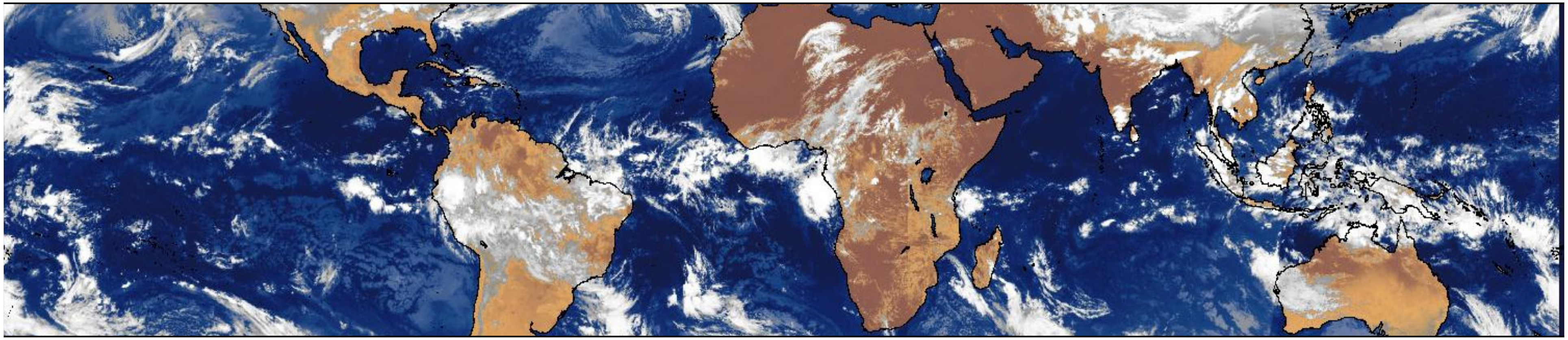
A new Approach to the Detection and Tracking of Mesoscale Convective Systems in the Tropics using MSG



Courtesy of SATMOS

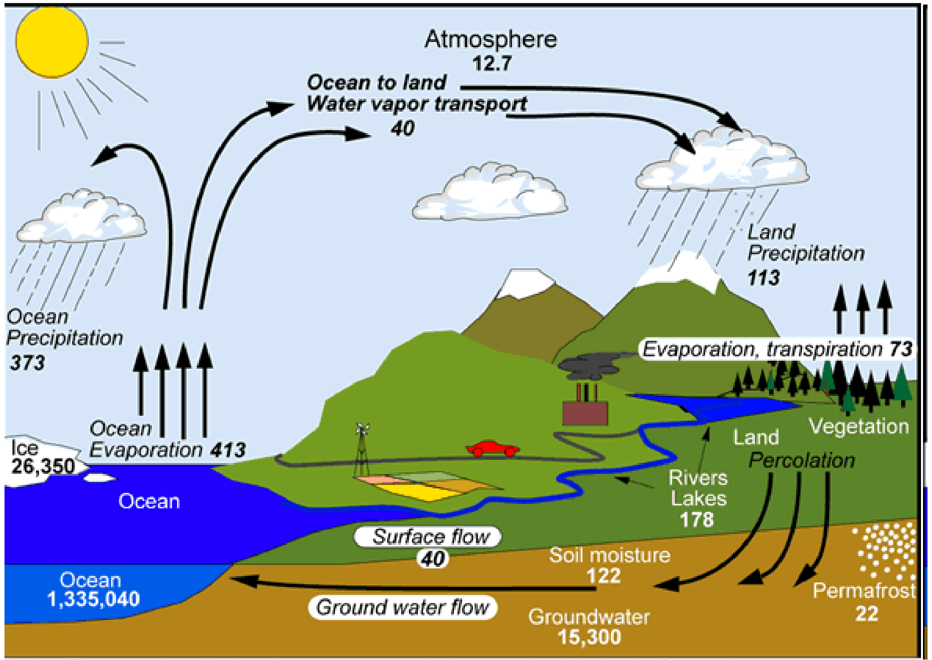
LMD

Thomas Fiolleau
Rémy Roca

Outline of the talk

- **Introduction**
  - the Hydrological and Energy Cycle in the tropics
  - Background on convective systems
- **Data and Methodology of the new tracking algorithm**
  - Illustration of the new tracking methodology
- **Comparison of the new algorithm with the area-overlapping tracking methodology**
  - Analysis of a Case Study over West Africa.
- **Conclusions & Perspectives**

Introduction



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

•**Comprehension of water cycle and Energy budget is of major importance to have a better understanding of the Tropical climate**

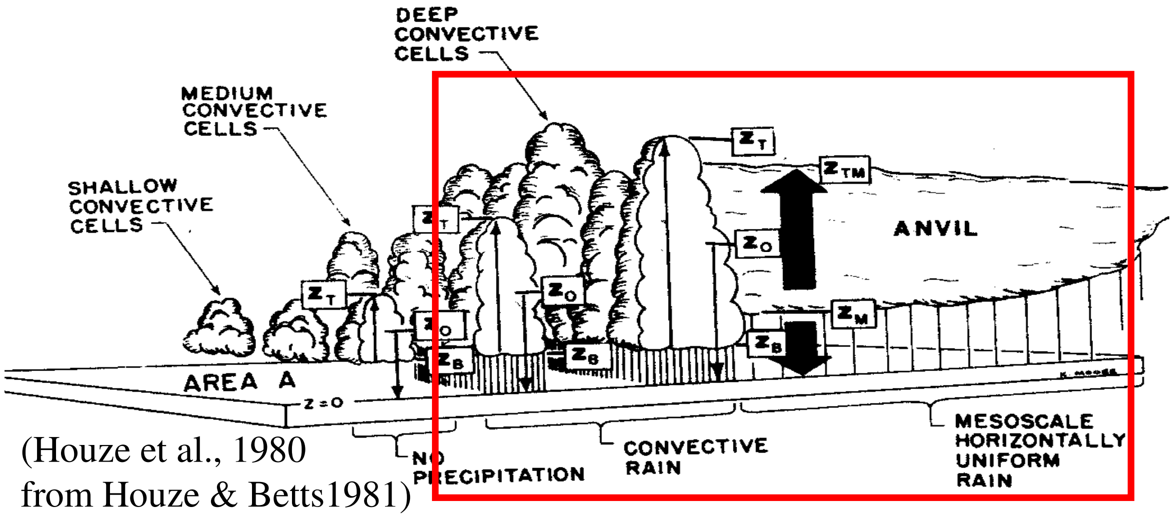
- **Deep convective cloud central elements of the tropical climate with a strong influence on the water and energy cycle.**

→ the major provider of **rainfall at the ground**

→ the major provider of **atmospheric heating through latent heat release**

→ the **main source of cloudiness** that drives the radiation budget in the tropics.

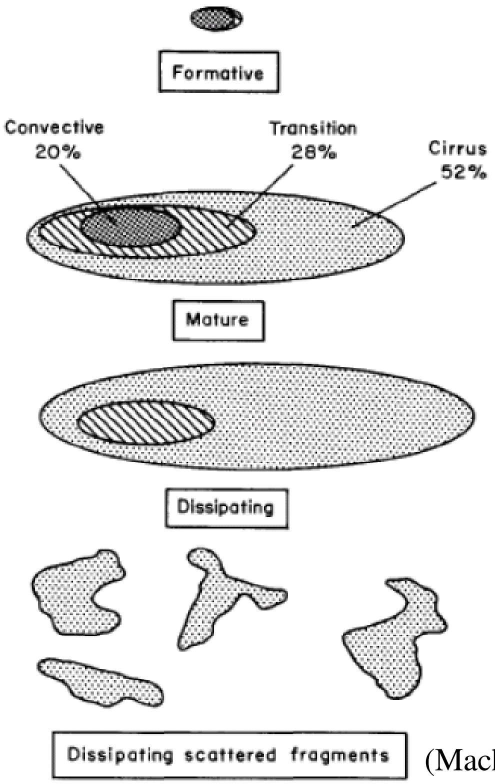
Background on Convective Systems



(Houze et al., 1980
from Houze & Betts1981)

Deep Convective Systems in the Tropics:

→**Organized cloud clusters** spanning a **wide range of spatial scale and degree of organization**.



(Machado & Rossow 1993)

Life cycle of convective systems:

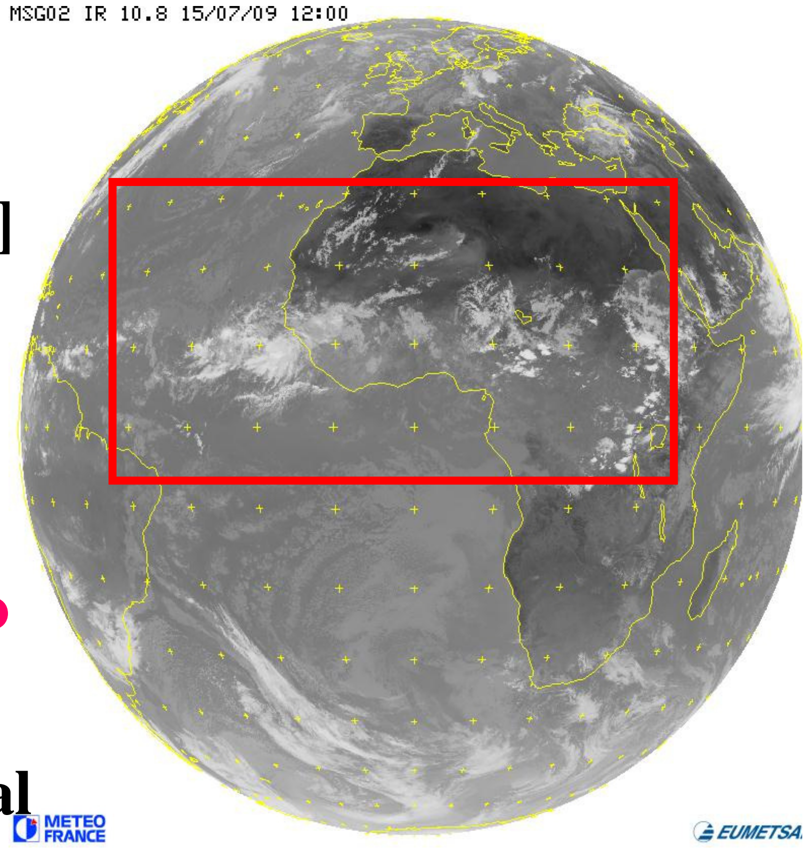
→Schematic cloud structure in an average tropical convective system in its formative, mature and dissipating stages

→ Monitoring these systems through their life cycle to survey the variability of the tropical water and energy budget from a physical perspective.

Data

Use of Geostationary satellite data

- **10.8µm** channel from MSG
- **Study Area: [40°W:40°E; 15°S:30°N]**
- **Period from June to September 2006**



Use of automatic tracking algorithms to detect and follow convective systems

→Characterization of the morphological aspects of Convective Systems:

Degree of organization of convection, of occurrence, of this type of system, on the evolution of the cold cloud shield life cycle…

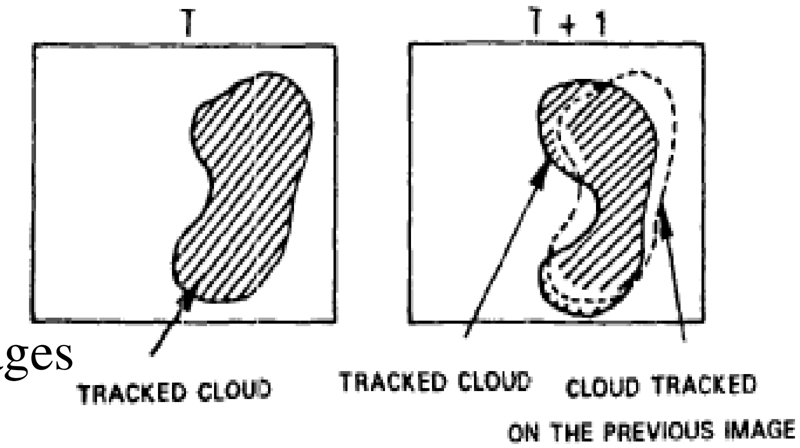
work related to automatic tracking algorithms among other techniques

Area-overlapping techniques:

Williams and Houze (1987) and Arnaud etal (1992)

→ automated method based on a minimum overlapping area between MCSs in successive images.

→ 233°K threshold.



(Arnaud et al., 1992)

Adaptative threshold techniques:

Morel and Senesi (1999)

→RDT (Rapid developing Thunderstorm), an adaptative temperature threshold of the infrared images

→Detection of the cloud systems earlier in their initiation stages.

Correlation techniques:

Carvalho and Jones (2001)

→developement of an efficient method based on maximum spatial correlation tracking technique (MASCOTTE)

Split and Merge artefacts of individual systems.

→ Characterization of convective systems life cycle.

Methodology (1/4)

→ **Developpement of an algorithm based on an IR image segmentation with no or little dependence on any given threshold.**

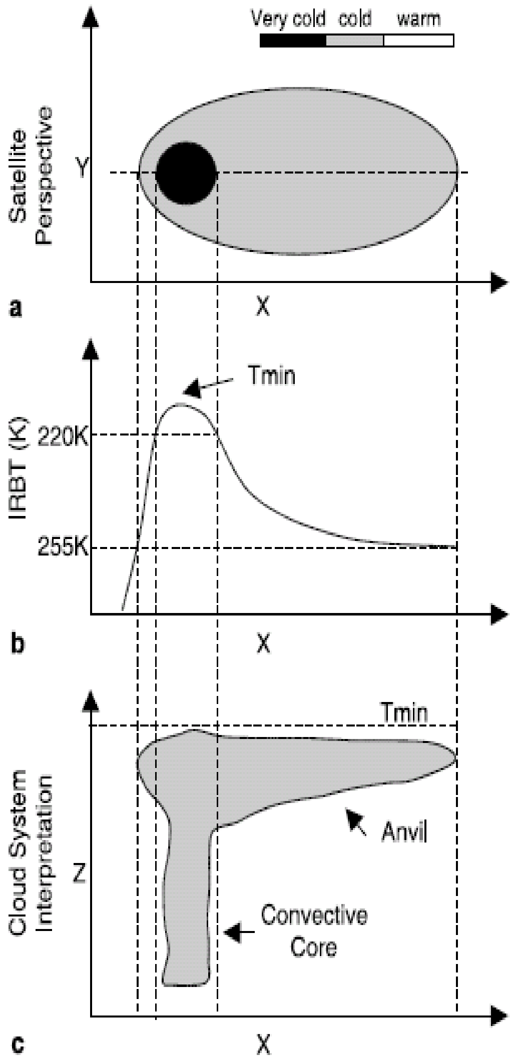
- **Detect and Spread (DAS) technique** (Boer and Ramanathan, 1997)
- DAS method tuned to **the tropical deep cloud detection** using INSAT (Roca and Ramanathan, 2000; Roca et al., 2005) and METEOSAT data (Roca et al., 2002).

→ Clustering technique which progress from the convective core to the cloud edges in multiple steps:

1- detection of the convective core in multiple steps.

2- Spread up of the convective core to the cold cloud shield edges in multiple steps.

→ **Introduction of an improved method for tracking the tropical MCS based on a 3D approach segmentation.**



Roca et al. 2005

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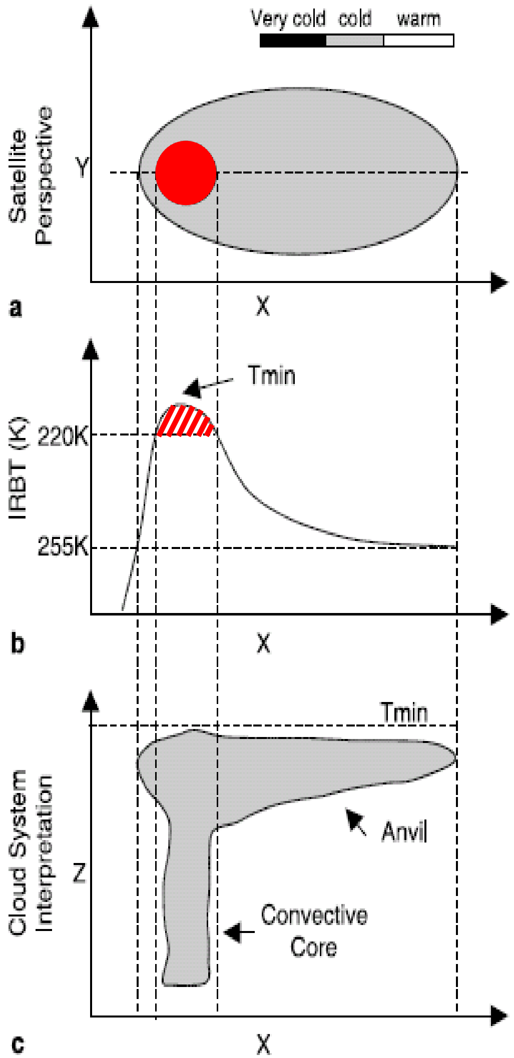

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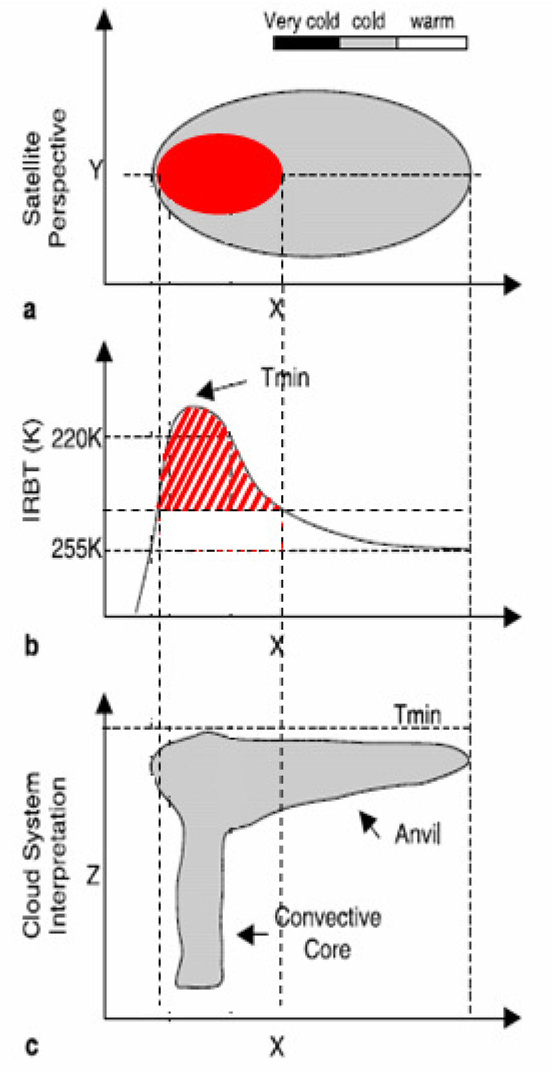

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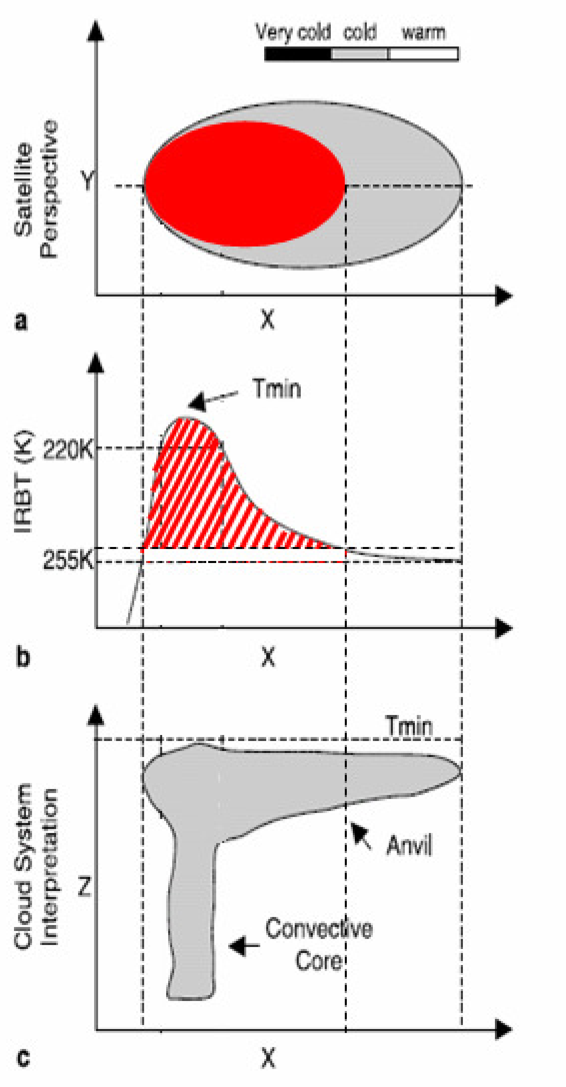

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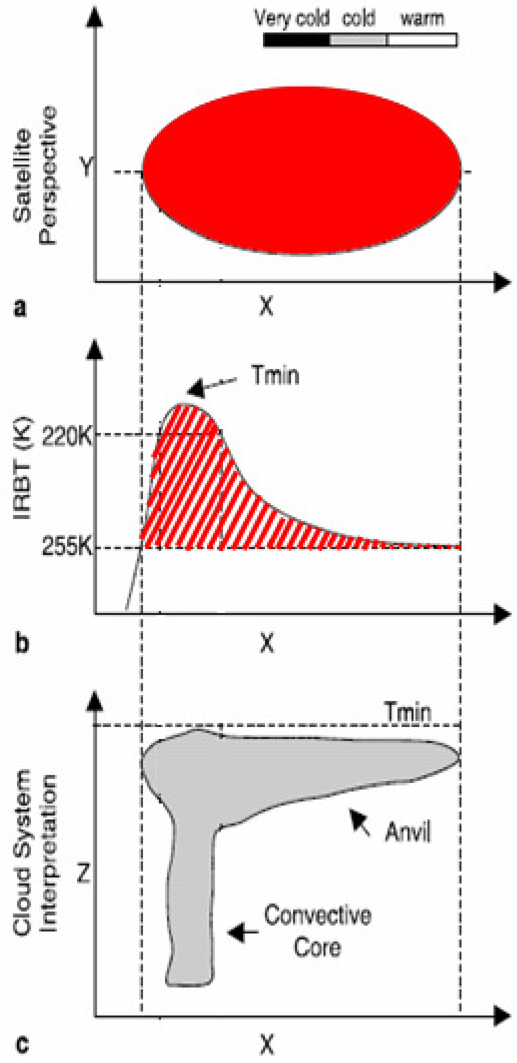
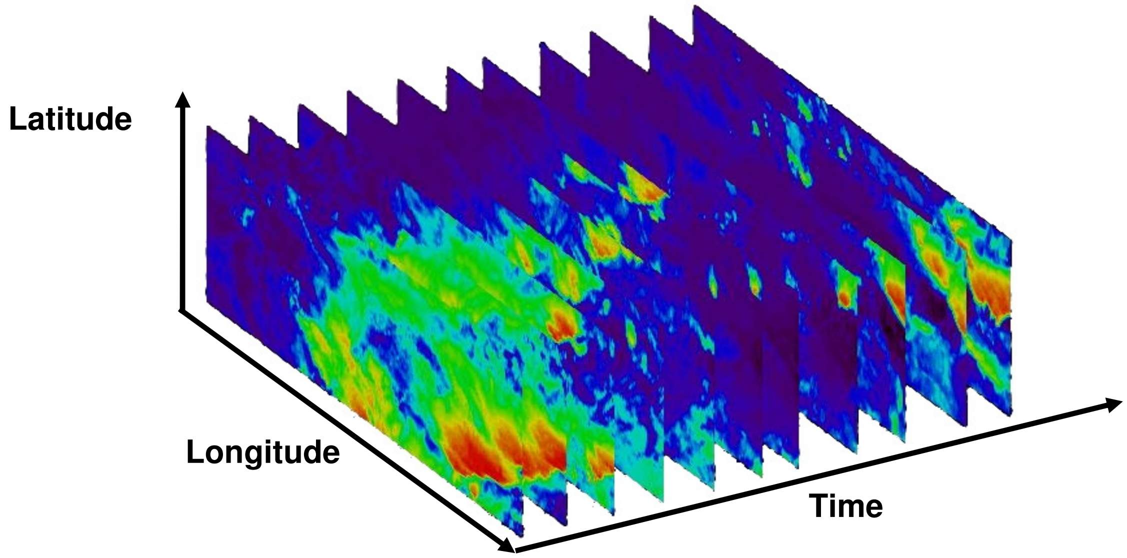


→ **Introduction of an improved method for tracking the tropical MCS based on a 3D approach segmentation.**

Methodology (2/4)

→ Generation of a 3D image corresponding to an IR images sequence, whose spatial axes are longitude and latitude

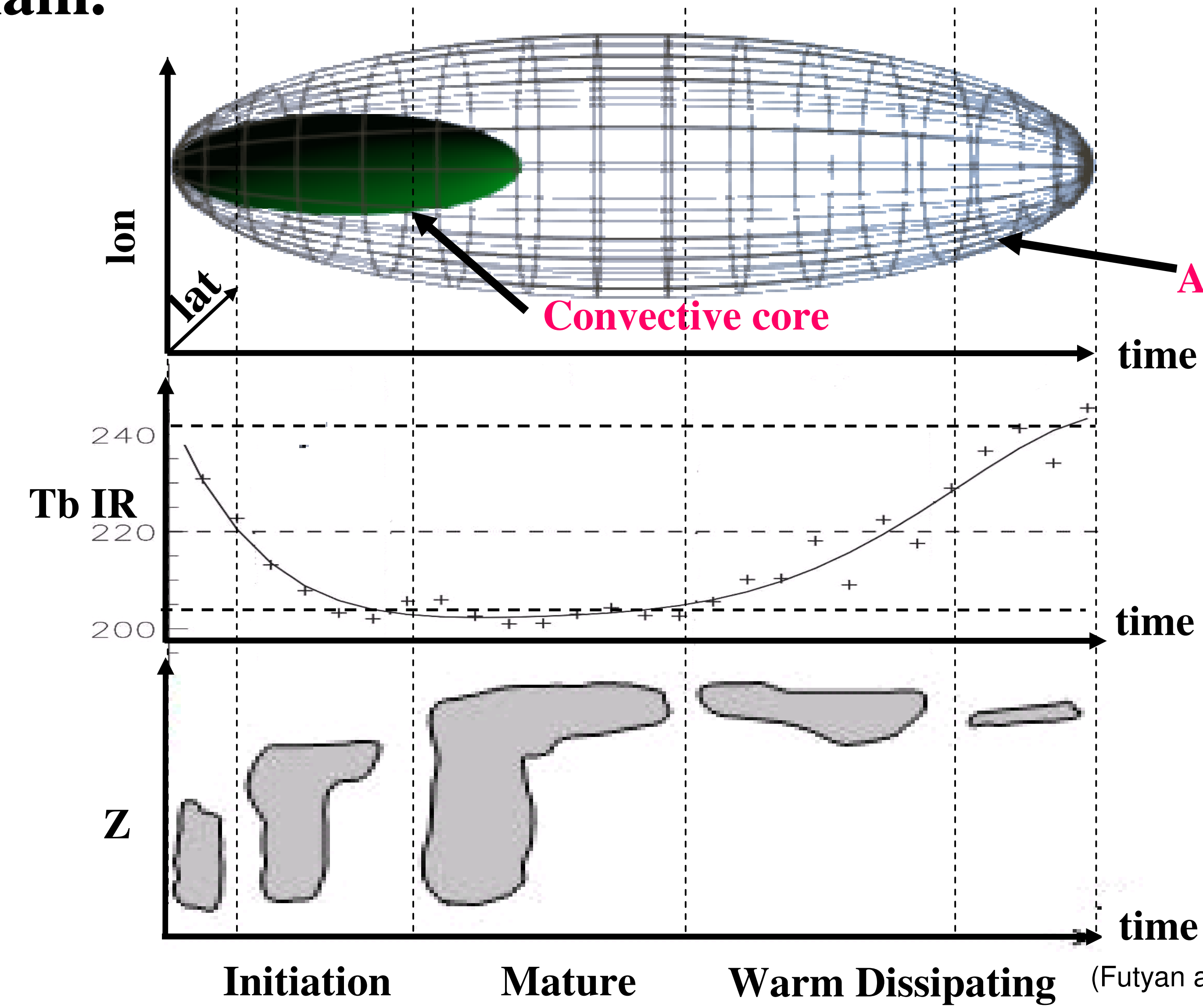


→DAS technique restricted to high cold clouds and extended in time to form a 3D segmentation technique (2D+time).

→Segmentation of moving objects in an IR image sequence by the DAS3D algorithm.

Methodology (3/4)

- **Schematic of a convective system in the spatio-temporal domain.**



(Futyan and Del Genio 2006)

Methodology (4/4)

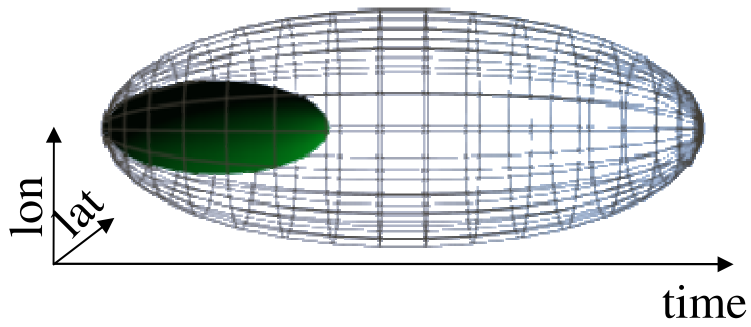
DAS3D: a generalized clustering technique which progress from the convective core to the cloud edges in multiple steps.

1 - A **3D segmentation of individual convective cores** in the spatiotemporal domain

2 – A **Spread up** of the convective core in the spatio-temporal domain to the cold cloud shield edges.

→ Associate the anvil cloud with the convective activity

- **Initial threshold at 190°K**
- **Warmest threshold value: 235°K**
- **Volume > 5000 km² + Time**
- **Life time> 1H30**



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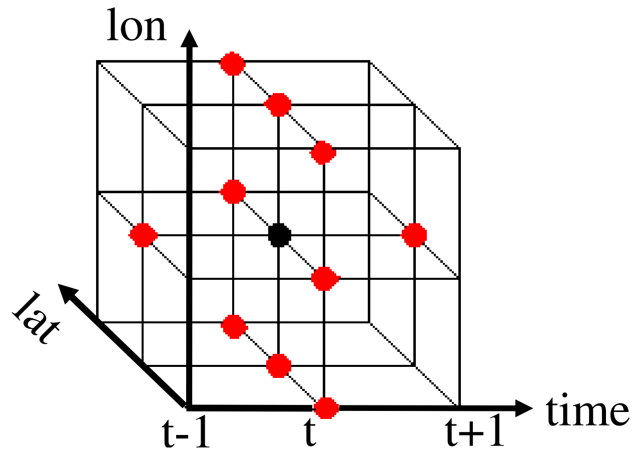
8-connected spatial neighbourhood

2-connected temporal neighbourhood (past and future)



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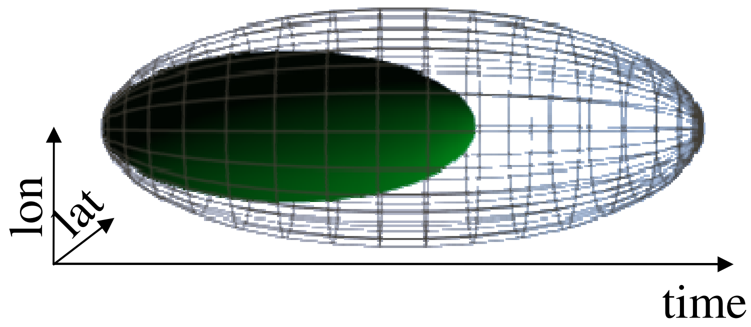

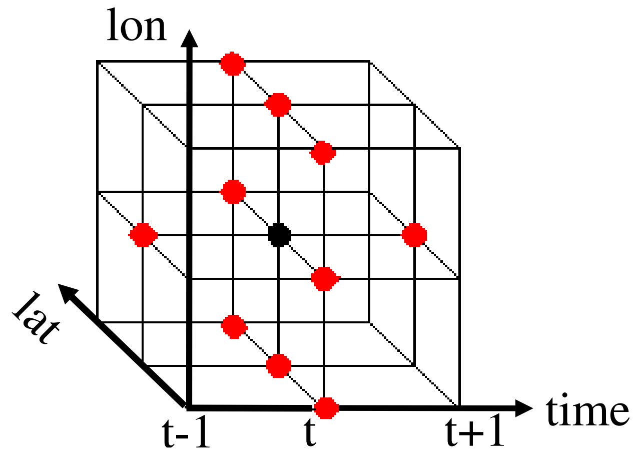

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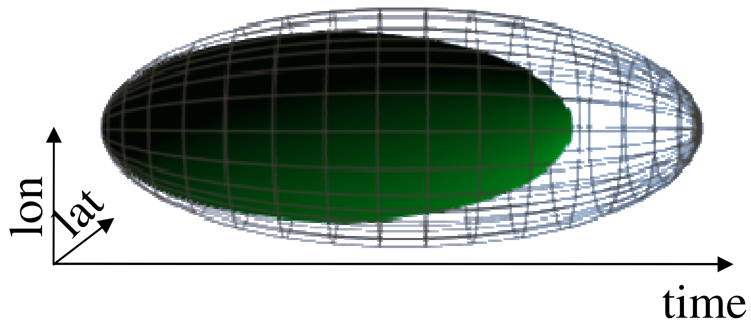

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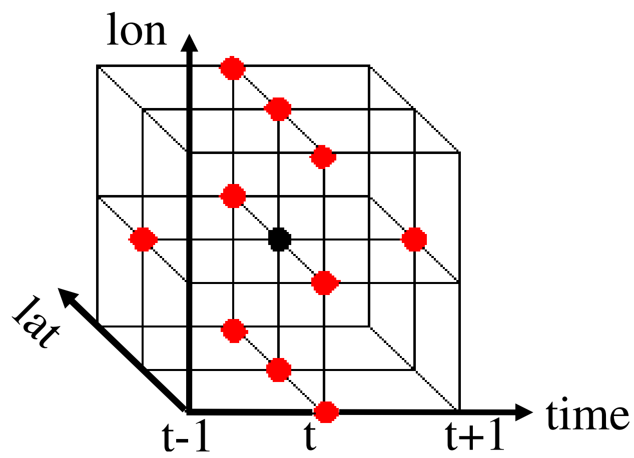

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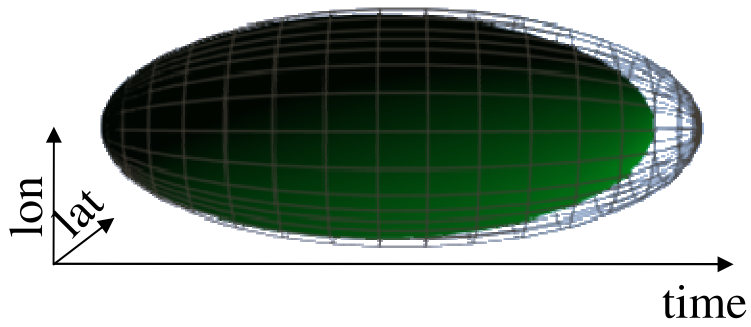

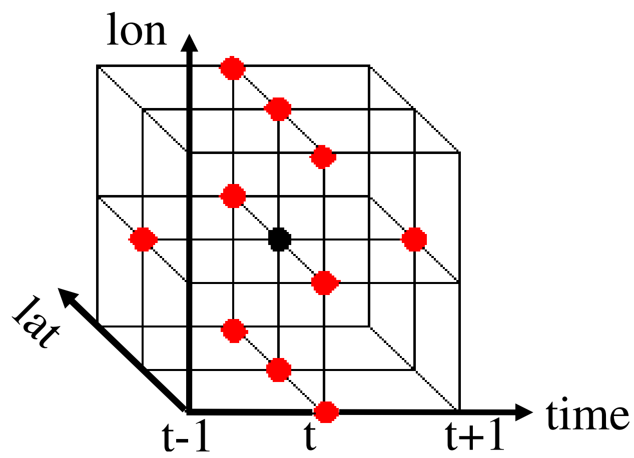

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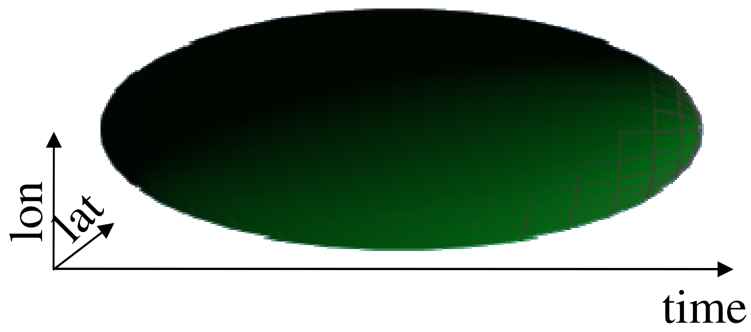


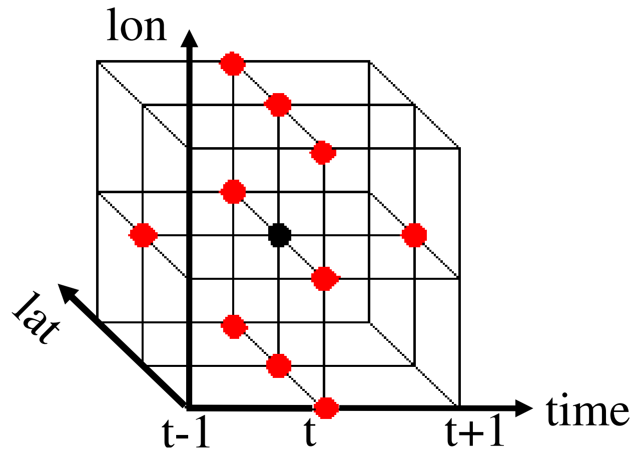
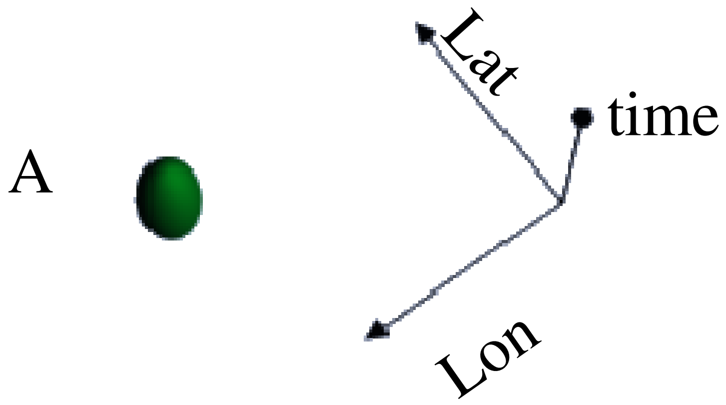


Illustration of the DAS3D methodology

Detection of the convective core set at **220°K**

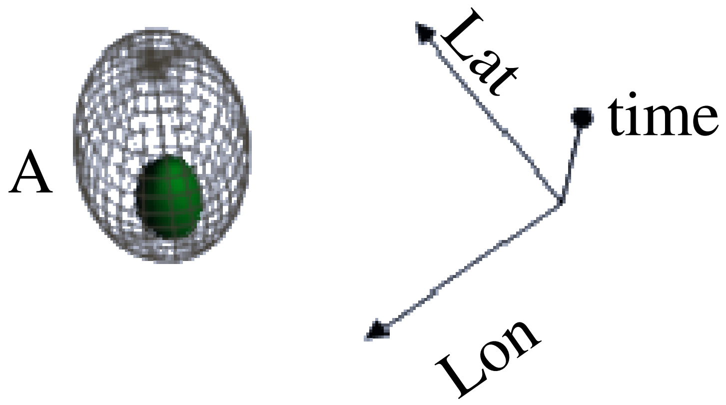


Schématic realized with the help of N.GIF

Illustration of the DAS3D methodology

Detection of the convective core set at **220°K**

Spread up of the convective core to a **5°K warmer threshold**



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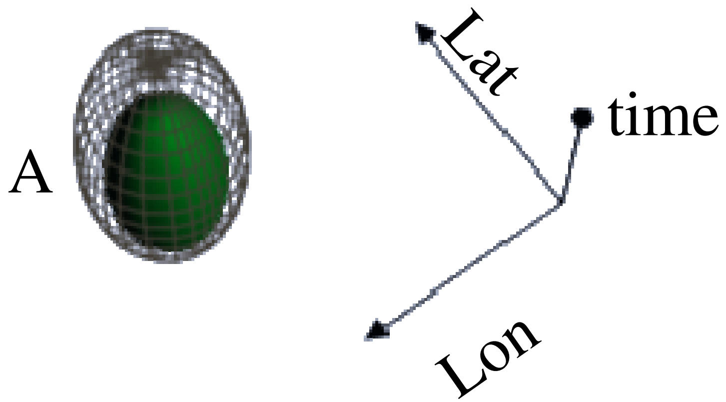

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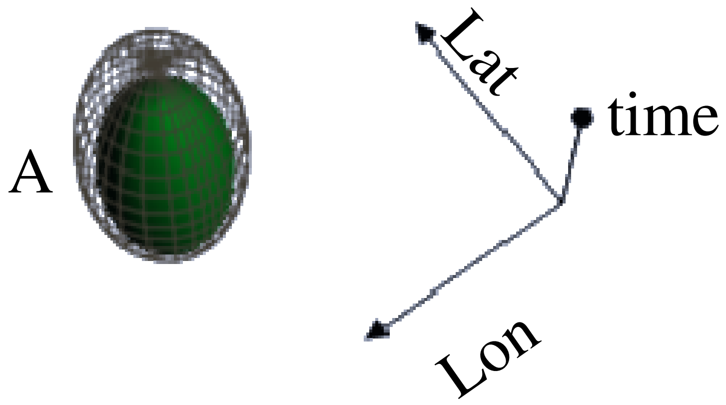

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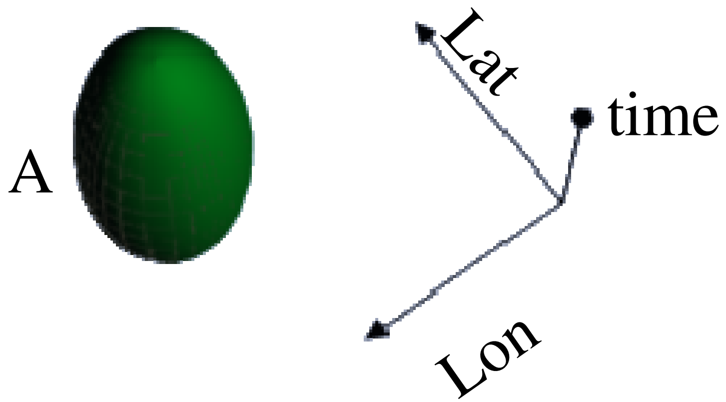

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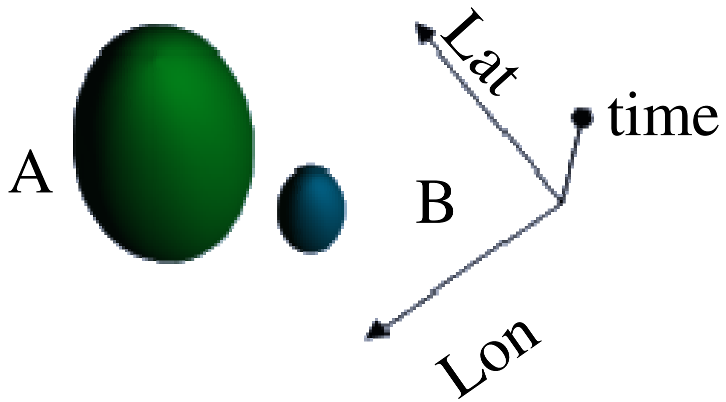

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Illustration of the DAS3D methodology

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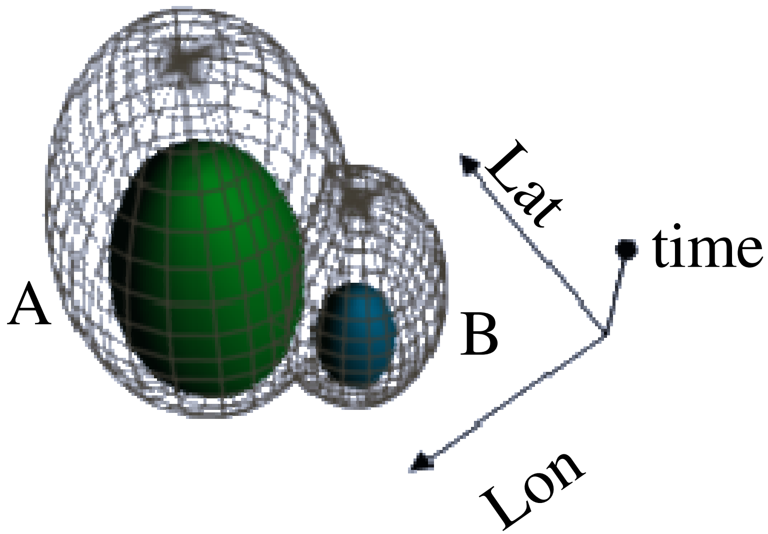

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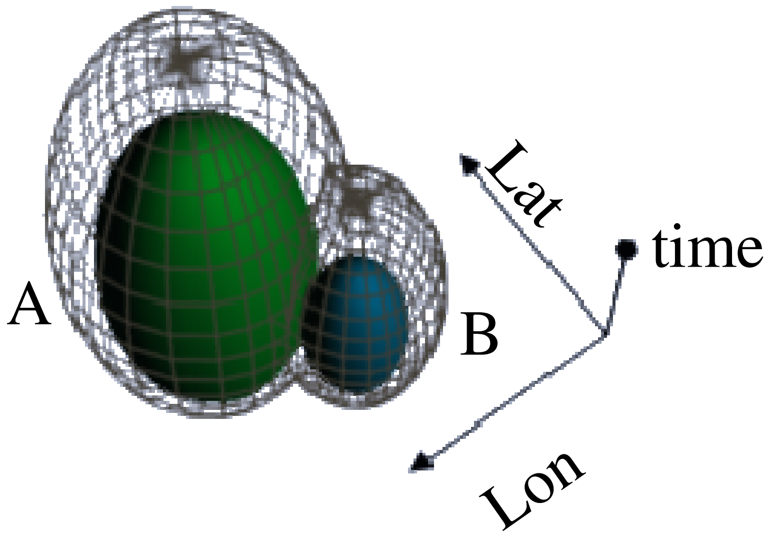

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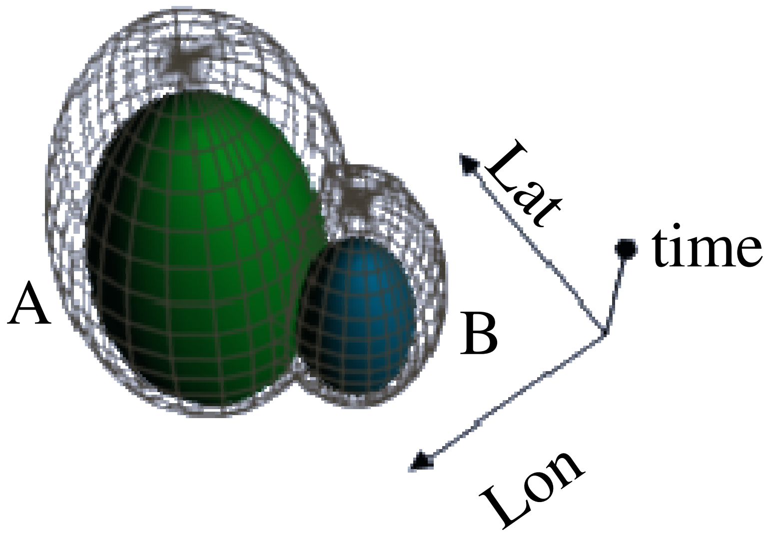

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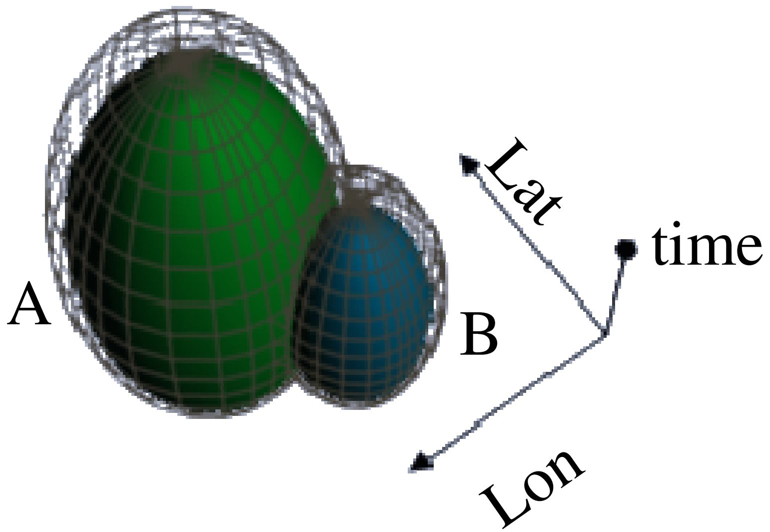

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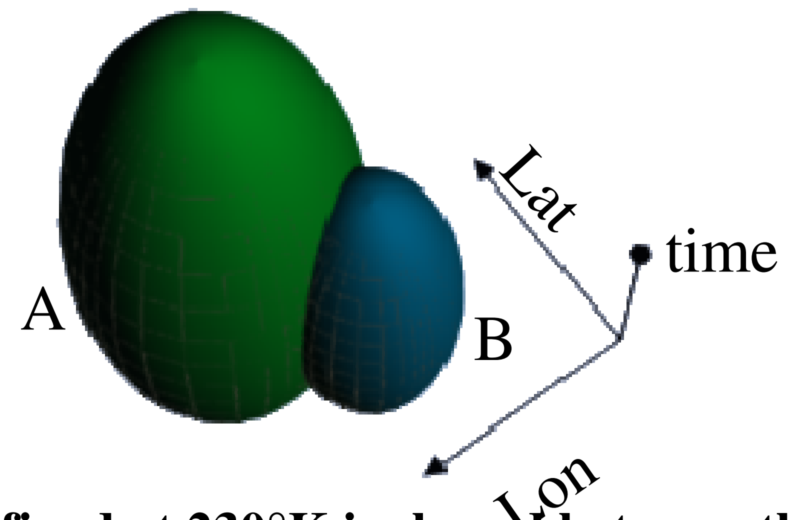


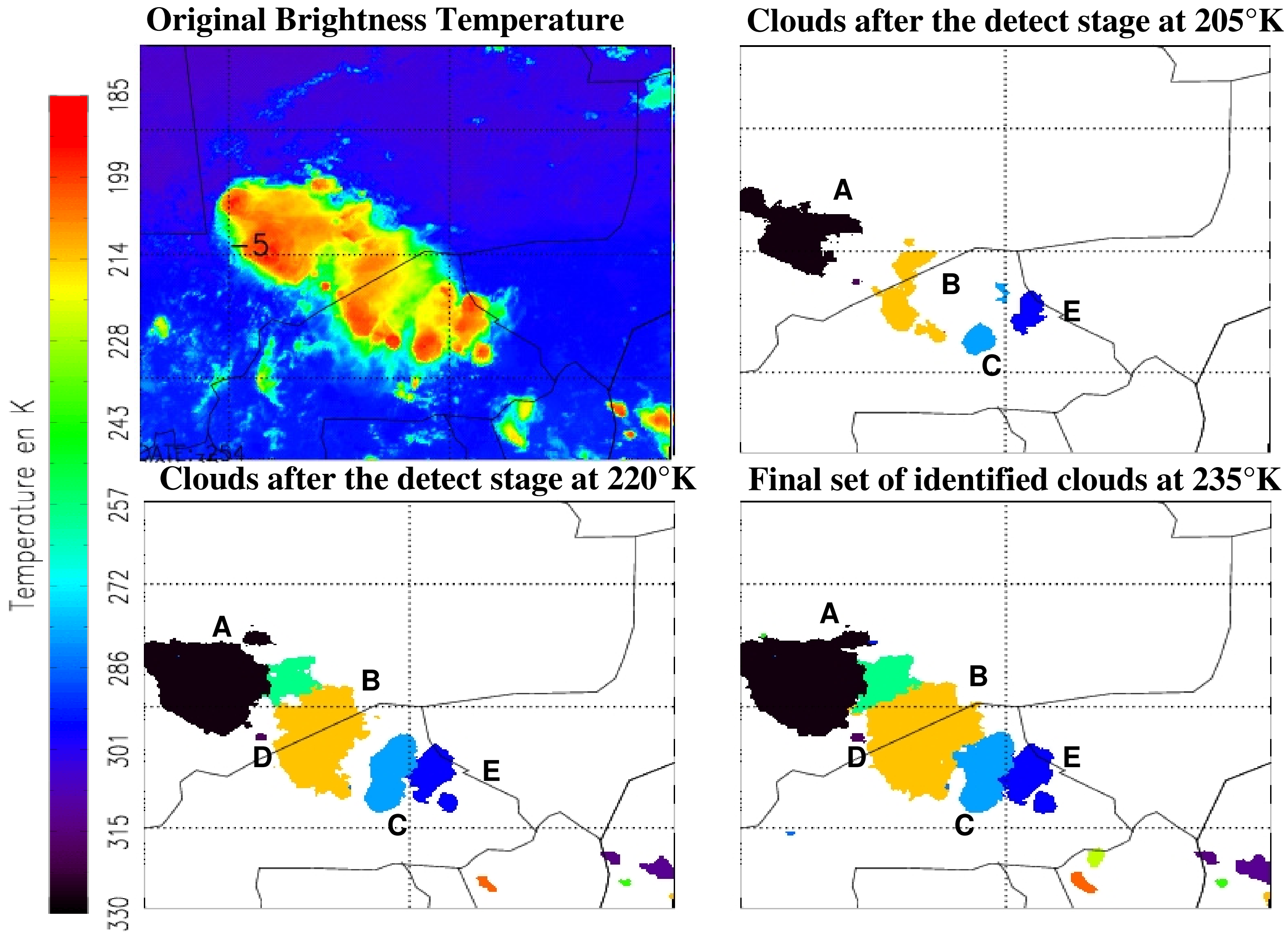
→The warmer anvil cloud defined at 230°K is shared between the system A and the system B.

→Individual systems characterized over their life cycle in a 3 dimensional spatiotemporal image

→ Supression of the split and merge artefacts during the life cycle of individual systems

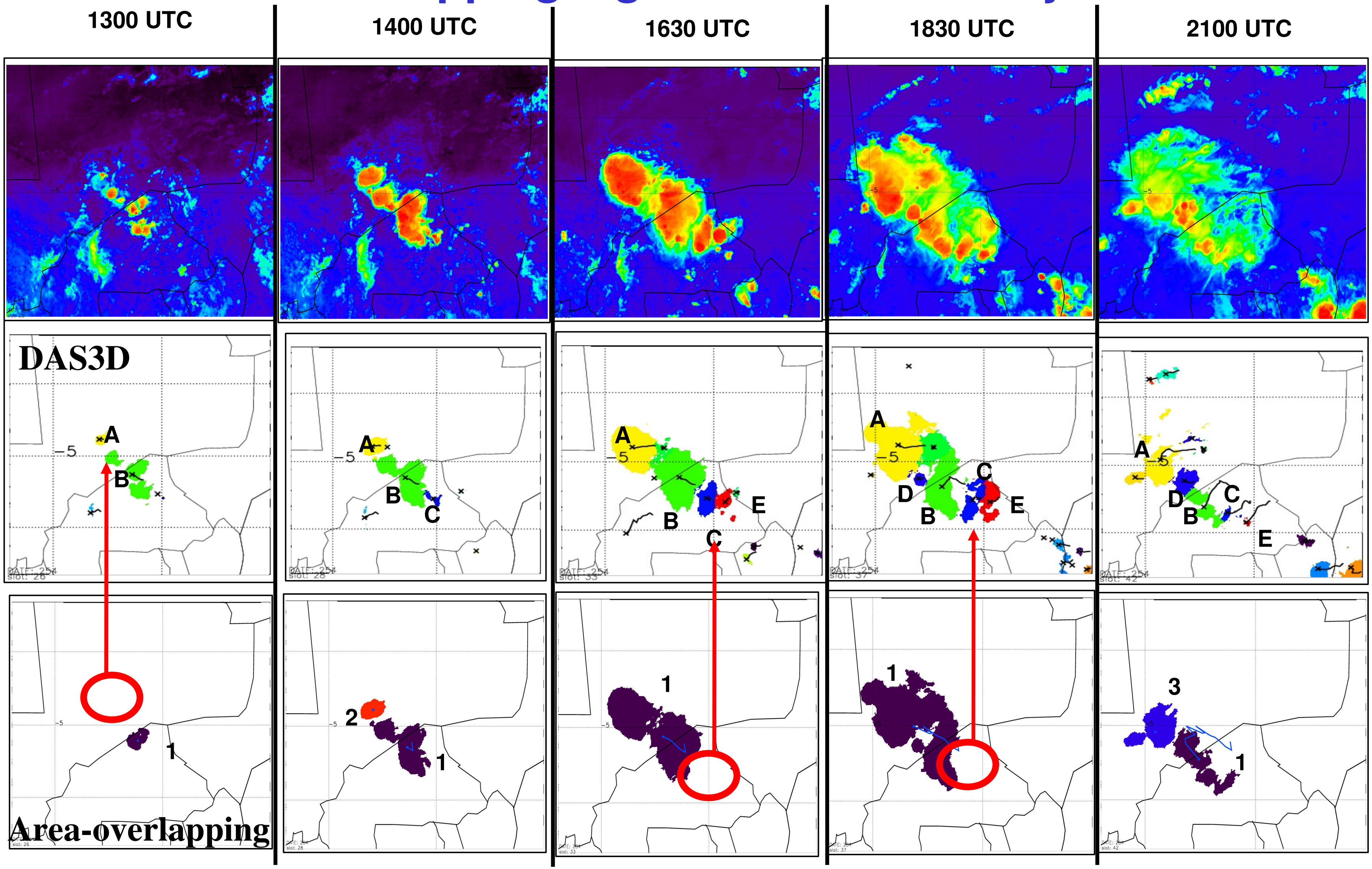
Outputs of the DAS3D algorithm

Case Study September 11th 2006, Niamey at 1630UTC



→ **Segmentation of the IR image in terms of individual convective systems, including core and anvil.**

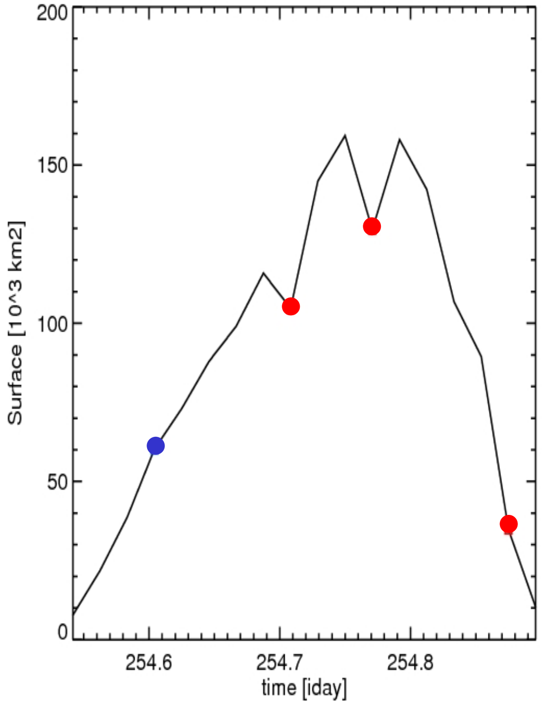
Comparison of the DAS3D methodology with the area-overlapping algorithm: Case Study



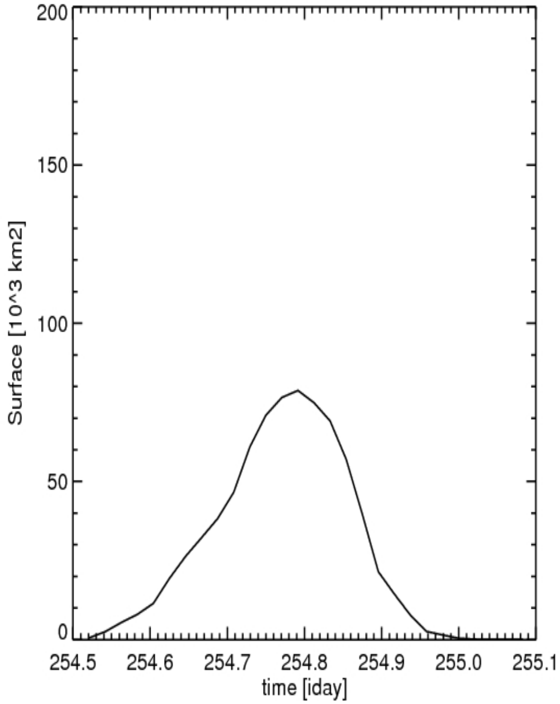
Comparison of the DAS3D methodology with the area-overlapping algorithm: Life cycle

Evolution of the MCS cold cloud shield area through their life cycle

cluster 1 processed by the area-overlapping algorithm



Cluster A processed by the DAS3D algorithm



- Red points and blue points indicate respectively merges and splits.

Surface Max of MCS 1 :160000km²
Surface Max of MCS A: 79000 km²

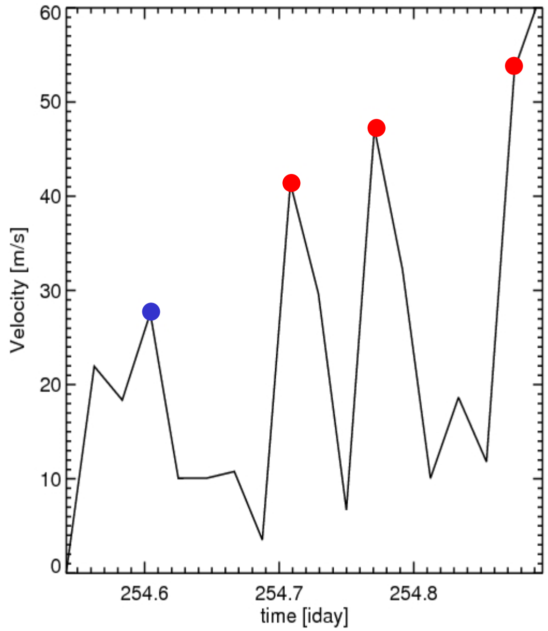
→Noisy evolution of the cold cloud shield of MCS 1 (area-overlapping) explained by successive split and merge artefacts during its life cycle.

→Evolution smoother of the cluster A area (determined by the DAS3D methodology) due to the lack of split or merge artefacts during its life cycle.

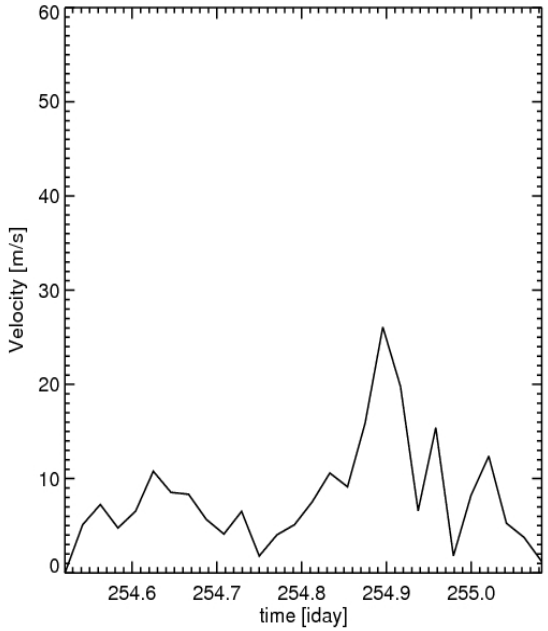
Comparison of the DAS3D methodology with the area-overlapping algorithm: Life cycle

Evolution of the MCS propagation speed through their life cycle

cluster 1 processed by the area-overlapping algorithm



Cluster A processed by the DAS3D algorithm



- Red points and blue points indicate respectively merges and splits.

Propagation speed: displacement of the centre of gravity

Vmax MCS 1 = 60m/s
Vmax MCS A = 26m/s

→Abrupt variations of the propagation speed of cluster 1 (area-overlapping) explained by successive merge or split artefacts through its life cycle.

→ Evolution smoother of the propagation speed of the cluster A determined by the DAS3D algorithm

Conclusion

- Developpement of a new tracking algorithm: DAS3D

- Segmentation of individual convective systems through their life cycle in the spatio-temporal domain

- Detection of the convective systems earlier in their initiation stages and later in their dissipation stages

- Suppression of Split and merge artefacts during the MCS life cycle.

→ Improvement of the characterization of the main morphological aspects of the convective systems life cycle

Perspectives

- Extend the convective events to the full upper level cloudiness
  - Multi spectral observations of SEVIRI sensor.
  - Use of the classification of high clouds from the SAFNWC

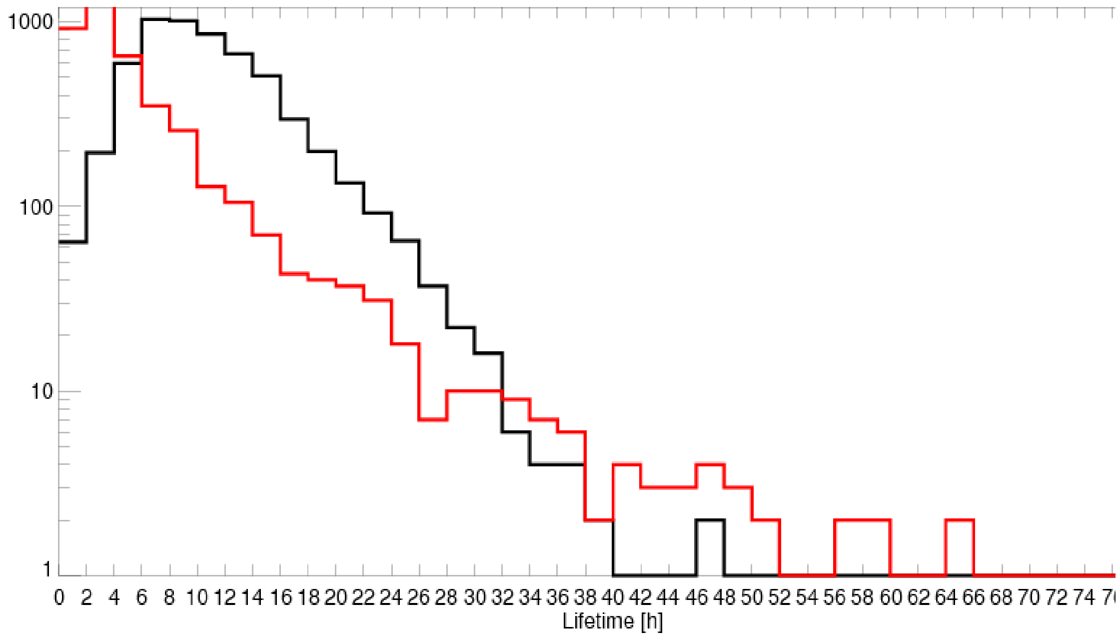
- Collocation of the low earth orbiting measurement (microwave) in space and time to combine rainfall estimates and the MCS cloud shield along the life cycle of the system. (Megha-Topiques)

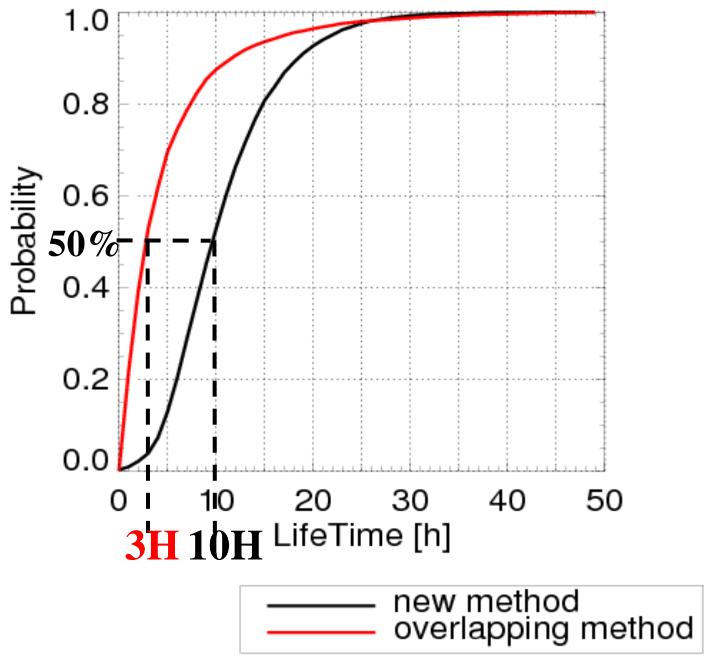
Thank you for your attention

I will be graduated next year

I’m looking for a Post-Doc

Comparison of distributions at the seasonal scale





DAS3D methodology:

→population detected by DAS3D: 8475 MCS

→Lifetime max: 47h

→**50% of the total population < 10H**

Area-Overlapping methodology:

→population detected by the overlapping method : 5775 MCS

→Lifetime max: 80,5H (MCS ayant subi plusieurs fusions durant son cycle de vie)

→**50% of the total population < 3H**