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Soil moisture uncertainty in models

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Abstract

This project aimed to understand uncertainty in land surface model (LSM) predictions of soil moisture (SM) over Africa, which is a result of uncertainty in the prescribed rainfall and soil parameters. To investigate the rainfall uncertainty a realistic range of rainfall scenarios for 2008 were run through an LSM. The daily rainfall timing and intensity was varied to see if this impacted the uncertainty. The highest uncertainty occurred when the daily rainfall was split over 3 hours instead of 1. The soil parameter uncertainty was investigated by varying model soil parameters within observed limits. This was by far the largest source of uncertainty.

Introduction

Soil moisture could be used as a risk index for agricultural insurance products, and would be an improvement over the current use of rainfall as an index as it is more representative of the actual water available to crops. This requires knowledge of the soil moisture at high spatial resolution. Ground measurements of soil moisture are too spatially and temporally sparse to be useful, and satellite observations are unreliable due to vegetation coverage. LSMs can be used to calculate the soil moisture, but are subject to a wide range of uncertainties, most notably that from satellite-derived precipitation amounts used to drive the model and soil type. Before the model outputs can be used for insurance, these uncertainties need to be understood.

Research questions:

1. How does rainfall uncertainty translate to modelled soil moisture uncertainty?
2. Is the modelled soil moisture more sensitive to the timing or spread of the daily rainfall?
3. How sensitive is the soil moisture to changes in the model soil type?
4. Do changes in the soil type affect the spread of the soil moisture outcomes due to rainfall uncertainty?

Methods

- To test research question **1** 200 **daily**-rainfall scenarios for **2008** were run through the JULES (Joint UK Land Environment Simulator) LSM at **Tamale in Northern Ghana**.
- Question **2** was addressed by varying the daily timing of the rainfall scenarios for a set soil type
- Questions **3** and **4** were addressed by varying the soil type in the model for two daily rainfall timings
- The daily rainfall scenarios were developed using a statistical method described in Grimes (2008).

Table 1: Summary of experiments carried out, including sub-daily rainfall timing, soil types and the figures they are shown in. The 'original' soil type is that of the ISLSCP II* soil texture map (Scholes and Brown de Colstoun 2011). The others are as Lu et al. (2007).

Daily Rainfall Timing	Soil Type	Figure
12:00-13:00	Original	Figure 1
12:00-15:00		
15:00-16:00		Not shown
12:00-13:00	Clay-loam	Figure 2
	Loamy-sand	
	Sandy-loam	
12:00-15:00	Clay-loam	Not shown
	Loamy-sand	
	Sandy-loam	

Results

Rainfall uncertainty

- Total uncertainty is greatest at the peak of the rainy season, although in percentage terms the uncertainty is greatest at the beginning of the season
- Spreading the rain over 3 hours (Figure 1, right) allows more to infiltrate into the soil as less goes into surface runoff, so the soil moisture amount increases faster
- This effect is greater for heavier rain events, thus the spread increases – the **sensitivity** to rainfall is greater

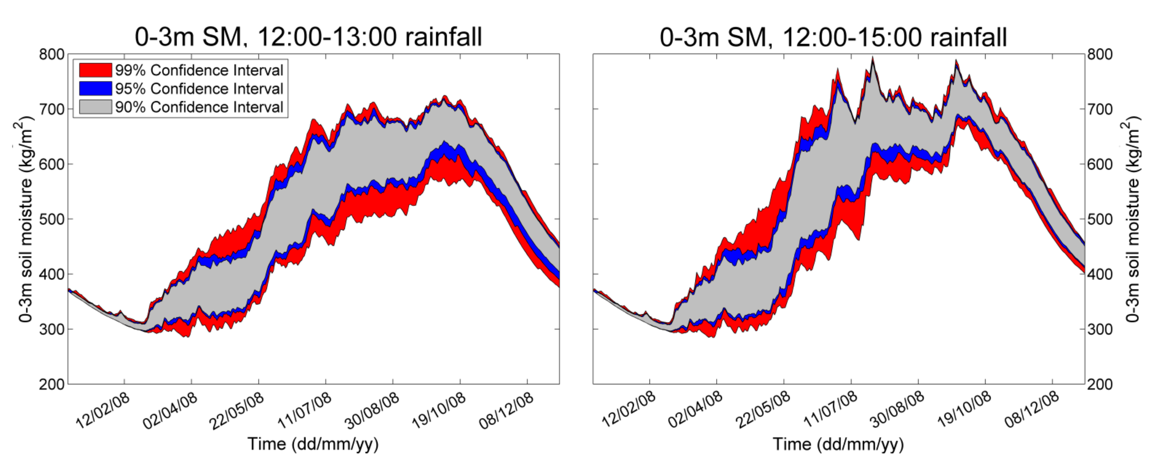

Figure 1. Spread of 0-3m model soil moisture outcomes from the 200 rainfall scenarios for daily rainfall between 12-1pm (local time, left) and between 12-3pm (right). Confidence intervals are the probability that the actual soil moisture will lie in the indicated bands for this soil type.

*The International Satellite Land Surface Climatology Project, Initiative II

Soil type uncertainty

- The two most extreme cases – clay-loam and loamy-sand are shown in Figure 2, left and right respectively
- The difference in the capacities of the soil types is large
- The seasonal cycle is reduced for clay soils as a result of a lower maximum infiltration rate for this soil type
- The **sensitivity** to rainfall amount also reduces for clay, as can be seen from the smaller spread (Figure 2, left)

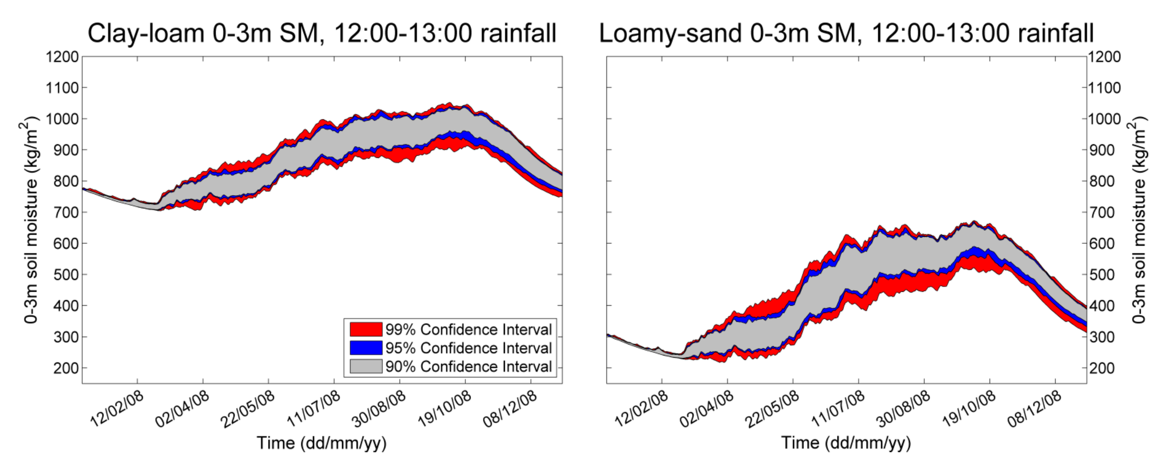

Figure 2. Spread of 0-3m model soil moisture outcomes from the 200 rainfall scenarios for daily rainfall between 12:00 and 13:00 for clay-loam (left) and loamy-sand (right). Confidence intervals are as Figure 1.

Comparing the uncertainties

- The rainfall uncertainty can be split into that from the satellite measurement of **rainfall amount** and that of the daily **rainfall intensity**.
- These are compared to the uncertainty from the **soil type** in Figure 3, which is the largest uncertainty source
- The rainfall amount uncertainty accounts for 30-50% of the total*.

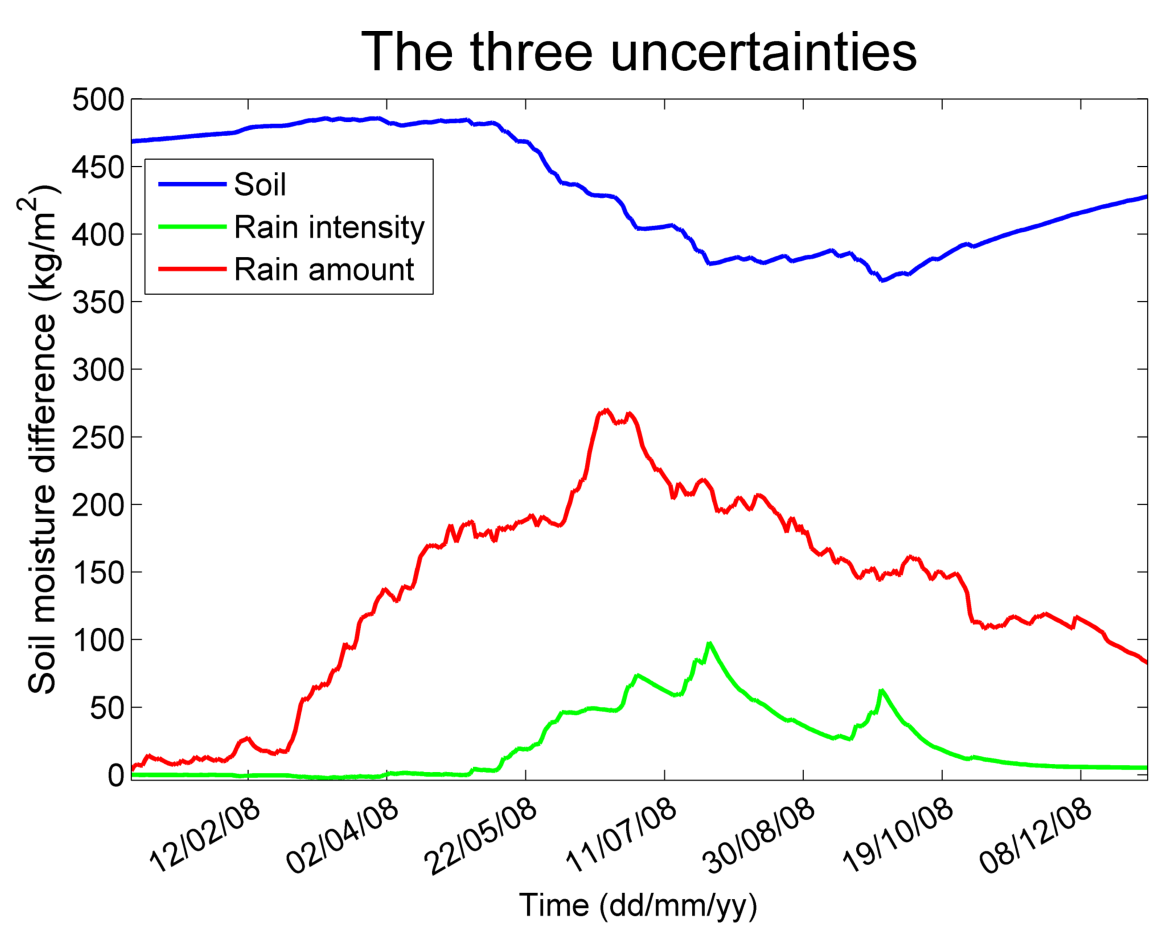

Figure 3. Representation of the relative sizes of the three main uncertainties in model soil moisture. See report for details of calculation.

*The rain amount uncertainty at the start of 2008 is too low as the model was only run for this year

Conclusions

Answers to research questions:

1. Uncertainty in the rainfall leads to large uncertainty in the model soil moisture. This uncertainty varies with the intensity of the rainy season, reaching a peak at a similar time to that of the rainy season.
2. The soil moisture is far more sensitive to changes in the intensity of the daily rainfall (Figure 1) than its timing (not shown), as the intensity affects how much of the rainfall can infiltrate into the soil.
3. Uncertainty in the soil type is the biggest source of uncertainty in model soil moisture from differences in the capacities of the soils. This result agrees with that of Hossain and Anagnostou (2005).
4. The soil type does affect the sensitivity of the model soil to rainfall. Clay soils are the least sensitive whilst sandy soils are the most.

Opportunities for further progress

- The model should be run for multiple years to examine how the uncertainty varies in dry and wet years
- The model soil moisture amounts should be verified against observations where possible
- The rainfall intensity uncertainty can be reduced by using hourly measurements of rainfall rather than daily
- Field measurements of soil type would significantly reduce the soil type uncertainty.

References

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