# Local Land-Atmosphere Coupling (LoCo): Analysis of Soil Moisture Feedbacks on Rainfall Frequency with Stochastic Rainfall Trigger Model


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## Introduction

Land atmosphere interaction and large scale circulation are two important factors that influence local climate. These two factors are often combined to explain local drought or pluvial phenomenon. Simple atmosphere boundary layer (ABL) models often used for analyzing land atmosphere interaction and are efficient for interpreting climate variability. However, These models usually have no advection component and only focus on single diurnal cycle. This study tries to embed advection to simple ABL models and extend individual diurnal cycle into multiple day evolution. The model is then tested in Central Facility, Southern Great Plains for its soil moisture - rainfall feedback and advection.

## Model

### Flowchart

Figure 1 shows the general steps for running the stochastic rainfall trigger model. Stochastic terms (slope uncertainties and advection) are first generated. Then, linear sounding profiles can be determined with the generated slope uncertainties. The convective trigger model is then used to estimate the rainfall occurrence. Stratiform trigger model is activated if no convective rain occurs. When there is a rain event, rainfall depth is modeled. After all these processes, average temperature and humidity of the next day can be calculated and prepared for the next loop.

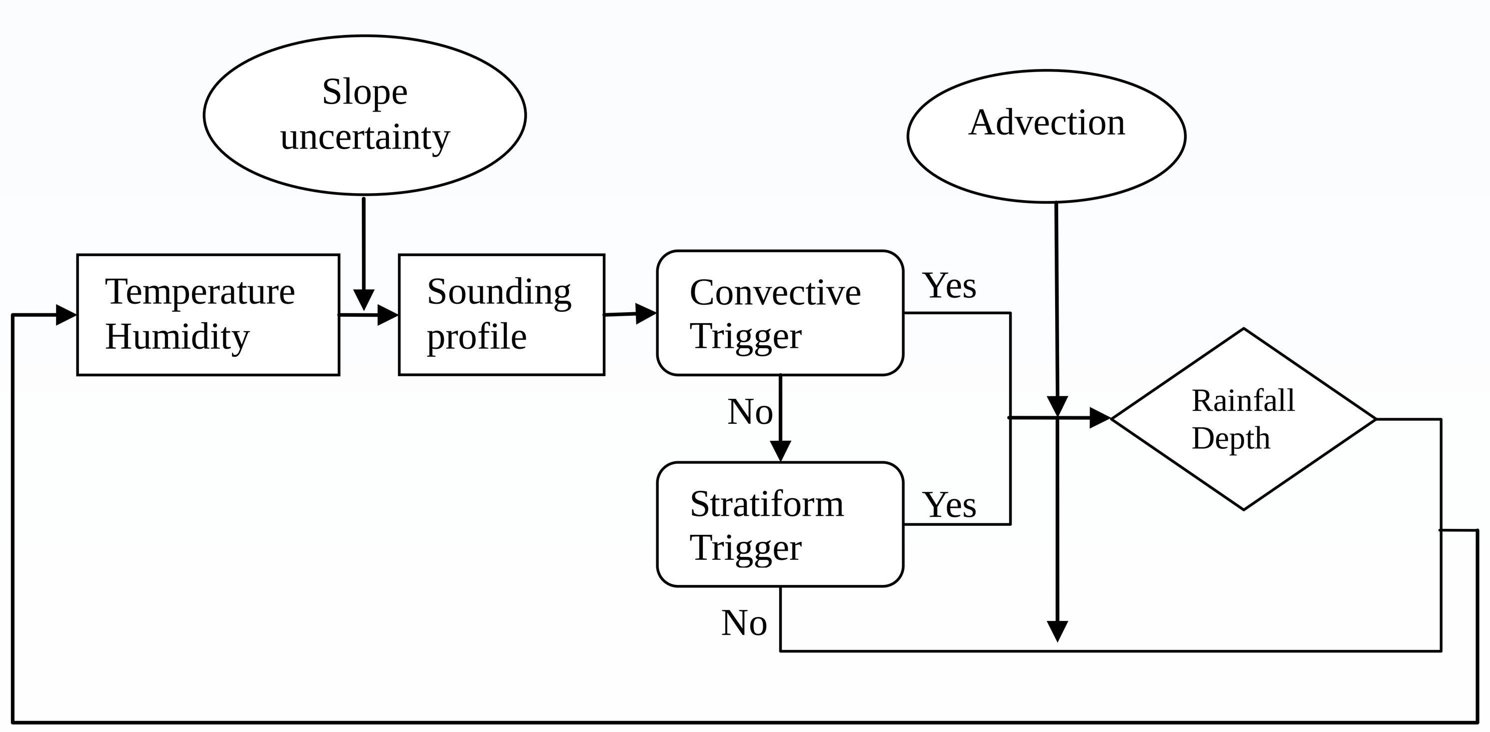



Figure 1. Flowchart of stochastic rainfall trigger model

### Memories and advections

ABL grows up during daytime by sensible heat flux and collapses at nighttime. Collapsed ABL stores certain memories from previous day and is also modified by horizontal advections. These memories and advections need to be identified.

For temperature, we use first order auto regressive model to distinguish memories and advections

$$\bar{\theta}_i = a_1\bar{\theta}_{i-1} + b_1 + \varepsilon_\theta \qquad P_{i-1} = 0$$
$$\bar{\theta}_i = a_2\bar{\theta}_{i-1} + b_2 P_{i-1} + c_2 + \varepsilon_\theta \qquad P_{i-1} > 0$$

Where, $\bar{\theta}_i$ is vertical averaged potential temperature in early morning and $\varepsilon_\theta$ is calibration residual and treated as advections.

For humidity, we integrate governing equations from surface to maximum ABL height ($h_M$) during two consecutive early mornings (24 hours)

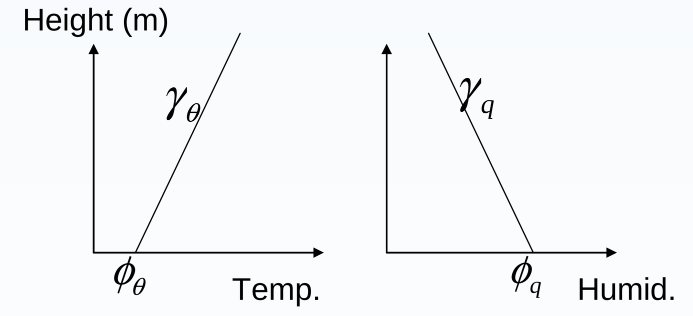
$$\bar{q}_i - \bar{q}_{i-1} = \frac{1}{h_M}\int_0^T \frac{LE}{\rho_a \lambda} dt - \frac{\rho_w \alpha P_{i-1}}{1000\rho_a h_M} - \frac{1}{h_M}\int_0^T dt \int_0^{h_M} \left(u\frac{\partial q}{\partial x} + v\frac{\partial q}{\partial y}\right) dz$$

Where, $\bar{q}_i$ is vertical averaged specific humidity in early morning and the last term is advections.

### Linear sounding profiles

There are good linear relationships between atmosphere sounding profile slopes and intercepts

$$\gamma_\theta = a_3\phi_\theta + b_3 + \varepsilon_{\gamma\theta}$$
$$\gamma_q = a_4\phi_q + b_4 + \varepsilon_{\gamma q}$$




Where, $\varepsilon_{\gamma\theta}$ $\varepsilon_{\gamma q}$ are slope uncertainties

### Stochastic terms

Advections are large-scale forcing factors and considered as white noise.

Slope uncertainties still have certain memories and are also influenced by the amount of advections.

$$\varepsilon_{\gamma\theta}(i) = a_5\varepsilon_{\gamma\theta}(i-1) + b_5\varepsilon_\theta(i-1) + c_5 + \omega_{\gamma\theta}$$
$$\varepsilon_{\gamma q}(i) = a_6\varepsilon_{\gamma q}(i-1) + b_6\varepsilon_q(i-1) + c_6 + \omega_{\gamma q}$$

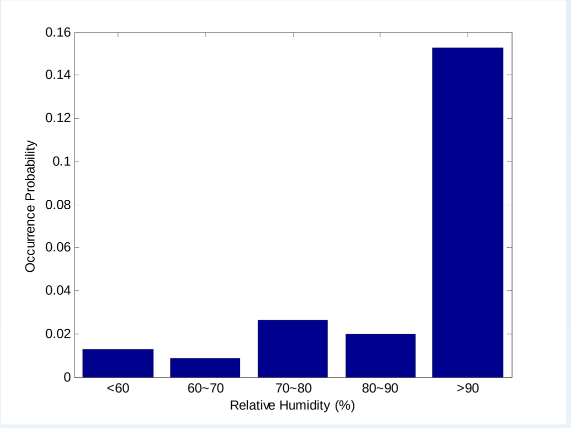
White Noise

### Rain trigger

Convective rain is triggered at certain probability when ABL crosses LCL.

Stratiform rain is usually triggered when relative humidity is high. Figure 2 shows probability of stratiform rain occurrence at different relative humidity ranges in non-convective days in CF-SGP in summer.

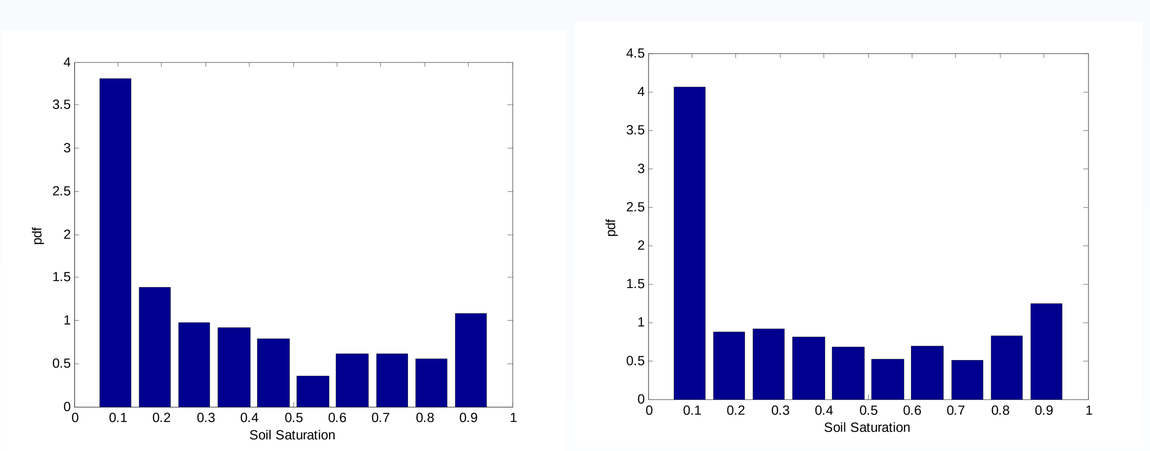
Figure 2. Relationship between relative humidity and stratiform rainfall occurrence probability given that no convective rainfall is triggered in CF-SGP site in summer



## Results

Model with parameters from CF-SGP runs for 2000 days. The simulated probability density function (PDF) of soil saturation was compared with observed data as shown in Figure 3. Preferential states can be identified for both results. Soil moisture – rainfall frequency relationships for different parameters were also calculated and plotted in Figure 4. Increasing memory capacity of soil moisture or decreasing advection makes the feedback clearer. This explains how advections influence local land atmosphere interactions.

Figure 3. PDF of soil saturation from simulation results (left) and from observations (right)



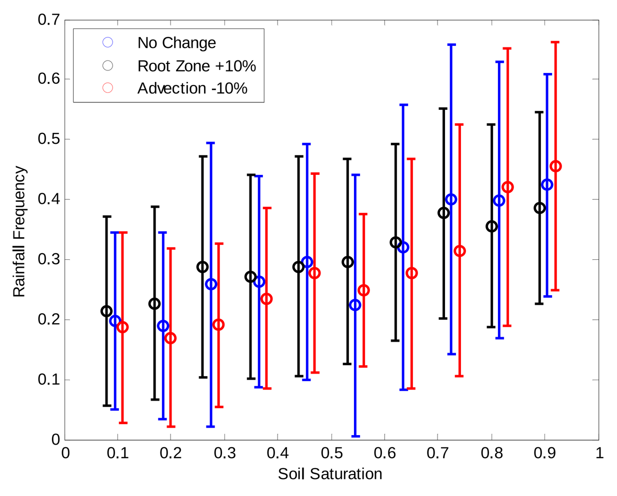



Figure 4. soil moisture – rainfall feedback in three conditions: No change; increasing root zone depth 10%; decreasing advection standard deviation 10%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