period December 2006 to February 2007 in the b_{bp} vs. [Chl] relationships (Fig. 5) appears in Fig. 6, yet it is closer to being within the RMSE of the b_{bp} vs. c_p relationship. Another set of points appears separately from the overall data set in Fig. 6, although with low c_p values of $\sim$ 0.06–0.07 m^{-1}. These data are for January and February of 2006, which were characterized by an exceptional vertical mixing of the water column with a mixed layer deeper than 2000 m (J.-C. Marty and J. Chiaverini pers. comm.), [Chl] of $\sim$ 0.05 mg m^{-1}, and a very low particle load. This situation actually persisted until mid-March, when phytoplankton bloomed so that c_p suddenly increased to values of $\sim$ 0.5 m^{-1} within 2 d: hence, the jump on Fig. 6 between the lowest c_p and the rest of the data set (nearly no intermediate conditions). This ensemble of points is not, however, atypical of the general b_{bp} vs. c_p relationship.

The backscattering ratio—The time series of $\tilde{b}_{bp}$ at λ = 442 and 555 nm are displayed in Fig. 7A for BOUSSOLE and Fig. 7B for PnB. Neither time series shows a clear seasonal cycle in $\tilde{b}_{bp}$. Average values at BOUSSOLE are 0.54% (standard deviation [SD] = 0.16) for λ = 555 nm and 1.01% (SD = 0.28) for λ = 443 nm. At PnB, the values are 0.88% (SD = 0.25) for λ = 555 nm and 1.14% (SD = 0.29) for λ = 443 nm. The $\tilde{b}_{bp}$ ratios do not show a trend with [Chl] (Fig. 8). The spectral difference in $\tilde{b}_{bp}$ from the blue to the green is larger at BOUSSOLE than at PnB.

Spectral dependence of particle backscattering—The γ parameter determined based on the BOUSSOLE and PnB data is plotted as a function of [Chl] in Fig. 9A and as a function of b_{bp}(555) in Fig. 9B. There is an overall decrease of γ with increasing [Chl], with values of up to 3–4 when [Chl] is $\sim$ 0.05–0.1 mg m^{-3} and values between 0 and 1 for larger concentrations. The slope of the best fit to the data is larger than that of other existing relationships (Morel and Maritorena 2001; Stramska et al. 2003; Huot et al. 2008) and closer to that of Loisel et al. (2006) (their fig. 7A), which was obtained from an inversion model using remotely sensed reflectances (Loisel and Stramski 2000). The γ parameter also exhibits significant correlation with b_{bp}(555) (Fig. 9B; statistics on the figure). The dispersion is large, yet the upper envelope of the data set follows quite well the relationships obtained by Stramska et al. (2006) with data from the north polar Atlantic. These comparisons must be interpreted cautiously because of the different ways in which values of γ are determined by different investigations.

Discussion

Chlorophyll as an index or predictor of b_{bp}—The data displayed in Fig. 5 indicate a general relationship between b_{bp} and [Chl] in open ocean waters spanning 2.5 orders of magnitude in [Chl]. The least-square fits obtained here are consistent with previously published relationships also obtained from field measurements in the north polar Atlantic (Stramska et al. 2003), the south Pacific gyre (Huot et al. 2008), or the equatorial Pacific (Dall'Olmo et al. 2009). The scatter around the average fit here and in the above previous studies is large; thus, aside from the first-order relationship, [Chl] is clearly not a great predictor of b_{bp}. Data in Fig. 5 essentially indicate that the average b_{bp} is higher when the average [Chl] is higher, with a large SD and significant outliers. In the [Chl] range of 0.3–2 mg m^{-3} there is virtually no relationship between b_{bp} and [Chl], while b_{bp} values span an order of magnitude for [Chl] $\sim$ 0.5 mg m^{-3}. Data plotted in Fig. 5 also show that the same low level of backscattering ($\sim$ 0.0005 m^{-1} at 443 nm and 0.0002 m^{-1} at 555 nm) is exhibited by waters with an order of magnitude difference in their chlorophyll contents, from $\sim$ 0.05 to $\sim$ 0.5 mg m^{-3}.

These results confirm the poor predictability of b_{bp} using [Chl] over a wide range of conditions, which is not entirely unexpected, as there are many cellular- and population-level processes that can affect the relationship between b_{bp} and [Chl]. Although phytoplankton cells themselves are not thought to be major contributors to b_{bp} (Stramski and Kiefer 1991; but *see* Dall'Olmo et al. 2009), recent work has indicated that photoadaptation and other physiological changes can alter the phytoplankton carbon (C) to Chl ratio (C : Chl) and likely the b_{bp} : Chl ratio (Behrenfeld et al. 2005). Furthermore, different phytoplankton groups and community structure will have different PSD, cellular geometries, and/or composition, all of which can lead to different b_{bp}–Chl relationships. Observations on phytoplankton cultures also show highly variable and species-dependent Chl–b_{bp} relationships (Whitmire et al. 2010).

The b_{bp}–Chl distribution from BOUSSOLE is further examined in Fig. 10 for λ = 555 nm, with an expanded scale in order to magnify the differences between clusters of points. These clusters are identified by specific symbols (as indicated in the figure). The observations can be partitioned into two regimes, as symbolized by the two dotted lines in Fig. 10. From a [Chl] of $\sim$ 0.3 to 1 mg m^{-3}, two distinct relationships appear, with a difference in b_{bp} by a factor of about 4 to 5 for a given [Chl]. After the intense winter mixing in January–February 2006 (circles in Fig. 10), a spring phytoplankton bloom abruptly developed, and [Chl] increased much faster than b_{bp}, which only increased from $\sim$ 0.0005 m^{-1} to 0.001 m^{-1} when [Chl] went from $\sim$ 0.05 to $\sim$ 1 mg m^{-3} (black inverted triangles). Then b_{bp} increased by a factor of 5, while [Chl] only increased by a factor of 2. Assuming that changes in b_{bp} are a proxy for changes in phytoplankton biomass, this evolution indicates that the increase of the phytoplankton biomass came after a period of chlorophyll synthesis. This is actually detectable in Fig. 4, where the slope of the [Chl] curve around mid-March is steeper than that of the b_{bp} curve, before both parameters reach their maximum at the bloom peak (this corresponds to the top right-most points in Fig. 10). Immediately after the maximum of the bloom the points move to the second b_{bp}–Chl relationship, with nearly no transition between both because [Chl] rapidly drops while b_{bp} remains high (black inverted triangles to the left). This indicates a much lower phytoplankton growth and an increase in the detrital pool because of grazing and cell degradation. Then the points follow the second relationship during summer (diamonds and stars), with concomitant changes in b_{bp} and [Chl]. During this period, there is a