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A vorticity budget for the Gulf Stream

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We develop a depth-averaged vorticity budget framework to diagnose the dynamical balance of the Gulf Stream, and apply this framework to observations and the ECCO state estimate (Wunsch and Heimbach 2013) above the thermocline in the subtropical North Atlantic.

Using the hydrographic and ADCP data along the WOCE/CLIVAR section A22 and a variety of wind stress data products, we find that the advective vorticity flux out of the western region is on the same order as the wind stress forcing over the eastern portion of the gyre. This is consistent with a large-scale balance between a negative source of vorticity from wind stress forcing and a positive source of vorticity in the western region. Additionally, the form of the vorticity flux indicates that the Gulf Stream has a significant inertial component.

In the ECCO state estimate, we diagnose a seasonal cycle in advective vorticity flux across a meridional section associated with seasonal fluctuations in Gulf Stream transport. This vorticity flux is forced by wind stress over the eastern subtropical North Atlantic and balanced by lateral friction with the western boundary. The lateral friction in ECCO is a necessary parameterization of smaller scale processes that occur in the real ocean, and quantifying these remains an open and interesting question.

This simplified framework provides a means to interpret large scale ocean dynamics. In our application, it points to wind stress forcing over the subtropical North Altantic as an important regulator of the Gulf Stream and hence the climate system.