Understanding the impact of surface heterogeneity on the diurnal cycle of deep convection

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Introduction

Modelling the diurnal cycle of deep convection is a long standing problem in both numerical weather prediction and climate modelling. There are major deficiencies in capturing both the phase and amplitude of the daily cycle of precipitation in tropical regions.

Here the role of idealised surface heterogeneity on the time of triggering, amplitude and spatial distribution of deep convection are investigated using the new Met Office NERC Cloud model (MONC – see Brown et al., 2015) and the idealised version of the Met Office UM.

- **Does convection respond to surface heterogeneity? If so, on what scale?**
- **Can parameterised convection produce the same response as explicit convection if given information about the surface heterogeneity?**

Simulation setup

- Idealised prescribed surface forcing with domain mean values based on EUROCS (Guichard et al., 2004), balanced by a specified large scale cooling of -1.75K/day during the day with an additional -3.1K/day cooling in the lowest 1km at night. (See talk by Chimene Daleu)
- Heterogeneity introduced through a prescribed checkerboard pattern (see Figure 1) with 3 patch sizes: 51.2 25.6 and 12.8km (known as H50, H25 and H12 respectively). Plus companion homogeneous simulations (P50-WET and P50-DRY).
- WET (DRY) patches have 30% of domain mean sensible heat flux subtracted from the sensible (latent) heat flux and added to the latent (sensible) heat flux (as in Lee et al., 2019).
- 512 x 512 grid points with 200m horizontal resolution with 99 vertical levels with a 20 km top.
- Relax to zero mean wind.
- Analogous runs performed with parameterised convection in the idealised UM with GA8 settings.

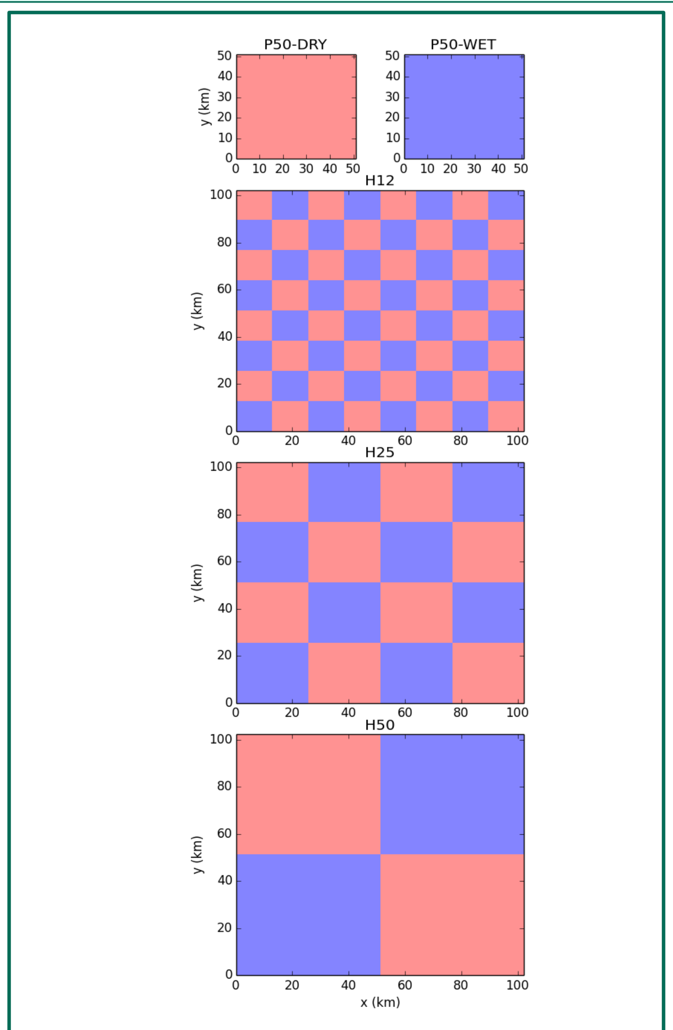

Figure 1: Schematic representation of the patch sizes imposed in the high resolution simulations and companion homogeneous patches.

How do the high resolution simulations evolve?

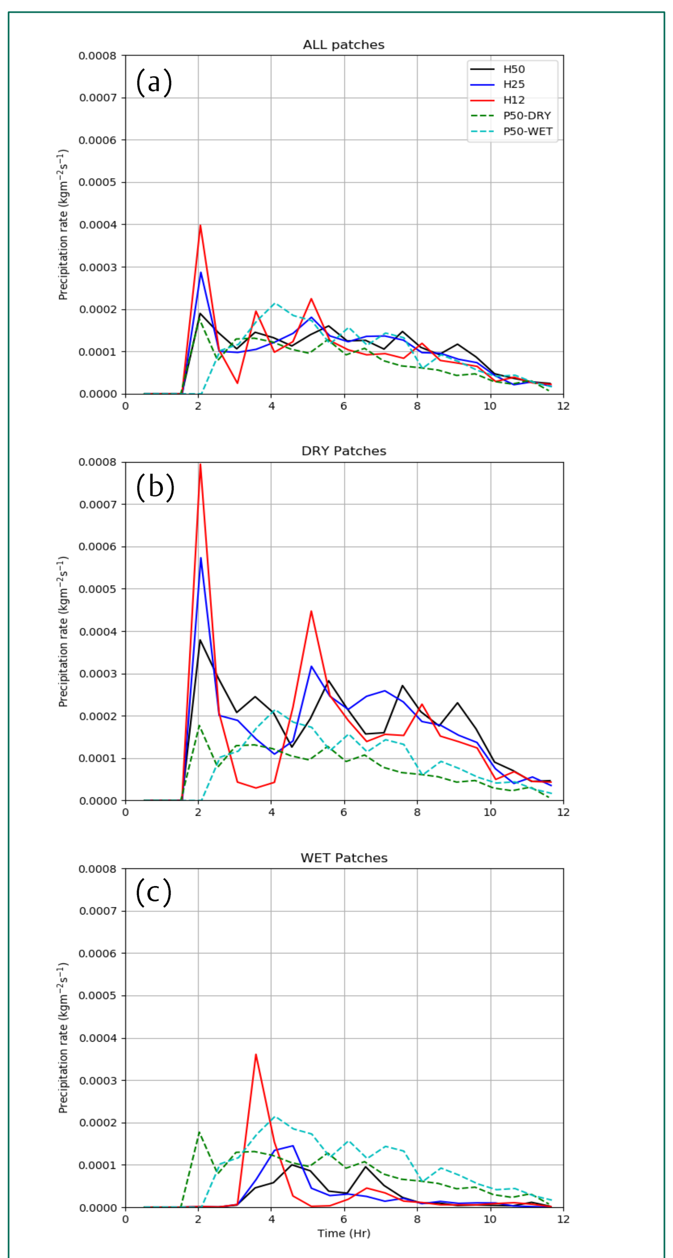

Figure 2: The time evolution of domain mean instantaneous surface precipitation for (a) the whole domain, (b) DRY patches, (c) WET patches. The evolution from the P50-DRY and P50-WET homogeneous simulations are shown with dashed lines.

- Precipitation starts at approximately 1.5 hours after the surface forcing in all the runs apart from the WET homogeneous patch (Figure 2a).
- Precipitation rates are larger over the DRY patches (Figure 2b) and precipitation starts in these patches before the WET patches .
- In all of the heterogeneous simulations there is an initial spike of precipitation after triggering followed by a minimum which recovers and then decays in phase with the surface forcing.
- WET patch precipitation lags DRY patch by approximately 2 hours.
- Precipitation in WET patches occurs later than in the both of the homogeneous surface simulations (dashed lines).
- The difference in sensible heat flux between the patches drives a sea-breeze like circulation (Figure 3a,d,g) with low-level convergence into the DRY patches.
- The onset of WET patch precipitation is inline with a switch in this circulation to give low-level convergence into the WET patches (Figure 3b,e,h).
- Once deep convection is established this circulation is not evident as it is disrupted by convective updraughts and cold pools (Figure 3c,f,i).

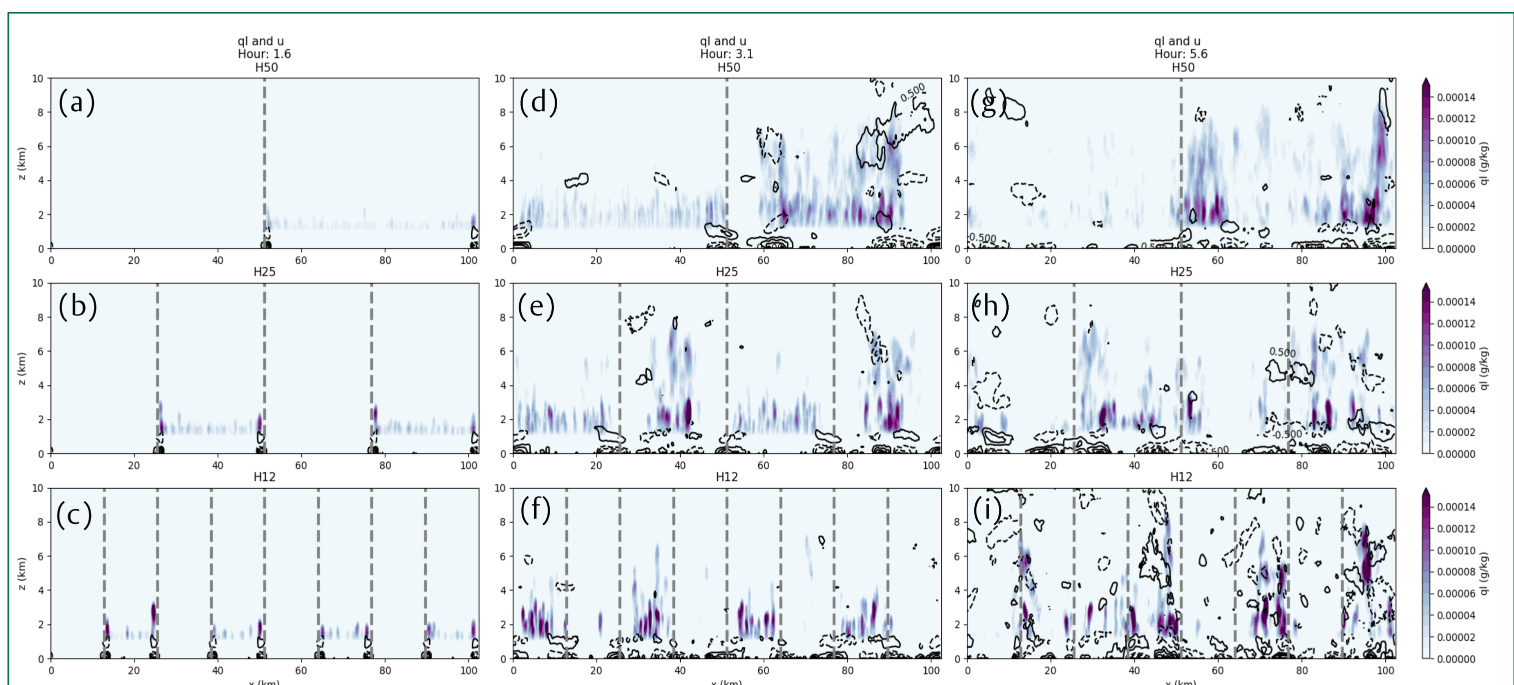

Figure 3: Vertical cross section of cloud condensate and horizontal wind (contour lines in m/s with dashed lines indicating negative x direction) for H50 (top row), H25 (middle row) and H12 (bottom row) before onset in DRY patches (1.6 hours), before onset in WET patches (3.6 hours) and once convection is established (5.6 hours).

Is there an impact on the spatial distribution of precipitation?

- The precipitation preferentially falls in the DRY regions (Figure 4).
- As the size of the patches decreases the distinction of the patch edge becomes more blurry and at H12 there is little precipitation at the edges of the DRY patches and a circular region of precipitation in the centre of the WET patches (Figure 4 f and i).

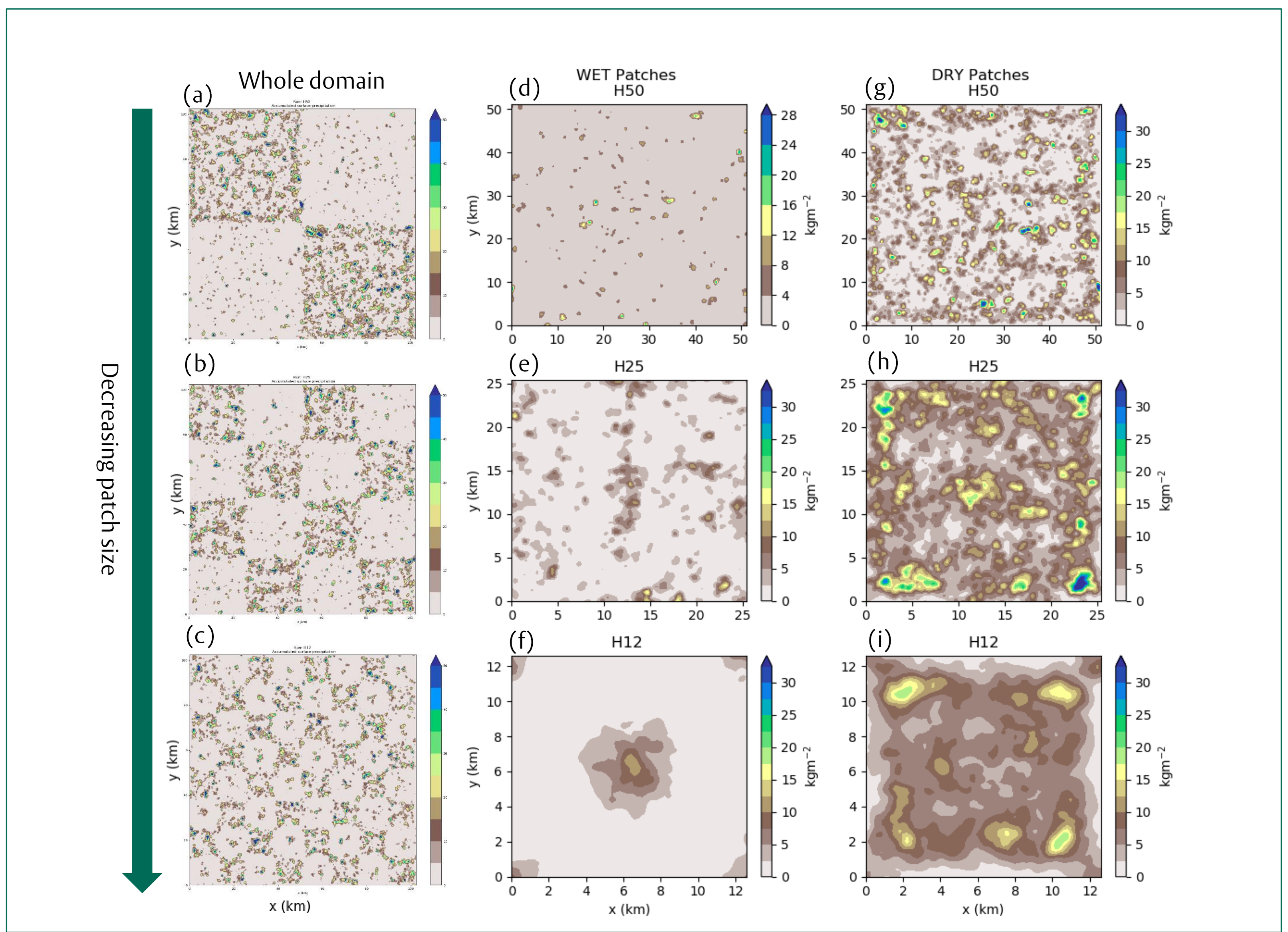

Figure 4: The spatial distribution of daily mean precipitation in the (a) H50, (b) H25 and (c) H12 runs. The composite spatial distribution in WET (d, e, f) and (g, h, i) DRY patches for the H50, H25 and H12 runs.

What happens when convection is parameterised?

A set of 8 idealised UM simulations were run for 10 days with varying patch size (12 and 24 km) and model grid spacing (6, 12 and 24 km).

- Precipitation rates are larger over the DRY patches (Figure 5).
- WET patch precipitation follows DRY patch by approximately 1 hour.
- Precipitation in WET patches occurs sooner than in the homogeneous surface simulations (dashed lines).
- Peak precipitation is later in simulations with patches that are the same size as the model grid (yellow and red lines in Figure 5).
- The spatial distribution of the precipitation clearly maps on to the patches when the model grid spacing is close to the patch size but is less distinct when smaller grid spacing used (Figure 6).

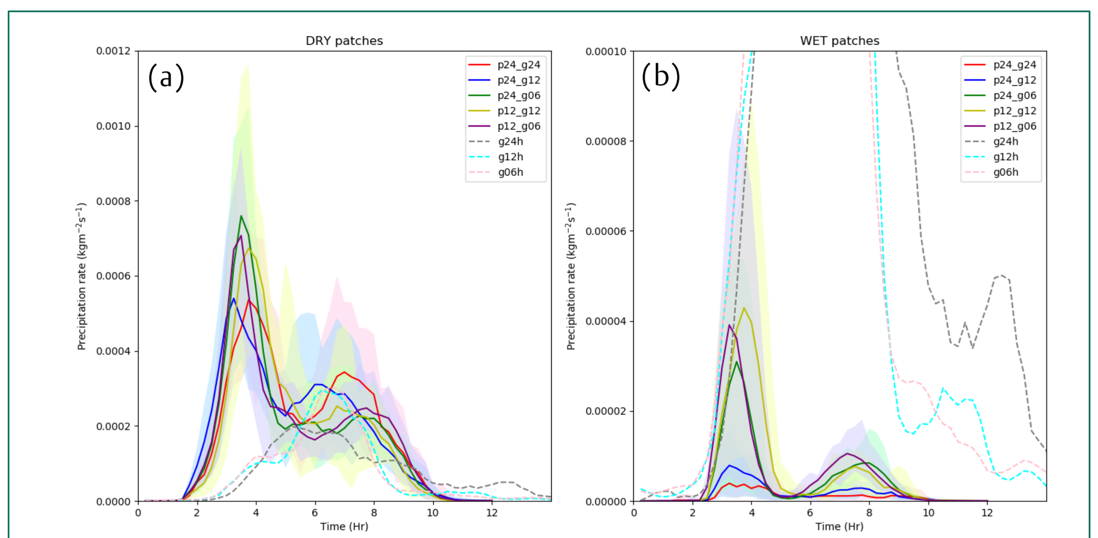

Figure 5: Evolution of precipitation in (a) WET and (b) DRY patches for the idealised UM runs with parameterised convection. Solid lines refer to runs with heterogeneous surface and dashed lines refer to companion homogeneous simulations. Shading indicates the range of precipitation rates over the ten day simulation.

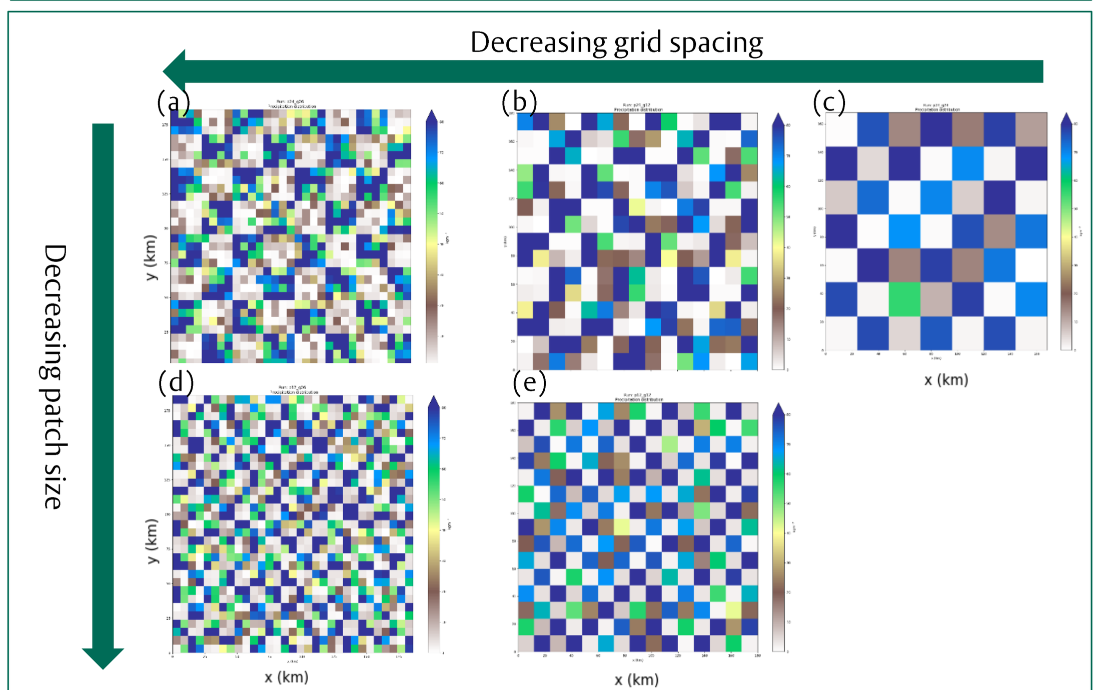

Figure 6: Spatial distribution of precipitation for the idealised UM simulations with parameterised convection – 24km patch with (a) 6km, (b) 12km, (c) 24km grid spacing, 12km grid with (d) 6km, (e) 12km grid spacing.

Next steps?

- Is the same behaviour seen on day 2 of the high resolution simulations?
- What is the response to forcing from a smoother surface heterogeneity forcing (e.g sinusoidal forcing)?
- What is the response if a mean wind is applied? Is the initial circulation set up?
- Is the response to the surface heterogeneity in the idealised UM the same with GA7 parameterisation settings?

References

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