Atmospheric Research 149 (2014) 244–254

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Observation of a freezing drizzle episode: A case study

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ARTICLE INFO

Article history:
Received 16 May 2014
Accepted 28 June 2014
Available online 04 July 2014

Keywords:
Freezing drizzle
Cloud chamber
Radiometer
Micro Rain Radar-2
MSG

ABSTRACT

On 5 February 2012 an episode of freezing precipitation took place in the Guadarrama Mountains, at the center of the Iberian Peninsula. This precipitation affected high elevations, where temperatures remained below freezing because of snow cover that had accumulated from snowfall during the previous days. The case study was recorded by surface synoptic observations (SYNOP) at Navacerrada Pass meteorological observatory (belonging to the National Weather Service of Spain). To study winter cloud systems during the TEcoAgua project, a multichannel ground-based microwave radiometer (MMWR), Micro Rain Radar (MRR-2), and isothermal cloud chamber were installed in the study area, thus permitting the monitoring of the freezing precipitation event.

Analysis using Meteosat Second Generation (MSG) satellite data and observations permitted the determination of factors that triggered the freezing precipitation event. Freezing drizzle was interspersed with the passage of a warm and cold front. During frontal passage, mid-level clouds inhibited the generation of freezing drizzle, with snowfall recorded in the study area. However, during the period between the two fronts, an absence of mid-level clouds permitted low-level orographic clouds to persist upwind of the mountain system, producing freezing drizzle at the surface. The decisive factors for the generation of freezing drizzle were high humidity at low levels, weak mesoscale updrafts caused by the topography, stability at mid levels, cloud-top temperatures warmer than −15 °C, and low concentrations of ice nuclei.

1. Introduction

Freezing precipitation (freezing rain, freezing drizzle or ice pellets) causes an accumulation of ice on the ground, which poses a threat to human activities such as road, rail, and aviation (landing and takeoff) transport. This precipitation can negatively affect homes, infrastructure and wind power generation, and cause power outages (Norrman et al., 2000; Juga et al., 2012).

On the European continent, the highest frequencies of freezing precipitation are in Central Europe, whereas in southwestern Europe such precipitation is almost completely restricted to mountainous areas (Carrière et al., 2000). A possible increase in the frequency and severity of freezing precipitation events in coming decades cannot be ruled out in regions that are now less frequently affected, and even regions previously free of this phenomenon may be impacted (Arctic Climate Impact Assessment, 2004).

There are two possible mechanisms for the formation of freezing precipitation. First is known as the warm nose, in which solid-phase hydrometeors melt to form rain or drizzle as a result of crossing a layer of above-freezing air (Huffman and Norman, 1988). In the second mechanism, supercooled droplets form by condensation. Once the droplets reach sizes more than 40 μm, they begin to grow via collision and coalescence with other droplets, quickly producing drizzle drops (Pruppacher and Klett, 1997). In this mechanism, cloud

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http://dx.doi.org/10.1016/j.atmosres.2014.06.014
0169-8095/

tops generally have temperatures warmer than −15 °C, which are unfavorable to crystallization processes, so the hydrometeors generally do not become solid (Bernstein, 2000). The second mechanism often results in freezing drizzle. A front is not necessary to produce freezing drizzle, nor is a warm layer with temperatures warmer than 0 °C above a temperature inversion layer at the surface (Rauber et al., 2000).

Factors needed to form freezing drizzle are cloud tops of −15 °C or warmer, narrow cloud thickness, weak mesoscale uplift, stably stratified conditions, high relative humidity (RH) at low levels, and low concentrations of both ice crystals and ice nuclei (Cober et al., 1996; Ellrod and Bailey, 2007).

During a field campaign including the day studied herein, daily ground measurements were made of ice nuclei (IN) concentration using an isothermal cloud chamber. IN concentration is a limiting factor in the process of glaciation; low concentrations favor freezing precipitation. For decades, IN concentration has principally been measured using the following techniques: particle capture on supercooled droplets, the drop freezing technique, continuous-flow ice thermal diffusion chamber, static isothermal cloud chamber, and particle sampling on filters followed by processing in static or dynamic chambers (Santachiara et al., 2010).

A multichannel ground-based microwave radiometer (MMWR) was installed in the Guadarrama Mountains during the TEcoAgua project to study in detail factors associated with freezing precipitation, through continuous logging of profiles of temperature, humidity and liquid water content (Solheim et al., 1998). This instrument has the advantage of high-frequency sampling of thermodynamic profiles, and can take measurements up to 10 km above the surface, with spatial resolution 50–250 m (Sánchez et al., 2013). Continuous measurement of water vapor and liquid water content (LWC) is useful because of their influence on cloud formation (Friedrich et al., 2012), and is therefore helpful for monitoring freezing precipitation events.

Finally, for cloud system observation, a Micro Rain Radar (MRR-2) was installed in the study area. Detection of freezing drizzle using radar is complex, because its reflectivity is similar to that of light snow (Straka et al., 2000). Moreover, there is an absence of a reflectivity bright band in cases with no warm layer (Lackmann et al., 2002). Cha et al. (2009) reported that unrimed snow growth leads to low-density snow particles, whereas higher density particles appear when snow particle growth is more affected by riming (snow growth by accretion of supercooled cloud droplets).

In recent years, the use of geostationary satellites to study cloud microphysical characteristics has increased because these facilitate determination of cloud top particle size and temperature, from which cloud-top phase may be obtained (Lensky and Rosenfeld, 2008). The study of the evolution of vertical profiles from the Meteosat Second Generation (MSG) satellite, which uses albedo in the 3.9 μm channel and brightness temperature (BT) in the 10.8 μm channel, can be used to estimate cloud phase (Drori and Lensky, 2010). This phase determines the type of precipitation at the surface. The use of red–green–blue (RGB) composite satellite images aids the understanding of processes that trigger precipitation (Lensky and Rosenfeld, 2003). We used such techniques to analyze the evolution of the microphysics and cloud vertical dimension during the freezing event described herein.

On 5 February 2012, a freezing drizzle episode was recorded between 11:00 and 13:30 UTC. This event occurred during a data-collection campaign pertaining to winter cloud systems that was part of the TEcoAgua project during the winter of 2011–2012 in the Guadarrama Mountains. This freezing precipitation event was between two snowfall periods at the surface, owing to the passage of first a warm front and then a cold front.

This article is organized as follows: Section 2 describes the study area and instrumentation is defined in Section 3. Section 4 contains observations from each instrument used in the field campaign. Finally, Section 5 summarizes the conclusions.

2. Study area

The TEcoAgua project experimental campaign included data collection on winter cloud systems in the Guadarrama Mountains, which are at the center of the Iberian Peninsula (Fig. 1). This mountain range has a southwest–northeast orientation, with maximum altitudes above 2000 m.a.s.l.

During winter 2011–2012, both the MMWR and MRR-2 were situated at 40°47′32.36″N, 4°0′38.43″W. This instrumentation was only 800 m northwest of Navacerrada Pass, at altitude 1880 m.a.s.l. This pass connects the provinces of Madrid and Segovia, and the Lozoya Valley. Owing to Navacerrada's proximity (less than 50 km) to a major urban center (Madrid), it has a large Influx of tourists, especially during winter since it is the main access to two ski areas. This increases vulnerability to weather-risk situations, such as heavy snow or freezing precipitation.

The isothermal cloud chamber was installed in the Lozoya Valley near Pinilla Reservoir, at 40°56′48.95″N, 3°46′36.59″W and 1100 m.a.s.l. This was only 26 km in a straight line from the instrumentation at Navacerrada Pass.

3. Instrumentation

3.1. Isothermal cloud chamber

Under the framework of the field campaign in the Guadarrama Mountains during winter 2011–2012, IN concentration at ground level was measured daily to analyze its connection with precipitation. The isothermal cloud chamber has a cylindrical tank with capacity 11 L. It also has a thermostat for setting the temperature at which nucleation processes will take place. IN concentration was measured at −23 °C. At the bottom of the cloud chamber is placed a tray with a solution of distilled water, sugar and glycerin. Then, the humidity in the atmosphere inside the tank is saturated using a light bulb surrounded by wet gauze. Ice crystals form and fall, and are measured over the tray. More details on this procedure are given in Castro et al. (1998).

3.2. Multichannel ground-based microwave radiometer (MMWR)

A MMWR (MP-3000A, manufactured by Radiometrics Corporation) was used to obtain continuous vertical profiles (with temporal resolution 2.5 min) of temperature, humidity, liquid water content and water vapor density, up to a height of 10 km. The data used were along the MMWR zenith. Data collected by this instrument in the Guadarrama Mountains