Arctic to the North Atlantic connectivity using Montgomery Potential on neutral density surfaces

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1. What we did?

- Examine how Arctic waters end up in the Atlantic
- Use connectivity of neutral density surfaces for this
- Track water parcels on neutral surfaces from Arctic to North Atlantic and back to determine source waters and transient times.

2. Why this matters?

- Arctic nutrients and contaminants can be large sources for the North Atlantic.
- Arctic freshwater efflux may weaken deep-water formation at convection sites in the North Atlantic.
- Connectivity varies and may change in the future so the fluxes of nutrients.

3. How is this done?

- We have examined ocean connectivity of neutral density surfaces by running Montgomery Potential Function analysis in Python for NEMO[1].
- The method analyses geostrophic flow on pseudo-neutral density surfaces and calculates surface buoyancy forcing on density outcrops[2].
- We have analysed NEMOv4.04 runs at 1/12 degree forced with JRA55 atmospheric reanalysis for the 2008-2021 period.
- Water pathways are tracked with the OceanParcels software[3].
- Particles were released on neutral density surfaces 25.8-28.0 in the Laptev Sea, in the Denmark and Davis Straits, and near the Flemish Cap and on the West European Shelf and tracked forward and backward (Figure 1).

4. What have we found?

- Analysis show known oceanic gyres, the Beaufort Gyre, Sub-Polar Gyre and Nordic Seas gyres, as well as convection sites in the Labrador and Irminger Seas and boundary currents (Figures 2,4).
- Travel time for particles from the Laptev Sea to the Great Banks is of about 6 years; across Atlantic – is another 6 yrs; and the the West European Shelf and UK Seas to the Arctic is about 12 years (Figure 3).
- These compared to the observed Technetium spread from Sellafield and Hague to the Western Barents Sea about 5 years[4]; to East Greenland – 17 years; to Iceland 25 years[5].
- There is a range of the density surfaces that follows continuous multidecadal geostrophic dynamics through the global ocean.
- High resolution (1/12 degree and finer) is important for connectivity.
- We have found large variation in depth of the water pathways, possibly due to eddies. (Figure 4).

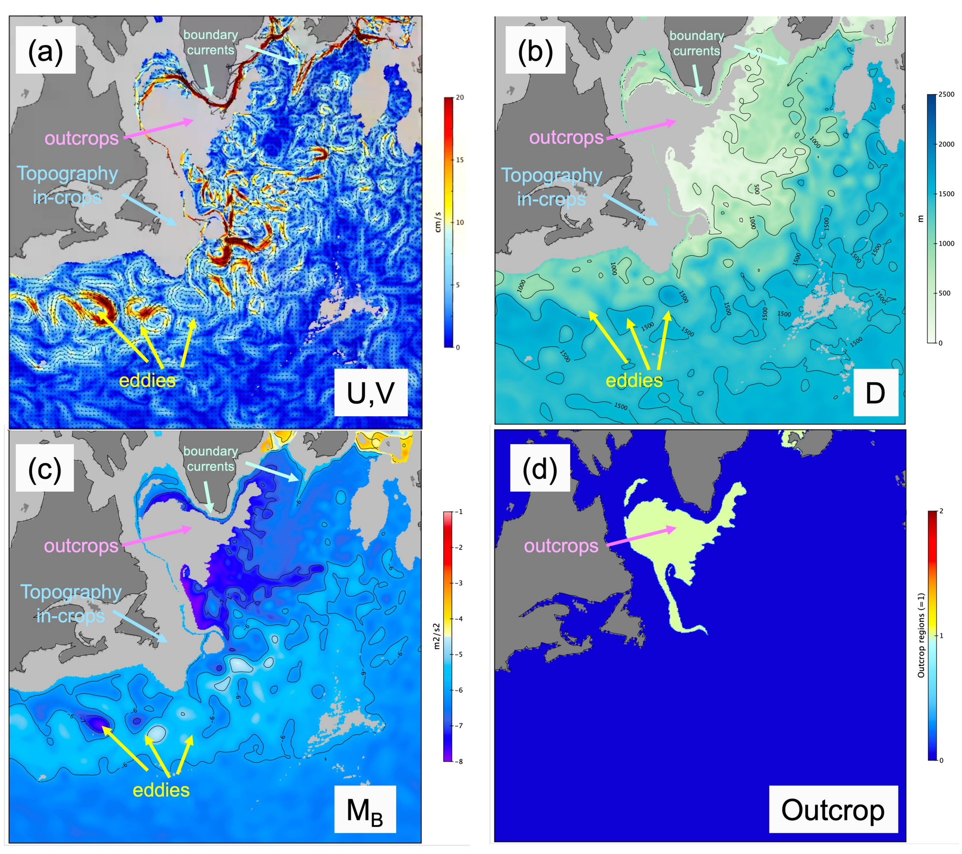

Figure 4. Ocean velocity (a) and Montgomery Potential (c) on density surface 27.8 along with depth (b) and neutral density surface outcrop (d) for Jan 2008. Eddy signatures are clear in velocity and Montgomery fields and cause large depth variations. Outcrop marks Subpolar Gyre ventilation.

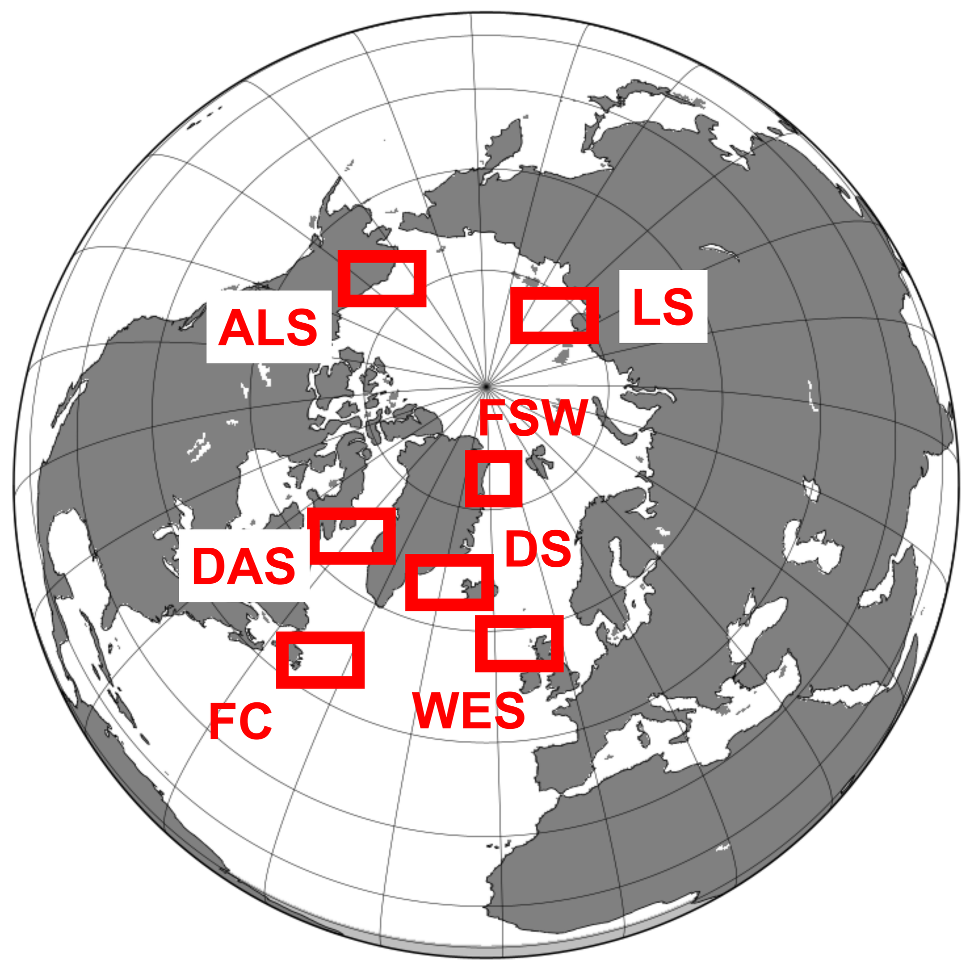

Figure 1. Particle release areas in the Laptev Sea (LS), on the Alaskan Shelf (ALS), in the Denmark Strait (DS), Davis Straits (DES), and Western Fram Strait (FSW), near the Flemish Cap (FC) and on the West European Shelf (WES).

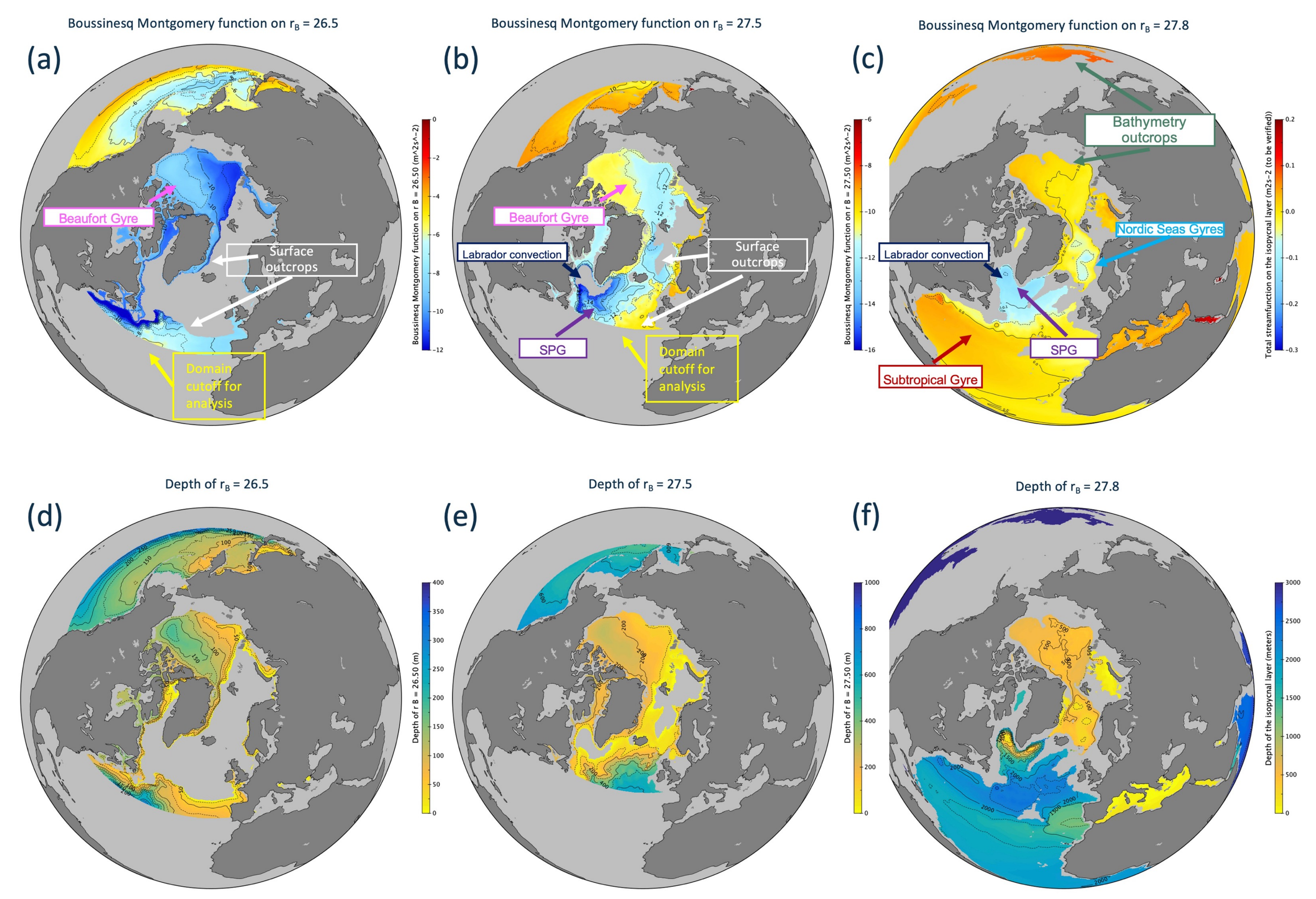

Figure 2. Annual Boussinesq Montgomery Potential on the neutral surfaces rB= 26.5 (Arctic surface waters), rB= 27.5 (Arctic halocline waters) and rB= 27.8 (Arctic and Atlantic waters) (a-c) and corresponding depth of the surfaces (d-f). Oceanic gyres, convection sites and density surface outcrops are marked: Beaufort Gyre (BG), Sub-Polar Gyre (SPG) and Nordic Seas gyres (a-c), Labrador convective site (b,c). NEMO 1/12 degree.

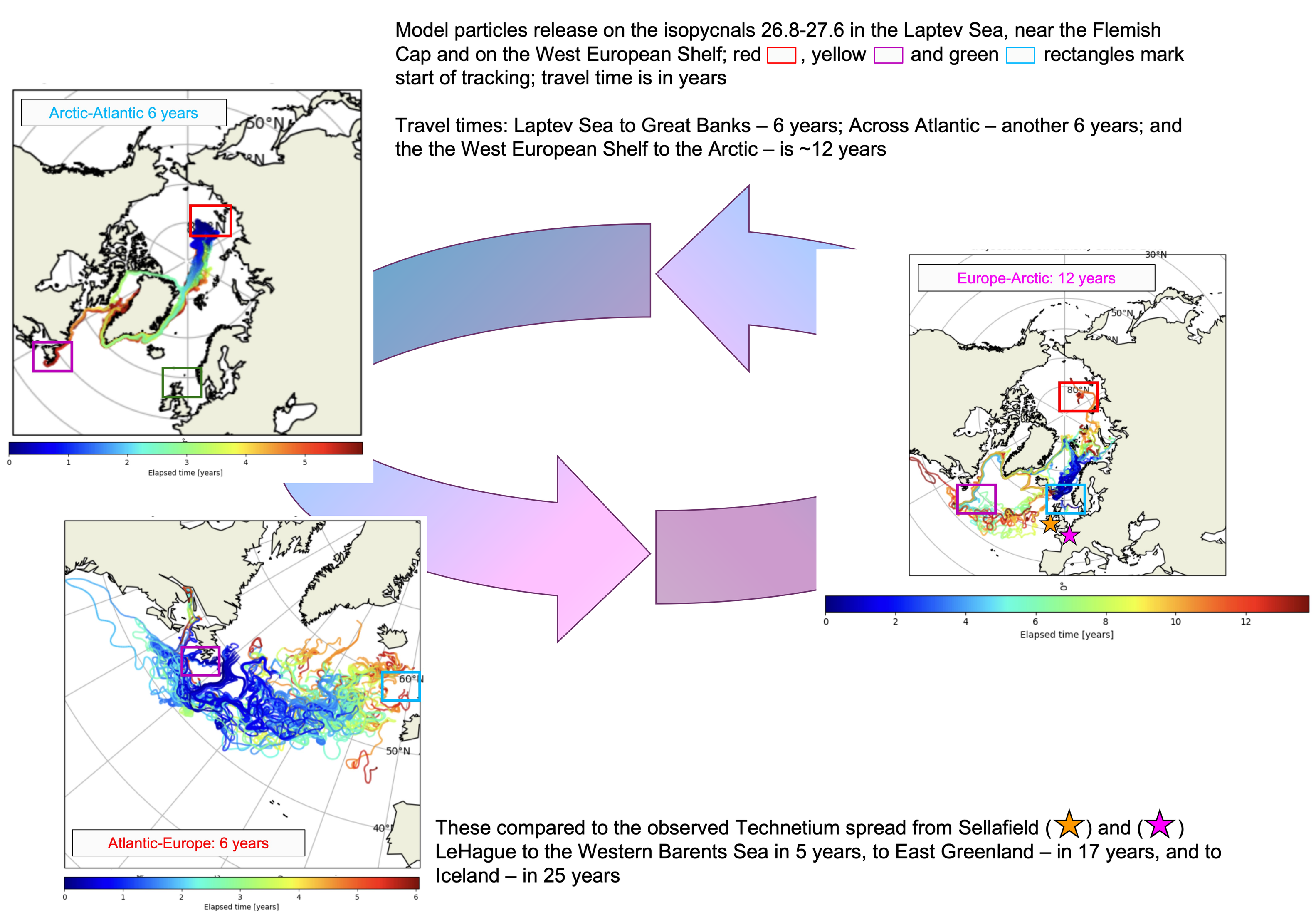

Figure 3. "Great loop of Arctic-Atlantic": releases on density surface 26.8 in the Laptev Sea, near the Flemish Cap and 27.6 on the West European Shelf. Forward tracking from monthly mean (U,V) 2008-2021.

References

[1]Python Montgomery code for NEMO 4.2 https://github.com/gnurser/nemo_monty.
[2]Aksenov, Y., et al., (2011), The Arctic Circumpolar Boundary Current, J. Geophys. Res., 116, C09017, doi:10.1029/2010JC006637.
[3]Lange, M. & van Sebille, E.: Parcels v0.9: prototyping a Lagrangian ocean analysis framework for the petascale age, Geosci. Model Dev.,10, https://doi.org/10.5194/gmd-10-4175-2017, 2017.
[4]Kershaw, P. J., et al. (2004). Variability in the supply, distribution and transport of the transient tracer 99Tc in the NE Atlantic. J. Mar. Syst., 44, https://doi.org/10.1016/j.jmarsys.2003.08.003.
[5]Lin, G., et al., (2022). Estimation of Atlantic Water transit times in East Greenland fjords using a 233U-236U tracer. Chem. Geol., 607, 121007, https://doi.org/10.1016/j.chemgeo.2022.121007.

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