actual physical processes of the atmosphere; he then asked the speaker for his opinion on the important trends of the future. Agreeing with this statement, Dr. Jenssen thought that important lines of research would be

(i) parameterization of sub-grid scale convective elements,

(ii) redundancy experiments to determine the most efficient use of data, and

(iii) investigations into theoretical and experimental predictabilities of atmospheric motions.

Dr. Priestley enquired where the main developments were occurring and whether it had definitely been determined whether orography, topography, or thermal effects caused anchoring of the general circulation features. In the speaker's opinion, the main numerical modelling work was in America and England, followed by Russia, France and Japan. Also, topography or orography, i.e. the effect of mountains, had caused the geographical anchoring of thermal systems in Kasahara's model.

Mr. Langford asked the speaker to elaborate on the difficulties of objective analyses, to which Dr. Jenssen replied that the most important problem was adjusting initial fields to provide internal consistency with the forecast models.

M.E.V.

26 June 1969

PLANT GROWTH WITHOUT TEARS, OR A MODEL OF A GROWING PASTURE

By G.W. Paltridge

Dr. Paltridge of the C.S.I.R.O. Division of Meteorological Physics, Aspendale, Victoria, introduced his subject by intimating that models were of two types, viz. pure simulation concerned only with the end result, and those in which interest is centred on how the model works. He stressed that his model was developed from physical principles and embraced the concept of specific layers within the crop canopy and throughout the root zone. Biochemical activity within the canopy was defined by the rate of production of dry matter in the various strata. With a given distribution of crop and root, and with soil-water and plant nutrients non-limiting, it is postulated that growth can be determined by the treatment of data for air temperature, wind speed, radiation and concentration of CO_2 in the atmosphere above the crop canopy. Growth rate (GR) is identified with the rate of photosynthesis (PS) and the relationship between PS of a given layer and the meteorological parameters indicated above is given as

$$PS = F(R, CO_2, A)$$

where F is a function,

R = incoming radiation at the layer,

CO_2 = concentration of CO_2 in the air of the layer,

A = biochemical capacity of the plant leaves of the layer.

From this it is inferred that, under the conditions prescribed, R, CO_2, or A may be the limiting factor in GR (growth rate) and the following conditions may prevail:

(i) with R limiting $PS = F_1 (R)$

(ii) with CO_2 limiting $PS = F_2 (CO_2)$

(iii) with A limiting $PS = F_3 (A)$

In order to determine which of these is limiting GR, the model produces results on the assumption that R, CO_2 and A (in turn) is the limiting factor. The lowest result of the three indicates the limiting factor.

Certain assumptions are made in deriving the forms for F_1, F_2 and F_3.

(1) F_1 expresses a simple proportional linearity - the proportion of photosynthetically active radiation absorbed indicates the amount of energy available for PS.

(2) F_2 is influenced by a number of variables including

(a) stomatal opening - it is assumed that the stomata are closed at night, that they open at dawn, and that the extent of opening is dependent on the air temperature, with maximum opening occurring at 30°C.

(b) a number of resistances to the movement of CO_2 from the air to the manufacturing site within the leaf, viz:

(i) boundary layer resistance - a function of wind speed,

(ii) stomatal resistance which is variable in terms of the factors affecting the degree of opening or closure of the stomata,

(iii) mesophyll resistance - which is assumed to be fixed for the plant.

(3) F_3 is a function of leaf temperature. Biochemical activity reaches a maximum at 30°C; at temperatures 0°C and 50°C the plant enters a phase of minimum biochemical activity.

An allowance of 10 percent of estimated dry matter production is made for night respiration. The weight of dry matter is assumed to be equivalent to the amount of photosynthate produced. Total growth for a time step is obtained by summing the dry weight production of all layers.

Function values are calculated on the following basis:

F_1 is estimated by determining the orientation of leaves within each of the stipulated layers within the crop canopy and by determining radiation flux falling on the average leaf in the layer.

The estimation of the value of F_2 is based on the concentration of CO_2 in the air in each layer of the crop canopy. Given the concentration of CO_2 in the air, the theoretical flux transfer through the canopy is a function of height within the canopy (from which it is to be inferred that it is also a function of growth rate in each layer).

F_3 is estimated from energy input adjusted to account for the dissipation of energy in sensible heat loss and in providing the latent heat of evaporation. A deficit of soil water has a direct effect on leaf temperature and therefore on F_3 (and on F_2 via stomatal aperture).

The model assumes that the plant will endeavour to maximise the growth rate, and that growth will occur on sites on the plant and within those layers of the canopy on, and within which, the greatest contribution can be made to the growth of the plant as a whole. Dr. Paltridge presented several examples of the application of his model to predict or describe the reaction of a pasture to varying meteorological conditions, e.g. the diurnal variation in growth rate resulting from varying intensities of insolation; the differing reactions of the plant in terms of geometry (development of different layers) in response to limitations imposed by either radiation, CO_2 concentration, or biochemical capacity. Accepting, for general purposes, a maximum growth rate of 35 mg/100 gm/hour, which differs from a purely theoretical maximum, he drew a curve for pasture growth rate against time. He showed a trial which demonstrated the diurnal variation in the ratio of total evaporative to total sensible heat loss, indicating the point at which this ratio discloses soil moisture deficiency.

At the conclusion of Dr. Paltridge's address many questions were directed to the speaker.

Dr. G.B. Tucker asked what degree of empirical tuning of the model was required to avoid such results as a top-heavy plant. Dr. Paltridge replied that the predicted growth was exactly as shown earlier in the diagrams, no empirical corrections being involved at all.

In response to a question from Mr. J.C. Langford, the speaker recalled the maximum growth rate of approximately 30 gm/metre^2/day for the model, in close accord with actual maxima found for real pastures irrespective of country, locality, etc.

Mr. I.C. McIlroy queried the effect of changed initial conditions (e.g. soil temperature) on the subsequent shape of the plant. Dr. Paltridge replied that this had a marked effect. However, in some cases the model soon stabilised.

Dr. F.A. Berson asked about the time lags involved in plant response to the external variables. In reply, Dr. Paltridge mentioned that the time steps used in the model corresponded approximately to one hour of growing time.

Further questions dealt with the advisability of pruning the plant at certain stages and the occurrence of negative growth rates.

W.F.N.-S.