Marine National Facility

CSIRO

RV *Investigator* Scientific Highlights

Voyage #:	**IN2016_V02**		
Voyage title:	SOTS+CAPRICORN+Eddy		
Mobilisation:	Hobart, Friday-Sun, 11-13 March 2016		
Depart:	Hobart, 1000 Monday, 14 March 2016		
Return:	Hobart, 0930 Saturday, 16 April 2016		
Demobilisation:	Hobart, Saturday, 16 April 2015		
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Principal Investigators:	Peter Strutton	**Project name:**	Eddy
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This voyage supported three projects and highlights are listed for each.

IMOS Southern Ocean Time Series automated moorings for climate and carbon cycle studies southwest of Tasman

Co-Chief Scientists:
Tom Trull, CSIRO Oceans and Atmosphere
Eric Schulz, Bureau of Meteorology

The Southern Ocean is an important part of the global climate system, soaking up carbon dioxide and heat to moderate the earth's atmosphere. The Southern Ocean Time Series observatory uses a set of automated moorings to measure these processes under extreme conditions, where they are most intense and least studied. The processes occur on many timescales, from the day-night cycle up to ocean basin decadal oscillations and thus high frequency observations sustained over many years are required.

Contribution to the nation

The research improves understanding of the global climate system by focussing on a key region –the Southern Ocean. Careful sustained observations over the last decade and into the next increases our knowledge of how the ocean interacts with the atmosphere. Improved understanding is essential to enhance advice to the nation on climate variability affecting us now, develop future scenarios and impact assessments, and to make optimal decisions that will affect the nation's future. The work also directly addresses the issue of how ocean biogeochemistry and productivity respond to ocean dynamics, which is an important input to projecting future biogeochemical and ecosystem states. In addition, enhanced understanding of process occurring in the region related to clouds, ocean mixing, waves and rain will also lead to improved forecasts and warnings issued to the public.

As a result of this voyage, we have assembled an integrated view of the seasonality of the processes that control the productivity of the Subantarctic foodweb. This analysis extends from the physics of ocean mixing and insolation, to the chemistry of ocean nutrients and the biological responses of phytoplankton and zooplankton.

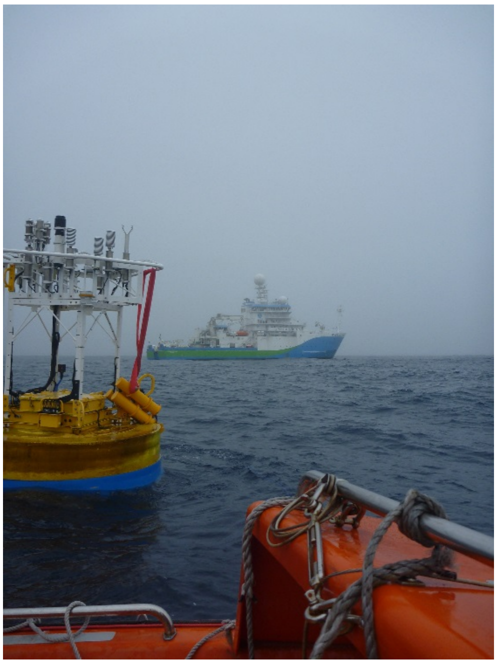

Figure 1. Photo of SOFS-5 mooring recovery (Photo credit Jamie Derrick)

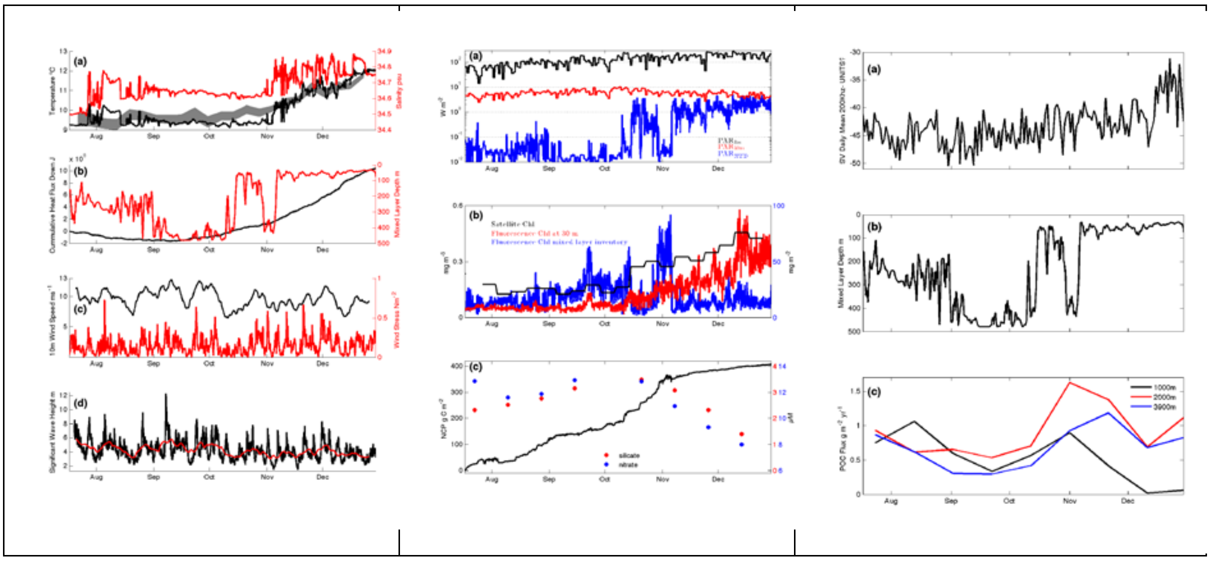

Figure 2. Seasonal records of Subantarctic environmental and ecological conditions

CAPRICORN - Clouds, Aerosols, Precipitation, Radiation, and Atmospheric Composition over the Southern Ocean

Figures 1 and 2 show cloud occurrence statistics compiled during the time spent sampling the cold eddy (Figure 1) and the warm eddy (Figure 2). Each figure shows a conditional frequency of occurrence of radar reflectivity in dB units as a function of height above the surface. Such plots are known as a contoured frequency by altitude diagrams (CFADs). Radar reflectivity (Z) is proportional to the square of the total condensed mass. A 3 dBZ change represents a factor of 2 change in condensed mass. Thus the vertical distribution of dBZ demonstrates the geometric characteristics of the clouds and the distribution of mass at a particular height. The frequency distributions below the CFAD show, respectively, the distribution of cloud base temperature, the fraction of time during which the wind was from the north (prefrontal) or from the south (post frontal) and the diurnal cycle of cloud frequency. In addition, the fraction of cloud bases that were supercooled (i.e. below freezing) and the fraction of clouds that were observed only by the lidar (i.e. below the sensitivity of the cloud radar) are also shown.

We find several fundamental differences between the clouds observed over the warm and cold eddies. Attributing most of these differences directly to the state of the underlying sea surface is clearly not reasonable. However, several factors are likely modulated by the fact that the underlying sea surface was colder or warmer than surrounding waters. We can divide the cloud distributions into the population of clouds that were observed above the boundary layer (heights in excess of ~2 km) and those clouds that were within the boundary layer. The clouds within the boundary layer are much more likely to have been influenced by the state of the underlying sea surface.

The free tropospheric clouds observed above 2 km are the result of large-scale meteorological features that propagated over the sampling area during the time the Investigator sampled was present there. The synoptic scale features that passed over the cold eddy tended to have deeper clouds with larger reflectivities. The large-scale feature that passed over the warm eddy was clearly less deep with lower radar reflectivities overall.

The striking differences between the boundary layer clouds over the cold and warm eddies are evident in the distributions of radar reflectivity. The convective boundary layer clouds over the warm eddy tended to have colder bases as depicted by the differences in cloud base temperatures but have larger radar reflectivity near their tops. This characteristic suggests that convective processes in the boundary layer were stronger over the warmer waters. The other difference is the absence of low values of radar reflectivity near the surface in the warm eddy. Over the cold eddy, low level clouds with drizzle as well as sea fog were frequently observed while such phenomena were absent over the warm eddy.

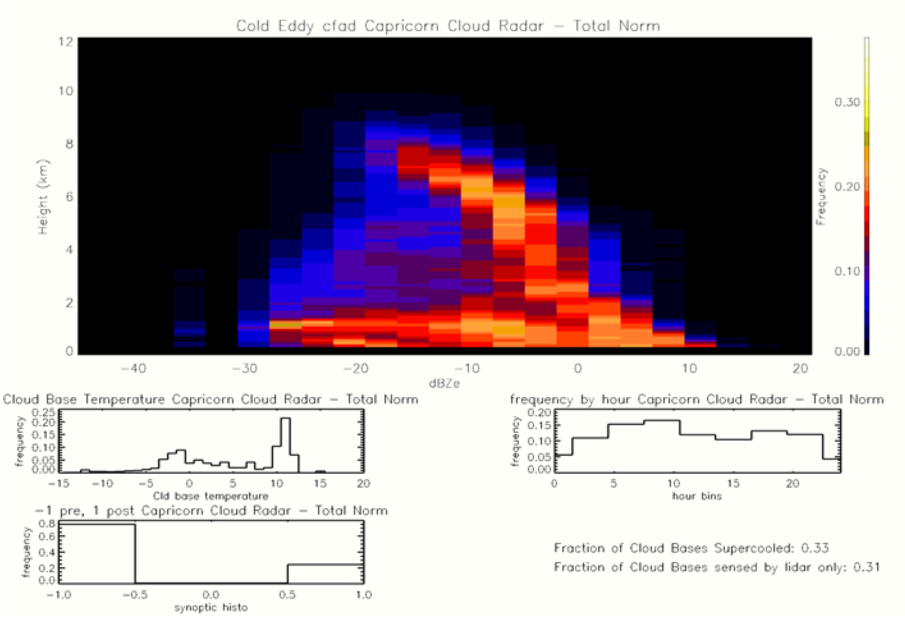

Figure 1. A conditional frequency distribution of radar reflectivity as a function of height over the cold eddy.

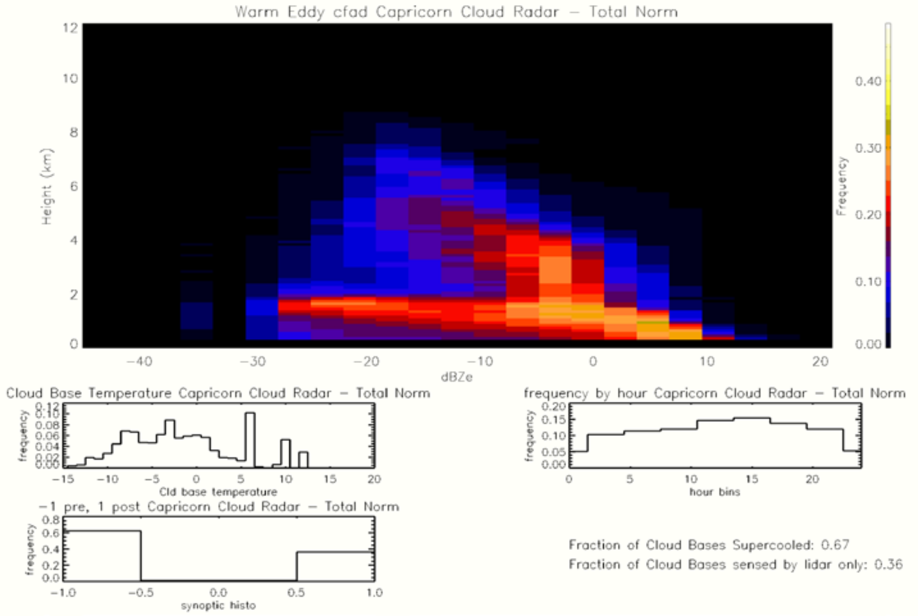

Figure 2. A conditional frequency distribution of radar reflectivity as a function of height over the warm eddy

Eddy - Linking eddy physics and biogeochemistry in the Antarctic Circumpolar Current south of Tasmania

Southern Ocean eddies are ubiquitous, and are particularly common and energetic in the Antarctic Circumpolar Current (ACC). They spin either clockwise, in which case they are called cyclonic in the southern hemisphere, or anticlockwise (anticyclonic). They displace the density field of the upper ~500m of the ocean and generate up- and down-welling. The sea surface temperature is cooler inside cyclones while anticyclones are warmer. These physical perturbations have significant impacts on ocean biogeochemistry and ecology, and, as we discovered, the atmosphere.

Unlike more accessible regions of the globe, like the temperate north Atlantic and Pacific, observations of ACC eddies are rare, partly because we have previously lacked the shipboard and autonomous systems to properly observe them. We have achieved the first detailed intercomparison of the two most common eddy types in the subantarctic, spanning eddy physics, the biological pump and iron biogeochemistry. Our observations featured two innovative approaches. First, we obtained a high resolution two dimensional slice through each eddy using an undulating vehicle behind the ship. This kind of data is still rare in oceanography and previously non-existent for Southern Ocean eddies and will guide our interpretation of more traditional, lower resolution sampling. Second, we achieved a detailed intercomparison of shipboard versus bio-float sensor datasets of unprecedented resolution, by staying with a recently deployed float for nearly a week in each eddy. Our observations will advance the understanding and modeling of Southern Ocean eddies, but have also revealed close coupling to the atmosphere above.