Metrics of organization

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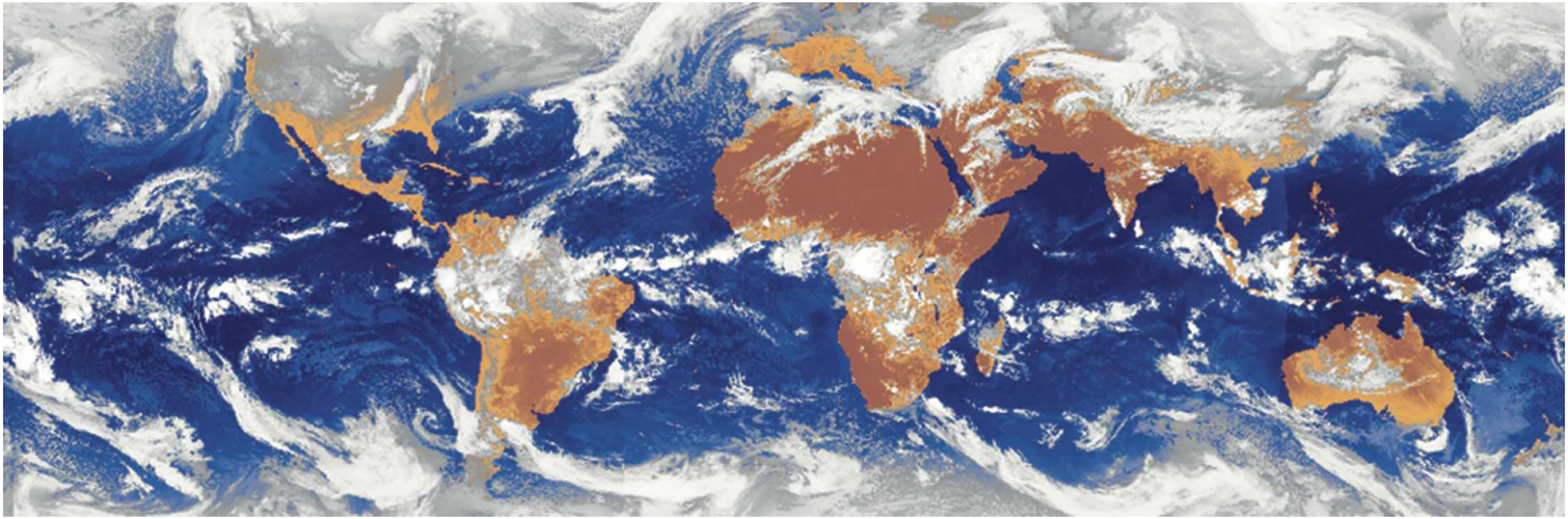
Organization of Deep Convection

- Occurs over a wide range of spatial and temporal scales.
- Is associated to regional increase in tropical precipitation
- Responsible for much of the rainfall and cloudiness over the tropics
- Suggested as a potential regulator of climate



Understanding of the mechanisms that lead to organization will pave the way to the inclusion of the effects of self-organization in **parameterizations of convection** in global circulation models

Diagnostics for organization

Organization metrics are used:

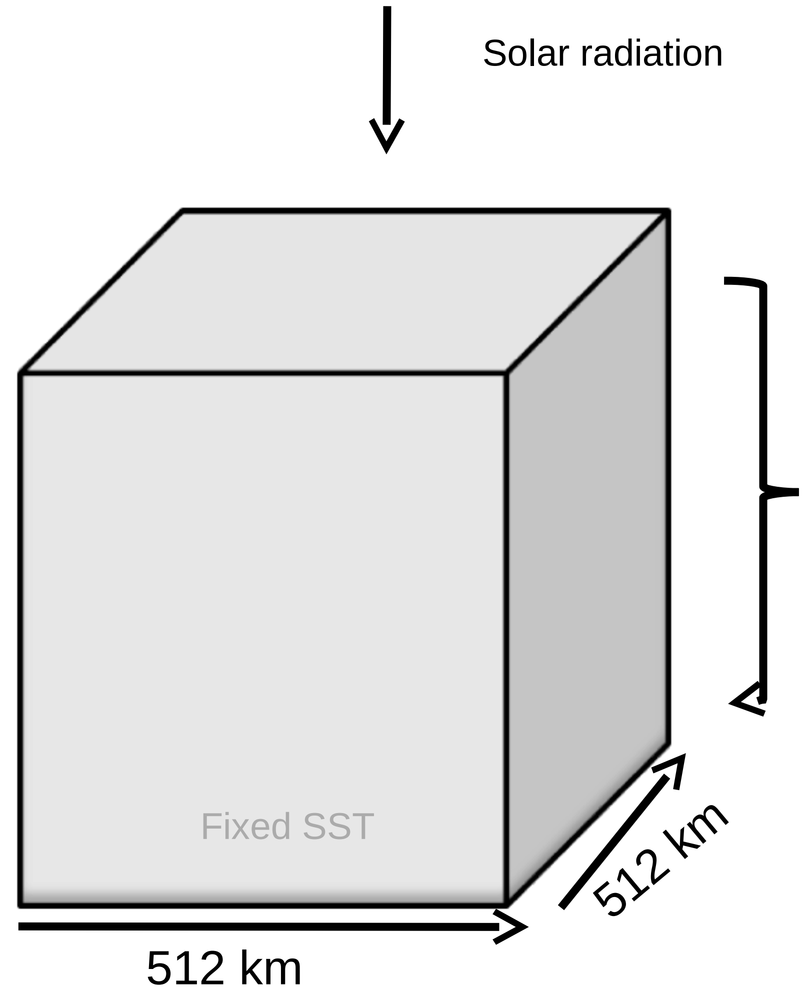
- Study and compare various mechanisms that dictates aggregation of convection in the models.
- Study relationships among convective organization, sea surface temperatures and other environmental conditions both in models and observations.

Outlines

- Identifying level of aggregation from model outputs such as:
  - Outgoing long-wave radiation (OLR), total column water vapor (TCWV) and vertical profile of relative humidity (RH)
- Some of the metrics used to measure degree of aggregation:
  - Subsidence fraction (SF), number of convective clusters (N), simple convective aggregation index (SCAI), organization index I_{org}
- Application of the metrics to:
  - CRM outputs
  - Observational data sets

RCE is a good starting point for understanding mechanisms of convective aggregation….

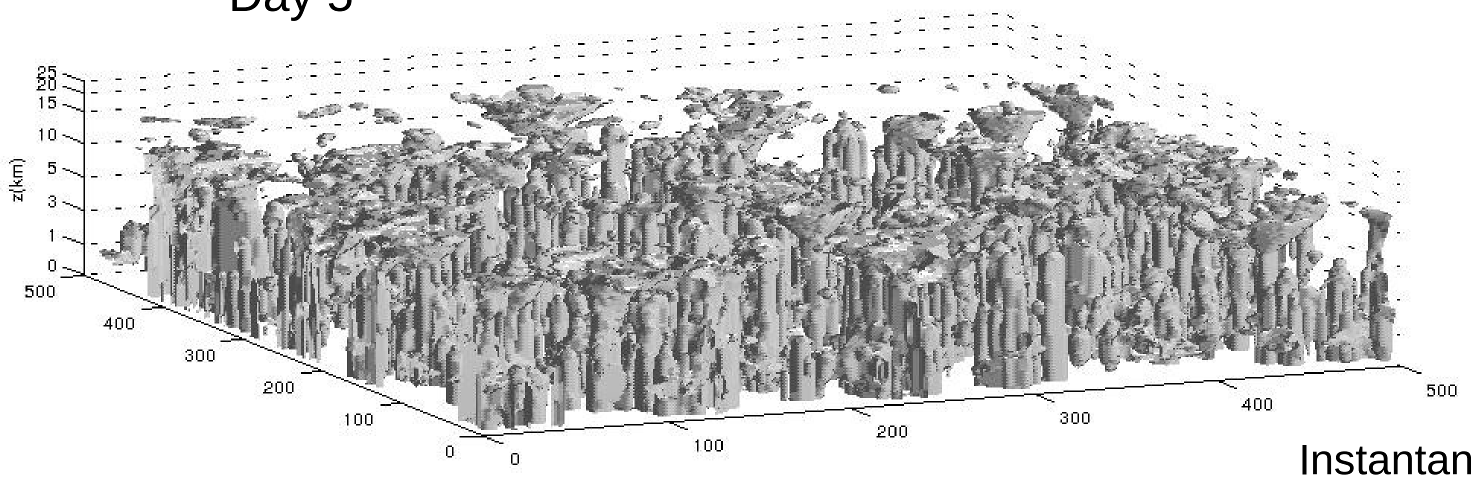
- Cloud resolution model (CRM) – WRF v3.5.1
- Horizontal resolution: 2km
- Vertical resolution 61 levels
- Interactive surface fluxes and radiation schemes
- Fixed SST of 301.5K
- Periodic lateral conditions
- 70 days



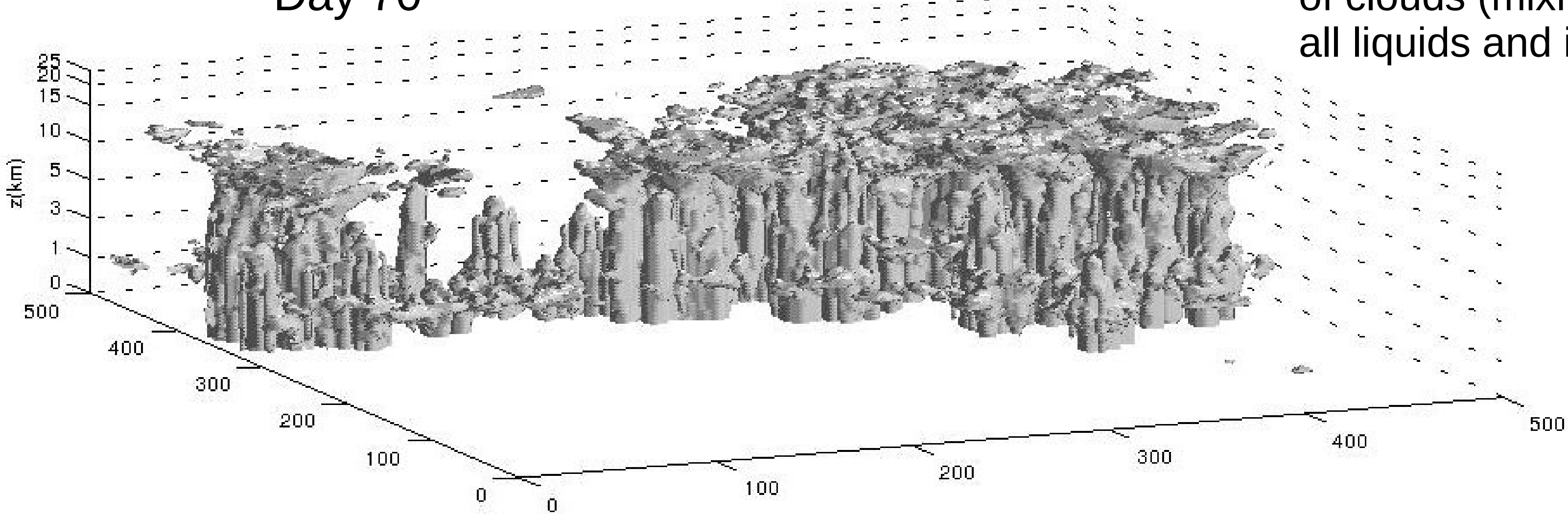
Spontaneous organization of Deep Convection

- **Under certain circumstances, convection aggregates into a single band/clump rather than being distributed randomly**

Day 5

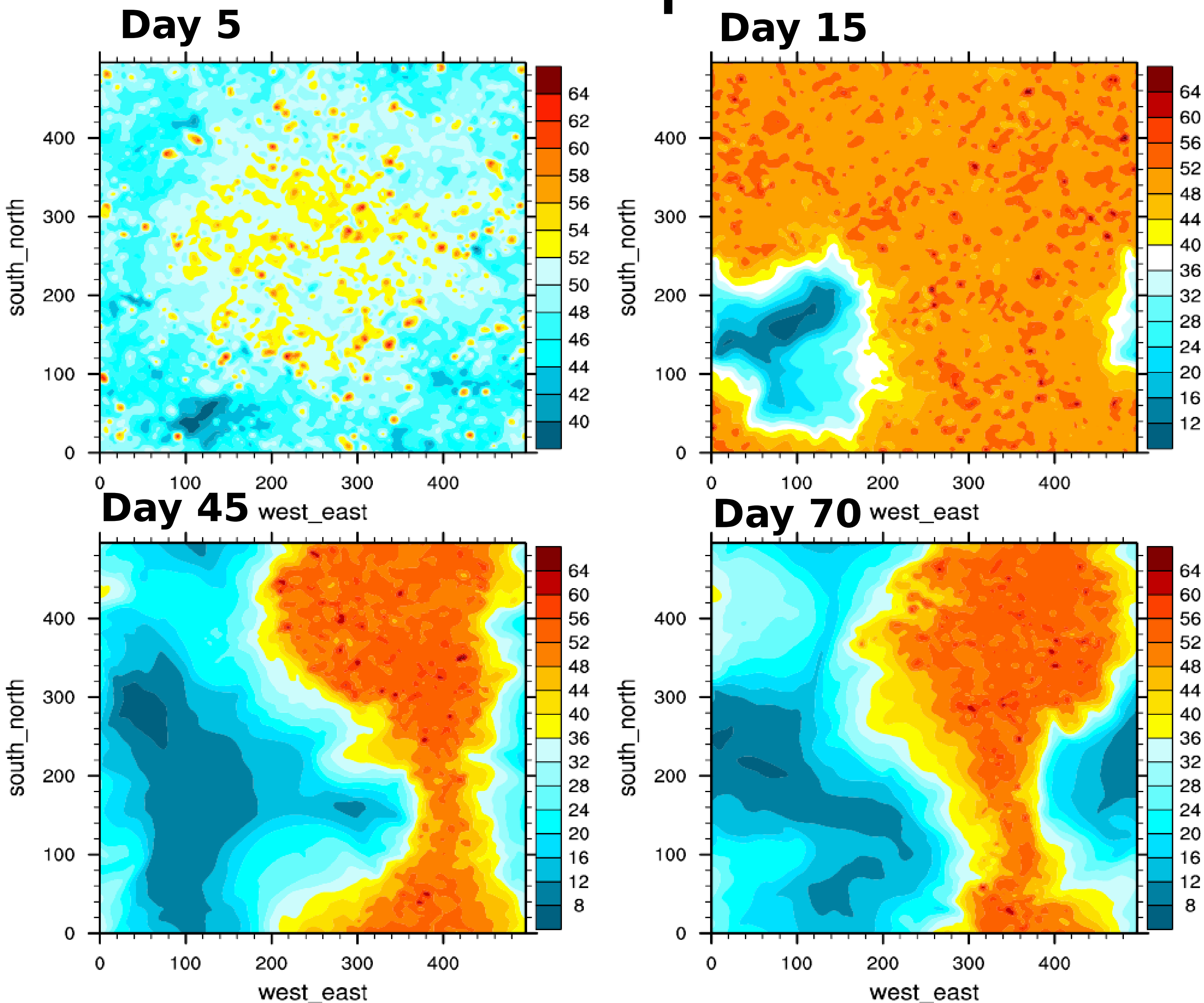


Day 70

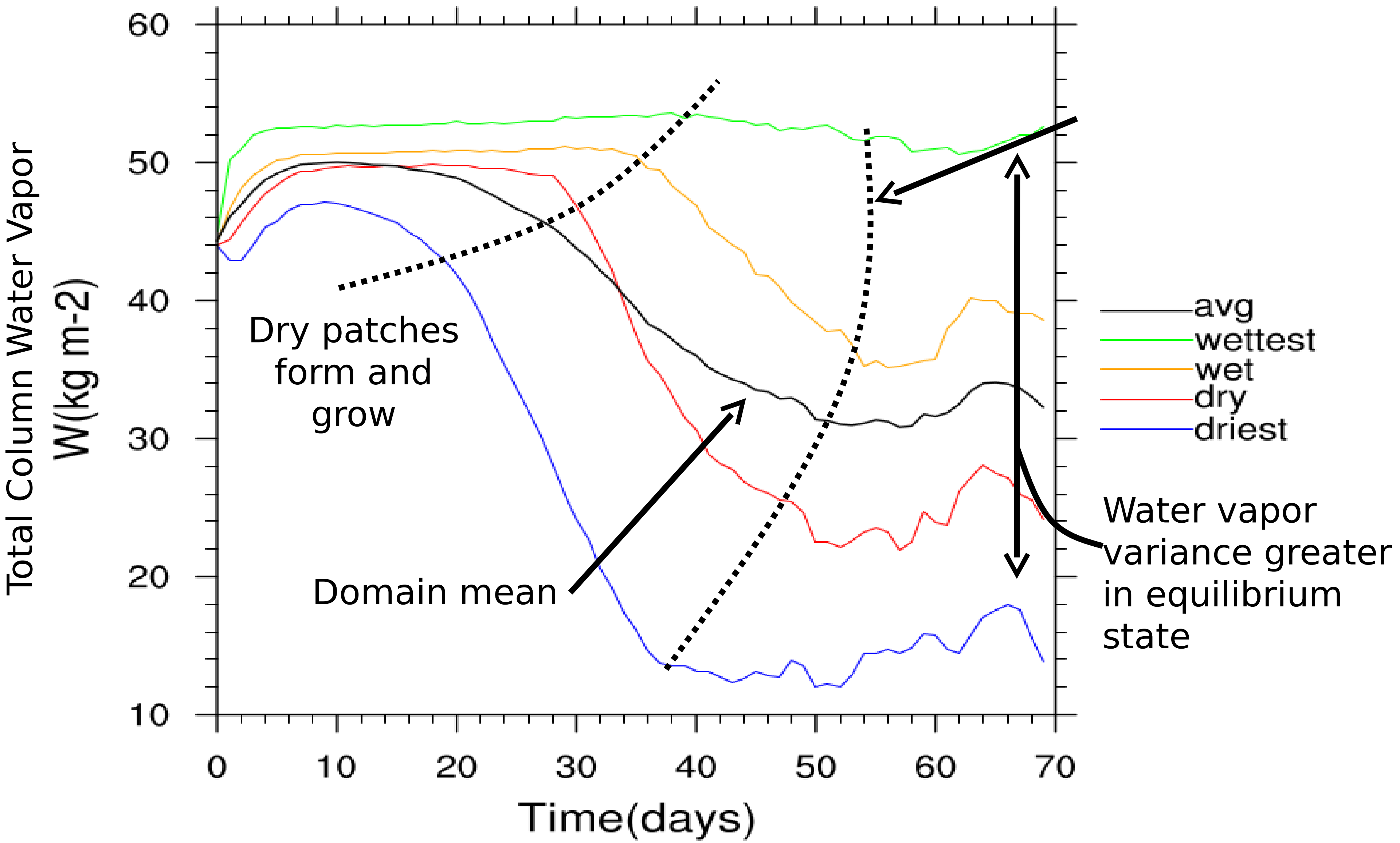


Instantaneous snapshot of clouds (mixing ratio of all liquids and ice)

Evolution of the total column water vapor

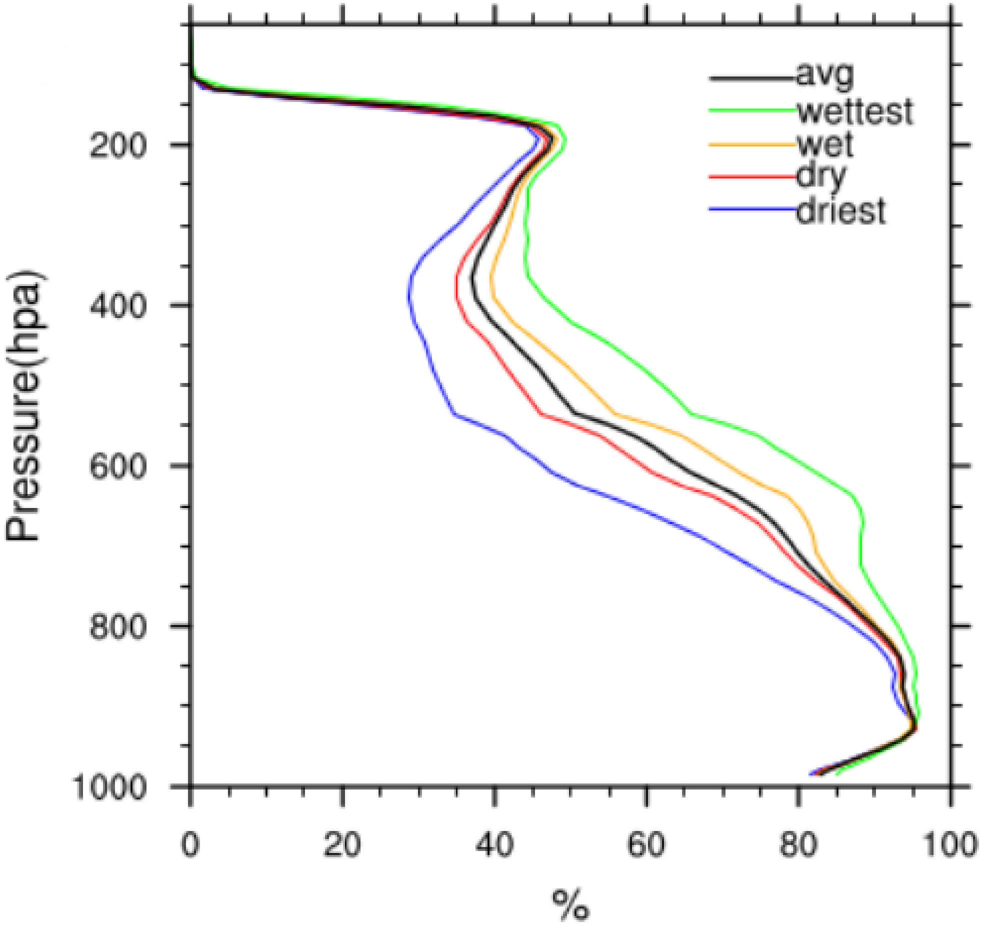


Evolution of the total column water vapor

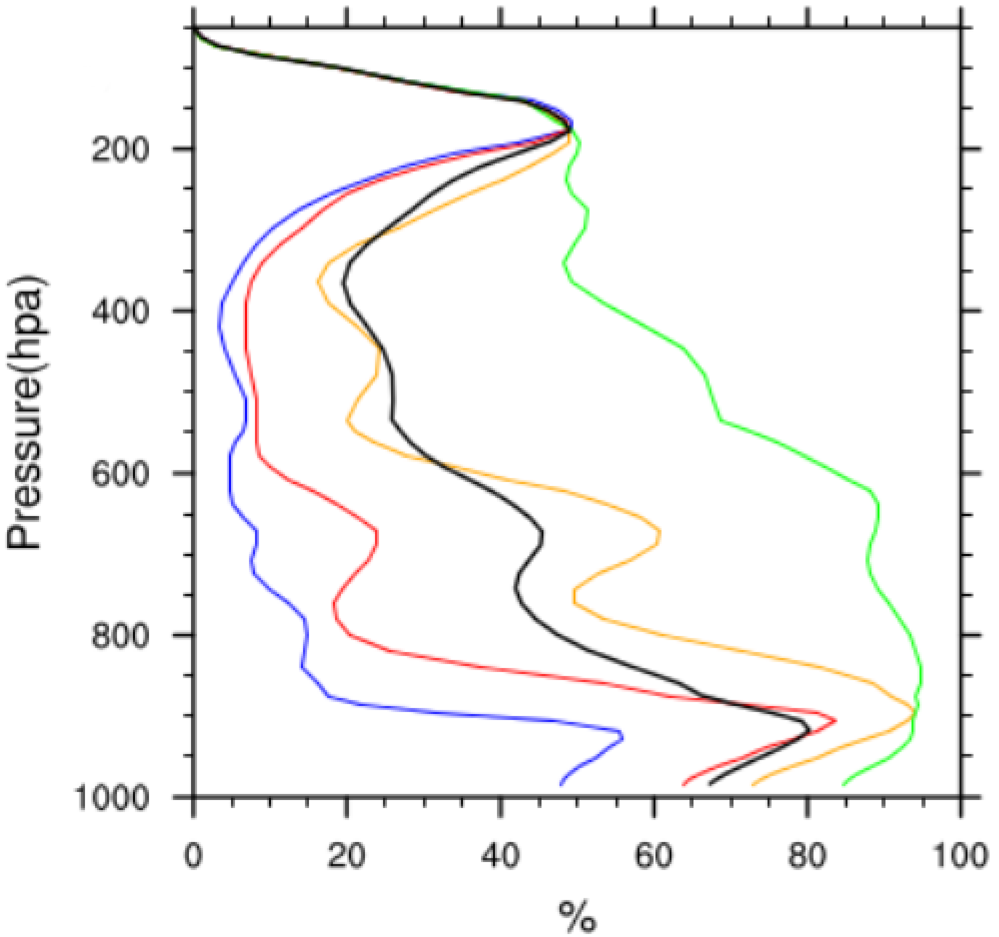


Vertical profile of RH

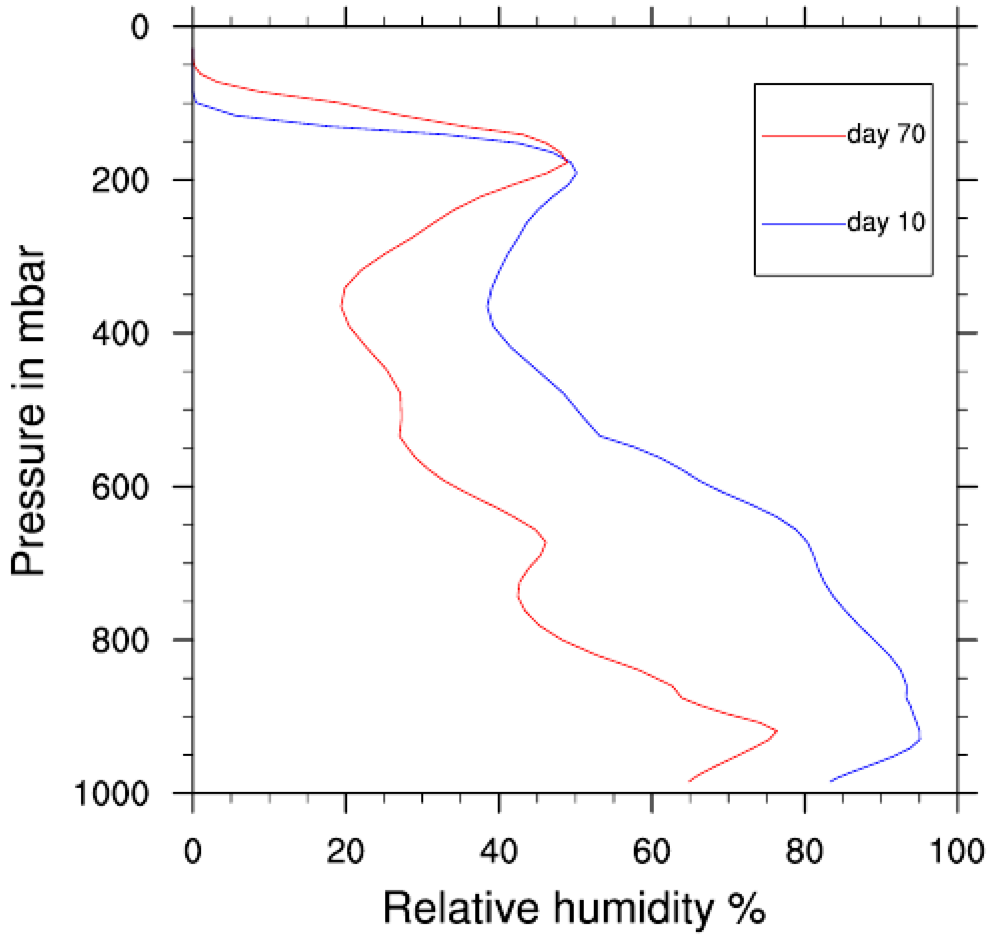
Day 5-9



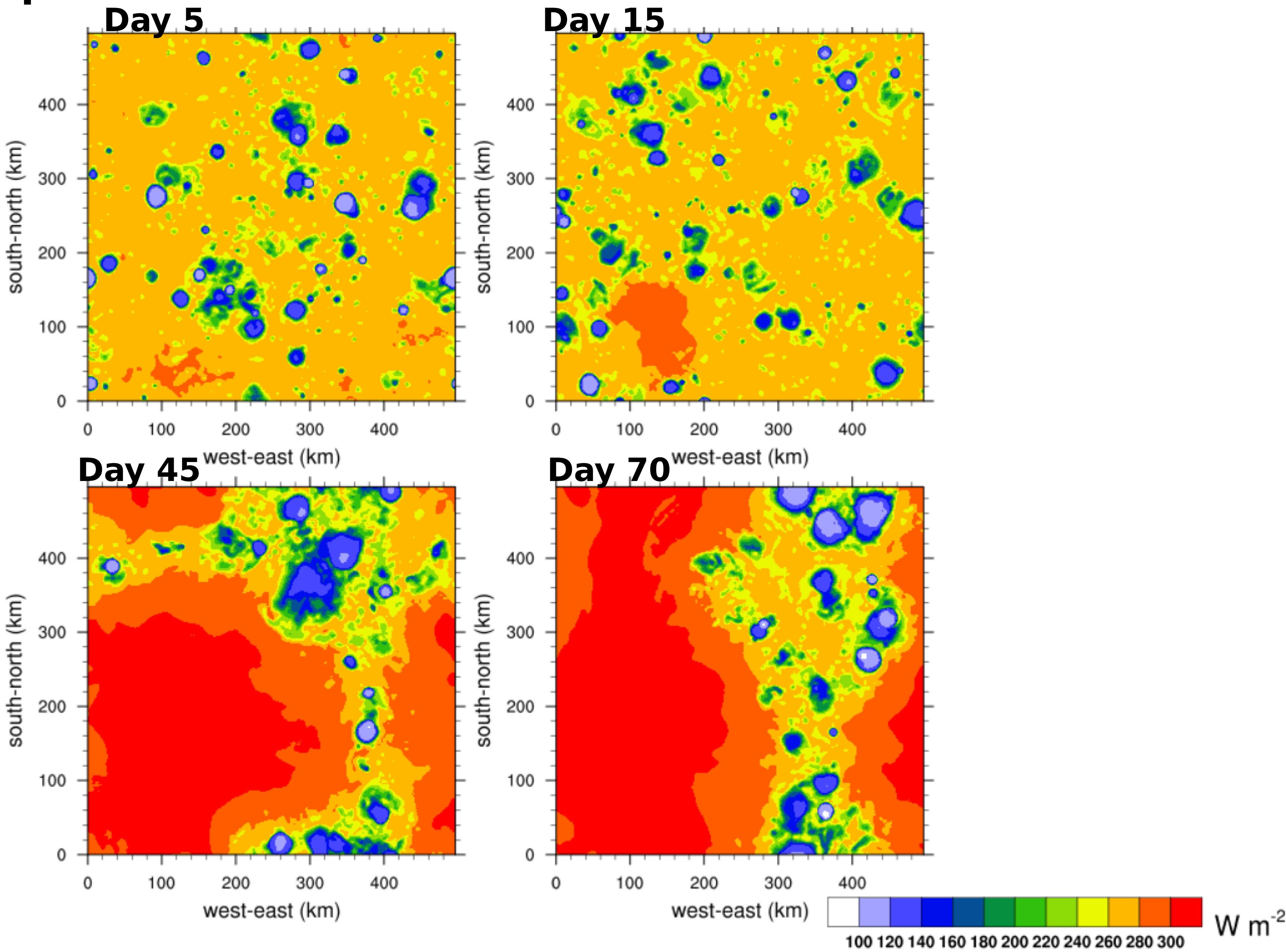
Day 65-69



Domain average vertical RH profile

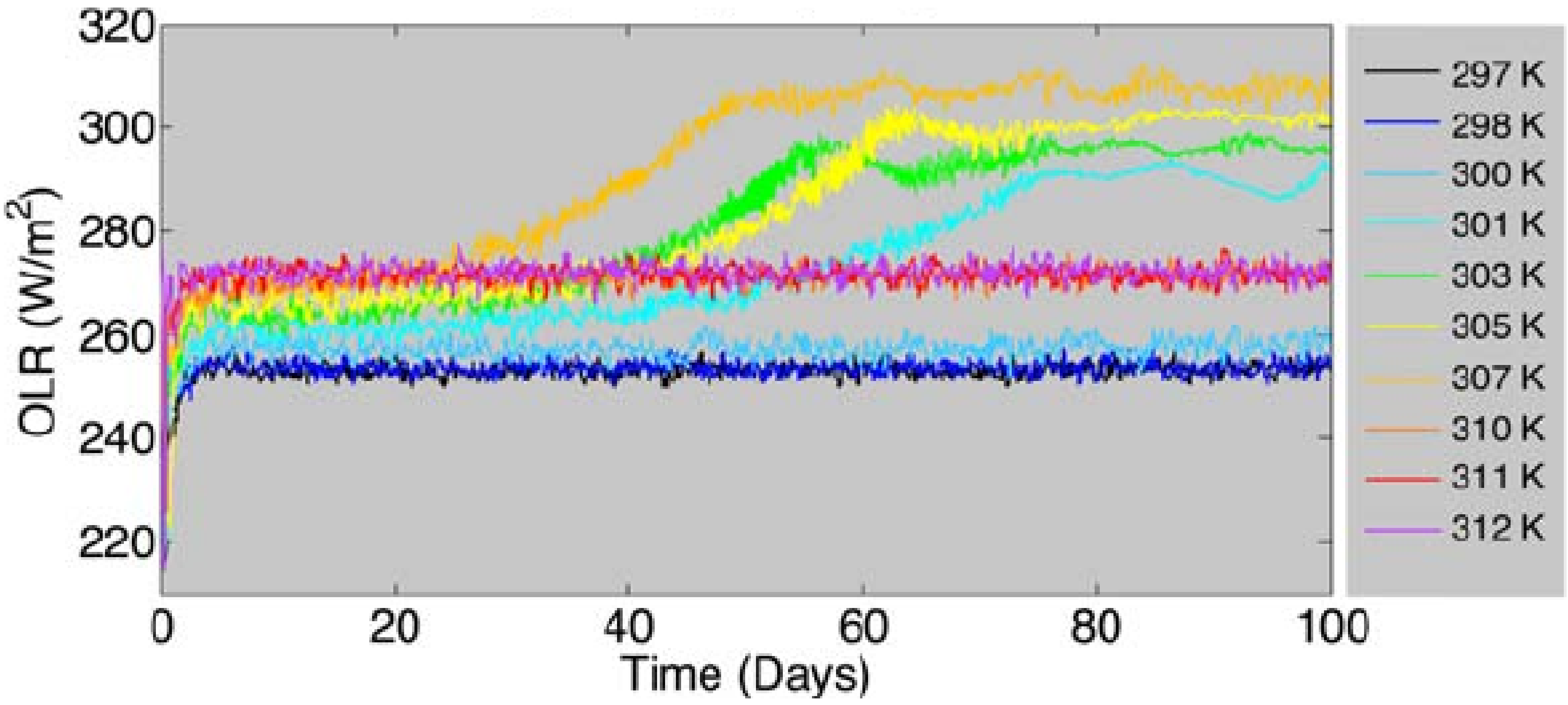


Spatial distribution of OLR



Evolution of domain average OLR

Used to compare simulations (e.g different fixed SST)



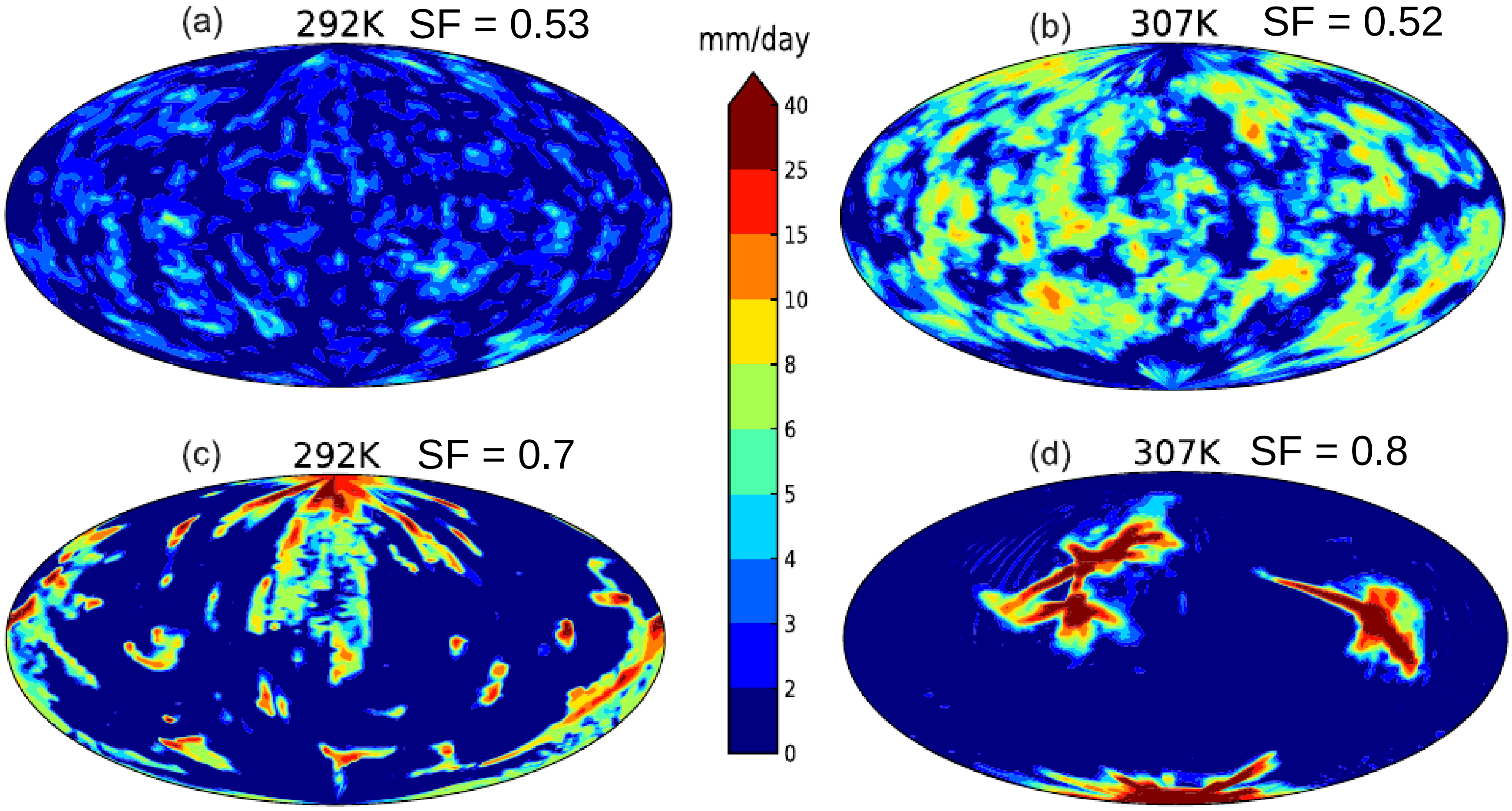
Wing and Emanuel 2014

Identifying level of aggregation from model outputs:

- Provides qualitative information about the degree of organization
- Have difficulty in providing a precise value regarding degree of organization. Since the field values are dictated by model configuration

Subsidence fraction, SF

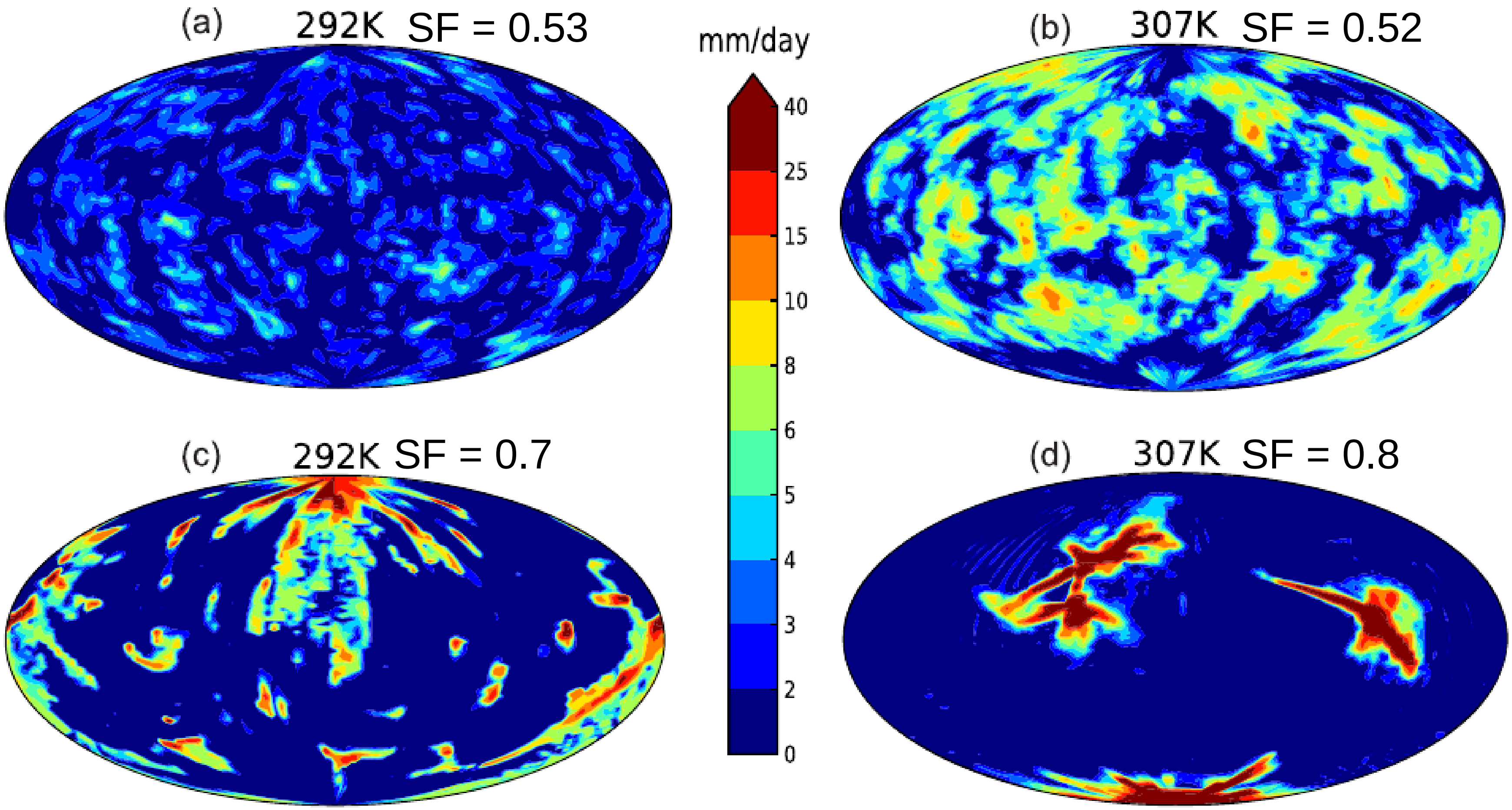
- Fractional area of large-scale subsidence in the mid-troposphere (W < 0 at 500 hPa)
- Large values of SF imply a greater degree of aggregation



Coppin and Bony 2015

Subsidence fraction, SF

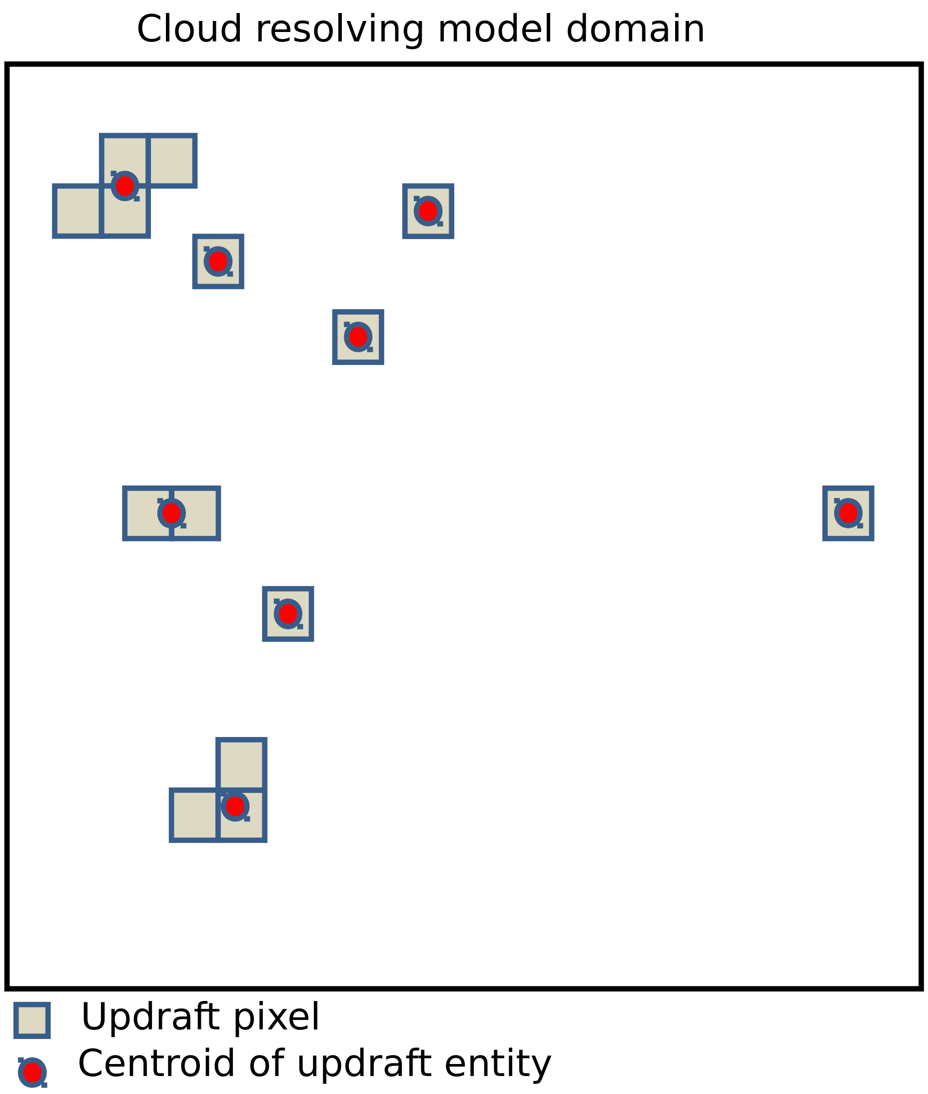
- Measures strength of a large scale overturning circulation
- Specially useful for GCMs with coarse resolution



But organization of convection takes place at multiple scales….

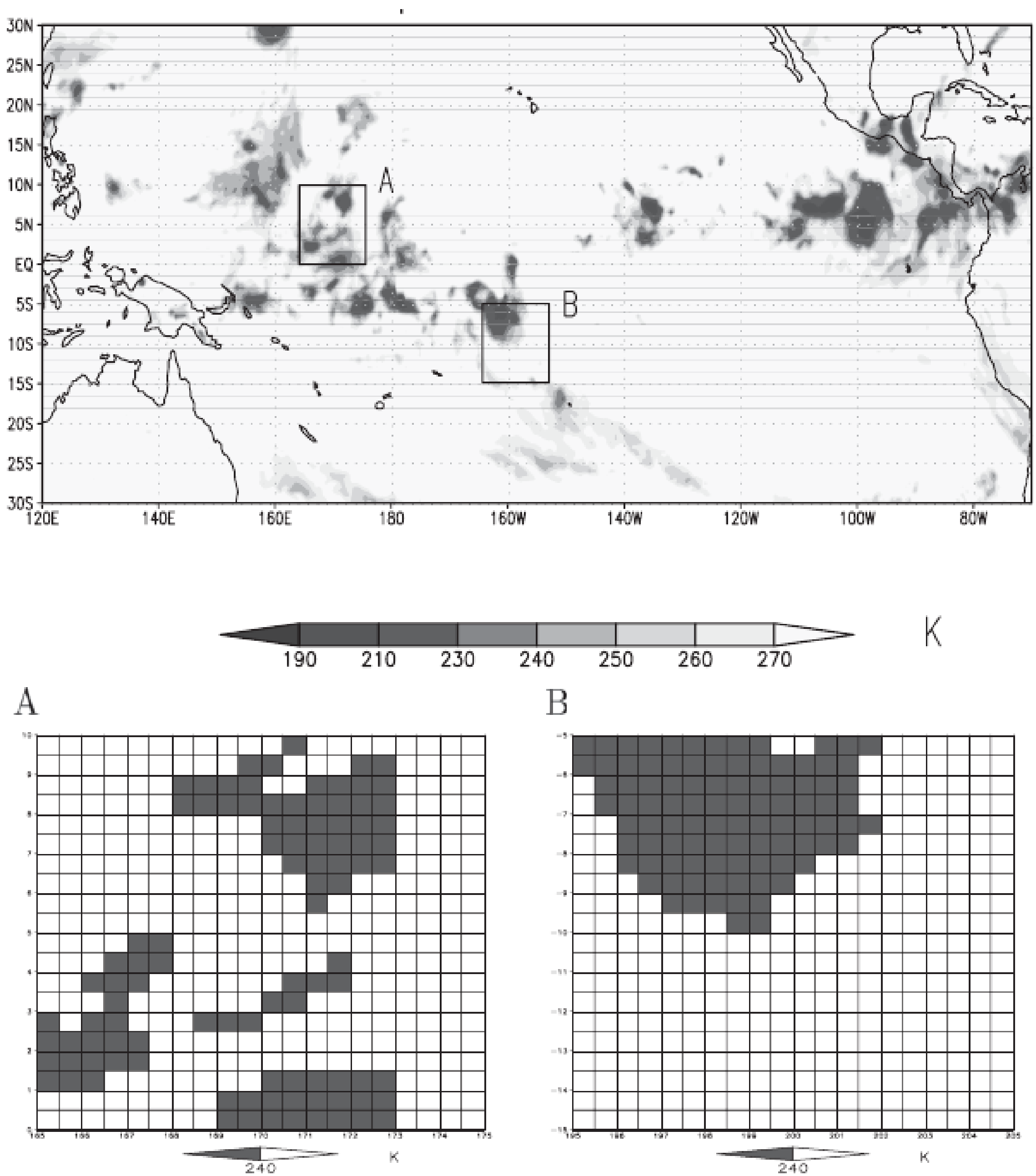
Coppin and Bony 2015

Number of convective clusters - N



1. Define criterion for convective “entity”: $w > 1 ms^{-1}$
2. Algorithm of clustering are applied to identify convective zones
3. Two pixels belong to the same cluster only if they share a common side
4. Calculate centroid of each entity

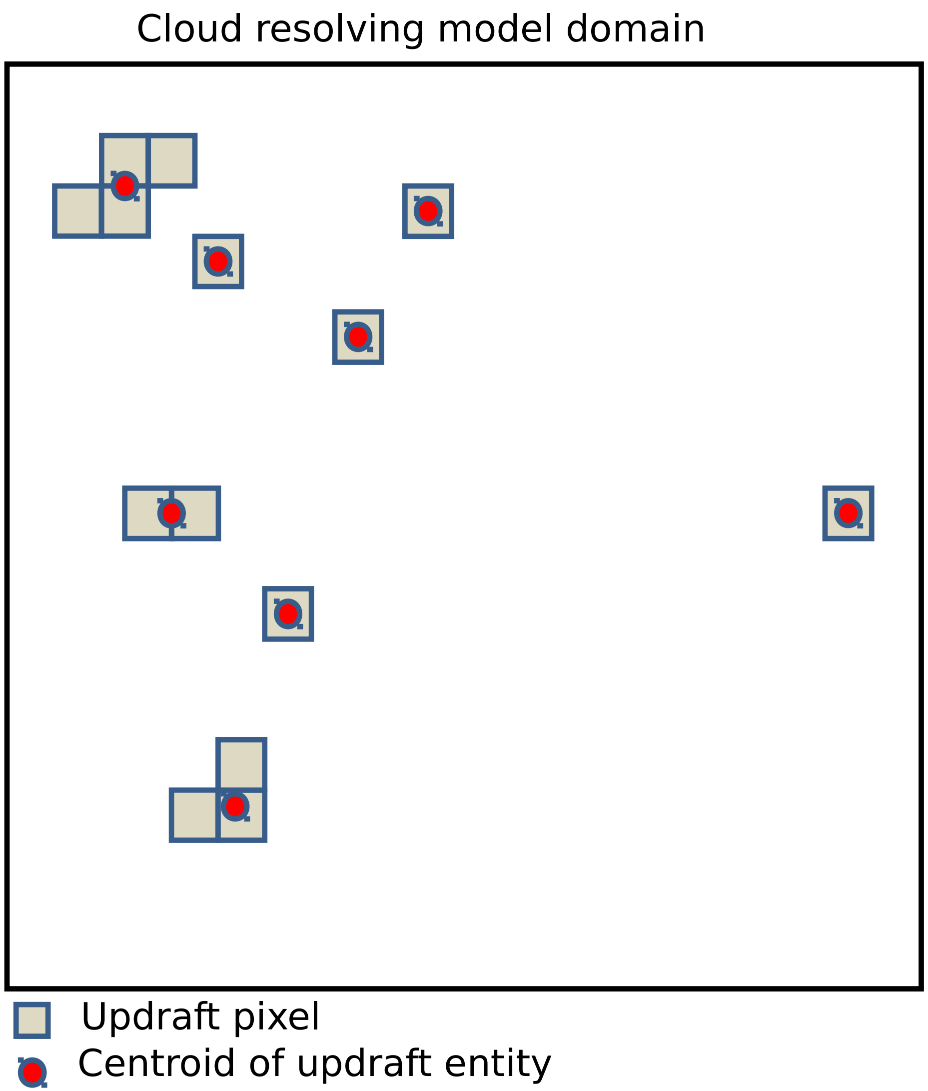
Number of convective clusters - N



1. Define criterion for convective “entity”: Tb < 240 K
2. Algorithm of clustering are applied to identify convective zones
3. Two pixels belong to the same cluster only if they share a common side
4. Calculate centroid of each entity

Snapshot of Tb from CLAUS data, Tobin et. al 2012

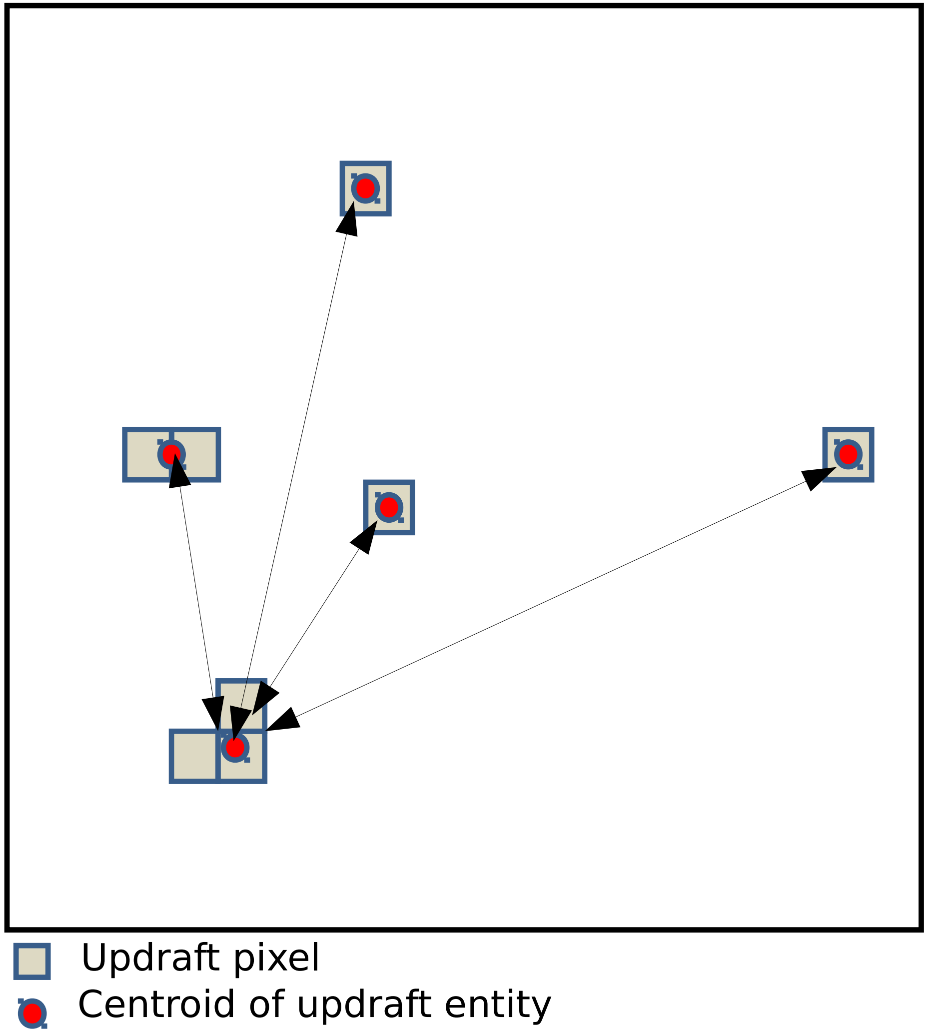
Number of convective clusters - N



1. Smaller N indicates strong organization
2. N depends on:
   - domain size
   - spatial resolution
   - threshold value

DO and D1

Cloud resolving model domain



Once the centroid of the clusters are identified we can calculate:

1. Geometric mean distance

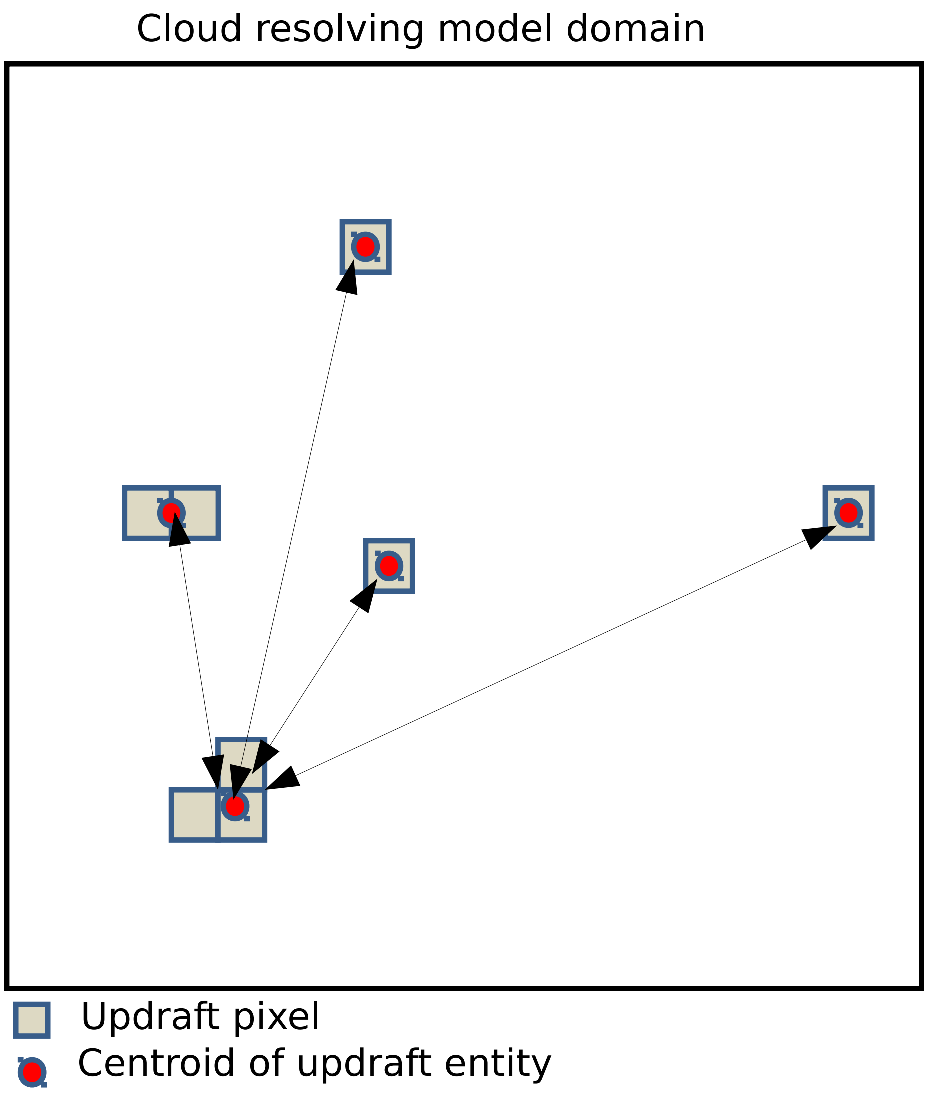
$$D_0 = \sqrt[n]{\prod_{i=1}^{n} d_i}$$

2. Arithmetic mean distance

$$D_1 = (1/n)\left(\sum_{i=1}^{n} d_i\right)$$

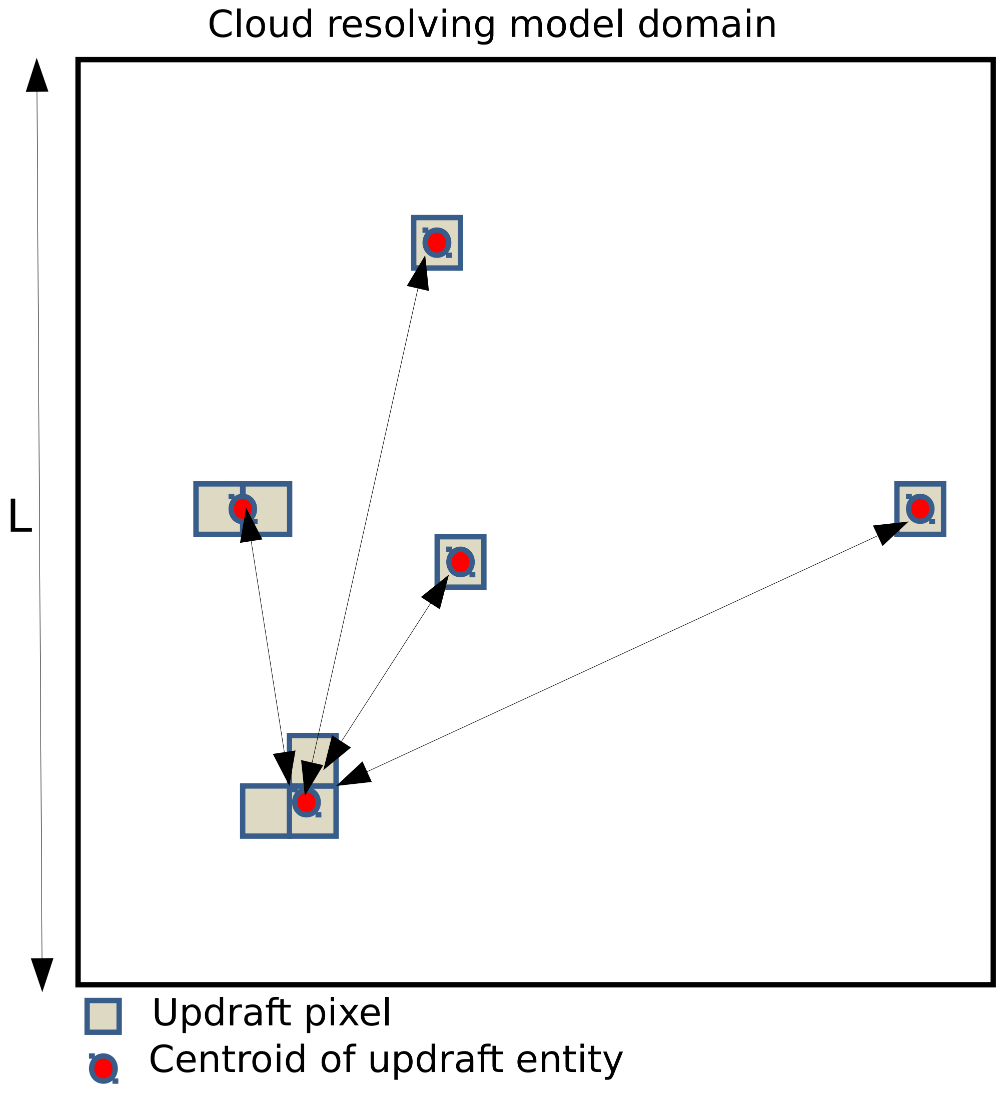
Where n is the number of pairs of clusters
n = N(N-1)/2
and d_i is distances between pairs

DO and D1



1. Smaller D0/D1 indicates strong organization
2. N depends on:
   - domain size
   - spatial resolution
   - N

SCAI



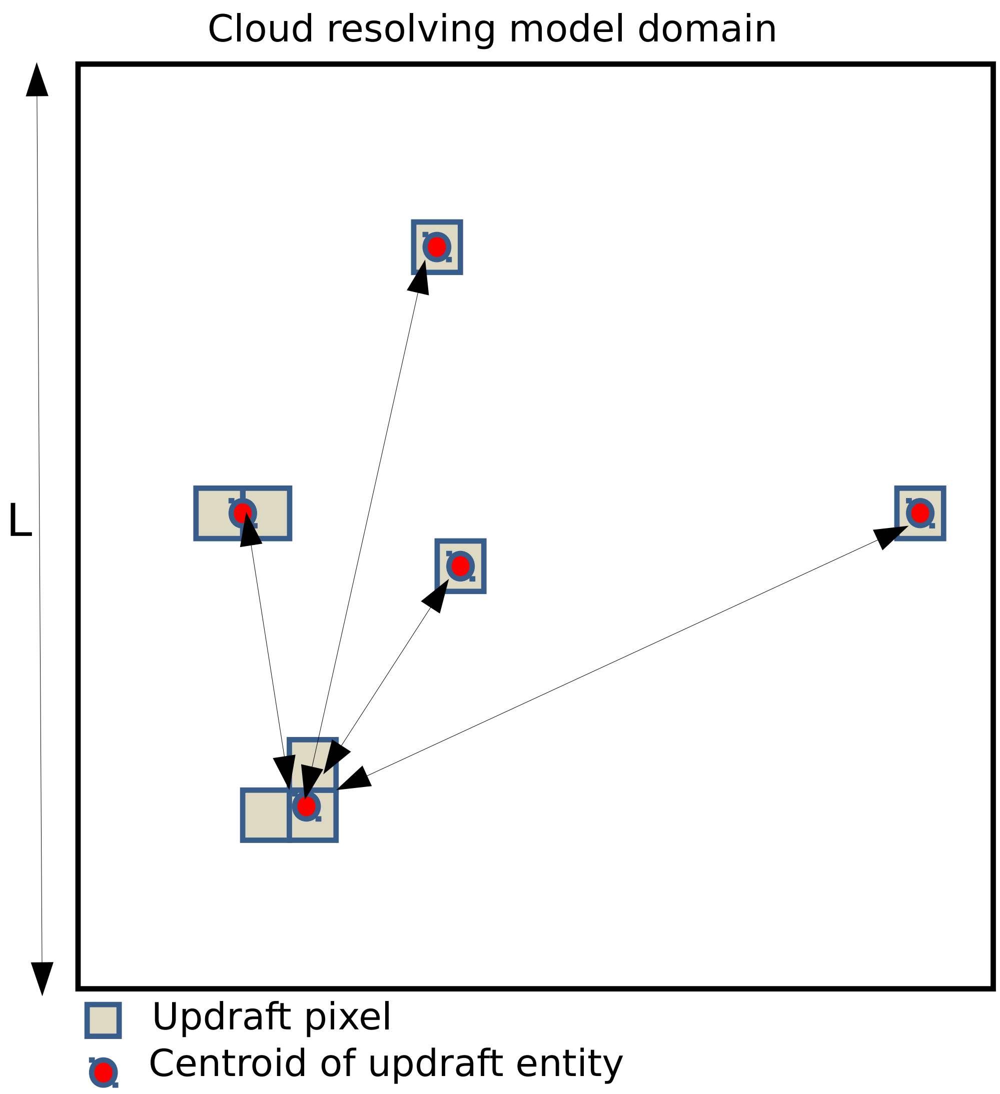
SCAI (simple convective aggregation index) – is the product of normalized D0 and N

$$SCAI = N/N_{max} * D0/L * 1000$$

- N_{max} – maximum number of objects in the domain (half of total number of pixels)
- L – the length scale of the domain

Tobin et al 2012

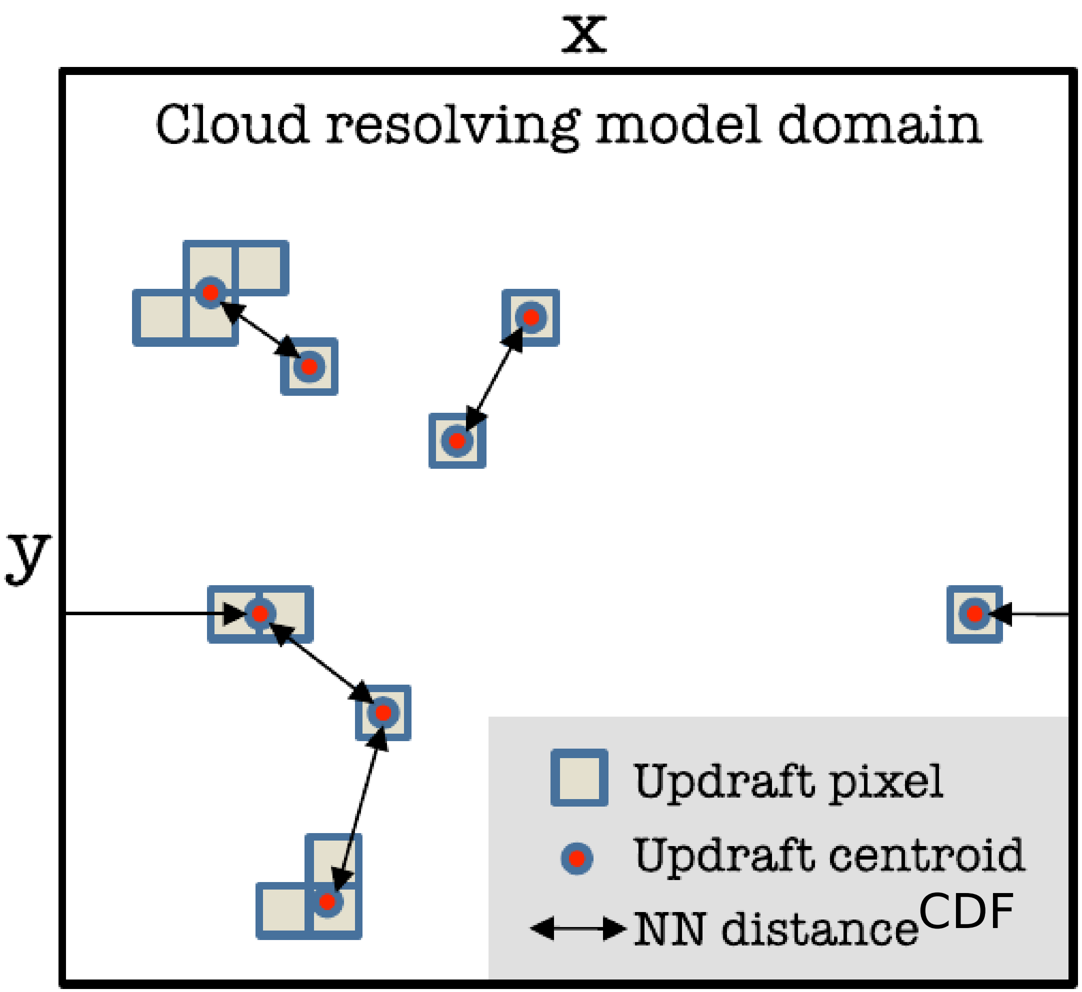
SCAI



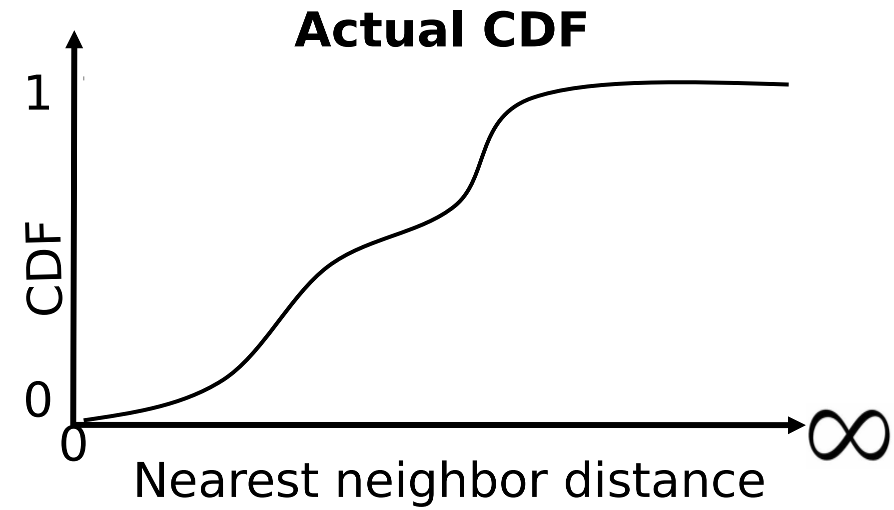
- Lower SCAI values are associated with more aggregated scenes while disaggregated scenes are linked with higher SCAI values.

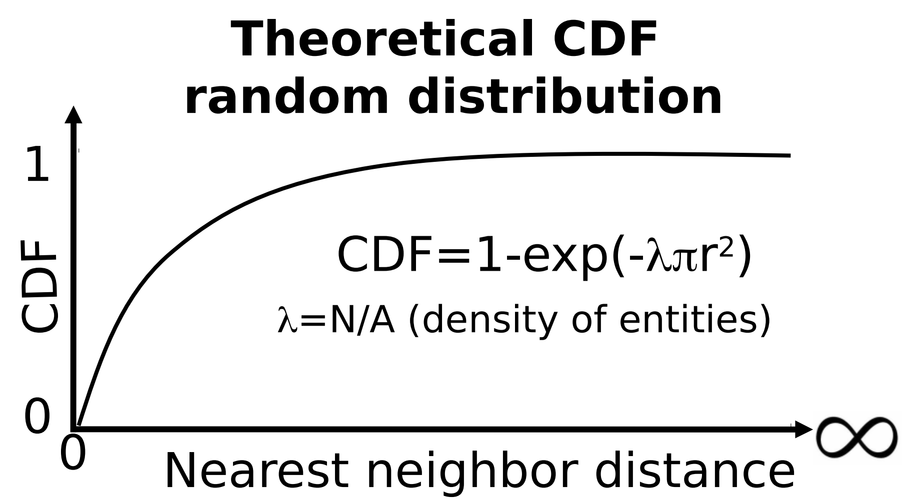
Tobin et al 2012

An Index for aggregation I_{org}

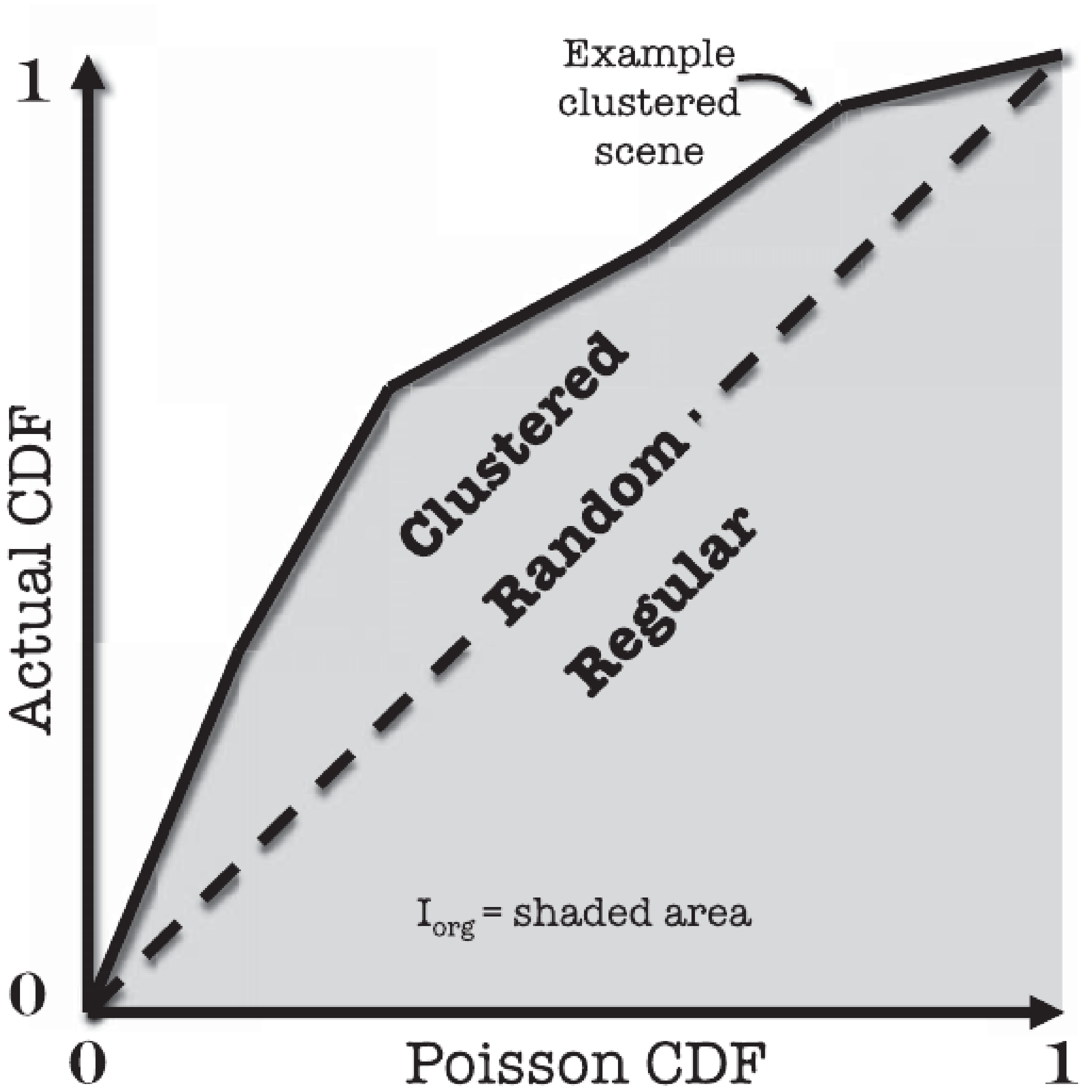


Nearest Neighbor distance (NND) based on Weger et al. 1992



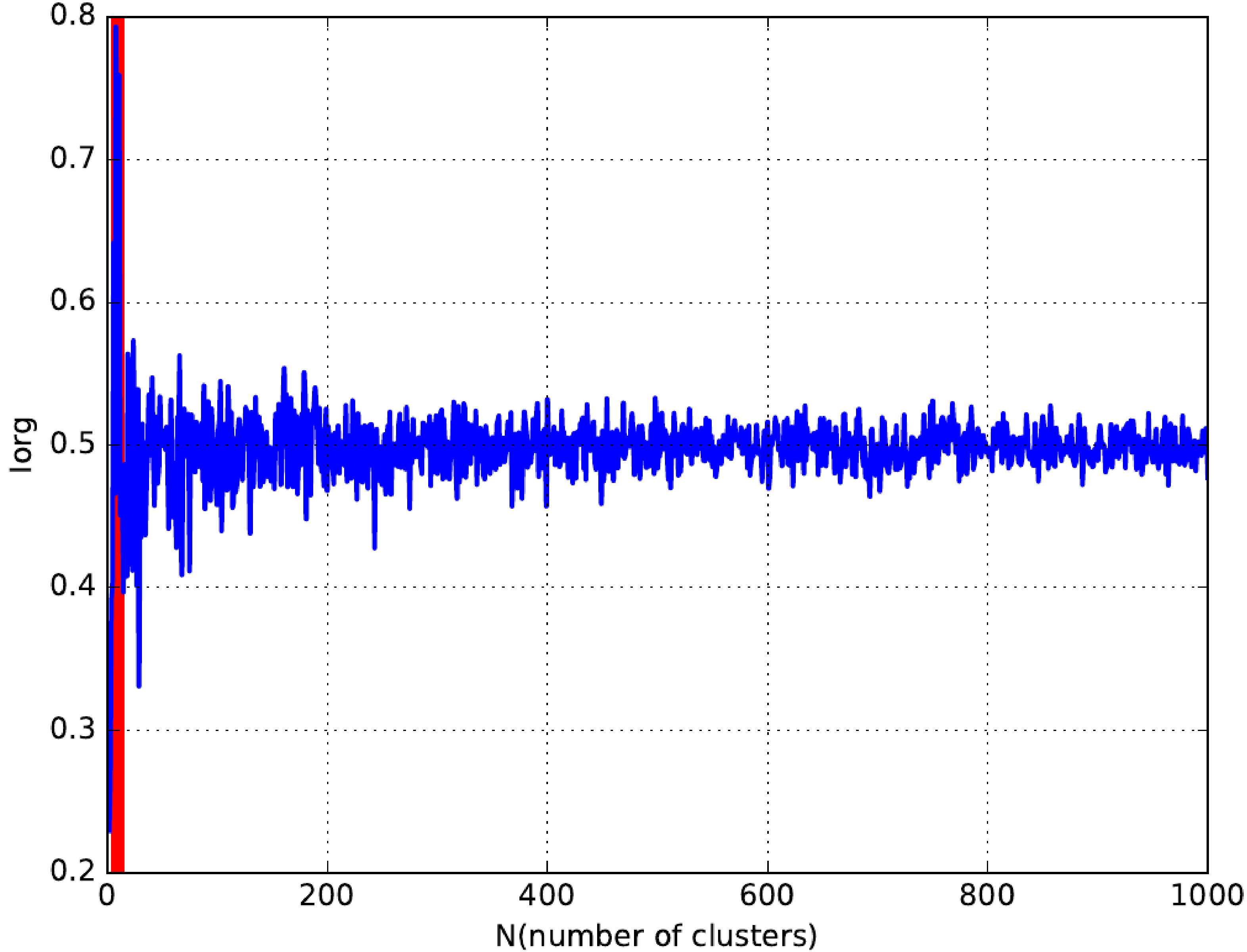


An Index for aggregation I_{org}



- Plot normalized NNCDF against theoretical (Poisson) CDF for random distribution
- I_{org} is the area under the curve
- Random convection will have I_{org} = 0.5, and clustered (regular) states will have values that exceed (are less than) this

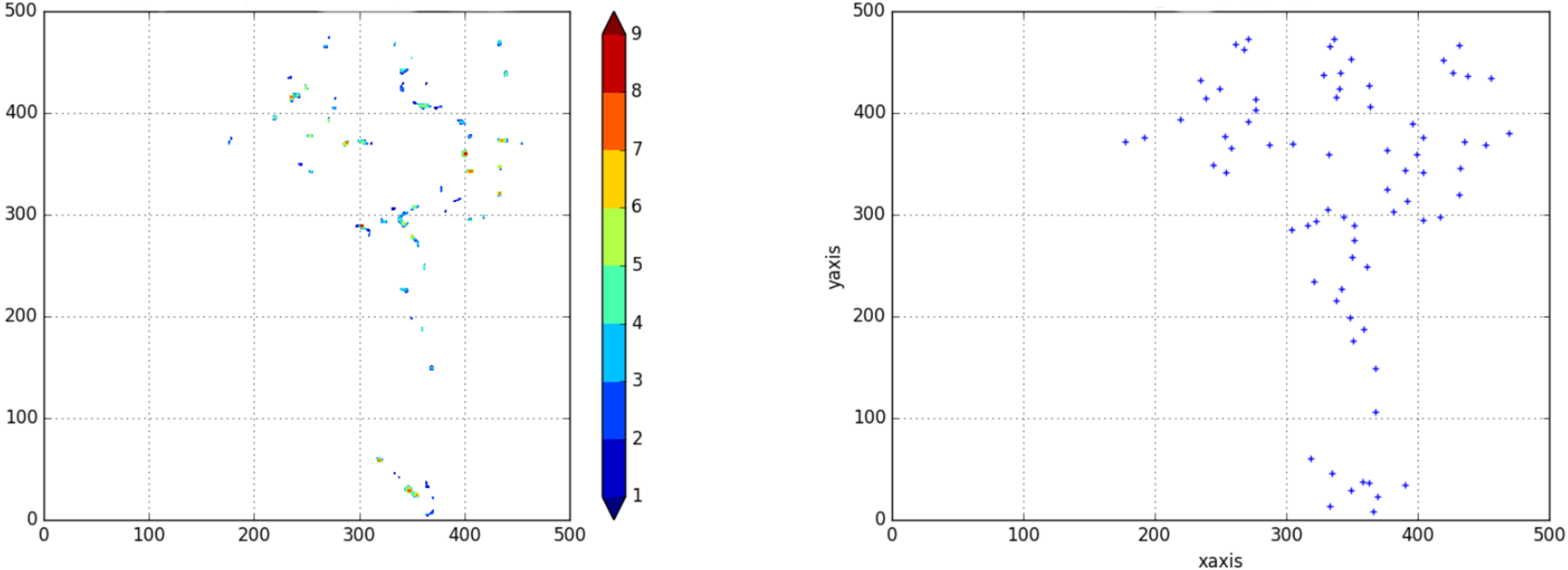
Tompkins and Semie 2017



- Randomly generated NN distance is used to calculate Iorg
- Enough number of convective points should be participated to obtain reliable Iorg value (in this case N > 20)

Application of I_{org} to the CRM simulation

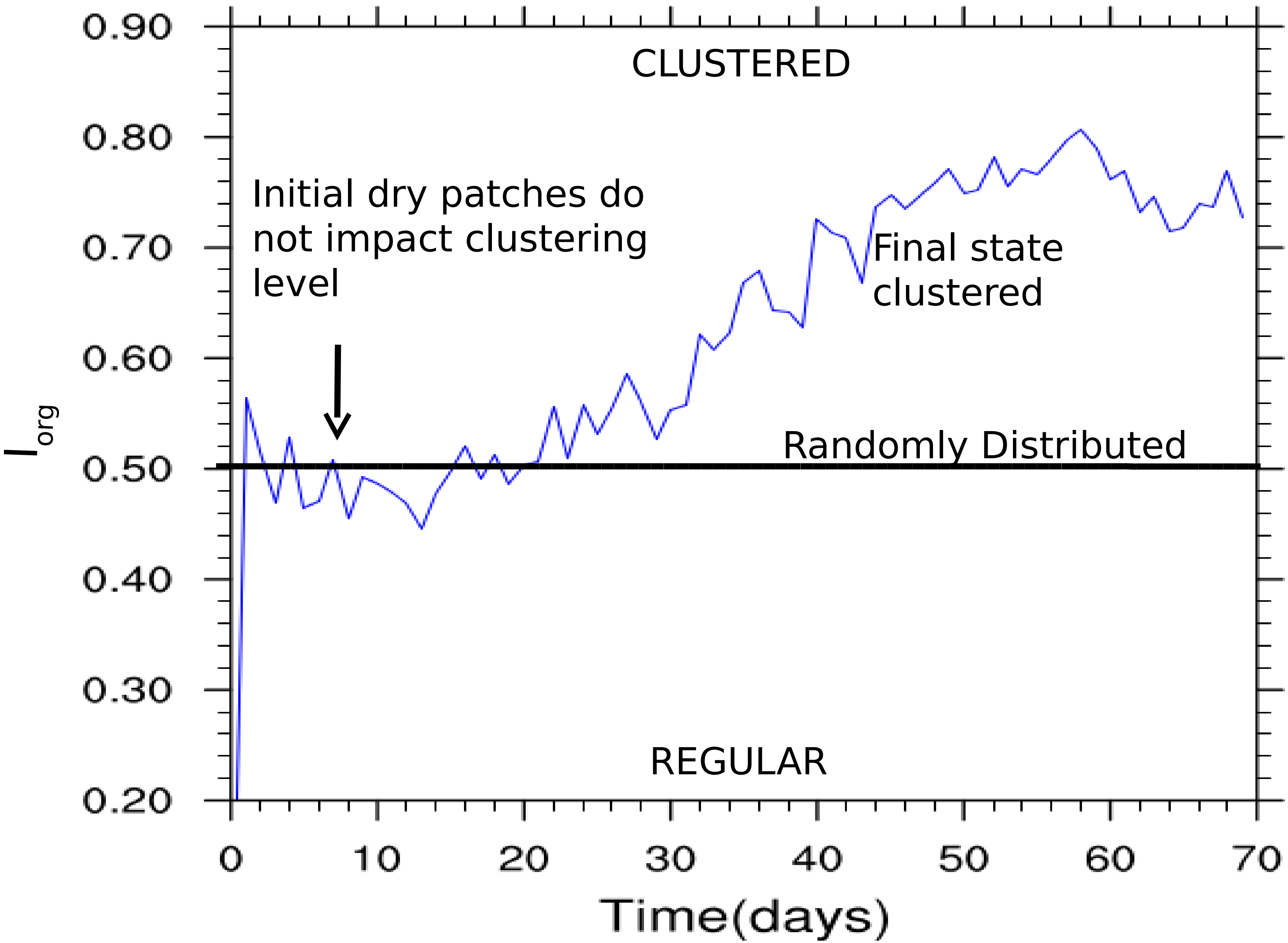
N = 75, I_{org} = 0.74



W > 1m/s at 850 hPa

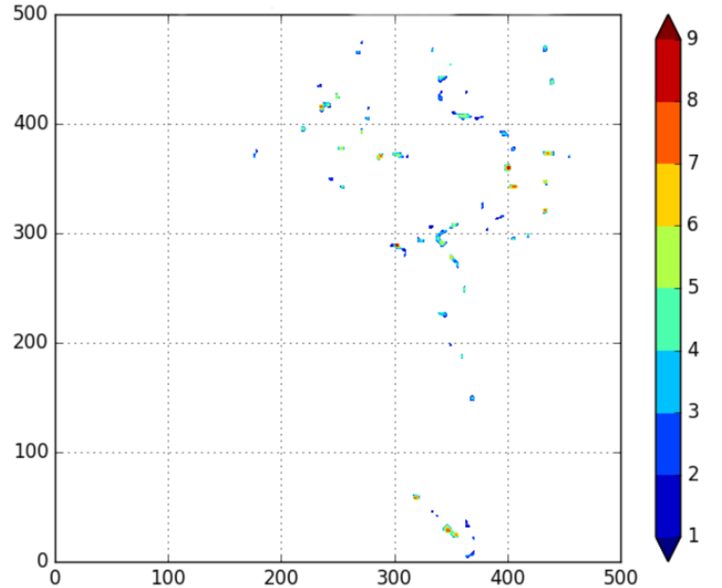
Centroid of convective clusters using the clustering method

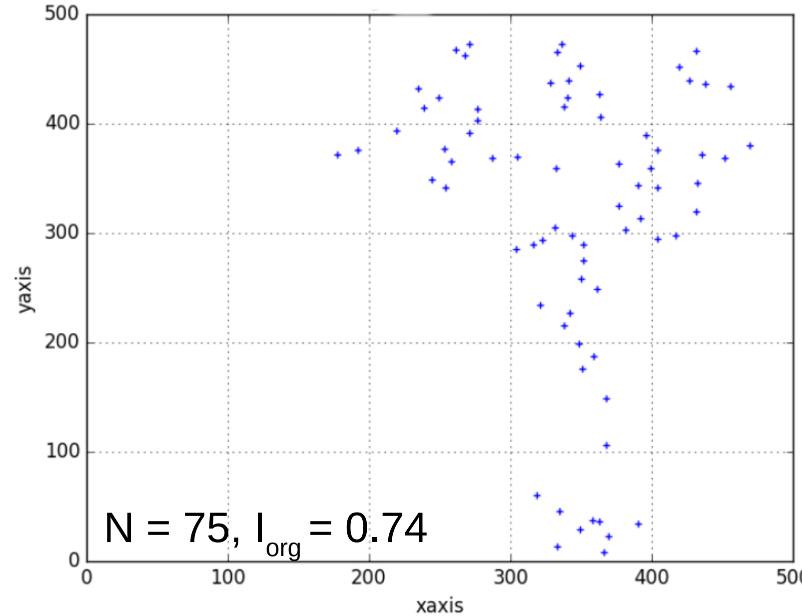
Application of I_{org} to CRM simulation



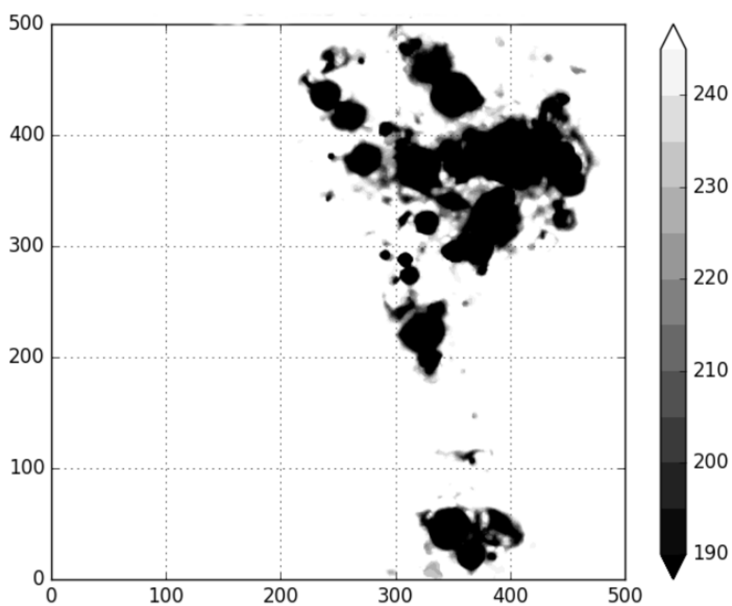
W and OLR are used to identify convective clusters

W > 1m/s at 850 hPa

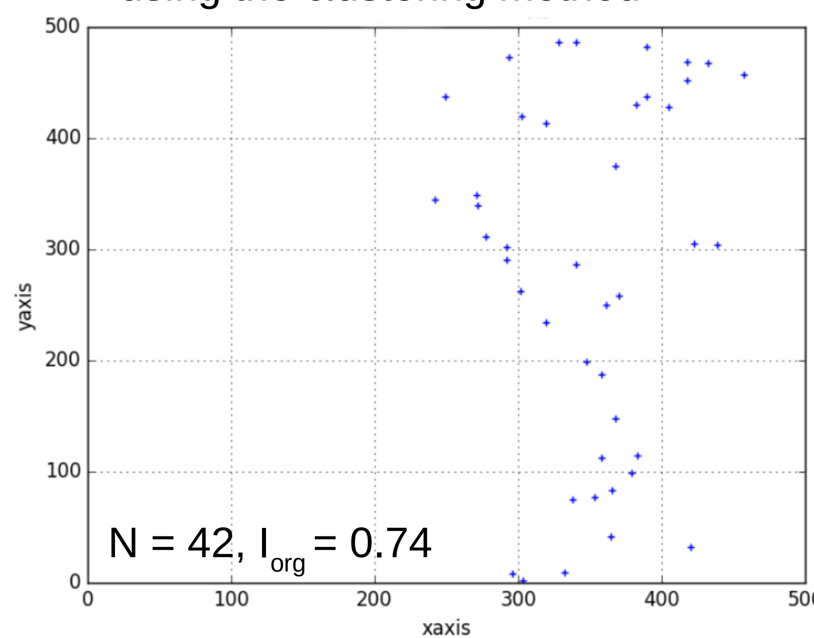




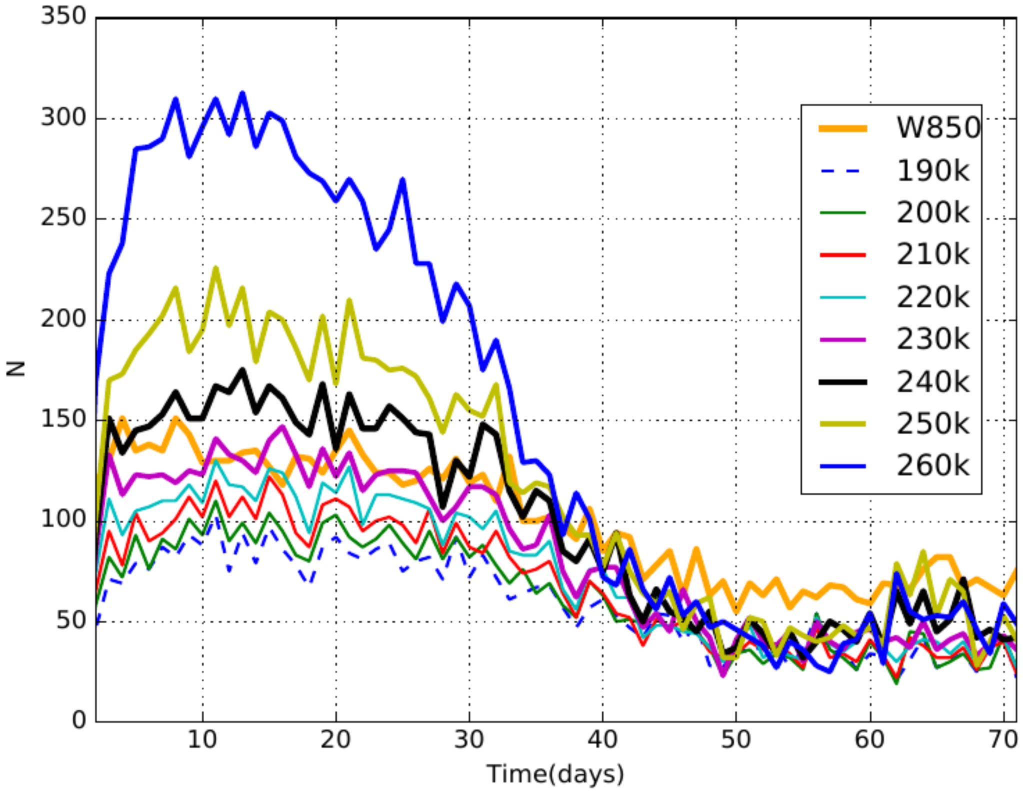
OLR < 240 W/m^2

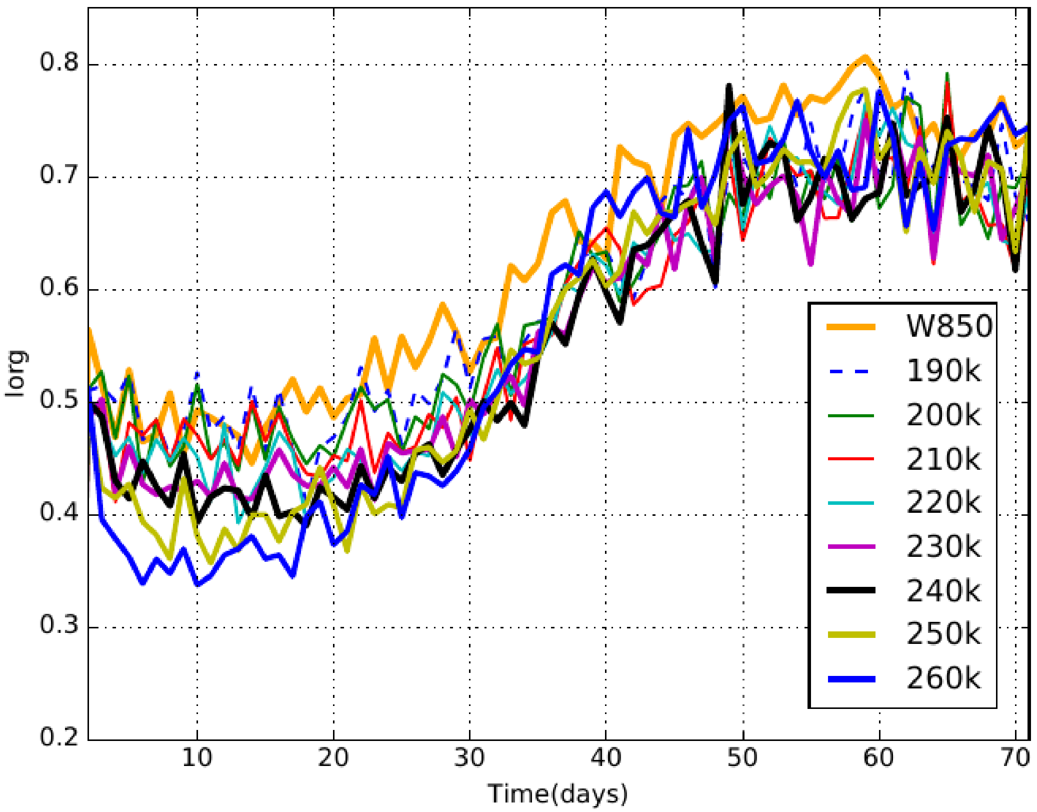


Centroid of convective clusters
using the clustering method



Comparing W850 and OLR having different threshold values to identify convective clusters

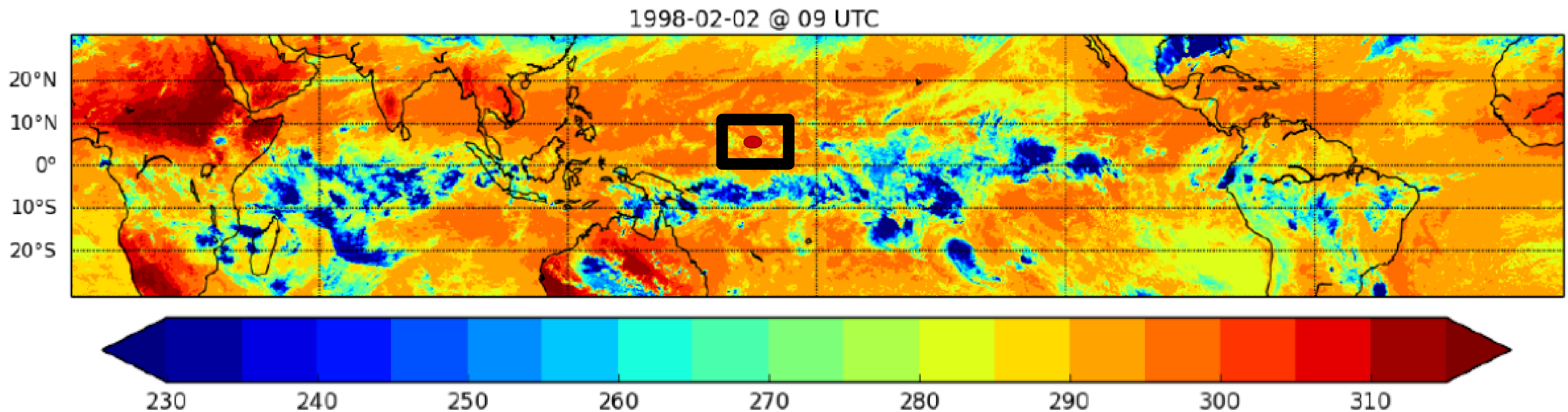


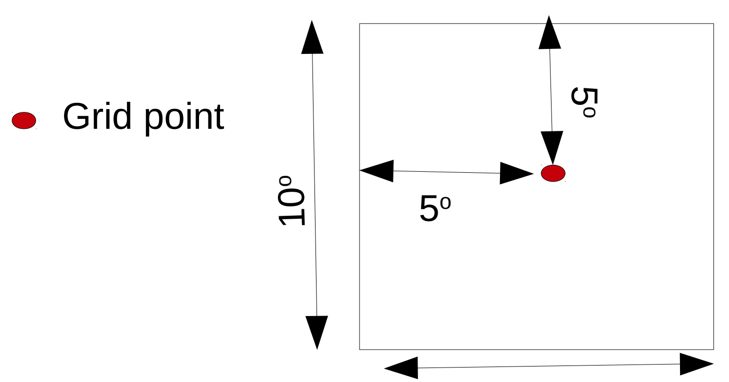


- Higher OLR threshold values display higher N and regular distribution at the beginning of the CRM simulation.
- All the cases properly represent the evolution of organization displayed in the CRM simulation.

Application of I_{org} to observation data

- 3 hourly brightness temperature near 11 microns of a calibrated and gridded geostationary satellite dataset GridSat with **0.07º Grid resolution,** is used to identify deep convective points,***Knapp et al. 2011***





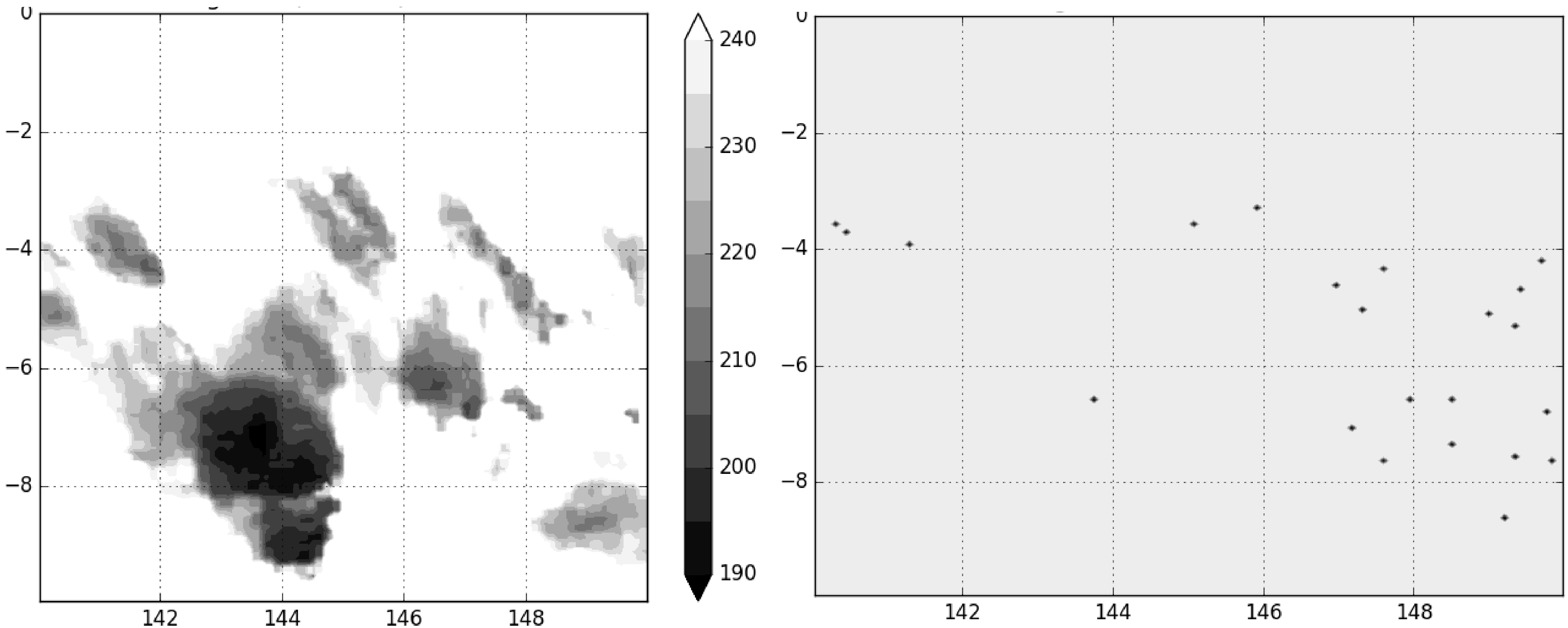
For each 10ºx10º box, calculate:

- N
- D0/D1
- SCAI
- I_{org}

Produce a dataset for a period of 1980 - 2017

Identification of convective cluster using ‘**clustering method**’

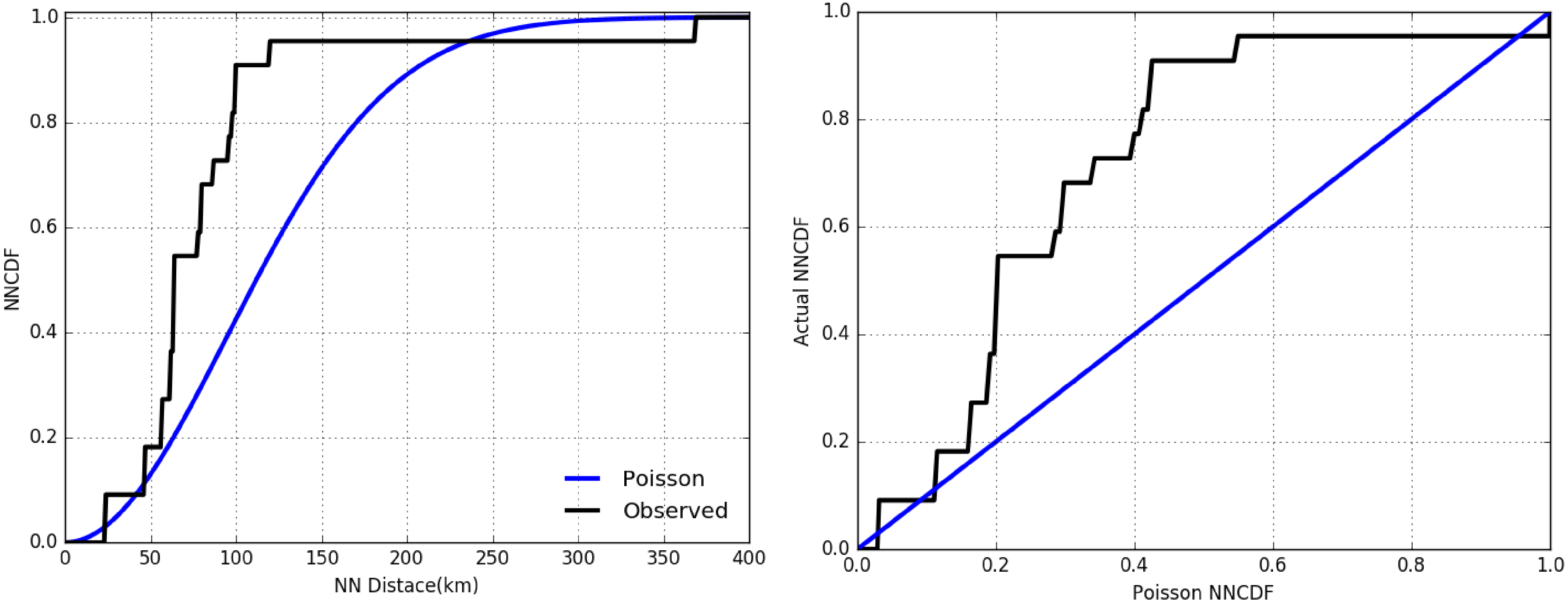
cfr = 0.26 N = 22



Merging of neighboring clusters might artificially reduce N

I_{org} calculated using '**clustering method**'

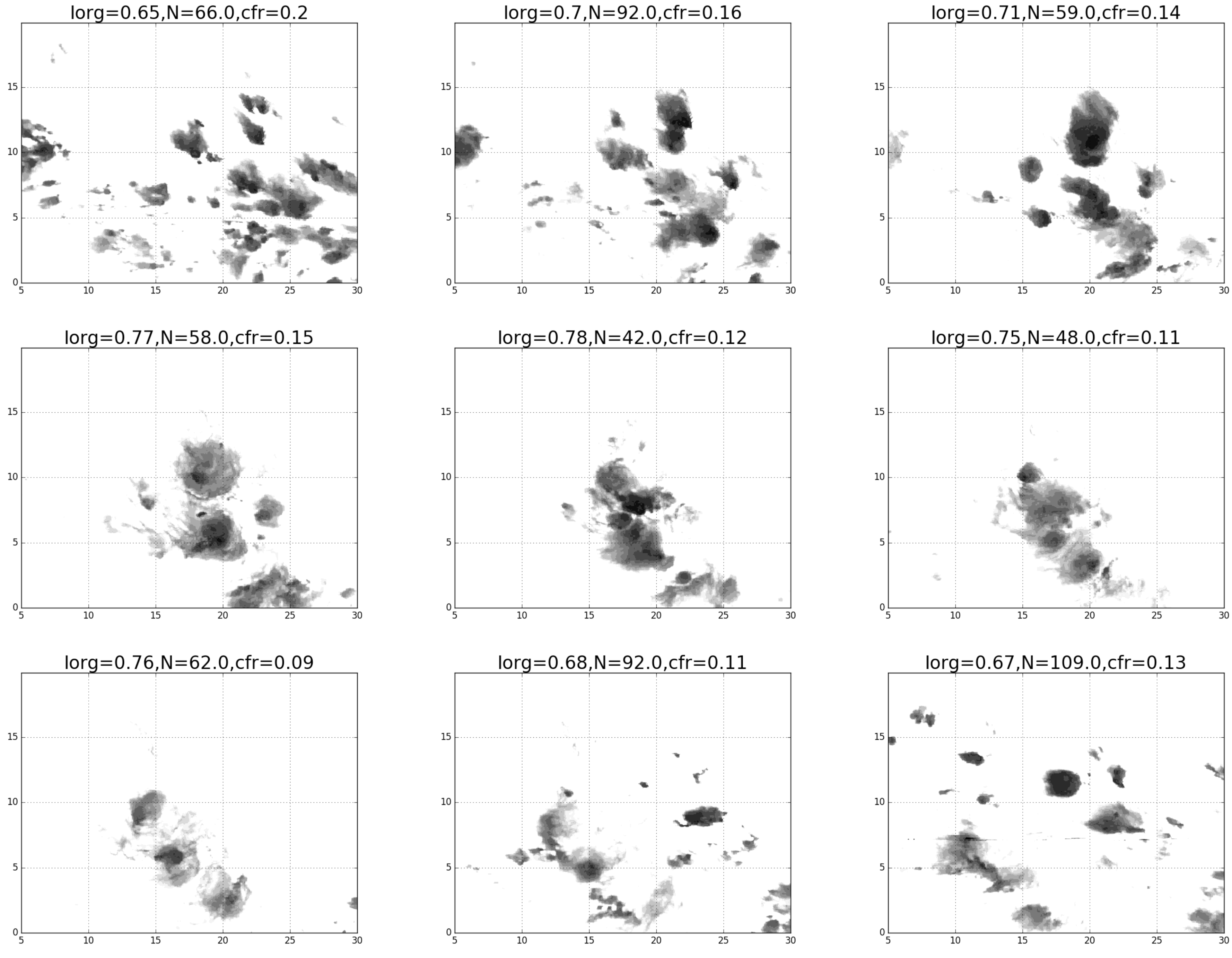
$I_{org} = 0.72$



- More than 90% NN distance is less than 100 km
- The observed NNCDF is above Poisson NNCDF, display a more organized situation

Diurnal Evolution, west African region ($0^o - 20^o$, $5^o - 30^o$)

July 30 at 18 UTC up to July 31 at 18 UTC



Diurnal Evolution, west African region ($0^o - 20^o$, $5^o - 30^o$)
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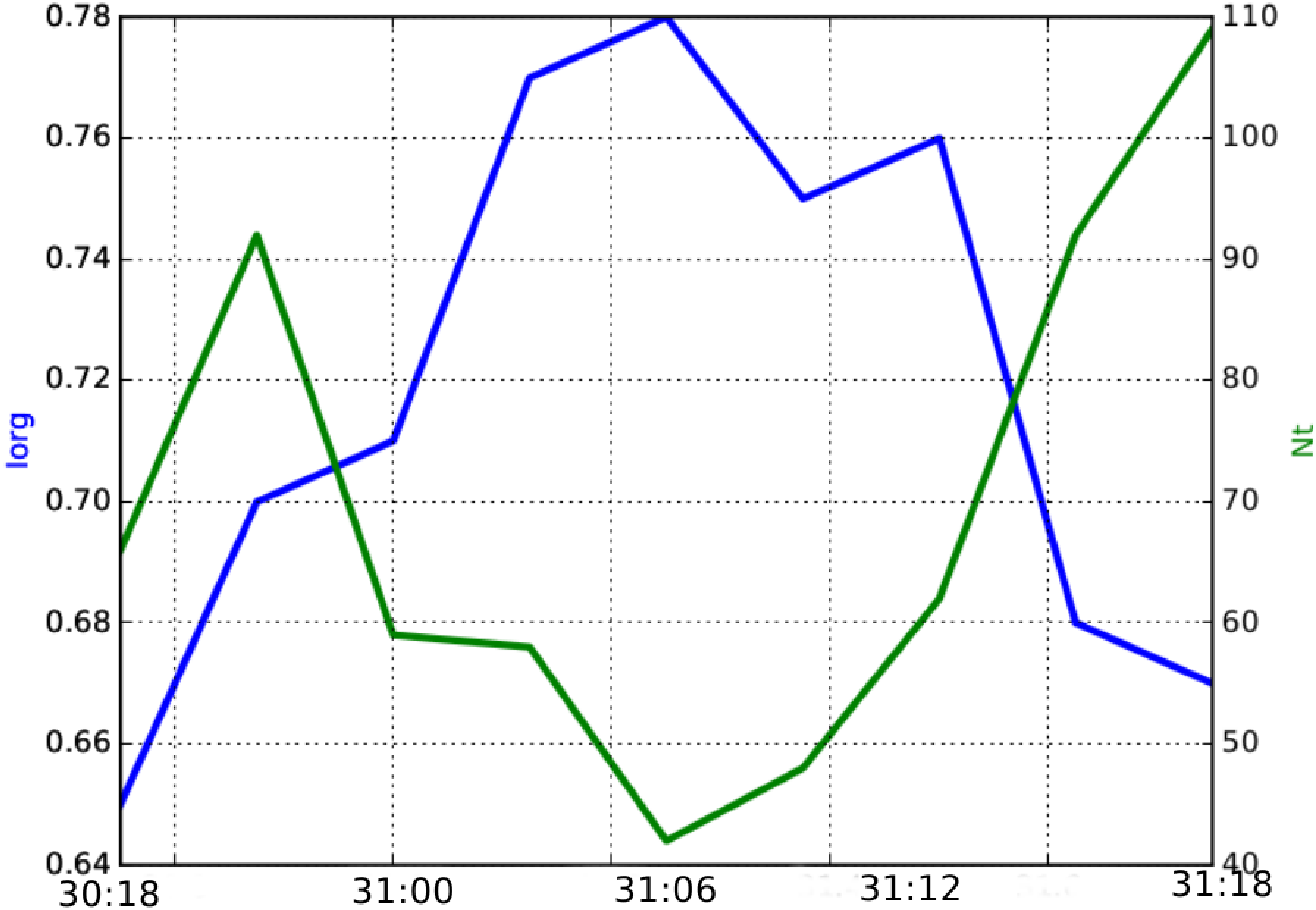


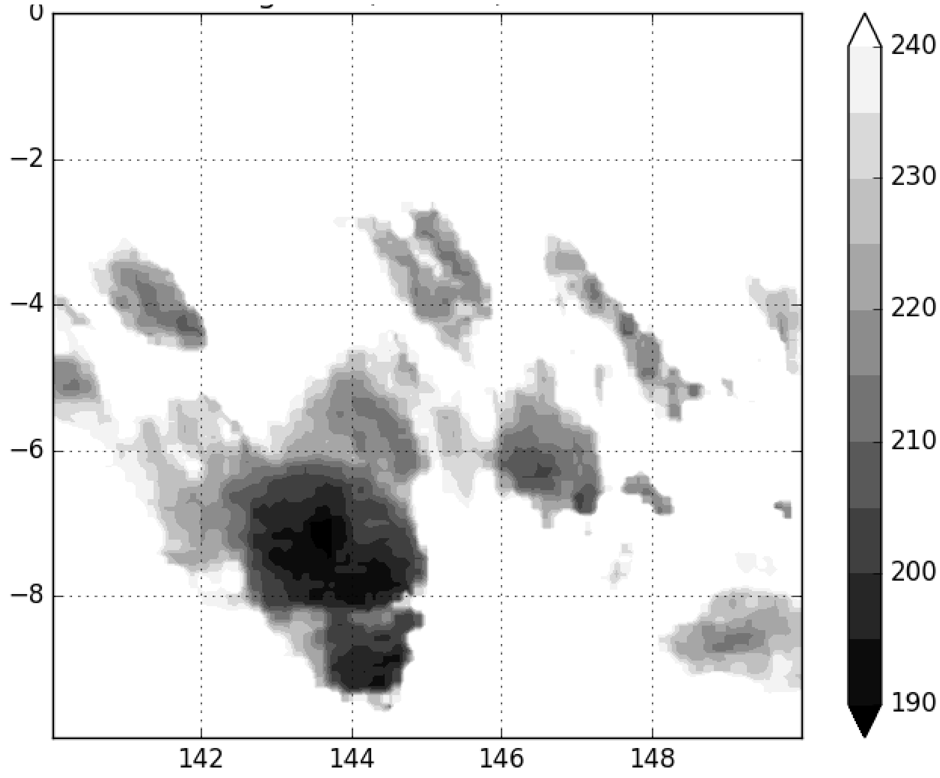
The diurnal evolution of Nt (Number of clusters), organization index (I_{org}) for the duration of 24 hours

Merging of neighboring clusters might artificially reduce N

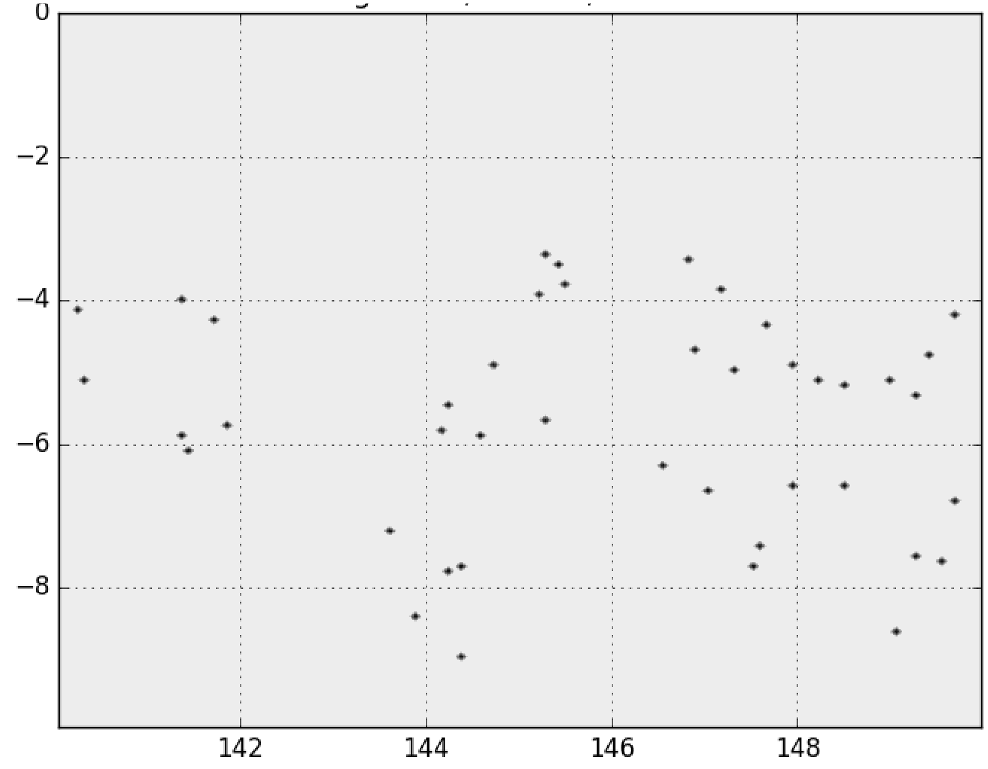
- To address this issue a local minimum approach applied to identify convective clusters.

Identification of convective cluster using ‘**local minimum method**’

cfr = 0.26



N = 43

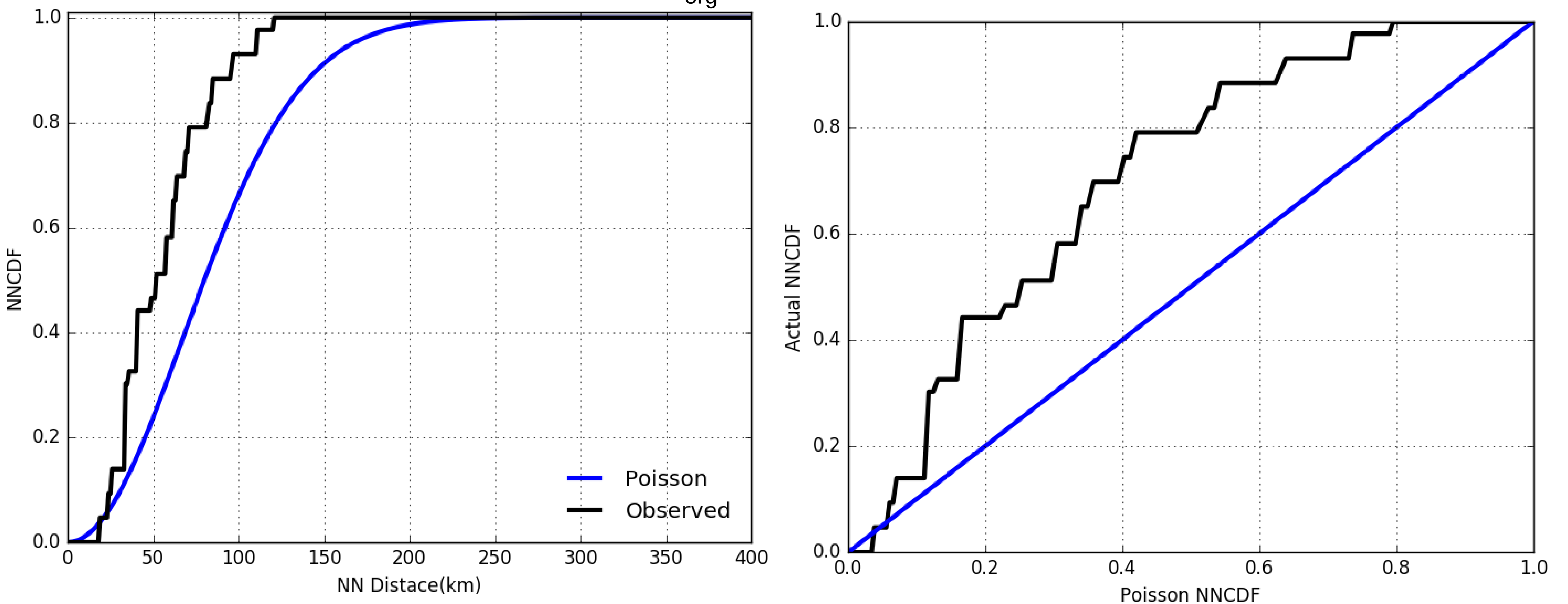


- Smoothing of Tb field at 0.7x0.7 degrees (10x10 Gridsat pixels) is applied to remove isolated convective pixels

- For each 3x3 GridSat pixels, we calculated the minimum Tb and if the Tb value is less than 240 K then it will be considered as a deep convective centroid

I_{org} calculated using ‘**local minimum method**’

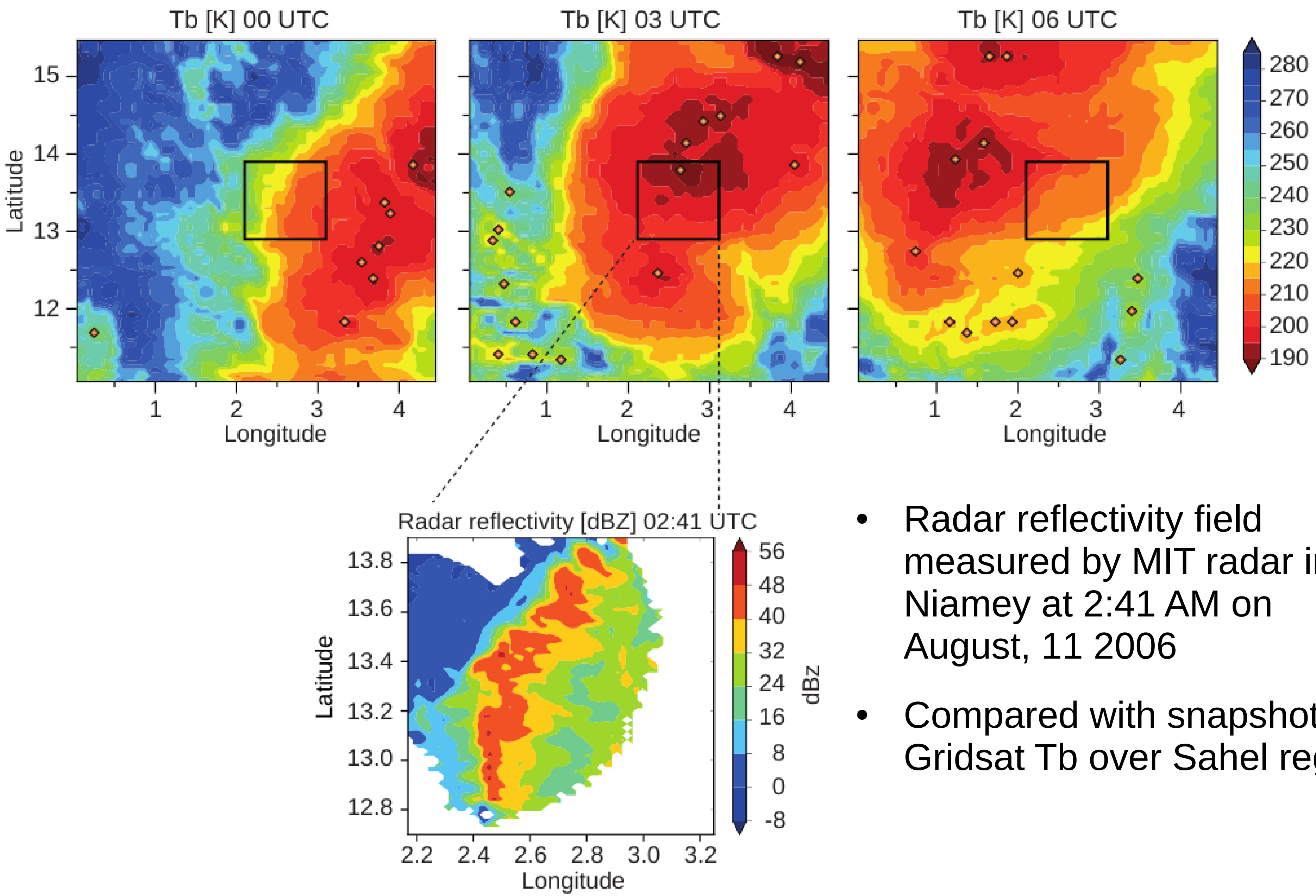
$I_{org} = 0.71$



- N increases from 22 to 43, however I_{org} is not not significantly changed.
- It will be part of our lab exercises if we can reach to same conclusions for others cases as well.

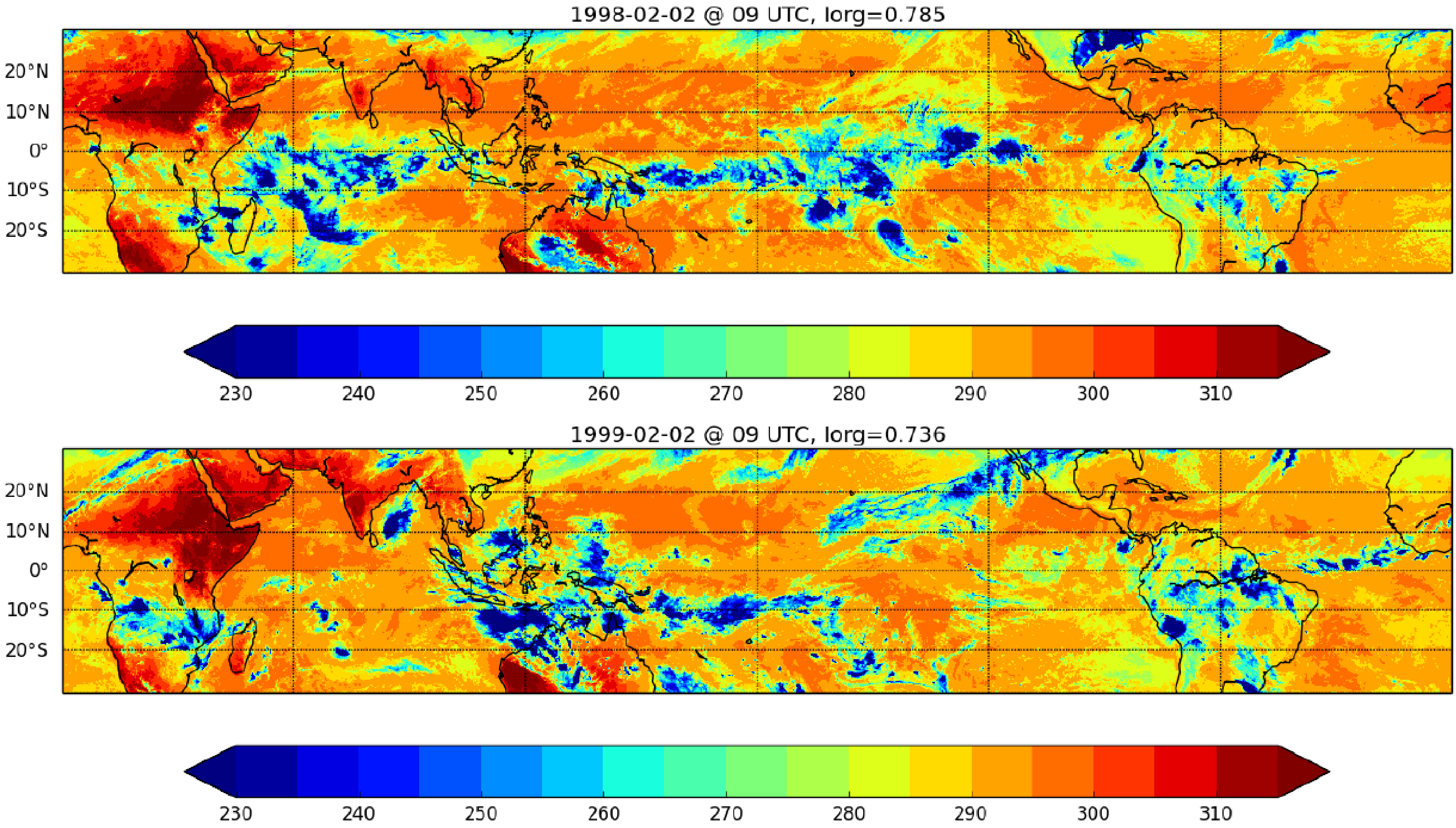
Identifying structure of the squall line over the Sahel region on August 11,2006

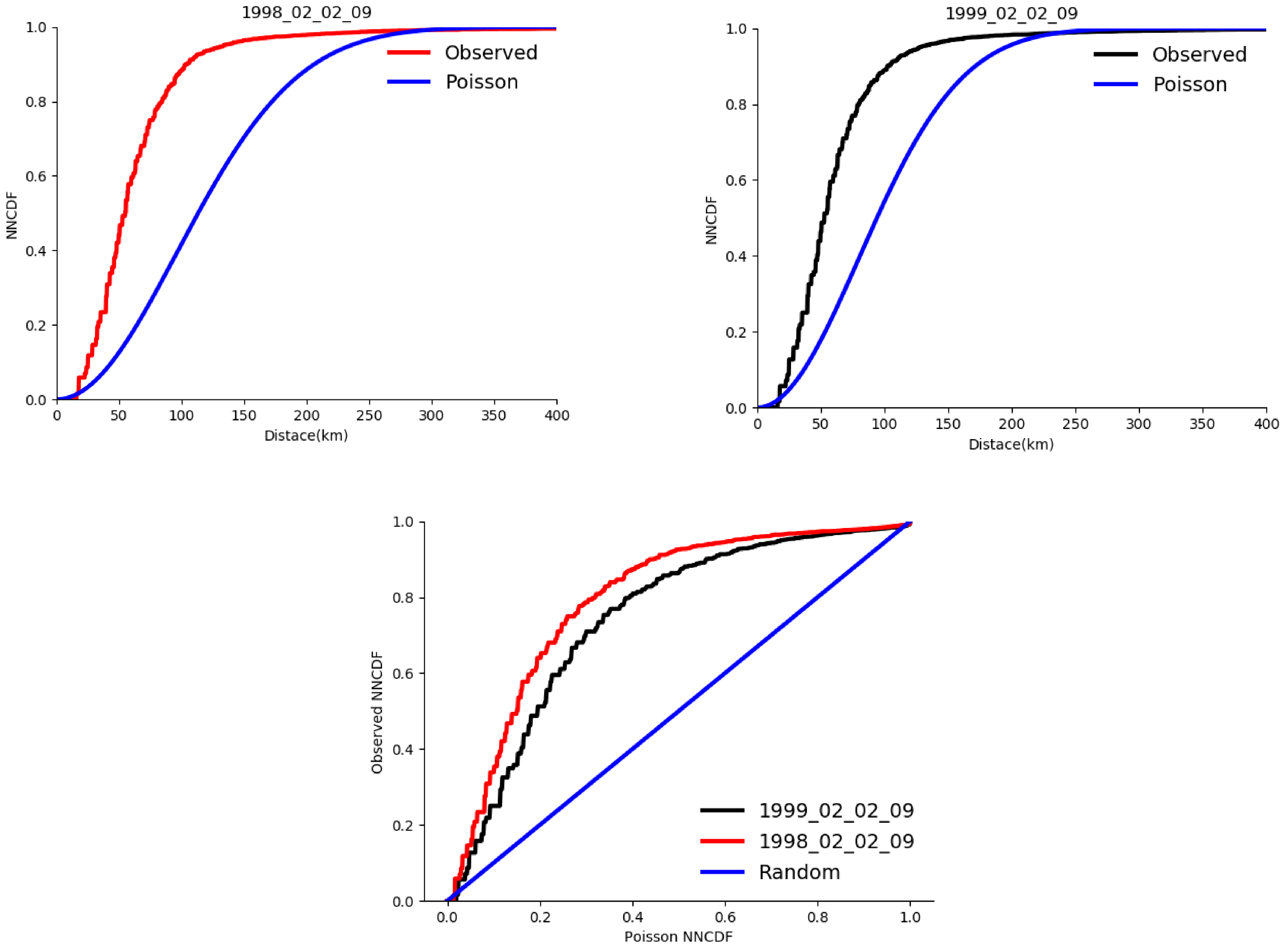
Gridsat Tb over Sahel region



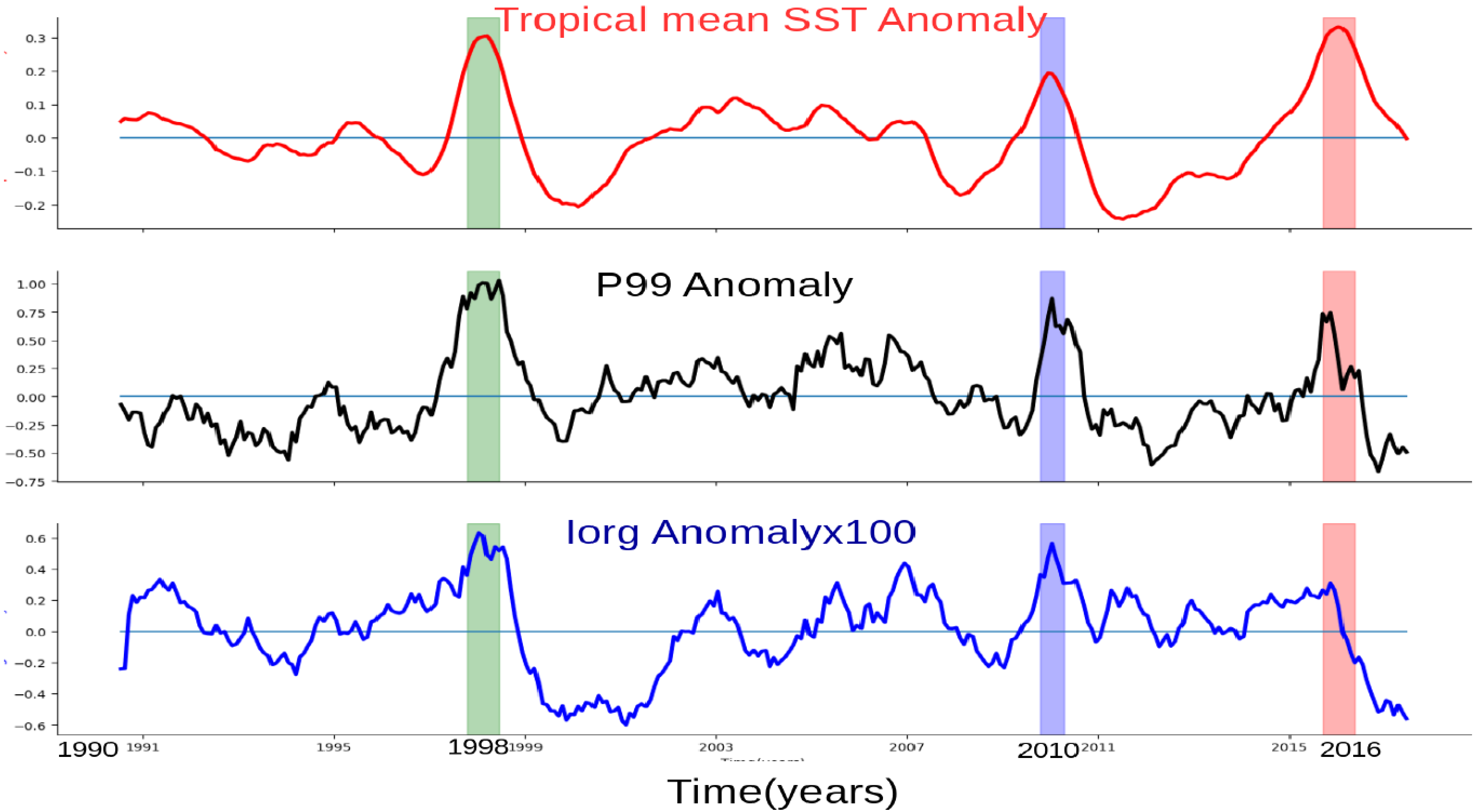
- Radar reflectivity field measured by MIT radar in Niamey at 2:41 AM on August, 11 2006
- Compared with snapshot of Gridsat Tb over Sahel region

Characterizing spatial organizations of deep convection in the tropics



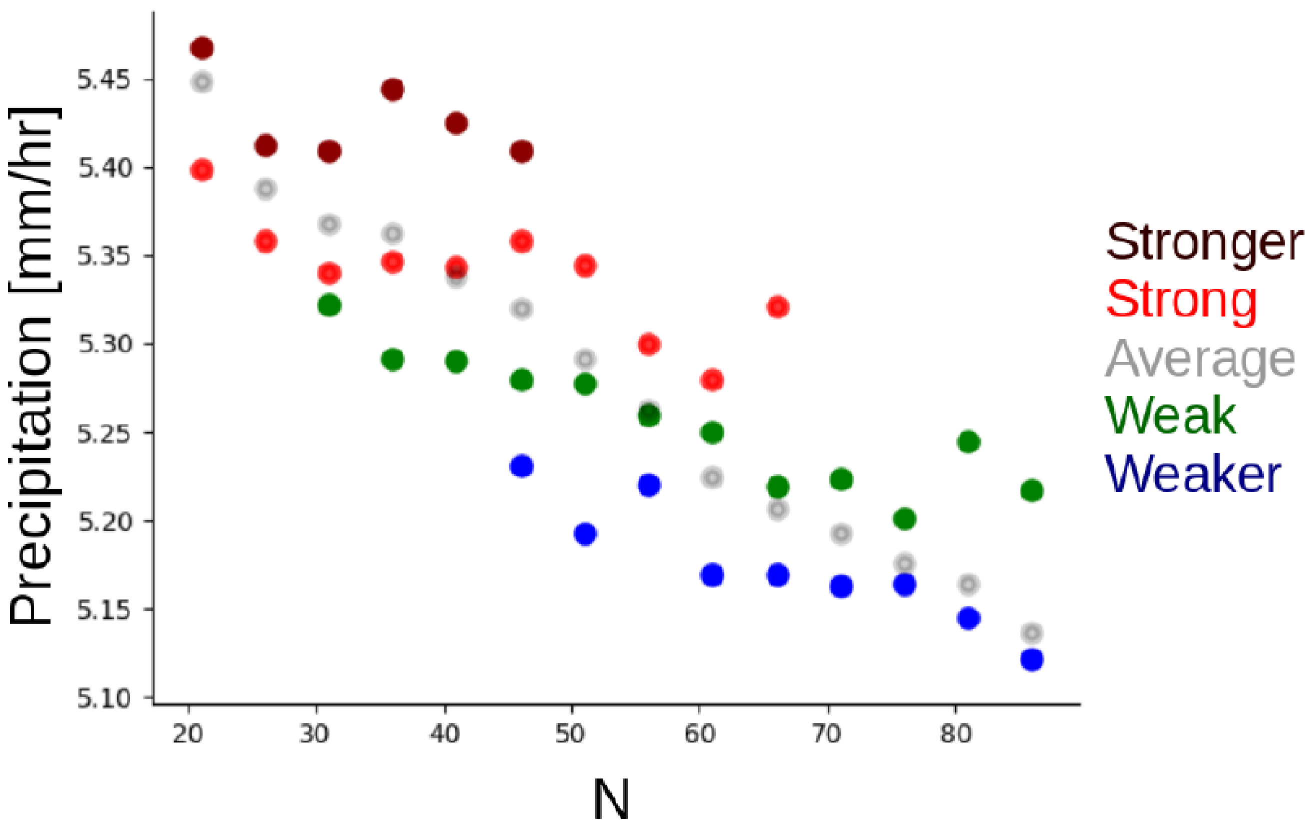

1998_02_02_09
Observed
Poisson
NNCDF
Distace(km)
1999_02_02_09
Observed
Poisson
NNCDF
Distace(km)
1999_02_02_09
1998_02_02_09
Random
Observed NNCDF
Poisson NNCDF

Large scale organization at inter-annual time scale



P99 - precipitation extremes from monthly GPCP v2.3 data

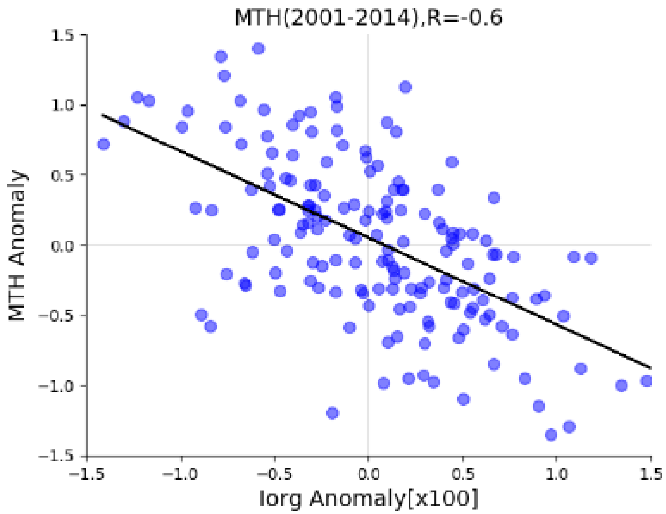
Precipitation extremes over Equatorial Indian ocean



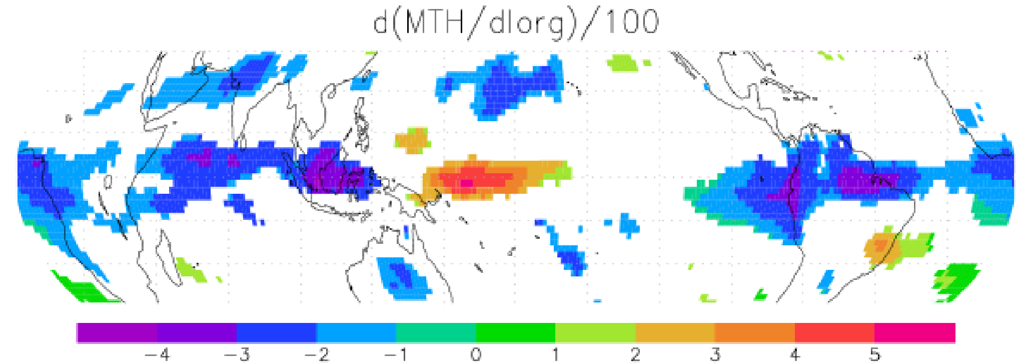
- Precip extremes decreases with N
- Strong aggregation is linked with strong precip extremes for a given N

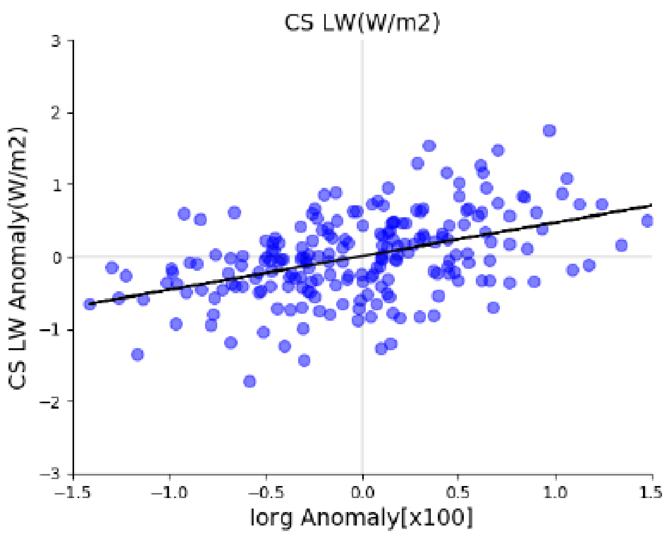
Similar relationship are also observed over other Equatorial oceans

Large scale convective aggregation related to humidity and clear sky OLR

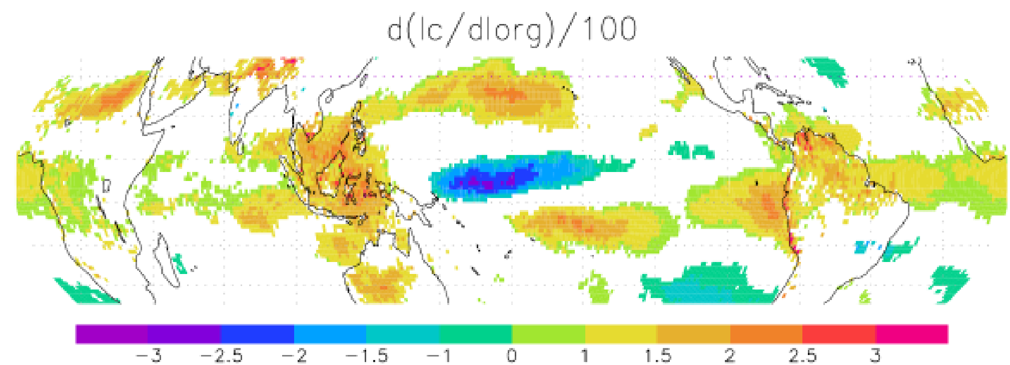


Microwave MTH observations





Clear-sky LW radiation from CERES



Strong aggregation is associated with

- dry tropical atmosphere
- enhanced emission of OLR

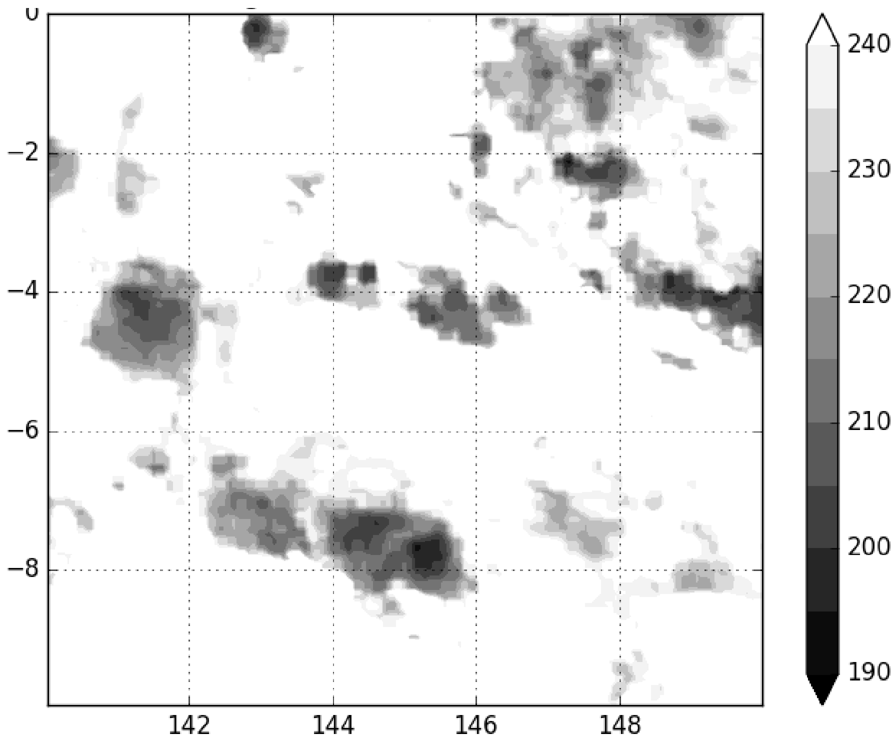
Bony et.al2019(submitted)

Thank you!

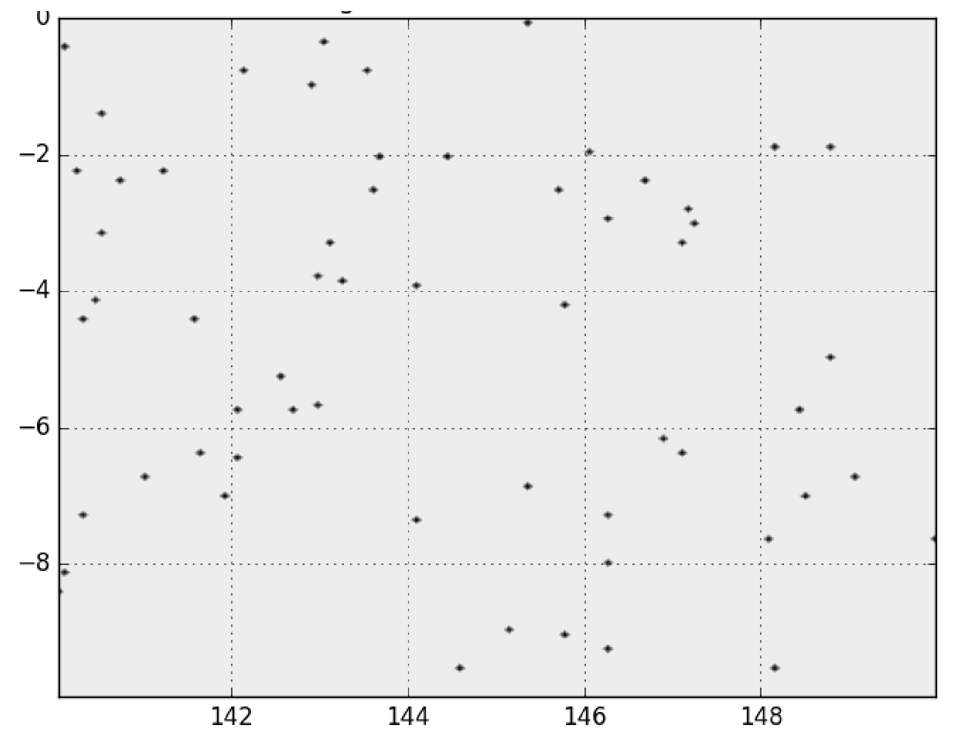
Additional slides

Identification of convective cluster using ‘**clustering method**’

cfr = 0.27



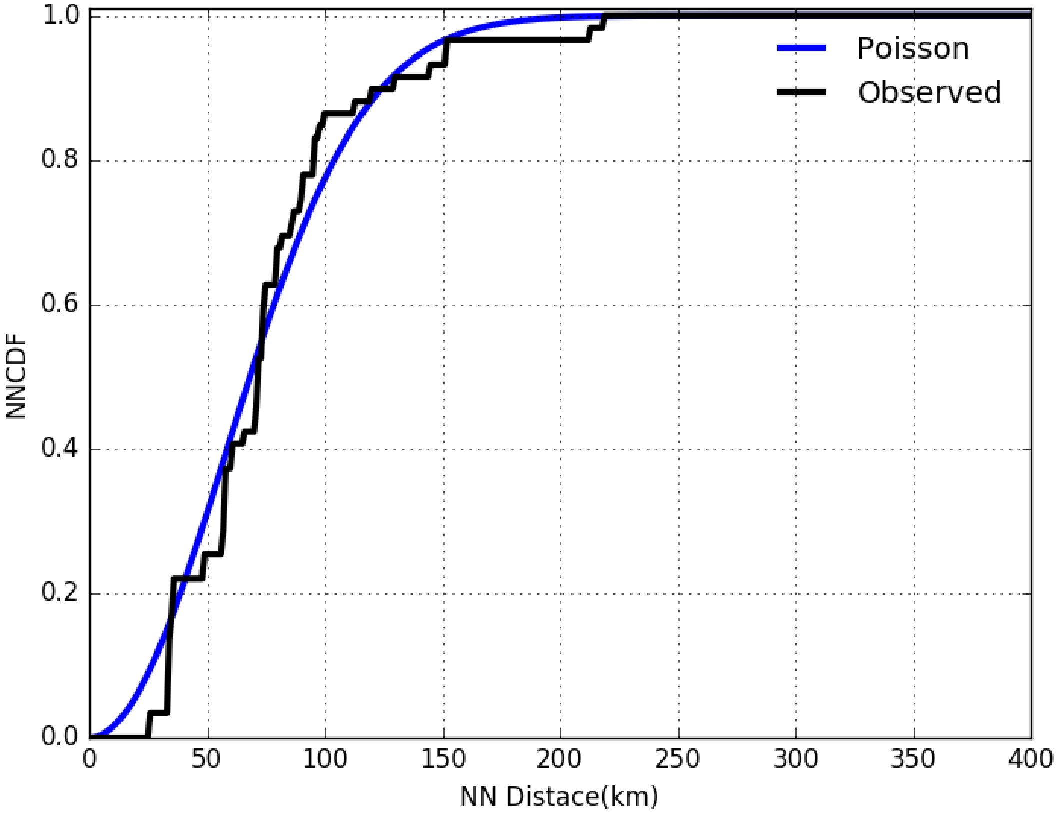
N = 59

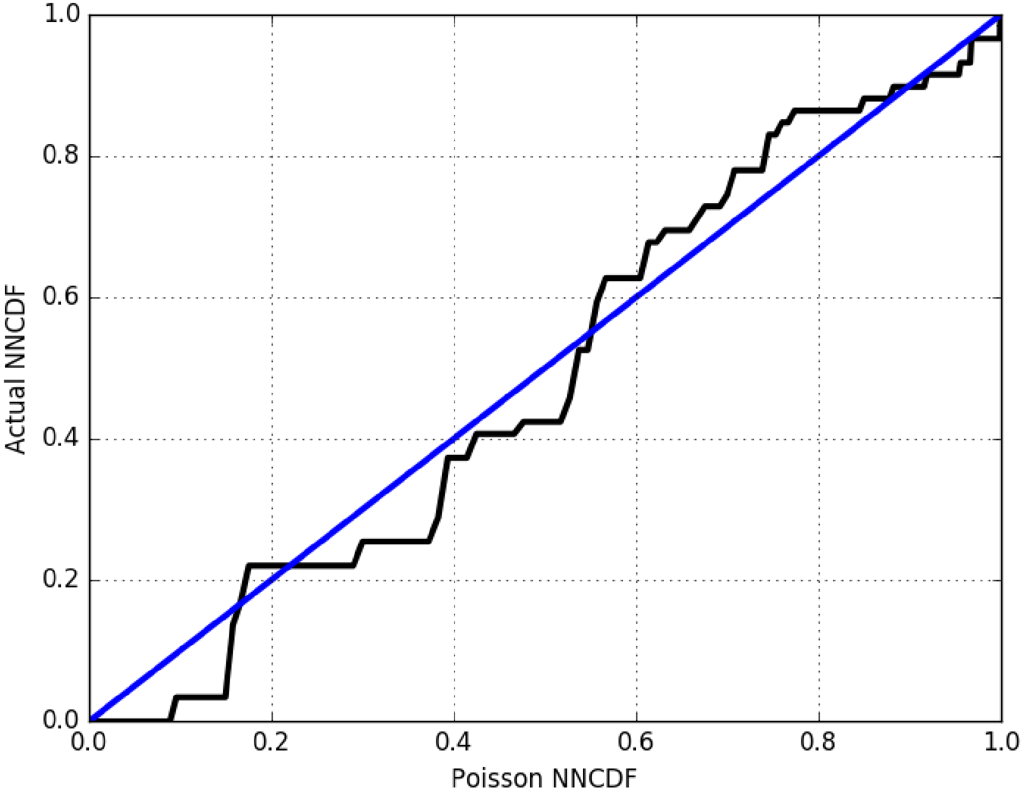


Merging of neighboring clusters might artificially reduce N

I_{org} calculated using '**clustering method**'

$I_{org} = 0.49$

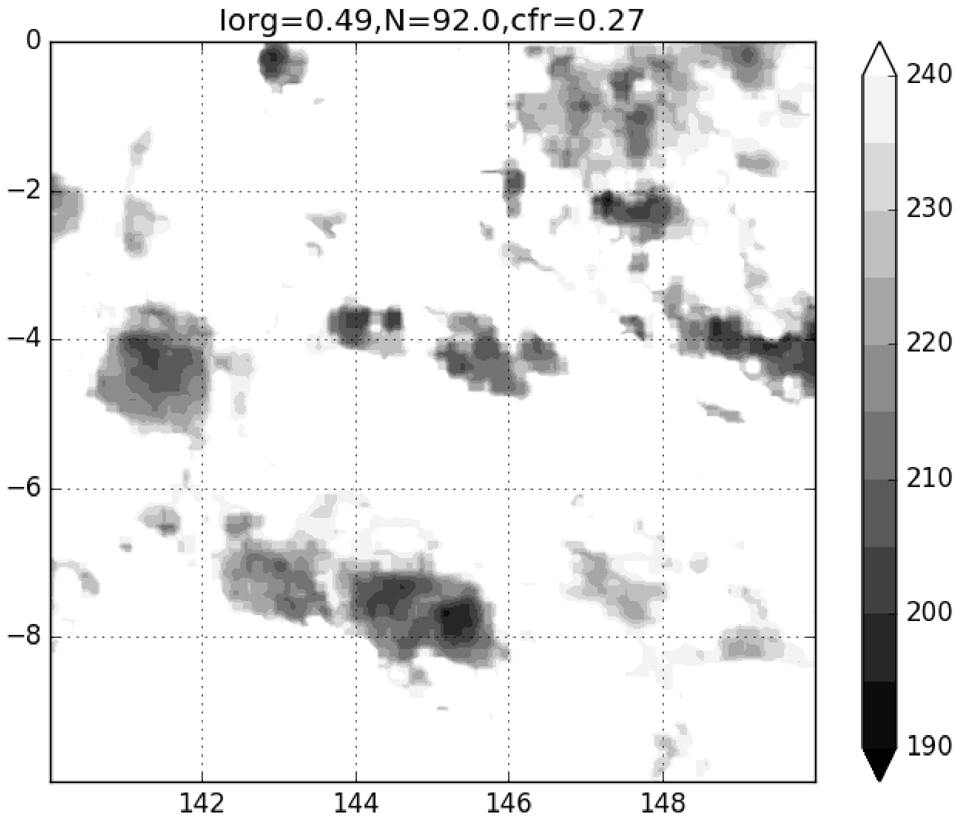




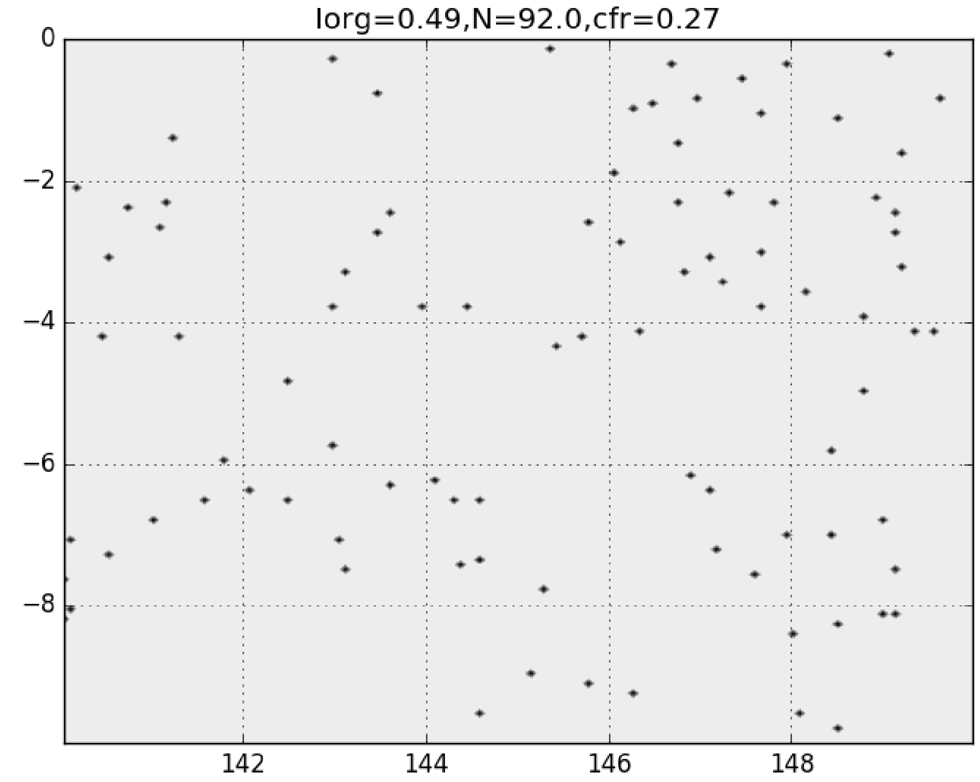
- The observed NN CDF almost overlap with Poisson NN CDF
- The deep convective clusters display a random distributions

Identification of convective cluster using ‘local minimum **method**’

cfr = 0.27

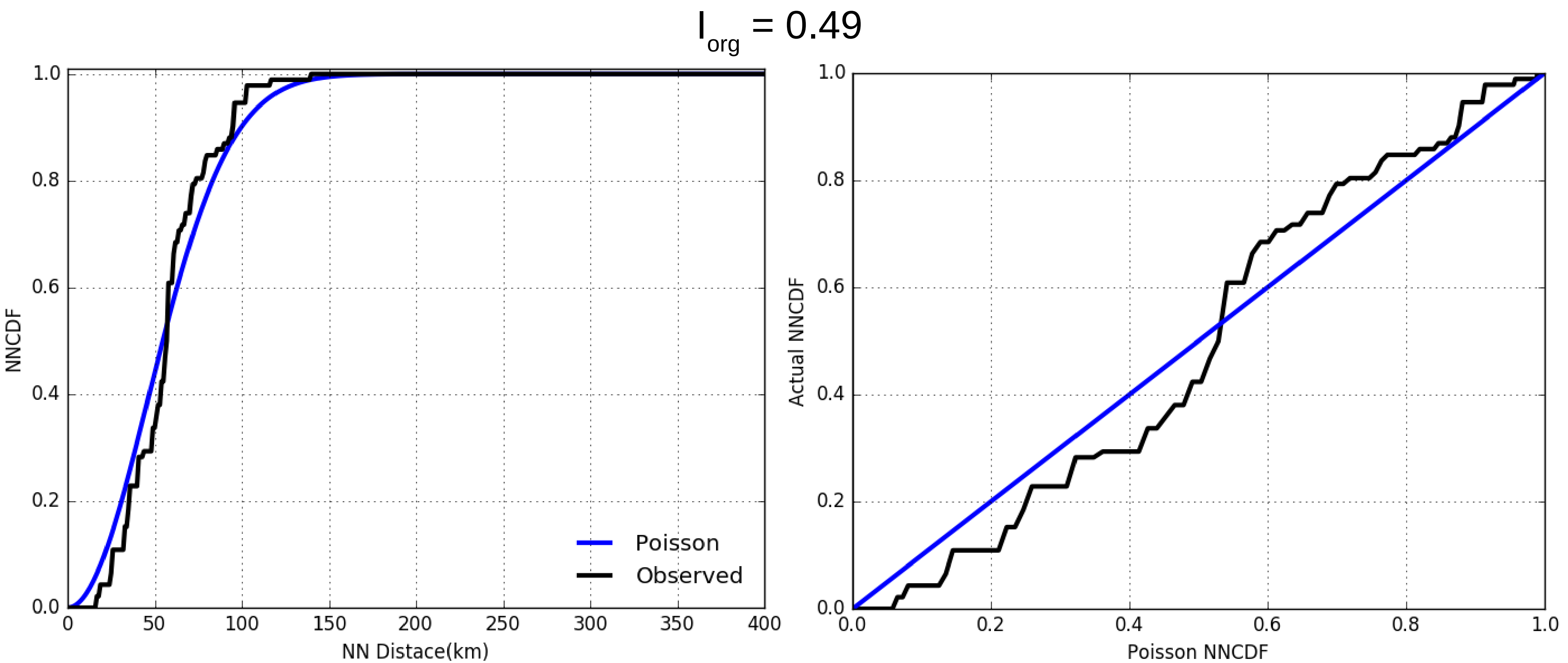


N = 92



- N increases from 59 to 92 but I_{org} values remains the same as the method changed from ‘clustering’ to ‘local minimum’

I_{org} calculated using '**local minimum method**'



- The observed NN CDF almost overlap with Poisson NN CDF
- The deep convective clusters display a random distributions

Spatial distribution of Vertical velocity