Precipitation distributions in high-resolution simulations of the warm pool

Chris Holloway, Steve Woolnough, and Grenville Lister email: c.e.holloway@reading.ac.uk

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
Walker Institute
University of Reading

1. Introduction

Distributions of precipitation rates are analyzed for high-resolution UK Met Office Unified Model simulations of a 10-day case study over a large (15,500 km x 4,500 km) tropical domain (Fig. 1b,c) as part of the Cascade project. Simulations with 12 km grid length and parameterized convection have too many occurrences of very light rain and too few of heavier rain when interpolated onto a one-degree grid and compared with TRMM data (Fig. 2). In fact, this version of the model appears to have a preferred scale of rainfall around 0.4 mm/hr (10 mm/day), unlike observations of tropical rainfall. On the other hand, 4 km (and even 12 km) grid length simulations with explicit convection produce distributions much more similar to TRMM observations.

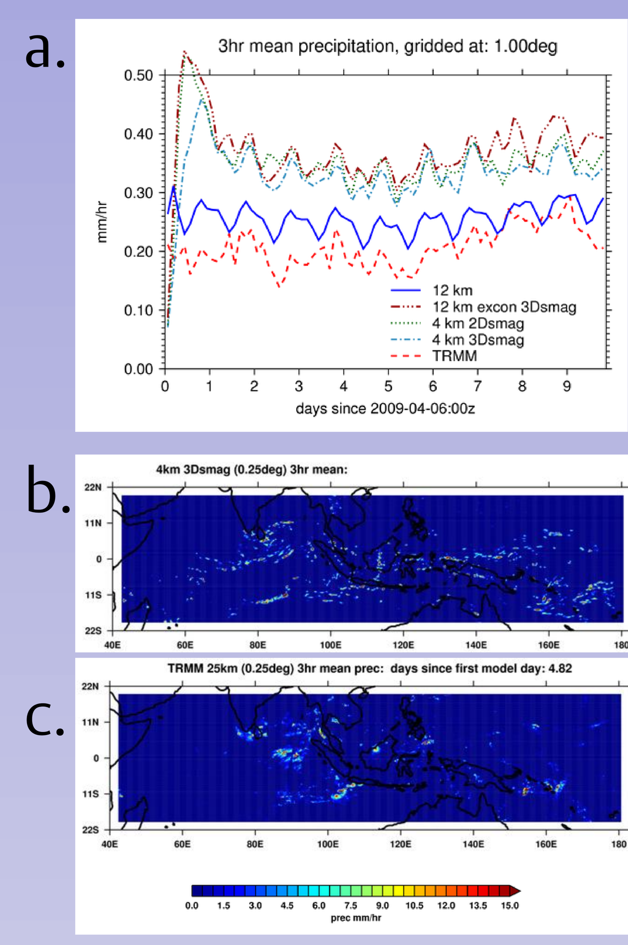
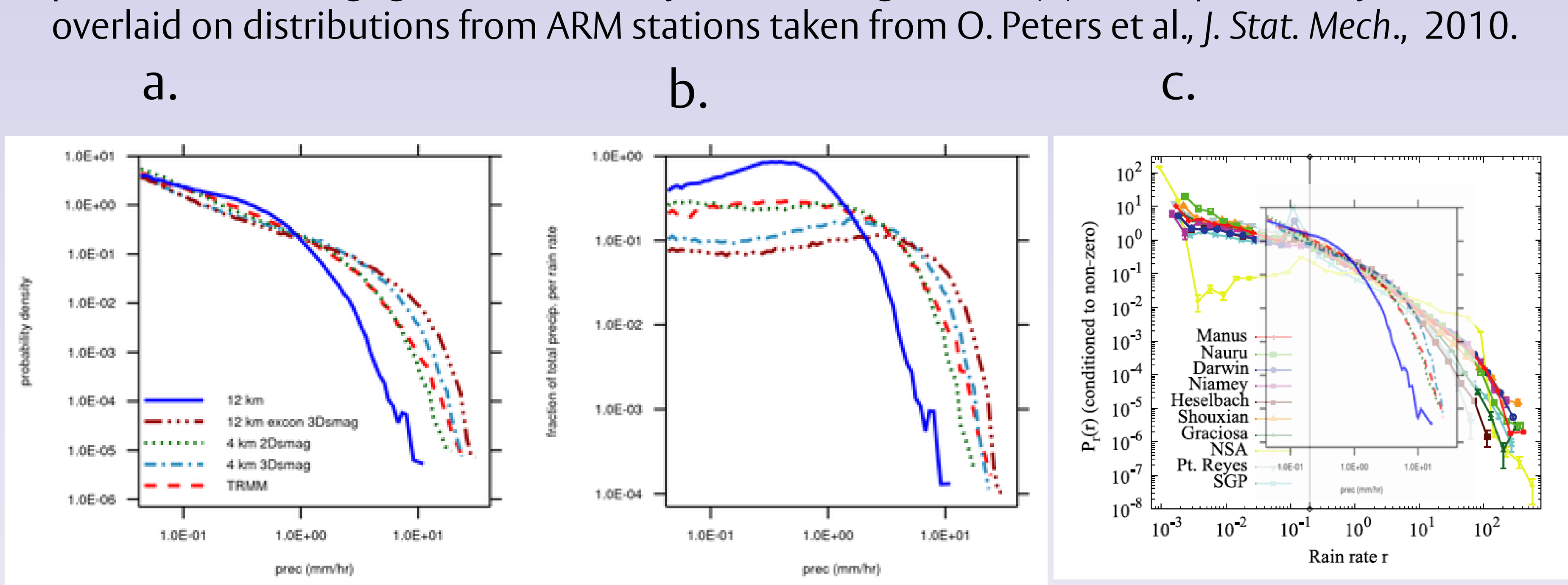


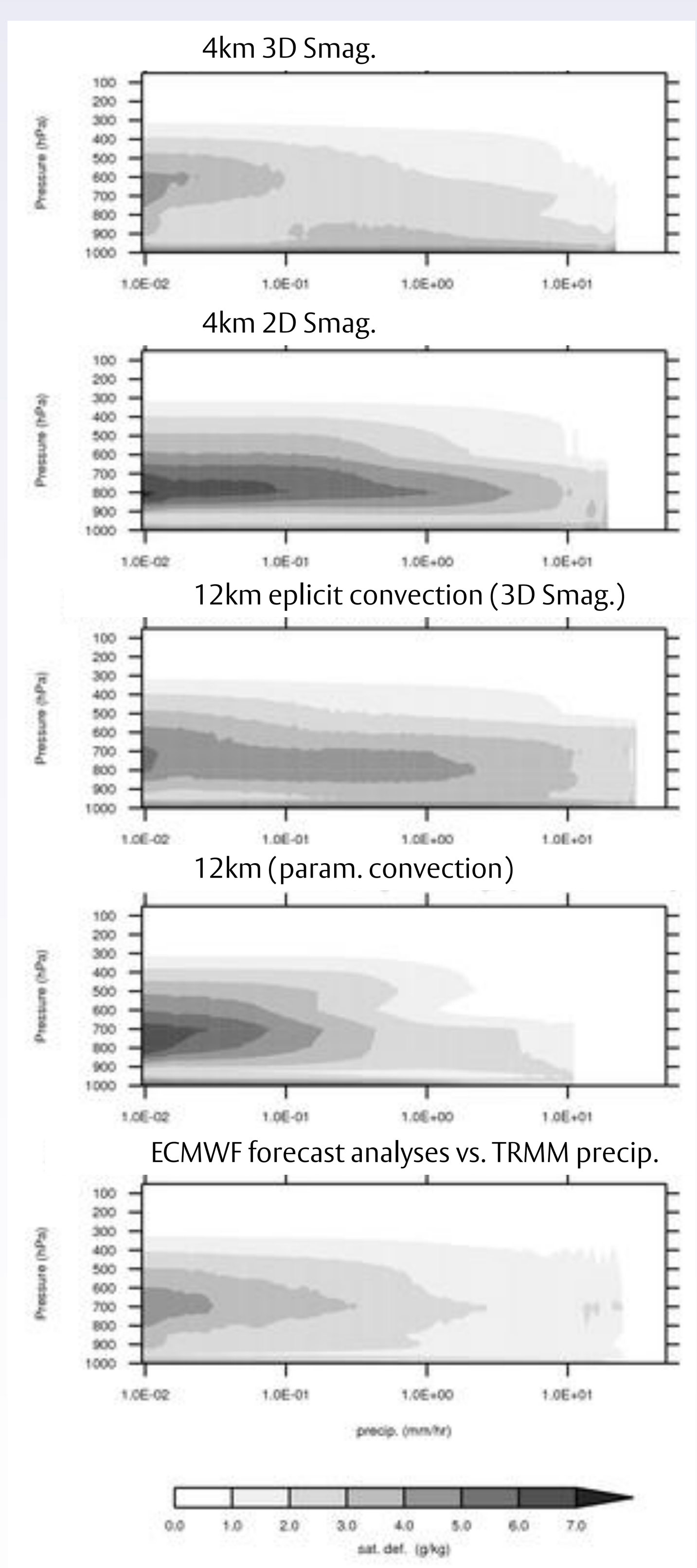
Figure 1
(a) Domain-mean precipitation for TRMM and four model runs.
Below: Example of 3-hr mean precipitation (at end of day 4) averaged onto 1-deg. grid for (b) 4km model with vertical Smagorinsky mixing (3D Smag.) and (c) TRMM rainfall.

Figure 2 Precipitation distributions: (a) probability densities, and (b) fractional rainfall amount densities for four model runs and TRMM merged precipitation data over sea points, on a 1-deg. grid and 3-hourly time averages, and (c) same probability densities overlaid on distributions from ARM stations taken from O. Peters et al., *J. Stat. Mech.*, 2010.



2. Distribution of precipitation

Domain-mean precipitation is higher for runs with explicit convection (Fig. 1a), likely because of strong spin-up and a subsequent feedback with the implied circulation at the lateral boundaries. Figure 2 shows that model runs with explicit convection have more realistic distributions of precipitation than the 12 km run with parameterized convection when compared with TRMM and ARM observations: the bulge in the 12 km model around 0.4 mm/hr suggests a preferred scale of rain rate, perhaps because the convective parameterization settles into equilibrium too easily and/or because it has insufficient scale interactions.



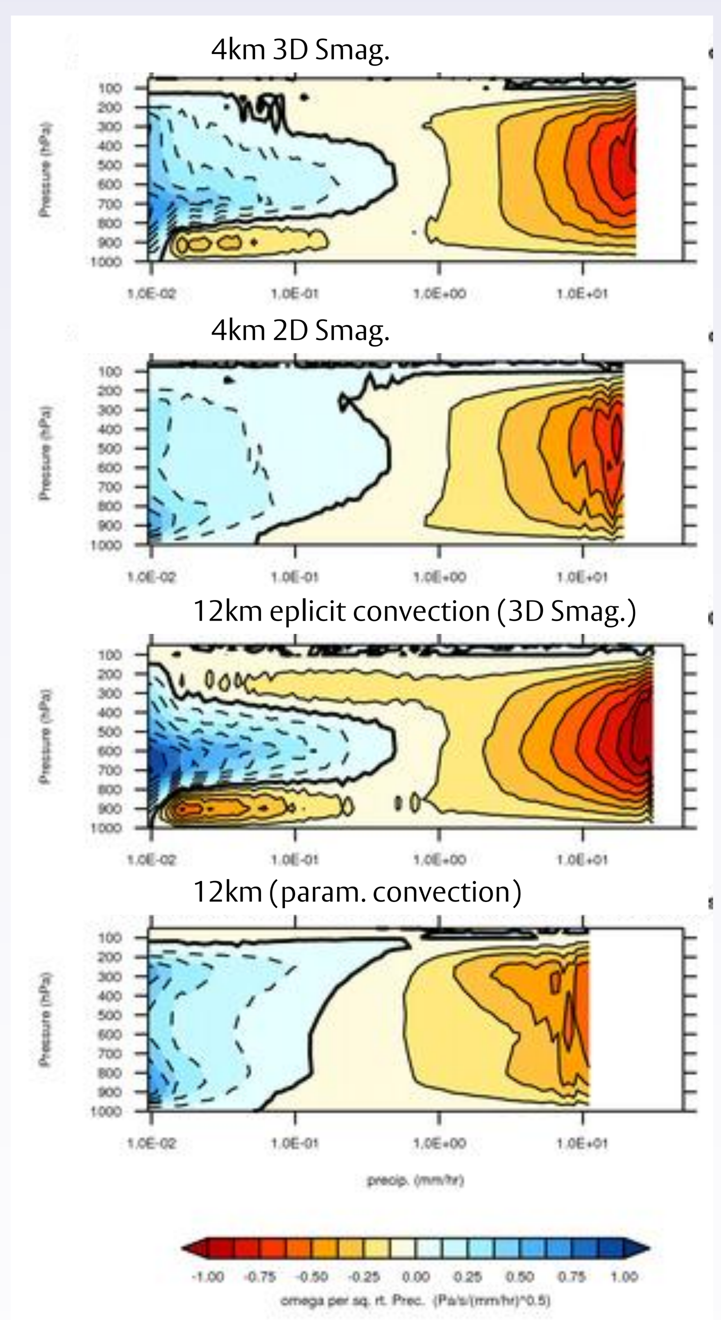


Figure 3 (Left) Saturation deficit for different precip. bins (over sea) for four model runs and ECMWF forecast analyses. (Right) Pressure velocity normalized by the sq. rt. of precip. for same precip. bins and four model runs. Contour int. is 0.125 Pa/s/(mm/hr)$^{0.5}$, with positive contours shaded.

3. Environment and heating/ moistening

The explicit convection runs have a greater sensitivity of precipitation to moisture and more realistic shallow convection *except* for the 4 km model without vert. (3D) Smag. mixing (Fig. 3). Implications of different precip. distributions for moistening and heating rates are shown in Figure 4.

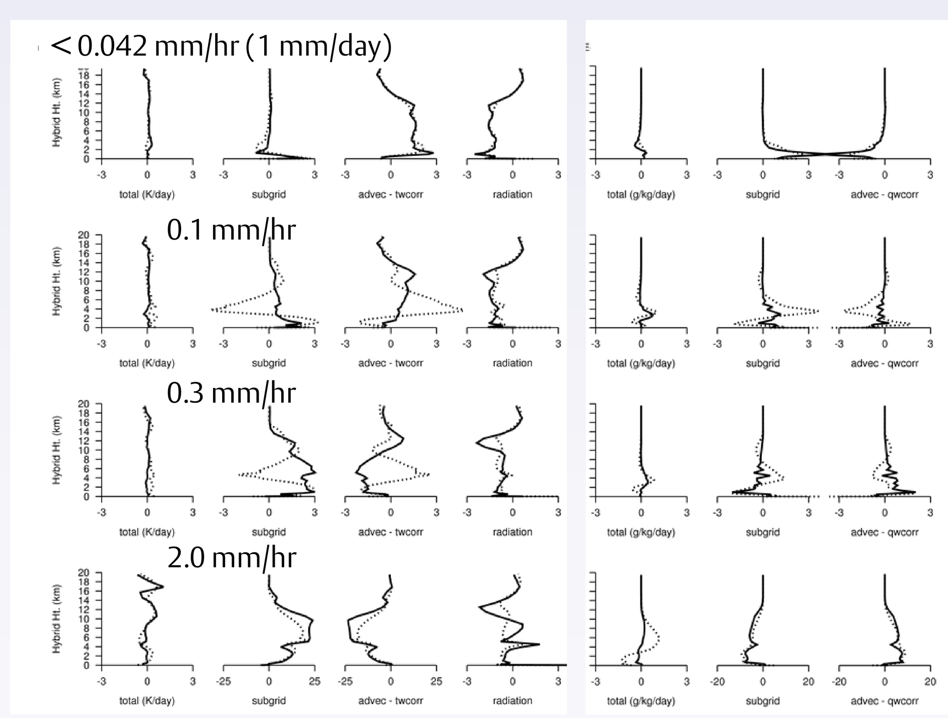


Figure 4 (Left) temperature and (Right) moisture increments for low rain points and three precip. bins (over sea) for the 12 km model run (solid line) and 4 km model run with vertical Smagorinsky mixing (3D Smag, dashed line).

4. Summary

- **4 (and 12) km model runs with explicit convection produce more realistic precip. distributions than parameterized convection runs.**
- **4km model with explicit convections has heating/moistening profiles that favor transitions between different rainfall regimes.**