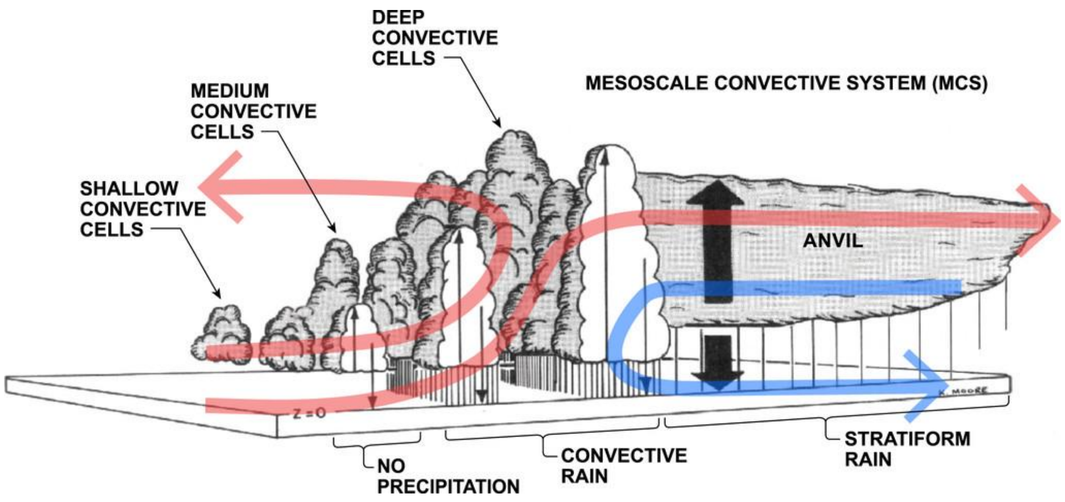
Department of Meteorology

University of Reading

# An introduction to MCS:PRIME

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ParaCon Plenary
Met Office
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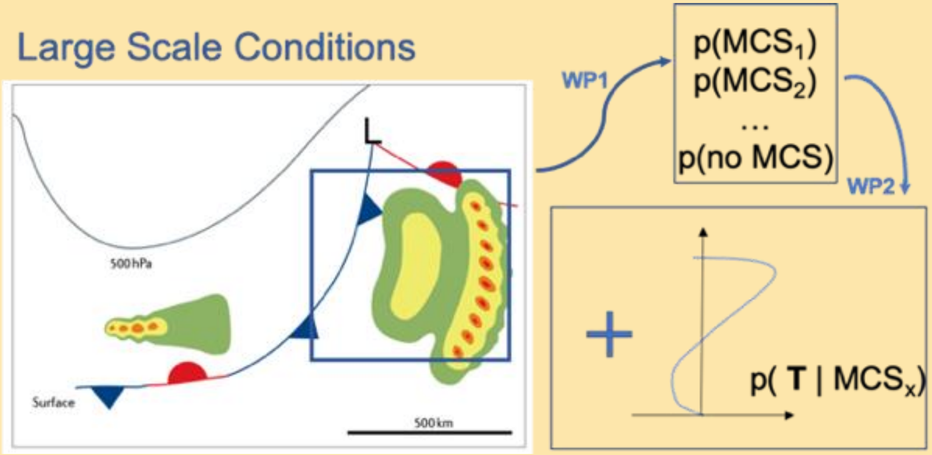
# Basic idea

- Target Δ ~10-50 km, grey zone for MCS
- Model may represent aspects of a mature MCS, but parameterization critical in initiation and early growth
- Physics-dynamics coupling acutely important but inherently uncertain
- Existing methods often applied indiscriminately (Shutts, SCV; Moncrieff, MCSP; Khouider/Majda, multicloud model)
- Simple-minded shear threshold beneficial for MCSP (Chen et al 2021)

# Basic Idea

Build a stochastic parameterization for missing tendencies due to MCS




1. Does the resolved-scale flow indicate that conditions are ripe for an MCS to develop (with some probability)?
2. What is the distribution of additional tendencies we should randomly sample if MCS development is indicated?

# Moncrieff et al (2017) scheme

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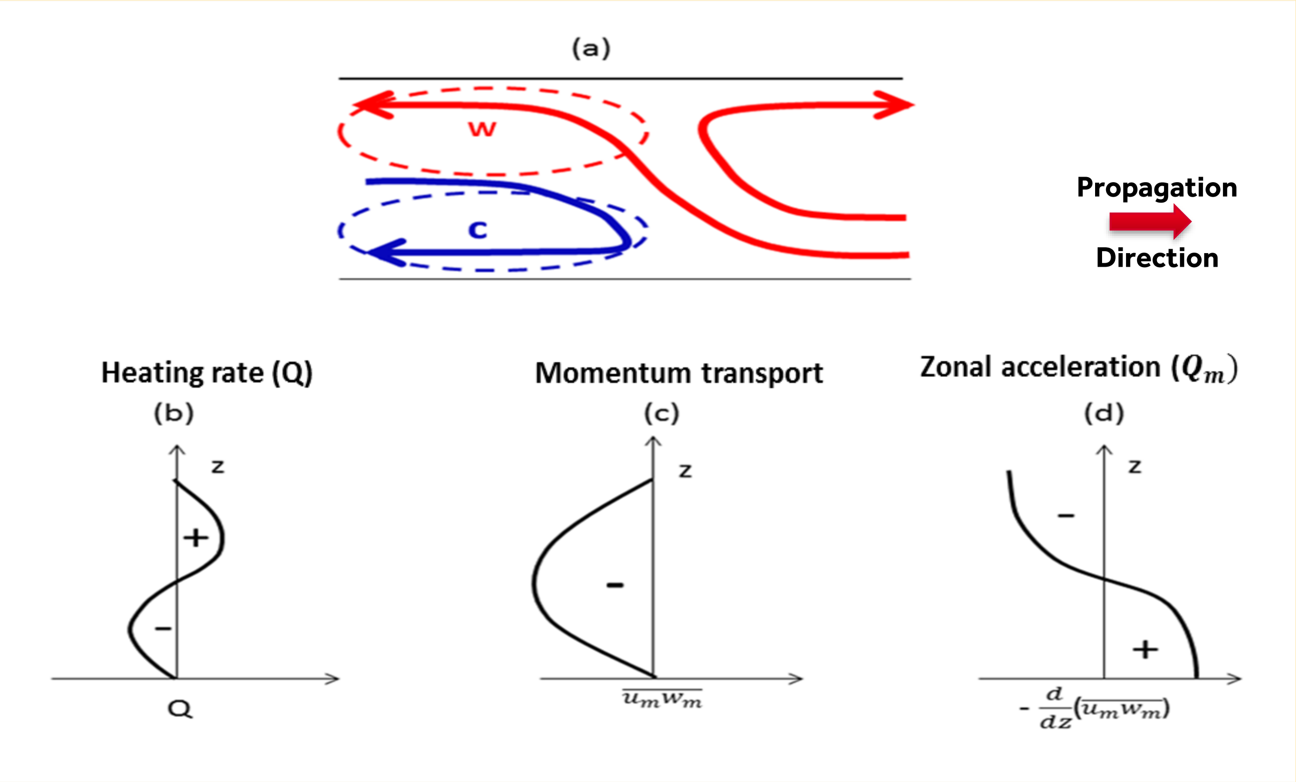
Idealization of slantwise overturning MCS model




Scaled by integrated heating from the convection parameterization

$$Q(p,t)= Q_c(\mathrm{t})[\alpha_1 \sin\pi \frac{p_s-p}{p_s-p_t} - \alpha_2 \sin 2\pi \frac{p_s-p}{p_s-p_t}]$$

$$Q_m(\mathrm{p,t}) = \alpha_3 \cos(\frac{p_s-p}{p_s-p_t})$$

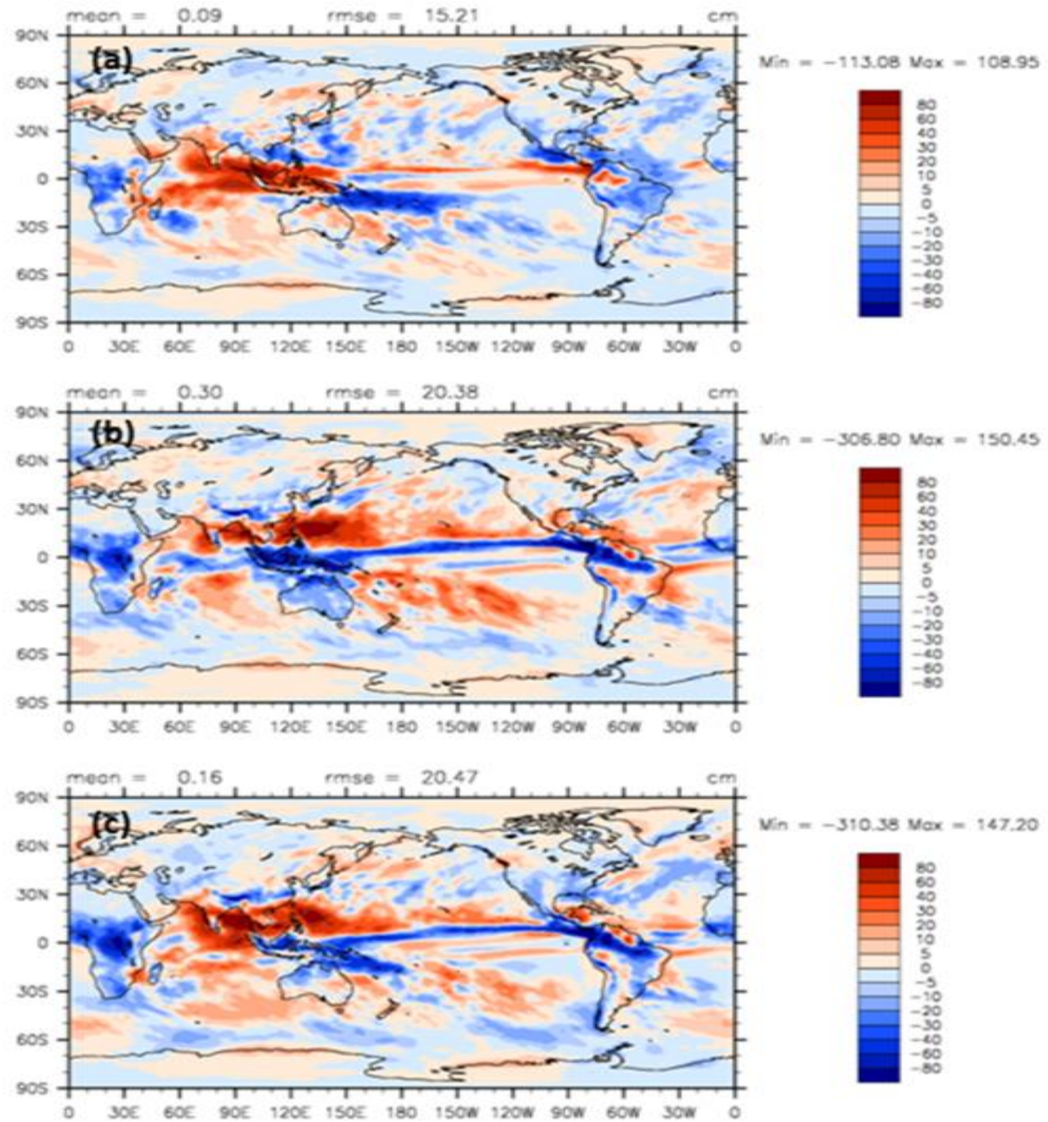
# Effects on precipitation

(a) Momentum transport

(b) Heating

(c) Both

Improvements across ITCZ and maritime continent in CAM, E3SM



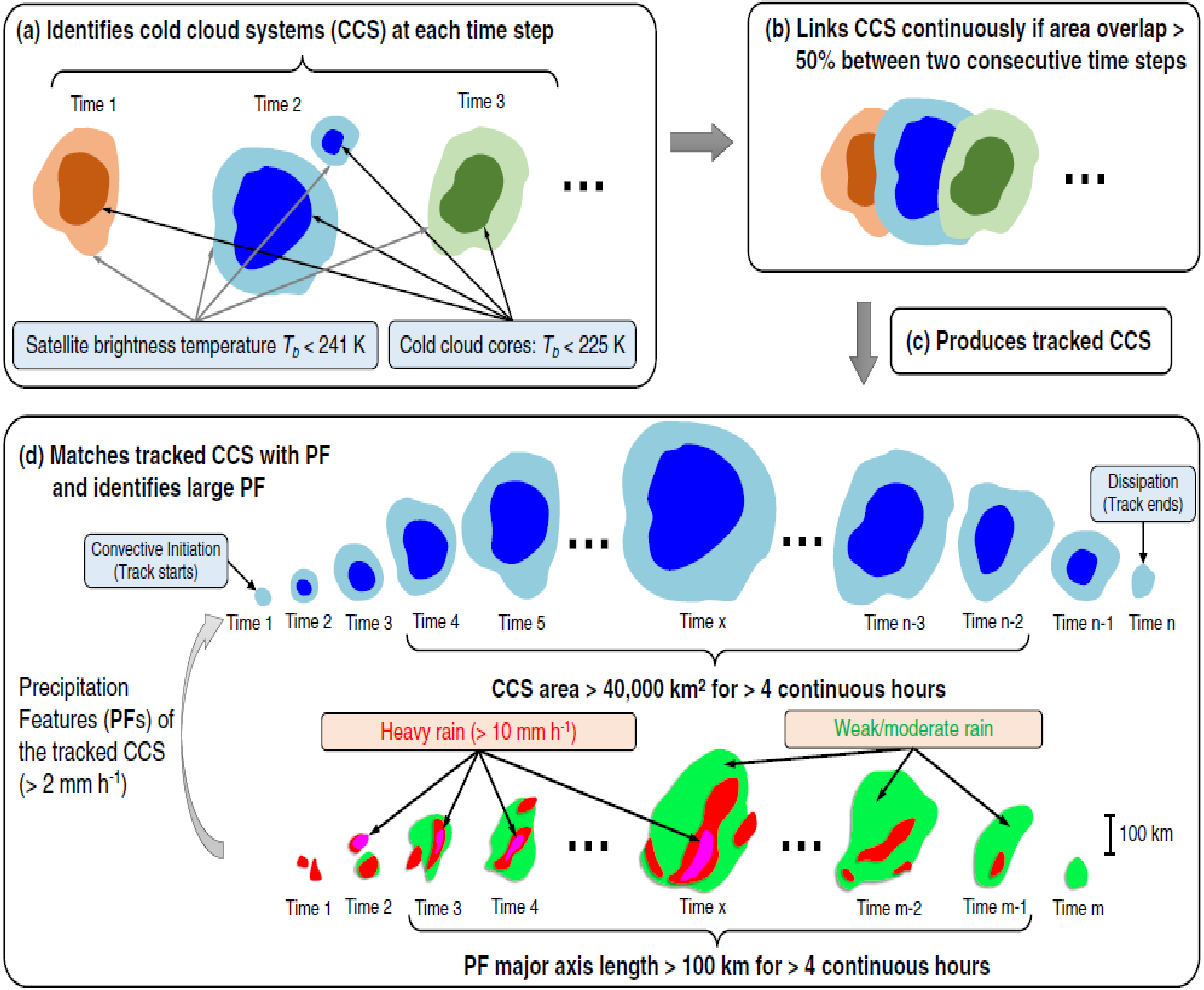

Moncrieff et al, 2017

# Q1 Are conditions suitable?

- Analyse database of observed MCS (Feng et al, 2021)
- Establish probabilistic connections between MCS occurrence and resolved-scale indicators
- Examine dependence on those indicators of the resulting MCS characteristics including their time and space scales

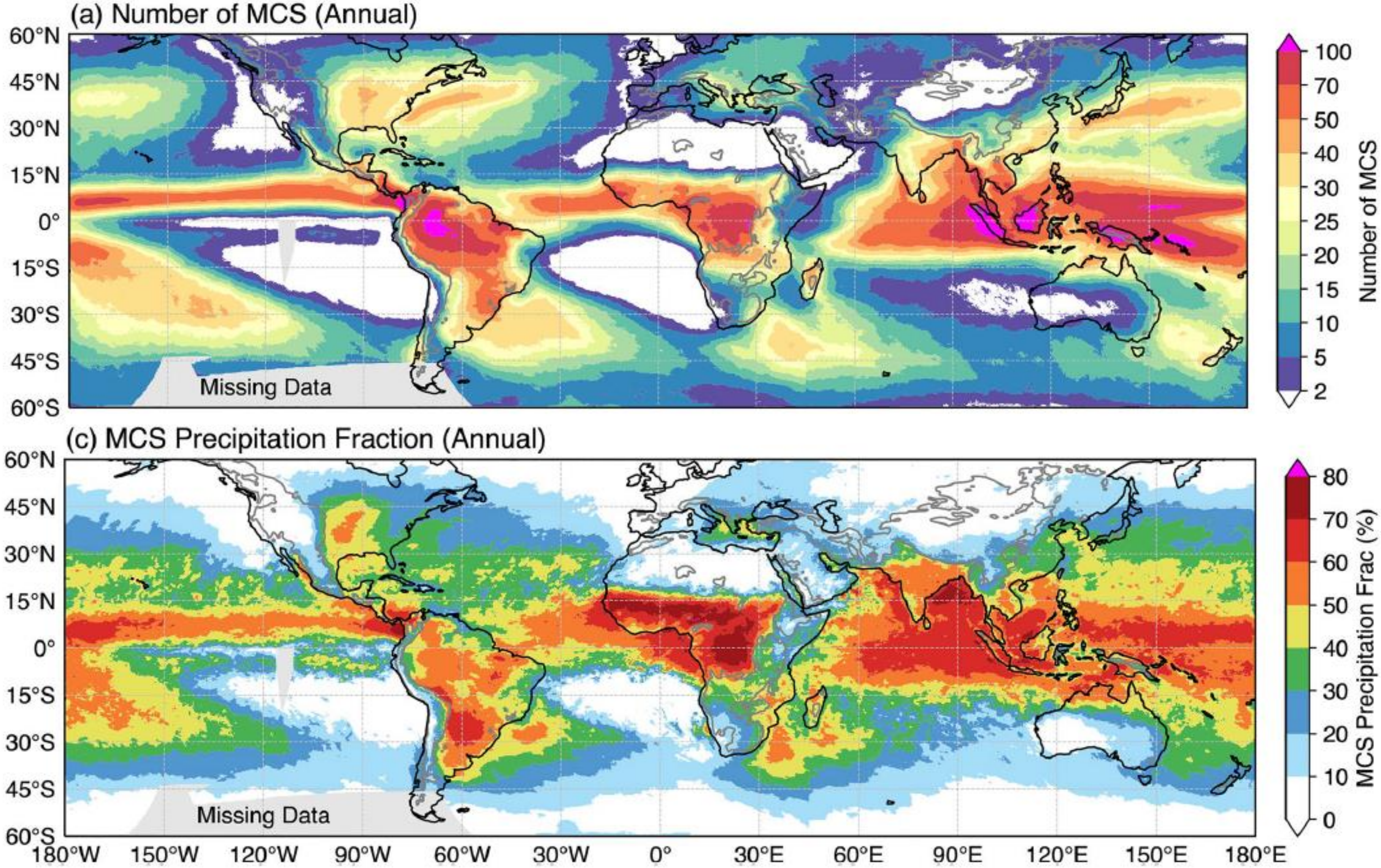
# The Database

- Based on merged geostationary satellite *Tb* data (NASA Global Merged IR V1)
- Combined with merged satellite precipitation data (IMERG V06B)
- Continuous global coverage from 60°S to 60°N with resolution ~4 km and 30 min
- MCS identification / tracking validated against weather radar data from US and China
- Cold cloud shield > $4 \times 10^4$ $km^2$ containing precipitation feature with major axis length >100 km
- PF area, mean rain rate, rain rate skewness, and heavy rain volume ratio > than lifetime dependent thresholds
- CCS and PF exist continuously for > 4 h



(a) Identifies cold cloud systems (CCS) at each time step
Time 1
Time 2
Time 3
...
Satellite brightness temperature $T_b$ < 241 K
Cold cloud cores: $T_b$ < 225 K
(b) Links CCS continuously if area overlap > 50% between two consecutive time steps
...
(c) Produces tracked CCS
(d) Matches tracked CCS with PF and identifies large PF
Convective Initiation (Track starts)
Dissipation (Track ends)
Time 1
Time 2
Time 3
Time 4
Time 5
Time x
Time n-3
Time n-2
Time n-1
Time n
CCS area > 40,000 km² for > 4 continuous hours
Precipitation Features (PFs) of the tracked CCS (> 2 mm h-1)
Heavy rain (> 10 mm h-1)
Weak/moderate rain
100 km
Time 1
Time 2
Time 3
Time 4
Time x
Time m-2
Time m-1
Time m
PF major axis length > 100 km for > 4 continuous hours

# #MCS and associated precip fraction




Feng et al, 2021

# Q2 What are the additional tendencies?

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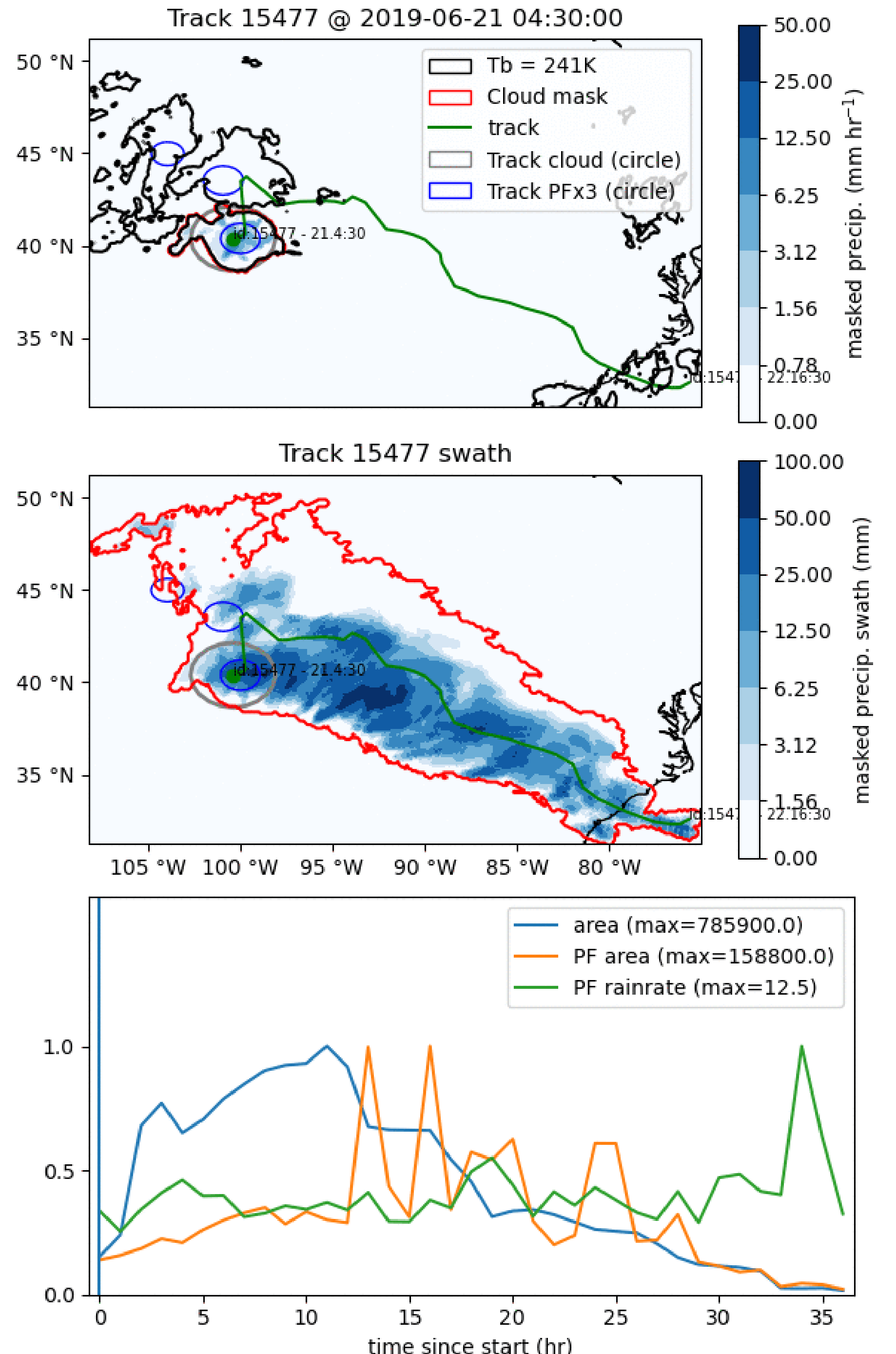
- Study operational archive of analysis increments for times and locations where MCS are found in the database
- Focus on situations where the model has an MCS in the ic's. Associate increments with errors in the coupling of the MCS to the large scales
- Do such increments match with SCV or MCSP?
- Characterise the probabilistic dependency of the MCS-associated tendencies on indicators
- Final scheme might be thought of as a targetted version of Piccolo et al (2019) method for perturbing ensemble

# Plans

- (Underway) Get to grips with database and analyse MCS existence and properties alongside large-scale state
- (Autumn) implement the Moncrieff et al (2017) scheme in the UM alongside CoMorph
- (Later) probabilistically activate it according to likelihood of developing an MCS given the resolved-scale conditions
- (Later still) improve the assumed tendency structure using probabilistic forms obtained from analysis increments




# An example MCS (21/06/19 over US)

Top: brightness temp (black), the MCS (red) and its path (green). Cloud area (grey circle) and precip cores (blue circles).

Middle: Precip swath and outline of cloud mask over MCS lifetime

Bottom: MCS area, precipitation feature (PF) area, and PF rainrate

# Distributions of all MCS

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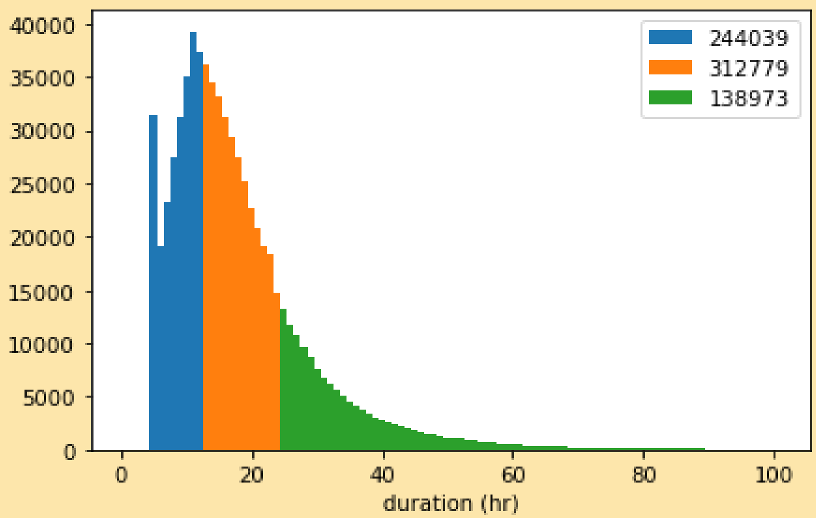
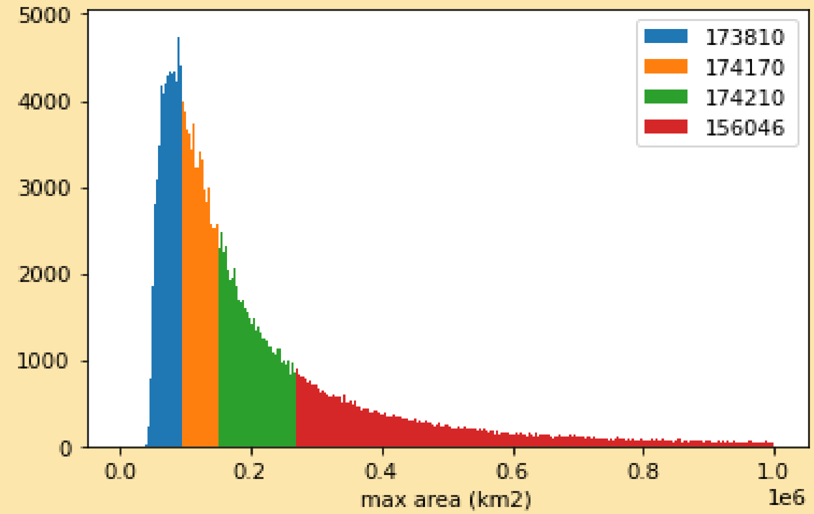
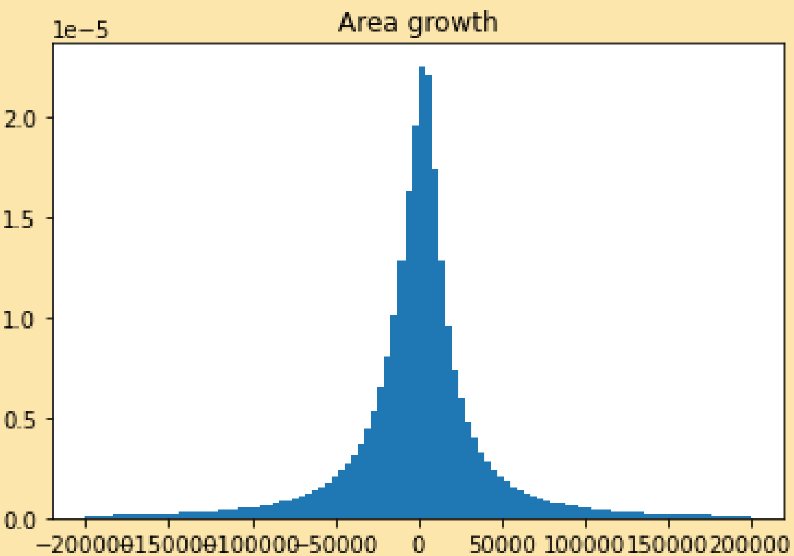
Durations and max area (grouped for possible stratification)




Area growth rate in 1h



# Composite lifecycles

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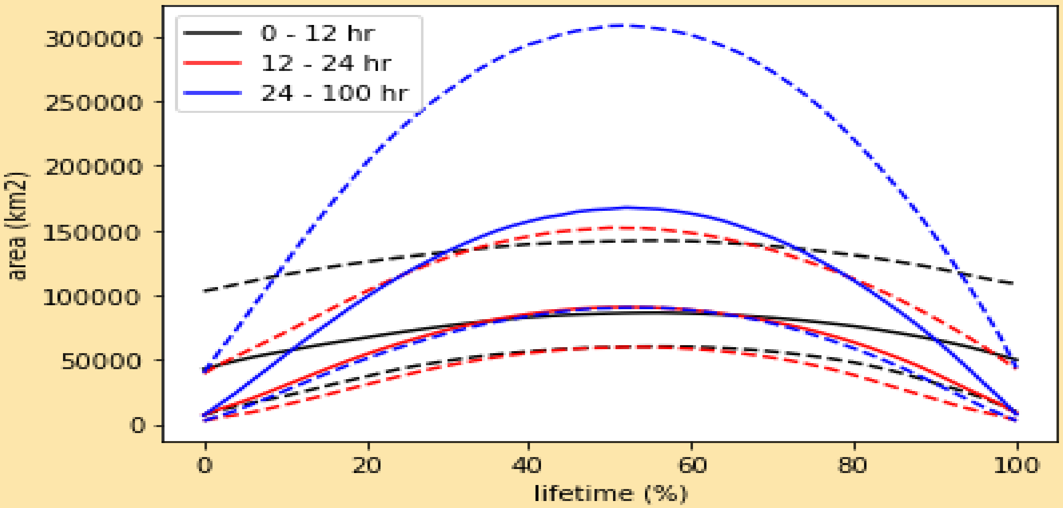
Area

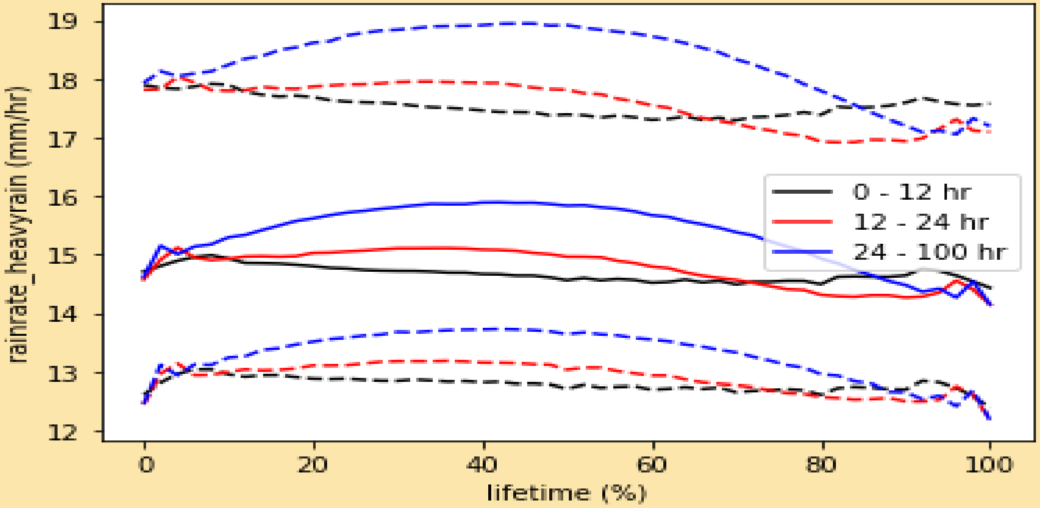



Black = short lived

Red = medium

Blue = long lived

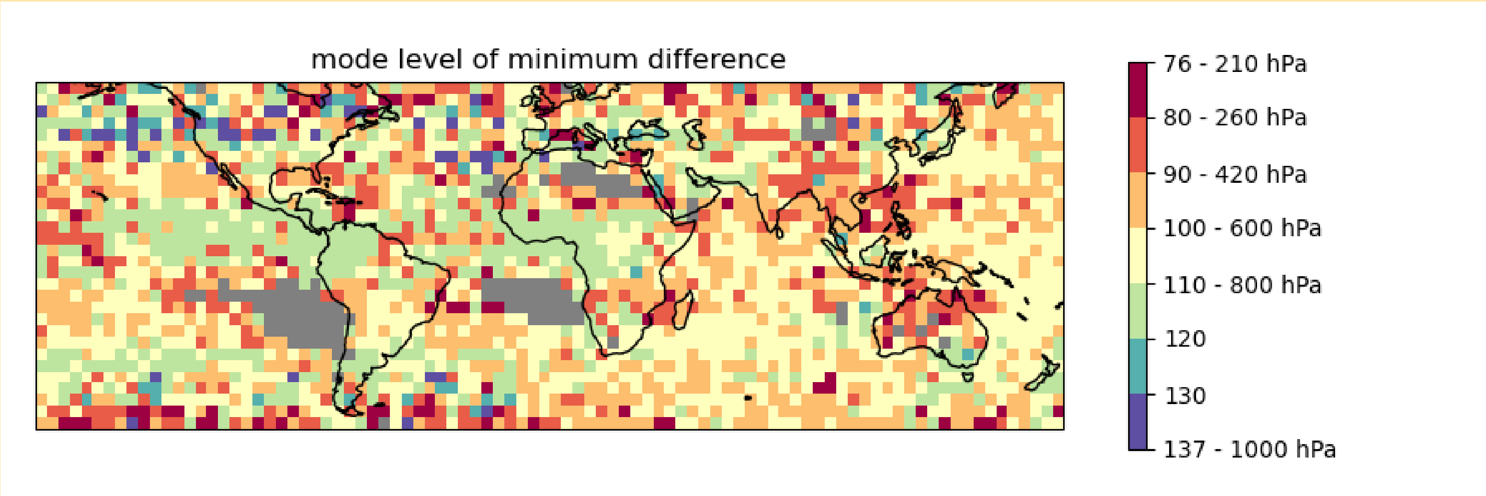
Mean rain rate within core (>10mm/h)



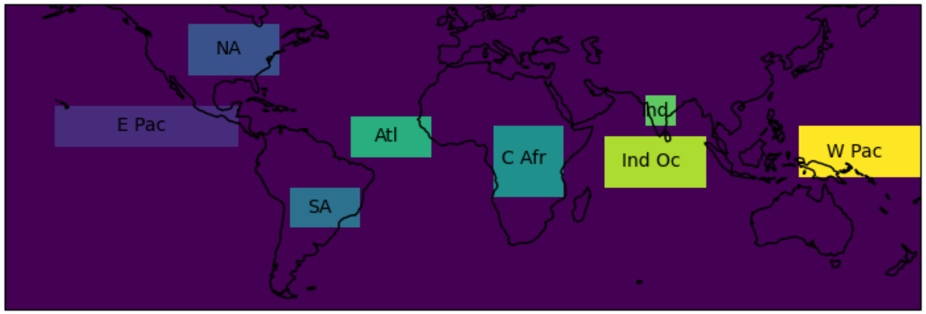

Solid is median, dashed 25/75%

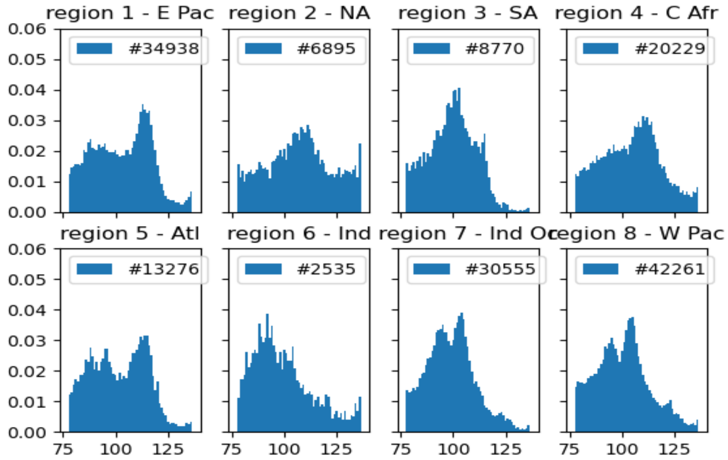
# Linking to ERA5

A steering level: where does *(u,v)* in ERA5 best match with the average propagation of the MCS?




2019 results only



# Summary

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- Attempt to build a representation of MCS effects
- Main differences from existing approaches are:

- To target these effects
  - We don't assume all convection is MCS-like (as in MCSP, SCV etc)
  - Or that all convection is non-MCS like (as happens if no MCS scheme in place)
- To design extra tendencies around analysis increments associated with MCS

- Coming soon(ish): CoMorph + MCSP should be an interesting starting point

# References


- Chen, C.-C., Richter, J. H., Liu, C., Moncrieff, M. W., Tang, Q., Lin, W., et al. 2021. Effects of organized convection parameterization on the MJO and precipitation in E3SMv1. Part I: Mesoscale heating. *J. Adv. Model. Earth Syst.*, **13**, e2020MS002401.
- Feng, Z., Leung, L. R., Liu, N., Wang, J., Houze, R. A., Li, J., et al. 2021. A global high-resolution mesoscale convective system database using satellite-derived cloud tops, surface precipitation, and tracking. *J. Geophys. Res.*,***126***, e2020JD034202.
- Moncrieff, M. W., Liu, C., & Bogenschutz, P. 2017. Simulation, modeling, and dynamically based parameterization of organized tropical convection for global climate models. *J. Atmos. Sci.*, **74**, 1363–1380.
- Piccolo, C, Cullen, M. J. P., Tennant, W. J., Semple, A. T. 2019. Comparison of different representations of model error in ensemble forecasts. *Q J .R. Meteorol. Soc*. **145**, 15– 27.

# Forecast busts

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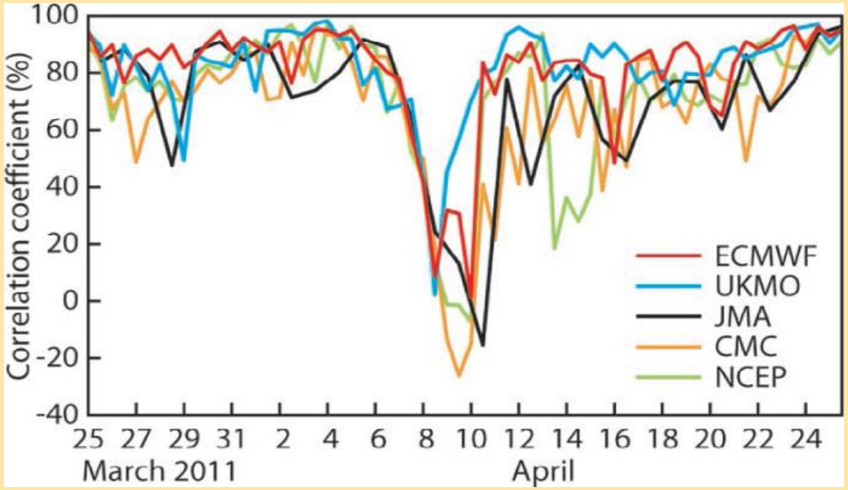
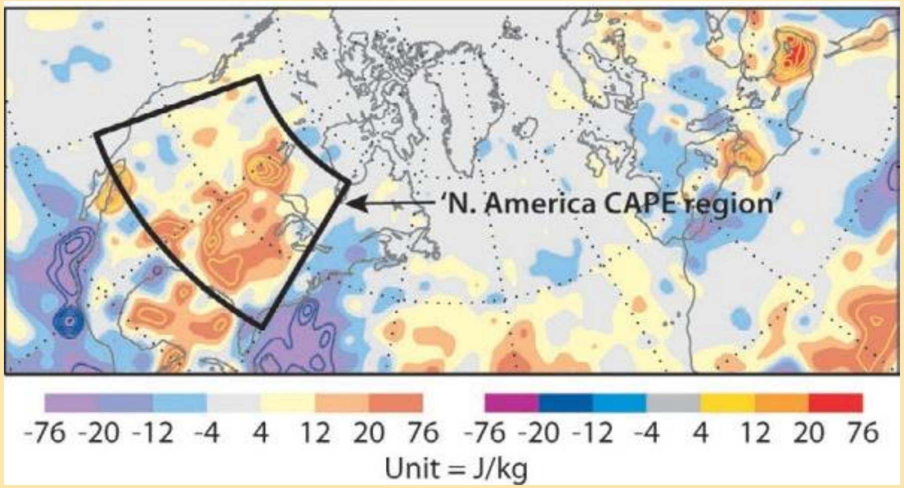
- In ECMWF model, forecast “busts” over Europe attributed to misrepresentations of MCS over US several days earlier




Spatial anomaly correlation of Z500 over Europe in T+6 day forecasts




Composite CAPE anomaly in the initial conditions for 584 busts

Rodwell et al, 2013

# Forecast busts

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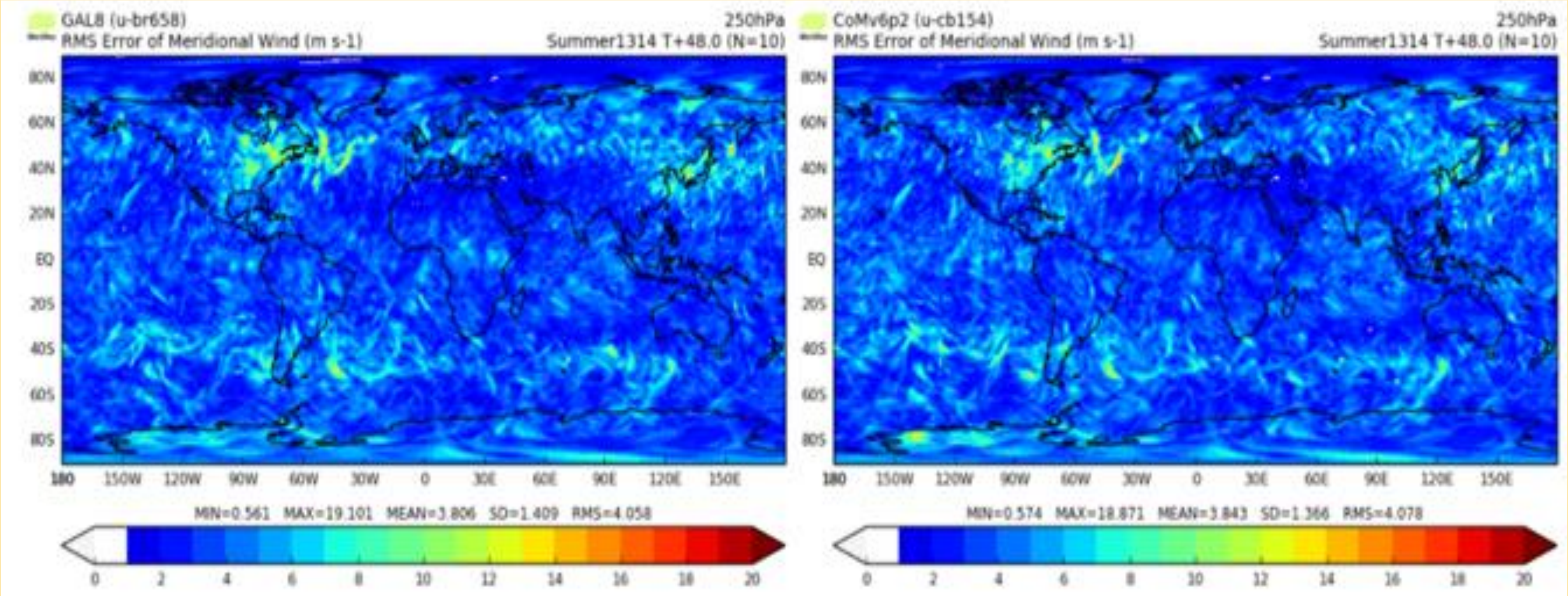
Also occur in UM (even with CoMorph)



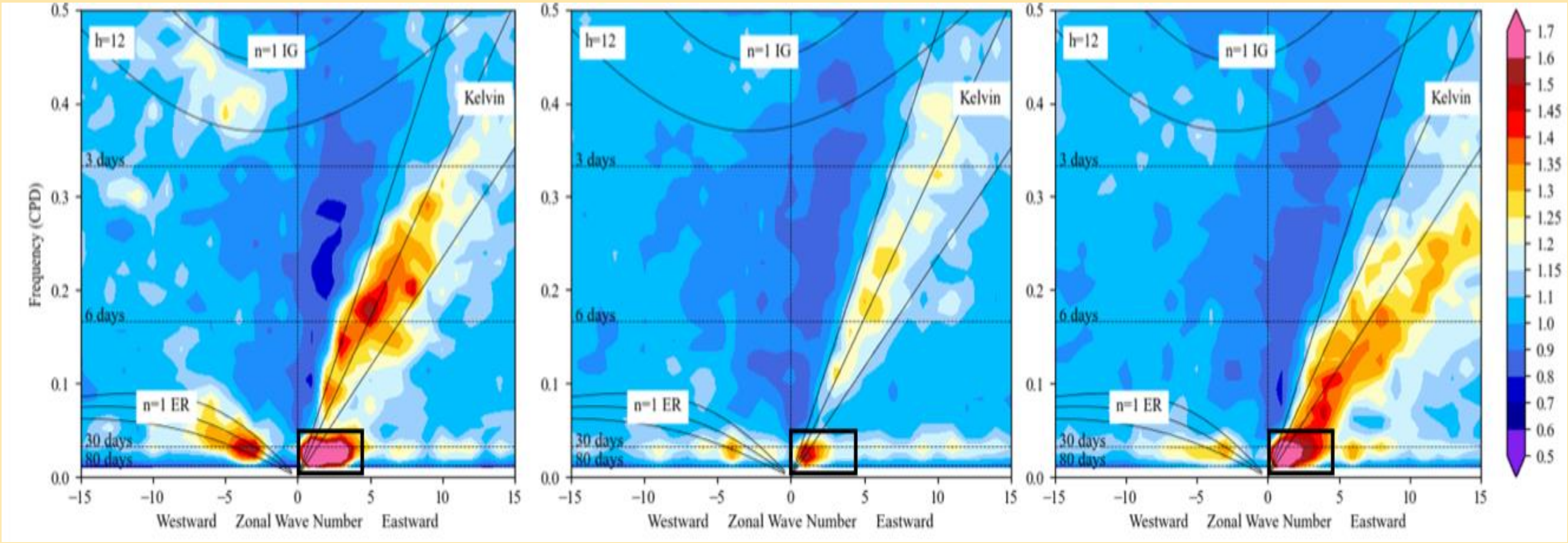

- 250hPa summer T+48 RMSEs of *v* for GA8 (left) and CoMorph 6.2 (right)
- 10 case studies over Summer



Alison Stirling, Adrian Lock, Michael Whitall, Keith Williams

# Build it on CoMorph

- Good numerics an important foundation
- Improved coupling to lower tropospheric moisture has led to improvements in tropical waves and MJO




- Observations (left), current UM (centre), with CoMorph (right).

# How is an MCS parameterization different?

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- An MCS is long-lived, spatially-organised group of individual convective elements, with coherent mesoscale overturning circulation on the scale of the system
- Relative to an isolated cell, feedback is dynamic as well as thermodynamic, and the heating profile is top heavy
- MCS form preferentially in environments with vertical wind shear, particularly low-level shear