大氣壓力之週期性波動

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Shu Chao, Periodic Pressure Osoillation At Tsing Hua Yuan, Peiping

Oscillations in pressure wind direction, and velocity are very common at Tsing Hua Yuan, Peiping, especially during winter. We have a striking example that took place in the early hours of Jan. 13th, 1939. The autographic traces are shown in fig. 1. All the said oscillations began at 1:53 A.M. and ceased at 5:oI A.M. (Some less distinct oscillations commenced at 1:20) Thirty one complete oscillations were registered during this period, and the average period for each wave was 6.06 minutes.

The mean amplitude of the pressure fluctution was 0.13 mm. A sharper set of six pressure waves was registered from 4:01-4:41, having an avevage amplitude of 0.23mm. The amplitude of the oscillation of the wind velocity averaged 0.22 m/Sec. until 3:30 A.M. with a mean wind velocity of 2.07 m/Sec. Then the mean velocity increased to 4.08 m/Sec., while the amplitude increased to 0.34 m/Sec. The amplitude of the oscillation of the wind direction was about 14.1° until 3:30 A.M. with the dominant wind direction of NExNNE. Then the dominant wind direction shifted to NxNNW while the amplitude increased to about 15.7°.

The interesting fact is that the thirty-one pressure crests coincided with thirty-one maximum wind backs, and what is more interesting, with thirty-one maximum wind velocities. Temperature and humidity varied slightly and with no periodic condition. But both are inverse functions. This shows the constancy of absolute humidity and indicates the homogenity of the air mass at surface. Therefore, these oscillations were due to some upper air phenomenon.

As is known, gravity-waves in atmosphere, analogous to gravity water waves, are produced above and below a surface of separation between layers of air of different density and in motion relative each to other. The theory was first given by Helmoltz. The waves conform approximately to the following equation.

$$L = \frac{2\pi}{g} U^2 \frac{(T'+T)}{(T'-T)}$$

Here L is the wave-length, g the gravity acceleration, T' the temperature in the upper and T in the lower and layer U half the wind difference between both layers.

Now, if we regard the above recorded oscillations in wind direction and velocity as representative for the wind discontinuity, we may, since an analysis of the wind is made in Fig. 2, apply a simple trigonometrical theorem in order to obtain the average approximatic convective velocities of 2.0 m/Sec. (OB), and 3.9 m/Sec. (OB') for the time before and after 3:30 A.M. respectively. With a period of 6.06 min. this gives wave lengths of 727 meters and 1418 metrs respectively, Similarly, we obtain the values of 2U=1.1 m/Sec. (AC), and 2.4 m/Sec. (A'C') respectively.

Since the mean surface temperature was 259°5. for the time from 2:00 - 3:30, and 259.6° for the time from 3:305.00, by the above formula, we obtain T'=259.7° and 259.8° respectively. In other words, an inversion of temperature of 0.2° occurred either before or after 3:3o A.M.

The weather chart of Jan. 13th (6A. M.) is reproduced in Fig. 3. It shows that a depression centred at the northeast of Tsing Hua Ynan, moved toward northeast, and finally centred at about Lat. 48°N. Long. 131 °E, (Point A, Fig. 3) after 24 hours (6 A.M. Jan. 14th). If we assume that the shape and size of this depression had no remarkable change for a short time. the depression would be possibly fomed at a region shown with a dotted circle in Fig. 3 at 2 A.M. Jan. 13th. (When the oscillations commenced). Then. it will be clearly seen that Tsing Hua Yuan which was in a sector of warm air, lay before a northeastward moving cold front during the time before 2 A.M. Then Tsing Hua Yuan was in a sector of cold air while the cold front had passed over during the time after 2 A.M. These facts were in perfect agreement with the records that indicate a higher temperature with dominant southerly winds and a lower temperature with dominant northerly winds at the time before and after 2 A.M. respectively. Therefore the oscillations were undoubtedly caused by the intermittent encrohment of overrunning cold air.

大氣中的重力波，常產生於兩種性質不同的氣流之間。倘接近地面的空氣溫度較低密度較大，上層反較溫暖而密度較稀薄時，則當此

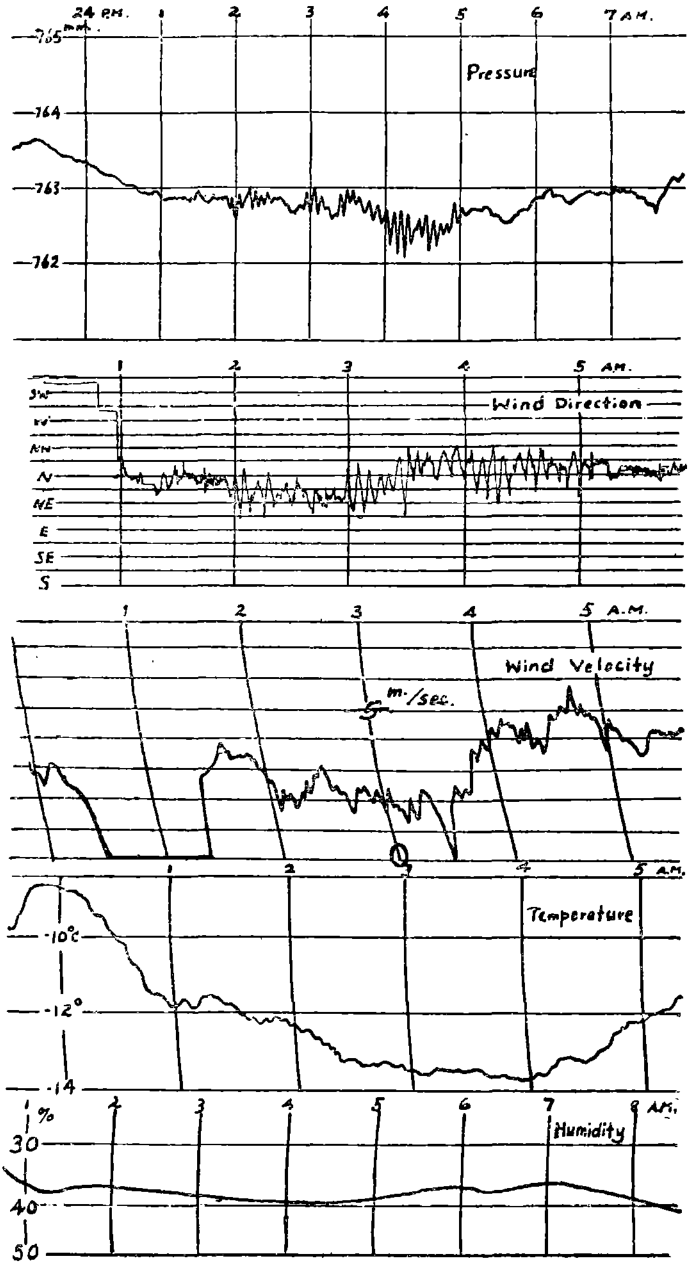
上下兩層空氣行動的速度的差異超過某種程度以後，在接觸面間卽將失去安定狀態，而造成波動現象。其情形同在水面因風而起的波浪，很相類似。

產生這類波動是很普通的。尤其在溫度逆增現象特別盛行的冬天，或者在時常有冷面侵入的地方。當空中產生這類波動影響到了地面時，地面的氣壓，風向，風速等就隨着起了帶有週期性的振動。平常從各種自記紀錄紙上就很容易察看出來。

二十五年一月十三日清晨，北平清華園曾發現這類波動的一個顯著例子(第一圖)。波動開始於當天一點五十三分，到五點〇一分始消滅。在這三小時又八分鐘的期間內，有三十一個完整的波動，每個波動的平均週期是6.06分鐘。氣壓、風向、風速的振動，都很相符合。每當氣壓增高時，風向逆轉，風力增大。因風向逆轉爲北或西北時，表示正當冷空氣的侵襲，所以氣壓增加，風速增大。其他溫度和相對濕度方面，並無任何顯著的振動現象。不過當溫度漸趨下降時，相對濕度漸趨增大；溫度上升時則反是。兩者適成相反作用。從這點可推想當時地面絕對濕度的穩定不變，或卽表示接近地面的空氣的單純性。證明當時波動現象的產生，並非由於地面部分的空氣，乃由於空中氣層間發生變故。

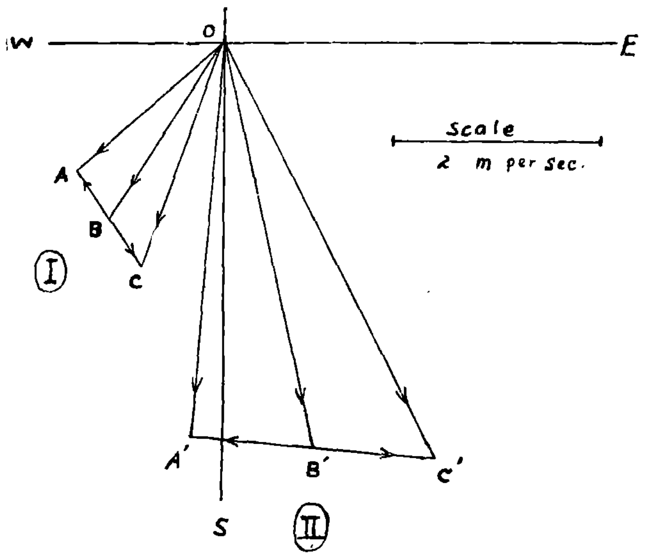
依據自記紀錄所測定的結果，氣壓振動的振幅平均爲0.13公厘。在四點〇一分至四點四十一分的期間內，有六個特別顯著的振動，平均振幅增至0.23公厘。在一點五十三分至三點三十分的期間內，最盛行的風向在東北和北東北之間，風向振動的平均振幅爲14.1度。同時期內平均風速爲2.07公尺/秒，風速振動的平均振幅爲0.22公尺/秒。三點三十分以後至五點〇一分止，其間最盛行的風向變爲北偏北西北，風向振動的平均振幅增至15.7度。同時期內平均風速爲4.08公尺/秒，風速振動的平均振幅增至0.34公尺/秒。

現在假定以上述風向和風速的振動情形來表示當時上下層空氣間


24 P.M.
1
2
3
4
5
6
7 A.M.
765 mm.
764
763
762
Pressure
1
2
3
4
5 A.M.
SW
W
NW
N
NE
E
SE
S
Wind Direction
1
2
3
4
5 A.M.
Wind Velocity
5 m./sec.
0
1
2
3
4
5 A.M.
-10°C
-12°
-14
Temperature
1
2
3
4
5
6
7
8 A.M.
%
30
40
50
Humidity

的不連續性，作第二面。

圖中「I」部分係一點五十三分至三點三十分一段期間內的情形



OC 爲增大時的平均風速 = 平均風速 + 風速的振幅 =2.07 +0.22=2.29 公尺/秒。

OA 爲減小時的平均風速 = 平均風速 − 風速的振幅 =2.07 −0.22=1.85 公尺/秒。

OC與OA的交角AOC爲風向的轉變 $=14.1^\circ+14.1^\circ=28.2^\circ$

AC 爲OA 和OC間發生變動的因素，其值等於上下層空氣速度的相差，因爲有了這個差數，才造成OA和OC間的變動。

$$AC=\sqrt{\overline{OA}^2+\overline{OC}^2-2\,\overline{OA}\cdot\overline{OC}\cdot\cos AOC}$$

$$=\sqrt{1.85^2+2.29^2-2\times1.85\times2.29\times\cos 28.2^\circ}$$

$=1.1$公尺/秒。

B爲AC線的中點，OB爲每個波動期內氣流前進的平均速度，亦卽波動的水平進行的平均速度。

因 $\angle ACO=\sin^{-1}\left(\frac{1.85\times\sin 28.2}{1.1}\right)=\sin^{-1}0.7946=52.6^\circ$

$$OB = \sqrt{\tfrac{1}{2}\overline{AC}^2 + \overline{OC}^2 - 2 \times \overline{AC}\cdot\overline{OC}\cdot\cos ACO^\circ}$$

$$= \sqrt{0.55^2 + 2.29^2 - 2 \times 0.55 \times 2.29 \times \cos 52.6} = 2.0\text{公尺/秒}$$

【先分解OC，OA，求其在OW(X軸)及OS(Y軸)上的平均值再合成之，所得交點B必在AC線上，且爲AC線之中點。又OB爲OC和OA變動中的平均值。其理可依普通三角原則及力的分解和成方法證之，玆從略。】

已知波動的水平進行的平均速度爲2.0公尺/秒，每個波動的週期爲6.06分，則波動的平均波長當爲

$2.0 \times 363.6 = 727$公尺

根據 Helmoltz 氏大氣重力波公式，設L爲波長，G爲重力加速度，U爲上下層氣流速度相差的半數，T′爲上層空氣的溫度，T爲下層空氣的溫度。則

$$L = \frac{2\pi}{G} U^2 \frac{T'+T}{T'-T}$$

現已知一點五十三分至三點三十分期間內地平均溫度

$T = 259.5°A$，又$G = 981$公尺/秒^2，$U = 55$公分(Cm) $L = 72700$公分，代入式內，得

$T' = 259.7°A$

卽當時上下層空氣間的溫度逆增平均爲$259.7 - 259.5 = 0.2°C$.

第二圖「II」部分，係三點三十分至五點〇一分一段期間的情形。當時地面平均溫度爲259.6°。依同樣理由可求得：

$OC' = 4.08 + 0.34 = 4.42$公尺/秒

$OA' = 4.08 - 0.34 = 3.74$公尺/秒

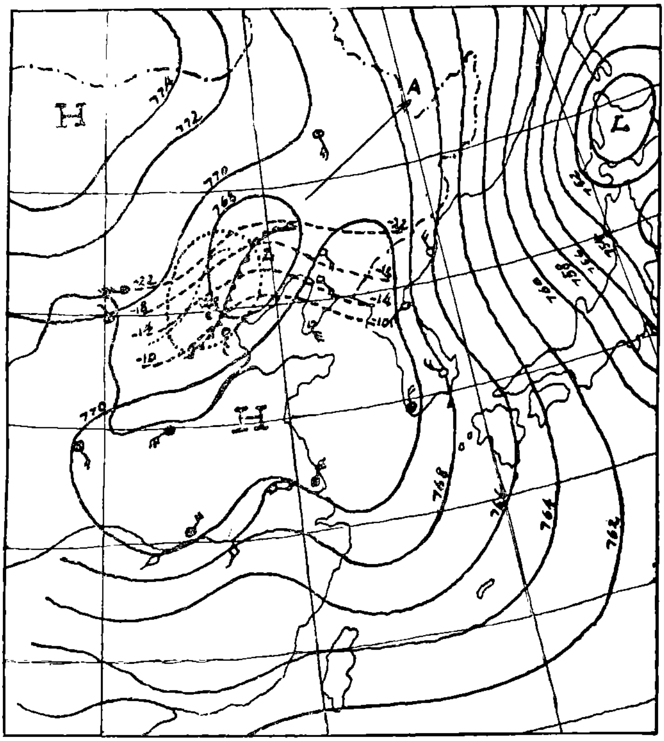
$A'C' = 2U = 2.4$公尺/秒(上下層氣流的速度相差)

$OB' = 3.9$公尺/秒

$L = 3.9 \times 363.6 = 1418$公尺(平均波長)

$T' = 259.8°A$

$T'-T = 259.8° - 259.6° = 0.2°C$（溫度逆增）



第三圖係一月十三日晨六時的天氣圖，當時華北的一個低氣壓中心在清華園東北部。圖中「A」處係次日（十四日）晨六時低氣壓中心所在。假定在短時間內這個低氣壓大小行徑沒有顯著的差別，則十三日晨二時左右低氣壓所在，將似圖中點線所示部分。由圖所示，可推想在十三日晨二時以前，清華園位於低氣壓的暖流部分，一個向東北進行的冷面的前方。晨二時以後，則漸入於寒流部分，而居於冷面的後方。查當時地面氣象情形如次：

日　期	12日							
時　刻	17	18	19	20	21	22	23	24
温　度(°C)	-3.1	-5.1	-6.1	-7.0	-6.0	-6.8	-8.1	-8.8
風　向	SSW	S	SSW	SSW	SSW	SSW	S	SSW
日　期	13日							
時　刻	1	2	3	4	5	6	7	8
温　度(°C)	-12.1	-12.6	-13.8	-14.0	-12.6	-12.2	-12.7	-13.9
風　向	SSW	N	NE	N	N	N	N	NNE

十三日二時以前温度較高，風向亦多偏南，二時後温度較低風向多偏北，此與冷面的經過亦很符合。所以這次波動現象的產生，實由於冷空氣間歇的侵入所造成。