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The properties of convective storms in central Mexico: A radar and lightning approach

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RESUMEN

Se emplean datos del radar de Cerro Catedral (una elevación cercana a la Ciudad de México) para investigar las propiedades de las tormentas convectivas que ocurren sobre el centro de México, una región de orografía compleja. La distribución espacial muestra que las tormentas tienden a formarse y moverse hacia el oeste del radar, sobre una banda estrecha de terreno elevado. No obstante, las tormentas con los mayores volúmenes y alturas en sus topes tienden a localizarse hacia el suroeste, sobre terrenos bajos. Cada elemento convectivo se enlazó con el número de descargas eléctricas a tierra producidas en su interior, según fueron detectadas por la World Wide Lightning Location Network (Red Mundial de Localización de Rayos). Las tormentas en las que se detectaron descargas y que tuvieron un promedio de más de seis rayos en su interior, fueron significativamente más grandes e intensas que las tormentas en las que no se detectaron descargas, y tendieron a localizarse sobre terrenos más bajos. La muestra de más de 98 000 celdas identificadas se dividió en cuatro grupos de acuerdo con la elevación, para investigar posibles tendencias de las propiedades medias relacionadas con la altura del terreno, como se ha informado para otras regiones en México. En tanto que el número de tormentas por unidad de área se incrementa con la elevación del terreno, los valores promedios de las propiedades relacionadas con el tamaño (área, volumen, tope del eco) y la intensidad (reflectividad máxima, número de descargas, altura de la reflectividad máxima, máxima altura del contorno de 30 dBZ), disminuyen. Estos resultados podrían vincularse con la posibilidad de que el espesor de la parte de la nube donde ocurren los procesos de lluvia caliente sea menor en terrenos más altos. Los ciclos diurnos de la convección y del número de descargas eléctricas al norte del radar muestran un régimen de precipitación típicamente continental, con máximos a las 18:00 LT en ambas variables. No obstante, al sur del radar el máximo de descargas se detectó cerca de la medianoche, lo cual se relaciona con la convección más profunda que ocurre sobre los terrenos bajos de esa zona durante altas horas de la noche y la madrugada.

ABSTRACT

Radar data from Cerro Catedral (a peak close to Mexico City) were used to investigate the properties of convective storms over central Mexico, a region with complex orography. The spatial distribution shows a preference for storms to form and move to the west of radar, over a narrow band of high terrain. However, the storms with the higher volumes and echo-top heights tend to be located southwestward over lower terrain. Each radar feature was matched with the number of cloud-to-ground (CG) lightning produced inside it, as retrieved from the World Wide Lightning Location Network dataset. The storms in which lightning was detected, with an average of more than six lightning bolts, clearly outperform in size and intensity the group of storms in which lightning was not detected, and tend to lie over lower terrain. The sample of over 98 000 identified cells was divided into four elevation groups to look for elevation trends in the mean properties, as reported for other Mexican regions. While the number of storms per unit area increases with terrain height, the average values for properties related to both size (area, volume, echo-top height) and intensity (maximum reflectivity, number of CG bolts, height of maximum reflectivity, maximum height of 30 dBZ echo) decrease. These results could be related to the possible shallower warm-cloud depths over the higher elevations. The

diurnal cycles of convection and lightning north of the radar show a nearly typical continental regime of precipitation in that zone, with maxima at 18:00 LT in both variables. However, south of the radar, a maximum in lightning activity occurs during late night and early morning, which is linked with the deeper nocturnal convection over the lower terrain in that zone.

Keywords: Convective storms, radar reflectivity, cloud-to-ground lightning, central Mexico.

1. Introduction

Central Mexico is a region characterized by a long belt of high terrain more than 2000 masl, which extends roughly in an east-west direction and covers a great portion of the so-called Mexican Plateau in its southernmost zone. There are places where the terrain descends abruptly to below 500 masl to the south (the Balsas River basin) and to the northeast (the coastal plain of the Gulf of Mexico), and zones with peaks more than 4000 masl (the Transversal Volcanic Axis, see Fig. 1). It also contains the greatest centers of population in the country including the State of Mexico and the Federal District, where large industrial zones exist.

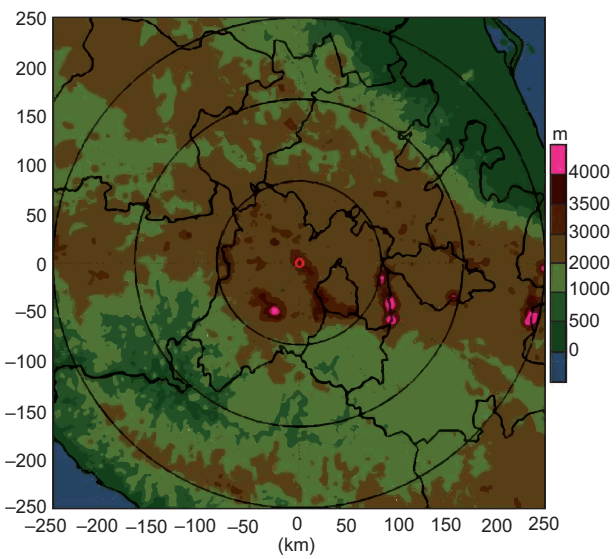

Fig. 1. Study region of 250 km in radius centered in Cerro Catedral radar. Topographic data is included.

The climate of central Mexico is well known and has been thoroughly described by many authors (Mosiño and García, 1974; Magaña *et al.*, 1999; Cortez, 1999, 2000; Valdés *et al.*, 2005; UNAM, 2007; Kucienska *et al.*, 2010). Most of the annual precipitation in this zone comes mainly from convection during a well-defined wet season (May-October), when the number of thunderstorms increases noticeably. This is linked with the northward movement of the North Atlantic Subtropical High and the arrival of deep tropical moist air from the Gulf of Mexico over the region (Mosiño and García, 1974). Summer precipitation in the Mexico basin has been found to be mainly the result of deep convection with dominant ice phase (Kucienska *et al.*, 2010; Montero *et al.*, 2011). The seasonal cycle of cloud-to-ground lightning strokes over continental Mexico shows a broad maximum during the summer months from July to September (Kucienska *et al.*, 2010).

However, there are very few studies using data with high temporal and spatial resolution. In particular, radar data have been scarcely utilized to characterize cloud systems in central Mexico. Most of the published studies are rather recent and have utilized radar in conjunction with rain-gauge data for a better estimation of surface rainfall over the Mexico basin (González, 1998; Méndez *et al.*, 2009, 2011; Vilchis *et al.*, 2011).

On the other hand, a comprehensive study on convective systems and precipitation has been done in northwestern Mexico in the context of the North American Monsoon Experiment (NAME) carried out during summer 2004 (Lang *et al.*, 2007; Rowe *et al.*, 2008, 2011). Utilizing data from the three-radar network during NAME, they found a marked diurnal cycle of convection, which begins early afternoon over the highest eastern peaks and moves westward over the coast of the Gulf of California during the late afternoon and early evening. They have also documented a marked elevation-dependent trend in convection, the latter being more frequent over higher terrain, but more intense over lower terrain.

In this study, we apply a feature identification algorithm to extract radar echoes associated with cloud systems in central Mexico during summer. Each radar feature was linked to cloud-to-ground (CG) lightning and topographic data to look for differences between CG and non-CG clouds and possible elevation-dependent trends of their properties. Spatial and