

# Soil Moisture and Snow Cover: Active or Passive Elements of Climate?

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## Abstract

Ensembles of predictability studies have been constructed using the NCAR CCM3 in which the relative roles of initial surface and atmospheric conditions over the central and western U.S. were compared in determining the subsequent evolution of soil moisture and of snow cover. Sensitivity studies were also made with exaggerated soil moisture and snow cover anomalies in order to determine the physical processes that may be important. Results with realistic soil moisture anomalies indicate that internal climate variability is the strongest factor, with the initial atmospheric state of lesser importance. The initial state of soil moisture is not important, a result that held whether simulations were started in late winter or late spring. Model runs with exaggerated soil moisture reductions (near-desert conditions) showed a much larger effect, with warmer surface temperatures, reduced precipitation, and lower surface pressures; the latter indicating a response of the atmospheric circulation. These results suggest the possibility of a threshold effect in soil moisture, whereby an anomaly must be of a sufficient size before it can have a significant impact on the atmospheric circulation and hence climate. Results from simulations with realistic snow cover anomalies indicate that the time of year can be crucial. When introduced in late winter, these anomalies strongly affected the subsequent evolution of snow cover. When introduced in early winter little or no effect is seen. Runs with exaggerated initial snow cover indicate that the high reflectivity of snow is the most important process by which snow cover can impact climate, through lower surface temperatures and increased surface pressures. In early winter, the amount of solar radiation is very small and so this albedo effect is inconsequential while in late winter, with the sun higher in the sky and period of daylight longer, the effect is much stronger. Subsequent accumulation of snow through the winter also helps to mask the original anomalies.

**Keywords:** climate; soil moisture; snow; drought; climate predictability

## 1. INTRODUCTION

The extent to which soil moisture and snow cover actively interact with the atmosphere leads to the possibility of a degree of predictability in precipitation at seasonal to interannual time scales. Enabling this potential predictability requires (i) understanding the physical mechanisms involved in this interaction, especially the way that soil moisture and snow cover can affect the atmospheric state and hence precipitation; (ii) evaluating the importance of these mechanisms relative to all the others (e.g., tropical sea surface temperature anomalies) that can also affect precipitation; and (iii) evaluating the time scales over which soil moisture and snow

cover are most likely to have a predictable effect on precipitation.

*Namias* [1959, 1988, 1991] suggested that reduced soil moisture during late winter and/or spring over a mid-continental region (such as the central United States) could help induce and amplify a warm, dry summer over the same region, in part by reduction of the local evaporative contribution, but also by modifying the large-scale atmospheric circulation through the so-called 'thermal mountain' effect [*Stern and Malkus*, 1953].

We ask the following questions: Does the current state of soil moisture have any predictive power in determining the subsequent evolution of the









