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Eulerian and Lagrangian Perspectives on Mesoscale Air-Sea Interactions

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Mesoscale ocean eddies can be likened to weather events of the sea, influencing a multitude of coupled air-sea processes that help in regulating heat and carbon uptake and consequently the climate. With the advancements in high-performance computing, we can now employ multi-decadal kilometre-scale coupled global climate models (GCMs) that effectively captures the intricacies of mesoscale ocean-atmosphere interactions and shed light on their implications at larger scales. While low resolution CMIP-type GCMs show a dominance of atmospheric-forced coupled variability, e.g. faster winds over ocean surface can enhance turbulent heat flux and thus cool sea surface temperatures (SSTs), satellite observations and eddy-resolving coupled models show a prevalence of mesoscale ocean-forced coupled variability over eddy-rich regions like SST front areas. Two ocean mesoscale dynamical processes can promote such ocean-forced coupled variability, namely through thermal feedback and current feedback. Consider the thermal feedback as an example; the destabilisation of the atmosphere above warm mesoscale anomalies amplifies the downward transfer of momentum from higher-altitude winds to the surface, known as the vertical or downward mixing mechanism. This, in turn, leads to enhanced surface winds and increased turbulent heat flux over warm SST anomalies. We employ a coupled 5km-ocean 10km-atmosphere ICON model to assess the global distribution of mesoscale air-sea coupling associated with these feedbacks and their implications on wind work and eddy-induced Ekman upwelling. Additionally, we show examples of such mesoscale coupling from a Lagrangian perspective through composites of tracked eddies, their impact on ocean upwelling/downwelling and their imprint on the overlying atmosphere beyond the surface like precipitation.