Wave Movements in the Plain

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This paper deals with the lanes of clouds with directional wind shear on the tops of the clouds and wave movements in the strata lying above them. This condition was discussed in Poland by the German meteorologist Dr. Jaeckisch on the occasion of the International Congress of OSTIV in 1968. It aroused much interest not only among meteorologists involved in soaring, but also among the pilots, many of whom claimed to have utilized these situations without being able to interpret them.

The question is so much more appealing to us who dedicate ourselves to the study of meteorology applied to soaring, and for pilots who are always searching for new soaring techniques. Dr. Jaeckisch, having excluded that the wave phenomena studied by him were of orographic origin, asks if it is the streets of convective cumulus clouds which determine the wave flow in the above lying strata, or whether conversely, one should not seek in the wave motion itself the determining cause of the formation of the streets of cumulus clouds. All this makes us realise how far off, unfortunately, is the solution to the question.

My inquiry among the Italien glider pilots was negative on this question, because all the situations which I have examined and all the experiments conducted up to now, on the subject of directional wind shear on the tops of the clouds, are associated with wave movements of orographic origin. Therefore, the result could not be otherwise, if one considers the fact that every valley in Italy is surrounded by mountain ridges which are more or less high.

Examination of Dr. Jaeckisch's paper during the course of round table discussions at Rome and Varese, brought forth some considerations which I think it worth while reporting. Above all, the useful and opportune initiative of Dr. Kuettner in continuing the research and extending it to other countries, outside of Germany, was made clear to all. Furthermore it was recognized that it was necessary to conduct an intensive case-by-case examination to ascertain that no orographic cause could induce the wave movements in question, because frequently even hills of modest elevation (200–250 m) or extensive urban areas, can produce an impulse capable of making the thermal inversions oscillate together with the overlying stable stratifications.

Often, even modest waves of a gravitational nature can become important as movements generating oscillations of a greater force. This happens, above all, when there are at the same time stratifications of very stable air present above the inversions.

On the top limit of these inversions, I observed wave phenomena of every kind and origin. I will limit myself to point out as an example one case observed recently at the airport of Rieti (Italy) and of which I also have a photograph taken by the pilot Prof. Francesco Pace (fig. 1). The case is one of gravitational waves associated with five little bands of altocumulus clouds formed on the top limit of the thermal inversion at an altitude of 5,000 m. Because of an increase of the wind from the SW at the height of inversion, there is successively superimposed on the gravitational waves a wave whose length and amplitude were much greater than those prevailing. The altocumulus bands, in a matter of a few minutes were swallowed up by a single large isolated cumulus cloud in the center of the valley of Rieti. The photograph illustrates the phenomenon at the beginning of the process of formation of the large cloud and the disappearance of bands of cumulus clouds, at 14.30 of April 5, 1970.

Another factor which should also be considered is the general meteorological situation, especially insofar as it concerns cold fronts in motion toward the region in which the wave movements, which interest us, have been observed. Both in Europe and in Argentina pre-frontal waves have been utilized by glider pilots even at notable distances from the atmospheric disturbances which generate them and which often are made visible by bands of clouds parallel to the moving fronts (fig. 2, 3).

To show with how much interest the Italian glider pilots have participated

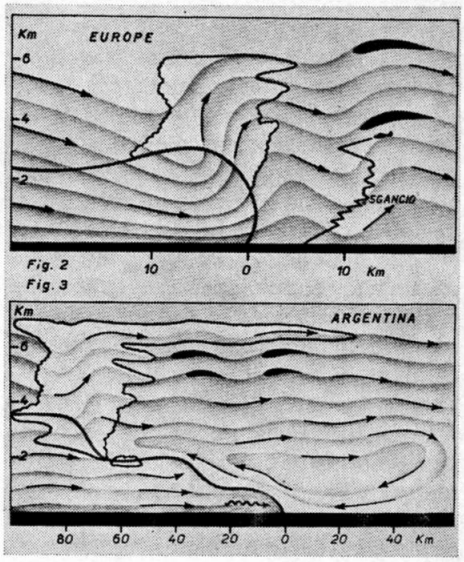
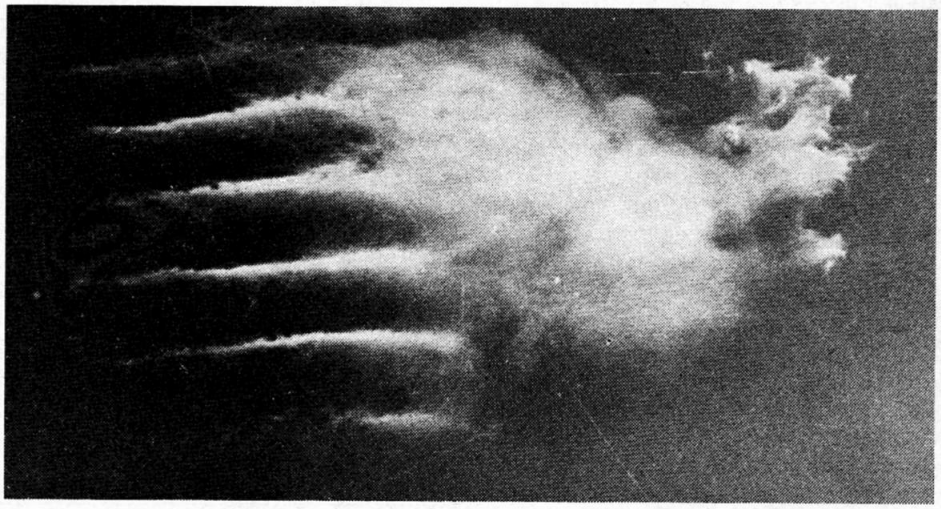


Fig. 1



in the round table discussions during which were examined the conditions which produced the wave situations mentioned by Dr. Jaeckisch in his paper, I summarize below Dr. Grassi's hypothesis regarding the cause of the wave movements in the plain, at great distances from the mountains, although this is not universally accepted in Italy. Because of this, I ask the competent experts present at this Congress, to be kind enough to give us a definitive answer on this question.

The presence of systems of waves in the atmosphere at a great distance from the mountains, the known cause of the waves, can also be considered as a phase of re-enforcement of the system because of the superimposition of the many coinciding wave phenomena. To hold this position one must admit that a distant mountain range produces not just one type of wave of a given wave length, amplitude, and phase, but rather a whole system of waves with frequencies, phases, and amplitudes within a certain spectrum. This means that the wave phenomena after having been reciprocally cancelled out over a long distance are found to re-enforce each other still further out, even at a very great distance from the source. In gliding terms, on getting further away from the mountain in the direction of the wind, the wave phenomenon can be weakened to the point of not being felt at all, only to reappear reinforced further out. Thus the zones of weakness and reinforcement repeat in alternating fashion.

The mathematical treatment of this phenomenon, which does not require new theories to be explained, is already well known as the mechanics of wave motion: by the normal procedure of the analysis of harmonic motion it is possible to extract the sine components which determine this phenomenon, only when it is possible (with measurements taken in the area) to describe the actual values point for point along the direction considered.

Now, I would like to talk about wave movements which are found in the plain, and which are definitely not of orographic origin. In 1952 I was in Argentina working as an assistant to Prof. Walter Georgii in the field of meteorology applied to soaring. On the occasion of the fourth Soaring Championships of Argentina, which were held from February 25 to March 7, 1952 at Trenque Lauquen, in the heart of the Argentinian pampas, a good 550 km from the Andes Range, there occurred a wave phenomenon of macroscopic dimensions which was observed and studied for the first time by Prof. Georgii, who formulated the following interpretation.

In the summer months in Argentina, there is often present an isobaric configuration (fig. 4) which is favorable to generating a vast current of air in a North-South direction, which between 33° and 40° S. Latitude acquires such an intensity that Prof. Georgii named it 'Surface Jet Stream'.

This current extends vertically from the ground to a height of 3,500 m and in its North-South movement is limited on the West by the Andes Range and on the East by the relatively cold air mass of the Atlantic. As long as these lateral guides are sufficiently parallel the current continues its movement unaltered: the baric force and the Coriolis effect are in equilibrium. But since an intrusion of cold air coming from the East flows into the continent, the corridor of the air current from the North is constricted. This constriction disturbs the equilibrium between the baric force and the Coriolis effect causing a lateral deviation, or else an acceleration of the flow in correspondence with the constriction. In an almost analogous way to what happens in a hydrodynamic canal, together with the horizontal convergence there develops a vertical divergence which provokes a wave oscillation in the upper layers of the current. The persistence of such a phenomenon on that occasion was notable: there were wave movements February 29, March 1, 2, 3, 4, 6, and 7.

The characteristics of these waves remained quite constant except for some small variation regarding the thickness and height of the stratum of oscillation, the length of the wave, and the intensity of the vertical movements. The wave length varied from 80 to 90 km.

The stratum in which the wave movement is produced varied in its upper limit, going above and below 3,000 m. The intensity of the vertical movements varies with the altitude and becomes stronger as one ascends. Thus in the measurements made by Prof. Georgii in an airplane on March 4 the following readings were registered:

at 1,000 m the climb 0.2 m/sec and the descent −0.9 m/sec

at 2,000 m the climb 0.5 m/sec and the descent −0.8 m/sec

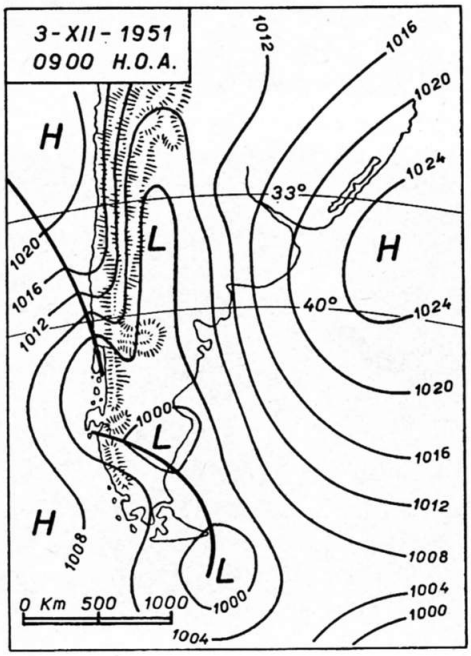
at 3,000 m the climb 1.0 m/sec and the descent −3.0 m/sec.

Up to 2,000 m, therefore, the amplitude of the oscillations is reduced and produces a turbulence of the normal thermal type; near 3,000 m, however, this amplitude increases notably giving evidence to the wave characteristic of these vertical wave movements. To confirm this, one merely has to consider that at the time of the sounding it would not have been possible to find vertical thermal movements at that altitude.

These wave movements are not stationary: in fact since they are caused by the promontory of the cold air which induces the lateral acceleration of the air current from the North, they accompany the movement of this promontory. And therefore, in the same locality large zones of ascending or descending part of the wave. The frequency of this alternation depends on the velocity of the displacement of the lateral mass of cold air and on the length of the wave, which being large notably reduces the frequency.

This alternation can be observed in figure 5, in which are compared the soundings of March 2 and 3, taken in the zone of Trenque Lauquen: whereas at the other altitudes there is almost a complete correspondence in the temperature readings, in the stratum of the waves at an altitude between 2,100

Fig. 4



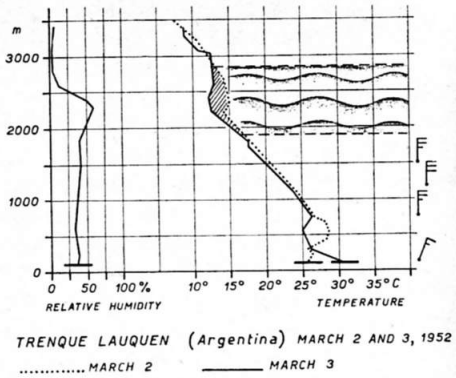
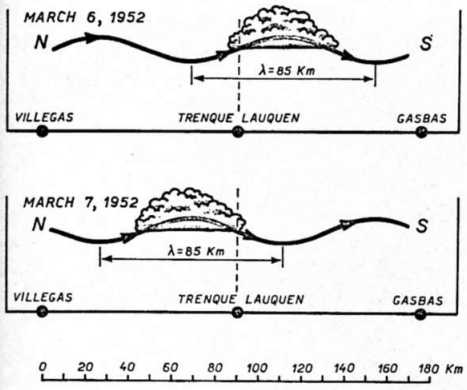


Fig. 5

and 2,700 m there is a notable difference in temperature, which is explained by a change of phase of the wave above Trenque Lauquen. This can be seen by examining figure 6. This typical situation, which as I said, is present in Argentina between 33° and 40° S. Latitude during the summer season, and whose isobaric configuration is illustrated in figure 4, generates a vast and intense current in the North-South direction. At times, it is associated with very beautiful lanes of cumulus clouds lined up parallel to the direction of the wind. These extend into the wide open pampas of Argentina for stretches of 70 to 80 km without a break in continuity.
Figure 7 presents a photograph of these lanes, taken at 16.00, February 27, 1951 by the old Argentinian glider pilot Henry Hoarckammer, in Forte 1, which lies between Neuquen and Bahia Blanca. The base of condensation of the lanes of clouds was about 2,500 m above the ground; their thickness was about 300 m. The wind at the surface was from the North-East, while higher up, according to the soundings of 08.00 of the nearby Meteorological station at Terlew, the following was recorded.

Fig. 6



Surface	360°	13 Kts.
600 m	320°	21 Kts.
1,500 m	360°	17 Kts.
2,100 m	350°	16 Kts.
2,500 m	340°	17 Kts.
3,000 m	330°	23 Kts.

It ist easy to see from these wind data, that these are definitely not lanes of cumulus clouds having a directional shear on the tops of the clouds much less can the wave phenomenon of macroscopic dimensions which could have existed above the overlying strata, be of the type proposed by Dr. Jaeckisch. Nevertheless, I wanted to conclude my exposition by mentioning these situations, especially for the benefit of my old friends of soaring in Argentina, who, perhaps, after the departure of Prof. Georgii, have not had the chance to give attention to these interesting phenomena.

Fig. 7
Fortin I (Rio Colorado) Argentina
27. 2. 1951 Condensation Level 2500 m