1 Summary

The present work has been performed in the framework of the research project AQUAPAST. The main focus of AQUAPAST is the reconstruction of past climate changes in the Alpine and the Mediterranean regions based on the analysis of the isotopic content of cave speleothems in the Trentino Province.

This research is motivated by the need to study the climate of the past in order to understand and detect the causes of the climate changes we are witnessing today (ICCP, 2001), and, if possible, to provide the basis for simulating future scenarios by means of suitable global climate models (GCM). The interest of the scientific community in the climate changes of the past is proved by the increasing amount of papers (Ayalon et al., 1998; Baldini et al., 2002; McDermott et al., 2001; Genty et al., 2003), workshops and reports. In particular, the target of the climatological studies is to understand the climate response to both the natural (solar -Hansen et al., 1997-, volcanic and so on) and anthropogenic forcing (greenhouse gases -WMO, 1999-, sulfate aereosol). The most monitored variables to detect climate changes are air temperature and precipitation. Besides overall properties of the series of daily or monthly average of these variables the frequency of extreme values are investigated. The analysis can be refined by studying the evolution of the previous variables on a regional scale pointing out local variabilities in atmospheric and oceanic circulations: El Niño-Southern Oscillation (ENSO), Monsoons, the North Atlantic Oscillation (NAO), the Artic Oscillation (AO) and so on. In fact the project AQUAPAST aims also at relating the past climatological changes to modifications in the atmospheric circulation and in particular in the water vapour transport mechanism over the Mediterranean area.

The contribution of the present thesis to the research project consist in setting up a methodology for the reconstruction and the analysis of the airstreams governing the transport of water vapour to the area of Trentino. The technique requires as input the output of both global meteorological and climatological models. Anyway a phase of tests was necessary: the methodology has been applied to the study of strong precipitation events occurring in the last decades over the Alps.

The Alps affect atmospheric dynamics on a broad range of horizontal scales (as classified by

Orlanski, 1975), the most relevant ones ranging from the meso-α (e.g. lee cyclogenesis and modification of upper level troughs, Tibaldi et al., 1990), through meso-β (e.g. modification of fronts by orography, Hoinka et al., 1990; Buzzi and Alberoni, 1992) up to the meso-γ (e.g. circulations in individual valleys and inside individual clouds).
Recent studies, especially those developed in connection with the Mesoscale Alpine Programe (Bougeault et al., 2001), have focused on the synoptic-scale situations which are most likely to produce severe precipitation events in the southern Alpine region. The physical mechanism of orographic precipitation has been explored in depth (Buzzi et al., 2003; Gheusi and Stein, 2002; Medina and Houze, 2003; Rotunno and Ferretti, 2001, 2003). However, little is known at present about the relation between detectable local and regional flow structures and the larger scale processes determining the moisture fluxes at lower levels and the water vapour transport and evaluation at upper levels. Indeed isotopic composition of water can be used as a suitable tracer to detect the origin of precipitating water. Measurements of the isotopic composition of precipitated water samples show that oxygen and hydrogen isotopes may vary considerably depending on the measurement location and the area where precipitating water originally evaporated (Longinelli and Selmo, 2003). On the other hand, the history of water vapour can be evaluated from the meteorological analysis of data and from the reconstruction of trajectories associated with precipitating systems. Lagrangian analysis provides for a method to understand the relationship between precipitation in a certain region and recurring specific meteorological features, such as PV-streamers (Massacand et al., 1998; Wernli et al., 2002) or peculiar interactions between large scale patterns of transport of water vapour in far regions where the air masses come from (Keil et al., 1999).

A detailed discussion on the motivations of the project AQUAPAST, as well as of the present work, is proposed in chapter 2, where the atmospheric mechanisms governing the water transport of vapour during cyclonic events are discussed in detail along with the method of Lagrangian analysis as an optimal way to understand them.
Chapter 3 provides a review of literature about the techniques of trajectory computation. In particular the various types of errors affecting the computation and their order of magnitude are estimated and discussed. As an example the numerous applications of the trajectory techniques to the long range pollution transport are briefly sketched. Finally an introduction is reported to the applications available so far in the literature of this method to the transport of water vapour.
The choice of the case studies to test the Lagrangian analysis as well as the results from the computation of ensembles of back trajectories are shown in chapter 4. The selected events are the flood events of 3-5 November 1966, 16-18 November 2000 and 24-26 November 2002. Emphasis is given to the regional budget analysis over the Mediterranean basin and in particular to the

estimation of the evaporation fluxes contributing to increase the moisture content of airstreams producing intense precipitation over the Alps during the selected events.
The identification of the flow patterns mostly contributing to precipitation requires suitable gathering of the ensemble trajectories into few most remarkable bundles. Clustering techniques applied to this purpose are presented in chapter 5. The attention here is mainly concentrated on the adoption of the most suitable phase space where trajectories can be represented as points and the "distance" between two trajectories is easily evaluated as the euclidean distance between the respective points. This allows for gathering similar trajectories of the ensemble to obtain a small number of clusters (cf. also Bertò et al., 2004).
Chapter 6 outlines comments and results deriving both from the budget and the cluster analysis and a conceptual model describing the airstreams flowing over the Mediterranean basin during extreme precipitation events is proposed. This provides a preliminary basis for the classification of meteorological situations producing intense precipitation events over selected target area in the Alps. Finally a preliminary test of the sensitivity of the trajectory method to the resolution of input data is reported.
The conclusions as well as possible future developments are summarized in chapter 7.