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Turbulent Lagrangian fCO_2 time series statistics in the Southern Ocean

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The Southern Ocean plays a crucial role in regulating Earth's climate, absorbing approximately 10 % of annual human CO_2 emissions (DeVries, 2014; Friedlingstein *et al.*, 2023). However, it is still a challenge to fully understand its carbon dynamics due to significant observational gaps, particularly during winter. Furthermore, the dynamics on small spatial and temporal scales are also poorly understood, despite their potential importance in shaping the overall carbon budget of the region (Guo & Timmermans, 2024). Between 2001 and 2012, researchers from the LOCEAN laboratory in Paris deployed 15 CARIOCA Lagrangian drifting buoys in this region to gain a deeper understanding of its spatial carbon dynamics (Boutin *et al.*, 2008; Resplandy *et al.*, 2014) at high-frequency (1-hour time resolution). In this study, we analyzed the time series of six of these buoys in the framework of Lagrangian turbulence (Kolmogorov, 1941; Landau & Lifschitz, 1944; Inoue, 1951). This is done using Lagrangian data on CO_2 fugacity (fCO_2), chlorophyll *a*, sea surface temperature (SST), and sea surface salinity (SSS) along their trajectories. Additionally, we examined the dynamics of the buoys' drifting speeds estimated from buoys location data.

Through Fourier spectral analysis and structure function analysis, we demonstrated that these time series exhibit scaling and intermittent behaviour, in agreement with the Lagrangian vision of the turbulent Richardson-Kolmogorov energy cascade in fully developed turbulence. Notably, at least two distinct spectral regimes were identified. Chlorophyll *a* and fCO_2 behave as active turbulent scalars, while SST and SSS depicted statistics compatible with passive scalars with a higher intermittency on timescales shorter than 4 days. The links between these time series were also investigated, using the generalized correlation functions (GCFs) and exponents (GCEs).

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