Persistent and highly contrasting biological patterns in the southwestern sector of the Atlantic Ocean: relating local circulation to phytoplankton pigment biomass

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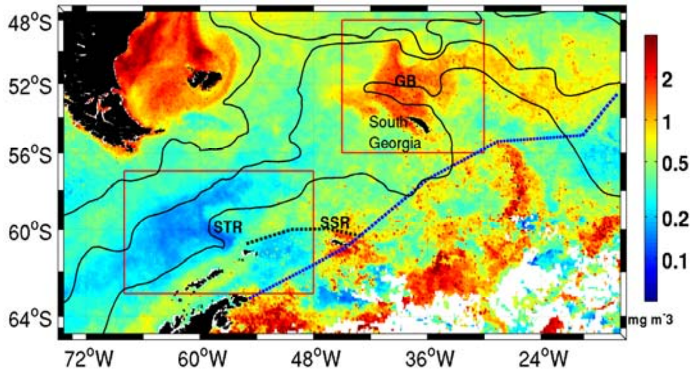


Chl-a December climatology (1997-2009); in the region south of the blue line the climatology is based on less than 6 years of data (out of 13). Data gaps due to clouds and/or sea-ice are shown in white. Red boxes indicate the two study areas surrounding the Shackleton Transverse Ridge (STR), and the Georgia Basin (GB). Fronts are from Orsi et al., DSRI 1995.

Background

Despite high concentrations of inorganic nutrients, primary productivity in the Southern Ocean is believed to be mostly iron limited; highest chl-a are thus measured along coastal regions (i.e. Antarctic Peninsula), downstream from islands (i.e. Island of South Georgia) or along marginal ice zones, which are shown to be natural sources of bio-available iron.

The intensity and recurrence of blooms is strongly dependant on bottom-up (i.e. nutrients inputs) or top-down controls (i.e. grazing), all of which may vary in time according to the physical and chemical environment.

Nevertheless, ocean color imagery for the southwestern sector of the Southern Ocean, which we here interpret with frequency plots, shows the presence of two areas where chl-a patterns appear to be stable in space and time. We show how topographic steering of the currents plays the major role in controlling the shape of the observed pigment biomass distributions.

Methods

Ocean color: SeaWiFS Level 3 monthly composites at 9 Km resolution were retrieved from the distributed Active Archive Center, from Sept. 1997 to Mar. 2010 (13 full seasons).
Surface circulation: AVISO Mapped Absolute Dynamic Weekly "delayed time" products were extracted and averaged to form a monthly climatology corresponding to the same time period of the SeaWiFS dataset.

For each given month, ocean color pixels falling within one of 4 chosen ranges (very low productivity, low productivity, medium productivity, high productivity/bloom) were flagged and counted. Results are displayed as frequency plots, where the color-scale indicates the number of years chl-a estimates in the given month fell within the selected range

Observations

Fig.1

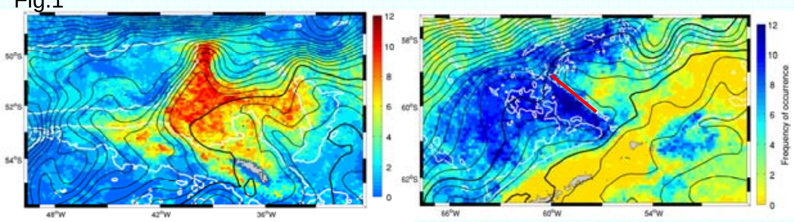
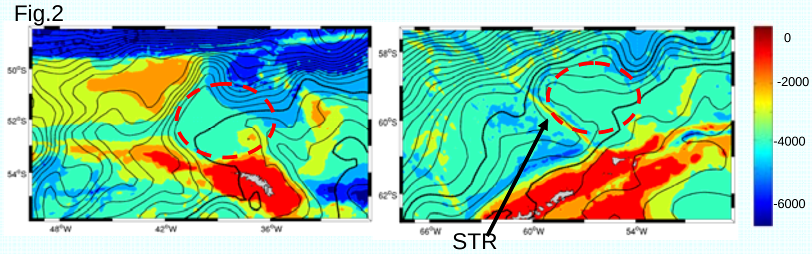


Fig.1: a) Frequency of occurrence of the high productivity range/ bloom (chl-a > 1 mg/m^3) around South Georgia and **b)** frequency of occurrence of the very low productivity range (Chla< 0.2 mg/m^3) around the STR. In both cases, ADT contours are overlaid (contour interval is 5cm). Values decrease from North to South and the -110cm and -90cm isolines are indicated with thick lines.

Fig. 2: Color-scale indicates bathymetry in the two study regions (meters); black-lines are ADT contours (indicated as above).

Fig.2



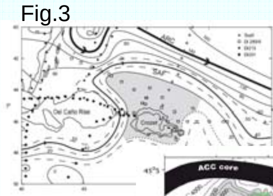
Stability of chl-a patterns - Figure 1: After obtaining frequency plots for each of the selected chl-a range, we found two regions - north of South Georgia and around the STR – where quasi-stable chl-a patterns are evidenced in December.

Topographic steering of the currents - Figure 2: Both in the region adjacent the South Georgia Island (left panels) and the STR (indicated by the arrow in the bottom right panel), ADT contours appear to follow tightly bathymetric features, thus giving evidence for topographically steered surface circulation.

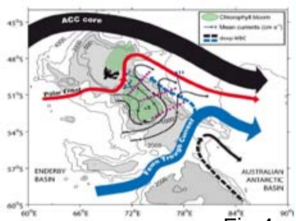
Surface circulation controls chl-a patterns: Combining ocean color frequency plots and ADT contours, we find a clear geometrical match. The location of ADT gradients often corresponds to the location of maximum frequency of occurrence gradients.

Stable meanders confine more productive waters: The red circles in Figure 2, highlight a cyclonic circulation, which embraces calmer waters. Here enclosed waters (carrying nutrients and phytoplankton cells) may be spatially confined by the faster flows found at the periphery of the circle, and thus isolated from the surroundings. Similar conditions (>chl-a in calmer entrained waters) have been observed also in the Crozet (Fig.3) and Kerguelen regions (Fig.4).

Fig.3



Crozet
Pollard et al., DSRII 2007



Kerguelen
Park et al., DSRII 2008

Fig.4

Conclusions

1. Surface circulation north of South Georgia and around the STR is markedly steered by bottom topography.

2. The South Georgia bloom and the region surrounding the STR exhibit very little inter-annual variability.

3. Little inter-annual variability of chl-a patterns may be explained by the topographic steering of the currents.

4. The presence of a meander stabilized by bottom topography may control the occurrence and position of high chl-a patches.