

# Thorium fluxes and carbon export from the Ross Sea: A preliminary report

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Export of organic carbon from the euphotic zone is an important parameter in modeling the global carbon cycle (Buesseler 1998a). Using  $^{234}\text{Th}$ , the 24-day, half life daughter of  $^{238}\text{U}$ , a consortium of oceanographic radiochemical groups (see acknowledgments) measured the removal of particles from the upper water column in the Ross Sea during 3 US JGOFS (US Joint Global Ocean Flux Study) sponsored cruises (October-November, 1996; Jan-Feb, 1997; and April-May, 1997) on the U.S. research icebreaker *Nathaniel B. Palmer*. The Ross Sea is an oceanic basin known to be a site of intense episodic plankton blooms following the spring ice breakup. The cruises were timed to bracket the bloom and capture in time the post bloom sinking particles. JGOFS participants were charged with characterizing the natural history, primary productivity and carbon removal rate of this bloom. We report here the sample sites and sample log of these three cruises during the 1996-1997 Austral spring-summer period. Data processing for these cruises is ongoing. Preliminary results can be found at the JGOFS website (<http://www1.whoi.edu/>) as well as maps, cruise reports and ancillary data.

The method of relating  $^{234}\text{Th}$  deficit to carbon export has been widely used and most recently overviewed by Buesseler et al. 1998a.  $^{234}\text{Th}$  is supplied at a concentration or activity equal to its radiogenic parent  $^{238}\text{U}$  which is conservative with salinity in aerobic oceanic environments. This activity is approximately 2.5 disintegrations per minute per liter (dpm/l) of seawater at a salinity of 35 per mil. The  $^{234}\text{Th}$ , in contrast to the  $^{238}\text{U}$  is particle reactive. The fraction of  $^{234}\text{Th}$  removed from the dissolved phase depends on the population and properties of the particles. Vertical removal of  $^{234}\text{Th}$  occurs as particles sink through the water column.  $^{234}\text{Th}$  will return to equilibrium with its uranium parent if no losses occur over a period of several half-lives (half-life = 24.2 days). Hence,  $^{234}\text{Th}$  is a self-replenishing tracer of particle export. At sea, collection of samples was done at discrete depths over the mixed layer using computer-controlled pumps (Challenger Oceanic and McLane Industries). Where wire time was not sufficient to permit deployment of multiple pumps, integrated samples were obtained using a depth averaging computer-controlled pump, the "Slurper" (Buesseler et. al. 1998b). The Slurper was slowly pulled through the desired depth range. Feedback between the depth sensor, computer and pump allowed discrete volumes to be sampled over small increments of the depth range. For example, 20-liter volumes at 5-meter intervals over a 100-depth interval would result in a 400 liter integrated sample.

**Stations and sample type for <sup>234</sup>Th, POC, and PON measurements.**

**Cruise NBP96-4B**

Station	Latitude S	Longitude (E=+; W=-)	Date	Sample Type
Orca	-76.50	-177.97	10/08/96	10M-300M; 7 point profile
"S"	-76.50	179.96	10/19/96	5-105M integrated
"O"	-76.46	175.92	10/20/96	5-105M integrated
Pseudo-Minke	-76.56	169.07	10/23/96	10M-720M; 7 pt. profile
Orca	-76.49	-177.80	11/02/96	10M-300M; 7 point profile
"O"	-76.50	175.99	11/04/96	5-105M integrated
"O"	-76.50	175.99	11/04/96	110M
122	-76.49	172.01	11/05/96	5-105M integrated

**Cruise NBP97-1**

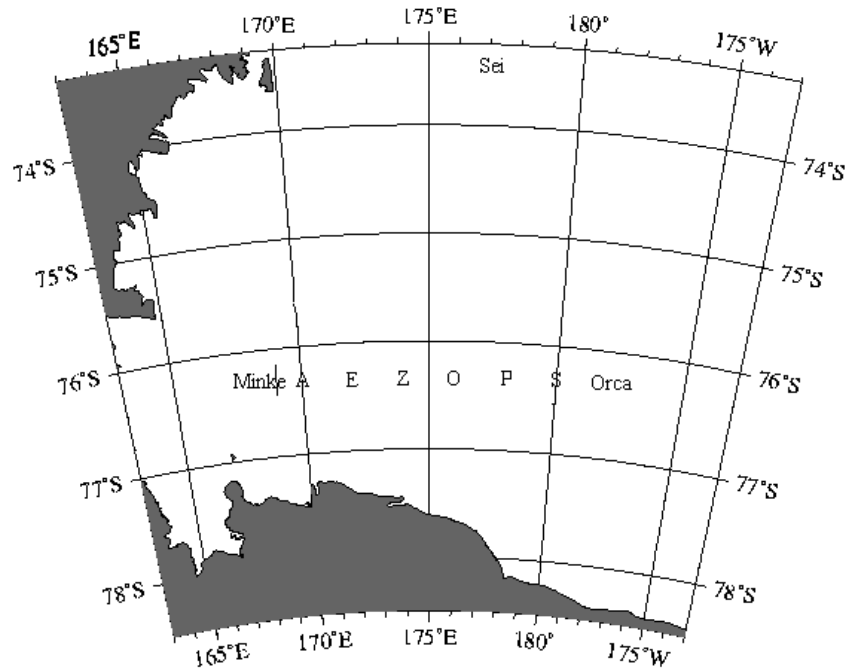
Station	Latitude S	Longitude (E=+; W=-)	Date	Sample Type
Minke	-76.50	169.00	01/13/97	10M-105M 4 pt. profile
Minke	-76.50	169.01	01/14/97	10M-110M integrated
"A"	-76.49	169.96	01/15/97	10M-110M integrated
"O"	-76.49	176.05	01/16/97	100M
"O"	-76.49	176.05	01/16/97	10M-110M; integrated
Orca	-76.50	-178.05	01/19/97	5M-105M; 4 pt. profile
Sei	-74.04	177.00	01/24/97	10M-305M; 5 pt. profile
Sei	-74.01	176.95	01/24/97	10M-110M integrated
Blue	-74.33	-175.99	01/26/97	5 pt. 1000M-1100M calibration
213	-76.59	168.91	01/28/97	10M-110M integrated
214	-76.56	170.26	01/29/97	10M-110M integrated
"O"	-76.40	176.31	01/31/97	100M
"O"	-76.40	176.31	01/31/97	10M-110M integrated
"S"	-76.51	179.99	01/31/97	10M-110M integrated
Orca	-76.50	-177.99	02/01/97	10M-500M; 6 pt. profile
224	-77.39	175.95	02/04/97	10M-110M integrated
225	-76.50	176.04	02/04/97	100M
225	-76.50	176.14	02/05/97	10M-110M integrated
Minke	-76.50	168.99	02/08/97	30M-600M; 5 pt. profile

**Cruise NBP97-3**

<b>Station</b>	<b>Latitude S</b>	<b>Longitude (E=+; W=-)</b>	<b>Date</b>	<b>Sample Type</b>
301	-67.63	175.16	04/10/97	4 pt. 1900M-2000M calibration
Sei	-74.35	175.97	04/13/97	5M-105M; 5 pt. profile
Orca	-76.44	-177.99	04/14/97	5M-105M; 6 pt. profile
Pseudo-Minke	-76.47	169.06	04/18/97	5M-105M; 6 pt. profile
RIS2	-77.99	-176.11	04/20/97	10M-75M; 4 pt. profile
Orca	-76.48	-177.96	04/23/97	5M-200M 7 pt. profile
"O"	-76.50	176.02	04/24/97	10M-125M; 5 pt. profile
Minke	-76.50	168.97	04/27/97	5M-200M; 10 pt. profile
Sei	-73.97	176.11	04/30/97	5M-200M; 8 pt. profile
Deep	-67.98	175.99	05/04/97	4 pt. 1500M calibration

Measurement of  $^{234}\text{Th}$  was made on two particle size fractions ( $>70\mu$  and  $1-70\mu$ ) and the dissolved phase (Hartman and Buesseler 1994) using at-sea beta and gamma counting instruments. Samples were returned to shore-based labs for POC/PON analysis of particulate phases and chemical yield measurements for the calibration of the at-sea counters. A flux or removal rate of  $^{234}\text{Th}$  is calculated from the difference between the measured and equilibrium activities and is integrated over the depth sampled. The ratio of carbon or nitrogen to thorium concentration on the filters is multiplied by the integrated thorium flux to give integrated carbon flux.

The majority of the station locations sampled in the Ross Sea during the three cruises fall on the  $76^{\circ}30'$  S. latitude or “AESOPS” line (figure). Major stations Minke and Orca define the eastern and western boundaries of the line while an additional northern station “Sei” was visited less frequently. Station “Blue” or “Deep” (not shown) were sampled off shelf for deep  $^{238}\text{U}/^{234}\text{Th}$  equilibrium deep water for method calibration. Additional stations were sometimes added as cruise time and conditions permitted and are referred to by a 3-digit number, the first digit referring to cruise 1, 2, or 3.



**Station locations for Ross Sea JGOFS stations.**

The first cruise, NBP96-4B (cruise participants: John Andrews and Dave Hirschberg), found high ice coverage of the sampling area. The phytoplankton bloom was only beginning to happen in the later days of the cruise when ice breakup was occurring. In fact, the ship was not able to occupy many stations sampled during later cruises due to

ice thickness.  $^{234}\text{Th}$  values were uniformly near equilibrium, implying no particle scavenging or export. Cruise 2, NBP97-1 (cruise participants: Lary Ball and Alan Fleer), did not schedule wire time for as many multipoint profiles, hence the large proportion of integrated samples. This cruise experienced an intense phytoplankton bloom primarily of genus phaeocystis. The  $^{234}\text{Th}$  shows deficits of up to 1.5 dpm/l in the region of station 214 (near station "A" on the map) signifying rapid particle removal. Cruise 3, NBP 97-3 (cruise participants: David Hirschberg and Ellen Rosen), was coincident with the end of the particle export period of cruise 2.  $^{234}\text{Th}$  during this period was beginning to return to equilibrium values with deficits on the order of 0.5-0.8 dpm/l typically. The station "Pseudominke," is exceptional in showing deficits on the order of the 1.5 dpm/l as for NBP97-1.

The studies discussed here represent the activities of three separate research teams. The thorium consortium during these Ross Sea cruises consisted of the groups of Ken O. Buesseler (Cafe Thorium: John Andrews and Lary Ball), Michael Bacon (Alan Fleer and Ellen Rosen) and J. Kirk Cochran (David Hirschberg). We thank the captain and crew of the *Nathaniel B. Palmer* and the members of the Antarctic Support Associates for their professional assistance in this field effort.

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