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MEASUREMENT OF ATMOSPHERIC FLUXES BY EDDY CORRELATION

By B. B. Hicks

Mr. Bruce Hicks of the C. S. I. R. O. Division of Meteorological Physics, Aspendale, presented some of the theoretical and practical aspects of the measurement of vertical fluxes of meteorological quantities in the boundary layer. The measurement of these fluxes has important agricultural application and more recently is playing an increasingly important part in numerical modelling of the atmosphere.

Providing sensors with suitable response times are available, the turbulent or eddy flux, F_s , of a quantity s can be calculated from the familiar relation

$$F_s = \rho \overline{w's'}$$

where the prime denotes departure from the mean value, w is the vertical component of wind velocity and ρ air density. In the case of water vapour flux, E , a suitable sensor does not exist. From the psychrometric equation it was shown that

$$E + H = \rho L (S + \gamma) \overline{w'T_w'}$$

where H is the flux of sensible heat, L latent heat, $S = \partial q_s / \partial T$ (q_s saturated specific humidity and T temperature), γ adiabatic lapse rate and T_w wet bulb temperature. A suitable sensor for T_w exists, permitting $E + H$ to be evaluated. The sensor to determine H is simply a thermistor, and thus an independent determination of sensible heat flux will allow E to be evaluated.

The instrument used to measure these fluxes is called a Fluxatron. The outputs of meteorological sensors (e.g. u and w from anemometers to determine shearing stress) have their dc component removed electronically and the resulting signal appropriately scaled using amplifiers. These signals are then multiplied and integrated to give the eddy flux. This system attenuates eddies of period greater than a value dictated by the averaging time of the instrument and less than a value determined by the response time of the sensor. In practice it is required that these attenuated eddies do not contribute significantly to F_s . The averaging time of the Fluxatron is 160 seconds, and the anemometers used have a response length of 0.6 metres (response time equals response length divided by wind speed). The temperature sensors used have response times less than the anemometers. It was shown that the "spectral window" for the Fluxatron in its shearing stress mode is sufficient to include practically all the cospectrum of u and w .

During February this year, evaporation measurements were made at Barren Box Swamp (area 30 km²) near Griffith, New South Wales, in an attempt to determine the effect of reeds (combungi) on evaporation. A reed-free lake, Lake Wyangan (area 2.4 km²) nearby, was used as a control. For various reasons the Fluxatron appeared to be the most practical method of estimating evaporation, although other methods, in particular the "bulk formula" approach, could be used over a clear water surface. Initial comparisons of the various methods indicated

that the eddy correlation technique gave satisfactory results. As insufficient Fluxatrons were available, the evaporation from the lake was estimated by the "bulk formula", and at the swamp both this and Fluxatrons were used. Table 1 summarises the results of four days measurement.

Table 1. Comparison of the evaporation from Barren Box Swamp and Lake Wyangan (in mWcm^{-2}) on four days in February. Column (1) using Fluxatron, columns (2) and (3) using the "bulk formula" approach.

Swamp		Lake
(1)	(2)	(3)
..	20	34
13	11	35
12	15	16
18	20	21

Between the second and third days 2 inches of rain fell over the area. It can be seen that the last two days had comparable evaporation rates, whereas on the first two days the evaporation rate at the swamp was much less. The reason for the difference before and after the rain is not fully understood, but may be due to an "oasis" effect or, more probably, to "freshening" of the reeds by the rainfall. The results imply that, in general, a reduction in water loss due to evaporation results from the presence of the reeds, although immediately after heavy rainfall the swamp evaporated as if it were a clear water surface. Mr. Hicks emphasized that it would be very risky to extrapolate these results to other situations.

The Fluxatron is a most suitable instrument for determination of shearing stress $\tau = \rho u_*'w'$. In neutral lapse rate, friction velocity may be evaluated from $u_* = \sqrt{\tau/\rho}$. This estimate does not require the conventional determination of the wind profile. The determination of u_* permits the estimation of the Monin-Obukov length scale, and in conjunction with a profile the von Karman constant. Results of the estimation of these parameters at Edithvale, Victoria, were presented. Despite the fact that this site is not particularly satisfactory for this type of measurement, quite good results were obtained.

In the discussion that followed, Dr. G.W. Paltridge suggested that suitable sensors for measurement of water vapour directly, and hence E, were available but were expensive. Mr. R.J. Taylor commented that these sensors often did not perform as well, or as conveniently as claimed.

Dr. G.B. Tucker asked whether, considering the small size of the lake and the swamp, horizontal gradients may not be playing an important part in moisture transports. This effect might be estimated using two Fluxatrons located in different parts of the swamp. Mr. Hicks agreed, but thought that the area was sufficiently large for Fluxatron measurements to be meaningful. He mentioned that Dr. A.J. Dyer has done some comparative measurements along the above lines.

Mr. D. Beaumont asked if the time of the year was considered important in the evaporation study. Dr. C.H.B. Priestley thought the month would be the worst for evaporation losses.

Mrs. J.M. Hopwood commented that the difference in area between the lake and the swamp could have an effect on the evaporation, particularly if the "oasis effect" is considered relevant.

R. R. B.

18 September 1969

SOME RESULTS OF THE METEOROLOGICAL ROCKET FIRINGS

By F.H. Callus

Mr. Callus of the Bureau of Meteorology, Melbourne, presented the details and results of a series of comparative meteorological rocket firings carried out at Woomera from September to December of 1968. This series was the result of a decision by an inter-departmental committee (WRE and Bureau of Met.) to conduct comparative field trials of the English SKUA rocket dropsonde system and the Australian KOOKABURRA rocket dropsonde system, in order to determine which would be the most suitable system for a possible regular sounding program to be run by the Bureau of Meteorology.

The aims of the trials were:

- (1) to compare sensors,
 - (2) to test the rockets,
 - (3) to test the associated ground equipment,
- and (4) to study the possibility of using Bureau personnel and equipment in a future program.

Both rocket systems eject their dropsonde payload at an altitude of about 70 km. In both systems the payload consists of a temperature sensor, associated telemetry and a parachute. Tracking of the payload by a modified WF44 radar could be used to determine the upper atmosphere winds down to 30 km.

Mr. Callus described the rockets and their associated equipment, and discussed the data reduction in some detail, with particular emphasis on the digital smoothing of the data. He explained that the firings were conducted in pairs (a SKUA and a KOOKABURRA firing an hour or less apart) separated by periods of from 2 to 6 weeks. In subsequent slides he presented the results of E-W and N-S wind components and the temperature profiles in their appropriate pairs for comparison, together with results from balloon ascents to 35 km.

In general the results compared well with similar Northern Hemisphere data obtained at White Sands and Cape Kennedy, U.S.A. There appeared to be no systematic difference between the SKUA and KOOKABURRA sonde results, except that at the lowest altitudes (30-35 km) the KOOKABURRA temperatures were slightly lower than the SKUA and balloon temperatures - Mr. Callus suggested that this was due to the blocking oscillator transistor of the telemetry system. There was