Weekly report no. 3 EIFEX ANT XXI/3 RV "Polarstern" 10 February 2004

The last week of January was spent mapping the eddy, finding its centre, measuring the initial conditions of the experiment and finally on early Monday morning (2nd February) we started fertilising the patch. We used the same procedure that had proved successful during our first experiment (EisenEx): Polarstern steamed at 8 km/hr along an outward spiralling track from the eddy centre while a weakly acidified, strong solution of ferrous (iron) sulphate was released into the ship's propeller wash. The spiral was 250 km long and its circles 1 km apart. By Tuesday morning we had fer--tilised a circular patch of 150 km2 area and 14 km diameter. The cruise track appeared as a perfect spiral on the monitor: proof of the splendid job accomplished by the ship's navigators using the technique they had developed during EisenEx.

The amount of iron sulphate released was calculated to raise iron concentrations in the 80 m deep mixed layer from the very low values characteristic of the ACC to values typical for productive coastal regions (from 5 to 100 nanograms/litre). This was achieved with 6 tonnes of iron sulphate (we still have 20 tonnes in reserve) equivalent to 1 kg for 2 million cubic metres. This figure conveys an impression of the minute amounts of iron required to revive anemic plankton. We used the same iron sulphate powder sold by gardening shops to improve lawns which costs a few hundred Euros per tonne. The iron solution was prepared by 2 volunteers working in shifts in a container equipped with a large funnel which emptied into either of the two 10 m3 tanks on the afterdeck. They wore plastic overalls and a gas mask to protect eyes and nose from the non-toxic but irritating powder. Each shift emptied 31 bags of 25 kg each washed down with sea water from the ship's fire hose into one of the tanks while the solution prepared previously in the other one was being released. A total of 9 tanks were filled and emptied.

The phytoplankton reacted immediately to the iron fertilisation by increasing the efficiency of their photosynthetic machinery: A bit like shifting gears in a car. This "fitness index" of algal cells is recorded continuously by an instrument that flashes nanosecond bursts of blue light at cells passing through a seawater intake pipe in the ship. The cells flash back "excess" light they absorbed but could not use, as a burst of red light which is measured by the instrument: a fast repetition rate fluorometer or FRRF) The more light the cells retain, the more efficiently their.machinery is running. This chemical factory is run by tightly linked molecules of different functions including pigments, enzymes and transporters. Iron-bearing enzymes are involved in energy transfer within the molecular machinery. Their numbers are low during iron limitation but increase when iron becomes available. The more of them, the more light that can be processed. Further, the light-capturing, water-splitting molecule chloro--phyll can only be made by enzymes containing iron, the more of these enzymes, the greener the cells become and the faster they can divide.

So far the FRRF had measured uniformly low values of this efficiency index (fv/fm between 0.28 and 0.32) everywhere, even where we had observed large quantities of healthy-looking, growing phytoplankton cells, particularly along the Polar Front. The phytoplankton in the eddy centre had the same low values and the few cells and short chains we found under the microscope also looked "wilted". Apparently the ACC phytoplankton were chugging along in first gear. While spinning our fertilisation circles the efficiency values along the western rim of our spiral jumped to over 0.4, the highest values we had recorded so far. The patch was spreading faster in this region, confirmed also by ADCP recordings and the drift path of a free-floating buoy we had deployed prior to fertilisation. The algae had shifted to second gear within hours of receiving their shot of iron. The algae in our patch had started to grow but the low number of seeding cells meant that even if they grew at their maximum rate, i.e. shifted to fourth gear, they would need 3 weeks to reach the levels already present in the Polar Front and another two weeks to reach the levels achieved by the EisenEx bloom in 3 weeks.

We had been eyeing the alternative eddy in the West, close to the Greenwich meridian at 2° E, all the while we were mapping this one at 18° E. It was a circular eddy which had formed in early December and resembled the al------time--ter images of the EisenEx eddy which had been such a success, because it stayed in position for at least 6 months and retained the rounded patch nicely in its centre. Since our patch would not take off before 3 weeks, a plan was hatched to steam to the 2° E eddy, examine its suitability with a few transects and if it passed the test we would fertilise it and stay there. If it did not, we would steam back to the first eddy and find our patch by using the FRRF. We did not expect to miss any fundamental insights in the first week or two of growth. The main incentive to shift eddies came from satellite images of chlorophyll in the ACC which clearly showed that the entire sector of the ACC to the west had concentrations similar to those present only along the Polar Front in our sector. The southern region from where our eddy core originated appeared ominously barren in the same images. If the eddy centre in the 2° E eddy was as green as indicated by the satellite, we would gain 2 weeks by conducting our experiment there, even if we fertilised a week later.

The decision was taken while fertilising the first eddy. A lengthy debate on the pros and cons of the plan based on the results of the first station in the eddy centre was carried out on Monday at the regular evening meeting that all attend. The advantage of our eddy was its youth and the stability of its centre, however, its low seeding stock of large diatoms capable of making the bloom (a tenth of that initially present in EisenEx) combined with a large population of hungry salps which filled the nets during the night hauls were its disadvantages.

Salps are peculiar, barrel-shaped, watery animals of 1 – 10 cm length that bear a vague resemblance to jelly fish although they belong to the ver-----te---brate line, i.e. we share common ancestors in recent evolutionary history. Salps swarm in the ACC and other low productive oceans because they use the same muscles to feed, swim and breathe simultaneously. This is an efficient way of living because it reduces construction costs and conserves energy. They pump large volumes of water through a fine-meshed sieve which collects plankton but serves also as a gill. The water is squeezed out, jet-like, at the end. They can swim 10 m in about a minute and migrate to the surface layer at night and spend the day at several 100 m depth. Salps seem to do best when phytoplankton concentrations are as low as in the patch. They multiply by growing a stalk and budding new indi---vid-u-als along it. In warmer waters several new, full-sized individuals can be produced per day and stalk. They would be the stuff of horror movies in the aquatic alien world. The salp sieves start clogging at higher plankton densities which must be a problem, as salps seem to avoid blooms. It is not known to what extent their formidable pumping and reproduction capacity contributes to keeping phytoplankton stocks low, but their abundance in the core would at least slow down bloom growth if not keep it in check altogether.

We decided to invest some time in inspecting the second eddy, so imme---di----ate-ly after fertilising our patch, we steamed due west on Tuesday morning to its site, some 2 1/2 days away. Fate struck on the way in the form of two strong storms in short succession which buffeted the ship and prevented any work. To avoid further discomfort we steamed 350 km north to calmer waters and let the storms pass along the latitude of our eddies. The storms also crossed our patch two days later, so we would have had to escape north there as well. The storms cost us three days and on Monday morning we approached our eddy on a course aimed through its centre. Full of suspense, we watched the temperature and salinity values on the monitors and followed the results of the CO_2, nutrient, chlorophyll and plankton measurements. The first relief came from regular observations of the phytoplankton under the microscope. As the ship plowed through the area of the eddy, we found lots of healthy looking diatoms. The other measurements confirmed the first impression. After completing the transect by the evening, the ADCP profiles indicated a band of strong, westward flowing currents where the southern border of the eddy was expected. The transect had indeed cut through an eddy! Further transects carried out during Tuesday indicated that we had located a distinct, albeit small eddy with a closed core of about 50 x 60 km. We decided to stay here and start with fertilisation on Wednesday. The novices were excited and impressed by the storms, but have since learned to cope with them as part of life in this remote region of the globe.

We send our greetings from a sturdy ship rocking and rolling along the boundary between the roaring forties and furious fifties,

Victor Smetacek