Insights into the Large-Scale Coherence of Convection Through Statistical Models of Cloud Regimes

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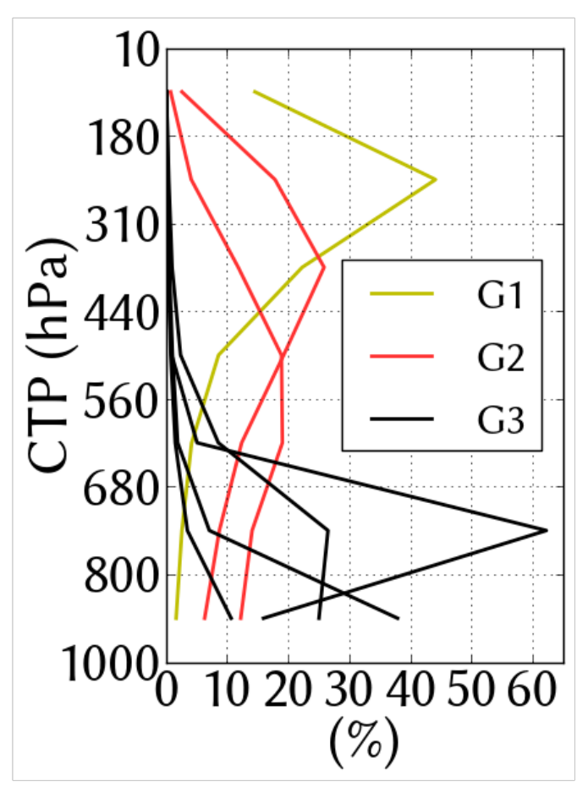
INTRODUCTION

- Convection is a critical process dominant in the tropics, controlling quantities such as rainfall and cloud cover, with an effect that spans across multiple orders of magnitude
- However, global climate models cannot resolve convection, so it has to be represented through parametrisation schemes, in which the statistical behaviour of convection inside a grid box is related to the resolved variables
- Current schemes in climate models are deterministic, which is undesirable because they cannot capture the statistical nature of convection in a grid box
- Many **stochastic** schemes have been proposed, but most of them are local
- **Local**: convection in a grid box is diagnosed from the resolved variables *without consideration* of the previous time step and surrounding grid boxes
- The goal of this study is to examine the **consequences of this local approach** on the **coherence of convection** in simple statistical models

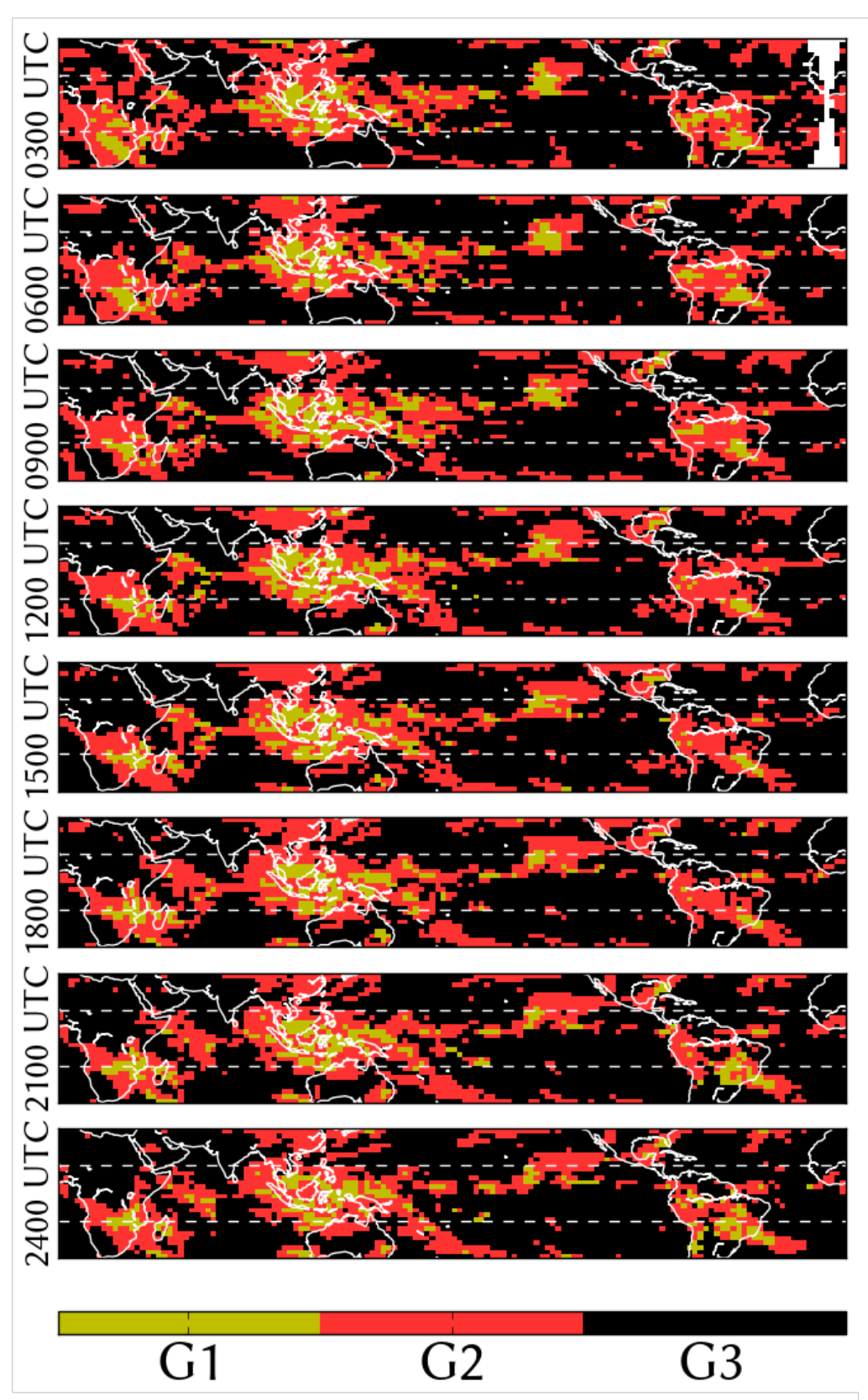
CLOUD REGIMES

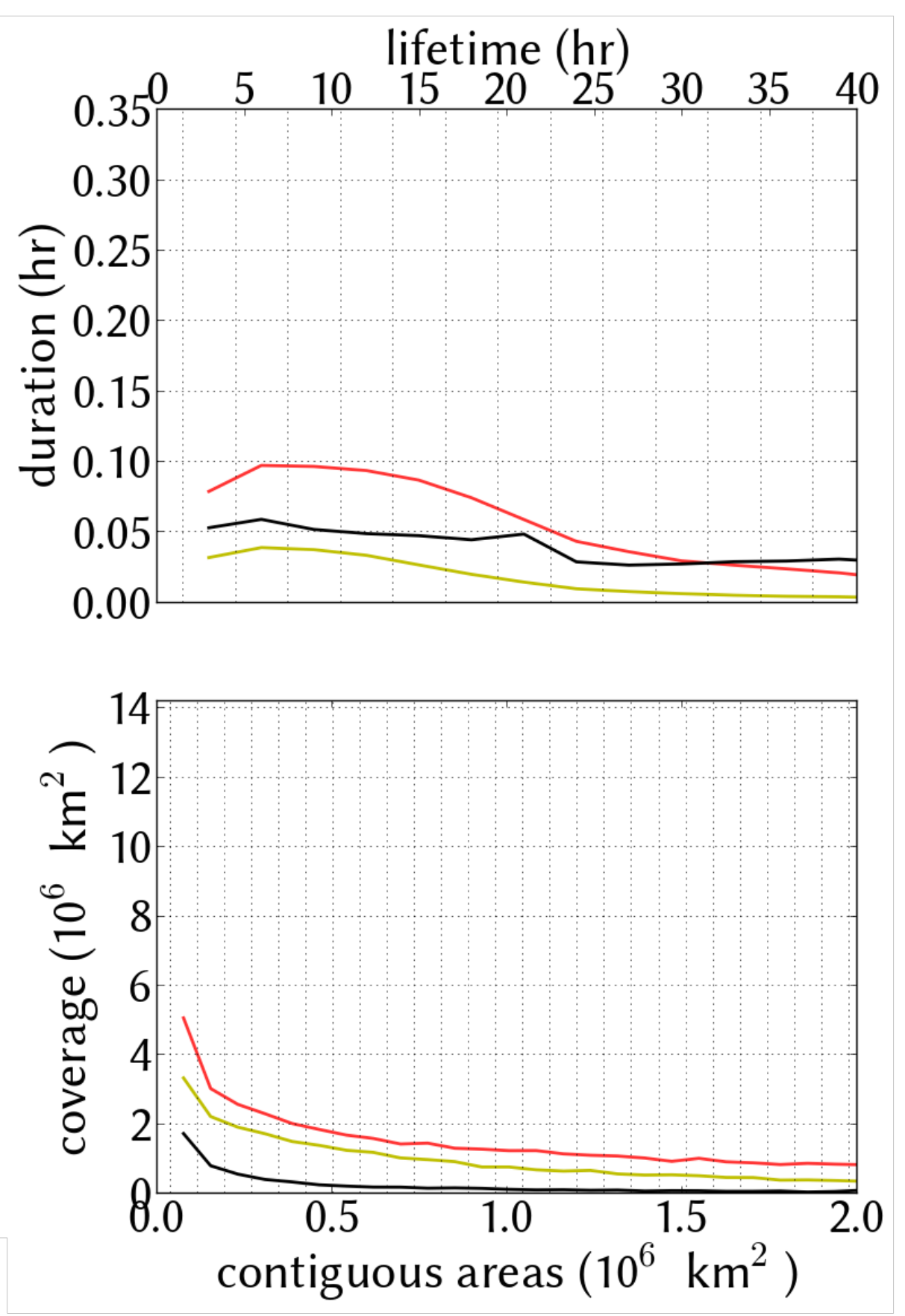
- An objective categorisation of cloud fields based on the distribution of their cloud top pressures and optical thicknesses (Jakob and Tselioudis, 2003; Rossow et al., 2005)
- Extended from daily to **3 hr time resolution** in Tan and Jakob (2013) using their cloud top pressures only
- **2.5° spatial resolution**, comparable to global climate models
- Seven regimes in 35°N/S, identifying cloud fields which represent **highly-organised deep convection** (G1), **less-organised deep convection** (G2), and **convectively-suppressed environments**(G3)
- We will use these cloud regimes as proxies for different states of tropical convection to study its coherence beyond a single grid box and time step

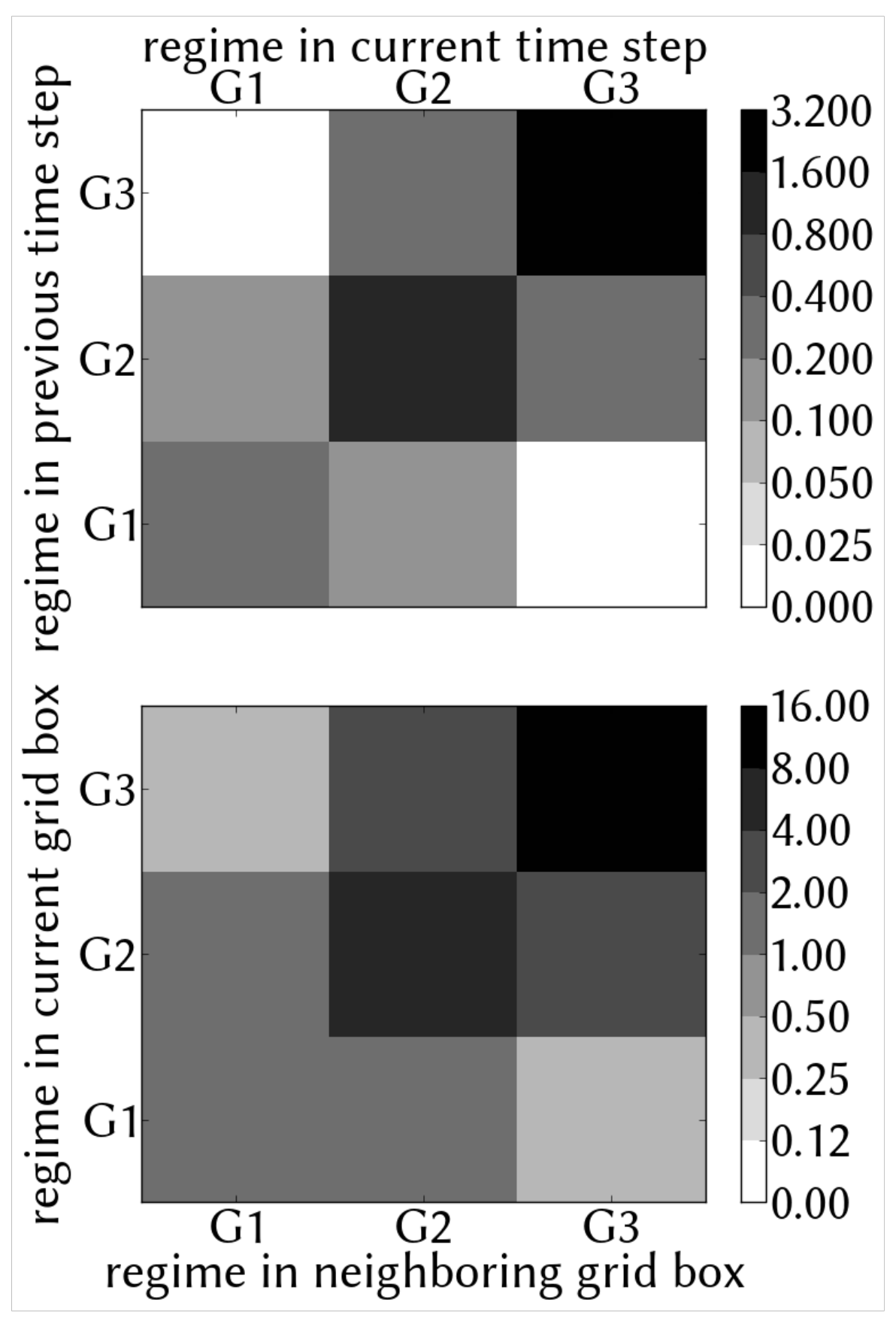


THE REAL WORLD

- We are interested in the coherence of convection in the deep tropics (15°N/S)
- **Coherence**: the ability to form structures *beyond* the grid box and time step
- Quantified through distributions of **lifetimes** and **contiguous areas**, presented as duration and coverage (histogram counts multiplied by bin value and a normalising factor)
- Can be interpreted as probability of having the regime at that specific value
- Inter-regime relationship can be shown by counting their **transitions** and **neighbours**



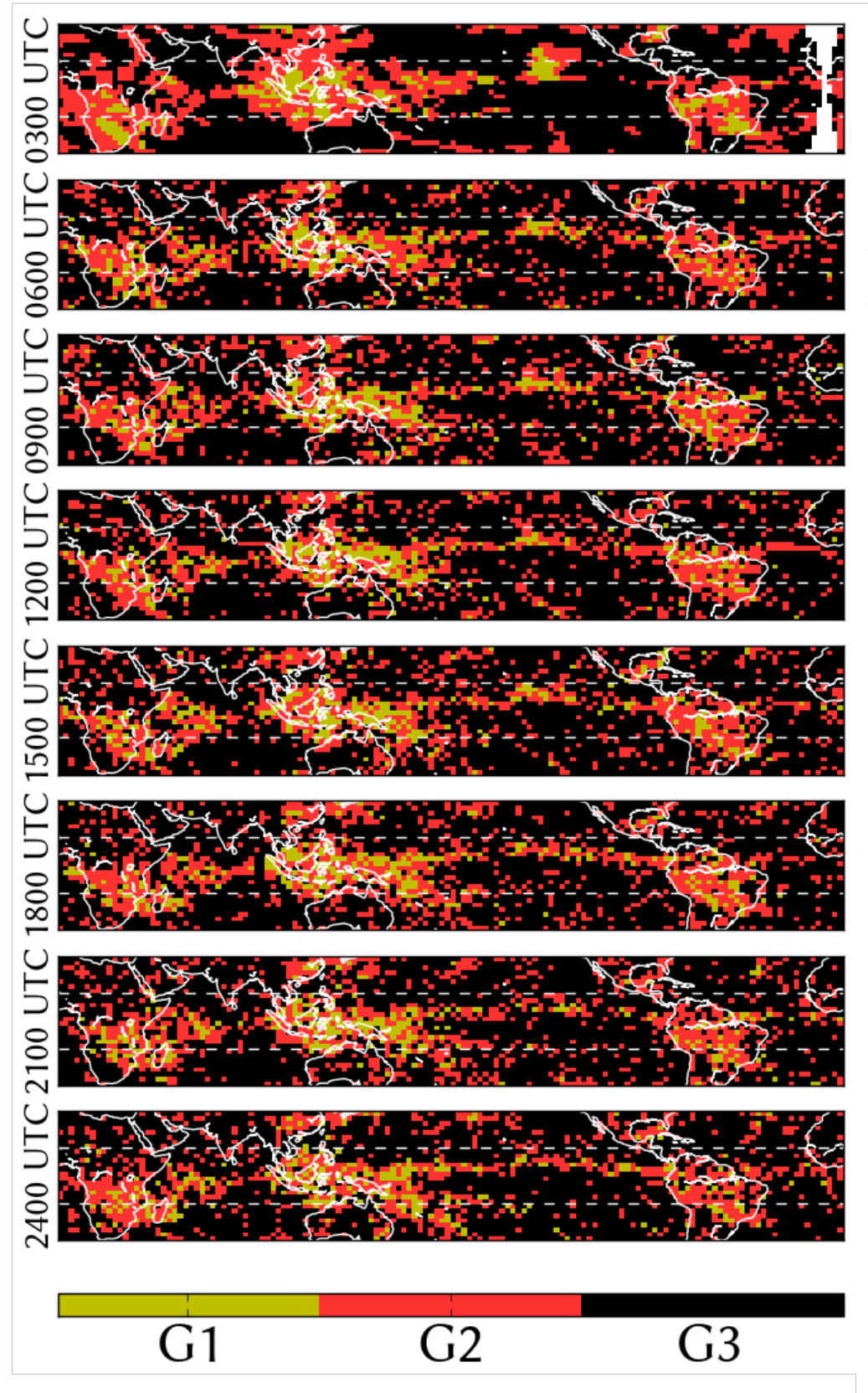


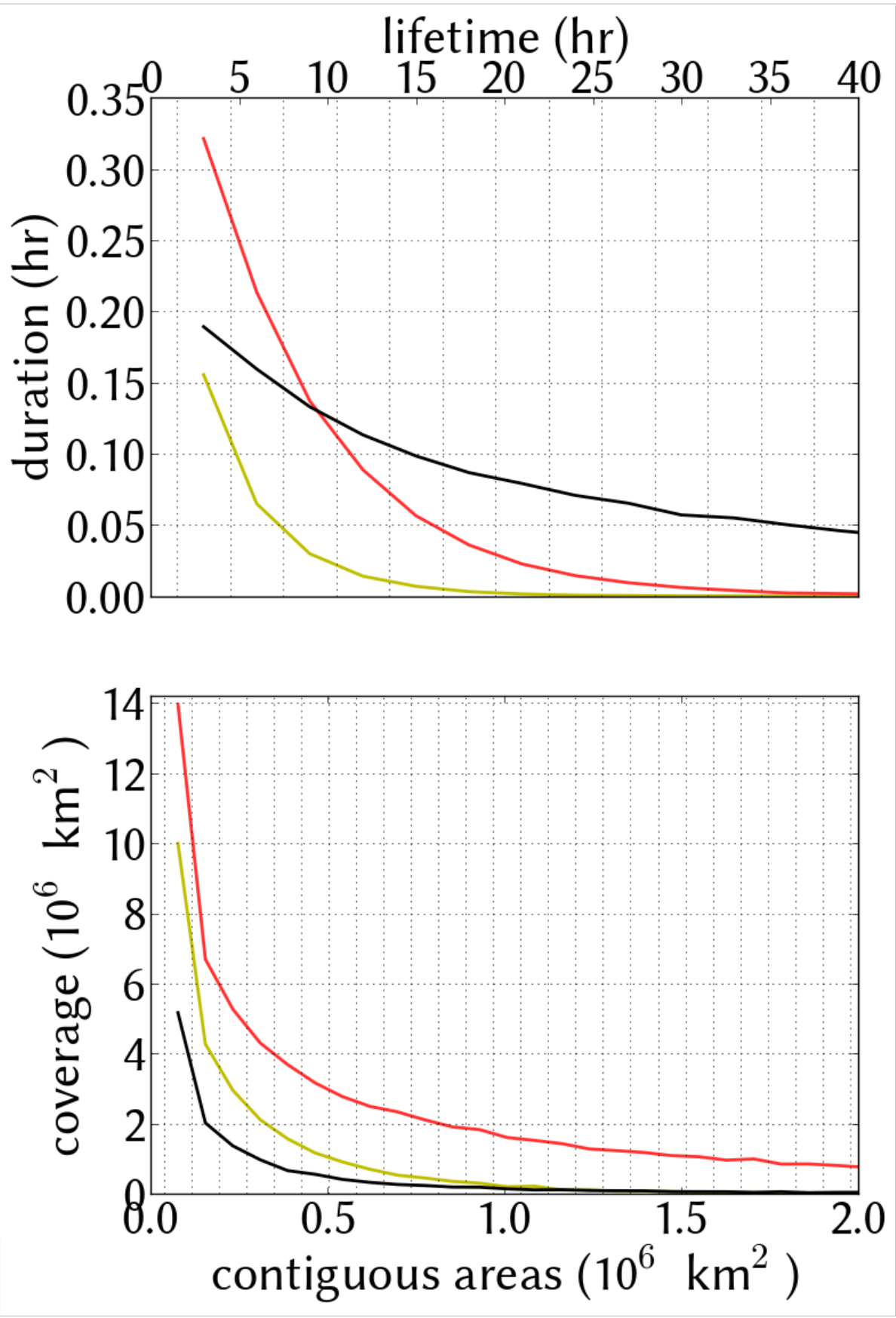


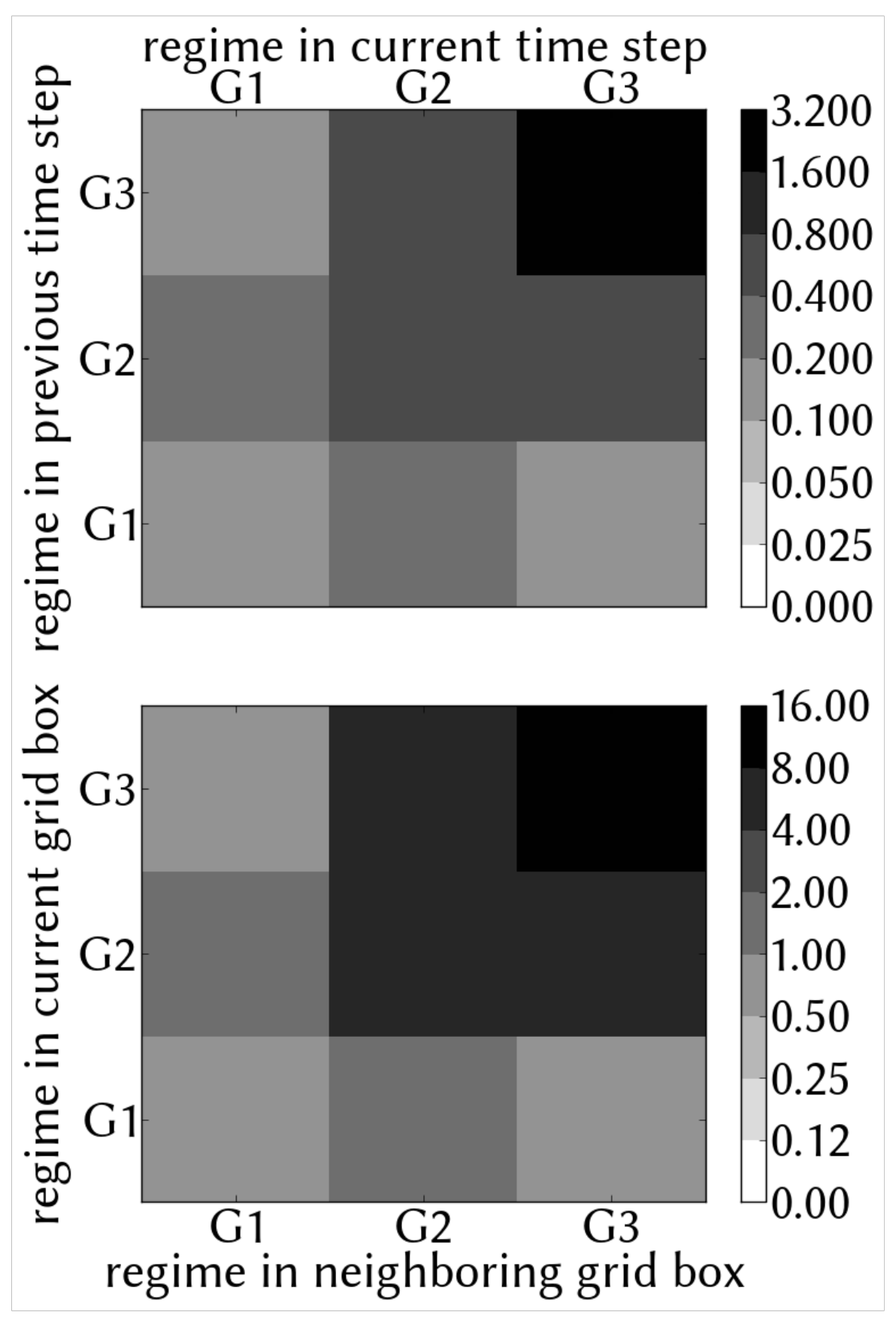
- More short-lived regimes and of smaller sizes than long-lived and larger regimes
- But still many occurrences of long-lived regimes and large in size
- Regimes are more likely to transition to or have as neighbors regimes of same or similar convective nature
- Duration increases from 3 hr to 6 or 9 hr, meaning regimes tend to last more than one time step
- This is not seen in coverage because of resolution mismatch: 2.5° / 3 hr ≈ 26 m / s
- **Conclusion: regimes have high degrees of spatiotemporal coherence in observations**

THE LOCAL MODEL

- Regimes can be composited with large-scale variables (Tan et al., 2013):
  - **saturation fraction** (moisture)
  - **K-index** (convective instability)
  - **vertical motion** (dynamics)
- Bin composites into multivariate histograms and normalise counts within each bin
- This gives us the probabilities of G1, G2 and G3 in each bin
- Model works by **looking up large-scale variables** of the grid box, finding corresponding bin, and **assigning the regime based on the probabilities**



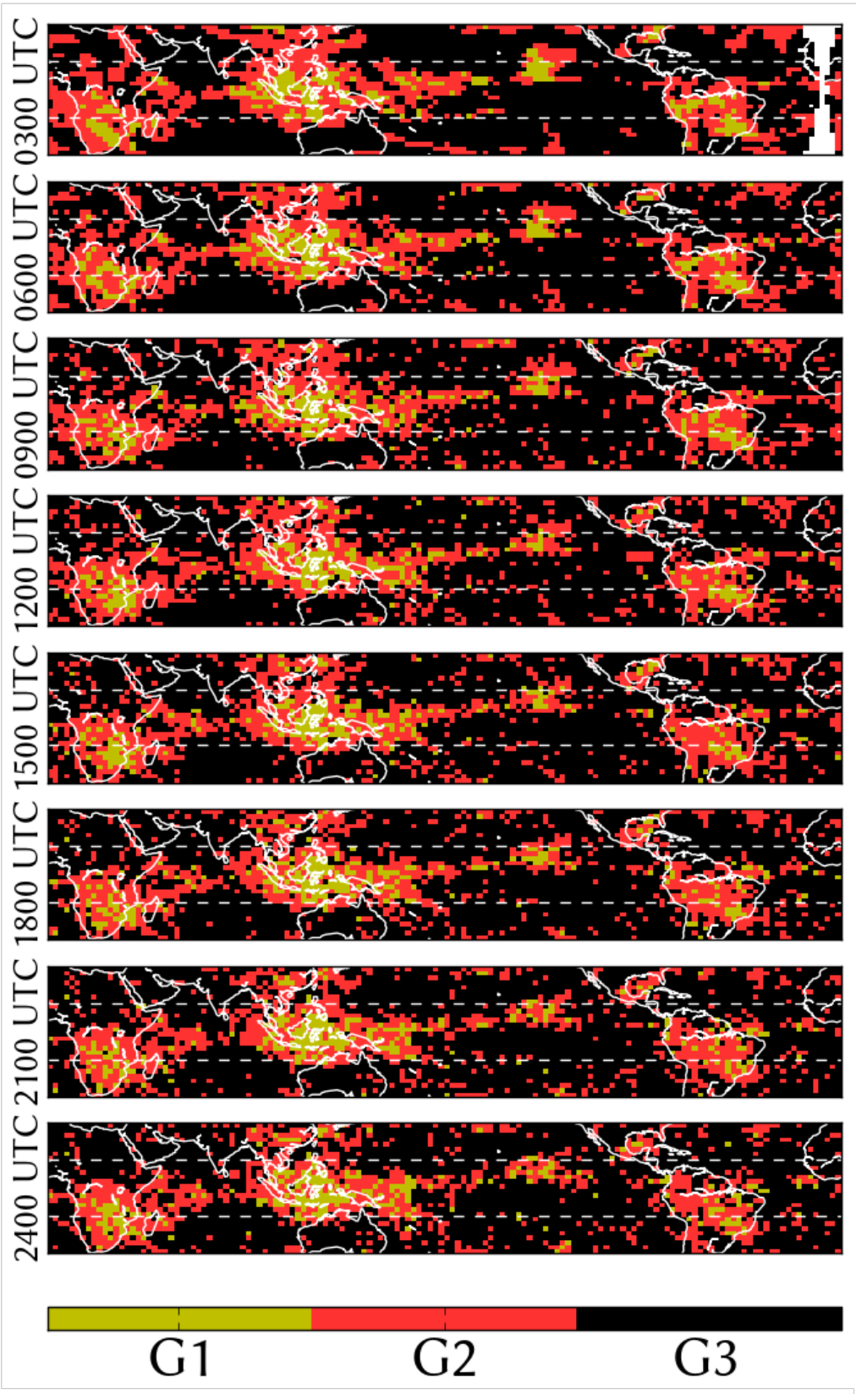


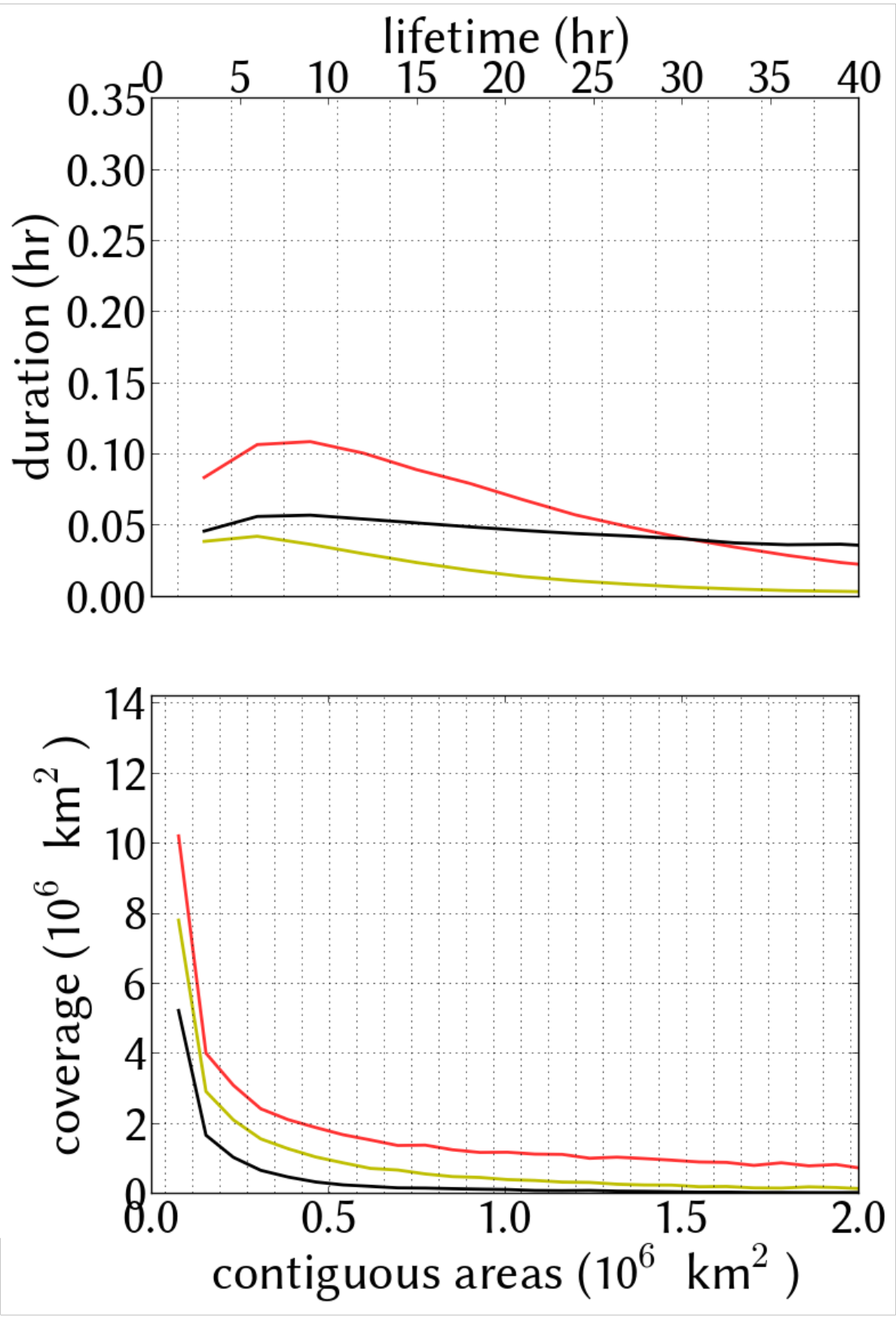


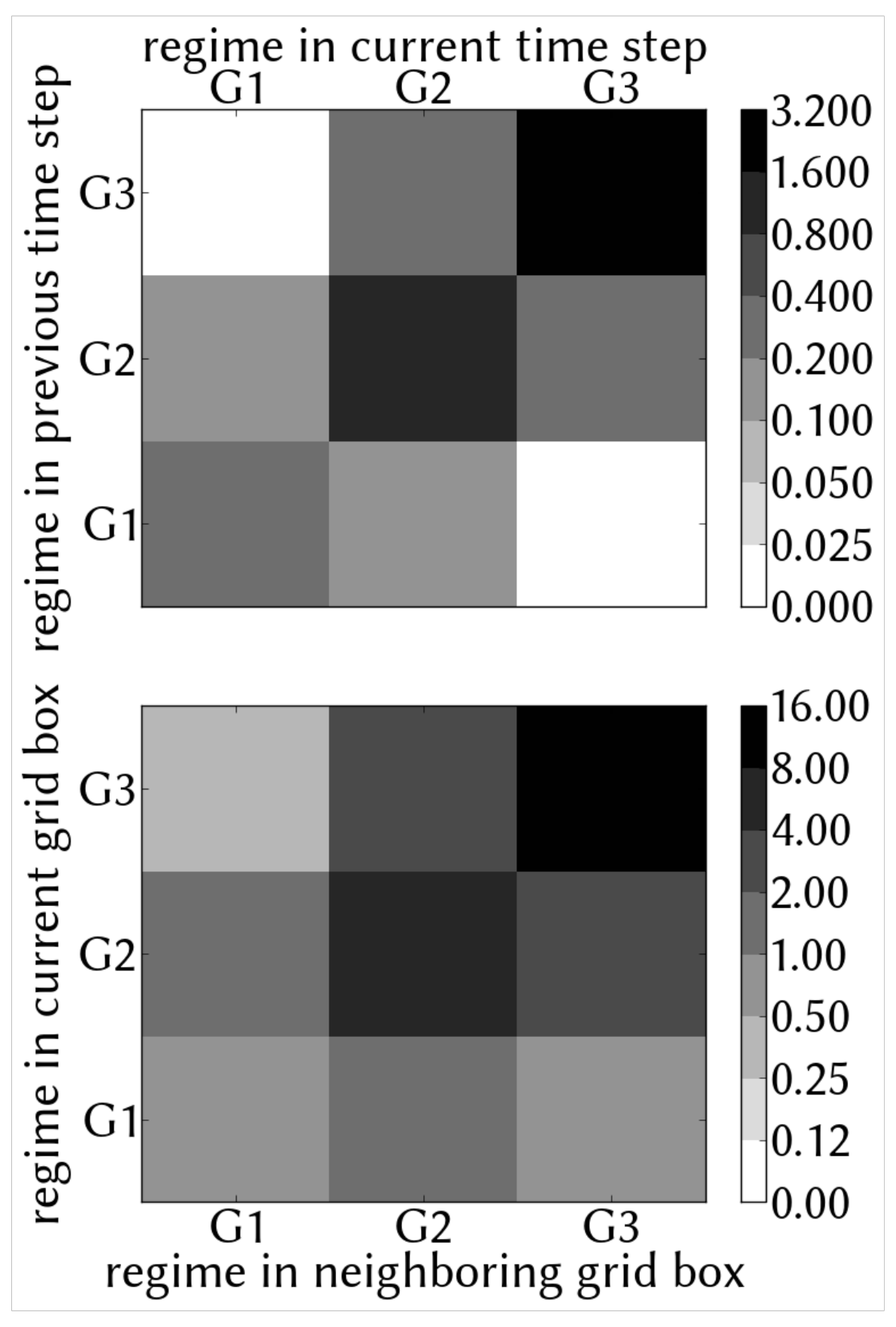
- Regime field noisy and flickers at each time step
- Durations are too high at short lifetimes and too low at long lifetimes
- Coverages of regimes of small areas are too high and those of large areas are too low
- Transition/neighbour counts are unrealistic, e.g. G1 is more likely to change to G2 than to remain in G1.
- **Conclusion: the local model produces regimes which lack spatiotemporal coherence**

MODEL WITH MEMORY

- We can incorporate memory into the model.
- Temporally, use Markov chain technique: composite variables with regime transition at each time step, giving a set of transition probabilities
- Spatially, use surrounding eight grid boxes in the previous time step, obtaining a set of surrounding probabilities
- Average and normalise the probabilities, with which we randomly assign the regime
- Model now has **temporal memory from previous time step** and **spatial memory from surrounding grid boxes**







- Regime field still noisy, but fewer one-grid occurrences and does not flicker much
- Substantial improvement in lifetimes, now closely resembles real world
- Transitions identical to observed counts within limits of histogram bins
- Slight improvement in area sizes: lower coverages at small sizes, but still unable to match real world
- Neighbour counts marginally improved, but G1 still performs poorly
- **Conclusion: the inclusion of spatial and temporal memory recovered some coherence in the model**

CONCLUSION

- States of convection as represented by cloud regimes have **coherence beyond a single grid box and a single time step in the real world**.
- However, when the regimes are represented in a statistical model adopting a **local approach**, the regime field is **bereft of coherence**.
- When **memory** is added in the form of the previous time step and the surrounding grid boxes, some of the **coherence is reclaimed**.
- Implication: a stochastic parametrisation of convection that neglects nonlocal effects may not attain the observed levels of coherence.

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Jakob, C. and G. Tselioudis, 2003: Objective identification of cloud regimes in the Tropical Western Pacific. *Geophys. Res. Lett.*, **30**, 2082, doi:10.1029/2003GL018367.
Rossow, W. B., G. Tselioudis, A. Polak, and C. Jakob, 2005: Tropical climate described as a distribution of weather states indicated by distinct mesoscale cloud property mixtures. *Geophys. Res. Lett.*, **32**, L21812, doi:10.1029/2005GL024584.
Tan, J. and C. Jakob, 2013: A three-hourly dataset of the state of tropical convection based on cloud regimes, *Geophys. Res. Lett.*, **40**, 1415–1419, doi:10.1002/grl.50294.
Tan, J., C. Jakob, and T. P. Lane, 2013: On the Identification of the Large-Scale Properties of Tropical Convection Using Cloud Regimes, *J. Climate*, **26**, 6618–6632, doi:10.1175/JCLI-D-12-00624.1.