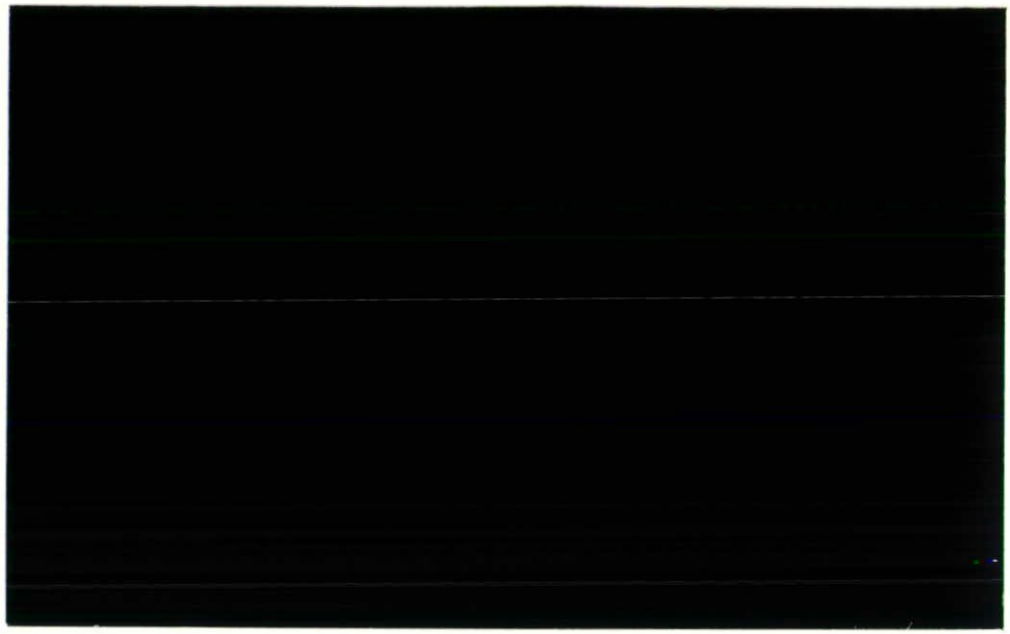
Institute of Hydrology



Natural Environment Research Council

T06050A1

CEGB RESEARCH FELLOWSHIP ON LAND SURFACE ATMOSPHERE INTERACTIONS

ANNUAL REPORT 1991

A.J. DOLMAN

Contents

Summary

This summary describes the research performed under the CEGB Fellowship on land surface atmosphere interactions during 1991.

1) A new formulation of the land surface scheme of the Hadley centre GCM was achieved. The set of biomes was redefined. Calibrations are currently available for 6 of the 12 biomes.
2) Aggregation mechanisms at a micro-scale (1km-10km) were studied using a two-dimensional model of the atmospheric boundary layer. Simple aggregation schemes were developed and tested and recommendations are given for the application of these.
3) In collaboration with the French National Meteorological Research Centre a study was initiated to investigate aggregation mechanisms at the meso-scale (10km-500km) using a mesoscale model to analyze some of the HAPEX-Mobilhy data.
4) Atmospheric profile data obtained during the SEBEX field experiment in the SAHEL were analyzed and regional values of z_0 for momentum were derived.
5) Future meso scale modelling plans were formulated for HAPEX-SAHEL and EFEDA. A research proposal was formulated to study biome change feedback .

1. Introduction

Research in land surface atmosphere interactions is recognized as a priority theme by the World Climate Research Programme (WRCP). Improvement in the representation of land surface atmosphere interactions in General Circulation Models (GCMs) is believed to be essential for adequate *regional* forecasting of future climate change. The existing international research programme, coordinated by WRCP and the International Satellite Land-Surface Climatology Project (ISLSCP) seeks to address the issues involved in this by attempting to understand the basic mechanisms of energy exchange over areas the size of a typical GCM grid square (roughly 10000 km^2). Within WCRP and ISLCP several large scale

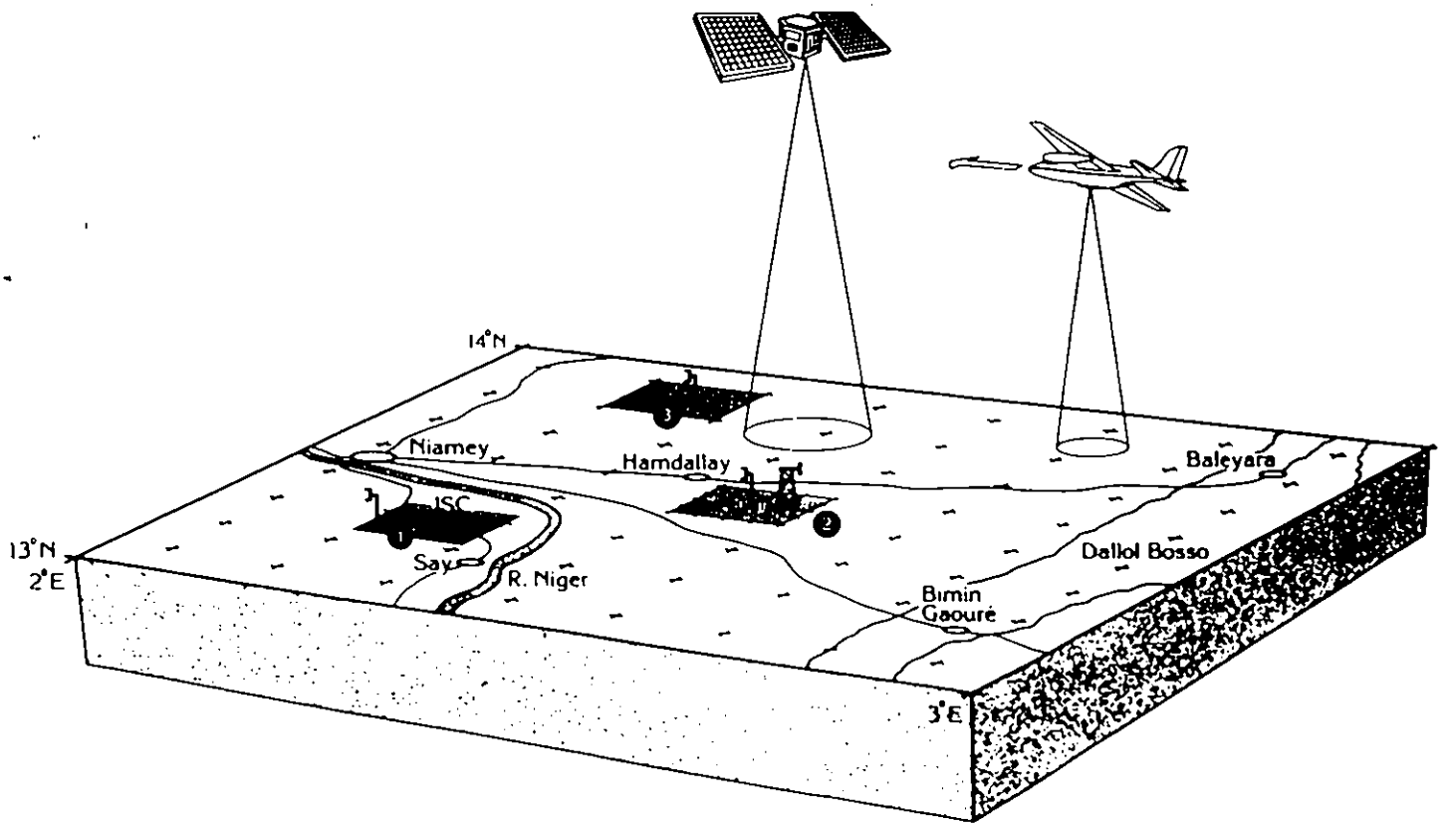


Figure 1. Diagram showing the design of the HAPEX-SAHEL experiment with three extensively monitored supersites and aircraft and satellite measurements.

field experiments are planned and executed to provide the data required for calibration and development of land surface parameterizations.

These experiments are designed to understand the physical process at the full range of relevant spatial and temporal scales. Figure 1 shows the measurement principles deployed in these experiments and a typical design for the HAPEX-SAHEL experiment . The research programme of the CEGB Fellowship is aimed at both understanding the mechanisms of the interaction of spatial scales and formulating adequate algorithms for aggregation from smaller to larger scales for use in GCMs. A range of meteorological and hydrological models is used for this purpose. Correct representation of these processes in GCMs is likely to reduce the current uncertainty in the regional predictions of climate change.

This report describes progress made in these areas during 1991.

2. Development of a new land surface scheme

Land surface parameterizations for use in GCMs have to be able to predict the correct area-average fluxes of sensible and latent heat and momentum. Within the MITRE Meteorological office Institute of hydrology TerREstrial model) project, a collaborative effort between the Institute of Hydrology and the Hadley Centre, the land surface scheme of the GCM is continuously being upgraded and calibrated. A new model structure was proposed to allow realistic calculation of the turbulent fluxes for a variety of land surface types encountered in the real world. Figure 2 shows a schematic of this model. It is novel in the GCM context as it makes use of the energy-combination equation to solve for the latent heat flux, rather than solving the transfer equations of heat and water vapour directly. Another important feature of the model is that it allows for soil vegetation interaction. Since 70% of the world's natural vegetation is sparse this is obviously important. Table 1 lists the biomes which are currently being calibrated with this model. With new data becoming available from the international experiments, calibration will be performed for other biomes.

TABLE 1 Calibration MITRE model

BIOME	CALIBRATION
Tropical Rainforest	Achieved
Tropical Savannah	Achieved
Agricultural Crop	Achieved
Deciduous Forest	Available
Coniferous Forest	Available
Prairie Grassland	Available
Bare Soil	In progress
Boreal Forest	Boreas Experiment (1993)
Snow	Boreas/in progress

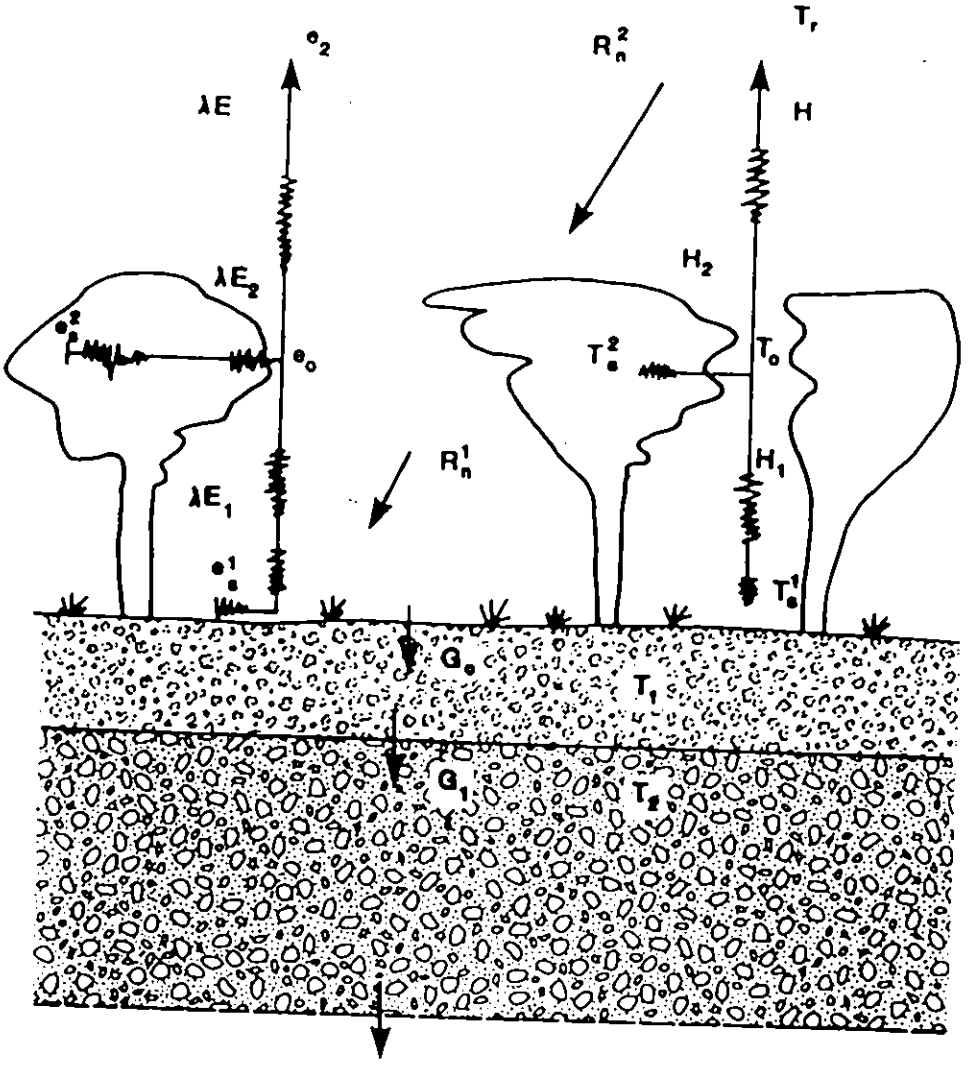


Figure 2. Schematic diagram of the MITRE model. R_n is net radiation, e and e_s vapour pressure and saturated vapour pressure, λE evaporation, H sensible heat flux, T and T_s air and canopy surface temperature, the subscripts 1 and 2 refer to the canopies of the under, or soil, and upper storey, $G_{0,1}$ surface and soil heat flux from surface to deep soil layer, $T_{1,2}$ soil temperatures. The symbols ⁄\/\/\⁄ denote resistances to water vapour and heat transport in the soil-vegetation-atmosphere system.

A redefinition of the biome classes is currently in progress. This redefinition will reduce the number of vegetation classes currently used in the GCM and will result in easily identifiable biome types which can be calibrated with data from field experiments. Initially a single layer version of the model will be implemented in the new Unified Model GCM and it's performance will be assessed using a 1-D version of this model for the Sahel. In Figure 3 and 4 examples are given of the calibration results for tropical rainforest and tropical savannah. In both cases the model gives acceptable predictions of evaporation. In calibrating the "agricultural crop" biome similarly good results were obtained for sensible and latent heat flux, but adequate estimation of the aerodynamic roughness properties of a growing crop appeared to be more difficult.

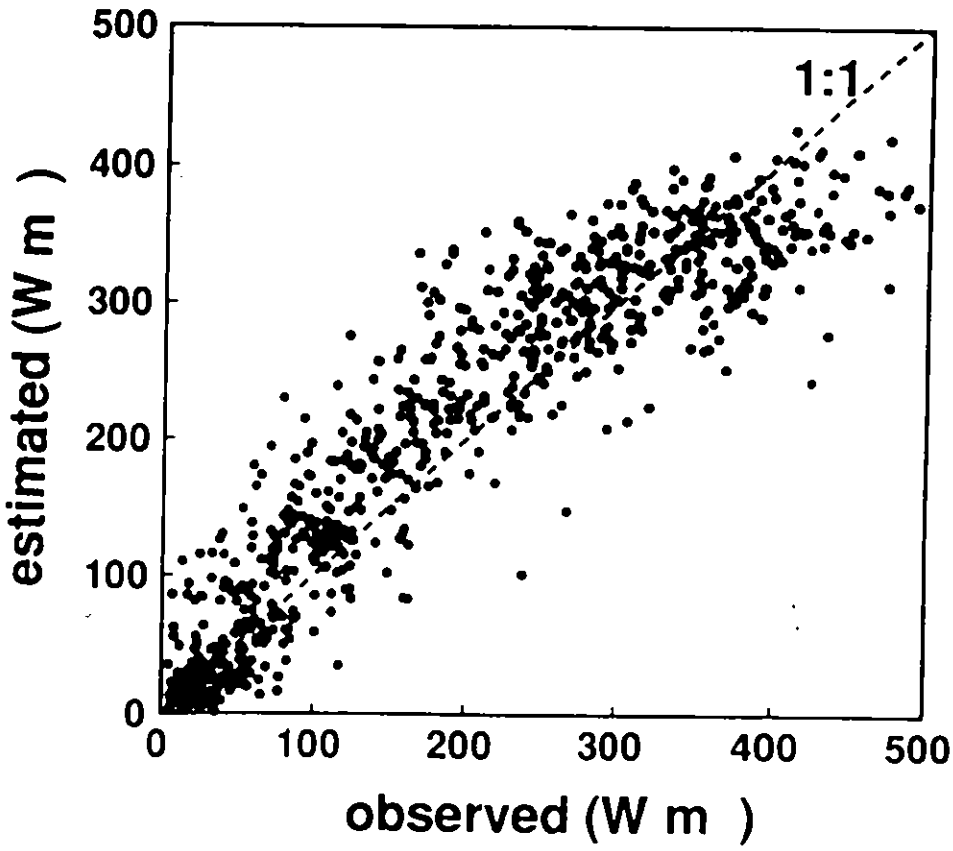


Figure 3. Observed and modelled evaporation for the tropical rainforest biome.

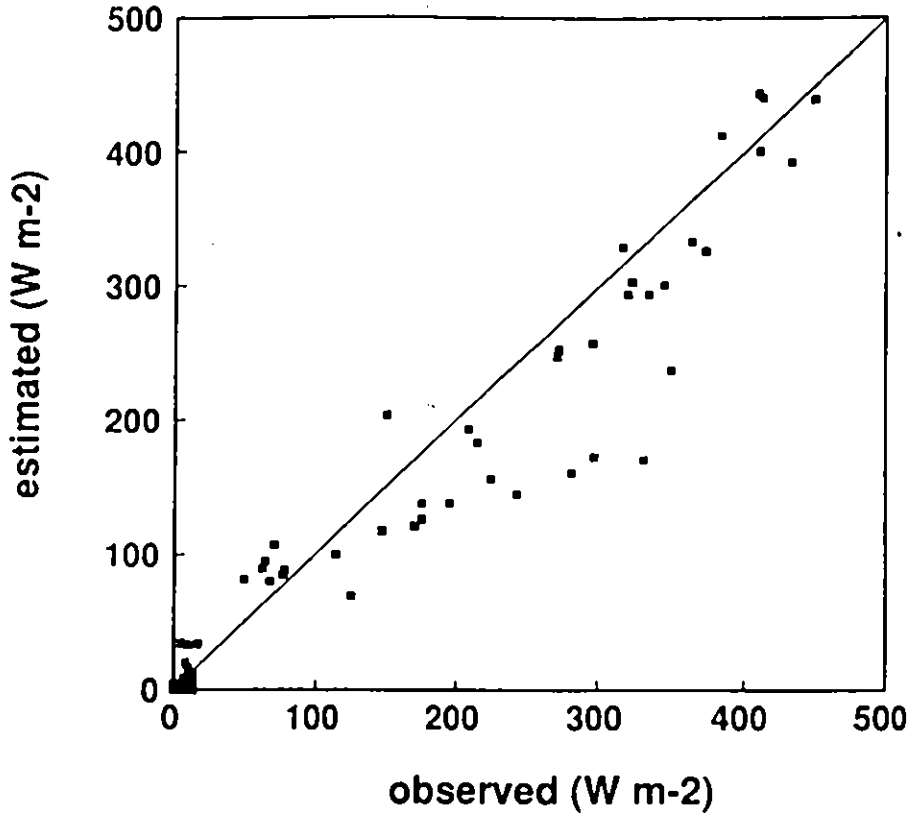


Figure 4. *Observed and modelled evaporation for the tropical savannah biome at the start of the drying season.*

3. Development of micro-scale aggregation methods

The aim of the "micro-scale" aggregation studies is to find ways of aggregating surface parameters at scales typical of the boundary layer (1-10km) into one single *effective* value for use in larger scale models. The effective value is defined as that value of the parameter which gives the correct area-average flux. To determine the aggregation mechanisms a 2-D boundary layer model is used to provide "true" values of the area-average flux and new, more simpler aggregation techniques are developed and compared with the results of the model.

It was shown that it is important to distinguish between the aerodynamic resistance for heat and moisture transfer when averaging over large areas. Three estimation techniques were tried out and compared with the 2-D boundary layer model results. One technique is based on the concept of a blending height, a height at which the surface fluxes are approximately still in equilibrium with the local surface, but at which the scalar properties or windspeed can be considered homogeneous. The two others are simpler procedures and just take the average resistance or the average conductance. The main difference between these methods and the previous method is that the latter do not take into account the overlying meteorology.

In Figure 5 the resulting fractional error in evaporation is shown for the three averaging techniques. The averaging method which uses the blending height concept gives consistently good estimates, but for many applications the simple mean of the average conductances and resistances may be sufficient. This study complements an earlier sensitivity study based on incorporating a probability distribution function in the Penman-Monteith equation.

In the near future the 2-D boundary layer model will be used to study aggregation in the real world using data from the EFEDA (ECHIVAL Field Experiment in Desertification-threatened Areas) and HAPEX-SAHEL experiments.

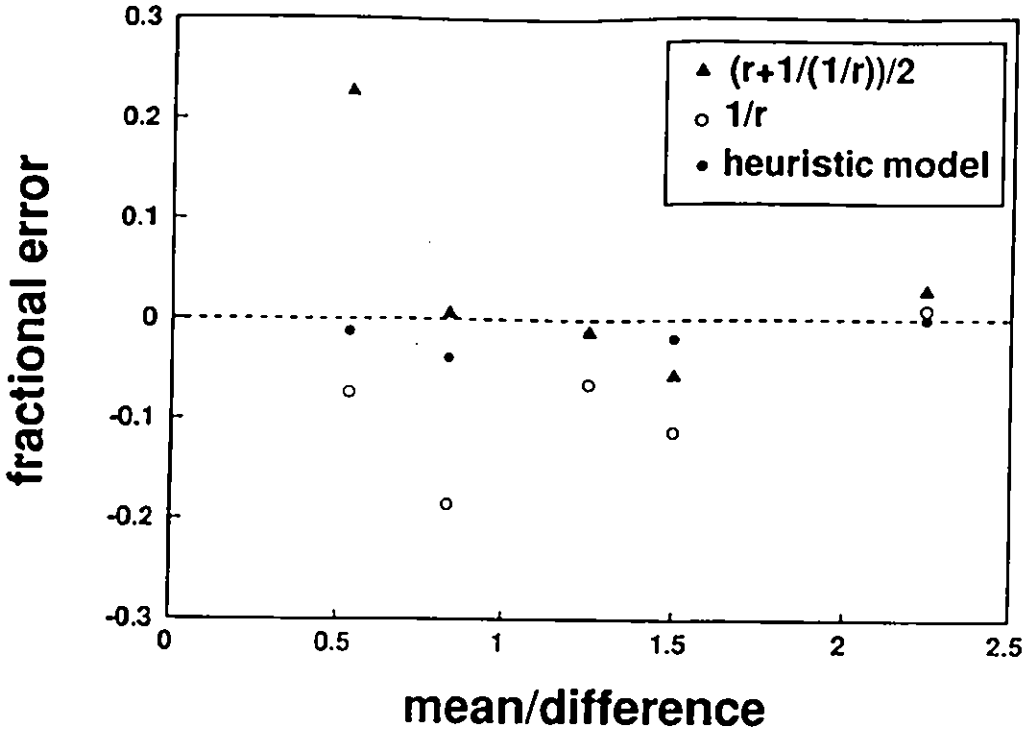


Figure 5. *Fractional error in evaporation as compared to the 2-D boundary layer model results for three averaging techniques of surface resistance (r) for heterogeneous terrain, plotted against the ratio of the mean over the difference of two resistances.*

4. Mesoscale modelling

Previous studies by the French National Meteorological Research Centre (CNRM) have shown how a mesoscale model can be used to provide area-average descriptions of surface energy exchange in dry, sunny conditions. With additional funding from the British Council's Alliance Programme a joint project was set up between IH and CNRM to investigate aggregation of surface fluxes in more extreme conditions i.e. when the surface of a GCM gridsquare is partially wet as a result of subgrid scale precipitation. This study follows on the work done earlier on parameterizing interception losses for GCM gridsquares. The ultimate aim is to develop an aggregation scheme which reflects the sub-grid meteorological conditions and distribution of rainfall in a GCM gridsquare. These aggregation schemes can then be tested in 1-D models. The general procedure for testing such an averaging scheme is illustrated in Figure 6.

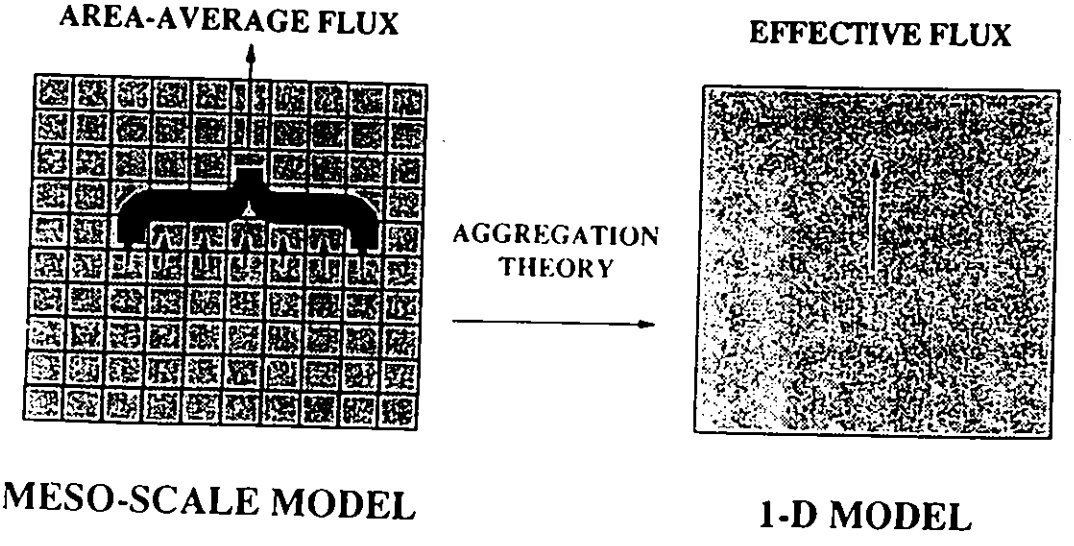


Figure 6. Diagram showing the derivation of effective parameters for use in large scale meteorological models.

A research version of the French Weather Service's mesoscale model, PERIDOT, was used to simulate a rainy day during the HAPEX MOBILHY experiment in 1986 . The results obtained from the model were compared with satellite and near surface observations of weather variables. The time series of wind, humidity and precipitation obtained at the Lubbon site (see Figure 7 for a location map) show the passage of the front from the Atlantic on that day (Figure 8). Figure 8 also shows the modelled time series. The agreement between the two is encouraging.

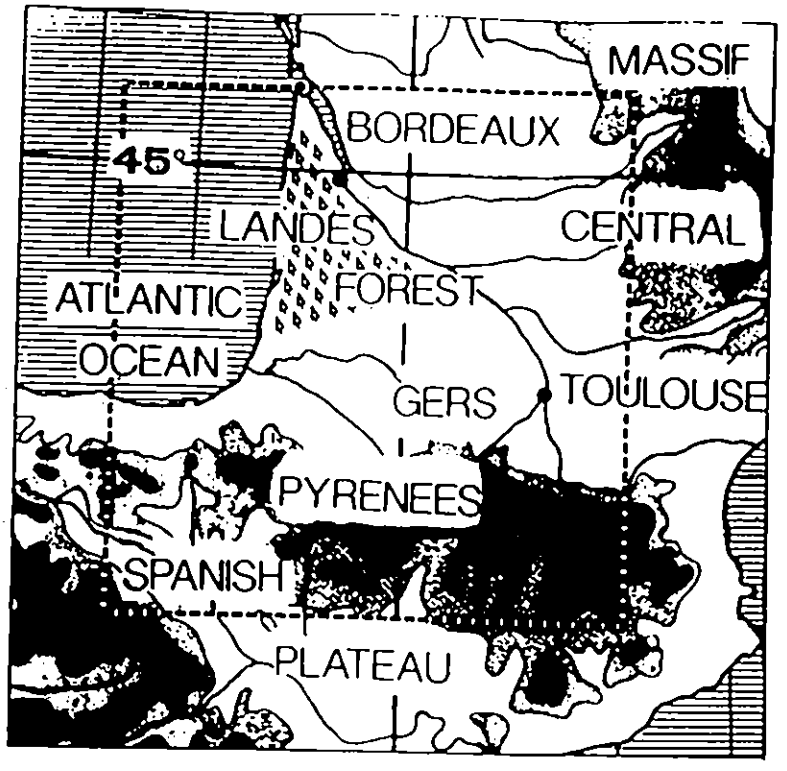


Figure 7. *Map of the mesoscale model domain with the dotted line showing the model boundary.*

Especially the humidity shows the passage of the front very clearly, and the model response is good. A banded pattern in precipitation was both observed and modelled, although the actual location of the bands did not correspond closely to that observed, due probably to poor initialization of the model from the large scale analysis. The model run is however sufficiently realistic to proceed with the averaging studies of the fluxes of heat and water vapour. This should be particularly interesting as a large variety of modelled meteorological conditions is

observed, varying from areas with high radiation, convectively unstable boundary layers to almost completely overcast conditions with stable boundary layers.
A sensitivity test with the model showed that the momentum roughness length is important in determining the location of the front and that wet forest-canopies may enhance rainfall downwind through a positive feedback loop with atmospheric humidity.

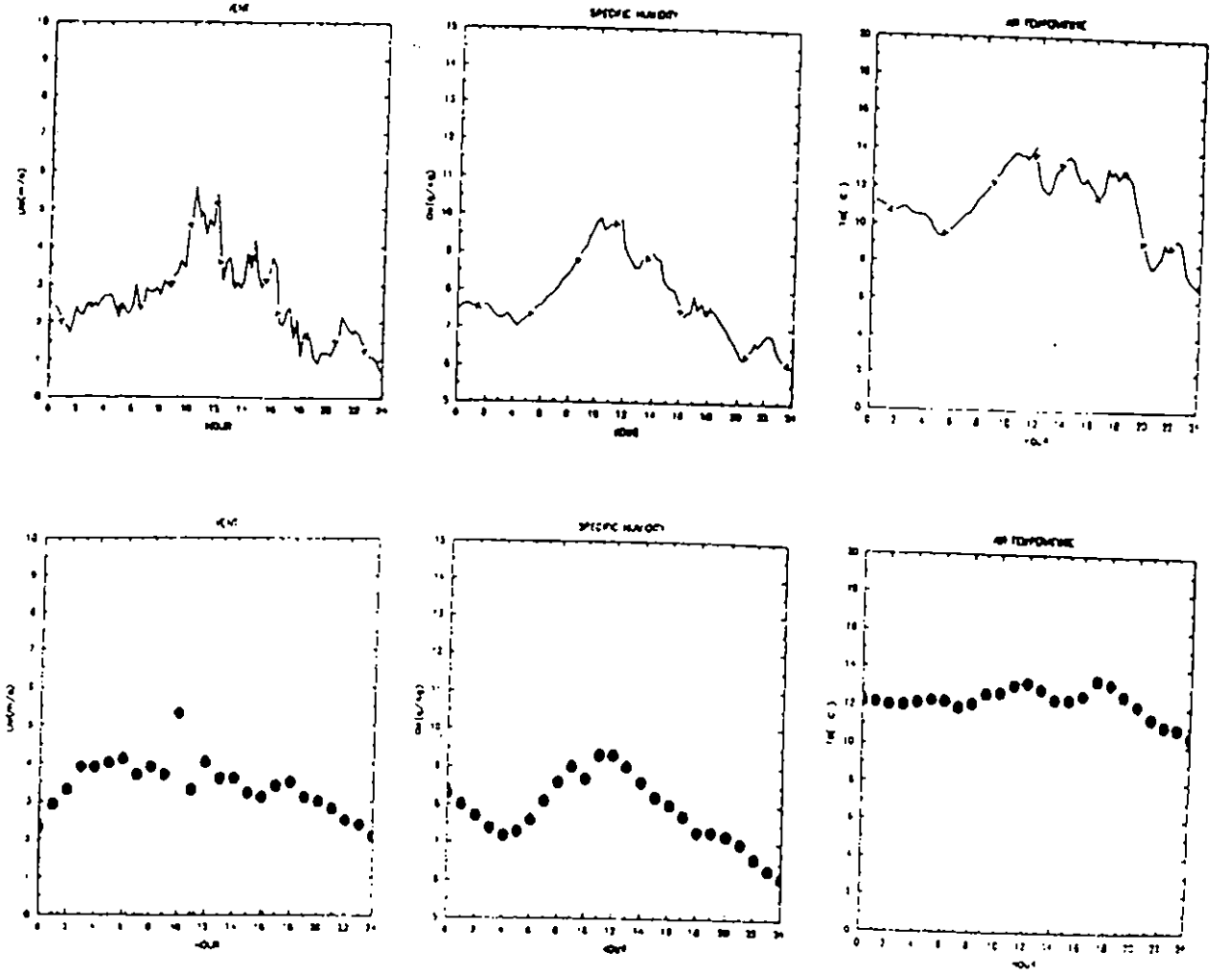


Figure 8. *Comparison of modelled (top three graphs) windspeed, humidity and air temperature with observations (lower three graphs).*

5. Experimental data analysis

Experiments with GCMs have shown that the roughness of the land influences the horizontal convergence of moisture in the atmospheric boundary layer. This suggest that a reduction in roughness may lead to a decrease in rainfall, similar in size to that from an increase in albedo through the Charney effect. Clearly it is important to have accurate estimates of the roughness parameters specified in the models, to be able to use these models in predicting climate change effects in desert margin regions such as the Sahel.

As part of the SEBEX (Sahelian Energy Balance EXperiment) experiment in Niger, tethersondes were used to study momentum and energy exchange on a regional scale. The profiles of windspeed were obtained with a mobile tethersonde system up to a height of 250m over an area of natural open forest, locally known

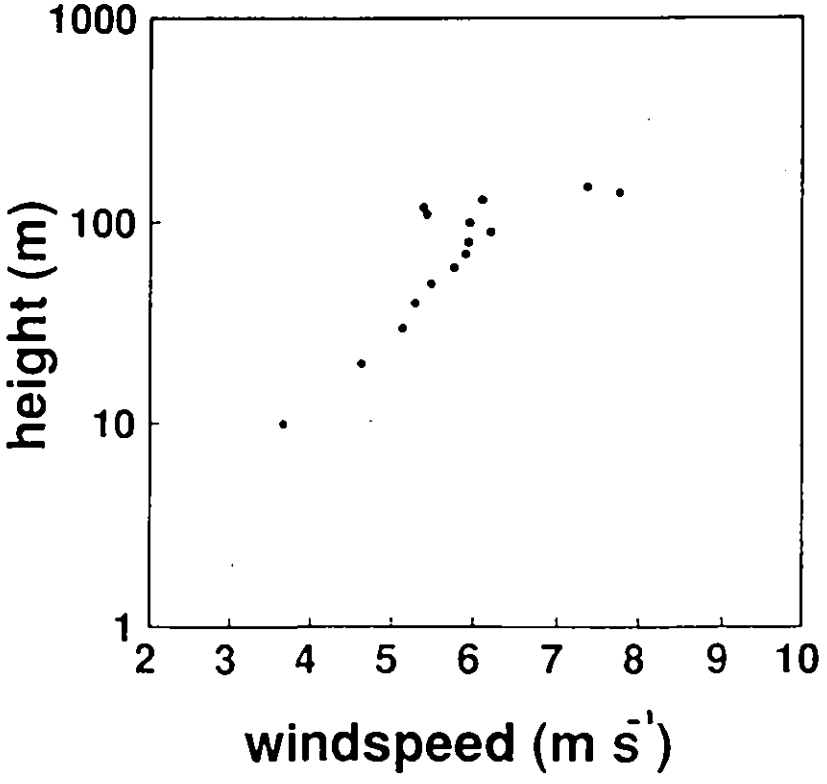


Figure 9. *Average windspeed profile over the Tiger bush as observed from the tethersonde profiles.*

as tiger bush. Tiger bush consists of stripes of bare soil interspersed with stripes of very dense vegetation, approximately 20 to 50 metres wide. This type of vegetation is the natural climax vegetation of the area. The interpretation of micrometeorological flux measurements is problematic as the source/sink areas for the turbulent fluxes change continuously and will comprise varying amounts of vegetation and bare soil. Tethersondes are able to give an adequate view of the regional behaviour of this type of vegetation and the effect of the micro scale heterogeneity on the area average fluxes.

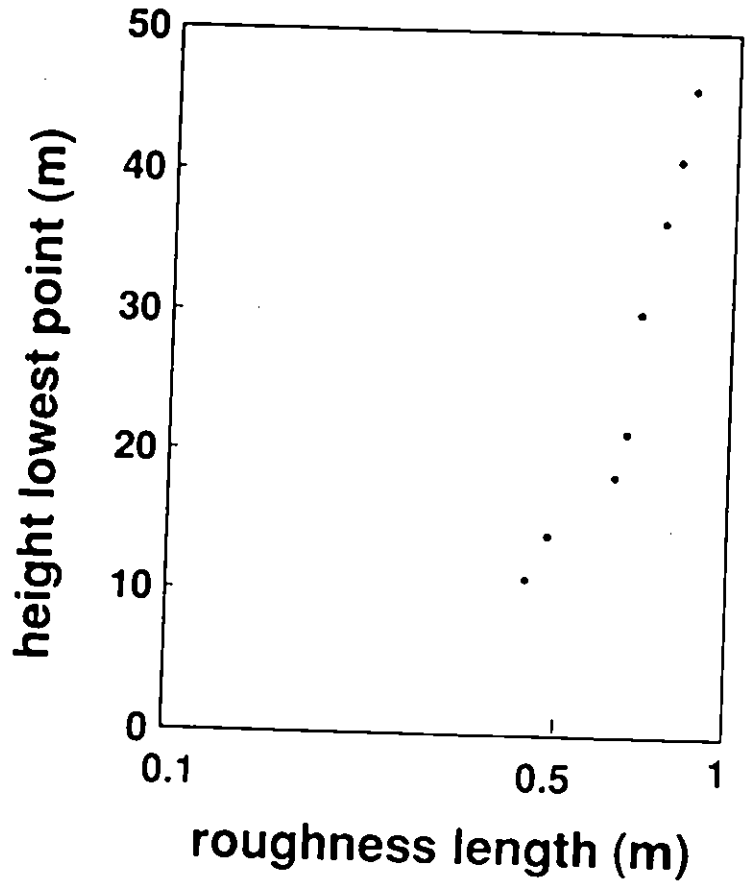


Figure 10. Roughness length for momentum as function of height for the Tiger bush.

Figure 9 shows a an average windprofile from the tethersondes, whilst Figure 10 shows the value of roughness length as a function of height. It is clear that the roughness length changes from a local value of 0.4m to a regional value of 0.8m over a height range of about 20 metres. Both the windprofile, which shows a small

kink in the profile at 40m, and the roughness length profile suggest that two separate regions exist in this case. One region near the surface where the windspeed profile is adapted to the local surface, and a higher region where the profile exhibited shows signs of adaption to a regional surface.

These results show that care must taken in using parameter values obtained at local scales for use in regional scale meteorological models.
In the future the tethersonde profiles will be analyzed for the humidity and temperature characteristics, whilst during HAPEX-SAHEL more measurements will be taken over different surfaces.

6. Progress in the IH land surface energy balance programme

The Institute of Hydrology has an ongoing programme of research in the area of land surface energy balances, which is aimed at improving the land surface representation in GCMs. Progress in this programme will be described briefly here.

The MITRE link with Hadley Centre was further strengthened. The collaboration initiated in previous years was extended and the regular meetings ensure a close coupling of the work done at IH to that at the Hadley Centre.

The ABRACOS (Anglo-BRazilian Climate Observational Study) project continued in its second year with the establishment of two new sites at Ji-Paraná in Rondonia, west Brazil, and Maraba in Pará, east Brazil. An extended set of data was obtained at the cleared site near Manuas. Climatological measurements made simultaneously over forest and clearings show the influence the surface can have on the local climate. This data has now been analyzed and will be used in calibration and deforestation studies with the Hadley Centre's GCM and the University of Maryland's/NASA GFDL GCM. It is hoped that these GCM experiments will provide the first accurate deforestation experiments of tropical rainforest, with both calibrations of forest and cleared areas based on data obtained by the Institute of Hydrology.

In July 1991 the EFEDA field experiment took place in an area threatened with desertification in Central Spain. This project involved measurements of micrometeorological fluxes by several teams from European universities and research establishments. Ground measurements were complemented by radio sounding and aircraft measurements of surface temperature and turbulent fluxes. In February 1992 preliminary data analysis and further modelling will be discussed at a meeting in Munich, Germany. The IH team had a successful

campaign and obtained 50 days of good measurements, which, are currently being analyzed.

The SEBEX experiment entered it's data analysis stage and this year has seen progress in the calibration of the multi-layer GCM land surface model with this data. Very encouraging results were obtained from the atmospheric boundary layer results. It was shown that by using an inverted form of a boundary layer growth model, it is possible to obtain estimates of regional sensible heat flux. This technique has considerable potential in remote, heterogeneous areas such as the Sahel.

7. Future research

A considerable amount of effort this year was spend by IH staff and the CEGB Fellow in preparation for the HAPEX-SAHEL experiment. HAPEX-SAHEL is a major international field experiment aimed at understanding the fluxes of heat, water vapour and momentum in an area of 1° by 1° in Niger, West Africa. Three supersites are identified along a north-south gradient and measurements will be taken over typical vegetation types of the area. IH has a leading role in this experiment with J.H.C. Gash for surface fluxes and A.J. Dolman for large scale modelling as "Science Drivers" and J.S. Wallace as Southern Site Captain in the Operations Committee, which will see the experiment though the present planning and execution stage.

Funding from the NERC TIGER programme was obtained to take micrometeorological and boundary layer measurements at the Southern Site and to undertake a major meso scale modelling exercise for this experiment. In collaboration with the Joint Centre For Mesoscale Meteorology (JCMM) of the University of Reading it is planned to initialize and run a meso scale model for the HAPEX area to understand the aggregation of fluxes at scales similar to that of a GCM. A suite of models, ranging from simple SVAT models, via 2-D boundary layer models, through to meso scale models and GCM's will be run to understand the land surface atmosphere interaction at the full range of relevant spatial scales. A similar modelling programme is planned for the EFEDA data, in collaboration with the meso scale modelling group at CNRM, France.

Through the MITRE project a proposal was formulated to quantify the possible feedback of biomes on climate change. An interactive biome model will be used to predict biomes globally and sensitivity runs with two times current CO_2 levels will be performed to assess the changes and whether such a biome model is a necessary requirement for a transient GCM experiment.

8. Collaborations

During the course of the Fellowship a number of collaborations were initiated. The most important are listed here.

University of Reading, Joint Centre for Mesoscale Meteorology, Prof. Dr. A. Thorpe. Mesoscale modelling for HAPEX-SAHEL.

Centre National de Recherche Météorologique, Toulouse. Dr. J-C. André, J. Noilhan & P Mascart. Alliance project: Mesoscale modelling of partially wetted GCM gridsquare areas and analysis and modelling EFEDA data.

Hadley Centre for Climate Prediction and Research. Dr. P.R. Rowntree *et al.* MITRE project: upgrading and calibration of land surface descriptions in GCMs.

Meteorological Office, Boundary Layer Branch. Dr. P..J. Mason. Micro-scale aggregation studies.

HAPEX-SAHEL. Science Driver Large Scale Modelling in Operations Committee. Collaboration with a large number of international research groups.

EFEDA. Participant in the modelling programme. Collaboration with a large number of international research groups.

University of Sheffield. Prof. Dr. I.F. Woodward. Biome Change Modelling.

9. Publications 1991

Blyth, E.M., Noilhan, J. & Dolman, A.J. (1991) A preliminary study of evaporation from partially wetted meso-scale areas. Progress Report Alliance Project IH/CNRM. Wallingford, 21 pp.

Blyth, E.M., Dolman, A.J. & Wood, N. (1992) The effective surface resistance to evaporation in heterogeneous terrain. To be submitted to the Quart. J. Roy. Meteorol. Soc.

Dolman, A.J. (1991) Review on "Land surface evaporation: measurement and parameterization" by T.J. Schmugge & J-C André, Springer, New York. Meteorol. Magaz., 120: 171.

Dolman, A.J. (1992a) A note on areally-averaged evaporation and the value of the effective surface conductance. J. Hydrol. in press.

Dolman, A.J. (1992b) A two-layer surface energy balance model for use in GCMs. in preparation.

Dolman, A.J., Gash, J.H.C., Roberts, J.M. & Shuttleworth, W.J. (1991) Stomatal and surface conductance of tropical rainforest. Agric. Forest. Meteorol., 54: 303-318.

Dolman, A.J. & Wallace, J.S. (1991) Lagrangian and K-theory approaches in modelling evaporation from sparse canopies. Quart. J. Roy. Meteorol. Soc. 117: 1325-1340.

Dolman A.J. & Gregory, D. (1992) The parameterization of rainfall interception in GCMs. Quart. J. Roy. Meteorol. Soc., in press.

Dolman, A.J. Lloyd, C.R. & Culf, A.D. (1992) Aerodynamic roughness of an area of natural open forest in the Sahel. Annales Geophysicae: submitted.

Gash, J.H.C., Wallace, J.S., Lloyd, C.R., Dolman, A.J., Sivakumar, M.V.K. & Renard, C. (1991) Measurements of evaporation from fallow sahelian savannah at the start of the dry season. Quart. J. Roy. Meteorol. Soc., 117: 749-760.

Lloyd, C.R. Culf, A.D. Dolman, A.J. & Gash, J.H.C. Estimates of sensible heat flux from observations of temperature fluctuations. Bound. Lay. Meteorol., 57: 311-322.

Agricultural and Forest Meteorology, 54 (1991) 303–318
Elsevier Science Publishers B.V., Amsterdam

Stomatal and surface conductance of tropical rainforest

A. Johannes Dolman, John H.C. Gash, John Roberts and W. James Shuttleworth
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(Received 1 November 1989; revision accepted 22 October 1990)

ABSTRACT

Dolman, A.J., Gash, J.H.C., Roberts, J. and Shuttleworth, W.J., 1991. Stomatal and surface conductance of tropical rainforest. Agric. For. Meteorol., 54: 303–318.

Although the absolute values of stomatal conductance of tropical rainforest vary greatly, there is some similarity in the response to humidity deficit and radiation. Stomatal conductance decreases downward through the canopy of Amazonian rainforest. Using a multi-layer approach and measured profiles of stomatal conductance and weather variables through the canopy, good agreement can be obtained between calculated and observed values of dry canopy evaporation. The relationship between the biological response of stomata to radiation at the leaf level and the response of surface conductance to radiation above the canopy is derived by relating the profile of stomatal conductance through the canopy to the attenuation of radiation. Simple use of responses derived at leaf level will greatly overestimate surface conductance if used with above-canopy radiation measurements.

Three models of surface conductance of the same Amazonian forest, varying in their degree of complexity, were tested against measured evaporation data for the Reserva Ducke forest in Brazil. A simple model with surface conductance varying only with time of day was found to model the observed data slightly better than a more complex environmental model. Using a constant value of surface conductance gave a poorer fit to the data, although the average evaporation can be calculated accurately. It is recommended that the more complex environmental model be used when estimates of evaporation are required under any conditions substantially different from those of the central Amazonian forest where the data were collected.

Q. J. R. Meteorol. Soc. (1991), **117**, pp. 749–760 551.508.72:551.573:551.584.42(662):551.501.4

Measurements of evaporation from fallow Sahelian savannah at the start of the dry season

By J. H. C. GASH, J. S. WALLACE, C. R. LLOYD, A. J. DOLMAN,
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(Received 26 June 1990, revised 12 February 1991)

SUMMARY

Micrometeorological measurements of evaporation were made for the first six weeks of the dry season at a fallow savannah site in the Sahel. The evaporation fell from typically 4.5 mm per day at the start of the dry season to 1.5 mm per day six weeks later. The surface conductance was modelled in terms of empirical functions of time of day, and the number of days since the final rain of the season. It was found that there was little variation in surface conductance within each day, with no significant correlation with solar radiation and only a weak correlation with humidity deficit. Daily values of the surface conductance necessary to estimate the actual evaporation, from the data provided by a standard climate station, were also derived.

Q. J. R. Meteorol. Soc. (1991), **117**, pp. 1325–1340 551.573:551.511.61:556.132.6

Lagrangian and K-theory approaches in modelling evaporation from sparse canopies

By A. J. DOLMAN and J. S. WALLACE
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(Received 29 November 1990, revised 13 May 1991)

SUMMARY

An evaporation model based on Lagrangian turbulent diffusion principles is developed and compared with simpler single- and dual-source K-theory models of evaporation. The performance of the Lagrangian model is assessed against observations of total evaporation by an eddy-correlation instrument and found to be satisfactory for a millet crop in west Africa. Three versions of existing simpler models containing K-theory descriptions of within-canopy turbulence are described and their results also compared. The two K-theory models that explicitly take into account the soil source perform better than the single-source Penman–Monteith model. A Lagrangian analysis does not seem to be necessary for this kind of crop because the low source-density profile of the crop, associated with a low leaf-area index, caused the near-field effect to be very small. The overall difference between the evaporation estimates of the dual-source and Lagrangian models is therefore small. It is concluded that, for practical purposes, K-theory remains an adequate approximation of turbulent transport in sparse-crop evaporation models.

ESTIMATES OF SENSIBLE HEAT FLUX FROM OBSERVATIONS OF TEMPERATURE FLUCTUATIONS

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(Received in final form 7 May, 1991)

Abstract. Comparisons between sensible heat flux measured using eddy correlation instrumentation and estimated using the temperature fluctuation method are presented for four types of surface in West Africa. Agreement between measured and estimated values is good. Regression of estimated on measured sensible heat flux gave a mean slope of 0.98 with a mean r^2 of 0.94 for bare soil, mature millet, fallow savannah and tiger bush. Estimates of heat flux from temperature fluctuations measured by an instrument mounted beneath a tethered balloon are also shown to be in close agreement with eddy correlation measurements made at the surface (regression slope = 0.98, $r^2 = 0.84$). The results provide evidence that the ratio σ_θ/θ_* is indeed a universal function of z/L for all the surface types considered.

Boundary-Layer Meteorology 57: 311–322, 1991.

Q. J. R. Meteorol. Soc. (1992), 118, pp. (XXX)–(XXX) (XXX) (XXX) (XXX)

The parametrization of rainfall interception in GCMs

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[1]Institute of Hydrology; [2]Hadley Centre of Climate Prediction and Research, Meteorological Office, Bracknell, U.K.

(Received 23 April 1991, revised 1 August 1991)

SUMMARY

Experiments with a one-dimensional version of the Meteorological Office's 11-layer GCM are used to derive a simple calibrated subgrid parametrization of rainfall interception by the Amazonian rain forest. Two interception parametrizations, both incorporating subgrid variability of precipitation within a GCM grid box are presented and tested, and compared with observations made at a single location. The 1-D model is a fully interactive atmospheric column and incorporates all the GCM physics but is forced at its boundaries by climatic data. The interception losses appear to be sensitive to what fraction of area in the GCM grid box is covered by the rain and to the precise formulation of the interception process. The implications for the parametrization of the wet area in a GCM grid box are discussed and suggestions are made as to how to parametrize the fraction of wetted area in a GCM grid box

A NOTE ON AERIALLY-AVERAGED EVAPORATION AND THE VALUE OF THE EFFECTIVE SURFACE CONDUCTANCE

Journal of Hydrology, in press

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ABSTRACT

The sensitivity of regional evaporation to spatial variability in surface conductance is investigated for vegetation with a fixed aerodynamic resistance. The effective surface conductance is shown to be a function only of the aerodynamic conductance and the probability density function, which describes the variation in g_s. Assuming a gamma probability distribution suggests fractional differences in evaporation and surface conductance which are typically less than 10% on average. Areal evaporation from dry regions is shown to be more sensitive to the spatial variability than evaporation from wet regions.

AERODYNAMIC ROUGHNESS OF AN AREA OF NATURAL OPEN FOREST IN THE SAHEL

SUBMITTED TO ANNALES GEOPHYSICAE
(17 December 1991)

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ABSTRACT

The determination of roughness length is described for an area of natural open forest (tiger bush) in the Sahel. It is observed that the estimated roughness length increases from a value of 0.44 m to 0.84 m with increasing height. The velocity profile in the lower part scales locally with the friction velocity as estimates of friction velocity derived from the profiles compare well with those from an eddy correlation instrument. The implications of these findings are discussed in the context of estimating adequate regional values of roughness lengths for use in large scale numerical models.

EFFECTIVE RESISTANCE TO SENSIBLE AND LATENT HEAT FLUX IN HETEROGENEOUS TERRAIN

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ABSTRACT

Numerical weather prediction models resolve mean variables at the scale of their grid length only. Effective surface parameters must therefore be used to relate the mean properties of humidity, temperature and wind speed to the mean surface fluxes. The effective parameters can be calculated using a finer grid model. In this paper, effective aerodynamic and surface resistances to sensible and latent heat flux for a surface which varies over a horizontal scale of one kilometre, are calculated from a two-dimensional model with a grid size of 30m and compared with simpler averaging techniques. The averaging techniques considered include taking the mean of the aerodynamic and surface resistances in parallel or in series, the mean of the solutions given by these two, and a heuristic model, which treats the different surface covers independently but assumes they are exposed to the same mean meteorological variables at a blending height. The heuristic model estimates the effective resistances consistently accurately but, in comparison to the other methods, requires more information.
For heterogeneous surfaces, the effective parameters for momentum and sensible and latent heat transfer do not bear the same relationship to each other as they do for homogeneous surfaces. Effective parameters for each type of flux therefore have to be calculated separately. In situations where negative sensible heat fluxes occur over rough ground, the effective resistance to sensible heat flux can be very large, becoming undefined in the extreme case where the area-average sensible heat flux is zero.

A PRELIMINARY STUDY OF EVAPORATION FROM PARTIALLY WETTED MESO-SCALE AREAS

Progress report 1991 ALLIANCE project
Mesoscale modelling with spatially variable surface conditions
28 June 1991

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SUMMARY

Results of the initial phase of the Alliance project "Mesoscale modelling with spatially varying surface conditions" are described. A mesoscale model was used to simulate weather patterns on the 5th June 1986 during the HAPEX-Mobilhy experiment in south-west France. The model is capable of simulating realistically the structure of rainfall as occurred in the observations. Some differences are observed in the actual timing and location of the front. The results obtained by two sensitivity test suggest that the roughness length of the vegetation is important in determining the location of the front and that high evaporation rates from wet canopies may enhance rainfall through a positive feedback loop with atmospheric humidity. The results of the model runs are of sufficient quality to be used in the next phase to develop averaging schemes for evaporation from partially wetted mesoscale areas.


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