15 August 1973

AN UNFASHIONABLE VIEW OF THE INTERACTION BETWEEN THE TROPICS AND MIDDLE LATITUDES

Professor C. S. Ramage

In introducing Professor C.S. Ramage of the University of Hawaii, Dr U. Radok pointed out how appropriate it was, some 25 years since the first colloquium was shared by C. Palmer*, the originator of many ideas in modern tropical meteorology, that this colloquium should be presented in the field of tropical meteorology by one of his associates, whose visit had been made possible by the generosity of the University of Melbourne.

Professor Ramage opened his talk by mentioning the recent trend, particularly among extra-tropical meteorologists, of regarding the tropics as an area which supplies energy and momentum to higher latitudes at its own discretion. The line-of-thought commonly followed is that the presence of the so-called cloud clusters is accepted and then the further development of these systems is considered together with the possible effect on mid-latitude circulations. Research has therefore been centred on the tropical boundary layer, the properties of clouds, both individually and in clusters, and the mechanisms by which energy can be exported from the tropics.

The purpose of the talk was to present an alternate view of the interactions between tropical and middle latitudes. The observational evidence used was drawn mainly from east Asia during the Northern Hemisphere winter as in this region data are relatively plentiful and at this time of the year the meridional exchange is most pronounced.

At this point, Professor Ramage posed a question which those present were invited to ponder and attempt to answer at the end of the talk. Given the typical winter circulation with the strong northeast monsoon in the lower troposphere, air is moving into lower latitudes and gaining heat and on reaching Indonesia ascends causing precipitation. The question asked was whether higher sea surface temperatures in the China Seas would be associated with relatively more or less precipitation over Indonesia. The speaker then proceeded to provide the information on which answers could be based.

Tropical meteorologists in both Asia and Africa have had great difficulty in tracking cold fronts as they move equatorward and this is particularly true when the cold outbreaks accompanying these fronts are strongest. Classical frontal theory suggests that the stronger the outbreak the more clearly defined the front. Forecasters have found that winds may suddenly strengthen well in advance of the frontal position, as predicted by conventional means, suggesting a rapid surge of air, but at the same time all traces of the front disappear.

A latitude-time section was shown containing surface winds over the South China Sea, daily rainfall at Borneo and pressure and dew point at Hong Kong for one month of particularly severe cold outbreaks. The most striking feature was that the increased rainfall in Borneo, stronger surface winds and the apparent frontal passage at Hong Kong occurred simultaneously. There was no gradual equatorward movement which would be consistent with the behaviour of a true front.

Having eliminated the possibility that these changes were frontal, Professor Ramage then suggested that they may be due to changes in the large scale meridional circulation. The Northern Hemisphere winter Hadley cell circulation, in the east Asia area at least, may have rapidly accelerated. The only apparent cause of such an occurrence was the presence of a very large amplitude trough in the mid-latitude westerlies which had appeared prior to the acceleration of the vertical cell.

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* See obituary

Rainfall observations in the area of Indonesia showed that when the precipitation was a maximum the upper troposphere was coldest and that no significant changes occurred in the lower troposphere. In these heavy rainfall situations it was found that the lapse rate at upper levels departed noticeably from the moist adiabat indicating the presence of an upper layer unstable with respect to saturated ascent. The speaker pointed out that if the tropics were in control of this process then the release of latent heat would be expected to quickly remove the instability, but this is not observed.

The sequence of events envisaged as being able to produce these phenomena was then summarized as follows:

1. A change in the speed of the vertical circulation is caused by
2. The enhanced flux divergence of heat in the upper troposphere which is due in turn to
3. Increased gradients resulting from mid-latitude changes. This increased divergence then
4. De-stabilizes the air in the upper troposphere and thus
5. Enhances and intensifies the large scale convection until
6. The flux divergence weakens or ceases causing
7. The accumulation of heat in the upper levels and resultant
8. Stabilization leading to
9. The disappearance of the vigorous convection.

In further support of this idea Professor Ramage compared an unusually wet month and a drought month over Indonesia, again emphasizing the relatively cold upper troposphere and the presence of high level instability for the former. The above process would also help to explain the observed variability of rainfall in this region. The islands lie in a very homogeneous air mass all year round with the sea surface temperature changing by only $1^{o}C$ and the diurnal variations would therefore be expected to dominate. The observed variability is however much more typical of mid-latitudes. The speaker stressed that while the energy production in the tropics may be governed by mid-latitude requirements, the method by which the energy is produced appears to be determined in the tropics. In different seasons and in different areas of the globe therefore the response ranges from typhoons to extensive cloud bands.

In support of this last point the results of numerical predictions at NCAR were cited. It was found that when the southern boundary in a Northern Hemisphere prediction model was shifted from $20^{o}S$ to $20^{o}N$ the mid-latitude forecasts were largely unaltered. The tropical circulation was of course, markedly different and this can be interpreted as meaning that the method by which the tropics choose to provide energy is of little consequence in mid-latitude forecasting.

Professor Ramage then returned to seek an answer to the question posed earlier.

Dr W.J. Gibbs enquired firstly as to the importance of orographic rainfall in Indonesia and suggested that the variability mentioned earlier could be due to convective cells generated in mountain areas moving in a variable environmental flow. The speaker replied that while orographic rainfall was certainly important it did not control the precipitation and that the variability could not be explained in this way.

Dr Radok queried the method by which the flux divergence could be maintained over the presumably long time which it would take the tropics to respond and drew an analogy between the exchange mechanism proposed above by the speaker and the situation observed in cut-off lows where latent heat is continually released and yet the cold pool does not warm. Professor Ramage, in reply, said that the tropics responded very quickly with time scales of the order of hours and thus the maintenance

of the divergence was not a problem. Commenting on the cut-off low situation, as a smaller scale version of what he had been discussing, the speaker indicated that typhoons can form near cold pools possibly because the local gradients are so large.

The answer to the initial question was provided by Dr Priestley,who surmised that the surge of air envisaged would not be markedly altered by a presumably small sea surface temperature increase, but instead the increased speeds would cause greater mixing of the surface layers of the sea as well as increased evaporation leading to a decrease in the sea surface temperature accompanying an increase in the rainfall over Indonesia.

The question of the contribution which the zonal Walker circulation cells may play in the suggested acceleration mechanism was raised by Dr Radok. Professor Ramage indicated that in a direct sense these cells were too weak to be of major importance, however there was a possible inverse relation between the strength of the Walker and Hadley cells but the exact connection had not been identified.

While the ideas presented appeared reasonable over the east Asia region, Dr Priestley enquired whether they were thought to be more generally applicable. In reply the speaker showed two slides of satellite picture mosaics for the region from approximately 60°E to 140°E taken 19 days apart in July 1967. The first, taken when the Southern Hemisphere Hadley cell was strong, showed extensive convective activity over the entire longitude band, while the second, obtained during a period of weak vertical circulation, showed very few clouds at all. It was pointed out that these types of changes are not typical and suggest that tropical forecasters should look to mid-latitudes and larger scales to improve their predictions.

Dr A.B. Pittock suggested that the simultaneous increase in the strength of the Hadley cell and in mid-latitude vortical activity was consistent with what would be expected on the basis of baroclinic instability concepts and that the cause and effect relationship had not been proved. While agreeing with these comments the speaker argued, using a heat engine analogy with the tropics as the fire and middle latitudes being the condenser that a greater degree of control would be exerted by the more variable temperature of the condenser, that is, the extratropical regions, rather than that of the fire.

Dr Radok then moved the vote of thanks to Professor Ramage for his very interesting talk.

K.J.W.