Scale-dependence of tropical oceanic deep convective systems' cloud shield morphology to environmental conditions

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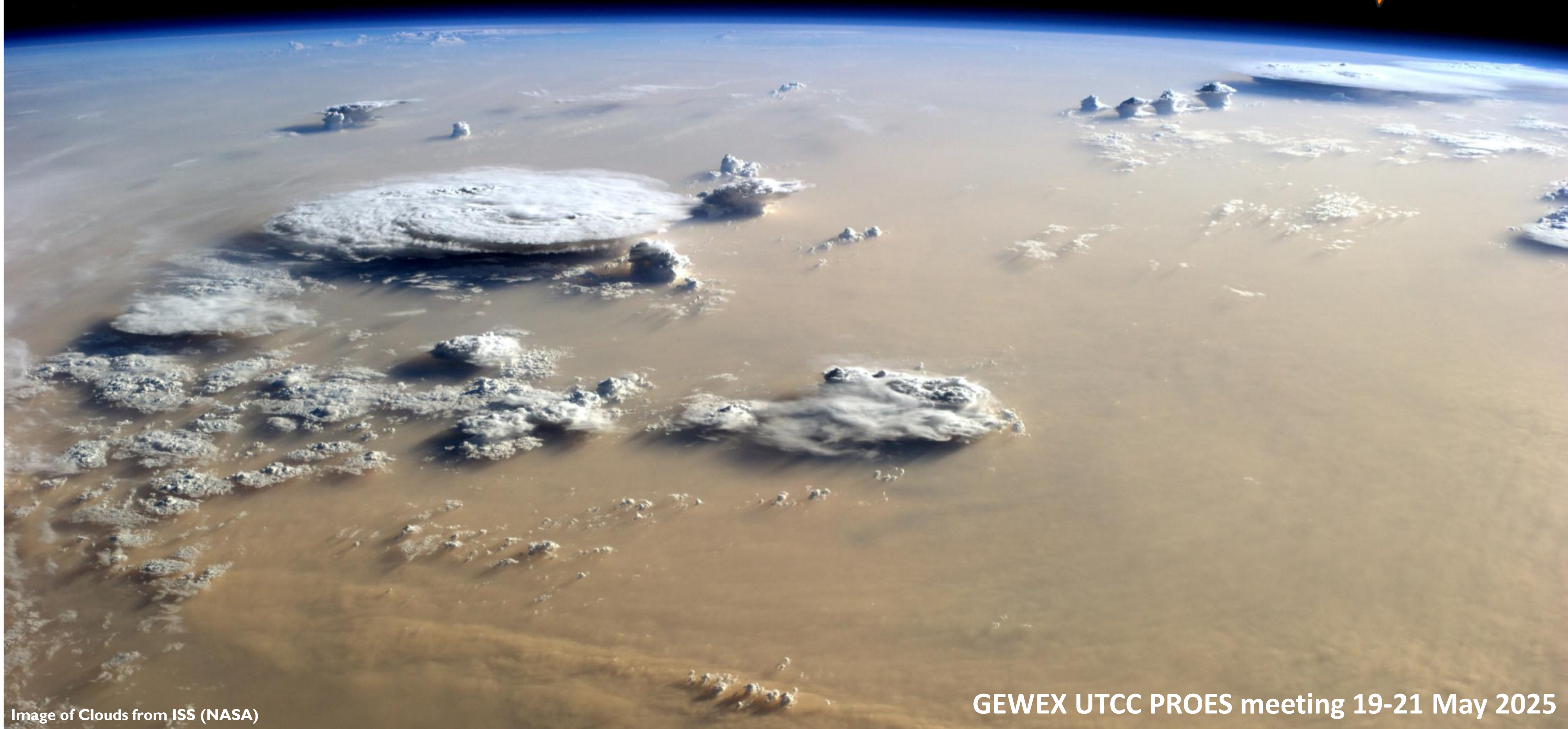


Image of Clouds from ISS (NASA)

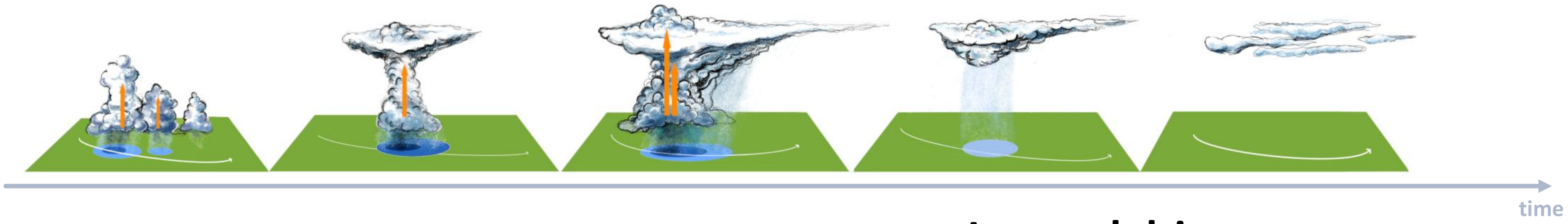
GEWEX UTCC PROES meeting 19-21 May 2025

What drives the convective system cloud shield morphology?

Deep convective systems

- convective cells organized in space and time
- upper-level cloud shield forming a consistent object in space and time

Wide range of time and spatial scale



Cloud shied morphological intensity

- **Growth rate** of the DCS cloud shield
- **Shape** (via Eccentricity)
- **Depth** (via cloud-top temperature)
- **Propagation speed**

Internal drivers

- Amount of deep convective cells
- Depth, mass flux,…
- Microphysical: stratiform precipitation
- Dynamics: mesoscale circulation
- Convective Organization

External drivers

- Wind shear
- Instability
- water vapor

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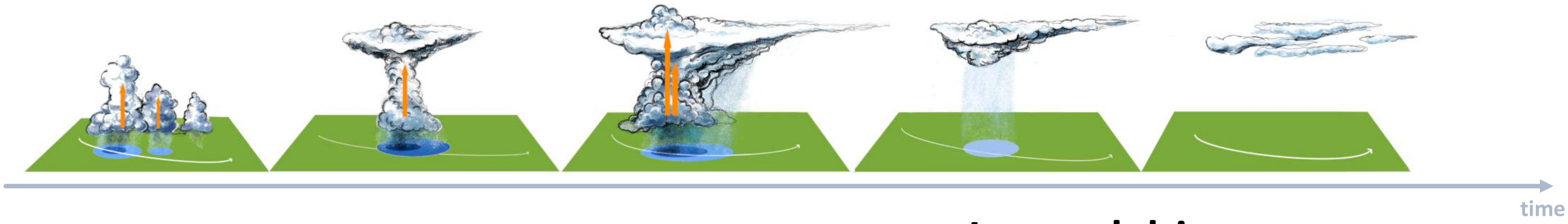

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How large-scale environmental factors statistically shape cloud shield characteristics?

Data and Method

Deep convective systems

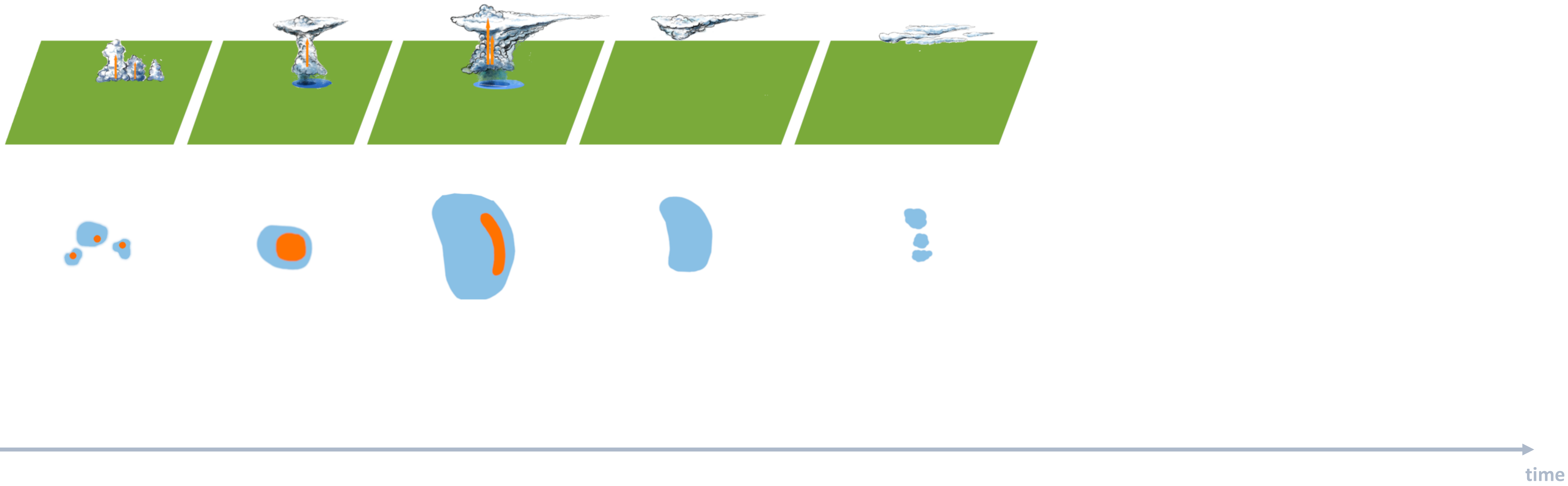
The **2012-2020 TOOCAN dataset**

Fiolleau and Roca 2024

https://toocan.ipsl.fr/

https://doi.org/10.14768/1be7fd53-8b81-416e-90d5-002b36b30cf8

- **Cloud tracking algorithm** applied to geostationary IR imagery
- **~ 700.000** Tropical Oceanic convective systems
- access to **Morphological metrics**



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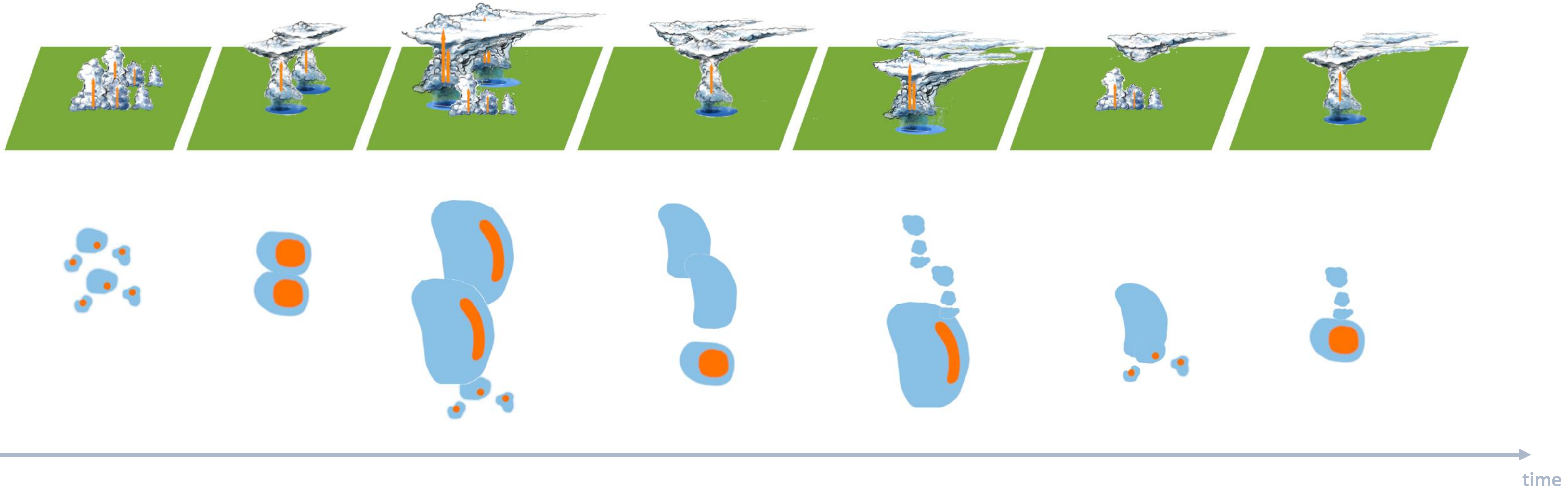

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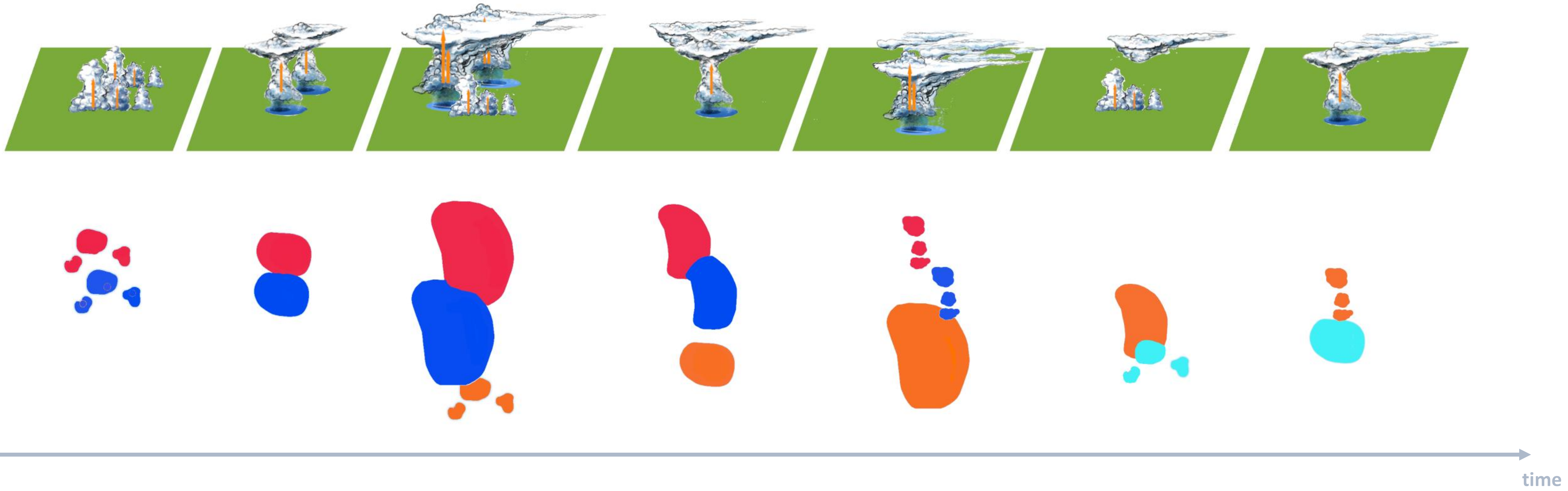

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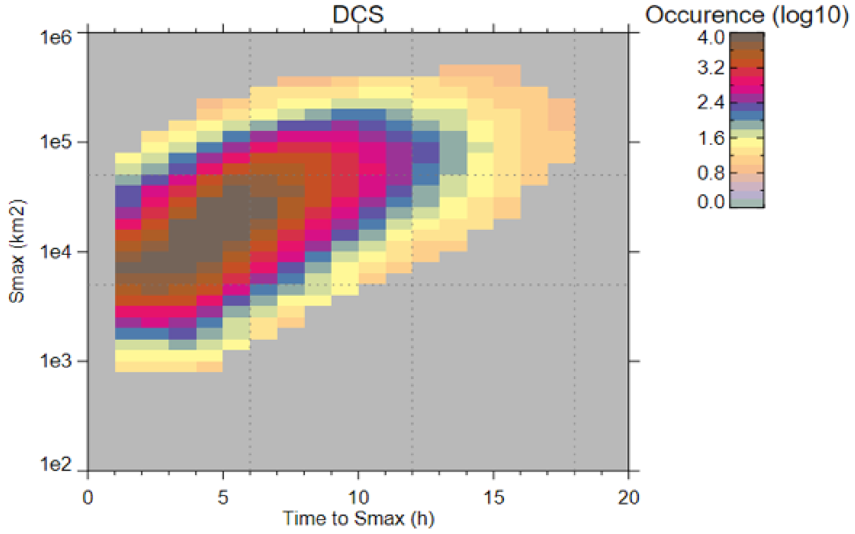
A Phase Space diagram



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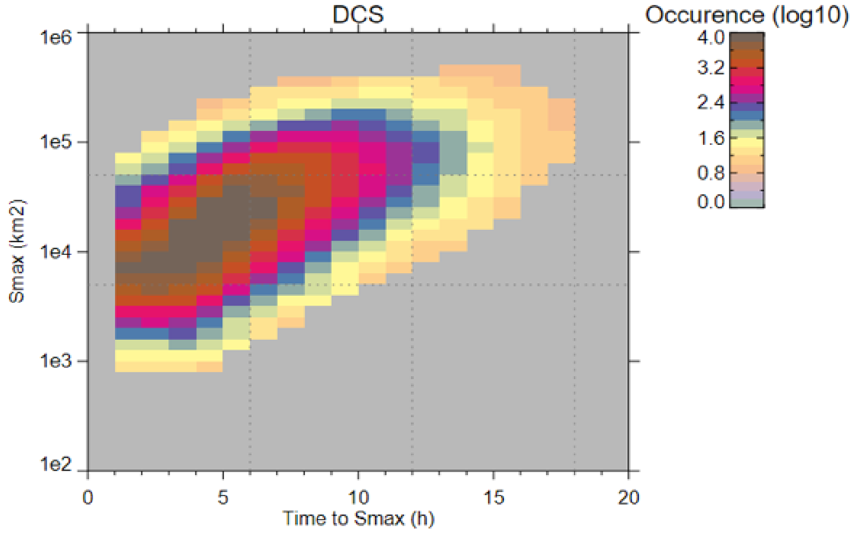


Environmental variables

3°×3° daily **ERA-5** averages, centered on **DCS genesis location**, using **same-day conditions**

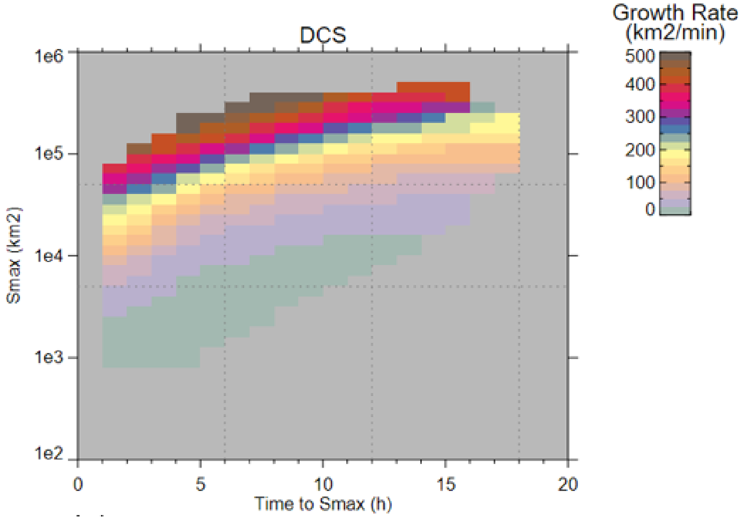
3 key parameters representing tropical convection ingredients:

- Wind Shear ➔ **Dynamics**
- Total Column Water Vapor, CAPE ➔ **Thermodynamics**

➔ Build robust statistics of the morphology – environment relationship across time to maximum and maximum area scales

Convective systems morpholgy

Mean growth rates in the phase space diagram



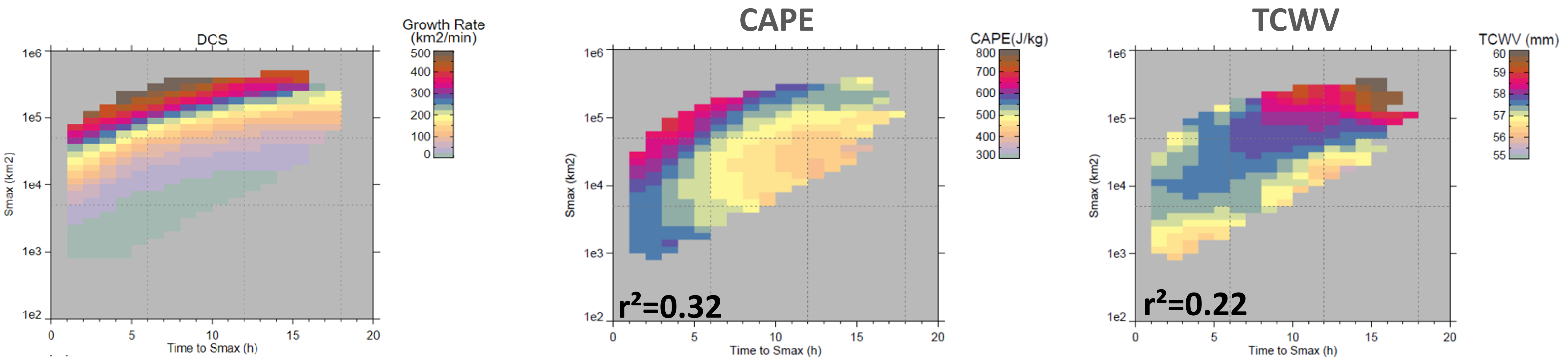
Scale-dependence behavior of growth rate

- **Growth rate increases with maximum area.**

  - **For short-lived systems:** Growth rate dependency on both Maximum area and time to maximum
  - **For the largest and long-lived systems:** growth rate dependency on time smaller.

Thermodynamical environmental variables

Mean thermodynamical variables in the space phase diagram



- **CAPE** increases with maximum extent, but decreases with time to maximum extent.

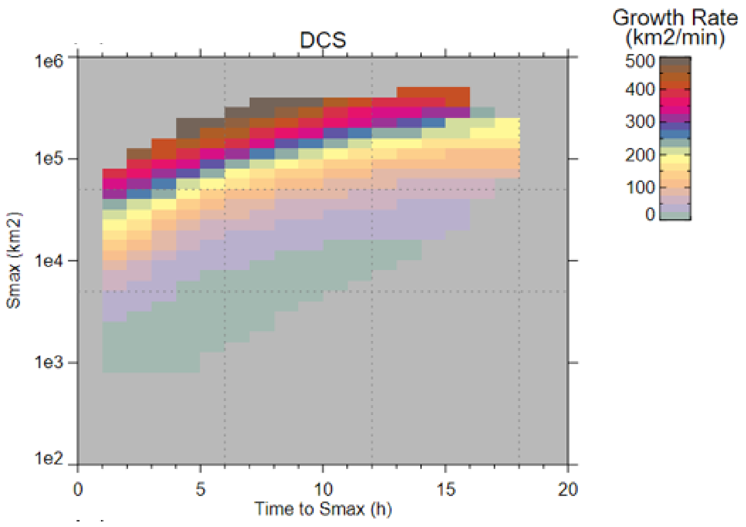
- High values of **TCWV**, Little variability across the time and spatial scales

How well the distribution of the thermodynamical variable explains the scale-dependence of growth rate across the phase space?

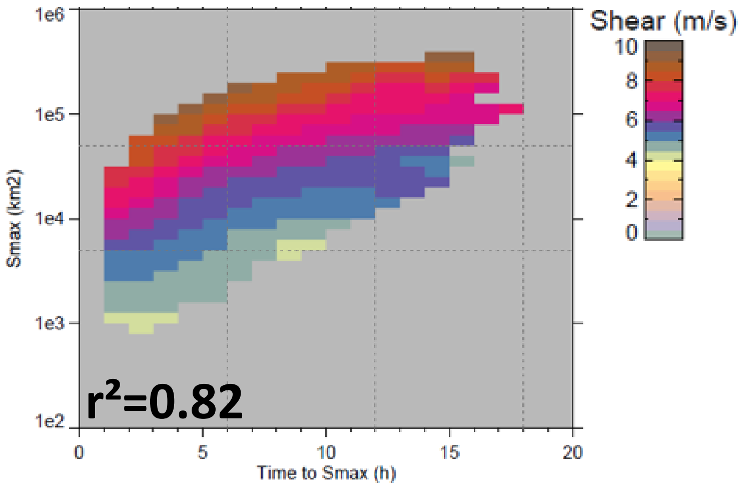
CAPE and **TCWV** weak correlation with growth rate

Dynamical environmental variables

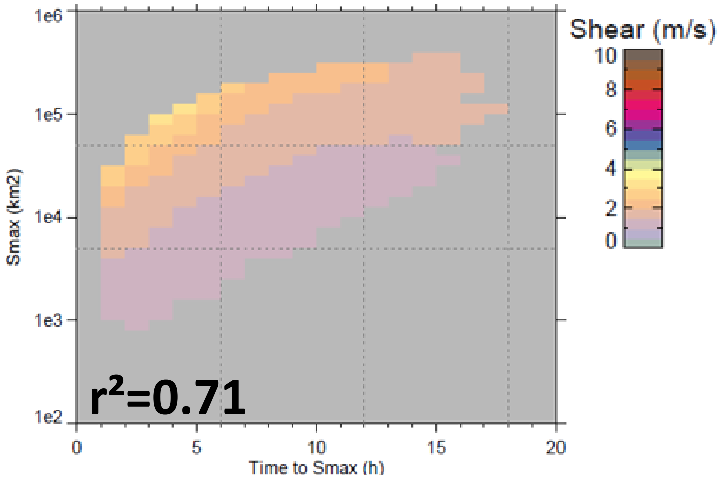
Mean dynamical variables in the space phase diagram



Deep Shear (400-1000 hPa)



shallow Shear (900-1000 hPa)



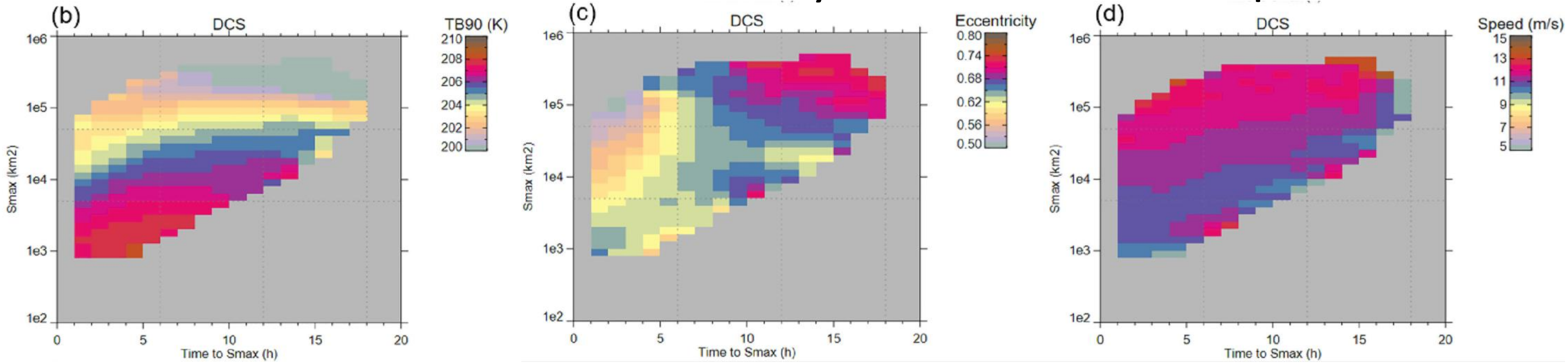
- Sensitivity of the deepest wind shear layers to both the time to maximum and the maximum area
- Weaker gradient as the layer is confined to the lower atmospheric levels.

How well the distribution of the dynamical variable explains the scale-dependence of growth rate across the phase space?

Strong linear correlation with shear in both the deepest and the lowest layers

Extension to other cloud morphological properties

90th BT | **Eccentricity** | **Speed**



r^2

Morphological properties	CAPE	TCWV	Shear 400 hPa	Shear 900 hPa
90th BT	0.06	0.53	0.65	0.34
Eccentricity	0.22	0.23	0.00	0.06
Speed	0.07	0.13	0.33	0.22

- Moderate r^2 of 90th BT with shear at 400 hPa and TCWV.
- Weak influence of environmental variables on eccentricity and propagation speed.

Relative contribution of each environmental variable

What is the relative contribution of each environmental variable in explaining the variability of morphological characteristics across the phase space?

A multiple linear regression approach:

Lag=0 day	2 predictors	3 predictors	4 predictors
Growth rate	0.85	0.85	0.86
90th BT	0.80	0.80	0.83
Eccentricity	0.62	0.64	0.64
Speed	0.33	0.34	0.34

Growth rate: strong r^2 attributed primarily to Deep shear, secondary to low shear

Depth (90^{th} BT) : strong r^2 with Deep shear and TCWV main contributors

Eccentricity and Speed less direct relationship to environment

Conclusion

Relationship of the **Scale dependence of cloud shield morphological properties** with **thermodynamic and dynamic environment**

- satellite-based dataset of convective systems
- ERA-5 data

- **Growth rate** is best explained by **deep-layer wind shear**, not by CAPE or TCWV
- **Depth** correlates with dynamics and only secondarily with water vapor.
- **Eccentricity and speed** show **low sensitivity** to environmental conditions.

➔ Dynamical drivers exert stronger morphological control than the thermodynamic factors

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RESEARCH ARTICLE
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Scale-Dependence of Tropical Oceanic Deep Convective Systems' Cloud Shield Morphology to Environmental Conditions

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Key Points:

- Observational data set reveals robust scale dependence between deep convective cloud shield morphology and initial environmental conditions
- Scale dependence of the system's shield growth rate is strongly related to the wind shear over a deep tropospheric