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Direct estimation of stomatal resistance for meteorological applications

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Abstract. Stomatal Resistance (*Rs*) is one of the most important parameters in the meteorological models for weather or climate analysis and hydrological scenario estimations. The information for estimating Rs is sparse particularly in the tropics limiting the development of a detailed global terrestrial biosphere-atmosphere interaction analysis. One of the reasons for the scarcity of tropical data is the high cost of instrumentation. A hypothesis is presented to estimate Rs from plant-nutrient status in a field study using stomatal aperture observations to develop a simple, cost-effective technique for first-order estimations. Comparisons with observations from a tropical field experiment are encouraging and an approach is suggested using this method for initialization of numerical models using remote sensing techniques based on nitrogen, humidity, and temperature as sufficient parameters.

Introduction

Stomatal resistance (*Rs*) is a pivotal parameter for soil-vegetation-atmosphere transfer (SVAT) studies [*Niyogi and Raman*, 1997]. *Rs* quantifies the transpiration influencing the evapotranspirative or the latent heat flux (LHF). An error in estimating *Rs* propagates into LHF estimation, which due to energy-balance, propagates into the sensible heat flux (SHF) calculations [cf. *Baldocchi,* 1994]. This affects features at diverse scales such as boundary layer development *[Alapaty et al,*. 1997a], local circulation [*Pielke et al.*, 1997], cumulus formation [*Hong et al.*, 1995], and even global precipitation and vegetation changes [*Archer et al.*, 1995].

Rs is modeled based on either photosynthesis (*An*) calculations [cf. *Niyogi and Raman,* 1997] or by scaling a minimum stomatal resistance (Rs_{min}) [cf. *Jarvis,* 1976; *Alapaty et al.* 1997a; however also see *Monteith,* 1995]. The photosynthesis approach is apparently more mechanistic and correct but is iterative and computationally expensive. This makes the Rs_{min} or the Jarvis-type approach more popular in the operational meteorological models. Also, within the uncertainties for the input parameters at a regional scale [*Alapaty et al.,* 1997b; *Niyogi et al.,* 1997], the two approaches are hypothesized to provide similar *Rs* outcome [*Niyogi and Raman*, 1997]. However, to test such a hypothesis and to analyze the regional or global hydrological or energy budgets and ecosystem dynamics, one requires data under different geographical setups with regionally representative values for *Rs*. To realize this objective, rigorous measurements at the "grass root" level with high spatial and temporal resolution are necessary particularly in the tropics and the developing countries [cf. *Korner,* 1994; *Schulze et al.,* 1994].

Rs measurements through porometery or gas-exchange techniques have high precision and accuracy and hence a justifiable high cost. However, for a typical tropical research station in a developing country, the instrument cost could be prohibitive. This is one of the practical reasons for the paucity of good and continuous data for evapotranspiration and ecophysiological interactions for such regions. It is for this purpose that a cost-effective approach that would give approximate *Rs* values is required. The methodology described here is directed towards this objective.

Objective

In the Jarvis-type approach, Rs_{min} has to be assigned *a priori* in the models based on available literature [*Alapaty et al.,* 1997a] or back-interpolation studies [*Dorman and Sellers,* 1989] and has a large uncertainty [*Alapaty et al.,* 1997b]. Rs_{min} can be, however, a link for the physiological and phenological composition of the vegetation when the approach is towards a dynamic analysis [*Henderson-Sellers,* 1993]. Recently, *Schulze et al.* [1994; henceforth S94], reviewed the available literature and showed a correlation between the plant nutrient status [leaf nitrogen content: *N*] and maximum stomatal conductance (g_{Smax} : inverse of Rs_{min}) represented as:

$$g_{Smax}\ (\text{mm. s}^{-1}) = 0.3012\ N\ (\text{mg.g}^{-1}) \quad (1)$$

The S94 result is exciting, as it forms a basis of including a mechanistic, albeit correlational, feature for determining Rs_{min} in the Jarvis-type analysis for observations or model analysis. Within this perspective, our emphasis is on the following issues:

(i) How does the nutrient-based N-Rs_{min} relation of S94 perform under typical tropical field conditions?

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