Variations in the Earth's Angular Velocity Resulting from Fluctuations in Atmospheric and Oceanic Circulation

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1. It is generally accepted that available aerological information concerning the distribution, in space and time, of the zonal component of the atmospheric circulation, is not yet complete enough to permit a reliable calculation of the angular momentum of the atmosphere.

If it is remembered that the zonal circulation varies strongly with longitude (NAMIAS and CLAPP, 1949), even probably more strongly in the northern than in the southern hemisphere, it will appear that a calculation based on the information available about the distribution of the zonal velocity in one or two meridional cross sections only, does not seem very satisfactory.

W. H. MUNK and R. L. MILLER (1950) have calculated the angular momentum of the southern atmosphere using winter and summer cross sections along the 150° E meridian, as established by F. LOEWE and U. RADOK (1950 a). These cross sections show that the wind speed in the center of the westerly jet exceeds 120 mi/h (at 25° S), in winter, and 50 mi/h (at 40° S) in summer.

More complete and recent information show (LOEWE and RADOK, 1950 b) that the summer southern "jet stream" would in fact be much more intense, exceeding 100 mi/h in the center. The dissimilarity or assymmetry of the westerlies in the two hemispheres is, in summer, much more marked than previously assumed.

We are of the opinion that the annual variation of the momentum transfer between the earth and the atmosphere offers a better basis for calculating the annual variation of the angular momentum of the atmosphere.

This transfer results from the friction between the earth surface and the atmosphere (including the pressure effect due to mountains).

Utilising tables calculated by V. P. STARR and his collaborators (1949) on the basis of numerous surface information, we believe to have followed a sound method in our calculations (VAN DEN DUNGEN et al. 1950).

2. The flux of west momentum across the earth's surface is an ascending one where easterlies dominate (low latitudes) and a descending one where westerlies dominate (middle latitudes). In the mean, as easterlies are better developed in the northern than in the southern hemisphere, the ascending flux of the low latitudes is not compensated in the northern hemisphere by the descending flux of the middle latitudes. A part of the ascending flux of the tropical regions of the northern hemisphere passes across the equator (WIDGER, 1949) and is compensated in the middle latitudes of the southern hemisphere, where more intense westerlies bring a descending flux of west momentum, more considerable than in the northern hemisphere.

Assuming that for the entire surface of the earth, at a uniform rate throughout the year, a complete compensation of the ascending and descending west momentum happens, we obtain (VAN DEN DUNGEN et al. 1950) a scheme of the fluctuations of the earth's rotation in good accordance with the published values (Stoyko, Finch, Uhink).

When numerical tables of the kind calculated by V. P. STARR and his collaborators and related to the southern hemisphere are available, the assumption about yearly compensation may be tested. It seems probable that a complete yearly compensation at uniform rate does not occur and this may open the way for a meteorological explanation of apparently erratic changes. In that connection it must be remembered that the reduction of the clock rates remains intricate and that future work may provide further valuable information in that field.

3. Column (4) of Table 2 in W. H. Munk and R. L. Miller cited paper needs, in our opinion, to be carefully examined. Let Δp represent the variation from January to July of the mean pressure p (on the ground) not reduced to sea level, along a parallel of latitude φ; obviously, the total mass of the atmosphere remaining constant, it is necessary that

$$\int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \Delta p \cdot \cos \varphi \cdot d\varphi = 0 \qquad (1)$$

In other words, the mean value of the Δp in the northern hemisphere must be equal and opposite in sign to the mean value of the Δp in the southern hemisphere. Dividing the surface of the spherical globe into zones of 5° and 10° latitude, let us denote by $[\Delta p]$ the mean values of Δp for every of these zones.

Equation (1) shows that the $[\Delta p]$ brought into a $(\sin\varphi, [\Delta p])$ diagram must appear such (stairs curve) that the algebraic sum of the areas comprised between it and the "$\sin\varphi$" axis be zero.

It is easy to check that the $[\Delta p]$ values tabulated by W. H. Munk and R. L. Miller do not fulfill this condition. As a special case, one finds with those values

$$\Big[\Delta p\Big]_{0^\circ}^{80^\circ} \equiv \begin{cases} +0.85 \text{ mb for the northern hemisphere;} \\ -2.19 \text{ mb for the southern hemisphere;} \end{cases}$$

it follows that

$$\Big[\Delta p\Big]_{80^\circ \mathrm{S}}^{80^\circ \mathrm{N}} \equiv -0.67 \text{ mb},$$

$\Big[\Delta p\Big]_{\varphi_1}^{\varphi_2}$ representing the mean value of Δp between latitudes φ_1 and φ_2.

It seems quite unlikely that this mean negative pressure difference between 80° S and 80° N could be balanced by a reasonable positive difference in the two small polar caps of 10° of latitude.

4. In their above quoted paper W. H. MUNK and R. L. MILLER (1950) report about our paper (VAN DEN DUNGEN et al. 1949) in terms such that it could be understood that we were not aware of the importance for the problem stated of the correction from sea level pressure to local pressure.

We believe that every reader who will have read through our paper will be aware that this was not the case. Our scheme was fully developed by one of our students, Miss M. LAURENT (1949, 1950).

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Reply

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La Jolla, November 15th, 1950

1. The effect of the wind circulation on the earth's rotation can be computed either from (a) changes in the angular momentum of the atmosphere as a whole, or (b) momentum transfer between atmosphere and earth. We have utilized the former method, and arrived at results consistent with astronomic observations; as described in the above note, VAN DEN DUNGEN et al. (1950)[1] utilized the latter method, with similar results.

It is true that for our method it would have been highly desirable to have had available additional meridional sections in the Southern Hemisphere, and we have said so in our article. In van den Dungen's method, the pressure effect due to mountains and a choice for the frictional coefficient between air and land, and air and water, is also not without uncertainties. Since the transfer of angular momentum over six months from the westerlies or the easterlies to the earth is large compared to the angular momentum of the atmosphere at any instant,

[1] This paper was apparently published at about the same time as our paper, but no copy has as yet been available to us. In our article we refer to van den Dungen's earlier paper in which the variations in the earth's rotation are ascribed to latitudinal changes of air masses.