J1.16 HYDROLOGICAL LAND SURFACE RESPONSE IN A TROPICAL AND A MIDLATITUDINAL REGIME

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INTRODUCTION: Despite compelling evidence that land surface processes have an impact both in the mid-latitudinal as well as the semi – arid tropical regions, there are unresolved questions related to the comparison of these two diverse regions. Some questions include, - how do the hydrometeorological / surface evapotranspiration features respond in these two different regimes? Is the strategy similar for the system to be in equilibrium both in mid-latitudes as well as water - stressed tropics? Are the land surface parameterizations sufficiently robust to handle these contrasting domains? Our intent is to address these questions and analyze the net direct and interactive surface feedback pathways using data from two specialized field experiments, one conducted in the semi-arid tropics (HAPEX-Sahel) and the other in the mid-latitudes (FIFE) using a soil vegetation hydrological scheme: Simplified Simple Biosphere (SSiB) Model. A series of statistical - dynamical experiments are performed using a combination of modeling and observational approach.

EXPERIMENTAL: For comparing the differences in the LSP response in the tropical and mid-latitudinal regimes, it is important to assess both the direct as well as indirect components of the feedback pathways. This is because often the direct (or the first order) and the indirect (or the interaction) terms can have similar magnitudes but different feedback pathways. Further, their tendency (or directions) can be such that the net effect is either additive or subtractive depending on the variable states. To explicitly resolve these direct and indirect effects, we adopted a “Level 3” or the Response Surface Methodology (L3RSM) based design. In the L3RSM approach, the system response is fitted to a second – order polynomial surface in terms of the experimental factors. The L3RSM experiment is a detailed interaction – explicit, nonlinear analysis, which resolves both the linear as well as the second-order nonlinear effects of the response. For the L3RSM using a modeling approach, the objective is to generate a matrix of results corresponding to different input variable settings: low ('-'), intermediate ('0'), and high ('+'). However, unlike a traditional one-at-a-time sensitivity-type analysis, the variables are assumed to alter simultaneously using different combinations. In our analysis, we developed two sets of experiments. In the first experiment, the model is centered over the FIFE region while in the second experiment it is centered over the HAPEX – Sahel domain. Six surface variables were systematically varied in SSiB following a matrix approach to develop 48 different combinations: soil wetness (*wet*), surface albedo (*alb*), minimum stomatal resistance (Rs_{min}), vegetative cover (*veg*), leaf area index (*LAI*), and atmospheric vapor pressure deficit (*vpd*). SSiB was run off-line for a 30-day period based on the FIFE and then HAPEX-Sahel observations as surface meteorological forcing (air temperature, humidity, wind, precipitation and net radiation). SSiB estimated fluxes for the FIFE and HAPEX – Sahel observations were analyzed for the indirect effects and indirect persistence. The methodology aimed at studying the contribution and cascading interactions of the surface variables (in this case: albedo, vegetal cover, leaf area index, soil moisture, surface temperature, and stomatal resistance) on the evapotranspirative fluxes because of the hydrological response of the LSPs. The output variables (latent heat flux and the evapotranspirative components) over HAPEX Sahel and FIFE region were analyzed for direct and indirect (first and second order) effects using a graphical analysis based on the main – effect, Pareto, interaction, and surface-response plots. Figures 1a and 1b show the sample Main effect and Pareto plots for the SSiB simulated evaporation rates over the FIFE region (in Fig. 1a), and the HAPEX – Sahel region (in Fig. 1b) respectively. The FIFE results generally indicate a relatively linear response to the surface variable changes as compared to the HAPEX Sahel area, where a strong nonlinearity is evident between the changes in the surface variables and the resulting response. Additionally, the pareto plots suggest that the interactions in the HAPEX Sahel region are dominated by soil moisture related linear and quadratic feedback effects while those over the FIFE show significant vegetation variable response as well.

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CONCLUSIONS: Summarizing the results from the two cases studied here, it is concluded that, the first-order or the direct pathways for the midlatitudinal and the semiarid tropical regime are fairly similar; while, the indirect or second - order pathways and interaction feedbacks are significantly different. Further, changes in surface variables have a significantly non-linear response on the latent heat flux. Also, the nature of the surface variable response is prone to be more non-linear for the semi-arid tropical case, as compared to the FIFE. Further, with regard to evapotranspiration as the effect, the interactive feedbacks are more active in the mid-latitudinal FIFE case as compared to the

HAPEX – Sahel case. This is true for both first as well as the higher order interactions. In general, the FIFE case is dominated by soil wetness related interactions while the semi-arid tropical / HAPEX- Sahel case shows vegetation related effects controlling the land surface response. An important feedback pathway is deduced from the analysis of the higher order interactions. With higher soil moisture values, as generally perceived for the mid-latitudinal domain, the soil wetness availability resulted in synergistic interactions with other surface variables. That is, there appears to be more communication between the various land surface variables through biophysical exchanges (including water vapor) in the moist mid-latitudinal regime. On the other hand, for semi-arid tropical regime, the results suggest, there are limited exchanges between the vegetation and the soil surface. That is, the surface components respond directly with the atmospheric forcing *via* limited modulation from vegetation to the bare ground. There can be several interpretations of this result. One, the interactions suggests, the mid-latitudinal vegetative transfer with higher moisture availability, may permit a diversified strategy for the surface. The relatively wetter mid-latitudinal conditions (as compared to semi-arid tropics) provide an opportunity for an efficient transfer and higher water use by the vegetation leading to higher fluxes. Additionally, it allows involvement and interaction of various biophysical as well as soil components, thereby creating a unified or effective resistance pathway. Thus, the mid-latitudinal vegetation and soil surface moisture transfer may be efficiently simulated by so – called *effective* surface representations schemes [in which soil and vegetation are represented by a single area – averaged surface. Conversely, since in the dry, semi-arid tropical regime there is limited interaction between the vegetation and the bare ground, the surface components may be individually linked with the atmosphere, and not as an 'effective surface'. Hence the single 'effective' or area-averaged vegetation and bare ground flux representation may have additional limitations in the semi – arid tropical conditions. This interactive or effective moisture feedback transfer strategy in the mid-latitudes, and the tropical one-on-one soil – atmosphere and vegetation- atmosphere transfer in the semi-arid tropics, can also be viewed in 'resource allocation' perspective. The unified response of the various components in the mid-latitudes, could play a balancing or compensatory role. A possible strategy is that, the midlatitudinal domain can try and sustain itself, or recover quickly, from external perturbations (e.g. drought) through synergistic interactions. On the other hand, for the semi-arid tropics, the different land surface in its 'non-diversified' approach cannot distribute its stress on the different surface variables. That is, the vegetation cannot expect sympathetic response from soil moisture and has to weather the stress independently. This lack of a unified strategy by the plants and soil as an effective surface could make the arid tropical region more prone to desertification and to a slower recovery from external perturbation, as compared to the mid-latitudes, under similar water stress situations.

Note: More details on this study can be found in:

Niyogi, D.S., Y.K. Xue, and S. Raman S.: 2001, Hydrological Land Surface Response In a Tropical and a Midlatitudinal Regime, *J. Hydrometeorology*, *in press.*

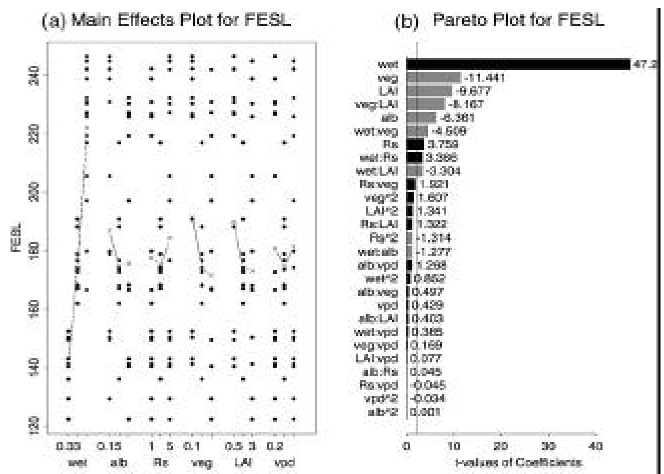

Fig. 1a Analysis Plots for SSiB simulated evaporative component over FIFE Domain. The response is generally linear for variable changes.

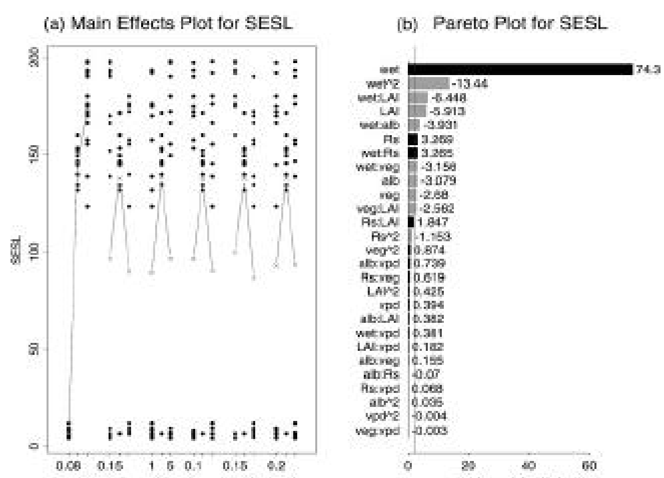

Fig. 1b Same as Fig. 1a except for HAPEX Sahel region. The response is generally non- linear for variable changes as compared to the FIFE case.