1. Introduction

Most of the kinetic energy in atmospheric and oceanic circulations is tied up in flows that are dominated by rotational effects and that evolve slowly compared to a pendulum day (the time it takes a pendulum to complete one circuit, which is one sidereal day at 30° latitude). These include all the major ocean currents, from the thermohaline circulation to mesoscale ocean eddies; and the major atmospheric circulation systems ranging from synoptic-scale disturbances to planetary wave and other major elements of the general circulation. For the purposes of this course, we mean to distinguish circulations such as these from comparatively fast circulations such as internal inertia-gravity waves, and sound waves, convection, and three-dimensional turbulence. As we shall see, there is strong evidence that there does *not* exist an exact means of separating slow, rotationally dominated circulations from the faster ones; nor can it be assumed that there is no interaction between them. Nevertheless, it is usually possible to distinguish between observations of these two classes of circulation. In the course, we use the term *quasi-balanced* to refer to flows in which most of the kinetic energy is tied up in motions for which the hydrostatic approximation is valid and in which horizontal pressure gradients are nearly balanced by centrifugal accelerations. A more formal working definition of quasi-balanced flows is *those flows most of whose salient characteristics can be derived from the instantaneous potential vorticity distribution together with certain balance approximations and boundary conditions.* Even this definition lacks rigor for

reasons we shall explore in due course, but it serves our purpose admirably in many ways, most especially as it stresses the central importance of *potential vorticity* in the description of the dynamics of quasi-balance flows.

The first part of this course will develop the *conservation* and *invertibility* principles that we will then use in the second part to describe the dynamics of quasi-balanced flows in the atmosphere and oceans. In doing so, we assume that you have taken a graduate-level course in geophysical fluid dynamics that covers the fundamental fluid laws at the level, say, of Joseph Pedlosky's book on the subject. You will find that the text entitled *Atmosphere-Ocean Dynamics,* by Adrian Gill (Academic Press, 1982) makes a nice companion to this course, though we will not by any means cover the same material in the same order. An essential reference is "On the use and significance of isentropic potential vorticity maps" by B. F. Hoskins, M. E. McIntyre, and A. W. Robertson, published in the *Quarterly Journal of the Royal Meteorological Society,* **111,** 1985, 877–946.

We begin with an elementary review of basic principles, followed by a derivation of various sets of filtered equations that will be used in the remainder of the course.

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