

The Effect of Turbulence on the Cloud  
Organization. The Santa Maria Case  
Study:

A tool to compare model performance  
and a proposal to improve entrainment  
in convective clouds.

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**And**

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# Meso NH Simulations:

- The Meso-NH (Lafore et al., 1998) version 4.9 was run using the two-way interactive grid-nesting method (Stein et al. 2000) with two nested grids with horizontal grid spacings of 10 and 2 km. The vertical grid consists of 62 levels and has a spacing varying from 60 m close to the ground to 600 m in the free troposphere.
- The initial and boundary conditions were provided by European Center for Medium-range Weather Forecasts (ECMWF) analysis and forecasts issued at 12 UTC each day from which the model was run for 36 h.

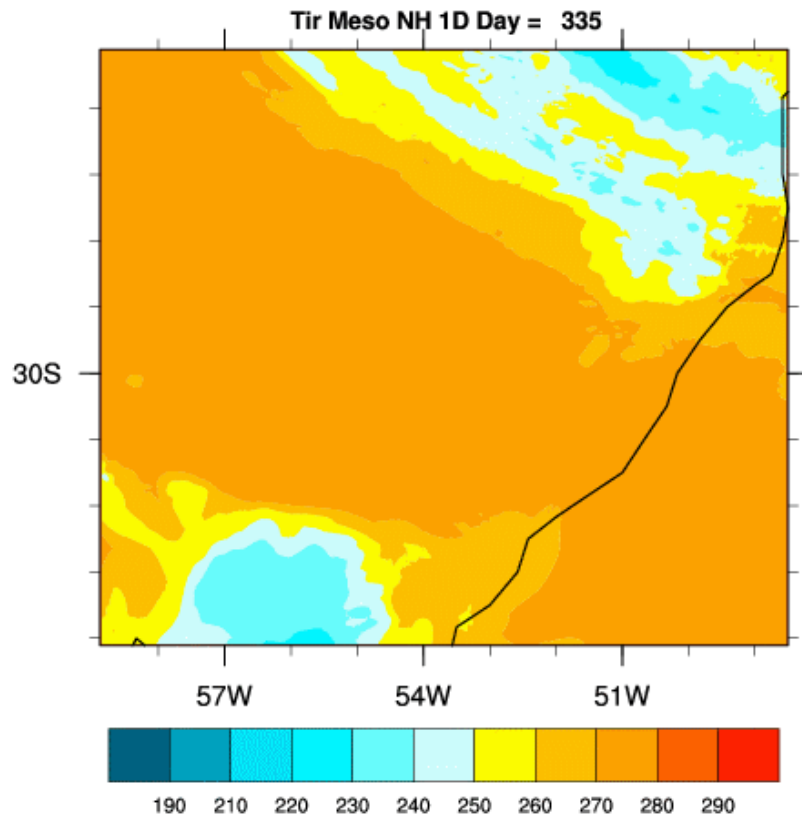
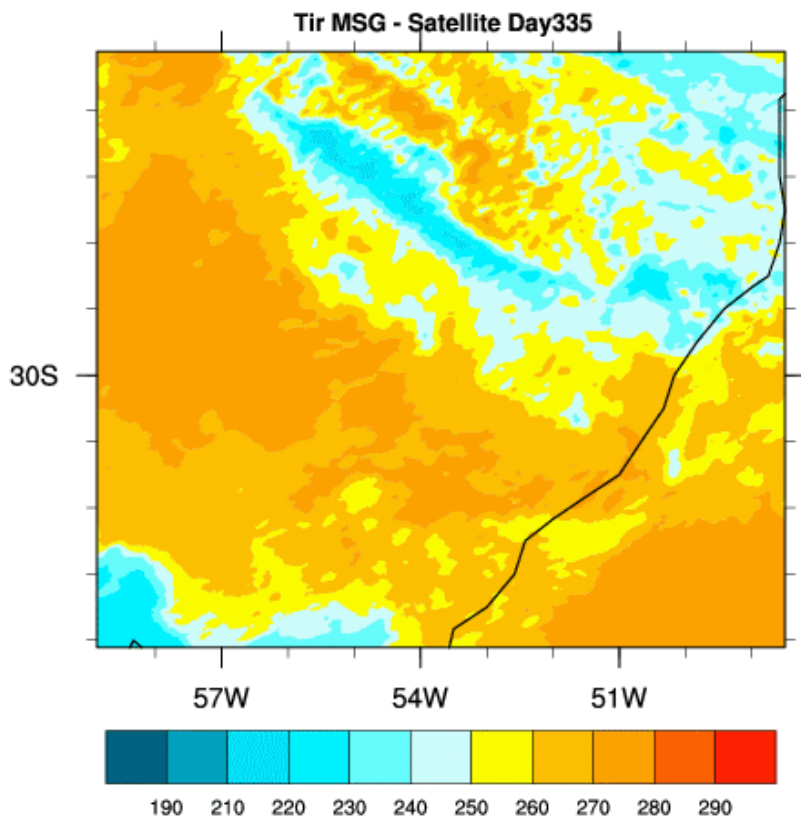
# Meso NH Simulations:

- The model includes a turbulence parameterization (Cuxart et al. 2000), an eddy diffusive Kain–Fritsch parametrization scheme for the subgrid shallow convection (Pergaud et al., 2009), a mixed-phase bulk microphysical scheme that predicts the evolution of the mixing ratios of six water species (water vapor, cloud droplet raindrop, ice crystal, snow and graupel, Pinty and Jabouille 1998), and sub-grid cloud cover and condensate content scheme (Chaboureaud and Bechtold 2005).

# Meso NH Simulations:

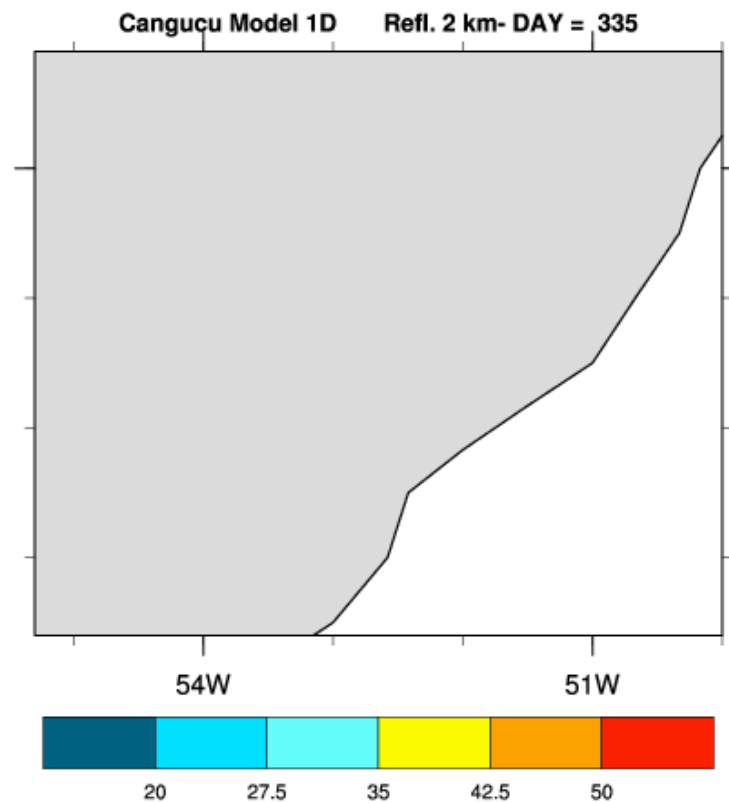
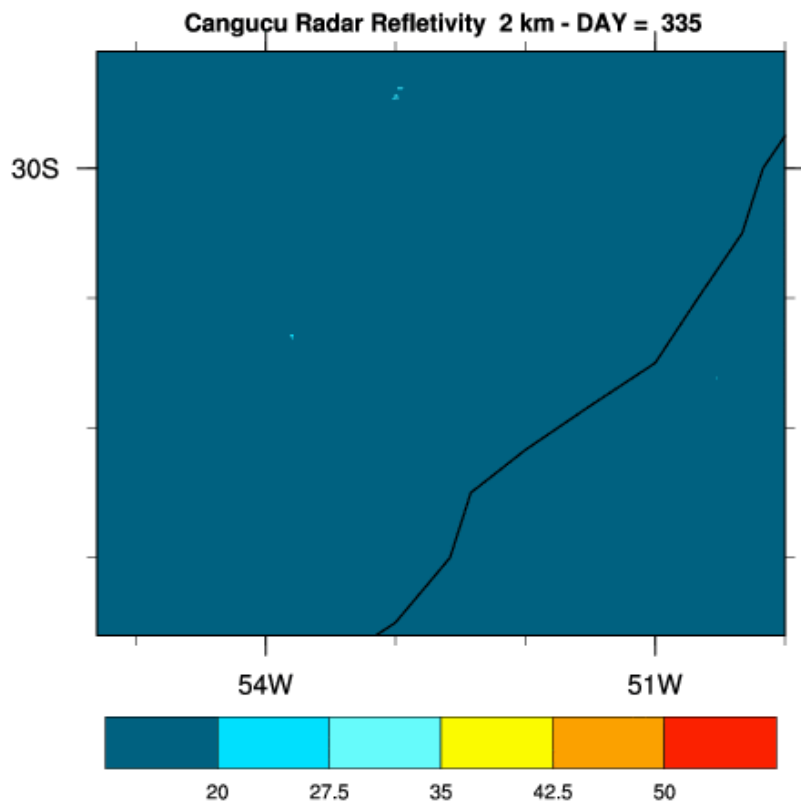
- the Meso-NH model by Bechtold et al. (2001) was activated for the 10 km grid, while convection was assumed to be explicitly resolved for the 2 km grid. From the model outputs, a large number of instruments can be emulated including satellite brightness temperatures (see Chaboureau et al., 2008, and references therein) and radar reflectivities (Richard et al. 2003).
- The model was run with the turbulence parameterization in 3D mode using the Deardorff mixing length and 1D mode using Bougeault and Lacarrère (1989) mixing length.

# Santa Maria CHUVA – MSG 11 microns and Simulation Model 1D Turbulence DAY=335 – 36 hours Simulation



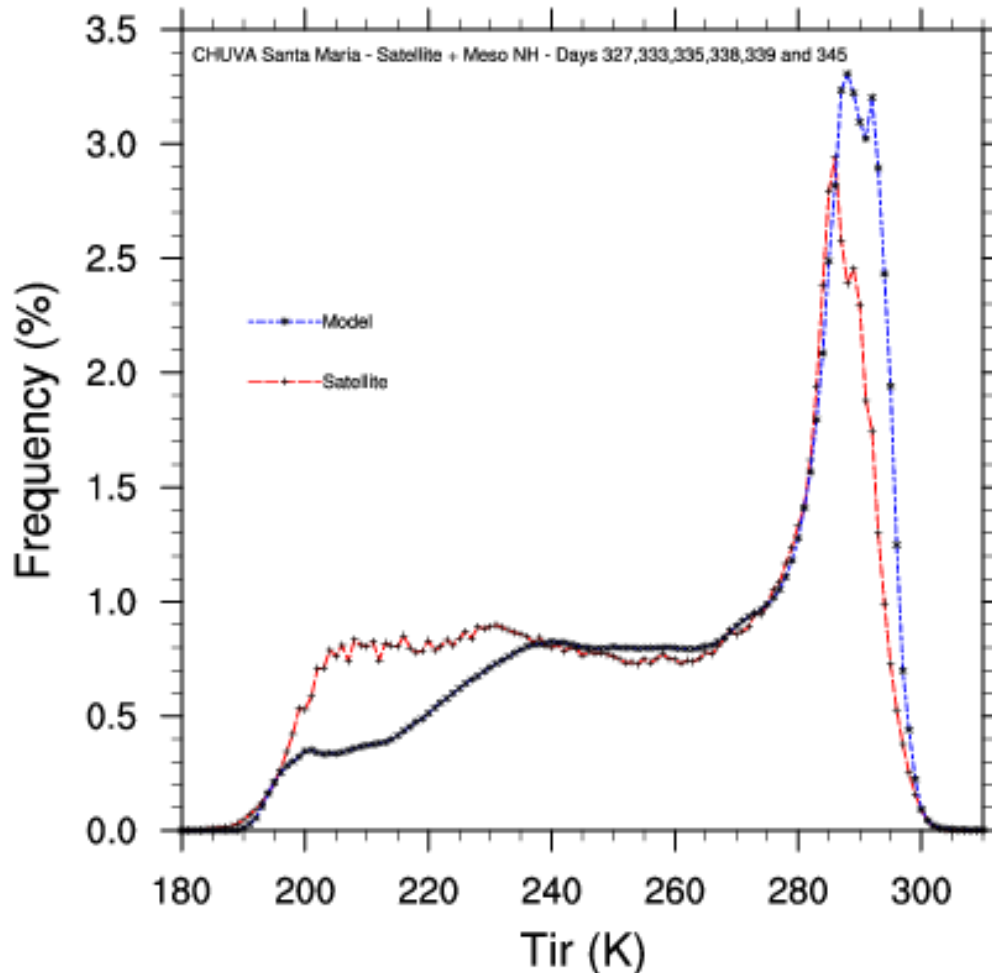
# Radar Canguçu

## CAPPI 2 km Reflectivity and Simulation Model Meso NH - 1D Turbulence DAY=335 – 36 hours Simulation (only Ref>20dBZ)



# Tir MSG 10.8 – The 6 Selected Days for CHUVA Sta Maria Meso NH Model 1D Turb. and MSG image (36 hours Simulation)

Hist. Brig. Temp. MSG10.8 - SAT and Model 36h Forecast

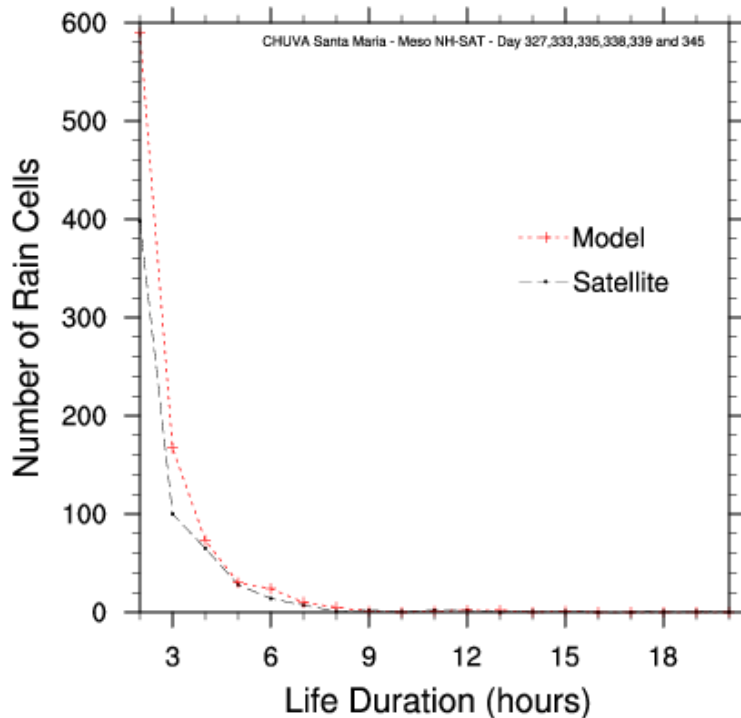


# Cloud Life Cycle Tir MSG 10.8 < 235K

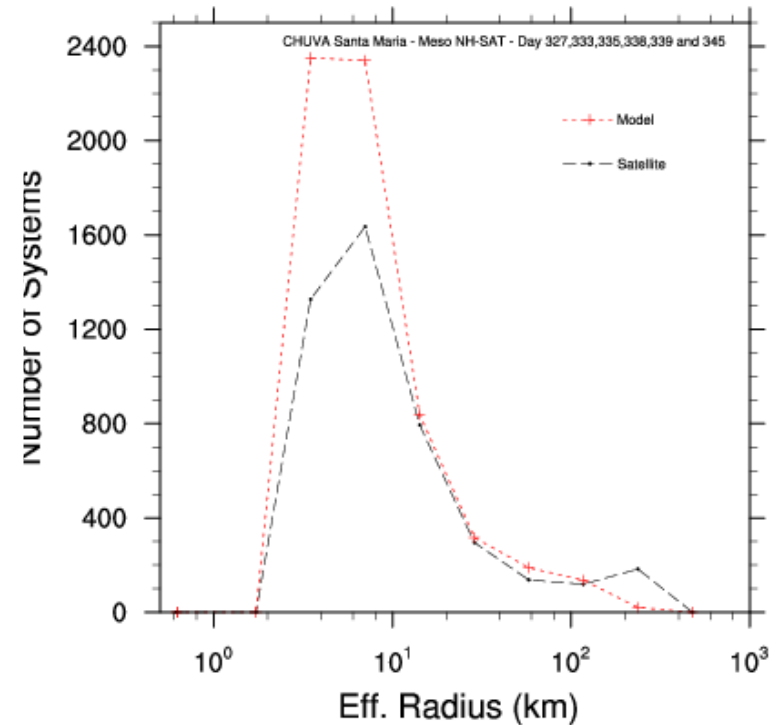
## The 6 Selected Days for CHUVA Sta Maria

### Meso NH Model 1D Turb. and MSG image (36 hours Simulation)

Cloud Org. Life Duration - Sat. and Model Tir<235K



Cloud Organization - Model - Satellite Tir <235K





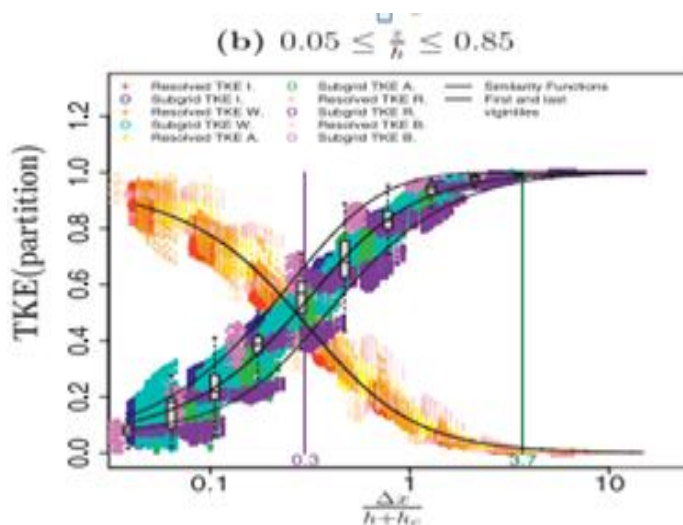
# What are the possible reasons?

- Larger number of small and short life cycle duration cells
- Do not reach the size of big cells observed in Satellite
- smaller population of cold top clouds.
- Small cells, simulated by the Model, have very deep cloud tops (will show)

**Possible Problem** – Entrainment is not well solved.

**Possible Solutions:** Sensitive Study of 1D and 3D Turbulence – change entrainment as function of size organization. Run with 200 meters (LES) – same resolution of X-Pol radar

Entrainment and turbulence explicit solved by high resolution Models



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## A Diagnostic for Evaluating the Representation of Turbulence in Atmospheric Models at the Kilometric Scale

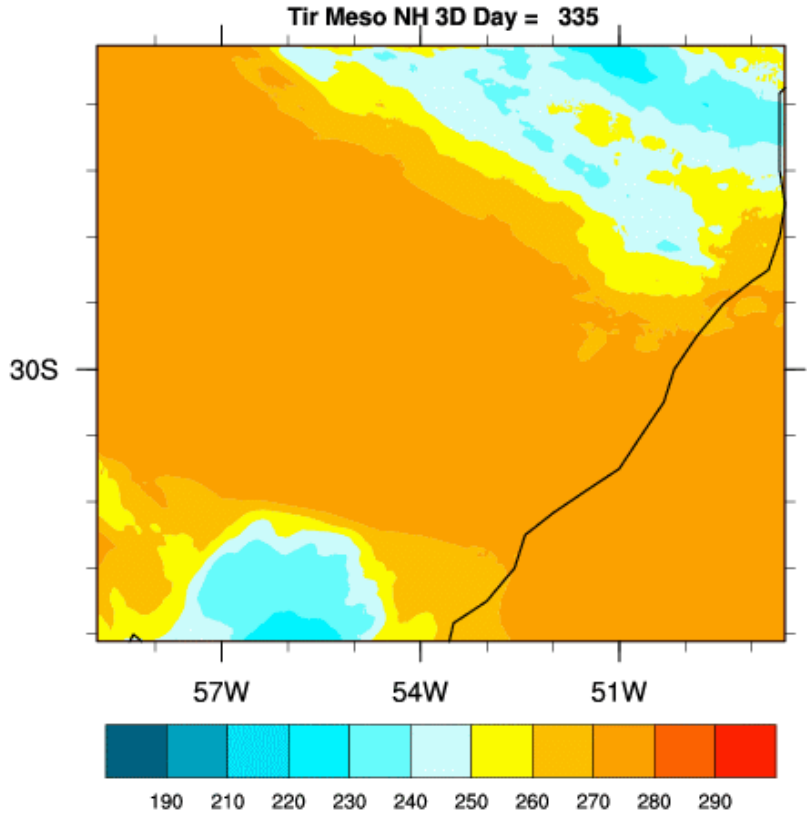
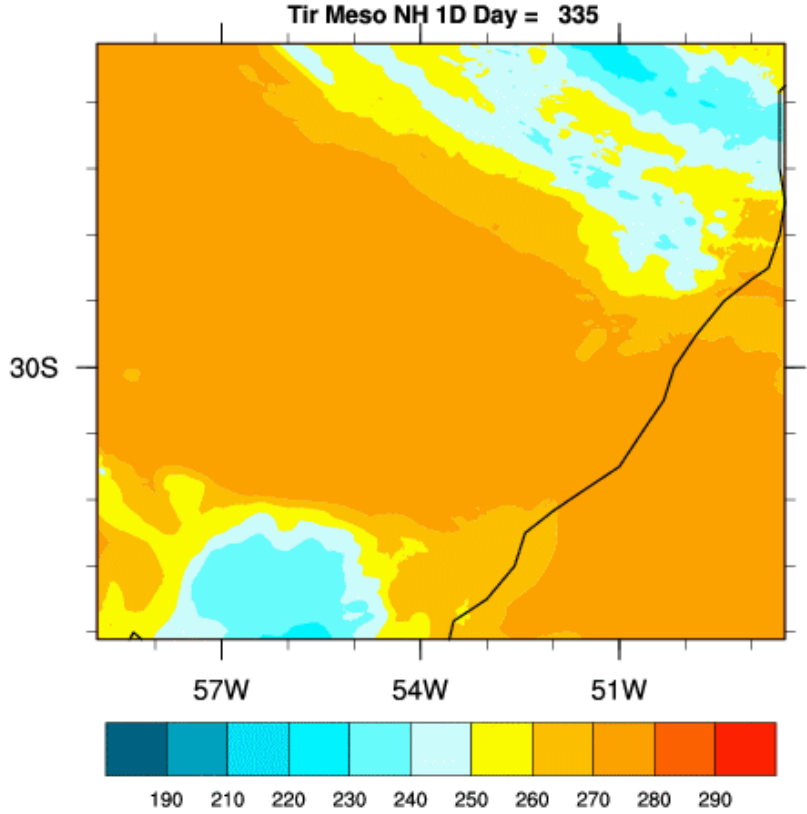
RACHEL HONNERT, VALÉRY MASSON, AND FLEUR COUVREUX

CNRM/GAME, Toulouse, France

FIG. 5. Partition of the resolved TKE (crosses; IHO: red, Wangara; orange, AMMA; yellow, ARM; pink, BOMEX; wheat) and subgrid TKE (circles; IHO: blue, Wangara; cyan, AMMA; green, ARM; purple, BOMEX; violet) as a function of the dimensionless mesh: (a) in the EZ and (b) in the ML. In the legend, I means IHO, A, means AMMA, W, means Wangara, B, means BOMEX, and R, means ARM. The vertical purple line represents the scale for which subgrid and resolved TKE have the same value. The black lines represent the partial similarity functions. The vertical dark green line is the scale for which the total TKE is more than 95% subgrid. The gray box-and-whiskers plots summarize the median and the variance of the resolved data per class of  $\Delta z/(h+h_c)$ . The gray line in (a) is the similarity function from (b). The fine black lines on both sides of the similarity functions are the first and the last quintiles of the data.

# Santa Maria CHUVA – MSG 11 microns - Simulation Model 1D and 3D Turbulence

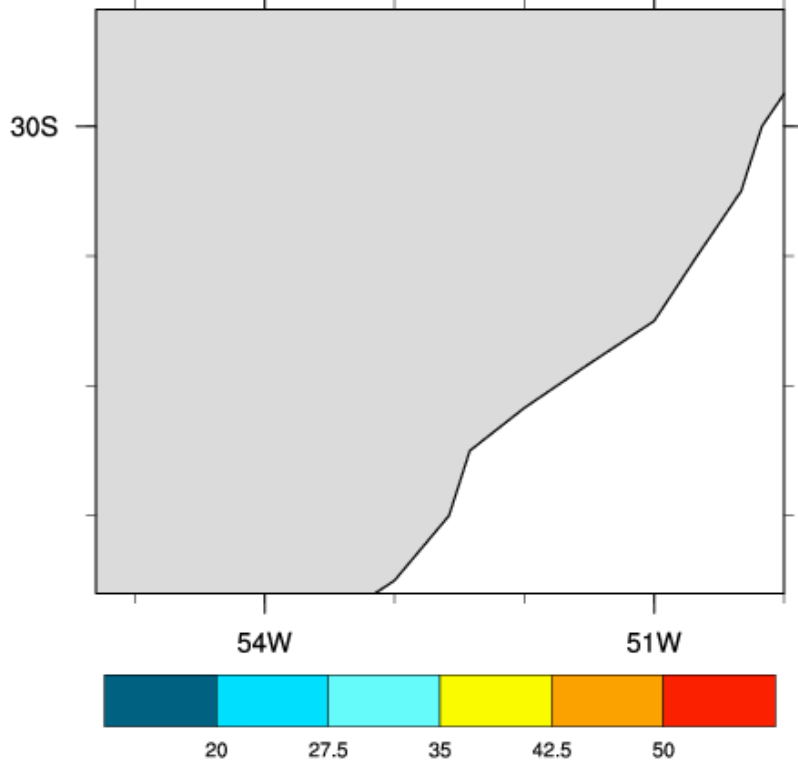
## DAY=335 – 36 hours Simulation



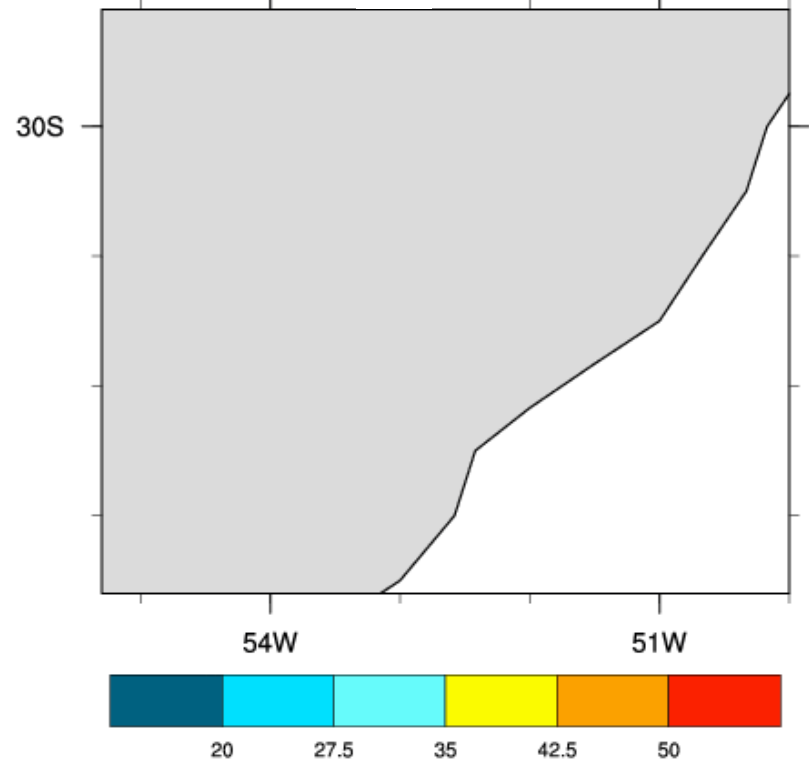
# Radar Canguçu

**CAPPI 2 km Reflectivity - Simulation Model Meso NH - 1D and 3D Turbulence  
DAY=335 – 36 hours Simulation (only Ref>20dBZ)**

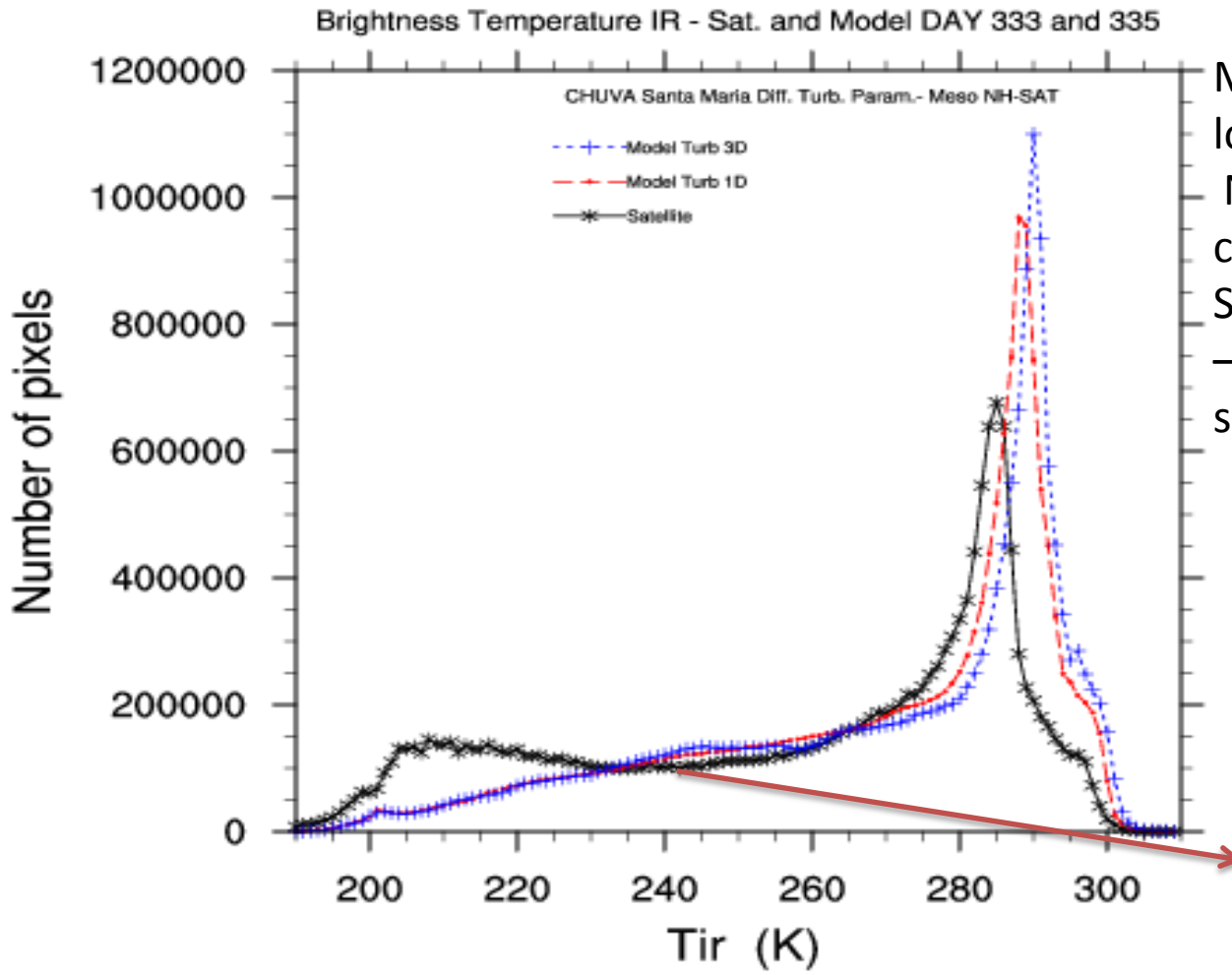
Canguçu Model 1D Refl. 2 km- DAY = 335



Canguçu Mode 3D Refl. 2 km- DAY = 335



# Brightness Temperature 10.8 – DAY 333 and 335 for CHUVA Sta Maria Meso NH Model 1D and 3D Turb. and MSG image (36 hours Simulation)

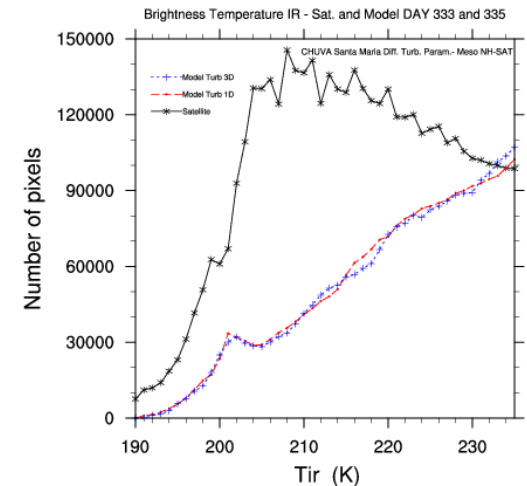


## 3D Effect

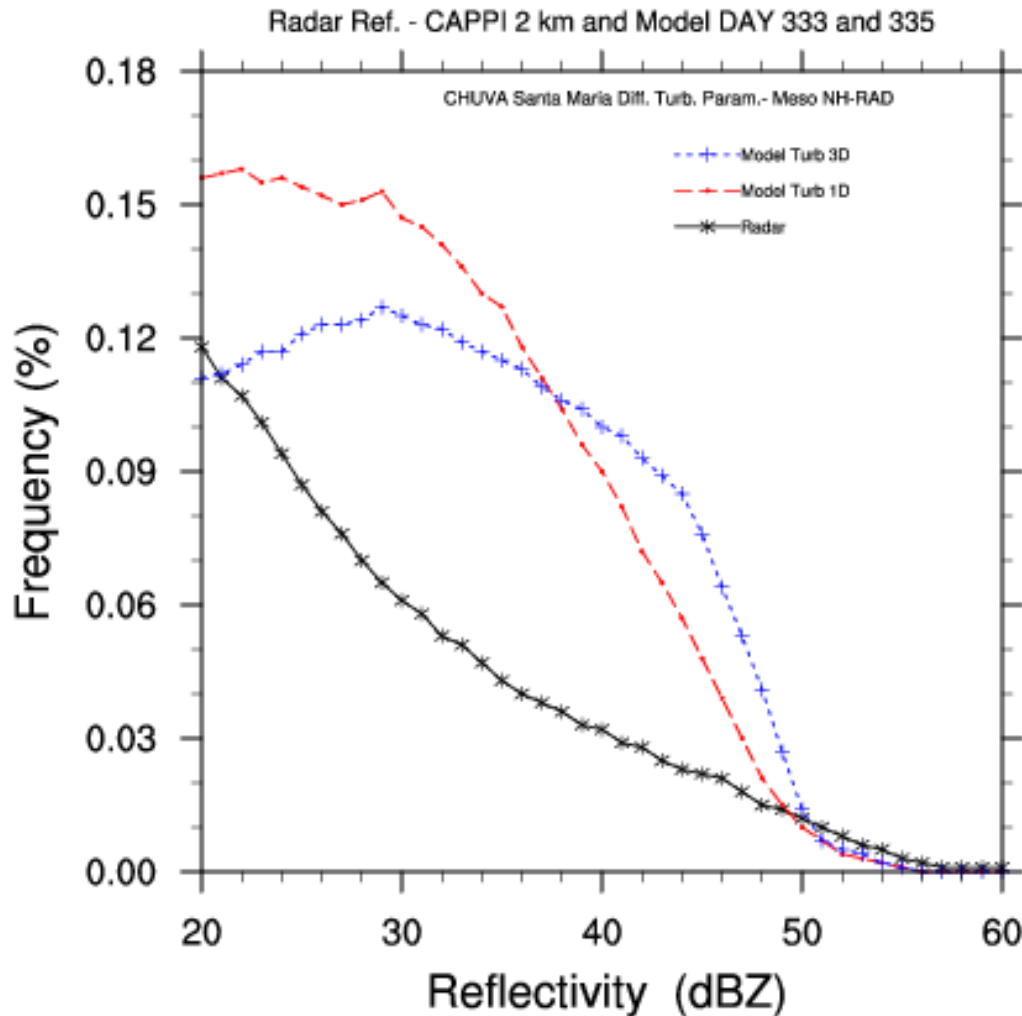
More clear sky and middle and low levels clouds.

Nearly no difference for Tir colder than 235K.

Satellite shows more cold clouds – Stratiform and Cirrus as we will see.



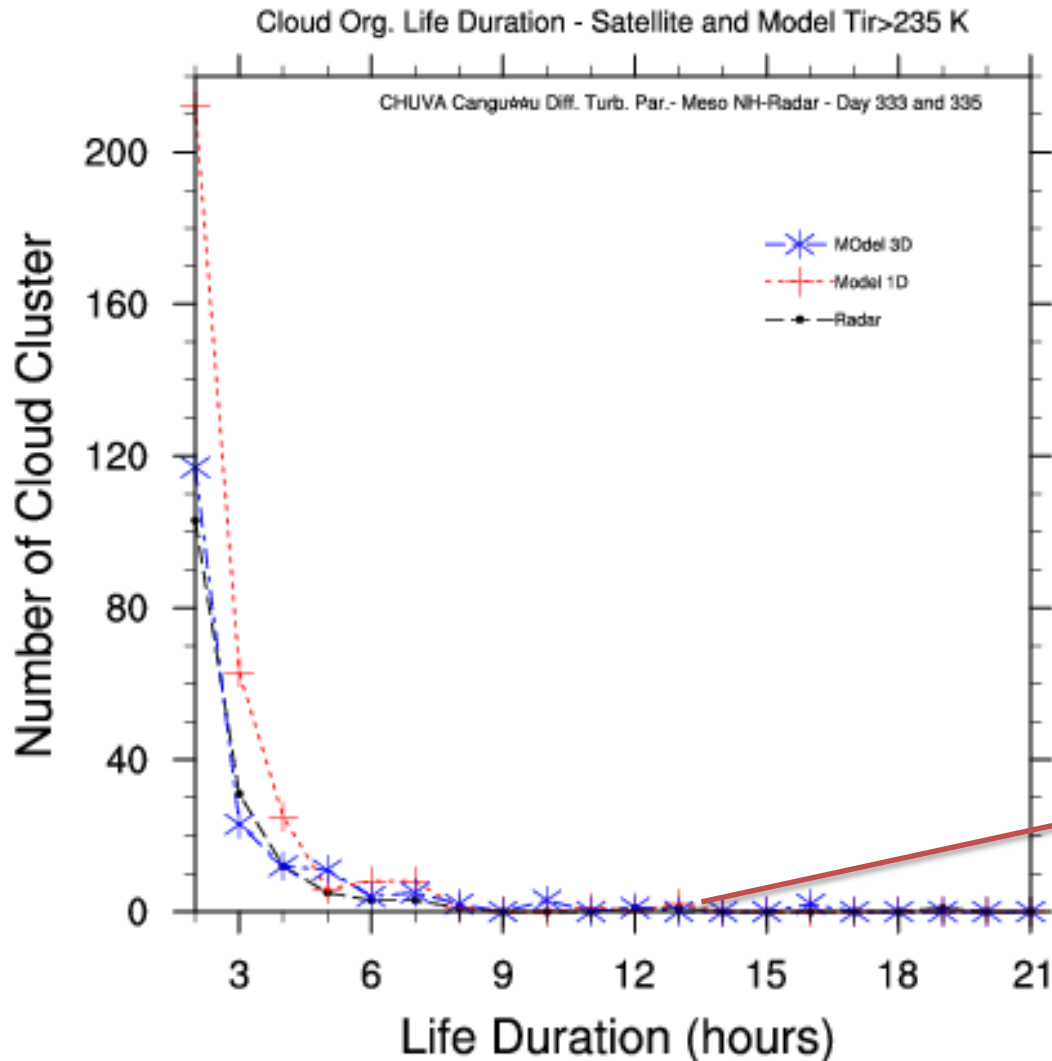
# DAY 333 and 335 for CHUVA Sta Maria Canguçu Radar CAPPI 2 km Reflectivity and Meso NH Model 1D and 3D Turb. (36 hours Simulation)



## 3D Effect

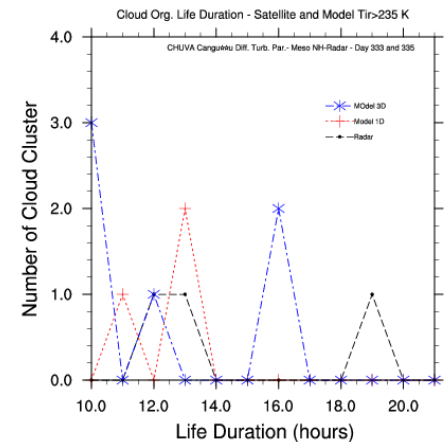
Model is very efficient in making rain droplets from cold radiances (moisture convergence). 3D reduce this effect for low ref. and intensify for large one.

# Brightness Temperature 10.8 – DAY 333 and 335 for CHUVA Sta Maria Meso NH Model 1D and 3D Turb. and MSG image (36 hours Simulation)

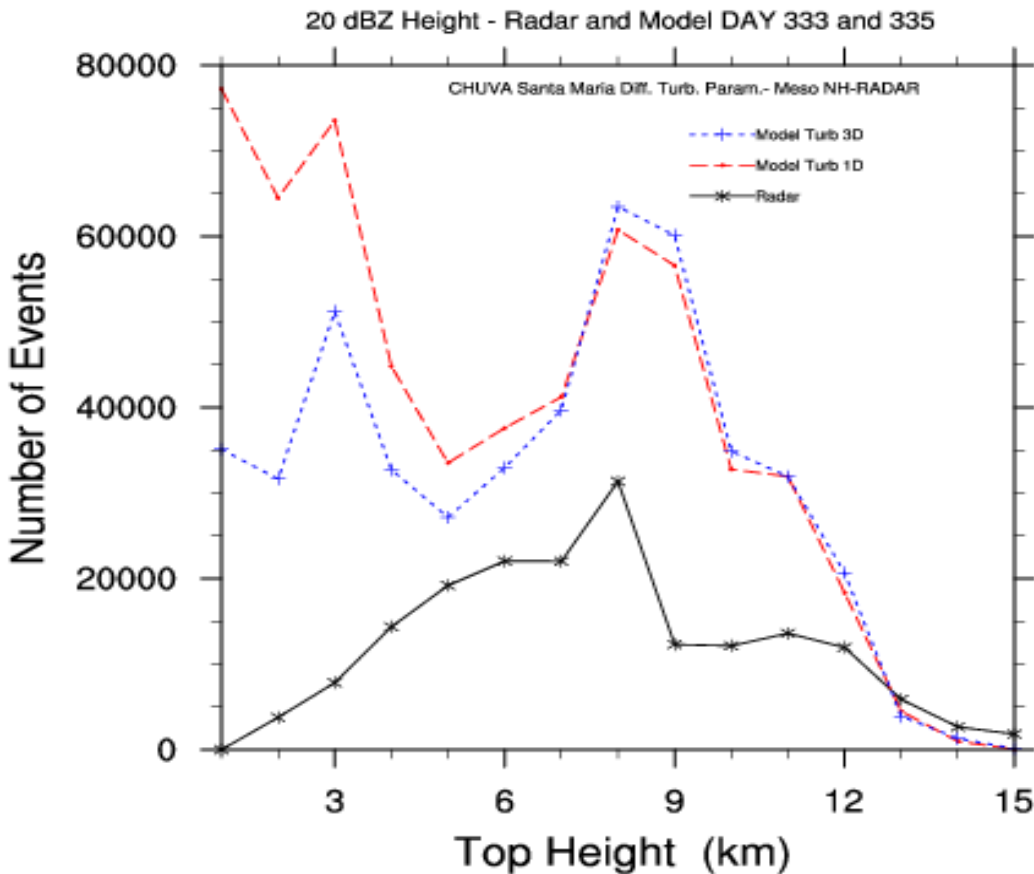


## 3D Effect

Distribution very close of the one observed by satellite.  
Increase life cycle duration of the large one and decrease of the smaller one



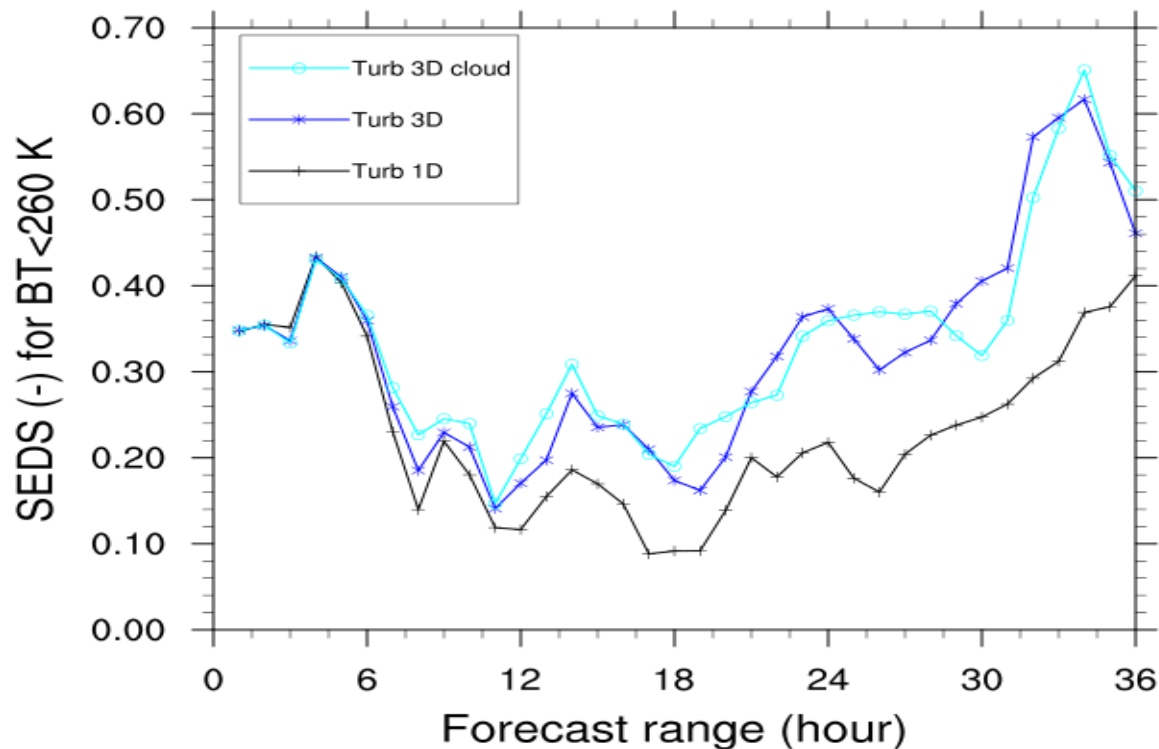
# Cloud Top Distribution



Model describes the maximum cloud top at around 8 km, in agreement with observation. Also the shape of the deeper cloud tops distribution agree very well with radar data observation.

Model produces more cells than observation. Model has a maximum population of low rain clouds that is not observed. 3D acts to reduce this population.

# Time evolution of a categorical score of $10.8 \mu\text{m BT} < 260 \text{ K}$



SEDS

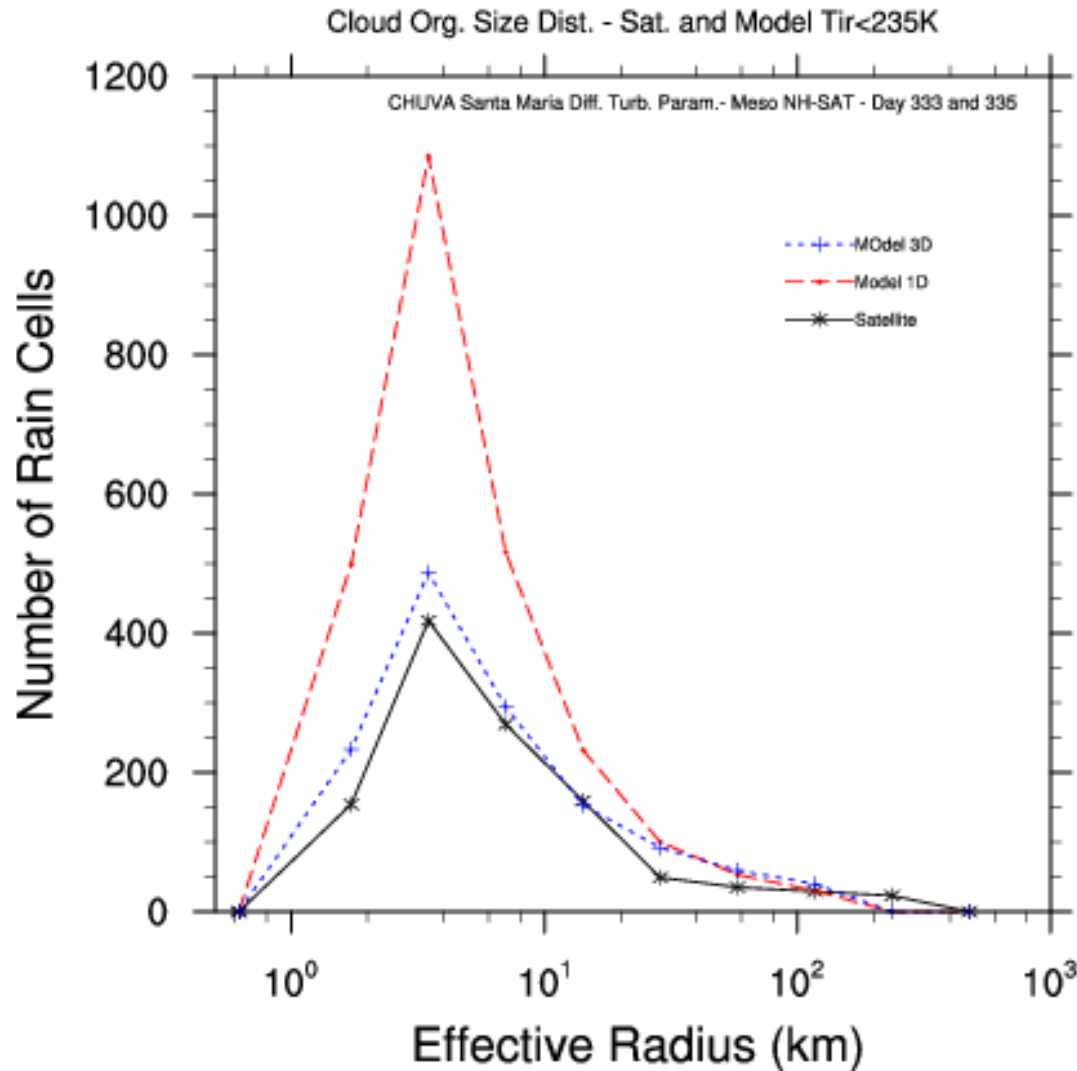
Symmetric Extreme  
Dependency Score.

**Day 335**

Larger the score, the better the forecast. Better forecasts are obtained when using the 3D turbulence scheme whatever the mixing length used inside the clouds.



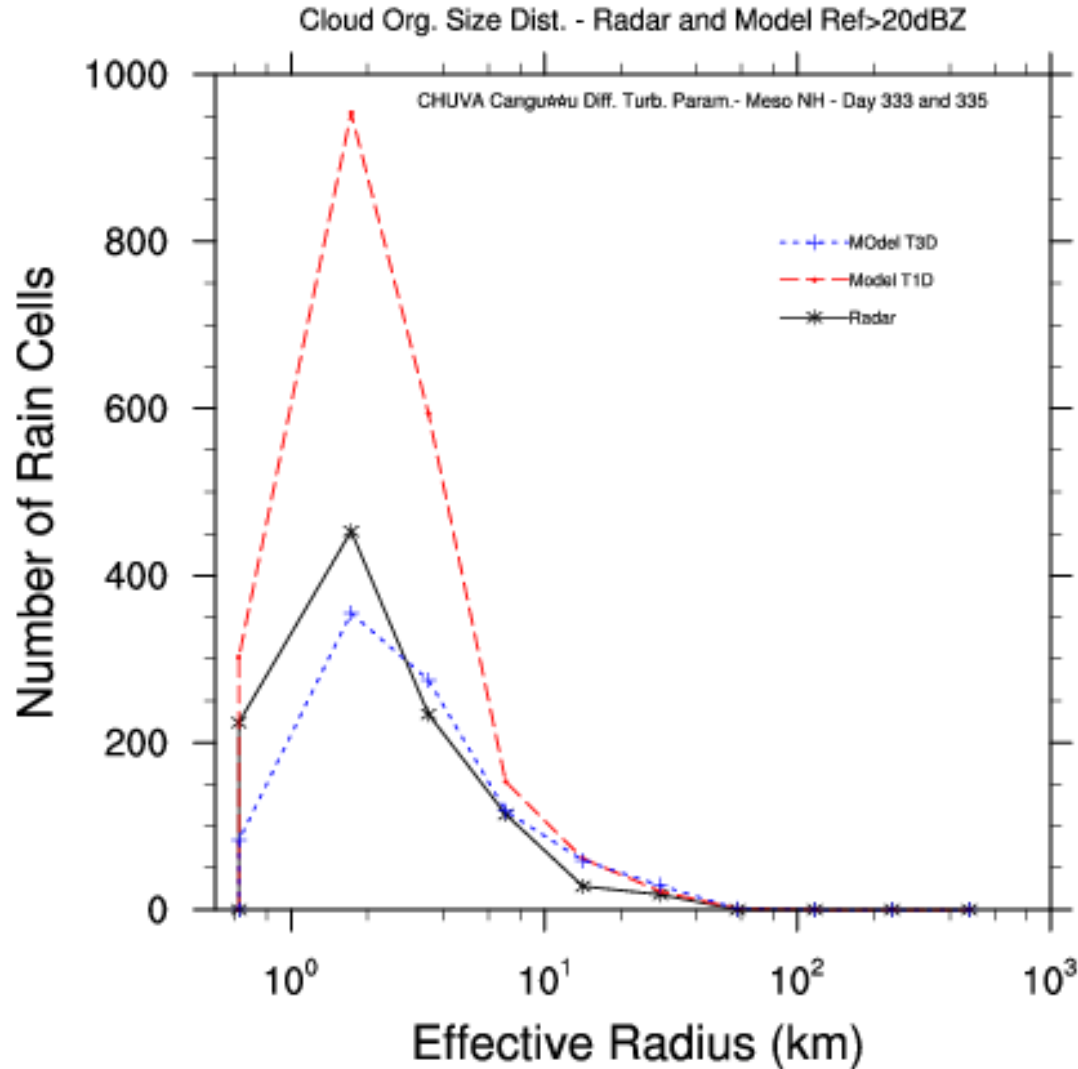
Brightness Temperature 10.8 – DAY 333 and 335 for CHUVA Sta Maria  
Meso NH Model 1D and 3D Turb. and MSG image (36 hours Simulation)



**3D Effect**

Decrease number of small cells do not act on the size of the large one.

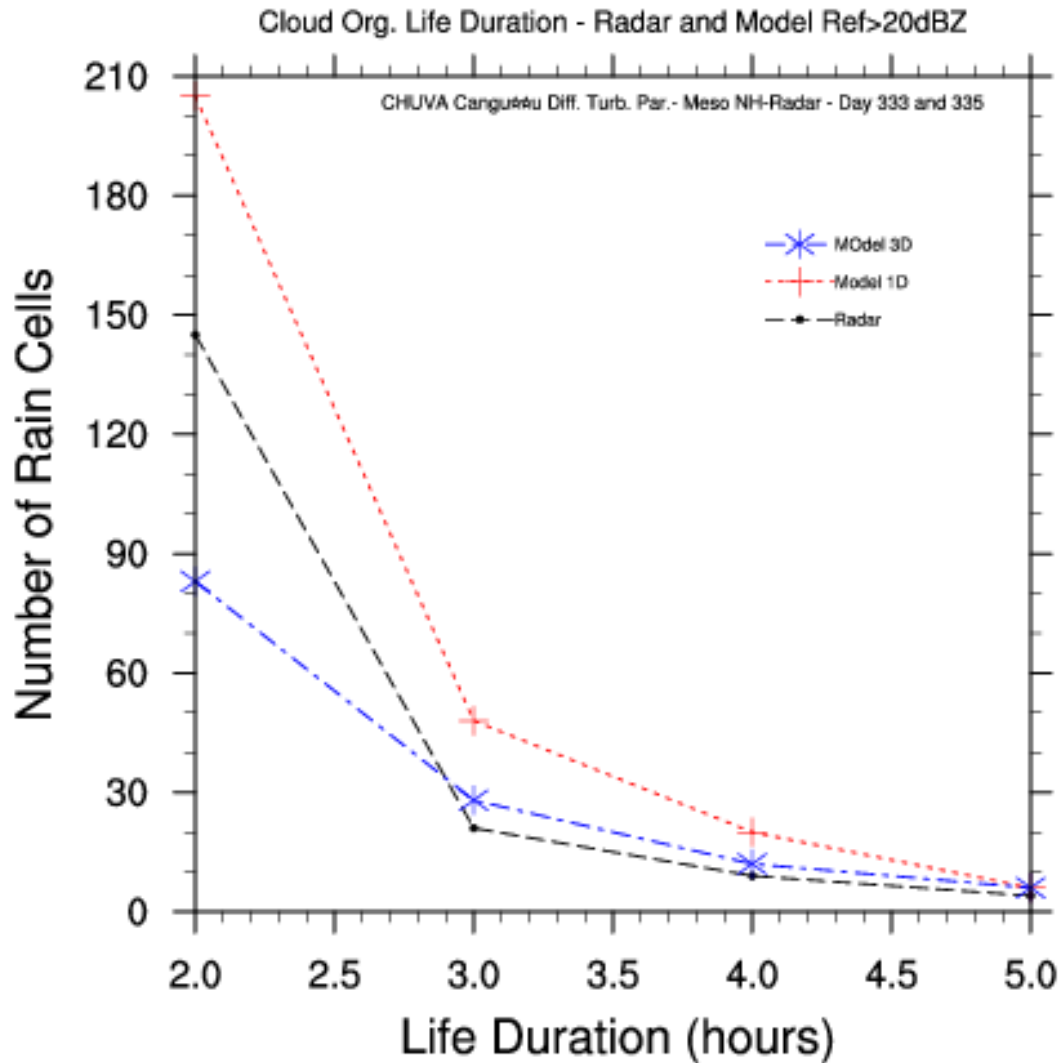
# DAY 333 and 335 for CHUVA Sta Maria Canguçu Radar CAPPI 2 km Reflectivity and Meso NH Model 1D and 3D Turb. (36 hours Simulation)



### 3D Effect

Distribution very close of the one observed by radar.  
Reduce the number of small rain cells

# DAY 333 and 335 for CHUVA Sta Maria Canguçu Radar CAPPI 2 km Reflectivity and Meso NH Model 1D and 3D Turb. (36 hours Simulation)

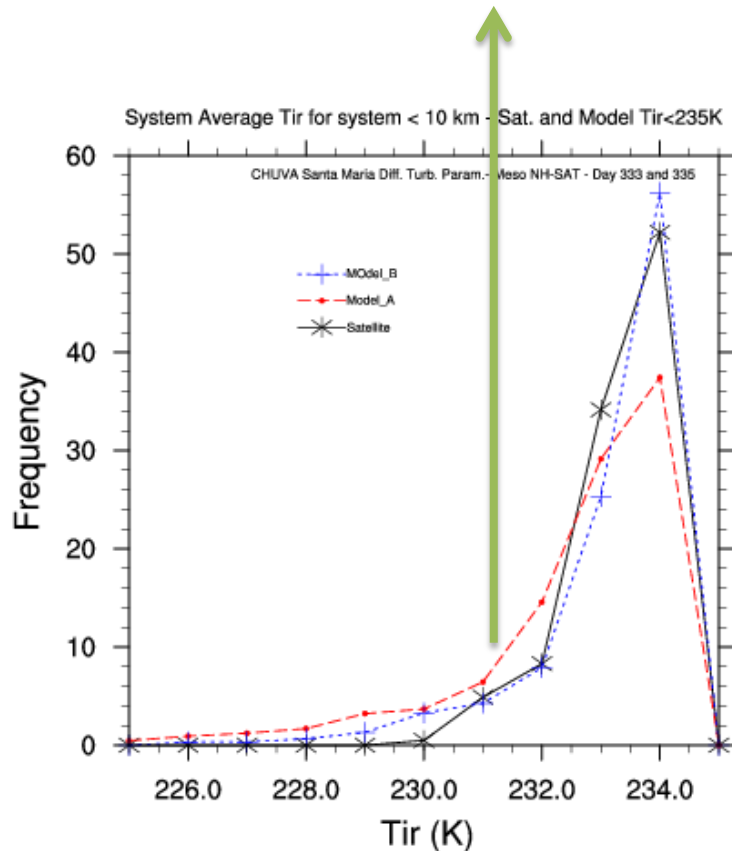


## 3D Effect

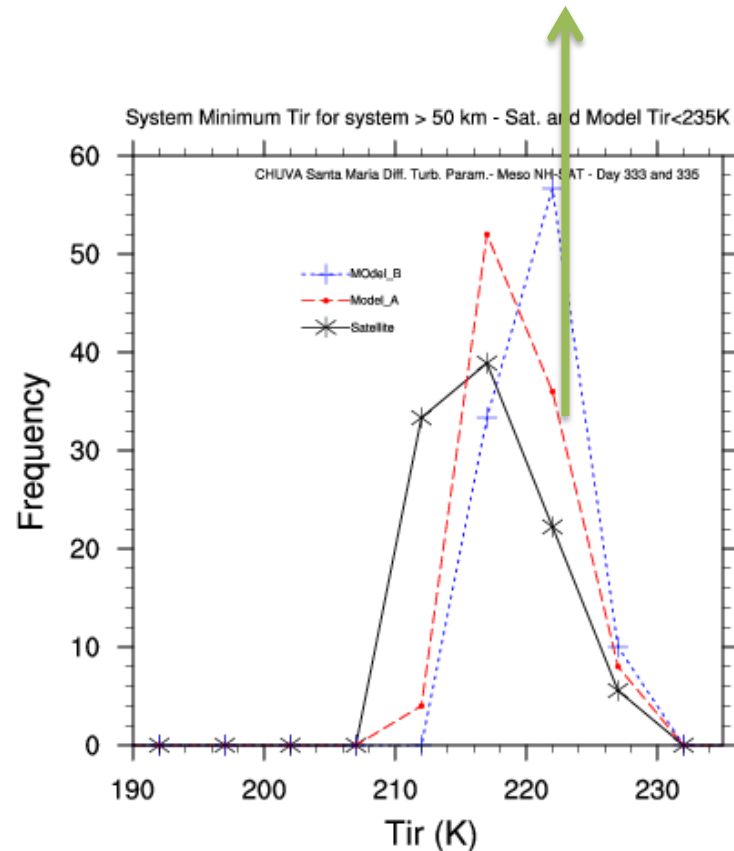
Distribution very close of the one observed by satellite.  
Decrease life cycle of short duration

# Average System Brightness Temperature for large and small cloud organization

Small Cells Model very deep :  
than observed



Large Cells Model less deep  
than observed, even more for 3D



# Conclusion

- Model produces more small cells and short life cycles and very deep than the one observed by satellite and radar.
- 3D Turbulence improve description of cloud organization in space and time. Does not change the general histogram of cold clouds ( $T_{ir} < 235K$ )
- A scheme taking into account size distribution could help improve the description for models having parameterized turbulence
- All set of images, already adjusted to the same grid is available for the Model intercomparison.

# Suggestion of Entrainment Adjustment as function of the cloud structure

