THE DILUTION METHOD - A MODELING STUDY

Oliver N. Ross, Elisa Berdalet, M. L. Artigas, Jaume Piera

Institut de Ciències del Mar (CSIC), Passeig Marítim de la Barceloneta, 37-49, 08003, Barcelona, Catalunya, Spain

The estimation of (species-specific) phytoplankton *in situ* growth rates (μ) is one of the fundamental parameters to understand population dynamics. As explained in the accompanying presentation (Berdalet et al. this workshop), estimating this parameter in the field is highly complex. One of the most accepted methods is the dilution technique (Landry and Hasset 1982; Calbet and Landry 2004) which has been designed to simultaneously estimate the growth rate and the grazing by microzooplankton on phytoplankton, another essential parameter to describe the population dynamics. The dilution technique involves the *in situ* incubation of organisms in bottles with particular nutrient enrichments at fixed depths.

We illustrate the limitations associated to this method and quantify the error associated with incubating the cells at a fixed depth, i.e. at fixed light conditions. By neglecting vertical mixing and the associated fluctuations in the ambient light levels, this incubation technique allows the organisms to acclimate their physiology to the ambient light level which results in different growth rates compared to freely mixing cells. Using a Lagrangian modeling approach we quantify the errors associated with this technique and suggest alternatives to minimize them (such as the yo-yo approach where the incubation models are cycled vertically through the water column, or the use of several incubation depth).

References

Calbet, A., and M.R. Landry. 2004. Phytoplankton growth, micro-zooplankton grazing, and carbon cycling in marine systems. *Limnology and Oceanography* 49: 51–57.

Landry, M.R., and Hassett R.P. 1982. Estimating the grazing impact of marine micro-zooplankton. *Marine Biology* 67: 283–288.

IS ALFACS BAY A PHYTOPLANKTON BLOOM INCUBATOR? *IN SITU* MEASUREMENTS AND MODELING APPROACHES, OPEN QUESTIONS

Oliver N. Ross*[1], Elisa Berdalet[1], Mireia L. Artigas[1], Clara Llebot[2], Andrea B. Hoyer[3], Norma Z. Neszi[1], Francisco Rueda[3], Marta Estrada[1]

[1]*Institut de Ciències del Mar (CSIC). Pg. Marítim de la Barceloneta, 37-49, 08003 Barcelona, Catalunya, Spain

[2]Center for Coastal Margin and Prediction, Oregon Health & Science University, 20000 NW Walker Rd, Beaverton, OR 97006 USA

[3]Water Research Institute, University of Granada, C/ Ramon y Cajal 4, 18071 Granada, Spain

Extended abstract

Alfacs Bay, is a shallow microtidal estuary in the Ebre Delta, with a high productivity (compared to the adjacent oligotrophic NW Mediterranean waters), which has allowed the development of valuable aquaculture activities. Unfortunately, recurrent harmful phytoplankton outbreaks (caused mainly by *Alexandrium minutum*, *Dinophysis* spp., *Pseudo-nitzschia* spp. and *Karlodinium* spp.) threaten this industry. It is crucial to provide local policy makers with detailed knowledge and tools to minimize the socio-economic impact on the local community. With this final aim, our study focused on the exhaustive and continued study of the phytoplankton dynamics in relation to the physico-chemical forcings in the bay in order to better understand the occurrence of recurrent HAB events.

The productivity of the bay is due in part to its semi enclosed characteristics, and also to the nutrient supply through the freshwater inputs coming from groundwater seepage and specially from the runoff of rice field irrigation channels discharging from its northern coast. At seasonal time scale, the buoyancy associated with freshwater inflows dominates the tidal forcing and yields a strongly stratified two-layered system, with the surface and the bottom layers flowing in opposite directions (classical estuarine circulation). At shorter time scales, wind controls the physical behaviour of the bay. When wind-induced mixing is low, the water column stratifies showing the typical estuarine circulation.

Data have been collected for 6 years using synoptic cruises, time series of physical parameters from moored instruments (CT-loggers, ADCP, fluorometer) to obtain information on the general circulation, chlorophyll distribution, and stratification in relation to the meteorological conditions, and combining them with 3D modeling. Some cruises coincided with the occurrence of harmful outbreaks. The field data showed the existence of a preferential phytoplankton accumulation area in the inner NE side of the Bay (e.g. Figure 1), and a special vertical distribution, maybe linked to stratifi-

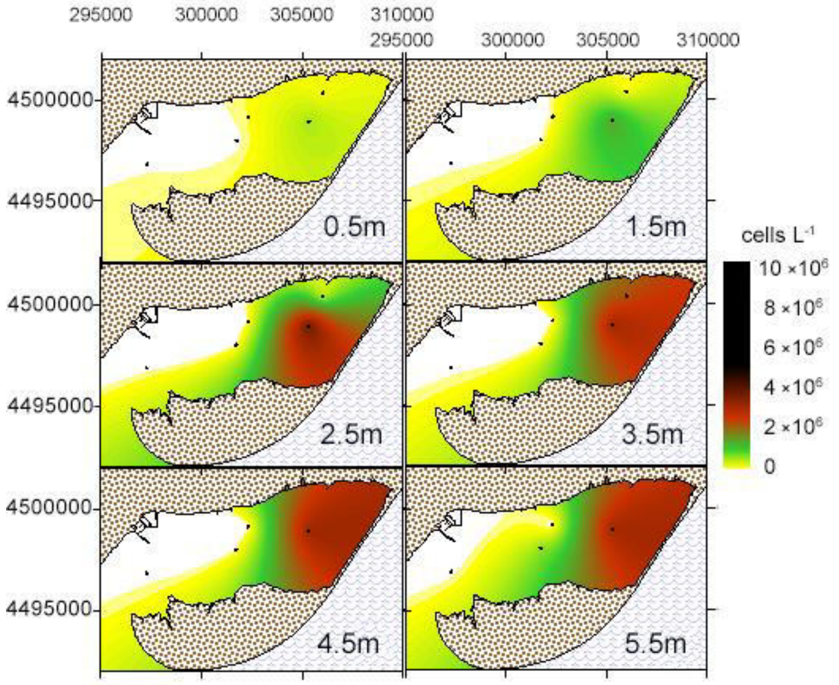

Figure 1. *Cell counts of Karlodinium spp. in June/July of 2007. Clearly visible is the preferential concentration in the NE interior of the bay and the lower part of the water column.*

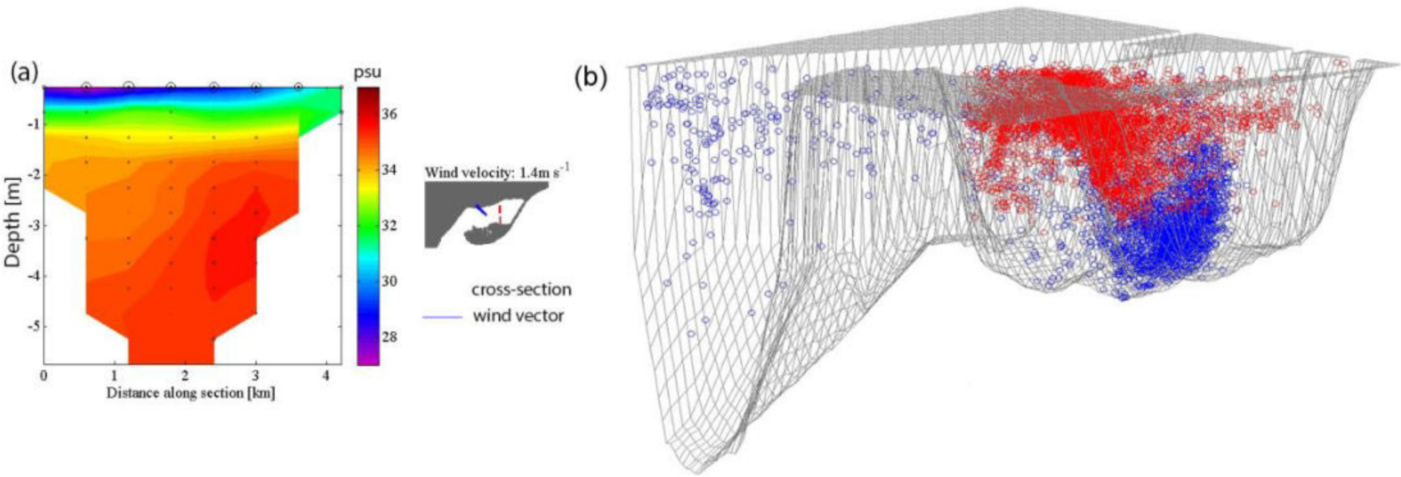

Figure 2. *Simulation result (a) the vertical salinity stratification during low wind intensities (the crosses and circles with dots inside them, represent the flow into and out of the bay respectively), (b) a snapshot of the coupled 3D hydrodynamic-particle tracking model including the bottom topography showing the particle retention in the NE interior.*

cation and/or biological behaviour. In addition to the nutrient supply, the hydrodynamic regime may explain the observed phytoplankton distribution patterns.

In particular the periodic suspension of the estuarine circulation due to wind mixing events, may facilitate bloom development in the bay's interior. This hypothesis was tested using new modeling approach featuring a 3D hydrodynamic model previously implemented and validated in Alfacs Bay (see detailed description in Llebot et al. accepted) in combination with a Lagrangian particle-tracking module (Ross and Sharples 2004; Ross et al. in preparation). Simulation experiments were performed for relevant periods for which cruise data was available, in order to compare the observed chlorophyll distributions with the modeled tracer concentrations. Two clouds (with 4000 passive tracers) were released, one in a vertically homogeneous distribution near the mouth of the bay and the other in the bay's interior. The estuarine circulation is particularly active when the water column is stratified and wind mixing is weak (Figure 2a), which drives the bottom particles towards the bay's interior, while flushing the particles in the surface layer out into the open Mediterranean. When wind-induced mixing is strong, the density stratification and associated estuarine circulation break down (not shown), and particles accumulate in the bay's interior (Figure 2b). When the freshwater inflow from irrigation channels is reduced and/or wind-induced mixing is high, the water column stratification decreases, resulting in a weakening of the estuarine circulation. Overall, this leads to increased residence times inside the bay.

References

Llebot, C., F.J. Rueda, J. Solé, M.L. Artigas, and M. Estrada. *In press*. Hydrodynamic states in a wind-driven microtidal estuary. Journal of Sea Research.

Ross, O.N., and J. Sharples. 2004. Recipe for 1-D lagrangian particle-tracking models in space-varying diffusivity. Limnology and Oceanography Methods 2: 289-302.

NEAR SURFACE TEMPERATURE STRATIFICATION AND THE WIND TRANSPORT OF SURFACE BLOOMS

Mary Carmen Ruiz-de la Torre, Helmut Maske, José Ochoa

División de Oceanología, CICESE, Carretera Tijuana-Ensenada No. 3918, Ensenada, B.C., México

Extended abstract

The near surface thermal stratification produces a thin (~2 m thick) and warm near-surface layer. This buoyant layer is sufficiently decoupled from the layer below, that it can be transported efficiently by the wind stress. Because in coastal upwelling areas the thermal wind is directed towards the coast during the day the buoyant layer is also transported towards the coast. During a surface bloom of *Lingulodinium polyedrum* on the northern Baja California coast (Oct. 2011) we measured near surface temperature stratification (NSTS) and drifter buoy trajectories (drogued at 1, 3, 5m). Temperature profiles during the bloom typically showed a gradient of about 0.2 to 0.5ºC between 1 and 3 meter depth. Generally NSTS took the shape of a continuous gradient and typically showed no marked discontinuity that would indicate a homogenous near surface layer (Figure 1). Temperature profiles inside and outside of the bloom showed differences in the upper 2.5 m; however, temperature gradients from 1 to 5 m for both cases showed similarities. Temperature differences are not simple to explain because the heat balance is strongly influenced by meteorological conditions with heat loss processes. We are still processing the temperature profiles to see if the high pigment concentration in bloom patches (> 80 mg m^{-3} chlorophyll) resulted in a significant increase in temperature due to high daylight attenuation at the surface. We expect that this mechanism would indirectly promote the transport of bloom patches towards the coast by thermal wind. The general pattern of drifter trajectories showed differences between surface (1m drogue), 3m and 5m drogue drifter trajectories. Drifter trajectories at 1 m were towards the shore following the wind direction whereas drifters at 3 and 5m depth showed trajectories parallel or away from shore. On three of the 6 days surface drifters did not have the same direction as the wind, which probably resulted from an interaction between wind and current forcing, but the differences in trajectory direction between 1, 3 and 5m drifters were maintained. Before the bloom condition, on three days we did a comparison of ADCP and drifter data and found similar behavior with different current vector directions at different depth (Figure 2). This shear flow pattern in the top few meters observed by us resulted in spiral current vectors that could turn in either direction depending on the azimuth relation of surface and deeper water current. Since this flow spiral responds on short time scales to varying winds, it bears no resemblance to Ekman-like spirals which are steady end conditions. The observed temperature stratification in the top few meters is a typical phenomenon in this regional and we propose that it is common feature in many other subtropical and tropical areas. In this work we also propose that the movement of the near surface layer, containing the surface bloom, is largely responsible for sustaining the bloom near the shore. We could demonstrate that during eight hours of active thermal breezes, typical for upwelling areas, the surface layer constituents including blooms were transported toward the coast about 2.7 km. Additional constituents that will be transported include all dissolved and particu-