# Ryan Abernathey: Research Statement

The overall goal of my research is to understand the factors which govern the large-scale ocean circulation, and resulting transport of heat and tracers, on timescales relevant for Earth's climate. The ocean components of global climate models are still relatively coarse and crude compared to their atmospheric counterparts, limiting our ability to make long term forecasts or study past climates. My driving principle is that the best way to improve this situation is through careful, focused studies of unresolved and / or poorly understood ocean processes.

My central focus so far has been the process of *mesoscale dynamics and transport*. The ocean mesoscale (roughly 10-300 km), characterized by a tangle of eddies, jets, fronts, and filaments, is the most energetic scale of ocean variability across the entire spectrum. Mesoscale eddies represent a powerful mechanism for transporting ocean tracers, yet they are not explictly resolved by most climate models. Building on my Ph.D. work *[Abernathey et al., 2010; Abernathey and Marshall, 2013]*, I have established myself as an emerging leader in the field of ocean mesoscale dynamics. In particular, since arriving at Columbia, I have applied novel methods to the analysis of satellite observations to quantify how and why mesoscale mixing varies spatially across the global ocean *[Klocker and Abernathey, 2014; Abernathey and Wortham, 2015]*. I am currently leading an international collaboration to synthesize the past decade of research on this problem in the form of a review paper.

A related but distinct problem is quantifying how mesoscale properties such as kinetic energy, eddy size, and mixing rates depend parametrically on external forcing (such as winds) and large-scale oceanographic properties (such as stratification). I began to explore this issue in my Ph.D. *[Abernathey et al., 2011]* and postdoc *[Abernathey and Cessi, 2014]*. We have recently shown that wind-driven changes in isopycnal mixing can overwhelm circulation changes in the Southern Ocean *[Abernathey and Ferreira, 2015]*. My recently funded NSF CAREER proposal, entitled *Evolution of Ocean Mesoscale Turbulence in a Changing Climate*, builds on these ideas by proposing a comprehensive framework through which to analyze changes in eddy properties over time. A paper on the time-dependent ocean mesoscale response to wind changes was recently submitted *[Sinha and Abernathey, 2016]*, my first with a student. In future work, we will analyze changes in mesoscale properties over the historical satellite period and, through high resolution global model simulations, into the anthropogenic future. This work will comprise the major part of my research effort over the next few years.

In addition to mesoscale dynamics, I maintain a strong regional interest in the Southern Ocean, which has emerged in recent decades as the central node of the global ocean overturning system. An ongoing, NSF-funded collaboration with colleagues at Scripps Institution of Oceanography (and affiliated with the large SOCCOM Project) involves the study of the thermodynamic processes involved in the upwelling of deep water in the Southern Ocean. This project was slow to spin up due to its technical complexity. However, we have recently uncovered some exciting new results regarding the importance of Antarctic sea ice in maintaining the Southern Ocean overturning circulation *[Abernathey et al., 2016]*.

Since arriving at Columbia, I have pursued a number of other collaborations with scholars at other institutions. I have worked closely with Anand Gnanadesikan at Johns Hopkins to understand the consequences of spatially variable mesoscale mixing for climate simulations. In a series of recent papers, we have examined how mesoscale mixing rates impact ocean circulation and stratification, anthropogenic $CO_2$ uptake, geochemical tracer distributions, the ocean biogeochemical pump, and ENSO variability. This collaboration has been a valuable way for me to broaden my research portfolio and engage with a range of topics within Earth system science. I have also worked closely with colleagues at NCAR in the analysis of a new generation of high-resolution, eddy-resolving global climate simulations. In particular, I contributed theoretical and diagnostic frameworks which have helped explain the behavior of ocean overturning circulation in these simulations.