OBSERVATIONAL EVIDENCE FOR SOIL MOISTURE PATTERNS AFFECTING DEEP CONVECTION IN MATURE MESOSCALE CONVECTIVE SYSTEMS (MCS)

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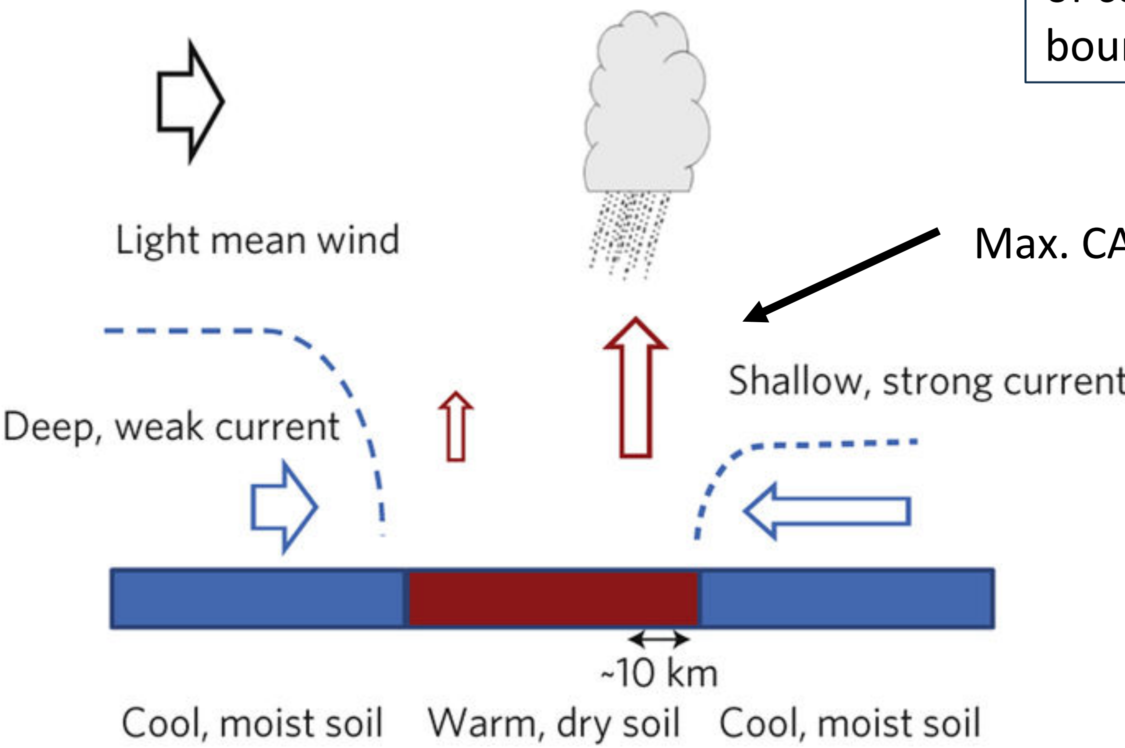
2: National Centre for Earth Observation, UK.

Surface sensitivity of MCS: afternoon-initiation case

Widely evaluated in models / observations:

Convection is fostered on the dry side of convergence zones of land-surface boundaries



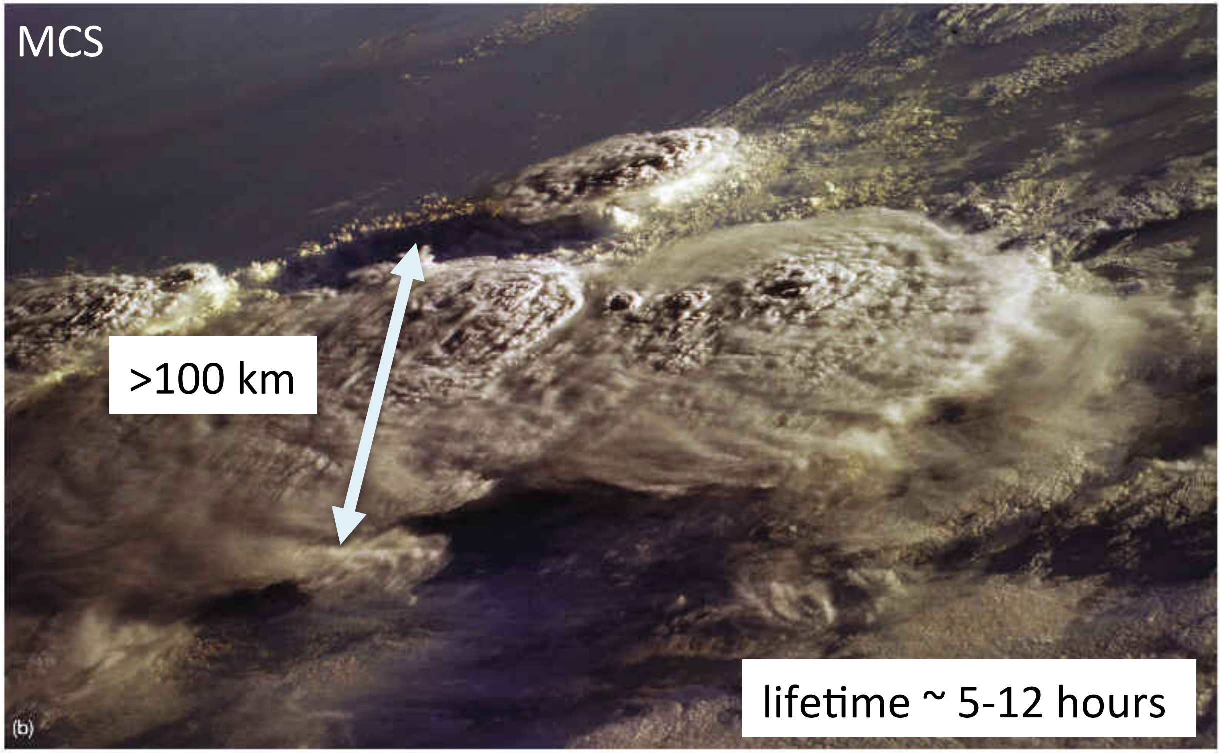
Taylor et al., Nat. Geosci. (2011)

Max. CAPE, max. Θ_e , convergence line

+ ~2 hours

Fully organised MCS

Surface sensitivity of MCS: the messy mature stage



ISS, NASA

- Low-level jets and elevated triggering
- Storm-induced gravity waves and cold pool dynamics

Surface sensitivity?

Models suggest:

- Intensification over wet soils / moist boundary layer (CAPE)

- **Do soil moisture conditions affect MCS propagation and can we observe it?**
- **If yes, at what scales?**

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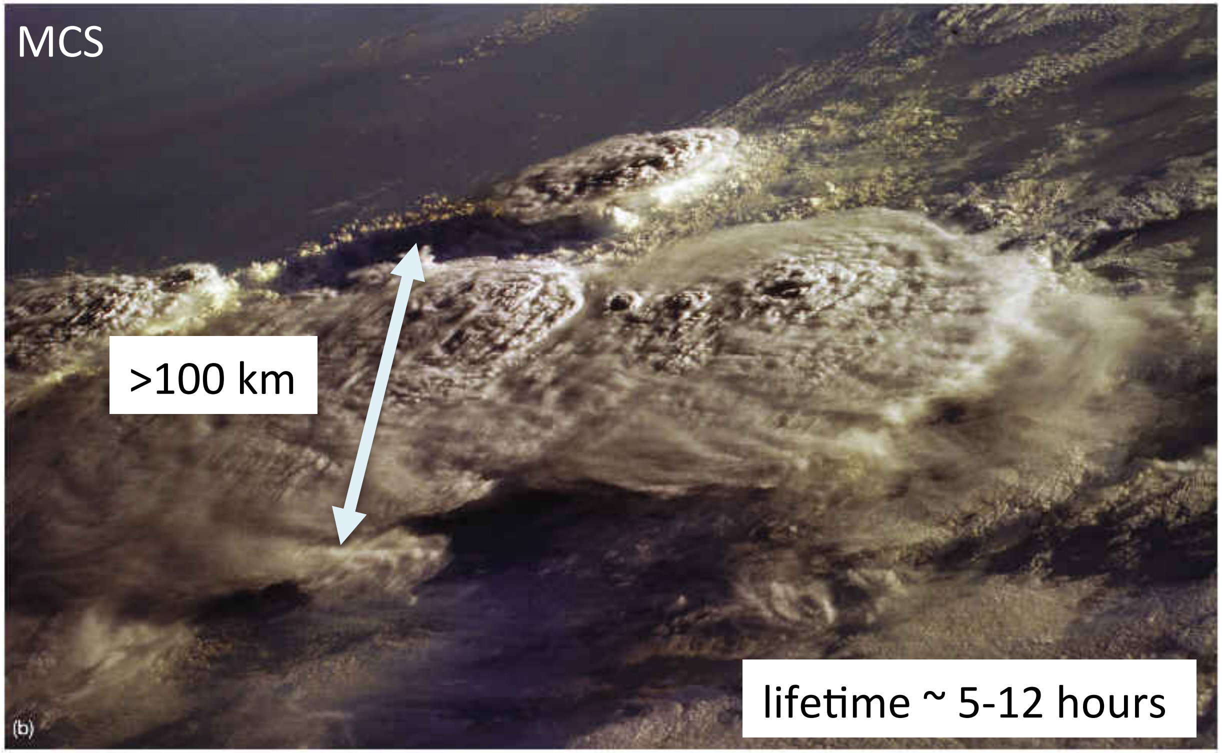
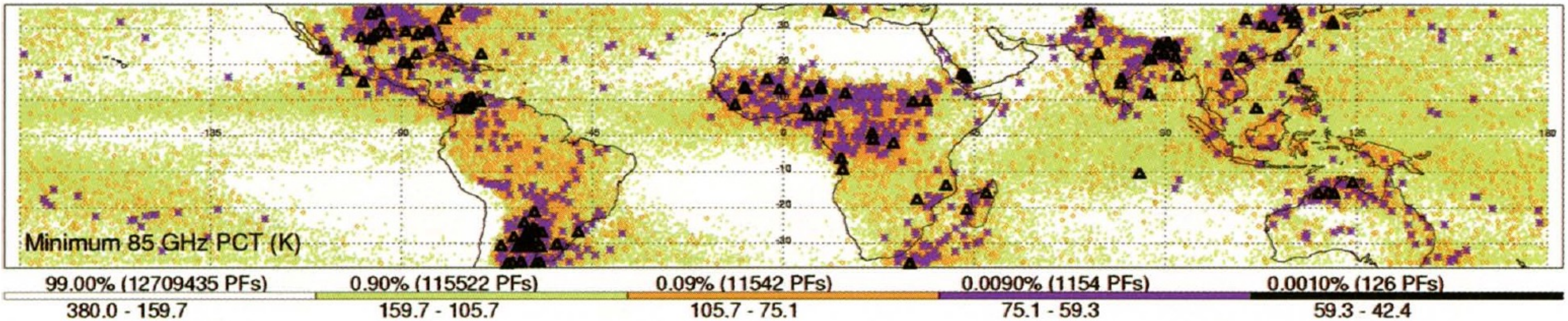
Surface sensitivity of MCS: the messy mature stage



ISS, NASA

Mesoscale convective systems: some of the most intense storms on Earth

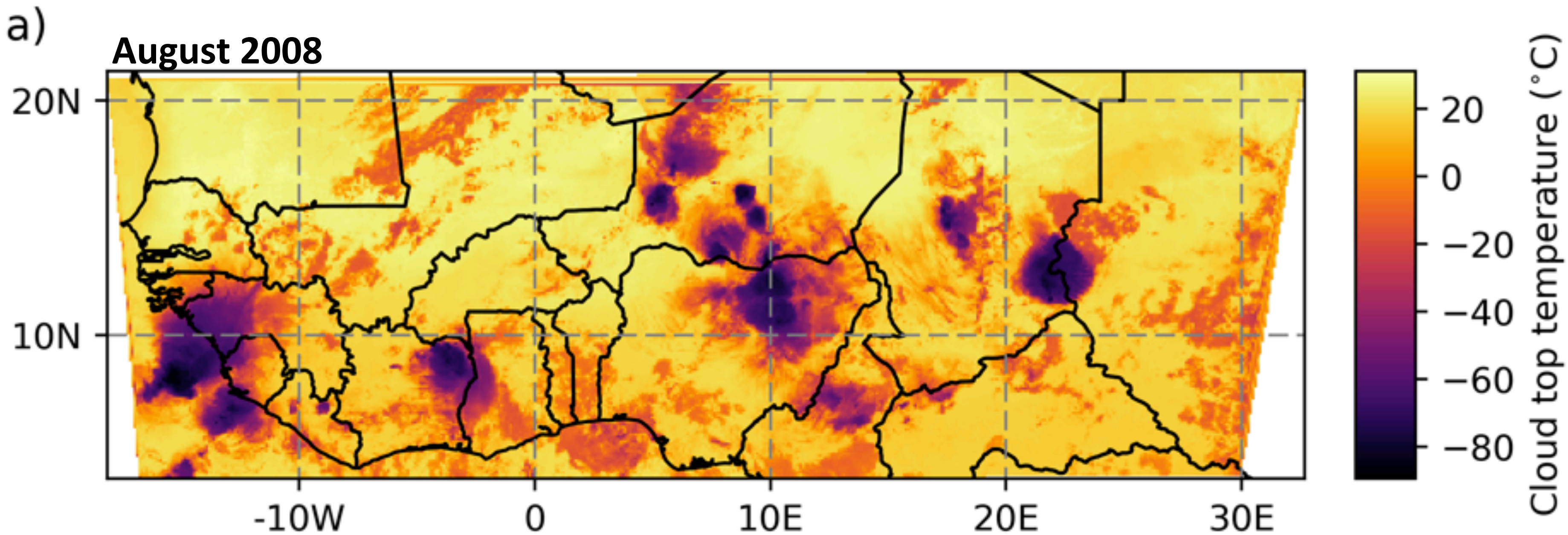


Zipser et al., BAMS (2006)

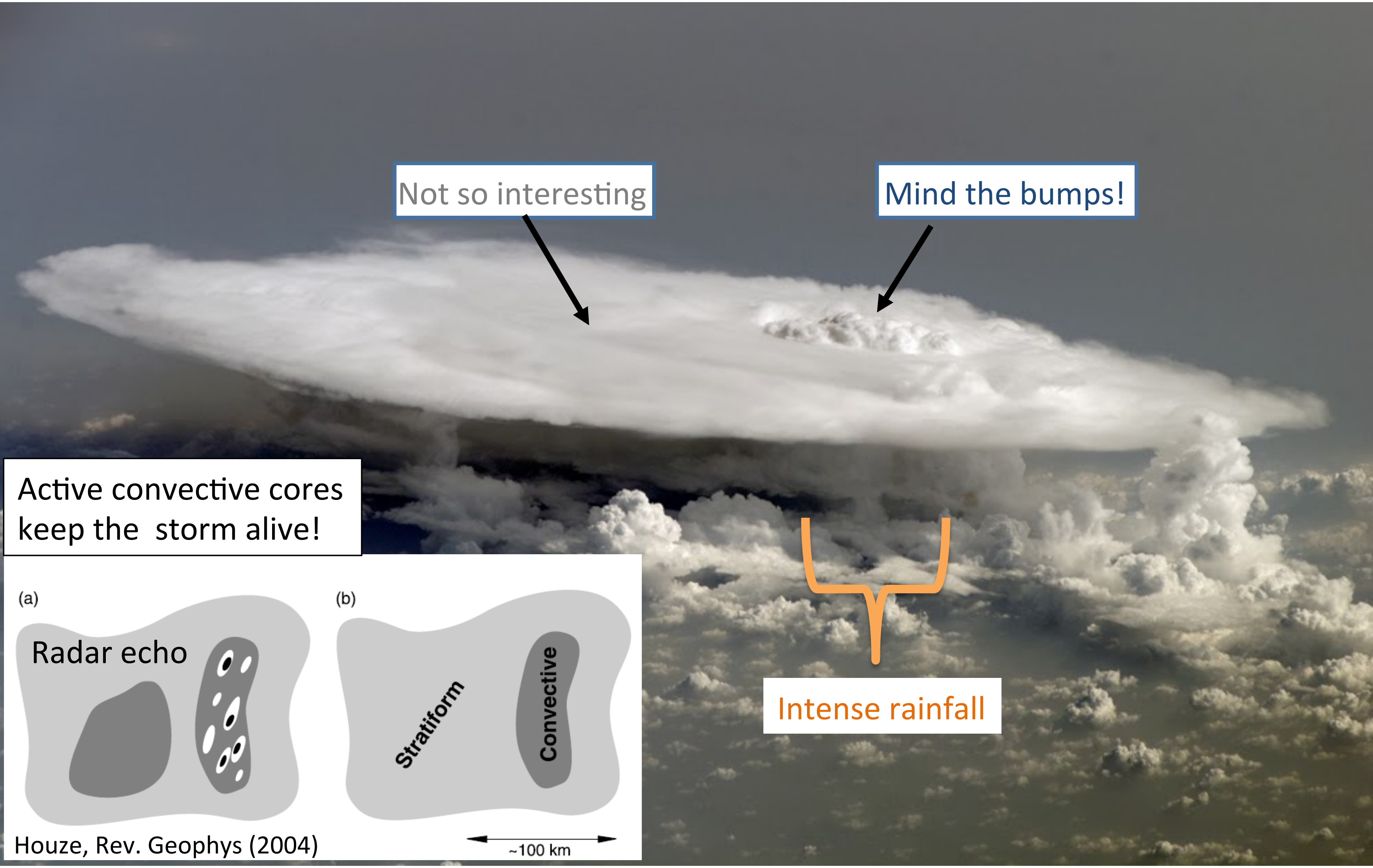
Observing MCS during the West African monsoon

Meteosat Second Generation cloud top temperatures (brightness temperatures < -40C)
Used here: Jun-Sep 2006-2010, hourly intervals, 5km

MCS > 15,000 km^2 , **-> 90% of extreme rainfall occurrence and 50-90% of annual rain**



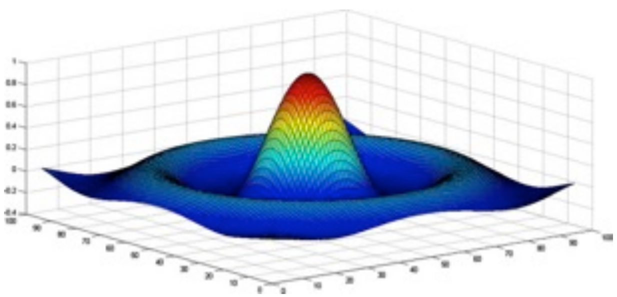
Deep convection: connecting lower & upper troposphere



Thunderstorm over West Africa

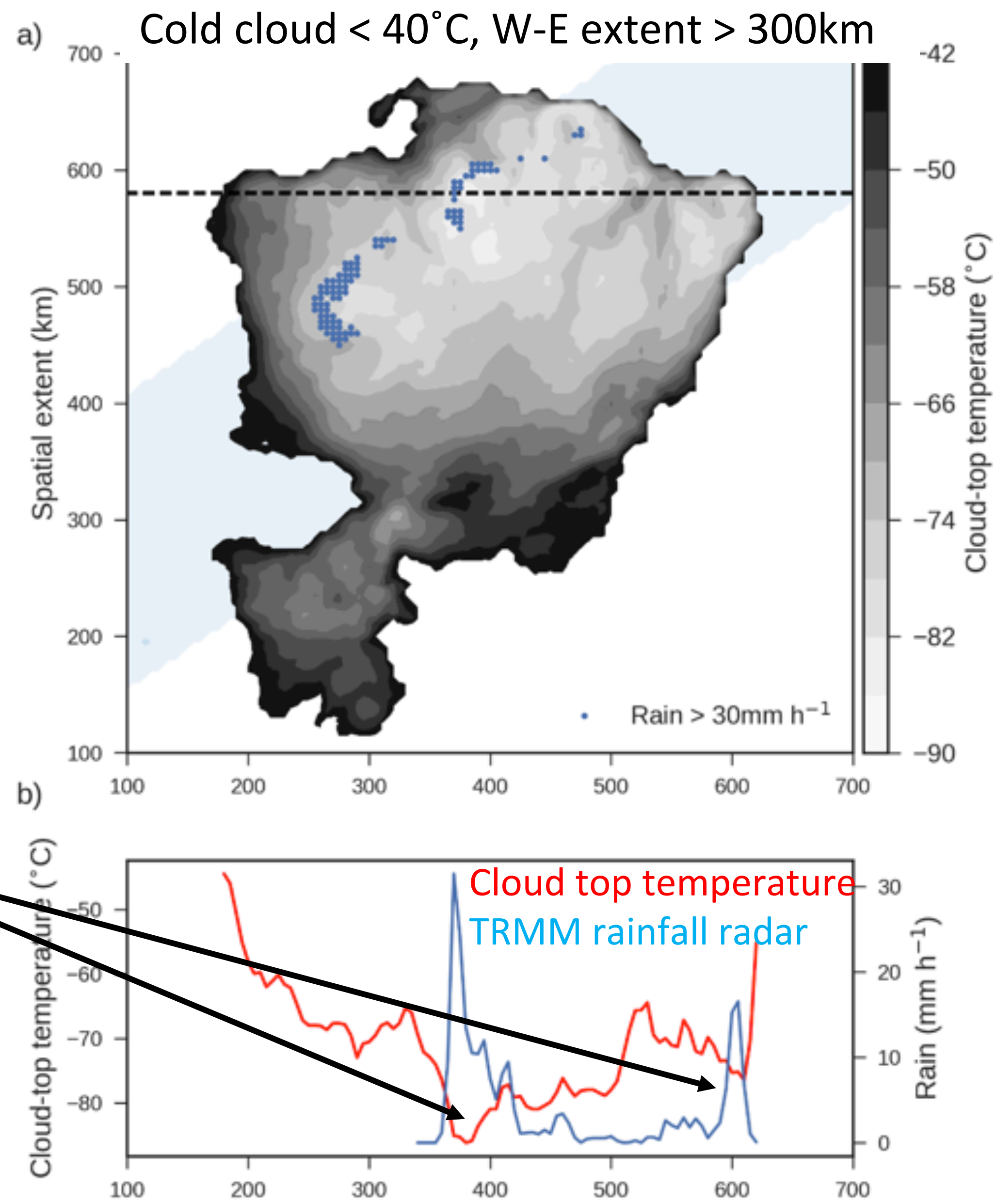
ISS, NASA

Detecting convective cores from cloud top temperatures



2D Mexican hat wavelet

We identify the centre point of such cold “convective cores” by performing a **wavelet scale decomposition of cloud top temperatures** *(Klein et al., JGR-A, 2018)*



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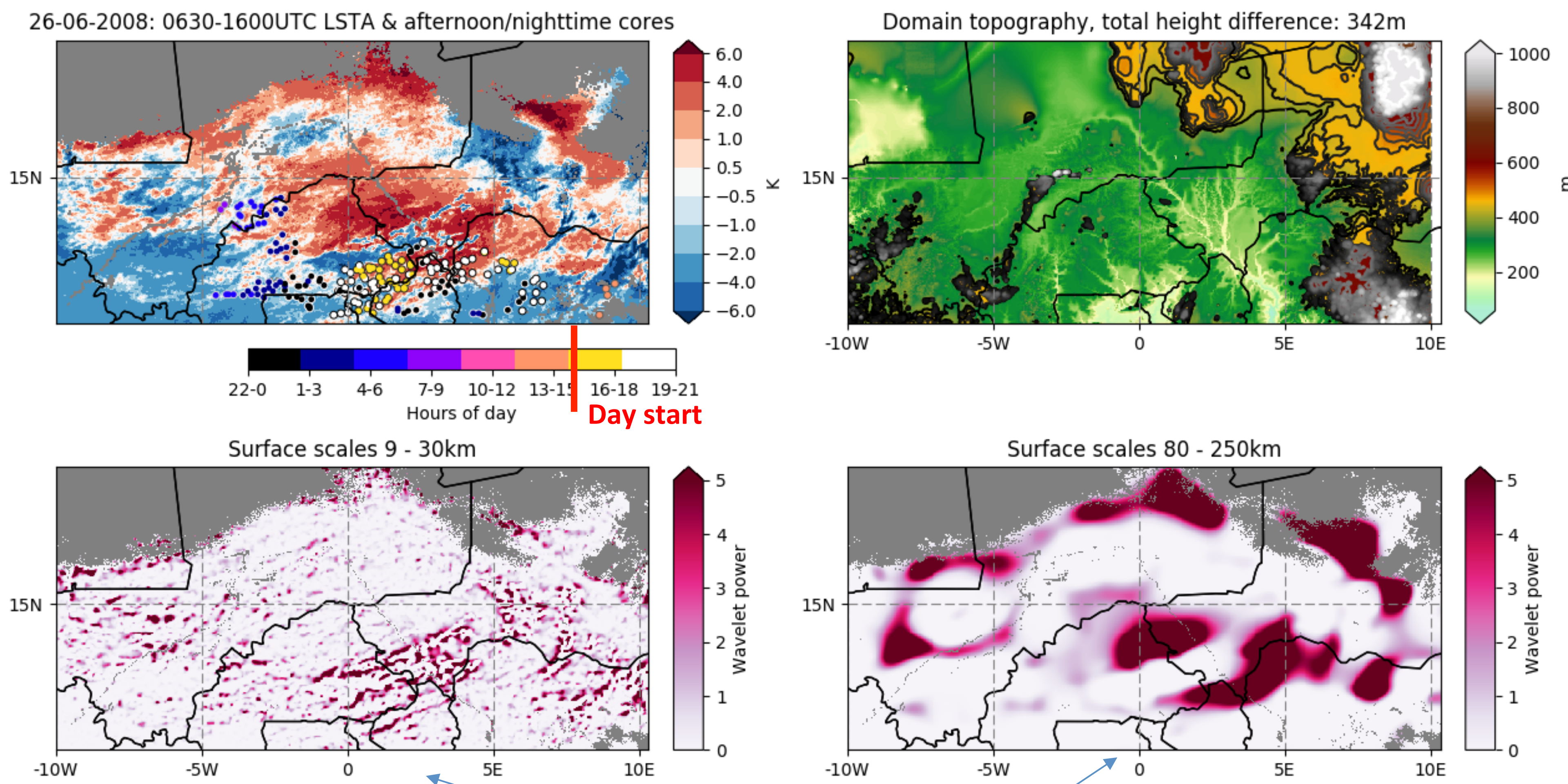
Matching up convective cores and wet/dry surface conditions at different scales

Scale decomposition of Meteosat land-surface temperature anomalies (LSTA):
17-0500UTC convective cores and preceding LSTA (06-1600UTC)

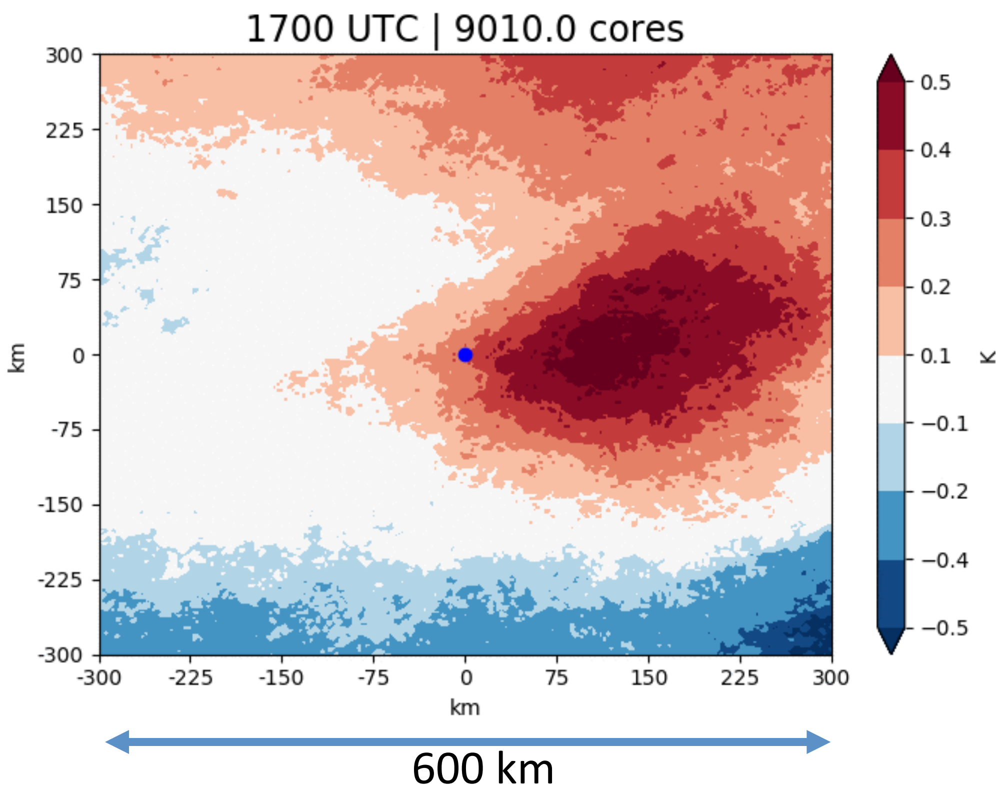
-> LSTA is a good proxy for soil moisture in the semi-arid Sahel



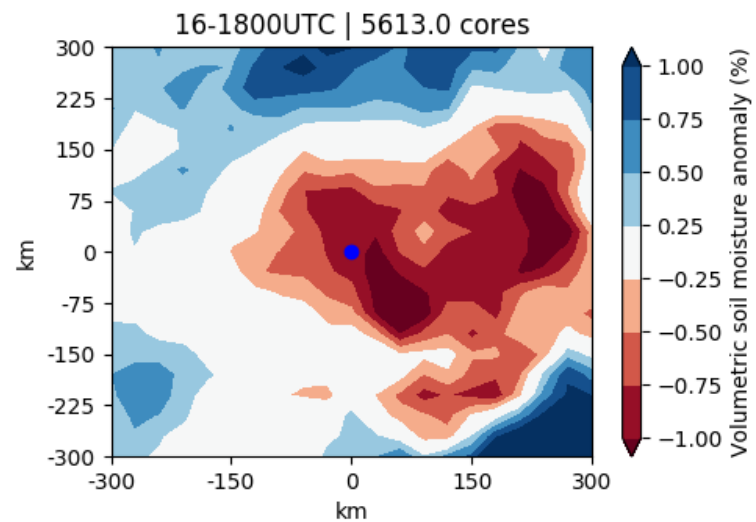
Positive amplitudes only

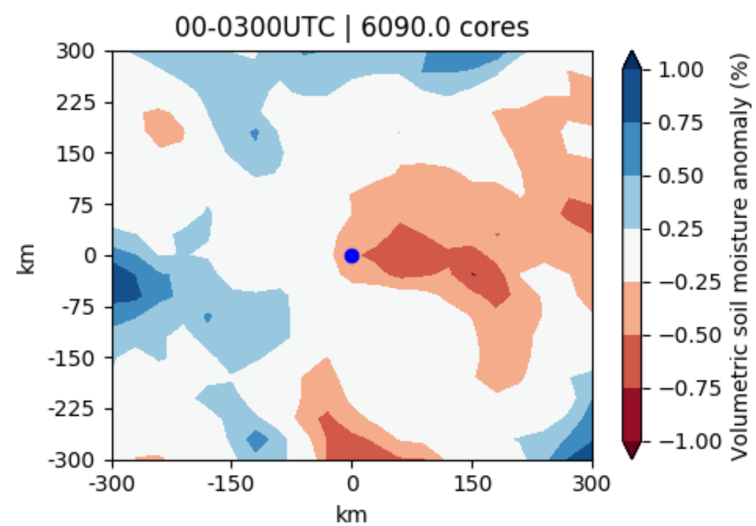
Composites of surface conditions centred on convective cores

Seasonal land surface temperature anomalies



Regional soil moisture anomalies (AMSR-E, 0.25˚) centred on intense rainfall (> 20 mm, TRMM radar)

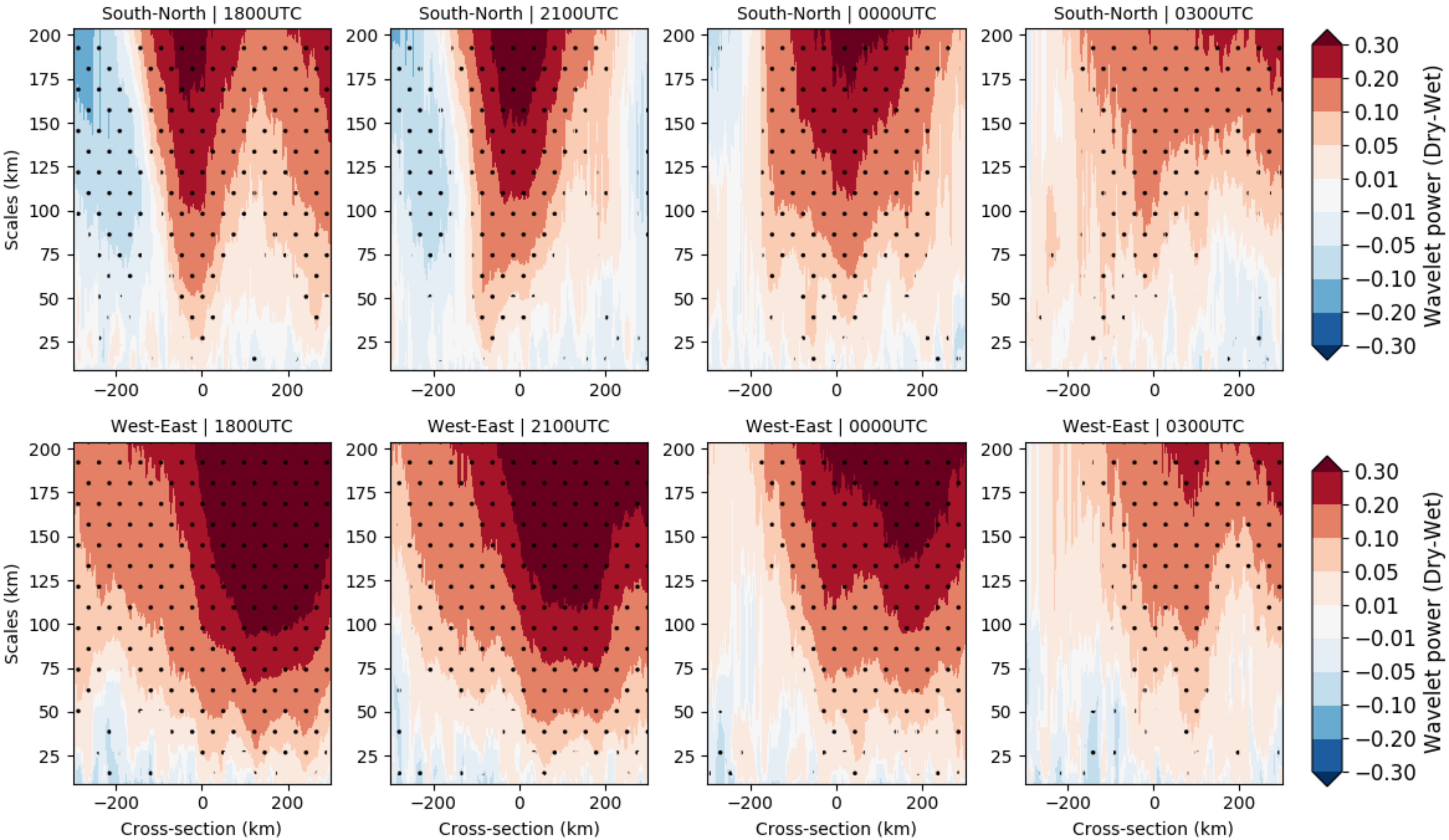




- ‘stationary’ ~2-3 hours warm upstream feature
- Persistent dry signal into nighttime hours

Scales of surface features throughout the day

Difference of wavelet powers for dry and wet LST anomalies centred on convective cores:



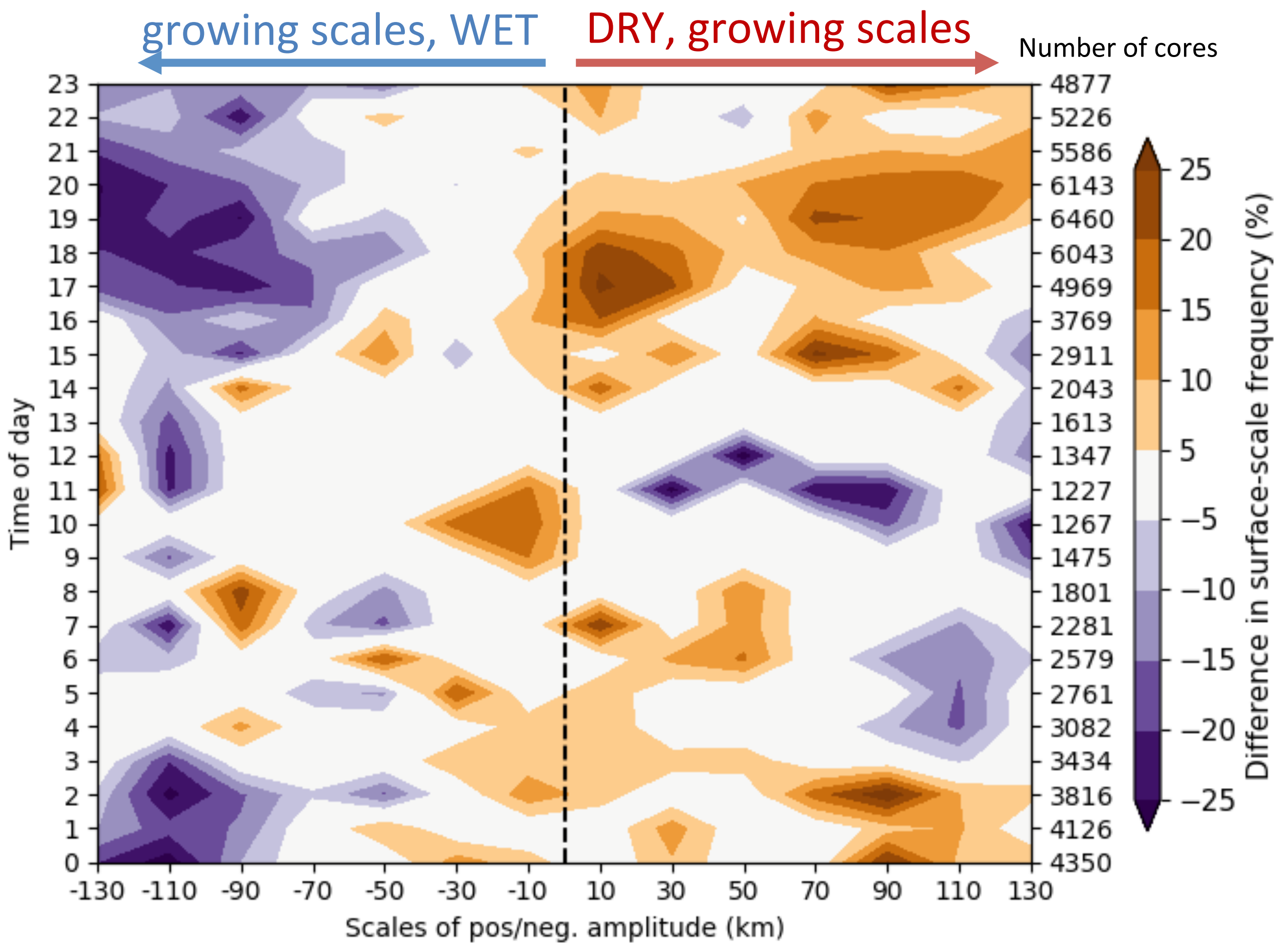
- Strong meridional temperature gradient down to ~25km as part of the larger W-E feature

-> propagation north of preceding-day storm tracks?

- Minimum significant scale of the warm feature is increasing through the night

The effect of surface features at different scales on the frequency of convective cores over the diurnal cycle

Difference in frequency of co-located scales in comparison to the total scale distribution:



Shown scales represent the scale of maximum wavelet power for the surface patch at the core location

10%-value: 1 in 10 convective cores could be affected

- Afternoon maximum similar to storm initiation case
- Large wet features > 80km decrease core frequency, even for nocturnal MCS
- Surface scale increase is consistent with increasing influence of advection

Summary

- We used a wavelet scale decomposition on cloud and surface features to evaluate sensitivities of convective cores within mature MCSs to surface conditions
- A dry-patch enhancement dominates even for nocturnal MCSs until ~0200UTC and is strongest in the afternoon
- The enhancement over dry patches follows a diurnal cycle and might reflect the smoothing of surface-induced variability in the planetary boundary layer
- No sign of a co-located or upstream positive wet feedback
- Potentially useful for forecasts of MCS propagation tracks
- What do models say?

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AMMA-2050

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Questions?

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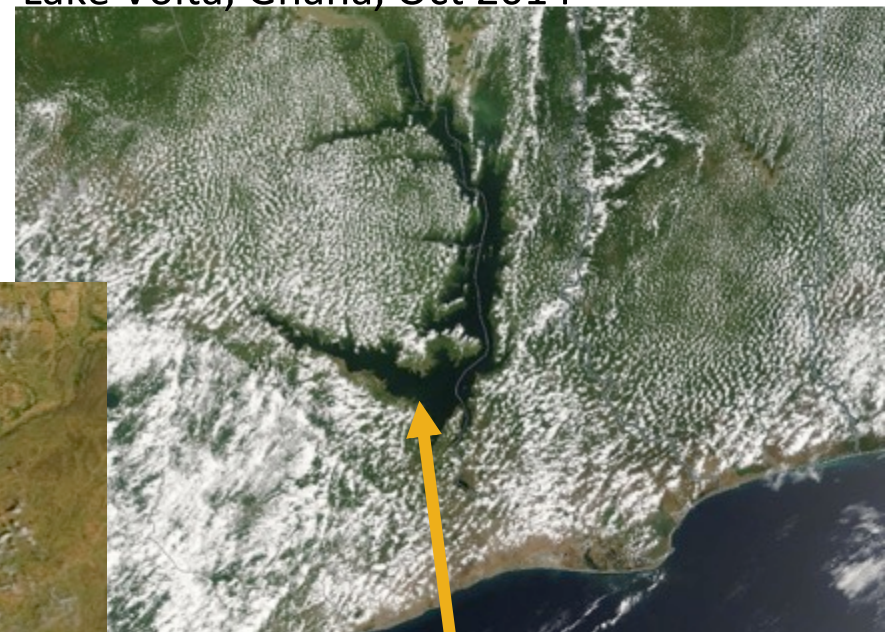
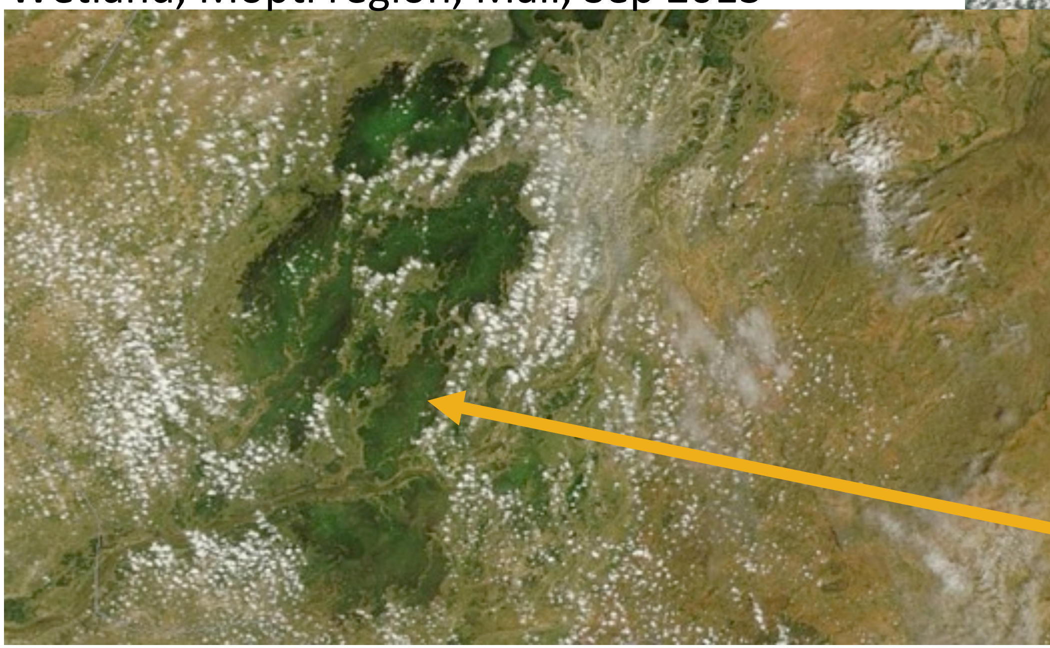
The surface can affect where clouds form

Lake Volta, Ghana, Oct 2014



Terra / MODIS

Wetland, Mopti region, Mali, Sep 2013



Terra / MODIS

- Cooler surface
- Small sensible heat flux
- Shallower boundary layer

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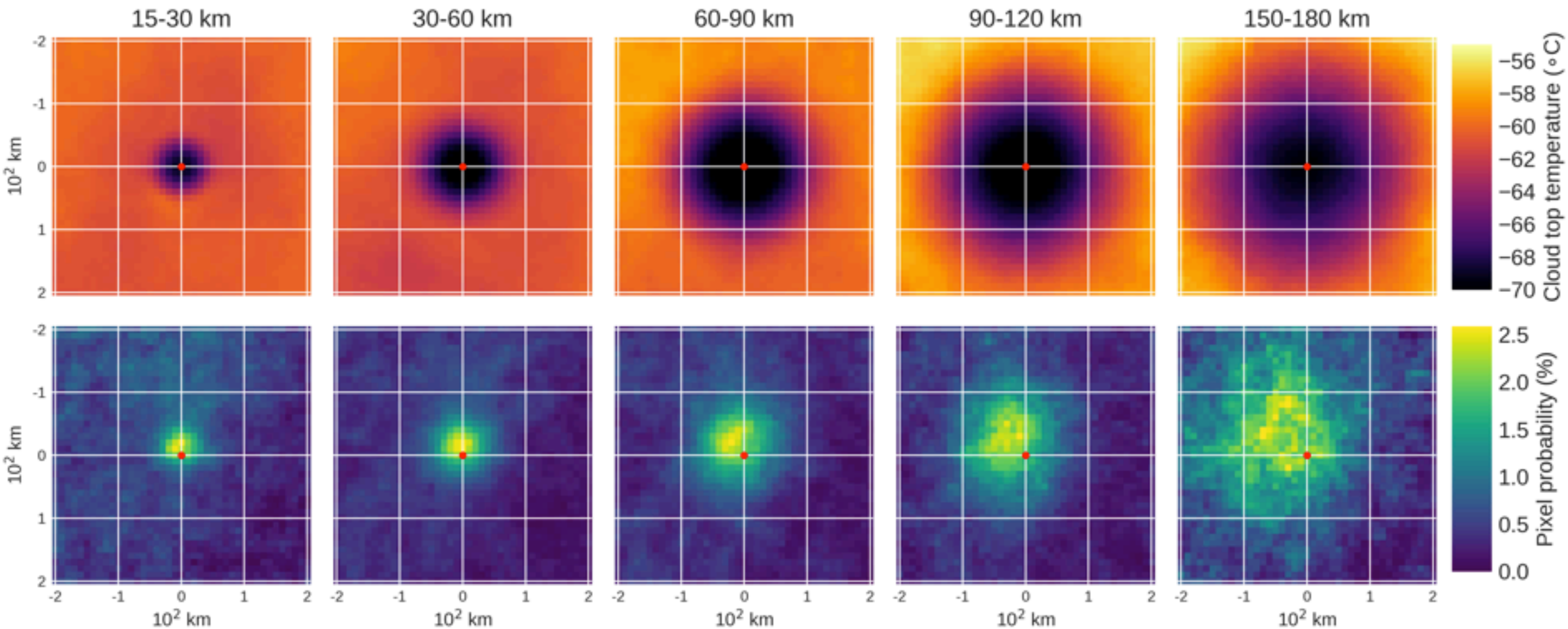
Scales of 'convective cores' and co-located TRMM PR rainfall

Composites centred on convective cores (<-50˚C): temperature & heavy rain probability



(*Klein et al., JGR-A, 2018*)

In 15km radius surrounding centre points for scales <= 60km:

- 1 in 3 sub-cloud features coincide with convective rain (> 8 mm/h)
- 8.3% are associated with heavy rain (99^{th} centile, > 30 mm/h)

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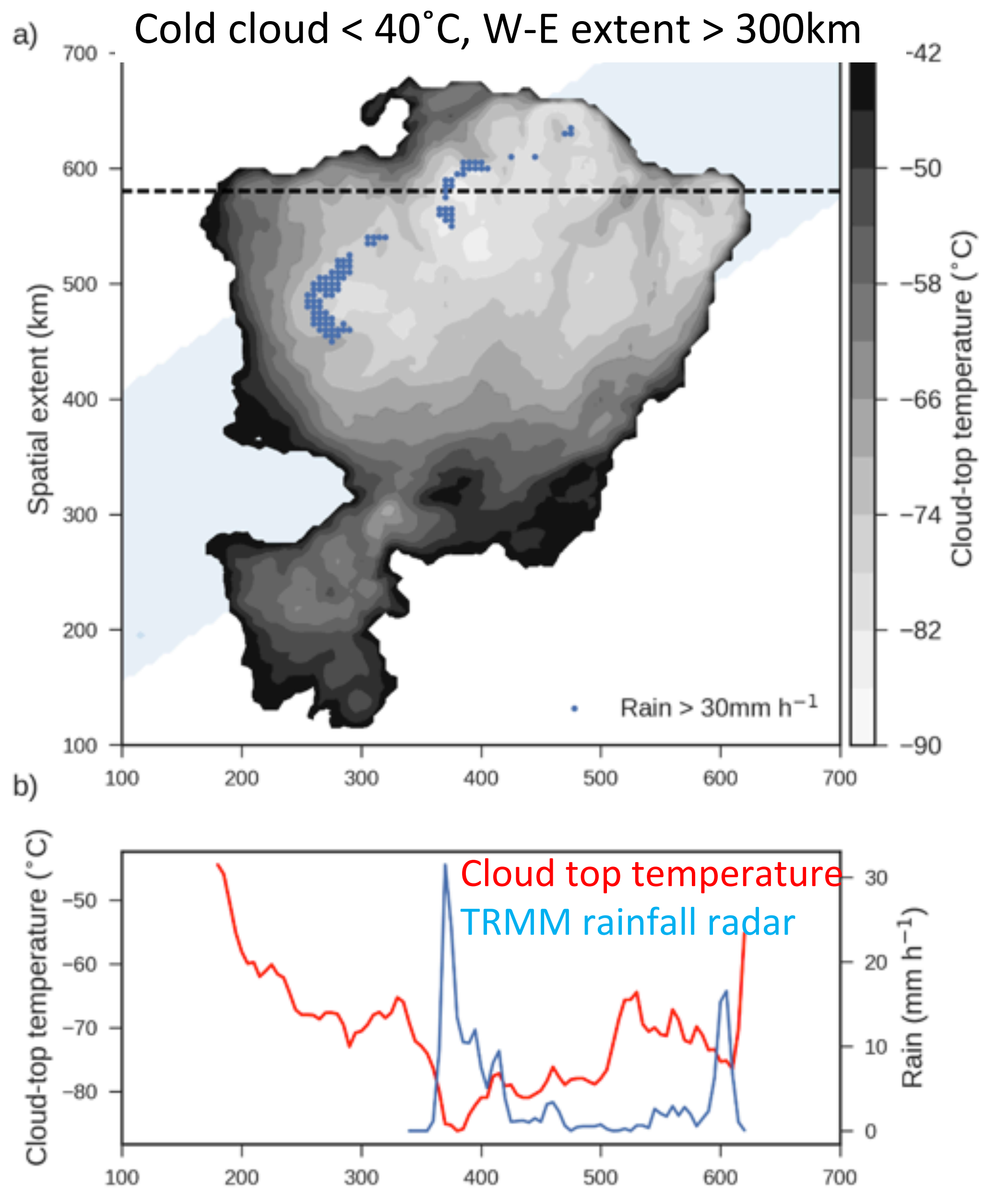
-> Rainfall is centred up to ~ 60km in convective cores

Detecting convective cores from cloud top temperatures

- Cloud-top temperatures indicate the height of the cloud top
- Coldest temperatures are often co-located with strong updrafts and intense convective rainfall



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Thank you for your attention!

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Sensitivities of nocturnal MCSs?

- Idealised simulations suggest preference for wet soils / moist boundary layer
- Effect of low-level jets at nighttime and elevated triggering (no contact to PBL anymore)
-

Birth and decay processes of convective cells cause storm size to grow

Average 12-14m/s propagation speed - ~ 43km/h -> 150km ~ 3h distance
15,000km2 = 70km radius
10m/s = 36km / h -> 150km~ 4h distance
MCS grow to 15,000km2 within ~ 4hours, do we see initiation point?
What about at midnight and after?

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