# Do small scales make a big difference?

**Building a South African Southern Ocean Carbon - Climate research capability (the journey, direction and science highlights)**

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I joined the Southern Ocean Carbon and Climate Observatory (SOCCO) at the time of its inception back in 2010. This presentation aims to share the journey from our humble beginnings to a leading research capability that addresses the role of the Southern Ocean in 21$^{st}$ century regional and global climate. As a small group, we needed a niche approach to this grand challenge, which led to the formulation of our underpinning hypothesis that fine-scale ocean dynamics are key to understanding climate sensitivity through their impacts on the variability and trends of carbon fluxes in the Southern Ocean. An emergent aim was to understand and constrain the seasonal cycle as the mode of variability that links ecosystems to climate. This approach required the use of observational and modelling platforms that could resolve the relevant scales and involved pioneering Southern Ocean robotics experiments, remote sensing and high-resolution modelling. It has been a journey fraught with difficulties and the occasional disappointment but ultimately eclipsed by moments of realisation of achieving innovative and pertinent science. Overall, SOCCO continues to make a growing contribution to our understanding of the role that fine-scale dynamics play in shaping the phasing and magnitudes of the seasonal cycle and its inter-annual variability.

Some key insights will be presented starting with one of our earliest publications which utilized ocean colour to summarise the varying regional response of phytoplankton biomass to different seasonal regimes. This thinking played a critical role in influencing the trajectory of our research and was formative in the development of our high-resolution observational strategy implemented in a number of Southern Ocean Seasonal Cycle Experiments (SOSCEx). Some key realisations emerging from SOSCEx include the important role of small scale variability in driving early blooms in spring and sustained blooms in summer; the seasonal progression of net community production and its sensitivity to fine-scale dynamics; seasonal trends and sub-seasonal variability in chlorophyll to carbon ratios; and the need to subsample at frequencies < 10 and 3 days to characterize intra-seasonal scales of variability in chlorophyll and $CO_2$ flux respectively. This fine-scale dynamics approach to physical-biogeochemical ocean observations also contributes to reducing uncertainty and biases of empirically derived products of $FCO_2$ and $pCO_2$. Our seasonal cycle lens has, in addition, enabled us to highlight the mechanisms behind previously underestimated biases in both biogeochemical and earth system models, with important implications for long term uncertainties in their projections. These results highlight the need for climate models to resolve both meso- to submesoscale and intra-seasonal processes to accurately reflect phytoplankton phenology and understand the sensitivity of primary productivity to climate change.