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Ocean Science Discussions

Interactive comment on "Silicon pool dynamics and biogenic silica export in the Southern Ocean, inferred from Si-isotopes" *by* F. Fripiat et al.

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Referee #1- This paper presents new Si isotopic data in the Southern Ocean, the data are numerous and of good quality. This manuscript only presents data of the sub-surface and deeper layers and discusses them in terms of mixing between the water masses. Another manuscript in preparation discusses the surface data in term of Si uptake. It would maybe be better to merge the two manuscripts and discuss the variations in the water column as a whole.

Authors - In this manuscript, the relation between mixed layers and the subsurface water masses is also discussed.

See: - First paragraph in the results section. - In the discussion 4.2, the mixed layer is

defined as being the late summer mixed layer when diatom growth ceased at the onset of the wintertime convective mixing.

Fripiat et al. (in prep) will present the whole bSiO2 dataset from this survey. The origin and fates of δ30SibSiO2 will be discussed on complete water column profiles and we propose a model for the seasonal variations of δ30Si in the mixed layer. We feel merging the two dataset into a single article would bring confusion to the reader and would result into a very long article.

Referee #1- I found the paper a bit confusing as it refers to numerous water masses without showing a complete schematic or figure. The results are there but they need to be presented more clearly and in a more synthetic way. One way to increase the importance of the manuscript would be to compile all data available in the Southern Ocean to complete Figure 6, maybe by having a two panels figure for the two basins (Atlantic and Indo-Australian).

Authors - In agreement with the comments of the reviewers, we agree that Figure 6 could be enhanced by comparing the Atlantic and Indo-Australian sections, and merged with Figure 4. Table 2 will be removed as it was ambiguous: different water masses were computed.

Specific comments

Introduction

Referee #1- P641, L16-17: please explain how the structure of the microbial food web impacts the N/Si decoupling

Authors - Grazing induces changes in the cell wall silicification in marine diatoms as an inducible defense against herbivory (Smetacek et al., 2004; Pondaven et al., 2007). The latter study demonstrates that grazing induced changes in cell wall silicification are of the same order of magnitude as those resulting from changes in the growth environment (Claquin et al., 2002, J. Phycol. 38, 922-930), which in turn results in a increase in Si:N and Si:C ratios.

Referee #1- P641, L19-20; Si remineralization can also be important

Authors - In agreement with previous works, we believe that only deep bSiO2 dissolution significantly impacts the silicic acid distribution by trapping silicic acid in the deeper circulation cells (Toggweiler et al., 2006; Sarmiento et al., 2007), long residence time in these waters allows to slowly dissolving biogenic silica to increase the silicic acid concentration. We'll provide this information in the revised manuscript.

Referee #1- P642, L27: I believe you mean Beucher et al., 2007

Authors - Right

Referee #1- P643, L10: Fripiat et al is actually in preparation (not 2011), the results are not available to the reader

Authors - We agree with the reviewer. In the revised manuscript "in prep" will be written instead of "2011".

Materials and methods

Referee #1- P643, L24: please specify the pressure used to filter the samples, diatoms cells can break under high pressure and release intracellular silicic acid which could affect the delta30Si of the dissolved and of the particulate Si

Authors - The pressure was less than 2 bars (corresponding to a water depth of less than 20m). We'll note this in the revised manuscript.

Results

Referee #1- P645, L20-23: confusing, we expect the average delta30Si to characterize the north-south gradients, what's the point of giving the above 100m vs. below delta30Si averages?

Authors - We'll remove this calculation in the revised manuscript as it was out of place.

This statement was already well seen with Figures 2 and 3.

Referee #1- P645-646, L26, 1-8: The water masses need to be defined and illustrated on a figure. I suggest a three panel ODV figure with temperature, salinity and oxygen with the fronts and location of the water masses. I would also extend the description of the different water masses and zones in the result.

Authors - We agree with the reviewers. These figures will be added in the revised manuscript. Nevertheless the description of the water masses in a circulation context was already discussed in the section 4.1 “general considerations”.

Discussion

Referee #1- P646, L20-26: Here again a figure would be more than useful, a figure like the one in Sarmiento et al., 2004 would really bring some clarity to the manuscript.

Authors - By adding the Temperature, salinity and oxygen section as asked in the previous comment, should comply also with this comment. In addition, the Figure 6 (which will be upgraded), by proposing a schematic view of these processes along with properties, seems to be enough and complementary to the T (°C), S (PSU), and O2 (ml l-1) sections.

Referee #1- P652, L10-15 discuss this in regards to Hendry 2011 Hendry, K.R., Georg, R.B., Rickaby, R.E.M., Robinson, L.F. & Halliday, A.N., Deep ocean nutrients during the Last Glacial Maximum deduced from sponge spicule silicon isotopes., Earth and Planetary Science Letters, 2010

Authors - In this section, we discuss about the impact of a circulation change in the subsurface and not in the deep water masses such as Hendry et al. (2010). Moreover: - The internal precision (1sd) in the relationship between Si(OH)4 concentration and δ30SiSi(OH)4 in sponge spicules is 20μmol l-1. Below 2000m across BONUS-Goodhope, the mean silicic acid concentration was 104 $\pm$ 22 μmol l-1. Subsequently only a large shift could be recorded in the sponge spicule. - This relationship implies a constant δ30SiSi(OH)4 across glacial-interglacial cycle which is so far unknown. In the modern ocean, strong gradient in the deep δ30SiSi(OH)4 are observed and such gradient could have changed across glacial-interglacial cycle, even if we keep the mean composition constant.

Referee #1- P653, L5-10: how would Si fractionation during dissolution influence this?

Authors - Si fractionation during dissolution at depth should supply the deep Silicic acid pool with light Si-isotopes everywhere in the Ocean regardless the surface silicic acid depletion levels. As no isotopic difference was observed for silicic acid between deep waters in the Atlantic (only few published profiles in BATS) and deep waters in the Southern Ocean (BONUS-Goodhope section), such effect in the deep waters has to be low or to not occur. Nevertheless, we found not necessary to speculate on this, owing to the few published data's in the Atlantic and Pacific Oceans.

Conclusion

Referee #1- P655, L18-19: are there references that illustrate this statement? Do the models (Reynolds, Wischmeyer) agree?

Authors - We'll add appropriate references in the revised manuscript on data (Cardinal et al., 2005; Beucher et al., 2008; this study; Figure 7). Model outputs (Wischmeyer et al., 2003, Global Biogeochem. Cy. 17(3), doi:10.1029/2002GB002022; Reynolds, 2009) show important inconsistencies compared to Southern Ocean observations, both for concentrations and δ30Si values, and these discrepancies will be discussed in the revised version.

Referee #1- References I don't think you can reference manuscripts submitted or in preparation.

Authors - We will update the references in compliance with OS editorial guidelines. These papers will be published soon in the special issues dedicated to the BONUS-Goodhope survey (Biogeosciences discussion and Ocean Sciences discus-

sion). Moreover, Fripiat et al. (submitted) is now Fripiat et al. (accepted).

Referee #1- Table 1 some of the standard deviations are extremely high (0.36‰ raising questions on the validity of the data.

Authors - Reynolds et al. (2007) did an inter-laboratory comparison of Si-isotope measurements. The diatomite (our reference standard) has a modal value of +1.25‰ with a 90% confidence limit between +0.85 and +1.61‰ (isotopic difference between lower and upper limits = 0.76‰. The standard deviation of the diatomite was estimated at 0.1‰ (1sd) in the latter study. Those errors are calculated from multiple replications. Since we have only duplicates or triplicates, it seems statistically normal to have some of our standard deviation higher than the accepted value of 2sd (0.20‰ $representing\sim$ 95% of the confidence interval, Reynolds et al., 2007). It should be statistically abnormal to have no values like that (in the $\sim$ 5%).

Referee #1- Table 2 these data would be better presented on a figure or schema that would locate the different water masses.

Authors - The upgraded Figure 6 should satisfy such recommendations. We decided to remove Table 2 since it is redundant and confusing with regard to the Figure 6.

Referee #1- Fig. 1 the font used is too small; the figure could show the different zones (so you would not need to describe them in the legend)

Authors - The font will be enlarged in the revised manuscript. It is the only place in the manuscript where the meaning of the abbreviations are shown.

Referee #1- Fig. 2 Fonts too small, the figure would be clearer if presented side by side, why do STF and SAF present two front lines in the BGH study (North and South?). Isolines are not visible in the delta30Si distribution

Authors - The font will be enlarged in the revised manuscript. The isolines are shown only for concentration below 5 μmol Si l-1 (same color in Ocean Data View giving difficult to discern such variation at low Si-concentrations). There are no isolines for the higher concentration and the isotopic composition. Sokolov and Rintoul (2009) demonstrate that each of the three primary ACC fronts could consist of multiple branches (e.g. north, middle, and south Polar Front). The northern branch of the Subtropical Front is clearly visible on the BONUS-GoodHope section. The southern branch of the Subtropical Front marks the southern limit of subtropical waters and is often met at the southern flank Agulhas rings or Agulhas eddies, as observed in the BONUS-Goodhope section (Dencausse et al., 2011, Arhan et al. 2011). The Subantarctic Front is relatively large and well defined on the BONUS-GoodHope section. We choose to show its northern and southern expression, as they are both well marked in the hydrological properties.

Referee #1- Fig. 3 font too small

Authors - The font will be enlarged in the revised manuscript.

Referee #1- Fig. 4 different font size (LCDW in legend), where does the PF AASW value come from (not in table 2 or Fig. 6)?

Authors - Owing to avoid ambiguity, we removed table 2 since different areas where computed. Only PF-AZ AASW was shown on Figure 6. We'll correct the different font size for LCDW in the Figure 4.

Referee #1- Fig. 6 this great schematic could be even better if you included all the masses and mixing (LCDW, AABW, thermoclines: : :), you could merged Fig 4 and 6 in a two panel figure where the mixing arrows would match the mixing lines (colors) and with different colors for the water masses. The figure could be enhanced if it also included the data from Cardinal 2005 and create a similar schematic for the Indo-Australian basin. This could be a great reference for models.

Authors - We agree and we've tried to satisfy the comments by upgrading the Figure 6 (comparison with Australian section and by merging with Figure 4). Nevertheless since only the upper meridional circulation of the ACC is discussed in Figure 6, we did not add the processes setting the distribution of the AABW and LCDW.

Interactive comment on Ocean Sci. Discuss., 8, 639, 2011.