Tracing Ocean circulation at the AR7W and OVIDE lines using artificial radionuclides

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HIGHLIGHTS

- In the subpolar north Atlantic ^{129}I and ^{236}U have been increasing since 2014.
- Water masses with high ^{129}I and ^{236}U concentrations are originating at high northern latitudes.
- The combination of ^{129}I and ^{236}U can tell about the evolution of Denmark Strait Overflow Water and East Greenland Current from Fram Strait.

BACKGROUND

The long lived **artificial radionuclides ^{129}I** ($T_{1/2}$ = 15.7 Ma) **and ^{236}U** ($T_{1/2}$ = 23.5 Ma) are suitable tracers for advective transport of water masses in the subpolar north Atlantic (SPNA)[1]. Their sources are the discharges from **nuclear reprocessing plants (NRP)** in Sellafield (green, Fig. 1) and La Hague (yellow), which release the radionuclides in **known quantities and annually changing discharge rates**. A global source to the Ocean surface were the **Global Fallout from the nuclear bomb tests**, mostly releasing ^{236}U [2].

The radionuclides discharged to the North Sea recirculate in the Arctic Ocean, and finally reach the western sub-polar north Atlantic (SPNA), mainly as part of the East Greenland Current (EGC). From the Labrador Sea they spread as intermediate waters toward the west[3].

The SPNA (Fig. 2) is a **key region for deep and intermediate water mass formation** and a main contributor to the lower limb of the Atlantic Meridional Overturning Circulation (AMOC). The tracers, predominantly label the waters of the **lower limb of the AMOC** and can help to study its variabilities and changes in its spreading pathways[4].

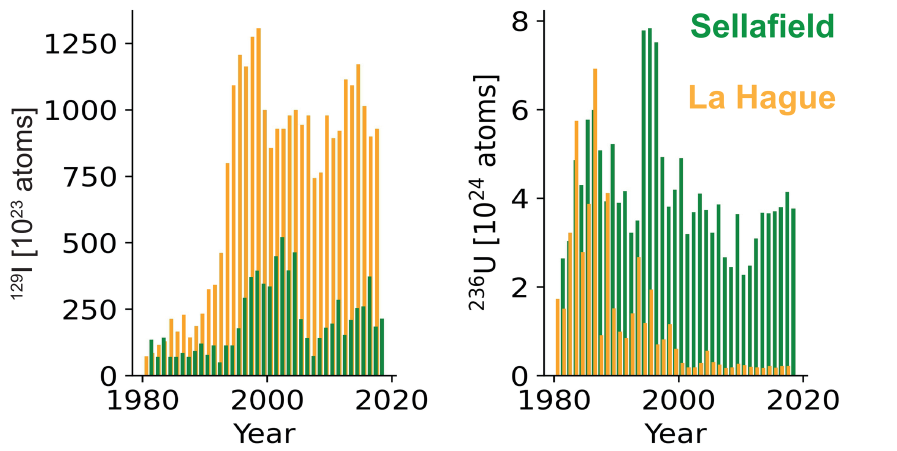


Figure 1: ^{129}I and ^{236}U discharge from EU nuclear reprocessing plants.

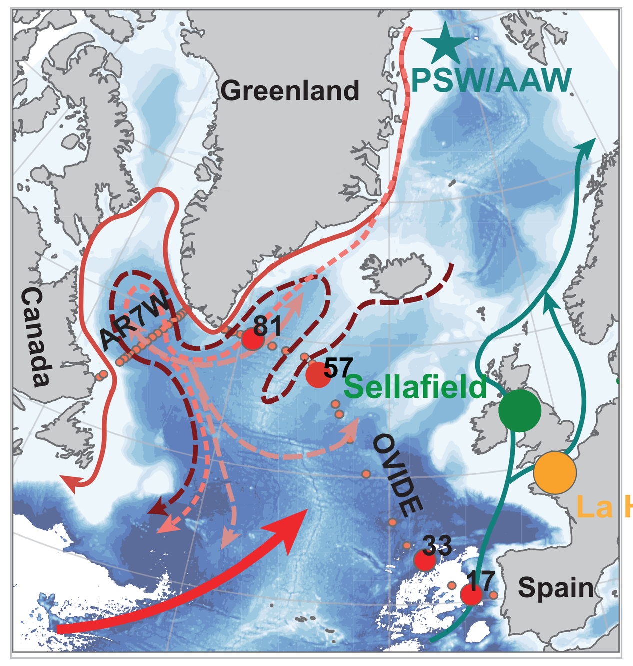


Figure 2: Subpolar north Atlantic, including sampling stations, schematic circulation and radionuclide sources.

Acronyms

Surface

- NAC: North Atlantic Current
- EGC: East Greenland Current
- ENACW: Eastern North Atlantic Central Water

Intermediate

- LSW: Labrador Sea Water
- ISOW: Iceland-Scottland Overflow Water

Deep

- DSOW: Denmark Strait Overflow Water

METHODS

Sampling:
- AR7W: RV Hudson in May 2020
- OVIDE: RV Sarmiento de Gamboa in June 2021

^{129}I Processing:
- Sample volume: 250 ml
- Chemical processing, purification and pre-concentration with DOWEX 1x8 Ion exchange resin, precipitation as AgI
- Measurements: Accelerator Mass Spectroscopy (AMS)

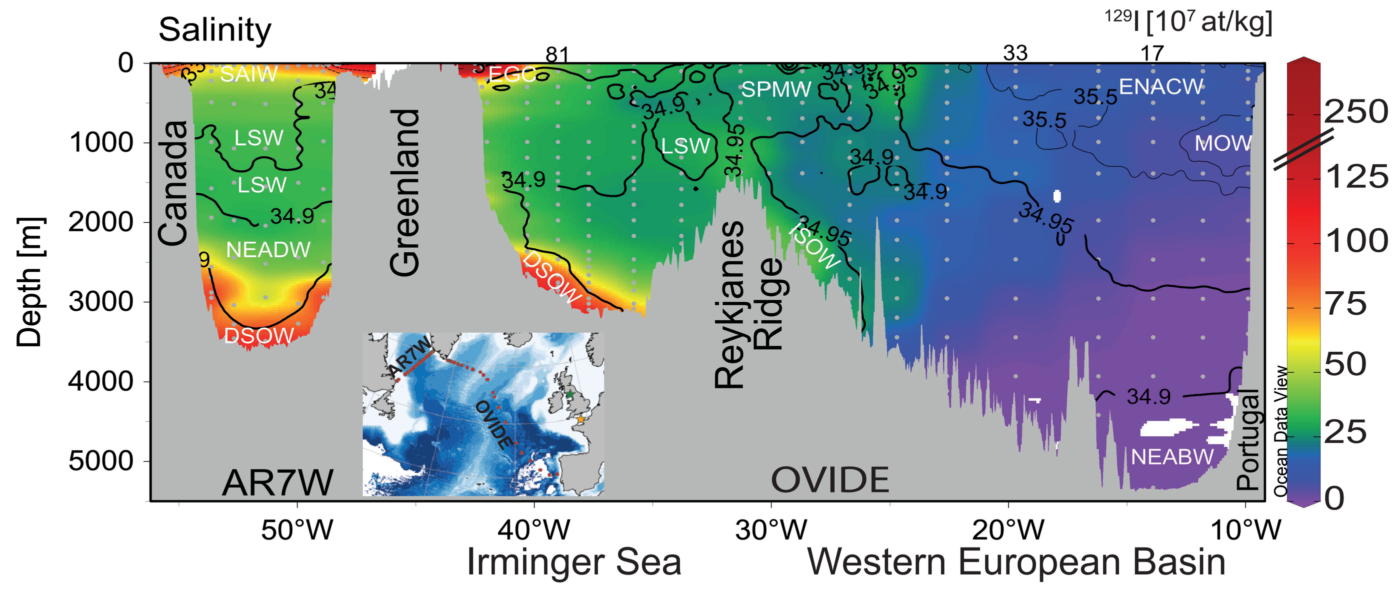
Data Analysis:
- Ocean Data View, Python

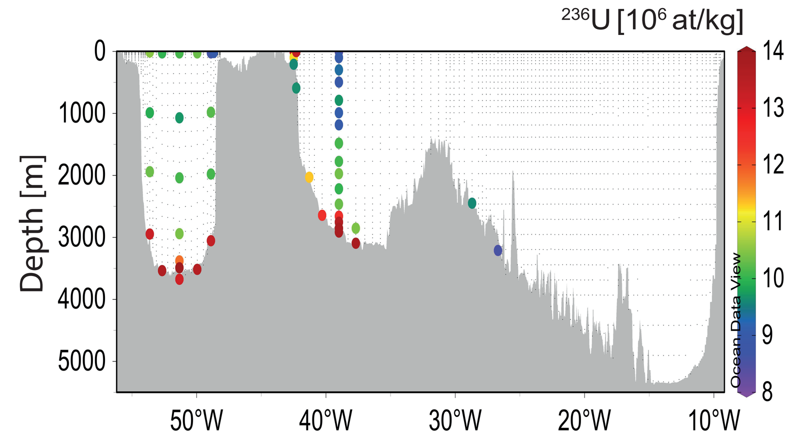
^{236}U Processing:
- Sample Volume 3-5 L
- Co-precipitation with $Fe(OH)_2$, purification and pre-concentration with UTEVA Ion exchange resin, reduction to UO
- Analysis with AMS

RESULTS & DISCUSSION

Hypothesis: The tracer concentration in SPNA can be influenced by: (i) releases from NRPs (Fig. 1), and/or (ii) changes of water mass formation/circulation (Fig. 2).

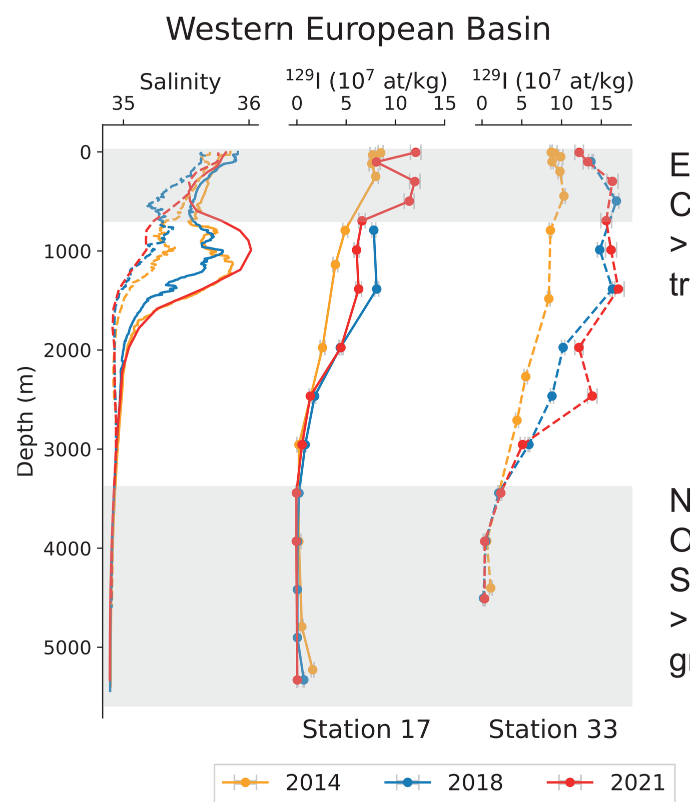
^{129}I and ^{236}U distribution in 2020/2021





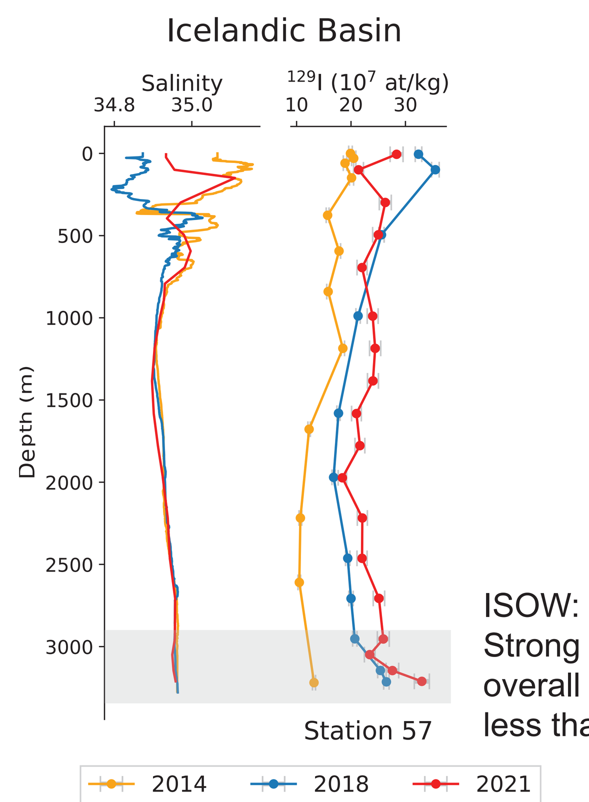
- Highest tracer concentration in water masses with origin in the Nordic seas (EGC, DSOW).
- Lowest ^{129}I concentration in waters with origin in the Southern Ocean (NEABW).
- ^{129}I concentration in EGC double as high as in DSOW, while both water masses have similar ^{236}U concentrations.
- ^{129}I concentrations along AR7W heterogeneous at the surface, which might be caused by eddies emerging from the boundary currents.

Temporal evolution between 2014 and 2020/2021

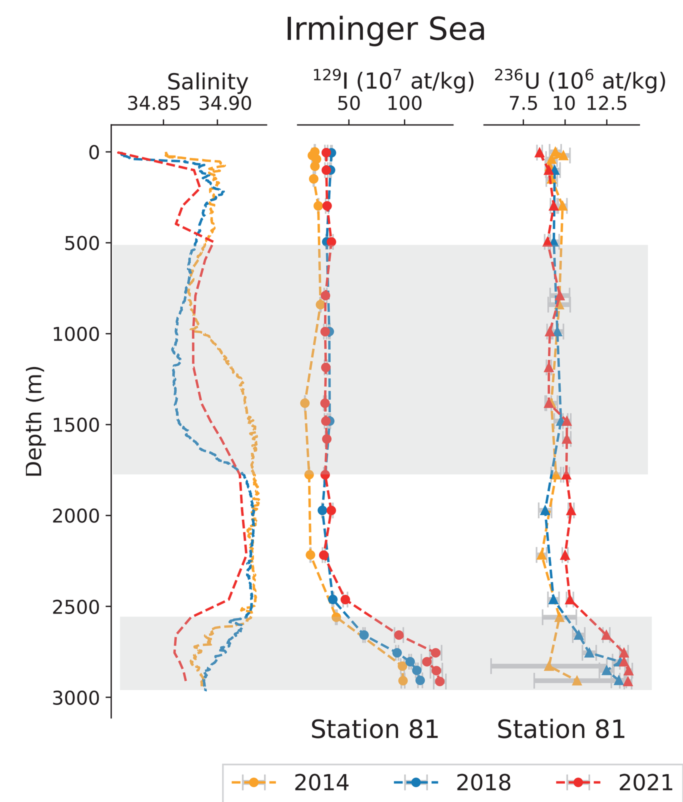


ENACW:
Constant increase
> Formation from tracer labelled SPMW

NEABW:
Origin at tracer free Southern Ocean
> Lithogenic Background



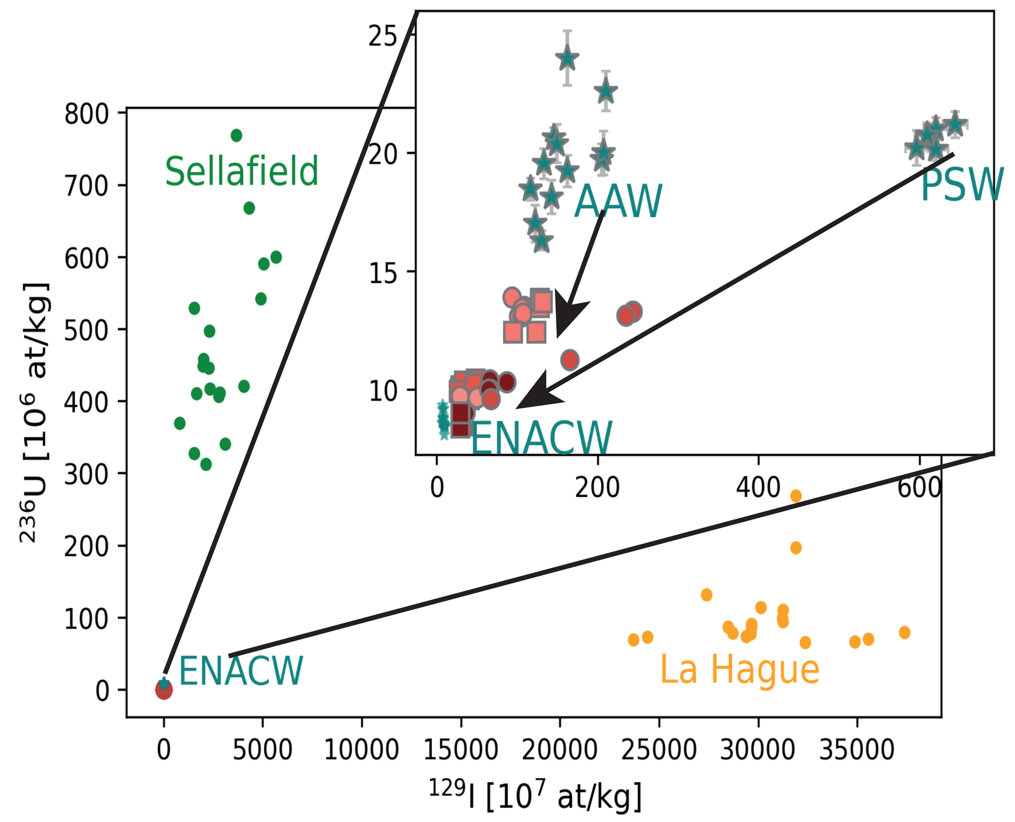
ISOW:
Strong increase, but overall concentration less than DSOW

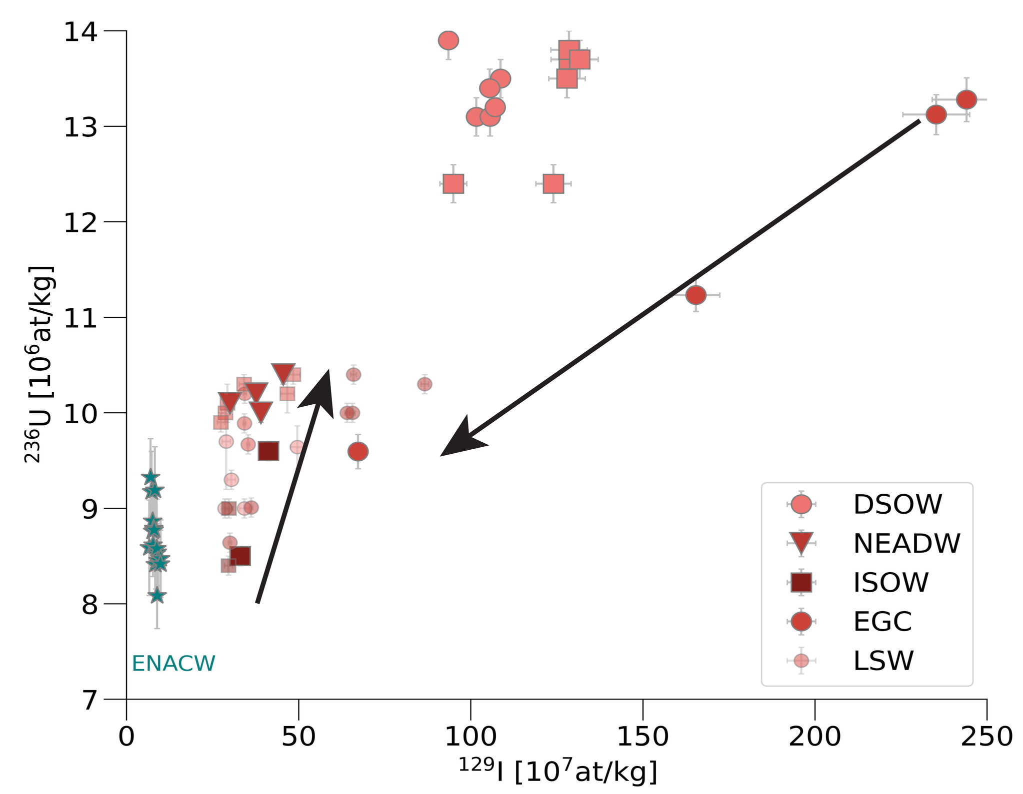


LSW:
Constant
> Convection from surface water, recirculation in the subpolar gyre

DSOW:
Strong increase
> Advective water with origin in the Nordic Seas strong influence of NRPs

Water mass provenance using ^{129}I and ^{236}U





The SPNA data fall between the releases from the NRPs (Sellafield and La Hague) and a third end-member; the water passing by the NRP's (ENACW).

End-members closer to the study area, and before the deep-water formation are located at Fram Strait (Arctic Atlantic Water (AAW) and Polar Surface Water (PSW)) [5].

- DSOW: dilution of AAW, two subgroups for different locations > probably different travel times
- EGC: dilution of PSW, dilution line formed via sampling towards the EGC
- ISOW: falls within the cloud of LSW which is mostly influenced by PSW
- NEADW: formed by mixing between ISOW and DSOW
- LSW: shift towards higher ^{236}U but comparable low ^{129}I suggests influence of a ^{236}U rich source, i.e. a water mass having stronger influence from Sellafield (e.g. ISOW)

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REFERENCES

[1] Castrillejo, M. et al., (2018) Tracing water masses with ^{129}I and ^{236}U in the sub-polar North Atlantic along the GEOTRACES GA01 section", Biogeoscience, Vol 15 p: 554-5564.
[2] Casacuberta, N. et al,. (2023), Nuclear Reprocessing Tracers Illuminate Flow Features and Connectivity Between the Arctic and Subpolar North Atlantic Oceans, Annu. Rev. Mar. Sci. 15:16.1-16:19.
[3] Castrillejo, M. et al., (2022) "Rapidly Increasing Artificial Iodine Highlights Pathways of Iceland-Scotland Overflow Water and Labrador Sea Water",Front. Mar. Sci. 9: 897-729.
[4] Lavender, Kara L. et al, (2005), "The mid-depth circulation of the subpolar North Atlantic Ocean as measured by subsurface floats",Deep S. Res I: Oc. Res Papers 52.5, pp. 767–785.
[5] Wefing, A.M. et al., (2019) "Tracing Atlantic Waters Using ^{129}I and ^{236}U in the Fram Strait in 2016", J. Geophys. Res.: Oceans 2019, Vol. 124 p.882-896.