RV SONNE

SO289 South Pacific GEOTRACES

18st February – 8th April 2022

Valparaiso (Chile) – Nouméa (New Caledonia)

5th Weekly Report

(21st March – 27th March 2022)

**Observations of surface ocean pH and $pCO_2$, and (micro-)nutrient control of ocean productivity in the South Pacific Ocean**

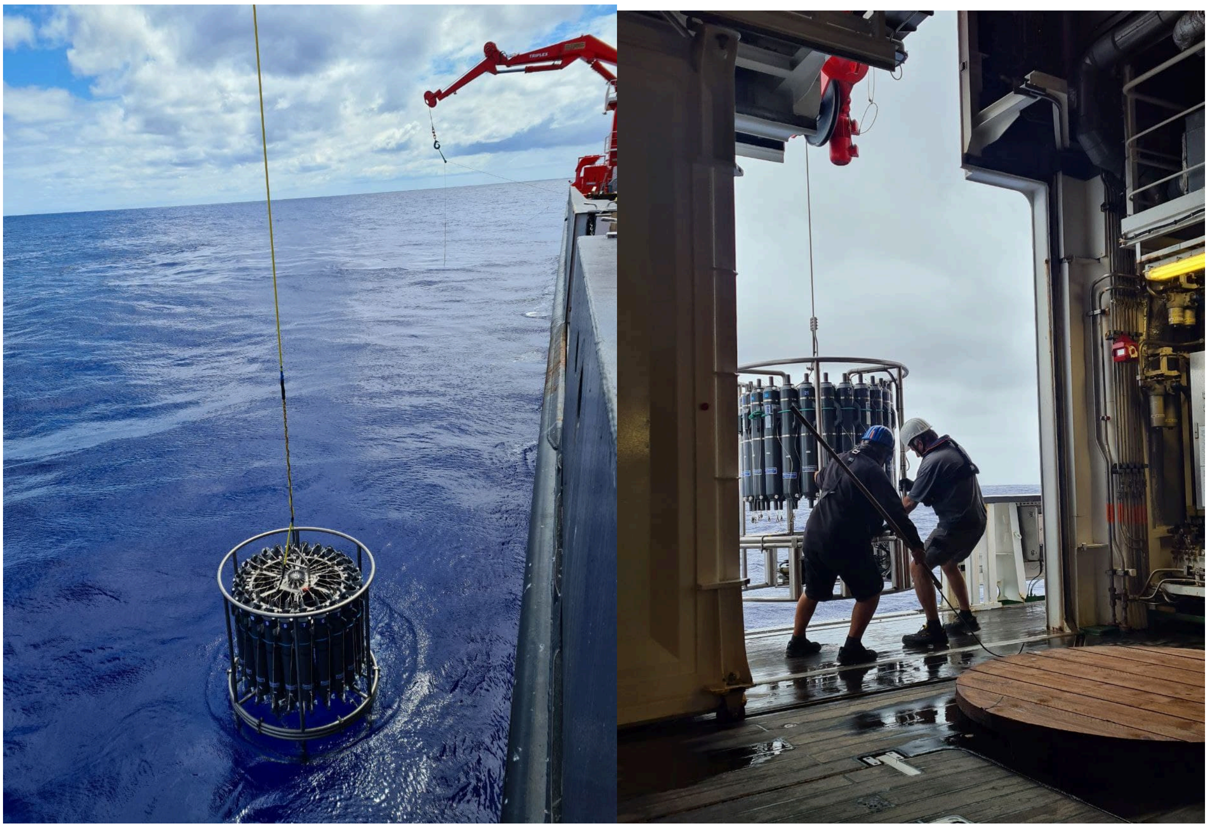

Figure 1: CTD deployments on Sonne. Photos by Juliane Tammen

***Progress:*** We have had a successful last few days, following our unplanned detour to Tahiti due to drop off a sick person. We commenced sampling again on Wednesday morning (March 23) just outside the EEZ of French Polynesia and have been able to conduct daily station occupations with CTD casts and in situ pump deployments. In order to optimise ship-time whilst sailing towards Noumea, we have chosen to steam more northerly along a 26°10 S latitude cruise track (instead of 32°30S). This transect allows us to use the shortest transect to New Caledonia and also to avoid entering the EEZ of New Zealand. The weather has been variable with winds up to force 6-7 Beaufort, and even 10 Beaufort whilst crossing a front, but this has

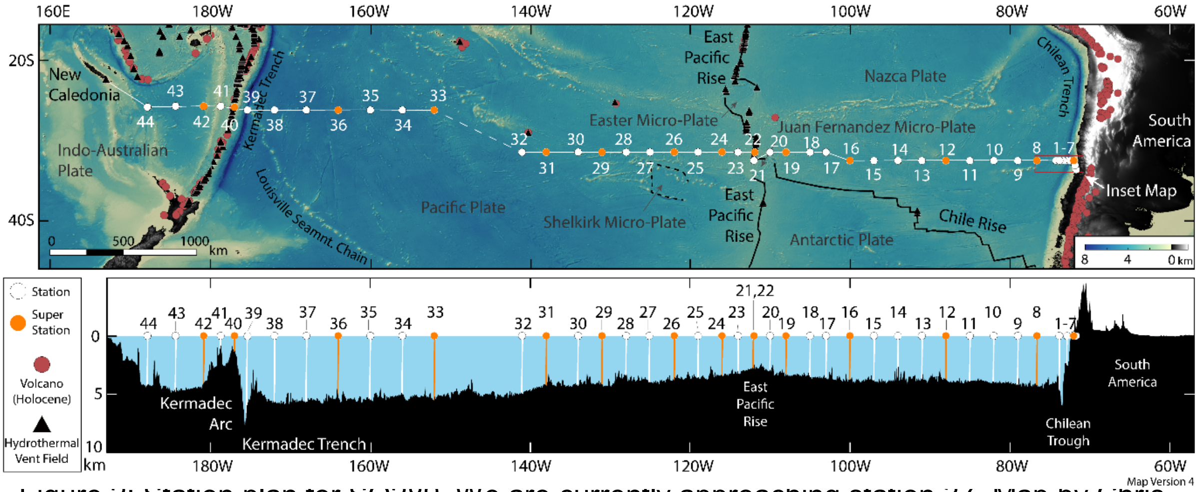

Figure 2: Station plan for SO289. We are currently approaching station 37. Map by Chris Galley.

not prevented us to work at the stations. We are currently heading for the Kermadec Trough and its associated hydrothermal systems.

***Surface ocean pH and pCO$_2$ observations:*** The South Pacific Ocean is dominated by a large ultra-oligotrophic gyre. Large regions of the subtropical waters of the South Pacific Ocean are considered a net $CO_2$ sink, operating primarily through the solubility pump, but only few data are available to confirm this. The anthropogenic carbon in the South Pacific Ocean occurs predominantly in surface and intermediate waters of the equatorward flowing Antarctic Intermediate Water (AAIW). The eastern boundary region is characterized by upwelling of $CO_2$ rich subsurface waters.

We collect samples in the water column from surface to the seafloor for land-based analysis of dissolved inorganic carbon and total alkalinity; these measurements will be conducted by Louise Delaigue at Netherlands Institute for Sea Research. Louise is also conducting automated surface ocean pH measurements using an optode electrode system. In addition,

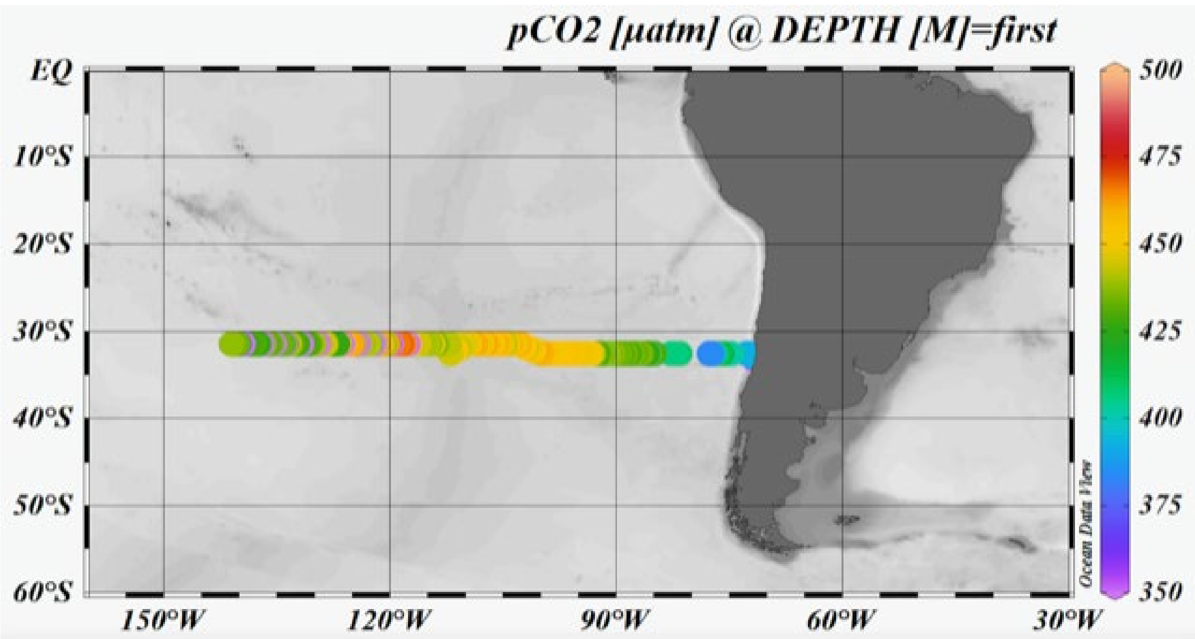

Figure 3: Surface ocean pCO$_2$ trend along our cruise transect. Figure by Li Qiu.

GEOMAR/Xiamen PhD student Li Qiu, is conducting continuous surface ocean measurements of $pCO_2$ and pH. The underway measurements are conducted in the ship's underway supply, which is taking water from a depth of 6.5 m. The $pCO_2$ measurements are conducted every minute, and the sensor is based on infra red detection of $CO_2$ after membrane equilibration (Contros HydroC sensor). The pH sensor measures total pH, using a spectrophotometric technique with meta cresol purple as pH dye. The instrument (Sunburst SAMI pH) conducts a measurement every 15 min along the transect.

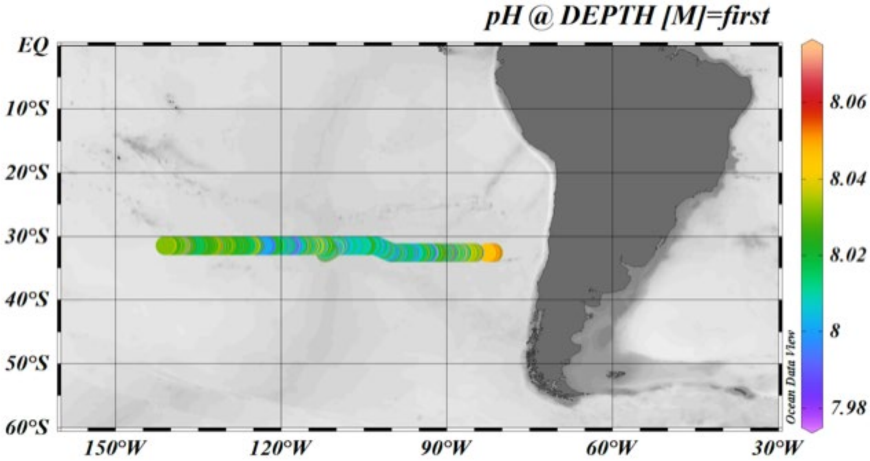


Figure 4: Surface ocean pH trend along our cruise transect. Figure by Li Qiu.

The $pCO_2$ data (Fig. 3) indicates values below current atmospheric $pCO_2$ (ca. 419 ppm) in the vicinity of the Chilean coast as a result of enhanced primary productivity in the nutrient enriched upwelling region (see Fig. 5). The enhanced phytoplankton growth in these waters take up $CO_2$ and thereby remove the high $CO_2$ levels in the upwelling waters and turning the coastal waters into a $CO_2$ sink. Along our transect away from the Chilean coast, $pCO_2$ gradually declined whilst the waters became less productive due to reduced nutrient supply. Consequently, the waters became a $CO_2$ source with $pCO_2$ reaching over 450 µatm in the subtropical gyre. We are now gradually moving out of the ultra-oligotrophic waters towards New Zealand and the productivity appears to be increasing and $pCO_2$ decreasing to atmospheric $pCO_2$ levels and below.

The pH observed pH trend mirrors the $pCO_2$ trend. (Fig. 4) The pH is highest towards the Chilean coast pH 8.04-8.06) and decreasing to 8.0 and below in the centre of the subtropical

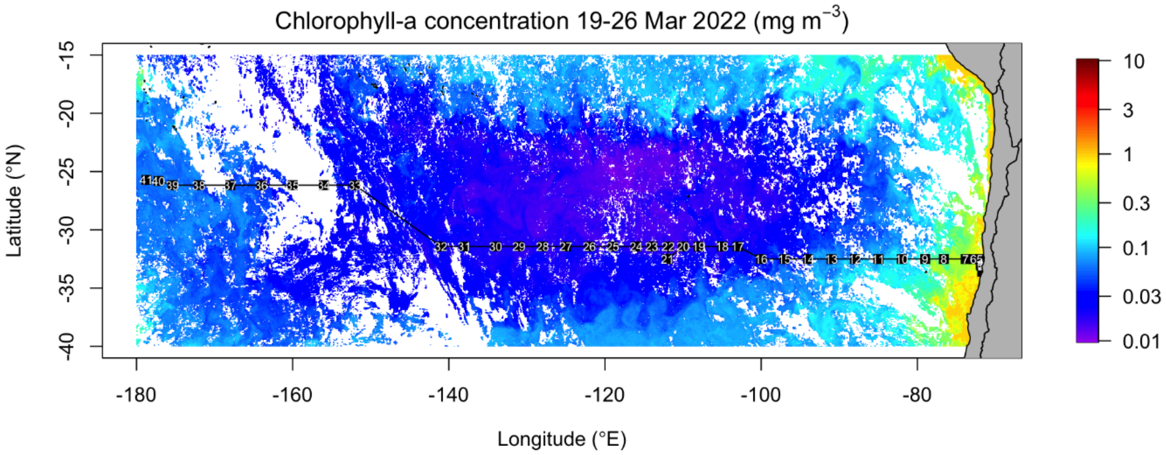


Figure 5. Satellite observation for recent days of surface ocean chlorophyll concentrations with stations and cruise track superimposed. The image shows the ultra low chlorophyll concentrations in the centre of the subtropical gyre. NASA MODIS Image obtained by Tom Browning.

gyre. Now we are moving towards slightly more productive waters, the pH is increasing towards pH 8.03 due to $CO_2$ uptake by phytoplankton and an associated increase in pH.

***Controls on surface ocean productivity:*** The study region is almost completely uninvestigated with regards to nutrient limitation; for example the basic experimental data is lacking to demonstrate limitation by nitrogen (N), phosphorus (P), iron (Fe), or other essential micronutrients. Some first-order predictions can be made from available distributions of nitrate and phosphate from the World Ocean Atlas. Calculation of the relative biological excess of P over N ($P^*=[P]–[N]/16$) reveals generally positive values throughout the cruise transect, suggesting P is probably significantly 'less limiting' than N; however P* values declining to <0.05 µM are evident in the central part of the transect— concentrations that have found to be serially limiting (i.e., approaching co-limiting) levels in the tropical North Atlantic. The eastern part of the transect passes through regions with >0.1 µM nitrate, and the presence of residual N is suggestive of (co-)limitation by another nutrient, and given the excess P, strongly indicates insufficient Fe. The low levels of N, P and Fe are the result of low supplies from subsurface and atmospheric sources.

Our team led by Tom Browning, and including Zhongwei Yuan, Haoran Liu, Julaine Tammen and also Zouzhou Wen, are investigating the (micro-)nutrient controls on phytoplankton productivity. The team collects surface ocean waters and incubates the waters for a period of 48 h on deck under controlled light and temperature conditions, following the addition of N, P, Fe and combinations thereof. Various variables, including chlorophyll a are measured following the incubation period. Figure 6 shows the results of an incubation experiment, indicating changes in chlorophyll-a biomass, a pigment found in all phytoplankton, in response to supply of N, Fe, or nitrogen and iron combined (N+Fe) after 48 hours. The experiment is conducted with surface water sample collected in centre of the subtropical gyre. The largest response is seen in response to N+Fe supply, suggesting both of these nutrients are approaching levels low enough to co-limit phytoplankton growth.

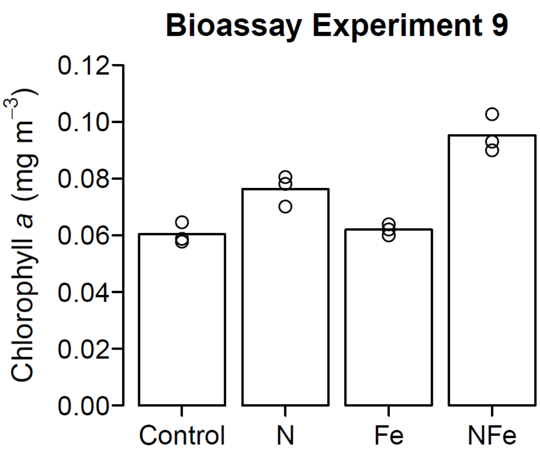


Figure 6. Changes in chlorophyll-a biomass, a pigment found in all phytoplankton, in response to supply of nitrogen (N), iron (Fe), or nitrogen and iron combined (N+Fe) after 48 hours. Experiment is conducted with surface water sample collected in centre of the subtropical gyre. The largest response is seen in response to N+Fe supply, suggesting both of these nutrients are approaching levels low enough to co-limit phytoplankton growth.

RV Sonne at sea 26°10 S/167°5W

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