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REMARKS ON ENTROPY AND ADVECTION IN EVAPOTRANSPIRATION PROCESSES

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When dealing with energy flux at the soil-atmosphere interface, it is costumary to introduce a term for advective energy in order to match the energy balance of the soil-plant-atmosphere system. While the computational aspects of the problem seem correct, the representation of the process seems too superficial.

Let us consider an isolated (adiabatic) system as shown in fig. 1a. The walls A-B-C-D-E-F-G-H are perfectly isolating; the surface AF of a wet soil is in contact with the air in chamber 1 (ABCF); this air is initially unsaturated, i.e. at relative humidity (in fraction) $RH_o < 1$. Chamber 2 (CDEF) contains air at the same RH_o and is separated from chamber 1 by the wall C-F which is air impermeable but not heat isolating. The system is initially at uniform temperature. The walls themselves are not considered as a part of the system.

Starting from time t = 0 the liquid water at the soil surface evaporates into chamber 1, due to the low water potential here (stage 1). This implies subtraction of sensible heat inside the system (latent heat of vaporization) and the whole system cools. Evaporation and cooling will cease when the water total potential becomes uniform throughout soil and chamber 1.

When this equilibrium (thermal and hydrological) is reached, let us modify the system as shown in fig. 1b (stage 2) so that its internal energy remains unchanged. We might imagine letting the box A-B-C-D-E run frictionless on horizontal rails without doing any kind of work(1).

Chamber 2 is now on the soil and this will resume evaporating

(1) Note that in a less schematic way an analogous process would occurr by simple removal of wall C-F after the 1st equilibrium stage was reached. We shall not take into account for our purposes the slight differences in total pressure between chambers built up by the evaporation process.

because of the lower RH of this chamber compared to that of the removed chamber 1. The system cools again and the soil drys to a new equilibrium.

The modification from stage 1 to stage 2 does not imply any energy exchange between the interior of the system and its surroundings (including the walls). The process occurring during stage 1 in this isolated system involves increase in entropy; the process ceases when increase in entropy is no longer possible (equilibrium conditions). The real nature of our shifting the system from stage 1 to stage 2 consists in making available for further evaporation the low entropy condition represented by keeping chamber 2 separated from the rest of the system; now soil plus chamber 2 again have the chance to increase their total entropy (some heat will also be drown out of chamber 1 through wall C-F).

The interesting point is that a promoting of evaporation has been brought about in passing from stage 1 to stage 2 by bringing over the soil an air mass at low entropy and not using its energy. We have "renewed" the sink for the vapor, while the energy for the evaporation was taken out at the evaporation site by the process itself and the energy of the incoming (advective) air had practically nothing to do with the process.

Let us imagine changing repeatedly the chambers over our soil with new chambers at initial, low values of RH_o. If RH_o is sufficiently low and the soil sufficiently wet, the temperature will decrease to very low values.

Consider now an open system (fig. 2) in which over the soil surface a uniform flow of unsaturated air (low RH_o) at constant temperature (equal to the initial soil temperature) is gently blown and there is no radiant energy from outside. The soil starts to evaporate and this process is sustained by the "negative entropy" flux associated with the air flow. The soil cools but, in this case, some heat will be transfered from the flowing air to the soil. If the water feeding of the soil is adequate and constant for a certain time, a steady state temperature regime will be set up so that the temperature at the evaporating sites in the soil remains constant in that the air releases an amount of heat equal to that used for water vaporization. In these steady evaporation conditions, the evaporation from the

soils would appear driven by advective heat only.

At a certain moment let us reduce abruptly the air flux on the soil. The evaporation rate is expected then to slow down gradually to a new equilibrium rate. The temperature should vary too, but the sign of this variation can be positive or negative according to the difference in rates of heat release (sensible heat) from the air to the soil and heat absorption (latent heat) for vaporization. If the air is sufficiently dry and the very slow air speed, there will be further cooling of the soil. If the air flow completely stops, the situation (at least temporarily) becomes rather similar to the one previously discussed in fig. 1, although the boundary conditions are now not well defined.

It is of interest to observe that while steady conditions, like those shown in fig. 2, are easily treated with energy balance concepts, all transient conditions from one to another steady or equilibrium condition are more readily explained in terms of "possibility of furthering the process", which is conceptually more directly related to entropy than to energy concepts, although no simpler to deal with quantitatively.

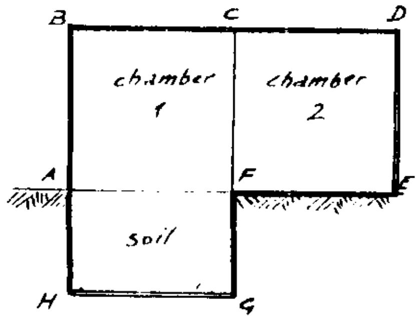

fig. 1a

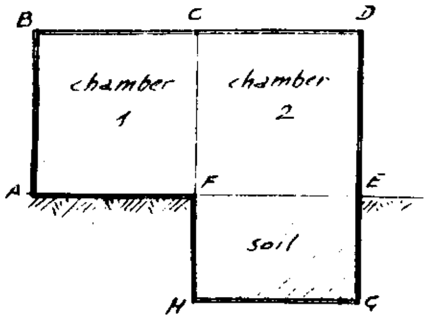

fig. 1b

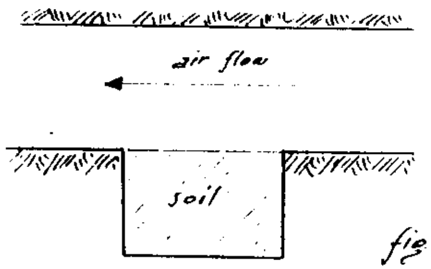

fig 2