La mer 29: 52-56, 1991
Société franco-japonaise d'océanographie, Tokyo

Oceanic angular momentum estimated with a general circulation model*

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Abstract: The oceanic angular momentum about the axis of the earth's rotation is estimated by using simulated velocity data from a world ocean circulation model. The Antarctic Circumpolar Current is of primary importance in the annual average of the total angular momentum, but not so in its annual variation. The oceanic angular momentum, either its annual average or annual range, is much smaller than the atmospheric angular momentum.

The relative angular momentum M per nuit volume about the axis of the earth's rotation is defined by

$$M = \rho u a \cos\phi, \qquad (1)$$

where ρ is the water density, u the eastward component of velocity, a the earth's radius and ϕ the latitude.

Equation (1) gives the total angular momentum if integrated vertically and horizontally over the whole oceans. Since no observational data of u are available, simulated data from a world ocean circulation modal are used instead. Our world ocean circulation model is described in other papers (ARAKAWA, 1990; ARAKAWA and TAKANO, 1991, in preparation), so that only its principal features are presented here. The ocean extends from 70°S to 70°N. Ice phase is ignored. The grid distance is 2° in longitude and latitude. Five levels are set up in the vertical. The bottom topography is approximated as realistically as possible. The circulation is driven by a prescribed surface wind stress and a surface heat flux which is made proportional to the difference between the predicted surface water temperature and a prescribed reference atmospheric temperature varying with latitude, longitude and time. The salinity is assumed to be a constant (35‰) everywhere. The water density is calculated as a function of temperature and pressure with the constant salinity. The external forcing varies with a period of one year.

The simulated result depends somewhat on parameter values such as coefficients of eddy diffusion, reference atmospheric temperature, constant of proportionality between the surface heat flux and the difference (surface temperature) − (reference atmospheric temperature). Therefore, four cases are dealt with as shown in Table 1, where k is the coefficient of subgrid scale vertical diffusion, A the coefficient of subgrid scale horizontal diffusion for heat, and d the constant of proportionality. The coefficient of horizontal diffusion for momentum is $10^5\ m^2/s$. The reference atmospheric temperature in Cases (3) and (4) is slightly different from that in Cases (1) and (2).

Table 1. Parameter values.

Case	k($10^{-4} m^2/s$)	A($10^3 m^2/s$)	d(W/m^2K)
(1)	0.3	1.0	60
(2)	1.0	1.0	60
(3)	1.0	1.0	30
(4)	1.0	2.5	30

Figure 1 shows the annual variation of the angular momentum. Agreement between curves for the last one year and the second last one year in Case (1) indicates that a statistically steady state is almost reached. In Case (4), too, two curves for the last two years fairly well agree with each other. While the results in the four cases are different in magnitude, they range from 0.70 to 1.53×10^{25} kg m^2/s. The annual range is 0.33, 0.40, 0.41, 0.35 $\times 10^{25}$kg m^2/s in Cases (1) to (4) with a maximum in June and a minimum in January. While the atmospheric angular momentum is not figured here, it is much larger in Novem-

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* Received August 16, 1991

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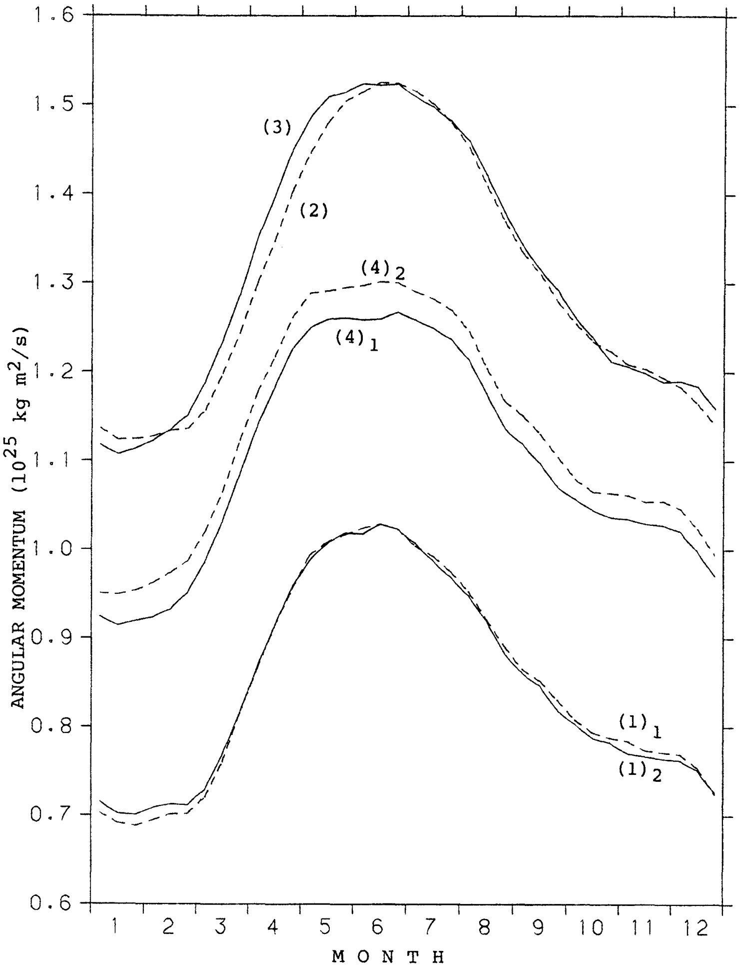

Fig. 1. Annual variation of the total angular monentum in Cases (1) to (4). Curve (1)$_1$ (broken line) denotes the second last one year cycle and Curve (1)$_2$ (full line) the last one year cycle in Case (1). Curve (4)$_1$ (full line) denotes the second last one year cycle, and Curve (4)$_2$ (broken line) the last one year cycle in Case (4).

ber-February than in June-September where it is negative (westward). Its annual range is about 10^{26}kg m^2/s, more than 20 times larger than the oceanic annual range (for example, ROSEN and SALSTEIN, 1983).

Figure 2 shows the meridional distribution of the annual average of the angular momentum per zonal band two-degree wide by a full line and the annual ranges by bars in Case (1), and Fig.3 those in Case (3). There are no significant differences between both cases, no significant differences between the four cases, either. The angular monentum is negative (westward) at middle latitudes. Although the equatorial currents flow westward near the equator, deeper eastward currents make the angular momentum eastward.

The baroclinic component of the velocity has almost no contribution to the angular momentum of vertical column. The Antarctic Circumpolar Current (ACC) which is predominantly barotropic is a main contributor to the angular momentum, though, compared with the other currents, it flows near the axis of the earth's rotation.

Table 2 shows the annual average of ACC

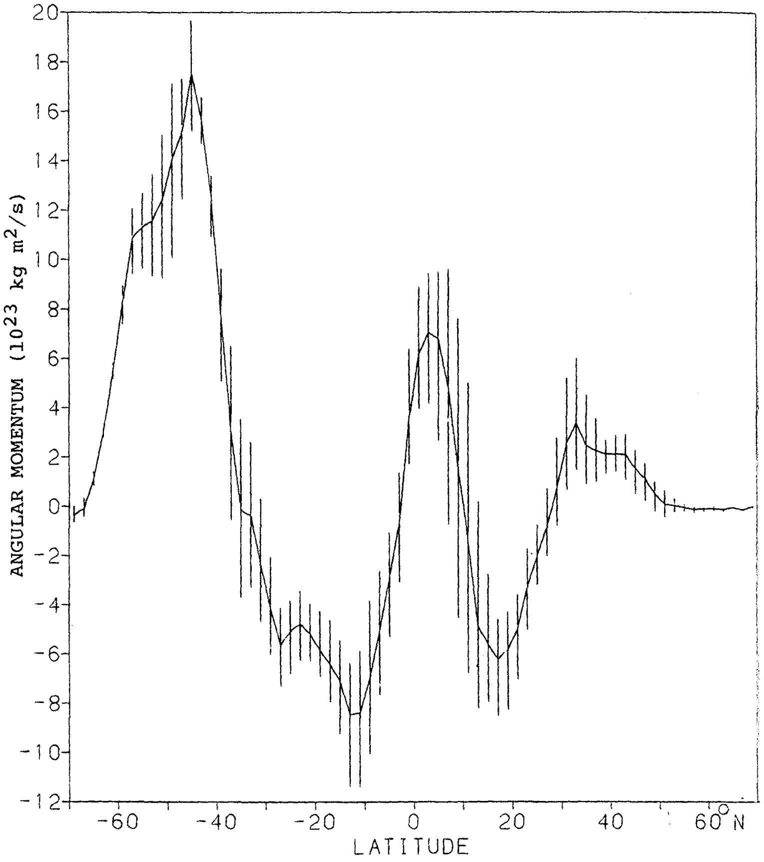

Fig. 2. Meridional distribution of the annual average in Case (1). Bars denote the annual ranges.

transport defined by the transport through the Drake Passage, its angular momentum estimated by assuming that it is located at 55°S, and the annual average of the total angular momentum of the world ocean. The total angular momentum is closely related, in magnitude, with the ACC transport and angular momentum. The ACC angular momentum is a little greater than the total angular momentum; the total of the angular momentum at latitudes other than the ACC latitudes almost vanishes or is slightly negative, as suggested in Figs. 2 and 3.

The ACC transport becomes maximum in May and minimum in January in all the cases, almost in phase with the total angular momentum shown in Fig. 1. However, the annual range of the ACC angular momentum is 0.067, 0.079, 0.138, 0.113×10^{25}kg m^2/s in Cases (1) to (4), respectively, which is much smaller than that of the total angular momentum (0.33 to 0.41×10^{25} kg m^2/s as men-

Table 2. Annual average of the ACC transport (sv) and angular momentum, and the total angular momentum (10^{25} kg m^2/s)

Case	ACC transport	Angular momentum	Total angular momentum
(1)	120.9	1.01	0.849
(2)	155.7	1.31	1.30
(3)	159.2	1.34	1.31
(4)	133.0	1.12	1.11

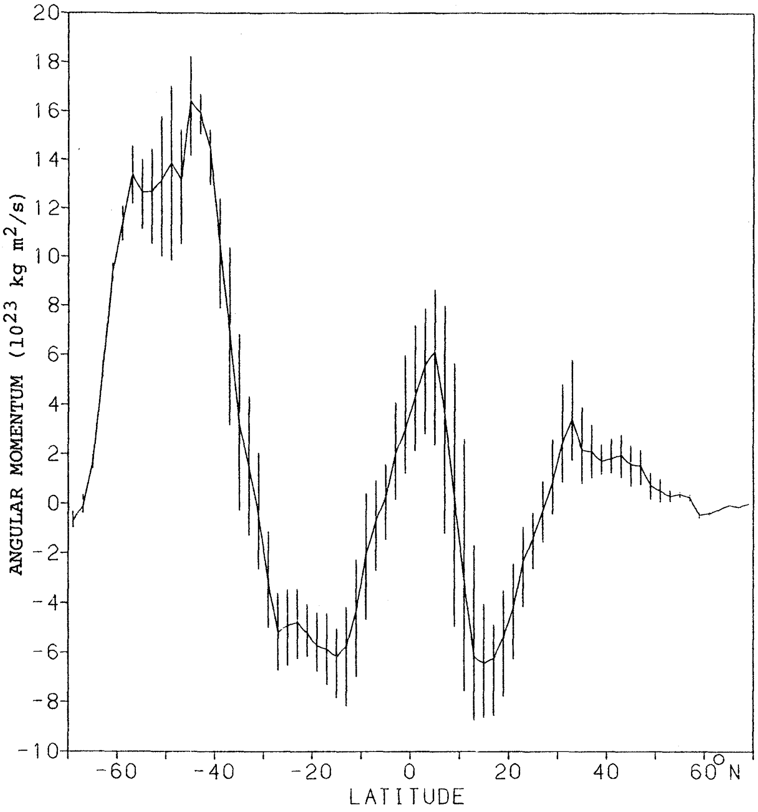

Fig. 3. Same as Fig. 2 except for Case (3).

tioned above). This implies that the ACC is not an important process in the annual variation of the total angular mometum, though it is of crucial importance in the annual average.

The Arctic Ocean is not included in the present study. The currents are basically anticlockwise there, but would not increase much the total angular momentum, because they are not only so weak but also located near the axis of the earth's rotation.

Corresponding to a coarse grid used in the model, the coefficient of the horizontal diffusion for momentum is large, which weakens the circulation. The angular momentum might become a few times larger with a much finer grid, but would still one order of magnitude smaller than the atmospheric angular momentum.

The oceanic angular momentum has no significant effect on the earth's rotation and the length of day.

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地球自転軸のまわりの海洋角運動量

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要旨：世界中の海水の大環境モデルから得られた流速データを使って，地球の自転軸のまわりの海洋角運動量を見積る。流速のシミュレーションデータは，うず拡散係数などの大きさによってある程度は変わるので，これらの値を変えて四つの場合について計算する。四つの結果の間に大きな差はない。年平均角運動量に対しては周南極海流の寄与がきわだって大きい。流速の傾圧成分からは大きな角運動量は生じないからである。角運動量は一年を通じて東向きであり，南半球の冬に大きく，夏に小さい。しかし，年変化に対する周南極海流の寄与は小さい。年平均も年変化も大気の角運動量にくらべるとずっと小さく，海洋角運動量は地球の自転速度・一日の長さに影響を及ぼさない。