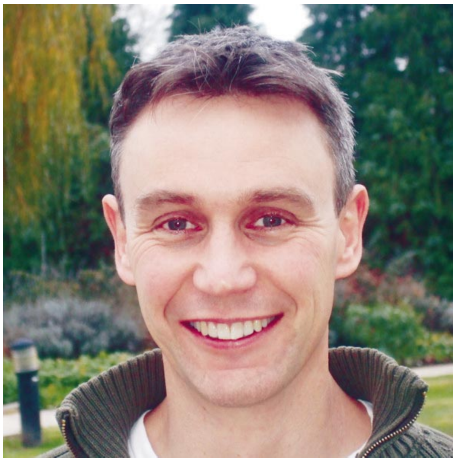

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AMMA is based on a French initiative and is a major international project funded by a large number of agencies particularly from France, UK, US and Africa, and by the European Union.

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Observing soil moisture – rainfall feedbacks

It is well-known that land surface features can affect local weather, as an example the preferential development of clouds over hills and along coast lines associated with sea breezes. These are well-observed and well-understood phenomena apparent often to the naked eye. In recent decades, meteorologists have become increasingly interested in how other, more subtle land surface features influence the development of clouds and storms.

Land surface – atmosphere fluxes of heat, water and momentum differ, for example, between forest and agricultural land. We might expect that approximately the lowest kilometre of the atmosphere, the Planetary Boundary Layer (PBL), will respond to these differences in fluxes, provided the surface features are large enough that the horizontal wind does not completely mix out the effect of the spatial variability in fluxes.

Mesoscale modelling studies show that around forests of several tens of kilometres, weak sea-breeze type effects can occur [1].

There is surprisingly little observational evidence of the many idealised modelling studies, perhaps reflecting the scarcity of strong mesoscale contrasts in land surface properties. Negri et al. [2] identified an enhancement of moist convection during the afternoon over deforested areas in Amazonia compared to the surrounding forest, though this effect was only detectable during the dry season, when the atmosphere is relatively quiescent.

The impact of soil moisture on precipitation is of considerable interest to the weather and climate modelling community. Soil moisture is a dynamic component of the land-atmosphere system, and any feedbacks between soil water and precipitation could either amplify or suppress climatic anomalies such as drought, depending on the sign of the feedback.

Soil moisture, and its control on surface fluxes, is not well simulated by atmospheric models, and there is a large potential range

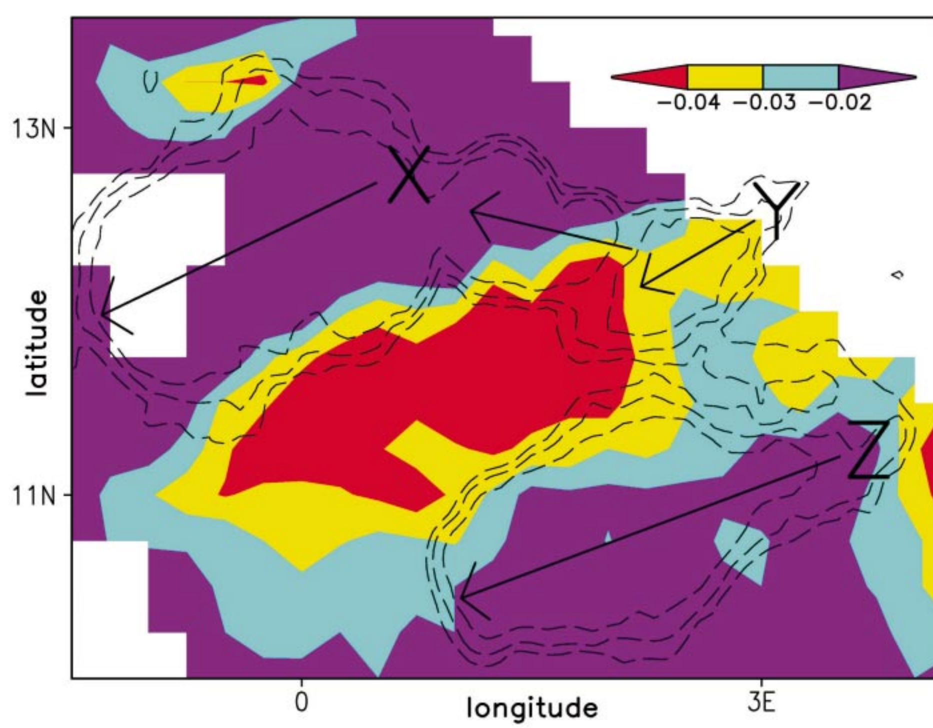

Figure 1. ➤ An example of convective cloud development (dashed lines) in a flat region of Burkina Faso, where previous storms have produced a landscape characterised by patches of high soil moisture (red shading). The patches are identified from anomalies in microwave polarisation ratio. Three storms develop (at X, Y and Z) and propagate in the direction of the arrows.

of feedback strengths produced by different models [3]. Due to the scarcity of appropriate observations at length scales where feedbacks operate, we cannot be certain which feedback processes dominate in the real world, or even their sign. Observational studies which capture key aspects of soil moisture – precipitation feedbacks therefore provide an important piece of the jigsaw in understanding the role of the land surface in current and future climate.

Precisely because soil moisture is very dynamic, knowledge of its spatial pattern is more limited than that of vegetation. Soil moisture is extremely heterogeneous, depending on spatial variations in soil and vegetation properties as well as climate, notably rainfall. Current satellites offer some possibilities to detect soil moisture by microwave, thermal and other sensors. In a recent study, we used passive microwave data to examine how mesoscale moisture patterns in the top centimetre of the soil affect the development of deep convection in the Sahel [4].

The Sahel, located at the southern border of the Sahara, is an ideal place for such studies as during the wet season, intense travelling convective storms are frequent, producing swaths of wet soil beneath their paths, often hundreds of kilometres in length on an otherwise dry surface. With only sparse vegetation, the fluxes are rather sensitive to the availability of near surface moisture for evaporation directly from the exposed soil. For a day or two after rainfall, passive microwave data shows where the evaporation rates are high and sensible heating is low.

From analysis of thermal imagery of deep (and cold) convective clouds, a strong impact of soil moisture on the development of storms during the afternoon and early evening was identified. It appears that storms tend to initiate and propagate preferentially over dry soil, at least during the initial stages of their life cycle. An example of such behaviour is shown in Fig 1. This implies a negative feedback locally, i.e. rain develops over dry soils, and contrasts with previous results showing enhanced rainfall over wet soils for mature storms [5].

The Special Observing Period of the African Monsoon Multidisciplinary Analyses (AMMA) in 2006 provided a unique opportunity to investigate the atmospheric response to soil moisture patterns. The research aircraft of the UK National Centre for Atmospheric Science targeted wet and dry features identified from near real time thermal imagery from the Meteosat satellite [6].

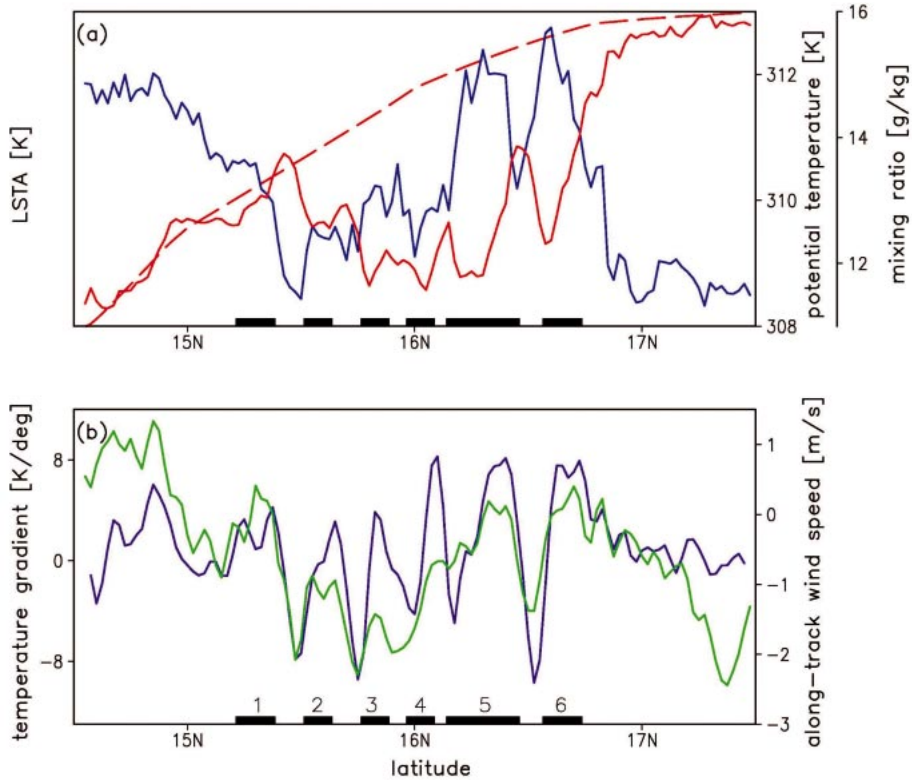

Figure 2. Measurements from an aircraft flying north-west at 170 m above a sequence of 6 wet patches identified from satellite imagery [6]. (a) The observed Planetary Boundary Layer (PBL) temperature (red solid line) increases towards the Sahara in the north, consistent with the large scale temperature gradient (red dashed line). Over the wet soils, however, air temperatures fall sharply, accompanied by an increase in humidity mixing ratio (blue). This is due to the strongly contrasting land surface fluxes. (b) The surface-induced gradients in air temperature (green) are strong enough to induce changes in the speed and direction of the wind (purple).

The aircraft data showed a strong response of PBL temperature and humidity to soil moisture (Fig. 2), even when flying over wet patches of less than 10 kilometres in width. The study showed that typical mesoscale soil moisture features produced daily by storms in the Sahel produce contrasts in sensible heating strong enough to induce sea-breeze type circulations. The convergence over the dry soil produces ascent, and this trigger for convection is thought to play an important role in the negative feedback detected from satellite data.

How soil moisture influences rainfall at other time and space scales in this sensitive and drought-prone region remains at the top of the agenda in the AMMA research programme. Understanding of the strength, and even the sign, of soil moisture – rainfall feedbacks, is crucial for improving weather and climate predictions for this, and also for other soil moisture "hotspots". ■

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