Transit Times in the North Atlantic DWBC Measured Using the Tracer Pair $^{129}$I/CFC-11

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$^{129}$I Tracer Characteristics

- $t_{1/2} = 1.6 \times 10^7$ y
- Measured by AMS (IsoTrace: Univ. Toronto)
- 250 ml samples
- $200$/sample for AMS
- Sample collection; cheap
- Nuclear fuel reprocessing plant source – Sellafield (UK) & La Hague (France)
Input to DSOW
Core has uniform flow, \( u \); interior has zero flow; mixing between regions is parameterized as relaxation with time scale, \( t_{\text{mix}} \); \( \alpha = \delta_b/\delta_i \) (= 0.1 in DWBC).
Tracer continuity equations:

\[
\frac{\partial c_b}{\partial t} + u \frac{\partial c_b}{\partial x} + \frac{1}{t_{mix}} (c_b - c_i) = S \\
\frac{\partial c_i}{\partial t} - \frac{\alpha}{t_{mix}} (c_b - c_i) = S
\]

\(c_b\) and \(c_i\) are tracer concentrations in boundary current and interior, respectively; \(S\) is tracer source or sink. Similar to Pickart et al. (1989); Rhein (1994); Doney and Jenkins, 1994.
\[ u = 2 - 3 \text{ cm/s} \]
\[ t_{\text{mix}} = 3.5 - 7 \text{ y} \]
Conclusions

- Boundary current model advection times ($t_{\text{adv}}$) of 5–7 y ($u = 3$ and 2 cm/s, respectively) and mixing times ($t_{\text{mix}}$) of 3.5–7 y (intermediate to low mixing regimes) are all consistent with $^{129}\text{I}/\text{CFC-11}$ results for the DWBC at Line W and the Labrador Sea.

- Values of $u = 5$ cm/s; $t_{\text{mix}} = 1$ y are consistent with best-fit values in models of Pickart et al., 1989; Doney and Jenkins, 1994; core velocity is similar to mean velocities from direct measurements. However, other tracer studies imply lower spreading rates.

- Line W $^{129}\text{I}/\text{CFC-11}$ results (2010-2012) will further constrain advection and mixing times.
Transit Time Distributions for Boundary Current Model:

\[ c(x, t) = \int_0^t c(x, t')G(x, t')dt' \]

\( c_o(t) \) = time varying, tracer concentration at \( r = 0 \)
\( c(x, t) \) = interior tracer concentration
\( G(x, t) \) is the TTD at location \( x \)

\[ G(x, t) = G_1 \delta(t - t_{adv}) + G_2 \Theta(t - t_{adv}) \]

\[ G_1 = e^{-t_{adv}/t_{mix}} \]

\[ G_2 = \frac{\alpha}{\zeta_{mix}} \frac{e^{-(\zeta_{adv})_{t_{adv}}/t_{mix}}}{I_1(2\zeta_{adv}/t_{mix})} \]

\( t_{adv} = x / u \) = advective time to reach point \( x \)
\( \zeta' = (\alpha u / x)(t - x / u) \)

\( I_1 \) = modified Bessel function of first order,
\( \delta \) = Dirac delta function
\( \Theta \) = Heaviside function

Waugh and Hall JPO 2005
Transit Time Distributions for Boundary Current Model:

\[ c(x, t) = \int_0^x c_o(t - t')G(x, t')dt' \]

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\[ G_1 = e^{-t_{adv}/t_{mix}} \]
\[ G_2 = \frac{\alpha}{\zeta t_{mix}} e^{-(\zeta^2)/t_{adv}} I_1 \left( 2\zeta t_{adv}/t_{mix} \right) \]

\( t_{adv} = x/u = \text{advective time to reach point } x \)
\( \zeta = (\alpha u / x)(t - x/u) \)
\( I_1 = \text{modified Bessel function of first order,} \)
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