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PROBLEMS OF VALIDATION OF HEAT AND MASS TRANSFERS MODELS

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PROBLEMS OF VALIDATION OF HEAT AND MASS TRANSFERS MODELS

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I. INTRODUCTION

The surface layers of the soil are directly subjected to climatic conditions (heating, evaporation) and soil tillage. The variations of soil moisture of the top layers are important in regards to :

- compaction of the soil : dry soils have distinctly different properties than wet soils.
- seed germination and root growth : both of these phenomena are highly sensitive to soil temperature and soil moisture conditions.

Consequently, it is necessary to understand heat and mass transfers in soils and to have physical and mathematical models of prediction.

II. PHYSICAL BASIS OF HEAT AND MASS TRANSFERS IN SOILS

The theory of heat and mass transfers in soils presume the following underlying hypothesis :

1- generally the soil surface is considered as a horizontal plane.

2- heat and mass transfers are modeled presuming that the direction of water and heat movement is vertical. The functions $K(\theta)$ and $\psi(\theta)$ are also presumed to be without hysteresis.

3- at any given time the water potential in both the vapor and the liquid phases are equal at a given depth.

According to these hypothesis, the combination of mass and energy balances with transfer equations leads to obtain a system of heat and mass transfer equations in both the liquid and the vapor phases.

Transfer equations are obtained using Darcy's law for the liquid phase, Fick's law for the vapor phase and Fournier's law for heat conduction.

The energy balance at the soil surface presents a physical and mathematical condition at the top of the system. Therefore, it is necessary to calculate or to know turbulent sensible heat flux, latent heat flux and heat conduction into the soil.

III. FORMING AND VERIFYING MODELS OF HEAT AND MASS TRANSFER

A numerical model based on the finite elements methods was developped. Generally, the most important soil physical properties are well presented by these models. For exemple, self mulching is well known from field data and is also well predicted by the modelds.

In view of the validation of the model, an experiment on a field of 1 ha was made by the Soil Science and Bioclimatology department of Institut National de la Recherche Agronomique and Institut de Mécanique de Grenoble.

The experiment was performed on a field with a regular grid layout. At different points on the grid, measurements were made in order to estimate water balance, water potential relations, transfer coefficients and temperature and water profiles.

Concerning these differents criteria, experimental data are presented. For example, it is shown that the spatial variability of water-potential relations is not very important. But the saturated hydraulic conductivity shows variations from one point of the grid to another and also between the top of the soil and the bottom. In this case, it is important to have a model that is able to simulate heat and mass transfers in the multilayered dimension.

In the field, it was shown that the water content profiles had a constant variability during the experimental period.

The difficult points to solve for are :

1- The measurement of heat conductivity ; because the estimation of heat conductivity from temperature profiles presumes only heat conduction which is not the case given also that mass transfers in the vapor phase have heat flux as well.

2- The measurement of the vapor transfer coefficient into the soil and its' importance in relationship to overall mass transfers.

For these reasons, validation of heat and mass models will require a period of calibration in view of estimation of these transfer coefficients followed by a period of simulation of heat and mass transfers.

IV. CONCLUSION

The validation of mass transfer and heat transfer models requires sophisticated field experimentation.

At the parcel level however the prediction which represents the average situation is what is sought.

It is thus necessary to utilize equipment capable of measuring the principle sources of spatial variability.