Sea shells record large biases from the marine bomb-^{14}C in NW European seawater between the late 1960s and 2019

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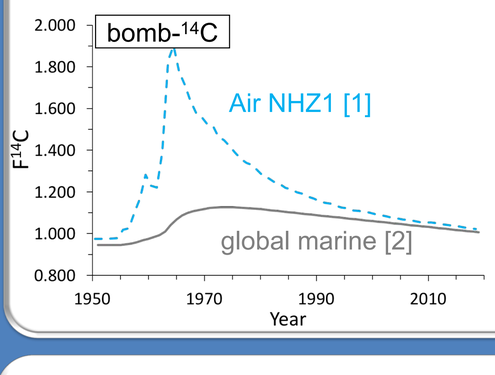
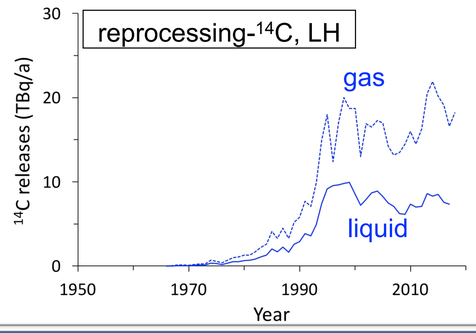
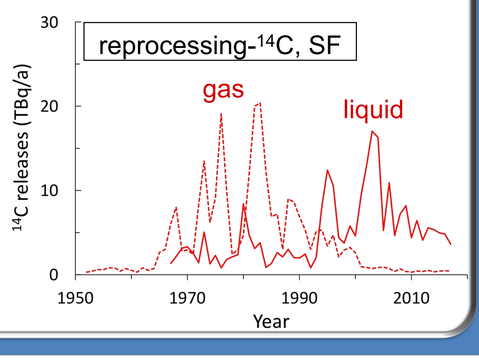
Abstract

- Accurate knowledge of **radiocarbon (^{14}C) content** in the sea surface mixed layer **is valuable for a broad range of applications** in oceanography.
- **Globally**, the above-ground nuclear weapon testings (**bomb-^{14}C**) in the 1950/60ies **has been the primary source** of increased atmospheric [1] and marine ^{14}C [2]. **Regionally**, however, other sources can be important. In Europe, the nuclear fuel **reprocessing plants** of La Hague (LH) and Sellafield (SF) **have discharged significant amounts of ^{14}C** since the 1950s that have been, in large part, documented or reconstructed.
- **Previous studies** conducted closeby or downstream of reprocessing plants **found ^{14}C above bomb levels** in seawater, biota and sediments [e.g. 3-5]. Yet, a comprehensive view on **the temporal evolution of ^{14}C in sea surface was still missing. Here, bivalve shells of known collection date and age are used to reconstruct the ^{14}C contamination since the late 1960s to 2019.**
- The results show **significant regional deviations from the global and regional marine bomb-^{14}C pulse** caused by liquid reprocessing releases that **can have important implications in** broad topics including **^{14}C-dating, tracer oceanography and nuclear forensics.**

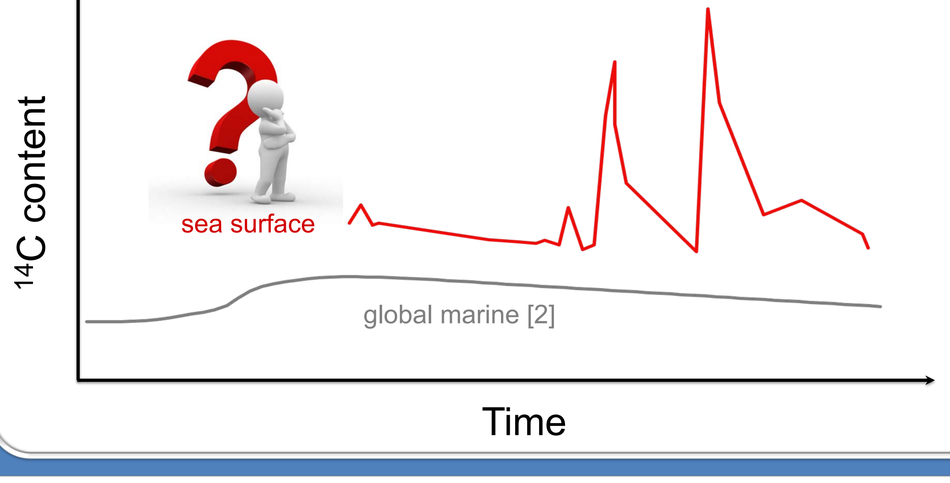




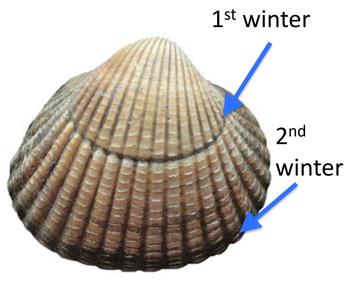


Research question

What is the impact of nuclear fuel reprocessing on the temporal evolution of ^{14}C in the sea surface mixed layer?

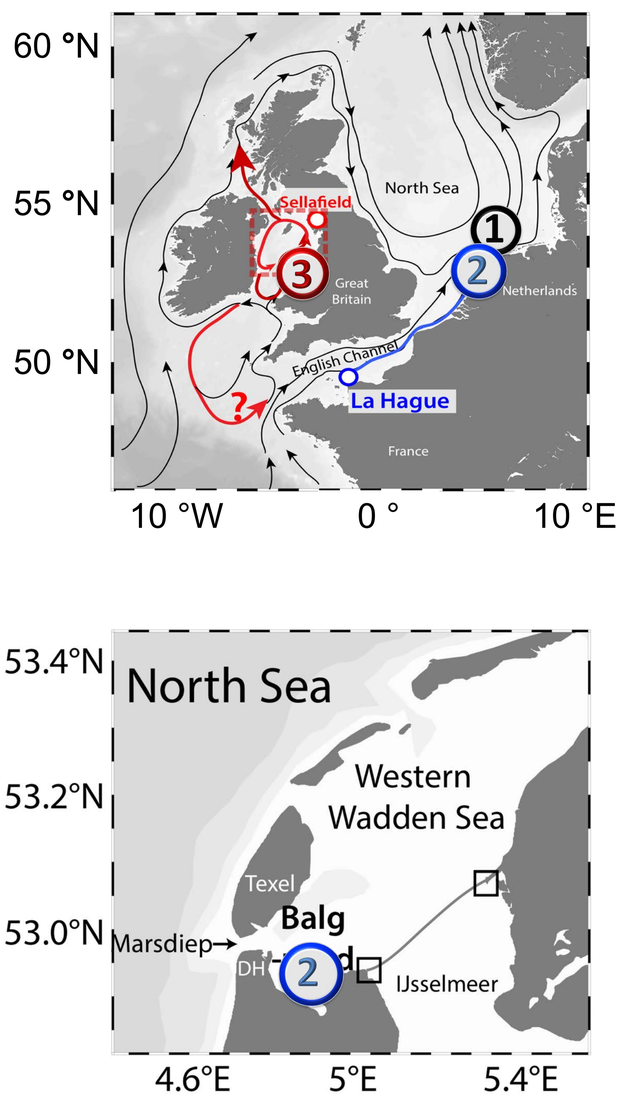


Materials and methods



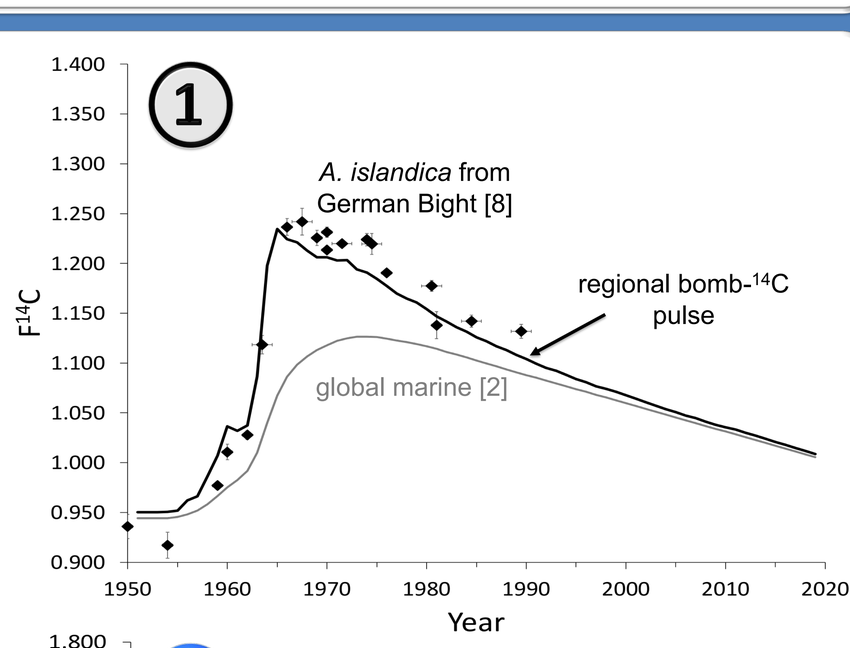
- Study areas nearby or along the path of reprocessing releases: Balgzand (1969-2018) and Traeth Melynog (1975-2019), locations 1 and 2, respectively, in the maps shown below.
- The european common cockle (*C. edule*) **bivalve** is **used as ^{14}C recorder** of surface seawater.
- Cockles were **captured alive** making elaborate age determination unnecesary.
- **Individuals with 2 ± 1 years of age were selected** mainly to accurately place data in time. Age was determined by counting of winter lines.
- **Bivalve shells were** stored after boiling and removal of the flesh, **cleaned** with deionized water **and ground** to powder size.
- Each sample, of about 1 mg, was prepared following [6].
- ^{14}C **measurement** was **done by gas ion source – MICADAS AMS at LIP.**

Results



1

- The marine bomb pulse in the surface mixed layer expresses regional differences [7]. Thus, **we used published shell ^{14}C data** of *A. islandica* [8] that was captured before the large reprocessing releases (see figures in Abstract) **to define a regional bomb pulse**.
- We found that ^{14}C displayed by *A. islandica* can be approached by combining 25% of the atmospheric 'Northern Hemisphere 1' [1] and 75% of the Marine09 curve [2].
- **The** calculated **regional bomb-^{14}C pulse** (black line) **was used to identify the excess ^{14}C** due to other anthropogenic sources, notably the discharge of liquid reprocessing-^{14}C.



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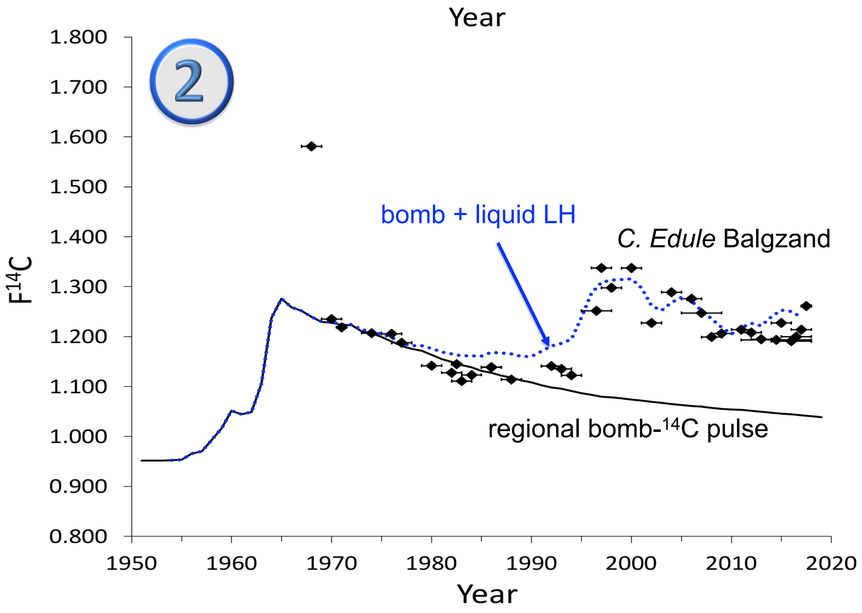
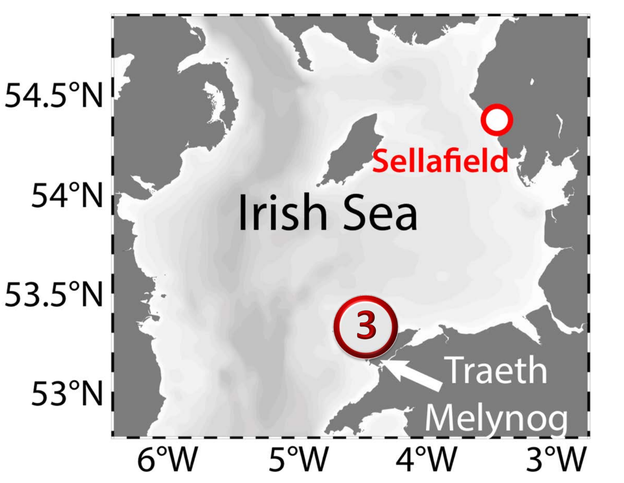
- **In Balgzand**, cockles generally presented F^{14}C values of 1.100 – 1.300.
- The **shell ^{14}C** content **was well above** the **regional bomb-^{14}C pulse after** the **mid-1990s**.
- **Shell ^{14}C are compared to simulated ^{14}C values** for the sea surface (blue line). The simulated ^{14}C reflects the regional bomb pulse with the addition of liquid releases of reprocessing-^{14}C from the La Hague plant.
- By applying a multiple linear regression we found that **the combination of both sources explained over 85 % of the temporal evolution (variability and magnitude) of ^{14}C in the cockles**.
- Results also imply that **other anthropogenic sources** (nuclear power plants, gas reprocessing releases, etc.) **play a minor role** in sea surface levels of ^{14}C.





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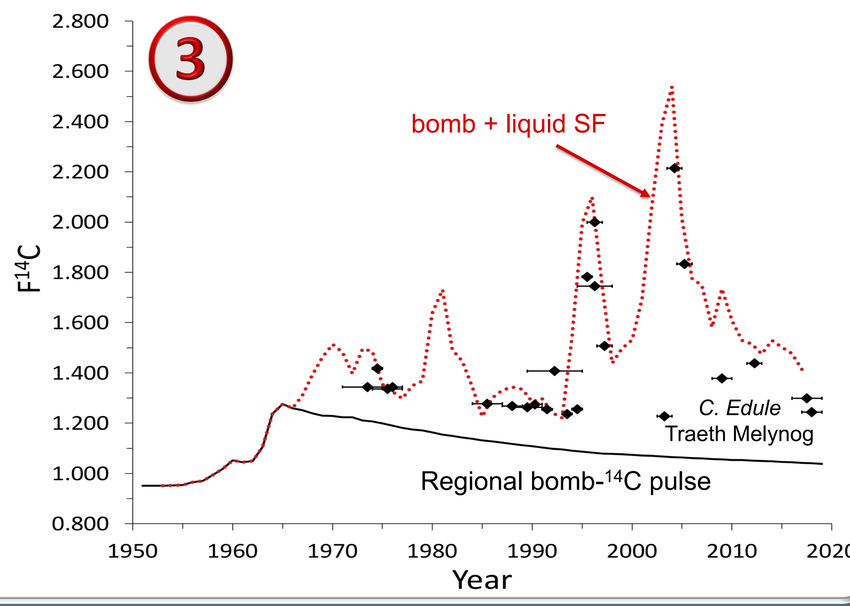
- **In Traeth Melynog**, cockles generally present F^{14}C values of 1.200 – 2.200.
- The **cockle ^{14}C** content **showed a greater temporal variability** than in Balgzand.
- In this case, the **shell data are compared to** the red dotted line representing the **simulated ^{14}C** values for Irish Sea surface waters. Here, the reprocessing component correspond to the liquid ^{14}C discharged from the Sellafield plant.
- A **similar regression model** was tested showing that the effect of the liquid reprocessing-^{14}C released from Sellafield explained 63% of the variance.
- **Overall, both datsasets** at Balgzand and Traeth Melynog **evidenced the impact of reprocessing** releases **on the** observed **temporal evolution of ^{14}C in the surface mixed layer**.



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