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How does the spatial scale of surface flux variability affect MCS properties?

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LMCS project

UKRI Natural Environment Research Council

EGU25 AS1.11, 30/04/2025

Flux variability ↔ MCSs in obs.

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Surface heterogeneity provides a control and source of predictability for MCSs across scales.

Small scale

Chance of Sahelian MCS initiation doubled over **~30km** soil moisture gradients due to enhanced local convergence.

Taylor *et al*, *Nat. Geosci.* 2011

Mesoscale

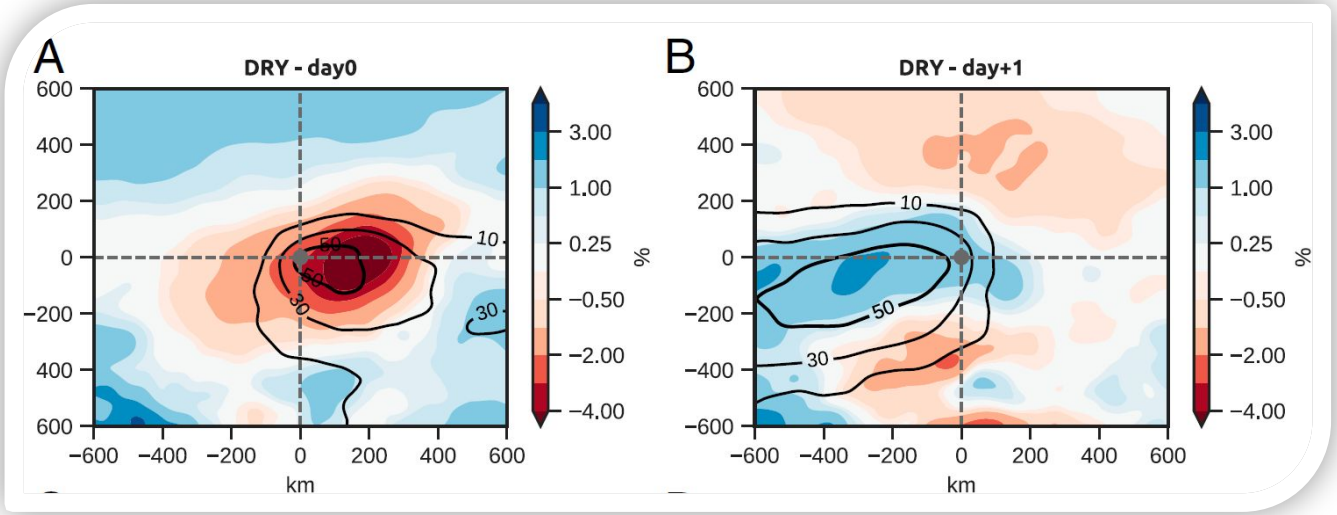
Mature MCSs favoured over **~200km** dry soil patches in Sahel. Post-storm rainfall suppressed for ~8 days.

Klein & Taylor, *PNAS* 2020
Taylor *et al*, *GRL* 2024

Synoptic scale

6° meridional SM gradients drive wind shear patterns globally; 10-50% increase in MCS rainfall on shear days.

Barton *et al*, *Nat. Geosci.* 2025



Q: How sensitive is this mechanism to the spatial scale of surface variability?

Scale sensitivity experiments

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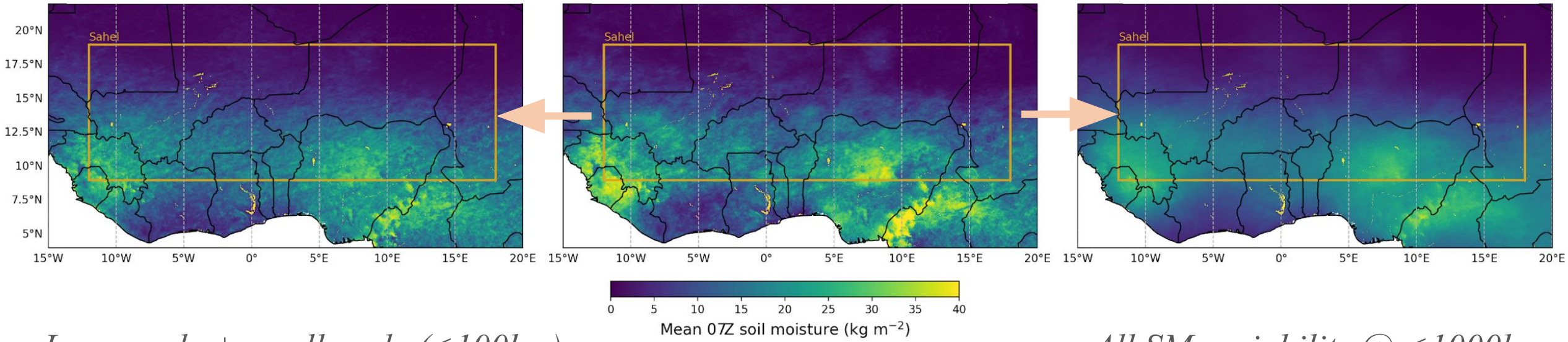
MetUM experiments initialised at 06 UTC with altered SM wavelet spectrum:

SM(Large+Small) D1

Control D1

SM(LargeOnly) D1



Large-only + small scale (<100km) wavelet modes

All SM variability @ <1000km scale smoothed out.

39 daily initialisations, each run **48hrs**

1.5km grid, explicit convection (RAL3.2)

3 x 39 x 2 = 234 CP model days

JULES land, SM from 10 year CP run

Sensitivty experiments - spectra

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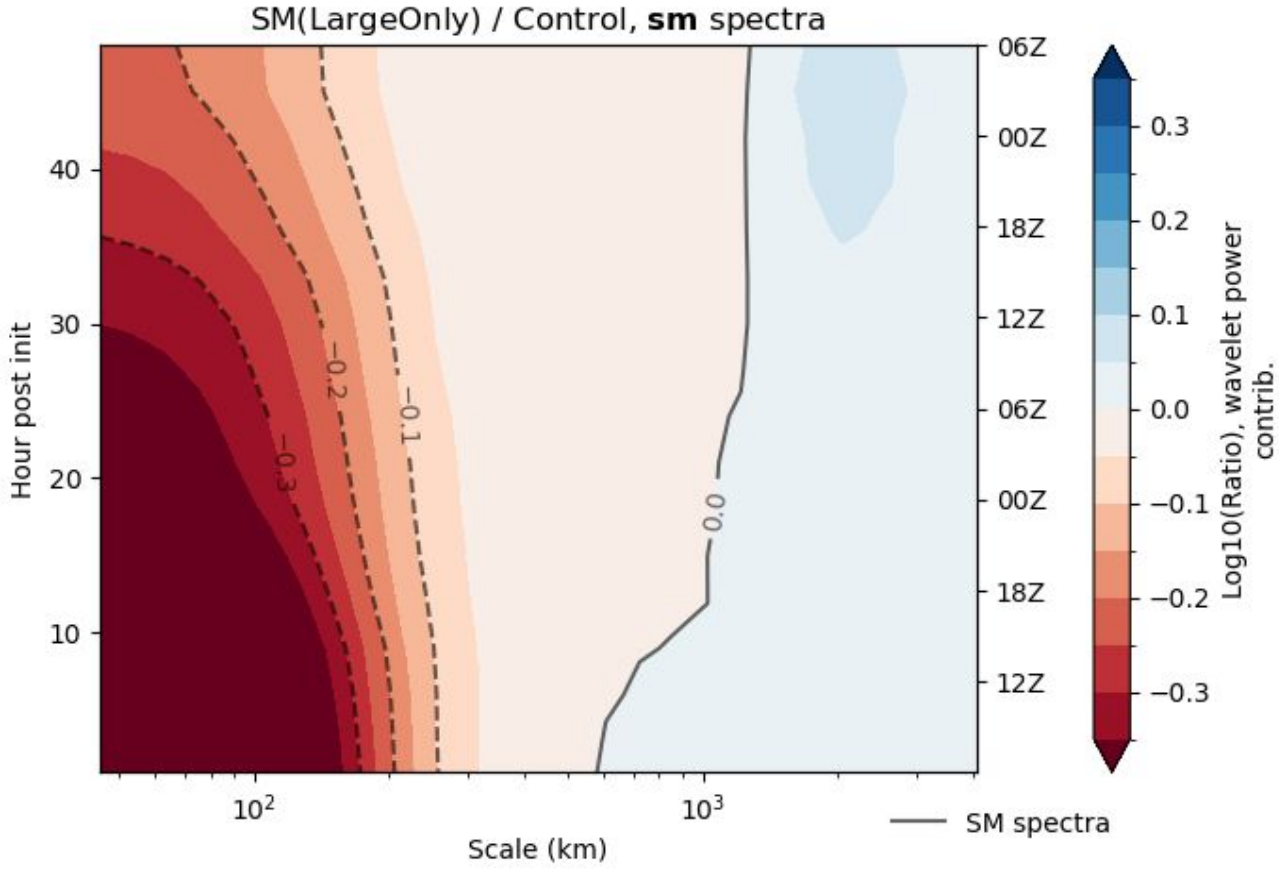
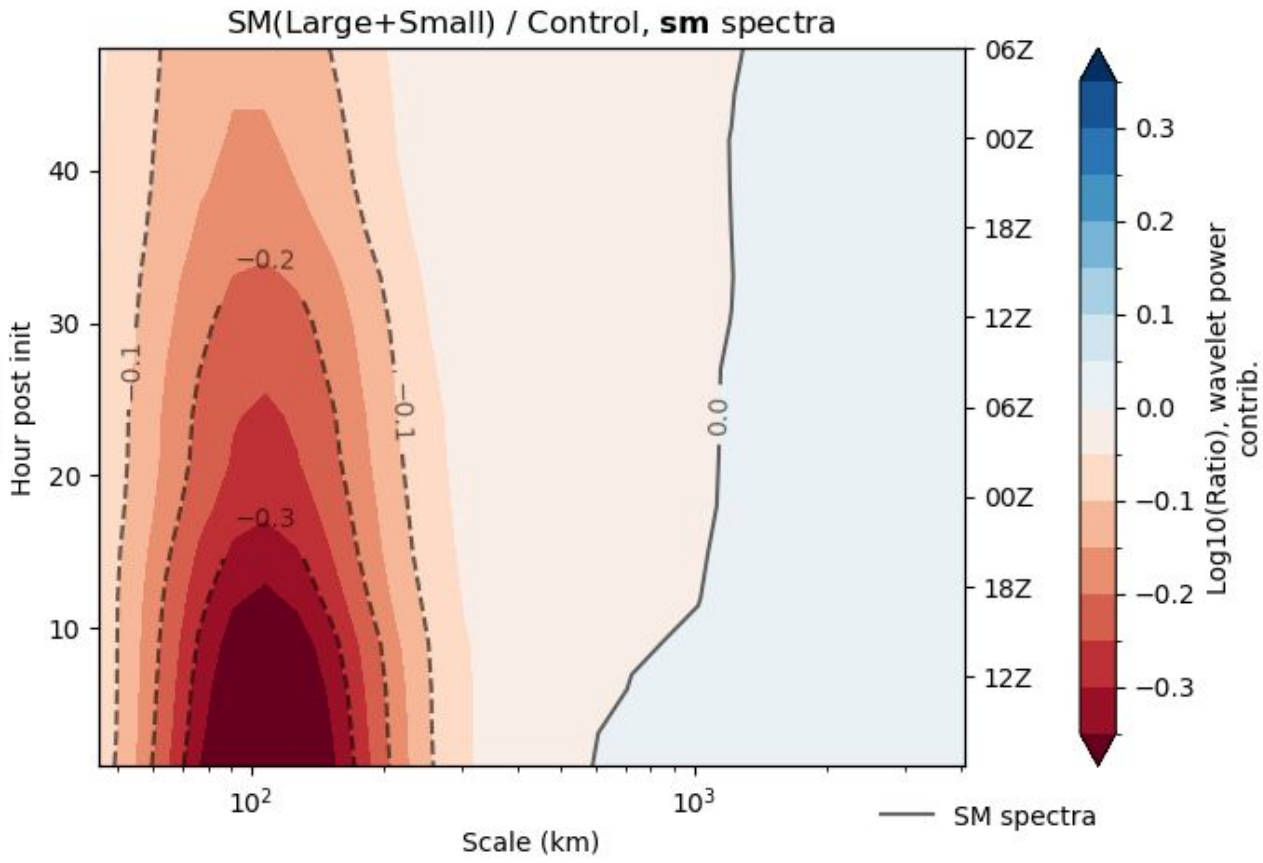
Plot ratio of mean percentage of total spectral power at given length scale, calculated every 3 hours through simulation.





Red shading = suppressed spatial variability in sensitivity expt at given scale

Impact of surface scales on MCS populations

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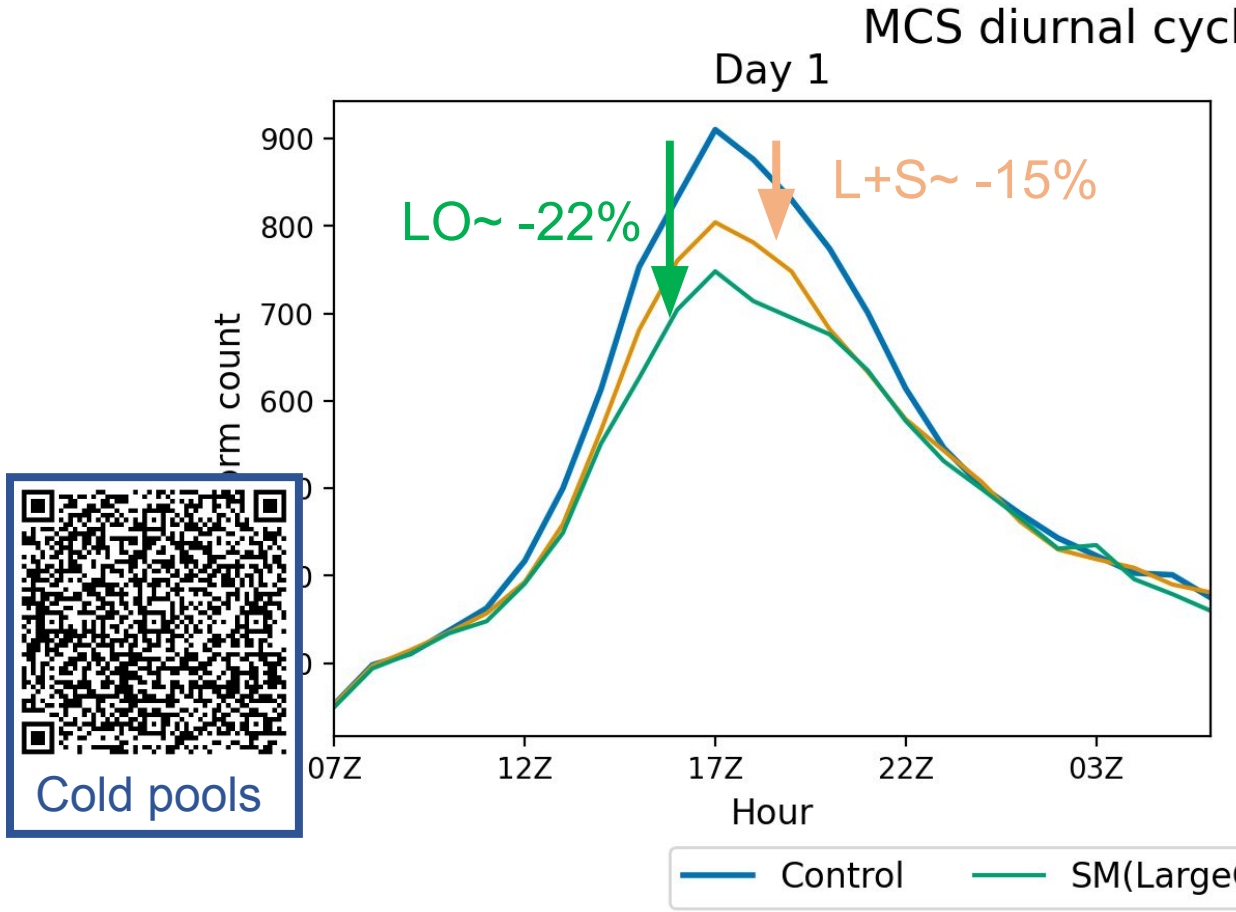
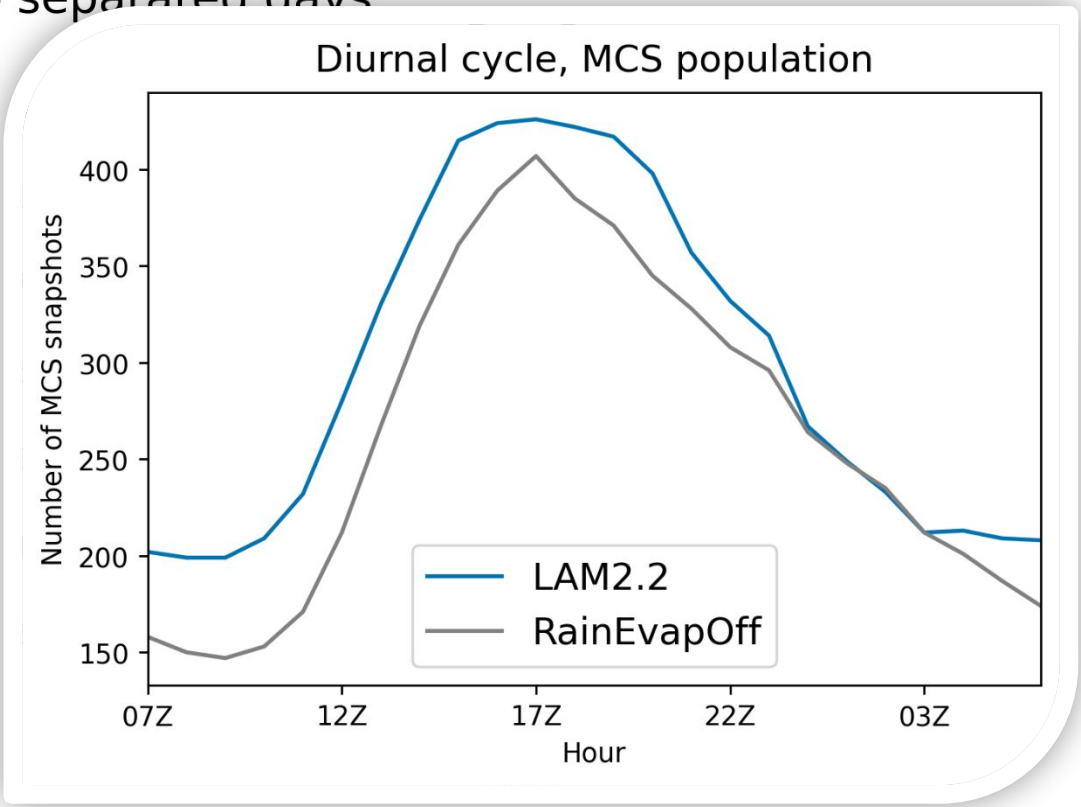
Track full MCS lifecycles with simpleTrack algorithm (BT + rain)



Cold pools



Peak counts ↓ when mesoscale SM variability suppressed. Begin recovery on D2.

SM variability stronger control on population than cold pools. Maybee *et al, in pub. QJRMS*

Impact of surface scales on MCS populations

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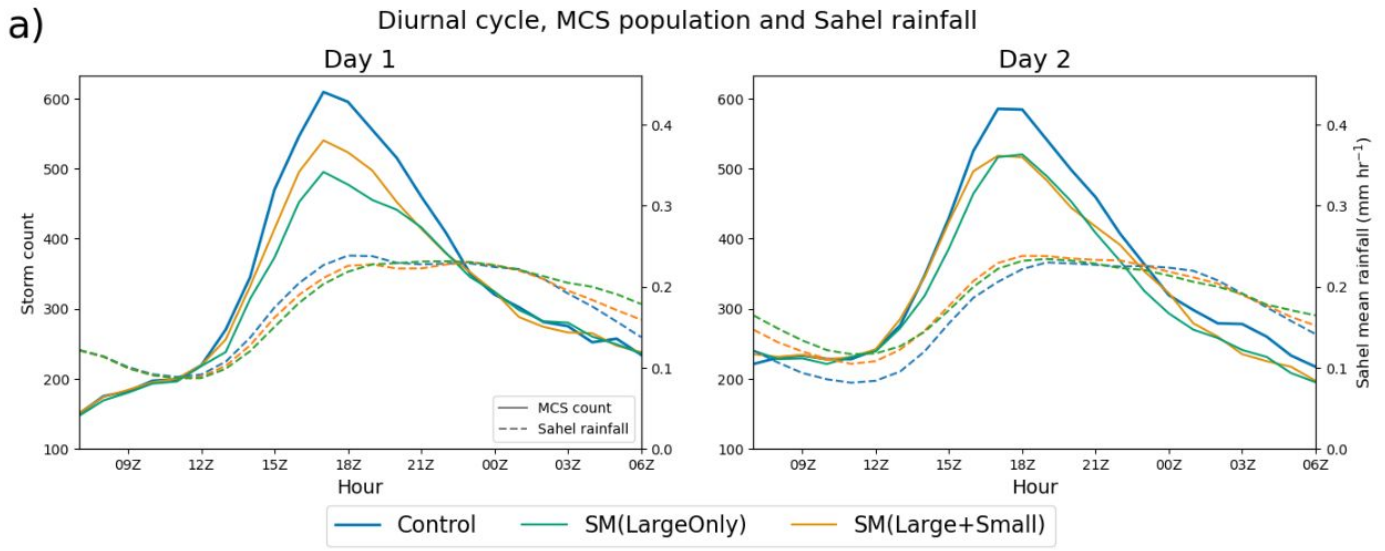
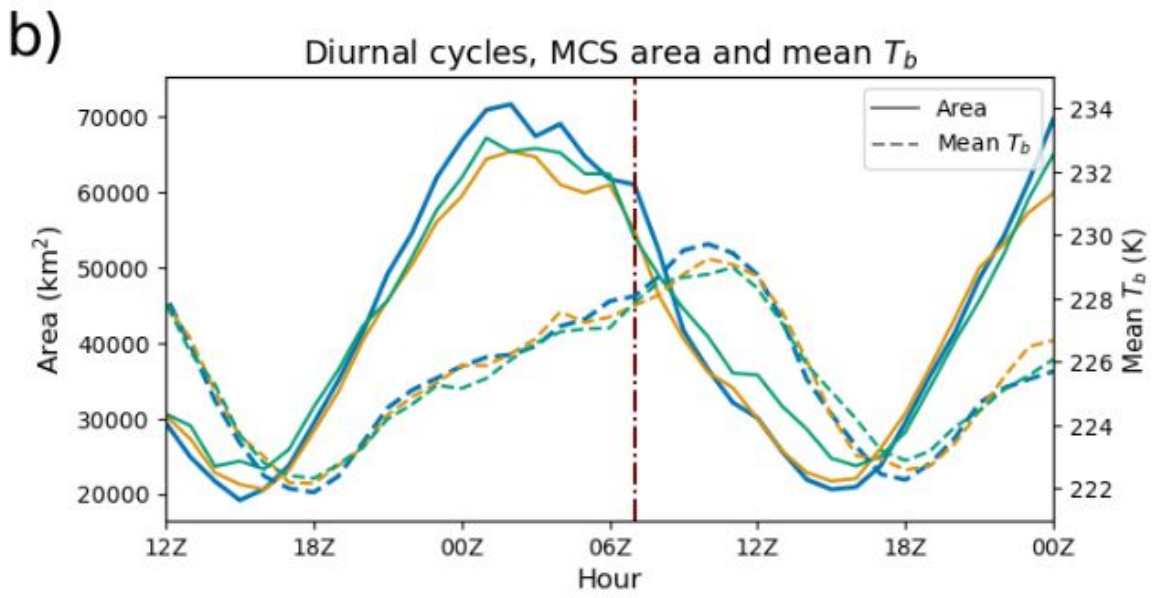
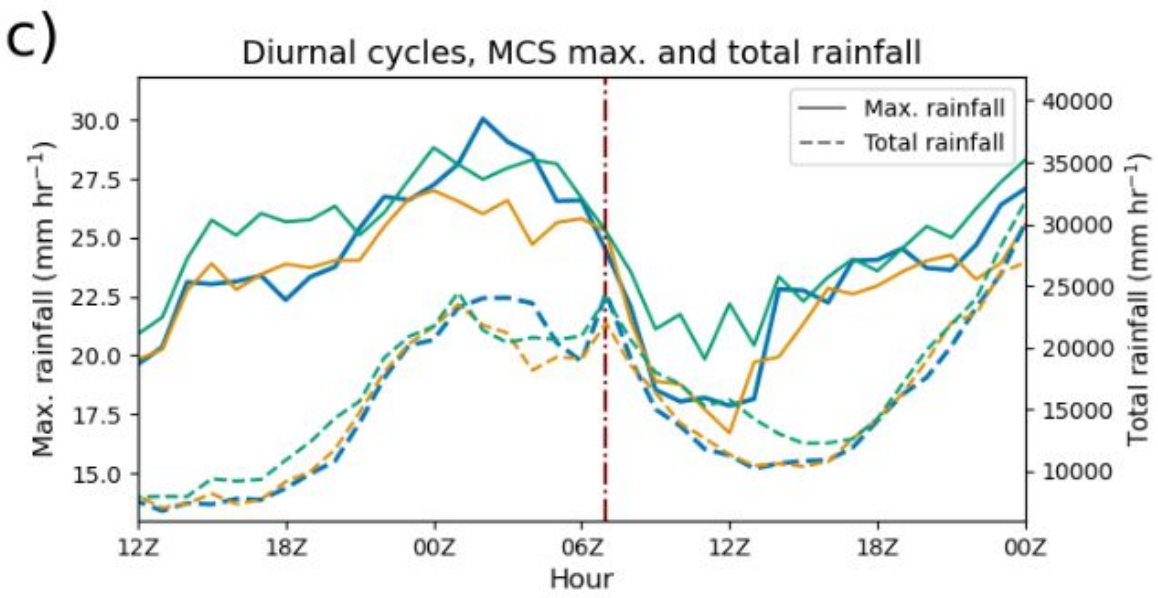
- Larger mean storm areas in Control – also higher regional cloud cover
- Comparable convective cloud temperatures
- More intense rainfall in SM(LargeOnly), with higher regional totals.







Why are mesoscale dry patches favourable?

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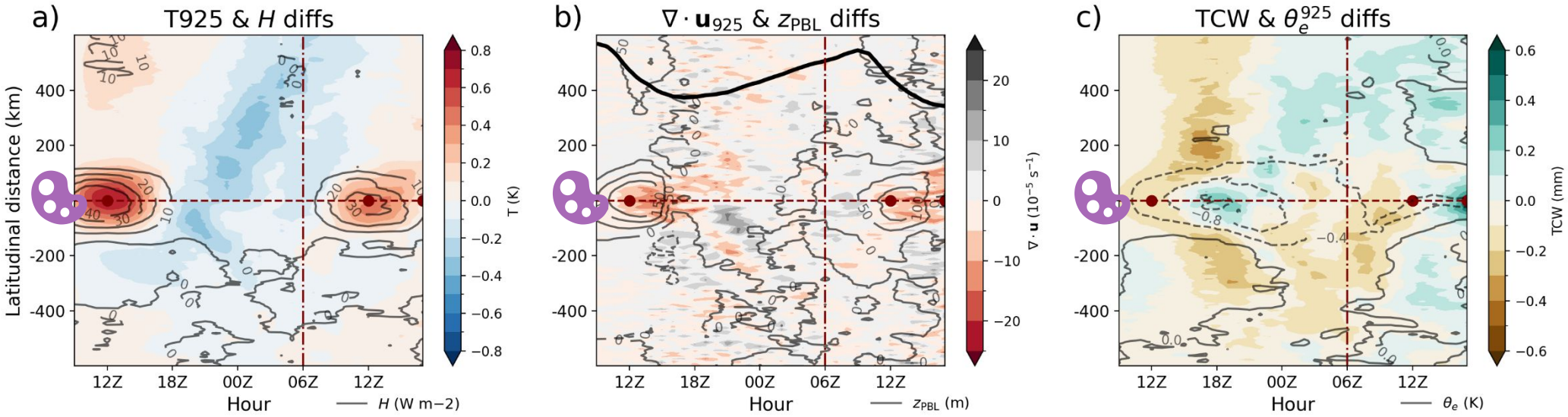
SM patches

Find patches removed in sens; field diffs post patch.

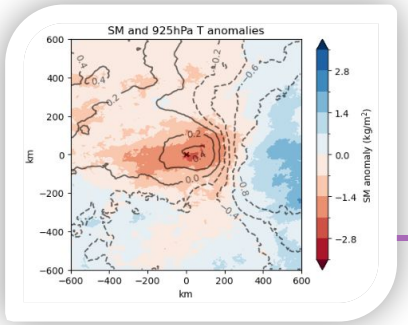
n=423, find via power maxima

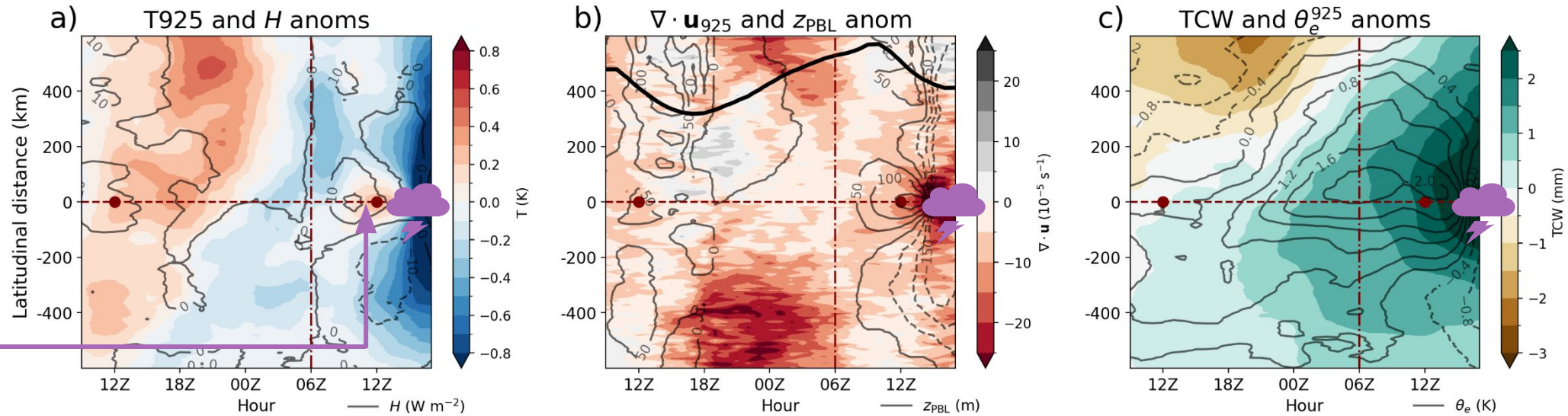


» Dry patch *H* anomalies ↑ PBLH, ↑ convergence, ↑ background nocturnal monsoon flow

Control MCSs

Fields prior to *n*=669 17Z cores





Why are mesoscale dry patches favourable?

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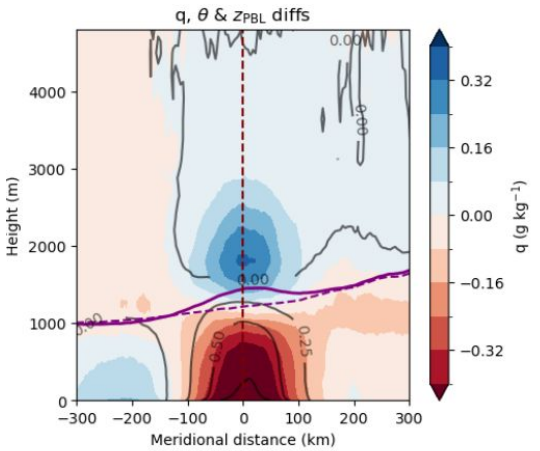
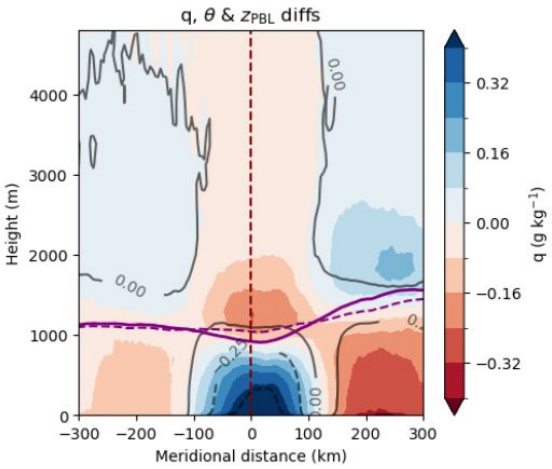
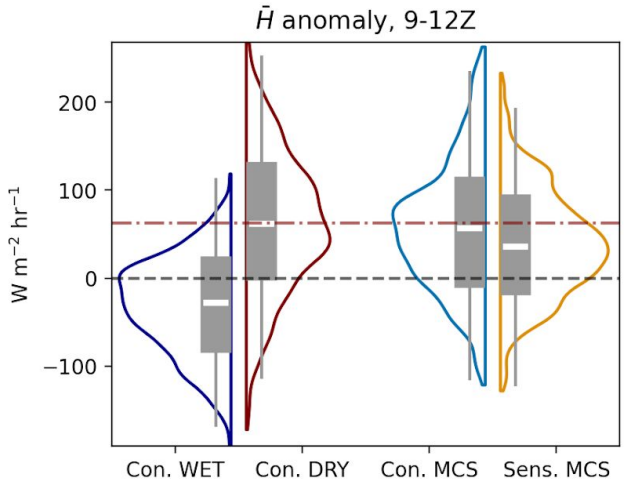
DRY diff

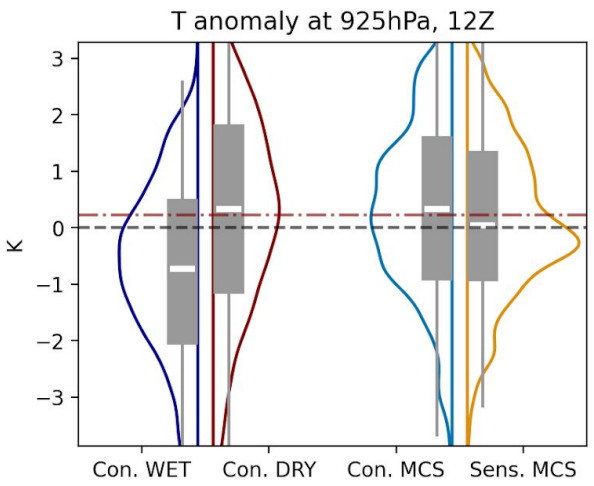


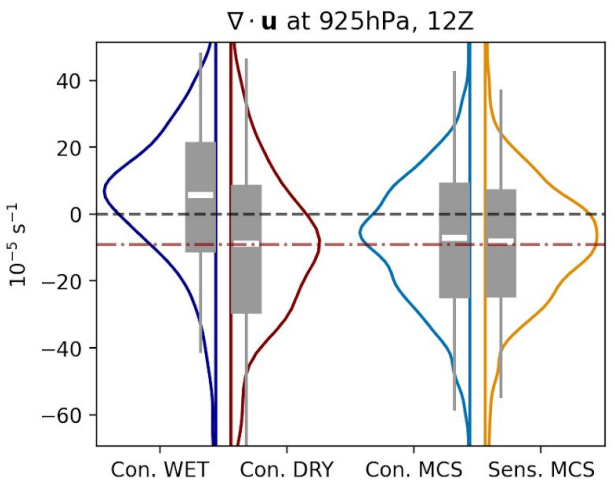
WET diff

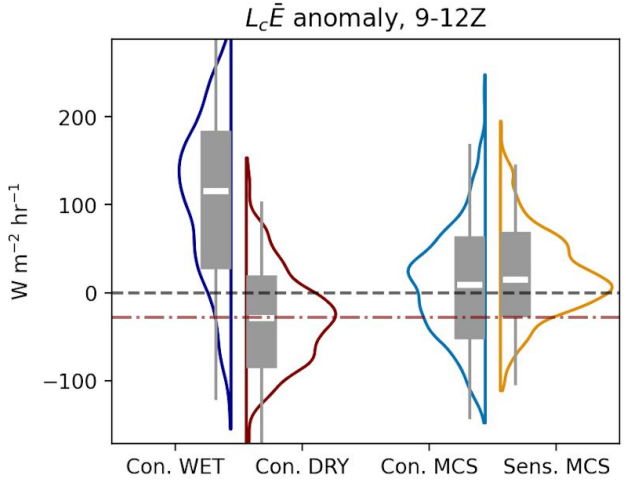


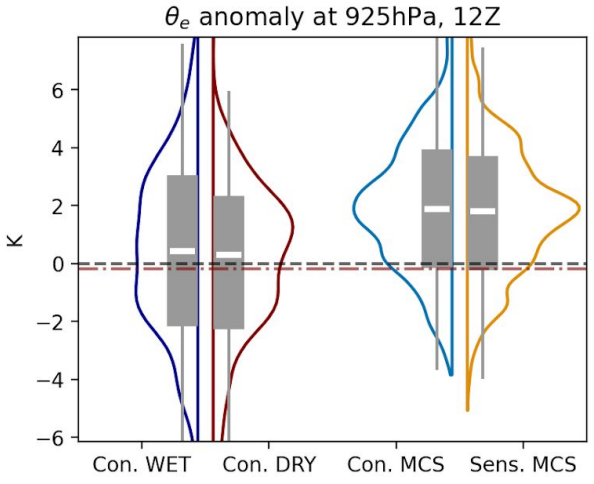
09Z SM patch vs 17Z D1 MCS core sampled field distributions

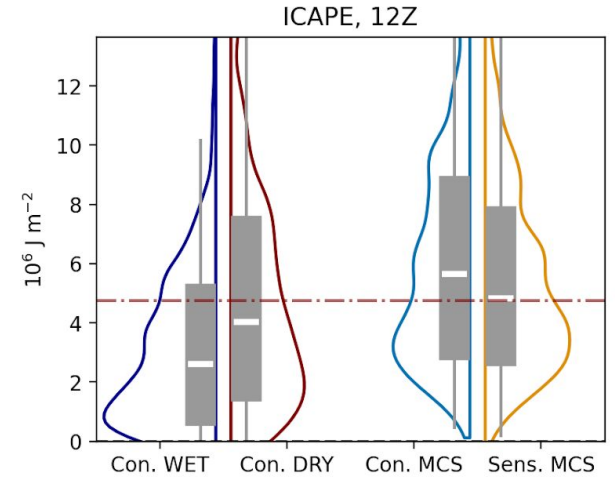












Distributions of pre-MCS conditions closer to DRY than WET patches, including column instability. WET patches inhibit mature convection.

Cloud-free slots can replace SM mechanism

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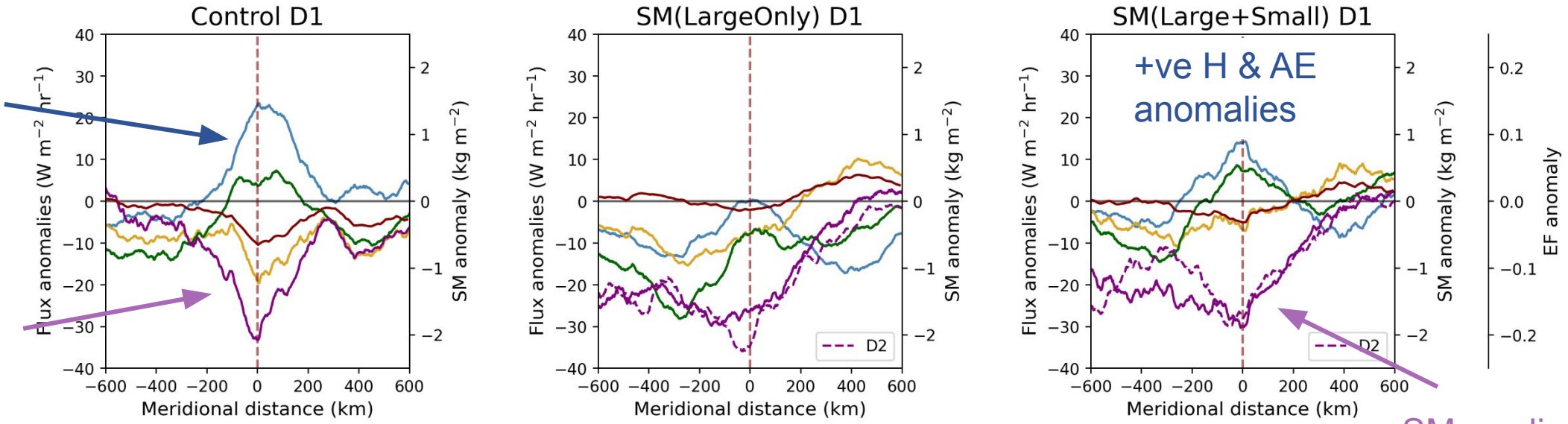
Mean 09-12 UTC fluxes, 17 UTC MCS core locations

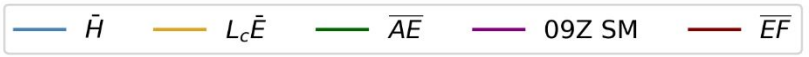
+ve H anomaly

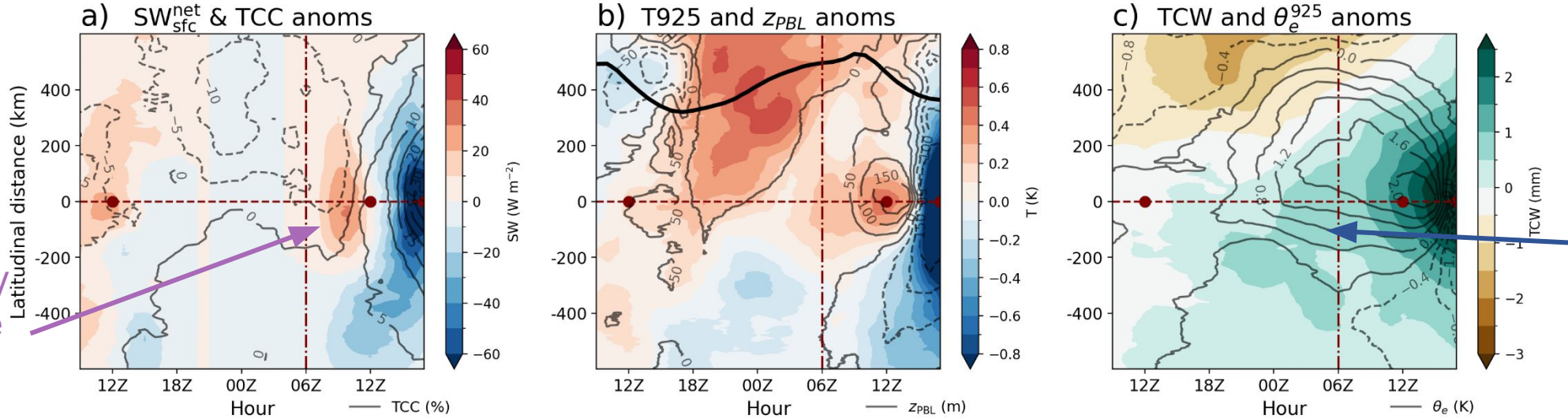
Mesoscale dry patch



SM gradients

SM(L+S) D2 pre-MCS fields:





Mesoscale SW anomaly in cloud-free slot

Nocturnal ↑q from monsoon

Conclusions

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- MetUM sensitivity experiments over West Africa probing influence of SM heterogeneity on MCSs.
- Mesoscale dry soil patches modify local PBL fields such that they are more favourable for mature MCSs.
  - ↑ *PBLH,* ↑ *convergence,* ↑ *nocturnal flow*
- Removing mesoscale SM variability reduces MCS population by ~20% at diurnal peak of convection.
  - *Stronger effect than cold pool suppression*
- Mesoscale cloud slots generate favourable dynamical conditions when SM heterogeneity removed.
  - *Thermodynamic environment dominated by monsoon flow*

SM heterogeneity enhances MCS activity and provides spatial predictability

See also for soil moisture: Barton *et al, Nat. Geosci.* 2025.

For cold pools: Maybee et al, 2025 (in press).

SM patch latitudinal transects