Treasure from Trash:
Using nuclear waste to trace ocean circulation around Iceland

Duncan Dale[1*], Andreas Macrander[2], Sólveig Ólafsdóttir[2], Rob Middag[3], Marcus Christl[4], Núria Casacuberta[1,4]
[1]Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich (CHN), 8092 Zürich, Switzerland, [2]Marine and Freshwater Research Institute, Hafnarfjörður, Iceland,
[3]Royal Netherlands Institute for Sea Research (NIOZ), Department of Ocean Systems, Texel, Netherlands, [4]Laboratory of Ion Beam Physics, ETH Zürich, Switzerland
*Correspondance: duncan.dale@usys.ethz.ch

Research Questions

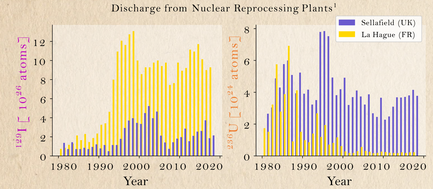
I. What is the potential of the ^{129}I - ^{236}U dual tracer for identifying and tracing water masses around Iceland?
II. Can the tracers be used to quantify the mixing of major water masses in the Nordic Seas?
III. Can they bring new insights into the origin and fate of the dense overflows that feed into the Atlantic Meridional Overturning Circulation?

I The Trash
The tool we use

^{129}I
$t_{½}$ = 15.7 Myr

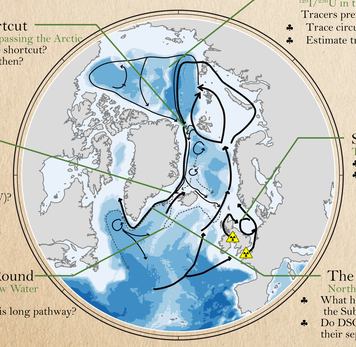
^{236}U
$t_{½}$ = 23.4 Myr

Discharge from Nuclear Reprocessing Plants[1]



How this Trash helps read a Treasure Map:
- Scarce in nature
- Long $t_{½}$
- Point-like source
- Well-quantified input
- Behave conservatively in open ocean seawater
- Input of two tracers from same source

II A Treasure Map
What we hope to find with the Trash



The Shortcut
Warm Atlantic water bypassing the Arctic
- How much takes the shortcut?
- What happens to it then?

The Well-trodden Path
^{129}I/^{236}U in the Arctic Ocean
Tracers previously used to:
- Trace circulation pathways ✓
- Estimate transit times ✓

The Great Waterfall
Denmark Strait
- What happens to the East Greenland Current (EGC) here?
- Which water masses go into Denmark Strait Overflow Water (DSOW)?

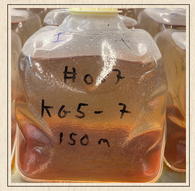
START HERE
Tracer releases
- Released from Sellafield (UK) & La Hague (FR)
- Mix in North Sea and transit north

The Long Way Round
Iceland Scotland Overflow Water
- What does it form from?
- How does it change along this long pathway?

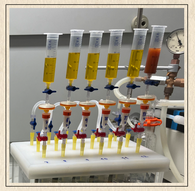
The Winding River
North Atlantic Deep Water
- What happens to the overflows in the Sub-polar North Atlantic?
- Do DSOW and ISOW merge or go their separate ways?

III Gathering the Trash
How we collect and handle it

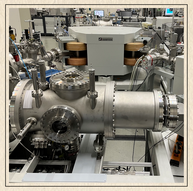
Cruises:
Iceland21 – MFRI Iceland (45 samples, Winter 2021)
MetalGate – NIOZ MetalGate Cruise (GEOTRACES) (95 samples, Summer 2021)
Plus data from:
Wefing et al. (2021)[2] - PS100 – R/V Polarstern (136 samples, Summer 2016)



Preconcentrate (^{236}U)



Purify

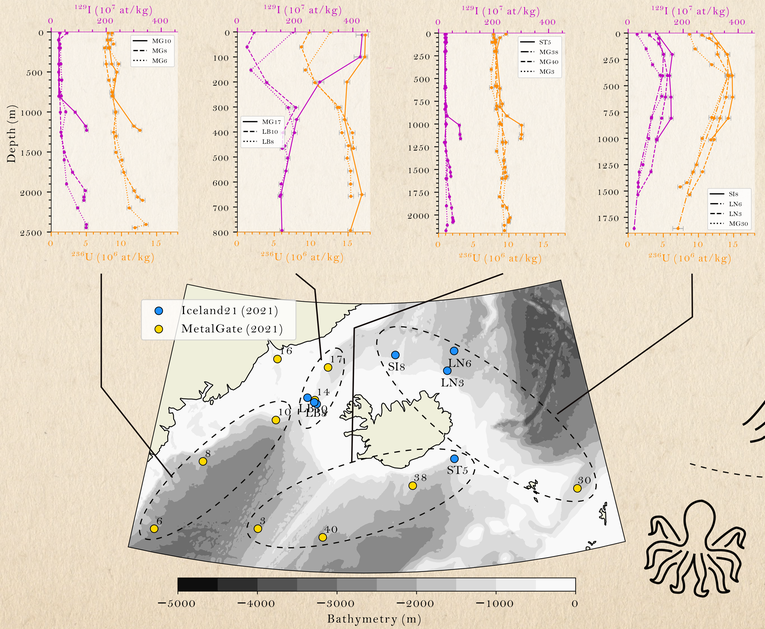


Measure (AMS*)

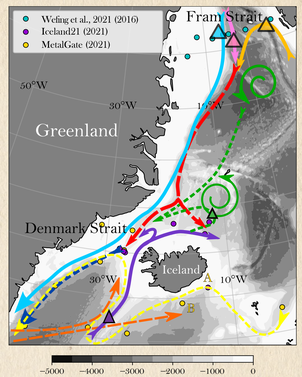
*Accelerator Mass Spectrometry – Laboratory of Ion-beam Physics, ETH Zürich

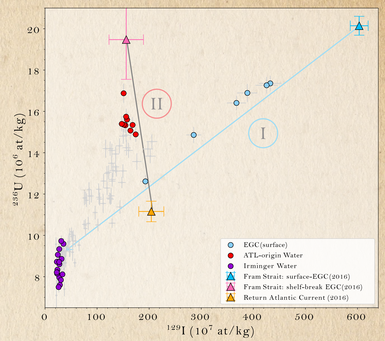
Seawater analysis using Python inc. gsw (TEOS-10) library

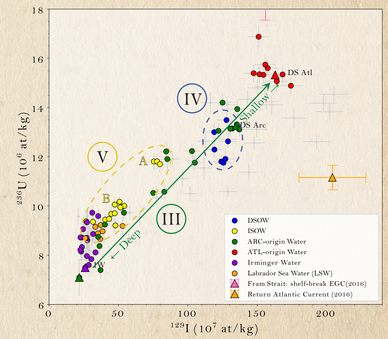
IV Treasure Ahoy!
How the Trash becomes our Treasure



V The Treasure
What the Trash tells us







Observations

I. **Surface EGC** mixes with **Irminger Water** as it approaches Denmark Strait
II. **Atlantic-origin water** in Denmark Strait is a mix of **Shelf-break EGC** and **Recirculating Atlantic Water** and can estimate RAC proportion at **15 – 58 %**
III. **Arctic-origin water** north of Iceland has a tracer gradient increasing from deep to shallow up until the Atlantic-origin water above it
IV. **DSOW** has a tracer signature like the upper Arctic-origin layer but may form from a mixture of Atlantic-origin water and deeper Arctic-origin water. Tracers can't discern if Irminger Water or Labrador Sea Water are also partially entrained.
V. **ISOW** at **point A** is transformed by **point B** where the entire downstream pathway forms a relatively tight cluster. This may be due to mixing with **Labrador Sea Water** from this point OR may be Arctic-origin water "leaking" across the ridge SW of Iceland

VI More Treasure…

Treasure to take home
- First systematic deployment of ^{129}I - ^{236}U dual tracer in Nordic Seas: Distinct signatures in key water masses
- Tracers clearly indicate origin of water masses, especially Atlantic vs Arctic-origin
- Can quantitatively estimate mixing of water masses in some situations
- Provides a tool and new end-members to define tracer space and overflow pathways downstream

Treasure still to be found…
- Further 200 samples collected N and E of Iceland (2022) under analysis
- 100 samples to be collected off Grand Banks (CA-NL) in 2023 to track southbound overflows
- This study only is a steady-state treatment. Repeat sampling in key locations will enable construction of Nordic Seas tracer input functions and estimation of transit timescales of circulation in the Sub-polar North Atlantic

References
I. Christl, M., et al., *Reconstruction of the 236U input function for the Northeast Atlantic Ocean: Implications for 129I/236U and 236U/238U-based tracer ages. Journal of Geophysical Research: Oceans, 2015.* **120(11): p. 7282-7299**
II. Wefing, A.-M., et al. *Annual variability of the long-lived anthropogenic radionuclides 129I and 236U in the Fram Strait and their use as water mass composition tracers. in EGU General Assembly Conference Abstracts. 2021.*

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