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Interaction between multi-layer vegetated surface and atmosphere: an introduction to modelling with Fluent

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Motivation:

From the perspective of global exchanges, the domain of semi-arid or arid Mediterranean zones is large and interesting. The surface they occupy is vast and their exchange processes, particularly sensible heat, play an important role. Furthermore, in such regions, a lot of specific surfaces could be used for human activities if more water remained available. To fight against outside advective aridity and to reduce stronger solar energy, oases are developed, which are complex and efficient multi-layer systems (soil–vegetation–fruit-trees and palm-trees) which allow production. These systems diminish inside aridity, modify mass and energy budgets, reduce the needs in irrigation and enhance water efficiency of agricultural production. In order to apprehend quantitatively the oasis as a system, with a detailed knowledge of the processes leading its exchanges with the atmosphere, we choose to use a CFD tool to describe with precision the structure of the canopy, from the top (shape of crowns) to the bottom (soil roughness) and to simulate a flow inside an oasis.

Methods, Tools:

Our choice was for the software FLUENT and its k-ε model. We assess the ability of this tool to respond to our needs.

Firstly, we show that Fluent can reproduce the bidimensional structure of an adiabatic, stable atmospheric boundary layer (ABL). (a) The model is typically conform to the ones used in local studies of atmosphere dynamics. (b) The profiles obtained match

with theory when boundary conditions and grid are well chosen.

Secondly, we show that Fluent can simulate the interaction between the roughness of a surface and the structure of the roughness layer: we study the laws linking the classical gauges of momentum absorption (C_d, u_*, z_0, d) to the geometry of obstacles over a surface (roughness density). Obstacles used are idealized transverse dunes of varying heights. Then, in order to take into account the horizontal spacing of obstacles such as trunks, branches, leaves, above soil surface, we extend this work to porous medium with obstacles. To assess the validity of the previous laws through such complex medium, "porous walls" are used.

Results:

Therefore, different 2D simulations of the flow inside and outside idealized structures of palm stand are compared, in each of which three budgets are linked: (i) turbulent momentum budget (ii) energy budget (iii) water mass budget. We show the classical "oasis effect" for momentum through the different layers until soil surface or vegetation surface and assess the global roughness of the system. We study the link between the oasis structure (ie scaling parameters such as the sizes of trees and surface vegetation, spaces between trees and leaf density or Leaf Area Index for surface vegetation) and turbulent transfer of momentum (spatial variation of the mean wind speed, of the turbulent momentum flux, and other turbulent quantities).

The second step will be the description of water vapour and temperature profiles according wind and evaporation fluxes from local to global system. A comparison with an analytical model will be done.

Prospects:

Some of the prospects of this on-going work are:

(i) to assess the weight of horizontal or vertical heterogeneity of a canopy structure on the different budgets and on the microclimate of this system;

(ii) with this knowledge and the help of some crop model (continuum soil- plant- atmosphere), to assess the effects on water needs for plants and the water used efficiency (and therefore study the crop coefficients);

(iii) to study the regional impact of such systems on vegetation-atmosphere exchange, and thus improve their regional parameterization for GCMs.