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THE DETECTION OF MESOSCALE FEATURES WITH AN AUTOMATED REGIONAL SURFACE OBSERVING NETWORK IN BRAZIL.

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1. INTRODUCTION

An automated environmental monitoring network of 38 surface stations that cover most of Paraná state, in southern Brazil, is maintained in operational mode by Instituto Tecnológico SIMEPAR since 1997 (Fig. 1). Despite not characterizing a true *mesonet* (Nascimento and Maggiotto 2005), this surface network has shown, to a certain extent, the capability of detecting some interesting mesoscale features associated with convective activity. To illustrate that, one such representative event is described in this article, highlighting the relevance of regional automated observing networks for the monitoring of mesoscale circulations.

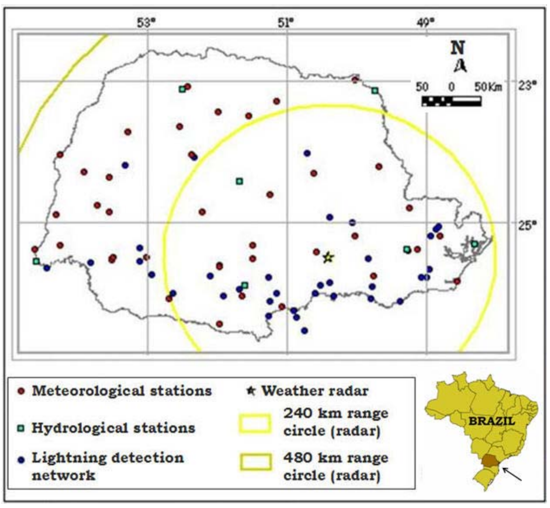

Figure 1: Map of Paraná State (Brazil) with the geographical distribution of SIMEPAR's automated surface stations.

2. VARIABLES MEASURED BY SIMEPAR'S SURFACE NETWORK

Every SIMEPAR's surface station is equipped with a standard set of instruments common to the entire network, while additional sensors are installed in a few stations (see Nascimento and Maggiotto 2005 for further details). Table 1 lists the atmospheric variables measured in a standard automated station.

Table 1: Meteorological variables measured by SIMEPAR's automated surface observing system (standard stations).

Variable	Sensor type (resolution)
Atmospheric pressure [1]	Aneroid barometer (0.1 hPa)
Air temperature [1]	Thermistor (0.1 ^{0}C)
Precipitation [2]	Tipping-bucket rain gauge (0.1 mm)
Relative humidity [3]	Sorption humidity sensor (0.1 %)
Solar radiation [3]	Pyranometer (1.0 W m^{-2})
Wind speed and direction [4]	Propeller vane (0.1 m s^{1} and 1.0^{0})
Gust speed and direction [5]	Propeller vane (0.1 m s^{1} and 1.0^{0})

[1] Hourly mean, minimum and maximum values; [2] hourly and daily totals; [3] hourly mean value; [4] values at the top of the hour, [5] hourly maximum gust.

Mesoscale surface observing networks (*mesonets*) typically report atmospheric variables at each 5 minutes (Brock *et al* 1995, Schroeder *et al* 2005), which is a good temporal resolution for monitoring mesoscale features (e.g., Fiebrich and Crawford 2001). Such temporal resolution is not available in SIMEPAR's network. Nevertheless, as shown below, some interesting atmospheric patterns induced by local convection are (at least partially) detected by this regional surface observing system.

3. DETECTION OF MESOSCALE FEATURES: THE 17 FEBRUARY 2004 CONVECTIVELY-INDUCED PRESSURE DISTURBANCES

From the late morning to early afternoon of 17 February 2004, a mesoscale convective system (MCS) was observed over east-central Paraguay. Figure 2 shows a time sequence of visible imagery from GOES-12 satellite over subtropical South America during that period. Red arrows display the location of the MCS, with its southern portion in dissipating stage.

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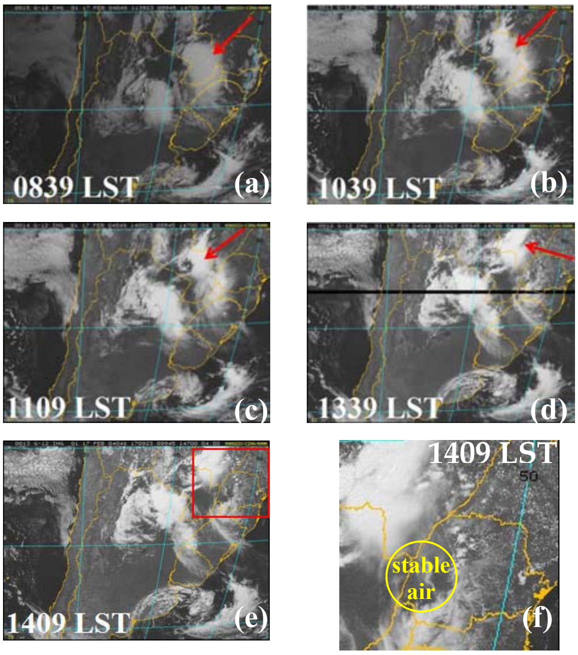

Figure 2: Time sequence of GOES-12 visible imagery over subtropical South America for 17 February 2004. Southern Brazil's local standard time (LST) is shown in each panel. Panel (f) is a close-up view at 1409LST for the area enclosed by a rectangle in (e), showing Paraná State.

The conceptual model developed by Johnson and Hamilton (1988) describes mesoscale surface circulations and pressure perturbations induced by mature MCSs, as depicted in Figs. 3a-b. In the most convectively active region of the MCS, where heavier precipitation occurs, a surface mesohigh is observed (Fig. 3a). The mesohigh owes its existence mostly to the evaporative cooling of raindrops in the sub-cloud layer (Johnson 2001). Trailing the mesohigh, a surface mesolow ("wake low") is occasionally found. The generation of the wake low is, in part, due to sub-saturated subsidence on the rear flank of the MCS (Fig. 3b), and can also be interpreted as a gravity wave response to lower-stratospheric cooling associated with the stratiform precipitation (Haertel and Johnson 2000).

In a dissipating MCS the mesohigh is no longer well characterized — because of the interruption of the convective precipitation — whereas the wake low may persist (see Fig. 3c) due to the prevailing downward (and, most often, sub-saturated) motion observed in the stratiform sector during the decaying stage of the MCS. In the 17 February 2004 case, both mesohigh and mesolow generated by the MCS were detected by SIMEPAR's stations in the western portion of Paraná state.

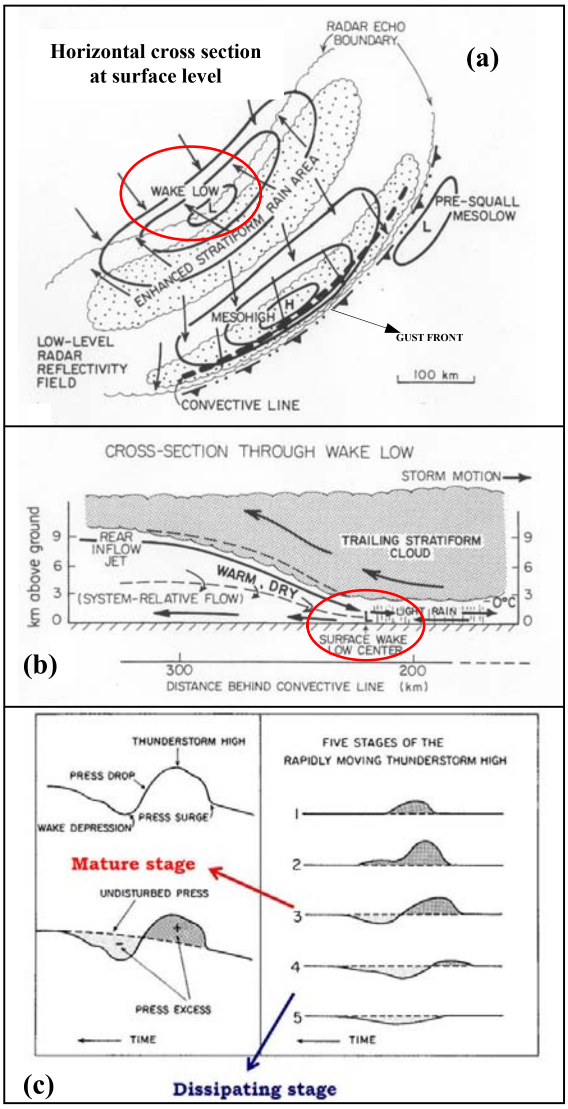

Figure 3: (a) Schematic representation of the surface pressure field (thick solid lines) induced by a mature MCS; (b) vertical cross section through the rear flank of the MCS; (c) time evolution of the surface pressure perturbation in a rapidly moving MCS. (Panels (a) and (b) adapted from Johnson and Hamilton (1988); panel (c) adapted from Fujita (1955)).

Figure 4 shows, for that day, 24-hr time series of hourly mean, maximum and minimum station-level pressure and hourly mean air temperature from 00:00 LST to 23:00 LST for several stations located in the far west Paraná (see Fig. 5 for map). All stations reported substantial rises in surface pressure during the late morning hours — for all sites this pressure rise becomes better characterized when compared to the hourly mean pressure averaged for the entire month of February 2004 (black thick line in each panel).

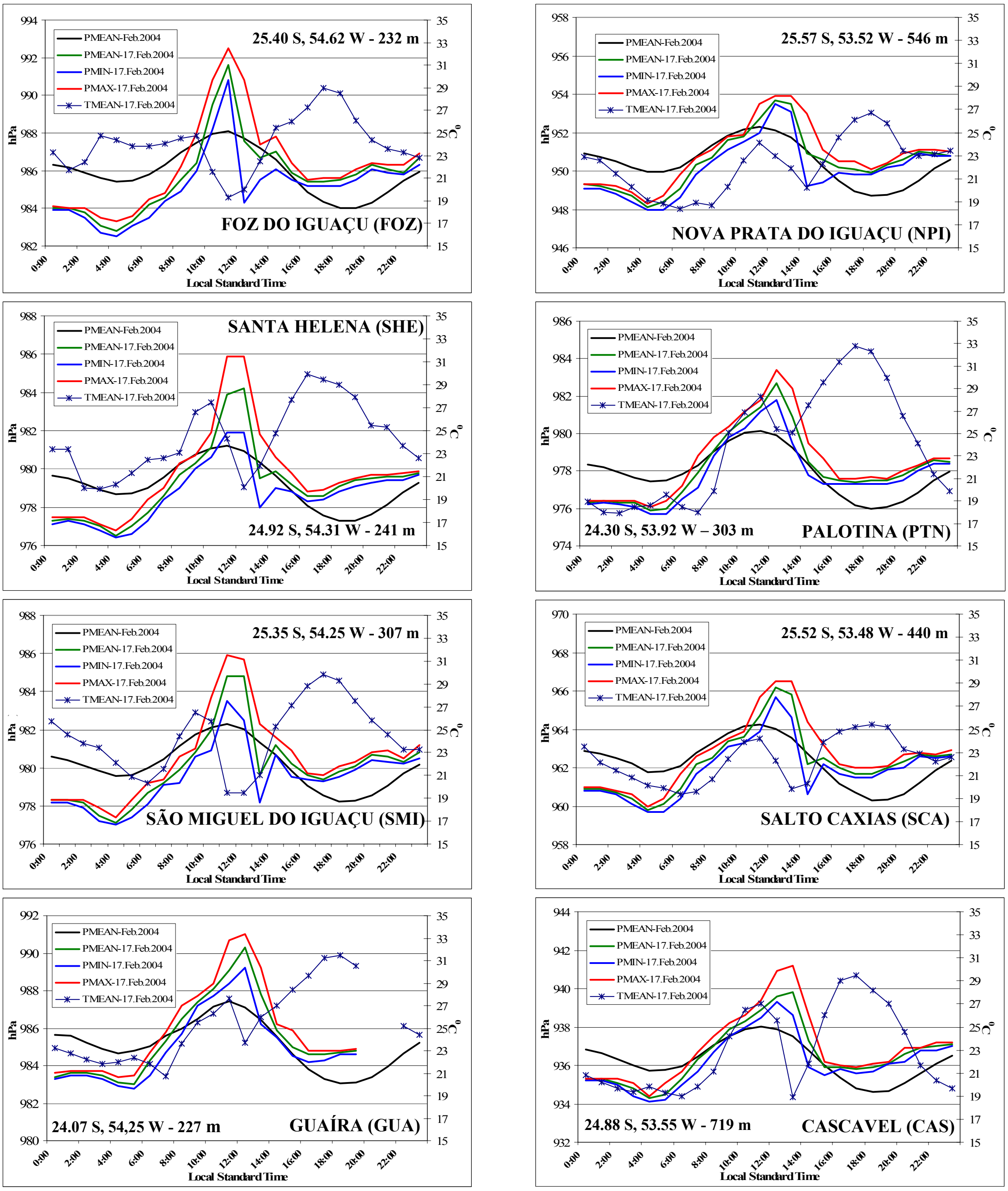

Figure 4: Time series of hourly mean, maximum and minimum station-level pressure (hPa) (respectively, green, red and blue lines) and hourly mean air temperature (^{0}C) (blue line with marker) from 00:00LST to 23:00LST for 17 February 2004 for SIMEPAR's observing sites located in western Paraná State. The hourly mean station-level pressure for the entire month of February 2004 (thick black line) also is shown for comparison. Station geographic coordinates and elevation are indicated in the panels. Figure 5 highlights location of the sites.

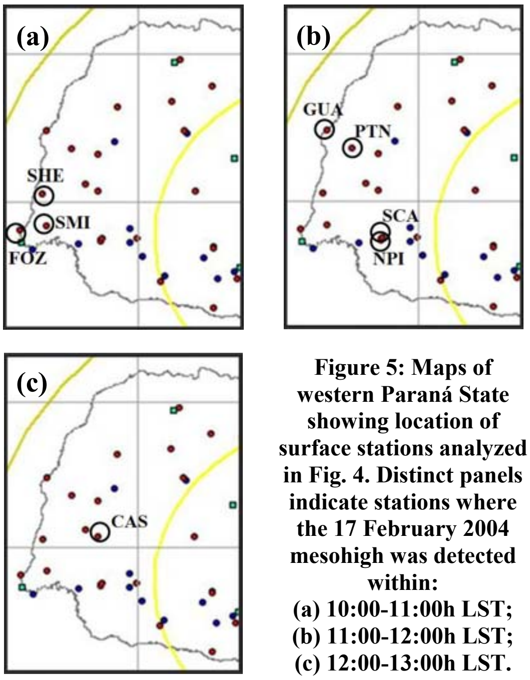

Figure 5: Maps of western Paraná State showing location of surface stations analyzed in Fig. 4. Distinct panels indicate stations where the 17 February 2004 mesohigh was detected within: (a) 10:00-11:00h LST; (b) 11:00-12:00h LST; (c) 12:00-13:00h LST.

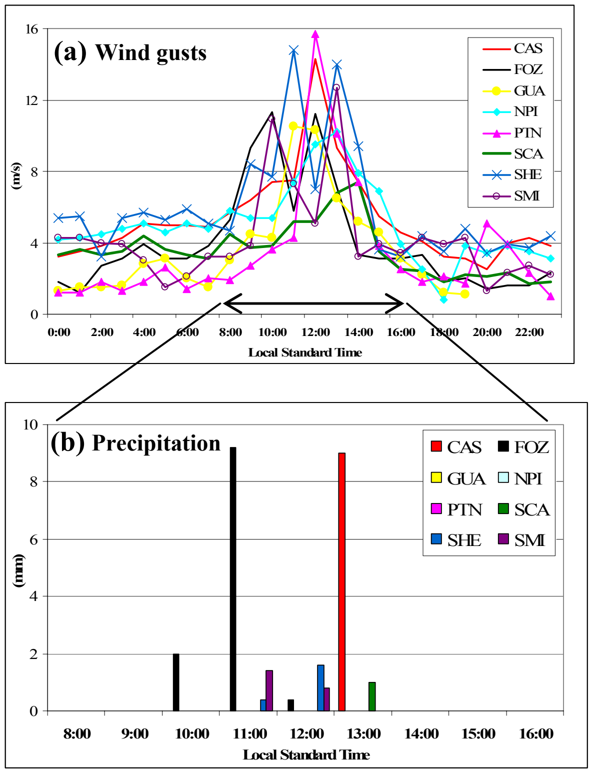

Figure 6: Time series for 17 February 2004: (a) hourly maximum wind gusts (m s^{-1}) from 00:00 to 23:00h LST; (b) 1-hr accumulated rainfall amount (mm) from 08:00 to 16:00h LST. Same observing sites as in Fig. 4.

The combined analysis of Figs. 2 and 4 strongly suggests that the pressure jump in western Paraná was associated with an advancing surface mesohigh produced by the MCS in Paraguay, which propagated into Brazilian territory in the late morning hours of 17 February 2004. Additional support for this statement is given by the evolution of the temperature field (Fig. 4). Every site reported an important temperature fall at roughly the same time of the pressure rise, with larger temperature falls being found in stations where stronger pressure drops were detected. This behavior is in agreement with the hydrostatic relation between convectively-generated mesohighs and cold pools. (In CAS, FOZ, SCA and SMI, the minimum temperature for the day was found between 11:00h and 13:00h LST). Furthermore, weak to moderate wind gusts were detected in all sites during the same time frame (Fig. 6a). (Stronger gusts may have occurred without being detected due to some sampling limitations for wind gusts of SIMEPAR's stations (Nascimento and Maggiotto 2005)).

Note, also, the earlier detection of the pressure jump in stations located further to the west (Figs. 4 and 5), characterizing the eastward progression of the mesoscale feature. Despite the presence of a mesohigh and cold pool, most stations reported little or no rainfall (Fig. 6b). This finding indicates that those mesoscale features were remnants of a MCS in dissipation. In fact, satellite imagery in Fig. 2 shows, over Paraná state, an eastward-moving feature that resembles a surface outflow boundary with "orphan anvils" aloft left by the decaying portion of the MCS.

Following the mesohigh/cold pool, a considerable pressure fall was observed in all selected stations (Fig. 4). Table 2 summarizes the largest depression in the hourly mean pressure reported by each site on 17 February 2004. The sharpest pressure falls (reaching -5.2hPa/1hr) were found before 1 PM in the three westernmost stations (FOZ, SHE and SMI). The low pressure was accompanied by clear skies (Fig. 2) — the satellite image in Fig. 2f displays a pool of stable air behind the outflow boundary — and a temperature rise (Fig. 4). This evolution is in close agreement with the conceptual model of a decaying MCS (described in terms of surface pressure by stages 4 to 5 in Fig. 3c), with the pressure fall being the manifestation of a wake low discussed before. The concomitant observation of a temperature rise appears to be hydrostatically related to the wake depression. Clear skies trailing the outflow boundary (see Fig. 2f) certainly favored the recovery of the diurnal cycle of temperature after the passage of the mesohigh. However, we hypothesize that sub-saturated subsidence induced by the decaying convection is partially responsible for that temperature rise.

Table 2: Most significant fall in 1-hr mean pressure reported by the selected stations on 17 February 2004. The corresponding 1-hr time window is also indicated.

Station	Pressure variation (hPa) [Time - LST]
CAS	-2.5 [13:00-14:00h]
FOZ	-4.0 [11:00-12:00h]
GUA	-2.5 [12:00-13:00h]
NPI	-2.6 [13:00-14:00h]
PTN	-2.4 [13:00-14:00h]
SCA	-3.6 [13:00-14:00h]
SHE	-4.7 [12:00-13:00h]
SMI	-5.2 [12:00-13:00h]

This hypothesis is supported by the evident dissipation of the cirrus deck (“orphan anvils”) over western Paraná state (Fig. 2), which is a typical observation after surface-based convection is ceased and the circulation becomes dominated by weak sub-saturated downdrafts.

4. FINAL REMARKS

The monitoring of mesoscale circulations in real time is crucial for nowcasting purposes, where automated regional/mesoscale observing networks play a fundamental role. Conventional synoptic-scale observing networks do not report meteorological variables on an hourly or sub-hourly basis necessary for mesoscale weather analysis, and are not conceived to provide sub-synoptic space coverage for atmospheric observations.

A regional network of automated surface stations is maintained by Instituto Tecnológico SIMEPAR in operational mode since 1997 in southern Brazil. Despite some important limitations on data collection and transmission (Nascimento and Maggotto 2005), this network has shown some capability to detect atmospheric phenomena on the mesoscale. One episode — involving convective activity in decaying stage — in which such capability became evident is described in this article.

Without the regional automated observing system, the weather event analyzed here would not be adequately monitored. For example, the substantial fall in the mean surface pressure reported by several stations on 17 February 2004 could only be characterized as a propagating mesolow associated with decaying convection because of the joint analysis of several weather variables measured on the regional scale (plus satellite imagery). Inability to monitor the phenomenon on the time and space scales in which such systems typically evolve could lead to wrong diagnosis and nowcast of the state of the weather in a regional basis. More specifically, the strong (and relatively widespread) pressure falls could have been wrongly diagnosed as a manifestation of cyclogenesis associated with cloudy and rainy conditions, not observed on the 17 February 2004 case.

During the conference, another example illustrating the important role played by SIMEPAR’s regional network for monitoring mesoscale weather features in Paraná state will be shown.

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