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Cloud life cycle investigated via high resolution and full microphysics simulations in the surrounding of Manaus, Central Amazonia

Theotonio Pauliquevis (1), Helber Barros Gomes (1), Henrique de Melo Jorge Barbosa (2)

(1) Departamento de Ciências Exatas e da Terra, Universidade Federal de São Paulo (UNIFESP), Diadema, S.P., Brazil; (2) Instituto de Física da Universidade de São Paulo (IFUSP), São Paulo, S.P., Brazil

Corresponding author: theotonio@gmail.com

ABSTRACT

In this study we evaluate the skill of WRF model to simulate the actual diurnal cycle of convection in the Amazon basin. Models typically are not capable to simulate the well documented cycle of 1) shallow cumulus in the morning; 2) towering process around noon; 3) shallow-to-deep convection and rain around 14h (LT). The fail in models is explained by the typical size of shallow cumulus (~0.5 – 2.0 km) and the coarse resolution of models using convection parameterization (> 20 km). In this study we employed high spatial resolution (Dx = 0.625 km) to reach the shallow cumulus scale. . The simulations corresponds to a dynamical downscaling of ERA-Interim from 25 to 28 February 2013 with 40 vertical levels, 30 minutes outputs, and three nested grids (10 km, 2.5 km, 0.625 km). Improved vegetation (USGS + PROVEG), albedo and greenfrac (computed from MODIS-NDVI + LEAF-2 land surface parameterization), as well as pseudo analysis of soil moisture were used as input data sets, resulting in more realistic precipitation fields when compared to observations in sensitivity tests. Convective parameterization was switched off for the 2.5/0.625 km grids, where cloud formation was solely resolved by the microphysics module (WSM6 scheme, which provided better results). Results showed a significant improved capability of the model to simulate diurnal cycle. Shallow cumulus begin to appear in the first hours in the morning. They were followed by a towering process that culminates with precipitation in the early afternoon, which is a behavior well described by observations but rarely obtained in models. Rain volumes were also realistic (~20 mm for single events) when compared to typical events during the period, which is in the core of the wet season. Cloud fields evolution also differed with respect to Amazonas River bank, which is a clear evidence of the interaction between river breeze and large scale circulation.

OBJECTIVES

MAIN

Investigate the diurnal cycle of convection in the Amazon basin. In particular, was given focus in the formation of shallow convection and its subsequent conversion in deep convection, with main emphasis on the correct representation using the WRF mesoscale model.

SPECIFIC

- From the sensitivity tests using the WRF model, define the best parameterization sets for the Amazon region.
- Evaluate the ability of the WRF model to simulate the atmospheric circulation patterns over Amazon region for a representative case study, with views in the seasonal scale simulations .

PARTNER INSTITUTION

UNIFESP – Universidade Federal de São Paulo – 1933

INPE

Universidad Nacional Autónoma de México – Por mi raza hablará el espíritu

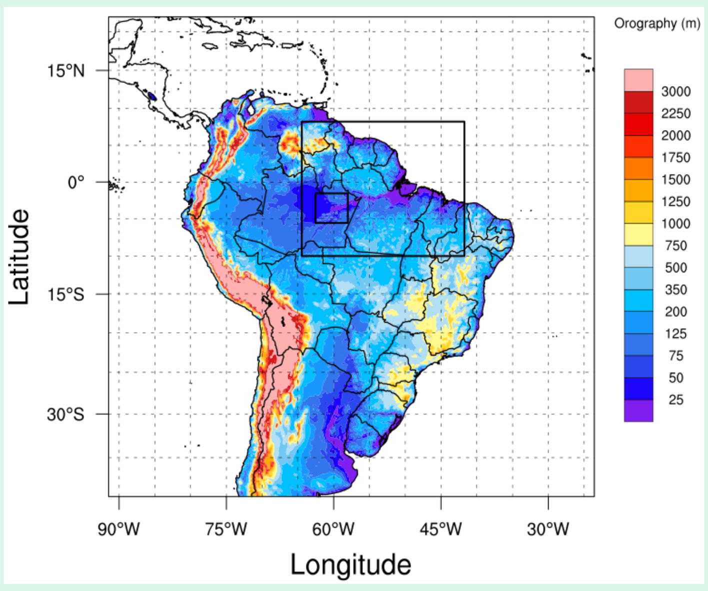
USP

INPA – Instituto Nacional de Pesquisas da Amazônia

UEA – Universidade do Estado do Amazonas

ACONVEX site: data for validation

Domains of simulations



Input data:

The initial and boundary conditions for WRF were provided by ERA-Interim reanalysis (Uppala et al. 2008). The ERA-Interim is the latest global atmospheric reanalysis produced by the European Center for Medium Ranger Weather Forecasting (ECMWF) are available on a 1.5° x 1.5° grid. To verify the cloudiness and synoptic systems associated with cloud patterns, the GOES-12 satellite images in the visible, water vapor and infrared channels were used to compare and validate simulations. To validate results of simulations it was employed analysis data from GFS/NCEP with 0.5° grid resolution and 4 daily outputs (6h/6h). In addition, corrected vegetation (USGS + PROVEG), albedo and greenfrac (computed from MODIS-NDVI + LEAF-2 land surface parameterization) maps (Beck et al. 2013) was used instead of the standard fields provided with the original WRF packet. Another improvement was the emplyment of pseudo analysis of soil moisture (GPNR), which is an operational product from CPTEC/ INPE.

Simulations/grids: Period: 25-28/Feb/2014

• 10 km – Solves the large-scale weather systems.

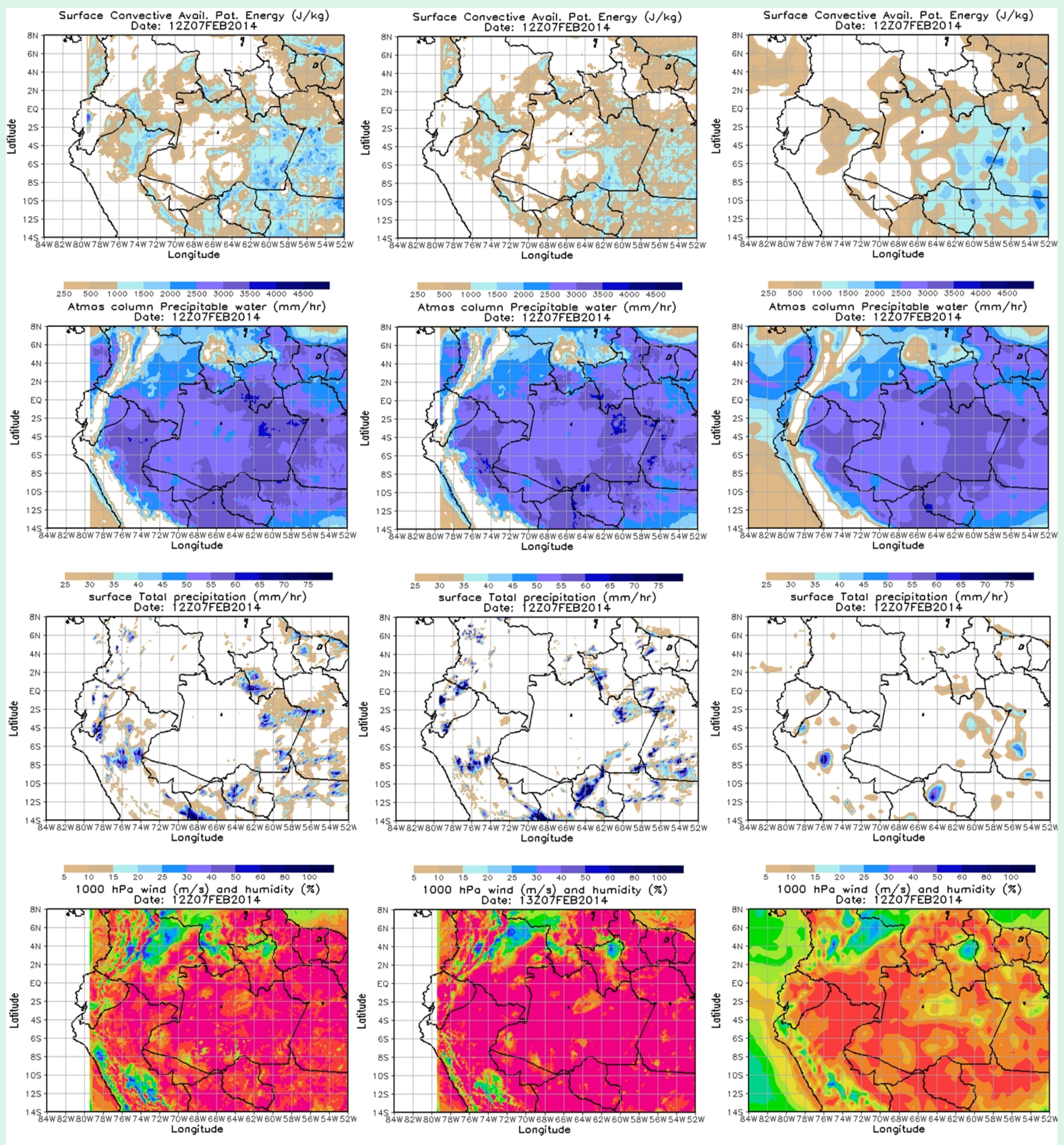
• 2.5 km – Simulates the known mechanisms of finer scale, which are responsible for the cloud formation in the region such as the propagation of squall lines from the eastern portion of the basin that move westward, from the Atlantic to Central Amazonia.

• 0.625 km – This is the finest grid. It is centered in the urban Manaus area, and it reaches both sites of GoAmazon and CHUVA projects.

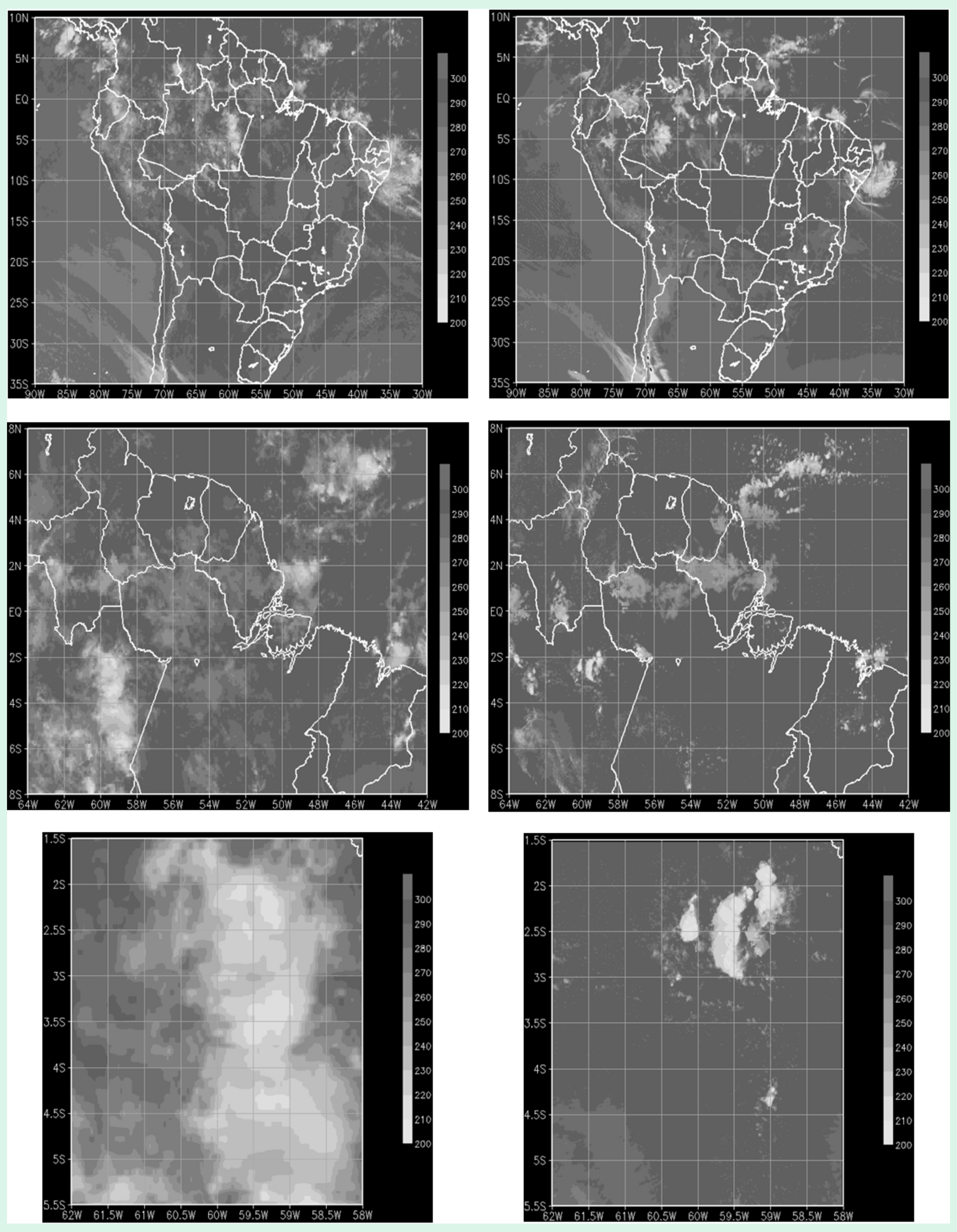
Sensitivity Tests Period: 07-09/02/2014

EXP	CUMULUS	MICROPHYSICS	RADIATION	SOIL MOISTURE
1	BM	WSM5	GFDL	Default
2	BM	WSM6	GFDL	Default
3	BM	WSM6	RRTMG	Default
4	GR	WSM5	GFDL	Default
5	GR	WSM6	GFDL	Default
6	GR	WSM6	RRTMG	Default
7	KF	WSM5	GFDL	Default
8	KF	WSM6	GFDL	Default
9	KF	WSM6	RRTMG	Default
10	**BM**	**WSM6**	**RRTMG**	**Obs soil mositure + Megan**
11	**GR**	**WSM6**	**RRTMG**	**Obs soil mositure + Megan**
12	**GR**	**WSM6**	**RRTMG**	**Obs soil mositure + Megan - 36hs**

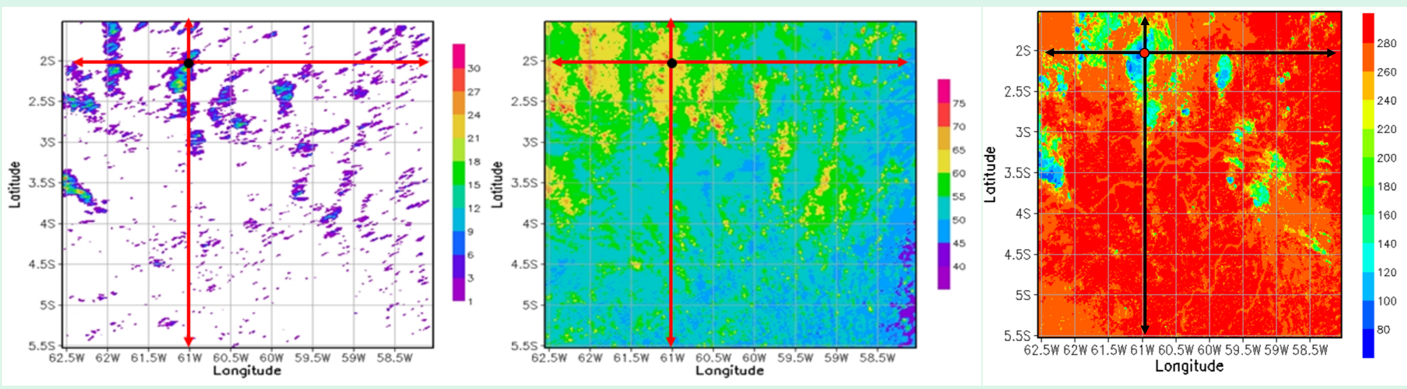
RESULTS



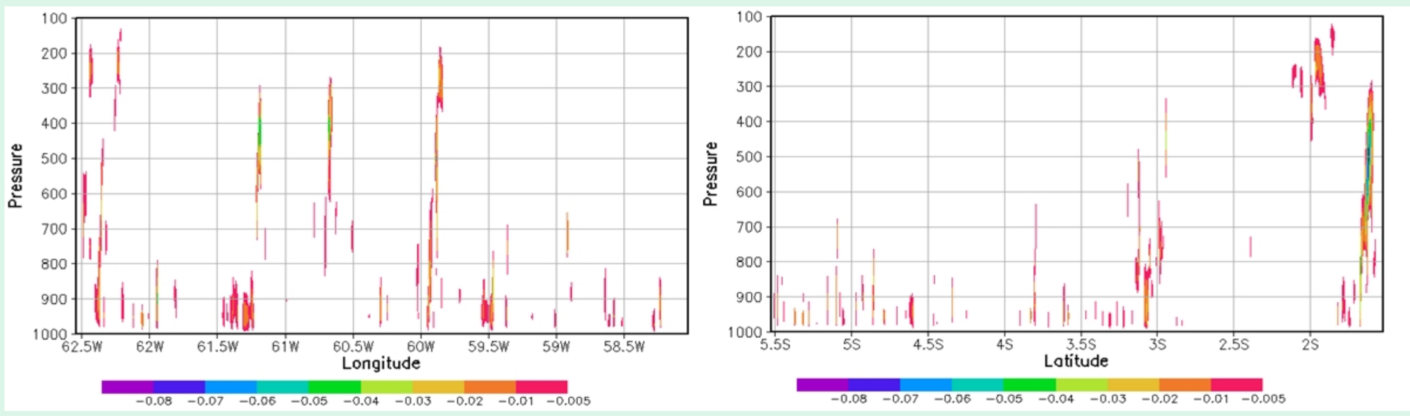
CAPE (first line), IPW (second line), precipitation (third line) and humidity at 1000 hPa (fourth line) for the highest (left column) and worst (center column) result of WRF model and GFS analysis (right column) for the 07 February 2013 at 12 UTC.



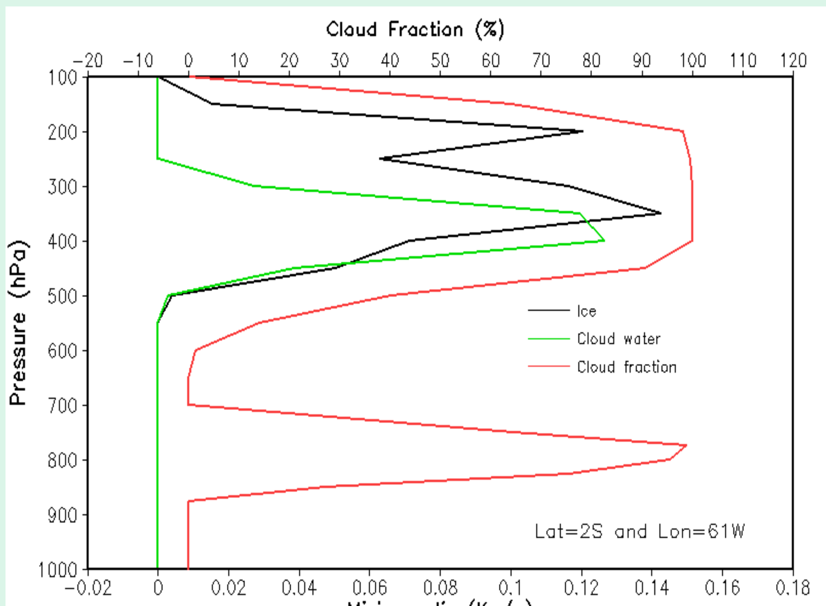
Infrared brightness temperature from the GOES-12 satellite (left column) and estimated by WRF model (right column) for the 03/07/2013 14 UTC. (first line) 10 km, (second line) 2.5 km e (third line) 0.625 km.



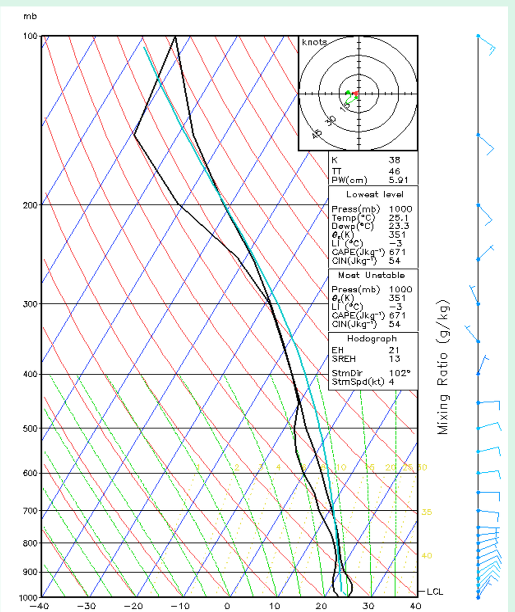
Precipitation (left column), IPW (center column) and OLR (right column) from WRF model on the 0.625 km grid for the 28th February 2013 16 UTC. Unit: mm/hr.



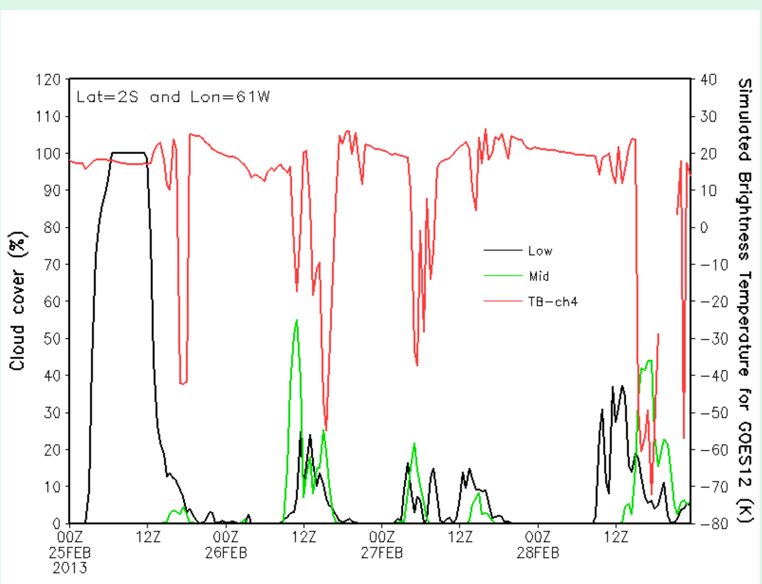
Vertical cross-section of vertical velocity along 2.0° S (left column) and 61° W (right column) from WRF model on the 0.625 km grid for the 28th February 2013 16UTC. Unit: Pa/s*10E-4.



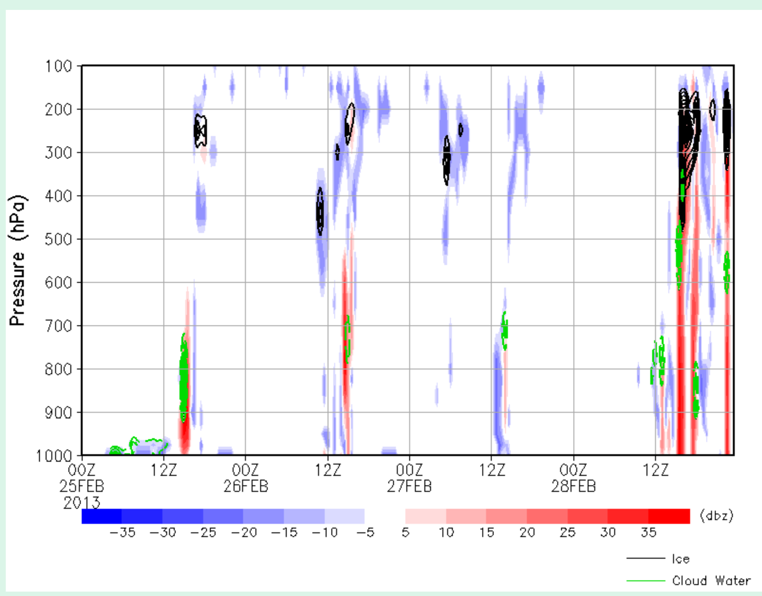
Vertical profiles of mixing ratio (kg/g) and total fraction (%) along 2.5° S and 61° W for the 28th February 2013 16UTC. Lines: Black (ice mixing ratio), green (cloud mixing ratio) and red (cloud fraction).



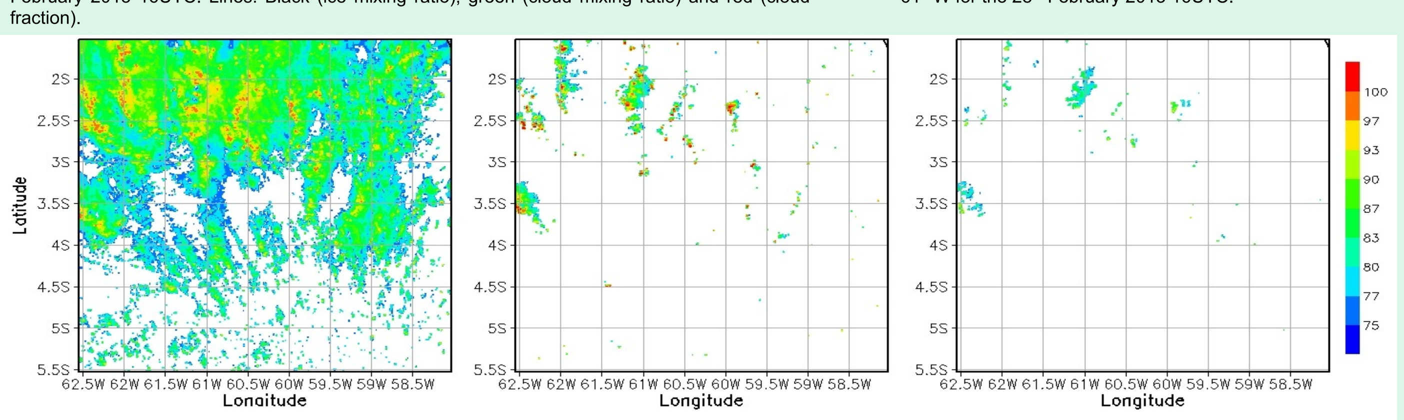
Skew-T - Log P thermodynamic diagram along 2.5° S and 61° W for the 28th February 2013 16UTC.



Diurnal cycle of cloud cover (%) and brightness temperature estimated (k) by WRF along 2.5° S and 61° W in the period 25-28th February 2013. Lines: Black (low clouds), green (mid clouds) and red (brightness temperature, channel 4).



Diurnal cycle of vertical profiles along 2.5° S and 61° W of radar (dbz, shaded), ice (black contours) and cloud water (kg/kg, green contours) in the period 25-28th February 2013.



Cloud cover estimated by relative humidity of particular layers for the 28/02/2013 16UTC. Low (1000-650 hPa, eft column), mid (600-400 hPa, center column) and high cloud (350-200 hPa, right column). Display shades only where relative humidity is over 75%.

CONCLUSION: From the sensitivity tests with the WRF model it was possible to define the best parameterization sets for the 3 nested grids and evaluate their ability to simulate the circulation patterns and spatial distribution of precipitation through case study. Preliminary results showed that in the whole context WRF fields fitted quite well with analysis. Features as circulation patterns (at all levels of atmosphere), spatial distribution of precipitation and cloudiness presented a good agreement with observations. Diurnal cycle of convection, which is commonly a trick problem in several models dealing with convection in the tropics, as shown in lat/lon figures, appeared naturally without any extra forcing. It shows that the correct choice of microphysics, soil moisture and correct surface scheme associated with an adequate resolution were sufficient to make natural convection arise in cloud fields, and its associated quantities. Nevertheless, some bias also appeared: it was observed a tendency to underestimate low clouds amount, and it slightly anticipates the convection. These differences deserve more efforts, which are the next steps of this research.

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