Correspondence

Comments on the paper “Western Boundary Currents and Vertical Motions in the Subarctic North Pacific Ocean”,* F. C. W. Olson**

The paper on “Western boundary currents and vertical motions in the subarctic North Pacific Ocean” by Jotaro Masuzawa which appeared in the June 1960 issue of this Journal impressed me as a notable contribution to the oceanography of this important area. There are two comments I would like to make which may provide further support for the conclusions obtained by Masuzawa.

In the first place, I was struck by the fact that no mention was made of the effect of the excess of precipitation over evaporation in this area. This matter can be settled quite readily by reference to Jacobs (1951). From this we find that the area north of the 40°N parallel is 14.9 x 10^46 cm^3. The mean annual excess of precipitation over evaporation is estimated from Jacobs’ Figures 46 and 47 to be roughly 40 cm/year. The net southward transport across the 40°th parallel is thus somewhat less than 2 x 10^11 cm^3 sec^-1, which is less than 1/40 of the value computed by Masuzawa and therefore of little significance in the over-all effect.

It is interesting that the qualitative study by Muromcev (1958) on the general circulation in the Pacific agrees completely with the more detailed findings of Masuzawa. Muromcev indicates not only a northward current at 2500 meters in the western part of the Pacific but also mentions ascending currents in the intermediate waters.

Finally, I must express my pleasure in the detailed calculations on vertical velocities given in this paper. Vertical velocities have been neglected too long by oceanographers. The more data we have on this subject, the sooner will we have a proper understanding of oceanographic phenomena.

References


Nak. SSSR. Geografic Series, 1958, 4, pp 24-32.

Masuzawa’s reply

It seemed to be clear that the effects of both precipitation and evaporation are negligibly small in the water budget which is considered in my paper, comparing with the transports in the ocean. However, as Mr. Olson pointed out, I should have presented the estimation of the order roughly.

I did not know the paper of Muromcev on the general circulation in the Pacific. I would like to appreciate Mr. Olson for his friendly comments and informations.

Comment on the paper “Western Boundary Currents and Vertical Motions in the Subarctic North Pacific Ocean”, by Jotaro Masuzawa in Journal of Oceanographical Society of Japan 16 (2).

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This paper deals with interesting features of vertical structure of the western boundary current near northern Japan. Masuzawa derived the total volume transport of the western current by use of the method developed by Stommel (1956). Similar procedure was applied by myself to determine transports in the upper and lower layer in the ocean divided by an arbitrary interface (Ichiyе, 1960a). In the North Pacific this procedure works well in obtaining water balance in a region surrounded by coasts and latitude circle, because there is almost no transport through Bering Strait.

Although the procedure can be successfully applied in determining a large scale feature of water budget in the ocean, particular care should be taken in its application in deriving detailed vertical structure of the current. The total transport across a section between two stations on a latitude circle is essentially determined by the integral of wind stress curl between the stations. The most important thing in applying the method to actual oceans is to have a good estimate of mean values of the wind stresses over the ocean, to which the results, particularly structures of vertical currents are quite sensitive, as pointed out later by Stommel and Arons 1960). The particular latitude, 40°N chosen by Masuzawa,

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unfortunately, happens to be most vulnerable to two kinds of sources of errors in estimating wind stress curl.

The integral of wind stress curl along a latitude circle is divided into two parts like

\[ \int_a^b \mathbf{\omega} \cdot d\mathbf{z} = \int_a^b \frac{\partial v}{\partial x} dx - \int_a^b \frac{\partial u}{\partial y} dy = \tau_y(b) - \tau_y(a) - \int_a^b \frac{\partial \tau_x}{\partial y} dx \]

(1)

in which \(x\) and \(y\) are coordinates directed to the east and the north, respectively, and \(a\) and \(b\) are \(x\)-coordinates of two stations. Generally the part of the integral including \(\frac{\partial \tau_y}{\partial y}\) is more important than the part due to \(\tau_x\). The values of \(\frac{\partial \tau_y}{\partial y}\) might be fairly accurately determined from the tabulated data of wind stresses for 5 degree squares (for example; Hidaka, 1958) along the latitudes where \(\tau_x\) is almost a linear function of \(y\). (The latitudes between 20°N to 35°N where subtropical easterly winds change to westerlies satisfy this condition). According to Hidaka's table, maximum values of \(\tau_x\) are found at 37.5°N in winter, 42.5°N in spring and 47.5°N in autumn (there is no definite maximum in summer, owing to weak westerlies). In the annual mean, two maxima of \(\tau_x\) in the westerly are seen at 47.5°N and 42.5°N. This implies that \(\tau_x\) is not a linear function of \(y\) near the latitude of 40°N and thus the gradient \(\frac{\partial \tau_x}{\partial y}\) determined from values of \(\tau_x\) tabulated at 5 degree intervals is not accurate.

Another source of errors in Masuzawa's calculation of wind stress curl is that the integral (1) along 40°N shows a large amplitude of annual variations. The results of calculation based on Hidaka's table are tabulated in Table 1, in which the integral of (1) is shown for different seasons, in western (150°E to 175°W) and eastern (175°W to 130°W) section and for two parts due to \(\frac{\partial \tau_y}{\partial x}\) and \(\frac{\partial \tau_x}{\partial y}\). This table indicates that the total transport across 40°N is directed to the north in winter, owing to the strong shear of the westerlies in the western section, quite contrary to Masuzawa's result which is obtained from the annual mean wind stresses. (The individual values of the integral \(\int (\frac{\partial \tau_y}{\partial y}) dx\) in the table may not be accurate as discussed above, but we are concerned with their seasonal change). His data of hydrographic stations were obtained in summer and early autumn. Although the summer value of the integral (1) is close to the annual mean value adopted by him, there is a possibility that the transport may be about twice his value for the western boundary section which was occupied in September. Under such circumstances, his elaboration in calculating vertical currents at each level for west and east sections is hardly justified, since he combined several sources of data obtained at different periods of time.

Incidentally, two problems may be imposed on deep water circulation in the area concerned. One problem is to determine the response of transport of the western boundary section to the seasonal change of the integral (1) along the latitude circle as shown in Table 1. Particularly it is interesting to see how the transport may change in winter. For this problem the same section must be surveyed at least each season of the year. (In such surveys, intervals of sampling layers below 2000 m should be taken at about 300 m as in many Atlantic surveys carried out by Woods Hole group, because transport below 2000 m is sensible to slight changes in density structure in dynamic calculations).

Another problem is related to the counter current under the Kuroshio flowing eastward 30°N and 40°N. Transport of the counter current which is directed to the west has almost the same amount as that of the Kuroshio above the depth of 1200 m (45×10^6 m³/sec versus 56×10^6 m³/sec; Ichiyoe, 1960b). On the other hand, transports below 1200 m in the western boundary sections are all directed to the north from 15°N to 45°N (Ichiyoe, 1960a). Therefore, it

<table>
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<tr>
<th>Table 1. Integral of wind stress curl 40°N. ((\rho\beta)^{-15}) curl (zd\mathbf{z})</th>
<th>Western Section</th>
<th>Eastern Section</th>
<th>Total Section</th>
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<tr>
<td>(A)</td>
<td>(B)</td>
<td>(A + B)</td>
<td>(A)</td>
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<tr>
<td>A=((\rho\beta)^{-1})(\partial \tau_y/\partial x)dx, B=((\rho\beta)^{-1})(\partial \tau_x/\partial y)dx</td>
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is expected that the counter current approaching the coast might increase the northward transport between 30°N and 40°N. But actually the transport in the lower layer of the western sections does not show such an increase within a range of these latitudes (figure 8; ICHIYE, 1960a). This inconsistency may partly be due to the condition that my calculation of transports is based on the annual mean of wind stresses and hydrographic data distributed at random in regard to season. However, there are two mechanisms that may explain such inconsistency. One mechanism is that the excess of the water transported into the lower layer of the western boundary region by the counter current is removed upward through interface. The other mechanism is that the excess water may flow back to the south near the coast and escape the estimation of transport in the network of stations. This question might be again solved by taking a close network of deep sea stations at suitable places near Japan.

The oceanographic data in the vicinity of Japan heretofore are notoriously disorganized in spite of their abundance, because very few hydrographic cruises were operated strictly on the basis of scientific interests in the past. I hope that such situation will be improved and more reliable data will become available in this very important area.

References


Masuzawa’s reply

Unfortunately I had not had an opportunity to read the instructive papers, “On water budget in a two layered ocean” by ICHIYE nor “On the abyssal circulation of the world ocean I, II” by STOMMEL and ARONS before I prepared the manuscript of my paper.

I recognize that there will be a possibility of having fairly serious errors in the calculation of the wind stress curl on the 40°N latitude, because I employed only the wind stress values tabulated at five degrees intervals. And also, the transport of the western boundary zone may change considerably in response to the seasonal change of the wind stress curl, but unfortunately we have had no suitable data. Therefore, as the first step of the investigation, I took no heed of the season when the hydrographic stations were occupied and I adopted the annual mean of wind stress curl, in order to obtain roughly the average structure of deep water motion in the subarctic North Pacific. However, it might be true that this procedure will be probable to lead to a misleading idea about that. I hope that the conclusion of mine could be accepted as hypothetical one based upon the assumptions and procedures which are not satisfactory but still be valid to the first order of approximations.

Of course, I agree with ICHIYE on an opinion that our hydrographic observations in the past were not quite satisfactorily organized. During these years we have been trying to take the suitable network of deep-sea stations and to improve the selection of intervals of sampling layers in the deep water as much as possible. We regret, however, that the matters have not yet become much improved. At last, I would like to acknowledge Dr. T. ICHIYE for his frank comments and advice.