*For submission to xxxxxxx*

*Please do not distribute*

Spatial variability of pico-phytoplankton in the North East Pacific

Sophie Clayton1, 2, Francois Ribalet1, Hilary Palevsky1, Jarred Swalwell1, E. Virginia Armbrust1

Keywords: phytoplankton, spatial variability

1 School of Oceanography, University of Washington, Seattle, WA 98105, USA

2 eScience Institute, University of Washington, Seattle, WA 98105, USA

Corresponding author:

**Abstract**

Words:

**1. Introduction**

Long history of observing patchiness in phytoplankton…

Why care about phytoplankton scales of variability? Phytoplankton account for roughly half of all global primary production (Field et al 1998, Behrenfeld et al, 2006). Implications for stability of ecosystem and impact on trophic interactions (need ref here).

We want to know if there is some intrinsic variability in the system…

Previous work: the spatial variance is controlled by the scale at which heterogeneity is introduced into the system, and the reaction time scale of the tracer in question… assuming the same input scale, tracers with shorter reaction time scales have more variance at smaller scales (Mahadevan and Campbell 2002). Differential diffusion can also have an impact (double check conclusions here) (Bracco et al. 2009).

Previous observational studies have used a range of different instruments to measure biological variables, over a range of different scales…

Flow cytometry in the Celtic Sea, small area (Martin et al. 2008)

Model studies because difficult to get observations at the appropriate scales…

Any studies that explore biologically mediated spatial variability?

To date, no studies have been undertaken that combine good spatial coverage with consistent methods over a range of different environments. Here we present a study of the scales of variability of picophytoplankton in the North East Pacific Ocean in late summer 2013. This particular study region is quite different from most previous studies, we go from a coastal upwelling region to the HNLC region in the North Pacific Subpolar Gyre and across the transition zone into the oligotrophic Pacific Subtropical Gyre.

**2. Materials and Methods**

*2.1. Cruise outline*

General outline of the cruise (Fig.1)

*2.2. SeaFlow underway flow cytometer*

Take description from previous papers (Ribalet et al. 2010; Swalwell et al. 2011)

*2.3. Underway O2/Ar productivity estimates*

*2.4. Analysis of spatial variability*

We split the underway data into segments that were at least 200km long, with no gaps in the data greater than 20km (Fig.1). The data is interpolated onto a regular 1 km track, and the large scale trend is removed with a high-pass filter.

Spectral analysis: calculate power spectral density, and then bin the spectra into 10 bins per decade, confidence intervals are computed using chi-squared distribution (\*\*ref\*\*).

**3. Results**

*3.1. Physical context*

Describe the regional context and reference

*3.2. Spatial variability across regions*

Data for each segment (Fig. 2)

Spectra (Fig. 3) for each biological variable and density as the physical variable.

Table 1. Estimated spectral slopes for each variable and the ratio of each biological variable to density.

What is the variance of each community for each segment as a percentage of its mean abundance? How about correlation with physical variables? Correlation between communities?

Possibly add data on Pro and Syn ecotypes form the station data at the end of each segment?

**4. Discussion**

Pitfalls of using spectral analysis, e.g. problems with using fluorescence data and multiple ways of generating the same slope (Franks 2005) – this is mostly a non-issue for us as we use cell counts for the phytoplanton populations and the fluorescence data is used only for biomass (and all tracks completed in a few hours).

Pro, syn and picoeuks behave differently. Pro doesn’t care about physics, and all variability is around a very constant background value, seems to be purely due to biological variation. Possible mechanisms for this: this is tightly coupled predator-prey system (Ribalet et al. 2015), but pro division rates are so high that if there is a slight perturbation to predation pressure, there can be a large and quick response, resulting in large fluctuations… Need to think about resilience and possibly compare estimates of resilience for different ecosystem structure (e.g. predator-prey vs resource competition).

*Prochlorococcus* has high genetic variability (Kashtan et al. 2014) which could also be driving these fine scale patterns, creating heterogeneity in the fitness of the community, or its susceptibility to predators (Menden-Deuer and Rowlett 2014).

**5. Conclusions**

**6. Acknowledgements**

**7. References**

Bracco, A., S. Clayton, and C. Pasquero. 2009. Horizontal advection, diffusion, and plankton spectra at the sea surface. Journal of Geophysical Research **114**, doi:10.1029/2007jc004671

Franks, P. J. S. 2005. Plankton patchiness, turbulent transport and spatial spectra. Marine Ecology Progress Series **294:** 295-309

Kashtan, N. and others 2014. Single-Cell Genomics Reveals Hundreds of Coexisting Subpopulations in Wild *Prochlorococcus*. Science **344:** 416-420, doi:10.1126/science.1248575

Mahadevan, A., and J. W. Campbell. 2002. Biogeochemical patchiness at the sea surface. Geophysical Research Letters **29:** 32-31-32-34, doi:10.1029/2001gl014116

Martin, A. P., M. V. Zubkov, M. J. Fasham, P. H. Burkill, and R. J. Holland. 2008. Microbial spatial variability: An example from the Celtic Sea. Progress in Oceanography **76:** 443-465, doi:10.1016/j.pocean.2008.01.004

Menden-Deuer, S., and J. Rowlett. 2014. Many ways to stay in the game: individual variability maintains high biodiversity in planktonic microorganisms. J R Soc Interface **11:** 20140031, doi:10.1098/rsif.2014.0031

Ribalet, F. and others 2010. Unveiling a phytoplankton hotspot at a narrow boundary between coastal and offshore waters. Proc. Natl. Acad. Sci. U. S. A. **107:** 16571-16576, doi:10.1073/Pnas.1005638107

Ribalet, F. and others 2015. Light-driven synchrony of Prochlorococcus growth and mortality in the subtropical Pacific gyre. Proceedings of the National Academy of Sciences of the United States of America **112:** 8008-8012, doi:10.1073/pnas.1424279112

Swalwell, J. E., F. Ribalet, and E. V. Armbrust. 2011. SeaFlow: A novel underway flow-cytometer for continuous observations of phytoplankton in the ocean. Limnology and Oceanography-Methods **9:** 466-477, doi:10.4319/lom.2011.9.466

**Figure Legends**

Figure 1.

Figure 2.

Figure 3.

Figure 4.

**Table 1.** Estimated spectral slopes for each of the physical and biological variables analysed for each of the cruise track segments. We also include the ratio of the biological spectral slopes to the density spectral slope.