# Supplementary information

## The GYR station as a representative end member of ultra-oligotrophy

One of the objectives of the BIOSOPE cruise was to perform a detailed investigation (~5 days) of a station corresponding to the most oligotrophic conditions of the global ocean. The choice of this station was first guided by the historical analysis of SeaWiFS ocean color data from which it was concluded that the lowest chlorophyll concentration of the global ocean were encountered at 26°S 115°W, west of Easter Island (see http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16409).

The cruise took place in austral summer, when the conditions are expected to be most oligotrophic. To evaluate how this season is representative of the oligotrophic conditions in the SPG, an historical record of SeaWiFS data for the SPG has been analysed (Figure 1). During the austral summer, the surface chlorophyll concentration in the vicinity of the GYR station is the lowest, returning each year to around 0.02 mg Chla $m^{-3}$. If the surface of the region with surface chlorophyll concentration lower than 0.03 mg Chla $m^{-3}$ is chosen as a measure of the oligotrophy of the SPG (Fig. 1), the austral summer shows its maximal spatial extension with an area around 7 $10^6$ $km^2$ (roughly 3 times the area of the Mediterranean Sea).

In summary, the GYR station is located at the centre and most oligotrophic zone of the SPG and is surrounded by a large mass of water with similar biogeochemical characteristics. It was investigated during its most oligotrophic period. Thus, the data acquired at the GYR station are representative of an end-member of oceanic hyperoligotrophy. Any extrapolation of production and flux data acquired at this station to other oligotrophic zones of the global ocean thus represents a minimal estimate.

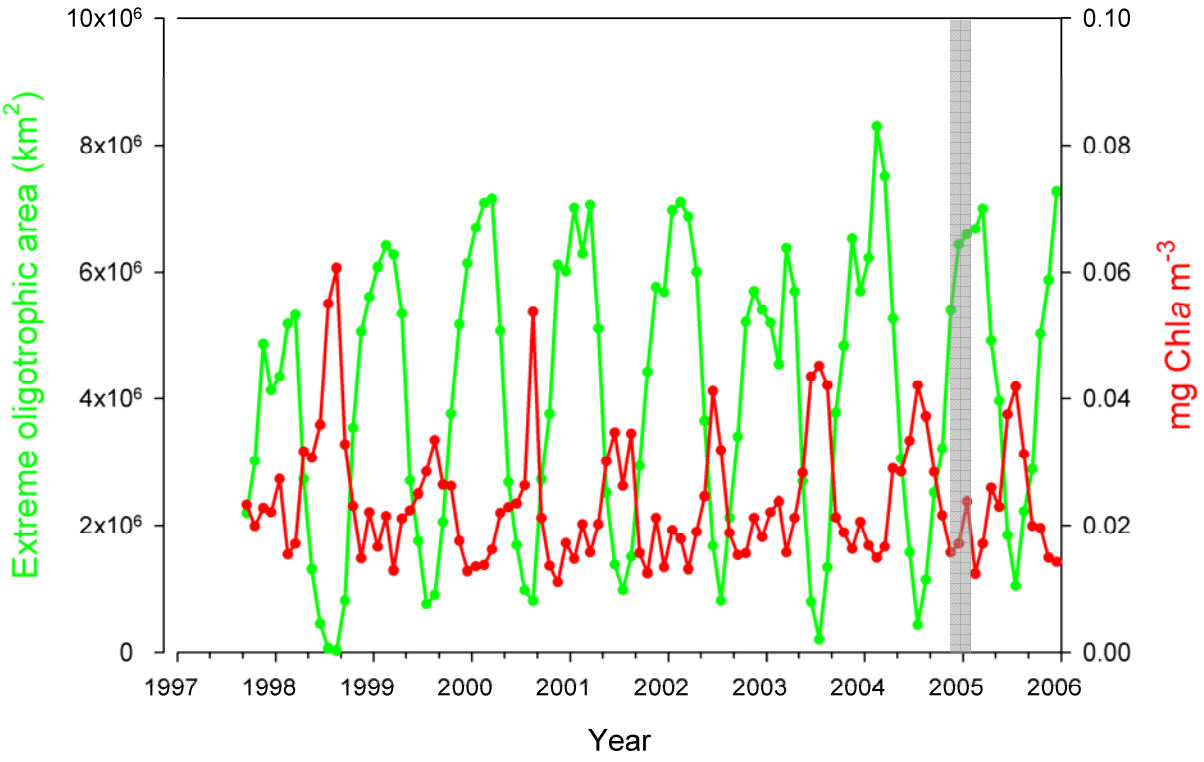


**Fig. 1**: Temporal evolution of oligotrophic conditions in the South Pacific Gyre. The green dots identify the variation in the area of waters with surface Chl*a* concentration lower than 0.03 mg $m^{-3}$. The red dots represents the mean Chl*a* concentration within a square of 50 km x km centered on the GYR station. The greyed band area identifies the time period of the BIOSOPE cruise.

**Significance of $c_p$ variations at the diel scale in terms of POC variations**

The two sources of variation in $c_p$ are the cell number (N, cell) per unit volume (V, $m^3$) and the cell attenuation cross section $\sigma_c$ ($m^2$ $cell^{-1}$) such that:

$$c_p = N/V\ \sigma_c$$

with $\sigma_c = \sigma_g\ Qc(d, n)$

where $\sigma_g$ ($m^2$ $cell^{-1}$) is the geometrical cross section and Qc(d, n) (dimensionless) is the attenuation efficiency, which is a function of cell size (d, m) and refractive index (n, dimensionless).

Diel changes in $c_p$ are thus recording processes that affect cell abundance (grazing, sinking, lysis and cell division) as well as $\sigma_c$ (growth, respiration and cell division). Cell concentration is linearly related to $c_p$, and hence similarly recorded as a change in POC. The effect of growth, respiration and cell division on the attenuation cross section, and thus on POC, is more complicated and can be addressed as follows.

When a cell is assimilating $CO_2$ by photosynthesis, respiring or assimilating DOC, it changes its internal carbon concentration. This can be achieved by means of two extreme processes, with reality likely being some combination of the two: 1) by keeping a constant cell size and changing its refractive index due to variations in the internal carbon concentration; or 2) by changing the cell size while keeping a constant refractive index by the exchange of water with the environment. In both cases, only Qc is affected. In the first case due to its effect on n, and in the second due to its effect on d. In both cases, processes of growth, respiration and DOC assimilation are measured by $c_p$.

The effect of cell division on the attenuation cross section can be quantified using the Van de Hulst approximation, and assuming a refractive index of 1.05. In the size range (0.5-2 μm) for cells dominating phototrophic (*Prochlorococcus*, *Synechococcus*, picoeukaryotes) and heterotrophic (heterotrophic bacteria) growth and respiration in these oligotrophic

systems, if the whole community is experiencing synchronous cell division, $c_p$ will decrease by at most 20%. That is, even without any changes in POC (all carbon remains in the daughter cells, repackaged in twice the number of cells with each half the volume), the $c_p$ measurement would estimate a decrease associated only with changes in cell size during division. This estimate is extremely biased as it is based on the following unrealistic assumptions: (1) all particles contribute to $c_p$ changes at the diel scale, and (2) these particles all divide once per day. We will now consider more realistic conditions to obtain an improved estimate of this bias.

Cytometric measurements performed every 3 hours over the course of the study show at most a 35% variation for *Prochlorococcus* cell densities between sunset minima and sunrise maxima. At the same time, picoeukaryotes do not show any trend in cellular abundance. Using the method proposed by Claustre et al., 1999 relying on cytometric determination, the contribution of picoeukaryotes, *Prochlorococcus* and *Synechococcus* to $c_p$ is estimated to be ~ 5%, ~ 12% and 0%, respectively. If this phytoplanktonic assemblage alone (~17% of $c_p$) was responsible for diel changes in $c_p$, the net and gross growth rates of this assemblage in the photic zone would be ~ $1.4d^{-1}$ and $2.4d^{-1}$, respectively. These are admittedly very high (Maranon, 2005) values, and this implies that heterotrophs, in addition to phototrophs, contribute to the recorded diel changes in $c_p$. Using cytometric counts, heterotrophic bacteria are estimated to contribute 13% of $c_p$. Other (larger) heterotrophs are assumed to also contribute an additional 13% of $c_p$ (see ref Claustre et al., 1999 for this assumption). A reasonable estimate of 43% can thus be made for the contribution of living particles (phototrophs and heterotrophs) to $c_p$ (the remainder being attributed to bio-detritus or other particles, and corresponding to a background level of $c_p$ at the diel scale). Given this information, we provide a “worst case scenario” for the bias in the $c_p$ signal due to cell division. To do this, since we do not have diel cell counts for the heterotrophic particles (26%

of $c_p$), we assume that they undergo 100% cell division between sunrise minima and sunset maxima. It then follows that cell division by living particles would be responsible for at most a 6% decrease in $c_p$ (0.8% for *Prochlorococcus* and 5.2% for heterotrophic particles). This value must be compared to an average daily change of ~18% for $c_p$ in the photic zone. In any case, this 6% bias is still an uppermost limit because: (1) it is assumed that the number of heterotrophic particles doubles between sunrise minima and sunset maxima, and (2) heterotrophic particles also contain larger predators (nano-heterotrophs, 5-10 μm, representing ~50% of the heterotrophic pool) whose division has a weak impact, if any, on the decrease in $c_p$ (*e.g.* 8-9 μm cells have no impact).

Claustre, H., Morel, A., Babin, M., Cailliau, C., Marie, D., Marty, J. C., Tailliez, D., and Vaulot, D.: Variability in particle attenuation and chlorophyll fluorescence in the Tropical Pacific: Scales, patterns, and biogeochemical implications. Journal of Geophysical Research, 104**,** 3401-3422, 1999.

Maranon, E.: Phytoplankton growth rates in the Atlantic subtropical gyres. Limnology and Oceanography, 50**,** 299-310, 2005.