Abstract View

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On the Time-Dependent Meandering of a Thin Jet

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ABSTRACT

A thin-jet model predicts the location of the axis of a strong current such as the Gulf Stream by using the vertical and cross-stream integrated vorticity balance, under the assumption that the meandering scales are large compared to the width of the jet. We demonstrate that such an integral provides a matching condition upon the barotropic component of the wave or eddy fields which, on either side of the jet, have north–south scales on the order of the meander wavelength. For steady meanders, these exterior fields do not influence the path and our model reproduces the dynamics of Robinson and Niiler, but for the transient case the determination of the jet axis motion and of the external field is a coupled problem.

When the disturbances in the axis position are time-dependent but are very small, the exterior wave problem can be linearized and the matching conditions can be applied at the mean position of the jet. We can therefore derive a dispersion relation for the meandering motion, allowing us to compute the phase speed and growth rates for the meanders in terms of the wavenumber and two integral properties of the stream: the mass and momentum transports. This dispersion relation predicts instability for wave shorter than a critical scale.

We also derive via standard four-dimensional instability theory a long wave approximation to the dispersion relation for perturbations of a quasi-geostrophic jet with both horizontal and vertical shears. The result is identical to that from the thin-jet theory for an interesting class of perturbations which we therefore identity as meandering modes. Thus thin-jet theory has been calibrated by reduction to both finite amplitude steady meandering and infinitesimal instability cases. For the understanding of large amplitude, time-dependent motions of the Gulf Stream and their role in the general circulation, the thin jet theory offers a semi-analytical approach for process studies.

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