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WORKSHOP ON REMOTE SENSING TECHNIQUES WITH APPLICATIONS TO AGRICULTURE, WATER AND WEATHER RESOURCES

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SOIL ATMOSPHERE PROCESSES

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1.- Introduction

Nowadays we are able to get a tremendous volume of information from satellites and it is an open question how it can be beneficially digested and used.

We may use them as photographs or, using modern technology, put them into the computer. At the same time, we have seen the development of powerful physical-mathematical models which attempt to describe the physical processes in the world around us. Our goal is to take advantage of the physical-matematical models which attempt to describe the physical processes in our own enviroment.

For these models, additional land-surface data are needed, because of their more detailed representation of surface processes. There exists an interrelation between the large- scale land-surface properties and climate, and a possibility of feedbacks, through which land-surface induced by climate changes may accelerate or decelerate these changes. This has to be explored thoroughly, because it is a central question within the climate complex. In Figure 1 we may follow the main link.

For the study of such processes, information is needed about the real world in order to:

- develop mathematical approximations which correctly describe the processes that occur.
- check on the realism of computer models at different time scales
- run computer models in order to identify the critical parameters in the system and to analize the impact upon the system if such parameters are changed.
- initialize computer models if they are used to predict fu ture changes.

A closely related question is how the vegetation reacts if the temperature and precipitation patterns change and how agriculture, water and renewable energy resources are af fected by climate variations, which may be enforced by the raising amount of radiatively gases in the atmosphere and modification of land-surface characteristics.

An additional complication is introduced into the climate system by the action of mankind. Since man is chang ing the biota of the continents to a large extent, he may already interact with the climate system through the altera tion of the surface conditions. There would be only one way of assesing these changes rapidly and on a global scale: by means of satellite observations. It presently seems promis ing that measurements from satellites are capable of detect ing and quantifing modifications of the land-surface that may become evident in changing soil properties, vegetation, erosion or desertification. There are also models under development which aim to predict enviromental and e.g. yield changes in dependence of climate trends. It is this area that in the first instance motivated scientist to improve the methods of satellite data evaluation in order to provide the diagnostic and model supporting data for climate impact studies.

A project was established to conduct basic research to im prove our understanding of the processes involved in the in teractions between the biosphere and the atmosphere with the aid of measurements from satellites. Namely, the Interna tional Satellite Land-Surface Climatology Project (ISLSCP, 12 references). It is part of more general efforts to clarify the role that changes the land-surface characteris tics play in climate. The prime goals of the project are to direct research into the deduction of climate relevant in formation about the land-surface from the measurements made by different satellite systems, and to prepare the ground for a multi-year homogeneous and validated data set of several key quantities which can be used in climate studies.

A research programm that adresses this problem globaly may develop in four components:

1. Adaptation of existing soil-vegetation-atmosphere models and their refinement with respect to hydrometeorological and plant-radiation interactions.

2. inference of area-averaged physical-biological land- surface characteristics from spectral radiances measured by satellite-borne

instruments.

3. Validation and callibration of the methods that are used to extract this information and of the parameterization schemes used iclimate models by means of direct measurements at the ground.

4. Sensitivity studies of interactions between the land- surface and climate using climate models in order to narrow down the requirements for type, accuracy and frequency of the satellite observations.

The land surface characteristic parameters which govern energy exchanges at the earth surface are presented in the simplified scheme of Figure 2 which is equally valid for a local scale (as usually considered) or a larger scale cor responding to satellite resolution.

Land surface parameters which govern energy and water exchanges at the earth's surface

The land surface characteristics parameters which govern energy exchanges at the earth surface are presented in the simplified scheme of Figure 2. In Figure 2, R_g and R_a are the global incoming solar (shortwave) and atmos pheric (longwave) fluxes; H and LE are sensible and latent heat fluxes; G, the flux in the soil; R_n the net radia tive flux; T_a, e_a and u_a, the air tempera ture, the relative air moisture and the horizontal wind speed at an altitude z_a; T_s, the surface temperature; e_s, the relative surface moisture; T_g, the soil moisture at depth L; σ, the Stephan-Boltzman constant; a, the surface albedo; ε, the surface emissivity; z_o, the surface aerodynamic roughness; λ and C_p, the thermal conductivity and heat capacity of the soil.

For a given set of boundary conditions (both corresponding to atmospheric air mass T_a, e_a , u and depth soil T_g, Θ_g characteristics) the response to the input of downward radiative fluxes R_g and R_a by the combination of energu budget and water balance, imposes to a surface defined by its properties (a, ε, z_o) and the underlying soil thermal and hidraulic characteristics (λ, C_p, C_Θ, K) an in stantaneum equilibrium which results in exchanged fluxes (R_n, G, H, LE) and surface temperature and moisture (T_s, e_s).

From that description, three kinds of land surface parameters appear as useful for the assesment of energy exchanges:

- Those which define the surface itself and may be con sidered as inputs in climate modeling (namely albedo a, emissivity ε, aerodinamic roughness z_o, soil thermal inertia $\sqrt{\rho\lambda C_p}$ and soil hydraulic characteristics (C_s, K_s);
- Those which express the state of equilibrium (T_s,e_s) or the resulting fluxes (R_n, G, H, LE) which rather respond to outputs of the system;
- Those which allow to monitor the spatial extent to surface coverage; vegetated areas using vegetative indexes, open water areas and their evolution, snow cover and snow water content, ice, sand transportation, etc.

The Use in Climate Modeling

As previously mentioned, these parameters which govern surface processes are frequently involved in climate modelling at various scales (large scale in GCMs, mesoscale in mesos cale models and local in current simulations), but they are generally guessed or simulated using very single extrapola tion procedures without precise assessments, except for lo cal scale experiments. Their possible derivation from space opens new perspectives in climate modeling, that we propose to classify in 4 categories:i)derive measured sets of land surface parameters to be used as inputs in climate models, ii)validate outputs of simulation studies, iii) test the validity of approximative relations assumed between inputs and outputs from direct measurements on large scales, iv) allow the modeling of physical processes like evaporation.

These four levels can apply to every kind of climate modelling or simulation, but they may be more easily exposed as an illustration for a specific case study as for in stance, the well-known problem of Charney feedback mechanism for explaining the drought enhancement by the reduction of rainfall in the border of deserts (Charney, 1975 and 1977).

The List of Relevant Parameters

Among all the cases studied, the high interest goes to the following parameters: a, ε, for surface characteristics; T_s as a consequence of the equilibrium state; R_n and LE for climate modelling. Let us add that, if we compare that list to the previous list of parameters which govern energy exchanges at the surface, only one is omitted, namely the roughness parameter z_o. Its direct inference from satellite observations is not presently ac cesible, principally because its exact definition is purely derived from aerodynamic considerations. Some relation with the mean height of surface elements has been empirically derived by various authors which also implies some link with albedo. There is some hope for the future, but no precise research has been done.

The determination of land surface parameters For this purpose, meteorological satellites (Meteosat, GOES, NOAA, etc.) are the most convenient. This convenience arises from their time-frequency (half hour or 12 hours) and the lower spatial resolution and wider coverage.

The derivation of surface albedo is possible through dif ferent methods from METEOSAT (Pinty et al, 1985; Dedieu et al, 1987; Vukovich et al, 1987) and, in general, they are able to get a precision of the order of plus or minus 0.05. The surface temperature and emissivity are closely linked from the well known Stefan-Boltzman law. Most of the authors take $\varepsilon = 1$. This leads to about one degree of underestimation for surface temperature (remember that 0.01 error in emissivity gives an error of 0.2° C (See Galli et al, 1982; Price, 1983; Seguin et al, 1988; Lagouarde et al, 1986).

To give some values, we have to mention here that despite of a higher agreement with corrected values, the comparison be tween ground and satellite values still displays about5° of uncertainty in some cases. Of course this difficulty may be due to the comparison of ground surface measurements on some square meters to satellite estimates on a more than 30 km^2 scale.

The situation is more favorable with NOAA data, where the avaiolability of two channels in the thermal IR allows us to use the "split-window methos". The agreement is generally satisfactory for sea surface temperatures estimates (within 1° C), but the adaptation to land surfaces is less straightforward. Lagouarde et al (1986) mentioned 3 to 4° C of underestimation. Anyway, it is hoped that studies in progress will allow to estimate land surface tem peratures within 2° using atmospheric corrections based on TOVS.

The computation of surface fluxes characterize the soil atmosphere interfase. Due to its almost nothing thick, the best way to know its "ghost" temperature is to measure the fluxes from it. There are different ways to attack the problem. We will present here an atmospheric boundary layer model approach, with the goal to compute regional evapotranspiration through soil moisture availability.

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CLIMATIC CAUSE-AND-EFFECT (Feedback) LINKAGES

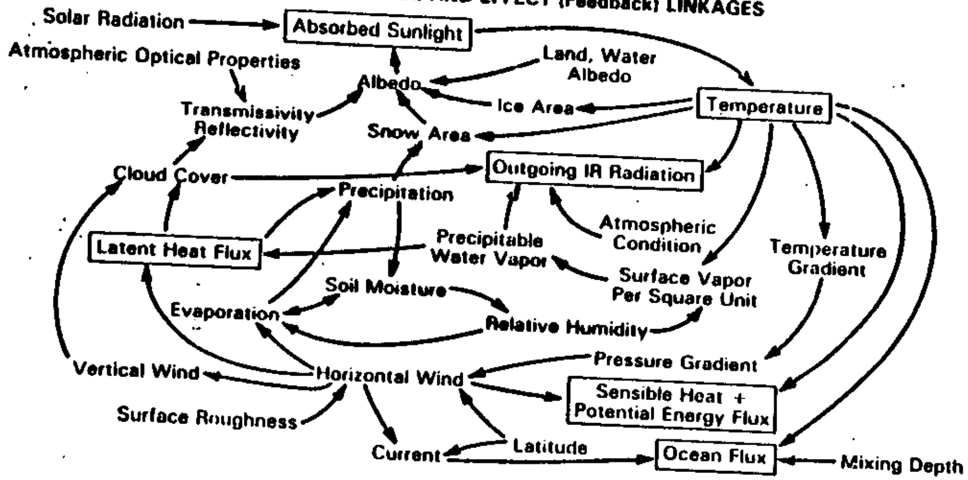

FIGURE 1

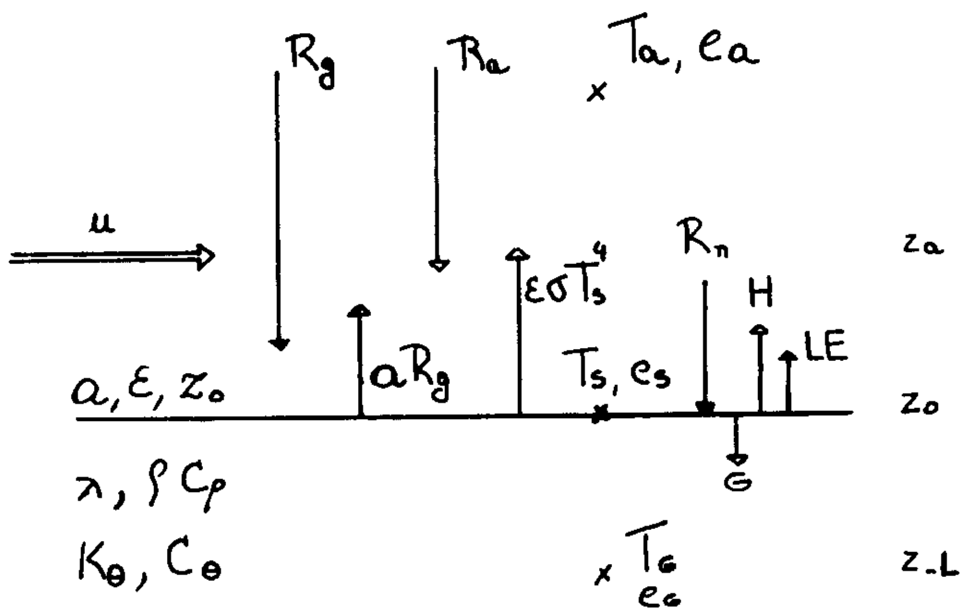

FIGURE 2