Impact of exposure to O_3 and Heat on Mortality. Disentangling short from long term effects and estimating costs

1. Contexte/justification scientifique

Décrire le contexte dans lequel se situe le projet et l'état de l'art associé. Préciser la problématique des thématiques santé-environnement ou santé-travail associée au projet en faisant le lien avec les questions à la recherche.

Recently, the Lancet commission on Climate Change and Health stated that climate change is the greatest global health problem of the century and that it threatens to undermine the last 50 years of gains in development and global health (Watts et al. 2015). The expected health effects of climate change will vary globally. In Western Europe, the most important anticipated health effects are those related to extreme weather events, notably heat waves, and those related to air pollution exposure. France and Western Europe already experienced the devastating effects of the 2003 heat wave, which resulted in more than 70,000 excess deaths (Robine et al., 2008). Climate change projections forecast that exceptional weather events such as the heat wave of 2003 in Western Europe or the mega-heat wave of 2010 in Russia may become increasingly frequent under certain future scenarios, especially in Southern Europe (Watts et al., 2015). High air pollution levels are also at present an important public health problem in Europe and they are considered as the principal indirect effect of climate change on health in Western Europe. Currently, it is estimated that there are 432,000 premature deaths due to exposure to elevated level of particulate matter (PM), and 17,000 premature deaths due to ozone (EEA, 2015a).

Tropospheric ozone is created in the atmosphere via reactions of precursor emissions (nitrogen oxides and non-methane volatile organic compounds) in the presence of sunlight, and its creation is maximized under conditions of high solar radiation and high temperatures (Monks et al., 2015). Ozone is the pollutant expected to increase the most with global warming because the frequency of stagnation episodes is projected to increase over northern mid-latitude continents and the ventilation is projected to decrease in Europe (Jacob and Winner, 2009).

Despite the fact that emission control legislation in Europe has achieved substantial reductions in anthropogenic ozone precursor emissions over the last decade, the issue of non-attainment of the target value for ozone in most EU Member States persists (EEA, 2015b). The local/regional management of precursor emissions has resulted in a reduction in the magnitude and frequency of peak ozone episodes across Europe. However, the non-linear relationship between the concentrations of precursors (both anthropogenic and biogenic) and ground ozone concentration, as well as the influence of baseline/background hemispheric ozone and the transboundary nature of ozone and its precursors have resulted in annual mean levels remaining constant or in some cases increasing across Europe; hence the continued exceedances of the target value (Bach et al., 2014).

Since the formation of ozone requires sunlight, ozone concentrations show a clear increase as one moves from the northern parts to the southern parts of the continent, with the highest concentrations in some Mediterranean countries. During summer 2014, France and Spain were the only European countries that reported exceedances of the 1-hour O_3 air quality standard (information threshold) for more than five days (1-hour average concentration of > 180μg m^{-3}) (EEA, 2015b). In the same period, O_3 concentrations higher than the alert threshold (1-hour average concentration of > 240μg m^{-3}) were also observed in four locations in southern France. Spain presented the highest number of exceedance days of the daily maximum 8-hour average concentration of 120μg m^{-3} established for the long-term protection of human health. In terms of future projections, France and Spain are among the European countries expected to have the highest increases in O_3 concentrations in upcoming years (EEA,2015b; Orru et al., 2013).

Many studies have been conducted in several parts of the world to assess the relationship between ambient temperature and mortality, and many of them focused on the effects of high temperatures (Basu et al., 2002; Gasparrini et al., 2015). It is now well known that the relationship between temperature and mortality is U-shaped, with mortality increasing with both extreme heat and extreme cold. Mortality in Mediterranean countries was found to increase by 21% during heat waves, with an effect that was 3 times higher for heat waves of longer duration (d'Ippoliti et al., 2010). All of the studies on the effects of heat were time-series studies examining short-term effects. Long-term effects, i.e. those produced by having a long-term exposure to high temperature, have been little studied for various reasons. First, exposures averaged over periods of 1 to 3 months are strongly correlated with season, and it would be extremely difficult to separate the effect of such long-term averages from that of other seasonal changes. Second, studies using longer averages (e.g. years) face the problem that temperature tends to be homogeneous within regions. This limits the use of cohorts based on a single location or region, and requires basing the inferences on between-region comparisons that are hampered by other ecological differences such as air conditioning use and lifestyle.

O_3 has been related to respiratory and less conclusively to cardiovascular mortality (WHO, 2013). Most of the evidence of the relationship between ozone and mortality comes from studies on short-term effects (WHO, 2013). In the context of short-term effects, even the largest, multi-centre studies are based on a collection of big cities (Gryparis et al., 2004), while usually the highest concentrations of ozone are found in rural areas that are downwind the main urban areas. As an example, a study that quantified the impact of ozone on mortality in Europe at present and in the future used an exposure-response function obtained from a meta-analysis of studies based on 15 large European cities (Orru et al., 2013). Studies performed for entire countries, including all the different types of regions (urban and rural) are strongly needed to better quantify the effects of ozone in the entire population. There are few studies on the long-term effects of ozone on mortality. A recent large-scale U.S. study including over 600,000 participants followed for 22 years reported positive associations between mean annual daily 8-hour maximum O_3 concentrations and both respiratory (HR = 1.12, 95% CI 1.08-1.16) and cardiovascular (HR = 1.03, 95% CI 1.01-1.05) mortality in multipollutant models adjusting for both $PM_{2.5}$ and NO_2 concentrations (Turner et al. 2015). The strongest associations were reported for mortality from diabetes (HR = 1.16 95% CI 1.07-1.36) and dysrhythmias, heart failure, cardiac arrest (HR = 1.15 95% CI 1.10-1.20) specifically. There was also some evidence for effect modification of both respiratory and cardiovascular associations by temperature. In contrast, no associations were reported in a large-scale U.K. patient cohort (Carey et al. 2013; Atkinson et al. 2013). Further research on the long-term health effects of O_3 is needed particularly in other geographical settings.

Climate change and air pollution are intertwined, as temperature and UV radiation constantly interact with pollution to form new mixtures. Ozone is a good example, since ozone concentrations increase during heat waves occurring during stagnation periods characterized by high pressure and low winds. The most important heat waves in Europe, such as the European heat wave of summer 2003, were characterized by high O_3 levels (Filleul et al., 2006; Leonardi et al., 200; Watts et al. 2015). Thus, it is important to study heat and air pollution concurrently, even so when evidence suggests that the two exposures may interact in their relationship with health effects. For example, an experimental study in humans found different effects of ozone on fibrinolysis (the physiological breakdown of blood clots) according to temperature: while ozone activated the fibrinolytic pathway at moderate temperatures, it impaired it at elevated temperatures (Kahle et al., 2015). Time series studies in Europe have also reported that the effects of heat waves on mortality was larger during high ozone days (Analitis et al,. 2014).

For assessing the impact of climate change and pollutant emissions on ozone and temperature, most of the studies are based on numerical models using three approaches: (1) keeping anthropogenic emissions constant and considering only the effect of climate change (Carvalho et al., 2010; Manders et al., 2012), (2) maintaining the meteorological conditions constant and changing the emission scenarios (Dentener et al., 2005; Zhang et al., 2010), and (3) considering the combined effect of changes in climate and anthropogenic emissions (Orru et al., 2013; Markakis et al., 2014; Trail et al., 2014). IPCC global emission scenarios developed in the last years are used to perform the future-year climate simulations: IPCC IS92 (Langner et al., 2005); IPCC SRES scenarios (Trail et al., 2014) and IPCC RCP scenarios (Lacressonniere et al., 2014; Sá et al., 2016). These studies suggest that interaction between climate change, pollutant emissions and atmospheric concentrations is still under discussion and more research is needed in order to understand and accurately predict the changes in pollutant levels under future climatic conditions and at different spatial scales. When performing these studies, the spatial resolution of the model becomes a key parameter, especially in areas with complex topography that enhance the development of mesoscale phenomena such as sea-breezes and mountain-valley winds. In this sense, the use mesoscale CTM instead of global models helps to reproduce these convective processes that contribute to the accumulation and recirculation of aged air masses and ozone aloft. There are very few studies using regional-scale CTMs that account for the effects of climate change and emissions on air quality concentrations over complex terrains (Markakis et al., 2014; Sá et al., 2016). In this sense, the objective of this study is to evaluate air quality over France and Spain in 2050 using a CTM model under the IPCC scenarios.

As described above, a large part of the research on the health effects of heat and ozone has been based on time series studies estimating short-term effects. One of the difficulties of short-term studies is accounting for the effect of short-term mortality displacement or harvesting, the phenomenon by which extreme temperatures or high pollution levels advance the death of very frail individuals or even terminal cases by just a few days or weeks. If short-term mortality displacement accounts for a high percentage of the excess deaths observed during a specific event, the public health impact of the problem is of less importance than if deaths are advanced several months or years. Some time series studies have used methods to correct for mortality displacement of up to a month (Baccini et al., 2008). In the context of heat, those methods have concluded that short-term mortality displacement accounts for some but not all of the effects. For example, a study in France quantified that short-term mortality displacement only accounted for 10% of the deaths during the 2003 heat wave (Le Tertre et al., 2006), but it has been estimated to account for up to 70% of the excess mortality during heat waves by other studies (Baccini et al., 2008). In the context of air pollution, some studies have also concluded that the observed mortality increases associated with particles are not explained entirely by short-term mortality displacement (Zeger et al., 1999). Quantifying mortality displacement remains an incompletely resolved problem (Armstrong et al., 2014). In particular, one of the important limitations is that existing methods only control for displacement of a short-time period, of up to one month.

2. Description du projet - Objectifs du projet

Décrire brièvement en quoi consiste le projet. Préciser son originalité et son apport à l'état des connaissances au niveau international. Expliciter l'impact attendu du projet en santé-environnement ou santé-travail.

The main objective of the proposed project is to **assess the public health impact of ozone** (O_3) **and high temperatures on mortality in France and Spain, using** national-level data **including** both **urban and rural areas**.

The specific objectives are:

1. To assess the effect of both short-term and long-term exposure to O3 and heat, and their interaction, on all cause and cause-specific mortality, in France and Spain, providing national and regional-level estimates of the association for 2000 to 2015.

2. To improve the estimation of the public health impact of O_3 and heat by estimating effects on mortality that take into account short-term mortality displacement (the bringing forward in time of deaths that would have occurred within a few days).

3. To investigate the simultaneous impacts of future climate and anthropogenic emission projections on air quality over France and Spain in 2050.

4. To assess the cost of the burden of mortality due to O_3 and high temperatures at present and under future climate and anthropogenic emission projections; and assuming compliance with WHO guidelines.

Our study will overcome many of the limitations of previous studies by:

i) Performing time-series analyses to simultaneously estimate short-term effects in two countries (France and Spain). This will provide estimates in rural areas, which are often not included in studies on the health effects of both heat and O_3. Many rural areas in France and Spain are exposed to high levels of O_3.

ii) Performing studies on the long-term effects of temperature and O_3 using data from mortality registries. Often, data from mortality registries is only used to conduct time series studies that estimate short-term effects that may be influenced by short-term mortality displacement, and therefore do not provide a clear measure of underlying public health impact.

iii) Providing further insights on the independent and joint effects of O_3 and heat on mortality.

Furthermore our project will estimate realistic monetary costs associated to premature O_3 and temperature mortality (e.g. by discounting short-term mortality displacement) at a regional scale, which will provide useful information for policy makers.

iv) Developing statistical methods to integrate a large number of time series analyses across the two countries while accounting for heterogeneity and spatial patterns.

v) Assessing the simultaneous impact of climate change and anthropogenic emission projections on ground O_3concentration and the subsequent effect on public health in 2050 at high resolution (25 km) over Spain and France using a mesoscale air quality model (CMAQv5.0.2) that includes the state-of-the-art in atmospheric chemistry and aerosol dynamics.

3. Méthodes/description du projet

Décrire en détail le projet et les méthodes utilisées en démontrant la faisabilité du projet. Entrent dans ces champs les mesures adoptées pour garantir la confiance sur la qualité des résultats.

Data sources:

Mortality data

Data on daily mortality counts will be collected from the National Statistics Institutes for all of Spain and France, at the smallest possible level of scale (IRIS or comune in France, municipality in Spain) for the time period 2000-2015.

Daily counts will be collected for specific groups of causes of death, for specific age groups (0-14, 15-34, 35-64, 65-74, 75-84, 85+), and separately for men and women. The main analyses will be conducted for all natural mortality, but analyses will also be conducted for specific mortality causes. Cardiovascular and respiratory causes are the main causes for which effects of O_3 and heat have been reported. These main groups will be broken into more detailed causes as detailed in the table below. For heat, increased mortality has also been reported for diabetes, mental and nervous system disorders, and kidney and urinary system diseases (Basagaña et al., 2011), so these causes of death will also be investigated. Table 1 displays the International Classification of Diseases (ICD) ICD-9 and ICD-10 codes of the selected causes of death:

Table 1. Cause of death using the ICD codes

Cause of death	ICD-9 code	ICD-10 code
Natural causes	001-799	A00 – R99
Diabetes	250	E10 – E14
Cardiovascular diseases	390-459	I00 – I99
Cardiac diseases	390-429	I00 – I52
Acute coronary events	410-411	I20 – I23
Conduction disorders	426	I44 – I45
Arrhythmias	427	I46 – I49
Heart failure	428	I50
Cerebrovascular diseases	430-438	I60 – I69
Respiratory diseases	460-519	J00 – J99
Low respiratory tract infections (LRTI)	466, 480-487	J09–J18, J20-J22
Acute bronchitis, bronchiolitis, unsp. LRTI	466	J20 – J22
Pneumonia	480-486	J12 – J18
Influenza	487	J09 – J11
Chronic obstructive pulmonary disease (COPD)	490-492, 494,496	J40 - J44, J47
Mental and nervous system disorders	290-389	F00-H95
Kidney and urinary system	580-599	N00-N39, N99

Air quality measured data

Historical O_3 and other air pollutant (namely PM_{10}, $PM_{2.5}$ and NO_2) concentrations for the period 2000 – 2015 will be retrieved from the European air quality database 'Airbase', which is maintained by the European Environmental Agency (EEA) and contains validated air quality monitoring data for more than 30 participating countries throughout Europe, including France and Spain (EEA, 2015c). The air quality data (O_3, PM_{10}, $PM_{2.5}$ and NO_2) obtained from Airbase will be used to compute concentrations for daily maximum 8-hour average concentrations for O_3 and SOMO35, an indicator for health impact recommended by WHO and defined as the yearly sum of the daily maximum of 8-hour running average over 35 ppb.

Meteorological measured data

Temperature at ground level will be retrieved from historical daily data from the European Climate Assessment Dataset (ECA&D) (http://eca.knmi.nl/dailydata/index.php), which contains daily data from 88 meteorological stations in France and 101 stations in Spain. Gridded data (25x25 km) is also available at the ECA&D website, which will be used to assign temperatures to location without meteorological stations. If needed, additional data will be requested from the national meteorological institutes. Projections for years 2025 and 2050 will be obtained from the same meteorological outputs used to simulate projected O_3 concentrations (see next section) in order to maintain consistency.

Air quality and meteorological simulations: historical and projections

The historical air quality information from measurement stations will be complemented with predicted concentrations over Spain and France (study domain) using the CALIOPE air quality modelling system. Modelled data will provide geographical patterns of pollutant concentrations for the study domain, which will be used to impute pollutant concentration in areas without air quality stations. On the other hand, temperature and O_3 projections with the CALIOPE system will allow assessing the impact of climate change and anthropogenic emission projections on public health in 2050 at high resolution over France and Spain. Originally, CALIOPE is configured to provide 48 h air quality forecasts over Europe (www.bsc.es/caliope), and has been described and evaluated in detail elsewhere (Pay et al., 2010, 2012). For the present study, CALIOPE configuration will be adapted to be used in climate studies as shown in Figure 1.

The working domain will cover continental Europe at 25x25 km (ranging from approximately 16.0-63.7 latitude and from 40.0-54.0 longitude) in order to simulate the local production and transboundary fluxes of pollutants inside Europe that affect France and Spain. The WRF meteorological model (Skamarock and Klemp, 2008) will be used to produce dynamical downscaling of the global climate model (GCM) ECHAM5/MPIOM (Roeckner et al. 2003), which constitutes one of the GCMs used in AR4 (Randall et al. 2007) with a high performance over Europe below the known radiative forcing for the 20th century (van Ulden and van Oldenborgh, 2006), and particularly in the Western Mediterranean (Nieto and Rodríguez-Puebla 2006). Anthropogenic emissions will be estimated using the HERMES model (Ferreira et al., 2013) and considering the official emission inventories and projections reported by France and Spain under the UNECE LRTAP Convention (http://www.ceip.at/). Biogenic emissions will be estimated using the MEGAN model (Guenther et al., 2006) as a function of the temperature and ground level shortwave radiation from WRF. The meteorological and emission outputs will be coupled to CMAQv5.0.2 chemistry transport model (Byun and Schere, 2006) to simulated projected O_3 concentrations. Outputs from the MOZART-4 global chemistry transport model (Emmons et al., 2010) will be used to provide chemical boundary conditions to the modelling domain and reproduce the intercontinental transport of pollutants that influences the levels of pollution in Europe.

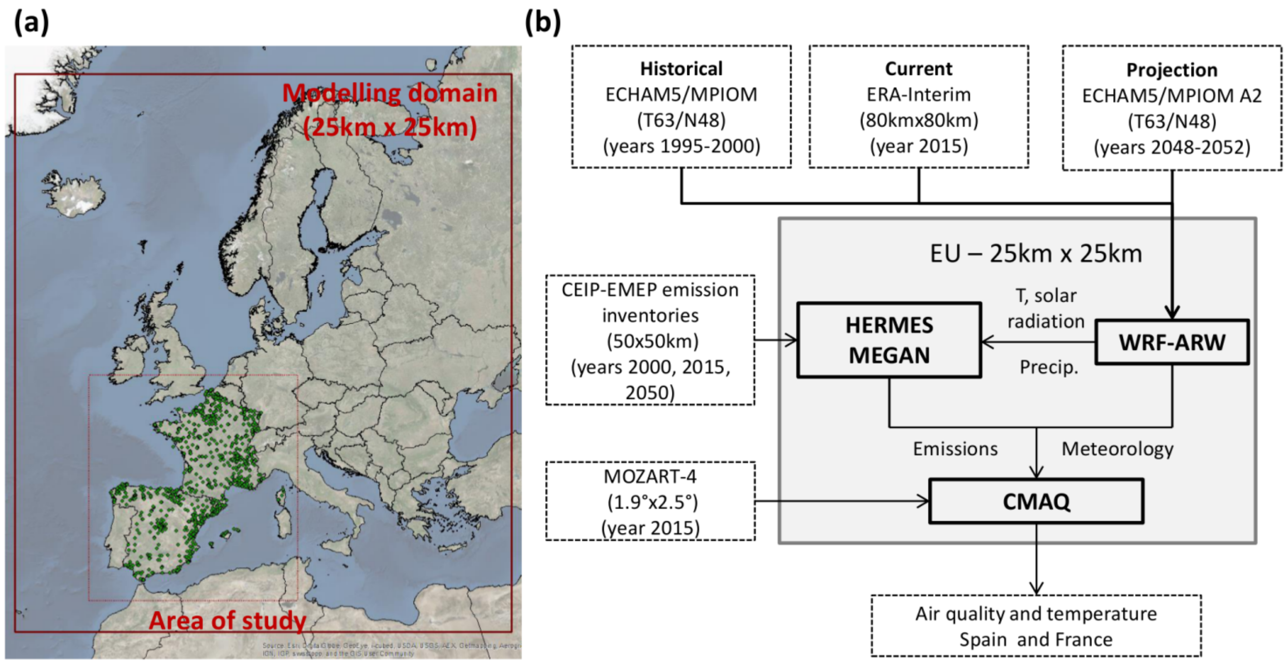

Figure 1. (a) Area of study and modelling domain together with Airbase air quality observations over Spain and France (green dots). (b) CALIOPE configuration for the present study

Table 2 summaries the strategy to simulate air quality and temperature with the CALIOPE system for climate projection for 2050. First (**current**), we will simulate a reference year 2015 for the model evaluation using ERA-Interim re-analysis data as input. Second (**historical**), we will model historical air quality and temperature over 5 years (1995-2000) forced with the global climate model ECHAM5/MPIOM. Third (**projection**), we will predict a 5 future years around 2050 (2048-2052) using the projection of the ECHAM/MPIOM model under greenhouse gas global emission scenario A2, which is one of the higher emissions scenarios of the Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000). The election of this scenario is preferred because, from an epidemiological point of view, it allows determining the largest impact of exposure to O_3 and high temperature. This methodology allows the quantification of the model uncertainty for a reference year 2015 by means the comparison with available observations. Projections will be compared with historical simulation to quantify the changes in O_3 and temperature and isolate the model uncertainty in both periods.

Table 2. Main characteristic of the CALIOPE simulations for the present study.

Simulations	**current**	**historical**	**projection**
Period	2015	1995-2000	2048-2052
Meteorological forcing	ERA-Interim	ECHAM5/MPIOM	ECHAM5/MPIOM A2
Anthropogenic emissions	EMEP 2015	EMEP 2000	EMEP 2050
Boundary and initial conditions	Mozart 2015	Mozart 2015	Mozart 2015

Statistical analysis:

The first task of the project is to define small and homogeneous geographical areas based on the spatial distribution O3 and temperature and data availability. Analyses of short-term effects linking daily mortality counts with O3 and temperature will be performed using time-series quasi-Poisson regression models incorporating distributed lag nonlinear models to account for nonlinearities and delayed associations (Gasparrini et al. 2015). We will develop an extension of this methodology to analyse all geographical regions in a single step while accounting for spatial structure and heterogeneity between regions. Analyses will examine the interaction between temperature and O_3, and will investigate this interaction separately according to the following classification of area: urban areas, rural areas that are downwind of urban areas, remaining or rural areas. All models will be fitted for mortality for all natural cause, and cause-specific mortality (above). We will fit two-pollutants models to test the independent effect of O_3 (adjusting the O_3 estimate by NO_2, PM_{10} and $PM_{2.5}$). This short-term analysis will estimate short-term mortality displacement of up to one month using the methodology that is currently used in most studies.

The analyses of long-term effects will be based on yearly age-standardized mortality rates according to the methodology described by Goggins et al. (2014). Generalized additive models will be used to link mortality rates with yearly excedances of O_3 levels and degree-days over a heat threshold. Analyses will be conducted using several thresholds (WHO guidelines, EU air quality directives) to define excedances. With this methodology, any association we observe between mortality and O_3 or heat will be free of short term mortality displacement, as the methodology will detect deaths that were brought forward by more than a year. We will conduct the analyses at both the national level and also by smaller geographic regions to explore geographical patterns in results. Analyses will be adjusted for time trends and for area-level socio-economical indicators available at census tract level such as deprivation indices or unemployment rates. We will conduct analyses stratified by age, sex and cause of death using the same causes as described above for the analyses of short-term effects.

Calculation of public health impact and costs:

The number of deaths attributable to heat and O_3 will be obtained using the above-described concentration–response functions (CRFs), stratified by age, sex, area (urban/rural) and cause of death. To calculate the mortality burden of heat and O_3 pollution at the local level, we will follow COMEAP methodology (2010). Starting from attributable deaths, the years of life lost to the population will be estimated by summing the years of age-specific remaining life expectancy associated with each of the attributable deaths. In case of unavailability of local life-tables, COMEAP suggested a simpler approach using the average loss of age-specific life expectancy associated with attributable deaths in their national estimates, of approximately 12 years. However, this estimation was done in UK and must be redone for France and Spain. Then the change in life expectancy (LE) has to be valued by VOLY (value of a life year) to calculate the cost. Several estimates are published. Alberini et al. (2004b) used data from Contingent Valuation (CV) survey of Krupnick et al. within the NewExt phase of the ExternE project series of the EU DG Research (see www.externe.info) a VOLY of 50,000€ was recommended for the EU15. For Desaigues who performed a 9-country European CV survey of Willingness-to-Pay (WTP) for a LE gain of 3 and 6 months due to reduced air pollution in order to establish an European VOLY, the recommended VOLY estimates are EU15 + Switzerland is 41,000 €. But the VOLY in poor health is much lower than for good health so a morbidity estimation at the local level would provide better precision. The Aphekom study used 3 values for life year lost: a central (86 k€), a low (40 k€) and ahigh (132 k€) estimate. Recently, for France, a Prime Minister commission (Commissariat général à la stratégie et à la prospective) value a VOLY at 115 k€.

Comparison of pollution predicted values with WHO recommendations will allow to calculate benefits. Sensitivity analyses will be performed to estimate the impact of change in the age structure of the population, or morbidity prevalence, according various hypotheses. Monte-Carlo methods, by sampling in the joint distribution of estimated CRFs parameters, will be used to calculate uncertainty of burden estimates.

Feasibility and quality assurance:

The feasibility of the project is guaranteed as a large part of the data needed for the project is already publicly available and the rest (e.g. O_3 and temperature projections) will be derived by members of the team with extensive expertise in air quality modelling. CALIOPE system has been already evaluated in operational and diagnostic evaluation studies (Pay et al., 2010; 2012) and has taken part of different model intercomparison studies with well known European models (Schaap et al., 2015; Bessagnet et al., 2016). For the present study, the performance of the CALIOPE system will be evaluated as well through a comparison between the air quality and meteorological data simulated for 2015 and observational data. Furthermore, in order to isolate the model uncertainty, changes in temperature and air quality will be assessed in terms of differences between projections and historical simulations over a 5-years period. When possible, our results on projections will be compared to other projections derived by other teams to ensure that reasonable values are obtained. Even though most of the data we will use from public datasets has already gone through a quality assurance process, all data used in the project will go through a process of data cleaning to detect inconsistencies and correct potential errors. The codes of the statistical analyses will be made available so that analyses can be reproduced.

4. Les partenaires

Décrire brièvement les équipes partenaires et leurs atouts pour mener à bien le projet.

The project team is formed by established researchers with consolidated experience in research projects, with experience as principal investigators, a strong records of scientific publication in the top journals on environmental sciences and public health, and with expertise covering all the areas needed for the project, namely air quality modelling, the health effects O_3, the health effects of high temperatures, statistical analysis and health impact assessment. The different members of the team established on-going collaborations and have a number of scientific publications together, which ensures a fruitful collaboration for the present project.

4.1 INSERM (Institut National de la Santé et de la Recherche Médical-www.inserm.fr)-UMR1168

The UMR 1168 is a mixed research unit including INSERM researchers and Université Versailles Saint Quentin (UVSQ) professors. It is a research center with strong expertise in epidemiology and public health. They study the determinants (physical, biological, environmental, behavioural and social) of aging and chronic diseases (including respiratory, musculoskeletal disorders and obesity), as well as the impact of aging on health care use. Their research is based on a conceptual framework, in which the fragility plays a central role. Their research mobilizes complementary approaches in epidemiology, public health and clinics.

Bénédicte Jacquemin (MD PhD, CR1, epidemiologist) will coordinate the project. She works mainly on the air pollution effects on health. She leads the air pollution research field in her Inserm team and is actually doing a long sabbatical at CREAL. She has participated in many European projects including ECRHS, ESCAPE and MED-PARTICLES. She leads a project on the association between air pollution and socioeconomical status funded by ANSES. She coordinates the air pollution exposure in a project funded by the ARC in France (OCAPOL: A longitudinal observatory of the effects of chronic exposure to outdoor air pollution). She is member if the Expert Committee coordinated by ANSES, on source and composition of particules, where she leads the health chapter.

Philippe Aergeter (MD PhD, PUPH) is Public health full professor at Université Versailles St-Quentin. He has been working on medical informatics (DRG system, expert systems), biostatistics (survival models), and epidemiology (health services research, environmental epidemiology) since 1985. He works as head of clinical research unit in AP-HP hospital, providing with this team methodological support, biostatistical or health-economics analysis for more than 50 projects. He is PI and coordinator of 5 French Health Ministry projects (including two on health effects of environmental conditions, one on elderly people, the other on a pregnant women who used assisted reproductive techniques) and he works also as an expert for French proposals.

4.2 CREAL (Centre for Research in Environmental Epidemiology - www.creal.cat)

CREAL (Barcelona, Spain) is a global leader in environmental epidemiology research with a strong focus on the influence of environmental exposures on human health. During the 7th Framework program of the European Commission, CREAL researchers participated in 19 European consortia, coordinating 7 of them and leading work packages in 16 projects. Researcher at CREAL were pioneers in the investigation of the effects of air pollution and temperature on health in Europe.

Xavier Basagaña (PhD, biostatistics) is Associate Research Professor at CREAL and will co-coordinate the project. His research focuses on the health effects of extreme temperatures, the health effects of air pollution and the development of new statistical methods. He has been principal investigator in 5 research projects (national and European) and has participated in several other European projects, in many of them as leader of the statistical group. He has published more than 116 papers in scientific journals. He is a member of the Expert Committee on the health effects of heat waves for the Spanish Government, a member of the working group on Climate Change Adaptation of the Catalan government, and is currently writing the Health chapter of the Third Report on Climate Change in Catalonia for the Catalan Government.

Michelle Turner (PhD, epidemiologist) is Research Fellow at CREAL. Her primary research interest is examining environmental influences on risk of cancer and other chronic diseases, with a strong focus on ambient air pollution exposures. She is the lead author of a recent large-scale analysis of O_3 and mortality in a U.S. prospective study (Turner et al. 2015). She currently has 63 published manuscripts in leading peer-reviewed journals, including various aspects of air pollution associated mortality. She is the recipient of a prestigious Banting Fellowship. She is currently co-author of the upcoming U.S. Environmental Protection Agency Integrated Science Assessment for Particulate Matter which will serve as a key input to air quality regulations in the U.S. and recently served on the National Institute of Environmental Health Sciences (NIEHS) Committee on External Exposure Assessment.

4.3 BSC-CNS (Barcelona Supercomputing Center – Centro Nacional de Supercomputación, www.bsc.es)

The BSC-CNS (Barcelona Supercomputing Center – Centro Nacional de Supercomputación) is the national supercomputing facility in Spain. BSC-CNS manages MareNostrum, one of the most powerful supercomputers in Europe. The mission of BSC-CNS is to investigate, develop and manage information technology in order to facilitate scientific progress. The Earth Sciences department of the Barcelona Supercomputing Center (ES-BSC) was established with the objective of conducting multi-facet research in Earth system modelling. The ES-BSC focuses research on climate predictions, global and regional climate modelling, atmospheric emissions, air quality and mineral dust transport. It is structured in four groups working on climate prediction and modelling, atmospheric composition forecasting, computational services for Earth sciences and Earth system services. The combination of all these capabilities makes the Department a place unique in Europe where research on computing and Big Data, Earth system modelling, and services work together to address some of the most challenging technological and scientific problems in the field from a completely new perspective.

María Teresa Pay (PhD, air quality modeller) worked as Marie Curie postdoc (2013-2016) at École Polytechnique (France) analysing the air pollution dynamic in the Iberian Peninsula using the CHIMERE model. She is a researcher focused on air quality forecast and impact assessment using the CALIOPE air quality system. She is a scientific expert in the Task Force on Measurement and Modelling (TFMM) under the EMEP and the United Nations - Economic Commission for Europe (UNECE).

Marc Guevara Vilardell (PhD, atmospheric emissions). His main expertise includes emission modelling, GIS and environmental impact assessment. He is co-chair of the Emissions Working Group of the FAIRMODE community. He currently coordinates the development and implementation of an air quality forecast system for the Mexico DF Environment Secretary. He has participated in the Spanish air quality-related CALIOPE-And project as well as in several national technology transfer projects related with air quality impact assessment.

5. Organisation du projet

Expliciter le rôle de chacun dans le projet et l'organisation globale du projet On explicitera également le calendrier, les jalons, l'organisation du projet, le traitement des risques.

	Partners			Timeline		
	INSERM	CREAL	BSC	Year 1	Year 2	Year 3
Task 1 Coordination	X	X		X	X	X
Task 2 Historical air quality, meteorology and epidemiological data collection and cleaning (2000-2015)	X	X	X	X		
Task 3 Historical (1995-2000) and current (2015) air quality and meteorology simulations			X	X		
Task 4 Definition of the geographical areas	X	X	X	X		
Task 5 Air quality and meteorological projections (2048-2052)			X	X	X	
Task 6 Analyses of the historical and current impact of O_3 and high temperatures on mortality	X	X			X	X
Task 7 Analyses of the impact of O_3 and high temperatures on mortality according to the forecasted changes in O_3 and temperature by 2050	X	X			X	X
Task 8 Health-economic analyses	X	X			X	X
Task 9 Communication	X	X	X		X	X

Task 1: Management of the project, responsible B Jacquemin and X Basagaña

Task 2: Compilation and treatment of measured data about air quality, meteorology and epidemiological data.

Task 3: Simulation of the current (2015) and historical (1995-2000) air quality and temperature in Europe. The 2015 simulation will be used to evaluate the modelling system against observations compiled in Task 1, while the historical period of 5 years will be used as a baseline to estimate the changes of O_3 and temperature in comparison with the future period simulated in Task 5.

Task 4: Define the smallest geographical areas with air pollution and mortality data available taking into account that the existing air pollution maps are 12.5x12.5 km and the simulations maps will be 25x25 km.

Task 5: Simulation of projected (2048-2052) air quality and temperature in Europe and quantification of the difference in O_3 concentration and temperature when compared to the baseline period (2000-2015).

Task 6: the statistical and epidemiological analyses will be undertaken for each of the described objectives.

Task 7: analyses of the impact of O_3 and high temperatures on mortality according to the forecasted changes in O_3 and temperature by 2050

Task 8: estimation of the monetary cost.

Task 9: writing of scientific papers, presentation of results in scientific conferences, organization of workshops the dissemination and the communication of the results trough scientific conferences and publications.

A more detailed calendar has been uploaded as a different document as indicated by the call.

This project present few risks of feasibility as a large part of the data needed for the project is already publicly available and the rest (e.g. O_3 and temperature projections) will be derived by members of the team. The main risk we could face is a potential administrative delay in obtaining the mortality data from public organism. However, we have had previous successful experiences obtaining similar databases. This risk will be minimized by requesting the required data immediately as the first action of the project.

6. Actions de valorisation

Action prévues pour valoriser les résultats du projet.

Three main scientific publications are planned to valorise this project:

1. One answering the main objective thus is providing country estimates of the impact of O_3 and heat on mortality, in Spain and France for the last years, including urban and rural areas and taking into account the harvesting effect.
2. To investigate the impacts of future climate and anthropogenic emission projections on ground O_3 concentration in 2050 at high resolution (25 km) over Spain and France using a mesoscale air quality model that includes the state-of-the-art in atmospheric chemistry and aerosol dynamics.
3. To assess the health impact on mortality of the forecasted changes in O_3 and temperature by 2050.

Communications for the scientific publication in international conferences are also planned.

We plan to communicate the results to stakeholders, as the results of the project can be of importance for regulatory purposes and for the design of preventive plans.

7. Considérations légales et éthiques

Points spécifiques sur des projets réclamant des autorisations préalables. Points spécifiques sur des projets faisant appel à des expérimentations animales (règle des 3R).

This project has no specific ethical requirements, as it will only include anonymized general population data.

8. Références

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