Report of the Third Annual Line P Workshop, Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, BC, March 16 and 17, 2010

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Prepared with the help of **Bill Crawford**, Institute of Ocean Sciences, Fisheries and Oceans Canada, April 2010.

Introduction

Fifty-seven ocean scientists, academicians and technicians met in March 2010 to share recent observations along Line P, as well as to present their current research interests and proposed future sampling plans. "Line P" is a 1400-km-long set of ocean stations off Canada's West Coast, monitored for over 50 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, in the 1950s. Fisheries and Oceans Canada has financed ship time and core scientific studies for most of these years. With more international and academic partners joining the program, leading to more diverse studies, it became useful to meet to compare insights and plan future programs. At the 1st workshop in February 2008 scientists met to discuss future experiments and techniques. The 2nd workshop in March 2009 focused more on scientific results, as well as on promoting collaborations and optimizing ship time and space. For this third workshop in March 2010, optimizing ship time and space became critical since all cruises are fully booked with more people on waiting lists.

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

Marie described the basics of the Line P Program; what sampling is done at what station, what is the distance/timing between stations, how long each cruise lasts, etc. She also described the paperwork needed and schedule for the next year:

- Requests for security clearances and work with radioisotopes have to be started at least two months prior to the cruise.
- All scientists joining the cruise need to bring along their passport.
- DFO needs to be acknowledge whenever cruise data are being used for publications, presentations or posters.
- The participation line-up for the three coming Line P cruises was presented. There are several scientists now on the waiting list because the CCGS *John P Tully* has a limited number of berths for scientists.

Wendy Richardson (IOS/DFO): *Nutrient storage study: quality comparison of fresh, cool, and frozen seawater sample results.*

Wendy presented the preliminary results of a "nutrients experiment", started during the February 2010 Line P cruise, trying to answer the following questions: do we need to analyse the nutrients fresh at sea, or can we keep the samples cool and bring them back to land for analysis in the lab, or freeze them at sea for later analysis on land? And if frozen, how long can the samples stay frozen for? The pros for analysing the samples at sea are the following: nutrients have been analysed at sea since 1987, so it's a better continuity in the dataset. There is a possibility that some people need "real-time" nutrient values (although they still have to wait 24 hours or so for the results). Frozen values are not considered WOCE (World Ocean Circulation Experiment) standards. Silicate values below 400 m lose quality when the samples are frozen. The pros for bringing the samples back to the lab are the following: It would free up a berth and two bench spaces in the main lab. Working conditions can be rough at sea, both for the analyst and the analyser. The temperature variations in the main lab are not good for data quality. Having the instrument in the lab allows the analysis of more samples during the year.

The experiment consisted of taking 20 samples from each of 6 depths (10, 250, 400, 600, 1000, and 4000 dbar) at station P20: 4 samples analysed fresh at sea, 4 samples kept cool on the ship and analysed back in the lab, and 12 samples frozen, to be analysed in 3 weeks, 4 months, and 12 months following the sampling date. The results of the studies are that the samples do not need to be analysed at sea on every cruise, but once per year would be good practice. The samples could be kept cool for shorter cruises and/or frozen at sea. Another experiment was also performed in order to study the impact of using used tubes to sample nutrients. It seems that greater variation in the results was due to the type of tubes used than to the timing of the analysis or the freezing of the samples. New tubes will therefore be used on Line P cruises from now on. Finally the importance of drawing the samples carefully was reiterated.

Meghan Cronin (NOAA/PMEL): *Ongoing Ocean Station P Time Series.*

Meghan gave a presentation about the ongoing Ocean Station P time series, based on a talk given at the Ocean Sciences Meeting in February 2010. She talked about the work done at Station P during the last 60 years, including the Weather Ships, MILE, STREX, SUPER, Ocean Storms Fall, and others. She also mentioned that Station P is part of OceanSITES as well as of OOI (Ocean Observatory Initiative). As part of OOI, a new Wave Rider mooring will be deployed in June 2010 and will need servicing until June 2013. A new sensor, the Passive Aquatic Listening Device, will be deployed on the Wave Rider buoy and will listen to rain, wind, bubbles, marine life, and ships traffic. This new mooring is needed to improve mixed layer models. The ADCP (Acoustic Doppler Current Profiler) mooring does not have funding and will be recovered in June 2010 and not re-deployed.

As for the surface mooring, deployed for the first time in June 2007, its primary purpose is to monitor the carbon cycle and ocean acidification. The CO_2 decreased in August 2008 due to increased productivity (see **Roberta Hamme**'s presentation). The surface mooring data are also used to compare O_2/N_2 ratio in order to determine biological drawdown of oxygen by plankton. The surface mooring has a full set of sensors to measure meteorological data such as air-sea heat, moisture and momentum fluxes, mixed layer heat, and freshwater budgets. Sea-water temperature is measured in the top 300 m, sea-water salinity in the top 200 m, and UV is

measured at 5 m. A University of Washington Glider was sampling in a butterfly pattern around Station P but its mission ended in January 2010. It was measuring the spatial variations of temperature, salinity, and dissolved oxygen. The oxygen is monitored by the Line P program, by the mooring, and by satellite. (Note: the Glider sampled from OSP to the continental slope off Juan de Fuca Strait in January to April 2010, and was recovered in early April 2010).

Lisa Miller (IOS/DFO): *pH on Line P: Then and Now.*

This presentation was a collaboration among **Lisa Miller**, **Jim Christian**, and **Debby Ianson**, all of IOS/DFO. There is a new pH sensor now in use on the Line P cruises. Historically, pH was measured at OSP (Ocean Station Papa) in 1956, but it was stopped in 1959**.** Beginning in February 2008 full profiles were sampled at the 5 main stations, and in June 2009 the profile at P2 was added. **Jim Christian** has spent considerable effort to recover pH and alkalinity data from historical data. From alkalinity and DIC (Dissolved Inorganic Carbon) pH can be calculated, but the calculated values of pH are not as accurate as the direct pH measurements. Jim found reasonable agreement in most cruises. **Debby Ianson** used the alkalinity and pH data in her modelling of the shelf waters of the Vancouver Island southwest coast. The pH there is high in summer at the surface, but it sometimes dips after upwelling events.

Sophie Johannessen & Michael Arychuk (IOS/DFO): *Line P pCO_2: program update and 30-year trends.*

Michael discussed how the data quality has improved following the changes that were made to the system, mainly with the pump diaphragms and the modifications to the software. These changes were started about two years ago and took three months to complete. More specifically, regarding the pumps, the old ones were not suited for saltwater environment. Diaphragm degradation led to flow inconsistencies or pump failure. For the software, the old version allowed no trouble-shooting. Now the display shows variables such as gas flow or water flow with a 10-hour buffer. Real time data is also displayed for days rather than hours.

As for the Li-COR traps, these were checked by **Marty Davelaar**. A manual was finally found saying that the internal traps should be changed every year. This had not been done since 2002 or so. A schematic diagram is now available, as well as a detailed set-up manual that was tested when a new technician was able to set-up the system without help simply by following the manual instructions. Some daily operations checks were also implemented and an instrument log book now accompanies the system. **Sophie** presented the pCO_2 results from cruise 1973-08 and 2003-27, showing how different the data look. She showed how for the surface coastal waters off Vancouver Island the pCO_2 is linked to the multi-variate El Niño Index (MEI), whereas in the surface oceanic waters of Line P, pCO_2 is linked more closely to the Pacific Decadal Oscillation (PDO).

Nadja Steiner (IOS/DFO): *DMS at Line P – observations and modeling.*

Nadja started by presenting the general science of dimethyl sulfide (DMS), as well as some new hypothesis/understandings recently published. DMS might disperse all through the troposphere and then come back to the marine boundary layer, with different impact than what is commonly assumed with the CLAW hypothesis (Charlson, Lovelock, Andreae and Warren). A problem

here is that the model parameters are not well known and small changes in parameters cause significant changes in model output.

Kiene and Slezak (2006) report problems in standard sampling for dissolved dimethylsulfoniopropionate (DMSPd). During the recent SOLAS conference in Barcelona (2009) it was discussed that the DMSPd turnover times are so fast that it is not necessary to include this process in global climate models, although Nadja does need a good summary of DMS budget in her model. However, the spread in DMS observed at Station P and along Line P looks very large and is difficult to understand. There is lots of variability along Line P – is this linked to ENSO? There are some features in the observations that are not simulated by the model; it is possible that there are some issues with the observations.

Regarding the unusual bloom at Station P in August 2008 not showing in DMS data, this is probably due to the ship arriving after the bloom of small phytoplankton but before the bloom of larger diatoms, therefore the DMS had already reached normal values. Until large variability in yields and in DMSPd measurements are better understood we must proceed with caution in implementing a mechanistic marine sulfur cycle into comprehensive climate models.

Elizabeth Asher (UBC): *A new generation of DMS time-series measurements along Line P: Observations, predictions and process studies.*

Elizabeth presented the work she will be doing for her Master's Degree with **Philippe Tortell** at UBC. She told us that the measurements of DMS in summer on Line P are about 95% of the global ocean measurements. Historical data might show a weak daily cycle in DMS values, but the new UBC measures show other processes might be happening as well. They use the MIMS (Membrane Inlet Mass Spectrometry) to obtain a much better resolved surface structure than the IOS/DFO 6 surface measurements could ever obtain. They also try to use PAR and Chlorophyll-*a* data calculated from satellite to compare with UBC surface DMS values along Line P. The coccolitophores produce lots of DMS. Elizabeth will also participate in the La Perouse (West Coast Vancouver Island, May 2010) cruise as well as **Debby Ianson**'s Ocean Acidification cruise in July 2010.

Josiane Mélançon (U Laval): *Impact of eolian iron on phytoplankton and dimethylsulfide (DMS) production in the northeast subarctic Pacific.*

There are two main sources of iron deposition in the Pacific Ocean attributed to airborn dust: Asian deserts, and volcanoes. The marine DMS accounts for 50% of all natural sulphur emissions to the atmosphere. These cool the atmosphere by stimulating cloud formation. Some factors influence the net DMS production, such as the health and growth phase of phytoplankton for example. And the phytoplankton community and its production of DMS is in turn impacted by eolian dust deposition. Other factors impact the iron biochemistry such as ocean acidification.

Josiane's project involves 4-day incubations at sea as well as trace-metal clean sampling, and she is planning to participate in the summer Line P cruises until 2011. In 2009 she used commercial dust from the Gobi desert as well as Beijing dust for on-board incubations along Line P. In 2010 she will also use volcanic ashes from Reboubt (Alaskan volcano), Chaiten (Chilian volcano), and she's still trying to get ashes from the Kasatochi (Aleutian volcano). Her preliminary results are that the dissolved iron increases as the dust is added but the nitrate

consumption does not change. It was suggested that she try inoculating with iron from deep waters as well.

Yiming Luo/Bart de Baere/Drew Snauffer (UBC): *Paleotracers at Station Papa.*

Yiming gave the first part of this presentation by talking about how he uses Th and Pa isotopes to study particle dynamics and overturning circulation. ^{234}Th is used for export flux. It is low at Station Papa compared to Station Aloha (HOTS, near Hawaii), likely due to scavengers at Papa. Pa is lower at Station Papa in the top 2000 m than at HOTS due to upwelling of deep waters at Papa.

Bart then talked about the use of elemental ratios (e.g. Mg/Ca) and δ^{18}O in foraminifera and diatoms as paleotracers. He developed an instrument at UBC (the "Belgomatic") to uncover the elemental geochemistry of foraminifera. He analysed samples from bongo nets obtained from **Doug Moore** and **Moira Galbraith** of IOS/DFO and discovered different growth phases based on the time-rate of extraction of minerals. For the future he wishes to sample foraminifera at narrow depth ranges. He is interested in working with **Doug Yelland** of IOS/DFO on the June Line P cruise since Doug will be operating the Multinet zooplankton sampler.

Drew concluded the talk on paleotracers by discussing Neodymium in seawater. Neodymium is used as a water mass tracer, especially for changes in distribution of water masses in paleo times. Line P is an especially interesting area to perform these studies because of the change in water type from the shelf to the deep sea. This might help shed light on past Arctic circulation. The proposed future work is to do vertical neodymium profiles at stations along Line P as well as redeploying the sediment trap moorings at Station Papa.

Nutrient storage study discussion

Following these presentations, before breaking for lunch, we discussed the results of the nutrients storage study. Most agreed that analysing the nutrients fresh at sea only once per year was satisfying. No one present had requests for "real-time" nutrients data. **Philippe Tortell** brought up the point that, should someone need real-time nutrients values, it was possible to use a fluorometer to obtain them; we don't need the whole auto-analyser on board. **Jay Cullen** also noted that there are some nitrate sensors that can be used on the CTD to obtain nitrate profiles.

Seth Bushinsky (UW): *Development of an in situ oxygen Optode calibration system at Station Papa.*

Their group has an in situ oxygen optode on the Papa mooring. It is difficult to measure carbon export from the surface water, but they have an O_2 mass balance model that makes use of O_2/C stoiciometry: the export of carbon leaves excess of oxygen near the surface. Even better is to consider N_2. This tested well with Winkler O_2 measurements. The problem is that ±0.5% error in O_2 concentration results in ±50% uncertainty in biological O_2 term, and they see ~1% drift in Aanderaa optodes and higher drift in SeaBird Clark Electrode style O_2 sensors. They are thus trying to develop a system to calibrate the optode system on the mooring. The initial results show some promises – the difference with their optode is small and steady in time. This method might also help calibrate the optode on the Argo floats. The optodes can have an offset from "batch calibration" of up to 20%. It is best to calibrate over both temperature and oxygen ranges.

Christina Schallenberg (UVic): *Kinetic experiments of superoxide decay at two stations along Line P.*

Christina's work is to measure the decay of superoxide along Line P. Superoxide is a very reactive radical that can act as both electron donor and acceptor. It has the ability to reduce trace metals such as iron and copper in the surface ocean, which - in the case of iron at least - can make these metals more bio-available. She mainly uses kinetic experiments to measure superoxide decay to investigate the sinks for this chemical. Along Line P, Christina's plans are to study the process of superoxide decay in different seasons and possibly with different concentrations of metals added. She would also like to experiment with time of day, i.e. day versus night, to distinguish photo-production from biochemical sources. Another goal is to further explore the possible links between superoxide production and trace metal bio-availability. Finally, investigation of biochemical superoxide production as a possible indicator of the physiological state of the phytoplankton community might provide a link with the DMS production.

Kendra Mitchell (UBC): *Microbial community of the oxygen minimum zone along Line P.*

Kendra studies the microbes in the oxygen minimum zone (OMZ) since the members of these communities and their metabolisms are largely unknown. The OMZ is expanding and intensifying, and the mineral cycling is dominated by microbes. This work is the first along Line P or any oceanographic transect to use metagenomics to examine the community of the OMZ. Kendra's group collects 0.2 – 3.0 µm fraction from large volumes of water at 10, 500, 1000, and 2000 decibar to extract the community DNA. From there they obtain the taxonomic structure, the community metagenome, and they quantify the dominant community members, allowing them to relate the communities to their geochemical setting. The microbial community they have observed is diverse, especially the bacteria. Their future work involves mining this data for metabolic genes involved in carbon fixation, as well as nitrogen and sulphur cycling, and to continue to relate community structure and dominant member abundance to the geochemical setting of the OMZ.

Jody Wright (UBC): *Temporal variation in bacterial community structure in the ocean's interior at Ocean Station Papa.*

Jody's work is closely related to **Kendra Mitchell**'s project presented previously, and focuses mainly on spatiotemporal dynamics of bacterial community structure in the OMZ at OSP. Specifically she wants to determine the taxonomic diversity of microbial communities within the OMZ at OSP, or in other words: who is there? Are there spatiotemporal patterns in microbial community structure, and what are the patterns over depth and time? And how do these patterns relate to ecosystem function (i.e. biogeochemical cycling of C, N, and S)? Jody described her sampling procedures, and introduced the GATE tool: Grid Analysis of Time-series Expression, which is a software platform for analysis and visualization of high-dimension bio molecular time-series. The present conclusion of her studies is that the microbial community structure within the OSP OMZ is dynamic and temporally active; they are continuing to test for evidence of seasonality or other forms of periodicity. The next question they want to answer is: How does variation in community structure relate to changing fluxes of biogenic materials, and to water column biogeochemistry and community metabolism?

David Semeniuk (UBC): *Trace metal bioavailability to marine microorganisms – Revisiting the copper prime paradigm along Line P.*

Trace metals can control primary productivity, by their limitation, but also by their toxicity. But what controls trace metal bioavailability? **David** presented the original questions of this project, which started around 2006: What is the bioavailability of Cu bound to different organic ligands? And what is the bioavailability of Cu bound to the *in situ* ligands at Station P? Their initial conclusions were that Cu uptake is likely independent of [Cu'] (copper ligands), Cu update may depend on oxidation state, and *in situ* treatment resembles glutathione treatment. Then in 2008 they asked slightly different questions: What is the bioavailability of Cu(I) and Cu(II) bound to different organic ligands? And do bacteria and eukaryotes have a preference for Cu(II) or Cu(I)? After further studies their revised conclusions are that Cu uptake is independent of [Cu'], uptake depends on the oxidation state of Cu, bacteria prefer Cu(I) whereas eukaryotes prefer Cu(II), and *in situ* treatment resembles glutathione. Their future plans are to answer the following question: How important is Cu(I) as a source of Cu for primary productivity? They would like to couple Cu speciation measurements with Cu uptake assays, and they want to do some Cu/Fe co-limitation incubation studies at Station P to see if there are some seasonal or light changes.

Patrick O'Hara (EC/DFO/IOS): *Seabird sentinels of Line P: Progress on understanding climatic-oceanographic relationships.*

Patrick gave this presentation on behalf of **Sarah Ann Thompson** and **William Sydeman** from the Farallon Institute for Advanced Ecosystem Research in Petaluma, CA, and **Ken Morgan** from Environment Canada at IOS. The Line P seabird observation project is part of a bigger program that includes the CalCOFI observations off southern California, as well as Continuous Plankton Recorder studies in the subarctic Pacific Ocean and collaboration with the U.S. National Marine Fisheries Service. The general goals of the program are to investigate how seabirds respond to changing climate and ocean habitat conditions. Along Line P, 35 surveys have been conducted since 1996 to try to answer the questions: How many birds are there? Where do they occur? How are their populations responding to changes in ocean conditions? After filtering, transforming, averaging, and calculating seasonal density anomalies, it seems that the total number of birds along Line P has increased since the summer of 2004. In the future they would like to work more in collaboration with physical scientists and biological oceanographers to answer some of their questions.

Karina Giesbrecht (UVic): *Comparing productivity methods on Line P: O_2/Ar with ^{13}C and ^{15}N incubations.*

Karina's presentation was about the differences between "incubation based" and "non-incubation based" methods of measuring biological productivity. The first method involves dual-tracer $^{13}C/^{15}N$ incubations. Its integration time is 24 hours and it integrates over the euphotic zone. The advantages are that it is simple to sample, as well as the fact that, as just mentioned, the integration depth is the euphotic zone. On the other hand, there are some containment effects that can be hard to handle, and the incubators that are needed. The second method is based on O_2/Ar measurements. The time integration is approximately 2 weeks, whereas the spatial integration is the mixed layer. Its advantages are that no incubation is required, and it does integrate over a longer time scale. On the other hand winter mixing and gas exchange parameterization can affect the measurements.

The methods were compared on all three cruises in 2009 at P4, P16, and P26, and at Papa only in August 2008. Since the February results were affected by winter mixing, only the values of June and August were used. Karina's conclusions are that both incubation ($^{15}NO_3^-$) and non-incubation (O_2/Ar) based estimates of Net Community Production (NCP) are equivalent along Line P in the spring and summer, whereas ^{13}C-based productivity is approximately 3.5 times greater than NCP for the same time of year.

Roberta Hamme (UVic) and Philippe Tortell (UBC): *Constraining uncertainties in the quantification of the Subarctic Pacific biological pump.*

Roberta and **Philippe** presented a new project for Line P involving, besides themselves, **Jay Cullen** (UVic), **Maite Maldonado** (UBC), **Ricardo Letellier** and **Maria Kavanaugh** (Oregon State University), and **Zbigniew Kolber** (UC Santa Cruz). It is a collaborative study of the factors governing net/gross primary productivity and net community production along Line P (NPP/GPP and NCP). Some of the research objectives are: The mechanistic understanding of the effect of species composition, iron, light, and temperature on the distribution of energy between the electron transport rate, oxygen, and carbon; the determination of the spatiotemporal variability in GPP:NCP in the HNLC (High Nutrient Low Chlorophyll) region of the NE Pacific; and the error analyses to determine the relative impacts of methodological, physiological, and ecological variability on their ability to constrain GPP:NCP. The available methods of measuring productivity are active fluorescence, incubations, mixed layer tracers, and remote sensing. The Productivity Comparison Project would involve their participation in four cruises during 2011-2013: two summer cruises and two winter cruises. They would study three stations in each region: coastal, intermediate, HNLC, for a total of nine stations/cruise. The methods to be compared are incubation/non-incubation in order to determine GPP, NPP, and NCP. The ancillary measurements needed include dissolved iron, optics, and usual hydrographic data. They would also like to perform iron fertilization incubation experiments.

Gillian Stewart (CUNY): *Plankton community structure, POC export, and short-lived natural radionuclides.*

Gillian presented this new project which is in collaboration with **Bradley Moran** (U. Rhode Island) and **Michael Lomas** (Bermuda Institute of Ocean Sciences). The two big questions they ask are: How variable is the partitioning of particulate organic carbon (POC), ^{210}Po, and ^{234}Th (and their ratios) between suspended and sedimenting particles and the dissolved pool, and their subsequent export fluxes, in response to seasonal variability in the euphotic zone plankton community? And how do remineralization and decomposition rates of POC, ^{210}Po, and ^{234}Th vary with the packaging and export of materials produced by the planktonic community in the surface ocean under low and high flux conditions? The motivation behind these questions is to understand the variable efficiency of the biological pump and the ocean's capacity to sequester CO_2. It is important to work in an HNLC region where long time series are available. They want to open the black box of "biology" in geochemist's view of the ocean, and want to compare polonium versus thorium as a tracer of POC. The three hypotheses to check are:

- seasonal shifts in plankton community structure result in variations in C export (quality and quantity),

- size fractionated samples and taxonomy will allow for determination of the role of large and small cells in POC export,
- Po/Pb will track this differently than Th/U because Po behaves more like organic matter.

Gillian then described the logistics of the work they want to do on the Line P cruises.

Toby Westberry (OSU): *Surface Bio-optical measurements along Line P.*

This project involves, along with **Toby**: **Mike Behrenfeld** (OSU), **Emmanuel Boss** (U Maine), and **Mike Sieracki** (Bigelow Lab), and is based on the hypothesis that a seasonal plytoplankton bloom exists in the subarctic NE Pacific and is *comparable* to the North Atlantic Spring Bloom, but is masked by low Chl:C due to iron limitation. This is based on the following lines of evidence: satellite observations, photo-acclimation model, seasonal drawdown of nitrate, and iron enrichment experiments. The questions they would like to answer are: Why is there higher beam attenuation (c_p) and particulate backscatter (b_{bp}) per unit Chl than expected? Why is the backscattering ratio higher than expected? Can we separate physiology (e.g. photo-acclimation) from growth rate effects in optical indices? And can we relate optical proxies to phytoplankton biomass (not POC!)? Toby is planning to participate in the August 2010 Line P cruise.

Dave Mackas (IOS/DFO): *A decade of change in the Alaska Gyre: Comparison of three NE Pacific zooplankton time series.*

This talk is a collaboration with **Sonia Batten** (SAHFOS, Nanaimo, BC), and **Ken Coyle** and **Russ Hopcroft** (U Alaska, Fairbanks). The marine ecosystems undergo large multi-year changes in productivity and composition. To describe and understand them, we need good and ongoing time series. **Dave**'s talk compares some results from three of these time series in the Alaskan Gyre: the Southern Gyre – Line P net tows (since 1996), the Mid Gyre – CPR lines (since 2000), and the Northern margin – Seward AK line (since 1998). The comparison includes sampling methodology, schedule, and data processing methods. The results are:

1. There are two modes of recent physical variability: an interannual temperature variability along Line P, as well as a circulation variability in the Alaska gyre as seen by Argo drifters.

2. There is variability of zooplankton seasonal timing: later when colder.

3. There are anomalies of zooplankton amounts: *Neocalanus* & *Eucalanus* have been increasingly successful since ~2004 in the southern Alaska Gyre. Their upward trends are correlated with increased strength of the North Pacific Current, and also with cool temperatures in 2007-2008. In contrast, recent cold years had low May biomass on the Alaskan shelf. It is not yet clear how much of this is caused by reduced productivity, and how much by very delayed phenology.

Second general discussion

At the end of this first day we held a general discussion. The points brought forward were:

We should collect dissolved oxygen and salinity samples for calibration of the CTD on the outbound part of the cruise *as well as* on the return trip.

It is ok to freeze the nutrient samples, but this method is not suitable for silicate data below 600m. We will have to keep some samples cool to be analysed later at IOS for silicate.

We could bring **Jay Cullen**'s nitrate sensor on Line P cruises. The sensor could be put in line with the Thermosalinograph to see what the nutrients (nitrate) look like at the surface.

Dissolved oxygen values can drop along the intake pipe on the ship. This pipe should be checked with O_2 samples analysed with the Winkler method. The loop intake should be cleaned prior to every cruise.

Bill Crawford (IOS/DFO): *Weather anomalies and ocean temperatures in Gulf of Alaska.*

Bill presented maps of average sea surface pressure (SSP) in January-February relative to 1968-1996 as well as during La Niña winters, and the wind patterns that are associated with the SSP. They show that winds and storm tracks come more from the west along Line P in La Niña winters. These stronger westerlies bring cooler waters to Line P. The air pressure contours in Jan-Feb 2009 were La Niña-like. This corresponds with the cold waters seen on the BC coast at that time.

Bill then presented the SSP maps for the 2010 winter. For Jan–Feb 2010, the Aleutian Low was deeper, and the North Pacific High was weaker. The conditions in the 2010 winter were El Niño like, bringing warmer weather and more rain along the North Pacific coast. The effects of these air pressure patterns on the sea level are that very few Haida and Sitka eddies were present in 2008 and 2009 due to strong westerly winds in winter, whereas more eddies could be observed in 2009 due to strong southerly winds near shore.

Bill ended his presentation by showing **Marie Robert**'s graphs of temperature, salinity, and sigma-t anomaly along Line P, as well as the dissolved oxygen field graph, comparing the conditions in February 2009, June 2009, August 2009, and February 2010.

Howard Freeland (ISO/DFO): *Argo views of recent variability in the Gulf of Alaska.*

Howard first presented an update of the current state of the global Argo array, in the world's oceans as well as in the NE Pacific. He then showed how the density stratification at Station Papa varied over time as observed by Argo, specifically pointing out three occasions where the 25.8 density line reached the surface since 2001. Argo is really useful at 'seeing' the value of the mixed layer depth (MLD), an indicator of the strength of stratification in the NE Pacific. Howard then showed that the Argo data confirm the warming seen along Line P during the 2009-2010 winter, as presented by **Bill Crawford** in the previous talk using actual Line P data.

The changes in the circulation patterns in the Gulf of Alaska were then discussed. Howard's conclusions were that in the Gulf of Alaska we have just come out of a period of relatively weak stratification and we appear to be switching to a period of more intense stratification; this will imply shallower mid-winter mixed layers. The near-surface waters warmed significantly between the end of 2009 and the beginning of 2010. And the circulation is highly variable. The amount of water flowing in the North Pacific Current has declined from recent high levels to near normal, but the amount of water heading southwards in the California Current is at record low levels. The result is that the fraction of the North Pacific Current that flows in to the Gulf of Alaska is at record high levels.

Roberta Hamme (UVic): *Volcanic ash fuelled the August 2008 bloom event.*

This project was a collaboration of many people, and started during the 2nd Line P Workshop when many participants mentioned their "unusual results" during the August 2008 Line P cruise. Indeed, the area-averaged satellite chlorophyll data in August 2008 were the highest even seen. **Roberta** and colleagues used results from the SERIES Iron-enrichment experiment of July 2002, some laboratory experiments results, as well as mooring and glider data from the University of Washington and data from the Line P cruise to conclude that the bloom was likely caused by iron fertilization from the volcanic ash of the Kasatochi Volcano in the Aleutian Islands which erupted on August 8, 2008 into a low pressure system. Other hypothesis were studied (eddies, dust transport, lateral transport and mixing) but were determined to be unlikely cause.

Jody Klymak (UVic): *Measurements of lateral stirring on Line P.*

Jody presented the results he obtained with his Moving Vessel Profiler (MVP) along Line P in August 2008. First he gave some information about the MVP itself and the sensors that are on it. He then presented graphs of temperature along Line P. The MVP can look at horizontal stirring by sub-mesoscale eddies. From the shore to 600 km there was strong horizontal stirring, and from 600 to 1100 km offshore there was weak horizontal stirring, as measured by spiciness. The eddies show up really well in T-S plots, but the density anomalies are masked by internal waves. What is needed is more statistics, and time evolution over a few months to give mixing estimate.

Steve Romaine (IOS/DFO): *Ship time.*

Steve presented the process chief scientists on DFO Vessels have to go through in order to obtain ship time for their programs. There are more days requested than available every year on every vessel. Line P is the biggest user for ship time in OSD with 30% of all the available days on the *CCGS John P Tully.* It is very important to write Memorandums of Understanding (MOUs) between external participants and DFO, and to show the importance of the Line P Program to DFO. It is important to realise that Line P is a DFO ocean-climate project that is under-funded, and that DFO relies on outside sources to contribute scientific insight and assistance on Line P cruises to achieve its mandate.