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A RADAR-BASED CLIMATOLOGY OF HIGH PRECIPITATION EVENTS IN THE EUROPEAN ALPS: 2000-2007

James V. Rudolph*, K. Friedrich,
Department of Atmospheric and Oceanic Sciences, University of Colorado at Boulder, Colorado, USA

U. Germann
MeteoSwiss, Locarno, Switzerland

1. INTRODUCTION AND MOTIVATION

Precipitation is a key element in the water cycle, and precipitation characteristics such as frequency, intensity, type, and duration are likely to be affected by changes in regional and global climate. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) emphasizes that changes in precipitation related to climate change will exacerbate the current stress on water resources from population growth and land-use change. Despite detailed precipitation monitoring in North America, Australia, Europe, and some Asian countries, large uncertainties about past and present global and regional precipitation amounts remain. Accurate quantification of observed precipitation variability on annual, decadal, seasonal, and centennial time scales is necessary for assessing past and present climate variability, validating multi-scale numerical weather prediction and climate models, constructing regional climate-change scenarios, and determining strategies for water resource management.

Mountains play an especially important role in the hydrologic cycle with implications for runoff, flooding, water storage, and glacier-mass balance (Beniston, 2005). Changes in precipitation frequency, intensity, and rain/snowfall ratio in mountainous regions are of major concern, affecting both the localized alpine area and the lowlands that depend on precipitation in the mountains for their fresh water supply. Understanding past and future precipitation characteristics in mountainous regions is essential to develop water policy and management strategies for responding to the impact of future climate change. The 2008 IPCC technical paper on climate change and water notes that there is insufficient information on the effect of climate change where topography generates fine spatial scales in climate, and also that further development is needed of catchment scale climate models that are more relevant to water management (IPCC, 2008).

The European Alps provide an ideal laboratory for studying multi-scale processes related to the interaction between mountainous terrain and weather regimes with different air mass characteristics (advected from the Atlantic, the continent, and the Mediterranean Sea). Furthermore, the Swiss radar network in the Alps provides a unique basis for a precipitation climatology that enables high-quality, high-resolution, four-dimensional analysis that is not possible with rain gauge data. A climatology approach allows the analysis to go beyond individual case studies to understand precipitation intensity, frequency, duration, and spatial distribution over an extended period of time. This study presents initial findings from an analysis over the years 2000-2007.

* *Corresponding author address:* James V. Rudolph, Univ. of Colorado, ATOC, UCB 311, Boulder, CO 80309-0311; email: james.rudolph@colorado.edu

2. OBJECTIVES

The intent of this study is to utilize operational radar data to develop a fine scale precipitation record for the European Alps that is used to identify steady-state and intermittent precipitation characteristics and their temporal and spatial variation. Specifically, the climatology provides analysis of precipitation distribution in time, horizontal and vertical space, and precipitation type, and relates the distributions to upstream conditions and orographic effects. The goal of this study is to analyze the spatial and temporal distribution of heavy precipitation (> 20 mm/h) within the Swiss radar network during 2000-2007. The specific research goals are organized around two objectives: 1) investigate the relationship between precipitation characteristics (e.g., distribution, intensity) and synoptic, meso-, and convective scale orographic precipitation forcing mechanisms, and 2) investigate the spatial and temporal variation of these precipitation characteristics. Preliminary results from the analysis will be discussed in this study.

3. METHOD

Data from the Swiss radar network forms the basis of the analysis. The Swiss radar network includes three C-band Doppler weather radars at Lema, Albis, and La Dole (Fig. 1). Each of the radars scans 20 elevations every 5 minutes monitoring radar reflectivity up to a range of 230 km and Doppler velocity up to 130 km. A thorough description of the Swiss radar network is found in Joss *et al*, 1998; Germann and Joss, 2004; and Germann *et al*, 2006. The analysis is based on precipitation estimation at the surface combining the three Swiss radars resulting in a 30 minute running average of surface precipitation on a 2 x 2 km^2 Cartesian grid. The estimate is updated every 5 minutes.

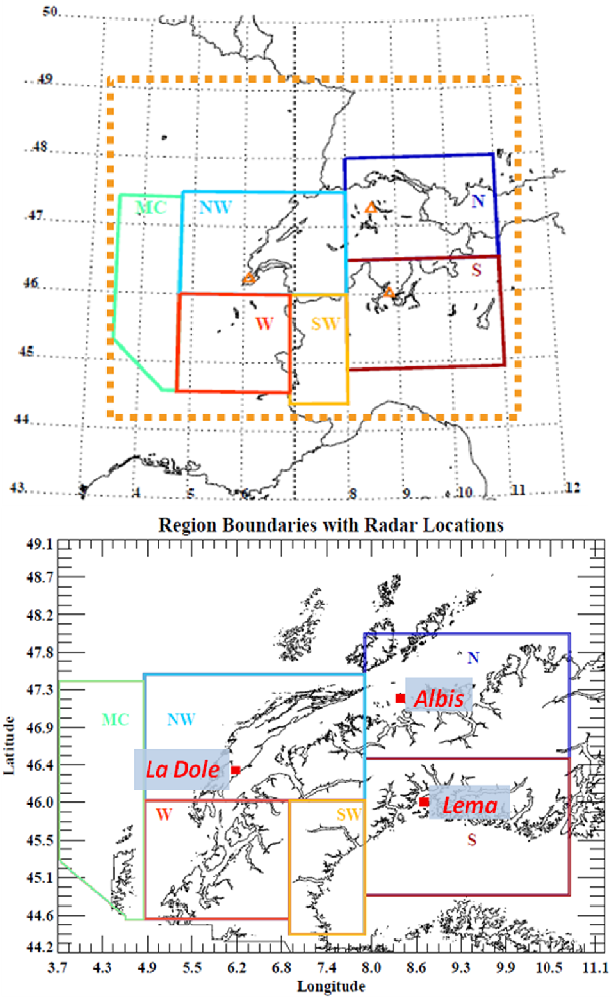

Figure 1: Regional boundaries: ***Top*** – Regional boundaries shown with solid color lines, thin black lines are European country borders, dotted orange line is extent of radar coverage, and Swiss radar locations are indicated with orange triangles. ***Bottom*** – Regional boundaries shown with solid color lines, thin black lines are 800 m above sea level topography lines, and Swiss radar locations are indicated with red squares.

The precipitation rate is read on the hour and half hour over the time interval of interest. In the first step, seasonal precipitation patterns and variations are analyzed during Spring (March – May), Summer (June – August), Fall (September – November), and Winter (December – February, the year associated with the Winter season is the year of January/February). For this analysis, two rainfall rate parameters have been defined: *frequency* and *interval*. The frequency parameter indicates geographic extent and duration of heavy precipitation, i.e., number of pixels having a rain rate greater than 20 mm/h. Frequency is calculated as the total number of occurrences of pixels for each year and season. A quality control (QC) procedure was applied to remove noisy data and data related to non-precipitating objects. The QC procedure involved gathering frequency data during a time frame where the radar reflectivity showed a lack of precipitation (clear air). Pixels which showed a rain rate of greater than 8 mm/h during the interval of clear air are omitted to generate the “QC’d” frequency data. The time interval used to represent clear air is Jan. 28, 2007 18:00 through February 4, 2007 22:00.

The interval parameter indicates the number of hours between widespread high precipitation events. Interval is calculated as the number of hours between events where greater than 50 pixels (200 km^2) in a region have a rain rate in excess of 20 mm/h. Events are required to be separated by more than 12 hours in order to be considered separately for the interval calculation.

Frequency and interval are calculated for each season and year for six regions as shown in Fig. 1: Northern Alps (N), Southern Alps (S), Northwestern Alps (NW), Southwestern Alps (SW), Western Alps (W), and Massif Central (MC). It is desirable to divide the Alps into various regions to facilitate analysis of the interaction between upstream conditions and topography. The first requirement for defining the regions is that each is contained within the geographic boundaries of radar coverage. Secondly, the regions are defined such that they are roughly aligned with the topographic aspect, or primary direction that the terrain is facing.

4. RESULTS AND ANALYSIS

Fig. 2 below is a graphic example of the results obtained from the frequency parameter (each season of 2007 is shown as an example). It is apparent from Fig. 2 that during 2007 summer was the season with the largest area having experienced a rain rate greater than 20 mm/h. In addition, the southern region contains more numerous and widespread high precipitation events. Frei and Schär (1998) found increased precipitation amounts on the south side of the Alps, a characteristic that resulted in the southern region as target area for the Mesoscale Alpine Programme (MAP) (Volkert and Gutermann, 2007).

Frequency, i.e., total number of pixels, normalized by the total number of pixels in each region is shown in Fig. 3 for the seasons of 2000-2007. A high frequency parameter indicates the greatest geographic extent of high precipitation events. Again, for this study, high precipitation events are defined as events having rain rate greater than 20 mm/h. Fig. 3 indicates that summer months have the highest frequency in all regions over

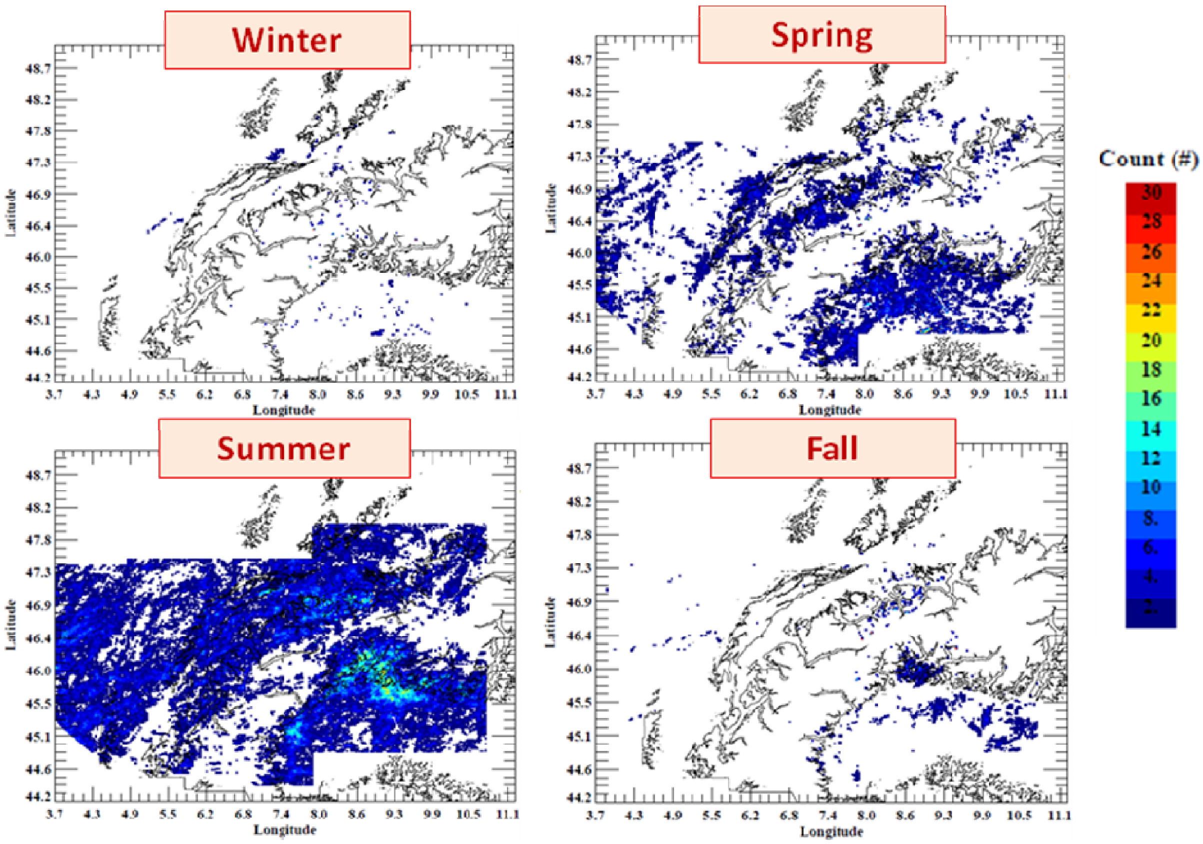

Figure 2: Frequency data for all seasons of 2007 with QC applied. Black lines indicate 800 m above sea level topography.

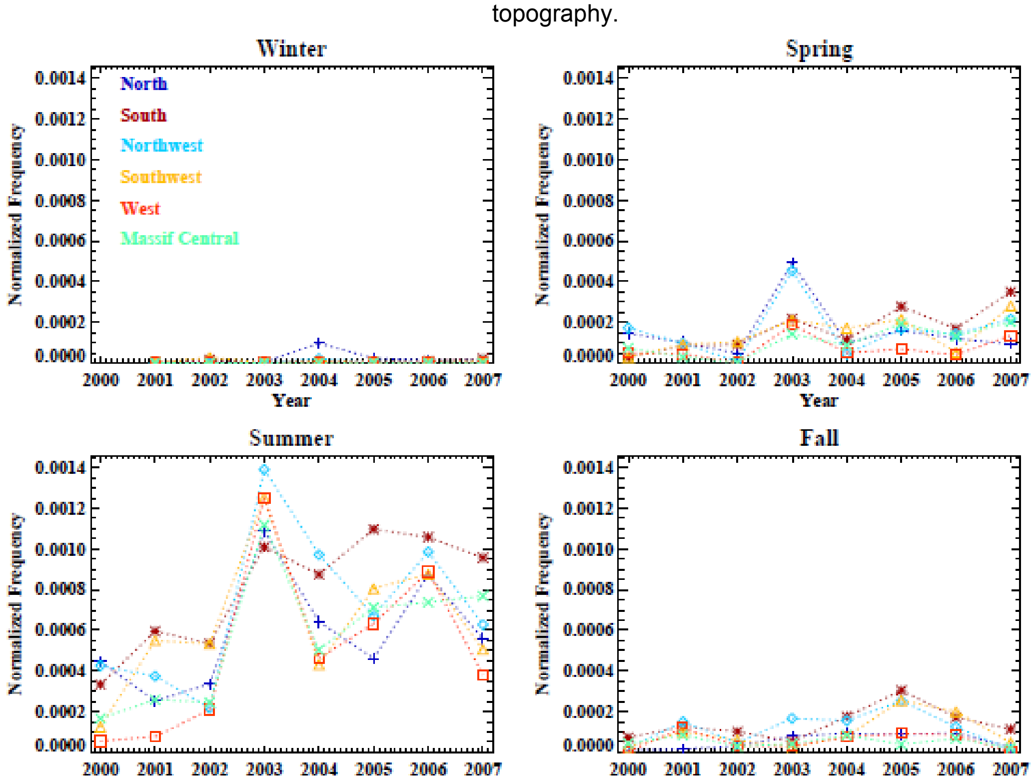

Figure 3: Frequency over all regions for all seasons of 2000-2007.

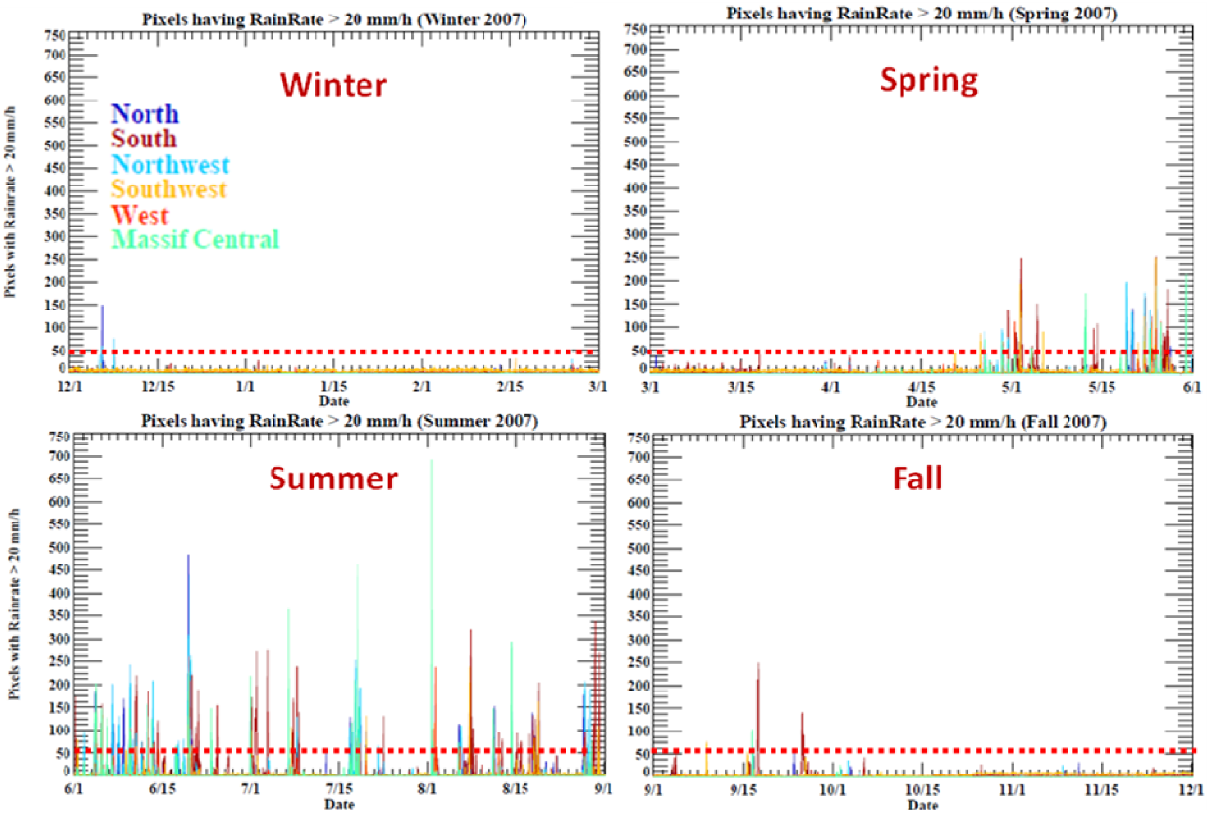

Figure 4: Interval for all regions and seasons of 2007. The red dotted line indicates the threshold of 50 pixels (200 km^2) used to calculate the interval between high precipitation events.

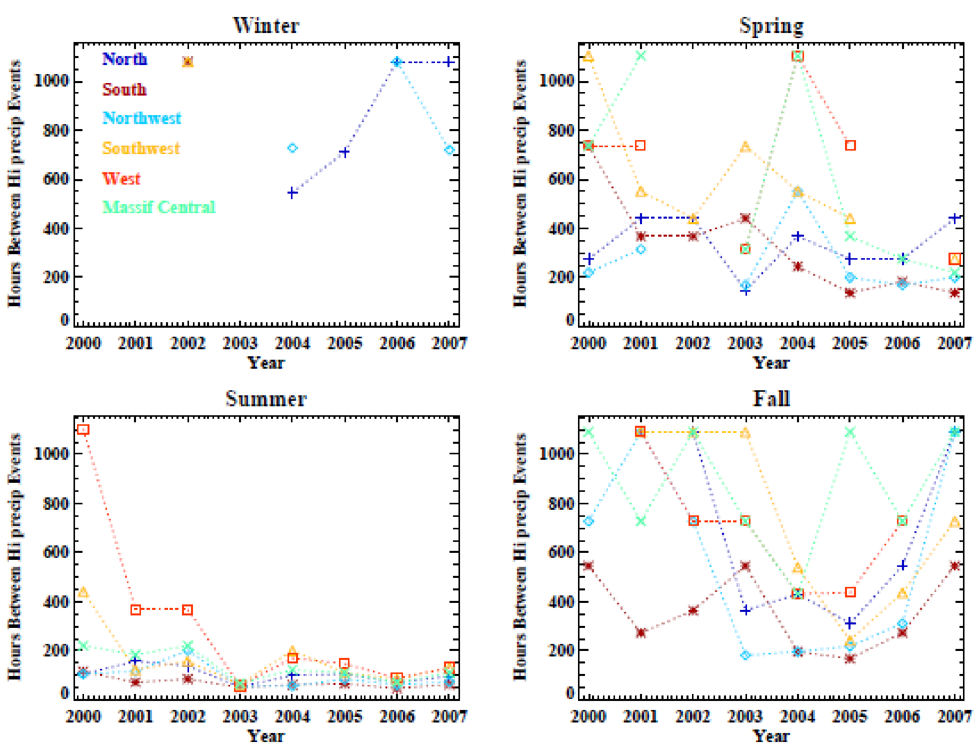

Figure 5: Hours between widespread high precipitation events for all regions over all seasons of 2000-2007 (interval parameter).

the period of 2000-2007 while winter has the lowest frequency. The south region has the highest mean frequency value while the southwest region has the lowest mean value. Qualitatively, it also appears that the frequency has slightly increased when comparing 2000-2002 and 2004-2007.

Comparison of the frequency parameter for each season within each region using the student's t-test with a 95% confidence interval shows that frequency in summer is significantly different than each of the other seasons in all regions (figure not shown). Spring, fall, and winter are not found to be significantly different. Therefore, in general, summer has the most widespread occurrence of events having rain rate greater than 20 mm/h for all regions.

Interval data for all regions and seasons of 2007 are shown in Fig. 4. Similar to the frequency analysis, the interval data in Fig. 4 indicate that summer had the most frequent high precipitation events during 2007.

Fig. 5 shows the interval parameter for all regions and seasons over the years 2000-2007. The lower values for the summer season indicate a generally shorter interval (2-6 days in 2005-2007) between widespread high precipitation events. Large variations in the intervals between the regions are observed in fall. During spring, the northern and southern regions have intervals of 200-400 hours between 2000-2007 while larger variations were observed in the western regions and the Massif Central. Missing data points in any panel (most apparent in winter) are indicative of seasons when a high precipitation event did not occur. A missing data point means that at no time during the season did an area larger than 200 km^2 have a precipitation rate greater than 20 mm/h.

The intervals between high precipitation events for each season within each region were also compared using the student's t-test with a 95% confidence interval. In each region, winter consistently has the longest interval between high precipitation events while summer has the shortest interval.

5. SUMMARY AND CONCLUSIONS

Preliminary results from the development of an operational radar-based precipitation climatology for the European Alps appear promising. Six regions aligned with the general topography of the Alps are established to enable sub-analysis at the 100s of km scale. In addition, two parameters, frequency and interval, are defined to characterize high precipitation events. The frequency parameter quantifies the area and number of occurrences within a region (geographic extent) that experienced a rainfall rate of greater than 20 mm/h. The summer season has the highest frequency values for all of the defined regions. The interval parameter indicates the hours between widespread high precipitation events. For all regions, high precipitation events are most frequent in summer and least frequent in winter over the years 2000-2007. The south region experienced the least number of hours between high precipitation events while the west region had the longest duration between events.

Future work will include an analysis of the effect of upstream conditions on precipitation at the synoptic, meso-, and convective scales, and a comparison of results to long-term rain gauge data. In addition, the three-dimensional spatial nature of radar data will be leveraged to study features of vertical structure such as melting layer. Ultimately, the intent is to apply results to the assessment and validation of climate models.

6. ACKNOWLEDGEMENTS

The primary author would like to thank MeteoSwiss for providing the operational radar data and products, and the University of Colorado at Boulder Department of Atmospheric and Oceanic Sciences for funding this research.

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