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

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• OUTLINES

• THE FORTRACC TECHNIQUE
  • MAIN ALGORITHM DESCRIPTION – TRACKING MODULE
  • SOME CHARACTERISTICS OF SOUTH AMERICAN MCS
• MCS LIFE CYCLE AND PRECIPITATION: URUGUAY BASIN APPLICATION

• THE FORTRACC TECHNIQUE – NOWCASTING MODULE

• CONCLUSIONS
Hourly average area expansion, water vapor wind divergence and wind divergence from radiosonde for 200 hPa level at WETAMC/LBA region.
Accuracy of Rainfall Nowcasts

GRID MESH 20 km - Jun-Oct 2002

Extrapolation

Critical Success Index (CSI)

Forecast Length, hours

Predictability

Cross over region

NWP

Courtesy of Shingo Yamada - JMA
CPC-ESSIC-CICS Joint Seminar at Climate Prediction Center – March 21, 2008
Conex space generation ("clusters"). Temperature threshold $T \leq 235$ K – Minimum Area $A_{\text{MIN}} \geq 150$ pix
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 (*)
- Posición del centro de masa del SCM
- Posición ponderada del centro de masa del SCM
- Posición del pixel de temperatura mínima
- Posición del extremo sur del SCM
- Posición del extremo norte del SCM
- Posición del extremo este del SCM
- Posición del extremo oeste del SCM

PARAMÉTROS RADIATIVOS (**) (*)
- Temperatura media del SCM
- Temperatura mínima del SCM
- Temperatura mínima utilizando un retículo de 9 píxeles
- Gradiente medio espacial
- Desvío estándar de las temperaturas de brillo
- Histograma de la temperatura de brillo, de cada SCM, cada 2 grados

(*) Todas las unidades están expresadas en K

INFORMACIÓN SOBRE TOPES FRÍOS
- Numero de topes fríos (como clusters fríos) incluidos en cada SCM
- Tamaño medio de los topes fríos
- Tamaño de los tres mayores topes fríos
- Posición de los tres mayores topes fríos
- Correlación espacial entre los píxeles de un SCM respecto a un sistema cartesiano
- Excentricidad

- Fragmentación
- Inclinación

PARAMÉTROS MORFOLOGICOS
- Temperatura media de los topes fríos
Tracking Methodology

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

(a) Regular tracking (continuity), (b) split and (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).
Del Plata basin basics:
Member countries
Del Plata basin basics: Geography and Demographics

- 3 million km² – 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, Iguazu, Pilcomayo, Bermejo
- Basin area:

<table>
<thead>
<tr>
<th>Country</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brasil</td>
<td>45.7%</td>
</tr>
<tr>
<td>Argentina</td>
<td>29.7%</td>
</tr>
<tr>
<td>Paraguay</td>
<td>13.2%</td>
</tr>
<tr>
<td>Bolivia</td>
<td>6.6%</td>
</tr>
<tr>
<td>Uruguay</td>
<td>4.8%</td>
</tr>
</tbody>
</table>
- 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:

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>61 millions</td>
</tr>
<tr>
<td>1994</td>
<td>116 millions</td>
</tr>
<tr>
<td>2025</td>
<td>290 millions (estimated)</td>
</tr>
</tbody>
</table>

Human induced changes

Consequences

- Agricultural intensification and expansion
  - Soil compaction
  - Desertification
  - Sediment erosion, transportation and deposition
- Loss in biodiversity
- Urban environmental degradation
- Extreme events
  - (Floods, Droughts, “El niño”, “La niña”)
- Water quality
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
• TRACKING MODE: DIURNAL CYCLE

![Graphs showing diurnal cycle](image)
• TRACKING MODE: DIURNAL CYCLE
CPC-ESSIC-CICS Joint Seminar at Climate Prediction Center – March 21, 2008
Time evolution of size (top) and % of Ci (bottom)
MCS Life Cycle Schematic Representation (after Machado y Rossow, 1993)
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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Iguazu river basin: green dots are raingauge stations (daily accumulation)

Rain event from raingauge measurement:
• RR > 25 mm/day - minimum area = 50000 km²
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 (‘families’) that affect the raingauge stations with rr > 25 mm/day
• 32 families were selected
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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EVOLUCION DE LOS SCM

10:15

19:15

23:15

02:15
CASE STUDY

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

Cooling rate ~ 12 K/hour
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• MCS displacement (speed and direction)

• MCS area evolution (growth or decay)
• MCS displacement estimation

\[
\begin{align*}
\text{VE}(t+1) &= V(t) + \Delta V(t) \\
\Delta V &= V(t) - VP(t)
\end{align*}
\]
- MCS area evolution estimation

\[ \frac{d(\text{area})}{dt} = \frac{\text{lifetime}}{\text{life cycle}} \]  

Machado and Laurent 2004
• MCS growing evolution estimation

\[ A(t) = \alpha \cdot e^{at^2+bt+c} \quad \quad \quad \quad \Delta E = \frac{1}{A} \left( \frac{\partial A}{\partial t} \right) = at + b \]
Sistemas Convectivos - DSA/CPTEC/INPE

Data: 20070328 - Hora: 0800 GMT

Diagramas:
- Evolución de la Fracción Convectiva (%)
- Evolución de la Temp. Mínima del SC (K)
- Evolución de la Área del SC en Pixel
http://moingatu.cptec.inpe.br/paginas/fortracc/fortracc.php
• FORECAST MODE: NOWCAST STATISTICS

<table>
<thead>
<tr>
<th></th>
<th>30 min</th>
<th>60 min</th>
<th>90 min</th>
<th>120 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACU</td>
<td>0.98</td>
<td>0.98</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>BIAS</td>
<td>0.96</td>
<td>0.95</td>
<td>0.91</td>
<td>0.87</td>
</tr>
<tr>
<td>POD</td>
<td>0.77</td>
<td>0.64</td>
<td>0.54</td>
<td>0.44</td>
</tr>
<tr>
<td>FAR</td>
<td>0.20</td>
<td>0.32</td>
<td>0.41</td>
<td>0.49</td>
</tr>
</tbody>
</table>
• FORECAST MODE: NOWCAST STATISTICS

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Forecast</th>
<th>Non-Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>∆ Size (in %)</td>
<td>∆ Tmed (in K)</td>
</tr>
<tr>
<td>30</td>
<td>-1.87%</td>
<td>0.25</td>
</tr>
<tr>
<td>60</td>
<td>-4.20%</td>
<td>0.59</td>
</tr>
<tr>
<td>90</td>
<td>-7.80%</td>
<td>0.75</td>
</tr>
<tr>
<td>120</td>
<td>1.81%</td>
<td>0.75</td>
</tr>
</tbody>
</table>

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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(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.