Implementation of PLACE Land Surface Hydrology in MM5

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1 Introduction

This paper presents the implementation scheme for coupling the land surface hydrology component of PLACE (Parameterization for Land-Atmosphere-Cloud Exchange) model [*Wetzel and Boone*, 1995] with MM5 version 1. This land surface model is one of the participants of PILPS [Project for Intercomparison of Land-Surface Parameterization Schemes, *Henderson-Sellers et al.*, 1993] and has its strength in accounting for land surface heterogeneity in soil moisture and vegetation through: (i) sub-division of a grid element into mosaics; and (ii) use of probability distribution function for soil moisture and plant resistance variabilities. In section 2 we present a brief review of the land surface hydrology component of the PLACE model. Section 3 describes the basic scheme of its implementation in MM5.

2 PLACE Land Surface Hydrology

The salient features of PLACE land surface hydrology (described in detail in *Wetzel and Boone*, [1995]) are:

1. The surface energy budget equation is given as

$$b_m \frac{\partial T_s}{\partial t} = R_{\rm net} - E - G - H$$

where $b_m \frac{\partial T_s}{\partial t}$ represents the energy storage by biomass and litter that has a water equivalent heat capacity given as b_m. The temperature T_s, which is assumed constant throughout the biomass layer, is equal to the soil surface temperature. It also serves as upper boundary condition for the computation of soil heat flux, lower boundary condition for the computation of sensible heat flux, and the skin temperature for the outward longwave radiative flux computation.

2. The available surface water is held in seven reservoirs of plant internal store, dew/intercepted precipitation, surface soil layer, two root zone soil layers and two deep soil layers. The lower two layers regulate long term availability of water while the top five layers provide water directly for evapotranspiration. The evaporative flux (E) computation allows for the simultaneous calculation of potential and demand limited rates from both vegetation and bare soil. The averaged flux for each mosaic is computed using an assumed distribution for both soil moisture and vegetation resistance.

3. The ground heat flux (G) is computed using the soil temperature flux equation

$$G = \gamma \frac{\partial T_g}{\partial z}|_{z=0}$$

where $\frac{\partial T_g}{\partial t} = \kappa \frac{\partial^2 T_g}{\partial z^2}$, $\kappa = \frac{\gamma}{C_s}$ and $T_g|_{z=0} = T_s$. T_g is the temperature of the soil, κ the soil thermal diffusivity, γ the soil thermal capacity and C_s the volumetric heat capacity of the soil which is a function of the volumetric soil moisture. The temperature is computed at seven layers using an implicit time differencing scheme.

4. The sensible heat flux (H) is computed using

$$H = \rho c_p \frac{\theta_s - \theta_m}{r_l + r_a}$$

where ρ is the air density, c_p the specific heat of air at constant pressure; θ_m and θ_s are the virtual potential temperatures of the bulk boundary layer and at the surface, respectively; and r_a and r_l are the aerodynamic and laminar resistances.

All computations are performed for each mosaic independently and the grid level fluxes are computed as the area weighted average of each mosaic inside a grid element.

3 Implementation Scheme

PLACE land surface hydrology is a one dimensional model with no transport of fluxes between either grid elements or between mosaics within a grid element. It is implemented in MM5 as such, i.e., as an one dimensional model at every grid element of the MM5 computational domain (or nested domains). For this to be feasible, initial state variables (such as soil moisture in each soil layer), and vegetation and soil characteristics need to be specified for each mosaic of every grid element. To accomplish this a pre-processor called PRE-PLACE is developed whose objective is to provide these values through a file that can be read by the coupled MM5-PLACE model. The hierarchical location of PRE-PLACE in the general scheme of the coupled model is shown in Figure 1 and details of the implementation are shown in figure 2 and are discussed below.

3.1 PRE-PLACE

The pre-processor is concieved such that it can be developed as a tool to provide initialization for the hydrology model using sophisticated techniques and other data (such as STASGO). At this time, however, vegetation and soil characteristics, and initial conditions are specified as a function of the 13 vegetation classses already used in MM5. The important vegetation characteristics that are needed are:

- The albedo, roughness length and emissivity of the surface.
- The heat capacity of the boimass layer for vegetation alone.
- The area averaged dew and/or intercepted precipitation on the surface.
- The fraction of the surface covered by green transpiring vegetation.
- Critical water potential at which stomata close due to water stress.

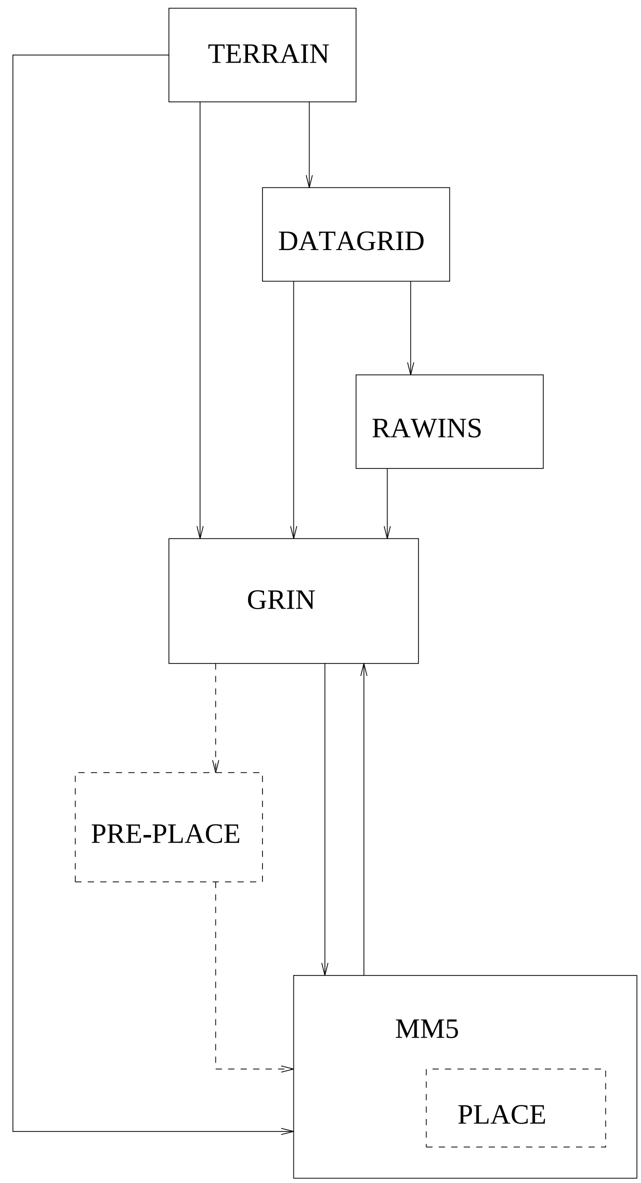

Figure 1: Schematic showing the hierarchical location of PRE-PLACE in the general MM5 model structure

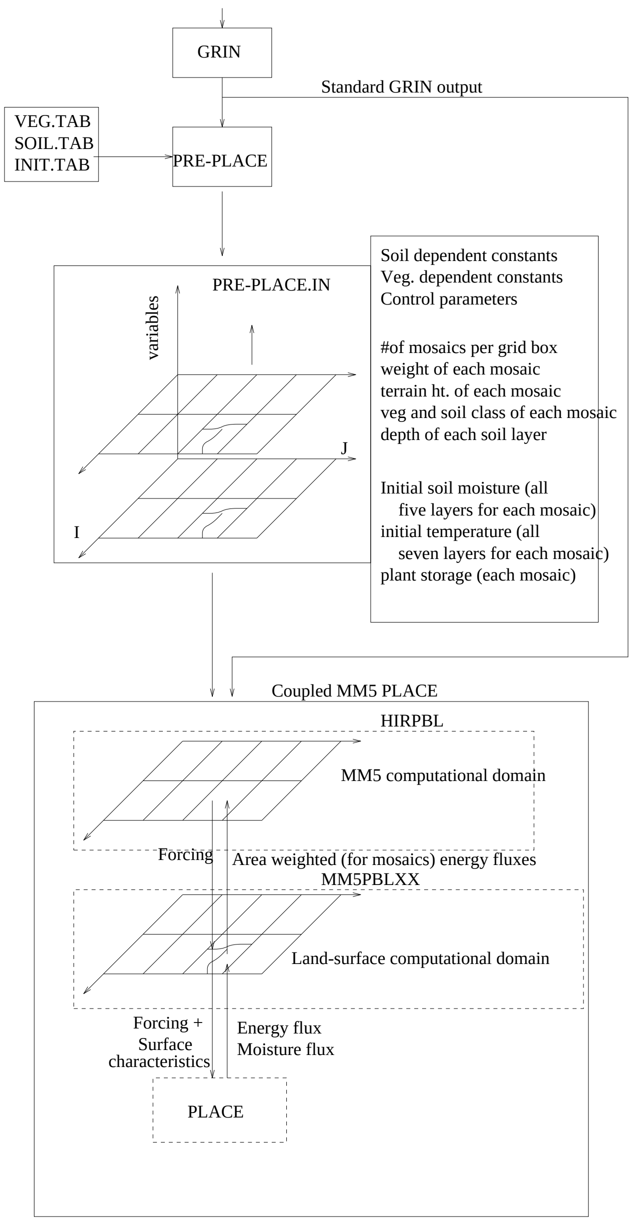

Figure 2: Schematic showing the detailed structure of the output of PRE-PLACE and the coupled structure of HIRPBL and PLACE through the interface routine called MM5PBLXX

- Minimum and maximum stomatal resistance.
- Internal plant resistance between root and leaf.
- Fraction of roots in the topsoil layer.

The important soil characteristics that are required are:

- Albedo of bare soil.
- Hydraulic conductivity at saturation and Brooks-Corey power parameter.
- Standard deviation and coefficient of variation of volumetric soil water content (for all soil layers).
- Field capacity, and wilting and saturation point soil water content.
- Saturation soil water potential.

The above information along with initial conditions (as a function of vegetation class) and some constants are read in by PRE-PLACE through lookup tables. It also reads in vegetation class, initial snow cover and surface temperature at each grid element from front end GRIN output and combines it with those of the lookup tables to specify the necessary parameters for each mosaic of a grid element and creates the input file for initialization of the hydrology model (see Figure 2).

3.2 Coupled MM5 and PLACE model

The one dimensional PLACE land surface hydrology model is coupled to MM5 through the Blackadar high resolution planetary boundary layer routine (HIRPBL). The PLACE model is driven by the forcings obtained from HIRPBL at the lowest σ level. The forcing variables are

1. downward short and long wave radiation;
2. lowest σ level temperature, wind velocity, presure and specific humidity;
3. surface level precipitation;
4. pbl height and height of the lowest σ level.

The interface between HIRPBL and PLACE, called MM5PBLXX, assigns a common forcing to all mosaics within a given MM5 grid box and also computes the area weighted (over the relative weights of the mosaics) enery flux for each grid box and passes it back to HIRPBL. The variables that are passed back are:

1. latent, sensible and ground heat fluxes;
2. ground temperature.

In addition to these, several prognostic and diagnostic variables of the land surface component (such as water stores in each reservoir, temperature in each layer, runoff, base flow etc.) can be output for post-processing.

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