forecAsting System for urban heaT Island effect

"Implementation of a forecAsting System for urban heaT Island effect for the development of urban adaptation strategies" (LIFE ASTI)

Action C.6 **Report on heat health warning models definition protocol**

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HEAT HEALTH WATCH WARNING SYSTEMS (HHWWS)

This document presents the protocol for the definition of heat health Watch Warning Systems developed for Rome and Thessaloniki within ASTI LIFE that will be used to forecast at risk conditions for health using weather forecasts developed in C2.

Heat health warning systems are one of the core elements of a heat adaptation plans as defined by WHO Guidance (WHO 2008). Heat warning systems serve as tool on which prevention and emergency measures should be modulated based on the severity of risks.

Throughout the epidemiological literature, heat has been associated with impacts on health, in particular a non-linear association between temperature and mortality, has been identified in time series studies, specific to each geographic location with increases in the risk of mortality as tempertuares rise above or go below a specific threshold (Gasparrini et al. 2015). When considering heat wave episodes, studies have shown that extreme events have an even stronger impact on mortality. A European study conducted to evaluate the impact of summer 2003 showed that heat waves of high intensity and long duration had a greater effect on mortality (D'Ippoliti et al. 2008).

Heat warning systems are different from a weather forecast of a heat wave event in that they identify temperatures that are harmful for health, specifically in this case are associated to a significant increase in mortality. Thresholds and levels of warning are set based on specific health risk thresholds (increases in daily mortality).

Within LIFE ASTI, a new HHWW will be developed for Thessaloniki. While the Rome system, which has been operational since 2005, will be modulated to give graded warning within the city taking into account the high resolution forecasts provided in the project in C2. The urban heat island and differences in risk across the city due to susceptibility factors such as socio-demographic and health conditions will be accounted for. This report provides a protocol for HHWWS definition and steps that need to be carried out to achieve them.

i. Data collection

a. Mortality data

Daily mortality counts were collected for both cities.

For Rome, deaths occurring within the city and among the resident population by age among the elderly (65+ years) were considered and available from the SISMG – Rapid mortality surveillance system of the Italian Ministry of Health managed by DEASL which enables to have mortality data with a delay of a 1-2 weeks. Data is available from 1996-current. This data will be available throughout the project also to evaluate the impact of each summer and to carry out KPIs on potential reduction in heat attributable deaths at the end of the project and after life.

For Thessaloniki, daily total mortality counts were provided from MOT for the period 2013-2018 and will be used to define the HHWW model and updated at the end of the summer season to evaluate the impact of heat waves in Thessaloniki. Table 1 shows average daily deaths in the summer period and by month. In Thessaloniki there are on average 8 daily deaths with a standard deviation of 2-3 deaths in the summer months. While in Rome there are 54 daily deaths with a reduction in the month of august and September.

Table 1. Mortality data descriptives by month for Thessaloniki and Rome period 2013-2018.

	Thessaloniki Daily deaths		**Rome** Daily deaths	
	mean	St.dev	mean	St.dev
May	8.4	2.9	54.4	8.2
June	8.9	3.0	54.6	8.8
July	8.4	2.8	54.7	9.3
August	8.9	3.1	53.4	9.1
September	8.1	2.8	51.5	8.0

b. Meteorological data

For each city air temperature and dew point temperature data from airport or urban stations were retrieved for Rome and Thessaloniki.

For Rome the reference weather station is Ciampino airport. Three hourly weather data for air temperature and dew point temperature was provided by DEASL, which manages the Italian HHWW for the Ministry of Health.

For Thessaloniki hourly weather data (air temperature (°C), relative humidity (%), wind speed (m/s) and direction (degrees) from 9 urban monitoring stations was provided by MOT and AUTH for the period 2013-2018.
Table 2 shows average temperatures by month in each city, values are comparable with slightly higher values in Thessaloniki.

Table 2.Temperature data descriptves by month for Thessaloniki and Rome period 2013-2018.

	Thessaloniki Temperature		**Rome** Temperature	
	mean	St.dev	mean	St.dev
May	19.7	2.6	18.0	2.5
June	23.9	3.1	22.5	2.5
July	26.4	2.2	25.6	2.3
August	26.7	2.2	25.4	2.3
September	22.0	2.8	20.9	2.4

After having carried out a descriptive assessment of data completeness and location of the stations it was decided with MOT and AUTH to consider ΕΠΤΑΠΥΡΓΙΟ as the refernce station. Figure 1 shows the temperature trend in the study period for all the weather stations provided. Descriptives for each of the stations by month in Thessaloiniki are shown in figures 2-6.

Figure 1. Trend in daily mean air temperatures in the 8 stations in Thessaloniki.

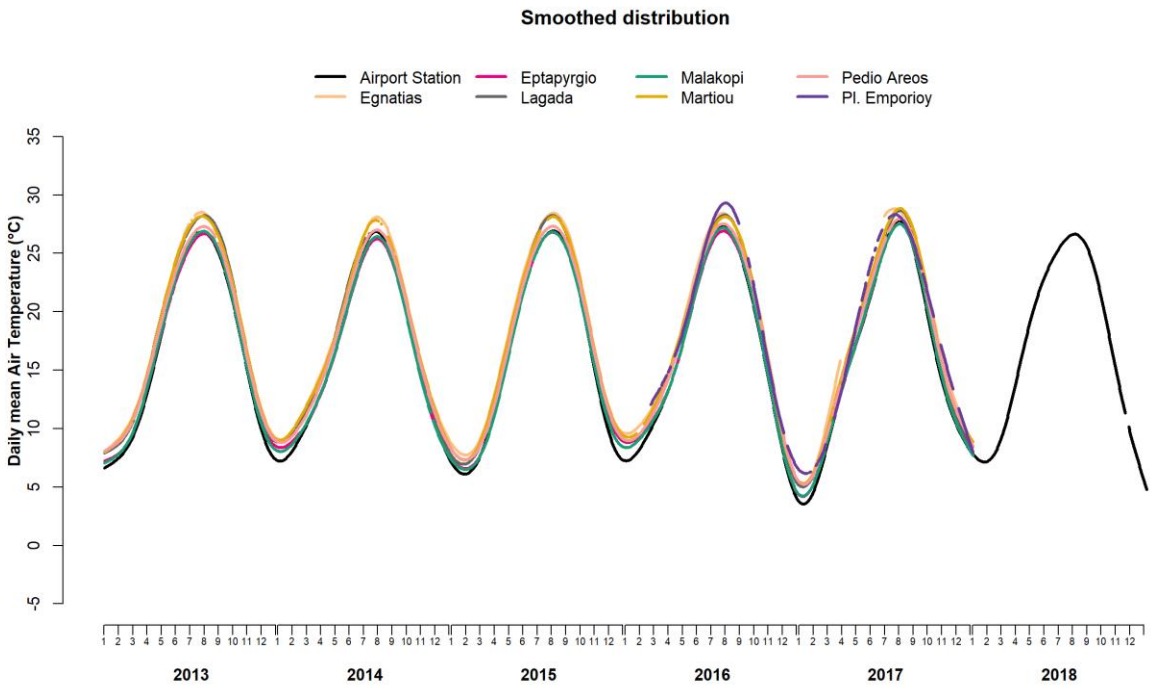


Figure 2. Boxplots of mean temperature in May for the different weather stations in Thessaloniki.

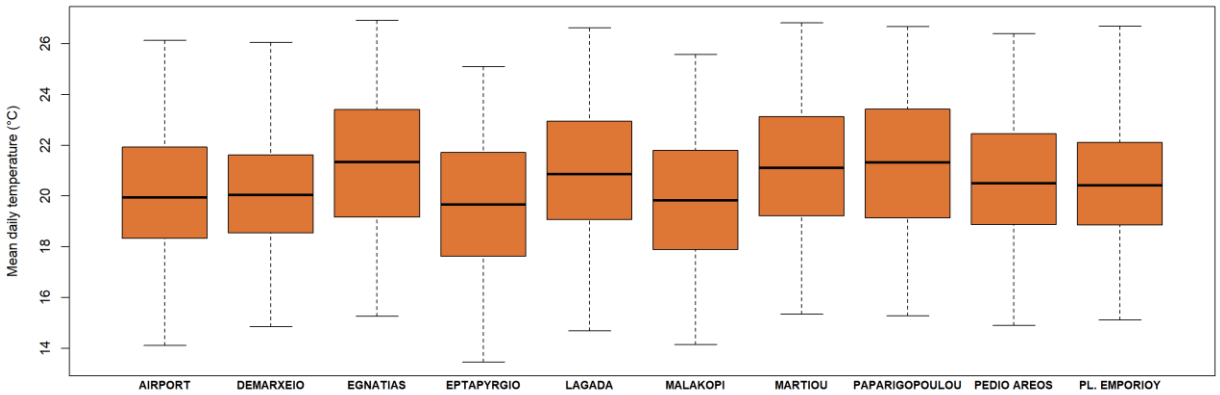


Figure 3. Boxplots of mean temperature in June for the different weather stations in Thessaloniki.

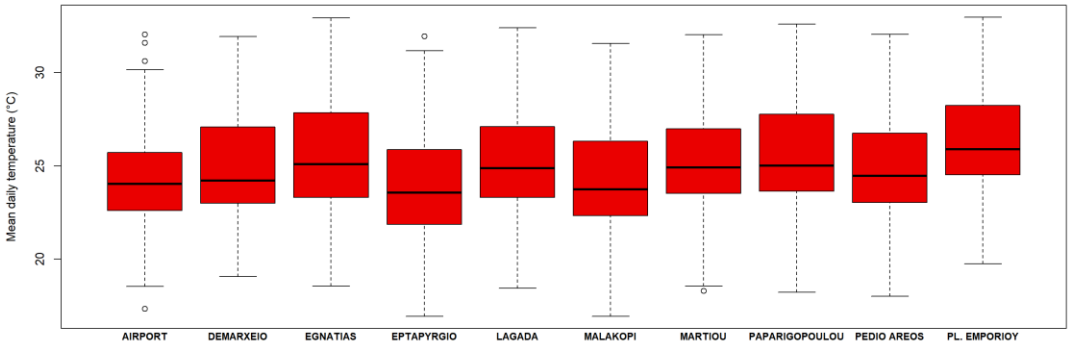


Figure 4. Boxplots of mean temperature in July for the different weather stations in Thessaloniki.

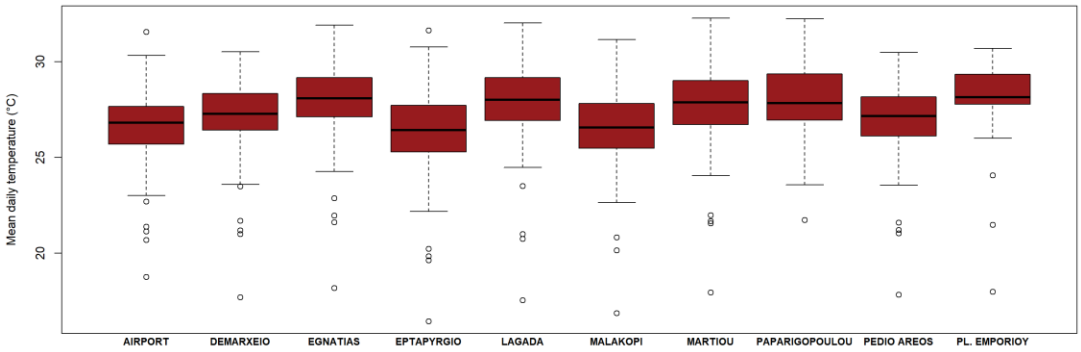


Figure 5. Boxplots of mean temperature in August for the different weather stations in Thessaloniki.

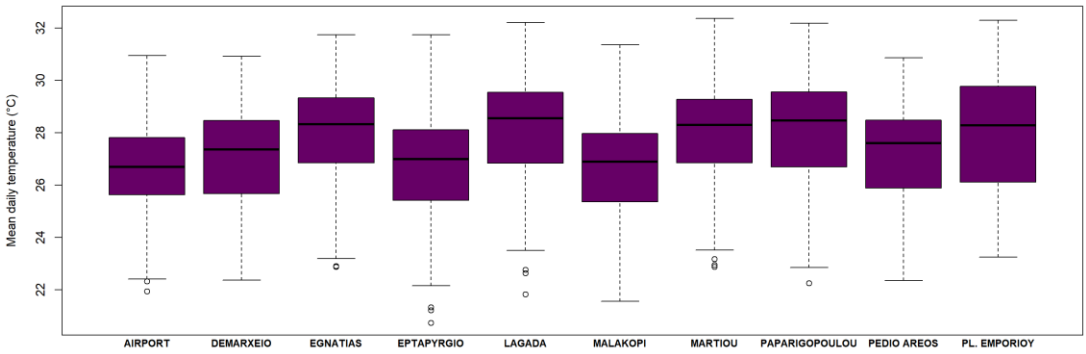
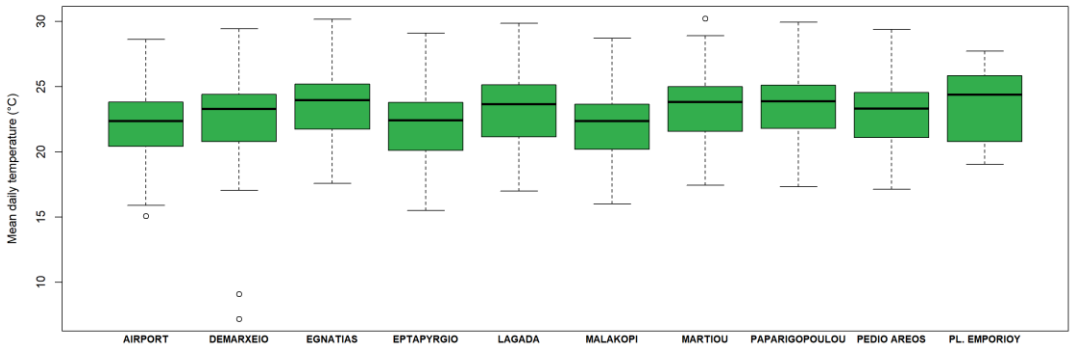


Figure 6. Boxplots of mean temperature in September for the different weather stations in Thessaloniki.



Apparent temperature, an indicator that combines air temperature and humidity, was calculated using the following formula:

$$Tapp = -2.653 + 0.994Ta + 0\ 0153(Td)^2$$

Where Ta = air temperature °C;
Td= dew point temperature °C

The maximum value among the diurnal values was calculated and is considered as exposure indicator in the temperature-mortality association and definition of HHWW as starting point to replicate the methodology used for the Rome model. Other temperature parameters and thermal bioclimate indices defined in C1 will be calculated and assessed for the temperature-mortality association.

ii. Data analysis

An exploratory time series analysis on the association between heat and mortality was carried out for Thessaloniki and Rome for a description on the association and the lag structure in each city. Poisson regression models were run separately in each city; the associations between the daily number of deaths and the daily maximum apparent temperature (Tappmax) were modelled using a distributed lag non-linear model (DLNM), a flexible way to capture both the complex non-linear association and the lagged dependencies of exposure–response relationships (Gasparrini et al. 2010). A lag window of 7 days was considered, accordingly to what is known from literature on the relationship between heat and mortality. Using this methodology, it was also possible to account for both seasonal and long-term trends.

Preliminary results on daily mortality and mean temperature for Thessaloniki are shown in figure 7 with increases in the risk of mortality for values of tappmax above 32°C and a significant risk from 34°C. The lag structure for Thessaloniki is shown in figure 8 and a significant risk in mortality from day t+1 after exposure up to 5 days is observed. Similarly for Rome the curve has a similar j-shape with significant risks in mortality from 32°C and for lags 0-6 days (Figures 9-10).

Figure 7. Association between maximum apparent temperature and mortality in Thessaloniki, summer period 2013-2018.

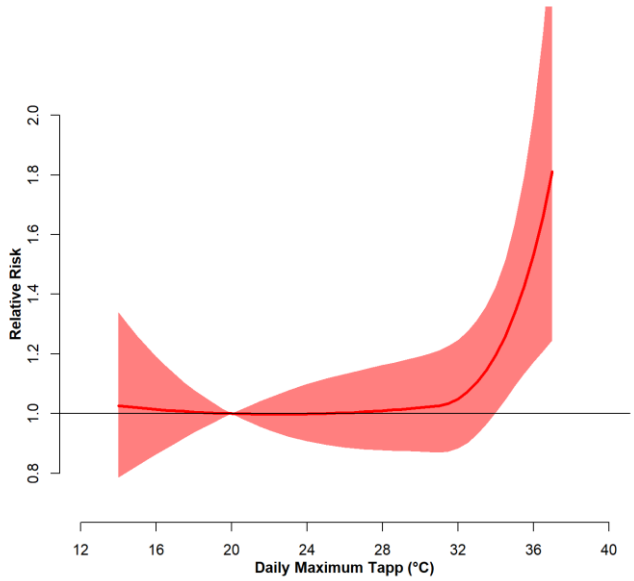


Figure 8. Lag structure between risk of mortality and heat exposure in Thessaloniki.

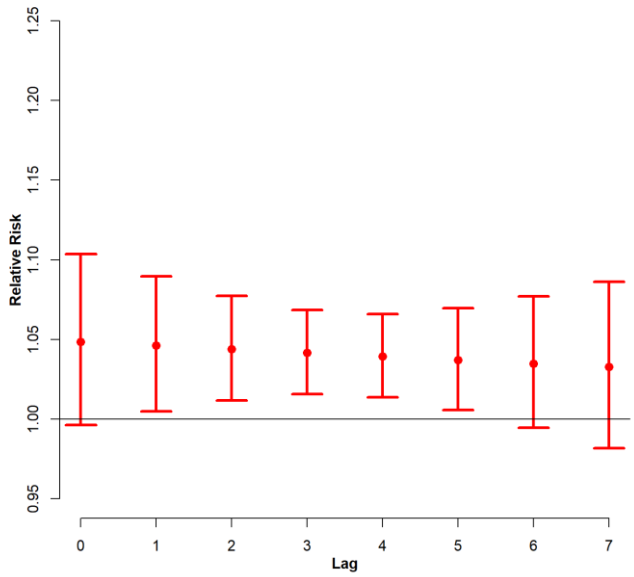


Figure 9. Association between maximum apparent temperature and mortality in Rome, summer period 2013-2018.

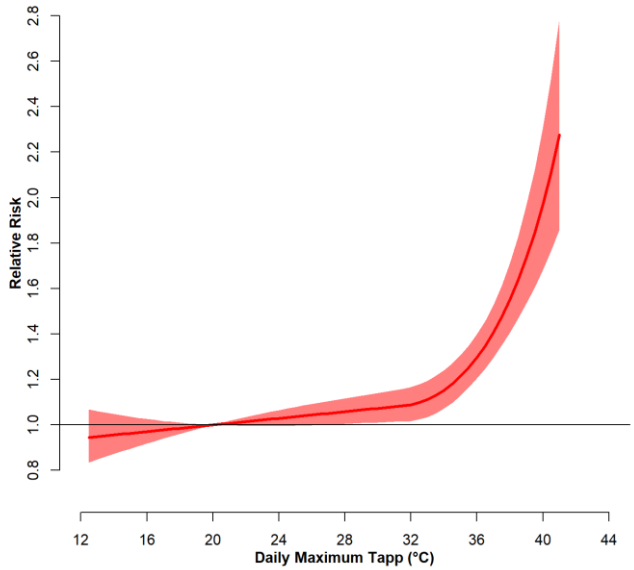
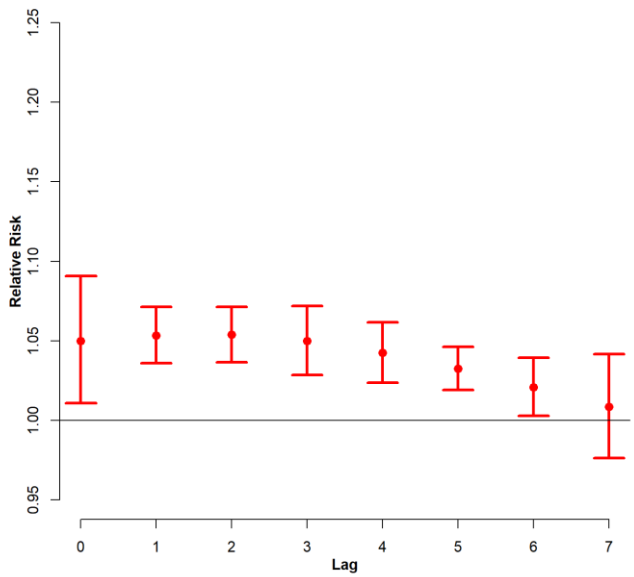


Figure 10. Lag structure between risk of mortality and heat exposure in Rome.



iii. HHWW model definition

In Italy, city-specific heat warning systems have been operational since 2004 in major cities including Rome and are part of the Ministry of Health national heat prevention plan (Michelozzi et al. 2010). The tappmax threshold model is defined on the basis of the relationship between mortality and Tappmax investigated through a city-specific Poisson regression model. The explicative variables included in the model are:

- holidays, month (May–August),
- the interaction between Tappmax and month
- the number of consecutive hot days with Tappmax above the threshold.

For each value of Tappmax, the model estimates the associated increase in daily mortality and, on the basis of these results, defines monthly thresholds. A progressive increase in threshold levels was observed.

This model implies a graded classification of risk defined as:

- low (<20% excess in mortality)
- high (≥20% excess in mortality).

Threshold levels for warnings are then defined on the basis of the data as shown below in figure 11, yellow corresponds to an Alert – Level 1 warning and orange corresponds to level 2 – Alarm warning. In Italy level 3 – heat wave warning is the 3rd consecutive day of level 2.

Figure 11. Rome thresholds and mortality excess predicted by the tappmax regression model.

5	29		9.9		10.4	14.3			
5	30					-6.1	4.4		
6	31	1.2	5.7						
6	32	6.1	5.3						
6	33	22.7	20.5	19.1	18.6				
6	34	18.5	16.5	18.5	13.8	17.2	17.8	18.7	19.7
6	35	25.0		25.4	30.9		29.4		
6	36	50.0	49.3		50.0	50.2		61.8	
6	37				52.4	58.1	60.9		
6	38						89.9		
7	33	5.4	6.7		0.4		6.4		12.0
7	34	5.9	9.1	6.4	9.6	2.8		13.0	14.0
7	35	11.1	9.2	12.1	7.0	10.2		20.4	
7	36	27.1	24.3	21.8	27.1	25.8	36.9		25.2
7	37	20.4			15.8	26.4	26.0	28.7	21.4
7	38								28.8
7	39			8.4					
8	34	4.7	13.4						
8	35	11.7	16.0	11.7	13.9				
8	36	23.8	22.9	26.4	17.6	19.1	27.4		
8	37	18.6	18.0	18.3	13.2				21.9
8	38		35.8	29.0	33.2	32.7		45.3	
8	39	23.2	31.8						

For Thessaloniki , the same threshold model will defined on the basis of the relationship between mortality and Tappmax investigated through a city-specific Poisson regression model. The explicative variables to be considered in the model are:

- month (May–september),
- the interaction between Tappmax and month
- the number of consecutive hot days with Tappmax above the threshold.

For each value of exposure, the model estimates the associated increase in daily mortality and, on the basis of these results, defines monthly thresholds. If a progressive increase in threshold levels is observed, a graded classification will be defined as was done in Rome.

Figure 12. Thessaloniki thresholds and mortality excess predicted by the tappmax regression model.

mm	tappmax	1	2	3	4	5	6	7	8
5	27								
5	28								
6	31								
6	32								
6	33								
7	31								
7	32								
7	33								
7	34								
8	31								
8	32								
8	33								
8	34								
9	27								
9	28								
9	29								
9	30								

Preliminary results or a possible graded warning grdi is shown above for Tappmax by month. The as general indication, as Thessaloniki has smaller number of daily deaths it was less clear to identify cut-offs of level 1 10% excess mortality and level 2 >20% . We also took into account the monthly 90th percentile of Tappmax as threshold for level 2 (May:26.3°C, June:32.7°C, July: 33.8°C, August 33.8°C, September :29.8°C) and number of days in the time series in order to not have too many warning days.

Different temperature exposure indicators will be tested: Tappmax, tmean, tmax, and other thermal bioclimate indices defined in C1 such as DI and UTCI. All results will be discussed with MOT and AUTH and final thresholds defined. Different forecasting grid points will also be evaluated in the trial period and model run using forecast data as well.

iv. HHWW model validation

Testing of the models will be carried out in summer 2019 and predicted warning days will be compared to observed warning days (calculated using observed weather data). This will allow the goodness of forecast produced in ASTI LIFE to be evaluated as well as predictive capacity of

the model itself. To account for health impact mortality on HW days (predicted and observed) will also be evaluated.
In Rome the model is consolidated and has been operational since 2005 and the goodness of fit is mainly on the ASTI LIFE forecast, while in Thessaloniki the model is new and will be run in test mode to evaluate both forecasting ability and appropriateness of thresholds identified.

v. References

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