Report of the 14th Annual Line P Workshop, Fisheries and Oceans Canada, Zoom platform, 10 March 2021

Chaired by **Marie Robert**, Line P program manager, Institute of Ocean Sciences, Fisheries and Oceans Canada (DFO/IOS).

Introduction

For the first time in 14 years, the Line P Workshop in 2021 has gone virtual! Seventy-two ocean scientists and technicians met in March 2021 via Zoom to share historical and recent observations along Line P, as well as to present their current research interests and proposed future sampling plans. "Line P" is a 1425-km-long set of ocean stations off Canada's West Coast, monitored for 65 years by weatherships and research vessels. It began with sampling from weatherships during their transits to and from Ocean Station Papa (OSP) at 50N, 145W, from the 1950s until 1981. Fisheries and Oceans Canada has financed ship time and core scientific programs since 1981. With more international and academic partners joining the program, leading to more diverse studies, it became useful to meet annually to compare insights and plan future sampling programs. Unfortunately due to the COVID-19 pandemic no external collaborators sailed with us on the two Line P cruises of August 2020 and February 2021. Since instrumentation was not impacted by these restrictions, here is a short summary of each presentation from this 14th annual workshop largely (but not only!) focussed on moorings and Argo data.

Marie Robert (DFO/IOS): *Overview of the Line P Program.*

Since there are always new Line P Program or workshop participants present every year, the full version of the "overview of the Line P Program" talk was presented, detailing the work that DFO employees perform on Line P cruises. Other points of interest were:

- Only eight berths are available at the moment for science on the *Tully*. This restriction on the number of berths may be lifted if the pandemic allows, but at the moment we are only planning on single cabin occupancy.
- Line P data are available on the Website at https://www.waterproperties.ca/linep, or contact me at Marie.Robert@dfo-mpo.gc.ca.
- The 2021-2022 Line P cruises are planned as follow:
    - 2021-006 will go from 2 May to 18 May 2021.
    - 2021-008 will go from 24 August to 7 September 2021.
    - 2022-001 will go from 22 February to 12 March 2022 and we're hoping to do some coastal work at the end, weather permitting.
- Because of the reduced number of berths available, everyone participating to a Line P cruise has to stand a 12-hour watch.
- We may be able to collect water for those not on board, but it has to be 'easy sampling' due to the reduced number of participants.
- Thanks to Stephen Page for technical support and to Steve Romaine for assistance with question periods.

Annika Margevich (NOAA): *A 70 year meteorological time series at Station Papa from an Ocean Weather Ship (1949-1981) and a NOAA Surface Mooring (2007-Present).*

Annika Margevich[1,2,3], Meghan F Cronin[3], Nicholas Bond[4]

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This talk will focus on the use of two meteorological time series taken at OWS P from 1949 to the present day for investigating two hypotheses that might partially explain the surface freshening observed at Station Papa over the 70-year period. The two time series used in this study consist of a 31-year observational time series collected by ocean weather ships stationed at OWS P from 1949 to 1981 and a 13-year time series collected from the NOAA surface mooring that was deployed at the same location in 2007. Our first hypothesis is that increased rainfall, either as a result of more frequent or more intense storms, contributes to the surface salinity to decrease. The second hypothesis is the atmosphere at Station P has become more moist, thus reducing evaporation (i.e. latent heat loss) and thereby leads to freshening of sea water. Climatologies computed for the mooring and for the weather ship, show that the first hypothesis is correct, while the second is not. Rainfall has increased at Station P over the last 70 years, but so has evaporation, although to a lesser extent such that the net precipitation minus evaporation is now larger than it was during the ocean weather ship era. The increase in evaporation appears to be due to the increase in sea surface temperature. Other processes associated with shifts in the subpolar gyre likely also play key roles in the freshening but are not addressed here. The OWS Papa rainfall data used in this study were found in a Fortran code provided by Dr. Bill Large (NCAR). It is critical that these long OWS Papa data are properly archived.

Jim Thomson and Jie Yang (UW-APL): *Station P waverider surface mooring updates.*

We present an update on the waverider surface mooring at OWS-P. This UW-APL mooring measures surface waves and ambient noise (using a sub-surface PAL sensor). Recent observations and seasonal trends will be presented. The UW-APL mooring was replaced in summer 2020 as part of a NOAA effort. In January 2021, the wave sensor began to malfunction and is awaiting replacement. There is also a need to recover the sub-surface remnant of the mooring (with the PAL) left behind in summer 2020. Continued operation of the waverider mooring is pending new funding by the NSF (proposal submitted Feb 2021).

Jacki Long (MBARI): *Leveraging observations from Line P to enhance depth-resolved products from profiling floats.*

A commonly used net primary production (NPP) algorithm, the Carbon-based Production Model (CbPM), developed for use with satellite observations has recently been adapted for application to biogeochemical profiling float observations of backscatter and chlorophyll fluorescence. This adaptation now allows for both depth-resolved and depth-integrated NPP estimates in regions where satellites cannot observe. However, temporal variations in the relationship between chlorophyll concentration and fluorescence are known to occur and are particularly common in High Nutrient Low Chlorophyll regions, such as the Northeastern Pacific Ocean, when

phytoplankton are stressed by changes in iron availability. Here, seven years of fluorescence data from three biogeochemical floats are calibrated to chlorophyll concentrations from routine Line P Cruise observations to obtain a better estimate of float-based chlorophyll as an input to CbPM. Using the adjusted data, float estimated CbPM-NPP is compared to satellite estimated CbPM-NPP and persistent discrepancies are identified and diagnosed. Even with the identified discrepancies, a significant relationship between annual NPP anomalies and annual sea surface temperature anomalies is found, providing insight about ecosystem functionality during two recent marine heatwaves. A depth-resolved proxy for phytoplankton stress based on the newly adjusted float chlorophyll data may provide complementary information for interpreting variability in phytoplankton community structure.

Ahron Cervania (UVic): *Wind-driven isopycnal oxygen variability insights from lag-corrected Argo floats.*

Ahron Cervania, Roberta Hamme

Since the mid-2000s, Argo profiling floats equipped with oxygen sensors have been deployed in the vicinity of Station P, provided a new dataset for examining natural variability of dissolved oxygen in the region. I will present work using oxygen sensors on 8 Argo profiling floats to understand the drivers of variability at Station P, focusing on the σ_Θ = 26.5 kg m^{-3} isopycnal. First, a technique to correct the oxygen sensor lag within the oxycline is presented and the uncertainty of the lag-corrected profiles is evaluated with a Monte Carlo analysis. Second, float gain values, used to correct for sensor drift over time, are checked by comparison to spatially and temporally collocated shipboard observations at Station P and updated as necessary. Finally, time-series of properties on the σ_Θ = 26.5 kg m^{-3} isopycnal spanning late 2008 to early 2016 are generated from float profiles within a 150 km radius of Station P. There is a continuous decrease in oxygen saturation on the isopycnal (~10%) from late 2009 to early 2011, which does not appear to be due to a change in equilibrium concentration or a shift in water mass sampled. Simultaneously, the isopycnal is observed to shoal by ~50m, indicating a change in wind patterns. Possible mechanisms to explain the observed oxygen decrease are that the vertical displacement of the isopycnal enhanced organic matter respiration or that the horizontal advection water to Station P from the ventilation region was slowed thereby increasing water mass age. A second shoaling event occurring from 2014-2015 may support the mechanism of enhanced organic matter respiration.

Patrick Duke (UVic): *Estimating the Northeast Pacific Ocean CO_2 flux from Station Papa to the Salish Sea using a neural network approach.*

Patrick Duke, Roberta Hamme, Debby Ianson, Peter Landschützer, and Mohamed Ahmed.

Understanding natural variability in the marine carbon system can help inform observational programs such as Line P, optimize modelling for future climate projections, and inform adequate climate actions. Here, we use a neural network approach as a method of gap-filling sparse observations to basin wide estimates. We compiled partial pressure of CO_2 (pCO_2) observations from regional sources including La Perouse and Line P cruises, and the international SOCAT database, as well as a range of predictor variables including physical oceanographic reanalysis products, and satellite based biological estimates. With the predictor variables acting as proxies

for known processes affecting pCO_2, we are able to create non-linear relationships to interpolate observations from 1998-2019 in the Northeast Pacific. Currently, we are building this approach and are hoping to use unpublished Line P underway data from 2009 through 2020 as a truly independent evaluation dataset. Given the cruise track along the coastal to open ocean continuum, the variability captured over the last decade will hopefully prove to be a formidable test for the regional neural network method.

Yibin Huang (NOAA PMEL & UCSC): *Insights on the biological pup in the northeast Pacific from biogeochemical profiling float observations.*

Biological-mediated carbon transfer from the surface to the depth plays a vital role in regulating the oceanic sequestration of carbon and the Earth's climate. The recent advent of the biogeochemical-float (BGC-float) provide a powerful means to characterize biological pump at spatiotemporal resolutions that were previously out of reach. In this talk, I will present two lines of our work forged to better understand the biological pump by leveraging the multiple BGC-floats deployed in Northeast Pacific including the development of a novel approach for remote partitioning of distinct biogenic carbon export and a synthesis of mesopelagic remineralization and upper layer carbon export (supply) that helps solve an enduring mystery of carbon budget in the mesopelagic zone.

Michael Livingston (UVic): *Drivers of carbon gel concentrations in the NE Pacific.*

In recent years there has been an increased focus on the role of transparent exopolymer particles (TEP) on the cycling and export of carbon in the surface ocean. TEP, formed from the exudation products of phytoplankton and bacteria, creates a gelatinous matrix in the upper layers of the ocean that acts to promote the aggregation of particulate organic matter (POC). It has recently been proposed that due to its low density, high concentrations of TEP relative to POC act to increase the retention time of POC in the surface ocean. Therefore, TEP is an important element in the functioning of the biological carbon pump, and it is essential to understand how the concentration of these gels in the ocean will change in future decades.
The main drivers behind TEP production and its dominance within the POC pool remain somewhat poorly understood. Here, I present data from three Line P cruises (and two La Perouse cruises) from June 2019 – February 2020 and propose the main drivers behind TEP in the ocean. Furthermore, it may be possible to predict the concentration of these carbon gels (and their fraction of the total POC pool) from variables such as nutrient concentration, chlorophyll and temperature.

Robert Izett (UBC): *Net community production from Line P and La Perouse surveys: Summary of results from 2015-2019 and plans for the future.*

Robert Izett & Philippe Tortell

Marine net community production (NCP) represents the balance between primary production and community-wide respiration, and thus constrains an ocean region's capacity for CO_2 sequestration and biomass production. In the past two decades, NCP in the mixed layer has been quantified from high-resolution, underway measurements of the tracer $\Delta O_2/Ar$ (i.e. the "biological O_2 saturation anomaly") made by ship-board mass spectrometry. As Ar is a biologically inert analog of O_2, the O_2/Ar ratio is insensitive to physically induced changes in O_2

saturation state and NCP is proportional to $\Delta O_2/Ar$ if vertical mixing of O_2 across the base of the mixed layer is negligible. However, in many ocean regions, such as the physically dynamic waters of the Vancouver Island continental shelf, the vertical mixing of O_2 can significantly bias NCP estimates derived from $\Delta O_2/Ar$. Moreover, ship-board mass spectrometry is cost-prohibitive to many research groups, and the coverage of $\Delta O_2/Ar$ observations is limited to research cruises with dedicated operating personnel and infrastructure. In this workshop, we present results from Line P and La Perouse cruises between 2015 and 2019 summarizing progress towards addressing these limitations. Specifically, we describe an approach for refining NCP estimates for vertical O_2 mixing fluxes using surface and subsurface N_2O measurements and present a new approach to deriving NCP from fully autonomous surface measurements of the seawater O_2/N_2 ratio. We summarize by presenting preliminary results from an empirical statistical algorithm that predicts the synoptic NCP distribution from commonly measured oceanographic variables and describe future plans in the Tortell group for continued NCP observations from Line P surveys.
(Could not present).

Robyn Taves (UVic): *Ocean Station PAPA August 2019: marine heatwave effects on upper trace metal distributions in the subarctic NE Pacific.*

The subarctic NE Pacific experienced a marine heatwave, "Blob 2.0", during the summer of 2019. This sudden change to the environment resulted in strong net community production (NCP) and significant consumption of mixed layer macro and micronutrients at Ocean Station PAPA (OSP) in August 2019. The trace metal concentrations in the mixed layer were similar to that of the 2014/15 Blob, but differed in NCP and macronutrient depletion. The 2019 silicic acid to nitrate consumption ratio ($\Delta Si:\Delta N$) and cadmium to phosphate ratio (Cd:P) suggest the OSP phytoplankton community was dominated by larger phytoplankton, likely resulting from an input of iron to the system.

Wylee Fitz-Gerald and Racquelle Mangahas (UBC): *Are Asian-derived anthropogenic aerosols controlling phytoplankton at Ocean Station PAPA?*

Wylee Fitz-Gerald, Racquelle Mangahas, Jian Guo, and Maria T. Maldonado

Atmospheric aerosols are often a source of nutrients to the ocean and have been shown to enhance primary productivity in some regions. However, the phytoplankton response to Asian derived atmospheric aerosol inputs in surface waters in the North East Pacific may be complexed. Long-range transport Asian derived aerosols are composed of a mixture of natural and anthropogenic aerosols, and while natural aerosols are often enriched in essential trace elements (i.e. Fe), anthropogenic aerosols may contain high levels of potentially toxic metals (i.e. Cu). We are investigating the physiological impacts of Asian-derived aerosols on phytoplankton at Ocean Station PAPA. Water and aerosol samples were collected along Line P, characterized and used for laboratory culture experiments with ecologically relevant phytoplankton species of various taxa. Culture treatments included in situ conditions, and various combinations of added macro- and micro-nutrients, as well as organic metal chelators. Preliminary data indicate a diverse phytoplankton growth response to Station Papa water collected in different months and years. This suggests seasonal variations in nutrient concentrations in the area that may be linked to atmospheric aerosol deposition. Consistent with previous investigations, our preliminary data

suggest that the concentrations of Fe at Station Papa are often limited, but other trace metals, such as Cu, may be detrimental for the growth of some phytoplankton taxa. An interaction between vitamins, Fe and Cu nutrition was also found in some diatoms.