The Climate of Italy

4

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Abstract

The chapter highlights the main features of the climate of Italy. In particular, it identifies and defines the main climatic regions and the local factors that control the type of climate according to the Köppen classification. Furthermore, it shows the distribution of the main meteorological variables, temperature and precipitation, and the climatic variations that affected Italy in the last decades. The Italian climate displays remarkably varied features due to the complexity of its territory. Climatic variations recently observed show some common elements throughout the country, i.e. a gradual increase in temperature and a change in the annual distribution of precipitation. These changes are more remarkable in the Alpine region.

Keywords

Italian climate • Climate regions • Temperature • Precipitation • Climate variations

4.1 Introduction

Italy stretches across the centre of the Mediterranean, from a latitude of 36°N to a latitude of 47°N. This remarkable extension makes the climatic conditions very variable. Moreover, the orography is very complex due to the presence of mountain chains of the Apennines and the Alps. They influence the pathway of weather fronts and interact with the dominant winds, thus exposing different areas of Italy to specific types of circulation. The Alps and the Apennines in fact have a barrier effect: the former protect the Po Plain and the Venetian Plain from the cold northerly currents, while the latter, developing along the entire peninsula, limit the influence of the moist westerly air to the Tyrrhenian side, which is in turn protected from the cold easterly winds that hit the Adriatic side during the winter season. Winter is in fact colder on the Adriatic coast than on the Tyrrhenian coast at the same latitude (Mennella 1967; Pinna 1977).

It is also necessary to point out the mitigating effect of the Mediterranean Sea, which generally has a destabilizing effect on the air masses that flow there, favouring the development of depressurizing systems (cyclogenesis) close to the Italian peninsula. The distribution of atmospheric pressure over the Peninsula and over the surrounding seas (Adriatic, Ligurian, Tyrrhenian, Ionian seas) during different seasons is one of the fundamental factors that condition the trend and regime of meteorological elements.

4.2 Local Factors and Climatic Regions

The concurrent influence of various geographic factors (including different altitudes, different distances from the sea, different morphological characteristics of marine basins, presence of particular coastal currents, exposition to dominant winds etc.) determines the existence of different climatic regions, whose borders can be represented as shown in

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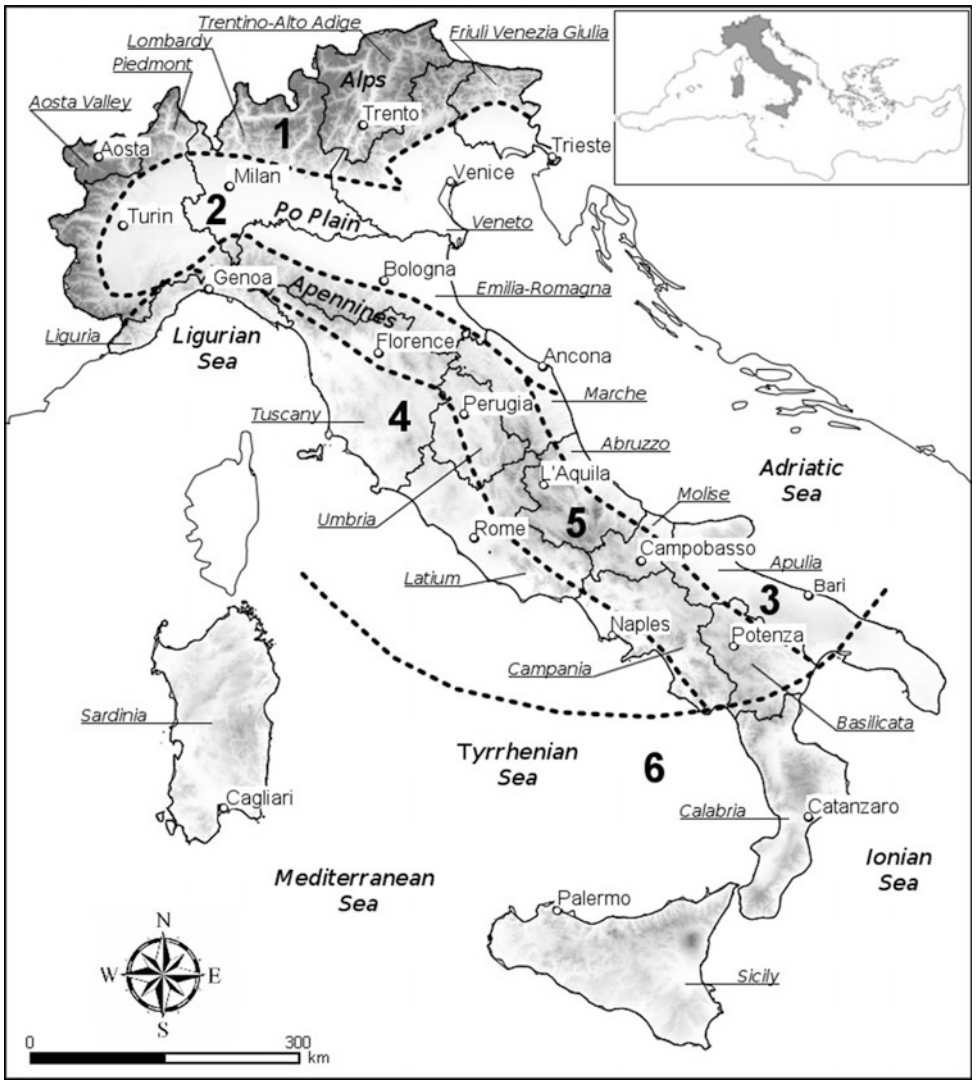

Fig. 4.1 The climatic regions of Italy: (*1*) Alpine Region, (*2*) Po Plain and Upper Adriatic Region, (*3*) Central-Southern Adriatic Region, (*4*) Ligurian and Tyrrhenian Region, (*5*) Apennine Region, (*6*) Mediterranean Region (scheme proposed by Cantù 1977, redrawn by D. Garzena)

Fig. 4.1, on the basis of the scheme proposed by Cantù (1977), which gives particular prominence to weather types that occur over the regions. These regions have to be considered as macro-sections; it is obvious that sub-units exist within these portions, each with its own particular climatic conditions. The main climatic regions are: (i) the Alpine Region, (ii) the Po Plain and Upper Adriatic Region, (iii) the Central-Southern Adriatic Region, (iv) the Ligurian-Tyrrhenian Region, (v) the Apennine Region and (vi) the Mediterranean Region.

The *Alpine Region* includes the Aosta Valley, Trentino-Alto Adige and the mountain sectors of Piedmont, Veneto, Lombardy and Friuli Venezia Giulia. This climatic region is all above 1000 m a.s.l. and—in autumn, winter and spring—is affected by a series of low pressure zones arriving from the Atlantic, the Gulf of Genoa and the Mediterranean Sea. The Alpine climate is conditioned by the altitude, and it can be considered as a cold temperate type, which becomes of a nival type at altitudes above 2700–2800 m. The Alps and the pre-Alps receive high amount of rainfall, with peaks of 3000 mm per year in the sectors which are more exposed to the cold air masses coming from the Pole and the hot air coming from Africa.

The *Po Plain and Upper Adriatic Regions* are made up of an extensive basin that is surrounded by mountain chains to the north, west and south, with no relief on the east side. Considering the orography, this climatic region is limited by the 1000 m contour line on the Alpine side and by the watershed line on the Apennine side. During winter, the entire region is covered by a layer of cold and stagnant air that is several thousands metres thick. The outstanding feature of this climatic zone is its accentuated seasonal excursion with maximum temperatures in summer that often exceed 30 °C and winter minimums that often fall below zero. Rainfall is not very abundant, between 600 and 800 mm per year, with a higher frequency in autumn and

spring. During summer, stormy events are also quite frequent.

The *Central-Southern Adriatic Region* includes the eastern peninsular part of the Apennine watershed, between the 43° and 39° parallels. This region has thermal and rainfall behaviour of a Mediterranean type, but also shows continental characteristics that are dictated by the mitigating influence of the Adriatic Sea and the favourable exposition to currents flowing from the north and from the east. Rainfall is not abundant, between 600 and 700 mm per year. Rains are more frequent in spring and autumn, and the latter is the rainiest period of the year. When the synoptic situation is such that it favours currents from west to southwest, anomalous torrid hot or warm waves can also occur in the middle of winter. In the cold season, the minimum temperatures drop to values of around 0 °C, and in high summer they exceed 30 °C.

The *Ligurian and Tyrrhenian Region* includes Liguria, the coastal sectors and the bordering hinterland of Latium, Tuscany and Campania. Even the western part of Umbria, although it shows some continental aspects, is affected by the mitigating action of the Tyrrhenian Sea. The climate in these regions, which can be defined as Mediterranean, is milder and wetter than the Adriatic sector at the same latitude, because of the presence of the Apennines. On average, rainfall is between 800 and 1000 mm per year, but there are important differences in relation to the closeness of the Apennines to the coast. Summers are hot and dry, with maximum temperatures that often exceed 30 °C. Windward low pressure areas can be observed during autumn, causing flash floods and devastating effects in the provinces of Genoa and La Spezia, especially in recent years.

The *Apennine Region* includes the mountainous sectors of Emilia-Romagna, Tuscany, Latium, Marche, Campania, Abruzzo, Molise, eastern Umbria and most of Basilicata. The characteristics of this climatic area are determined by altitude, and are comparable with those of the cool continental temperate zones, with lower thermal values as the altitude increases. Rainfall reaches values of more than 1500 mm per year on the slopes that are more exposed to the dominant western winds.

The *Mediterranean Region* includes Calabria, Sardinia, Sicily, the coastal areas of Basilicata and south Apulia. These zones have a similar climate to that of the Tyrrhenian Region, but with a marked intensification of the Mediterranean characteristics, and the appearance of some subtropical sections in the internal parts of Sicily and Sardinia. The sea markedly influences climatic parameters. Summers are dry and hot, with temperatures that can even exceed 40 °C, when the African cyclone is developing, while winters are very wet with rainfall that is prevalently of a downpour or stormy type.

The occurrence of different baric situations and specific local conditions determines the frequency, intensity and direction of winds in Italy. Anemometric observations show that only generally moderate variable winds (with the exception of local breezes), which precede, accompany or follow atmospheric low pressure areas, are present throughout Italy.

In general, the areas which overlook the Ligurian Sea and Tyrrhenian Sea suffer above all from winter westerly winds. These winds have northwest direction over Sardinia (Mistral), southwest direction over the eastern Ligurian coasts and over the upper part of the Tyrrhenian Sea (Libeccio), and western direction over the central part of the Tyrrhenian Sea (Ponente). The directions of the winds are reversed on the Adriatic side. The winds in the northern and central parts prevalently arrive from the north and northeast, while those in the southern part are from the south and southeast. Winds from the south and southeast are frequent in the southern parts of the peninsula. The Ionic coasts are hit by lukewarm and moist Scirocco winds, while the extremely hot and moist African Scirocco wind blows from southeast and reaches Sicily.

4.3 Climate Classification

Classifying climate means defining its characteristics in different places, considering the most important climatic elements.

The most famous climate classification and to which reference is made regularly in climate descriptions is that proposed by W. Köppen (Pinna 1978). It is based on the distribution of mean annual and monthly temperature and rainfall, and distinguishes five main climate groups in the world.

The Italian peninsula falls completely within the Mediterranean climate area, which is part of the meso-thermal type climates and, to be more precise, of subtropical climates with dry summers. In reality, besides the typical Mediterranean climate, there are also areas with other meso-thermal climates, or areas with situations of micro-thermal or altitude climates. A climatic classification based on the Köppen–Geiger scheme (Fig. 4.2) and only referring to thermal aspects is outlined below.

1. *The Ligurian-Tyrrhenian, Middle Adriatic, Ionic and Mediterranean coastal regions* (Cs). Two types of climates can be found within this group:
   (a) *Subtropical temperate*. This climate is marked by limited (almost non-existent in summer) and very irregular rainfall. It affects the hottest areas along a narrow strip of the southern Italian coast and that of the islands. Mean annual temperature >17 °C; mean

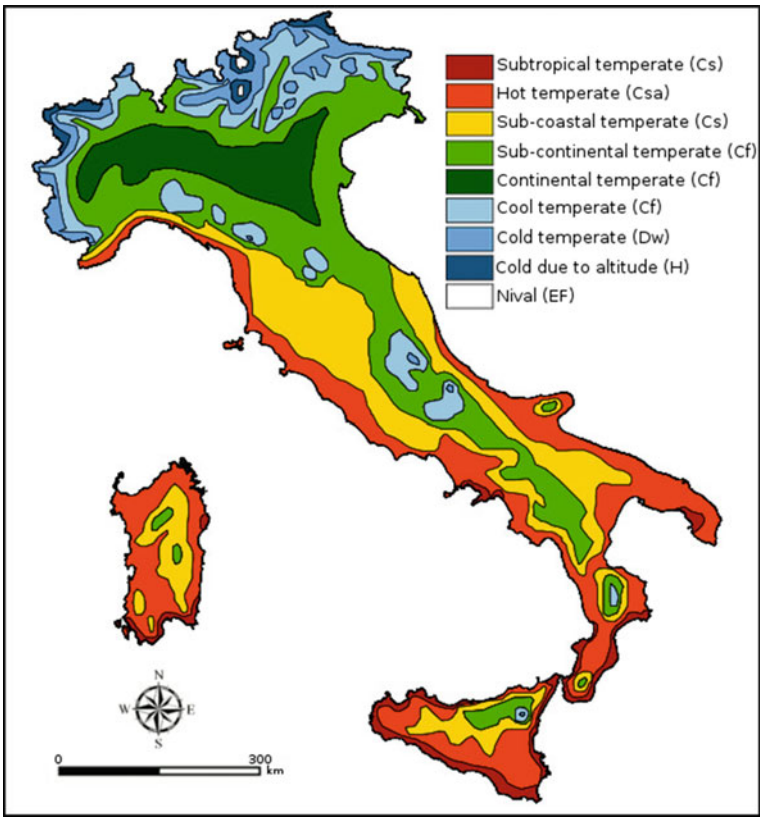

Fig. 4.2 Map of climatic classification by Köppen and Geiger (after Pinna 1978, redrawn by D. Garzena)

temperature of the coldest month >10 °C; five months with a mean temperature >20 °C; annual temperature from 15 to 17 °C.

(b) *Hot temperate*. This climate is usually characterized by summer droughts (Csa), and it affects the Tyrrhenian coastal area from Liguria down to Calabria, the southern part of the Adriatic coast and the Ionic zone. Mean annual temperature from 14.5 to 16.9 °C; mean temperature of the coldest month from 6 to 9.9 °C; four months with a mean temperature >20°C; annual temperature from 15 to 17 °C.

2. *The internal sub-coastal region* (Cs) includes the hilly zones of the Tuscan-Umbrian-Marche pre-Apennines and the lower slopes of the southern Apennines. Mean annual temperature from 10 to 14.4 °C; mean temperature of the coldest month from 4 to 5.9 °C; three months with a mean temperature >20 °C; annual temperature from 16 to 19 °C.
3. *Po and Venetian plains, Upper Adriatic and internal peninsular regions*. Two types and two sub-types can be identified in this climatic region:
   (a) *Sub-continental temperate* (Cf), which affects part of the Venetian Plain, the Friulian Plain, the coastal area of the Upper Adriatic Sea and the internal peninsular region. Mean annual temperature from 10 to 14 °C; mean temperature of the coldest month from −1 to 3.9 °C; two months with temperature >20 °C; annual temperature from 16 to 19 °C.

   (b) *Continental temperate* (Cf), which affects all of the Po Plain and part of the Venetian Plain. Mean annual temperature from 9.5 to 25 °C; mean temperature of the coldest month from −1.5 to 3 °C; three months with a mean temperature >20 °C; mean annual temperature >19 °C.

   Two sub-types that show a remarkable extension can be identified within the temperate type of climate: the *hot summer temperate climate* (Cfa) and *lukewarm summer temperate climate* (Cfb).
4. *Pre-Alpine and Middle Apennine region*. A *Cool temperate* (Cf) climate can be identified. This affects the pre-Alps and the axial zone of the Apennines, which sometimes presents sub-continental characteristics. Mean annual temperature of 6 to 9.9 °C; mean temperature of the coldest month from 0 to −3 °C; mean temperature of the hottest month from 15 to 19.9 °C; annual temperature from 18 to 20 °C.
5. *Alpine and Upper Apennine region*. A *Cold temperate* (Dw) climate can be identified. This affects an area of the Alps and the summit areas of the higher Apennine groups. Mean annual temperature from 3 to 5.9 °C; mean

temperature of the coldest month >−3 °C; mean temperature of the hottest month from 10 to 14.9 °C; annual temperature from 16 to 19 °C.

6. *Alpine region*. Two types of climate can be recognized
   (a) *Cold due to altitude* (H) which affects the highest sectors of the Alps and the summit areas of the higher Apennine groups.
   (b) *Nival* (EF), which affects the Alpine zone above 3500 m, with the presence of perennial snow.

4.4 Temperature Distribution

In general, the mean temperature throughout Italy decreases in winter as the latitude, altitude and distance from the sea increase. However, this trend shows significant exceptions, above all as a result of the barrier effect of the main mountain chains (Rapetti and Vittorini 1989). It has already been mentioned how, at the same latitude, the Adriatic coast, which is open to winds from the north, is relatively colder than the Tyrrhenian coast in winter. The thermal contrast between the Po Plain (which is covered by a layer of cold air in winter) and the Ligurian Riviera, which is sheltered from the arrival of cold air from the north by the Marittime Alps in the west, is even more accentuated. The annual thermal excursion fluctuates, over most of the Italian territory, between 14 and 25 °C; in general, temperature increases when moving from the coast towards the internal part, and then diminishes passing from the plain to mountains. The lowest values of thermal excursion are recorded over some parts of the western part of Liguria and over some sections of the western coast of Sardinia as well as the southern sections of Sicily. The highest values are instead found in the southwestern sector of the Po Plain (Pinna 1978).

On the basis of the map of mean annual temperatures that are recorded in Italy (Fig. 4.3), mean values of more than 16 °C can be observed over the western part of Liguria, along the Tuscan coastline, along the coast between Abruzzo and Apulia, along the Ionian coast of Basilicata and Calabria, and along all the coastal sections and internal flat areas of Sicily and Sardinia. In the peninsular areas, the isotherm passes locally in a more or less decisive way towards the corresponding hinterland. Most of the Apennine range, the Sardinian mountains, the pre-Alps and the Alpine valleys record mean values ranging between 10 and 12 °C; mean annual temperatures ranging between 5 and 10 °C are instead recorded on the top of Mt. Etna, on the highest summits of the Apennines and on most of the Alpine range, where mean annual values below 5 °C can even be recorded on the highest peaks.

The absolute mean extreme values of the temperature fluctuate between 44 and 45 °C—recorded in July over some locations in southern Italy—and −30 °C, recorded at some locations in the Alps in January.

The highest temperature in Italy, since 1951, was recorded by the Air Force Military meteorological network, which is affiliated with the World Meteorological Organization, and was equal to 47 °C; it was measured by the Foggia Amendola station on 25 June 2007 (Fig. 4.3). The lowest temperature was measured in February 1929, at 4554 metres, at the Regina Margherita hut on Monte Rosa. On that occasion, the temperature dropped as low as −41 °C. Always in the Italian Alps, the −34.6 °C measured at Plateau Rosa on the 6 March 1971 stands out, and this was followed by the −30 °C that was measured at Dobbiaco on 1 January 1953. Whilst for the cities on the plain, the lowest temperatures were recorded in Florence (12 January 1985) and Tarvisio (7 January 1985) with −23 °C.

4.5 Precipitation Distribution

The mean annual rainfall distribution, though generally depending on the latitude, is also influenced by altitude and aspect. The mountainous zones in Italy in fact receive a greater quantity of water than the plains and the coasts, especially when they are exposed to moist currents from the sea. The rainiest areas in Italy (mean annual rainfall between 2500 and 3500 mm) are located in the Carnian and Julian Alps, in the pre-Alpine section between Lake Maggiore and Lake Como, in the eastern Ligurian Apennines, in the Apuane Alps and in the highest sectors of the Tuscan-Emilian Apennines (Fig. 4.4). In general, rainfall is more plentiful along the Ligurian-Tyrrhenian side (which is open to currents from the west and to the perturbations that accompany these currents) than on the Adriatic-Ionian side (see Rapetti and Vittorini 1989). Less abundant rainfall is generally recorded on the plains and along the coasts. Rainfall is particularly scarce (below 500 mm/year) along the coast in some parts of Apulia, Sicily and Sardinia. Low values are also found in the bottom of some Alpine (Aosta Valley, Susa Valley, Valtellina, Pusteria Valley) and some Apennine valleys, which are protected by elevated mountainous ramparts. In the Po Plain, rainfall diminishes from east to west, as it does from the high altitudes to the low plain. The mean annual number of rainy days is higher on the western sides of the peninsula (110–120 days in the Alps, pre-Alps) and in the most elevated areas of the Alps and Apennines. It is lower in the western Po Plain, and along the coastal plains of Southern Italy and the islands. The pluviometric regime presents a remarkable variability

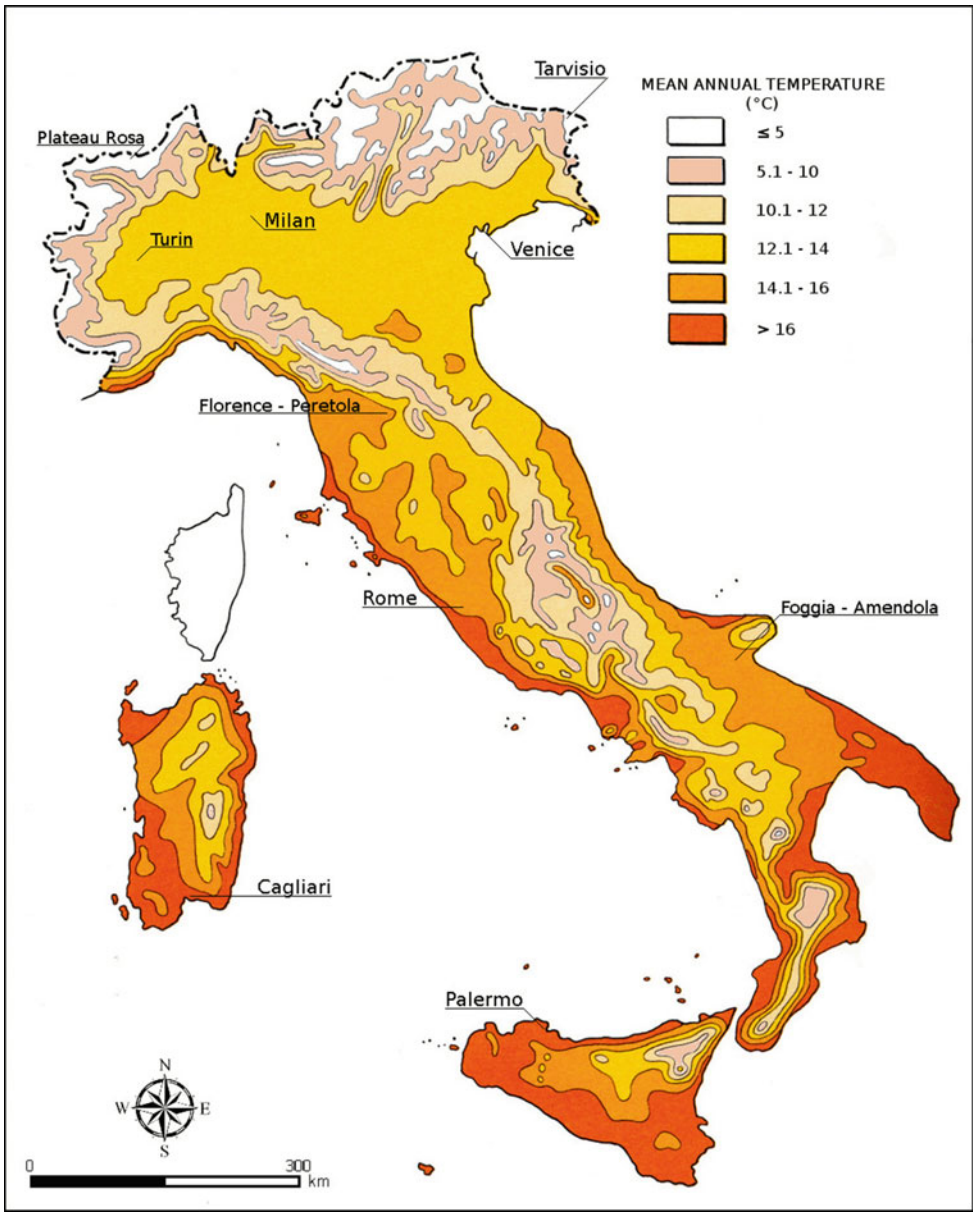

Fig. 4.3 Map of mean annual temperatures from 1961 to 1990 in Italy. *Source* SCIA system by ISPRA (www.scia.isprambiente.it)

(Pinna and Vittorini 1985) and the following main types can be distinguished:

- Continental regime is characterized by an accentuated maximum summer rainfall and an accentuated minimum winter rainfall: it affects some Alpine and pre-Alpine areas.
- Pre-Alpine regime affects almost all of northern Italy and the upper part of Tuscany, with two maximum rain periods in spring and in autumn, and two minimum periods in summer and winter. In some zones, such as in Piedmont, the spring maximum is prevalent, while the autumn one is prevalent in other zones.
- Apennine regime presents a main maximum rainfall period at the end of autumn and a main minimum period in summer; a minor minimum occurs at the end of winter.
- Sub-coastal regime is rather similar to the previous one, with less accentuated minor minimums and maximums which, going towards the south, almost level out.
- Mediterranean regime: this type presents a maximum winter rainfall and a minimum summer rainfall: it affects Sicily, Calabria and parts of Apulia.

The location that shows the highest rainfall in Italy is Musi (633 m) in Friuli Venezia Giulia exposed to the moist and rainy Scirocco and Libeccio winds, thanks to which it

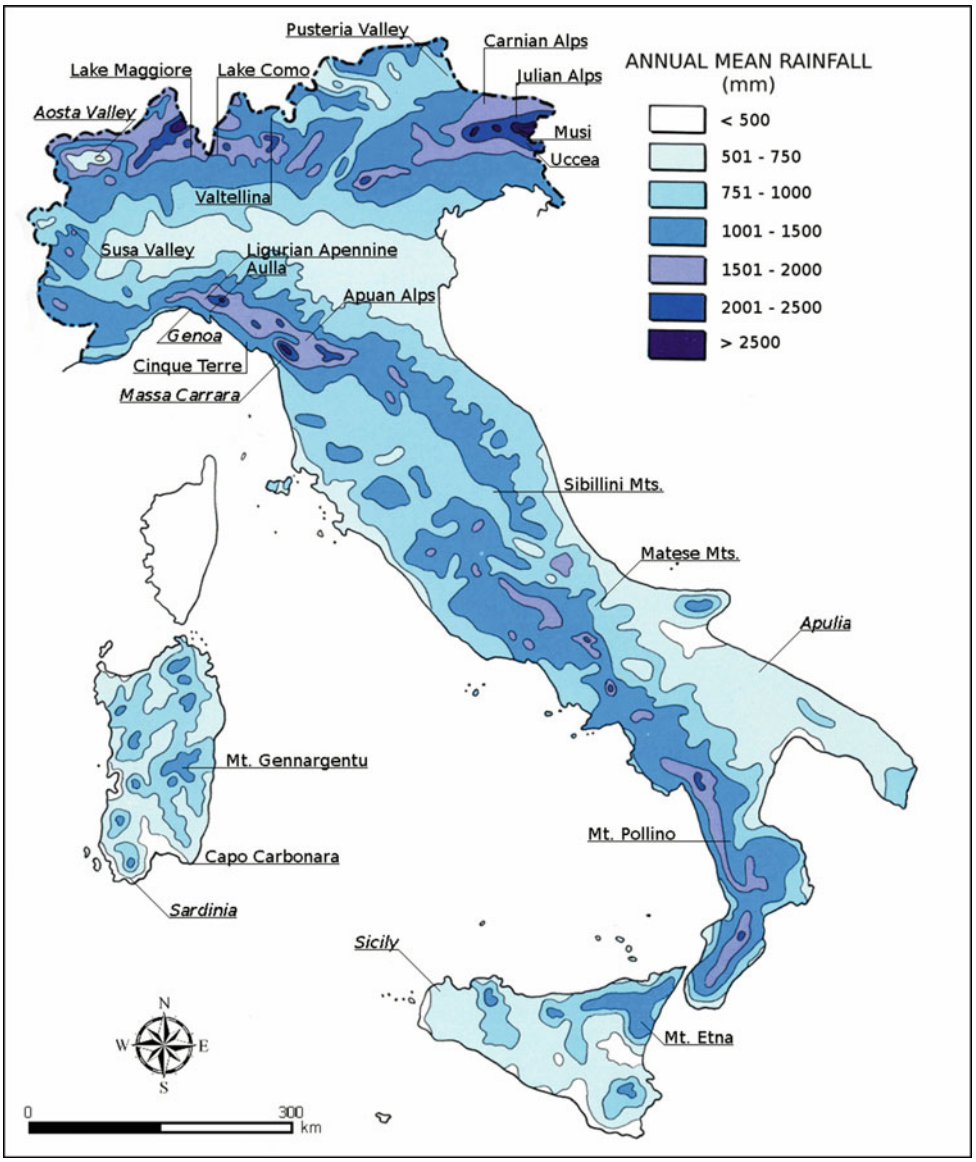

Fig. 4.4 Annual mean precipitation from 1961 to 1990 in Italy. *Source* SCIA system by ISPRA (www.scia.isprambiente.it)

manages to accumulate a total mean annual rainfall of 3300 mm. In this area, the maximum quantity of rain cumulated in a year was recorded at Uccea in 1960 with 6012.9 mm.

The location with the lowest precipitation throughout the entire Italian territory is that of Capo Carbonara, in the municipality of Villasimius, in Sardinia, with a mean yearly rainfall of 237.8 mm in the 1971–2000 30-year period.

As far as snowfall in Italy is concerned, unlike what can be observed for rainfall, precipitation events are particularly abundant on the most internal elevations, and also on the slopes that back on to the sea. This shows that altitude and continental nature of weather are the main factors that determine the rather low temperatures that occur during the winter period.

These events increase over the Po Plain, from east to west. They are somewhat modest at the bottom of the alpine valleys, but increase rapidly towards the top of the valleys, above all in the Western Alps—which are more internal and therefore subject to more continental weather.

Mean annual snowfall between 20 and 50 cm occur on the plains of northwest Italy, in the Alpine valleys, in the plain areas of Emilia-Romagna close to the Apennines, along the coastal section in the first part of the hinterland in the Marche region, and along the whole Apennine ridge at the altitude of transition between the high hills and the

mountains; the high hills and low mountain areas of Sardinia also fall into this category. As far as the mountainous areas are concerned, snowfall increases with altitude, and above all with exposition to the moist currents from the Mediterranean and Balkan seas. As far as the Apennines are concerned, the snowiest areas are generally those of the Tuscan-Emilian regions and that of the Adriatic side—in particular between Sibillini and Matese mounts—as well as the areas closest to the sea of Mt. Pollino, Mt. Etna and Mt. Gennargentu.

4.6 Climatic Variations

The analysis of the temperature series gathered throughout the Italian territory makes it possible to point out two sub-periods, since 1961 until 2010, which are characterized by opposite trends. A decreasing trend can be identified from 1961 until the end of the 1970s, while a sudden increase in temperature can be observed from the eighties onwards.

A decrease in the mean temperature of 0.3 °C/10 years has been estimated from 1961 until the end of the seventies (Fig. 4.5a). The most noticeable decreases are calculated on the series of the minimum temperature, where a decrease of −0.84 °C has been identified for the twenty-year period, while a decrease equal to −0.51 °C has been found for the maximum temperatures (Toreti and Desiato 2007). A sudden change in the temperature trend has been observed from the 1980s until today (Fig. 4.5b, c). The maximum and minimum temperatures have begun to increase. The most notable increase, that is of 0.6 °C/10 years, has been calculated on a series of maximum temperatures, and this is followed by the minimum ones with 0.5 °C/10 years. An increasing trend has also been calculated for the temperature range, the summer days and the tropical nights.

A relevant increase of temperature was calculated in particular in the Alps, for locations above 2000 m. For these areas the maximum increase was estimated for minimum temperature of up to 2.8 °C in the last 50 years (Acquaotta et al. 2015).

A stationary trend has been observed in Italy in the period 1961–2010, as far as rainfall is concerned. The cumulated annual rainfall has neither increased not decreased in the north, in the centre or in the south of Italy. A decreasing

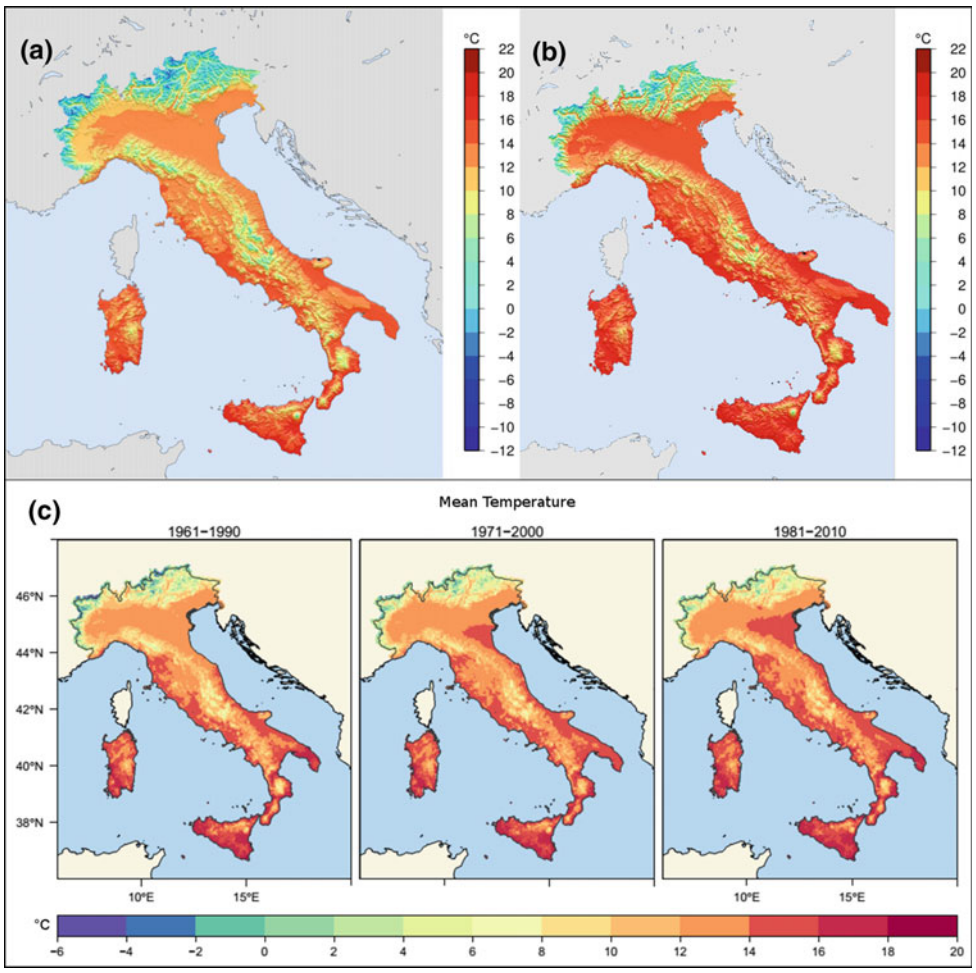

Fig. 4.5 **a** Mean temperature of Italy in 1978; **b** Mean temperature of Italy in 2011; **c** Mean temperature in three different 30 years periods. *Source* SCIA system by ISPRA (www.scia.isprambiente.it) (Desiato et al. 2015)

winter trend has been observed at a seasonal level in the north and centre of Italy. In the north, a decrease of −1.5 mm/year has been recorded, while in central Italy the decrease, which is equal to −7.7 mm/year, has been calculated starting from 1988. More consistent variations have been found for the number of rainy days. The overall number of rainy days throughout the entire national territory has diminished by about 14%, without any significant differences between the northern and central-southern regions (Brunetti et al. 2006). The greatest contribution to the decrease has been calculated for the winter season. This behaviour points out a variation in the occurrence of rainfall events. Heavy rains have increased over the 1961–2010 period and 2011 was characterized by extreme events (Fig. 4.6). The recent flash floods that hit the Liguria (Genoa, Cinque Terre) and North Tuscany (Aulla and Massa Carrara) regions between the end of October and beginning of November 2011 are examples of this behaviour. In fact, on 25 October 2011 nearly 542 mm of rain, a third of the average annual rainfall, fell in six hours. The city of Genoa was rocked by severe flash floods on 4 November 2011, when nearly 500 mm of rain fell in six hours. Six people perished and millions of Euros in damages occurred. The next event occurred in Genoa on 9–10 October 2014, with 188 mm in 24 h, causing one fatality.

A decreasing trend in snowfall has been pointed out in Italy over the Alps from 1961 until the 1970s. An inversion in tendency has been registered from the 1970s onwards,

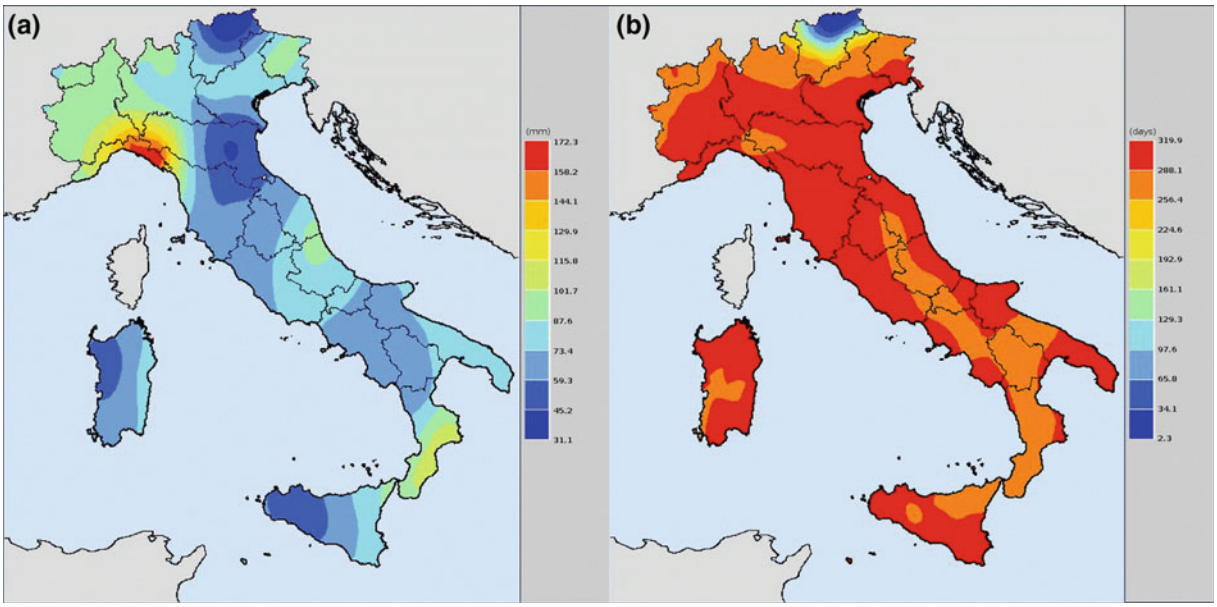

Fig. 4.6 Distribution of heavy precipitation (**a**) and distribution of dry periods in Italy in 2011 (**b**). *Source* SCIA system by ISPRA (www.scia.isprambiente.it)

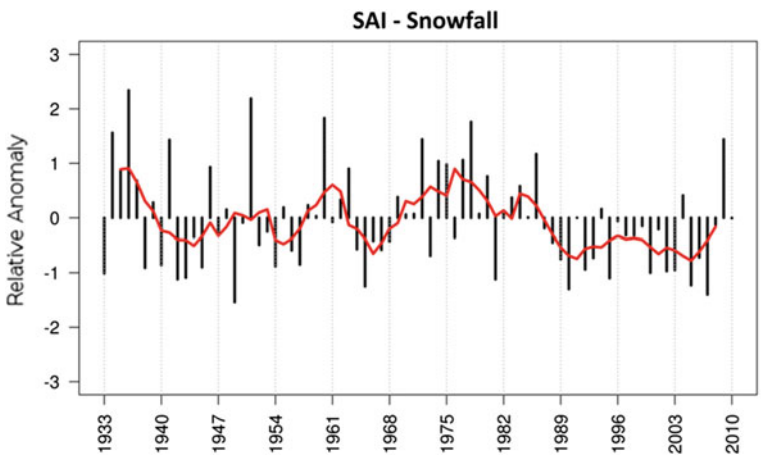

Fig. 4.7 Snowfall Standardized Anomaly Index (SAI) of Piedmont highlighting the greater variations of the variable from his mean value. The snowfall data are calculated using the dataset from all of Piedmont high altitude stations from 1961 to 2010. The *red line* shows the moving mean value for 5 years (reference period from 1971 to 2000)

until and including all the 1980s. Abundant snowfall has been recorded over the entire Alpine range (Fig. 4.7). However, in the last few decades, a decrease has continued to be recorded, although this decrease is more moderate than in the previous years (Auer et al. 2007).

The reduction in the snow cover is more remarkable at lower altitudes, between 800 m and 1500 m, and in the spring season, from March till April. The maximum decrease was recorded in the nineties, with −14 days/10 years, while the decrease over the last decade has been more moderate, −8 days/10 years (Terzago et al. 2013).

As far as snowfall in the winter season is concerned, decreasing trends of between −44 cm/10 years and −4 cm/10 years have been calculated from December to April. The most important decrease has been identified at the end of the 1970s and during the 1990s. Two contrasting trends have been also observed over the Apennines from 1987 until today. In the northern Apennines, both snowfall and snow cover have shown decreasing trends, which are comparable with those of the Alpine chain. The maximum decrease has been recorded for stations located at altitudes below 1300 m. Instead, increasing trends have been calculated for the central part of the Apennines.

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