Saturday 9 May 2009 JD 129

We completed the overnight SF_6 and MVP 6 km x 6 km box survey at 03:10 this morning. CTDs #54 and #55 were deployed at 04:00 and 05:00 respectively in waters with surface concentrations of SF_6 of around 1200 fmol l^{-1}. Surface nitrate concentrations were 7.75 µmol l^{-1} and the 1% light depth was 50m. These CTDs were followed by vertical casts of the turbulence probe from 06:24 until 08:33, a CTD (#56) at 09:04, and an Apstein net (#17) at 10:11. At 08:00 our position was 21^{o} 30.70 N 017^{o} 59.50 W, sea surface temperature was 17.9 ^{o}C, air temperature was 18.5 ^{o}C, salinity was 36.02, barometric pressure was 1014, water depth was 1329 m and the winds were northerly 10 knots. The underway fluorescence was 0.34 fluorescence units (or 1.28 µg chlorophyll l^{-1}). The day continued with vertical casts of the turbulence probe from 10:27 until 11:30, a CTD (#57) at 12:07, two optics rig deployments (#010 and 011) at 12:35 and 13:21 respectively, and further vertical casts of the turbulence probe from 14:12 until 17:30. We monitored the surface SF_6 concentrations throughout the day and repositioned the ship into waters with SF_6 concentrations higher than background levels before each CTD deployment. The buoy and highest SF_6 concentrations were often not in the same place. The edge of the SF_6 patch was quite distinct, and even when in the SF_6 patch, it was easy to drift out of it – for example, simply by turning the ship to heave to. The surface waters contained the dinoflagellate *Noctoluca*, a type of phytoplankton which has the ability to phosphoresce (produce flashes of light when stressed). We filter seawater through filter paper with a pore size (e.g. 1 µm) designed to capture phytoplankton – this filtration process causes *Noctoluca* to 'light up' the filter paper with tiny green flashes of light.

The MVP was deployed at 17:45, to start the overnight SF_6 and MVP 6 km x 6 km box survey. However, at 18:25, as the ship turned to starboard to begin the first line of the survey, the MVP line over the port quarter tangled with the turbulence probe winch and the MVP launched itself on to the ship causing damage to its CTD and fins. The mapping survey continued, collecting only ADCP data. During the day, the aerosol collector pump stopped working (photo 1 – metal 'beehive' shaped box with pump and filters inside). The large filters through which the air is pumped will be analysed by Alex Baker (University of East Anglia) to determine the concentrations of nutrients and metals which the phytoplankton receive from the air (possible dust input from the Sahara Desert). Ian Slater (Chief Engineer) repaired the broken motor using spare parts from a washing machine ! Meanwhile, to reduce the possibility of the detachment of the GPS drifters from the equipment and drogues again, Dan Comben has substantially strengthened the attachment points of the drifters (photo 2). Many thanks to Ian and Dan.

Sunday 10 May 2009 JD 130

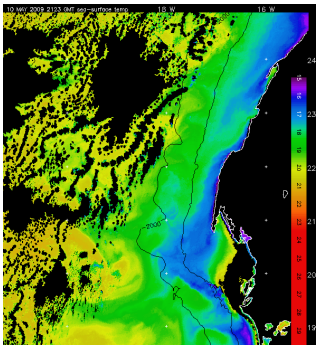
The ADCP survey continued until 04:00 when we deployed CTDs #58 and #59. SF_6 concentrations had reduced ten-fold, the patch was very streaky and not very close to the buoy, and so we had to reposition the ship between the two CTDs in order to stay within the patch. At 06:00 we surveyed the region and deployed drifter #5988 in what appeared to be a distinct patch of SF_6 at a concentration of 40 fmol l^{-1}. We then went in search of the ADCP buoy which was not moving with the patch. We retrieved this at 07:56 before returning to drifter #5988 for the 09:00 CTD. At 08:13 we were at position 21^{o} 39.30 N 017^{o} 58.43 W, the sea surface

temperature was 18.1 ^{o}C, fluorescence was 0.86 fluorescence units, salinity was 36.03, air temperature was 18.3 ^{o}C, air pressure was 1014, and we were in a depth of 1250m of water. The data from the 05:00 CTD showed that the water around us was forming horizontal layers, so that in some places the SF_6 was only in a 7m layer at the surface. After the 09:00 CTD, we deployed an Apstein net and then a CTD at 11:50 at the same time as an optics rig deployment. Dan, Kev, Dave and John mended the turbulence probe winch (very many thanks) after its fight with the MVP yesterday, and Riqui, Bea and Thomas took advantage of this and made several successful vertical casts of the turbulence probe. The data from these and the CTDs suggest that the SF_6 is subducting (or moving below another layer of water), so that we are unable to map its distribution based only on our 2D surface measurements.

During the afternoon, Carol, Phil, Andy, Riqui, Tim and Gavin met to discuss how to proceed. With continued light winds, high spatial heterogeneity on space scales of a few hundred metres, subduction and surface layering of the SF_6, it is highly unlikely that we will be able to measure any SF_6 concentrations above background levels (6 fmol l^{-1}) tomorrow. Reminding ourselves of our scientific priorities i.e. being able to physically describe the volume and movement of upwelled water in order to quantify its impact on the photochemical and biological production and consumption, and air sea exchange of climate relevant gases, we felt we had three options open to us: 1) continue to follow the buoys, despite no longer being able to measure SF_6, 2) carry out a transect study, moving offshore from high to low productivity waters, choosing sampling sites along a gradient of some indicator of upwelled water e.g. nutrient or dissolved gas concentrations or 3) move to another site and try again to release and follow the SF_6. Option 1 had the advantage that the study sites along the track of the buoys could be linked, however buoys and SF_6 patches rarely follow the same path, and so this would not be an unequivocally Lagrangian experiment, thereby reducing the possibility of budgeting gases or following a biological succession in plankton species. Option 2 had the advantage of minimum risk, assuming the impact of upwelling decreases with increasing distance offshore. However the disadvantage would be that each sampling station would represent a 'snapshot' of that particular place and time, with little relationship to each other in terms of plankton succession or temporal trend. Option 3 had greatest risk (bearing in mind the difficulty of tracking the SF_6), but would best achieve the scientific challenge we had set ourselves – to follow a temporal trend in upwelled water. This temporal trend could perhaps be extended if we did several short term Lagrangian studies each starting at a different place along a filament continuum.

Writing down these options now (a few days later), belies the complexity (and length of time) of our discussion. We decided that we would prefer to follow option 3, and re-assess options 1 and 2 if 3 fails. After dinner, we held a full science meeting to discuss the options and propose we follow option 3. This was agreed, and so the task now was to find the best place to undertake our third SF_6 deployment.

Monday 11 May 2009 JD 131



With the decision to move site, we would spend today retrieving the four drifters and surveying possible deployment sites. We picked up the ADCP buoy at 07:20, the wire walker buoy at 08:07, the drifter at 09:23 and the Carioca buoy at 12:38. At 08:58 we were at position 21^{o} 33.01N 018^{o} 07.65 W, the sea surface temperature was 18.4 ^{o}C, the fluorescence was 0.3 fluorescence units, salinity was 36.15, air temperature was 18.2 ^{o}C, air pressure was 1014, water depth was

1851m, and the winds were NE 20 knots. As the MVP is not operational, we planned an ADCP survey to search

for an area with lower chlorophyll, but still some westward flow of water. We have a forecast for strengthening winds on Wednesday, so the hope is that we can position ourselves to take advantage of newly upwelled water moving offshore. The latest satellite image of sea surface temperature (figure 1) suggests that offshore movement of upwelled water is greatest at around 20°N rather than the 21°N filament where we are now. We therefore headed south and prepared for an ADCP survey (the MVP still being out of action) and a transect across the filament collecting surface water samples for the measurement of inorganic nutrients, plankton community structure, DMS, oVOCs (oxidized volatile organic compounds), pCO_2, O_2, and the genetic (DNA/RNA) diversity of the plankton.

We had an emergency muster station at 16:15, with a simulated fire in the engine room and the scientists practised using the fire hoses over the side. Dave, Kev, John and Dan continued to do miracles with the mangled turbulence probe winch and the MVP. The transect across the filament started at 20:00. Glen (photo 3) and Simon (photo 4) collected water samples at 10 minute intervals for

plankton community structure and nutrient analysis respectively. Carol monitored the temperature, salinity, fluorescence, pCO_2 and O_2 sensors, Simon collected samples for DNA/RNA diversity and Frankie collected samples for DMS analysis (photo 5). The last sample was collected at 02:00, and all the data should be available in the morning.