Forecast and Tracking of Active Cloud Clusters (ForTrACC) using Satellite Infrared Imagery

Daniel Vila

CICS/ESSIC – UMCP

colaborators: Luiz Augusto Machado, Henri Laurent and Ines Velasco

- **OUTLINES**
    - THE FORTRACC TECHNIQUE
        - MAIN ALGORITM DESCRIPTION – TRACKING MODULE
        - SOME CHARACTERISTICS OF SOUTH AMERICAN MCS
    - MCS LIFE CYCLE AND PRECIPITATION: URUGUAY BASIN APPLICATION
    - THE FORTRACC TECHNIQUE – NOWCASTING MODULE
    - CONCLUSIONS

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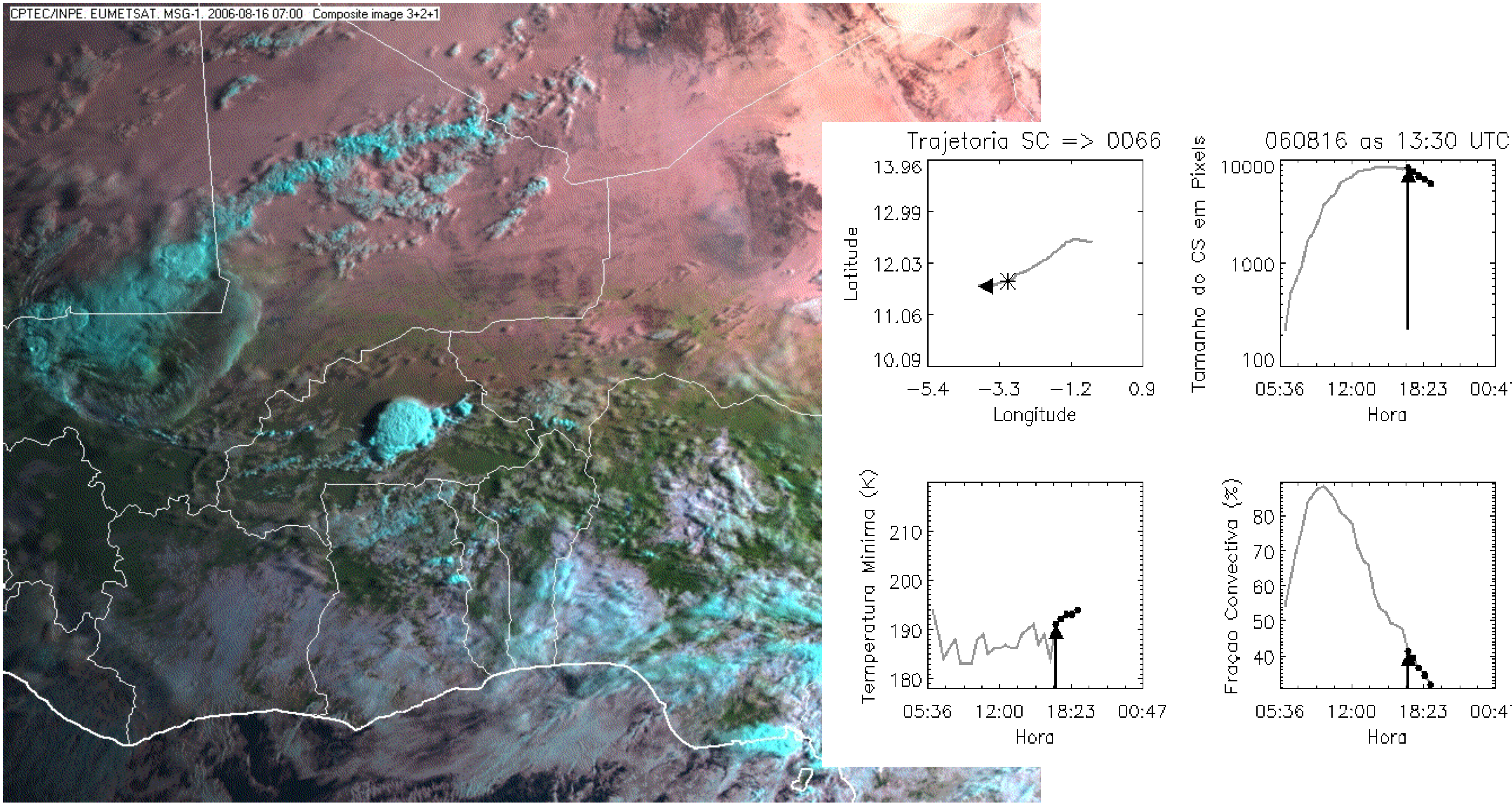

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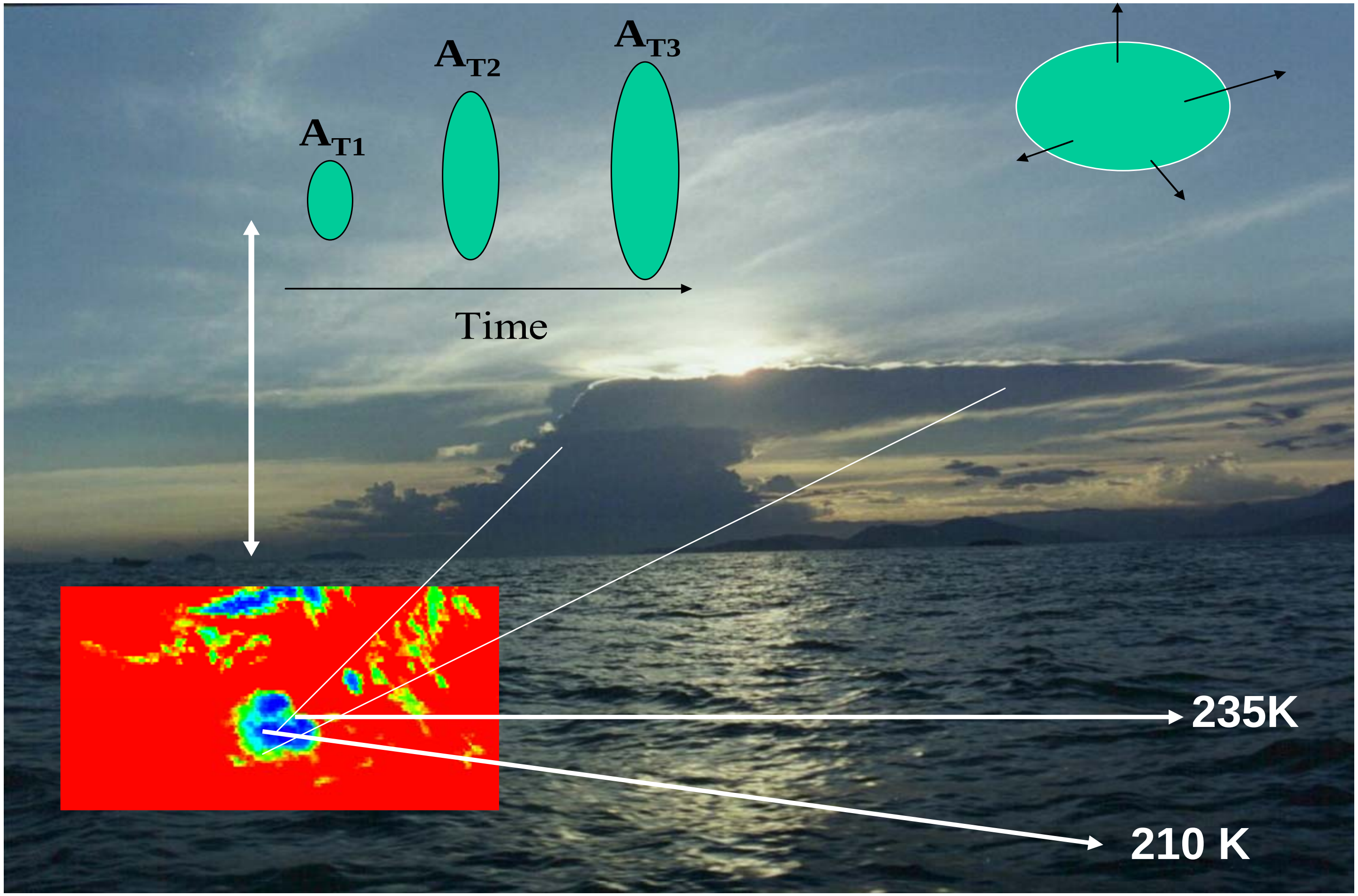
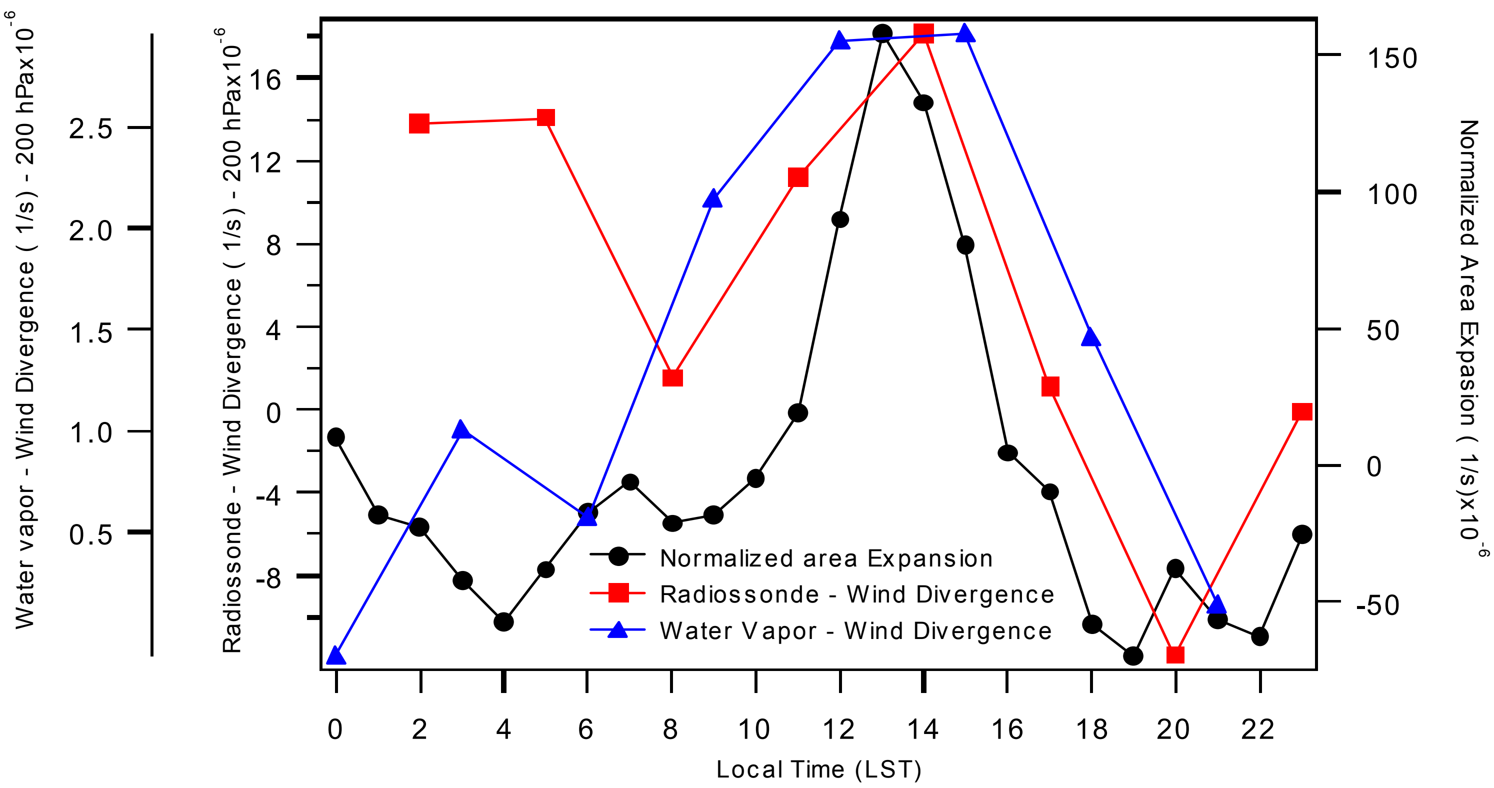


A_{T1}
A_{T2}
A_{T3}
Time
235K
210 K



Hourly average area expansion, water vapor wind divergence and wind divergence from radiosonde for 200 hPa level at WETAMC/LBA region.

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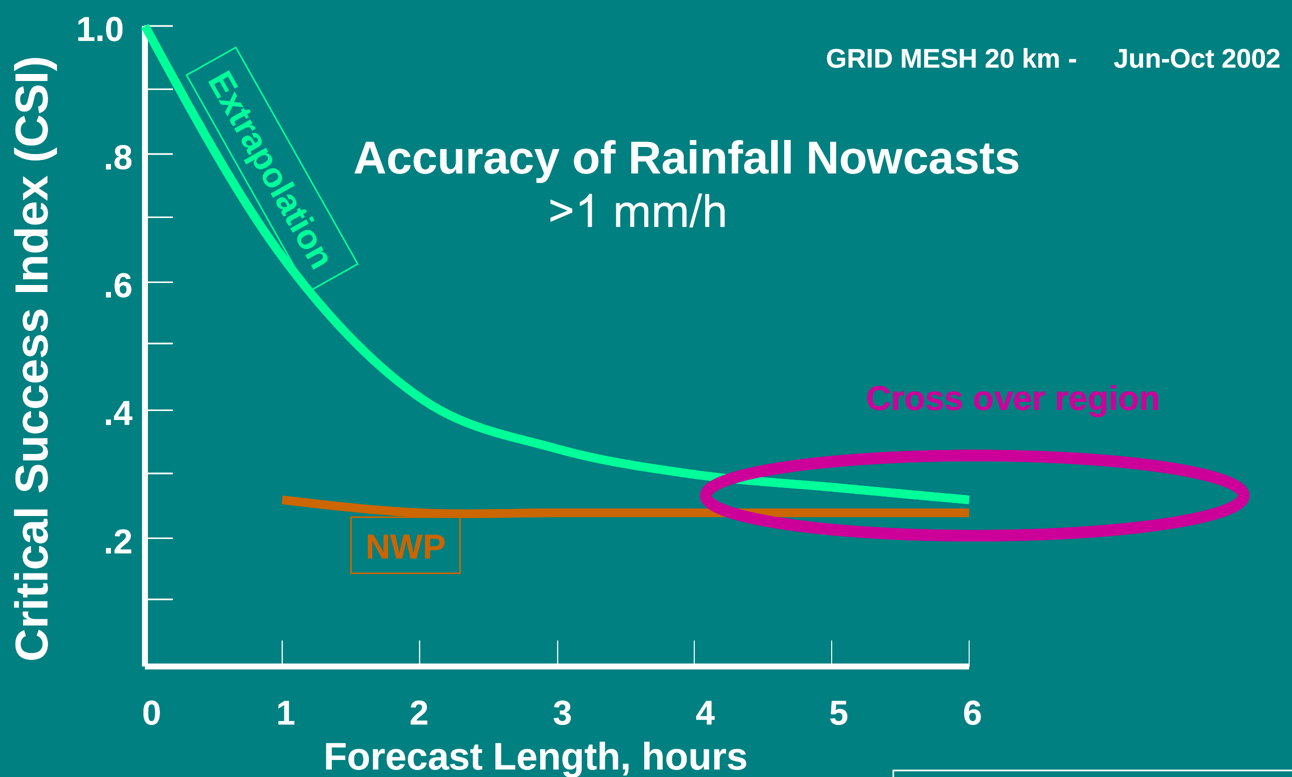
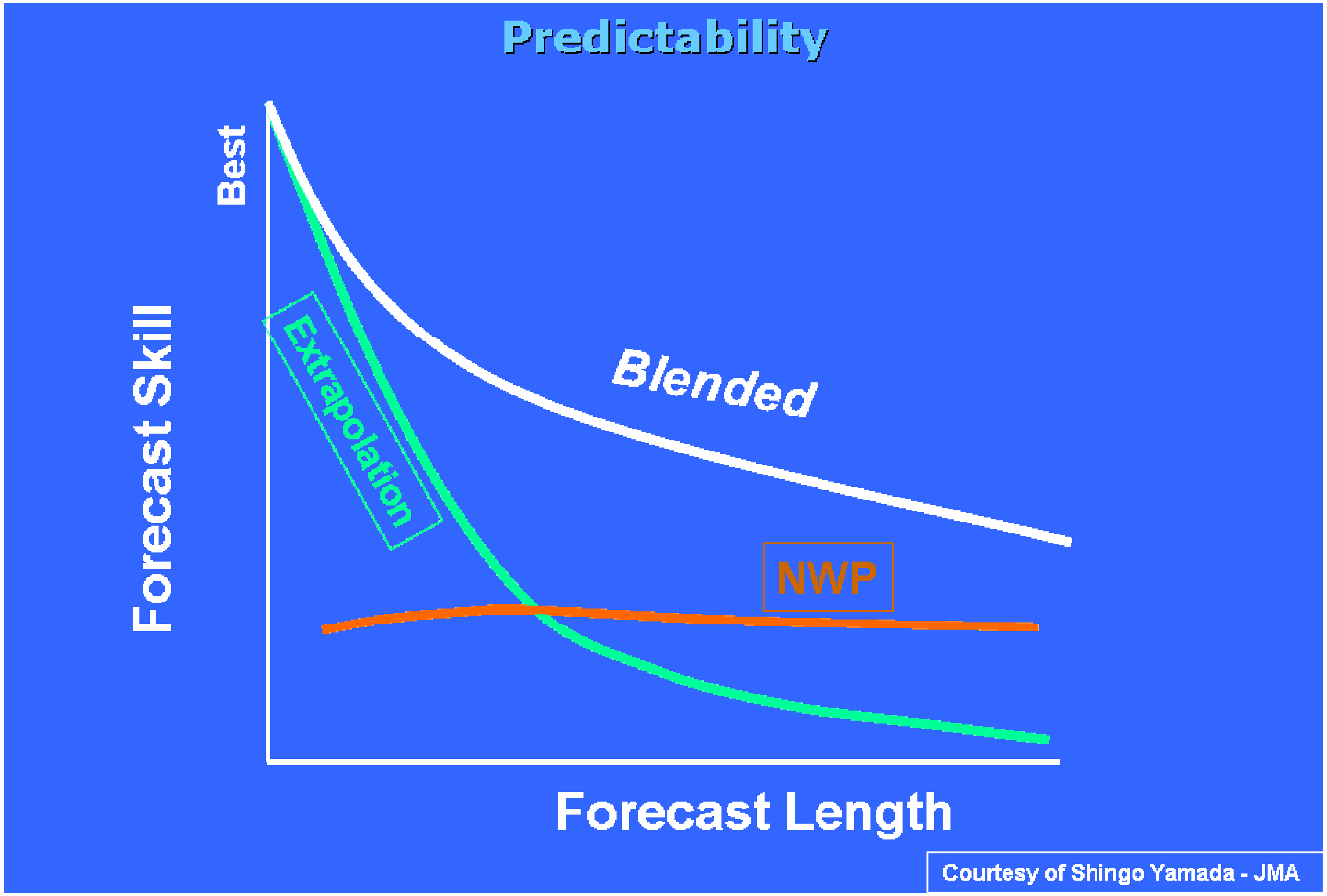
Predictability



Courtesy of Shingo Yamada - JMA



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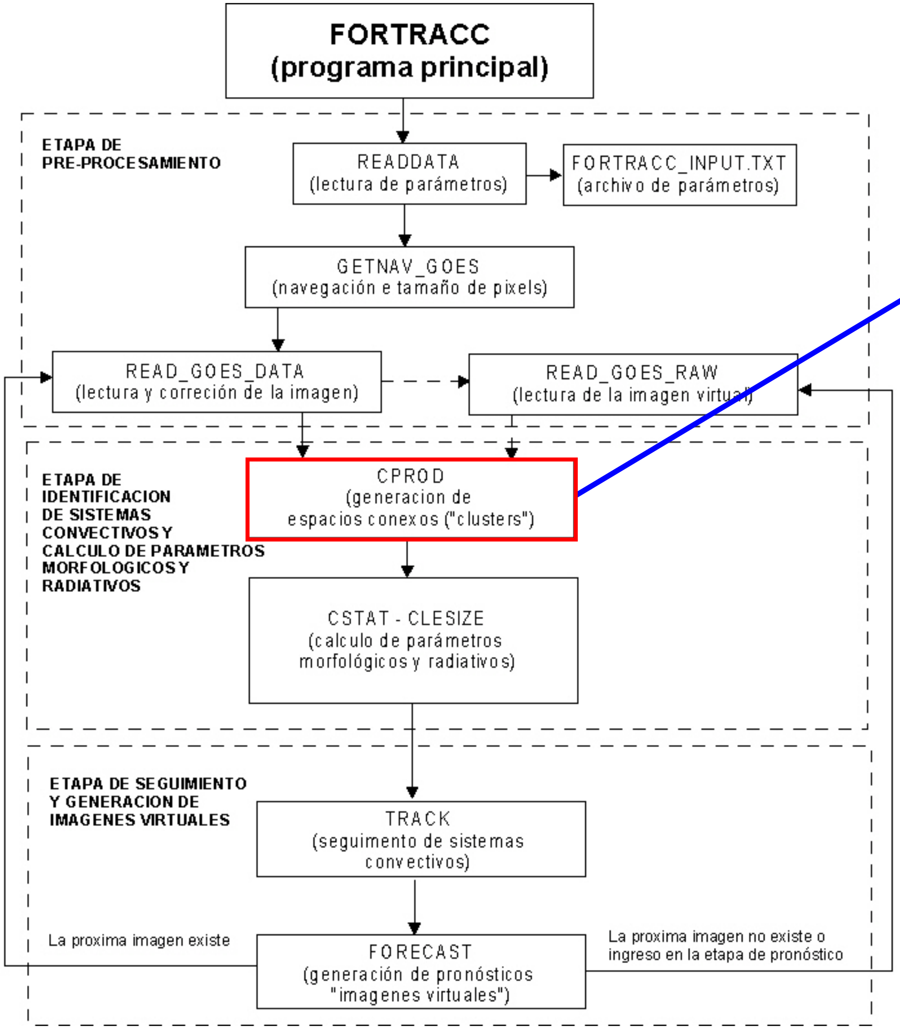

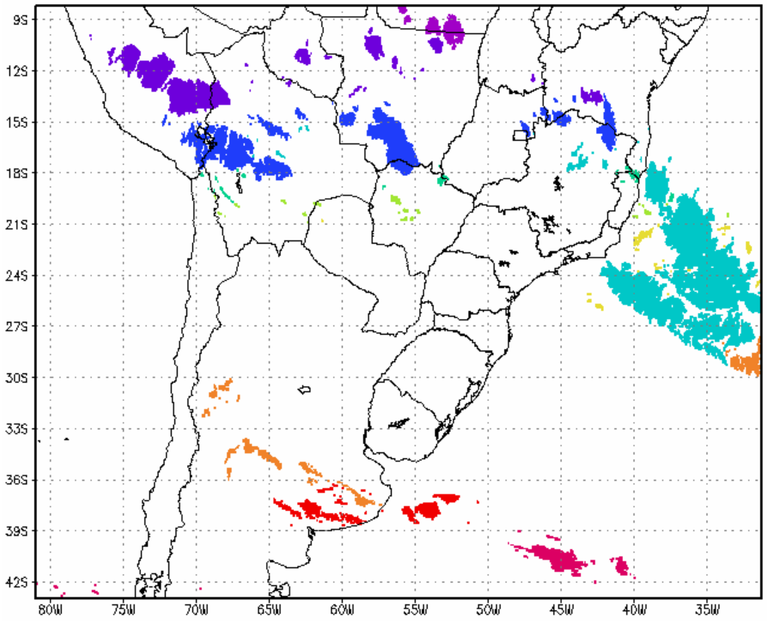

Conex space generation (*"clusters"*). Temperature threshold $T \leq 235$ K – Minimun Area $A_{MIN} \geq 150$ pix

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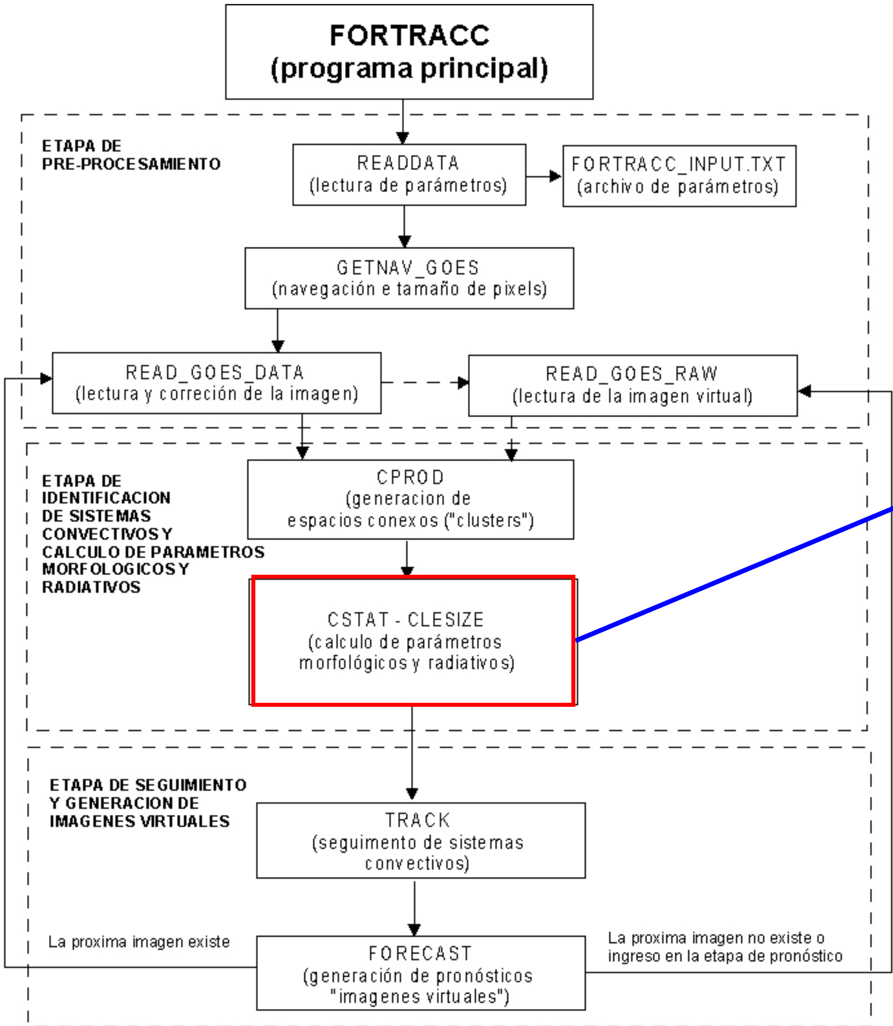

DATOS BÁSICOS	
Día y hora UTC de la imagen	
Numero de sistema	
Tamaño del SCM (en píxeles)	
Umbral de temperatura para la identificación de los SCM	
Umbral de temperatura para la identificación de los topes fríos incluidos en los SCM	
DATOS DE POSICIÓN (*)	**PARÁMETROS RADIATIVOS (**)**
Posición del centro de masa del SCM	Temperatura media del SCM
Posición ponderada del centro de masa del SCM	Temperatura mínima del SCM
Posición del píxel de temperatura mínima	Temperatura mínima utilizando un retículo de 9 píxeles
Posición del extremo sur del SCM	Gradiente medio espacial
Posición del extremo norte del SCM	Desvío estándar de las temperaturas de brillo
Posición del extremo este del SCM	Histograma de la temperatura de brillo, de cada SCM, cada 2 grados
Posición del extremo oeste del SCM	
(*) en latitud y longitud	(**) Todas las unidades están expresadas en K
INFORMACIÓN SOBRE TOPES FRIOS	**PARÁMETROS MORFOLOGICOS**
Numero de topes fríos (como clusters fríos) incluidos en cada SCM	Correlación espacial entre los píxeles de un SCM respecto a un sistema cartesiano
Tamaño medio de los topes fríos	Excentricidad
Tamaño de los tres mayores topes fríos	Fragmentación
Posición de los tres mayores topes fríos	Inclinación
Temperatura media de los topes fríos	

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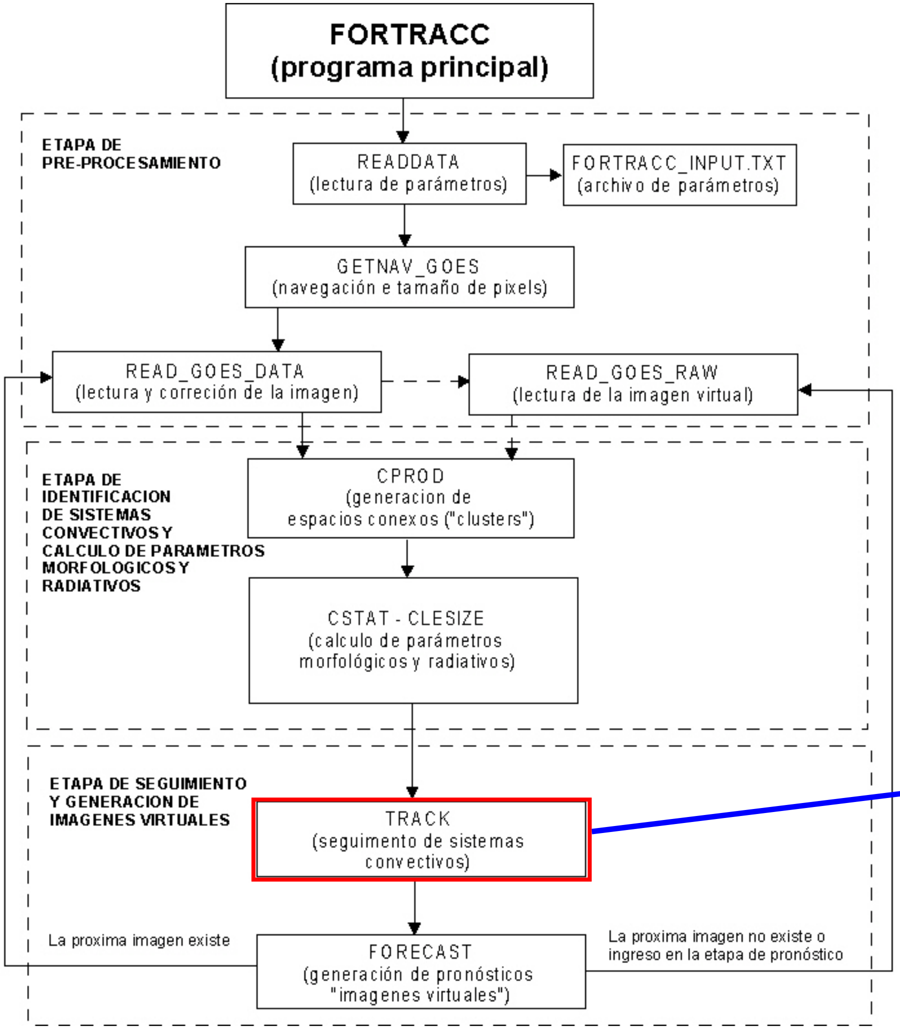
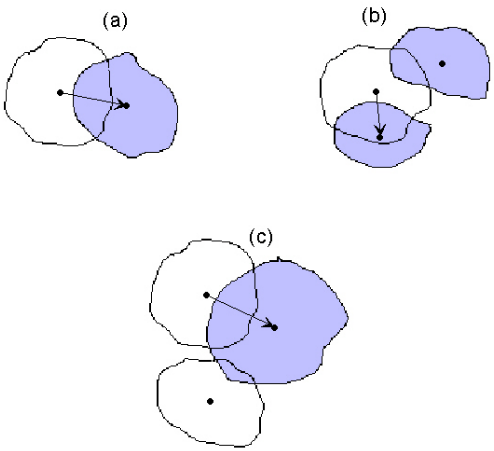


Tracking Methodology

- Based on overlapped area between consecutive images (1/2 hour)
- Minimum MCS size: 150 pixels



(a) Regular tracking (continuity), (b) split y (c) merge.

White MCS: t - Purple MCS: $t+\Delta t$

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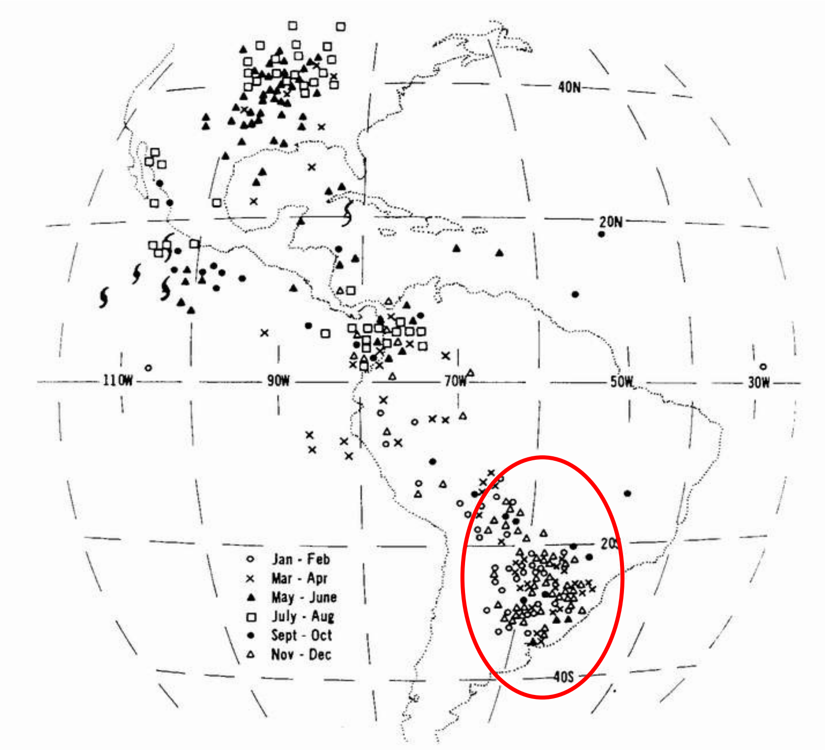
Why Del Plata basin?



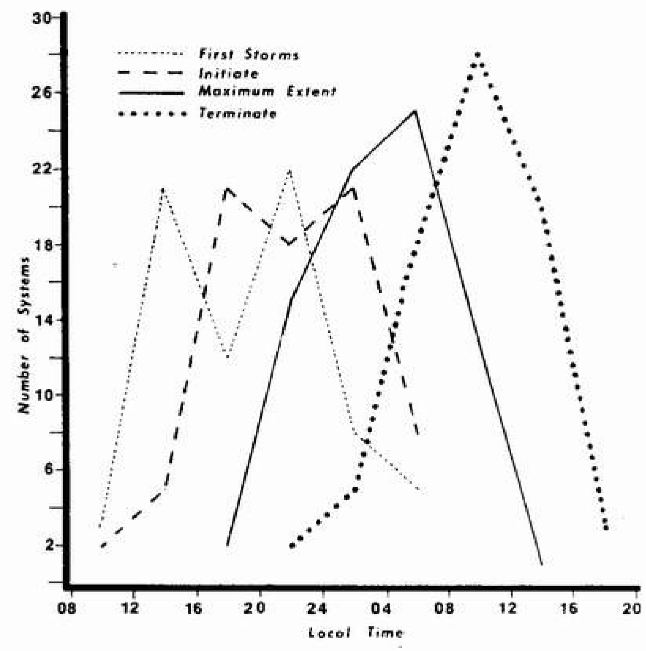


Fig. 3. Life cycle of MCCs over mid-latitude South America for the 1981–1982 and 1982–1983 warm seasons (see Table 1).

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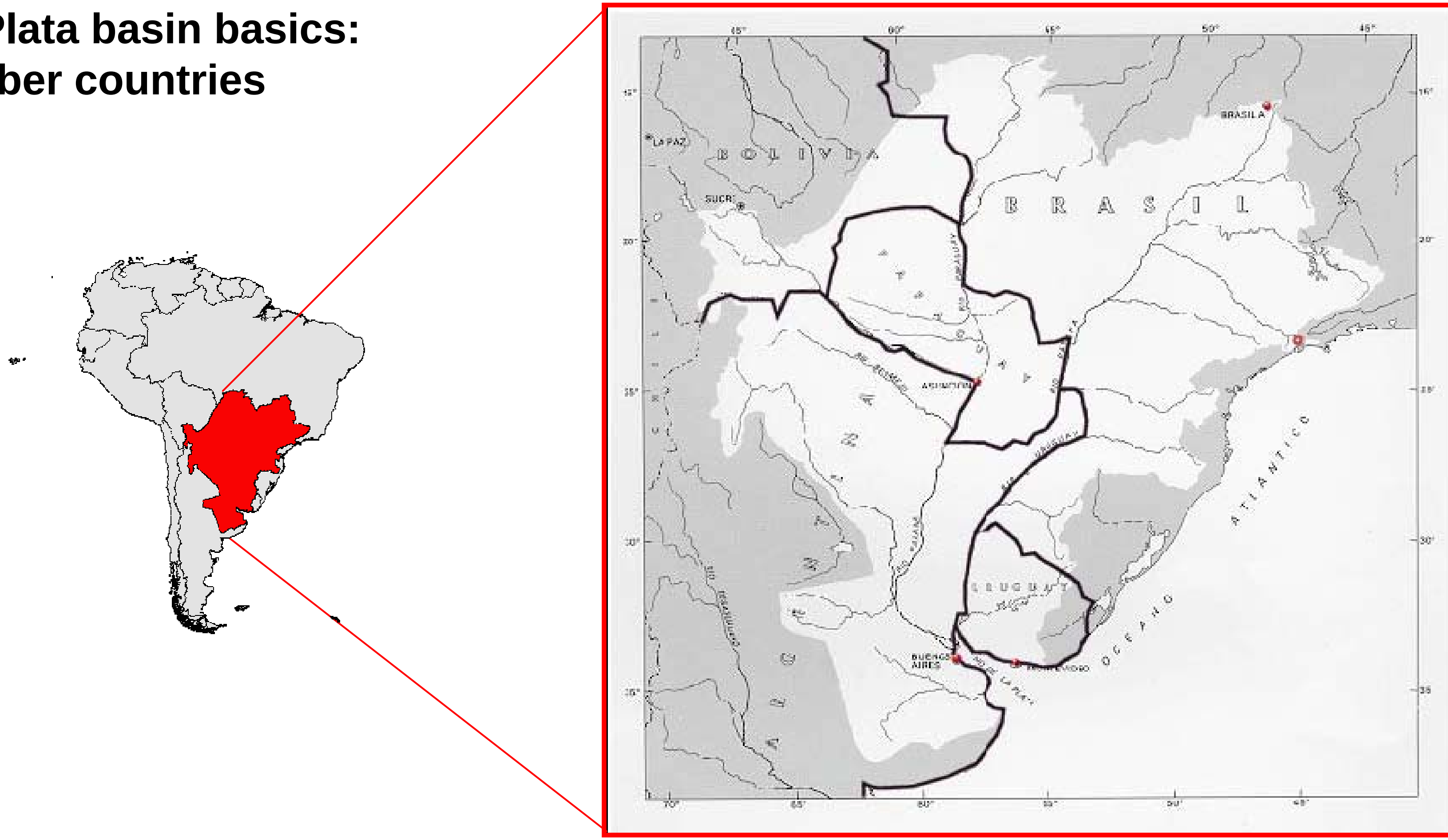
Del Plata basin basics: Member countries



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Del Plata basin basics: Geography and Demographics

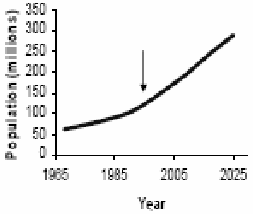
- 3 million km^2 – 5th largest in the world
- 70% of GNP of five countries combined
- 50% of population (>100 million people)
- Main rivers: Paraguay, Uruguay, Parana, Rio de la Plata, Tieté, Iguaçú, Pilcomayo, Bermejo
- Basin area:

Brasil	45.7%
Argentina	29.7%
Paraguay	13.2%
Bolivia	6.6%
Uruguay	4.8%

- Climate variability: Tropical (N), Subtropical, Temperate (S), Arid (NW)

- Capital cities of 4 countries (Buenos Aires, Brasilia, Asunción, Montevideo) → Urbanization
- Population growth in the watershed:

1968	61 millions
1994	116 millions
2025	290 millions (estimated)



Human induced changes

Consequences

→ Agricultural intensification and expansion
- Soil compactation
- Desertification
- Sediment erosion, transportation and deposition

→ Loss in biodiversity

→ Urban environmental degradation

→ Extreme events

(Floods, Droughts, "El niño", "La niña")

→ Water quality

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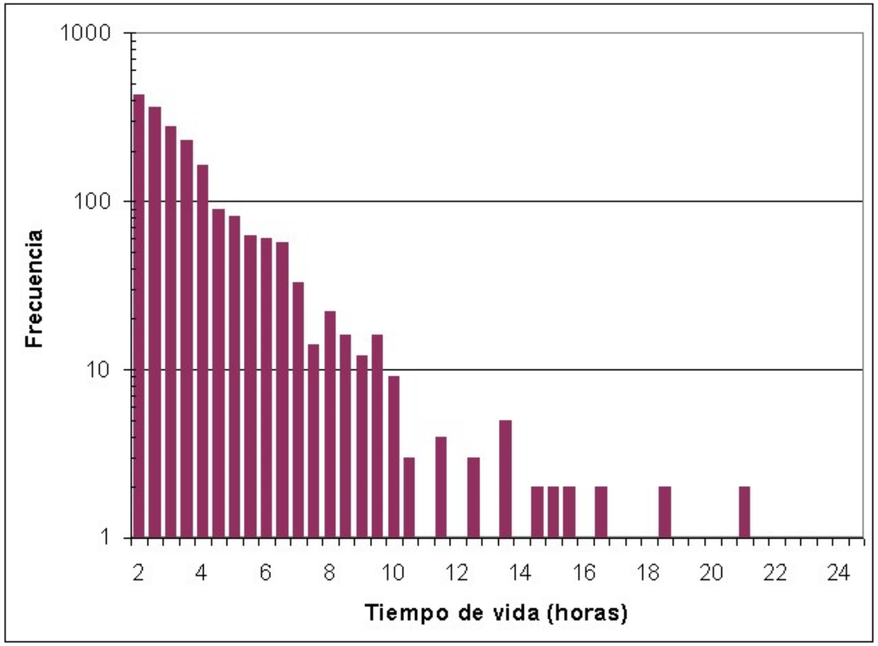

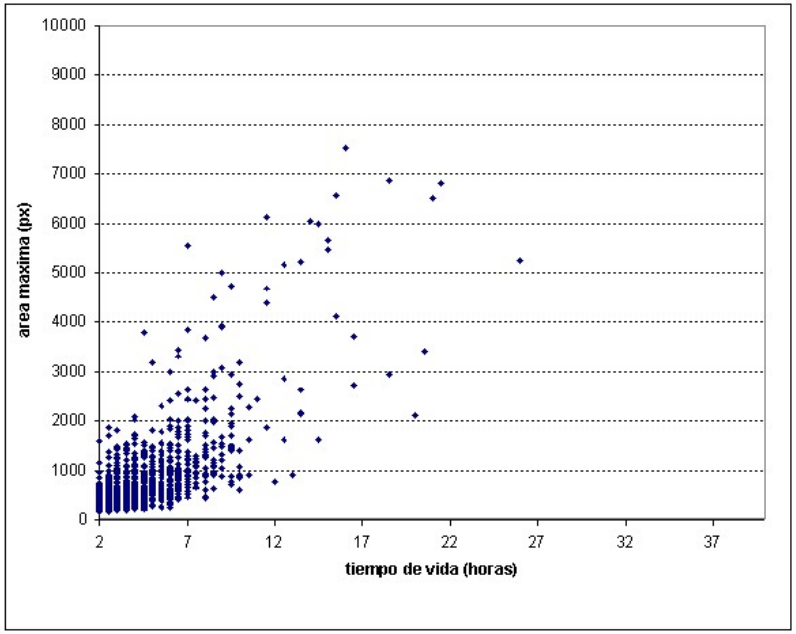

82% of families have no split and no merge but mean lifetime is around 2.2 hours

Larger lifetime cycles are associated with larger maximum areas

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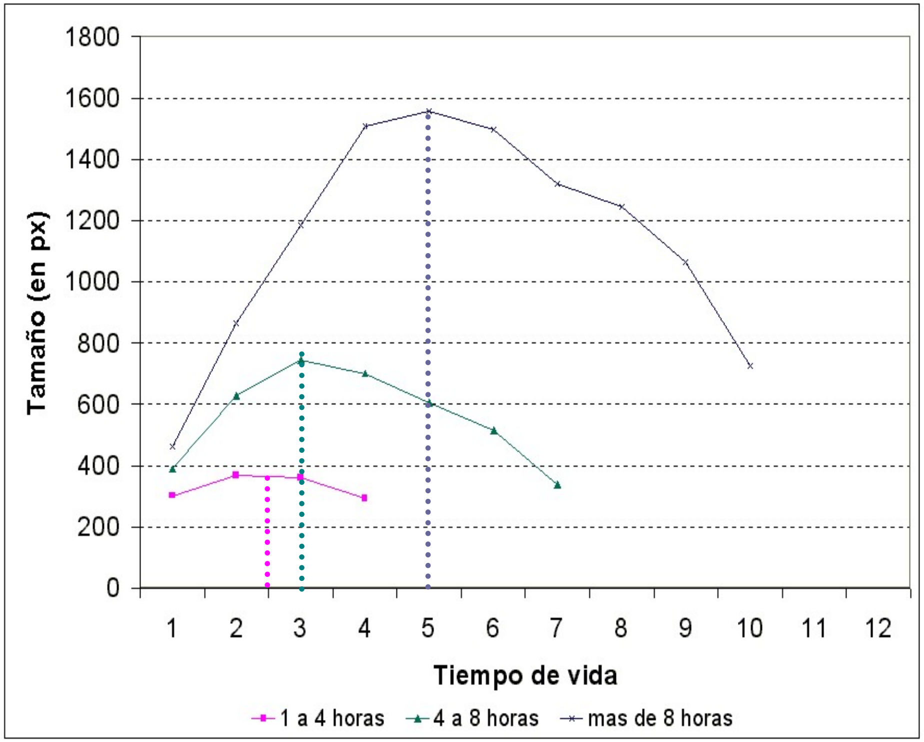
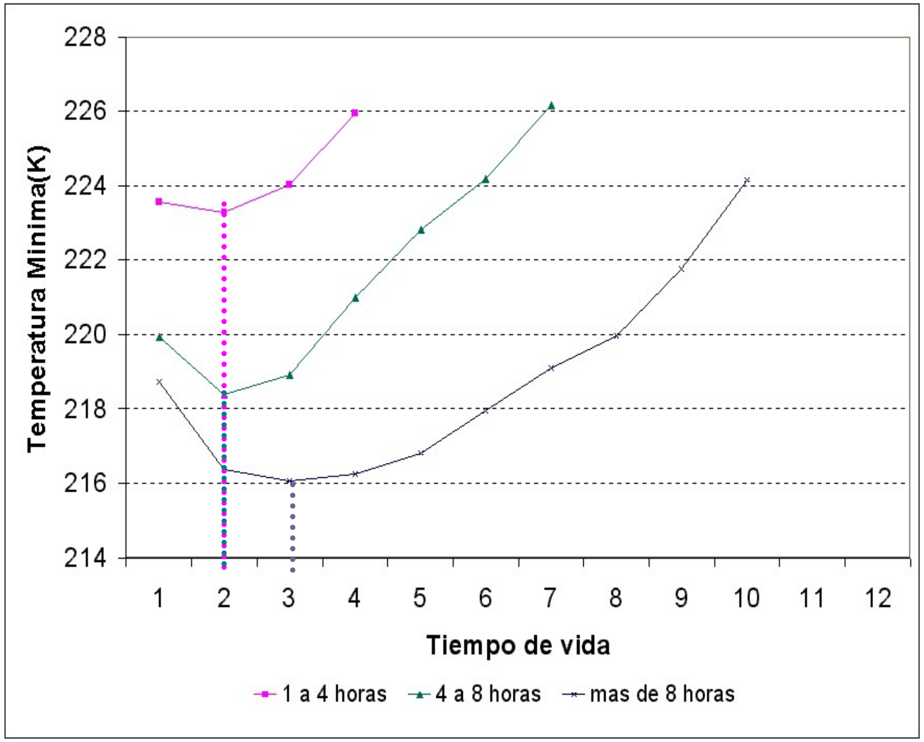
- **TRACKING MODE: DIURNAL CYCLE**





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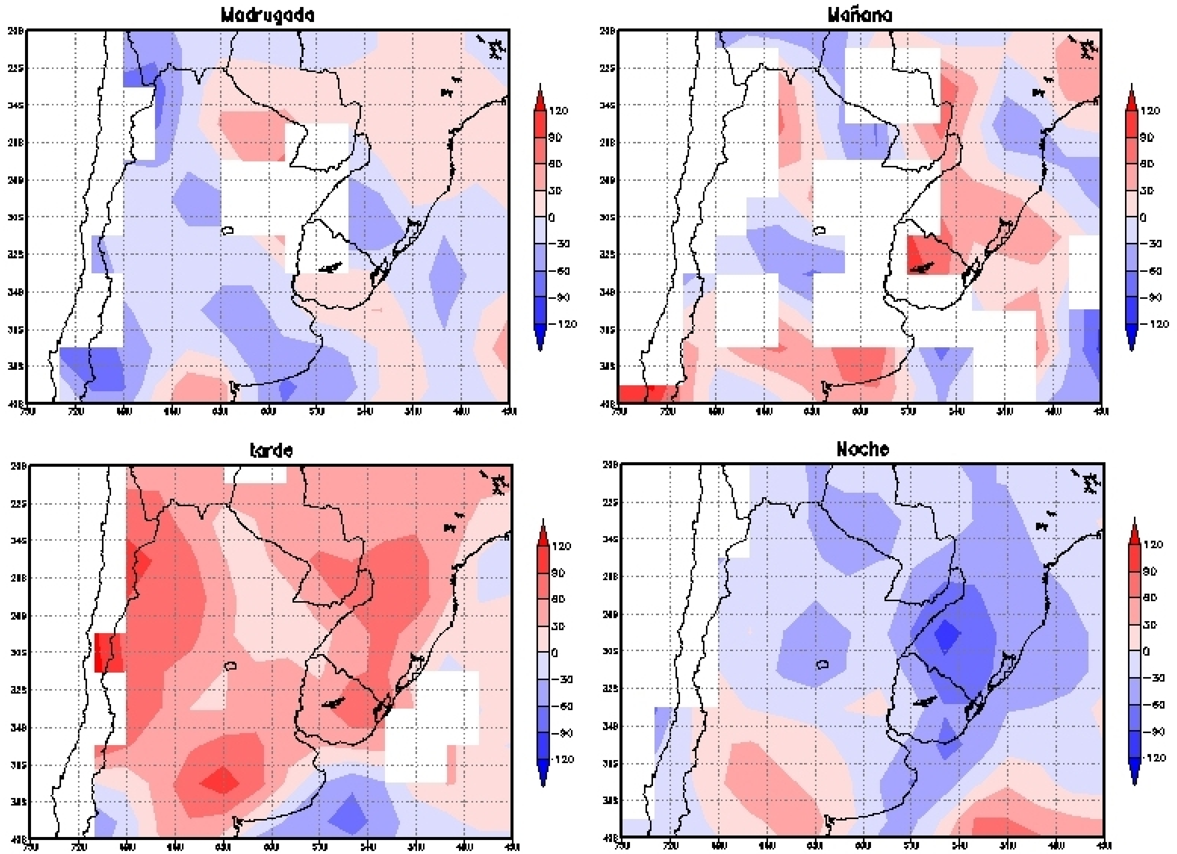

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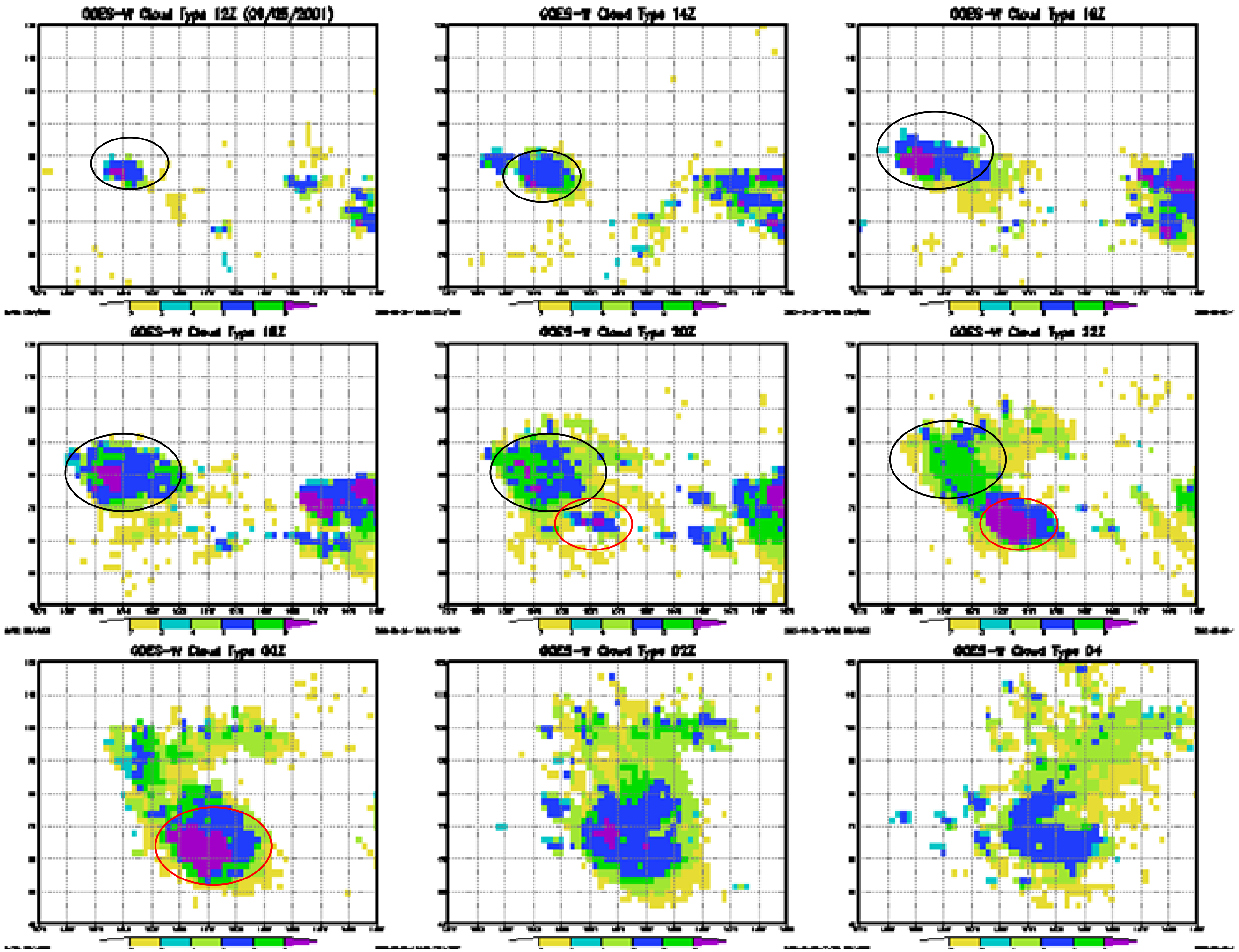

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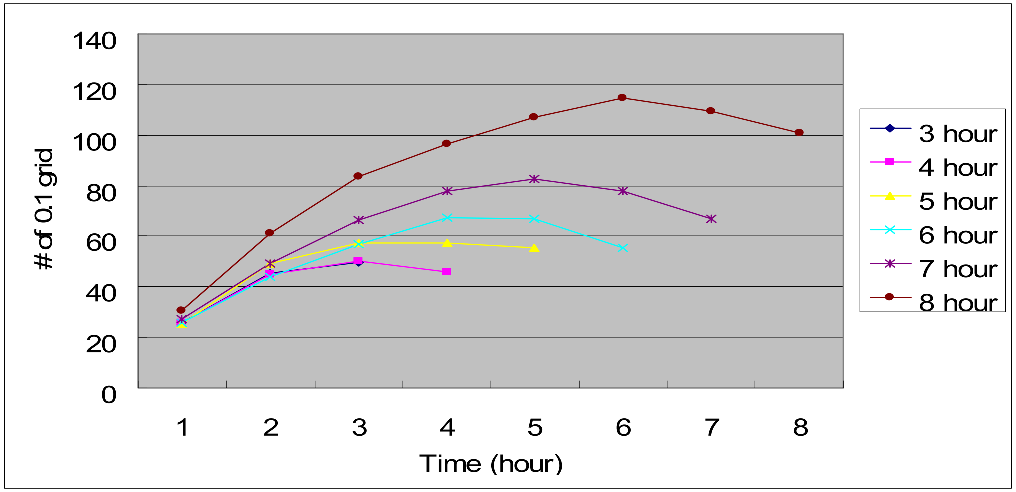
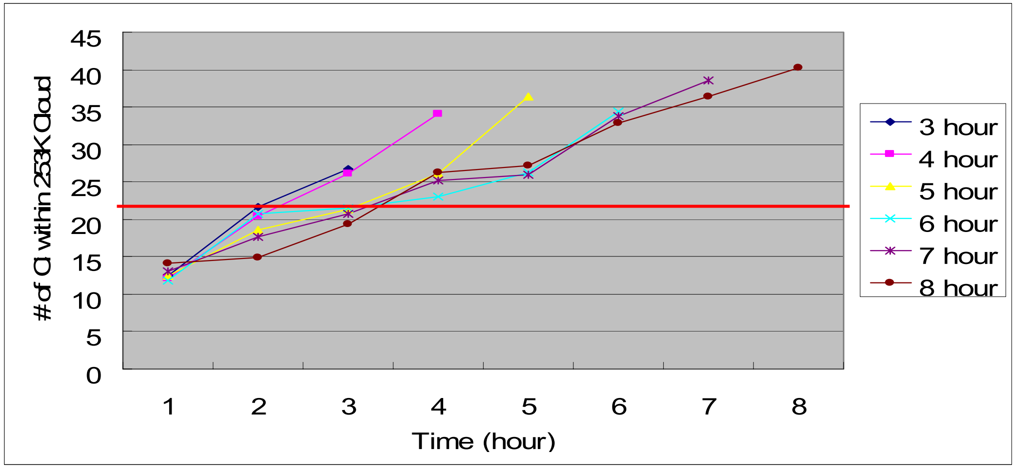
Time evolution of size (top) and % of Ci (bottom)





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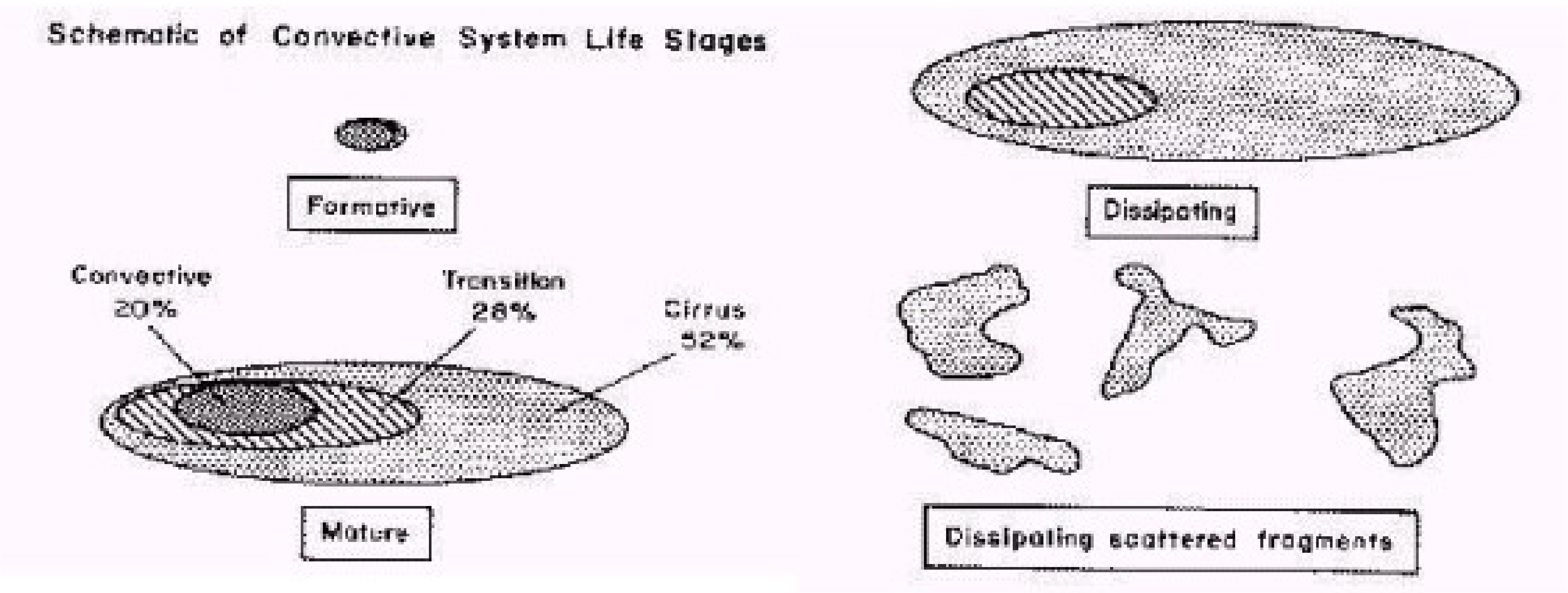

MCS Life Cycle Schematic Representation (after Machado y Rossow, 1993)

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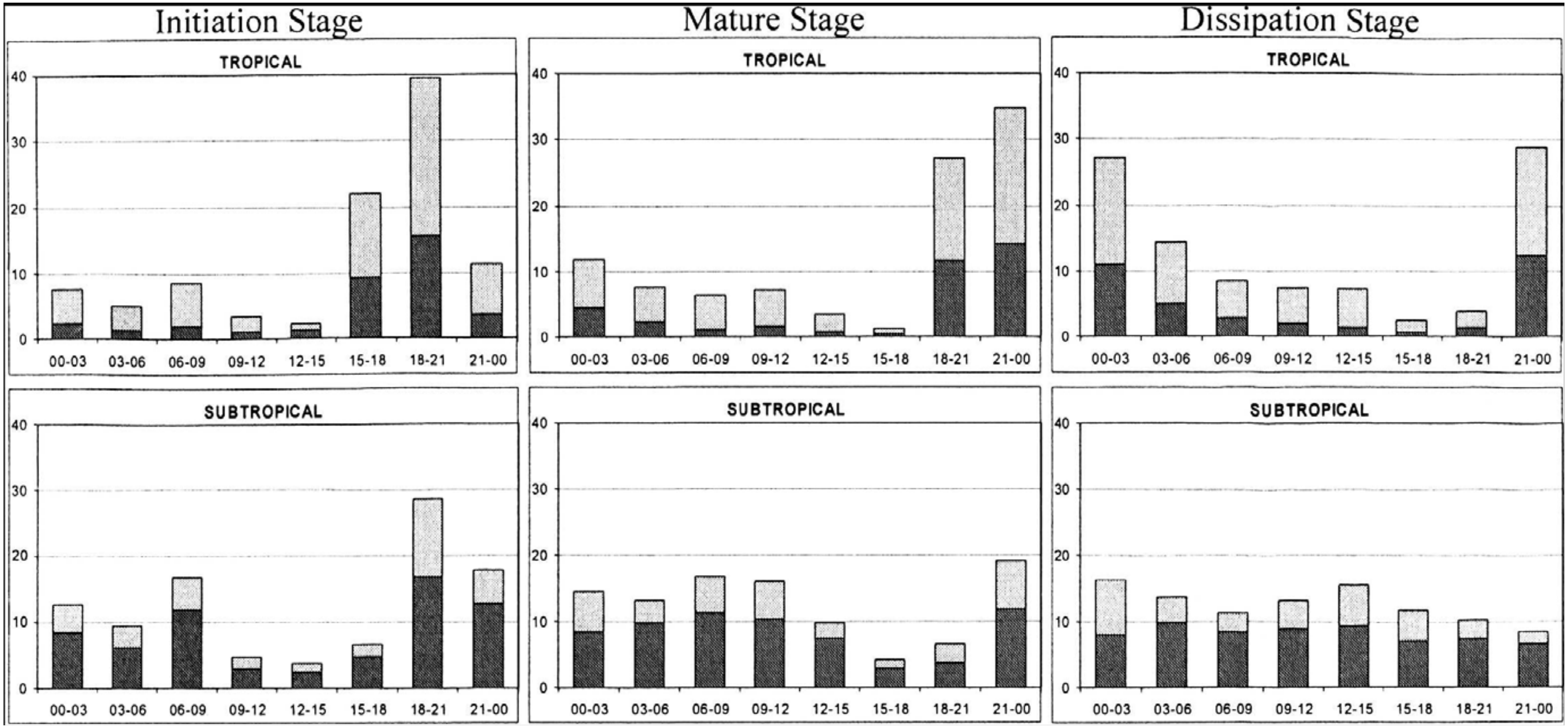

Figure 1: Frequency distributions in percent of MCSs for SALLJ (dark gray) and NOSALLJ (light gray) samples of (left) initiation, (middle) maximum extent, and (right) dissipation time in UTC in a tropical environment over South America (from Salio et al, 2007).

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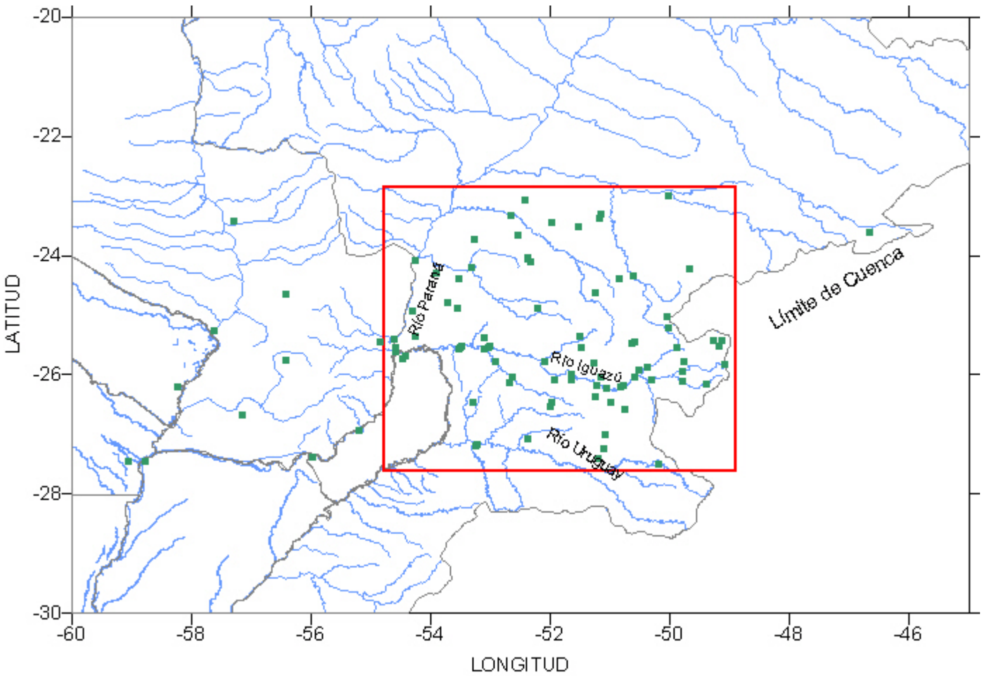
- **APLICATIONS: RAINFALL ESTIMATION**



Iguazu river basin: green dots are raingauge stations (daily accumulation)

Rain event from raingauge measurement:

- RR > 25 mm/day - minimum area = 50000 km^2

or

- RR > 75 mm/day in (at least) one raingauge.
- 17 day were selected

Rain event from satellite detection:

- For those days classified as rain event from raingauge measurement, were selected all MCS ("famlies') that affect the raingauge stations with rr > 25 mm/day
- 32 families were selected

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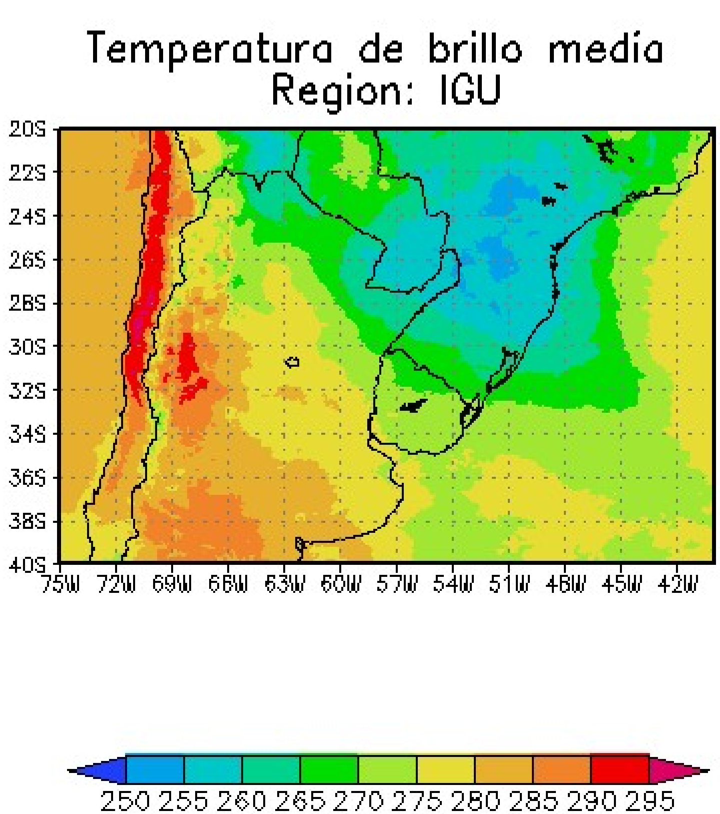
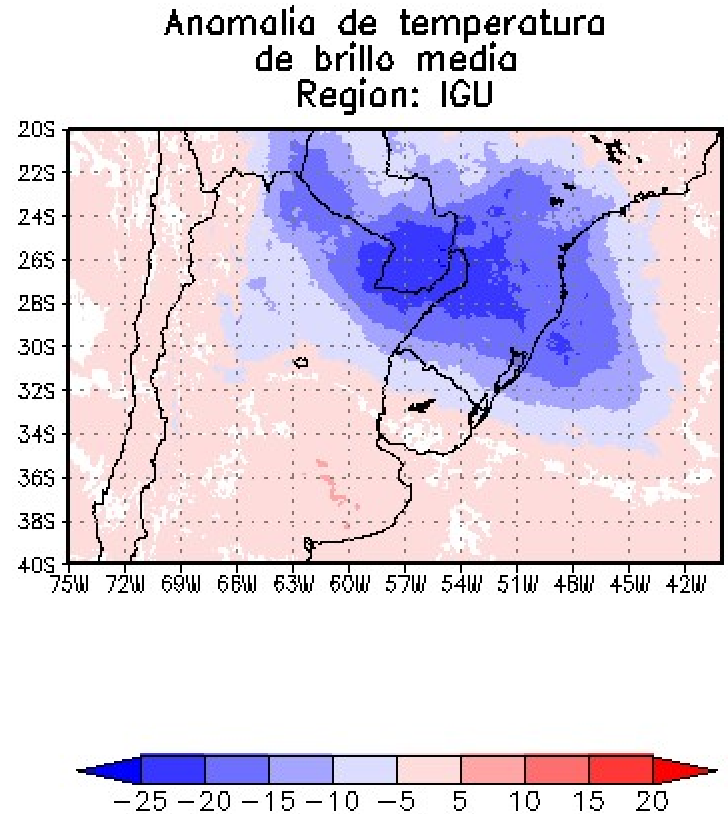
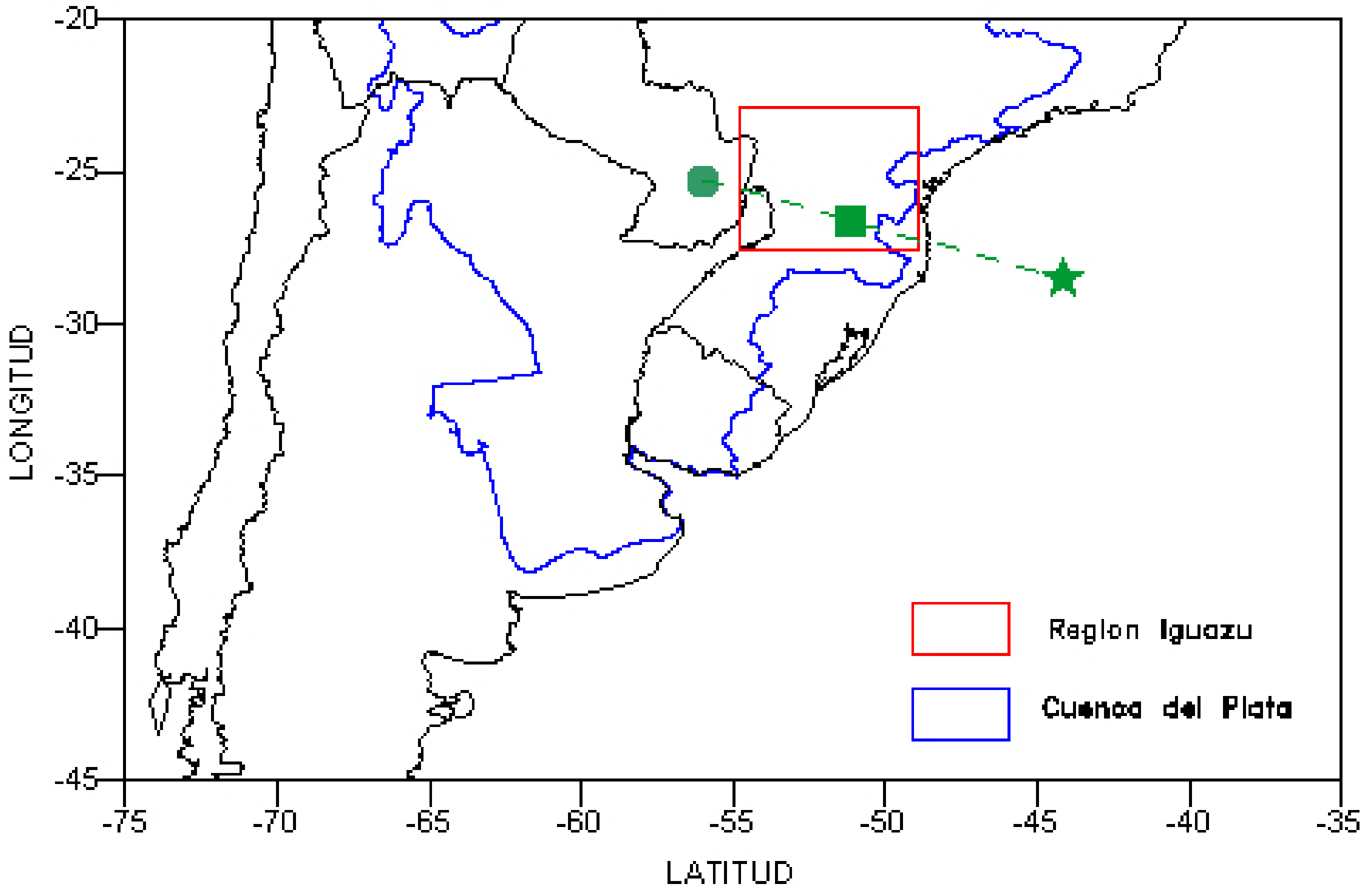
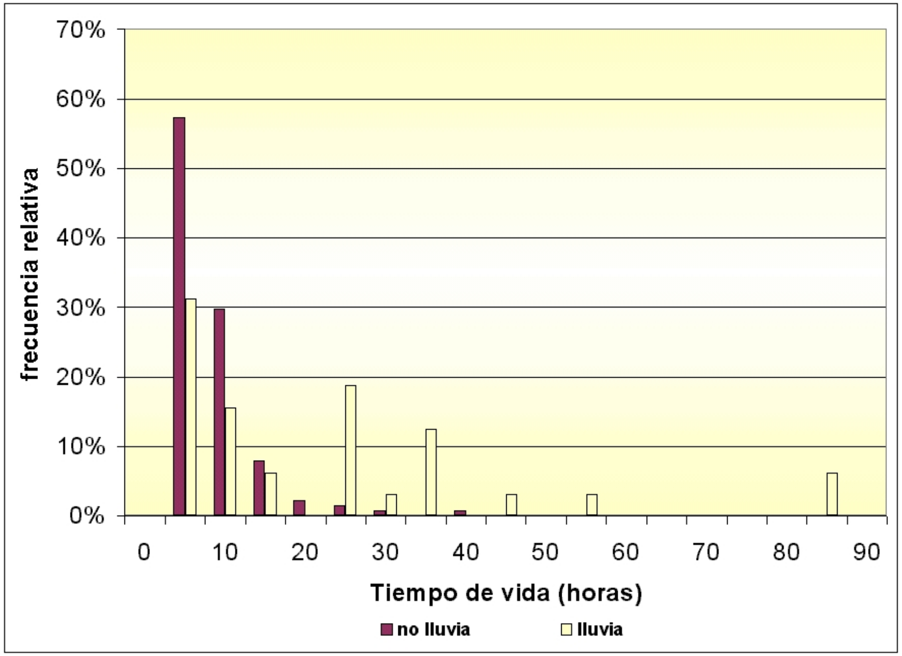


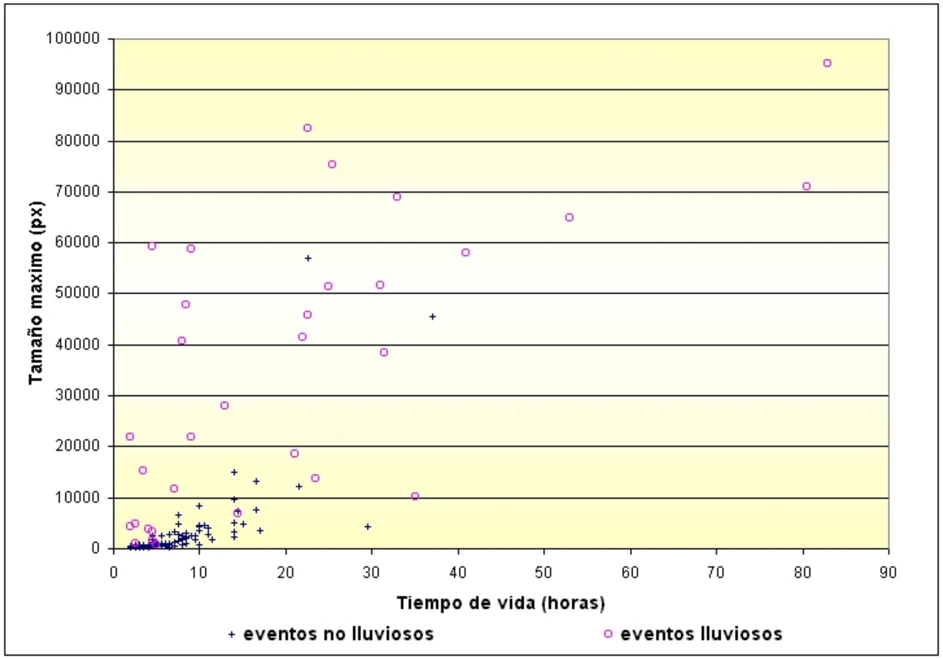


Mean brightness temperature (left) and brightness temperature anomaly (right) for selected cases.

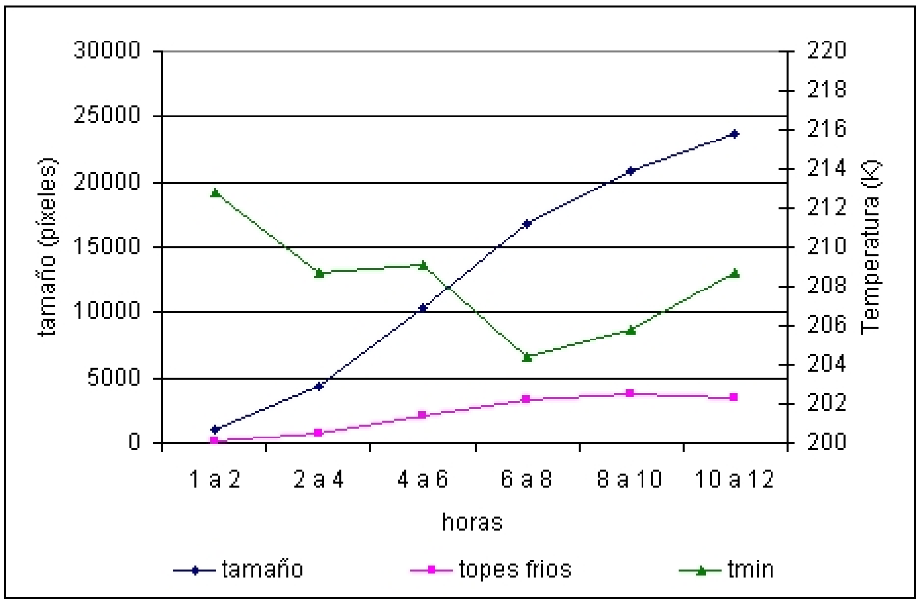


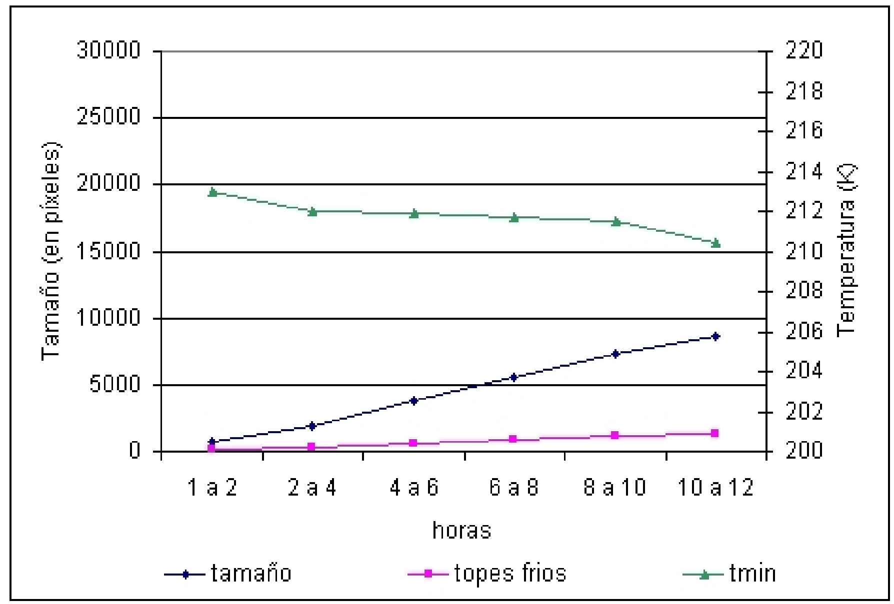
Mean trajectory of composite (32 MCS families). Green circle correspond to initial stage, box to maturity (maximum extension) and star to dissipation.





Relative frequency of life time for rainy and non-rainy MCS (left) and life time – maximum extent scatter plot for rainy and non-rainy MCS.





Mean temporal evolution of families composition: size, minimum temperature and convective area (T < 210 K) for rain events(left) and non-rain events (right)

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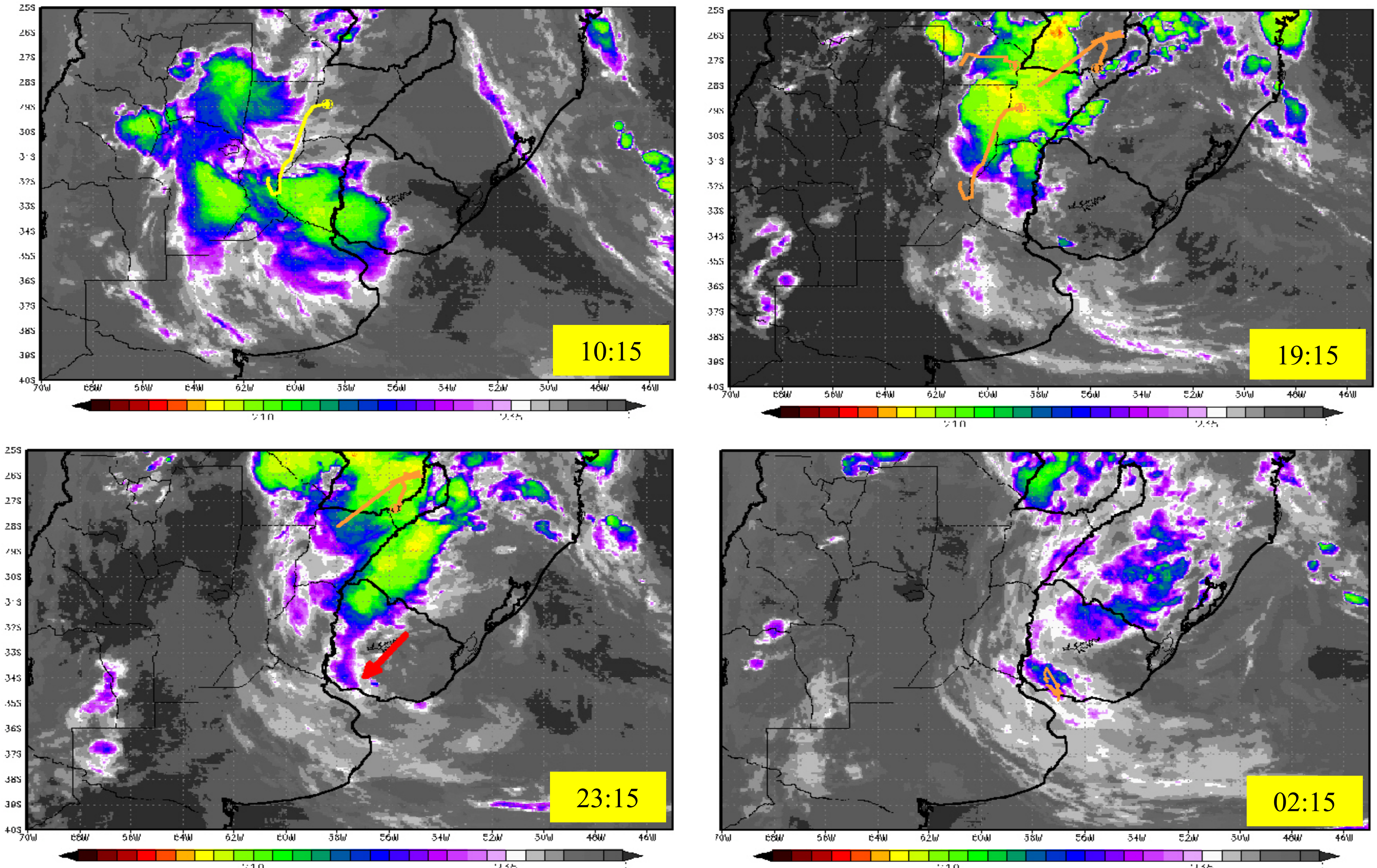

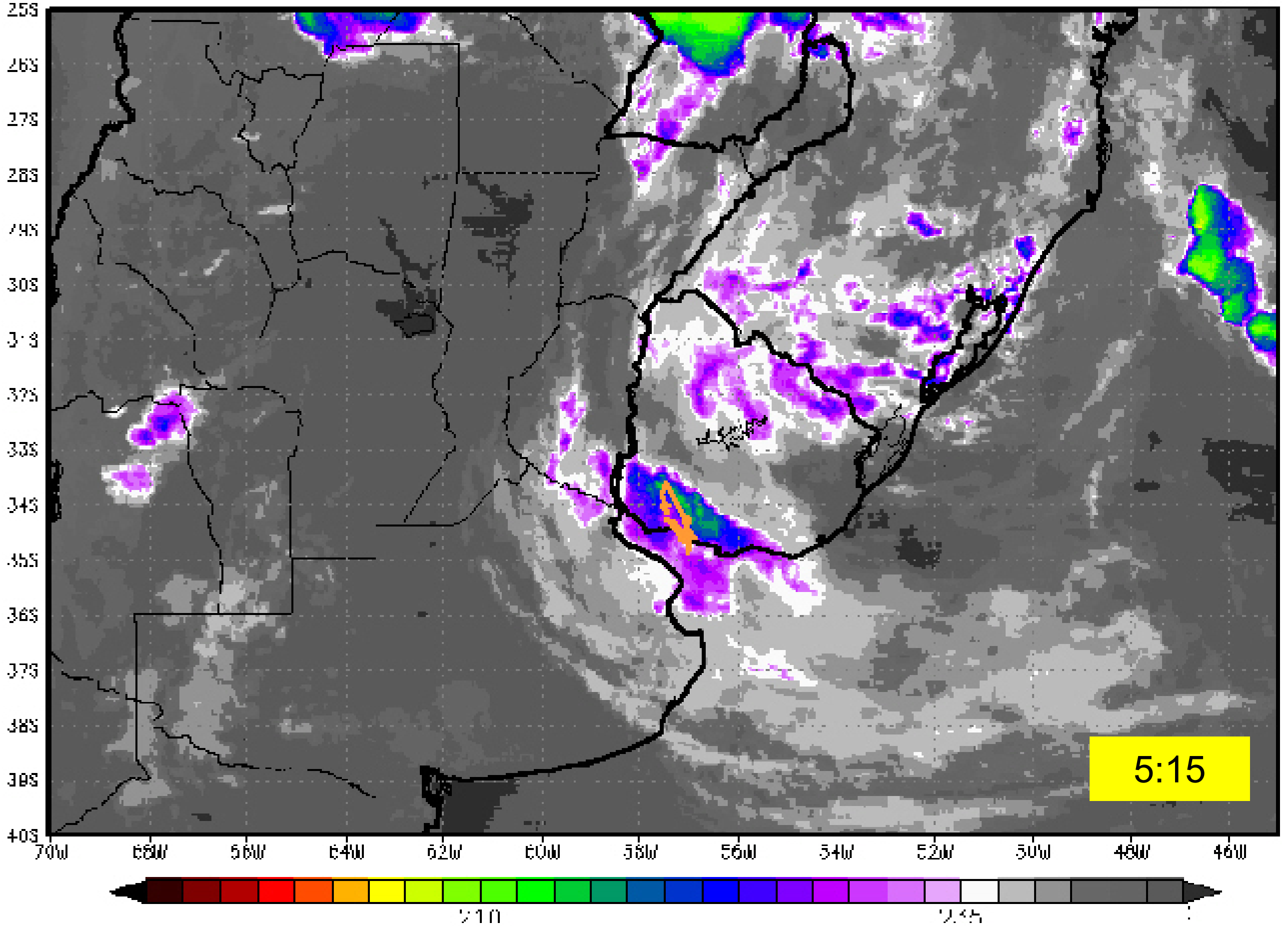

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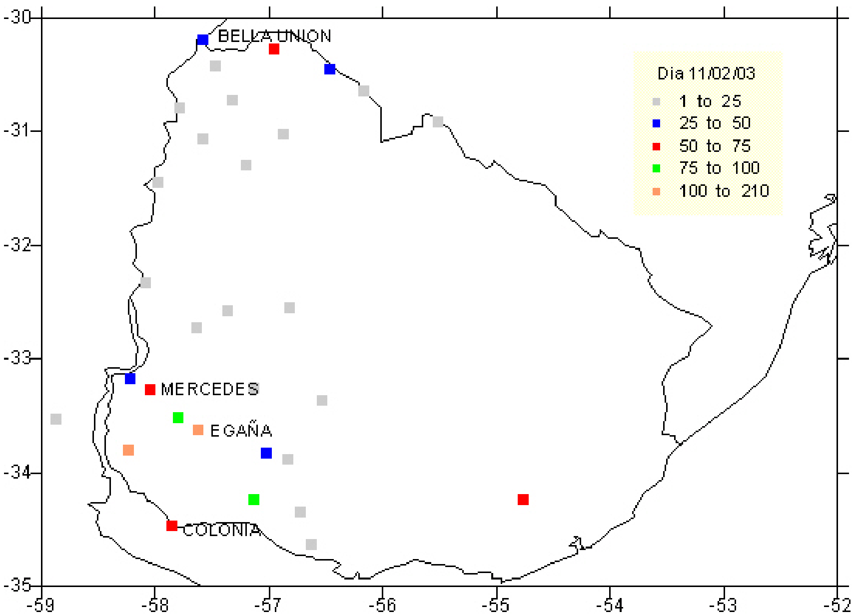
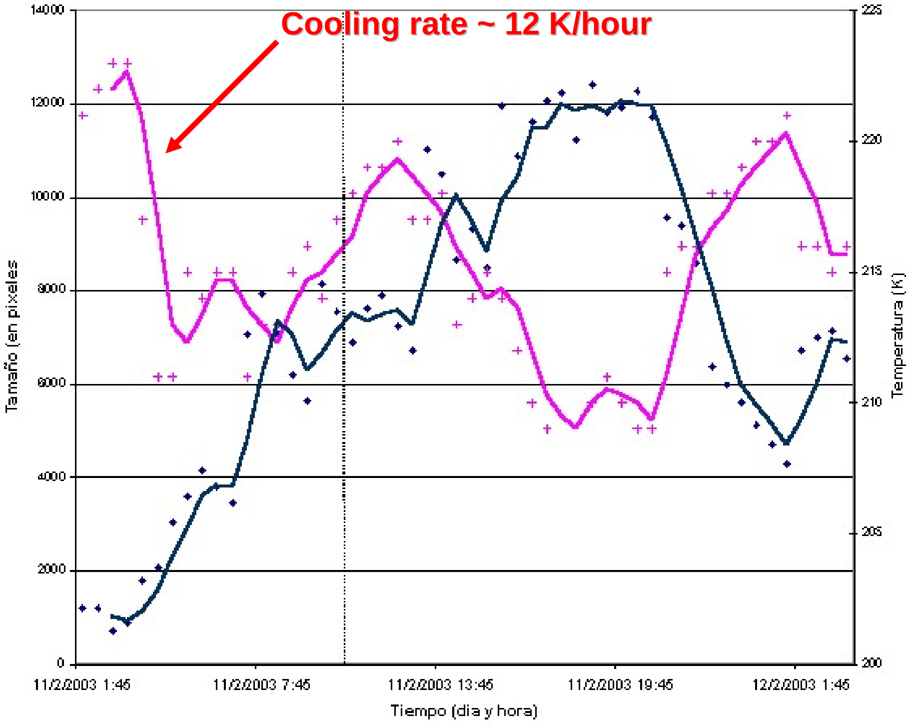
- **CASE STUDY**





24-hour accumulation (left) and size and temperature evolution of selected MCS (right)

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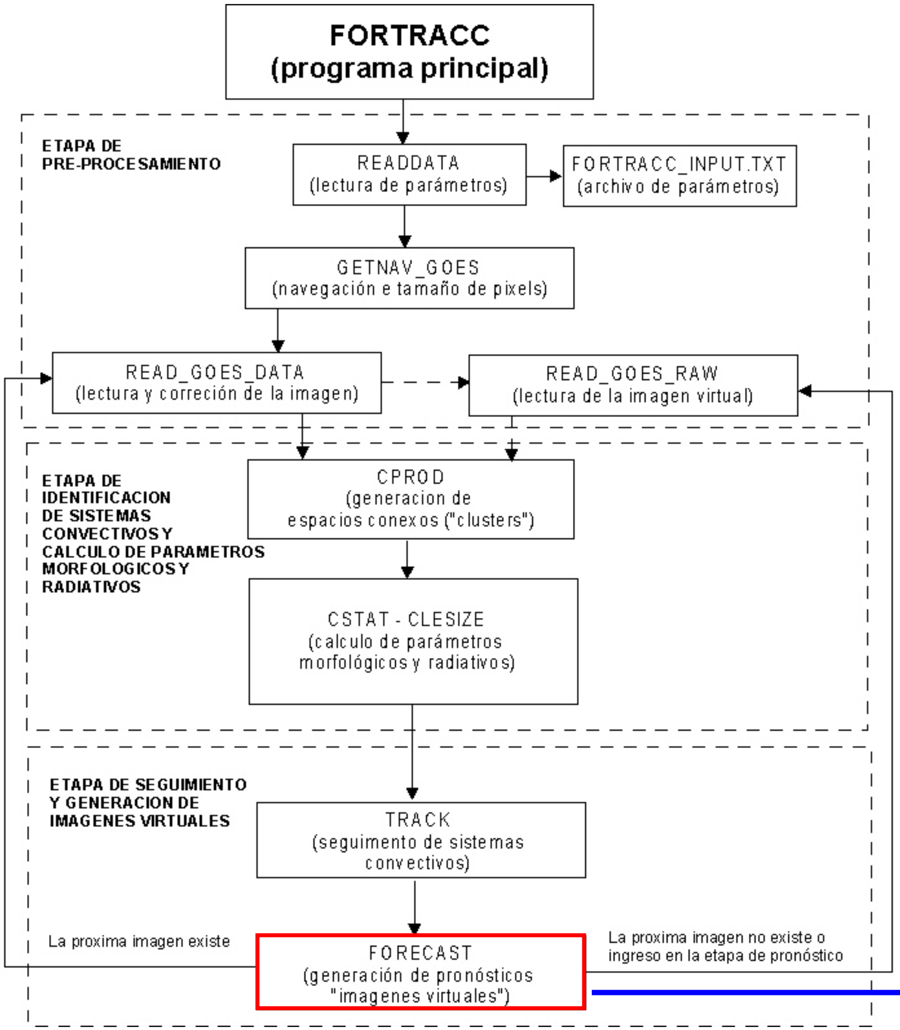
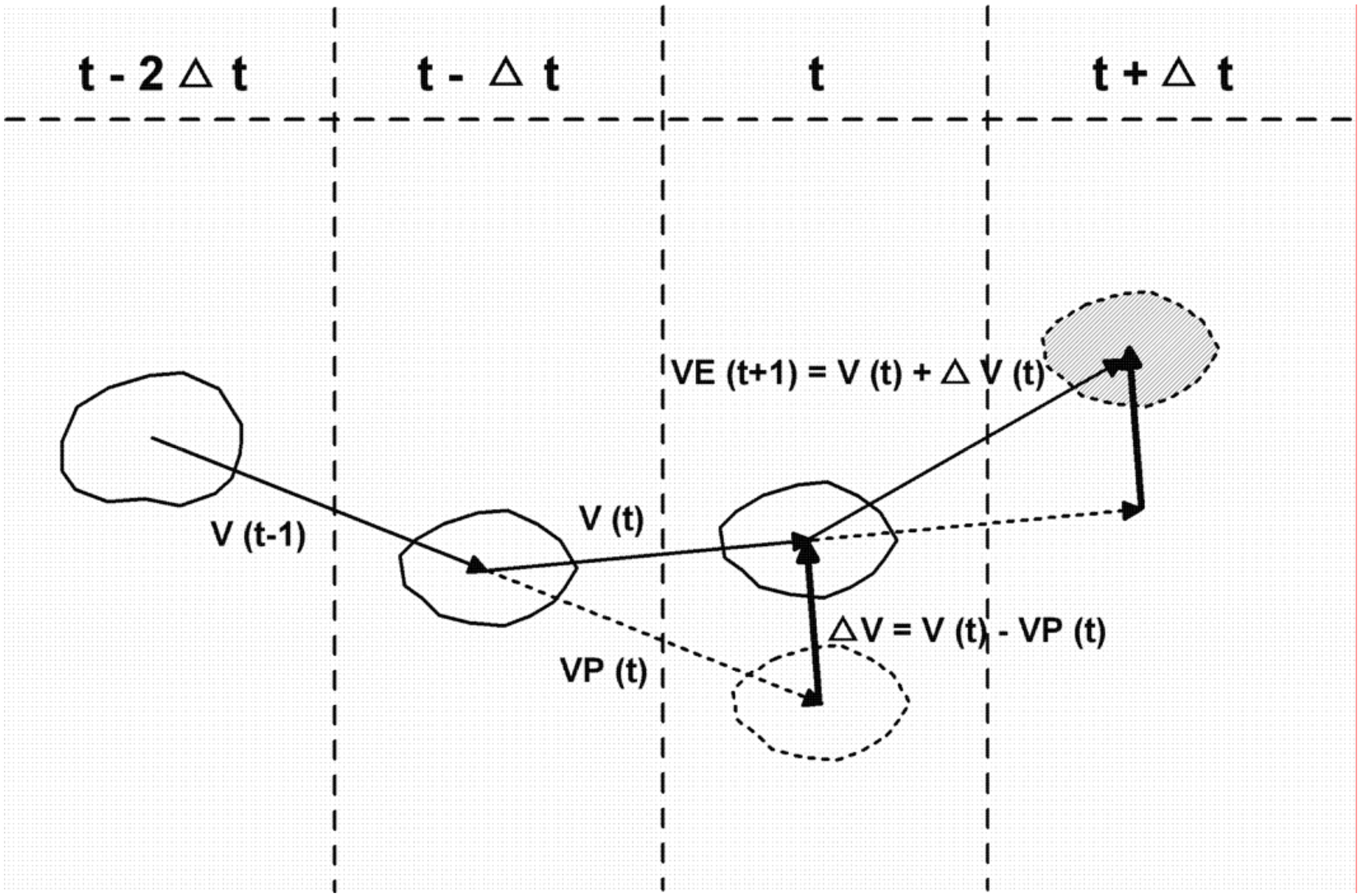
- **OUTLINES**
  - THE FORTRACC TECHNIQUE
    - MAIN ALGORITM DESCRIPTION – TRACKING MODULE
    - SOME CHARACTERISTICS OF SOUTH AMERICAN MCS
  - MCS LIFE CYCLE AND PRECIPITATION: URUGUAY BASIN APPLICATION
  - THE FORTRACC TECHNIQUE – NOWCASTING MODULE
  - CONCLUSIONS



- MCS displacement (speed and direction)
- MCS area evolution (growth or decay)

- MCS displacement estimation



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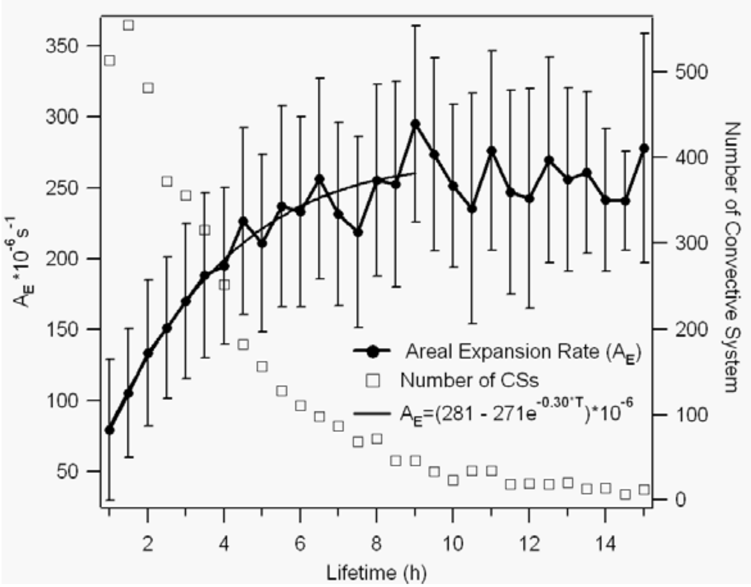
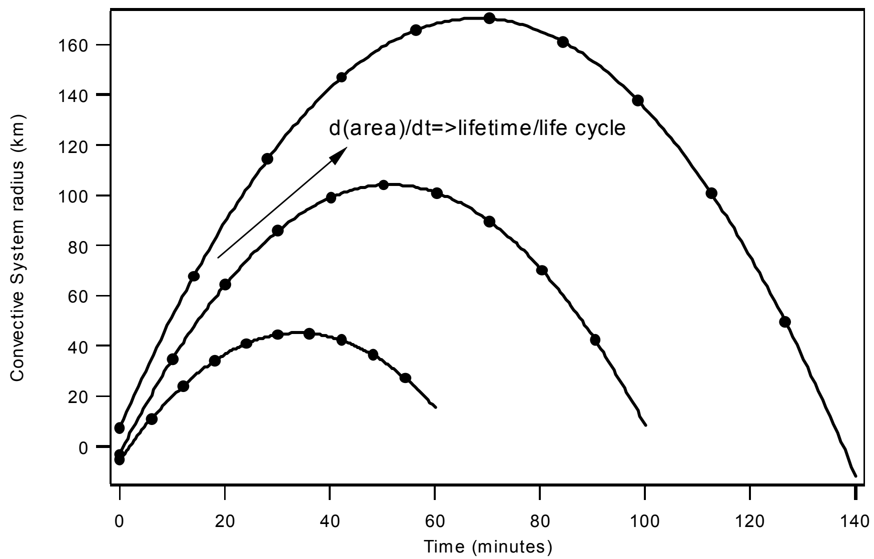
- MCS area evolution estimation





Machado and Laurent 2004

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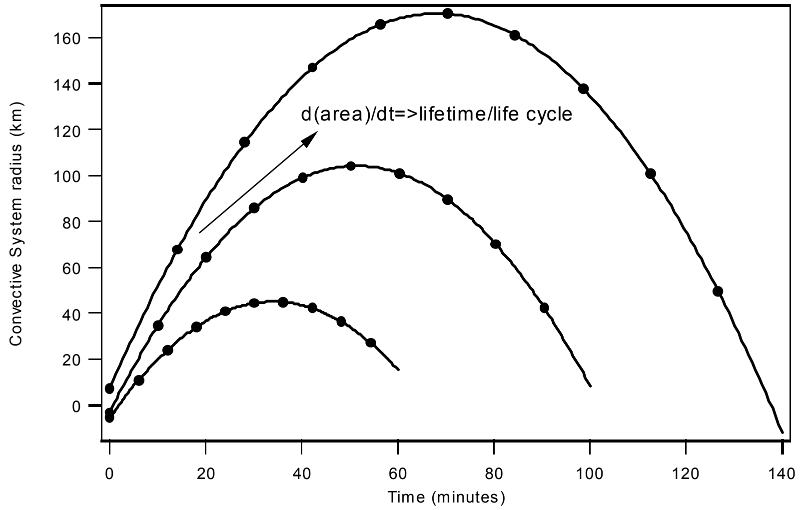
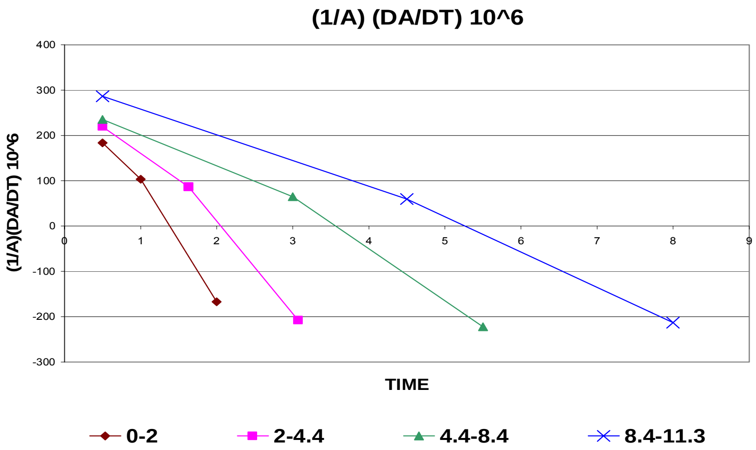
- MCS growing evolution estimation





$$A(t) = \alpha * e^{at^2+bt+c} \Rightarrow \Delta E = 1/A*(\partial A/\partial t) = at + b$$

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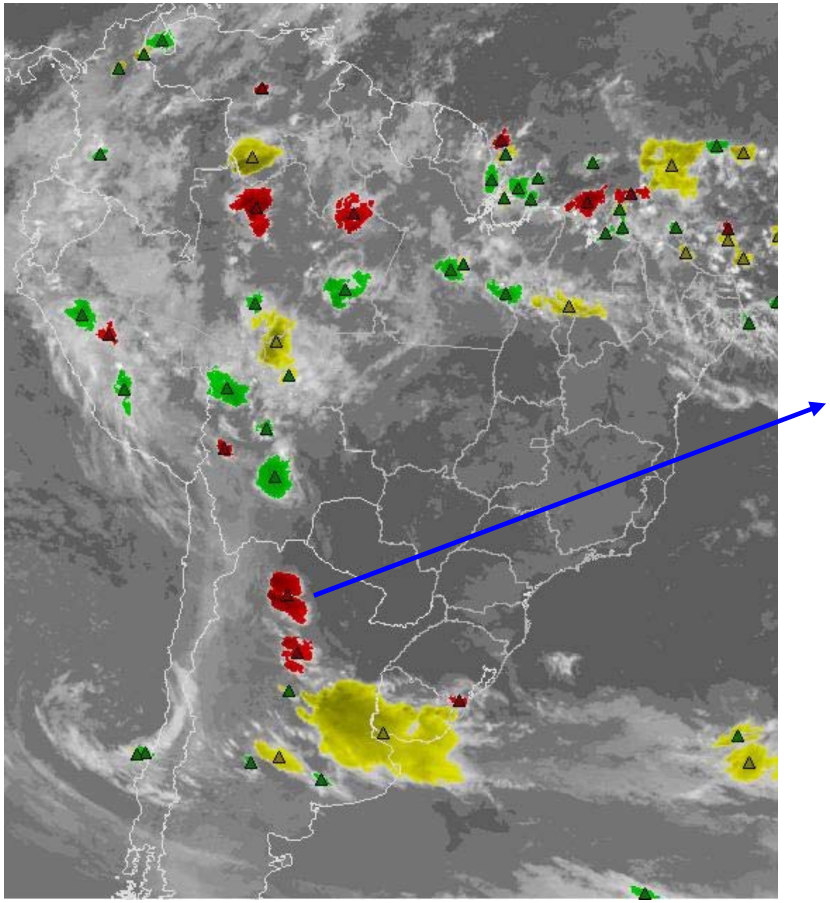

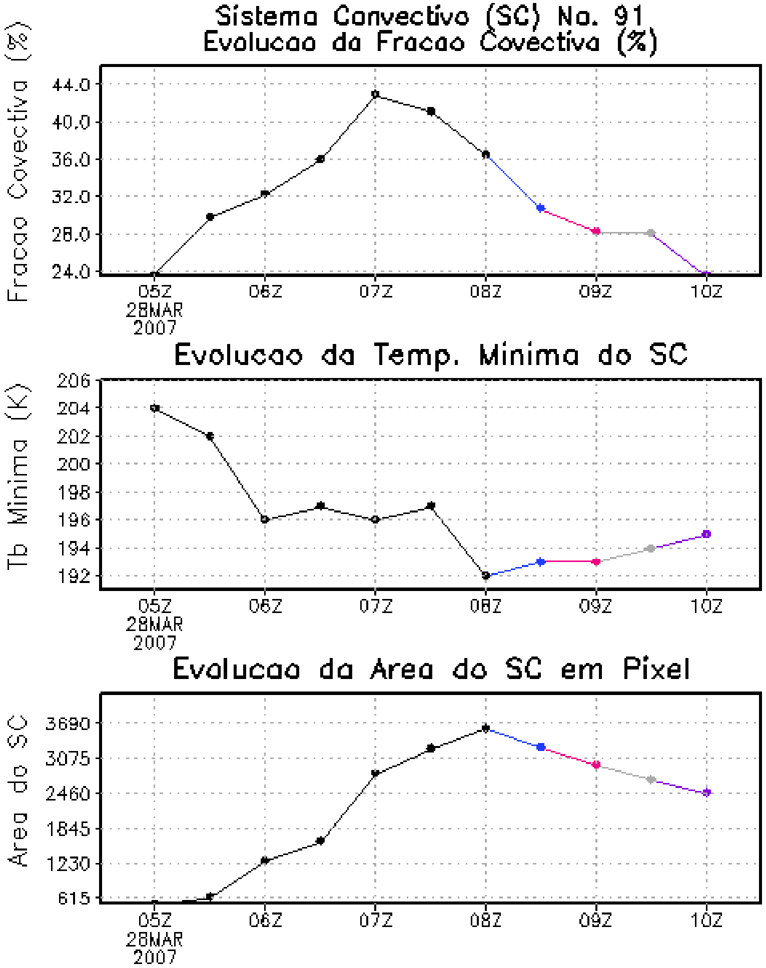

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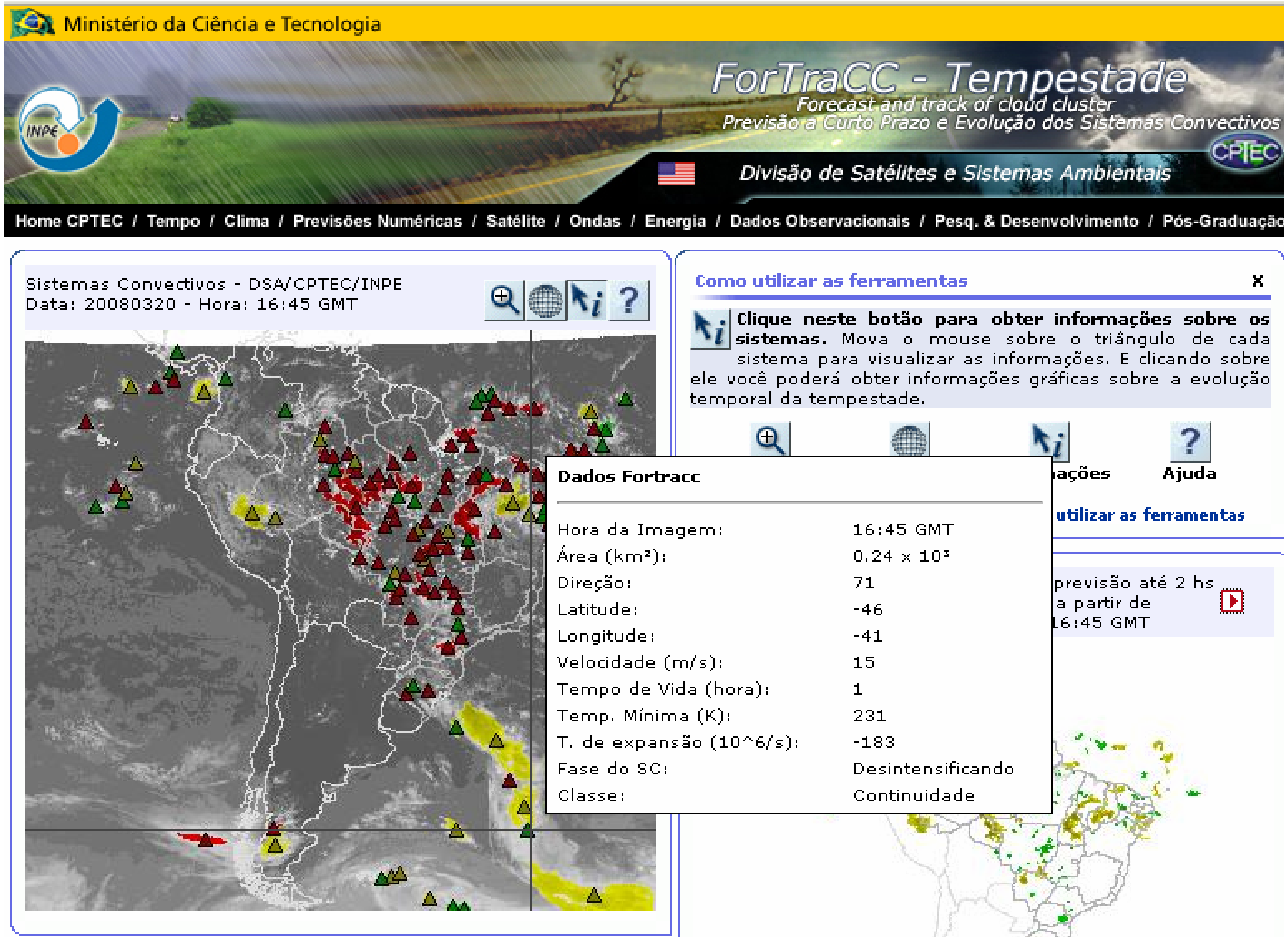

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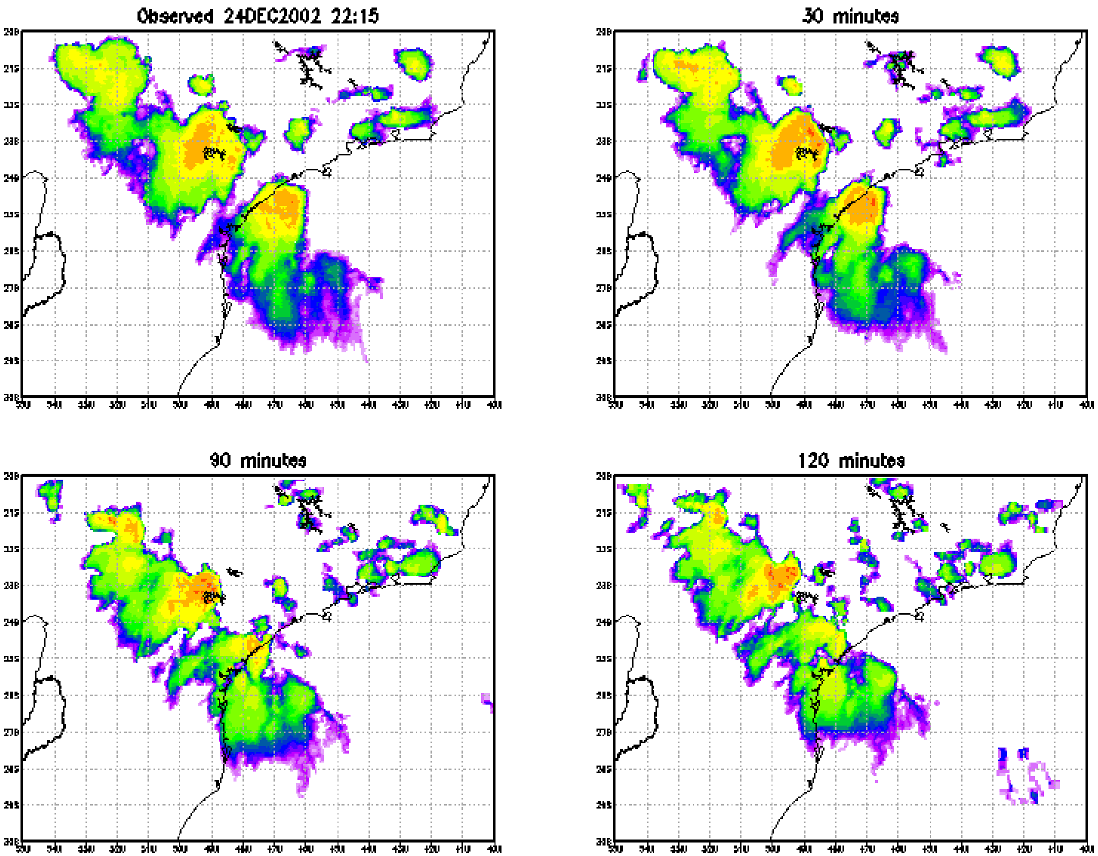
- **FORECAST MODE: NOWCAST STATISTICS**



	30 min	60 min	90 min	120 min
ACU	0.98	0.98	0.97	0.96
BIAS	0.96	0.95	0.91	0.87
POD	0.77	0.64	0.54	0.44
FAR	0.20	0.32	0.41	0.49

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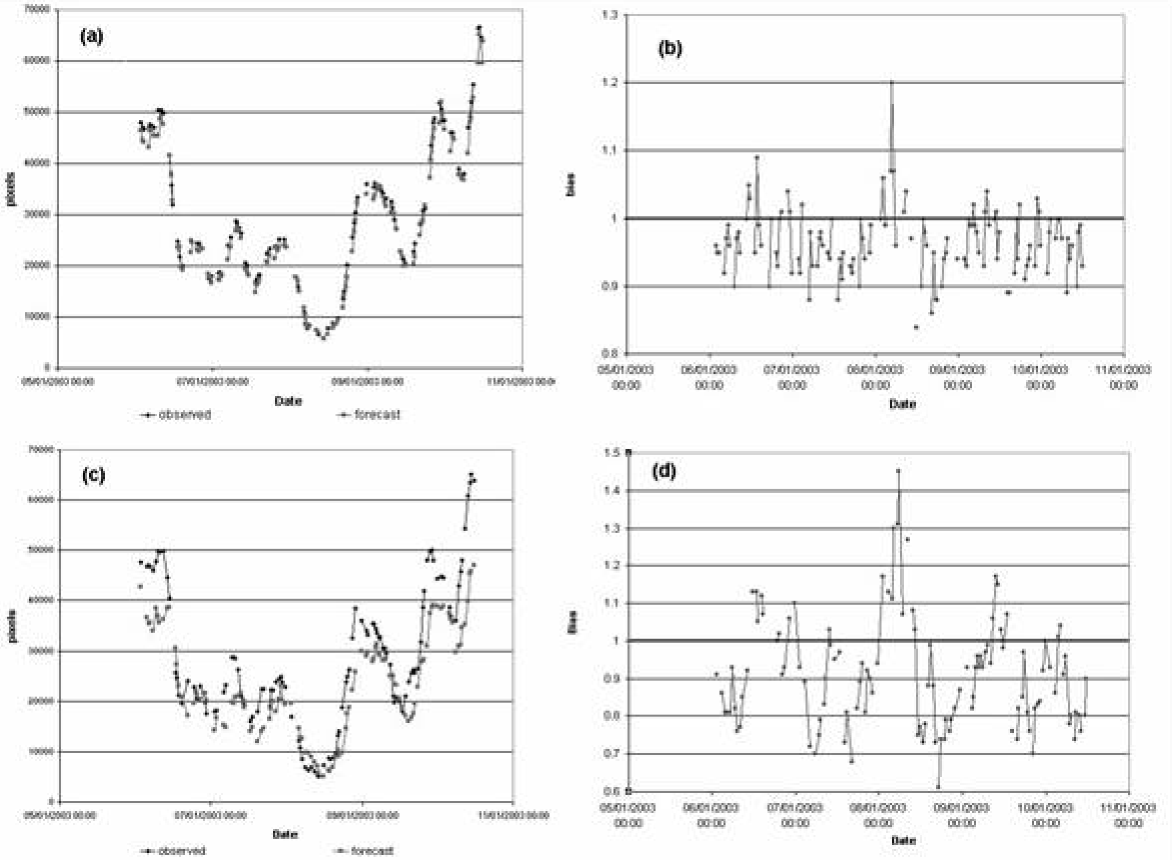
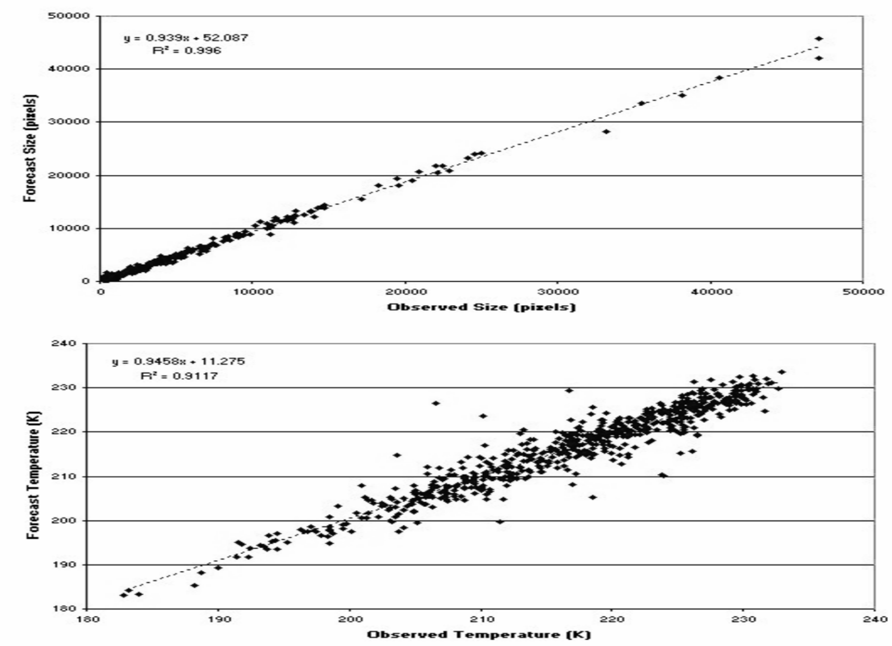
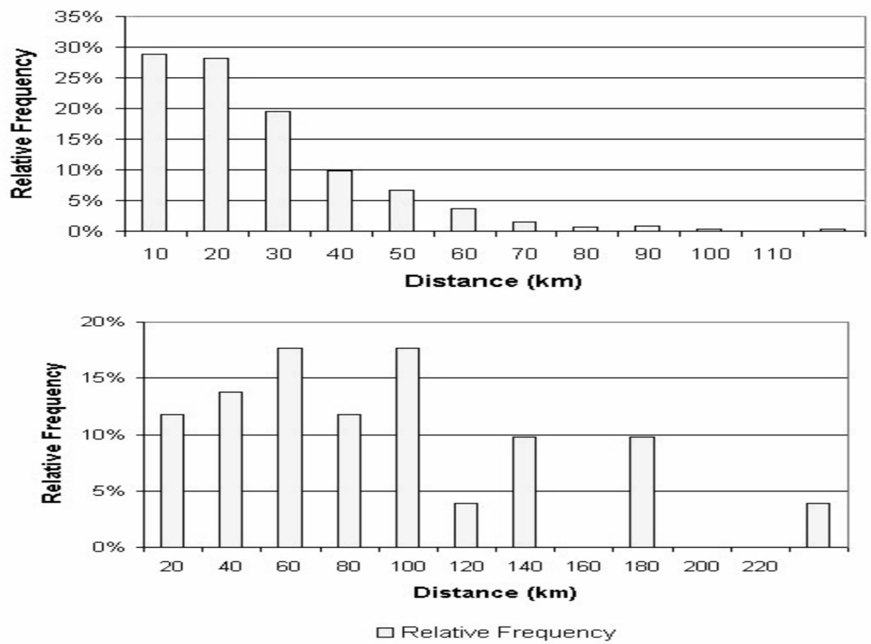


Number of observed and forecasted MCS pixels per image during the period 6 – 11 January 2003 for 30 minutes forecast range. (b) BIAS Score per image for the same period for 30 minutes forecast range. (c): Idem (a) for 120 minutes forecast range. (d): Idem Figure (b) for 120 minutes forecast range. Blanks in the solid line corresponds to missing data (GOES 8 Southern Scan was not available)



Observed and forecasted MCS size and minimum temperature. 30-minutes forecast



Relative frequency of distance classes between observed and forecasted mass center. 30-120 minutes forecast

Time	Forecast			Non-Forecast		
	Δ Size (in %)	Δ Tmed (in K)	Δ Tmin (in K)	Δ Size (in %)	Δ Tmed (in K)	Δ Tmin (in K)
30	-1.87%	0.25	0.35	-3.17%	0.34	0.46
60	-4.20%	0.59	0.66	-8.24%	0.50	0.62
90	-7.80%	0.75	0.52	-23.50%	0.79	0.93
120	1.81%	0.75	-0.35	-28.80%	1.00	0.88

Mean bias (Δ) of the size (expressed in % to express the relative variation in size) and minimum temperature for forecast and non-forecast (conservative situation).

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CONCLUSIONS

(a) Considering the forecasted and observed pixels with brightness temperatures below 235 K (independently of their positions) it is observed that the model tends to underestimate the amount of pixels, this underestimation getting on average larger with longer forecast lead times.

(b) The proposed methodology follows the diurnal cycle of cold cloud cover (Tir < 235K) *cloud coverage* with acceptable accuracy in amplitude and phase.

(c) The mean accuracy (ACU) obtained with this technique is about 95%. This high value is mainly due to the correct prediction of no MCS occurrence. In the case of POD and FAR (that do not include this case) a gradual lost of quality is observed. POD decreases and FAR increases with the forecast range.

(d) The behavior of individual MCS shows a good agreement between observation and forecast of size and minimum temperature for 30-minutes forecast range with a lost of quality for higher forecast range.