[課程博士・論文博士共通]

博士学位論文内容要旨
Abstract

専　攻 Major	応用環境システム学	氏　名 Name	エルミニオ　フォロニ　ネト
論文題目 Title	Quasi-horizontal measurements of biophysical microstructure (準水平的観測方法による植物プランクトンの微細な分布状態に関する研究)		

This dissertation presents a new tethered quasi-horizontal microstructure profiler, the TurboMAP-Glider (TMG). It is a unique instrument, capable of measuring ocean microstructure temperature, turbulent velocity shear, chlorophyll-a fluorescence and turbidity simultaneously through a quasi-horizontal perspective. Four field experiments were carried out near Joga-shima (Japan) to test the TMG flight performance, and these results as well as comparisons with a vertical profiler, the TurboMAP-L (TM), are described here. The TMG was capable of flying with an angle of attack of less than 25 degrees and was reasonably stable for up to 300 m horizontally over 100-m depth. Its shallow path angle (13 degrees) provides a very high vertical resolution for a range of wing angles and weights, and is easily adjusted for variations in the density of water since the path angle is independent of the weight and buoyancy of the glider. This platform measures ε as low as 0.5×10^{-10} m^2 s^{-3}, which is in the order of the lowest dissipation rate of turbulent motion. I have used the ratio (a) between the Thorpe length (L_T) scale and the Ozmidov length (L_O) scale as a tracer to demonstrate that most of the TMG density inversions are due to horizontal variability and not to vertical overturning. The a ratio deviation is caused by false water displacements generated by horizontal inhomogeneity, which indicate that the false density overturns observed by the TMG are observational evidence of internal waves or Kelvin-Helmholtz instabilities crossed by the glider demonstrated theoretically by Thorpe (2012). The correlation between (L_T) and the isotropy index (I) is almost absent in the TMG dataset. However, using the TM, we observed a strong correlation, with a coefficient of correlation equal to 0.47. The good correlation is expected once the displacements observed from TM are real, and (L_T) is linearly correlated to (L_O). These results reinforce that care must be taken when using gliders to calculate water displacements and possible inhomogeneities need to be considered.

Also, some new and relevant empirical results about the differences between the vertical and quasi-horizontal application of high-resolution chlorophyll-a fluorescence sensors are presented here. The averaged chlorophyll-a distribution was considered to be the same during the observations, whether sampling vertically or quasi-horizontally. In 2013, we observed a shift from a normal distribution to a skewed extreme value distribution with a reduction in sample volume whether sampling vertically or quasi-horizontally. However, in 2014, we observed from both instruments that phytoplankton may be gathering in patches at the centimeter scale similarly to what is observed at the millimeter scale. The probability density function (PDF) of log-normalized chlorophyll-a measured using the laser fluorescence probe was best fit by the Gumbel distribution whether the quasi-horizontal profiler or the vertical profiler was used. Still, despite the similarity between the fluorescence distributions obtained from both instruments, the quasi-horizontal sampling showed an increase of high concentration chlorophyll-a peaks when compared to the vertical sampling. Although at large scales, the averaged volume of chlorophyll-a is considered homogeneous, at small scales, phytoplankton patches are not negligible, and the quasi-horizontal and vertical samplings are different,

even when turbulence is considered isotropic. The TMG increases the probability of reaching phytoplankton patches during its path, which is one remarkable difference between TMG and TM. The fluorescence measured by the laser sensor shows that the phytoplankton spatial variability becomes increasingly intermittent and patchy when measured with increased resolution. According to Doubell et al. (2009), these patches of chlorophyll-a identified by the laser probe are constituted by an increase of biomass, which may include individual phytoplankton cells as well as chains and aggregates. The laser-induced fluorescence sensor measures only active chlorophyll-a, and we are unable to specify the contents from any of the measurements. Therefore, we defined phytoplankton patches as high chlorophyll concentration peaks that exceed the background value by a factor of 2. In this work, I discuss spatial distribution of phytoplankton patches in terms of distance between chlorophyll-a peaks (peak-to-peak distance – PtoP), as well as the number of patches and their relationship with turbulence using data from TMG and TM. Importantly, the peak-to-peak (PtoP) results imply that high chlorophyll-a concentration of phytoplankton tend to be distributed randomly in the water column. However, when small patches are considered, the distribution shows clustering differentiating itself from a random distribution. The PtoP uncoupling from a Poisson process starts with distances smaller than 20 mm, which is larger than expected due to the resolution limitation of the sensors. Despite the significant coefficient of correlation, the unclear relationships observed between turbulence and phytoplankton patchiness suggest that location, water types and dynamic regimes may need to be considered when trying to establish a connection between these particles and turbulence intensity.