An Observation of Divergence in the Alaskan Stream

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13 April 1971 and 28 June 1971

Parachute drogue data (originally discussed by Reed and Taylor, 1965) in the Alaskan Stream, the swift boundary flow along the south side of the Aleutian Islands, have been reexamined in light of a recent paper in this journal on divergence in the Gulf Stream (Chew and Berberian, 1971). Three drogues at 5 m (see Fig. 1) revealed net westward velocities of 70, 79 and 83 cm sec$^{-1}$ (AS, BS and CS, respectively) and a diurnal, alternating (east-west) tidal flow with a maximum velocity of $\sim 25$ cm sec$^{-1}$. Some interesting features of these measurements are the curvature and crossing of drogue paths and the changes in area defined by the three drogues. Fig. 2 shows the tidal flow (after Reed and Taylor, 1965), the area defined by the triangles as indicated by the isochrones in Fig. 1, the separation between drogues BS and CS (where the paths cross and the difference in net flow is smallest), and the angular orientation of line segment BS-CS. The change in areas suggests that divergence was present during eastward tidal flow.

The data were first subjected to a trend test (see, for example, Bendat and Piersol, 1966, 158–159) to ascertain if the variations observed could result from stochastic processes rather than divergence of the mean motion. The drogue separations (AS-BS, AS-CS and BS-CS) all revealed a trend at the 2% level of significance for the period 1200-2400 (all times GMT) 8 June ($\lambda = 13; A = 7, 2$ and 4, respectively). The drogue areas do not reveal a trend prior to 1800 8 June, but afterward they do ($N = 12, A = 7$), even though the last 3 hr show a reversal. This evidence, plus that based upon the rotation of the line joining drogues BS and CS (Figs. 1 and 2), strongly suggests that divergence occurred after 1800.

In principle, the horizontal divergence may be estimated from

$$\text{div}_\lambda = \left(\frac{1}{A}\right) \left(\frac{dA}{dt}\right),$$

where $A$ is the area determined from a drogue triad as in Fig. 2. A 6-hr period (0900 8 June to 0100 9 June) was chosen where the data points lie close to a mean line clearly indicating divergence. The change in $A$ during this period is 5.3 km$^2$, and the mean $A$ is about 9.6 km$^2$; this yields

$$\text{div}_\lambda = 2.6 \times 10^{-4} \text{ sec}^{-1}.$$ (2)

It is, of course, very desirable to check this estimate because of the possibility that some part of the change in area may result from turbulence at scales less than that of the drogue separation (R. O. Reid, personal communication). Furthermore, it is believed that the areas were increased (about 25% is suggested by a calculation) by the difference in net flow between drogues AS and BS whose separation increased essentially linearly from about 1500 8 June to the end of observations. Because line BS-CS rotated much more than line AS-BS, it seems probable that divergence was strongest in the region of drogues BS and CS, and its magnitude will be estimated with the data from these paths.

![Fig. 1. Parachute drogues (AS, BS and CS) at 5 m tracked by the Coast and Geodetic Survey ship Explorer, 8-9 June 1959 (Reed and Taylor, 1965). The paths are indicated by isochrones for each hour (GMT). The 500 and 1000 fathom (fm) isolaths (1 fm = 1.829 m) are also shown.](image-url)
Unfortunately, it is not clear exactly when the divergence ceased. After 0100 GMT 9 June, the velocity difference between the two drogues increased markedly to 20 cm sec$^{-1}$, whereas prior to that time it was quite constant at about 5 cm sec$^{-1}$. (The increase in eastward velocity shear during 1900–0100, which is in keeping with the observed rotation, results not from a change in velocity but from a reduction in the north-south distance between the drogues.) It is believed that the differential velocity change after 0100 may not be related to divergence but to changes in flow caused by the drogues moving into much shoaler water than to the east. Although the above two estimates of divergence are essentially in agreement, they may not be highly reliable as previously noted. It does appear, however, that a gain of about $5 \times 10^{-5}$ sec$^{-1}$ of clockwise relative vorticity occurred in conjunction with the divergence during a 6-hr period.

Such large changes in relative vorticity in the Alaskan Stream may be rare, however. One reason is that the tidal flow was near the expected maximum for the month based on the tidal amplitude recorded at nearby gages. Furthermore, it is suspected that the tidal flow at this location is stronger than it is throughout most of the Stream. For example, an observation at 122 m near 158W (average depth of about 3000 m) revealed a semidiurnal, rotary tidal flow of only about 10 cm sec$^{-1}$ (Reed, 1971). Consequently the stronger, alternating tidal flow shown in Fig. 2 may result from topographic influences in the shoaler water near the break of the continental slope. Nevertheless, at certain times and places large changes in relative vorticity occur.

**Acknowledgments.** I am indebted to Dr. Glenn A. Cannon for a critical review of the manuscript and computations, and Prof. Robert O. Reid provided much valuable advice.

**REFERENCES**


