A NOTE ON THE ATMOSPHERIC SOLITARY WAVE

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ABSTRACT

An attempt is made to show that a single elevation of permanent type may exist in a two-layer atmosphere at the interface between the two layers. The compressibility of the air, friction, the earth's rotation, and its spherical shape are neglected. It is assumed that the free surface of the upper layer remains undisturbed at all times, and that the hydrostatic relation holds in the upper layer when the lower layer is disturbed.

It is found that, under these simplifying assumptions, internal solitary waves may exist in the atmosphere. The shape of these waves and the conditions attending their formation are found to be identical with those of shallow water waves as given by Keller.

1. Introduction

Solitary waves have been observed and studied in shallow water of uniform depth ever since Scott Russell (1844) published his work describing these disturbances. A water solitary wave is usually defined as a single elevation, in the surface of water, which travels for a considerable distance with little or no change of type (see Lamb, 1932).

Various attempts have been made to study some of the theoretical aspects of a solitary wave. Thus, Rayleigh (1876), McCowan (1891), Korteweg and DeVries (1895), and others have endeavored to show that a single elevation of permanent type can exist if certain conditions are satisfied both by the underlying flow and by the shape of the elevation. More recently, Keller (1948) has re-examined the whole problem of periodical waves of finite amplitude, and has been able to re-establish Korteweg and DeVries' conclusion that the solitary wave may be considered as a special case of periodic waves whose wavelength is infinity. Munk (1949) has been able to show that the solitary-wave theory is capable of explaining the behavior of breakers as they approach the shore and just before they break.

Because of the similarity between the behavior of a shallow fluid with a free surface and that of a shallow layer of cold air over which rests a deep layer of potentially warmer air, the writer (Abdullah, 1949) was led to the conjecture that solitary waves may exist in the atmosphere. The detection of such disturbances has been difficult because of their small dimensions and relatively fast movements. The first clear indications of the existence of such atmospheric disturbances were pointed out by Fawbush and Miller (1954), who observed that small migratory anticyclones, which they called "bubbles," are sometimes observed in connection with tornado formation. The writer wishes to express the idea that those "bubbles" are of the same nature as the atmospheric solitary waves.

Fawbush and Miller's work has further called attention to the possible far-reaching effects of these micro-anticyclones on the local weather, in particular to the possibility that they may act as the trigger to release the instability of a conditionally unstable atmosphere. This instability may manifest itself in the form of some convective phenomena, or even in the form of tornadoes.

It therefore seems desirable to carry forward a somewhat detailed investigation on these disturbances for the purpose of establishing the possibility of their existence in the stmosphere, and for obtaining some insight to their general behavior and the conditions that are favorable to their formation.

In a separate paper (Abdullah, 1955), the writer has attempted to make a synoptic study of a more or less well-defined case of an atmospheric solitary wave. In that paper, the suggestion was made that the term "atmospheric solitary wave" may be used to designate a single elevation in the cold air which travels at the surface of the inversion layer. If this suggestion is adopted, one may speak of solitary waves that change type and eventually break, and of solitary waves that preserve their type in the usual hydrodynamic sense. Both classes may be generated by the same kind of mechanism, for instance, by a single oscillation of a cold mass of air in contact with the incipient stratified atmosphere. The main difference between the two kinds is the existence of the proper vertical accelerations in the permanent type class, and their absence in the breaking class.

Because the breaking kind may be included in the long-wave theory, which has been studied somewhat

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