Particle flux at the Iberian Margin

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Introduction

Studies of processes at continental margins such as in the OMEX framework are important contributions to understanding of carbon fluxes and those of other biogenic and non-biogenic matter in the oceans. The Iberian Margin, as the second OMEX investigation site, provides unique features for undertaking such studies due to its particular bottom topography, current regime and particle export dynamics in surface waters. Its steep slope is in contrast to features encountered at the Goban Spur, and seasonal changes in current direction yield an alternation of upwelling and non-upwelling in surface waters, controlling seasonal changes in particle production, food web dynamics and, hence, also particle exports.

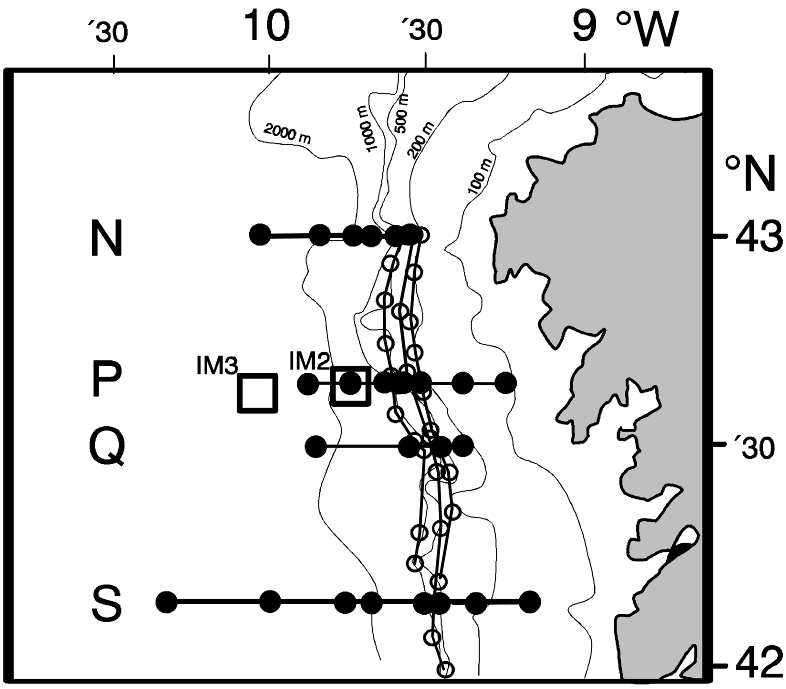

Figure 1: Sediment trap mooring positions IM 3 and IM 2 in the OMEX Box (open squares); transects across the Iberian Margin (N to S; filled circles) and along-slope transects between 43° and 42°N (open circles) conducted in March 1998.

Particle flux was investigated by means of sediment traps in two moorings through summer 1997 to winter 1999 (Fig. 1; Tab. 1). Mooring positions had been selected for a high probability to encounter differences as to lateral inputs of particles originating from the shelf (secondary fluxes). Mooring IM 2, thus, was positioned 10 nautical miles from the shelf break (200-m isobath) at a water depth of 1500 m, and mooring IM 3 was placed 15 nautical miles further to the west at a water depth of 2200 m. A second criterion for the site selection was that both should be under the influence of upwelling and, hence, experience vertical particles fluxes from seasonally varying epipelagic export regimes. This was ensured by placing both moorings at approximately 42° 38´ N, a latitude for which satellite pictures give a high probability of encountering an upwelling filament that may extend far off the shelf over the adjacent ocean basin. Both positions further met requirements for mooring work as to bottom topography.

Particle flux assessment was paralleled by current and transmission/backscatter measurements during cruises, with results to be placed in the context of pelagic production seasonality and changes in hydrographic conditions. In the following we present results from the first flux investigation July 1997 - February 1998 that covers an upwelling summer/autumn and a non-upwelling winter period. Samples from a second series (February 1998 - January 1999) are being analysed in the laboratory presently and will be added to this time-series later. Results give information on the origin of settling particles in terms of primary (pelagic) and secondary (resuspended / laterally advected) sources and on changes in biogeochemically relevant composition. They evidence the importance of sporadic flux events at a scale of weeks and of seasonal patterns related to pelagic system dynamics in the upwelling cycle. Further to particle flux data, results of mappings of suspended matter in the OMEX box are presented. These were conducted on transects (Fig. 1) during a winter/ early spring cruise to document intermediate and bottom-near nepheloid layers which may play an important role in the interaction between the shelf to the adjacent deep-sea basin.

Methods

Details of instrument deployments in moorings IM 2 and 3 (Fig. 1) are given in Table 1. For the first time-series July 1997 - February 1998 presented here, samples are at hand for the 600-m and 1100-m depth horizons for both stations (no data from IM 3 trap at 1750-m trap which had malfunctioned).
Kiel type sediment traps (manufacturer Aquatec, Kiel) were deployed together with Aanderaa current meters (fitted with transmissiometers or optical backscatter sensors). For comparability between sites, the same deployment depths were chosen as at the OMEX Goban Spur locality. Traps were pre-programmed to intercept particles with a 1.5 - 2 weeks resolution, and samples were preserved *in situ* with mercuric chloride to prevent organic matter degradation. Laboratory treatment followed JGOFS standards including a thorough picking of swimmers prior to splitting samples for various analyses. Trap data are presented for mass flux (determined gravimetrically) and fluxes of POC (gas chromatography using an Heraeus CHN analyser) and particulate biogenic Silicon (Opal-Si; determined colorimetrically following alkaline wet digestion of samples; data corrected for leaching in collection cups).

Table 1: Configurations of sediment trap moorings IM 2 and IM 3 at the Iberian Margin during two deployment periods June 1997 - February 1998 and March 1998 - January 1999 (*in situ* pumps deployed during the second period only).

Mooring ID	Water depth	Position	Instrument Depth	Instrument
IM 2	1500 m	42°39’ N, 9°42’ W	580 m	Sediment trap
			600 m	Current meter
			650 m	*In situ* pump
			1050 m	Sediment trap
			1070 m	Current meter
			1120 m	*In situ* pump
IM 3	2230 m	42°38´ N, 10°02´ W	570 m	Sediment trap
			590 m	Current meter
			645 m	*In situ* pump
			1050 m	Sediment trap
			1070 m	Current meter
			1750 m	Sediment trap
			1770 m	Current meter

During the second deployment period both moorings were fitted with *in situ* pumps (Baltec, Norderstedt, Germany) to filter and preserve suspended particles during each trap-sampling interval.

Distributions of water column suspended matter in the OMEX box was monitored by means of a SeaTech transmissiometer or an optical backscatter sensor attached to a CTD. Raw data are given to qualitatively show the presence of intermediate and bottom-near nepheloid layers (INL and BNL) on transects along the margin at the 500-m, 1000-m and 1500-m isobaths (at 43° to 42°N) and across the margin on transects N to S in the OMEX box (Fig. 1).

Results and Discussion

A. Suspended particle distribution

Suspended particle distribution as deduced from transmissiometer profiles on transects in the OMEX box during February/March 1998 are given in Figure 2 and 3. Intermediate nepheloid layers were commonly and most pronouncedly observed at about 200 - 300 m depth but profiles often contained multiple INLs as well. Pronounced ones were found within a limited distance of the shelf break only, at water depths <1500 m. It is concluded that mooring IM 2, located at this water depth (distance of ca. 10 nautical miles west of the 200 m isobath), is more likely to receive lateral particle injections from such INLs than mooring IM 3 placed another ca. 15 nautical miles west at 2200 m water depth. The poleward current appears to form a barrier to cross-slope SPM transport below surface layers so that high particle loads are limited to close to the shelf break. Figure 2 shows a case on the P-transect, where an INL extends well beyond the IM 2 position in March 1998.

Findings on this and other transects perpendicular to the slope suggest that the 200 - 300 m INLs originate from BNLs that preferentially leave the sea bed at water depths of 200 m or shallower. Profiles taken on transects along the slope (Fig. 3), on the other hand, confirm that INLs and BNLs are distributed heterogeneously along the continental margin. Preferential source areas, possibly related to canyons, cannot be pointed out based on our data set. These must be investigated with a finer spatial resolution in relation to bottom topography.

B. Particle flux at the Iberian Margin

Measurements of bulk variable in trap samples enable us to differentiate spatial and temporal patterns and to point out different sources of the flux. Figure 4 depicts mass flux and POC and Opal-Si fluxes for moorings IM 3 (25 nautical miles west of the 200 m isobath) and IM 2 (10 nautical miles west of the 200 m contour) between July 1997 and February 1998. A comparison of the Iberian Margin with the OMEX I Goban Spur site has to be based on daily fluxes, averaged for the July - February period, as a complete annual cycle still is not yet at hand. The Goban Spur data were calculated accordingly for this purpose. Table 2 also includes results from the Porcupine Sea Bight and the Bay of Biscay for comparison. The following patterns emerge.

At a seasonal scale, fluxes of all variables are elevated during August at both sites and at both sampled depth horizons. Sea surface temperature distribution in the upper water column off the northern Iberian Margin, as investigated by the OMEX Remote Sensing Group, clearly shows upwelling conditions prevailing at both mooring positions during this time. This is known to promote diatom growth based on new production, and associated food web dynamics commonly enhance particle exports with a prominent autotrophic component. This is indeed supported by ongoing microscopic analyses that evidences numerous diatoms, pennate and centric species, in trap samples from July/August. The siliceous component is dominated by empty diatom valves (intact and broken ones) but also plasma-filled cells are found. This is a clear indicator that freshly produced autotrophic matter with a prominent diatom component is being exported under such conditions. Fluxes during this time are elevated both at 600-m and at 1100-m depth suggesting a rapid vertical transfer of these exported particles.

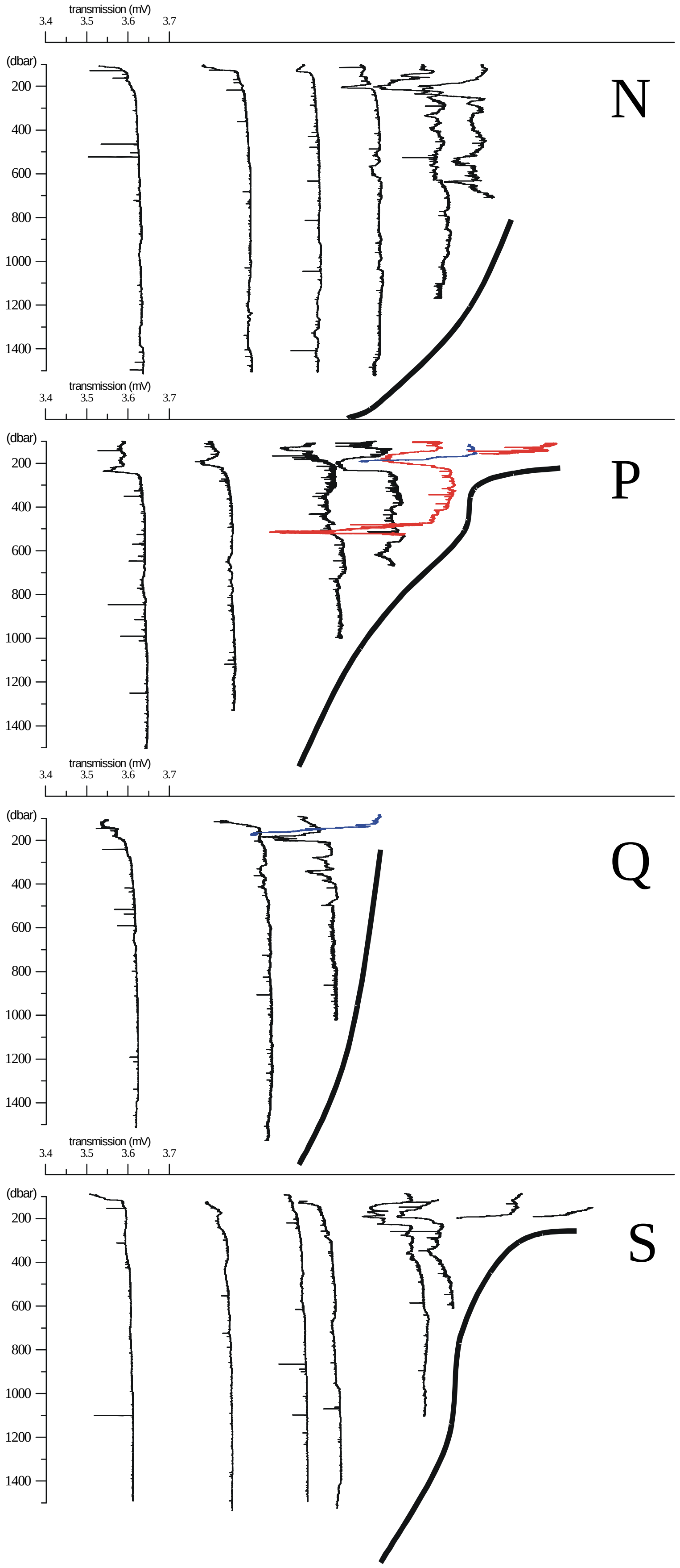

Figure 2: Transmissiometer profiles below 100 m depth (raw data; mV) taken on across-slope transects N to S (see map Fig. 1) in March 1998. Arrow marks approximate position of mooring IM 2 (distance between profiles not strictly proportional to real distance).

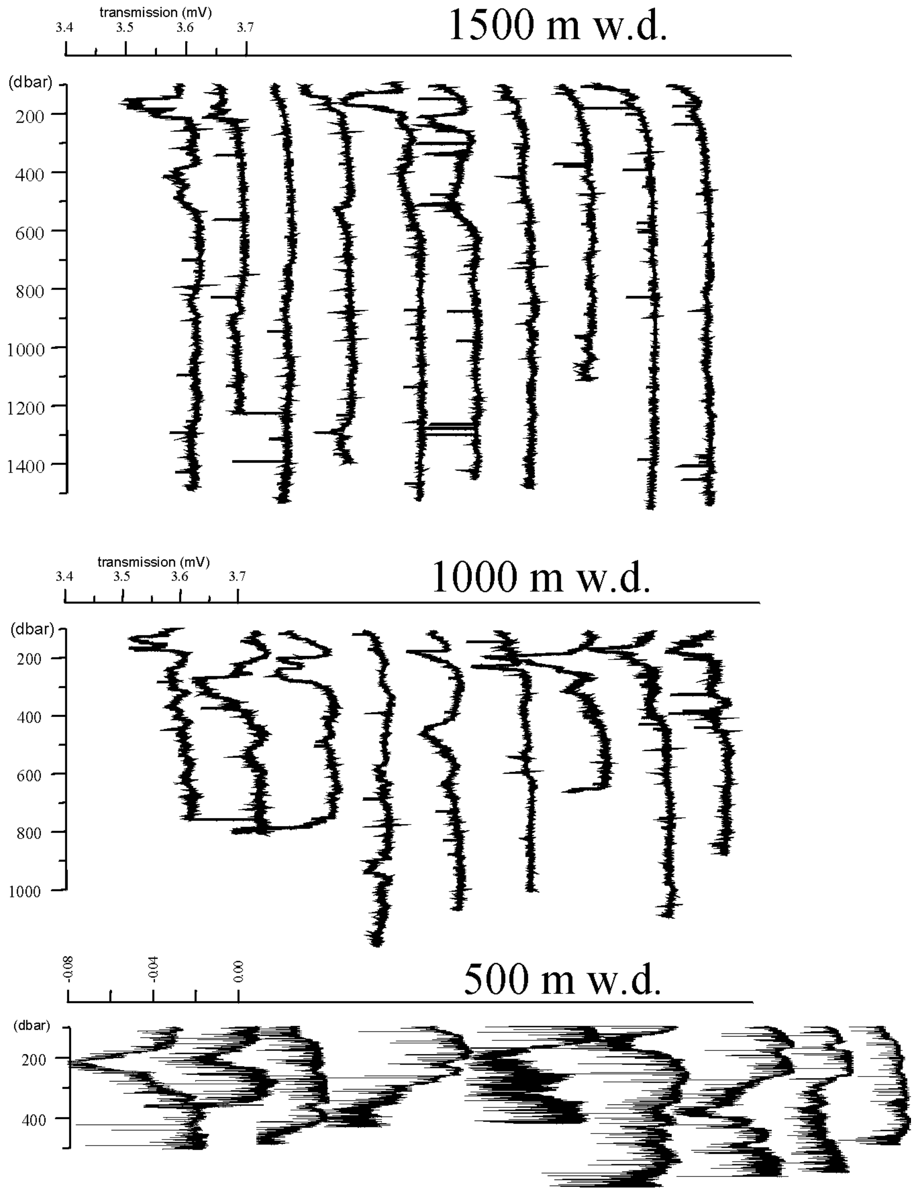

Figure 3: Transmissiometer profiles (raw data; mV) below 100-m depth taken on along-slope transects following the 1500-m and 1000-m depth contours. Lower plot gives backscatterometer readings (raw data in mV, multiplied by -1) along the 500-m isobath.

Elevated exports from summer upwelling were followed by a period of reduced fluxes until December during which, however, sporadic flux events were recorded. These can be seen in particular at the shallower depth horizon and, with an increase in magnitude, at the IM 2 position closer to the shelf break. Composition of intercepted particles clearly differs from that during the prior upwelling period as they contain little Opal only. Opal-Si fluxes remained at the seasonally lowest at both sites and at both sampling depths, highlighting a seasonal shift in the export regime established in the epipelagial over the traps. Qualitative microscopic inspections show an according change in the composition of hard-shelled plankton in trap samples. Small dinoflagellates and abundant tintinnid *Loricae* from a variety of species indicate that a more regenerated type of production prevailed during this period.

A second major seasonal increase in fluxes was recorded during winter (January) which presently is difficult to relate to pelagic system dynamics and possible changes in hydrographic/ chemical growth conditions in the OMEX Box. It is evident that material exported during this period is rich in Opal (*i.e.*, diatom remains) again. Differences seem to prevail as to the vertical transfer between 600-m and 1100-m depth and/or regarding lateral injections received by the deep traps. For IM 3 fluxes clearly decline vertically in January which was not the case during the summer upwelling period when secondary fluxes seem to have played a more important role this far off the shelf break. Such a comparison is difficult for mooring IM 2 due to a hiatus in the 600-m time series. The fact that mass and POC fluxes in this period (2.3 g m^{-2} d^{-1} and 79 mg m^{-2} d^{-1}, respectively) were the highest ones recorded during this whole time-series, however, suggests that lateral particle injection from the adjacent slope was a process of paramount importance at IM 2 in winter. We expect a better understanding for this pattern and for particle sources from ongoing microscopic inspections and from stable isotope analyses of these trap samples.

Average daily fluxes for the July - February period (Table 2) evidence that values close (10 nautical miles) to the shelf break at IM 2 are significantly higher than 15 nautical miles further off at IM 3. Most pronounced this is at 1100-m depth where total flux of 269 mg m^{-2} d^{-1} is higher by a factor of 4 on average. This is well in line with a significant higher lithogenic component at the IM 2 site (29% and 40% of total flux for 600 m and 1100 m, respectively). Trap results thus confirm those of the INL-survey on transects which suggested the prominent importance of sedimentary particle transport by INLs close to the shelf break. On average for the July - February period, particle flux at the Iberian Margin is much higher compared to the OMEX I Goban Spur site. Mass fluxes at IM 3 and IM 2, of 193 and 269 mg m^{-2} d^{-1} respectively, exceed those at the Goban Spur by a factor of 2 - 10 which we take as an indicator for the smaller distance of both IM moorings to the shelf break. The percentage contributions of POC and Opal to the biogenic flux are strikingly similar at both OMEX sites, whereas those of carbonate appear elevated by 10% or so at the Iberian Margin.

Table 2: Comparison between different continental margin sites as to mass flux (dry weight; average daily fluxes for respective sampling periods) and percentage contributions by lithogenic particles to total flux as well as those of carbonate, particulate organic carbon and Opal-Si to biogenic flux.

Location	***Mass Flux*** *(mg $m^{-2}d^{-1}$)*	***Lithogenics*** *(%mass flux)*	***CaCO3*** *(% biog. flux)*	***POC*** *(% biog. flux)*	***Opal***[§] *(% biog. flux)*
IBERIAN MARGIN*					
IM2a- 600 m	*193*	*29*	*63*	*15*	*7*
IM2a-1100 m	*269*	*40*	*72*	*10*	*7*
IM3a- 600 m	*137*	*11*	*73*	*10*	*7*
IM3a-1100 m	*85*	*17*	*73*	*9*	*9*
GOBAN SPUR*					
OMEX 2-600 m	*51*	*16*	*57*	*18*	*6*
OMEX 2-1050 m	*76*	*41*	*65*	*14*	*8*
OMEX 3-600 m	*29*	*0*	*61*	*18*	*4*
OMEX 3-1440 m	*104*	*38*	*65*	*13*	*10*
BAY OF BISCAY[1]					
MS2-1900 m	*323*			*4 (% total flux)*	
P. SEA BIGHT[2]					
PSB-1750 m	*82*		*50 (% total flux)*	*5 (% total flux)*	

[§] Fluxes uncorrected for leaching in trap cups

* Mean fluxes from July to January for the Iberian Margin (1997-1998) and Goban Spur (1993-1994)

[1] Etcheber *et al.*, 1996; mean annual fluxes

[2] Lampitt *et al.*, 1995; mean annual fluxes for Porcupine Sea Bight.

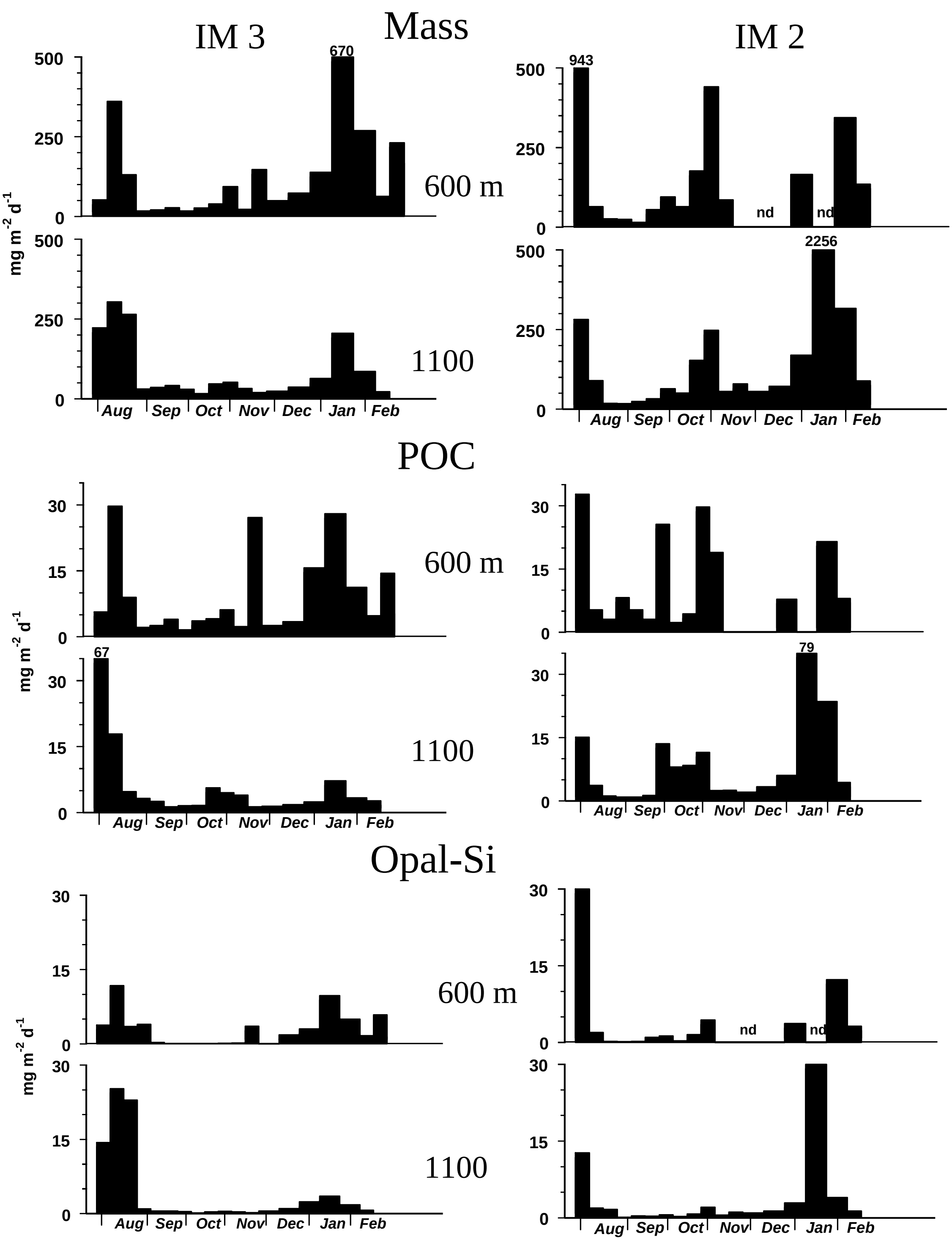

Figure 4: Particle flux at 600 m and 1100 m depth at the IM 3 and IM 2 positions: Mass flux (dry weight), particulate org. carbon (POC) and Opal-Si flux between July 1997 and February 1998. Hiatus in the IM 2 series (samples biased by fish in sampling jar) are marked n.d. (no data).