Upper ocean export of particulate organic carbon in the Bering and Chukchi seas estimated from thorium-234

Hao Ma [1,2], Mingduan Yin[2], Liqi Chen[2], Jianhua He[2], Wen Yu [1,2] and Shi Zeng[1]

1. Department of Engineering Physics, Tsinghua University, Beijing China;
2. Key laboratory of Global Change and Marine-Atmospheric Chemistry, Third Institute of Oceanography, State Oceanic Administration, P.R. China

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Introduction

- **The euphotic zone:**
- 1. active water depth in the ocean for marine phytoplankton to convert inorganic carbon into organic carbon, resulting in a CO_2 exchange across the atmosphere/ocean interface.
- 2. important layer for the production of biogenic matter and for the vertical transport of particles to the deep sea.

- **POC** (particulate organic carbon) **export flux** from the euphotic zone to the deep ocean:
- 1. '*Export production*': critical index of the 'ability' of biological pump.
- 2. necessary measurement to determine the biogeochemical cycling rates of particle-reactive elements and constituents in the ocean.

Approaches to estimate POC export fluxes

1. sediment traps: hydrodynamic situations; ‘swimmer’; expensive (Buesseler, 1991)
2. radioactive isotope tracing technique: ^{234}Th-^{238}U disequilibrium method

Thorium-234(^{234}Th):

1. radioactive nuclide; high particle reactivity; produced *in-situ* by decay of ^{238}U
2. scavenged and removed rapidly with sinking particulate matter
   → ^{234}Th deficiency relative to ^{238}U (especially in the upper water column)
3. half life: 24.1d → tracing biogeochemical processes in the timescale similar to particle dynamics in the upper ocean (Cai et al., 2002; Waples et al., 2006)
4. **robust** method to estimate POC fluxes (Buesseler et al., 2006)

Experimental

Study area and sample collection

1. the Second Chinese National Arctic Expedition (CHINARE) from July to September 2003 on board R/V 'Xuelong'.
2. depth profiles of dissolved and particulate ^{234}Th in upper water columns collected at two stations in the Bering Sea (basin) and another one station in the Chukchi Sea (shelf).

Analysis and measurement

1. ^{234}Th: similar to traditional $Fe(OH)_3$ co-precipitation method with alpha-spectrometer and beta-counter (Anderson and Fleer, 1982; Chen et al., 1997);
2. ^{238}U ($dpm \cdot L^{-1}$)* =0.07081×salinity (Chen et al., 1986)

* *dpm means decay per minute and equals to 1/60 Bq*.

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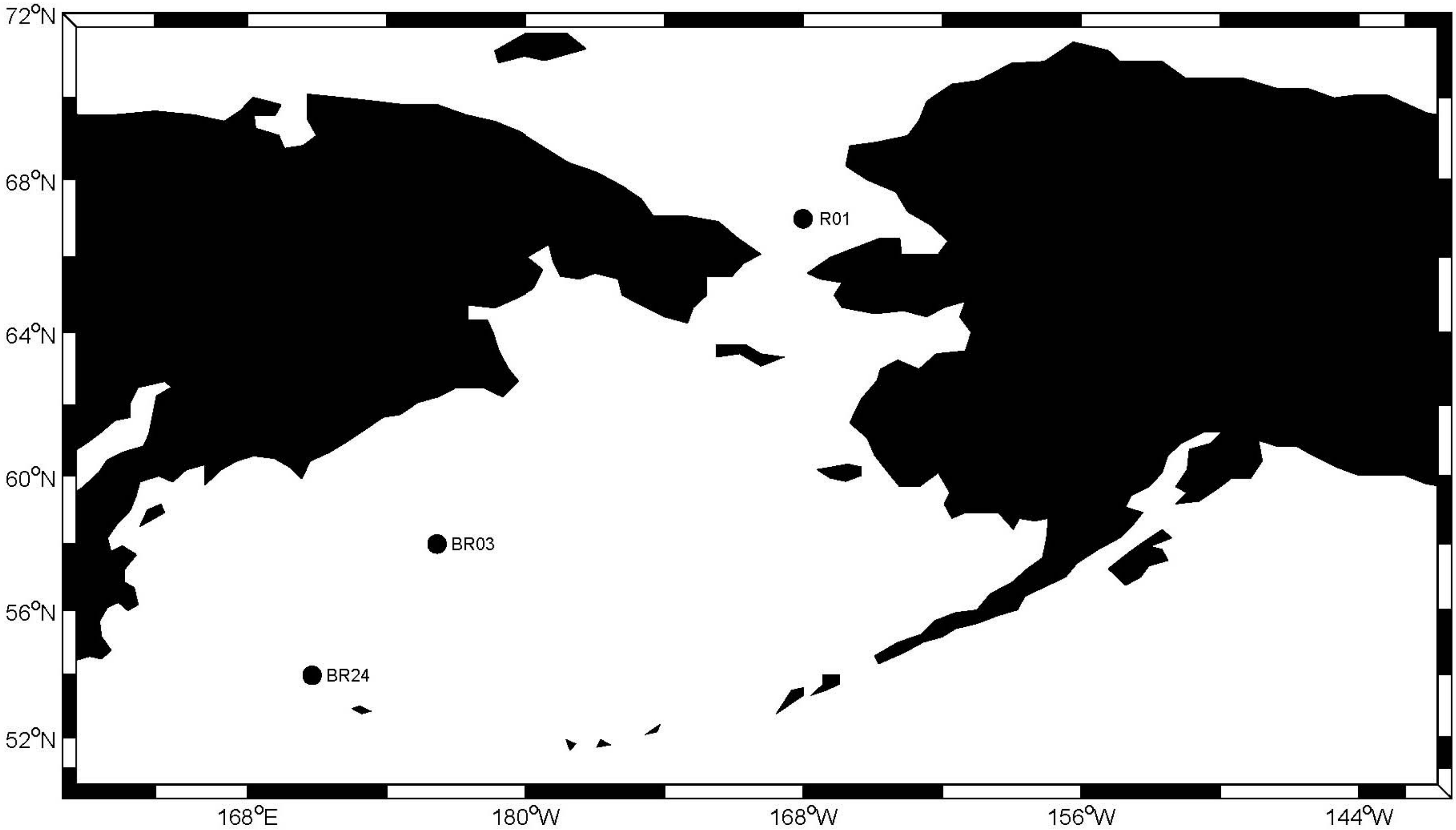
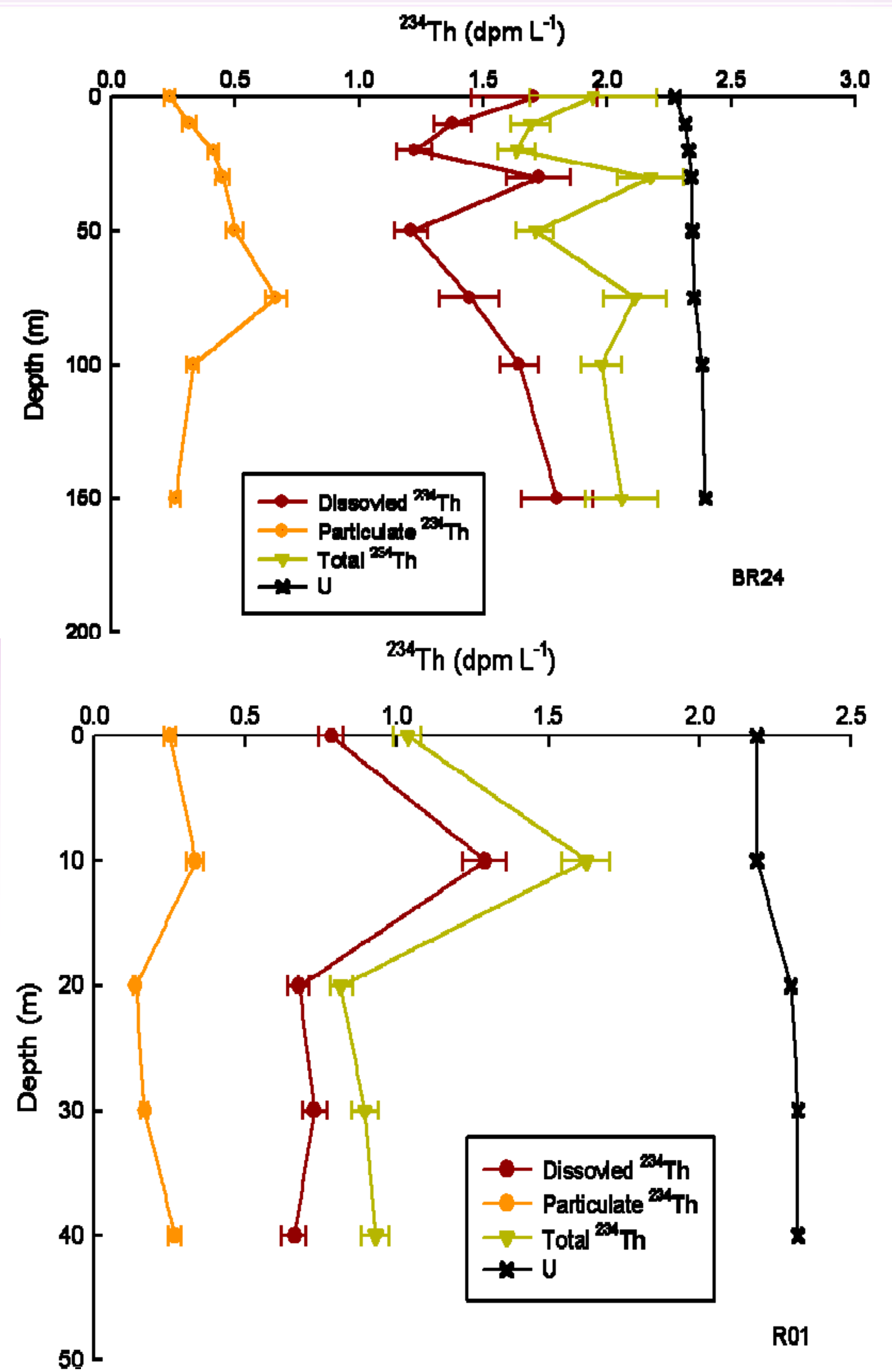


Fig.1 Sampling stations



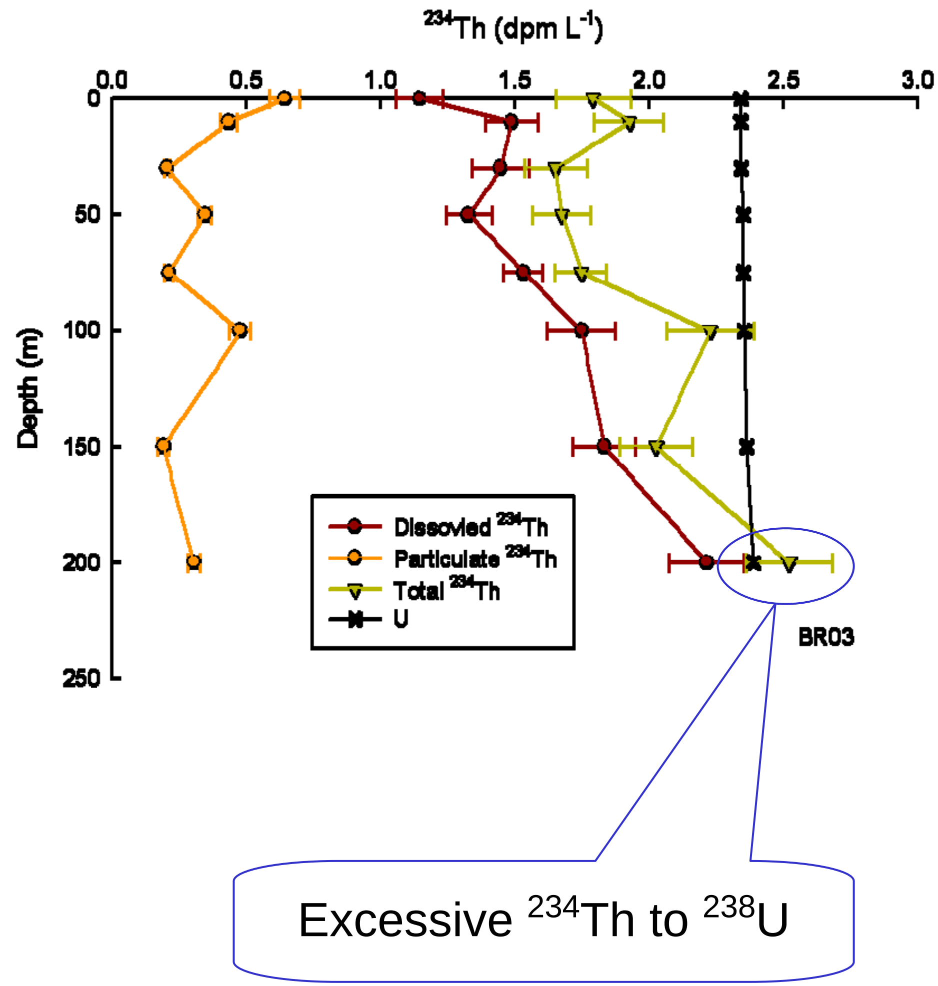


Fig.2 Depth profiles of ^{234}Th

Depth profiles

1. Particulate ^{234}Th: about 9%~36% of total ^{234}Th (dissolved plus particulate)
2. ^{234}Th shows apparent deficiency relative to ^{238}U in the euphotic zone → scavenged and removed with sinking particles to the deep ocean
3. tending to achieve a balance between total ^{234}Th and ^{238}U under 100m
4. BR03: excessive total ^{234}Th to ^{238}U, 200m depth : re-mineralization…
5. R01: total ^{234}Th notable deficiency as compared to ^{238}U, 40m depth: re-suspension of particles from bottom sediments…

Model

$$\partial A_{Th} / \partial t = 0 = \lambda \cdot \left[A_U - \left(A_{DTh} + A_{PTh} \right) \right] - P_{Th} + V$$ (Coale and Bruland, 1985)

A_U, A_{DTh} and A_{PTh} represent the activities ($dpm \cdot L^{-1}$) of ^{238}U, dissolved ^{234}Th and particulate ^{234}Th, and λ is the ^{234}Th decay constant ($0.02876\ d^{-1}$).
The term P_{Th} ($dpm \cdot m^{-3} \cdot d^{-1}$) represents the removal rate of particulate ^{234}Th due to particle sinking and V**,** the contributions of advection and diffusion to the ^{234}Th fluxes.

1-D steady state irreversible model neglecting V

$$\partial A_{DTh} / \partial t = 0 = \lambda \cdot A_U - \lambda \cdot A_{DTh} - J_{Th}$$

$$\partial A_{PTh} / \partial t = 0 = J_{Th} - \lambda \cdot A_{PTh} - P_{Th}$$

$$\tau_D = A_{DTh} / J_{Th}$$

$$\tau_P = A_{PTh} / P_{Th}$$

Table 1 Resident times of ^{234}Th with respect to particle scavenging and removal

Stations	Depth of the euphotic zone /m	τ_D /d	τ_P /d	^{234}Th fluxes/ dpm m^{-2} d^{-1}
BR24	50	57.5	29.8	678.6
BR03	50	52.1	20.5	849.4
R01	40	29.1	9.8	1366.5

POC export fluxes

= ^{234}Th fluxes × (POC/part.^{234}Th)$_{\text{bottom of euphotic zone}}$

(Buesseler, 1998)

Results:

Bering Sea (basin): BR24: 11.66 mmol C m^{-2} d^{-1}

‘HNLC’ BR03: 11.69 mmol C m^{-2} d^{-1}

Chen M. et al. 2003: 10~15 mmol C m^{-2} d^{-1}

Chukchi Sea (shelf): R01: 21.32 mmol C m^{-2} d^{-1}

High productivity

MA Q. et al. 2005: 1.6~27 mmol C m^{-2} d^{-1}

ThE ratio

= POC export flux / primary productivity

(Buesseler, 1998)

- The fraction of carbon uptake removed from the upper ocean via sinking particles
- the efficiency of biological pump in the upper water column

Primary productivity

Bering Sea:

19.8 mmol C m^{-2} d^{-1} (Chen M. et al., 2003)

Chukchi shelf:

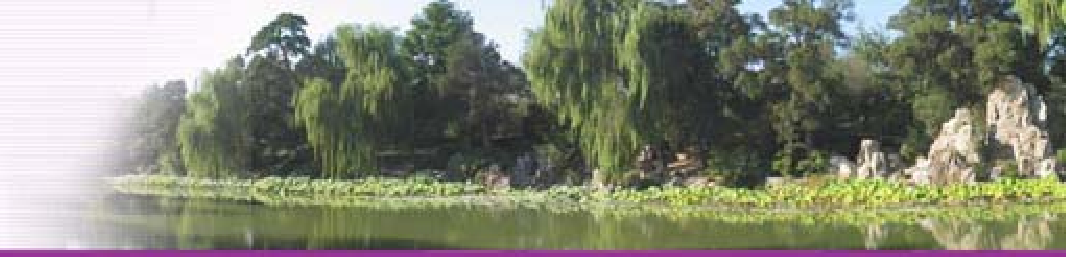
42.5 mmol C m^{-2} d^{-1} (Chen M. et al., 2002)

→ **ThE ratio**:

Bering Sea (basin): ~59% of carbon uptake by phytoplankton exported

Chukchi Sea (shelf): ~50% of organic carbon synthesized by phytoplankton exported

High ThE ratios in high-latitudes due to presence of large phytoplankton, particularly diatoms (Buesseler, 1998)



Summary

1. POC export flux of the Chukchi Sea (shelf, ~21.3 mmol C m^{-2} d^{-1}) was almost twice higher than that of the Bering Sea (basin, ~11.7 mmol C m^{-2} d^{-1}).
2. High ThE ratios in both investigated areas (>50%).
3. The high POC flux and ThE ratio indicate that Chukchi Sea has an actively running biological pump and is an important global carbon sink.
4. The high ThE ratios suggest the Bering basin may have great potential to absorb more CO_2 from atmosphere under certain conditions (e.g. iron fertilization…)

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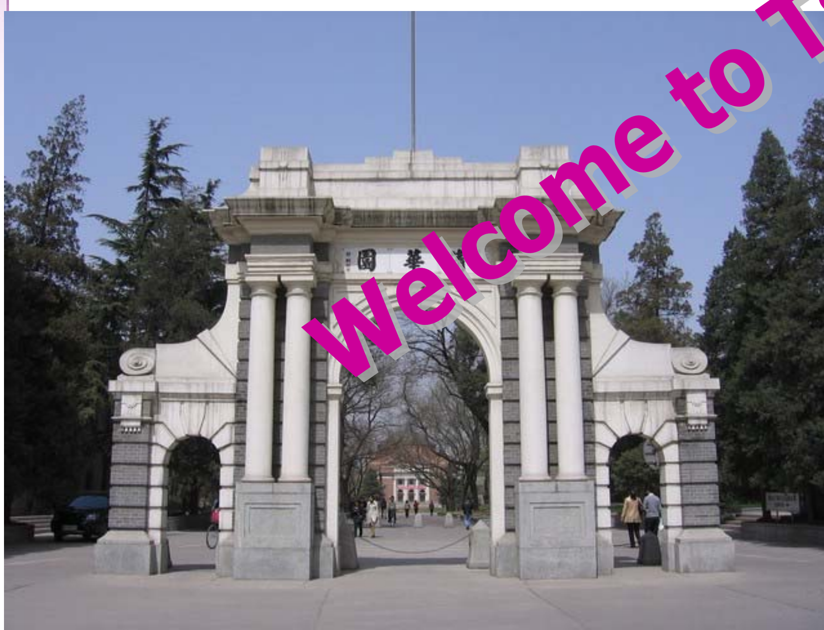

Thank you!