

CHAPTER 1 – INTRODUCTION

1.1. AN OVERVIEW

Large volcanic eruptions are a well-known source of the natural variability of climate, and have received major attention during the last decades. The recent trend to global warming detected since the mid-nineteenth century makes it necessary to identify the causes of this process and determine the weight of the anthropogenic “fingerprint”, among other factors [Bradley, 2000; Crowley, 2000; Mann, 2000; IPCC, 2001; Jones *et al.*, 2001; Bertrand *et al.*, 2002]. To solve this problem, the role of factors like the increase/decrease in solar irradiance [Rind, 2002] and the reduction/increase in volcanism [Robock, 2000] should be elucidated. Crowley [2000] recently found that 41% to 64% of the preanthropogenic (prior to 1850) low-frequency variance in the Northern Hemisphere (NH) temperatures is due to external factors, i.e. volcanism and solar variability (22% to 23% of the decadal-scale variance was explained only by volcanism). In contrast, only about 25% of the twentieth-century temperature increase can be attributed to natural variability. It is crucial, therefore, to isolate the natural forcing signals of past climates to understand and model the present and future evolution of our climate.

Most studies on the influence of volcanism on climate have used the global or hemispheric scale, and very few reports focus on the regional scale. In this regard, this research work is a novelty, as it analyses the effects of major volcanism on the climate of the Iberian Peninsula and Balearic Islands, which have a strategic latitudinal situation. Placed in the middle of the domains of western circulation and the subtropical world, this area is also known for its complex geography (a peninsula surrounded by seas, between two continents and with marked orography), and remarkable climate. Jointly with the regional approach, this study not only analyses the response of the Iberian temperature to volcanic forcing, but also the effects on rainfall distribution and circulation patterns.

1.1.1. The forcing mechanism

Identified as a key source of climatic change in the past [*Sadler & Grattan, 1999; Firth & McGuire, 1999*], large volcanic eruptions can modify in a few weeks the Earth's radiative balance and climate, as a consequence of the massive injection of gases and solid particles of aerosols¹ into the stratosphere. The major component of volcanic eruptions is magmatic material, which is referred to as ash or tephra. These particles fall out of the atmosphere very rapidly, on timescales of minutes to a few weeks in the troposphere. Thus, the belief that volcanic ash is the main cause of global climatic modification is false, as it only affects the local climate of the area close to the eruption source. Volcanic eruptions also emit gases, especially H₂O, N₂, and CO₂. Both H₂O and CO₂ are major greenhouse gases, but their atmospheric concentrations are so large that individual eruptions have a negligible effect on their global concentrations. By far, the main climatic effect of explosive volcanic eruptions is exerted by the emission of sulfur species to the stratosphere, mainly as SO₂ but sometimes as H₂S. Both sulfur species react with OH and H₂O to form H₂SO₄ aerosols, which are responsible for complex energetic and chemical reactions: some of the light is backscattered, thus reflecting sunlight back to space, increasing the net planetary albedo and reducing the amount of solar energy that reaches the Earth surface. That is the main potential effect of great volcanic eruptions on global climate: negative radiative forcing and, as a result, a global cooling effect on the surface (figure 1.1). The magnitude of this mechanism is shown by the amount of SO₂ injected into the stratosphere during the last large event of the 20th century, the eruption of Pinatubo (June 1991), when of 20 Mt² of SO₂ were released and the volcanic cloud encircled the Earth in just three weeks [*Bluth et al., 1992*].

¹ Aerosol: a liquid droplet or solid particle suspended in a gas

² Mt = megaton = 10⁶ T = 10⁹ Kg = 10¹² g = teragram

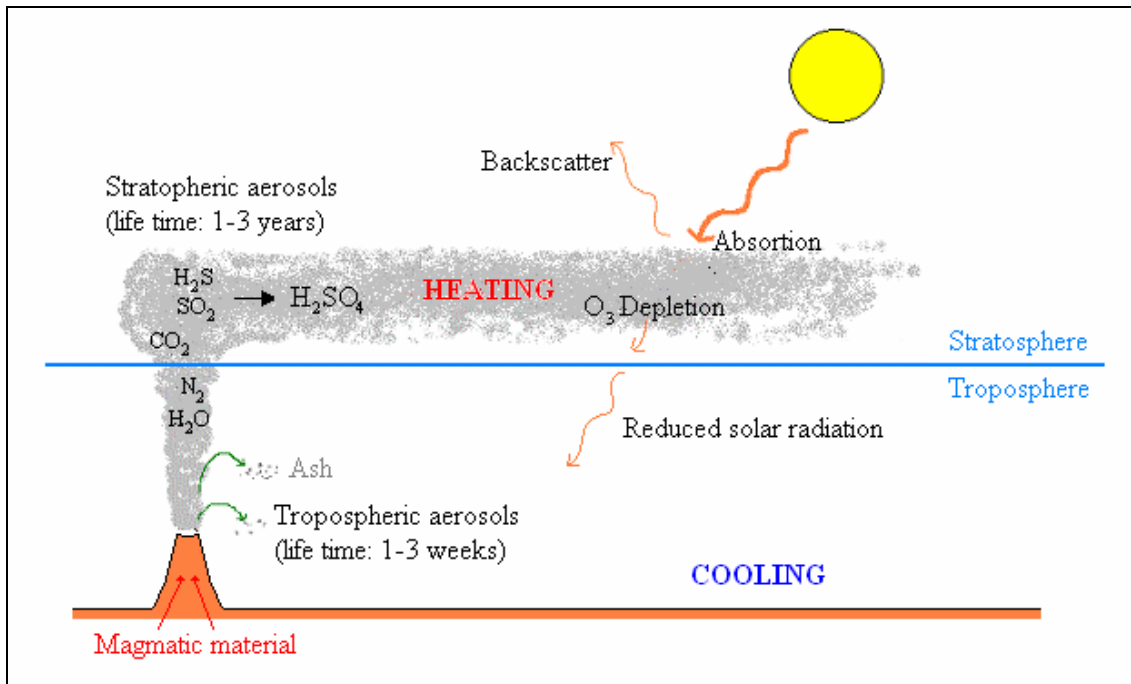


Figure 1.1. Diagram of the emission of volcanic materials into the atmosphere and their effects on solar radiation.

1.2. OBJECTIVES

1.2.1. Main objective

The main goal of the research is to detect the volcanic signal in the climate of the Iberian Peninsula and Balearic Islands, and to analyse its possible effects on temperature, precipitation and sea level pressure. The most sensitive sectors to the forcing and the presumable length of the impact within the study area will also be thoroughly analysed. In both cases, the role of the latitudinal location of the eruptions will be taken into account.

1.2.2. Specific objectives and structure of the memory

- Chronology of volcanic events. Chapter 2 focuses on the various chronologies of eruptions that have been constructed. As is well known, several factors determine the resulting climatic effects (especially the chemical composition of volcanic emissions). Records of explosive volcanism are quite diverse and feed from many sources. Nowadays, satellite records are the most reliable source, as they provide precise information of the chemistry and amount of aerosols emitted. Unfortunately, these measurements are only available for the last three

decades of the 20th century and for remote events, this information is lacking and even the geographic location of the eruption is unrecorded. Therefore, it is necessary to use as many sources as possible, although each method has its own limitations. Several attempts have been made through the construction of indices of volcanism, using documentary sources, dendrochronological measurements and even coral records.

- Identification of the volcanic signal in Iberian surface temperature records. Once the eruptions with climate effectiveness have been identified, chapter 3 analyses their effect on the Iberian temperature dataset. The global/hemispheric surface air temperature response shows cooling, principally within two and three years, depending on the latitudinal location of the eruption. In this section, we evaluate the global response in our area and aim to identify a similar behaviour, with special emphasis on the magnitude and length of the impact, as well as the seasonal component. The spatial pattern of the response is also analysed for a 20th century sample of eruptions, and the distinct response of maximum and minimum temperatures is detected. Superposed Epoch Analysis (SEA) is the methodology used in this case and in the following chapter.

- Identification of the volcanic signal in Iberian rainfall records. In chapter 4, the rainfall parameter is analysed similarly to temperature. Thus, the influence of volcanic forcing on the distribution of the monthly Iberian and Balearic rainfall is discussed, and the most sensitive areas and, again, a possible seasonal component, are detected. Although radiative forcing of the climate system clearly results from large volcanic eruptions, there is increasing evidence of a dynamical response that may lead to changes in rainfall distribution in our sector, especially in wintertime.

- Surface atmospheric circulation over Europe following major volcanic eruptions. Chapter 5 explores the dynamical mechanism of circulation anomalies over Europe in the years following explosive tropical eruptions. The Principal Component Analysis (PCA) technique is applied (also referred to as Empirical Orthogonal Functions, EOF) to detect persistent spatial patterns over the domain during the post-volcanic period. In this section, the winter North Atlantic

Oscillation (NAO) pattern response to high latitude and tropical eruptions is also analysed.

Finally, chapter 6 is dedicated to the discussion and conclusions of the research work.

