explained as the accumulative result of many meso-scale downdrafts initiated through evaporation from falling rain. Thus it is suggested that processes on the convective scale can influence the large-scale structure of tropical disturbances.

In consequence of the downdrafts, air with equivalent potential temperature $10^{o}K$ lower than elsewhere appears in the main convergence zones at the surface. This represents a strong deterrent against hurricane formation. The low energy values, represented mainly by low dew-points, develop along relative trajectories of the surface wind field in spite of maxima of evaporation from below. This demonstrates that the energy transfer from the sea does not determine the magnitude or even the sign of changes in surface heat content. A numerical model for incorporating the meso-scale downdrafts in computations based on synoptic-scale grids is developed.

To illustrate the synoptic background of the proposed model the speaker showed a number of slides describing the three dimensional structure, and moisture and temperature anomaly patterns, through a Carribean Tropical Disturbance. He then suggested qualitatively the role of meso-scale downdrafts in determining the structure of tropical systems and followed this with a brief mathematical description of the proposed model.

In the subsequent discussion Mr. R.H. Clarke asked whether the vertical humidity distribution should not be a parameter in the model. The speaker replied that the equations could be broken into separate moisture and heat budgets. Dr. G.B. Tucker pointed to the difficulties which would be encountered in divergence assessment over the Indian Ocean and wondered whether satellite data might help. Professor Riehl replied that in the study he had described, divergence had been measured by kinematic methods. High tropospheric cirrus shields would frequently obscure the lower tropospheric features which would provide the basis for satellite assessments of divergence.

Mr. K.T. Morley questioned the validity of ignoring horizontal mixing at the 'boundary' in the proposed model and Mr. J.C. Langford suggested the importance of radiation processes. Dr. D. Sargent asked the speaker for comment on the nature of doughnut-shaped cloud systems in the tropics observed by the ATS Satellite, but Professor Riehl said he had not yet seen these and could advance no explanation.

Note: Professor Riehl indicated that a report on the investigation which he had outlined to the Colloquium would be submitted for publication in the near future.

J.W.Z.

21 September 1967

MOUNTAIN AIRFLOW – LEE WAVES

By C.E. Wallington

Mr. Wallington introduced the subject of his talk with photographs of lee wave clouds over various parts of the earth. He then outlined how lee waves were first noticed visually and then later by glider and powered aircraft pilots.

Conditions that appear necessary for lee waves to occur were then stated as:-

(i) There is usually a layer of air in the lower troposphere whose stability is greater than the air above or below it.

(ii) The wind speed at geostrophic level is greater than about 15 knots.

(iii) The wind is approximately constant to the stable layer.

Scorer's natural wave length of an air stream was mentioned and special reference made to the two-layer airstream of two different natural wave lengths. It was pointed out that in such an air stream a composite wave length would be anticipated.

An interesting analogue was drawn between coil springs of varying toughness and the air flow over mountains. By substituting a tough spring for the stable air where the restoring force on a perturbation is greatest and a weak spring for unstable air, it was noticed that lee wave type oscillations occurred with a tough spring between two weak springs; but with uniform springs waves did not occur.

The phase effect is one in which waves are either amplified or attenuated, depending on whether consecutive ridges are a whole or fractional number of natural wave lengths apart. Further examples of lee waves were then mentioned. These included the Crossfield Helm in England and the Sierra Wave in the U.S.A.

Mr. Wallington then discussed rotor flow, in which severe turbulence occurs in the cloud at the top of a wave in certain cases. The typical vertical profile for this type of flow was said to be an increase of wind speed to a stable layer with a decrease through this layer and then again an increase in wind speed in the less stable air above.

One cause of the turbulence was said to be the superadiabatic lapse rate induced by the cyclic motion of the air around the inversion in the region of the rotor.

The success achieved by Mr. Wallington in computer modelling of lee wave development at the C.S.I.R.O. Computing Research Centre was illustrated by showing predicted wave patterns in the Canberra area.

Agreement was achieved between the computer predicted wave length and the actual wavelength in an occurrence of lee waves over Tasmania on 17 April 1966. This occurrence was recorded by satellite photograph, and described and analysed in Australian Met. Magazine, Volume 14, No. 3 (September 1966) by I.R. Andersen.

The interaction of lee waves, foehn winds and katabatic or gully winds was mentioned as the case when the zero vertical displacement streamline of the lee waves is below the mountain ridge. This causes partial cutting off of the flow on the windward side of the ridge. If a saddle in the mountains is below the zero displacement level while the surrounding mountain tops are above this level, reinforced gully winds may occur down the lee valley from the saddle.

Mr. Wallington concluded his address by saying that there is scope for further research in this field, particularly in relation to:

(i) The partial blocking of flow just mentioned.

(ii) Pulsation of a rotor in certain cases where it has been observed that the rotor gradually moves downstream, e.g. one mile downstream in ten minutes, and then rapidly reforms again upstream in its original position.

(iii) The likelihood that moving waves may help in understanding eddy motions in the atmosphere.

In the discussion following Mr. Wallington's lecture:-

Mr. C. Rider — noting that the speaker had followed Scorer's treatment, metioned that in some studies of the Sierra wave a different approach had been developed in which stability is not considered as important as shear. He (Mr. Rider) had studied a case of lee waves in Tasmania on this basis with good results and therefore asked how important is the inversion?

Mr. Wallington — agreed that sometimes shear is more important but the same results should follow from both techniques. He commented on the strong shears in the Japanese and New Zealand regions.

Mr. Rider — then asked if Mr. Wallington was concerned that as a product of a perturbation theory he was getting rotors.

Mr. Wallington — replied that this did not invalidate the use of the perturbation theory.

Mr. R.H. Clarke — spoke briefly on the significance of Reynold's number on C.A.T. development.

Mr. Rider — emphasised the importance of wind shear in this context.

Dr. G.B. Tucker — suggested that the question was whether one is concerned with aerodynamically smooth or rough flow.

Mr. Wallington — disagreed.

Mr. Rider	expressed his unwillingness to accept that lee waves are an important cause of clear air turbulence.
Mr. Wallington	then suggested that in this case Mr. Rider would have to explain the greater incidence of C.A.T. over land than over sea.

I.R.A.