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What is the mechanism for the initiation of convection caused by land-surface induced flows?

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The objective of this study is to uncover what mechanisms lead to the organization of convection in the presence of land-surface induced mesoscale flows. A considerable number of modelling studies, as well as recent observations, have demonstrated how mesoscale heterogenities in land-surface type can affect low-level temperatures, via changes in Bowen ratio and albedo, thus initiating mesoscale flows. These mesoscale flows in turn favour the initiation of convection over the warmer surface, but close to the land-surface boundaries. Various satellite climatologies show an enhancement of shallow cloud over crops, compared to adjacent forest, which is consistent with initiation of convection caused by land-surface induced flows.

The source of the initiation of convection is usually attributed to convergence, but in the authors' opinion insufficient consideration has been given as to what exact mechanism leads to enhanced convection within these convergence zones, and whether the vertical velocities caused by mesoscale convergence zones are significant. In order to better understand the impact of land-surface induced flows on cloud cover and rainfall, particularly in the presence of different dynamical and thermodynamic synoptic conditions, the cause of the land-surface induced organization of cloud initiation must be better understood.

There are three general mechanisms that could explain how mesoscale convergence promotes the initiation of convection. Firstly, a purely dynamical response due to increased vertical velocities from the mesoscale convergence. Secondly, a thermodynamic response due to moisture convergence from a cool, moist region (lower Bowen ratio) to a warmer drier region (higher Bowen ratio). Finally, mesoscale convergence may be of secondary importance, and the observed organization could simply be attributed to higher turbulence giving stronger warm moist updraughts over warmer regions.

The Met Office Large Eddy Model was used to investigate the source of the initiation of convection in the presence of land-surface induced mesoscale flows. Aircraft observations of mesoscale flows initiated by boundaries between crop and forest were found during the African Monsoon Multidisciplinary Analyses (AMMA) campaign (Garcia-Carreras et al., 2010), and this case-study was used as the basis for the simulation. A 2D simulation at 250m resolution (cloud-resolving) with prescribed surface fluxes was completed, with varying Bowen ratio set to follow the land-surface observed in the AMMA case-study. The land-surface variations had a clear impact on the modelled boundary-layer temperatures and winds, with enhanced cloud-cover over the warmer cropland, consistent with the observations.

Higher stability over the forested regions led to positive anomalies in equivalent potential temperature. The initiation of convection was closely linked to the advection of air with high equivalent potential temperature from over the forest to the warmer cropland region. This then produced a peak in convective available potential energy (CAPE) over the crop, but close to the land-surface boundaries, thereby organizing the patterns in cloud cover. An increase in the stability over the forest in the afternoon also caused a marked suppression in cloud cover over the forested regions throughout the domain.