# Diatoms from the surface waters of the Southern Ocean during the austral summer of 2004

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**Thirty four surface water samples collected during the Pilot Expedition to Southern Ocean in the austral summer of 2004 along the latitudinal transect 25°S–56°S, were studied to understand the distributional pattern of different diatom species and their relationship with changing sea-surface temperature (SST), salinity and nutrient availability. Among the diatom species identified, *Fragilariopsis kerguelensis* (O'Meara Hust.) is dominant, contributing more than 90% of the total recorded from 41°S latitude polewards. All other species show a sparse distribution. There is a total absence of diatoms from 25°S to 40°S where SST ranges from 27.8°C to 18.3°C, salinity from 34.9 to 35.6 psu and the concentrations of nutrients (silicate and nitrate) are comparatively lower. However, the phosphate concentration does not show any control on the growth of diatoms in this region. The measurement details of dominant species *F. kerguelensis* from Subtropical Front to Polar Front Zone indicated an increased size relationship with decreasing SST and increasing nutrient concentration.**

**Keywords:** Diatoms, Southern Ocean, nutrients.

SOUTHERN Ocean plays a significant role in the global climate cycle due to its vital influence on processes such as the formation and spreading of major water masses, currents, deep-ocean ventilation, nutrient cycling, atmospheric heat transfers as well as sea-ice formation[1–3]. It encompasses a wide range of hydrographic regimes, which includes coastal margins, dynamic fronts and open ocean waters. This diversity in hydrographic conditions coupled with extreme seasonality results in spatial and temporal variability in the abundance of biological productivity in this region. Schematically, Southern Ocean is composed of two different kinds of compartments, one favours growth of calcareous microorganisms and other closer to Antarctica is dominated by siliceous microorganisms, the diatoms. These constitute the calcareous and siliceous components of the Southern Ocean.

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Diatoms are unicellular, photosynthesizing algae, covered externally by siliceous skeleton (frustule) and are found in almost every aquatic environment including fresh and marine waters and soils. Diatoms contribute up to 75% of the primary production of the Southern Ocean, thus playing an important role in global cycling of silicic acid and carbon[4]. Based on their excellent preservation potential and frequent occurrence, they are widely used as a proxy in reconstruction of past sea-surface temperature (SST)[5–7]. Research on present day diatom populations show that certain diatom species dominate specific ranges of ecological conditions, and thereby record the changes in salinity, SST and sea-ice extent[8].

## Materials and methods

The Pilot Expedition to the Southern Ocean (PESO) was launched in January 2004, 34 surface water samples were collected onboard *ORV Sagar Kanya* along the latitudinal transect between 25°S and 56°S (Figure 1) at nearly one degree latitudinal interval by using 10 L Niskin water samplers attached to a CTD frame. About a litre of water sample was taken from each sample and then filtered through pre-weighed nucleopore filters (0.4 μM), air dried and stored in a petri dish. A portion of the filter paper was directly placed on a glass slide and a drop of Canada balsam (mounting material with refractive index > 1.7) and toluene were put on the slide before putting cover slip. The slides were then kept on a hot plate for 15 min at 130°C to drive out toluene and were later allowed to cool. All the slides were then studied under Nikon Eclipse E600 POL microscope and counting of species was done using Image Pro Plus Software. The identification of diatoms up to species level was done following Castracane[9], Mereschkowsky[10], Hustedt[11], Fryxell and Hasle[12], Hasle and Semina[13], Priddle *et al.*[14], Fryxell and Prasad[15], Armand and Zielinski[16]. Counting of different diatom species was done by using standard method developed by Schrader and Gersonde[17], and Armand[18]. The present study arrived at analysing the spatial distributional pattern and abundance of different diatom species in the surface water. The relative abundances of different diatom

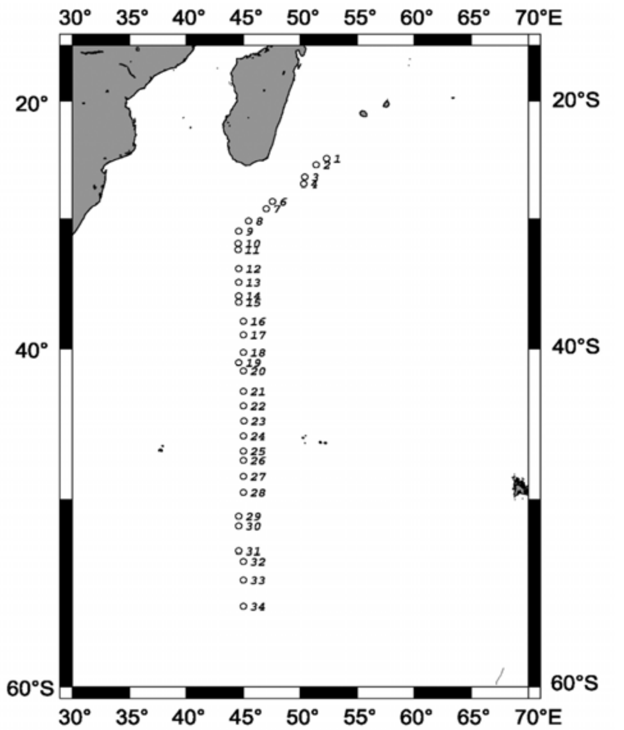


**Figure 1.** Location map showing stations of surface water collection.

species from the surface water samples were studied to document the change in distributional pattern with respect to latitude, its relation to the SST, salinity and nutrient availability.

## Hydrographic data

Hydrographic data reveals significant variations in the temperature and salinity values from the tropical to polar waters. The higher salinity and temperature values are associated with the waters of tropical zone from 25°S to 40°S, which continuously decreases up to Sub Antarctic Front (SAF) and Polar Front Zone (PFZ) (Figure 2). The highest temperature values of 27.8°C were recorded at station 1 at 25°S lat. in tropical zone and lowest value of 2°C was recorded at 54°S at station 33 in PFZ. The highest salinity values were also recorded in the tropical zone at station 8 at 30°S, which is > 35 psu and the lowest value of 33.58 psu was recorded at 54°59′S at station 33. There is a decrease in temperature and salinity values from the tropical to polar waters, which has a significant influence on the growth and productivity of diatoms in this region as reported earlier[19,20].

## Results and discussion

### *Nutrient details*

Nutrients also indicate significant variations from the lower to higher latitudes in silicate and nitrate concentrations. The concentrations increase significantly from Subtropical Front (STF) and reach a maximum in PFZ. The highest silicate value (55.15 μM) is recorded at station 30 in PFZ at 51°59′S, whereas the lowest value (1.72 μM) is recorded at station 23 at 45°S in SAF (Figure 2). The highest nitrate values (36.73 μM) in PFZ and the lowest value (0.38 μM) is registered in tropical waters at 26°S. The concentration of phosphate however does not show significant variation and it varies only at a few places from tropical to polar waters. The nutrient concentration is inversely proportional to SST and salinity, which shows a decreasing trend towards PFZ. The increasing concentration of silicate and nitrate towards higher latitudes has a positive influence on the growth and productivity of diatoms, which is reflected by the appearance of diatoms in the STF region. Similar results from surface sediments were reported by earlier workers[21].

### *Diatom abundance*

In the present study a total of six diatom species were identified, which include *Fragilariopsis kerguelensis* (O'Meara) Hust., *F. separanda* Hust., *Thalassiothrix* spp. group Schimp.ex G.Karst, *Thalassiosira gracilis* (G.Karst) Hust., *Dacytliosolen* spp. Castrac. and *Chaetoceras* spp. (Figure 2). *F. kerguelensis*, the most abundant diatom in Antarctic water[22] is however, the only dominant species which constitutes more than 90% of total diatoms and is found along the 41°S–56°S transect. Rest of the species show very low abundance and are occasionally present. The study area has been divided into three broad zones on the basis of physical parameters[23], viz. STF, SAF, PF.

## Species abundance in each zone

### *Tropical zone*

The zone from 25°S to 40°S shows a complete absence in terms of diatoms, with diatoms registered in the sample collected at 41°59′S. The complete absence of diatoms in this region is related with high SST, salinity and low nutrient availability in terms of silicate and nitrate.

*Subtropical frontal zone:* The zone is well represented by many diatom species among which *F. kerguelensis* is dominant and shows the maximum abundance in terms of total diatom percentage. The other species include *Thalassiothrix* spp. and *F. separanda*. The higher abundance of *F. kerguelensis* in this region as compared to tropical region is related to decrease in SST (7°C) and salinity (1 psu) values. Increasing nutrient concentration in terms of silicate and nitrate as compared to the tropical waters also shows a positive relationship with the abundance of diatoms in this region.

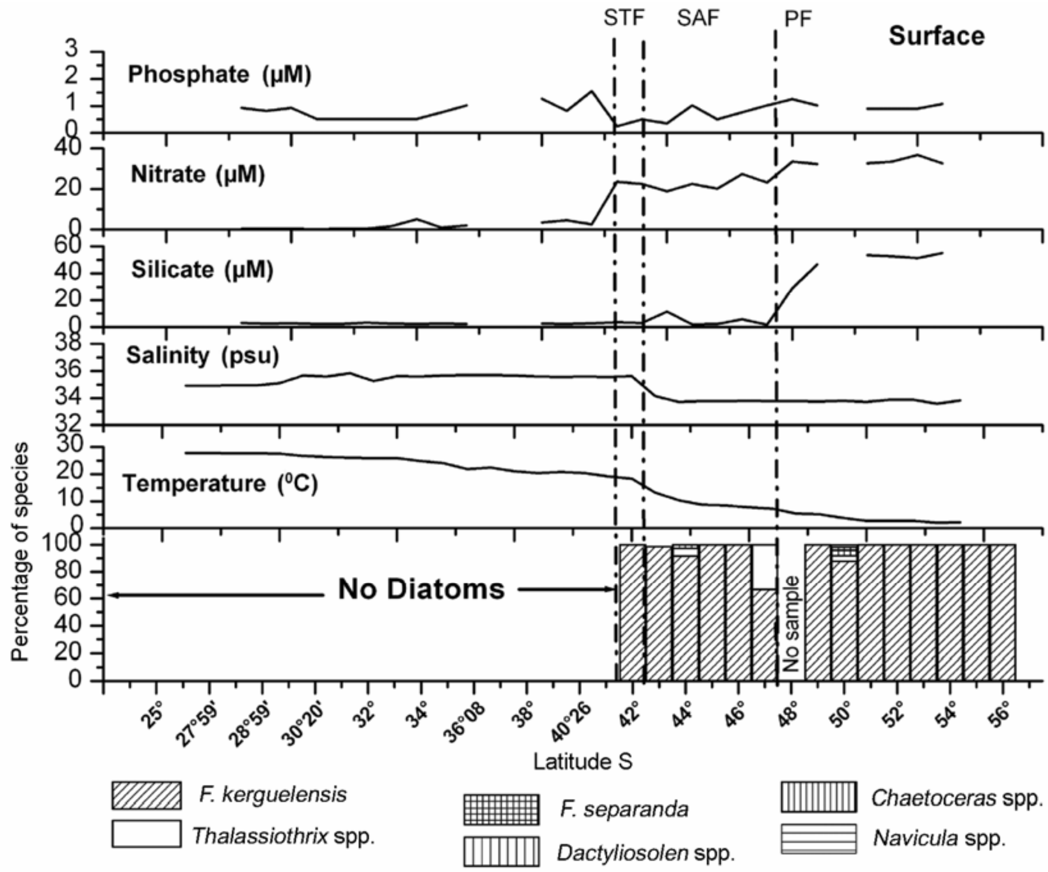


**Figure 2.** Latitudinal distribution of diatom species along with sea surface temperature, salinity and nutrients (silicate, nitrate and phosphate). Note: from sampling station nos. 1–19 diatom species were not recorded in the study area.

*Subantarctic frontal zone:* The zone starts from 42°S and continues up to 47°S which is represented by diatom species *F. kerguelensis*, *Thalassiothrix* spp., *F. separanda* and *Chaetoceras* spp. As in STF, *F. kerguelensis* here too shows a dominance and is represented by more than 90% of total diatoms. Abundance of diatoms increases with decreasing SST and salinity, which drops significantly from 41°S latitude polewards. The temperature in this zone reaches 5°C and salinity reaches 33 psu, with increase in the concentrations of silicates and nitrates. The higher concentrations of silicate and nitrate favour the growth of diatoms[24] which is the likely factor responsible for growth of diatoms in this region. The phosphate concentration in the study area doesn't have a significant effect on the growth of diatoms.

*Polar front:* The PFZ is also represented by diatom species like *F. kerguelensis*, *Thalassiothrix* spp., *F. separanda* and *Dactyliosolen* spp. Among these species, however, *F. kerguelensis* is the only dominant species, which constitutes > 90% of total diatom abundance. As in STF and SAF the growth of diatoms here too depends on the increasing nutrient concentration (nitrate and silicate) and decreasing SST and salinity.

In a recent study[24] species measurement of *F. kerguelensis* was carried out to find the variation in the size with respect to glacial and interglacial events. In present study measurement details of one dominant species *F. kerguelensis* was also carried out, which shows increasing size relationship with decreasing SST and increasing nutrient concentration. This suggests that cooler waters and enhanced nutrient concentration favours larger diatom size, as shown by variability in average valve length of *F. kerguelensis* from STF (9 µm) to that of SAF (9.06 µm) and PFZ (13.77 µm). This relationship could be useful for down core studies for marking the colder and warmer events in the immediate past.

The total diatom count however, from STF to PFZ is significantly less. There seems to be two plausible reasons. The total number of samples between STF and PFZ are significantly less and some localized factors might have some role to play. Further, the low diversity possibly could be linked to low iron input in the study area, as the iron in traces is an important constituent for higher productivity[25].

The present study may not able to answer with conviction the low numbers of diatoms encountered in this region, therefore this study needs to be substantiated by a

**Appendix 1.** Co-ordinates of each sampling station along with date and time of sampling operation, sea-surface temperature and salinity

| Sampling station no. | Date D M Y | Time GMT | Latitude | Longitude | Temperature (°C) | Salinity(psu) |
|---|---|---|---|---|---|---|
| 1 | 25 01 04 | 15 02 | 25°02′18″ | 52°32′21″ | 27.8 | 34.91 |
| 2 | 26 01 04 | 11 50 | 25°58′52″ | 51°40′47″ | 27.8 | 34.91 |
| 3 | 27 01 04 | 02 22 | 26°59′53″ | 50°41′00″ | 27.7 | 34.94 |
| 3A | 27 01 04 | 11 08 | 27°16′52″ | 50°33′42″ | 27.7 | 34.94 |
| 4 | 27 01 04 | 18 15 | 27°59′48″ | 50°00′00″ | 27.6 | 35.11 |
| 6 | 28 01 04 | 19 05 | 28°59′26″ | 47°59′31″ | 26.7 | 35.68 |
| 7 | 29 01 04 | 03 55 | 29°19′30″ | 47°00′47″ | 26.3 | 35.58 |
| 8 | 29 01 04 | 16 40 | 30°20′28″ | 45°48′12″ | 26.0 | 35.82 |
| 9 | 30 01 04 | 05 55 | 31°00′39″ | 44°59′40″ | 25.9 | 35.26 |
| 10 | 31 01 04 | 13 52 | 32°00′00″ | 44°57′27″ | 25.9 | 35.61 |
| 11 | 01 02 04 | 06 54 | 32°50′30″ | 44°54′06″ | 24.9 | 35.58 |
| 12 | 02 02 04 | 00 45 | 34°00′05″ | 44°59′12″ | 24.0 | 35.67 |
| 13 | 02 02 04 | 12 17 | 35°04′46″ | 44°59′46″ | 21.9 | 35.69 |
| 14 | 03 02 04 | 03 33 | 36°08′08″ | 44°59′37″ | 22.4 | 35.70 |
| 15 | 03 02 04 | 20 17 | 36°59′16″ | 44°59′17″ | 21.1 | 35.67 |
| 16 | 04 02 04 | 11 02 | 38°00′44″ | 45°00′07″ | 20.4 | 35.60 |
| 17 | 05 02 04 | 05 20 | 39°00′00″ | 45°00′00″ | 20.8 | 35.55 |
| 18 | 06 02 04 | 08 03 | 40°26′04″ | 45°00′03″ | 20.4 | 35.60 |
| 19 | 06 02 04 | 20 50 | 41°00′22″ | 44°59′52″ | 19.1 | 35.56 |
| 20 | 07 02 04 | 17 27 | 41°59′44″ | 45°00′48″ | 18.3 | 35.62 |
| 21 | 08 02 04 | 09 15 | 43°01′11″ | 45°00′27″ | 13.1 | 34.15 |
| 22 | 09 02 04 | 10 16 | 44°00′15″ | 45°01′36″ | 10.2 | 33.70 |
| 23 | 10 02 04 | 03 00 | 45°01′23″ | 45°06′08″ | 8.6 | 33.77 |
| 24 | 10 02 04 | 16 08 | 46°00′45″ | 45°00′25″ | 8.3 | 33.78 |
| 25 | 11 02 04 | 04 10 | 47°00′25″ | 45°03′42″ | 7.7 | 33.78 |
| 26 | 11 02 04 | 23 00 | 47°59′36″ | 45°00′24″ | 7.1 | 33.78 |
| 27 | 12 02 04 | 19 46 | 48°59′42″ | 45°00′28″ | 5.4 | 33.77 |
| 28 | 13 02 04 | 14 20 | 49°59′33″ | 45°00′54″ | 5.1 | 33.73 |
| 29 | 14 02 04 | 04 37 | 51°00′15″ | 44°59′46″ | 3.8 | 33.79 |
| 30 | 14 02 04 | 19 07 | 51°59′51″ | 44°59′56″ | 2.7 | 33.70 |
| 31 | 15 02 04 | 06 12 | 53°00′00″ | 44°59′45″ | 2.7 | 33.88 |
| 32 | 15 02 04 | 19 50 | 53°59′49″ | 45°00′09″ | 2.7 | 33.88 |
| 33 | 16 02 04 | 17 25 | 54°59′50″ | 45°00′14″ | 2.0 | 33.58 |
| 34 | 17 02 04 | 11 45 | 56°00′14″ | 45°00′25″ | 2.2 | 33.81 |

future measurements using a mooring with a bottom tethered sediment trap.

## Summary and conclusion

A preliminary study on 34 surface water samples collected along a latitudinal transect 25°S–56°S revealed the presence of a few living diatom species *F. kerguelensis, F. separanda*, *Thalassiothrix* spp., *Dactyliosolen* spp. and *Chaetoceras* spp. *F. kerguelensis* alone contributed more than 90% of total diatom abundance and appeared at the STF at 41°S, continuing up to the PFZ. The abundances of other species is sparse. The measurement details of one of the dominant species *F. kerguelensis* indicated an increased size relationship from STF to that of PFZ with decreasing SST and increasing nutrient concentration. The total diatom count from STF to PFZ is less, and therefore a detailed study needs to be carried out in the area on an annual basis to get a broader and better understanding of the factors that affect the growth and distribution of diatoms.

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