A GLOBAL BUDGET OF CARBON AND NITROGEN IN THE ROSS SEA (SOUTHERN OCEAN)

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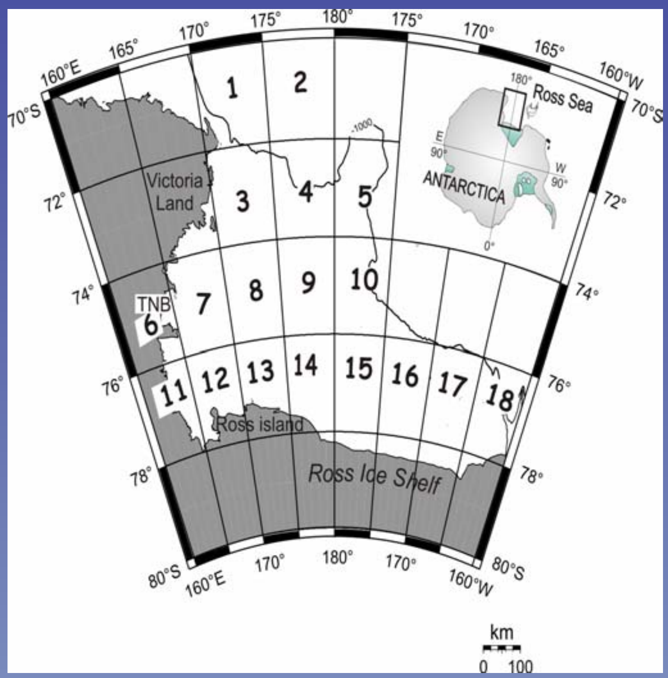
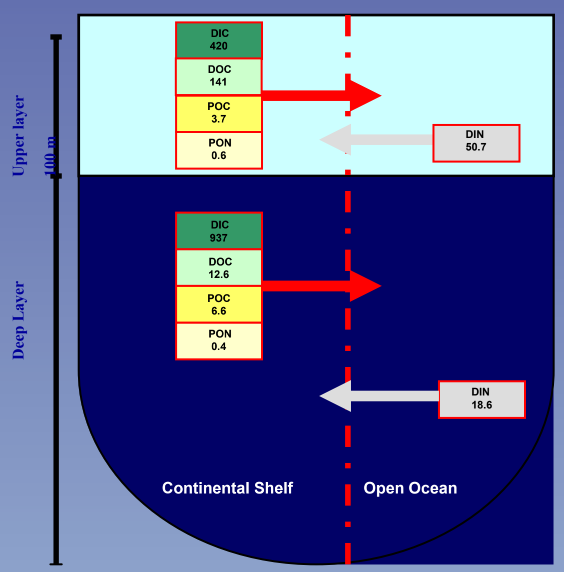
Global budgets of carbon and nitrogen in the Ross Sea Antarctica are presented; both vertical sedimentary fluxes and water mass lateral transport between the continental shelf area and the open Southern Ocean were taken into account. The budgets are based upon a large data base, using data from ten Italian oceanographic cruises carried out in the Ross Sea from November through February over 15 years as well as from literature data. In particular, we consulted the US JGOFS web site.

The Ross Sea is characterized by a large variability in space and time of macro and micronutrients and the primary production is high, about four times the values measured in other areas of the Southern Ocean.

To calculate an integrated budget of carbon and nitrogen, the Ross Sea was divided into 18 sub regions. Sub-regions 1-2 were considered as part of the open-ocean domain; for the continental shelf area, sub-regions 3 through 18, mean annual fluxes were calculated and multiplied by the sub-region surface area to obtain the integrated annual flux.



Antarctica with the Ross Sea



Ross Sea-Southern Ocean: lateral transport

Advective transport of materials between the continental shelf area and the open ocean were estimated from hydrological datasets of water mass lateral transport across the continental slope. Temperature and salinity were used to define the major water masses, (Modified C Deep Water-MCDW, High salinity Shelf Water-HSSW, Deep Ice Shelf Water-DISW) and weighted mean values for each water mass were calculated for dissolved oxygen (O2), dissolved inorganic carbon (DIC), inorganic nitrogen (DIN), dissolved and particulate carbon (DOC and POC) and particulate organic nitrogen (PON).

The highest export occurred from the deeper layer, despite the intense primary production in the upper layer during spring-summer. This is presumably due to the presence of sea-ice for large part of the year as well as on a complex equilibrium between the biological pump and the solubility pump.

In order to calculate the total budgets, we assume, as an approximation due to the lack of a convection model, the downward settling of particles being the only way of exchange between the upper productive layer and the deep layers; stratification usually occurs in summer with a warmer less salted surface layer and a deep winter-water layer. Several independent parameters were employed to calculate fluxes of carbon and nitrogen along the water column and eventually to the sediments:

- **Gross Primary production (GPP), Carbon Dioxide Production Rate (CDPR), drawdown of nitrate plus nitrite (∆DIN).**
- **Flux of POC and PON from sediment traps and, in some cases, from 234Th deficit**
- **Burial rates from core samples**

Primary production measurements

in situ *simulated conditions as well as PvsE experiments were performed in different areas and seasons over the last 12 years. and average photosynthetic parameters have been defined for each of the Ross Sea areas and depth layers. Total primary production for each of the Ross Sea sub-regions was estimated on the basis of in situ measurements (98 stations) and, for other 120 stations, by means of the equation of Saggiomo et al. (2002). The equation considers the photosynthetic parameters, mean daily irradiance and Chla concentration for each area and depth layer. Starting from the GPP and its partitioning, it has been calculated the surplus of POC, DOC and PON produced in the respective pools*

Fourfold difference occurred in annual primary production between the different sub-regions, from 51 to 201 gC m-2 y-1. Highest values were measured in the southern part of the Ross Sea and low values were recorded in the northern and offshore areas. As a whole, we estimated an annual production of 4068 Gmol, on average 109 gC m-2.

Carbon Dioxide Production Rate CDPR

CDPR represents the rate of carbon remineralization (DOC and POC) carried out by the microbial community; community respiration was determined by means of the ETS activity along the water column in 49 stations for a total of 322 samples.

Nitrate drawdown

Nutrient concentrations were determined in 300 stations sampled during several cruises and distributed over the Ross Sea. The ∆DIN winter-summer deficit was estimated from the difference between the integrated quantities of DIN in the upper layer in summer and those occurring in winter. Winter nutrient concentrations were derived from the DIN concentrations recorded immediately below the upper mixed layer in each station that were considered as a memory of the winter values (Catalano et al. 1997). To calculate the inorganic carbon deficit (∆DIC) from ∆DIN (winter-summer) a C:N ratio of 6.7 was used.

Net community production (NCP), defined as primary production minus the rate of carbon remineralization, in the upper layer was used to estimate the net carbon assimilation into biomass (∆POCNCP) and into the DOC pool (∆DOCNCP). .

In the deep layer (>100m), the vertical flux of POC and PON incoming from the upper 100 m was considered as the source of both DIC and DIN surplus by means of the CO2 production rate of the microbial community and the overall export to higher trophic levels (GRAZ) plus the dissolved organic pool.

Sediment traps

Downward fluxes of biogenic particles were estimated from the data collected since 1983 by several Italian and US research projects (ROAVERRS) at altogether 18 mooring sites (see authors for references).

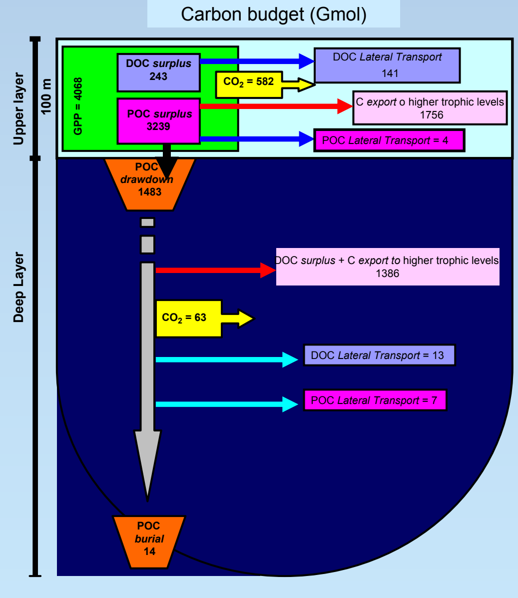
Mean annual fluxes of biogenic material ranged from 13.3 to 585 mmol m-2 for organic carbon and from 2.9 to 71.4 mmol m-2 of nitrogen. Highest fluxes occurred in the sub-regions 12 and 13. The integrated flux for the entire Ross Sea shelf area was 98.7 Gmol for POC and 12.3 Gmol for PON.

Burial rates

Burial rates were obtained from a total of 40 sediment cores (see authors for references).

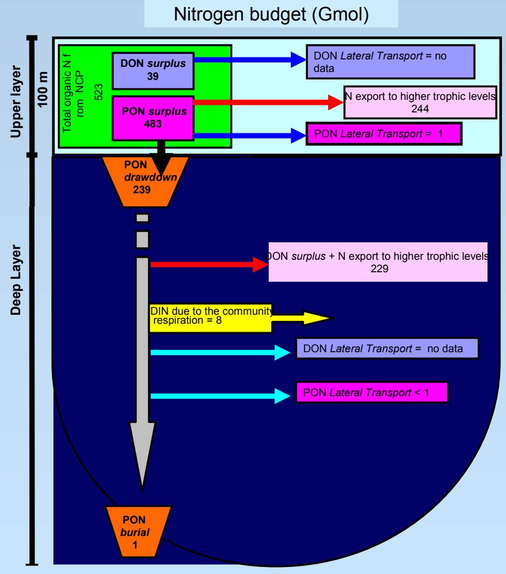
Average burial rates of biogenic material ranged from 3.8 to 343.8 mmol m-2 y-1 of carbon and 0.9 to 33.7 mmol m-2 y-1 of nitrogen; about 80% of total organic carbon and nitrogen accumulation in the sediments occurred in sub-regions 4, 11 and 12.

The annual amount for the Ross Sea as a whole was estimated 14.4 Gmol of carbon and 1.4 Gmol of nitrogen.



The wide range in POC export (1285-1681 Gmol) depending upon to which extent DIC lateral losses were considered as resulting from the consumption of new production; the mean value is reported.

Our results are consistent with previous POC fluxes calculated by summer nitrate drawdown (Nelson et al.,2002). Estimates of POC export to the deep layer from sediment trap data have been also evaluated and an underestimate of approx. one order of magnitude has been calculated. Such large discrepancy has been already pointed out in several studies. In our case, some explanation might come from the position of sediment traps at –200m, out of reach of icebergs; it is possible that further remineralization and grazing on particulate matter occurs in the 100-200m depth interval.



The PON drawdown, directly derived from nitrate plus nitrite summer deficit found in the upper layer, is one of the independent parameters used to calculate the nitrogen budget. It was here preferred to the sediment trap data to evaluate the PON export from the upper layer (Nelson et al., 2001).

Nitrogen budget is however still incomplete due to two major shortcomings: the data on dissolved organic nitrogen were too few and no data were found as to the denitrification rate in the Ross Sea. These two lacks shall have to be filled in order to obtain a more reliable picture of nitrogen cycle in the Ross Sea.

Conclusions:

Our estimate indicates that the amount of carbon recycled within the Ross Sea is almost one order of magnitude higher than the carbon exchange with the open ocean.

The deep layer, the most relevant for the continental shelf pump, releases carbon to the open ocean as DIC (937 Gmol) DOC (13 Gmol) and POC (7 Gmol).

On the other hand, the nitrogen balance is strongly positive for the Ross sea: less than 1 Gmol is released to the deep open ocean and 19 Gmol is imported from the open ocean to the Ross Sea.

The burial of C into the sediments is negligible: less than 0.55% of the POC resulting from the net community production. A large portion of the particulate matter produced in the upper layer, 3142 Gmol of carbon and 473 Gmol of nitrogen, is exported to higher trophic levels and, partially, to DOC and DON pool. This finding seems quite reasonable taking into account the high biomass supported by the primary production in the Ross Sea.

The POC surplus evaluated as the sum of the carbon exported to the deep layer and that transferred to higher trophic levels also provides an indication of potential CO2 demand due to the biological pump in the Ross Sea.

References

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