

# <sup>234</sup>Th-Derived Particulate Organic Carbon Export Flux in the Labrador Sea: Significance of the POC/<sup>234</sup>Th Ratio as a Function of Particle-Size

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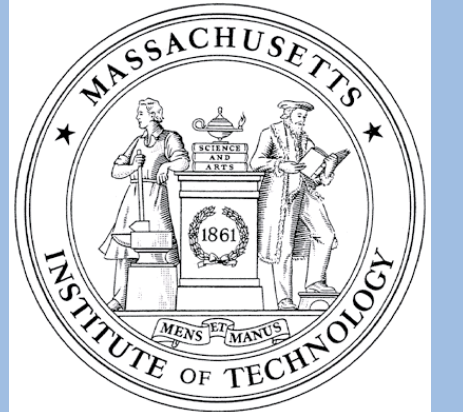
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## Abstract

Measurements of <sup>234</sup>Th/<sup>238</sup>U disequilibrium and the POC/<sup>234</sup>Th ratio of sinking particulate matter in the upper ocean are increasingly being used in oceanographic field programs to estimate the downward flux of particulate organic carbon (POC) from the euphotic zone. It is clear that the POC/<sup>234</sup>Th ratio of marine particles can vary significantly in space and time due to changes in biological productivity, particle export and particle size distribution. Developing a quantitative understanding of the processes controlling the variability in POC/<sup>234</sup>Th ratios of marine particles is essential for validating the use of <sup>234</sup>Th to estimate POC fluxes from the surface ocean. Here we report water column measurements of POC/<sup>234</sup>Th ratios in three particle size-classes (1-10 μm, 10-53 μm, and >53 μm) from four stations occupied in the Labrador Sea, July 1999. Samples were collected for determination of dissolved and particulate <sup>234</sup>Th activity and POC concentration using large-volume in-situ pumps and Go-flo bottles. Results indicate: 1) <sup>234</sup>Th/<sup>238</sup>U disequilibrium at all locations, and 2) a decrease in the POC/<sup>234</sup>Th ratio with increasing particle size and, for the intermediate and large-size fractions, with depth. Variability in the POC/<sup>234</sup>Th ratio with particle size is consistent with simulations derived using a physical adsorption-aggregation model of Burd et al. (2000). <sup>234</sup>Th-derived POC export fluxes for the intermediate and large particle size-fractions are similar in magnitude, on the order of 3.2 - 32 mmol C m<sup>-2</sup> d<sup>-1</sup>. The implication is that intermediate size particles (10-53 μm) contribute significantly to the total POC flux, which would have been underestimated by calculations based on the large particle size-class (>53 μm) POC/<sup>234</sup>Th ratio.

## Study Area

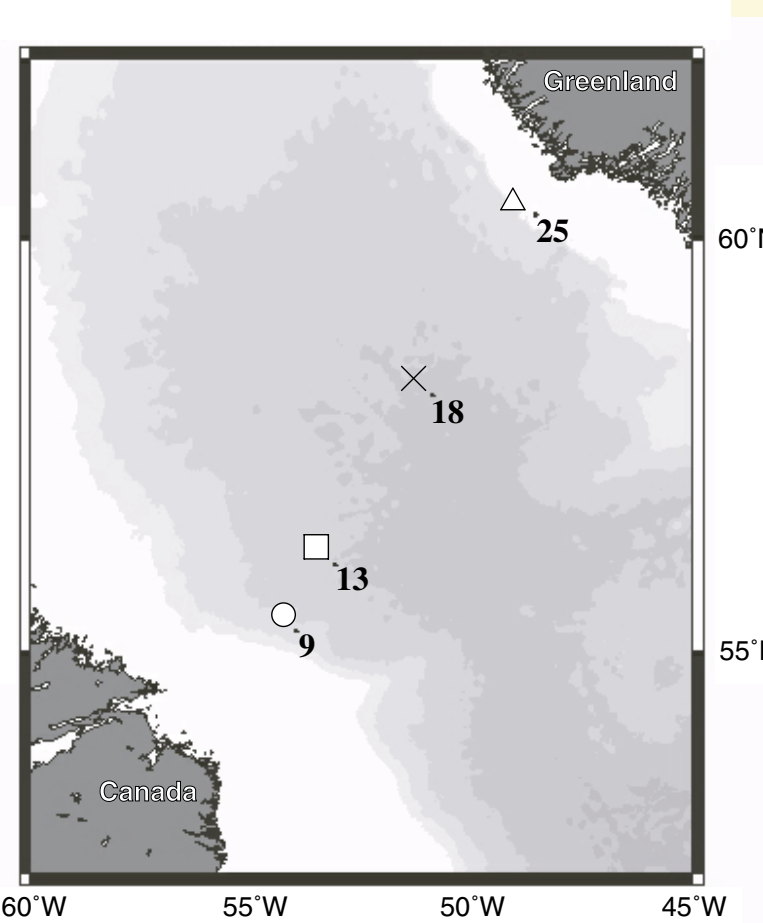


Figure 1. Map of Labrador Sea showing location of sampling stations. Measurements of particulate organic carbon (POC), <sup>234</sup>Th and <sup>238</sup>U activity at four stations in the Labrador Sea were made to determine the <sup>234</sup>Th-derived POC export flux at the end of the spring bloom season in July 1999 on the CSS Hudson.

## Hydrography and Primary Productivity

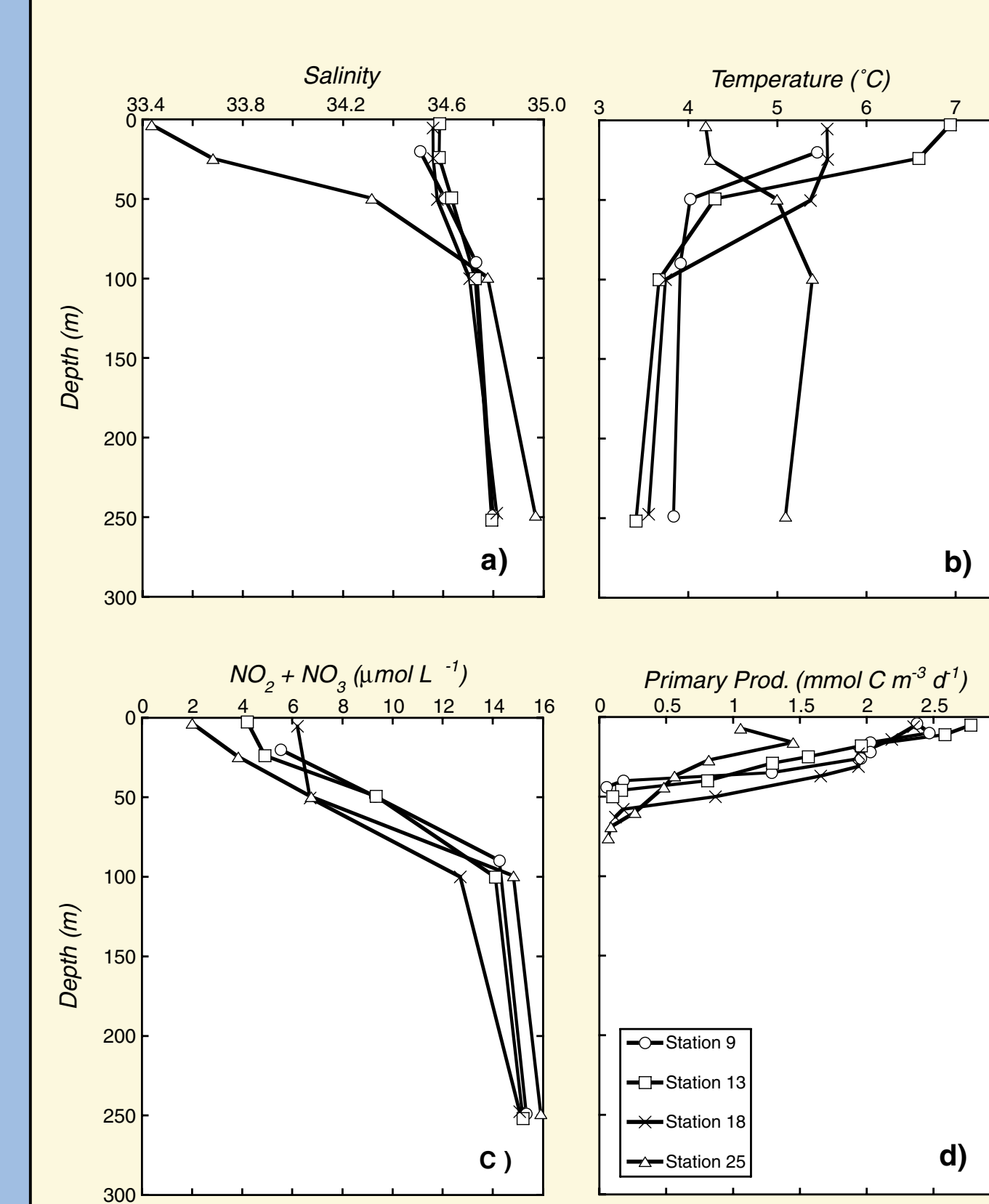


Figure 2a, b, c, and d. Depth profiles of salinity (a), temperature (b), nitrate+nitrite (c), and primary productivity (d).

- Surface waters at station 25 are cooler and less saline due to fresher, colder waters that enter the basin near the southern tip of Greenland.
- Pycnocline is evident between 50 and 100 m.
- Primary productivity decreases to light-limited levels at 50-75 m depth.

## <sup>234</sup>Th Activity Profiles

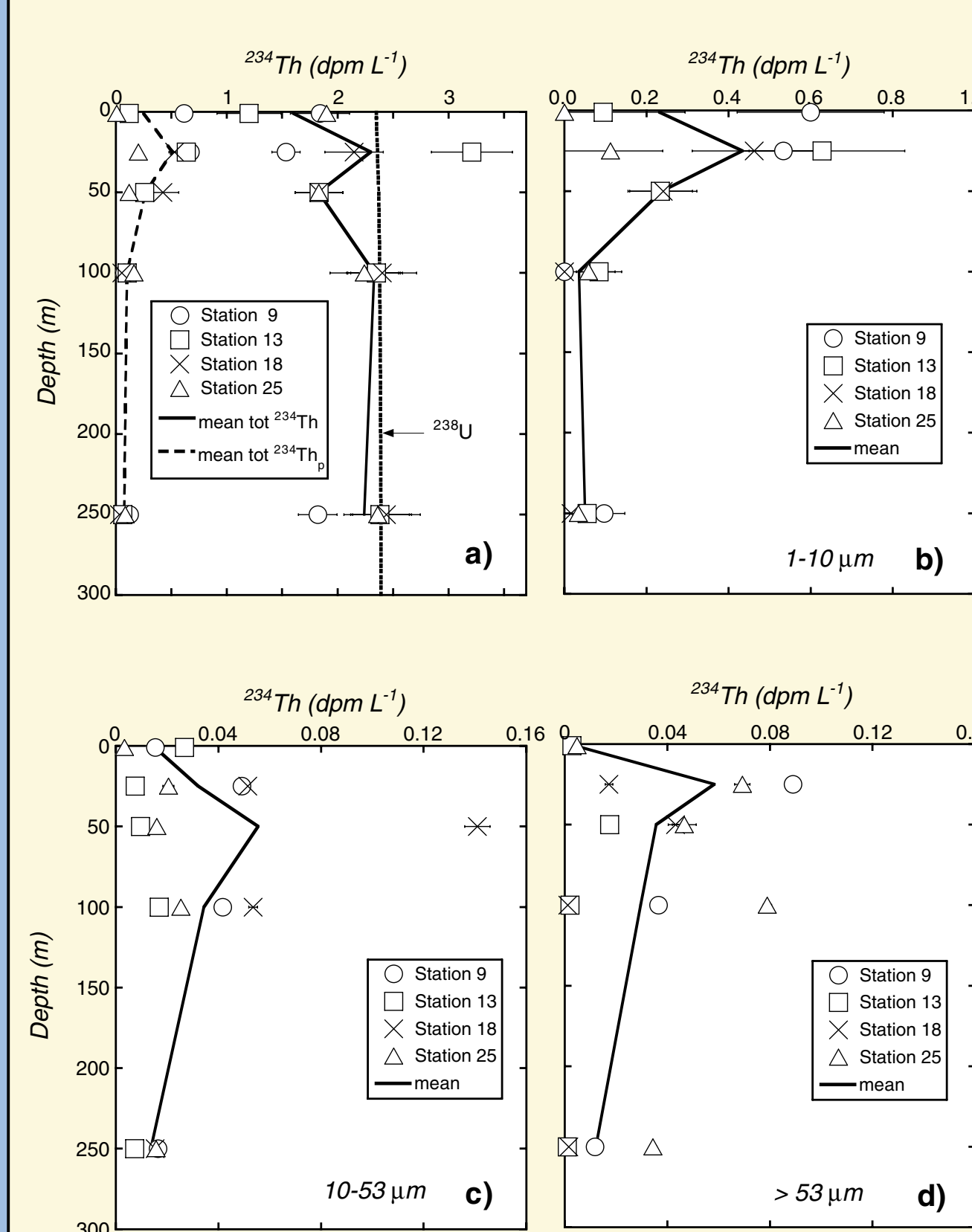


Figure 3a, b, c, and d. Particulate <sup>234</sup>Th activity and the <sup>234</sup>Th deficit shown between <sup>238</sup>U and total <sup>234</sup>Th activity (a), <sup>234</sup>Th activity for the 1-10 μm (b), 10-53 μm (c), and the >53 μm size fractions (d).

- Upper ocean <sup>234</sup>Th deficit is evident at all stations.
- Particulate <sup>234</sup>Th activity decreases with depth for all size fractions.
- <sup>234</sup>Th activity of the small size fraction (1-10 μm) is less than intermediate (10-53 μm) and large (>53 μm) size fractions.
- Similar <sup>234</sup>Th activities observed for intermediate & large size fractions.

## POC and POC/<sup>234</sup>Th Ratio Profiles

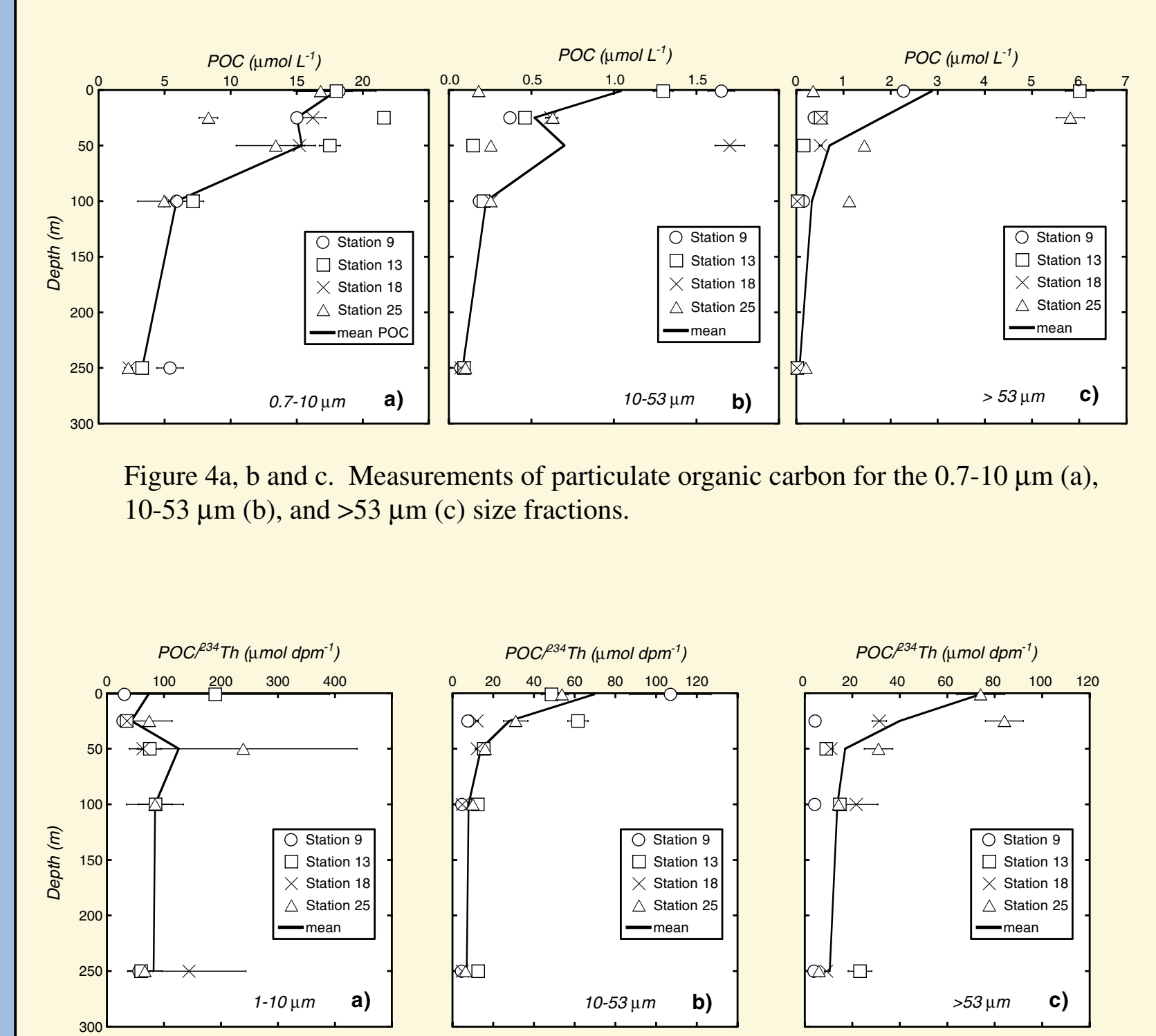


Figure 4a, b, and c. Measurements of particulate organic carbon for the 0.7-10 μm (a), 10-53 μm (b), and >53 μm (c) size fractions.

Figure 5a, b, and c. Depth profiles of POC/<sup>234</sup>Th ratio for the small (a), intermediate (b), and large (c) size fractions.

- POC concentrations decrease with depth for all size fractions.
- POC concentrations of the small size fraction are an order of magnitude greater than the intermediate and large size fractions.
- POC/<sup>234</sup>Th ratio of 1-10 μm size fraction is invariant with depth; marked decrease in ratio for intermediate and large size fractions.

## Methods

- Sample collection**
  - <sup>234</sup>Th and POC collected by large-volume in-situ pumps and Go-flo bottles
  - Water was pumped sequentially through filters: 53 μm Nitex → 10 μm Nitex → 1 μm pre-filter → 2 MnO<sub>2</sub> cartridges
  - >0.7 μm POC determined using Go-flo bottles.
  - New production was estimated using <sup>13</sup>C primary productivity values of incubation bottles.
- Sample processing**
  - Dissolved and 1 μm particulate <sup>234</sup>Th: gamma counted.
  - 10-53 μm and >53 μm particulate <sup>234</sup>Th: beta counted.
  - Methods after Buesseler et al., 1992; Moran et al., 1997; Charette and Moran, 1999.
- POC: Carlo-Erba CHN methods after Pike and Moran, 1997.
- Data Analysis**
  - <sup>234</sup>Th activity for the intermediate and large particle-size classes were decay corrected using Sigma Plot.
  - <sup>238</sup>U activity determined from CTD data using the equation  $^{238}\text{U} = 0.07081 \times \text{S}$  (Chen et al., 1986).

## References

- Buesseler et al. (1992) Deep-Sea Research 39, 1103-1114.  
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 Holmes, R.H. (1956) Bull. Bingham Oceanogr. Coll. 16, 3.  
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## Acknowledgments

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## POC Export Flux Model

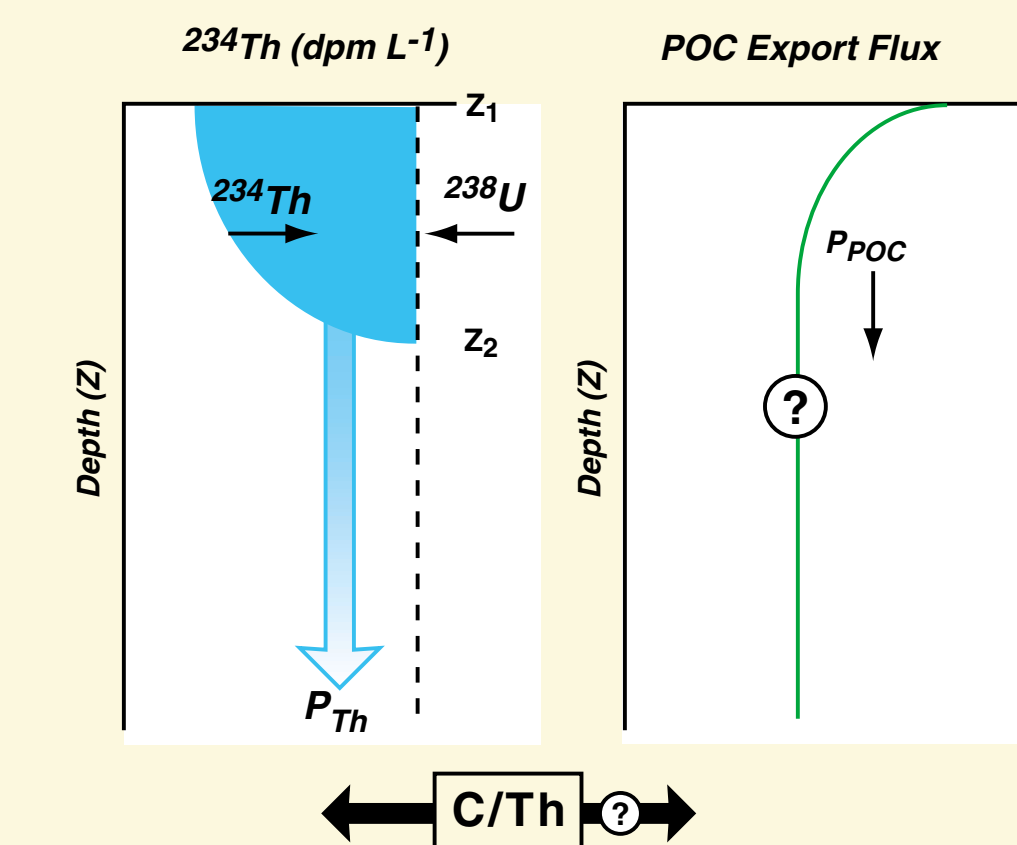


Figure 6. <sup>234</sup>Th/<sup>238</sup>U systematics and the POC export in the upper ocean.

## Background

- <sup>234</sup>Th is a particle reactive radionuclide and is a useful tracer of particle export on time scales of days to months ( $t_{1/2} = 24.1$  d), (Coale and Bruland, 1985).
- <sup>234</sup>Th is produced continuously by the alpha decay of <sup>238</sup>U.
- Due to particulate scavenging and export, there is a <sup>234</sup>Th deficit that results in a corresponding <sup>234</sup>Th flux,  $P_{Th}$ .
- The unknown POC flux ( $P_{POC}$ ) is calculated using the above equation.
- <sup>234</sup>Th-derived POC export has typically been determined using the (POC/<sup>234</sup>Th) >53 μm ratio.
- This study investigated the variability in the POC/<sup>234</sup>Th ratio as a function of particle size (1-10 μm, 10-53 μm, and >53 μm).

## Size-fractionated POC/<sup>234</sup>Th Ratio

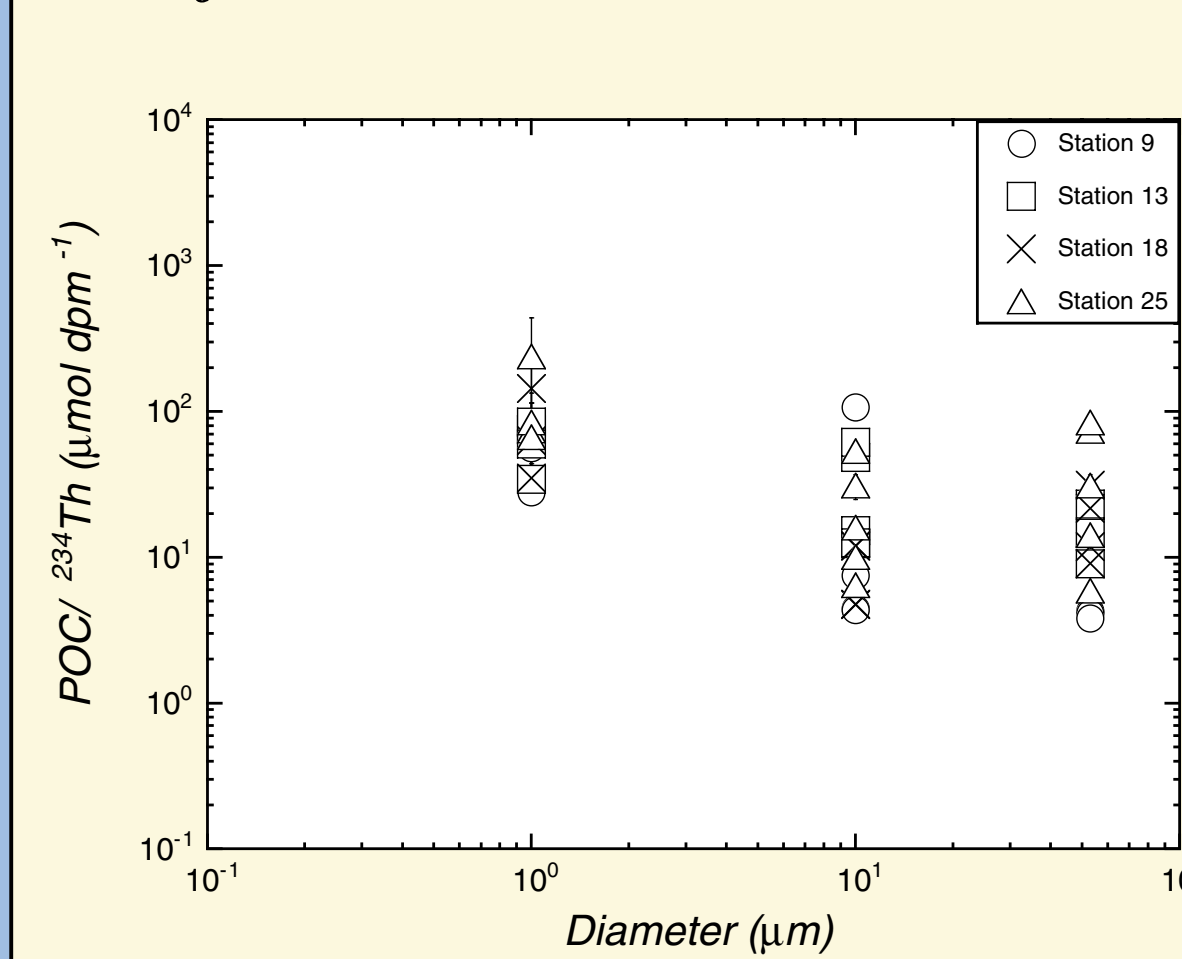


Figure 7a. POC/<sup>234</sup>Th ratio plotted against particle size.

- Inverse relationship between the POC/<sup>234</sup>Th ratio and the particle size.

- Similar POC/<sup>234</sup>Th ratios in 10-53 μm and >53 μm size fractions.

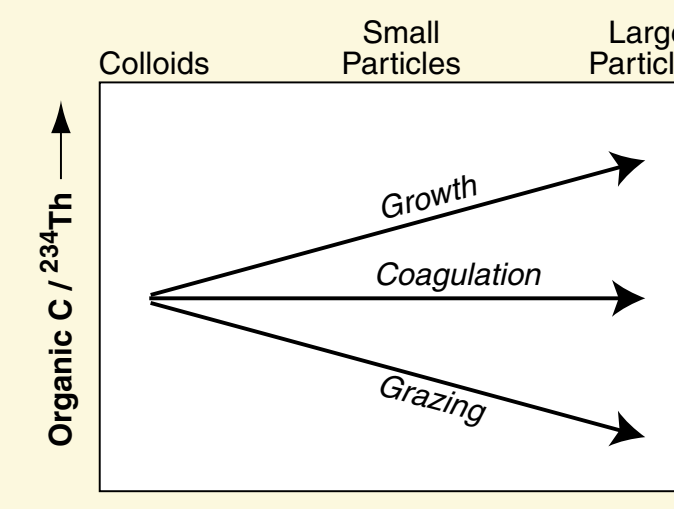


Figure 7b. Schematic of possible mechanisms affecting POC/<sup>234</sup>Th ratio as a function of particle size.

- Abundance and activity of protistan and metazoan grazers are highest during and after the phytoplankton bloom (i.e. spring through autumn), (Kielhorn 1952, Holmes, 1965).

- Grazing or remineralization by bacteria may be the cause for the decrease in POC/<sup>234</sup>Th with increasing particle size.

## Summary

### POC Export Fluxes and e-ratios

Table 1. Integrated primary productivity, particulate <sup>234</sup>Th export flux, POC/<sup>234</sup>Th ratios at 250 m, POC export flux, and e-ratios calculated for 10-53 μm and >53 μm particle size classes.

Sta.	Depth Range (m)	IPP (mmol m <sup>-2</sup> d <sup>-1</sup> )	P <sub>Th</sub> (dpm m <sup>-2</sup> d <sup>-1</sup> )	POC/ <sup>234</sup> Th <sub>250m</sub> (μmol dpm <sup>-1</sup> )	P <sub>POC</sub> (mmol m <sup>-2</sup> d <sup>-1</sup> )	e-ratio
				10-53 μm	10-53 μm	>53 μm
9	0-44	66.9	762.1	4.4	3.8	2.9
13	0-50	65.1	1002	12.6	0.1	0.2
18	0-63	84.3	2211	4.8	9.1	20.2
25	0-75	42.4	1413	6.4	5.9	5.1

- The POC/<sup>234</sup>Th ratio at 250 m was used to calculate the POC export flux.
- The values of POC/<sup>234</sup>Th, P<sub>POC</sub> and e-ratio of the 10-53 μm particle size-class are within the same order of magnitude as that of the P<sub>POC</sub> of the >53 μm size fraction.
- Particle scavenging and POC export is variable at the end of the spring bloom period in the Labrador Sea.
- A <sup>234</sup>Th deficit was observed at all stations.
- Measurements of particulate organic carbon and <sup>234</sup>Th activity in the Labrador Sea for the 3 size fractions indicate an inverse dependence of POC/<sup>234</sup>Th on particle size and depth.
- POC/<sup>234</sup>Th ratios and <sup>234</sup>Th-derived carbon export fluxes for the 10-53 μm and >53 μm size fractions were similar.
- Similar POC/<sup>234</sup>Th ratios in the intermediate and large particle size-class suggest the importance of an intermediate size fraction in POC export flux from the upper ocean.