

R E P L Y

by A. Garriock

Central Meteorological Bureau, Melbourne

25th November 1955

This suggested analysis meets all the observational data, and is better than mine in respect to the sequence at Amsterdam Island. The origin of the warm front occlusion postulated by Mr. Clarke is however not explained.

JOINT COLLOQUIA

On the 3rd November Professor P.A. Sheppard of the Department of Meteorology, Imperial College, London delivered a lecture on "The General Circulation of the Atmosphere" and on the 15th December he spoke on "The Department of Meteorology, Imperial College, London." Summaries of his two talks are given below.

The General Circulation of the Atmosphere

The general circulation is defined as the mean value of the zonal (east-west), meridional (north-south) and vertical motion of the atmosphere as a function of latitude and height, the means round latitude circles being taken over time intervals of order a season. Associated with the mean motion so defined there is a field of turbulence extending in scale from the energy - dissipating motions of order a centimetre up to the largest scale disturbances commonly referred to as long waves in the westerlies.

The broad features of the latitude, height distribution of zonal motion in the troposphere and lower stratosphere are reasonably well defined - surface easterlies and westerlies; upper westerlies with the sub-tropical jet stream - but the pattern and intensity of meridional and vertical motion remain to be determined except in lower latitudes where there is equatorward motion below and poleward flow aloft, no net meridional flow occurring across any latitude circle. The important problem posed is to determine how the observed pattern of mean zonal motion is self-maintaining in the presence of the other components of mean motion and of the associated fields of turbulence. The dynamics must be related with the thermodynamics and with the field of radiation, solar and terrestrial. The system is one of multiple feed-back, but at the expense of some over-simplification it may be inferred that radiation,

together with moderate and small scale turbulence, lead to a meridional temperature gradient in the troposphere which is almost necessarily reflected in an upper-troposphere polar low and a quasi-geostrophic polar vortex (upper westerlies).

The increase of westerly wind with height in the polar vortex leads to instability for disturbances on the scale of mid-latitude depressions, troughs and wedges. These systems are a form of slantwise convection (Eady) and realise energy by motions which are inclined to the horizontal at an angle about half that of the slope of the potential temperature isotherms; they transfer heat upwards and polewards whereas smaller scale systems (Cu, Cb) transfer heat upwards only. Both transfers are in the sense required by the distribution of source and sink of radiative energy in the troposphere.

Westerly momentum is probably transferred by turbulent motions from the upper westerlies to the surface in the surface westerlies and to the level of maximum easterly flow in the trades. Below the level of maximum easterly flow in the trades, westerly momentum is fed upwards from the surface (surface drag) so that there is a rather deep layer in the trades into which westerly momentum is fed both from below and above. Large equatorward motion (motion down the pressure gradient) is required to balance this convergence of westerly momentum in order that the trades be maintained. Little meridional motion on the other hand seems to be required in the lower-troposphere westerlies, because the surface friction is approximately balanced by the downward flux of westerly momentum from the middle troposphere.

There is a continuing loss of westerly momentum from the atmosphere in the belt of surface westerlies through surface friction, and a corresponding gain in trade latitudes by the same mechanism. The deficit in the one belt and the gain in the other must be balanced by a meridional transfer of westerly momentum from the trades belt to the belt of surface westerlies. This transfer takes place mainly in the upper troposphere (Priestley, Starr and White, etc.) and apparently derives from large scale turbulence (upper troughs and wedges), though the mean poleward flow aloft in trade latitudes (the obverse of the lower-troposphere equatorward flow) makes a significant contribution to perhaps 30° latitude or more.

In the upper troposphere the mean poleward motion of lower latitudes creates westerly momentum at a rate sufficient to make good a horizontal divergence of poleward transfer and a vertical divergence of downward eddy transfer of zonal momentum. In higher latitudes the upper level conver-

gence of poleward eddy transfer approximately balances the vertical divergence of downward transfer of zonal momentum.

The Department of Meteorology, Imperial
College, London.

The department is mainly post-graduate and provides for students with a good first degree in physics and mathematics a basic one-year course in the major branches of meteorology. The course may lead to the Diploma of Imperial College, or with dissertation and oral examination, to the degree of M.Sc. of the University of London. Students may or may not have had previous experience of meteorology but greater profit is likely to be derived by those who have had some experience of the subject.

Advanced courses of lectures are provided for second-year students on subjects to which their researches may be rather directly related. Colloquia at fortnightly intervals are also a feature of the department's activities.

In addition to the standard facilities (laboratories, library, etc.) the department has a wind tunnel, travelling laboratory, the use of a light aircraft, and two field stations. Investigations may broadly therefore be carried out wherever circumstances suggest.

The teaching staff consists of the professor, two readers and three lecturers. Research is necessarily directed mainly into those avenues which are the chief interests of the staff but a student wishing to research into some other aspect of meteorology will generally find it possible to do so and obtain guidance from the staff. The current lines of research are broadly as follows:

Professor P.A. Sheppard	Transfer processes on all scales General circulation
Dr. E.T. Eady	Structure and evolution of large scale systems Instability of fluids heated from below Dynamical climatology
Dr. R.M. Goody	Atmospheric radiation Atmospheric chemistry Ozone
Dr. R.S. Scorer	Lee waves and topographical effects on airflow Convection

Mr. F.H. Ludlam

Convection
Cloud physics, particularly
macrophysics
Synoptic studies

Mr. B.J. Mason

Cloud physics, particularly
microphysics

Close relations exist with the Institute of Meteorology, Stockholm (Professor C.-G. Rossby) and Woods Hole Oceanographic Institution.

About half the students in the department are generally drawn from overseas, many of them from overseas meteorological services. Research leading to the degree of Ph.D. of the University of London usually covers a period of three years.