National Oceanography Centre

Marine Systems Modelling

Mesoscale features dominating the Denmark Strait Overflow and our plan to improve the representation of overflows in global models

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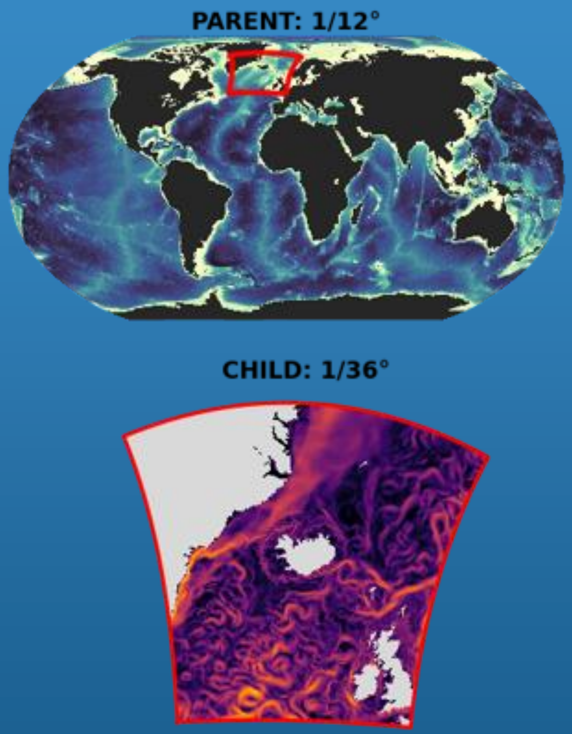

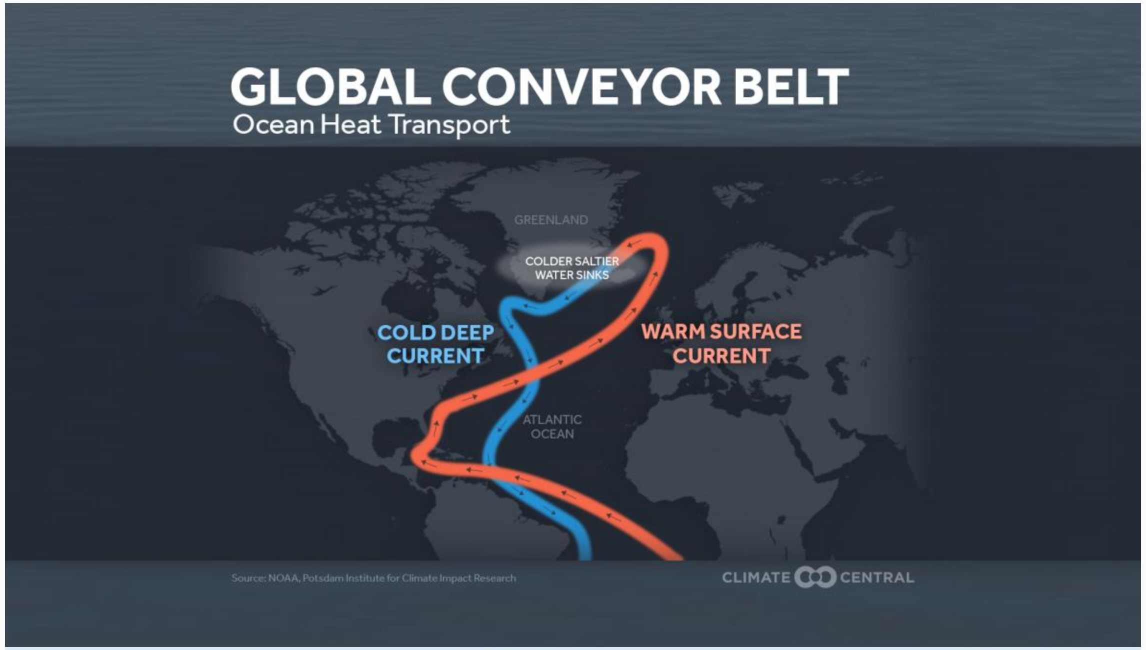

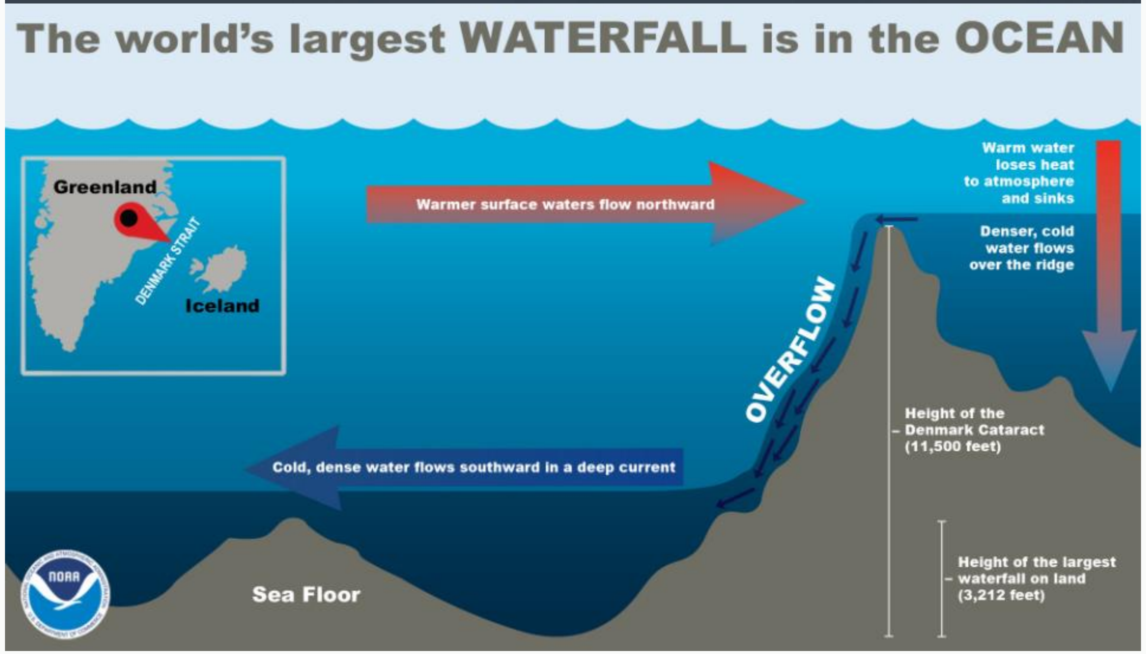

Denmark Strait is an ocean channel located between Greenland and Iceland. Its global importance is primarily due to the Denmark Strait Overflow, a bottom-trapped current transporting dense water from the Nordic Seas to the subpolar North Atlantic. After crossing Denmark Strait, the Denmark Strait Overflow Water is colder and denser than the surrounding water and sinks into the deep Irminger Basin. This sinking water is one of the drivers of the thermohaline circulation.

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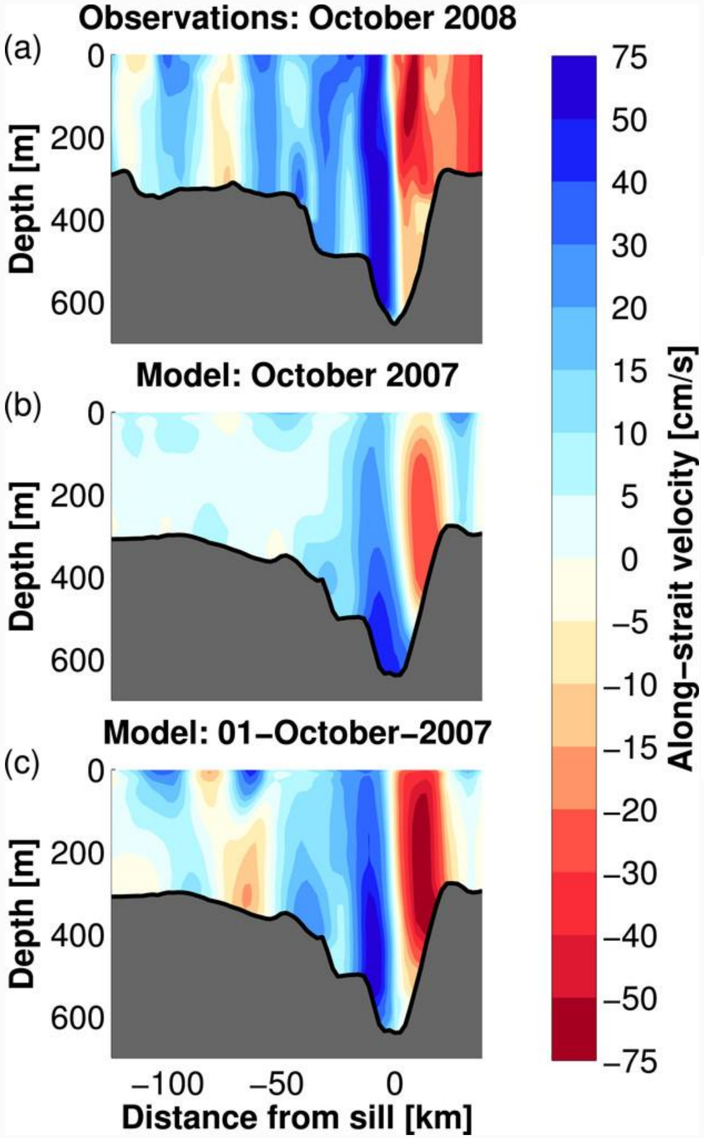
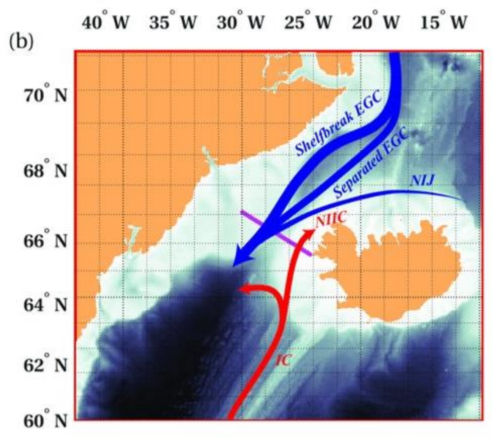
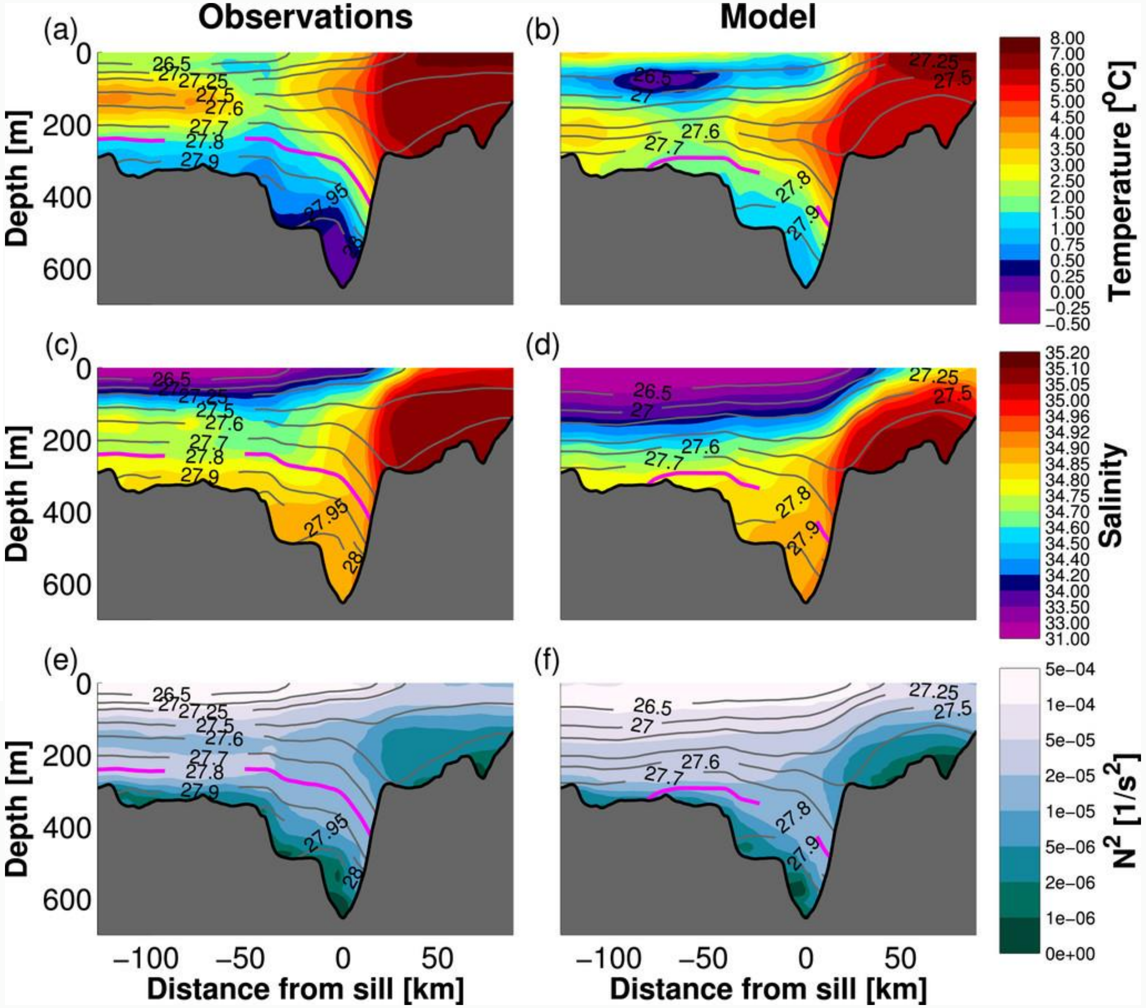
The hydrography and circulation in Denmark Strait simulated by *O*(1) km, realistic, regional models is in good agreement with the sparse observations available.







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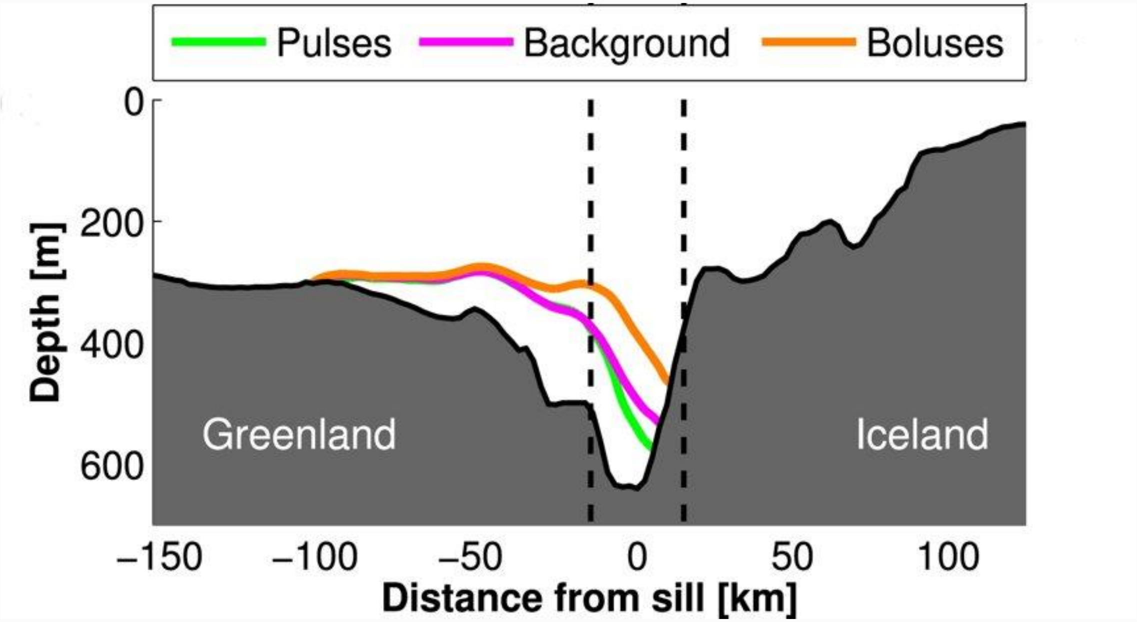
Almansi et al. (2017)

The high-frequency variability of the Denmark Strait Overflow at the sill



“Boluses” and “pulses” are the mesoscale feature controlling the high-frequency variability of the Denmark Strait Overflow. They both increase the southward transport of the overflow. In the former case, the large volume flux is primarily dictated by the increase in cross-sectional area of the overflow, whereas in the latter case it is mainly due to an enhancement of the near bottom flow.

The yearly mean southward volume flux of the Denmark Strait Overflow is about 30% greater in the presence of these mesoscale features.

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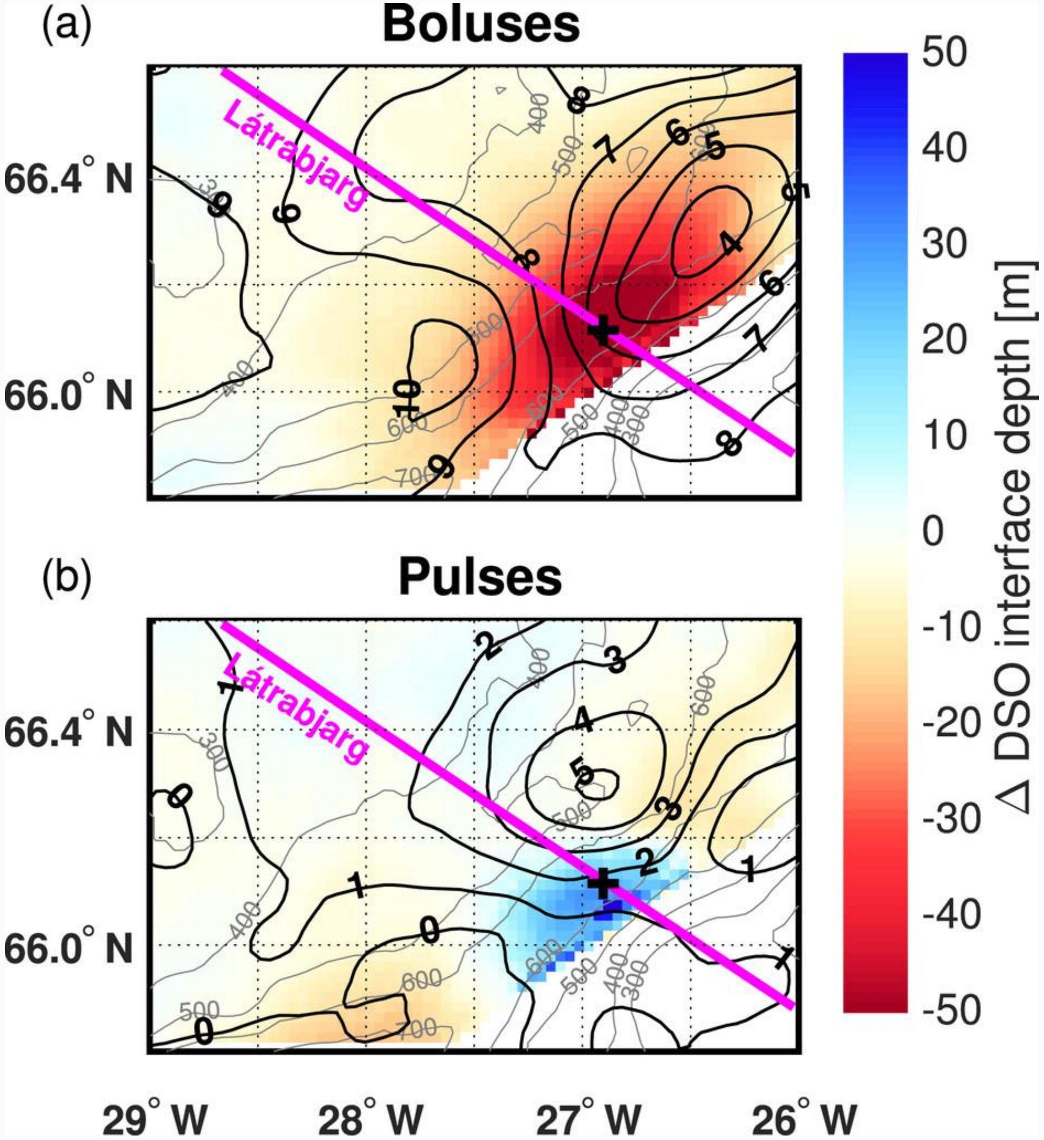
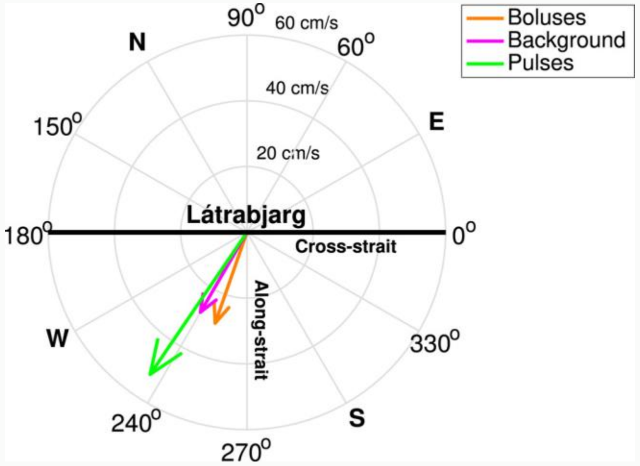
Almansi et al. (2017)

Sea Surface Height signature at the sill



Boluses are associated with a relative minimum upstream of the sill (bowl), whereas pulses are associated with a relative maximum upstream of the sill (dome). Assuming that the flow is in geostrophic balance, these anomalies imply enhanced flow toward Iceland during boluses (cyclonic) and toward Greenland during pulses (anticyclonic).



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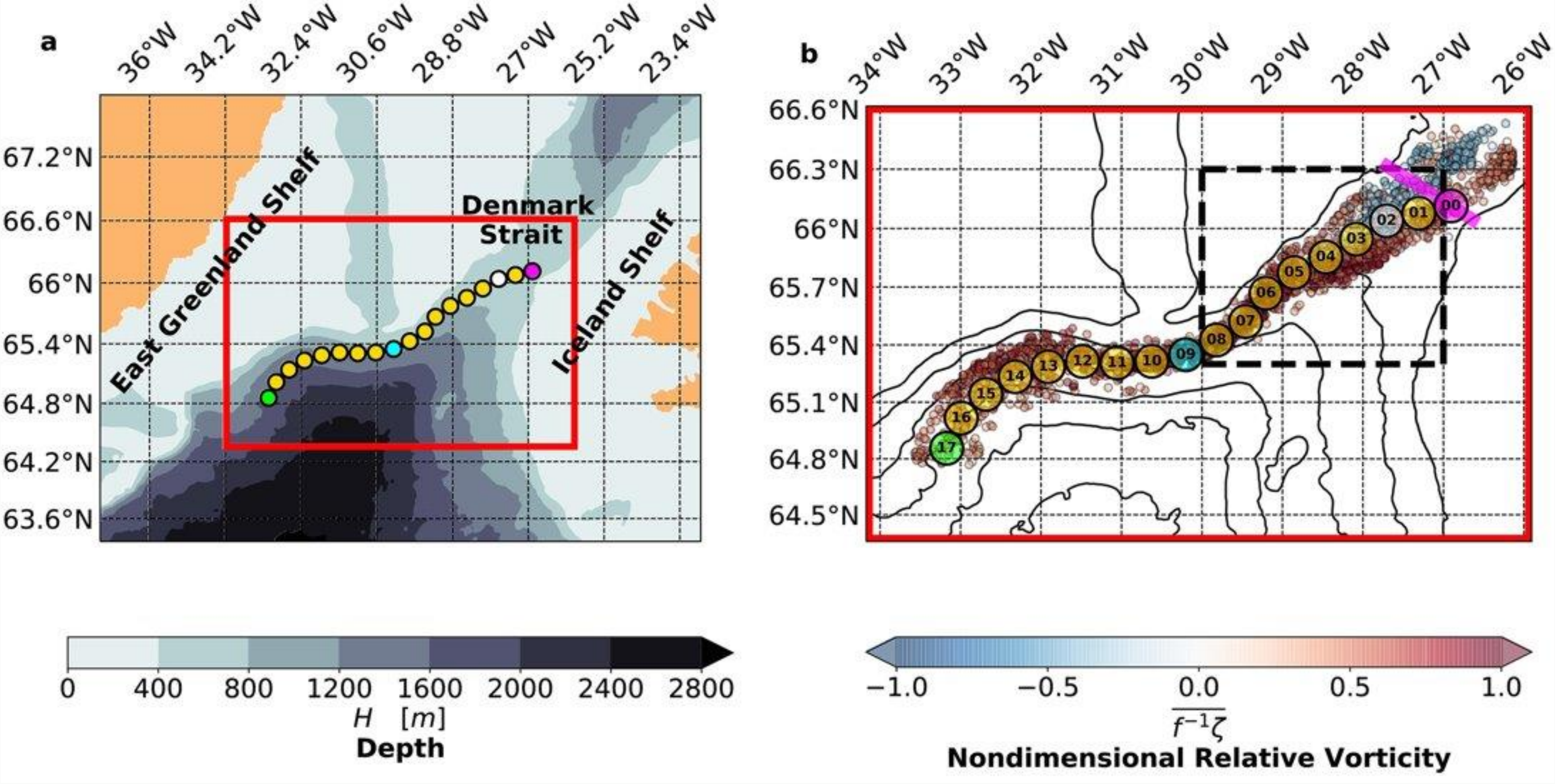
Almansi et al. (2017)

Downstream of Denmark Strait, the high-frequency variability of the overflow is dominated by the presence of energetic cyclones.



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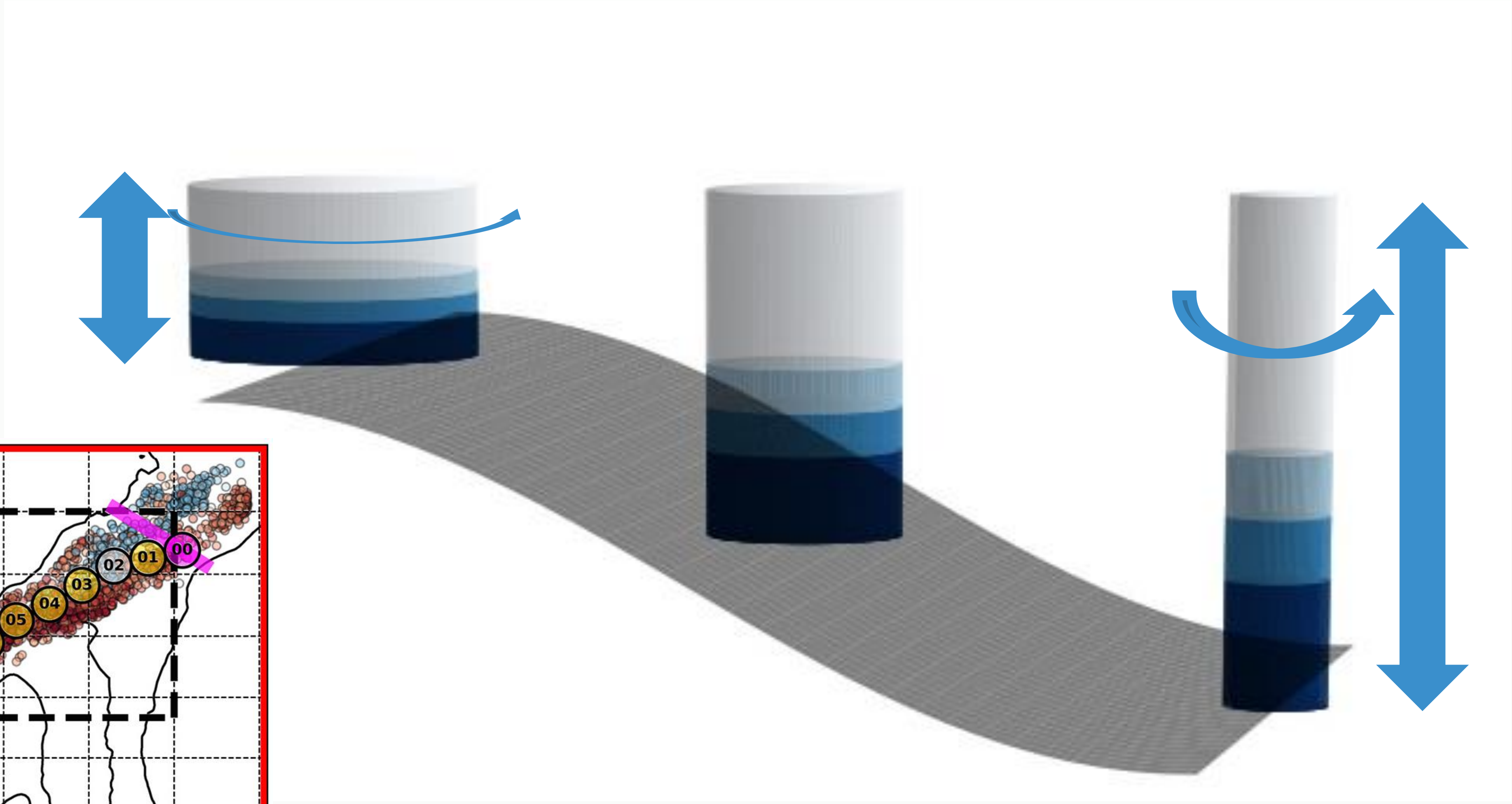
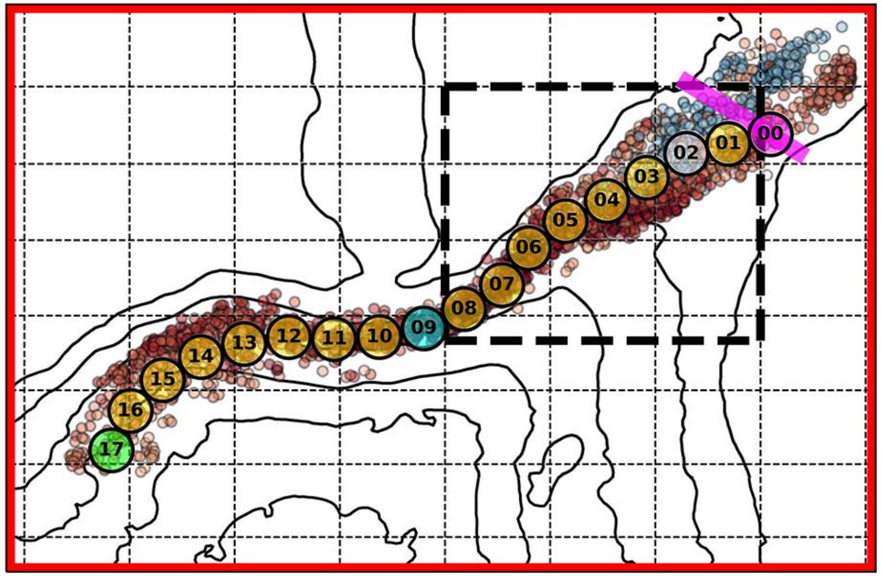
Cyclones associated with boluses form at the sill and, because of potential vorticity conservation and stretching of the water column, grow as they move south.





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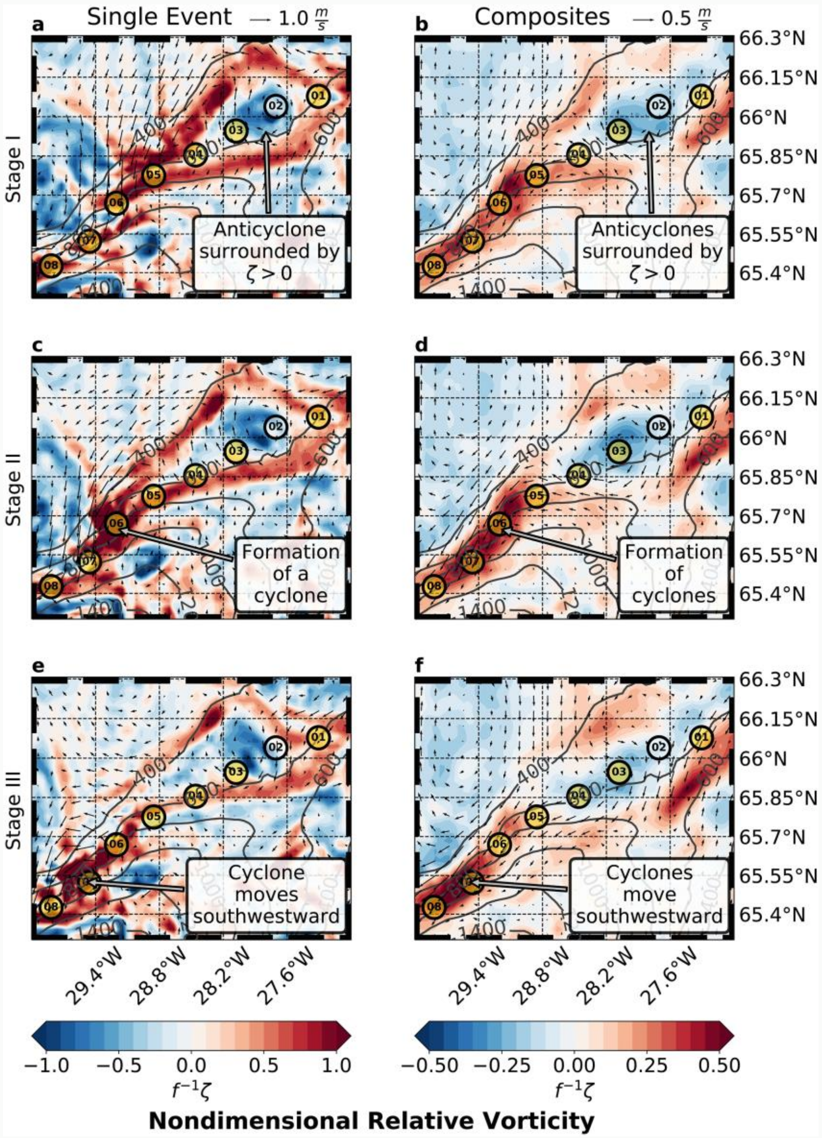
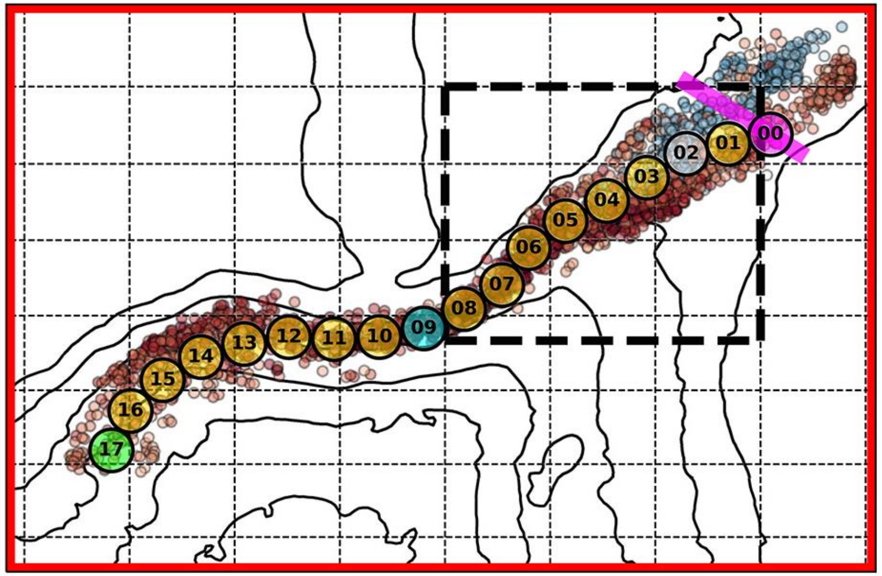
Cyclones associated with pulses form downstream of the sill, when the slow-moving anticyclones near the East Greenland shelfbreak start collapsing.





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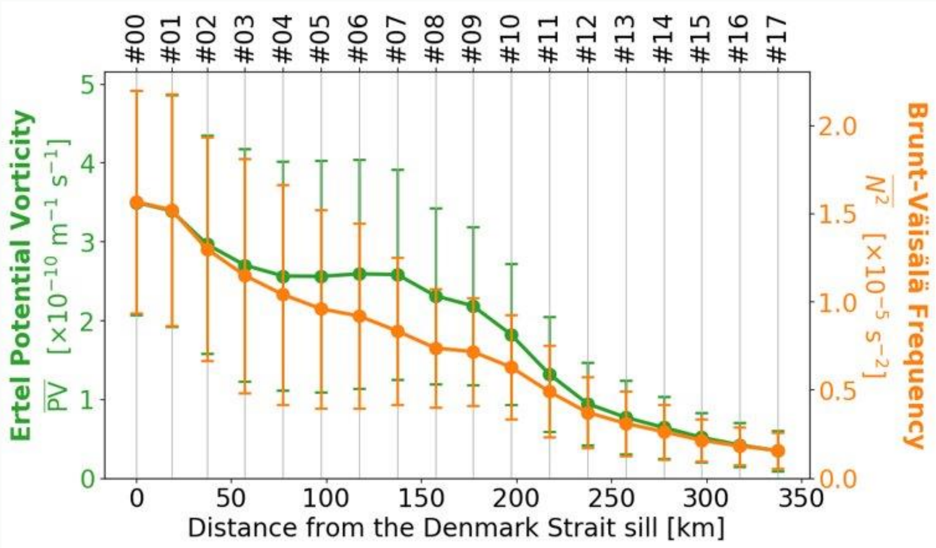
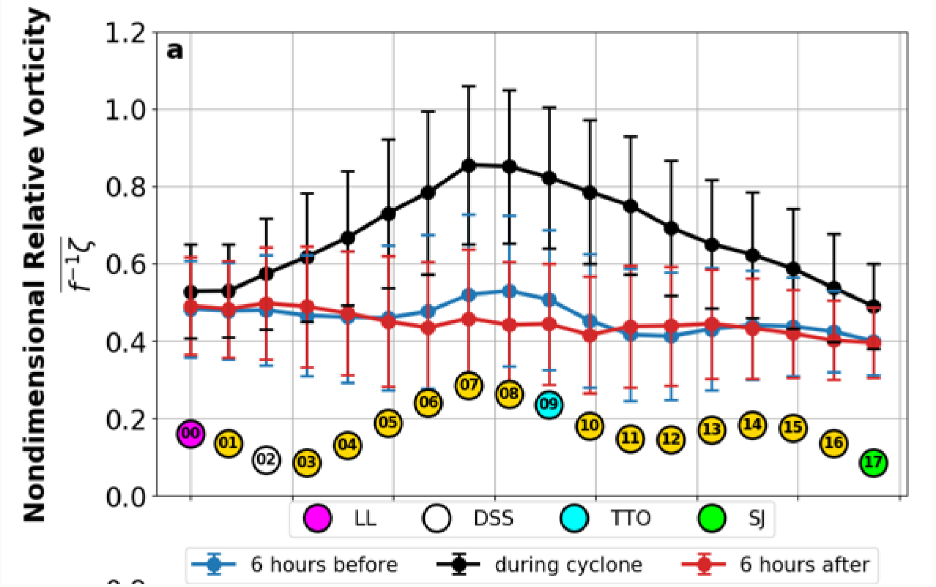
Downstream evolution of Denmark Strait Overflow Cyclones





Regardless of their formation mechanism, Denmark Strait Overflow cyclones grow in the first ~200 km downstream of the sill, then they progressively decay. The mean stratification of the cyclones decreases during their life cycle, while their initial increase in relative vorticity due to stretching is followed by a decrease. As a result, potential vorticity is only materially conserved during the growth phase.

$$\mathrm{PV} \approx (f + \zeta)\frac{N^2}{g}$$

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Almansi et al. (2020)

Conclusions

- Mesoscale features play a major role in controlling the properties of the Denmark Strait Overflow. As the cyclones interact with the dense water masses that descend into the subpolar North Atlantic, they affect the water masses sustaining the global circulation.
- Global simulations at kilometric scale are computationally expensive. Therefore, the difficulty to resolve the mesoscale dynamics dominating overflows is a significant weakness of current global/climate models.
- Recent developments of the AGRIF nesting tool allow to embed in NEMO configurations multiple nests with refined grids and independent vertical coordinate systems. Nests targeting key overflow regions will likely lead to significant improvements in global circulation models at affordable computational costs.

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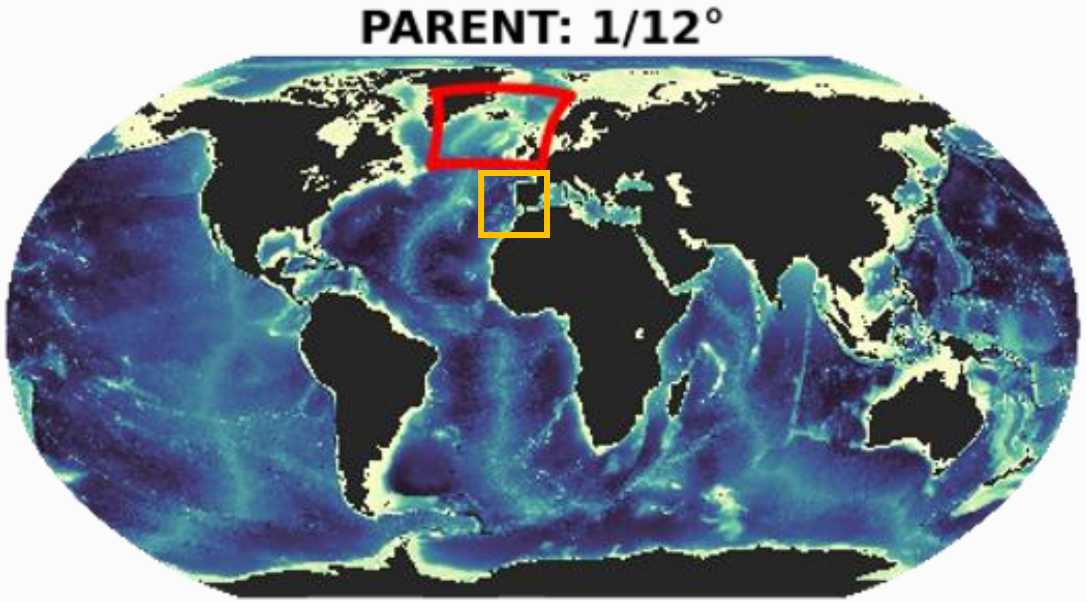
Global 1/12° parent domain with two 1/36° child domains

Target overflows:

- Denmark Strait Overflow
- Faroe-Bank Channel Overflow
- Mediterranean Overflow

Nests:

1. Greenland-Scotland Ridge
2. Gibraltar Strait (domain TBD)



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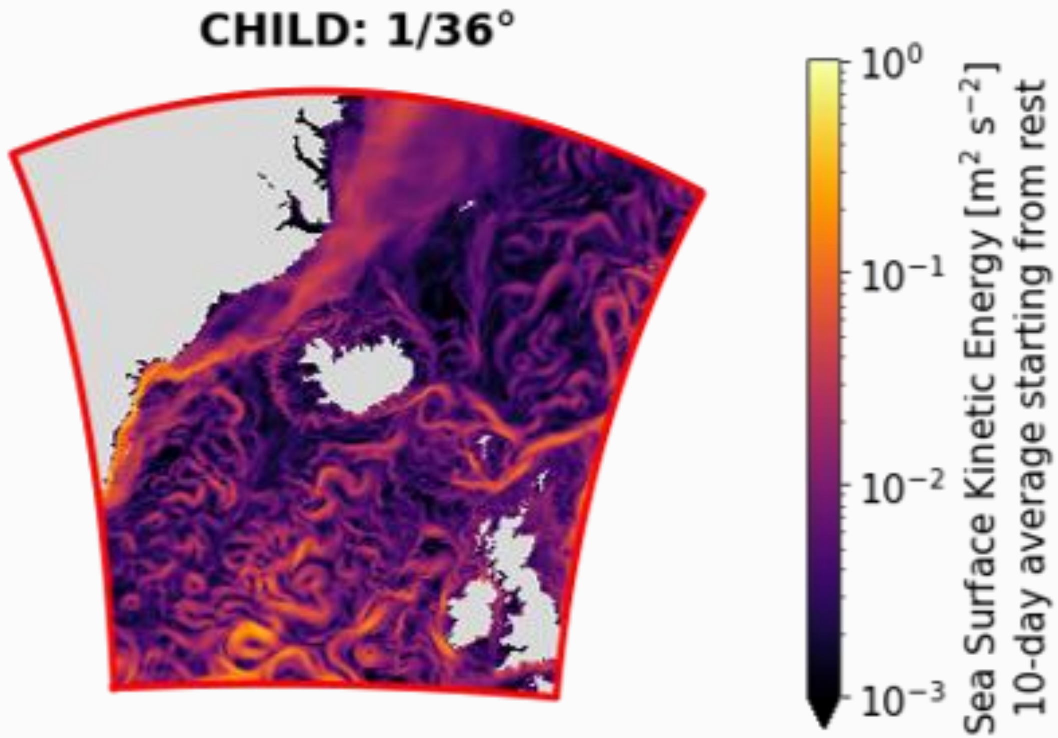
Current progress: GSRIDGE36; 5-year simulation

1/36° Greenland-Scotland Ridge regional setup in line with eORCA12.L75-GJM2020 but forced by DFS5.2 and ORCA0083-N06.

The regional simulation is currently being validated and will be used to test and determine the best vertical refinement and coordinate system for the nests embedded in the global run (z, sigma, transition z to sigma within the child domain).



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Ultimate goals

- Improve the representation of the dense currents overflowing from the Nordic Seas to the subpolar North Atlantic and assess the impact on the large-scale circulation
- Demonstrate new AGRIF functionalities (multiple nests with independent vertical coordinate systems)
- Evaluate the scientific performance of nests with sigma coordinates as opposed to z coordinates
- Identify enhancements that apply to any bottom-trapped dense current

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References

- Almansi, M., Haine, T. W. N., Pickart, R. S., Magaldi, M. G., Gelderloos, R., and Mastropole, D. (2017). High-Frequency Variability in the Circulation and Hydrography of the Denmark Strait Overflow from a High-Resolution Numerical Model. *Journal of Physical Oceanography* 47, 12, 2999-3013, https://doi.org/10.1175/JPO-D-17-0129.1
- Almansi, M., Haine, T. W. N., Gelderloos, R., & Pickart, R. S. (2020). Evolution of Denmark Strait overflow cyclones and their relationship to overflow surges. *Geophysical Research Letters*, 47, e2019GL086759. https://doi.org/10.1029/2019GL086759

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