# Evolution of anvil properties along tropical deep convection life cycle

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ISRO-CNES megha-tropiques

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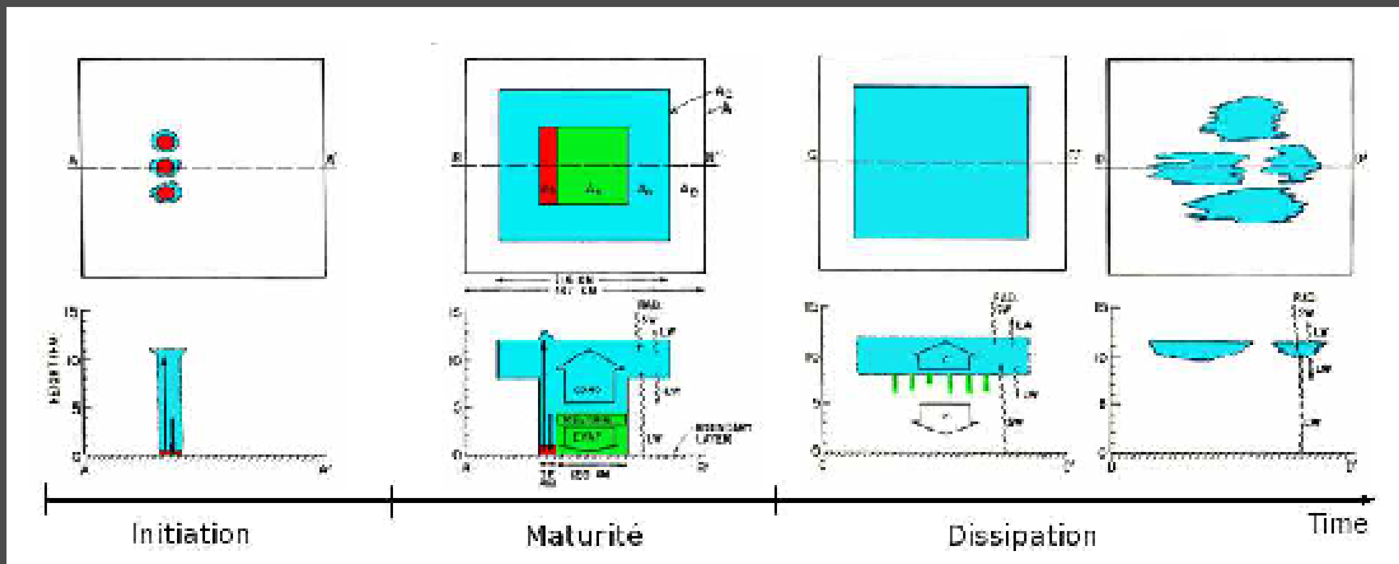
# Motivations :

MCSs are the major source of rain in the Tropics, however they also inject at mid to high altitude large quantity of ice that may persist several hours after rain has ceased.
MCSs can interact with the dynamical circulation through latent and radiative heating profiles
Importance of the MCS Life cycle / various MCS parts :




Houze, 1982

The life time of MCS anvil clouds + its size make its radiative impact non negligible.

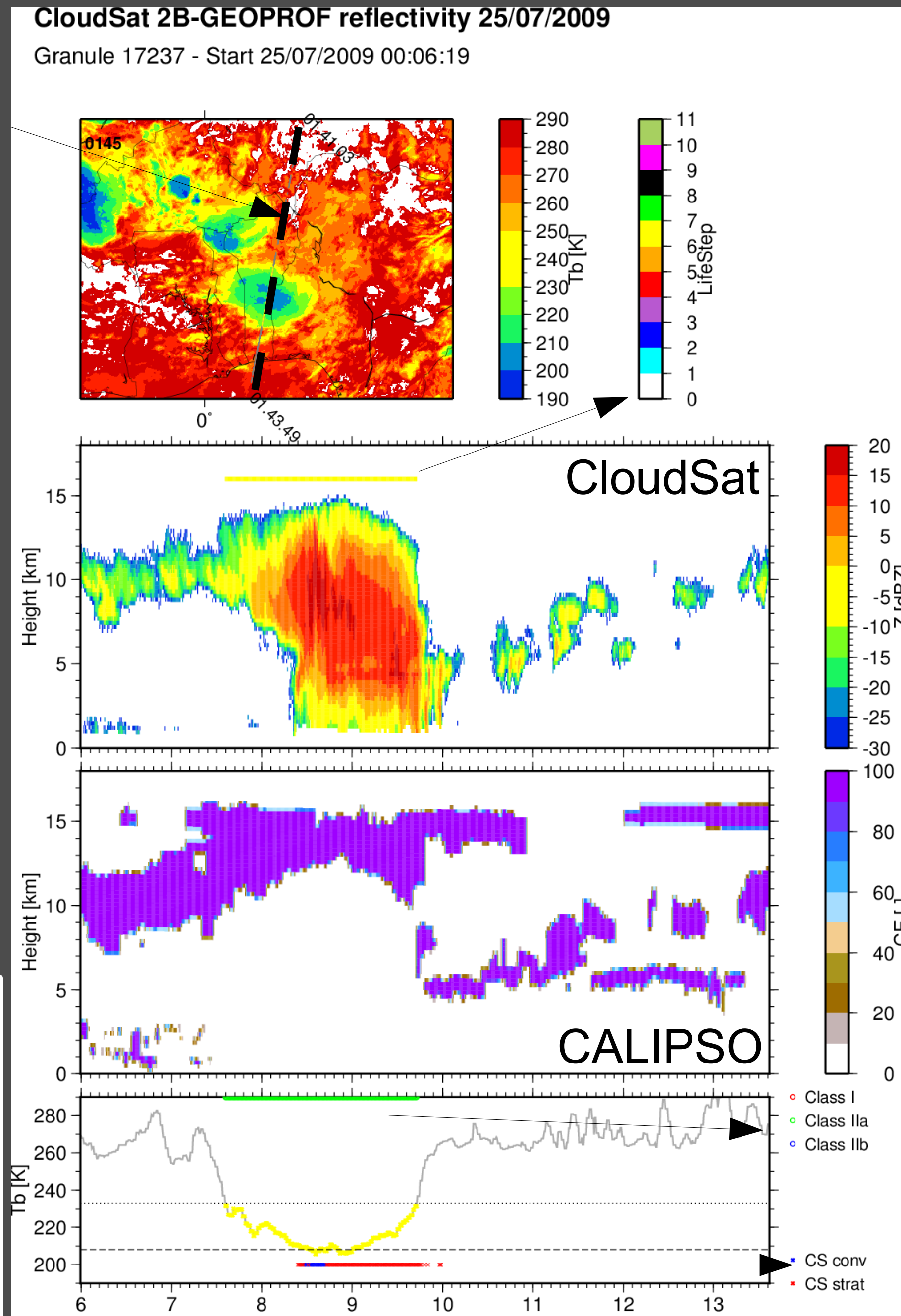
- How the associated radiative properties evolve along the life cycle ?
- Does it exists an internal variability related to MCS sub-regions (and how does it change in life cycle )?
- Are the radiative properties different from one geographical area to another (*i.e.* different environment) ?

**Need to document evolution within each MCS sub-region and within the life cycle**

# Composite along the MCS life : 10 life steps and 3 MCS sub-regions

Intersection of TOOCAN trajectories (Fiolleau et al 2013) with A-Train tracks

CloudSat track




Within TOOCAN, a MCS enveloppe is given by the 235 K level

TOOCAN + A-Train cross-points
- TOOCAN class (2a)
- TOOCAN Life Step
- CloudSat conv/strat flag (2C-PRECIP-COLUMN)

## Composited properties

Macrophysics
CloudSat + CALIPSO (2B-GEOPROF-LIDAR)

Microphysics
CloudSat (2B-GEOPROF)

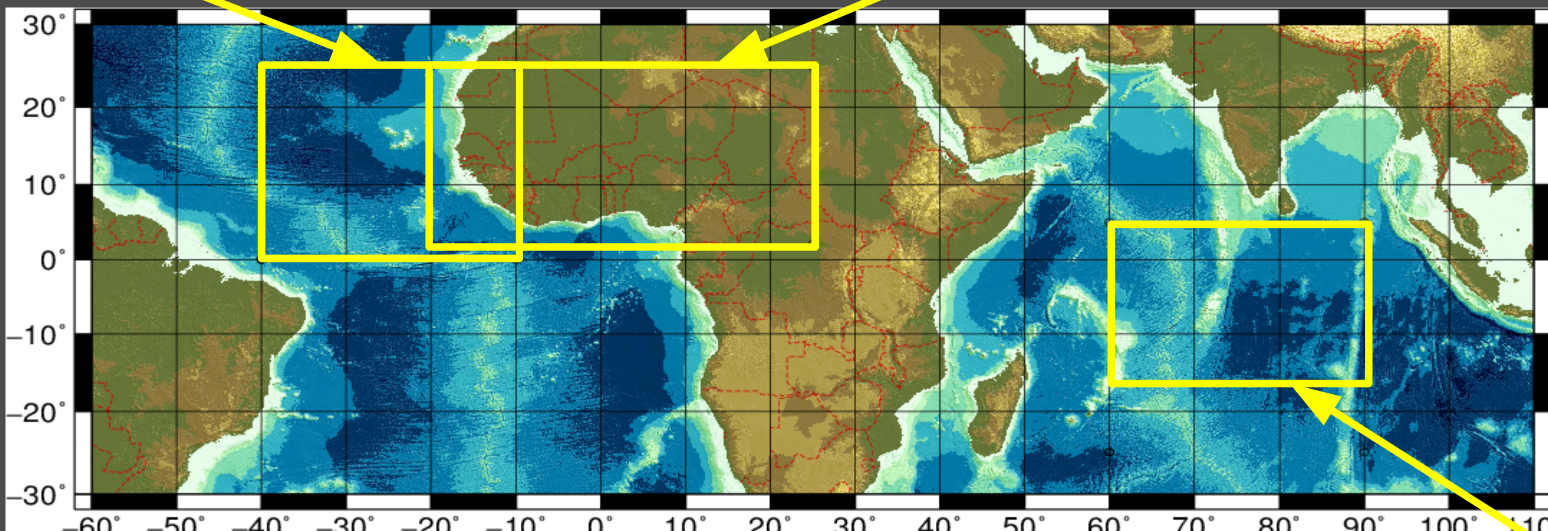
TOA/BOA radiative fluxes
CloudSat-CALIPSO (2B-FLXHR-LIDAR)
CERES-CloudSat-CALIPSO-MODIS (CERES-CCCM)

Radiative heating rate profile
CloudSat-CALIPSO (2B-FLXHR-LIDAR)

# Three constrasted tropical regions :

Atlantic ocean – ATL
Ocean only - summer
June to september
2006-2010

West Africa – AF
Land only - summer
June to september
2006-2010



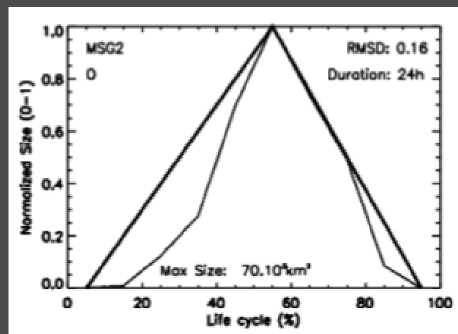

Open Indian Ocean – OIO
winter
November to February
2006-2011

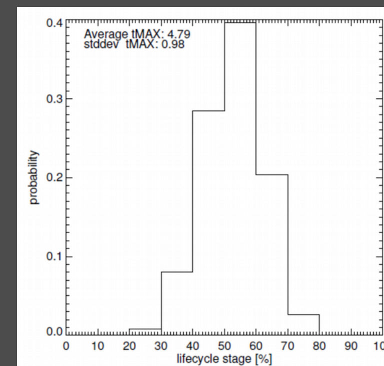
| | AF | | | ATL | | | OIO | | |
|---|---|---|---|---|---|---|---|---|---|
| | Conv | Strat | Cirri | Conv | Strat | Cirri | Conv | Strat | Cirri |
| 1 | 76/572 | 102/1259 | 127/2017 | **17/84** | 35/417 | 44/703 | 72/402 | 125/1989 | 180/2593 |
| 2 | 132/1166 | 168/3247 | 243/6938 | 66/582 | 108/2106 | 107/2336 | 144/974 | 243/4821 | 301/7836 |
| 3 | 165/2296 | 222/7460 | 259/10874 | 82/730 | 132/3296 | 141/3883 | 250/1754 | 412/12484 | 499/19373 |
| 4 | 140/1934 | 183/10329 | 233/12853 | 123/1163 | 177/7243 | 185/7093 | 320/2880 | 524/22113 | 641/24742 |
| 5 | 133/1756 | 173/12763 | 236/15156 | 99/847 | 156/7751 | 1828/8426 | 261/2009 | 507/21720 | 644/31906 |
| 6 | 100/1271 | 177/8537 | 244/15452 | 98/660 | 180/7411 | 223/9836 | 252/1670 | 546/24104 | 753/37457 |
| 7 | 85/627 | 167/9979 | 258/14361 | 85/609 | 159/6720 | 208/9236 | 179/1006 | 433/17818 | 655/33193 |
| 8 | 46/207 | 123/5492 | 213/9034 | 35/231 | 95/3508 | 150/4767 | 95/426 | 282/7979 | 499/20209 |
| 9 | 28/85 | 78/2395 | 159/5072 | **16/55** | 41/739 | 85/2311 | 33/72 | 118/1980 | 298/8833 |
| 10 | **3/8** | **15/165** | 37/433 | **0/0** | **3/21** | 21/235 | **4/6** | **19/197** | 86/1555 |

Some sub-regions at some life steps are not enough sampled because of their size

# Evolution of MCS sub-region surface :

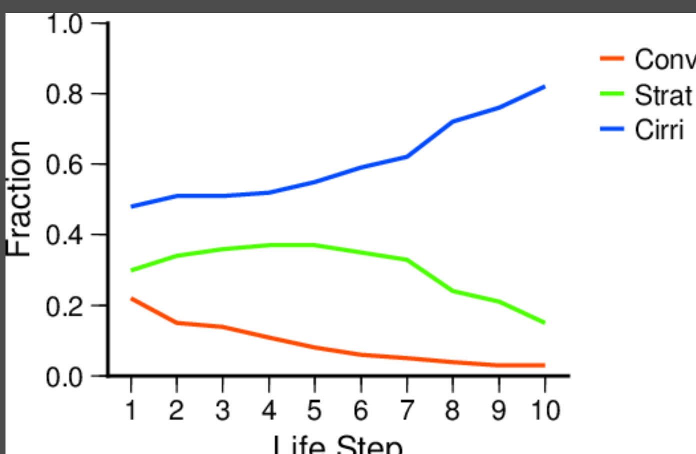
TOOCAN MCS trajectories and TRMM-PR tracks are sought :
- only 2a MCSs are kept (longer than 5 hours, one growth/decay of their cold surface)



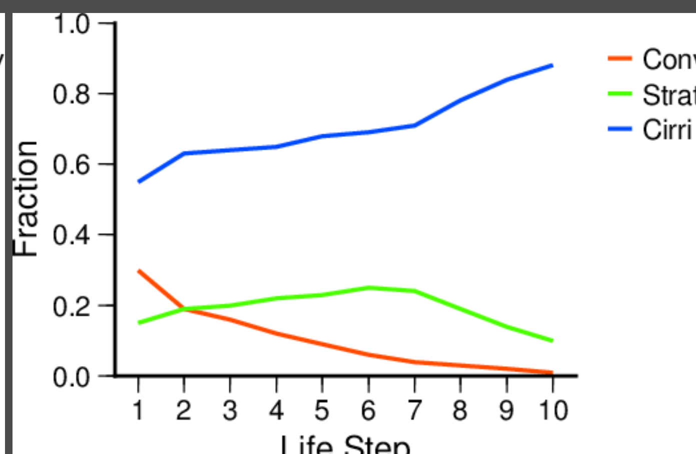




- at least 70 % of 235 K area of the sampled MCS must be in the TRMM-PR swath
- use of 2A25 convective/stratiform flag within the 235K area

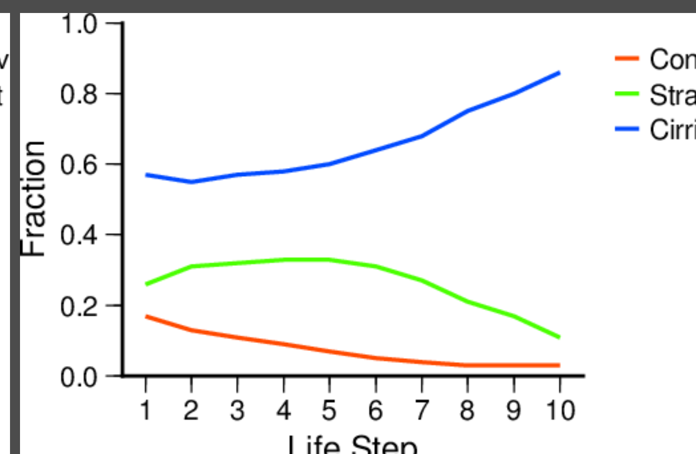
AF




ATL



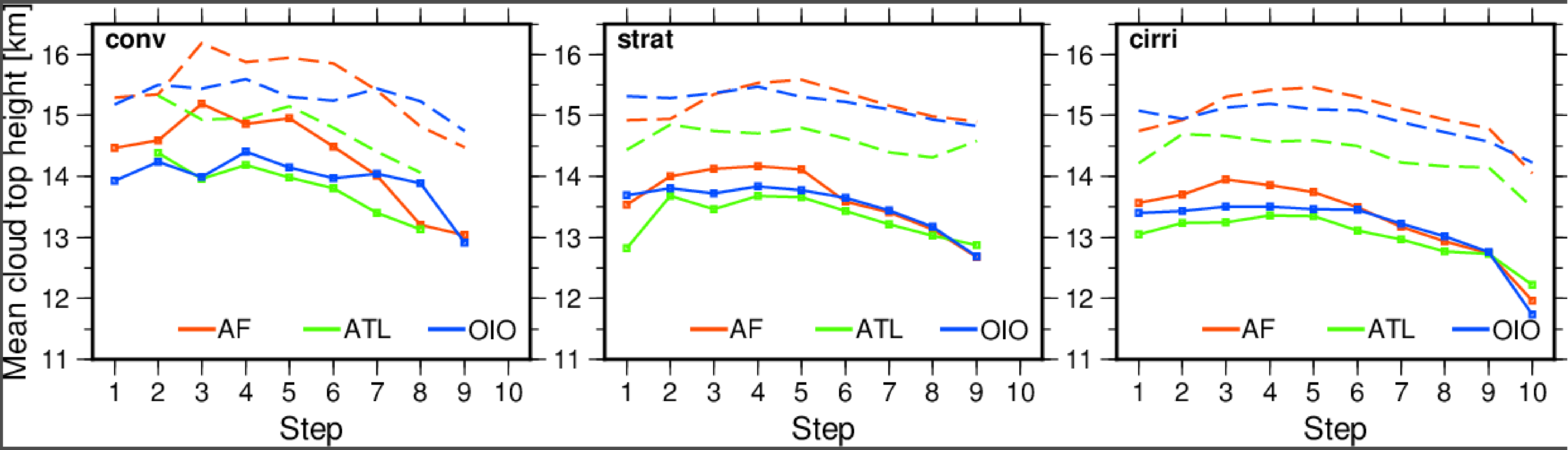

OIO




Cirriform region counts for more than half of the MCS area – only grews along the life cycle <=> the precipitating surface fraction is only decreasing.

# Differences in macrophysical properties :

Cloud top as as observed by CloudSat : ———— by CloudSat + CALIPSO : - - - - - - - -




Highest cloud top at the beginning of the life cycle for AF MCS (but rapid decrease after step 5) – Less pronounced life cycle for other regions

It exists a layer of thin particles at the top of the MCS – contribution to albedo (Jensen & DelGenio 2003)

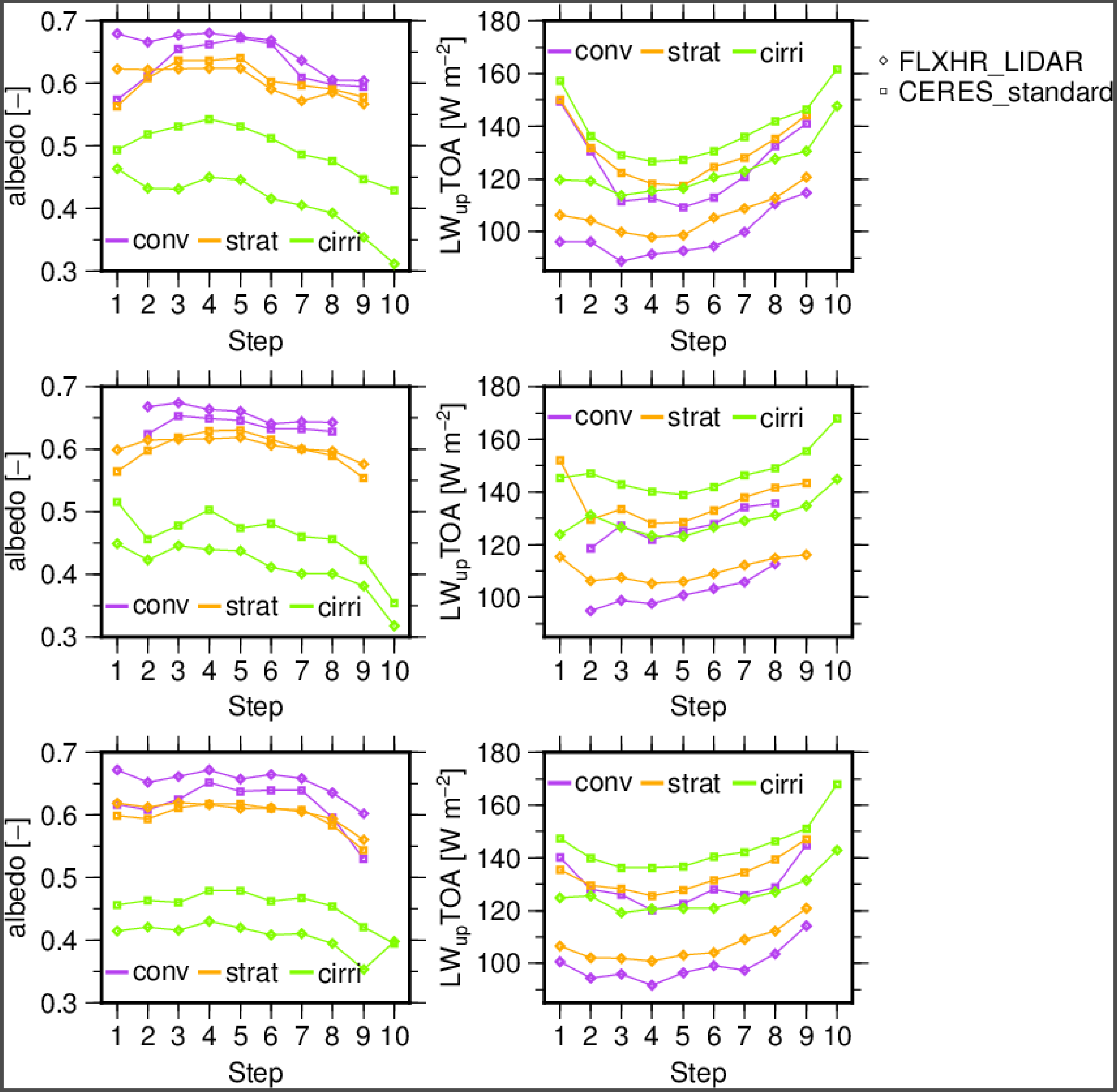
Decrease in cloud top faster for radar data than for lidar data => deepening of the small particles layer with the life cycle

# Evolution of radiative fluxes @ TOA :

AF

ATL

OIO




<u>albedo</u> : same order of magnitude (~0.6) for conv and strat different evolution according to geographical area : faster decrease in AF after step 5 (thinning of MCS anvil)

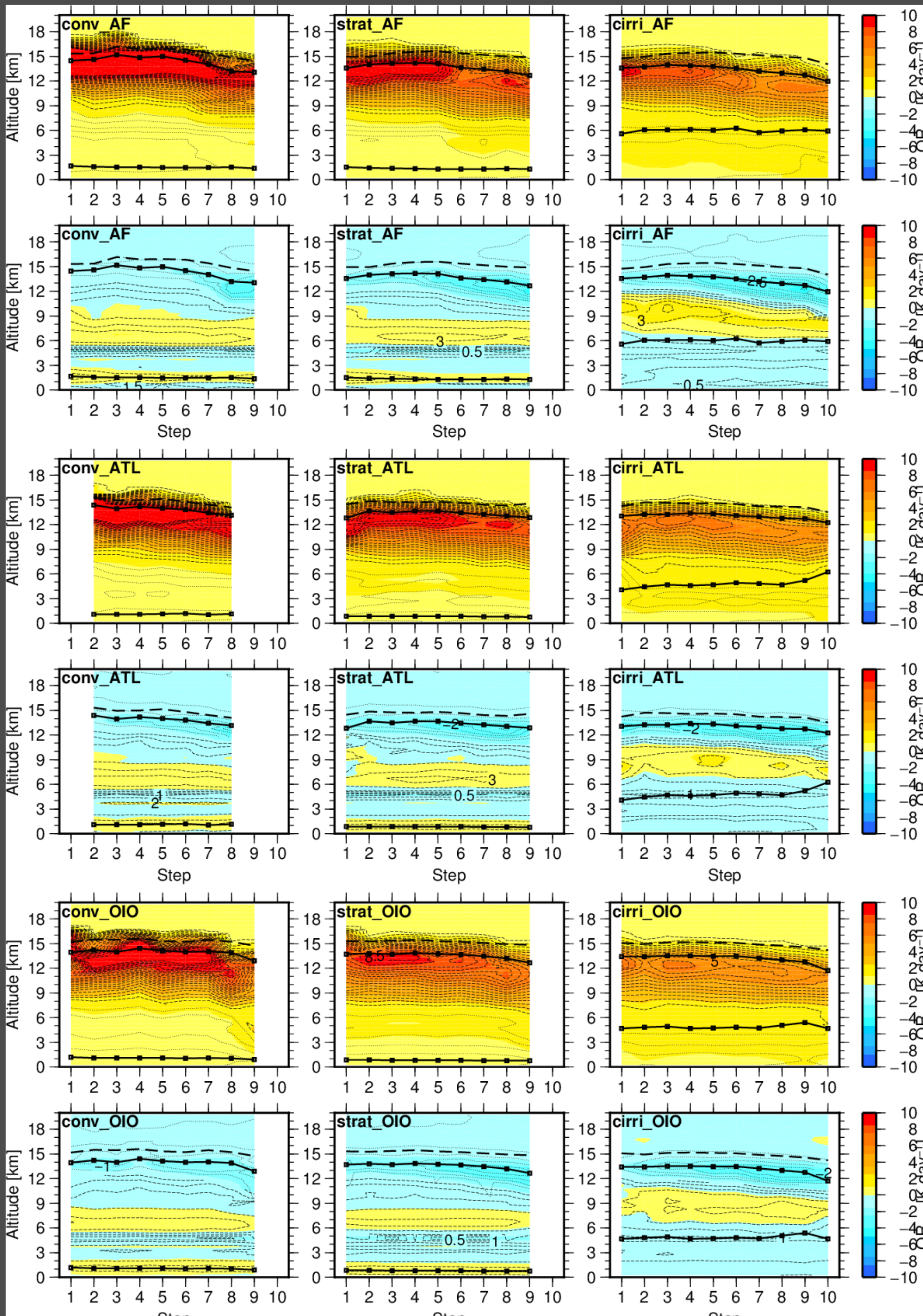
<u>OLR</u>: about 10 W m$^{-2}$ between the 3 sub-regions (larger values for cirri)
AF shows the more marked life cycle with a decrease up to step 4 (amplitude ~ 30 W m$^{-2}$ for AF / < 20 W m$^{-2}$ over ocean)
=> well correlated with radar cloud-top

# Evolution of the radiative heating profile :

AF

ATL

OIO



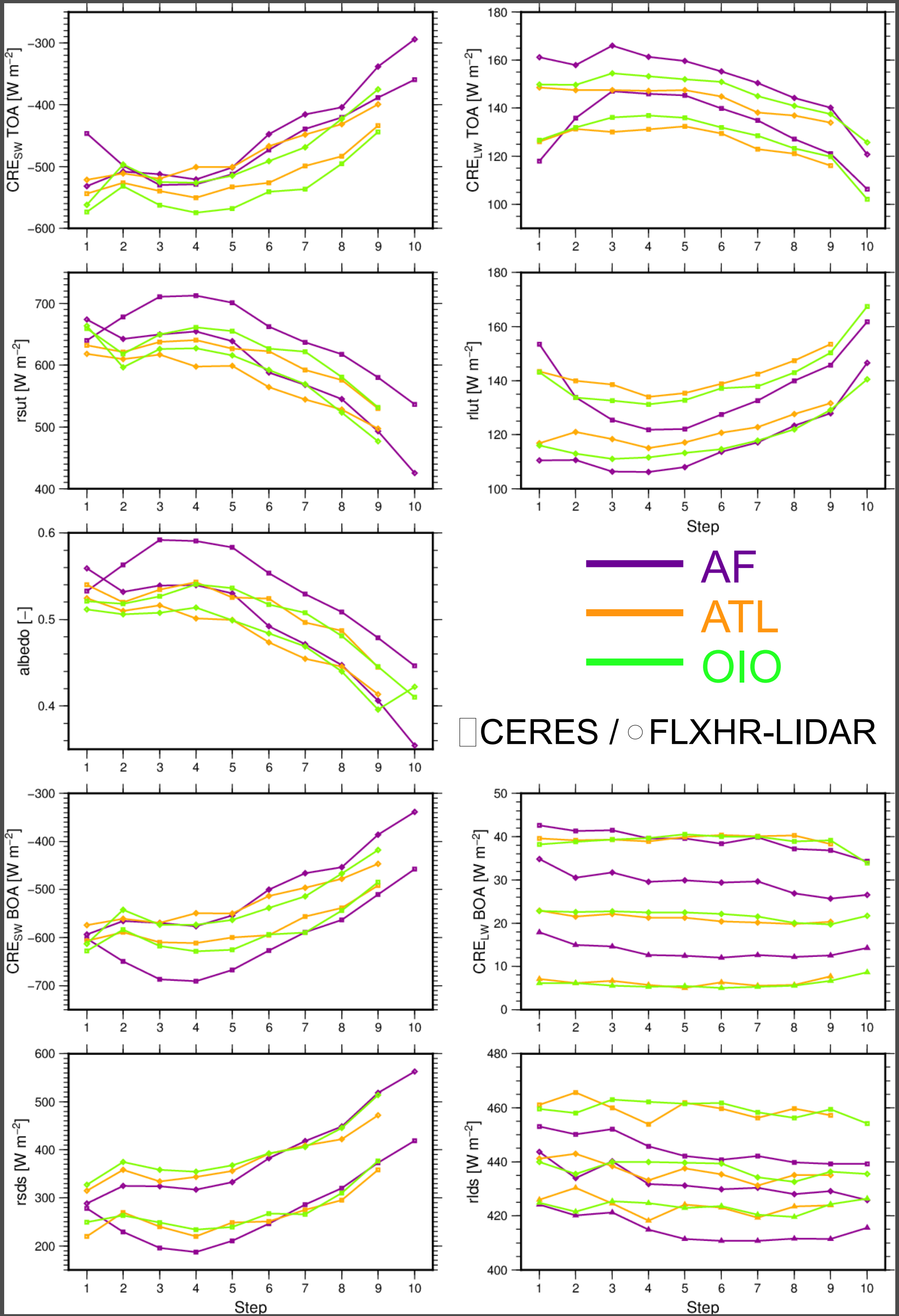

- - - - - - Cloud Radiative forcing > 0

· · · · Cloud Radiative forcing < 0

<u>SW</u>: strong heating below radar cloud top (forcing > 10 K day$^{-1}$) with decreased magnitude with life step

<u>LW</u>: cooling near cloud top / heating in the lower part of the anvil => fuel the internal anvil circulation

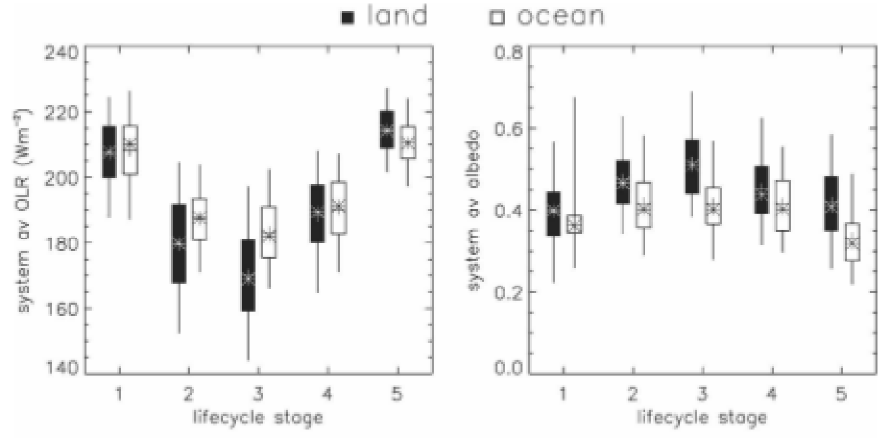
# Evolution of the radiative properties at the scale of the MCS :




Recombination of the former composites (parameter Q) weighted by MCS sub-region surface fraction (f) evolution

$$\langle Q(i) \rangle = \sum_{j=1}^{3} f_j(i) Q_j(i)$$

Can be compared to Futyan and Del Genio (2007)




- The size of the cirriform region (more than half of the 235K area) makes the system dominated by the radiative properties of this sub-region.
- Smaller/larger values for OLR/albedo compared to F&DG because of the 235K but similar amplitude, more amplitude for AF / ATL or OIO, not symetric evolution

# Future work - some directions :

- A composite approach has been implemented in order to document the physical processes along the MCS life cycle. The contribution of each MCS sub-regions with respect to the total impact of the MCS can be quantified – can help for evaluation/development of model parameterization.
- Complete the documentation of radiative heating evolution along the life cycle with the latent heating (ongoing work – see poster in session 2.3 @ GEWEX conference)
- What is the impact of the diurnal cycle (especially for continental MCS) ?
- What is the importance of the life cycle for the radiative budget at a regional scale ?