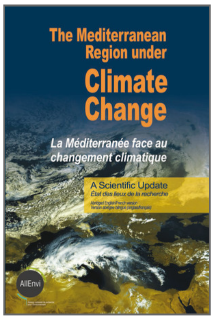

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Chapter 4

Air quality and climate in the Mediterranean region

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Abstract

Ambient air ranks number one among the natural resources vital to human beings, with an average individual daily need of 12 kg. Due to the specificities of the Mediterranean region (sunny, hot and dry climate; long-range transport converging over the basin), air pollution in reactive compounds over the Mediterranean is often higher than in most European inland regions. Climate change (increase in temperature and drought) and anthropogenic pressure (growing population) should significantly impact the regional air quality. As a result, Mediterranean inhabitants who are already regularly exposed to pollutant loads well above WHO air quality recommendations will be further exposed, resulting in an excess of premature deaths. Exposure monitoring and win-win strategies should be developed in the future both to improve air quality and develop a low carbon economy. The evolution of emissions under climate change is not always clear and much uncertainty remains around present emissions from large urban-industrial centers, although recent progress has been made on emissions of the different regional sources of pollutants. It has been established that the regional climate and water cycle are affected by atmospheric chemistry. By reducing solar radiation at the surface, aerosols reduce the yearly average precipitation in the Mediterranean by 10%, which is a major issue since water is already scarce. Aerosols could further reduce precipitations by reducing the size of cloud droplets or through the formation of cloud droplets and ice crystals. Moreover, recent *in situ* and model experiments indicate that anthropogenic nitrogen and desert dust phosphorus deposition in nutrient-depleted surface seawater favors phytoplankton development, which stimulates the sink of atmospheric CO_2 into marine sediments. But Saharan dust deposition by rain also stimulates bacterial growth, which reemits CO_2. The net effect of desert dust deposition at large scales needs to be established.

Résumé

L'air est sans aucun doute la ressource naturelle la plus essentielle à l'homme : chaque jour 12 kg d'air sont nécessaires à sa survie. Du fait des spécificités de la région méditerranéenne (climat ensoleillé, chaud et sec ; convergence de masses d'air d'horizons lointains), la pollution de l'air en espèces réactives y est souvent plus forte que dans la plupart de l'Europe continentale. Les changements climatiques (augmentation des sécheresses et de la température) et la pression démographique devraient dégrader encore la qualité de l'air. En conséquence, les habitants de la Méditerranée qui sont déjà régulièrement soumis à des niveaux de pollution bien au-dessus des recommandations de l'OMS devraient se trouver plus exposés encore, ce qui engendrera une surmortalité. Un meilleur suivi de l'exposition des habitants et des solutions « gagnant-gagnant » devraient être mises en place dans le but d'améliorer la qualité de l'air et de s'engager dans une économie décarbonée. Les conséquences des changements climatiques sur les émissions de polluants par les principales sources régionales ne sont pas toujours très claires. Il a été établi que le climat régional et le cycle de l'eau sont altérés par la chimie de l'atmosphère. En réduisant le flux solaire en surface, les aérosols réduisent les précipitations moyennes annuelles de 10 % en moyenne sur le bassin méditerranéen, réduisant un peu plus une ressource déjà rare. Les aérosols pourraient réduire plus encore les précipitations en réduisant la taille des gouttes d'eau dans les nuages ou en agissant sur la formation de cristaux de glaces. Par ailleurs, de récentes expériences indiquent que le dépôt atmosphérique d'azote et le phosphore issu des poussières désertiques à la surface des eaux pauvres en nutriments de la Méditerranée favorise le développement du phytoplancton activant par la même occasion l'absorption de CO_2 par l'océan. Cependant, il a aussi été observé que le dépôt de poussières favorise le développement de bactéries qui elles-mêmes rejettent du CO_2 du fait de la respiration. L'effet net du dépôt de ces poussières à grande échelle reste à établir.

Introduction

In this chapter, we consider relatively short-lived (<~1 month) particulate and gaseous tropospheric trace species that cause atmospheric pollution and have two-way interactions with climate. Emissions of long-lived greenhouse gases and their role, and evolution with climate change are dealt with elsewhere in this book.

Ambient air is one of our vital natural resources. Air quality in the Mediterranean region is generally poor, due to both particulate and gaseous pollution. For instance, particulate or ozone concentrations are generally higher in the

Mediterranean region than in most continental European regions, especially during the long dry and sunny summer season that characterizes the Mediterranean type of climate, (e.g. NABAT et al. 2013; DOCHE et al. 2014; MENUT et al. 2015). In addition, the Mediterranean region is a hot-spot for climate change (GIORGI and LIONELLO, 2008), whereas numerous two-way interactions take place between climate and air quality, which are not always well understood. In addition, the Mediterranean region is expected to undergo a major increase in population, especially the development of large urban centers on its eastern and southern sides (CIHEAM, 2009). Air quality is already very poor in such centers and has significant adverse effects on health (an average of more than 20 deaths per 100,000 inhabitants took place in 2008 in Egypt, Greece, Israel, Lebanon, Turkey; WHO, 2014). It is thus important to understand the impact of the expected climate change on atmospheric chemistry and the resulting surface air quality in the Mediterranean region (COLETTE et al. 2013).

Conversely, atmospheric pollution also affects the climate. The most obvious effect is global warming due to anthropogenic emissions of greenhouse gases (GHG), but anthropogenic aerosols and ozone, for instance, also perturb the Earth's radiative budget (IPCC, 2014). Up to now, future climate predictions have neglected feedback due to atmospheric composition, apart from that due to long lived GHGs. Atmospheric pollution, however, is also made up of many gaseous and particulate species that are more chemically active than GHGs and these short-lived species have various reciprocal interactions with climate, which must be accounted to better simulate their combined evolution. For instance, direct effects due to scattering and absorption of solar radiation by tropospheric anthropogenic aerosol particles compensate for and even cancel out the warming effect of GHG emissions in polluted regions at the regional scale (BERGAMO et al. 2008). But they are much more difficult to represent in climate models (i) because of the high temporal and spatial variability of their concentrations and optical properties whereas, in comparison, GHG vary very little in concentration (LE TREUT et al. 1998), and (ii) because to properly assess aerosol climatic impact, it is necessary to use coupled atmosphere-ocean dynamical models rather than fixed sea-surface temperature to account for a radiative impact that affects sea surface evaporation (NABAT et al. 2014). These reactive species form secondary products that are not directly emitted into the ambient air but control the concentration of fine particles in the background (QUEROL et al. 2009) and urban (EL HADDAD et al. 2011) Mediterranean air, they can be transported over long distances in the troposphere (LELIEVELD et al. 2002; RICAUD et al. submitted) and affect air quality at the surface (with profound impacts on human health) (KÜNZLI et al. 2000), perturb the radiative budget of the atmospheric column and modify cloud properties with significant consequences for the atmospheric water cycle and climate (NABAT et al. 2015), affect marine biogeochemistry (GUIEU et al. 2014a) and continental vegetation (PAOLETTI, 2006) through their deposition at the Earth's surface. There are thus many processes and different types of feedback to take into consideration when assessing interactions between air quality and climate and when modelling the present and future coupled air quality-climate system.

The present chapter is a contribution from the project ChArMEx (the Chemistry-Aerosol Mediterranean Experiment; http://charmex.lsce.ipsl.fr) of the multidisciplinary regional research program MISTRALS (Mediterranean Integrated Studies at Regional and Local Scales; http://mistrals-home.org) endorsed by ALLENVI. It summarizes current knowledge on the links (feedforward and feedback) between climate and the air resource in the Mediterranean region, on the impact of expected climate change and increasing anthropogenic pressure on that natural resource and its consequences for human health, highlighting on-going efforts and recommended research to overcome critical limitations of our present knowledge. In the following sub-chapter headed 'Sources of reactive species and source apportionment', we review emissions that affect the Mediterranean atmospheric environment and report source apportionment results in both coastal urban and background air. In a separate text box, we also present the regional emission database ECCAD/ChArMEx dedicated to the Mediterranean region. We describe the particular cases of large urban centers, aeolian erosion, and biogenic emissions of volatile organic carbonaceous species. In the sub-chapter headed 'High concentrations of aerosols and pollutant and greenhouse gases', we address the question of the high atmospheric loads of atmospheric pollutants in the Mediterranean region and our understanding of the reasons. We include a focus on secondary organic aerosols, a major component of fine particles in the ambient air and a challenge for atmospheric chemistry models because they are formed by complex chemical reaction chains from gaseous compounds emitted by both human activities and natural sources. The sub-chapter headed 'Atmospheric deposition to nutrient-depleted seawater' is dedicated to the deposition of aerosol particles to the oligotrophic Mediterranean Sea, a major pathway for the transfer of nutrients and contaminants, and its impact on surface marine ecosystems. The sub-chapter headed 'Impact of atmospheric chemistry on the regional climate' describes the impacts of atmospheric chemistry on climate and reviews recent results on their assessment. In the sub-chapter headed 'Impacts of air quality on health in the Mediterranean region', we report recent results on the detrimental effect of air pollution on human health. In the sub-chapter headed 'The (uncertain) future of air quality', we question our knowledge on the evolution of air quality in the coming decades. Finally, we summarize the main recent advances, open questions and related ongoing research and perspectives.