5. *On the Effect of Ocean Current, "Kurosiwo", upon Sea Level. Effect of Waves.*

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Effect of Ocean current.

In a previous paper,[1] the report was given of the result of the comparison of two curves of the monthly mean sea level for Aburatubo and Hososima corrected for the cyclonic factor=10 and 15 respectively, and it was shown that a parallelism may be observed between the two curves, at least for some months. This result may probably be due to the parallelism of the variations of water density in the two stations, which we may expect from the fact that the two stations are under the direct influence of the ocean current, "Kurosiwo."

To test this idea, a statistical investigation was made availing of the data comprising the values of the temperature and salinity of sea water at various depths, at a station 10 miles off Sionomisaki, in Kii, as well as another station 10 miles off Aburatubo, in Sagami, which were kindly placed at my disposal by Prof. M. Tauti of the Imperial Japanese Fishery Institute, Tokyo.

Firstly, the monthly mean temperature of sea water at the depth of 25 metres, 10 miles off Aburatubo, was directly compared with the monthly mean sea level at Aburatubo, corrected for the cyclonic factor=10, for the five years 1923–1927. Both the deviation of the temperature and the sea level, from the five year means of each month, were taken respectively and plotted in $\Delta T - \Delta L$ diagram as shown in Fig. 1.

Secondly, the density[2] of the sea water, reduced from the temperature and salinity at the depth of 25 metres, 10 miles off Aburatubo, was taken and similarly treated as shown in Fig. 2.

Thirdly, the values of the mean density of sea water reduced from the temperature and salinity at the surface and at the depth of 200 metres respectively, 10 miles off Sionomisaki, in Kii, were taken and compared with the sea level at Aburatubo. The data for the densities and the sea level, were quite similarly treated as in the preceeding two cases, as shown in Fig. 3.

Among 60 months taken, the observations of the temperature and salinity of sea water, were wanting in fifteen months, so that we were

1) S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, 7 (1927), Part 3.

2) The effect of pressure in situ is neglected.

obliged to put 12 months out of account, though a few months could be approximately replaced by the data off Nozimasaki, in Awa.

In Fig. 1, 2, 3, the centres of gravity of the points, distributed

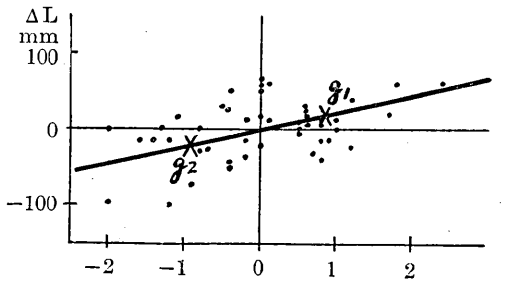


Fig. 1.

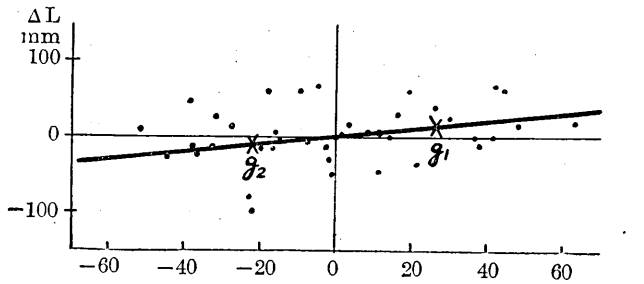


Fig. 2.

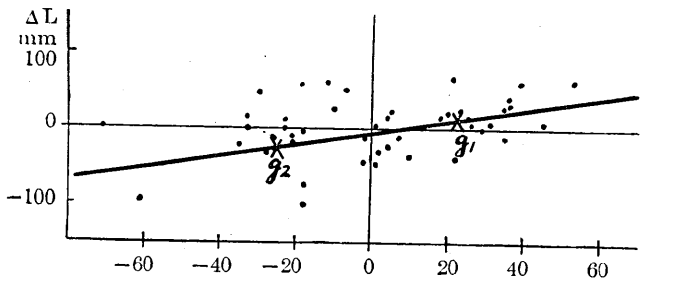


Fig. 3.

respectively in the right-hand side and in the left-hand side of the axis $\Delta\rho=0$, are denoted by g_1 and g_2, respectively. Drawing a straight line connecting g_1 and g_2, it is inclined to the axis of abscissa at a certain angle, and the points show a tendency to be rather widely distributed along this line on both sides. The straight line may be considered to show the effects of the anomaly in the oceanographical condition of sea water upon the sea level, as the effect of the regular annual variation of the density caused by the annual change of the meteorological conditions is considered to be eliminated already in the process of the above treatment. From the inclination of the line, we may obtain a ratio $\Delta L/\Delta\rho$, which may be called the "density factor" with respect to the monthly value. The factor thus determined roughly is 75, where ΔL is measured is millimetre and $\Delta\rho$ in 10^{-3}. If, on the other hand, we take the value of $\Delta\rho$ at Sionomisaki, instead of that at Aburatubo, we obtain a value of this factor still amounting to 50, which fact will suggest the effect of ocean current, "Kurosiwo", in govorning the anomaly of oceanographical condition along the Pacific Coast. The values of $\Delta L/\Delta T$ is estimated as 23, ΔT being measured in degree centigrade.

Though it is our ultimate aim to obtain the small residual values of the anomalies of monthly mean sea level after being corrected for the pressure, wind, cyclone and moreover for the temperature and salinity of water, we are at present obliged to give up the correction for the latter, as the data are wanting in 12 months among 60 months (1923–1927).

Next, we calculated the probable error, r, of the observed values of the monthly mean sea level, taking their deviations from the mean values for the five years above cited, and obtained the value of $r=52$ mm. We also calculated the value of r, taking the deviations from the 24 year mean for each month, and obtained the value of $r=32$ mm. Lastly, we calculated the probable error of the residual value of the monthly mean sea level after being corrected firstly for the cyclonic factor, and secondly corrected graphically for the density factor above explained, and obtained $r=23$mm.

These results show that, if we apply the corrections for the cyclone and for the density effect deduced from the scanty data for only five years, we may be able to get a decidedly smaller value of the probable error of the monthly mean sea level than that of the observed value, corrected merely for the average monthly variation deduced from the 24 year mean for each month. It will also be seen that the former value is less than half the value of the probable error of the observed value referred to the mean monthly values for the five years, with no correction for the

cyclonic and density effect. This will show the important significance of the said corrections.

Effect of Waves.

A recent investigation[3] of the present author regarding the abnormal rise of sea level in the Japan Sea Coasts of Etizen, Etigo and Ugo, on Jan. 2, 1929, has shown that at the time of the maximum rise of the sea level in the above region, the centre of cyclone had already passed over the Japan Sea area and was travelling on the Pacific Ocean near Hanasaki, in Nemuro, and that the change of the sea level could not be explained well by the direct influence of winds, and also that the effect of waves due to the cyclonic winds must be considered as one of the most important factors governing the variation of the sea level.

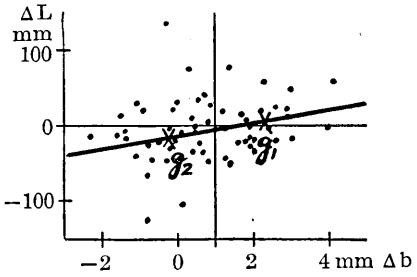
In connection with a further study of this latter effect, we tried to investigate the variation of the monthly mean sea level at Wazima, in Noto, comparing it with the corresponding barometer differences at various stations.

Before entering into this investigation, it was tested, if there might exist some sensible relation between the sea level at Wazima and the cyclone situated in the Pacific Ocean off the coast of Hanasaki, ignoring its direction of progress. The number, n, of the cyclonic days in the said region, was counted for each month from the Daily Weather Charts of the North Pacific Ocean, published by the Imperial Marine Observatory, Kôbe, for the five years (1923–1927). The deviation of n from the five year mean for each month was denoted by Δn. On plotting the deviation, ΔL, of the monthly mean sea level from the 25 year mean of each month, as ordinates, against Δn taken as abscissa, no systematic distribution of the points can be observed, though treated in the similar way as usual, showing no trace of sensible correlation suspected. Therefore, the cyclone in the Pacific Ocean off Hokkaidô affects the sea level at Wazima not merely by its position, but by the effect of its passage over the Japan Sea area.

Next, the diagrams were drawn with ΔL, above cited, as ordinates and the barometer differences, Δb, between (a) Sionomisaki, in Kii, and Aomori, (b) Genzan, in Korea, and Aomori, (c) Hamada, in Iwami and Akita, (d) Fuzan, in Korea, and Maoka, in Saghalien, respectively, taken from the Monthly Summary Report of the Central Meteorological Observatory in Japan, as abscissa, as shown in Fig. 4. In the diagram, the

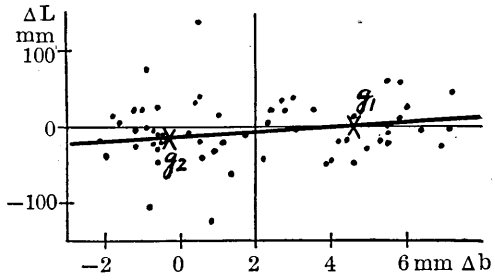
3) S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, 7 (1929), Part 3.

points, g_1 and g_2 are the centres of gravity of the points distributed in the right-hand side and in the left-hand side respectively of the axis of



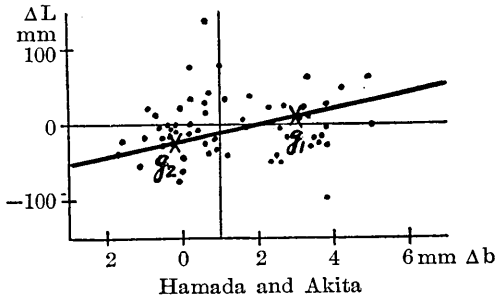
Sionomisaki and Aomori

Fig. 4a.



Genzan and Aomori

Fig. 4b.



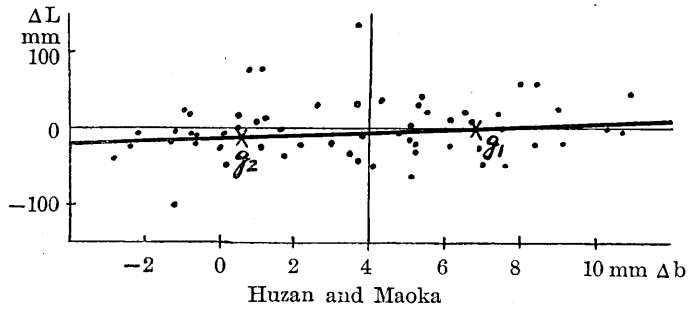
Hamada and Akita

Fig. 4c.

ordinates. The straight line, connecting the above two points, g_1 and g_2 is inclined to the axis of abscissa at a certain angle, of which the tangent is

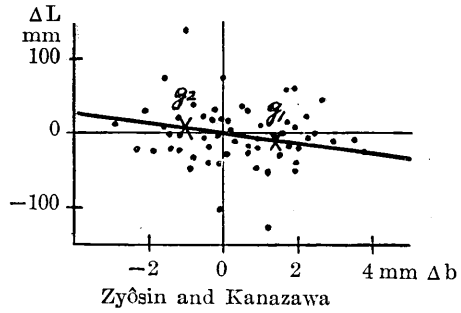
considered to show the correlation factor between the sea level and the barometer differences.

When the barometric pressure in the region of Kinai and Tyûgoku is decidely higher during a sensible epoch than that in the region of



Huzan and Maoka

Fig. 4d.



Zyôsin and Kanazawa

Fig. 4e.

Aomori, we may expect the effect of waves upon the sea level at Wazima, since the case corresponds barometrically to the case of a cyclone passing over the Japan Sea towards the Pacific Coast of Hokkaidô.

On the other hand, the barometer differrence between Zyôsin, in China, and Kanazawa was taken and similarly treated as before. The result shows, however, no such sensible correlation, or rather the straight line connecting g_1 and g_2, is inclined to the negative direction of the axis of abscissa at some angle as shown in Fig. 4e.

Unfortunately, the variation of the amplitudes of surface waves cannot be traced from the mareograms of Wazima, due to the ample damping of the tide-gauge, so that we were not able to undertake the direct

comparison of the amplitude of waves with the sea level of this station, and were obliged to take the data for the winds, instead of waves, under the assumption that the amplitude of waves at a station is a definite function of the wind velocity at a neighbouring station. Taking the direction of maximum frequency and the mean velocity of wind, which is given in the Monthly Summary Report of the Central Meteorological Observatory in Japan, as determining a kind of wind vector, the vector sum of the three vectors corresponding to the three stations, Miyadu, in Tango, Husiki, in Noto, and Niigata, in Etigo, is constructed and projected on NE-direction, which is nearly parallel to the coast line, and also on SE-direction respectively for each month of the five years (1923–1927). The average NE-component of the wind vector for the district being thus estimated, its deviation from the five year mean of each month was calculated and plotted in the diagram as abscissa, against ΔL above cited taken as ordinates, as shown in Fig. 5a. The straight line connecting the two points, g_1 and g_2 quite similarly as in the above cases, is inclined to

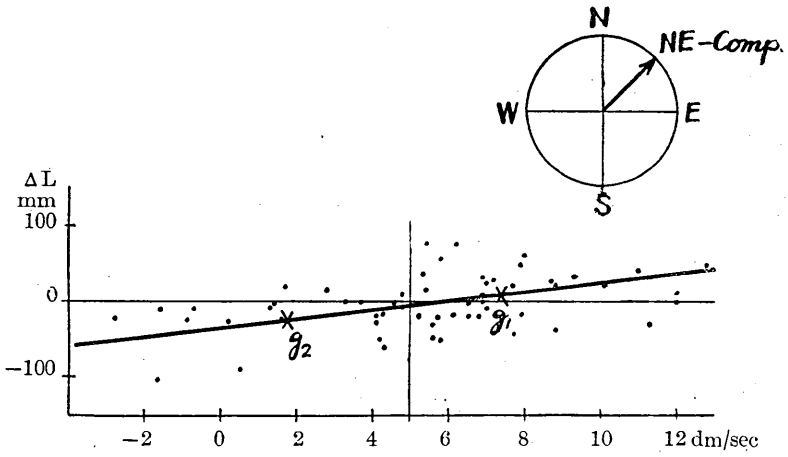


Fig. 5a.

the axis of abscissa at a certain angle. This fact may be considered to show the effect of SW-winds on the sea level at Wazima. On the other hand, the SE-components of the vector sum are taken and similarly treated as shown in Fig. 5b, in which the line connecting g_1 and g_2 nearly coincides with the axis of abscissa. We may, therefore, conclude that the effect of wind, if any, is chiefly determined by its component velocity towards NE.

It will be known that the height of waves caused by winds increases with the extent of open sea area towards the windward direction. As the NE direction roughly coincides with the larger axis of the Japan Sea, the

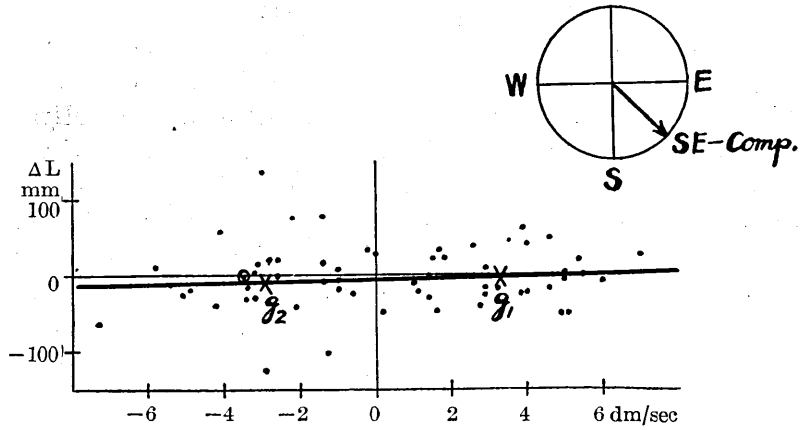


Fig. 5b.

effectiveness of this component in producing large waves may be expected in some measure from the said cause.

This result is also in a good agreement with the result already reported in a previous paper[4] with the title "On the effect of winds on sea level". In that report, a tentative explanation was suggested based on the wind-drift theory. After the important effect of waves has been established, we must admit that at least a part of the factors determining the sea level of this station is played by the waves, though the drift effect may also be extant.

In conclusion, I wish to express my best thanks to Prof. T. Terada under whose supervision the entire work has been carried out and who has given me many useful suggestions throughout the course of my investigation.

4) T. TERADA and S. YAMAGUTI, *Jap. J. Astr. Geophys.*, 4, No. 1 (1926).

5. 海水面に及ぼす海流の影響並びに波浪の影響に就て

山口生知

海流の影響

先に「地震研究所彙報第七號第一册昭和四年六月」の中に於て發表して置いたやうに 油壺に於ける月々の平均海水面の觀測値より低氣壓による影響を取り去ると、その殘りは可なり小さな値にはなるけれども、尙未だ不規則な變化が殘つてゐるので參考の爲に細島の觀測値に就いても同樣の修正を加へて之等二ケ所の値を比較して見た。所が或幾月かは海水面の變化の模樣が全く平行に行はれてゐるのを發見した。之は恐らく細島と油壺とは黑潮に對して同じ樣な影響の下にあるから、その黑潮に基因する海水密度の變化によるものではなからうかと推量した。

此推量が果して事實であるか否かを確める爲に次の樣な調査を試みた。卽ち水產講習所の田內博士より潮の岬沖及油壺沖 10 浬の所に於ける種々の深さの海水溫度及鹽分の値の材料を頂戴して、之等の値より透導した海水密度の月々の變化と海水面の變化との間に相關關係があるかどうかを調べて見た。

兩方の値共各月の平均の値よりの變動量を夫々 ΔL 及 $\Delta\rho$ として $\Delta\rho-\Delta L$ 圖を畫いて見た。それが第一圖、第二圖、第三圖に示さるゝものであつて、これを見れば大體に於て海水密度と海水面との間に或る相關關係のあることが窺はれる。京都帝國大學の野滿教授等は海水面の年變化について海水密度の年變化が大なる影響のあることを指摘して居られるが、その意味に於ける規則正しい海水密度の年變化による影響は上述の取扱方によつて旣に消去されて居る故に、結局海流（黑潮）の影響として海洋狀況に變動を與へたものと考ふることが出來る。

次に月々の平均海水面の觀測値の年平均よりの變動量並びに各月 24 年間平均値よりの變動量及び低氣壓並びに海水密度による影響を取り去つた殘りの量について、夫々公算誤差を計算してみると 52mm, 32mm 及び 23mm となる。この事實から吾々は次のことがいはれる。卽ちもしも海水面の月々の平均値に低氣壓及海水密度の變化による適當な修正を加ふる時は、僅か5年間の材料を以てして 25 年間の平均値を以て修正を加へたものよりも小なる公算誤差を得る事が出來、又無修正のものに比較すれば其半分以下の公算誤差を得るのである。これは低氣壓及海水密度による修正が如何に大切なものであるかを示すものである。

波の影響

昭和四年一月二日日本海々水面の異常に關する最近の研究（地震研究所彙報第七號第三册昭和四年十二月）に依つて著者は次の如き結論に到着した。卽ち日本海面の最も高まる時刻には颱風の中心は旣に日本海上を通過して北海道の東方太平洋上に在るといふ事、及海水面變化を支配する最も大切な因子の一つは波浪の影響であるといふ事である。

この研究の繼續として、然らば颱風の中心が北海道近くの太平洋上に表はれて居る時には、如

何なる方向より進行して來た颱風でも常に日本海輪島の海水面に影響を與ふるや否やを調べて見た。その結果は輪島の海水面を支配する低氣壓は、矢張り日本海上を通過するといふことが必要な條件であるといふことになつた。

次に輪島の月々の平均海水面と波との關係を直接比較研究して見たかつたのであるが、遺憾ながら輪島の檢潮曲線には、恐らく波が檢潮器の細管の中で衰滅した爲に、その痕跡を止めてゐない故に、止むを得ず波の代りに風を採つて調べることにした。これは波の振幅はその附近の風速の或一定の函數であるといふ假定の下に行つたのである。即中央氣象臺發行の氣象要覽から宮津、伏木、及び新潟の三ケ所の月々の平均風速及び最多風向を取つてその有向量的の和を作り、更に之を海岸線に殆ど平行なる北東方向及び之に直角なる南東方向に分解して、夫々その分風速度と輪島の月々の平均海水面との關係を調べて見た。その結果は第五圖 a, b に示さるる通り南東の分速度は殆んどその影響を認めることが出來ないが、北東の分速度即南西の風は相當の影響あることを示してゐる。

一體波の高さは外海洋の面積が風の方向に廣がつて居れば居る程一層增大するものであるが、丁度北東方向は日本海の長軸の方向と殆ど一致してゐるからその爲に南西の風が吹く時は大なる波浪を起して輪島の海水面を高めることになるものと考ふることが出來よう。

又この結果は既に寺田博士と共に研究して「海水面に及ぼす風の影響」と題して「日本天文學及地球物理學輯報第四卷第一號大正十五年」に發表して置いた結果とよく一致してゐる。あの時の論文に於ては風の爲に起る皮流の理論を基礎として說明を試みたのであつたが、その後波浪の影響が大切な因子であるといふことが確立された今日に於ては、輪島の海水面を支配する主なる因子は颱風に伴ふ波浪の影響であることを承認せざるを得ないのである。而して前に述べた皮流の影響の現存することは勿論であらふ。