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INFLUENCE OF ACOUSTIC-GRAVITY WAVES ON PROPAGATION OF LORAN-C

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Abstract

After improving Type P020 Loran-C Receiver, we obtained an output of phase difference with 1 μs full scale and therefore increased the resolution rate of phase difference ΔP between our clock and LC signals. When the weather changes we often record the obvious variation of ΔP. Sometimes, the period of the variation was about 9 min and the amount of the variation of ΔP was up to several hundred ns, and the attenuation of amplitude M of LC groundwaves was in excess of 8 db. After making a comparison between some results, we realize that the ΔP and M of LC groundwaves were affected by acoustic-gravity waves generated by cold (warm) currents or typhoons, and that the LC sky waves were affected by more acoustic-gravity waves with longer periods.

Introduction

For a long time, the typical precision of phase measurement of Loran-C groundwaves has been about ±0.1 μs, and such waves are used for high precision positioning of navigation, timing and frequency calibration. In recent years, scientists have studied the variation of LC groundwaves which is affected by the atmosphere (Samadar, 1980; Mungall,1981). And Dr. M. Takagi(1980),Dr.G.C. Rumi(1983) and Dr.Y.N. Huang (1985) reported that probably acoustic-gravity waves affected the propagation of VLF, LF and HF signals respectively. We also keep on receiving the LC groundwaves on a 24-hour basis. After improving Type P020 (modeled on the Model 2000C) LC Receiver, we obtained an analog output of phase difference with 1 μs full scale, and increased the resolution rate of phase dif. ΔP on the chart recorder up to ±10 ns and even fewer than ±10 ns. Then we discovered that the phase of LC groundwaves, sometimes, was unstable and variation of the phase was often in excess of ±50 ns, even up to several hundred ns. The wavelike variation of phase dif.,sometimes, became a very clear quasi-sinusoidal variation. Similar variations were also recorded by Model 2100 LC Receiver. So the variation may be caused by some waves generated by the atmosphere. The above mentioned is to be discussed as follows.

Possible influence of acoustic-gravity waves on LC groundwaves

1. We receive the LC signals of LC/9970-Y, LC/9970-M,or BPL. The

relative position between Nanjing and the LC stations is shown in Fig.1. In normal cases, the variation of phase dif. (or TOA) is very stable and nearly a straight line as shown in Fig.2a.

But we often recorded variations with periods of 2-10 min; sometimes, there was only a period of 9 min or so when the weather changed obviously. For example, many variations like that were recorded from late May to June 7, 1984. Fig.2b gives the records of phase dif. ΔP (with 1 µs full scale) and amplitude M of LC from 5 June 1900 UT to 6 June 0300 UT. After clarifying Fig.2b, we display the records in Fig.2c, from which we know that the period is about 9 min and the range of fluctuation of ΔP is from small to large. At about 5 June 0000 UT the variation of ΔP was only ±0.01 µs, it increased to ±0.2 µs at 2000 UT and the max. variation was about 1 µs at 6 June 0200 UT. Another curve in Fig.2b, one of M of LC signals, shows that the amplitude M of the beginning of the 4th cycle in LC groundwaves was also affected and fluctuated together with ΔP when the variation of the latter was larger.

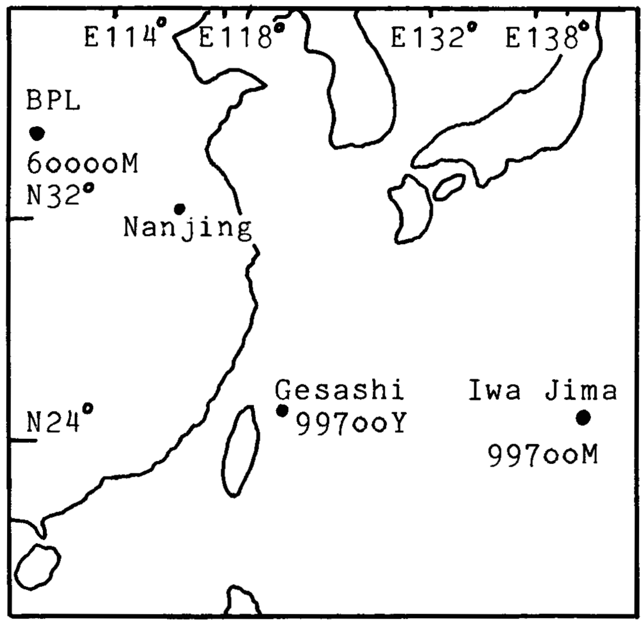

Fig.1. Map showing locations of Nanjing and some LC stations.

2. Meteorological facts The weather around Nanjing is changeable before and after June. Six satellite cloud charts (5 June 0000 UT to 6 June 1200 UT) are provided in Fig.3,showing there was a north west cold current moving from NW to SE and went over Nanjing at that time. A few hours before 5 June 0000 UT, a part of the cold front was on its way to Nanjing and the fluctuation was about ±10 ns. About 6 June 0200 UT the cold front came to Nanjing and quickly the fluctuation vanished and at 1200 UT or so the middle part of the cold current was near Nanjing. From Fig.4,we see that there was a marked drop in temperature and an obvious rise in pressure in here.

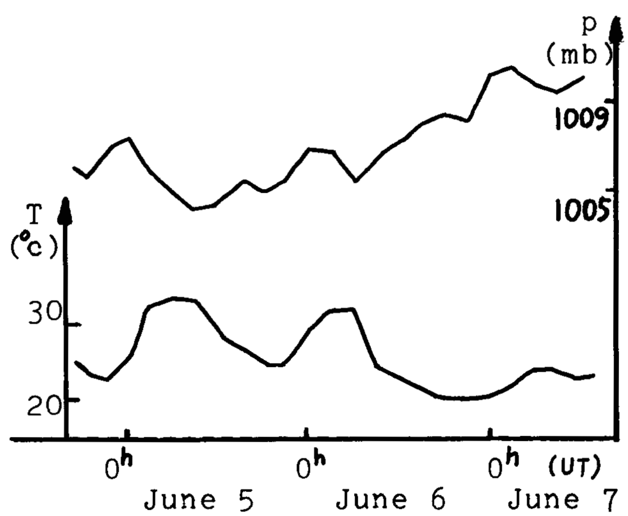

Fig.4. Temperature and presure in Nanjing.

3. Acoustic-gravity waves. In the atmosphere, once the air is

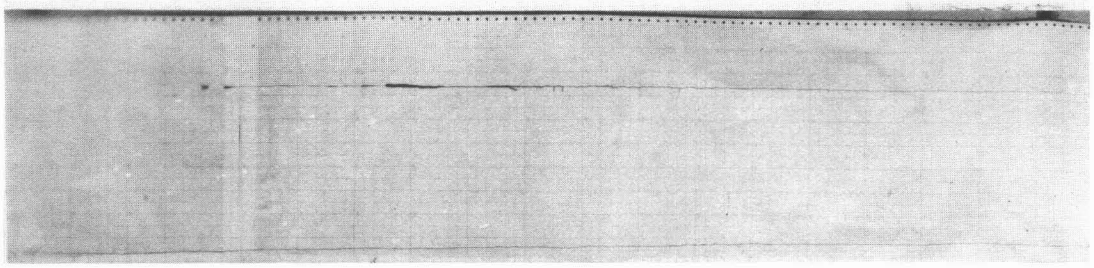

Fig.2a Top M of LC signals in normal case. Bottom Δ P of LC.

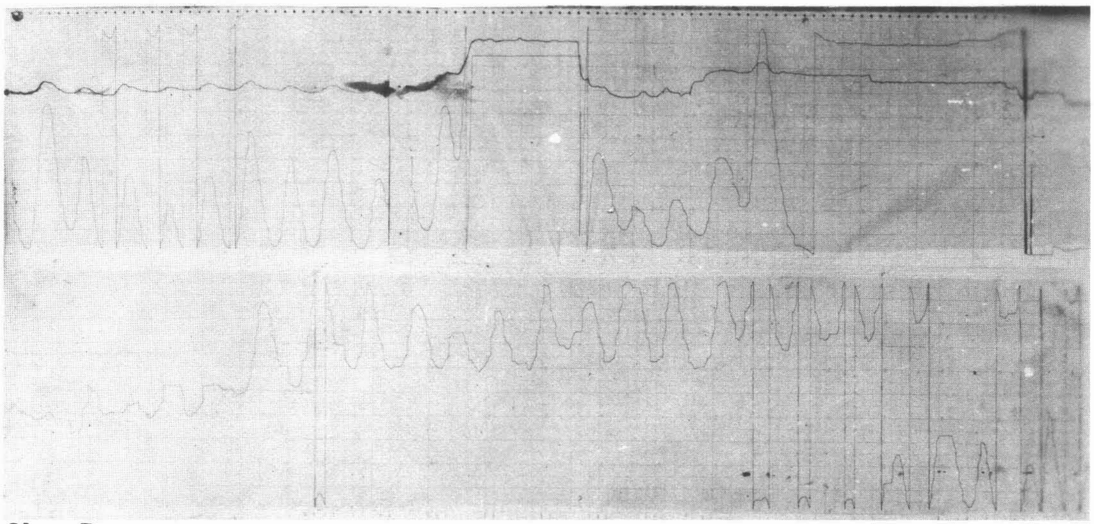

Fig.2b Record of ΔP and M of LC from 5 June 1900 to 6 June 0300UT

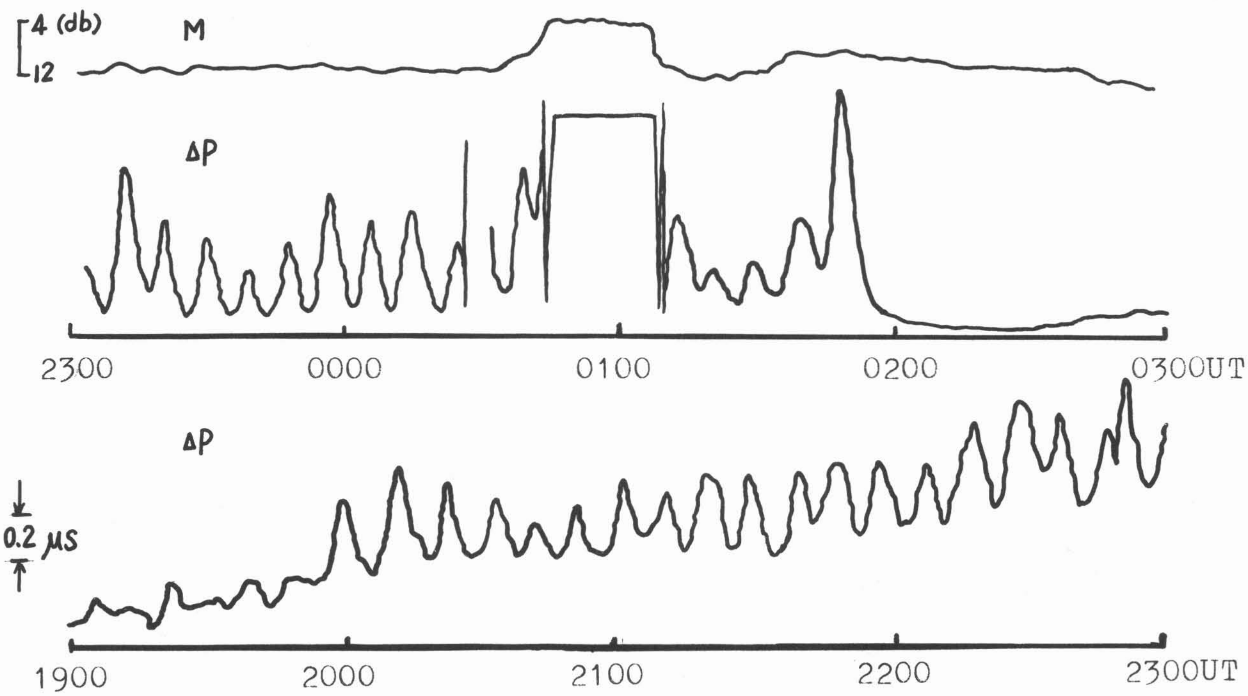

Fig.2c Top M of LC . Bottom Δ P of LC.

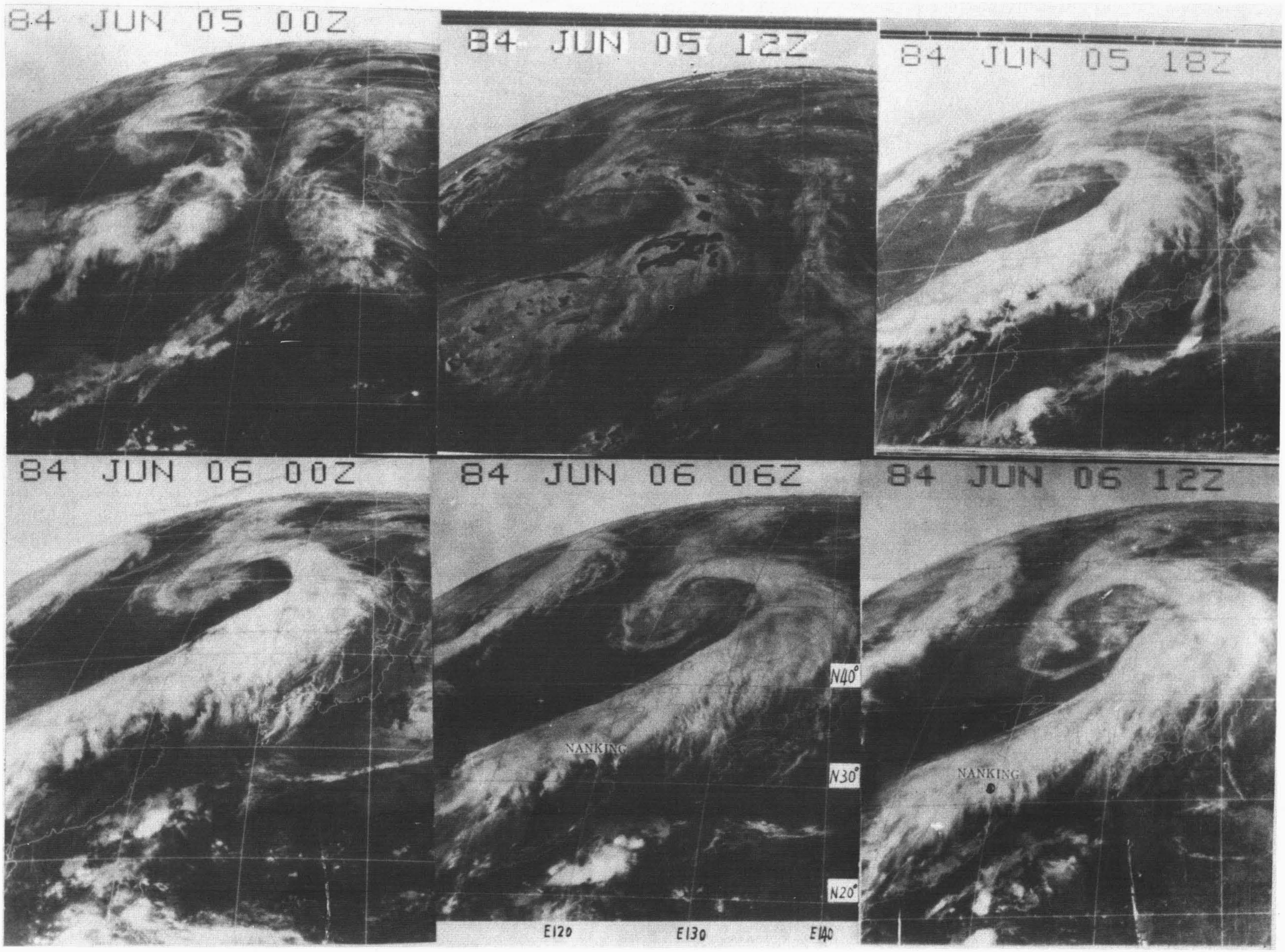

Fig.3 Six satellite cloud charts showing a cold current went over Nanjing.

disturbed, it will deviate from its equilibrium position, thus setting it in motion under the action of gravity. If the vibrations propagate in all directions, waves will appear, so that the temperrature(T), pressure(P) and humidity(e) also waver. The higher the altitude of waves over the ground, the longer the period is. But the delay of time of groundwaves, ϕ, is influenced by the reflective coefficient of radio-atmosphere, n, and we have

$$\phi = n_a d\frac{\omega}{c} + \left(n_a d\frac{\omega}{c}\right)^{\frac{1}{3}} \times \alpha^{\frac{2}{3}} \times \tau_0 \times (d/a), \qquad \alpha = 1+\frac{a}{n}\times\frac{dn}{dz} ,$$

$$n - 1 = 77.6(P+ 4810e/T)\times 10^{-6}/T.$$

Hence, when acoustic-gravity waves are going through the propagation path of LC, they are able to affect the propagation of LC signals. Our station, 262 m above the sea level, is located on the hill and is about 250 m higher than the plain around. So the fluctuation of ΔP is probably caused by the acoustic-gravity waves produced by the NW cold current. Thus the nearer to Nanjing the cold current moves, the larger the fluctuation of ΔP is. When the cold current reaches Nanjing and breaks the stable structure of the atmospheric layer around here, the acoustic-gravity waves disappear.

Analysis of results of both sky and ground waves

1. The influence of acoustic-gravity waves on LC sky waves seems to be observed by Dr.M. Takaji et al. The periods between 5 to 60 min and more were found by a power spectrum analysis. Fig.3 in his paper shows that there are some peaks on the power spectra and the corresponding periods are about 7, 9, 16, 40, 48 min, etc., but the period of peak with max. normalized, Pm, is 48 min. By comparing the results obtained from 7 nights' observations, we notice that the positions of peaks on the power spectra are almost at random and the periods of peaks are variable.

The influence of acoustic-gravity waves generated by typhoon on HF radiowaves(5.2 MHz and 7.8 MHz) was observed by Dr. Huang et al. The periods detected from power spectra are about 6-80 min and more. The period with max. spectral density was 13 min.

Possible influence of acoustic-gravity waves on VLF(GBR, 16 KHz) and LF(MSF, 60 KHz) was also recorded by Dr. Rumi, the results were similar.

2. As mentioned above, comparing the sky waves with groundwaves, we learn that the sky waves were obviously affected by acoustic-gravity waves with many longer periods (tens of mimutes). Next, in contrast with the LC sky waves reflected from D layer, HF sky waves were influenced by more acoustic-gravity waves with longer periods. It is well-known that the reflective layer of HF sky waves (E or F) is higher than D layer and the atmospheric buoyance period increases with the atmospheric altitude. Thus the aforesaid phenomenon, perhaps, is related to altitude.

3. The acoustic-gravity waves generated by cold(warm) current or typhoon should be related to the structure of cold (warm) current or typhoon and its dynamic process. The altitude of a cold current is about 0-3 km and the altitude of a typhoon center is about 3-15 km. It merits attention whether the altitude is related to the fact that the major period of acoustic-gravity waves generated by cold current was shorter than the period of the waves by typhoon. For this reason, we intend to make in-depth researches on the basis of analysing more data.

Conclusions

1. In the atmosphere,both typhoon and cold(warm) current can respectively generate acoustic-gravity waves, the influence of which on propagation of radiowaves from VLF to HF was obviously observed.

2. In conparison with groundwaves, sky waves may be affected by more acostic-gravity waves with longer periods

3. The influence of acoustic-gravity waves can be recorded by the LC receiver which has an analog output of phase dif. with 1 µs full scale, so the receiver can be used to study the influence.

4. Sometimes, acoustic-gravity waves probably affect the accuracy of radiopositioning (including GPS) and also the precise comparisons of both time and frequency via artificial satellite or by means of VLBI.

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