Chapter 5

Health consequences in the Mediterranean region

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Abstract

The Mediterranean basin is highly vulnerable to climate change, and a warming trend with changes in rainfall patterns with more heavy rains has already been observed. The frequency of dust storm and wildfire has also increased. Both non-communicable and communicable diseases will be seriously impacted by climate change since climate modification or air pollution influence the development of the former and weather conditions the latter. Different socio-economic characteristics within the Mediterranean basin will also exacerbate or on the contrary reduce health outcomes. Surprisingly few quantitative studies have explored the impacts of climate change on health in the Mediterranean region, and the few are geographically limited to specific areas of the basin.

Here we review the scientific literature on this topic and make some recommendations for the development of national and regional research, preparedness and adaptation policy in the Mediterranean region.

Résumé

La zone méditerranéenne est très exposée aux changements climatiques, et un réchauffement régional de la température avec une modification du régime des pluies, généralement plus fortes, est actuellement observé. Les tempêtes de sable et les incendies non contrôlés sont en augmentation. Les maladies infectieuses et chroniques humaines peuvent être affectées par ces bouleversements de façon directe ou indirecte ; les conditions bioclimatiques conditionnent le développement des agents pathogènes et de leurs hôtes vecteurs ou réservoirs ; les modifications du climat ou la pollution atmosphérique qui en dérive ont une influence sur le développement de certaines maladies chroniques. Des déterminants, en particulier socio-économiques, prévalant ou en évolution dans la zone méditerranéenne affecteront aussi la santé de la population. Curieusement, peu de travaux scientifiques ont étudié les effets des changements climatiques sur la santé humaine dans la région, et les quelques rares études restent géographiquement limitées à des zones particulières du bassin méditerranéen. Dans ce chapitre, nous synthétisons la recherche réalisée dans le domaine, et proposons des recommandations en termes de recherches scientifiques nationales et régionales, et de stratégies de préparation et d'adaptation à ce nouveau contexte.

Introduction

The consequences of global environmental changes for human health are among the top priorities of citizens worldwide. Climate change is one of many global environmental changes (land-use changes, ocean acidification, biodiversity loss, transcontinental trade and transportation, etc.), and there is ample evidence that it has already had significant effects on population health and additional consequences are expected in coming decades (McMichael et al. 2006, Costello et al. 2009). One of the critical issues is how and to what extent climate change, together with other associated environmental and social stressors, has consequences for the health of individuals and whole populations (Corvalan et al. 2005). Understanding such effects and possible interactions between different stressors is critical for effective public health decisions and strategies.

Climate change will have health effects worldwide, but here we focus on the Mediterranean region. Climate change has both direct and indirect effects on human health and both are relevant in this region. Direct effects include higher temperatures, increased UV irradiation and localized storms and floods. There is evidence that extreme temperatures are clearly associated with increased human mortality and morbidity, and recent findings show that heavy rainfall may accelerate the development of water-borne or vector-borne diseases. Indirect health effects are related to the deterioration of air, soil and water quality, which are expected to occur in the Mediterranean region. As an example, increased exposure to allergens, air pollution and infectious diseases that are related to climate change, will all significantly contribute to the increased frequency of respiratory diseases. Importantly, each of these indirect effects can also be triggered by other activities; for example, air quality is altered by climate change but also by industry, transportation, urbanization, etc. Concerning communicable diseases, many examples suggest a climate-driven cascade of effects model, notably a trophic one, for infectious disease outbreaks worldwide. Furthermore, interactions between climate change and the other stressors are very likely to take place and a major challenge will be to find out whether they act in an additive, synergistic or antagonistic manner. A major conclusion at this stage is that an assessment of the effects of climate change on health would be improved if it were combined with that of other environmental stressors (Flahault et al. 2015). Such an integrative approach is in line with the exposome concept and framework developed by Chris Wild from the IARC (Wild, 2005).

The duration and impact of heat waves are expected to increase with climate change. In a study on heat-related mortality rates in several European cities, Mediterranean cities including Barcelona, Rome and Valencia were found to be the most vulnerable to increased heat (Baccini et al. 2009). Similarly, the heat-related death rates in Lisbon are expected to increase significantly during the 21st century (Casimiro et al. 2006). It is expected that these adverse effects will primarily affect vulnerable individuals, notably the elderly, who are more likely to suffer from chronic diseases (Oudin Åström et al. 2015). Another likely consequence is the increase in exposure to UV with its consequences for skin cancers. Modifications in atmospheric pollutants including ozone are discussed in the following subchapters.

Changes in the precipitation patterns are also expected with increased risks of floods and droughts. They may differ from one region/country to the other (Messeri et al. 2015). In addition to their direct effect on health notably through mosquitoes able to transmit tropical infections, these changes will most likely impact agriculture and the food supply, as described elsewhere in this book. There is reason for concern that it may eventually lead to a change in the Mediterranean diet, which is among the strongest assets in terms of health for the inhabitants of this region. It would be extremely deleterious if climate change were to alter the balanced nutritional habits of the Mediterranean population. While plans should be proposed to prevent the consequences of climate change in the Mediterranean area affecting diet, it is equally important to ensure the sustainability of the assets of this region, in particular food habits.

When examining the literature on climate change and health in the Mediterranean region, it is striking to see that very little work - a large proportion of existing literature consists of reviews and editorials, not original studies - has been carried out both on non-communicable and communicable diseases, and there are still many open questions (Hosking and Campbell-Lendrum, 2012). It is thus crucial to increase the number and quality of the studies and to highlight the importance of health effects in the future. It is also crucial that research is carried out not only in the northern part of the Mediterranean region but also on its southern and eastern rims. This will also contribute to a better awareness of the citizens of the prospects of climate change.

Climate change will affect the health of the Mediterranean populations both directly and indirectly. It should be included with other changes in population, migration and nutritional habits since the combination of those changes could lead to even more harmful conditions. We believe that if health concerns are highlighted by international bodies, the involvement of the citizens will be stronger and more sustainable. We also believe that the effects of all stressors and changes should be taken into consideration and integrated, and that the assets of the Mediterranean population, such as healthy diets, should be supported and advertised. In addition to preventive and precautionary actions, more research should be conducted to support national and trans-Mediterranean public health decisions.

Sub-chapter 2.5.1

Climate change and infectious diseases in the Mediterranean region

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Concerning communicable diseases, it should be noted that, to date, the area surrounding the Mediterranean Sea has received little attention, and available datasets and results on the impacts of climate change on infectious diseases are few and far between (Navarra and Tubiana 2013). The effects of climate change on the spread and on the intensity of infectious diseases have been studied only in the countries along the north-western and western coasts of the Mediterranean Sea, whereas evidence is drastically lacking in the countries on the eastern and southern shores. These regions already face numerous humanitarian crises, from conflicts to natural hazards, and recent geopolitical changes, and climate change is likely to exacerbate the impacts on health. The Mediterranean climate and the proximity to the sea makes it attractive to people, which is resulting in a high rate of conversion of ecosystems for agricultural and other human uses with a parallel reduction in coastal wetlands and forests. As a result, the main constraint faced by the Mediterranean is linked to high population density and population growth, and the expansion of urban areas into peri-urban and rural landscapes. In addition, the risks for public health represented by emerging infections in the region due to the possible expansion of the range of some tropical vectors are an important source of concern widely reported in the media.

The Mediterranean region is known to be vulnerable to climate change, and a significant increase in mean temperature has been measured in the basin in recent decades. Extreme weather events have become more common with an increase in the frequency and severity of heavy storms like the "Cévennes episodes" in southern France or of heat waves on the western and southern ridges, parallel with a reduction in rainfall amounts. The projected decrease in precipitation in North Africa is also a major health concern because 22% of the world's water-poor population are concentrated in the Mediterranean region (Giorgi and Lionello, 2008). As a consequence of these ongoing changes, infectious diseases, being contagious or indirectly transmitted via a vector or a reservoir host or both, are expected to be affected. For some infections such as Chikungunya and West Nile viruses, climate change is still debated as the main driver of the increased risk of local transmission in the area, and for others, like many water- and food-borne diseases, the risk of spreading in the near future is real. Overall, adaptation to and preparation for changing patterns of infectious disease distribution in the Mediterranean basin is essential in the context of climate change.

Here, our aim is to identify the possible impacts of climate change on the emergence and spread of human infectious diseases in the Mediterranean basin, based on a review of the scientific literature. We limited our selection to evidence-based studies because, in most of the scientific literature, notably on vector-borne diseases, there still is remarkable confusion between climate-sensitive infections and diseases that are impacted by climate change (Guégan and Simard, 2015). We have different recommendations for individual Mediterranean countries and regional institutions, depending on their national or regional needs and vulnerability.

Extreme events do matter in the emergence of infectious diseases in the Mediterranean region

Vibrio parahaemolyticus, *V. vulnifucus* and environmentally-persistent *V. cholera*e are halophilic bacteria that live in marine, lagoon and estuarine environments. These bacteria are recognized throughout the world as agents of gastroenteritis in human resulting from consumption of raw or undercooked seafood and serious infections caused by exposure of skin wounds to seawater (Esteves et al. 2015). Even if the pathogenic form of *V. cholerae* causing cholera appears to be absent from the Mediterranean Sea, there is a risk that pathogenic strains might be introduced. There is some scientific evidence showing that sea surface temperature is a major factor explaining the population dynamics of vibrios in coastal marine ecosystems, and that long-term effects of ocean warming should increase the dominance of these vibrios within the plankton-associated bacterial community (Vezzulli et al. 2012). However, a study conducted in French Mediterranean coastal lagoons in 2011 and 2012 showed that the highest concentrations in vibrios were in the Palavasian coastal lagoons, with an abrupt decrease in salinity caused by heavy rainfall and major flooding in the fall. These results clearly showed that flood events can have a major effect on the abundance of these environmentally-persistent bacteria in the lagoons of southern France. It is thus clear that harvesting shellfish from lagoons where the environmental conditions have changed significantly after flooding may represent a significant risk to public health in other sub-regions of the Mediterranean basin.

In September-November 2014, the French Health authorities reported a cluster of 11 autochthonous cases of Chikungunya disease in the city of Montpellier in the vicinity of a recently imported case. It has been demonstrated that the density of the female disease vector *Aedes albopictus* increased rapidly after the extreme “Cévennes episode”, soon followed by an increase in the number of eggs collected in ovitraps (Figure 1). Observations suggest that the heavy rains after a period with little rainfall filled all the peridomestic containers where dessicated eggs of this mosquito were to be found, and that it was this situation that led to the increase in the number of mosquitos several weeks later (Roiz et al. 2015) (Figure 1). Before floods, accumulated temperatures are a good predictor of *Ae. albopictus* seasonal dynamics, but after accumulated rainfall over the four weeks prior to capture predicts the seasonal dynamics of this vector and extension of the transmission period of Chikungunya in Montpellier. This work presents the first evidence in support of a relationship between heavy rainfall and Chikungunya emergence in the Mediterranean region, and it goes against the common belief that heavy rainfall has a flushing effect on breeding sites, which in turn, negatively affects vector populations.

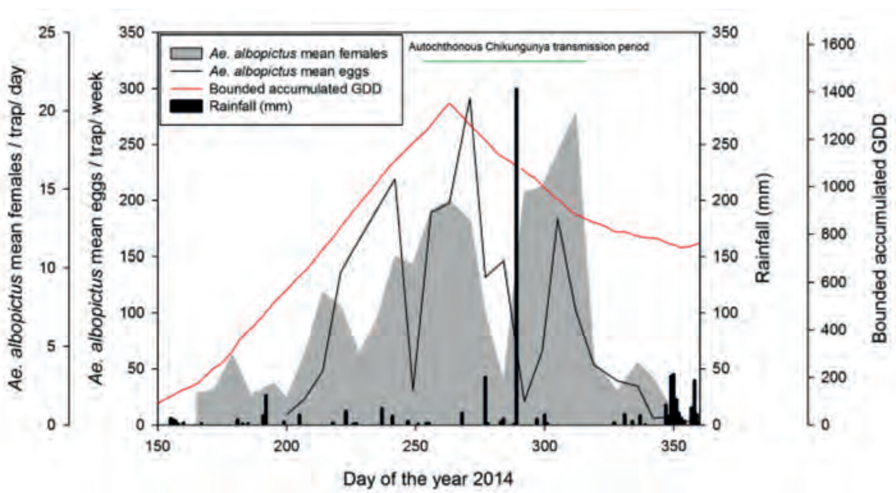

Figure 1
Number of female Aedes albopictus *tiger mosquitoes per trap per day (grey area) in different locations in Montpellier in 2014. Potential autochthonous Chikungunya transmission period (green line at the top of the figure). A massive rainfall event before day 300 was followed by a sharp increase in the number of female mosquitoes.*
PLoS Neglected Tropical Diseases *(2015). doi:10.1371/journal.pntd.0003854*

Taken together, these two illustrations clearly show that for water-borne and vector-borne infectious diseases, it is crucial to take extreme events into account in research on climate change and health. This is obviously the case for environmentally-persistent aquatic bacteria, but the same could be true for aquatic viruses that cause enteritis in human (and mass mortality in seafood mollusks; heavy rainfall can modify environmental conditions by decreasing water salinity, thus supporting the population dynamics of vibrios. Concerning vector-borne diseases, these extreme events may extend the period of infection transmission to human. These changes may increase the impact of many water-borne diseases like enteric fever, and vector-borne diseases like the West Nile virus, which are already problematic in the Mediterranean region (Vittecoq et al. 2013). Although very few cases of cholera have been reported in the Mediterranean basin in recent years (WHO 2016), *V. cholerae* was recently isolated from freshwater, water in coastal areas, and from seafood in European and North African countries (Eddabra et al. 2011; Senderovitch et al. 2010; Vezzulli et al. 2010). Recent geopolitical changes together with an increasing number of refugees fleeing ongoing conflicts in North Africa and the Middle East might generate favorable conditions for new cholera outbreaks, which often occur in overcrowded settlements. In this section, we do not review the impact of flushing caused by heavy rains, which may transport waste to the nearest stream, which, in turn, flows into larger rivers or into coastal lagoons and ends up in human populations. Human and animal waste contain bacteria, viruses and fungi that can be harmful to human, and their concentration may increase in the near future due to extreme flooding events interacting with failing sewage infrastructure.

Long term warming and infectious diseases in the Mediterranean region

Climate-sensitive diseases does not mean climate-change sensitive

As mentioned above, abiotic and biotic conditions in the environment determine the distribution of vector- and reservoir-borne diseases in that they influence the vector (or reservoir)-host-pathogen transmission cycle, including vector or reservoir distribution, abundance and diversity. Vector or reservoir host spatial distribution is constrained by the distribution of appropriate habitats, for instance, aquatic environments that support the development of larvae, and by the factors that determine adult mosquito habitats. However, not only the distribution of water for mosquito or rodent habitats needs to be taken into consideration but many other environmental parameters, for instance the vegetation type and cover. It is also important to take meteorological conditions into account in vector- and reservoir borne infections, and many studies have shown that the distributions of mosquito or rodent species are determined by winter and summer temperatures, precipitation patterns and most important, photoperiod (Guernier et al. 2004). Apart from mean temperature or precipitation values, minimum threshold values are also important as limiting factors for the development of the disease life cycle. Of course, other ecological and human factors may also influence the distribution of vector and reservoir populations, such as land use/land cover, urbanization or human population density. Climate influences different aspects of the vector (or reservoir)-host-pathogen system, and the potential impact of global warming on these diseases is still the subject of controversy (Guégan and Simard, 2015). In general, researchers consider that the effects of climate change, say an increase in mean temperature, will linearly affect mosquito distribution, abundance and longevity, pathogen incubation period and replication, and their interactions. Previous studies indeed concluded that high temperature and rainfall are positively associated with mosquito abundance, and hence with disease outbreak and spread, which is a simplistic view of disease transmission.

A recent survey conducted in the Doñana National and Odiel Natural Parks in south-west Spain by Roiz et al. (2014), based on data collected over a period of 10 years (2003-2012) consisting in bi-weekly surveys of seven mosquito species known to transmit West Nile virus, Usutu virus, dirofilariasis and *Plasmodium* protozoans, showed that the effects of climate and climate variability are species-specific, site-specific, time-dependent and are by essence non-linear in their reaction. Weekly temperatures are related to seasonal abundance patterns in the two mosquitoes *Culex pipiens* (a vector for West Nile and Rift Valley viruses) and *Ochlerotatus caspius* (a vector for West Nile and Tahyna viruses, and tularemia) while accumulated (1-4 weeks before) temperatures were shown to be positively correlated with *Cx. modestus* (a vector for West Nile and Tahyna viruses, and tularemia) and *Cx. perexiguus* (a vector for West Nile virus) abundances. On the contrary, accumulated temperatures were negatively correlated with *Cx. pipiens* and *O. detritus* abundances. These results clearly show that climate change will not necessarily lead to an increase in mosquito populations, and that over-simplified statements assuming that higher temperatures (or rainfall) lead to more mosquitoes, and hence increase the risk of epidemics, are not appropriate and overestimate the effect of climate change on real disease risks in the Mediterranean region (Guégan and Simard, 2015). Interestingly, this study showed that it is essential to carry out a careful analysis of temporal patterns of vector species in field data in order to analyze short, medium and long temporal trends and then distinguish the role played by climate variability and change from other important parameters in disease transmission. In any case, it is not possible to extrapolate from conclusions regarding climate change and mosquito abundances to the risk of disease outbreaks in the Mediterranean basin and elsewhere (Guégan and Simard, 2015). Recent modeling advances used to analyze the spread of mosquito species have shown for the tiger mosquito *Ae. albopictus* in southern France that human activities, notably transportation, are especially important for mosquito dispersion while land use appears to be a major factor influencing mosquito establishment, not climate change *per se* (Roche et al. 2015a). Monitoring and modeling both extreme events and long-term climate drivers of infectious disease outbreak and spread can help to anticipate, or even forecast, an upsurge of infections in the Mediterranean.

Some infectious disease study-cases in the region

The Mediterranean region has undergone several social, economic, political and environmental changes in recent decades. Wars have occurred in the Middle East and several countries in North Africa have experienced social and political instability and coups d'état. Many surrounding countries in both regions have also experienced wars, social instability, human migration, refugees, poor sanitation, and a low level of hygiene, with a high risk of consuming contaminated food or drinking water (Habib et al. 2010). Overall, all around the basin, increasing urbanization and human population density in coastal areas are critical in exacerbating air pollution and in creating ideal foci for the transmission of many contagious illnesses including diarrheal diseases and indirectly-transmitted diseases like dengue or Chikungunya virus infections. Natural environmental changes (warm temperature, less or heavy rainfall, longer periods of drought and extreme events) and human activities (transcontinental transportation of goods, animals and people within the basin, the disappearance of natural wetlands, coastal planning, dam construction on large Mediterranean rivers), all these changes may have enhanced natural cycle transmission of infectious agents. In this section, based on Rodríguez-Arias and collaborators' technical report (2008), we briefly review the emerging infectious diseases that pose serious health problems in the Mediterranean region. For eastern Mediterranean countries, Habib et al. (2010) and Khader et al. (2015) reviewed studies reporting the impacts of climate change on health or studied associations between meteorological parameters and human health outcomes, and the reader is invited to consult these references. Table 1 gives an overview of other potential infectious disease threats that could emerge in the near future in this area.

Visceral leishmaniasis is endemic around the Mediterranean basin and represents the main form of the disease. Countries on the northern rim of the basin like Spain, France, Italy, the Balkan sub-region, and Greece are where the disease transmission occurs. Generally, leishmaniasis occurs in rural areas, villages in mountainous regions and also in some peri-urban areas where dogs act as hosts for the disease life-cycle. This disease system is climate-sensitive, and strongly affected by changes in rainfall, temperature and humidity patterns. Global warming and land degradation together affect the epidemiology of leishmaniasis in a number of ways. According to WHO, changes in temperature, rainfall and humidity can have strong effects on sandfly vectors and reservoirs of rodent hosts by altering their distribution and influencing their survival and population size. Likewise, small modifications in temperature can have a profound effect on developmental cycle of *Leishmania* promastigotes in sandflies, thus supporting the development of the disease life-cycle in new as yet uncolonized areas. Finally,

Table 1
Climate-sensitive infectious diseases in the Mediterranean area and potential risk of emergence and spread. An asterisk means that since the information was originally published, cases have been detected in the area. Nota from the authors: "climate-sensitive diseases" does not mean that a formal demonstration of an effect of climate change has been demonstrated on the different listed diseases so far. These evidence-based studies of an effect of climate variability and change on the corresponding diseases were carried out at global scale. Modified from Rodriguez-Arias et al. (2008).

Infectious disease	Already present in the Mediterranean	Number of papers published (2007-2010)	Evidence for an effect of climate variability and change
Food- and water-borne			
Amoebiasis	Yes	4	No
Campylobacter enteritis	Yes	12	No
Cholera	No (potential risk)	9	Yes (South Asia, north-west South America, West Africa)
Cryptosporidiosis	Yes	22	No
Diphyllobothriasis	Yes	2	No
Escherichia coli infection	Yes	10	No
Food-borne *Vibrio* enteritis	Yes*	25	Yes (North Sea, Baltic, Atlantic Ocean, Mediterranean Sea)
Giardiasis	Yes	17	No
Legionella infection	Yes	17	No
Leptospirosis	Yes	21	No
Rotavirus enteritis	Yes	7	No
Salmonella infection	Yes	24	No
Schistosomiasis	Yes	3	No
Shigellosis	Yes	6	No
Strongyloidiasis	Yes	1	No
Typhoid and paratyphoid fevers	Yes	7	No
Air/human to human transmission			
Meningococcal infection	Yes	24	Yes (West Africa)
Vector-borne			
Typhus fever	Yes	12	No
Chikungunya virus disease	Yes	25	No
Dengue and dengue hemorrhagic fever	Yes*Some doubts	14	Yes (South-East Asia, northern South America)
Malaria	Yes	13	Yes (South-East Asia, East Africa, northern South America)
Rift Valley fever	Yes	6	Yes (South Africa)
West Nile virus infection	Yes	40	No (controversies)
Plague	Yes*	4	Yes (Central Asia)
Leishmaniasis	Yes	31	Yes (Southern Europe, South America)
Sandfly virus fever	Yes	15	No
Crimean-Congo hemorrhagic fever	Yes	24	No
Lyme disease	Yes	34	Yes (Northern Europe)
Spotted fever	Yes	21	No
Tick-borne relapsing fever	Yes	2	No
Tick-borne viral encephalitis	Yes	13	No
Tularemia	Yes	4	No
Filariasis	Yes	4	No

extreme climatic events and famine resulting from climate change can lead to massive displacement and migration of people to infected areas. Nowadays, we have a very limited understanding of the impact of climate change on leishmaniasis (re-)emergence and spread within the Mediterranean basin even if observations in southern France and northern Italy are congruent in showing the existence of a northwards colonization front. Local modifications in the environment like in Israel have favored the spread of rock hyrax colonies (*Procavia capensis*) close to human habitations, thereby establishing zoonotic transmission of *Leishmania (Leishmania) tropica*. Other concerns include the potential establishment of *Le. tropica* in Sicily, where the vector *Phlebotomus (Paraphlebotomus) sergenti* is locally abundant (Bates et al. 2015). In addition to the environmental risk factors for leishmaniasis transmission, urbanization, social instability, low hygiene education, inadequate housing and sanitation, domestic zoonosis involving dogs and HIV co-infection are important factors in leishmaniasis epidemiology.

The West Nile virus outbreaks that occurred in Romania (1996) and Israel (2000) followed a drought season, and the role of meteorological conditions is clearly important in the development and spread of this virus in the Mediterranean region. After high rainfall followed by a period of drought, pools become richer in organic materials and sediments from which *Culex* vector mosquitoes (see above) may benefit, thus extending their breeding season. These conditions are then optimal for bird species to congregate around rich pools with myriads of mosquitoes. The conditions are met for the virus to circulate easily (but see comments above about extreme events). In addition, warm temperature accelerates the extrinsic incubation period of viruses within mosquito carriers, and thus enhances the potential for transmission and dissemination (Conte et al. 2015). However, West Nile virus disease is a complex disease system where many parameters may act independently or synergistically (Chevalier et al. 2014, Roche et al. 2015b), and further studies are clearly needed in the Mediterranean to determine the exact role played by climate change in the observed emergence and spread of this disease (see Di Sabatino et al. 2014 for a recent review and Conte et al. 2015 for a time and space analysis of suitable habitats in the Mediterranean region and central Europe). Notably, habitat alteration and the disappearance of wetlands with increasing urbanization all around the basin might have profoundly modified bird species behavior and ecology.

In recent years, malaria has re-emerged in residual foci in Eastern Europe and the present climate change could actually increase mosquito vectorial capacity, especially in southern countries of Europe and the Mediterranean region. Malaria was endemic in Europe and the Mediterranean until the mid-20th century, but was considered eradicated on the northern rim of the Mediterranean Sea in the 1960s and 1970s. Southern Europe is among the most risky regions for malaria resurgence, especially for *P. vivax* malaria resurgence due to its climate characteristics, the proximity to Africa and Caucasus, and the presence of a range of more or less potential Anopheline vectors (Odolini et al. 2012). *Anopheles atroparvus* is known to be an efficient malaria vector and it is widely distributed in Europe, except in some Mediterranean regions including southern Italy, Greece and Turkey where *An. labranchiae* and *An. superpictus* are the dominant species. Studies on the receptivity of the European vector *An. atroparvus* revealed that it is not susceptible to the afro-tropical *P. falciparum* strains, which represents the dreadful killer of malaria forms, but is probably fully susceptible to infection by *P. vivax* strains imported from Africa. Since 2004, Morocco is considered to be malaria-free, but imported malaria cases in the northern central region highlights the potential risk of introduction of the parasite in this region. In summer 1997, one autochthonous *P. vivax* case occurred in Italy, in a rural zone where *An. labranchiae* occurs, and the same happened in Corsica in August 2006, where a case of indigenous *P. vivax* malaria - the first case of autochthonous transmission in France since 1972 - was diagnosed. Four years later, in 2010, Spain reported the first indigenous cases of *P. vivax* malaria in the province of Aragon, where the vector *An. atroparvus* is present. Then, in August 2011, a *P. vivax* infection was diagnosed in a Romanian traveler returning from Greece. Greece was officially considered malaria-free in 1974, but sporadic autochthonous cases were reported in 1991, 1999 and 2000 (Odolini et al. 2012). Recent studies in the Ebro delta in Spain, an historically endemic malaria area, showed that this ecosystem currently presents ecologically favorable characteristics, notably with the presence of *An. atroparvus* and its rice field landscape, for the re-appearance of malaria if an appropriate malaria strain were to be introduced and the extension of the potential transmission period due to ongoing global warming (Sainz-Elipe et al. 2010).

At present, there is concern about the possible emergence and spread of *Aedes*-borne viral diseases in the Mediterranean region. Dengue fever is the most important one, and dengue outbreaks were rather common in the Mediterranean at the beginning of the 20th century (Rezza 2016). Several epidemics also occurred in the 18th and 19th centuries in ports in the eastern Mediterranean and occasionally in the northern and western parts (Schaffner and Mathis 2014) (Table 2). The vector *Ae. aegypti* was re-introduced locally by vessels at that time and was widely present in southern Europe. Notably, the last major outbreak occurred in 1927/1928 in Athens and neighboring districts in Greece with a peak in August 1928 that affected more than 1 million people, and then left Mediterranean Europe. In September 2010, two cases of dengue were identified in Nice, southern France, and in the summer of the same year, another transmission event was detected in Croatia between August and October, 2010. Again, in 2013 and 2014, five autochthonous cases were identified in southern France in Bouches-du-Rhône and Var Departments. More recently, autochthonous cases of dengue were reported in Nimes, southern France (Succo et al. 2016). Since 2010, at least 23 cases of dengue have been reported by public health authorities in Mediterranean Europe. Chikungunya is another *Aedes*-borne viral disease threatening the health of Mediterranean citizens. In the summer of 2007, more than 250 cases of Chikungunya virus disease occurred in the north-east of Italy, and in September 2010 autochthonous transmission of the virus was identified in south-east France, in both situations, with primary cases returning from a visit in India (Rezza et al. 2007). In the Mediterranean area, *Ae. albopictus* (the main established vector) appears to be the vector implicated in all transmission events for dengue and Chikungunya. Nowadays, with the large epidemic of Zika virus, there is a possibility of an increased risk of Zika virus transmission within the Mediterranean basin during the summer season. However the risk of large scale outbreaks and endemicity for these *Aedes*-borne infections in the Mediterranean appears to be rather low. Climate change, which may favour overwintering of virus and mosquitoes in the region, is not the only driving factor that influences disease spread, and outbreaks caused by *Ae. albopictus* are less important than those due to its congener, *Ae. eegypti*, due to its feeding habits. In general, other important drivers of dengue transmission are socio-economic factors, including globalization, urbanization, and anthropological or social human behaviors. Nevertheless, the presence of *Ae. aegypti* now established on the Caucasian cost of the Black Sea, is less reassuring today (Schaffner and Mathis 2014).

Table 2
Historical and contemporary outbreaks of dengue fever in the WHO European region. Note that most of infected localities are in the Mediterranean region except the Canary Islands and Madeira in the Atlantic Ocean and Vienna, Austria in mainland Europe. From Schaffner and Mathis (2014).
The Lancet Infectious Diseases.

	Location	Notes
1784, 1788, 1793	Cadiz, Seville (Spain)	End of first pandemic, 1779–84
1861	Cyprus	–
1863, 1867	Cadiz (Spain), then Jerez, Seville, and other places in Andalusia	Imported from the West Indies by troops
1865	Canary Islands (Spain)	–
1881	Crete (Greece)	Half of the inhabitants affected
1887	Gibraltar	Fifth pandemic, 1887–89
1888–1889	Cyprus	–
1889	Athens, Piraeus, Salonica (Greece), Greek Islands (Rhodes, Chios, and others), southern Turkey, Izmir, Manisa to Istanbul, Trabizon (Turkey), Varna* (Bulgaria), Lisbon (Portugal), Israel	Around 80 000 cases in Izmir (80% of the inhabitants)
1889–1890	Istanbul, Izmir (Turkey), Napoli (Italy)	–
1895–1897	Athens (Greece)	–
1899	Antalya (Turkey)	–
1910	Athens, Piraeus (Greece)	–
1912	Israel	–
1913	Cyprus	–
1916	Dardanelles, Trabizon (Turkey)	–
1921	Vienna* (Austria)	–
1927	Malta	–
1927–1928	Piraeus, Athens, Euboea, Gulf of Aegina (Greece), Izmir to south of Rhodes (Turkey), Israel, Greece: DEN-1 and DEN-2 confirmed by retrospective serological study	More than 1 million of people affected (90% of the population in Athens); 1000–1500 deaths
1928	Cyprus, Andalusia	–
1929	Izmir	–
1929–1933	Greece	Confirmed by retrospective serological study
1945	Turkey, Israel (and other Middle East countries)	–
2010	Croatia; three DEN-1 clinical cases (including one reported in Germany) plus 15 recent infections	Virus probably introduced from Indian subcontinent
2010, 2013	France; DEN-1 cases (2010), one DEN-2 case (2013)	Viruses probably introduced from West Indies
2012–13	Madeira; more than 2200 DEN-1 cases from October, 2012, to January, 2013, plus 74 cases reported from Portugal mainland and 12 other European countries	Virus probably introduced from Venezuela

DEN-1=dengue virus serotype 1. DEN-2=dengue virus serotype 2. *Not clear whether data refer to a dengue outbreak or imported cases only, as there is no indication for the presence of A aegypti in Varna and Vienna.

***Table:* Historical and contemporary outbreaks of dengue in the WHO European region**

Research initiatives needed on communicable diseases for the future

To conclude this section, one personal observation that can be made compared to other regions of the world where climate-sensitive diseases have been studied is that studies on climate change and infectious diseases in the Mediterranean are sporadic, unfocused and often anecdotic from a data-orientated perspective, and too uncoordinated to make it possible to answer the question concerning the impacts of climate change on health. Habib (2011) made the same comment concerning chronic illnesses and socially situated health outcomes particularly impacted by climate change in the Eastern Mediterranean region. In general, studies do not formulate their findings within a conceptual framework that links them to climate change, but discuss how weather variations (which are not necessarily climate change indicators; see comments above) such as temperature, humidity and rainfall impact infectious diseases and their hosts. Concerning vector-borne diseases more specifically, most studies discuss the presence and development of a given potential vector species and the extension of its survival period, and very rarely or never analyze the association between the vector, the pathogen and the environment, and the possible changes in these interactions due to climate change (Guégan and Simard 2015). Longitudinal studies over extended periods of time and at different sites that investigate the link between climate change and infectious diseases are absolutely indispensable in the Mediterranean region since these studies represent the gold standard in climate change impact research today (Rodó et al. 2002, Morris et al. 2014). There is an absolute need for longitudinal studies to be extended to include more countries in the region and to include other environmental, ecological, social and economic factors that might affect the spread of the disease. Research on health outcomes of climate change requires multidisciplinary knowledge of complex and multi-layered environmental, social, economic, political and health processes, and it definitely requires the establishment of a strong trans-Mediterranean medical research and health coordinating body.

According to Navarra and Tubiana's (2013) book, the European Community funded FP6 Emerging Diseases in a changing European eNvironment (EDEN) integrated research program was an excellent opportunity to bring together researchers from different disciplines in Europe, Northern Africa and Turkey to develop systematic assessments of localized environmental, economic, demographic and health impacts of climate change on emerging infectious diseases. Even if this EC research initiative was not only focused on the Mediterranean region, a substantial part of the research activities were conducted in the Mediterranean basin, notable on leishmaniasis, malaria, tick-borne diseases, and West Nile virus and Rift Valley virus diseases.

The impacts of climate change on non-communicable diseases in the Mediterranean region

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According to the existing literature (Suk and Semenza 2011), climate change will increase the incidence of non-communicable diseases (NCDs), including cardiovascular disease (CVD), respiratory diseases, some cancers, mental disorders, injuries, and malnutrition and overall poor health among all populations through direct and indirect effects (see Table 1).

A number of studies have shown that the elderly, children, people with pre-existing chronic conditions (i.e. respiratory diseases, CVD, diabetes) and individuals with a low socio-economic status, are at higher risk of suffering from climate change effects.

Extreme weather and related events have direct health effects in the Mediterranean region

The frequency of extreme natural hazards and weather events including heat waves, cold spells, floods, storms and droughts has been increasing in recent decades in Europe and specifically in the Mediterranean region due to climate change. Among them, the key climatic change factors that directly influence NCDs are extreme temperature events, barometric pressure, floods and storms (see Table 1).

Since the 1960s, the Mediterranean region has become warmer with a significant increase in the frequency, intensity and duration of heat waves (Kuglitsch et al. 2010) and of related health effects. In the 'Assessment and Prevention of Acute Health Effects of Weather Conditions in Europe (PHEWE)' project, including Mediterranean cities, high temperatures had a specific impact on respiratory admissions, particularly in the elderly population (Michelozzi et al. 2009). This is because, among elderly, the body temperature increases with the mean outdoor temperature. Heat effects are also observed in children (Iñiguez et al. 2016), for whom hospitalization for natural causes rose significantly with heat in Rome and Valencia between 2001 and 2010. Patterns of delays and critical windows of exposure varied according to the outcome considered with respiratory and gastrointestinal diseases being the leading causes for short and long-term lags respectively. Less expected are the effects of cold spells that belongs to the kind of extreme events whose frequency is increasing due to climate changes. In adults, winter deaths are due to influenza, coronary thrombosis and respiratory diseases. Coronary thrombosis deaths peak about two days after the peak of a cold spell whereas respiratory disease, namely pneumonia and COPD exacerbations, peak about 12 days after the peak cold. The rapid coronary deaths are due mainly to haemoconcentration resulting from fluid shifts during cold exposure; some later coronary deaths are secondary to respiratory disease. In Italy, excess deaths among the elderly were recorded in the 14 cities that suffered from a cold spell in February 2012 (de Donato et al. 2013). Cause-specific analysis showed a statistically significant excess in mortality for respiratory disease, COPD, cardiovascular disease, ischemic heart disease. Similar results were reported for emergency room visits. In the PHEWE project mentioned above (Michelozzi et al. 2009), a decrease in temperature was associated with an increase in the daily number of total natural deaths and specifically with an increase in cardiovascular, respiratory, and cerebrovascular deaths, respectively. The increase was greater among older age groups. The cold effect was found to be greater in warmer (southern) cities and persisted up to 23 days, with no evidence of mortality displacement (Analitis et al. 2008). A recent study in the Czech Republic investigated differences in the effects on acute and chronic diseases following extreme cold and hot temperature (Davídkovová et al. 2014). While excess deaths due to ischemic heart disease (IHD) during hot spells were mainly of persons with chronic diseases whose health had already been compromised, cardiovascular changes induced by cold stress may result in deaths from acute coronary events rather than chronic IHD, and this effect was also important in the younger population. This suggests that the most vulnerable population groups as well as the most affected cardiovascular diseases differ between hot and cold spells, which needs to be taken into account when designing and implementing preventive actions.

Table 1
Direct and indirect effects of climate change on non-communicable diseases (NCDs).

Climate change effects		**Additional factors contributing to the indirect effect**	**NCD**	**Direction of the risk**
Direct:	*Indirect:*			
Heat extreme			CDV and respiratory morbidity and mortality	Increase
Cold extremes			Cardiorespiratory morbidity and mortality	Increase
Low atmospheric pressure during storms			ISP	Increase
Extreme weather events (floods, storms, etc.)			Injury, Impaired mental health, Impoverishment	Increase
Storms		Pollen breaking	Asthma	
Drought			Malnutrition, Impaired mental health	Increase
Pests		Increasing use of pesticides	Asthma, Parkinson's disease, Cancers	Increase
Aflatoxin (fungal metabolite)		Cereal contamination	Liver cancer	Increase
Increased temperature, windless conditions	Higher ground-level ozone	Urbanization	Increased respiratory tract irritation, CDV and chronic pulmonary disease hospitalizations, and lung disease mortality	Increase
Wildfires, drought	Higher Particular Matter level	Urbanization	COPD exacerbations, Mental illness	Increase
Altered trajectory of recovery of stratospheric ozone with changes in precipitation and cloud coverage	Altered ambient ultraviolet radiation (UVR)		Skin cancer Autoimmune diseases (multiple sclerosis)	Increase Decrease
Global warming	Higher pollen counts and allergenicity	Longer pollen season, modified pollen distribution	Allergic rhinitis (hay fever) and asthma	Increase
Floods	More molds		Allergic rhinitis, sinusitis and asthma, hypersensitivity pneumonitis, mycotoxin toxicity	Increase

*: in temperate zones including Mediterranean zones
ISP: Idiopathic spontaneous pneumothorax

The frequency of heavy precipitation and flooding events is likely to increase or to become more intense as a result of climate change in the Mediterranean region (see corresponding section). In the past decades, in Europe and specifically in the Mediterranean areas, they caused damage to properties, personal injuries, enteric infections, increase in mental health problems (anxiety, depression, sleeplessness, deaths or post-traumatic stress syndrome), and potential contamination by toxic chemicals in exposed and vulnerable people (Messeri et al. 2015). Unexpectedly, although the risk of death most obviously increased during the period of flooding, a controlled study of the 1969 floods in Bristol, United Kingdom, reported a 50% increase in all-cause deaths in the flooded population in the year following the flood, most pronounced among those aged 45-64 years.

In addition there is an increasing body of evidence for the occurrence of severe asthma epidemics during thunderstorms in various geographical zones including in the Mediterranean region (D'Amato et al. 2016). The main hypotheses explaining association between thunderstorms and asthma claim that thunderstorms can concentrate pollen grains and molds spores at ground level due to atmospheric pressure, which may then release allergenic particles of respirable size in the atmosphere after their rupture by osmotic shock. The pressure has been involved also in idiopathic spontaneous pneumothorax (ISP). Variations in the atmospheric pressure have been involved in the initiating mechanisms (rupture of lung blebs, bullas or damaged alveolar walls) of ISP due to increased trans-pulmonary pressure during storms (Alifano et al. 2007).

Chemical and biological air pollutants have indirect effects on health in the Mediterranean region

Climate change also increases the likelihood for individuals to be exposed to chemical air pollutants and bio-contaminants like viruses, bacteria, pollens and molds, which are established causes of NCD incidence or exacerbation (Table 1) (Ziska and Beggs 2012).

Climate change can affect air quality and *vice versa* air quality can impact climate change because many air pollutants are greenhouse gases due to human activities and natural phenomena (Ayres et al. 2009). Extra sunlight and higher temperatures due to global warming will lead to longer episodes of ozone peaks, generally in large cities. Higher concentrations of gases and particles are expected due to increased human activity and traffic in large cities where in the long run, a large majority of the world population will be forced to live as a result of climate change related factors, sea level rise among others. Air pollution has been linked to a broad spectrum of NCDs (diabetes, cardiopulmonary diseases, neurodegenerative diseases, etc.). High levels of vehicle emissions and westernized lifestyle have been correlated with increased aggravation of NCDs (Baldacci et al. 2015). Important data for the Mediterranean area result from *ad hoc* case studies (Baldacci et al. 2015). Among them, the European MED-PARTICLES project, which followed up climate, air pollution and health in 10 European Mediterranean metropolitan areas from 2001 to 2010. MED-PARTICLES findings provide support for short-term effects of $PM_{2.5}$ on mortality due to diabetes, cardiac causes, COPD, and to a lesser extent to cerebrovascular causes, in the European Mediterranean region (Samoli et al. 2014). Several PM constituents originating from different sources, were involved in the relationships between PM and hospital admissions in the Mediterranean area (Basagaña et al. 2015). In particular, black carbon (BC), which in western industrialized nations derives primarily from diesel engines and biomass burning, is a significant public health burden, particularly in European cities with high traffic density (Ostro et al. 2015). In addition, epidemiological and toxicological research suggests a causative relationship between air pollution and the increased incidence of NCDs although no specific data are available for the Mediterranean region due to the absence of longitudinal studies (Ahn 2014, Baldacci et al. 2015). This is why air pollution is considered to be one of the factors that may explain the increase in allergic and respiratory diseases and their worsening over recent decades.

In addition to anthropogenic air pollution, natural air pollution also constitutes a real danger for the people living within Mediterranean area. The concentration of particles will increase because of desertification and wildfires (D'Amato et al. 2015).

The number of wildfires has increased dramatically in Europe (Youssouf et al. 2014). In the Mediterranean area, forest fires usually occur during spring and summer, they overlap with Saharan outbreaks, are associated with increased temperature and their health effects are mostly due to an increase in particulate matter. Based on the literature, various studies have established the relationship between PM_{10} and $PM_{2.5}$ and cardiorespiratory symptoms in terms of emergency room visits and hospital admissions (Youssouf et al. 2014). Associations between wildfire emissions and various subclinical effects have also been established. However, few relationships between wildfire emissions and mortality have been observed (Youssouf et al. 2014). Certain segments of the population may be particularly vulnerable to smoke-related health risks. Among them, people with pre-existing cardiopulmonary conditions, the elderly, smokers and, for professional reasons, firefighters. Surveillance of wildfires and PM_{10} in 10 southern European cities in Spain, France, Italy and Greece (2003-2010) using satellite data showed that smoke was associated with increased cardiovascular mortality in urban residents, and PM_{10} on smoky days has a larger effect on cardiovascular and respiratory mortality than on other days (Faustini et al. 2105).

In addition, outbreaks of Sahelo-Saharan dust over Mediterranean areas are frequent and often exceed the European Union's 24-hr standard of 50 µg/m^3 for PM_{10}. Evidence for the effects of coarse particles ($PM_{2.5-10}$ and PM_{10}) on natural and cause-specific mortality, with stronger estimated effects on cardiac mortality has been collected during dust outbreaks in Rome (Mallone et al. 2011). Identification of PM_{10} originating from the desert through satellite images confirmed a positive association with mortality and hospitalizations in Southern Europe. Recent experimental work confirmed that the redox activity of particles is amplified by ozone, raising the possibility of a three-way interaction between particles, ozone and temperature in the future. The situation is particularly alarming in the Mediterranean area as shown by peaks of ozone and desert storms.

Excessive exposure of the skin to the sun causes skin cancer (Lucas et al. 2015). Solar irradiation also induces systemic immune suppression that may have adverse effects on health, such as through the reactivation of latent viral infections, but even beneficial effects through suppression of autoimmune reactivity. UV-B irradiation of the skin is the main source of vitamin D that plays a critical role in the maintenance of calcium homeostasis in the body in many geographic locations (Lucas et al. 2015). These dual results make it difficult to provide public health messages to guide safe exposure to the sun except that excessive exposure should be avoided.

Floods following extreme weather events and related humidity can lead to mold allergies and the development of asthma in susceptible individuals (D'Amato et al. 2015).

Lastly, climate is at the origin of a change in the geographic distribution of some plants, earlier onset and extension of the pollen season, and increased production of pollen and pollen allergens by the same plant due to the effect of the temperature (D'Amato et al. 2007). New plants can also arrive. Recent trends to warmer summers and increased volumes of international trade have accelerated the ragweed invasion notably. All these phenomena greatly increase the risk of allergic sensitization and of the development of asthma and allergic rhinitis.

Since airborne allergens and air pollutants frequently increase simultaneously in the atmosphere, enhanced IgE-mediated response to aeroallergens and enhanced airway inflammation could account for the increasing frequency of respiratory allergy and asthma in atopic subjects in the last five decades. Observation data show that exposure of pollens to high concentrations of air pollutants significantly increases their fragility and disruption, leading to subsequent release of pollen cytoplasmic granules into the atmosphere (D'Amato et al. 2015), which could increase the incidence of allergic airway disease in sensitized individuals by facilitating the bioavailability of airborne pollen allergens. Experimental data highlight a direct influence of elevated NO_2 on the increased allergenicity of ragweed pollen (Zhao et al. 2016). Climatic factors (temperature, wind speed, humidity, thunderstorms, etc.) can affect both components (biological and chemical) of this interaction.

Non-communicable disease concerns in the future

In Europe, an increase in the frequency and intensity of summer heatwaves is expected, especially in central, eastern and southern countries (McMichael et al. 2006). These changes will increase the burden of diseases and of premature deaths, particularly in population subgroups with limited adaptive capacity, such as the elderly and patients with COPD, but statistics on populations in different climates suggest that, given time, people will adjust to global warming with little change in either mortality. In contrast, global warming can be expected to reduce flu related deaths, especially in the case of people suffering from pre-existing NCDs. The number of extreme meteorological events will also increase. Pollens and molds will rise and engender allergic morbidity. Molds can also be at origin of other morbidities. Current indications are that air pollution will remain the main environmental cause of illness and death in the Mediterranean region, but these events are hard to differentiate from the morbidity and mortality due to the weather and other factors, and clear identification of air pollution deaths and diseases may need more extensive data than is currently available in the Mediterranean.

Sub-chapter 2.5.3

Final remarks and recommendations for the future

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Main remarks and recommendations

Further original research is absolutely indispensable, notably in the Mediterranean basin to assess climatic changes and their related health impacts (Hosking and Campbell-Lendrum 2012). Accomplishing this requires the establishment of a pan-Mediterranean research coordinating institution (Trans-Mediterranean CDCs) with ties to international funding organizations, stakeholders in the region and abroad, and established international and national scientific communities. The research groups involved in climate change and its impacts should be the promoters of this trans-regional programme that aims to train researchers to conduct longitudinal studies, in data acquisition and comparative analysis, and should guide research toward priority topics like observational studies, transdisciplinarity, analytical and epidemiological studies, and statistical analysis on spatio-temporal series of disease cases. They are few or no studies addressing important topics such as water supplies and waterborne diseases, food and malnutrition, and the health risks of extreme events other than the effects of heat (Hosking and Campbell-Lendrum 2012). In the same vein as that proposed by Negev et al. (2015), epidemiological data on major infectious diseases morbidity and mortality should be collected systematically, and consolidated with environmental, socio-economic, demographic and ecological data. Environmental management of infectious diseases like vector-borne diseases, which can require the elimination of breeding sites for mosquitoes through the use of insecticides, should be discussed regionally and weighed against pesticide toxicity through structured-decision making. Relevant examples could be adopted by other countries in the region. Ideally, health system preparedness for climate change-sensitive diseases should be evaluated regularly, specifically when environmental signals like the El Niňo phenomenon occur.

In the Mediterranean region where climate change may add to existing problems (drought, water scarcity, traffic, etc.), non-communicable diseases (NCDs) are strongly challenged by changes in the climate via both direct and indirect pathways (Cecchi et al. 2010). Climate change, and its driver greenhouse gas emissions, affect NCDs through: 1) an increased number of cardiorespiratory deaths and acute morbidity due to heatwaves; 2) increased frequency of cardiorespiratory events due to higher concentrations of ground level ozone; 3) changes in the frequency of NCDs due to transboundary long-range air pollution by particulate matter (e.g. related to fires and aerosols); 4) increased incidence of skin cancers due to excessive sun exposure of the skin; and 5) altered spatial and temporal distribution of allergens that increases the risk of allergic diseases. These pathways will not only affect patients with existing NCDs by causing their aggravation but may also influence the incidence and hence the prevalence of NCDs. People who are very young, old, poor, or who live in vulnerable areas are more fragile (McMichael et al. 2006). However, it is not easy to evaluate the impact of climate change and related factors on the prevalence, the severity and the incidence of NCDs. Research on the adverse impacts of climate change on NCDs should have the following goals: 1) Improve our understanding of the climate system and its drivers; 2) Improve our understanding of climate impacts and vulnerability; 3) Increase our understanding of adaptation pathways and their putative health costs; 4) Identify the mitigation options that reduce the risk of longer-term climate change; 5) Improve decision support and integrated assessment; 6) Link environmental, socioeconomic and health datasets through an exposomic approach that will provide new insights into the potential associations between climate change and human health and wellbeing.

These goals have to be based on cross-cutting research capacities: 1) Integrate medicine, toxicology, natural and social science, engineering, and other disciplinary approaches; 2) Ensure availability of observations, monitoring, and infrastructure for critical data collection and analysis; 3) Build capacity for climate assessment through education, training, and workforce development; 4) Enhance the development and use of scenarios; and 5) Promote international research and collaboration. These capacities are achievable in the Mediterranean region where important resources and competences exist.

Regarding training, researchers, medical doctors and public health epidemiologists should be trained to climate change risks and to long-term understanding of processes at work in human health outcomes, and not solely to short-term, molecular-based approaches. Public education and communication is essential and should be strengthened in the Mediterranean region with public involvement in prevention of outbreaks and in combating infectious disease foci like breeding sites for mosquitoes (Negev et al. 2015). Evaluation and assessment of the implementation of adaptation plans to climate change and health should be conducted according to structured-decision making and sustainable practices, and the French example of climate change and health assessment (Guégan and Pocher 2010) is a start in this direction. The Mediterranean should benefit from adopting an ecosystemic approach, the so-called OneHealth-EcoHealth concepts, to reach the sustainable development goals, and at least numbers 3 (good health and human well-being) and 13 (climate action). Health and well-being in the Mediterranean, whatever the borders and the sub-regions should be the unifying theme that enables crystallization of a trans-national initiative such as the Mediterranean Union. We also would like to stress the assets of the Mediterranean region with regard to health outcomes. Indeed, the Mediterranean diet displays a number of health benefits compared to other diets and it should be preserved at least to partially offset some of the detrimental effects that climate change may have. As previously mentioned another asset in the Mediterranean region is the wide range of skills and facilities that already exist. An integrative public health approach with investments in regional public health infrastructures should be applied here.

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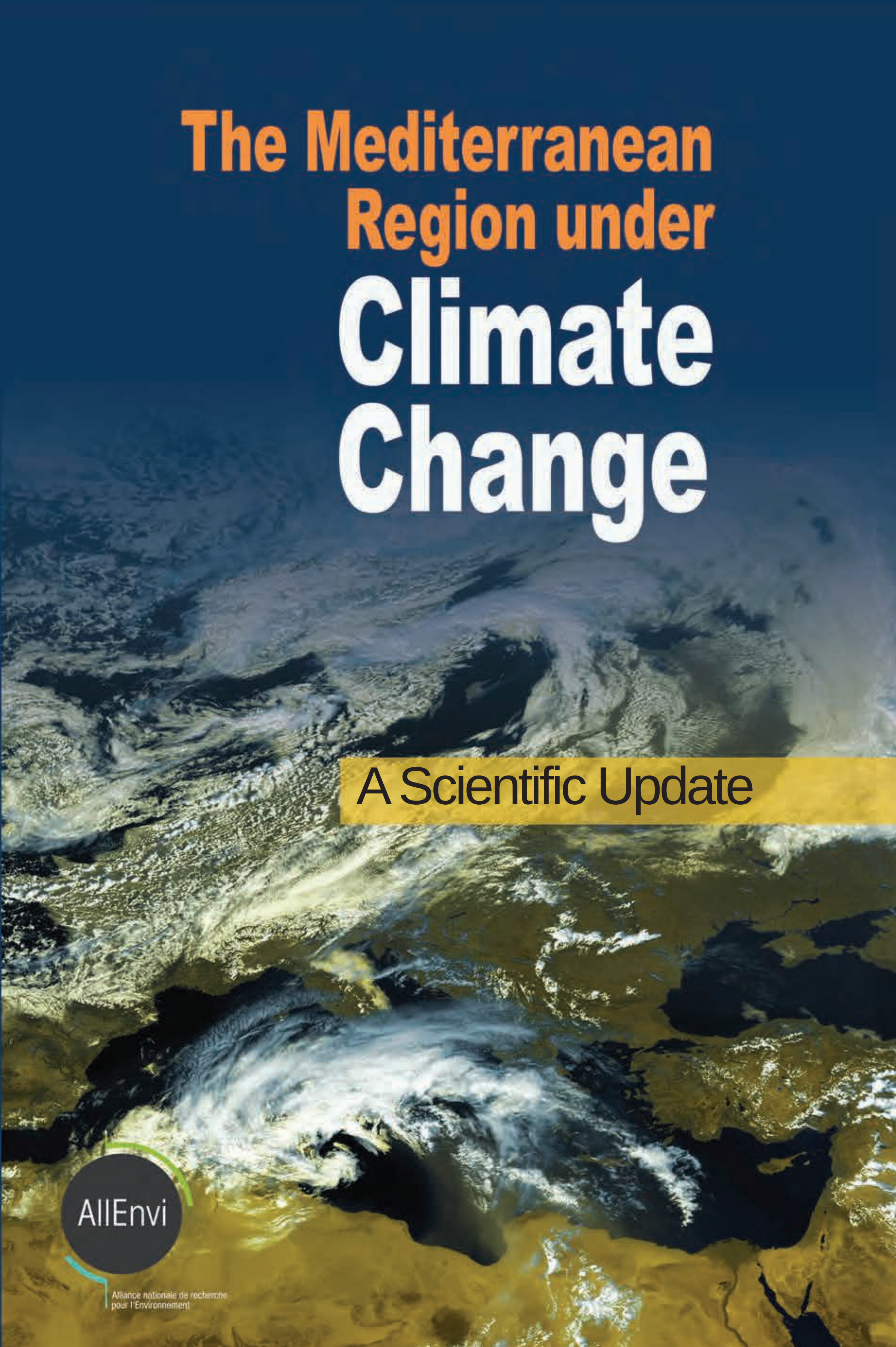
The Mediterranean Region under
Climate Change
A Scientific Update
AllEnvi
Alliance nationale de recherche pour l'Environnement

The Mediterranean Region under Climate Change

A Scientific Update

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