Case Study 2 “Temperature-related human mortality in European regions”: Product Development Report

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Summary for publication

In order to describe and model the relationship between ambient temperature and mortality, there are several different statistical and epidemiological methodologies. The objective of this deliverable is to describe the **methodology that we are going to use to develop and implement a prototype of integrated heat health early warning system for Europe**.

The definition of the risk of death associated with temperature depends on the intensity of the exposure (temperature) for a range of days leading to the health outcome. This has been described as the exposure-lag-response association. In this report we briefly describe the **Distributed Lag-Non Linear Model (DLNM)** framework, which is here used for the analysis of the delayed short-terms association between temperatures and mortality.

In order to develop the statistical temperature-mortality association, we calibrated the DLNM model with **two different datasets.** On the one hand, we used our own database of mortality, which contains information on daily mean temperature and daily counts of all-cause mortality for the period 1998-2012 in 147 regions from 16 European countries, representing around 420 million people. This mortality dataset is of restricted use and is not being made open, neither to project partners nor to the general public. On the other hand, our partners from the City Council of Almada provided a dataset with information on daily mean temperature and daily counts of all-cause mortality in Almada for the period 2000-2015. By using these two sources of information, we calibrated the temperature-mortality model that is going to be used to predict the temperature-attributable mortality in Europe as a part of the heat health early warning system. **This prototype of early warning system will use weather forecasts with lead times up to 15 days to predict the temperature-attributable mortality in Europe at the regional scale**.

As a result of the research involved in the case study (CS2), we published several scientific articles which validate the methodology (DLNM) to be used in the temperature-mortality predictions (next step of CS2). The results we here report also **highlights the importance of implementing public health preventive measures, such as heat health early warning systems, that have a positive impact on reducing heat-related mortality**.

Work carried out

Modelling the temperature-mortality relationship

In this stage of the study, we aimed to describe the best statistical approach to model the association between temperature and mortality, which is the core methodological issue of the prototype of heat health early warning system we are going to develop. The aim is to model short-term associations between temperature and mortality. To do so, we first characterised both temperature and mortality data. We worked with time series data of daily temperature and daily counts of deaths, and, in this context, trends and seasonality are the main methodological features to deal with. Figure 1 shows, on the one hand, a negative trend in European mortality during the study period, meaning a reduction in mortality across Europe (consistent with increased life expectancy). On the other hand, the plot depicts a seasonal variation in mortality data, which means that the pattern is repeated regularly within each year. Specifically, in Figure 2 we can observe that the number of deaths is higher during the winter months, especially from November to February, and then there is a decrease in mortality for the warmest months.

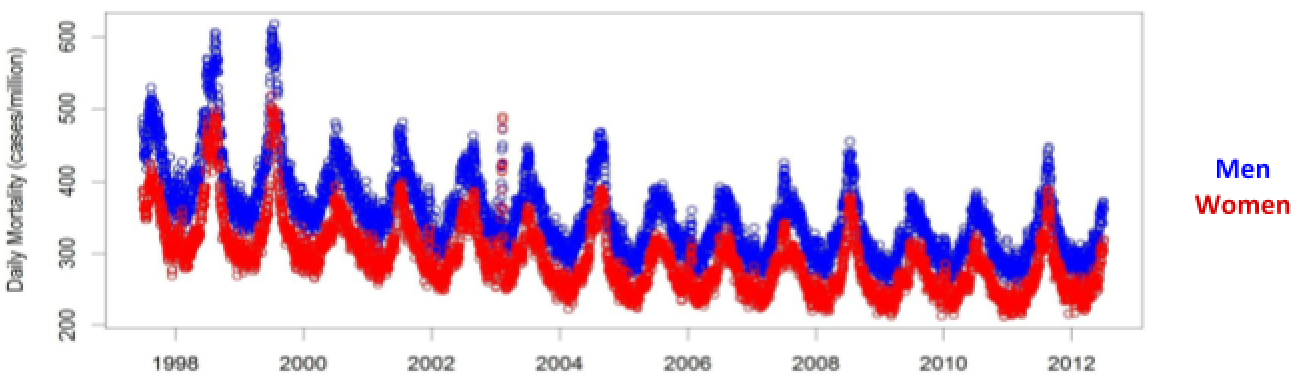


Figure 1: Daily mortality counts in Europe. 1998-2012. Source: elaborated by ISGlobal

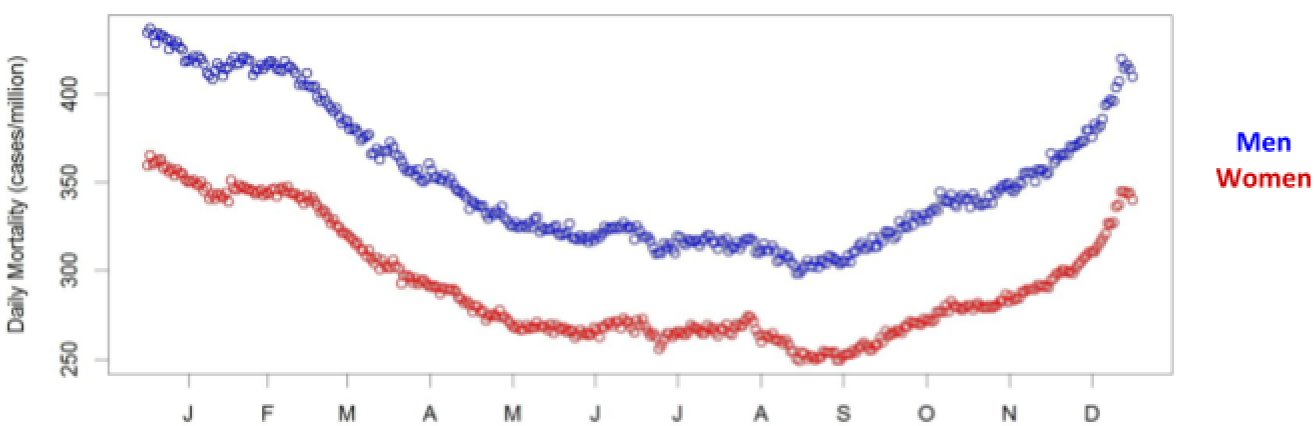


Figure 2: Average number of deaths by month in Europe. Source: elaborated by ISGlobal

Therefore, it is necessary to control for both trends and seasonal patterns in order to separate them out from the short-term associations between the exposure and the outcome that we are interested in modelling. Here “short-term” refers to the order of a few days or weeks.

Another issue to consider when modelling the temperature-mortality relationship is the lagged effects. Generally the association between temperature and mortality is delayed. That is, it has been shown that temperature effects on mortality are not only seen immediately on the same day of the exposure, but may persist for several days (Bhaskaran et al. 2013) (Figure 3). It should be noted that in general, the health effects of heat are more immediate than for cold, which persists longer due to the internal transmission dynamics of respiratory infections (Anderson and Bell 2009; Gasparrini et al. 2015). Typically, the most common choice in epidemiological studies assessing the relationship between temperature and mortality is to consider a lag period up to 21 days (i.e. three weeks) (Gasparrini et al. 2015; Guo et al. 2014).

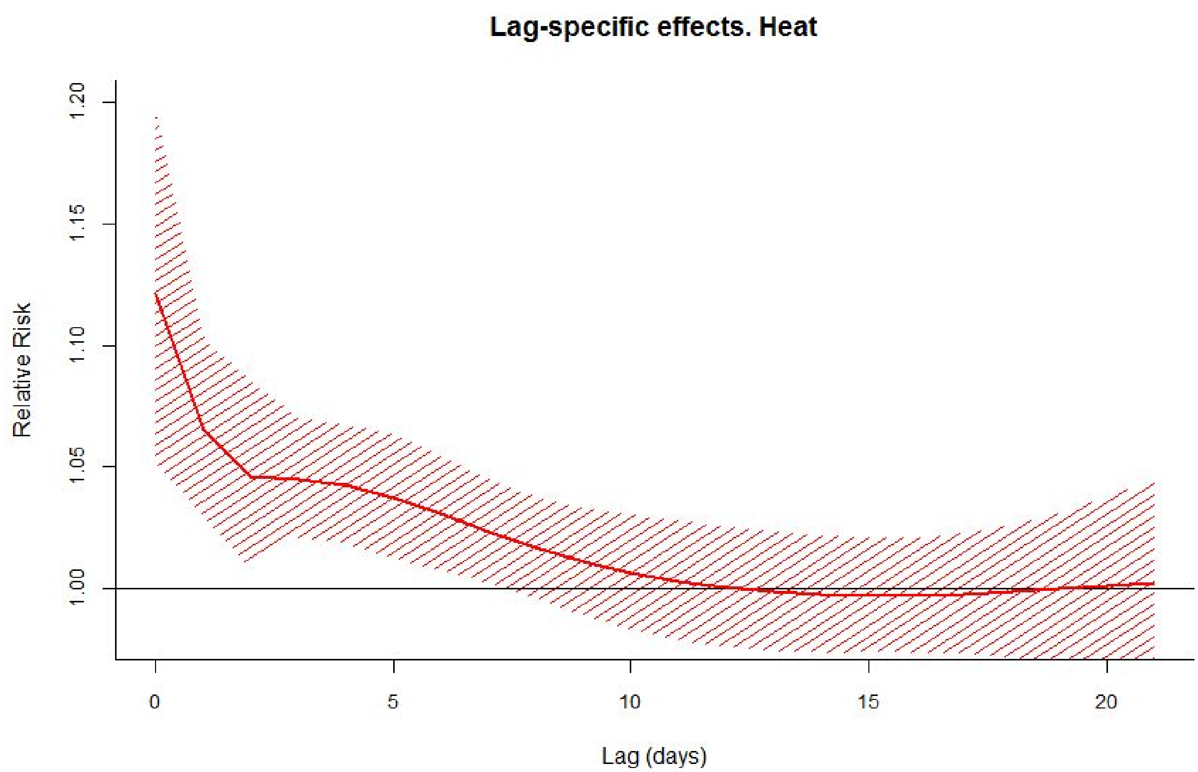


Figure 3: Lag structure of the temperature-mortality association for heat in Almada, 2000-2015.
Source: elaborated by ISGlobal

In this kind of analysis, population size is not included because all the mid- and long-term trends are controlled for in the analyses by including terms of seasonality and trends, and in particular, demographic changes are removed from the epidemiological analysis of the short-term effects of temperature on mortality.

The Distributed Lag-Non Linear Framework

We here describe the DLNM framework which allows to model exposure-lag-response relationships accounting for the methodological features already explained in the previous section. The DLNM approach is a common methodology applied in epidemiological research and has been used in numerous studies assessing the short-term association between an exposure (such as temperature, ozone, air pollution) and a health outcome (mortality, morbidity or occupational injuries) (Vanos et al. 2015; Aßenmacher et al. 2019; Martínez-Solanas et al. 2018; Martínez-Solanas and Basagaña 2019a).

The DLNM methodology allows to describe non-linear relationships as well as modelling trends and seasonal patterns. Moreover, this methodology incorporates an additional dimension to represent the risk depending on both intensity and timing of past short-term exposures (lagged dependencies). The DLNM methodology has been previously described in more detail elsewhere (Gasparrini, Armstrong, and Kenward 2010) and more information can be found on the website of the CS2 that it has been created during this stage of the study (http://www.heathealth.eu/).

Numerous epidemiological studies have been published based on this statistical method (Gasparrini et al. 2015; Guo et al. 2014; Achebak, Devolder, and Ballester 2019; 2018; Ballester et al. 2019; Martínez-Solanas and Basagaña 2019b). Figure 4 reports the usual shape of the association between temperature and mortality, which has a U-V-J shaped. These curves suggest an increase in the risk of death for temperatures above and below a temperature of minimum mortality. However, the shape of the association can be different within cities, as it depends on the degree of acclimatization of people living in those areas (Guo et al. 2014). In our CS2 we will contemplate the differences in the temperature-related mortality association in each European region, meaning that we will fit a model for each location allowing to have a different pattern in the temperature-related mortality association.

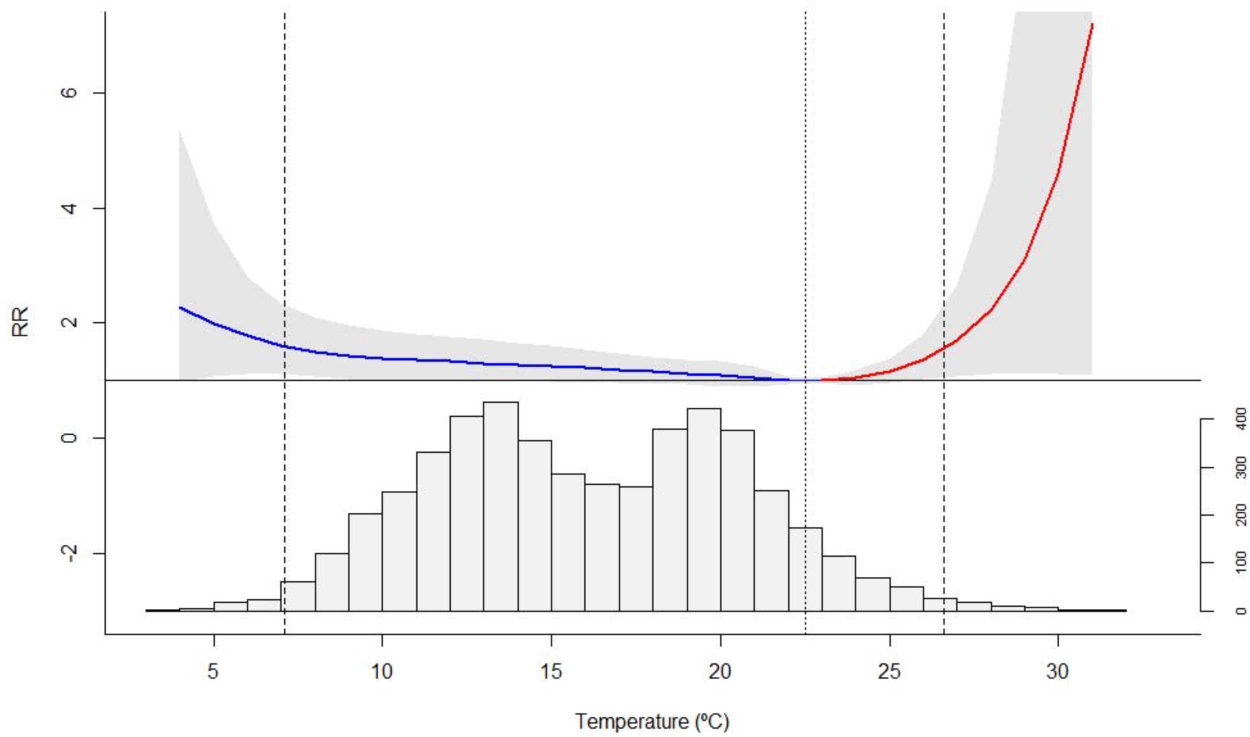


Figure 4: Overall cumulative temperature-mortality association and temperature distribution in Almada (2000-2015). Source: Elaborated by ISGlobal

The general assumption of the raw DLNM approach assumes that the exposure-lag-response function does not change during the whole study period. However, this cannot be certain, as adaptation has a key role in understanding the impact of ambient temperature on health in the last decades. Therefore, in order to include the possible change in the temperature-related mortality association, in the CS2 we will extend the methodology to the time-varying DLNM (Gasparrini et al. 2015; Achebak, Devolder, and Ballester 2018), which allows the exposure-lag-response relationship to change over the period, thus including a possible shift in the curve. With this approach we can test a possible adaptation to extreme temperatures and temporal variations in the temperature distribution.

Calibration of the statistical temperature-mortality model

Once we have chosen the best method to describe the relationship between temperature and mortality, we calibrated the model using two different data sources. First, we considered our own dataset of mortality and temperature. This dataset includes data on daily mean temperature and daily counts of all-cause mortality at the NUTS2 level in 16 countries, which represents around 420 million people. These countries are Austria, Belgium, Croatia, the Czech Republic, Denmark, France, Germany, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain, Switzerland and the United Kingdom

(England and Wales only). The study period covers from January 1st 1998 until December 31st 2012. In total, we gathered around 59 million deaths. This mortality dataset is of restricted use and is not being made open, neither to project partners nor to the general public.

In addition, we also used data from the city Council of Almada, provided by our colleagues in the CS2 from the Department for Innovation, Environment, Climate and Sustainability of the City Council of Almada. Almada's mortality data were made available by National Statistical Institute of Portugal and by the Health Analysis and Information Services of the Directorate-General for Health. The City Council checked for anomalies or blank records and the baseline data was provided to ISGlobal.
We had access to daily mean temperature and daily counts of all-cause mortality in the city of Almada, for the period 2000-2015. Overall, there were 28,450 deaths in Almada during the study period, representing a mean of around 1,780 deaths per year. Therefore, we also used these data to calibrate the statistical temperature-related mortality model.

Data preparation: obtaining weather forecasts
Based on the end-user requirements detected in the first stage of the study (deliverable *D.5.7 End-User Requirements Specification Report*), we found a need for including short-term predictions and warnings (beyond a few days) in the current heat health early warning systems. The majority of the European countries have heat-health action plans; however they do not use weather or climate forecasts with lead times beyond 1 to 2 days. Therefore, in order to develop a pan-European heat health early warning system addressing this gap, we considered daily time series of weather forecasts of 2m temperature (at the very least).

In this stage of the study, we evaluated different weather and climate products that could be used. On the one hand, services developed within Work Package 1 (WP1) can provide valuable seasonal and sub seasonal climate forecasts. Even though these products cover our methodological and technical requirements, the main limitation of using them is the relatively low number of forecast issuing dates (once per month). This does not allow to comprehensively perform a predictability skill analysis at lead times of up to 1 or 2 weeks, as stressed by the end-users.

In order to cover this limitation, we alternatively explored weather forecasting products. We found that the European Centre for Medium-Range Weather Forecasts (ECMWF) can provide ensemble weather forecasts for Europe. One of the ECMWF products, the Atmospheric model Ensemble 15-day forecast (ENS), provides weather forecasts covering lead-times up to 15 days (short-term predictions). ENS contains 51 ensemble member weather forecasts available four times per day at a spatial resolution of 0.5 degrees. Even though daily weather data is only available since December 2006, we are able to use these forecasts to create and develop the prototype of the heat-health early warning system. Indeed, considering that the mortality database is available from 1998 to 2012, these weather forecasts cover six full summers and six full winters.

Therefore, weather forecasts have been downloaded from the ENS model in this stage of the study. We obtained a time series analysis with the following information: coordinates (longitude and latitude), issuing date, forecast time and ensemble member. As mortality data have a different structure, we homogenized both climate and mortality datasets by transforming the gridded data into administrative units (countries and regions), thus we are able to have a single time series with all averaged data.

Retrofitting Almada’s Automatic weather stations

In 2017, the City Council of Almada has identified some hardware and software problems in the local weather stations and decided to update some of the equipment .

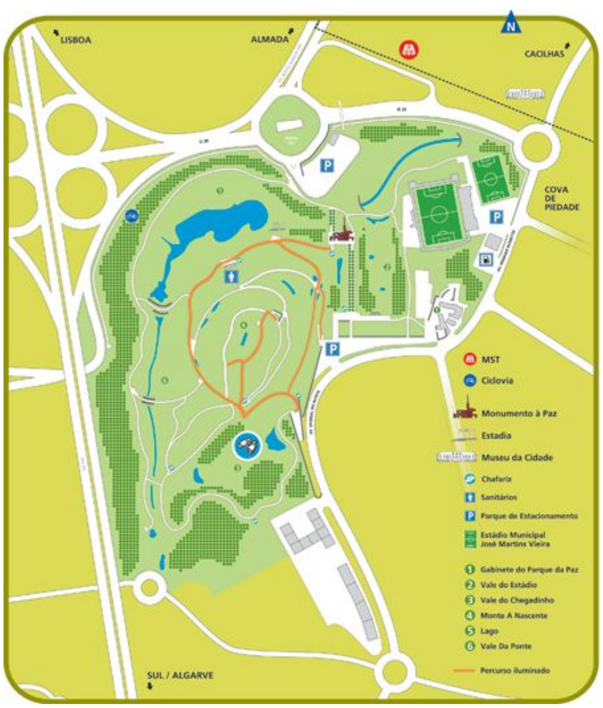
In the framework of Blue-Action project, the City Council could retrofit the existing automatic weather stations, in order to collect better data series to future work on temperature related mortality, especially during heat waves. This new equipment contributes to increase the baseline data and improves information about heat waves in Almada’s region, events projected to be more frequent in the future by climate evolution scenarios for Mediterranean latitudes.

The retrofit intervention included different actions, namely replace old equipment to comply with WMO standards or to improve increase the capacity of data collection.

This update improves the collection of meteorological data in Almada and the monitoring of the meteorological conditions, improving data quality. This new information contributes to validate futures forecasts in Almada's region.

At the present, this weather station is located in Almada and is surrounded by buildings, mostly higher than the structure where the measuring devices are installed. This influences negatively measurements, such as wind speed and wind direction.

The station is going to be transferred to the Parque da Paz, the largest green park in the city, and will be located in a more suitable location. This relocation to Parque da Paz is going to improve the quality of the station data. This is also a window of opportunity for changing the monitoring devices, improving the quality of the data collection.



Photos are courtesy of Almada Camara Municipal.

The City Council analysed and selected the most appropriate technical options on the market and proceeded with the respective process of acquisition of the equipment and their installation. The first phase corresponding to the purchase of the equipment ended in October 2019. The installation process is ongoing and is expected that the assembly is ongoing.

The following list identifies the equipment acquired by the City Council and the intended objectives and uses.

Equipment	Objective
Datalogger Campbel CR310 (Collection and archiving of accurate weather data)	Replace old equipment and improve sensors compatibility
Relative Humidity-Temperature Sensor Vaisala HMP155A + Sensor shelter (includes radiation shield, model DTR13, and sensor head bracket	Collecting Temperature and Relative humidity data in a fixed weather station
Temperature sensor, model TR4 (thermo recorder) data logger equipped with Bluetooth low energy.	Data loggers equipped with Bluetooth low energy to collect data temperature in “grey” artificialized public spaces. It has a dedicated apps for real-time monitoring of changing data and uploading recorded data to a free cloud service.
Udometer Lambrecht 15189	Replace old equipment to comply with WMO standards. Recording precipitation gauge

Main results achieved

The analysis of the most common approaches to model the relationship between temperature and mortality helped us to select the most appropriate methodology, which is DLNM. Using two different datasets, one covering data from 146 European regions for 15 years and another one with local information of the city of Almada with data for 16 years, we were able to calibrate the statistical model that is going to be used in the next step of the study.

Moreover, during this process our team at ISGlobal published several studies using the same DLNM methodology previously described and assessing the impact of ambient temperatures on mortality in Spain and Europe. Achebak and colleagues found a decline in the risk of heat-attributable mortality in Spain. They analysed temporal changes in heat-related all-cause mortality in the last decades in Spain and results suggested a strong and progressive reduction in the risk of death during the whole study period (covering from 1980 until 2015). Authors concluded that there is a reduction in the vulnerability to heat in Spain. This reduction approximately occurred at a constant rate (Achebak, Devolder, and Ballester 2018).

Using the same DLNM methodology, a study found a decrease in the risk of cardiovascular mortality over the last decades in Spain (Achebak, Devolder, and Ballester 2019), while in another study, the authors reported a large decrease in the risk of respiratory deaths in Spain due to cold temperatures and a much smaller reduction due to hot temperatures (Achebak et al., n.d.). Moreover, in this last paper results showed a complete change in the seasonality of the AF between the beginning and the end of the study period (1980-1994 and 2002-2016), with a displacement of the maximum monthly AF from winter to summer, and the minimum monthly AF from early and late summer to winter. These findings claim for urgent public health policies that aim to prevent the negative respiratory effects of warmer summer temperatures.

In terms of the European context, we conducted a study with the DLNM approach and the same European dataset we used for the calibration of the statistical model, previously described. This paper aimed to analyse temporal trends in heat-related mortality in Europe. Authors reported a reduction in heat-related mortality in Europe as a whole, even though there were some differences among countries (Ballester et al., n.d.). In addition, the authors described the effect of the Great Recession on annual and seasonal changes in all-cause mortality trends (Ballester et al. 2019). Results showed that the European countries with the largest economic slowdown were also those with the largest strengthening of the declining mortality trend and vice versa.

Moreover, our team have also published some scientific papers highlighting the relevance of the implementation of preventive measures as mechanisms to reduce the negative health consequences of the exposure to ambient temperatures. In one study conducted using the DLNM methodology, we analysed temporal changes in the effects of heat in Spain (Martínez-Solanas and Basagaña 2019b). This study also aimed to evaluate the implementation of a national heat health prevention plan. To do so, the study period was split into two, the second one characterized by the introduction of this plan. Authors found a significant reduction in the risk of death for extreme heat in the second period, which could be attributed to the implementation of the Spanish heat health prevention plan. In this context, it has been also shown the need to incorporate reliable sub-seasonal to seasonal climate forecasts into the heat-health action plans, in order to anticipate and therefore avoid temperature-related deaths (Lowe et al. 2016).

To sum up, results from all these epidemiological studies together with the calibration of the model, validate the DLNM methodology we are going to apply for the temperature-related mortality predictions. Furthermore, with the development of this prototype of heat health early warning system in Europe we will contribute to reduce the health burden of heat.

Progress beyond the state of the art

In this stage of the study we selected and calibrated the statistical model that is going to be used for the temperature-related mortality predictions. The use of a large dataset including temperature and mortality data from 16 European countries and covering a recent period of 15 years validated the DLNM methodology selected to analyse the relationship between temperature and mortality.

The work that has been done so far in the study establishes the methodological basis for the design and development of a prototype of heat health early warning system for European regions. Moreover, the availability of the weather forecasts downloaded from the ECMWF will allow to address the current gap in existing systems in terms of the predictive capacity, that is currently a limitation of lead times of a few days, within the temporal scales of weather phenomena and forecasting. With improved spatial resolution of climate data, together with a complete mortality dataset for 16 countries in Europe, we are able to build a prototype of heat health early warning system that can predict the impacts of heat on health and therefore activate preventive actions.

Impact

How has this work contributed to the expected impacts of Blue-Action?

The work we have done so far and explained in this deliverable established the basis for the next steps in CS2. The development of the prototype of heat health early warning system in Europe will contribute to the following Blue-Action impacts:

1. To improve the capacity to predict the weather and climate of the Northern Hemisphere, and make it possible to better forecast of extreme weather phenomena, regarding extreme ambient temperatures.
2. To interact with business stakeholders, which facilitate testing the delivering of new downstream products and services
3. In the medium and long-term, to develop risk-based forecasts of extreme weather phenomena at sub-seasonal-to-seasonal (s2s) time scales through an innovative, process-oriented description of the weather systems in which extremes are likely to form.
4. To improve stakeholders' capacity to adapt to climate change. The heat health early warning system may help to prevent potentially hazardous events and therefore may enhance the societal coping capacity and resilience.

Impact on the business sector

The development of a prototype of the European heat health early warning system is relevant for public and private sectors, as it will have several potential applications. We are working closely with the City Council of Almada, and other relevant national and international health agencies. In addition, the system will be built on the experiences of existing operational schemes. In terms of the private sector, it can be applied for a wide range of activities, including health insurance and occupational health and safety.

Moreover, we interacted with different stakeholders from the private sector, such as the responsible of ECMWF, with the objective to explore potential partners in the private sector to make the heat health early warning system operational. We will explore other stakeholders and possible collaborators in order to build future collaborations that can allow go beyond our prototype to an operational heat health early warning system.

Lessons learned and Links built

Different positive outcomes can be described from this deliverable. First, the calibration of the model with a large dataset using mortality data for 16 European countries gives validity and reliability to the use of the the DLNM methodology in the design and implementation of the prototype of heat health early warning system. Second, the work done together with the city Council of Almada allows to validate the statistical temperature-related mortality model in such a local context and strengthen our network of contacts. Finally, the use of the ECMWF model, after deciding working with weather forecasts, opens an opportunity to transform the system into an operational heat health early warning system, that can be further explored in the next steps of the study.

Contribution to the top level objectives of Blue-Action

This deliverable contributes to the achievement of the following objectives and specific goals of the Blue-Action project:

Objective 6 Reducing and evaluating the uncertainty in prediction systems

by choosing a validated and widely used statistical method to assess the temperature-related mortality association, which is the methodological basis of the prototype of heat health early warning system we are going to develop.

Objective 7 Fostering the capacity of key stakeholders to adapt and respond to climate change and boosting their economic growth

by integrating their needs in the design and development of the heat health early warning system

Objective 8 Transferring knowledge to a wide range of interested key stakeholders

by considering the weaknesses of the current schemes and the needs of stakeholders in the design and development of the heat health early warning system.

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Dissemination and exploitation of Blue-Action results

Dissemination activities

Type of dissemination activity	Name of the scientist (institution), title of the presentation, event	Place and date of the event	Type of Audience	Estimated number of persons reached	Link to Zenodo upload
Participation to a conference	Fifth International Conference on Climate Services (ICCS5). Participant: Joan Ballester (ISGlobal)	Cape Town (RSA), 28 - February- 3 March 2017	Scientific Community (higher education, Research), Policy makers	>500	https://www.zenodo.org/communities/blue-actionh2020/
Participation to a conference	Catarina Freitas; Sara Dionísio (ALM) oral presentation "Boost disaster risk reduction and territorial resilience at Local Level Almada's (Portugal) approach" in the "European Forum for Disaster Risk Reduction" organized by the United Nations Office for Disaster Risk Reduction	Istanbul (TR), 28 March 2017	Scientific Community (higher education, Research), Policy makers	40-50	https://www.zenodo.org/record/1292835#.XdUw_uQ3aUk
Participation to a conference	Action Plan to Avoid the Effects of Heat Waves on Health in Catalonia. Participant: Joan Ballester (ISGlobal)	Barcelona (ES), 27 June 2017	Scientific Community (higher education, Research), Policy makers	30-50	https://www.zenodo.org/communities/blue-actionh2020/
Participation to a conference	H2020 Climate Services projects workshop organised by EASME. Participant: Joan Ballester (ISGlobal) and Steffen Olsen (DMI)	Brussels (Belgium), November 29-30 2017	Scientific Community (higher education, Research),	50	https://www.zenodo.org/communities/blue-actionh2020/

			Policy makers		
Participation to a conference	Blue-Action's WP5 Meeting with GERICS. Participant: Participant: Joan Ballester (ISGlobal)	Hamburg (Germany), July 10-12, 2017	Scientific Community (higher education, Research)	20	https://www.zenodo.org/communities/blue-actionh2020/
Participation to a conference	2017 Community Earth System Model (CESM) Tutorial. Participant: Joan Ballester (ISGlobal)	Boulder (USA), 14-18 June 2017	Scientific Community (higher education, Research)	50-100	https://www.zenodo.org/communities/blue-actionh2020/
Participation to a conference	Kick-off Meeting of the Blue-Action Project. Participant: Joan Ballester (ISGlobal)	Berlin (Germany), 18-20 January 2017	Scientific Community (higher education, Research)	50-100	https://www.zenodo.org/communities/blue-actionh2020/
Participation in activities organised jointly with other H2020 project(s)	Kick-off Meeting of the PUCS Project. Participant: Joan Ballester (ISGlobal)	Antwerp (Belgium), 14-16 June 2017	Scientific Community (higher education, Research)	20	https://www.zenodo.org/communities/blue-actionh2020/
Participation to a conference	Nuno Lopes, Sara Dionísio (ALM) oral presentation “A Ilha de Calor na ELAC de Almada: Contributos dos Projetos NACLIM e BLUE ACTION” in the CLIMA2018 conference. The event was organized by the Portuguese Association of Environmental Engineers	Faro (PT), 22-23 November 2018	Scientific Community (higher education, Research), Policy makers	80-100	https://www.zenodo.org/record/1700551#.XdUznOQ3aUk
Participation to a conference	Joan Ballester (ISGlobal) oral presentation in the "First Global Forum for Heat and Health" (Global Heat Health Information Network)	Hong Kong (CN), 17-20 December 2018	Scientific Community (higher education, Research)	100	http://ghhin.org/assets//3.-Joan-Ballester---20181218_1stforum_ghhin_ballester_public.pdf
Participation to a conference	Catarina Freitas, Nuno Lopes (ALM) oral presentation to the the Municipality of Belo Horizonte (BZ) “Promover a resiliência em Almada: a Adaptação na Estratégia Local para as Alterações Climáticas” in technical meeting of the project “ International Urban Cooperation” with Brazilian Mission of the Municipality of Belo Horizonte.	Almada (PT), 14 May 2019	Policy makers	10	https://www.zenodo.org/communities/blue-actionh2020/

Others	Erica Martinez-Solanas (ISGlobal), poster presentation ("An integrated heat health early warning system for Europe") in the 31st annual conference of the International Society for Environmental Epidemiology	Utrecht (NL), 25-28 August 2019	Scientific Community (higher education, Research)	40	https://www.zenodo.org/record/3385391#.XW9e_Ufta70
Participation to a conference	Joan Ballester (ISGlobal), oral presentation ("Mortality Trends in Europe: Role of Macroeconomic Growth during the Great Recession") in the 31st annual conference of the International Society for Environmental Epidemiology	Utrecht (NL), 25-28 August 2019	Scientific Community (higher education, Research)	40	https://code.mpimet.mpg.de/issues/9297?issue_count=205&issue_position=1&next_issue_id=9274
Participation to a conference	Nuno Lopes, Catarina Freitas, Sara Dionísio, Cristina Almeida (ALM) oral presentation “Modelação de Alta Resolução da Ilha de Calor em Almada: diagnóstico e medidas de regulação microclimática” in the 6th Workshop about Adaptation to Clime Change organized by the Lisbon Metropolitan Area	Seixal (PT) 28 October 2019	Scientific Community (higher education, Research), Civil Society, Policy makers	40	
Participation to a conference	Catarina Freitas, Nuno Lopes, Sara Dionísio, Cristina Almeida (ALM) oral presentation **“**A Ilha de Calor na Estratégica de Adaptação de Almada: Modelação de Alta Resolução, Análise de Stress Fisiológico e Medidas de Regulação Microclimáticas” in the Seminar of the project “Adapt.Local.19 - Adaptação Local às Alterações Climáticas	Seia (PT) 15 November 2019	Scientific Community (higher education, Research), Civil Society, Policy makers	50	

Peer reviewed articles

The following articles are acknowledging Blue-Action:

Title	Authors	Publication	DOI	Is Blue-Action correctly acknowledged?	Open Access granted
Sex-age trends in heat- and cold-related mortality from cardiovascular diseases in a warming climate: A countrywide time-series study from Spain	Achebak H, Devolder D, Ballester J.	*The Lancet Planetary Health* **3**, E297-E306 (2019)	10.1016/S2542-5196(19)30090-7	Yes	Yes
Effect of the Great Recession on regional mortality trends in Europe.	Ballester J, Robine JM, Herrmann FR, Rodó X.	*Nature Communications* **19**, 679 (2019).	10.1038/s41467-019-08539-w	Yes	Yes
Heat-related mortality trends under recent climate warming in Spain: a 36-year observational study.	Achebak H, Devolder D, Ballester J.	*PLOS Medicine* **15**, e1002617 (2018).	10.1371/journal.pmed.1002617	Yes	Yes

Other publications related to this deliverable

Joan Ballester, Xavier Rodó, Jean-Marie Robine, François Richard Herrmann, European seasonal mortality and influenza incidence due to winter temperature variability, Nature Climate Change 6, 927-930 (2016) 10.1038/nclimate3070

Uptake by the targeted audiences

As indicated in the Description of the Action, the audience for this deliverable is the general public (PU) is and is made available to the world via CORDIS.

This is how we are going to ensure the uptake of the deliverables by the targeted audiences:

- Social media used by the project
- Webpage of the case study http://www.heathealth.eu/
- Publishing this report in the Zenodo repository
- Direct dissemination to other H2020 projects related to Climate Services.