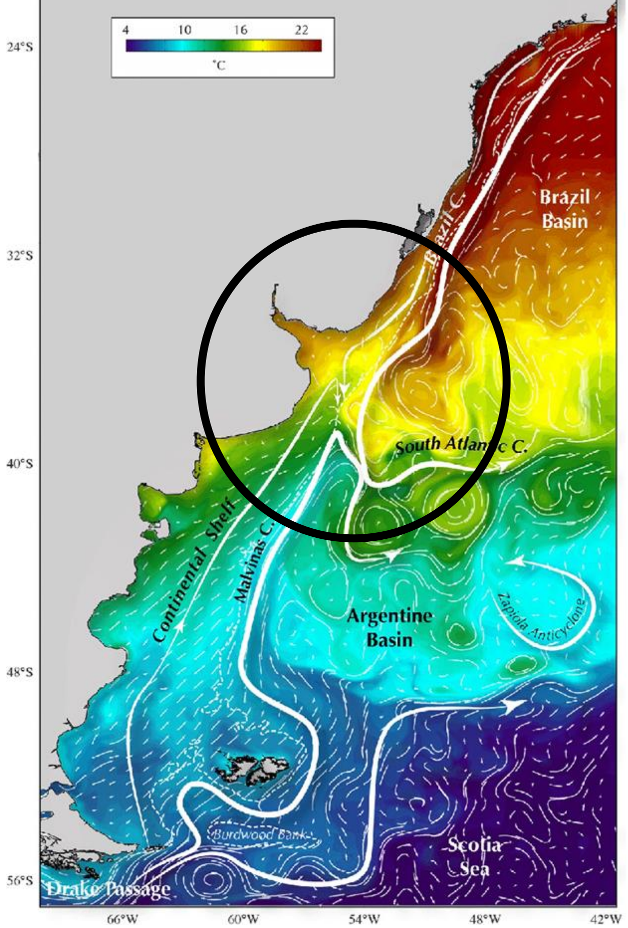
Planktic foraminifera are used widely to study oceanic circulation and past oceanic conditions

- During life they dwell in the surface layer of the ocean and build a calcite shell
- These shells can be found in ocean sediments and are used as a proxy for climatic conditions
  - ➔ However, due to transport by ocean currents, shells found in the sediment do not reflect oceanic conditions at that precise location (Van Sebille et al. 2015)
  - ➔ Expectation: at sites located in regions with strong or shifting currents the effect of transport on the foraminifera should be taken into consideration

One such a location is the Uruguayan Margin in the Argentine basin:

- Warm southward flowing Brazil current meets the northward branch of the Antarctic circumpolar current; the Falkland (Malvinas) Current.
- Generates one of the most energetic regions in the world, the Brazil/Malvinas Confluence (BMC)

Figure obtained from Piola and Matano (2001)

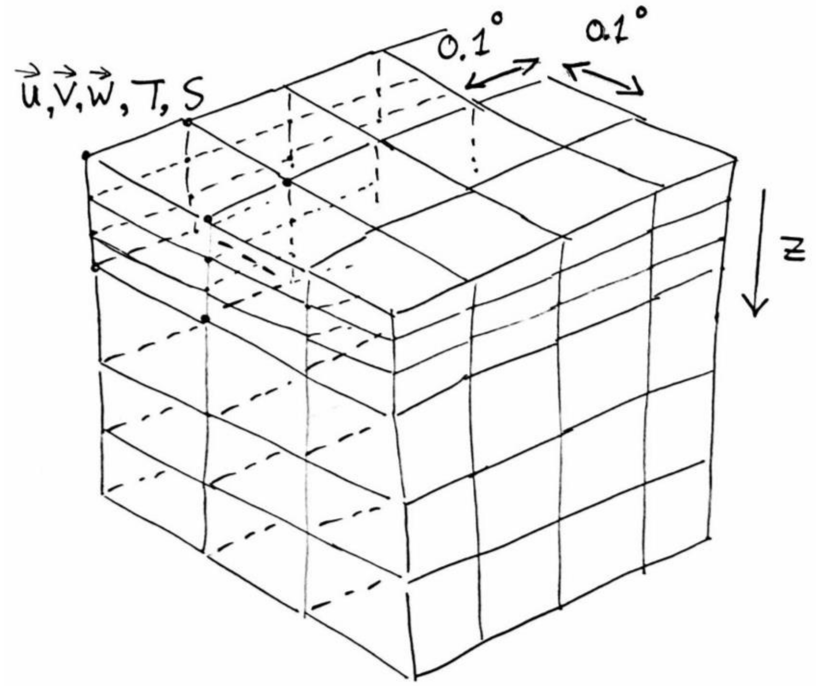


In this presentation we show the results of model simulations, in which we track virtual particles resembling planktic foraminifera. These simulations provided:

- Insights into effects of transport in immediate vicinity of one specific model release location, the 'sediment core site'
  - → Possible origin locations of particles
  - → Temperature signals reflected by particles
- Insight into effects of transport in the wider context of the Uruguayan margin

Methods

- Planktic foraminifera represented by virtual particles
- Advected in a 3D grid (similar approach as Van Sebille et al. (2015))
    - Grid created with data from model simulations of an OGCM (OFES (Sasaki et al. 2008))
    - → High resolution and present-day ocean configuration
    - → Containing local velocities, water temperatures and salinities.
    - → Ocean model data do not only contain large scale currents but also eddying behaviour of the ocean.



Python-based PARCELS code:

- Tracks the location of the virtual particles within our 3D grid
- Foraminiferal life traits added as characteristics:
    - Depth habitat
    - Lifespan
    - Post-mortem sinking speed
- Trajectory computed through Lagrangian ocean analysis:

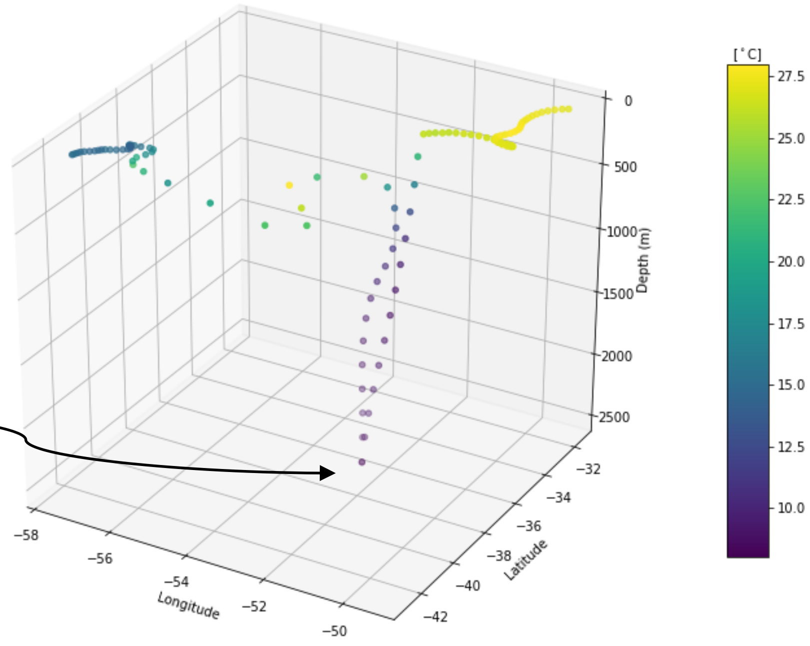
$$X(t + \Delta t) = X(t) + \int_{t}^{t+\Delta t} v(x, \tau) d\tau + Cb\Delta t$$

New position   Old position   3D velocity field   constant sinking

Methods

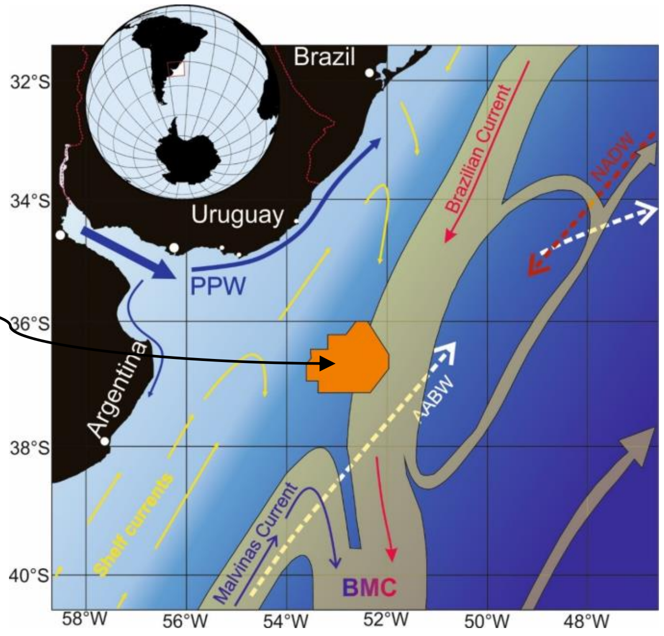
To determine origin of particle it is advected *back in time*:

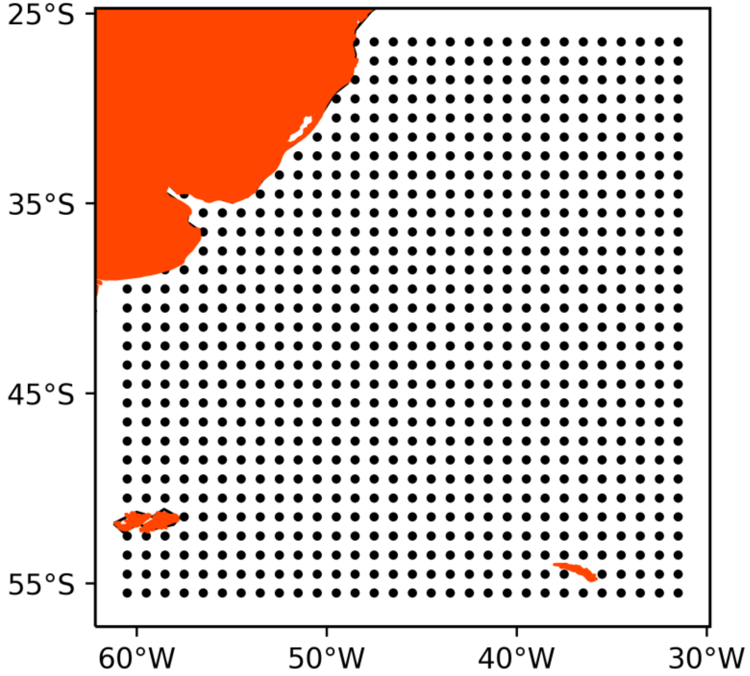
→ simulation starts with releasing particle at bottom of grid
→ It then 'sinks' upward until it reaches its depth habitat
→ From here it stops 'sinking' and starts 'dwelling', transported by the currents for the duration of its lifespan.
→ Final location can be interpreted as location where it started its life.



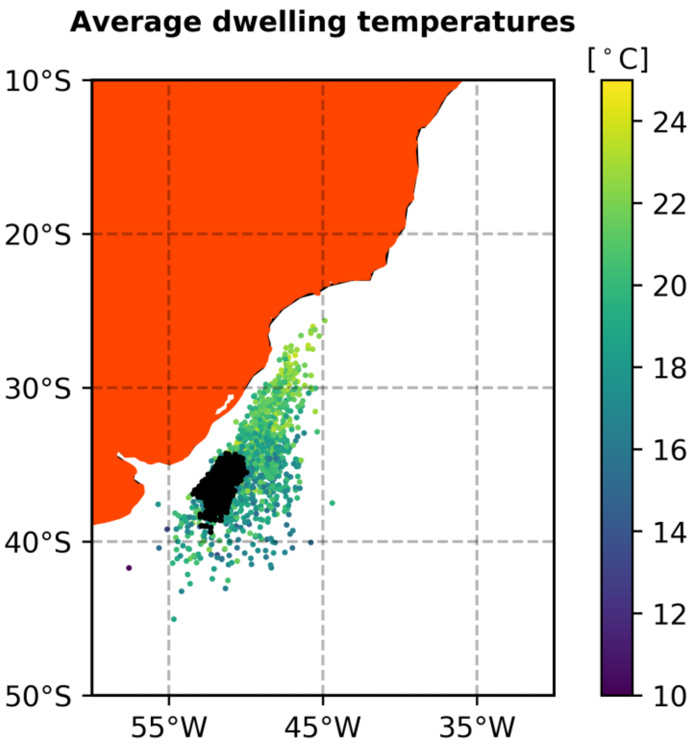
We investigated transportation at:

- 1) One specific model release location, the 'sediment core site'
- 2) A grid of release locations, spanning a wider area

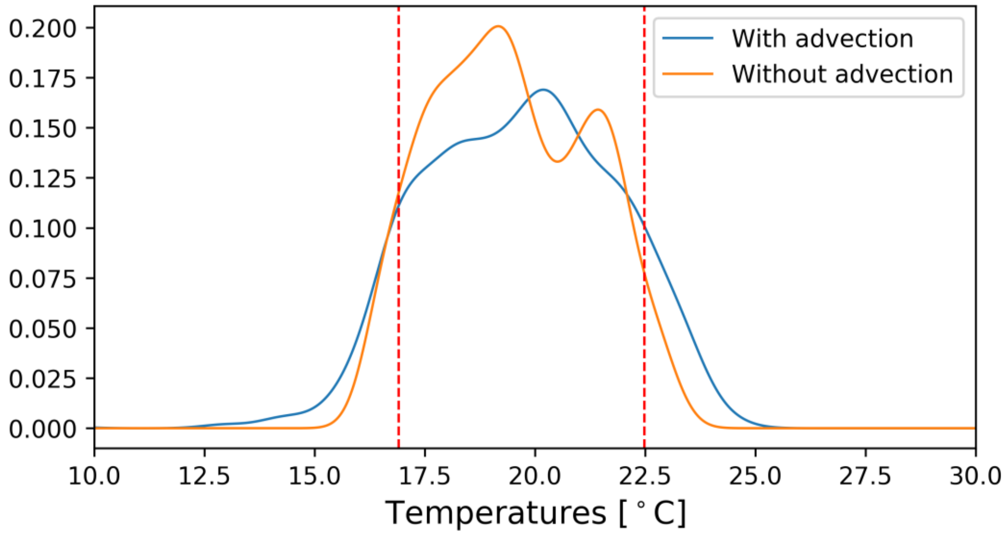




1) Figure obtained from Aze, Rogerson and Harvey (2018)



36.5S, 52.5W
Average dwelling temperatures



Results and discussion: Sediment core site

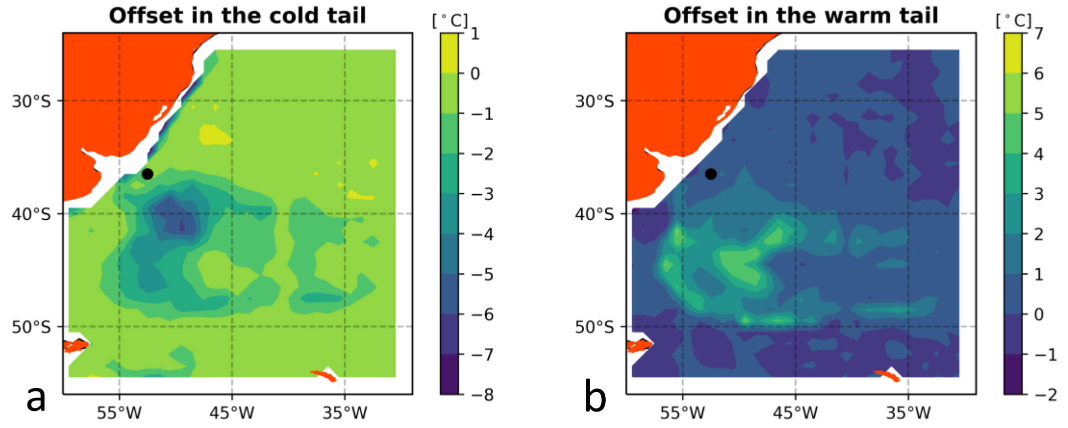
Map shows the distribution of origin locations (coloured dot representing the average temperature particles experienced during their life). Black dots indicate locations from which particles sink to the core site.

- Most lateral transport occurs during life, suggesting the particle sinks relatively fast.
- Average distance travelled during life = 1053 km
- Direct distances from core to origin are on average much smaller than distance travelled by the particle (mean= 408 km)
  - ➔ Since horizontal transport is on average relatively small, especially while sinking, particles will spend most of their life in waters close to the core site.
  - ➔ Conditions in the water column directly above the central core site influenced by same water masses also responsible for transporting the particles during their lifetime.

Graph shows range in temperature of advected particles with the range in temperatures right above the core site.

→ Distributions very similar (mean values of 19.5 and 19.6 approximately)

→ Small offset of 0.7 degrees for the warm and cold tails of the distributions.



Results and discussion: Grid of release locations

Maps of Uruguayan margin show the spatial range in offsets between a) cold tail and b) warm tail of the temperature range of advected particles and local water conditions above the core sites.

- Offset computed by subtracting the mean of the 10th (or 90th) percentile of the local distribution from the advected distribution.
- Round 40°S, 50°W, offsets between the cold and warm tails of the 'local' and 'advected' distributions can reach +/- 7°C.

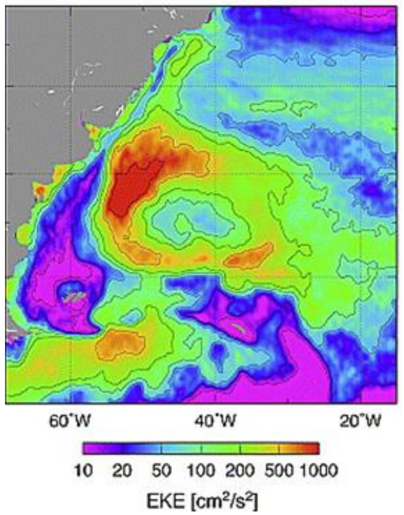
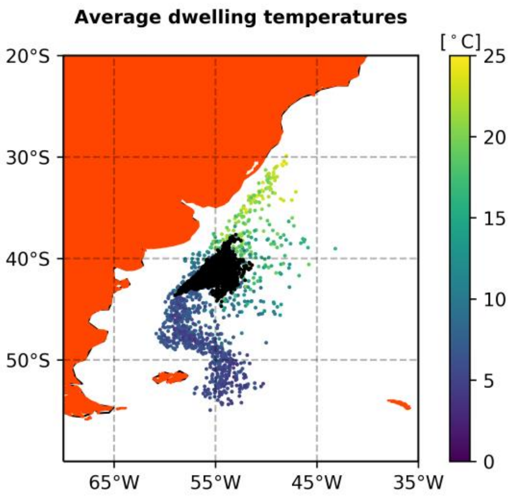


Figure obtained from Goni et al. (2011)

Observations from satellite altimetry show that for the real ocean this is the area containing highest eddy kinetic energy (EKE) in the Uruguayan margin.

➔ These large offsets can be related to strong currents both at the surface and at depth, causing larger distances to be travelled and transporting particles to the core site across sharp fronts in water masses present in the BMC and thus originating in a different water mass than the one they end up in.



Map shows distribution of origin locations for particles 'released' at location within the grid with the maximum offset in the warm tail.

➔ Particles here can indeed come from two distinct locations on both sides of the BMC, with large temperature difference between the furthest lying origin locations in the north and those locally above the core site.

Conclusion

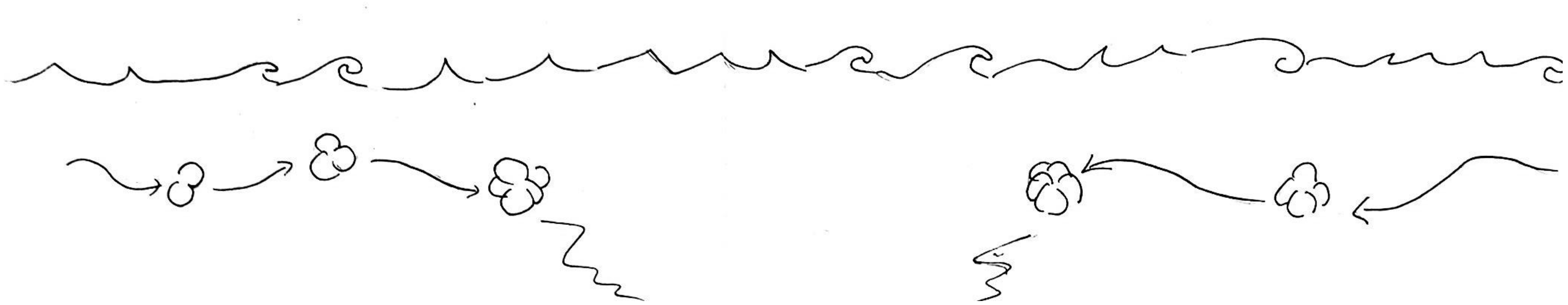
- When we focus on the tails of the modelled temperature distributions, which we assume to better reflect specific warm/cold dwellers present in an assemblage of foraminifera, we see an offset between local and advected particles.

- This offset is not very large when studying a site *outside of a confluence area* (‘ the sediment core site’, just north of the BMC) but can become very large when a site is *in the middle of the confluence*.

→ However, the MEANS of the advected and local temperature distributions are very similar.

- This shows that the mean ocean temperature signal reflected by foraminifera from a sediment core is not affected much by transportation.

→ However, when measuring single specimen within a sediment sample and aiming to reconstruct e.g. seasonal temperature extremes, transportation SHOULD be taken into account, since we have shown that these extreme temperature values belong to species transported from locations with water temperatures significantly different from the temperatures occurring above the core site.



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