about the mean profiles, and what errors might be expected in applying this approach quantitatively in numerical analysis. Mr. Martin said that, on the basis of the comparison between the cloud pattern types and the synoptic types, he would expect the errors to be small, but due to the small size of the samples so far considered, no estimates of error magnitudes had been made.

Mr. K. Spillane asked whether the cloud edge coincided with the boundary of the cold air both for cold fronts and for occlusions, to which Mr. Martin replied that the errors involved in gridding the satellite photographs made if impossible to arrive at definite conclusions on a very small scale. Mr. Spillane then enquired whether it had been possible to recognise areas of precipitating cloud through albedo variations, and Mr. Martin said that this had not been attempted - however, a good correlation had been found between precipitation type and cloud type.

Dr. Tucker made some comments on differences between the two hemispheres, observing that the horizontal dimensions of extra-tropical cyclones appeared somewhat smaller in the southern hemisphere, and that they may also move a little more slowly. If these observations are valid, they have interesting implications concerning the conversion of potential to kinetic energy by the cyclones, and also their predictability in numerical experiments. If it were necessary to reduce the grid-length in numerical prediction there would be a corresponding reduction in the period of effective forecasting. Mr. R. Maine noted that the Bureau was in fact using a grid-length approximately two-thirds the size of that normally used in the northern hemisphere. Mr. Martin commented that the systems he had studied often moved quite rapidly - occasionally with speeds of forty knots.

Mr. C. Wallington stated that it would be better now to forget the old "polar front" concept - in the modern view, a front may be regarded as a baroclinic zone which (after a possible initial formative stage) is self-sustaining. It is necessary to look upon fronts as essentially mesoscale, rather than planetary scale features. This has the advantage of freeing the analyst from the use of preconceived models. Mr. W.J. Gibbs said that he had noticed that, following the introduction of satellite photographs on an operational basis, both CAO (Central Analysis Office) and SHAC were using more "trailing fronts" than previously. He was unsure whether to attribute this to the influence of the satellite photographs, or to the influence of Mr. J.C. Langford (SHAC). Mr. Martin is preparing a fuller account of this work to be published in the IAMRC Technical Report Series.

T.T.G.

31 August 1967

THE HEAT ENERGY TRANSFER THROUGH A FOUR-LAYER SYSTEM: AIR/SNOW/SEA-ICE/SEA-WATER

By G.E. Weller

Mr. Weller of the Meteorology Department, University of Melbourne, was the speaker. It is observed that the northward extension of the Antarctic pack-ice during the southern winter leads to an effective doubling of the area of the Antarctic "continent". That this has a profound effect on meteorological processes over a large part of the Southern Hemisphere has been widely accepted but the nature of the effect has remained imperfectly understood. The results of the micrometeorological research undertaken by Mr. Weller at Mawson, an Australian Antarctic base, in 1965 are contributing significantly to such an understanding. A selection of these results was presented to the Colloquium and provided the basis for a lively discussion.

Mr. Weller opened his talk with some general remarks on ocean-atmosphere energy exchange processes, their magnitude and their significance. In suggesting the important role played by the Antarctic ice pack, he illustrated pictorially and diagramatically its appearance, structure, thickness and mean seasonal extent.

Moving from the broadscale approach to the micrometeorology of the problem, Mr. Weller discussed the structure of the sea-ice in terms of such parameters as density and salinity, and then outlined the nature of the physical processes (conduction and radiation) which effect energy transfer through such a medium. The meteorological and glacio-meteorological instrumentation employed in the 1965 experiment on a sea-ice surface 400 metres offshore from Mawson was described. This included a capability for measurement of temperature and wind profiles above the ice, temperature profiles and heat flux in the ice, sub-surface and supra-surface radiation measurements and a novel device for the automatic measurement of sea-ice thickness.

In presenting his results the speaker first discussed the radiation quantities, giving emphasis to the significance of the snow cover on the sea-ice in maintaining its high shortwave albedo. He emphasised also the great importance of radiation as an energy transfer process within the sea-ice, and quoted experimental extinction coefficients for snow and ice. The diurnal temperature wave at a depth of 30 cm was synthesised from a sinusoidal temperature wave of appropriate phase and the radiation curve. The heat flux at 30 cm within the ice was shown to be related to ice growth, the phase delay (which depends on the frequency of the heat flux waves and the ice thickness) being generally four or five days. Development of a heat budget for the sea-ice cover was then discussed and illustrated, and the accuracy of the assessment indicated.

The speaker then considered supra-surface aspects - transfer processes in the atmosphere. Temperature profiles over the sea-ice were found to be closely isothermal - with a tendency to slight inversion conditions in winter and slight lapse conditions in spring (data were available for the period June to November). A logarithmic temperature profile was assumed. From the wind profiles a roughness parameter of 0.013 cm was found for snow covered sea-ice and was related to the micro-structure of the surface. Due to the slight diurnal variation of elements Richardson's numbers were computed on a daily mean basis without incurring significant error. Heat exchange coefficients were calculated after Hoinkes and Untersteiner (1952) and used as the basis for computations of the eddy heat flux. Due to the lack of adequate instrumentation for profile measurements for the determination of latent heat fluxes in the polar regions and the unreliability of glaciological methods under the windy conditions experienced at Mawson, this component of the energy budget could not be computed for the upper sea-ice surface. The latent heat contribution to the energy balance at the ice/water interface was simply calculated by considering the amount of ice accretion or ablation.

In conclusion Mr. Weller set up the complete energy budget for the upper and lower surfaces of the sea-ice, with the latent heat flux as a remainder term for the upper surface and the eddy flux as the remainder term for the lower surface. He then made a comparison of his results with corresponding assessments for the open ocean, showing that the total energy supplied to the atmosphere from ice-covered regions is only of the order of one-seventh that available from the ice-free ocean.

In the ensuing discussion, Dr. C.H.B. Priestley enquired whether any relationship between roughness parameter and wind speed had been looked for, or found. Mr. Weller replied that he could detect no significant variation with wind. Dr. U. Radok commented that a slight correlation had been found at Byrd Base.

Mr. J.C. Langford asked the speaker to comment on the effect of the heat flux upward through the sea-ice on the surface air temperature distribution around the hemisphere, and suggested that the strong thermal gradient even in winter might be concentrated near the Antarctic coastline proper.

A discussion of the temperature distribution as shown in one of the introductory slides followed and Mr. H.R. Phillpot (who had produced the mean isotherm charts shown) commented on their derivation. In turn he asked Mr. Weller if he could account for the existence of apparently lower surface air temperatures well seaward of the coastline than on the coast itself, as found for example by a temporary station on an island seaward from Mirny. Mr. Weller, Dr. U. Radok and other members of the audience speculated on the problem but no general agreement was reached.

J.W.Z.

12 September 1967

CONVECTIVE PROCESSES IN TROPICAL DISTURBANCES

By H. Riehl

Professor Riehl, who is at present Head of the Department of Meteorology at Colorado State University, described work recently completed at Imperial College, London, in collaboration with R. Pearce. In summary, in their own words:-

"The cold-core structure of waves in the easterlies, frequently observed, can be