Journal of Oceanography, Vol. 54, pp. 185 to 198. 1998

P-Vector Inverse Method Evaluated Using the Modular Ocean Model (MOM)

PETER C. CHU[1], CHENWU FAN[1] and WENJU CAI[2]

[1]*Naval Postgraduate School, Monterey, CA 93943, U.S.A.*
[2]*CSIRO Division of Atmospheric Research, Aspendale, Victoria, Australia*

(Received 20 October 1997; in revised form 20 November 1997; accepted 4 December 1997)

Several major inverse methods (Stommel-Schott method, Wunsch method, and Bernoulli method) have been successfully developed to quantitatively estimate the geostrophic velocity at the reference level from hydrographic data. No matter the different appearance, they are based on the same dynamical sophistication: geostrophy, hydrostatic, and potential density (ρ) conservation (Davis, 1978). The current inverse methods are all based on two conservation principles: potential density and potential vorticity ($q = f\partial\rho/\partial z$) and require β-turning. Thus, two necessary conditions can be incorporated into any inverse methods: (1) non-coincidence of potential density and potential vorticity surfaces and (2) existence of vertical turning of the velocity (β-turning.) This can be done using the P-Vector, a unit vector in the direction of $\nabla\rho \times \nabla q$ (Chu, 1994, 1995). The first necessary condition becomes the existence of the P-vector, and the second necessary condition leads to the existence of the P-vector turning in the water column. Along this line, we developed the P-vector inverse method with a pre-requirement check-up. The method was verified in this study using the Modular Ocean Model (MOM) from Pacanowski *et al.* (1991) version of Bryan-Cox-Semtner ocean general circulation model (OGCM), which is based on the work of Bryan (1969). The statistically steady solutions of temperature and salinity from MOM are used as a "no-error data" set for computing absolute geostrophic velocities by the P-vector inverse method. Circulations are similar between the MOM statistically steady solutions and the P-vector solutions. Furthermore, the quantitative analysis shows that this inverse method has capability of picking up the major signal of the velocity field.

Keywords:
- P vector,
- inverse method,
- beta spiral,
- geostrophic balance,
- thermal wind relation,
- primitive equation model,
- stream function.

1. Introduction

Our understanding of the mid-latitude large-scale ocean circulation has been greatly benefitted by a remarkable set of papers by Stommel and collaborators (Stommel and Schott, 1977; Schott and Stommel, 1978, Beringer and Stommel, 1980), Wunsch and collaborators (Wunsch, 1978; Wunsch and Grant 1982), and Killworth (1986). Their work makes it possible to obtain ocean general circulations from observations of temperature (T) and salinity (S). The physical base for calculating geostrophic velocity from hydrographic data is the thermal wind relation

$$u = u_0 + \frac{g}{f\rho_0}\int_{z_0}^{z}\frac{\partial\hat{\rho}}{\partial y}dz', \tag{1}$$

$$v = v_0 - \frac{g}{f\rho_0}\int_{z_0}^{z}\frac{\partial\hat{\rho}}{\partial x}dz' \tag{2}$$

where (u, v), (u_0, v_0) are the geostrophic velocity at any depth z and at a reference depth z_0, $\hat{\rho}$ is the in situ water density, ρ_0 is the characteristic value of the density, and f is the Coriolis parameter, which is a function of latitude. Here the Boussinesq approximation has been used. As mentioned by Olbers *et al.* (1985), the quantities T, S are relatively easy to measure, and in contrast to velocity observations, the climatological signal in the T, S fields is less contaminated by energetic smaller-scale motions induced by eddies and waves. Equations (1) and (2) indicate that the hydrographic data only determine the baroclinic geostrophic currents. The reference velocity (u_0, v_0) still needs to be determined.

Based on the geostrophy, hydrostatic balance, and mass conservation, several major inverse techniques, i.e., the β-spiral method (Stommel and Schott, 1977; Schott and Stommel, 1978), the Wunsch method (Wunsch, 1978), and Bernoulli method (Killworth, 1986) have been successfully developed to quantify the geostrophic velocity at the reference

Copyright © The Oceanographic Society of Japan.