First results of lightning and radar observations in Minas Gerais, Brazil

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Introduction

The State of Minas Gerais is situated in Southeast Brazil (Fig.1a) and has a tropical savanna climate, characterized by summer rain and relatively dry winter months. During the austral summer, the region suffers from flooding problems, which have their natural origin exacerbated by anthropogenic actions. Therefore, at the end of 2011, a C-band dual polarimetric Doppler radar was installed 50 km west of Belo Horizonte (BH; Fig.1b) for monitoring, forecasting and warning of storms in this region, and in December 2013 the TITAN software (Thunderstorm Identification, Tracking, Analysis and Nowcasting; Dixon and Wiener, 1993) was implemented for the processing of radar data, which not only provides details of severe storm parameters and forecasts of cell tracks, but it can also overlay lightning data.

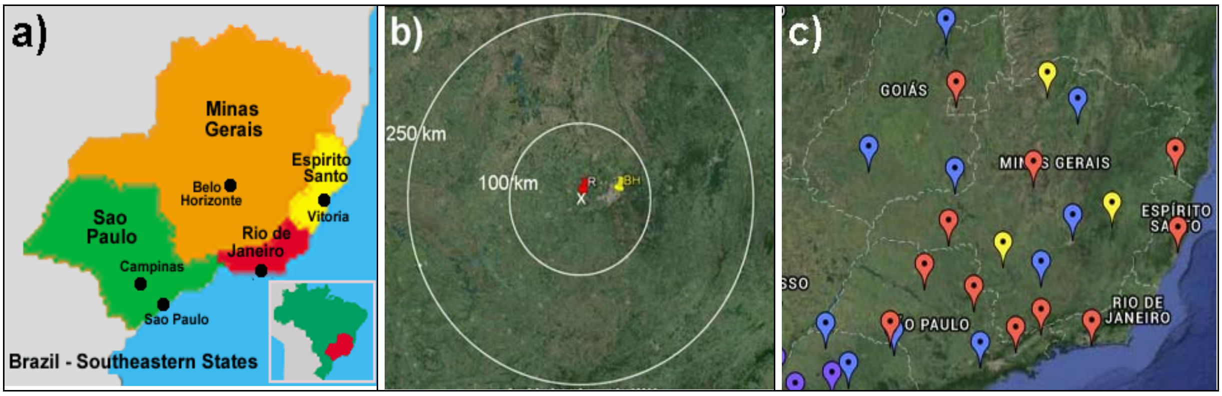


Figure 1. a) Southeast Brazil; **b)** Location of "Elefante Radar" (x) in Minas Gerais and of Belo Horizonte (BH);
c) Part of RINDAT Lightning Detection Network with relevant sensors (mixed types) in and around Minas Gerais.

Objectives

In this first analysis of radar and lightning observations in the State of Minas Gerais during the summer of 2013/2014, the interaction between thunderstorm cells and the generation of C-G (cloud-ground) lightning strokes is being presented in form of two case studies. The lightning pattern of a severe Hail Storm over Belo Horizonte is compared with that of a primarily stratiform rain situation, providing important information for Nowcasting in this region. Polarimetric radar data have not yet been considered in this preliminary study.

Data and Methodology

The radar data utilized in this study was generated by a C-band dual-pol Doppler radar located ca 50 km west of Belo Horizonte (Lat: -19,945°, Lon: -44,435°, 1271 + 18 m amsl). It has a 1° beam width, 400 km range for surveillance mode and 250 km in volume scan mode with 14 elevations from 0,5° to 26,5°, with a 200 m radial and 1° azimuthal resolution. Volume scans have a temporal resolution of ±7,5 min, interspaced by a 0,5° surveillance PPI.
The lightning data (cloud-ground strokes, CG) were retrieved from the RINDAT Lightning Detection Network (Fig.1c), applying the following filters: ≥4 sensors; negative strokes ≥7 kA; positive strokes ≥10 kA.
In order to overlay the radar images with the lightning strokes, the TITAN visualization program CIDD had been adapted for the radar range of the C-band radar in Minas Gerais. This Software was used to generate composite reflectivity fields for each volume scan of ±7,5 min duration, which were alternatively superimposed by the positive and negative lightning strokes corresponding to the same time interval. Vertical cross-sections were prepared to illustrate the 3-d storm structure.

Case studies

11 Dec 2013 – Stratiform rain area with isolated convective cells embedded at the leading edge

The synoptic situation was typical for a "South Atlantic Convergence Zone" (SACZ, Grosvenor et al., 2007). A weak extension of the Atlantic Ocean Anticyclone reaches over Northeast Brazil at the surface, but a shallow trough approaching from the south along the coast impacts on southern Minas Gerais around 00:00 UT. However, the driving force is the circulation at mid-levels (500 hPa), feeding moist tropical air around Northeast Brazil and returning via Amazônia with a northwesterly flow over central Minas Gerais. Thus, a convective leading edge, trailed by a large stratiform rain system with small convective cells embedded, approaches the radar from the west (Fig.2). Both vertical sections show small convective cells, especially section b at the clearly defined leading edge. Once the convection had passed over the radar, concentric rings of radar reflectivity clearly indicate the "Bright Band" (03:00 UT, melting zone; Fig.3) at around 5 km amsl (above mean sea level), which is a rare event in the Brazilian tropical region. It is noteworthy, that no more negative strokes were recorded at this time, while within the red circles 1-3 positive strokes each occurred.

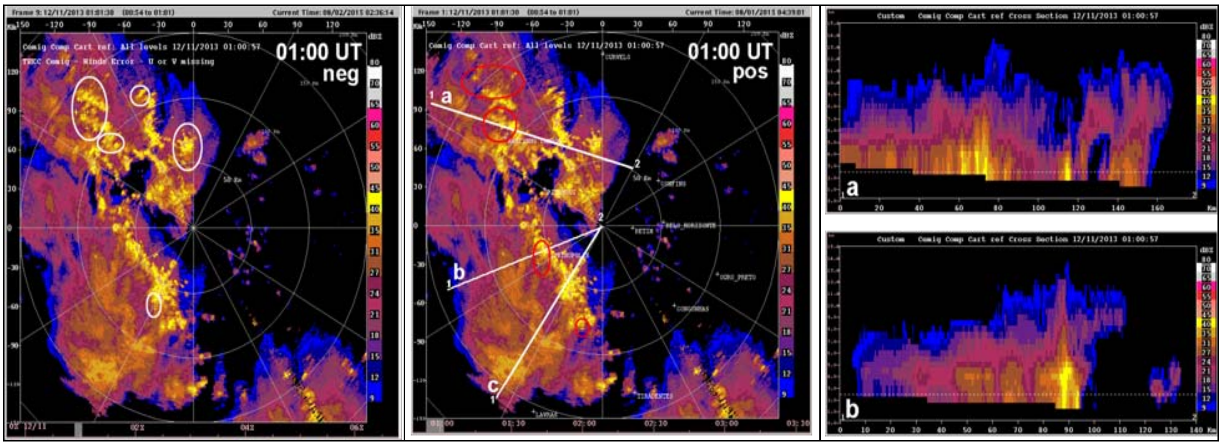


Figure 2. Composite reflectivity field on 11 Dec 2013 – 01:00 UT with negative CG (left), positive CG and base lines of vertical sections (center) and vertical cross-sections (height range 0-15 km) along base lines a and b (right).

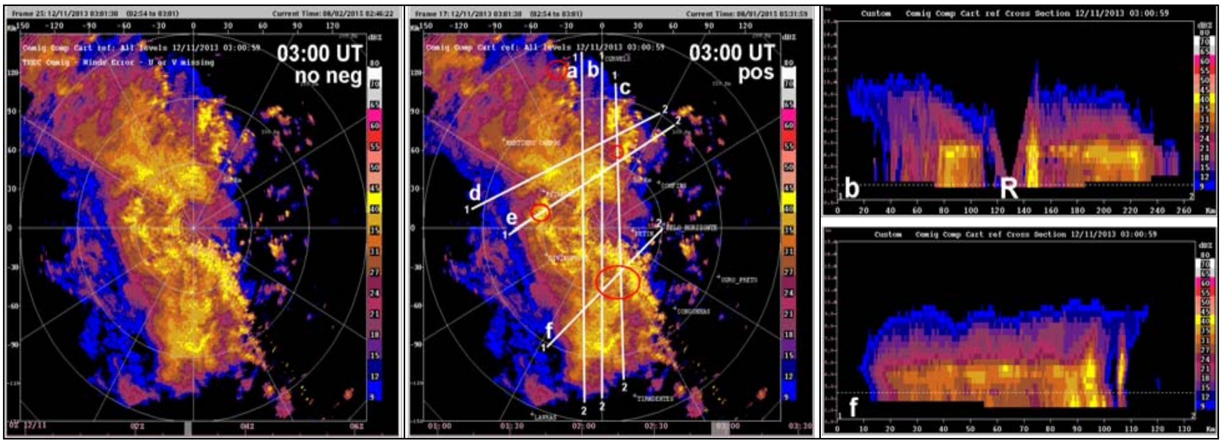
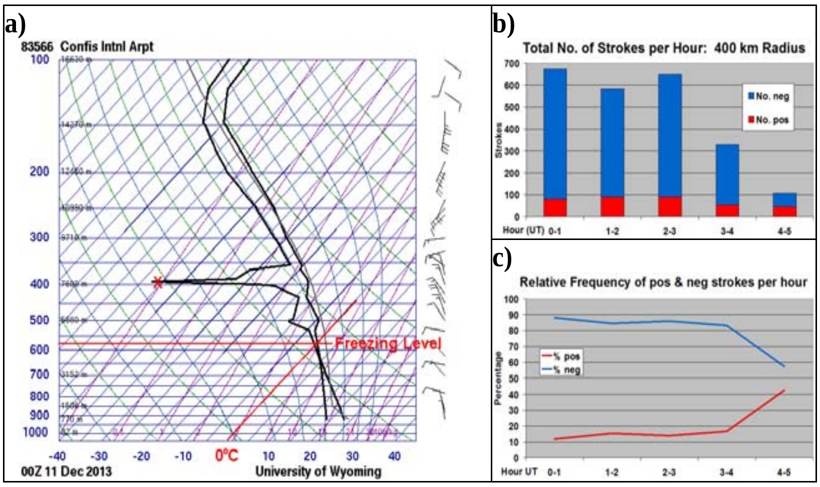


Figure 3. Composite reflectivity field on 11 Dec 2013 – 03:00 UT with no negative CG (left), positive CG and base lines of vertical sections (center) and vertical cross-sections (height range 0-15 km) along base lines b and f (right).

The 00:00UT Radiosonde ascent from Confins Airport (about 20 km north of Belo Horizonte) indicates the Freezing Level at about 4700 m (Fig.4a), which agrees well with the Melting Band observed by the radar. (The sharp drop of the dew point at 394 hPa (-52,3°C) is due to an instrumental error).



Figs.4b,c show the statistics of lightning strokes within 400km radius in the form of hourly total numbers and relative frequency of positive and negative CG from 00-05UT. The decay of the lightning activity after 03:00 UT, together with a relative increase of positive strokes is clearly visible. The weak convective leading edge of the rain area continued moving eastwards at about 40 km.h^{-1} until well after 05:00 UT with very little lightning activity having been recorded.

Figure 4. a) Radio sounding on 11 Dec 2013 - 00UT from Confins Airport
b) Total number of lightning strokes per hour; **c)** Relative frequency

20 January 2014 – Severe Hailstorm over Belo Horizonte

This day was characterized by synoptic conditions favourable for the development of afternoon convection (the 12UT sounding at Confins Airport already indicated a CAPE of >1000 J.kg^{-1}, Fig.5a). At the surface, a convergence zone extended from the Atlantic Ocean (AO) across northern Minas Gerais (MG) into Amazônia, while at mid-levels (500 hPa) the AO High protruded over Northeast Brazil, circulating tropical air anticyclonically around it, and thus advecting relatively moist air across MG. At 250 hPa, a trough extended from the AO over southern MG, all in all contributing moist air above the hot continent. Consequently, extensive multi-cellular storm complexes developed over central MG together with isolated convective cells in the south of the state.

Fig.5b shows the 250 km composite reflectivity field on 20 January 2014 at 17:00 UT, about one hour before the hailstorm, with lots of negative CG strokes, but positive CG strokes were only recorded in the far northwest sector, beyond the 240 km range.

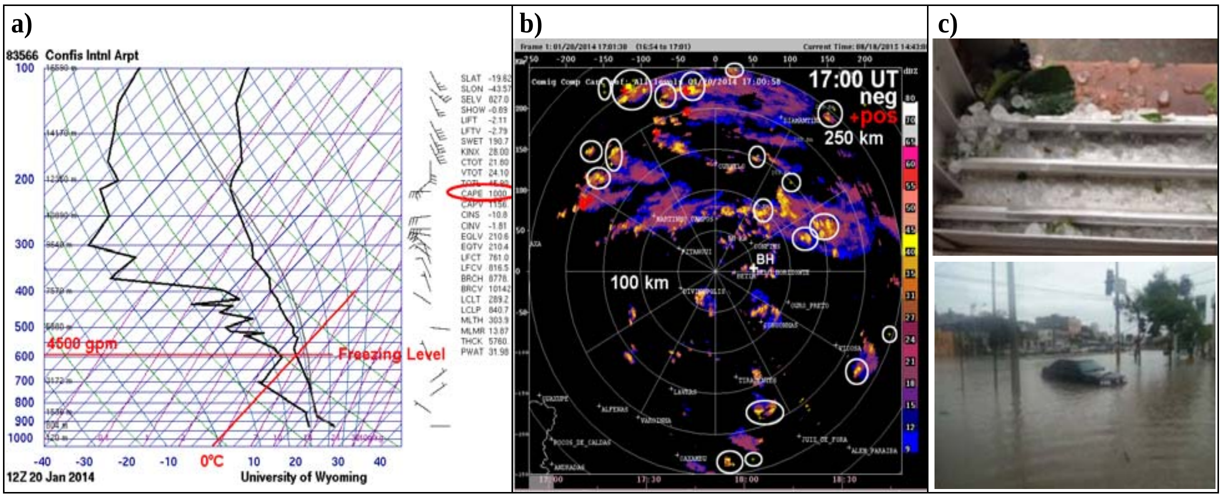


Figure 5. a) Radio sounding on 20 January 2014 - 12UT) from Confins Airport; **b)** Composite reflectivity field (250 km radius; pos & neg) at 17:00 UT; c) Hailstones (top) and Flooding of great parts of Belo Horizonte (bottom).

After 17:00 UT, a multi-cell complex developed rapidly through merging of earlier cells over the Metropolitan Region of Belo Horizonte, which caused severe hail damage and flooding between about 18:00 and 18:30 UT (Fig.5c). The hail fall was accompanied by a large number of negative C-G strokes, but almost no positive strokes were recorded during its life-cycle. Fig.6 shows the composite radar images at 18:08 and 18:23 UT, representing the most intense phase of the storm, overlaid by negative and positive CG strokes, respectively, as well as a vertical cross-section each. The multi-cellular complex was almost stationary, while expanding and contracting laterally.

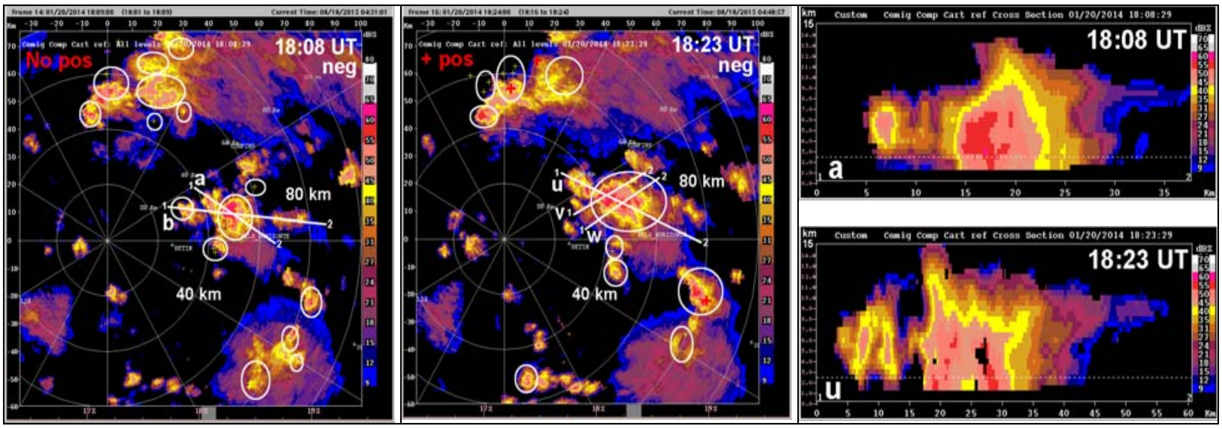


Figure 6. Composite reflectivity field on 20 Jan 2014 – 18:08 UT (left) and 18:23 UT (center) with CG strokes indicated, and vertical cross-sections along base lines a and u (right) at 18:08 UT and 18:23 UT, respectively.

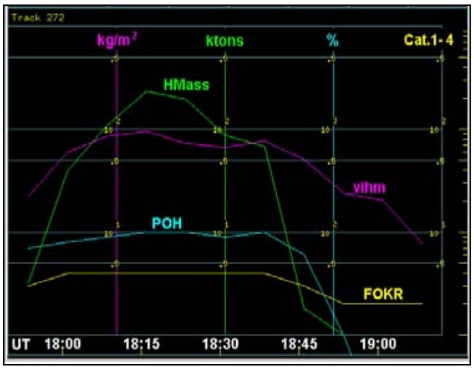


Figure 7. Time sequence of severe storm parameters calculated by TITAN for the period 17:45 to 19:15 UT.

Figure 7 shows time sequences of some severe storm parameters calculated by TITAN. The most intense phase of this storm complex falls into the period from 18:08 to 18:38 UT. The hail mass (HMass) culminated at 18:15 UT with 232,9 ktons, but all hail fell out between 18:38 and 18:45 UT. Furthermore, it is also noteworthy, that the Probability of Hail (POH; Waldvogel *et al.*, 1979), as well as the Foote-Krauss index (FOKR; Foote *et al.,* 2005), was at their maximum values of 100% and 4, respectively, from 18:08 to 18:38 UT, rapidly decreasing thereafter. Also, the vihm (Vertical Integrated Hail Mass, Foote *et al.,* 2005) peaked between 18:00 and 18:38 UT, after which it gradually decreased.

Preliminary results from this case study have shown, that 6684 strokes were recorded within a range of 400 km of the radar during a 24-hour period, of which only 12,4% were positive. The frequency of lightning strokes began to increase from 13:18 UT onwards, but until 19:30 UT only 8,5% of the strokes was positive, while from 17:00 – 19:30 it dropped to 8,0%. However, during the occurrence of the hailstorm over Belo Horizonte, only one positive stroke was generated by this particular storm complex.

Concluding Remarks

The two examples analyzed confirm significant differences in lightning activities between stratiform rain areas and convective storm complexes: On 11 December 2013, 15,4% of total lightning strokes were positive, while on the day with the hailstorm, 20 January 2014, only 8,5% were positive strokes; no significant differences were found for the mean peak power, with +25,5 and -29,0 kA for the stratiform case and +28,0 and -26,9 kA for the convective storms, while absolute maxima were +157 and -193 kA, and +132 and -210 kA, respectively.

Acknowledgements

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