Evaluation of Near Real Time Data from ECMWF during European Wildfires

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Prologue

The Mediterranean ecosystem has been shaped by its summer conditions, a combination of droughts, fire and a nutrient poorness of various soils have created communities of vegetation that can withstand these adverse conditions. The fires control age, structure and species composition of the vegetation, the frequency and intensity of fires are controlled by the vegetation and the climatic conditions. Fire balances the vegetation succession, and was a natural part of the vegetation cycle, however the rise of humans disrupted this cycle early on. The need for grazing by domestic animals and extensive agriculture caused humans to dominate the landscape (Moreno & Oechel; 2012).

In the 21st century, climate change has affected massively this vegetation cycle, fires are more intense and more regular. Every summer in the Mediterranean region fires erupt causing big problems in the urban environment and the wildlife of the ecosystem. 2017 was particularly bad in terms of forest fires, not just in the Mediterranean region but in America and Russia too, climate change was blamed for this by media, and government officials.

Fire emissions are extremely important as for some chemical compounds such as carbon dioxide and monoxide, the total annual emissions are comparable to what is emitted from anthropogenic sources (Crutzen et al; 1979). It is obvious that air quality is massively affected by the chemical compounds that are deposited by the biomass burning (Amiridis et al; 2012). This makes accurately modelling fires essential to depict the damage the fire did to the air quality in the area. However this is a challenging task as fires don’t last long and most of the times they occupy a small area, which creates a need for higher resolution modelling and continuous data. Another problem is the transportation of the various chemical compounds, which requires very accurate modelling of the meteorological conditions when the fire happened. All of these various difficulties make modelling accurately the spatial extent, optical properties and concentrations of the various aerosols that get released from the fire, from a standard Global Climate Model (GCM) very difficult.

The European Centre for Medium-Range Weather Forecasts (ECMWF) has such a model called Integrated Forecasting System (IFS). This research will attempt to validate the Near Real Time (NRT) data provided from ECMWF at the time of the fires. The optical properties of the aerosols emitted will be compared to station data from AERONET. The main reason behind this choice is the richer record of aerosol optical depth data than concentration data. Three fires will be used that occurred in 2017, two in the Iberian Peninsula, one in October and one in June. One in Greece, in August and the fire in Sweden in 2018. The two fires in the Portugal were large scale fires that caused human casualties and were one of the worst in the history of Portugal. The one fire in Greece was much smaller and there were no casualties, and the fire in Sweden was much larger and one of the longest lasting.

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Chapter 1: Introduction

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1.1 Generally

The four fires that are chosen have very different characteristics. Firstly the two fires in Portugal were large scale fires that were out of control for a number days. In the June event the fire started in the mountainous regions of the Pedrógão Grande municipality, the fire resulted in 66 deaths and 204 people injured. The cause of the tragedy most likely was a dry thunderstorm as an intense heat wave preceded the fires during the night in 17-18 of June. In contrast to the June event the fires started in 13th of October and they were exacerbated by the meteorological conditions as the hurricane Ophelia passed between the Azores and helped fan the fires into Spain. This event caused 45 deaths in Portugal and 4 in Spain.

In both cases meteorological conditions seem to have played a vital role in the tragedies. In the June event the sheer number of fires, a total of 156 fires erupted across the country in a very small amount of time, caused the event to grow out of control, while in the October event the hurricane caused the existing fire to grow out of control. In the June event the president of the Portuguese fire-fighters league believed it was caused by arsonists and in the October event the prime minister of Portugal believed the fire was also started by arsonists. Whichever the case may be the models will be tested in these different meteorological conditions in the same area.

In contrast to the Portugal fires, the fire in Greece was of very small scale and it lasted only a couple of days, however there were also fires in other countries northern of Greece and their aerosol might affect the way the model interpreted the spatial distribution of aerosols. Another key difference is that the fire in Greece was near Athens while the fires in Portugal were mainly in the mountainous regions.

In the wildfires in Sweden the situations was radically different as the fires really started in May and ended around August, with their peak being in July. The fires were caused by an unusual heatwave, as May and July were the warmest ever recorded in Sweden. The average temperature was more than 10 ^{o}C above normal. The fires were reduced in late July due to Sweden having the first significant rain in months. The fires couldn't be extinguished by the firefighters even though there was significant mobilization from neighbouring countries. The only reason there were no human casualties was because the fires happened in low human population density areas.

These differences between the events will help validate the model in different meteorological conditions, climates and scale of events. The ECMWF model has already proven to have deficiencies in the modelling of fires (Giuseppe et al; 2016), this research will aim to evaluate the weaknesses and strengths of the model during these events.

1.2 Methodology

Firstly, the duration and the source of the fire must be defined. For this process NASA's WORLDVIEW will be used to identify fires and thermal anomalies. Knowing the source and duration of the fire the wind trajectories must be found in order to find where aerosols get transported to, this step is extremely important because stations must be identified in the general direction of the wind trajectories in order to validate the ECMWF. A general tool used for trajectories of aerosols is National Oceanic and Atmospheric Administration's (NOAA) Hybrid Single-Particle Lagrangian Integrated (HYSPLIT) model (Draxler et al; 2003), the model constructs and maps trajectories for a theoretic single particle, the origin of the particle can be defined in various heights. For this research multiple trajectories will be constructed during the period and for different original heights. The results of the model will be used as a general guide to pick which stations to evaluate, that means that some stations that did not fall into the trajectories will be used in the evaluation. The reason being that the model might have deviations from the actual trajectories.

The stations will be chosen from the Aerosol Robotic Network (AERONET) and the main products that will be used are AOD. The data from AERONET will be compared to the NRT ECMWF data after the latter have been interpolated to the location of each station. In order to make the comparison more accurate the model and the stations will be compared on an hourly basis. The data must be compared on the exact time period because Aeronet data are collected through out the day but if the data of the model are on a particular hour there might be a spike of aerosols that would raise the AOD significantly. To avoid this mistake the model data will be downloaded on 12 UTC and the station data will be averaged over 12 +- 1 hour. This practically means that the Aeronet values of a station that were between 11 and 1 UTC will be averaged and then compared to the model values. This process will allow the comparison of the two datasets and the calculation of percentage loss for each day and a Root Mean Square Error (RMSE) for the total of days. The NRT ECMWF data also provide an estimation of 4 individual aerosol AOD's, Dust, Sea Salt, Black Carbon and Organic matter. These datasets give an insight as to what composition of aerosols exist over a given station according to the model's calculations. This will be important because some losses in the model estimations can be attributed to an overestimation of a different aerosol than the ones that are usually associated with fire.

In the days where there are large disparities between the model and the Aeronet data, it's important to also examine the inversions that are provided by Aeronet. The inversion code provides aerosol optical properties in the total atmospheric column derived from the direct and diffuse radiation measured by Aeronet Cimel sun/sky-radiometers. The code inverts sky radiances simultaneously at all available wavelengths for the complete solar almucantar scenario or principal plane scenario ($\sim 2.0^o < \Theta$) together with measurements of aerosol optical depth $\tau(\lambda)$ at the same wavelengths. Depending on the model of Cimel radiometer, the measurements may be taken on all or some of the following spectral channels: 0.34, 0.38, 0.44, 0.5, 0.675, 0.87, 1.02 and 1.64 μm. What is particularly useful is to plot the volume distribution of different particles. Fine mode particles mainly represent organic matter particles while coarse mode particles are either dust or sea salt aerosols. This distribution can be used to compare the aerosols that the model simulates above the stations with the actual distribution. This method is mainly limited by the scarcity of data, since the inversion datasets don't have as much data as the AOT datasets.

Chapter 2: Fires and aerosols

Chapter 2: Fires and aerosols

2.1 Generally

Large scale fires radically affect air quality, as was mentioned previously, this is due to the biomass burning. The aerosols that are emitted also affect the climate of the earth by changing its energy budget. Aerosols in general scatter and absorb radiation that enters the earth's atmosphere. Theoretically aerosols that absorb radiation should heat the earth and aerosols that scatter the radiation should cool the earth, however the different heights, extinction times, microphysical and optical properties of each type complicate the calculations. Furthermore the albedo of the earth's surface plays an extremely important role in the effects that the aerosols have in the atmosphere, a higher albedo will generally make aerosols heat the atmosphere because the more radiation get reflected back to the atmosphere.

The quantification of the actual effects of the aerosols on the earth's energy budget is further complicated by the indirect effects of the aerosols, as aerosols affect the hydrological cycle. Cloud formation requires nuclei for water vapor to condense and liquefy, aerosols such as dust, soot, black carbon from grassland or forest fires and sea salt act as condensation nuclei most of which are aerosols. Clouds in turn are very important for the earth's radiation budget as they cover 60% of the earth's surface and they can reflect of absorb light. A change in aerosols or condensation nuclei in general can increase or decrease cloud cover (Khain et al; 2008). Modelling all these different processes is extremely hard because the microphysics of the clouds are not clear yet. All these different processes make it very hard to identify the total forcing of the aerosols.

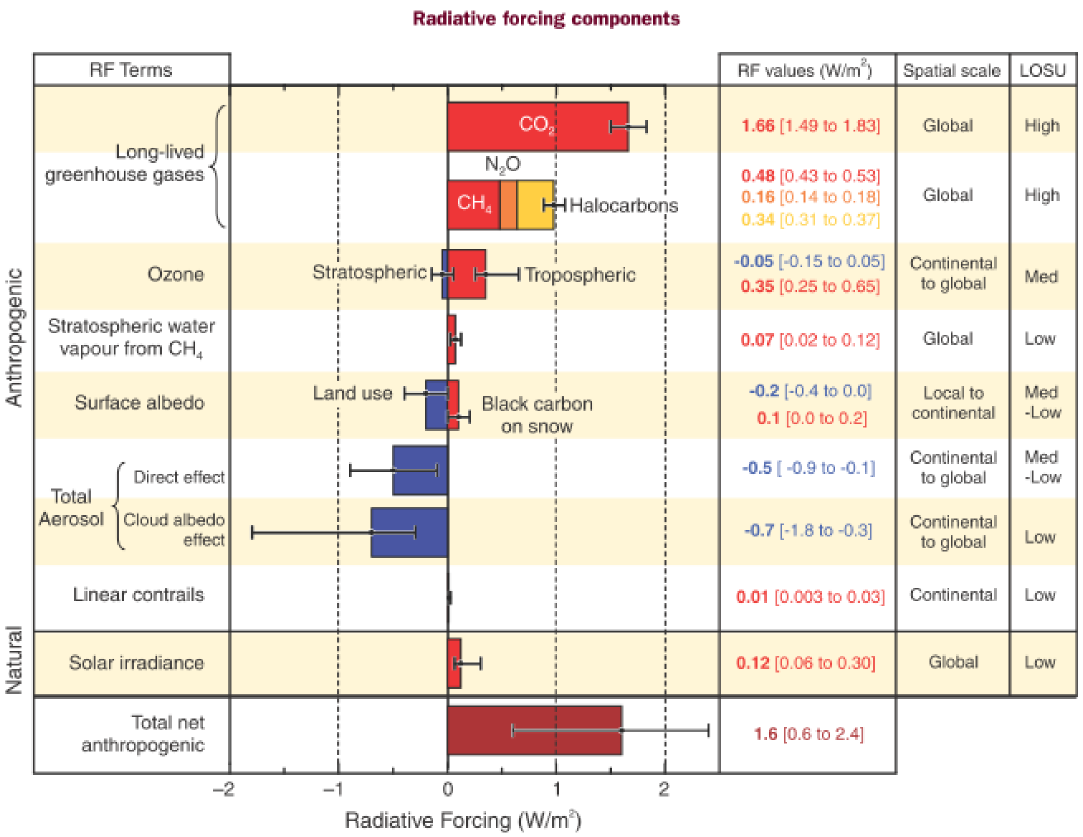


Figure 1: Anthropogenic forcing to the climate, aerosols have a very large uncertainty. (IPCC; 2007, Figure 2.4)

There are mainly two types of aerosols that are emitted from a wildfire Black Carbon (BC) and Organic Matter (OM) aerosols. Particles emitted from fires have significant effects on the climate system, first directly by absorbing and scattering incoming solar radiation (Carslaw et al; 2010), as most aerosols do, but more important are the indirect effects as they are harder to model and quantify. Fire aerosols can change the surface albedo when they are deposited on snow and ice (Flanner et al; 2007). They also interrupt the hydrological cycle by changing the atmospheric thermal structure (Kock and Del Genio; 2010) or by acting as condensation nuclei (Lu and Sokolik; 2013), which is also common among other types of aerosols. Black carbon and Organic matter aerosols emitted from fires are comparable to the anthropogenic emissions.

In the 2016 study by Jiang et al; (2016) they studied forest fires globally in the period of 2003-2011 and they found that globally biomass burning contributes 41% and 70% to the total emissions from BC and OM respectively, they also found that the

SO_2 that is emitted from fires contributes a much smaller percent (3%) than the BC and OM.

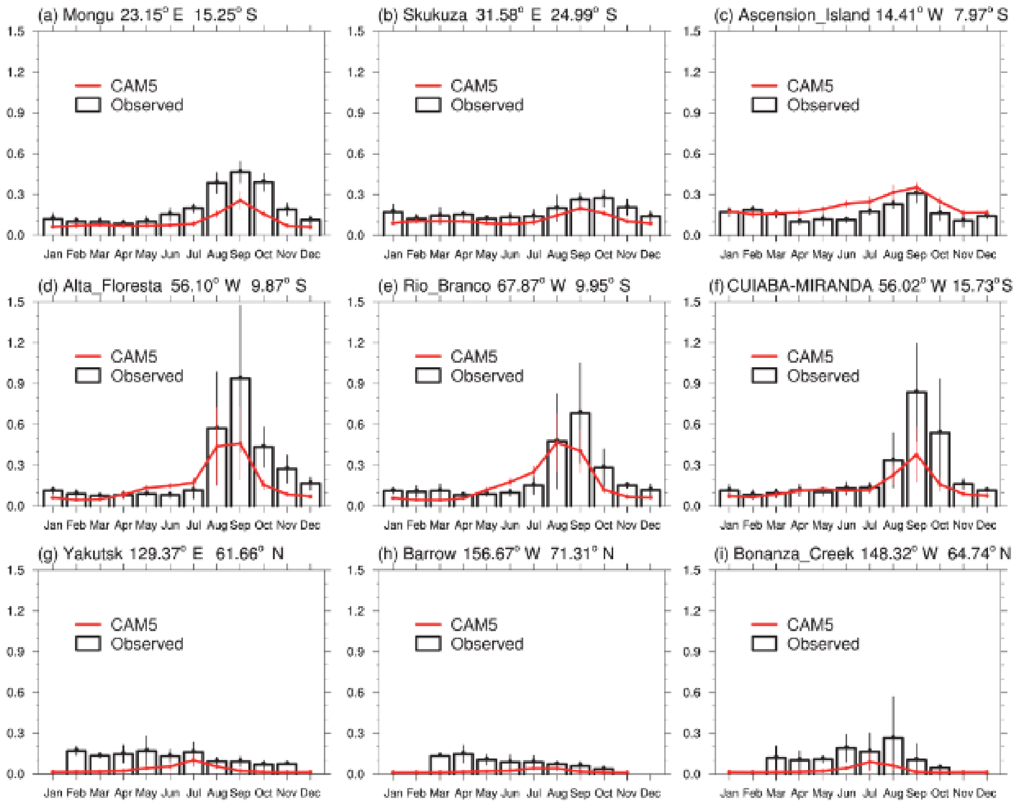


Figure 2: Comparison of modeled (CAM5) and observed (AERONET) values of the seasonal variation of aerosol optical depth (AOD) for the period 2003-2011. The upper, middle and bottom panels represent sites in southern Africa, South America and the Arctic respectively (Jiang et al; 2016, Fig. 2).

In the same study they also tried quantifying in W/m^2 the different effects of the aerosols, firstly the radiative effects due to aerosol-radiation interactions (direct effects) and also the radiative effects due to the aerosol-cloud and albedo interactions (indirect effects). They then calculated these effects for each of the aerosols individually using two methods, the first is by running the model in various conditions and then calculating the standalone effect of each aerosol, for example if one wanted to find the black carbon effects, they would simulate the fire normally first and then they would simulate it without black carbon then by subtracting the two they would find the effects of black carbon. This method is called BBFFBF in the paper, the other method that they used is one described by Ghan (2013).

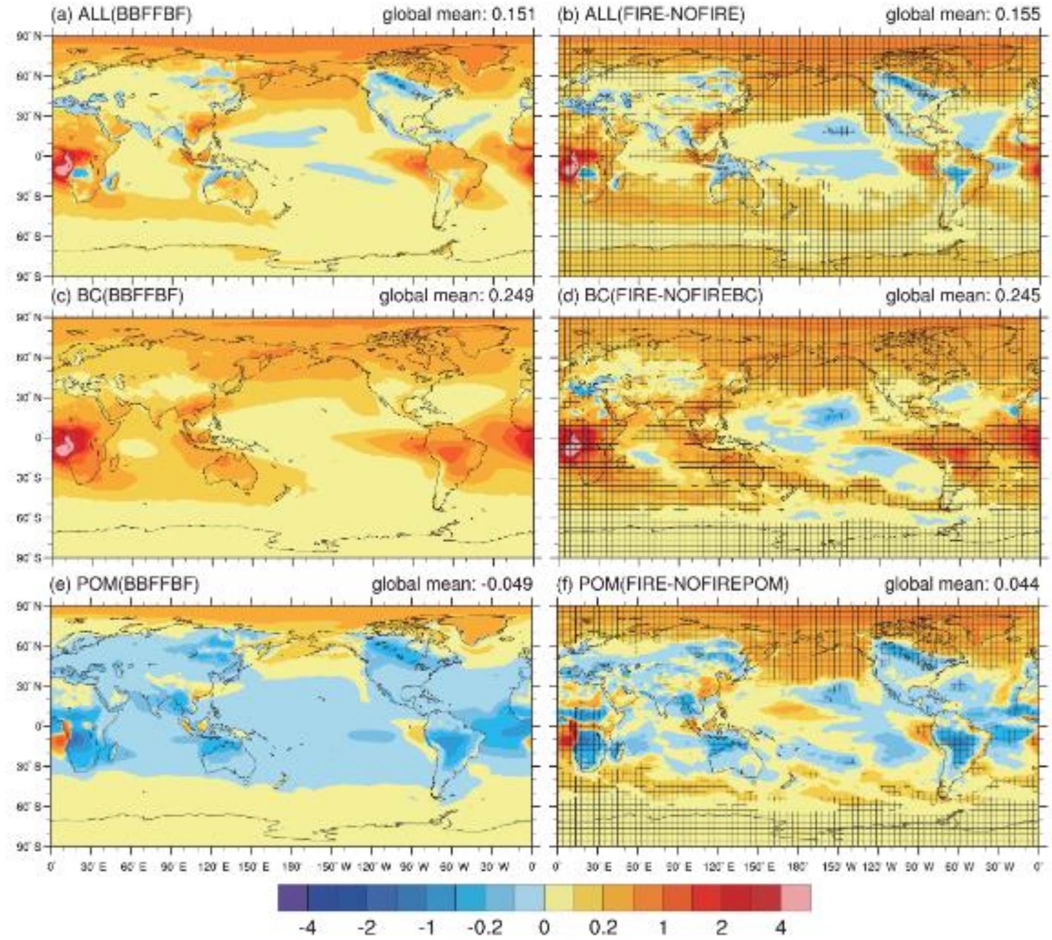


Figure 3: Annual radiative effects due to aerosol-radiation interactions in W/m² averaged over the 2003-2011 period. The first, second and third rows represent the total, black carbon and organic matter. The left panels represent the BBFFBF method and the right the method described by Ghan (2013). Regions in the right panels that have crosses represent statistical significance at the 0.05 level (Jiang et al; 2016, fig. 4).

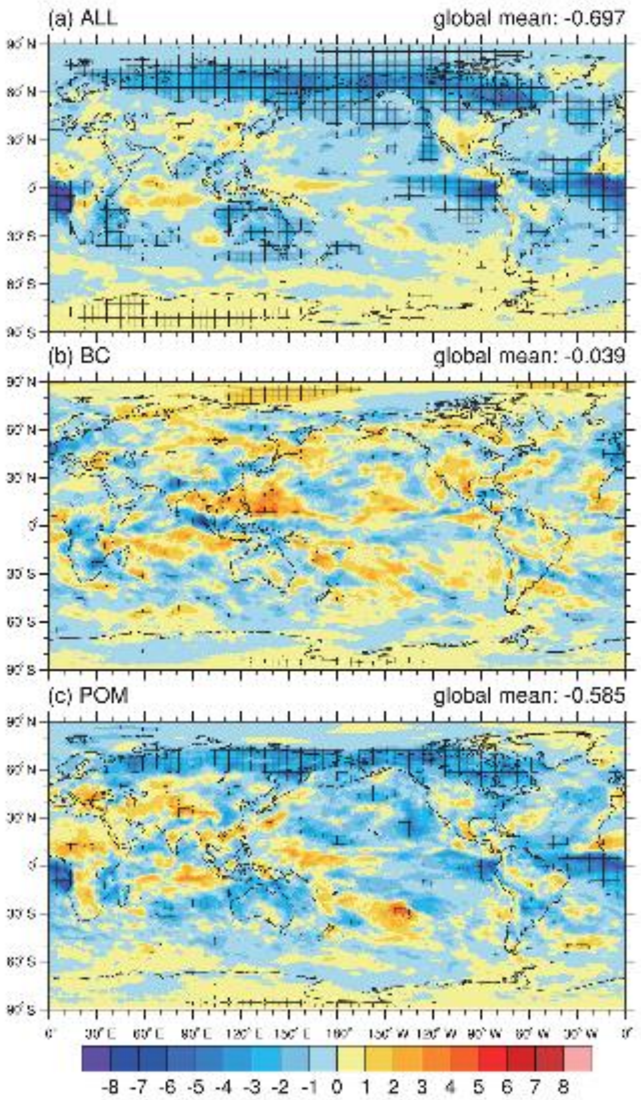


Figure 4: Annual radiative effects due to the aerosol-cloud interactions averaged over the 2003-2011 period. A) represents all fire aerosols, B) black carbon and C) organic matter, the plus signs indicate statistical significance at the 0.1 level (Jiang et al; 2016, fig. 6).

To calculate the aerosol albedo effects of the black carbon in snow they also used the Snow, Ice and Aerosol Radiative (SNICAR) model (Flanner and Zender; 2005).

From the graphs it can be seen that the aerosols have a general cooling effect on the atmosphere.

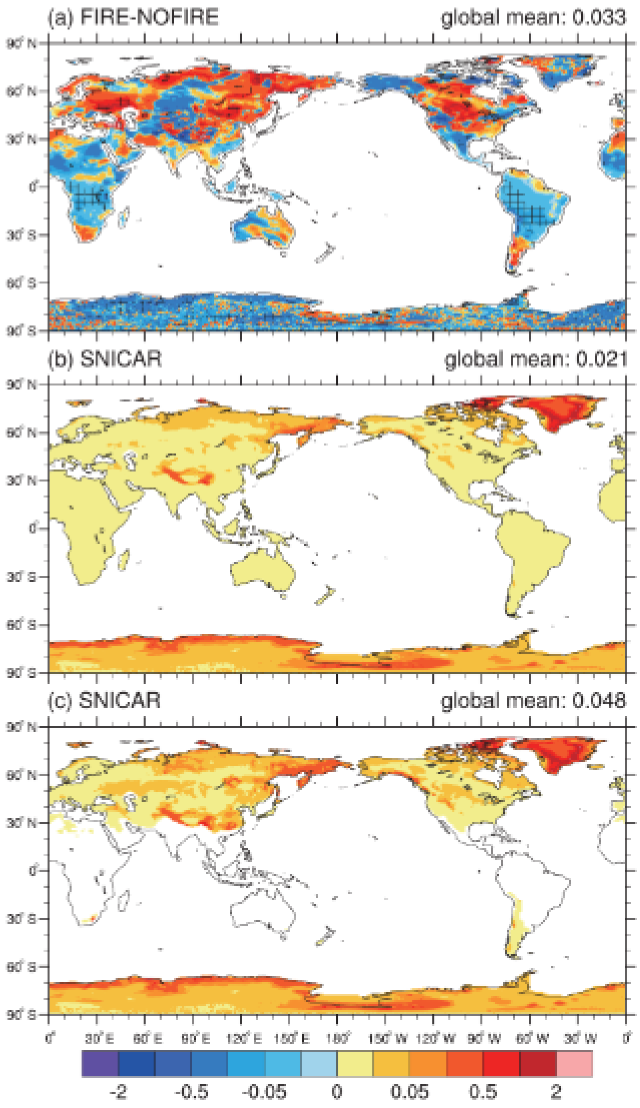


Figure 5: A) Annual mean radiative effect due to surface-albedo changes in W/m^2 averaged over the 2003-2011 period of all fire aerosols over land regions. Annual mean surface effect of Black Carbon in snow calculated from SNICAR over b) all times and c) only when snow is present. The plus signs in a) denote statistical significance at the 0.1 level (Jiang et al; 2016, fig. 10).

This research highlights the complexity of modelling the different effects fires have in the climate. As the authors noted there are still uncertainties and the model seems to underestimate observed AOD's when compared to real data from AERONET. However it is clear how big of an effect the fires have on the climate and how much progress can still be made.

The wildfires at the South American can give a better understanding of how far-reaching the effects of a wildfire can really be. Every year during the dry season large scale fires are observed and although natural occurring fires aren't uncommon during this season, most of the fires are a product of human activity. These fires are started in order to clean forests, savannas and grasslands for ranching or farming. In one particular event in 2002 the fires almost crossed the Atlantic Ocean (Freitas et al; 2005).

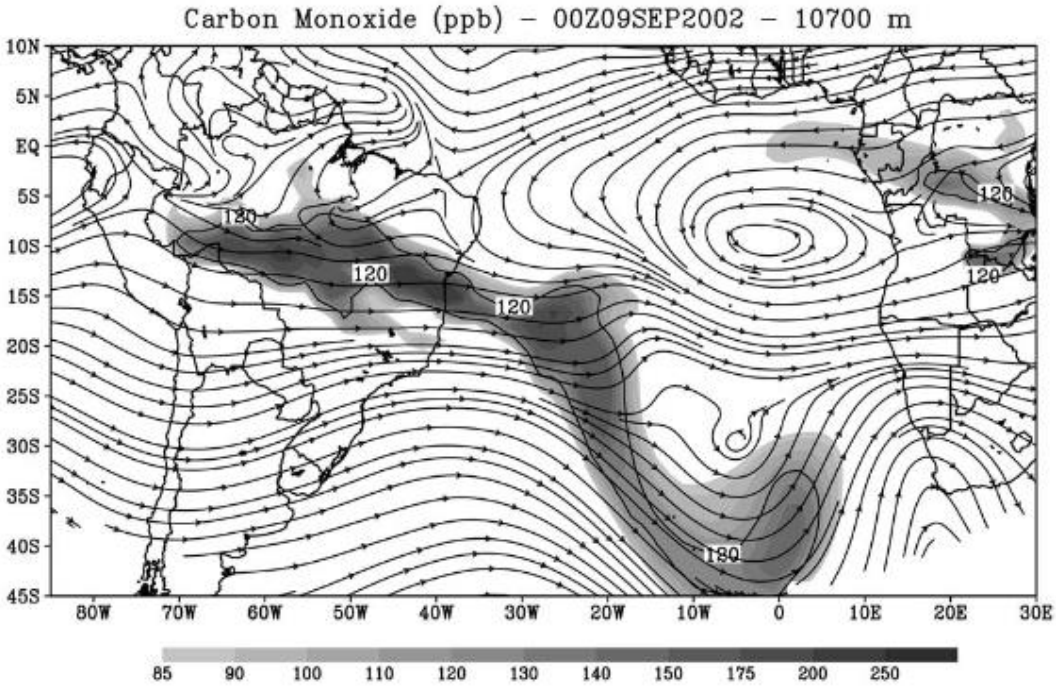


Figure 6: Long distance transport of CO at 10700m on 9 September (Freitas et al; 2005, Fig. 9)

Another example are the Indonesian fires where every year fires are used for deforestation for similar reasons to the ones in South America. These have been some of the most destructive fires in history. The wildfires that started in 1997 lasted well into 1998 and were one of the largest wildfires ever recorded. The fires were estimated to have released 0.81-2.57 gigatonnes of carbon into the atmosphere this is between 13-40% of the annual emissions from fossil fuel burning (Page et al; 2002).

2.2 Fires in the Mediterranean

As mentioned previously fires in the Mediterranean basin are common and are part of the vegetation cycle in the region. In fact there is evidence that fires were frequent during the last Quaternary (Carrion et al; 2003), this also evident by the plant species composition of the Mediterranean landscape. The spatial distribution of plant species has been structured according to the different fire regimes (Pausas & Verdu; 2008). This means that plants have already developed mechanisms in order to cope with fires, so fires are part of the natural process. However fire events in recent decades have increased.

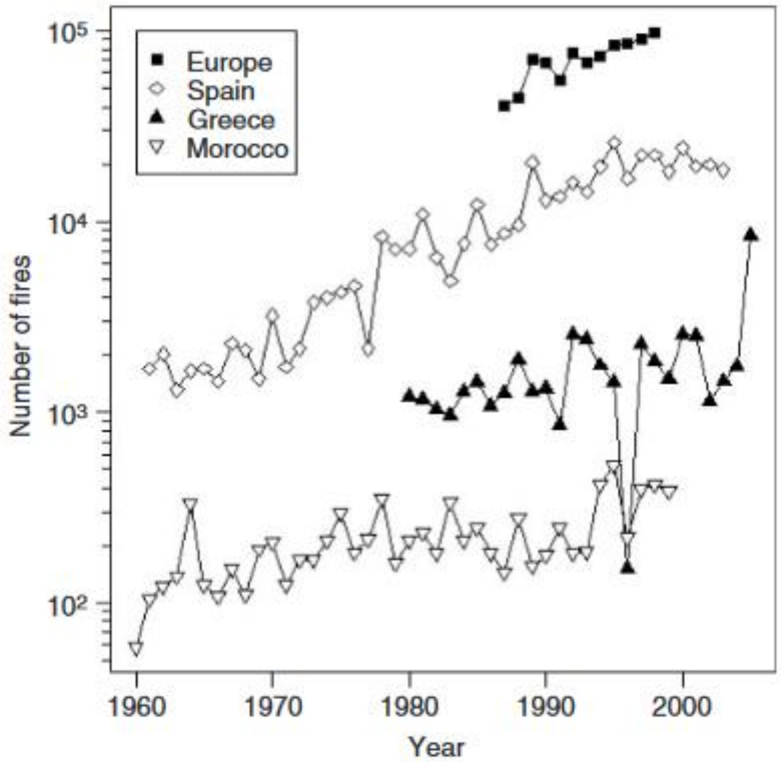


Figure 7: Evolution of number of fires during the last decades in different regions and in Europe (Pausas et al., Fig.2 , 2009)

The reason for this increase was studied by Pausas & Fernandez-Munoz (2012), and they found that the rural exodus during the 1970’s was partly to blame. The other big factor was climate change, and what the authors found is that the two driving forces work synergistically.

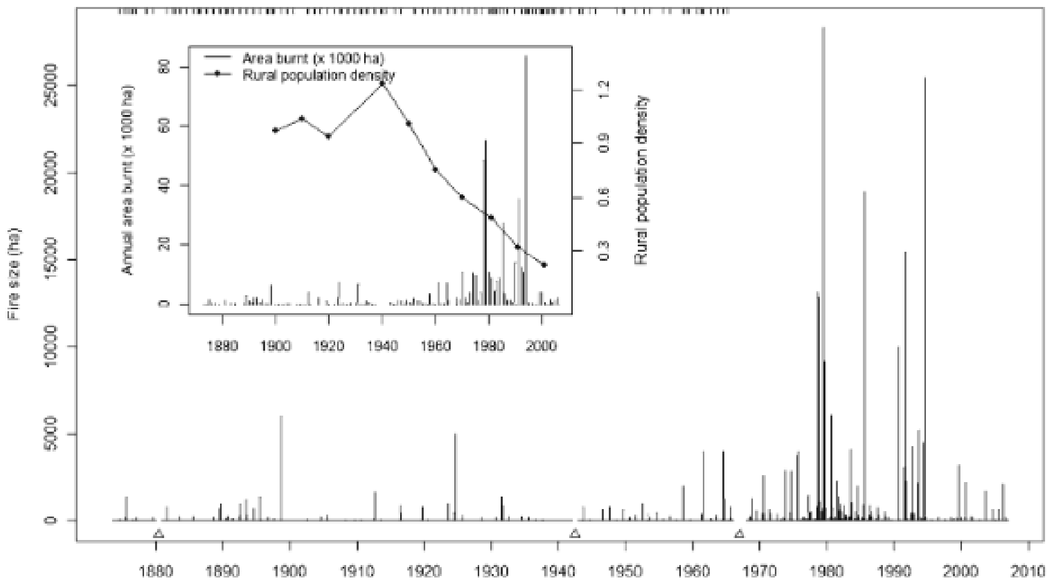


Figure 8: Fire occurrence and size in Valencia for the 1873-2006 period. The triangles in the x-axis indicated missing data, the ticks in the upper x-axis indicate unknown fire size. The inset figure represents annual area burnt (histogram) and the population density (inhabitants/ha), the fires that were of unknown size were given the mean size of the 1873-2006 period (Pausas & Fernandez-Munoz, Fig. 2 , 2012).

This means that the populations that inhabited the rural areas used to clear the land of fuels for the fire. Once the rural exodus started the fuel was left unmanaged thus it was easier during a drought season to have wildfires. This means that the dry conditions, that are projected to become more frequent (Allen et al., 2010), are causing fires and they are helped by a fuel accumulation due to land-use changes. Fire may be part of the ecosystem as mentioned previously but, they also pose a serious risk to humans, firstly due to human casualties and atmospheric pollution.

A study by Amiridis et al (2012) was done on the 2009 Attica wildfire in August, where wildfires ravaged the forests of the north-eastern fringes of Athens. During the fire North-eastern winds fanned the flames causing the fire to intensify and spread the front towards Mount Penteli. The plumes from the fire were directed towards the city.

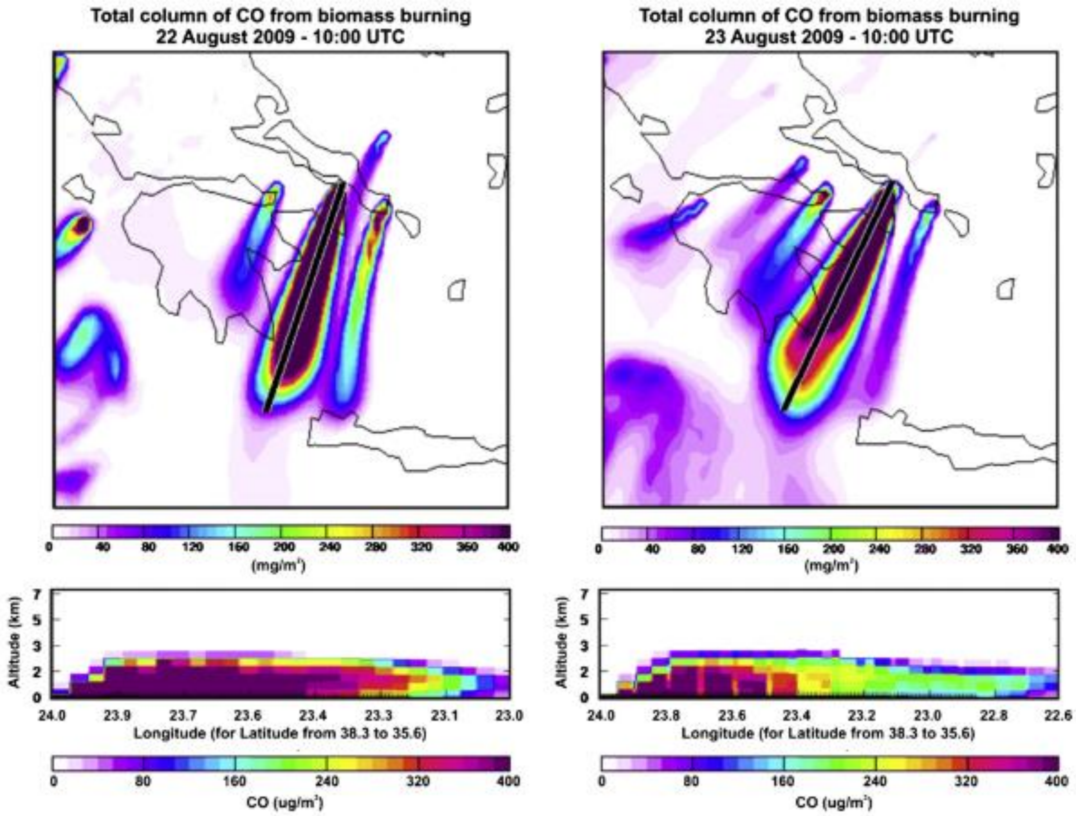


Figure 9: FLEXPART simulation of CO concentrations from the fires as captured by MODIS. The spatial distribution of the concentration is displayed in the upper panels while in the lower the vertical profile of the CO is displayed for the black line in each day (Amiridis et al; 2012, Fig. 4)

As expected the city was polluted massively, in the paper they found a reduction in solar irradiance of up to 70%. Fires in the general Attica region are common during the height of the drought season which means that pollution from wildfires is very common, in fact in a climatological basis the mean biomass burning contribution to pollution in Athens is ranging from 7% to 9% (Karanasiou et al., 2009).

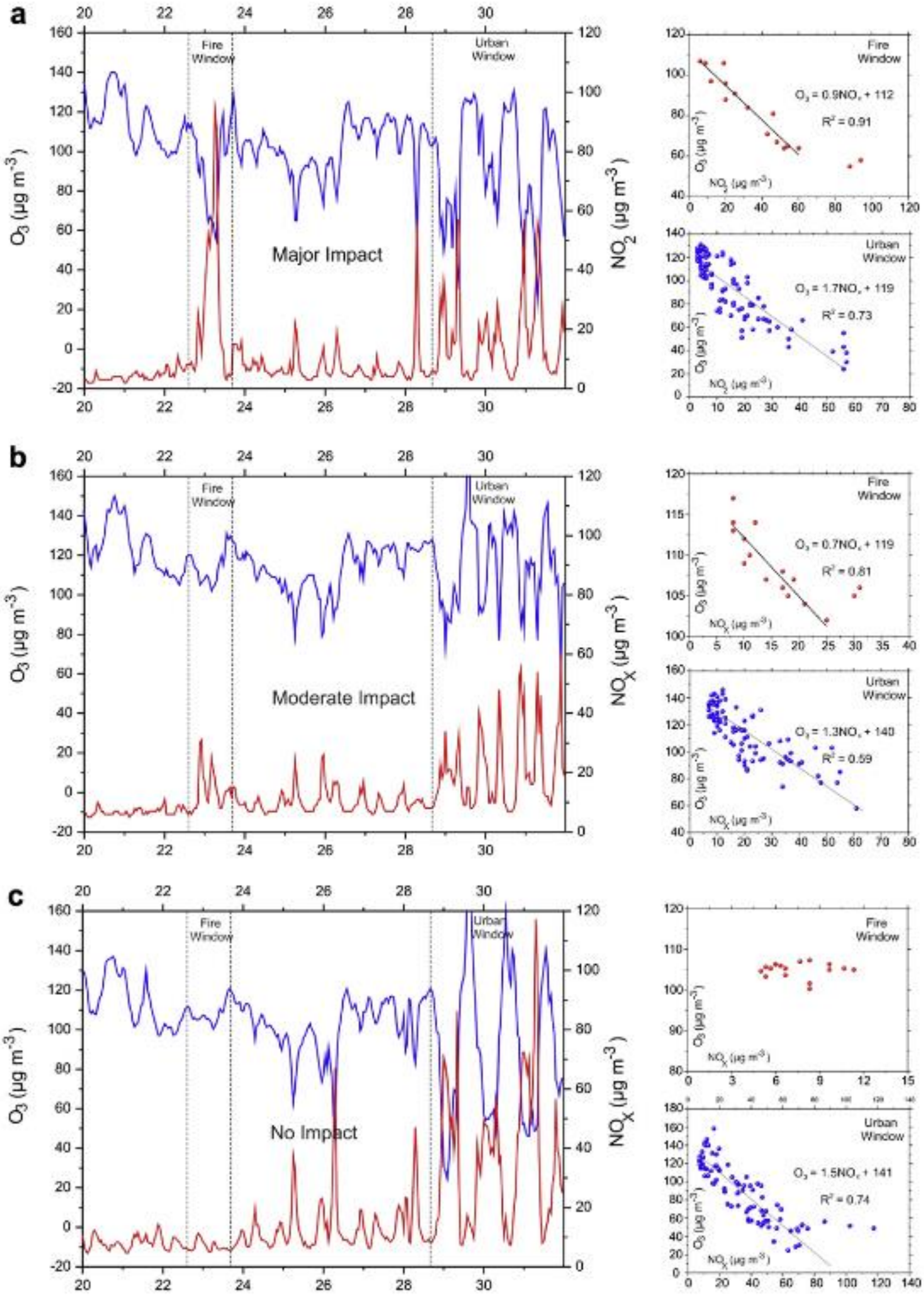


Figure 10: O_3 and NO_x surface concentration in Athens from stations that have a) major impact (Koropi) b) Moderate Impact (Ag. Paraskevi, Demokritos) and c) no impact (Maroussi, Lykovrish) from the fires. In the right panels, scatter plots of O_3 vs NO_x are presented along with linear regressions focusing on fire and a typical period of urban photochemical processes. (Amiridis et al., Fig.10, 2012).

Another hazard that comes after a large wildfire are increased risk for floods. Vegetation cover in general helps decrease surface runoff, when a forest is burned, especially in an area with a big slope, a heavy rainfall can potentially cause a flood. This was demonstrated by Cannon et al. (2008) where they studied areas that have been ravaged by wildfires in Colorado and Southern California, and in 25 recently burned basin debris flows were triggered within as little as 6-10 minutes of the rainfall starting. In response to long duration storms, debris flows were triggered in 68 recently burned areas. If the soil itself is left unaltered it is very capable of absorbing large quantities of water thus mitigating the surface runoff. However in cases of very large fires the soil temperature can increase enough to alter the clay mineralogy and form an impenetrable rocks (Dyrness & Youngberg, 1957), but this types of temperatures can only be reached in areas with the highest concentration of woody debris, making this an uncommon phenomenon. Some of the aliphatic hydrocarbons that are burned in the forest floors can move downward into the soil via convection, they then condense on the surface of cooler soil particles. They are believed to form a water repellent layer (DeBano, 1981) which decreases infiltration therefore causing more surface runoff.

The reduced vegetation cover on recently burned areas can also cause soil loss, because except from the vegetation removed, fires also remove the natural litter that exist in a forest floor, this leaves the soil uncovered and very vulnerable to erosion (McNabb & Swanson, 1990, p. 165-166). Although there are species that have adapted to constant fires as mentioned earlier their reoccupation of the area and the subsequent production of litter takes time.

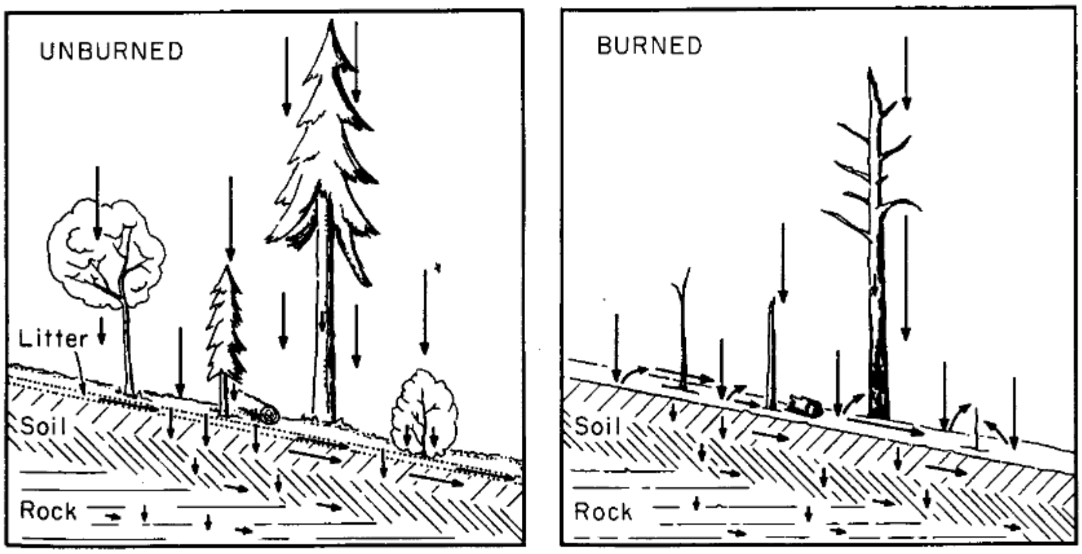


Figure 11: How vegetation and the forest floor reduce the energy of the water flowing through the litter and reaching the soil (McNabb & Swanson, fig. 14-2, 1990).

The foliage of the trees and the litter that cover the forest are important as they decreased the energy of the water droplets reaching the soil. A rain droplets falling into a forest will most likely fist drop onto the foliage of a tree or the litter in the ground reducing its kinetic energy, where as a droplet falling on a burned forest will actually drop on the ground removing more soil. More over a droplet that has first dropped on trees might actually split reducing its size which is also very important as bigger droplets remove more soil.

2.3 Future of Fires in the Mediterranean Region

When trying to analyze the possible future of fire occurrence it's important to break down the natural factors that cause a fire so it's easier to see how each one will be affected by climate change in order to make a prediction. Two factors where mentioned briefly previously, one being the climatic conditions of an area (droughts, wind speed, temperature) and the other is fuel accumulation (dead or dry biomass). But there are also anthropogenic factors which can't be modeled for the future for each area such as arson, land use changes, negligence or insufficient policies. In order to actually try to predict the future danger of fire in an area indices/models have been formulated. The most popular are the US National Fire Danger Rating System (NFDRS), the Canadian forest service Fire Weather Index (FWI) and the Australian McArthur (MARK-5) model. It's important to note that all of the previous indices/models are inherently probabilistic models since the values that are provided are related to the probability that an ignition will cause a major outbreak. This practically means that extreme fire danger may or may not be followed by a major outbreak depending on whether there is or isn't a natural or anthropogenic trigger.

Of all the indices/models that exist the FWI is the most widely used for both short and long term fire danger forecasts.

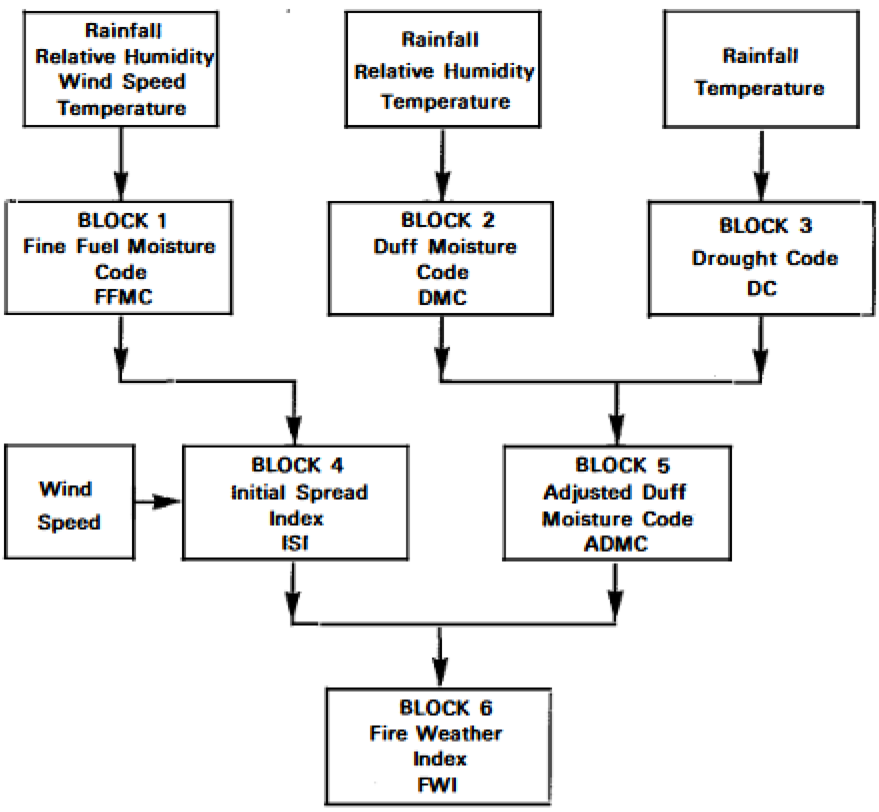


Figure 12: Diagram of parameters that are required for the calculation of the FWI (Van Wagner, 1987, Fig. 1)

This index was originally devised for fire danger estimations for the Canadian forests and since then it has been used worldwide for the fire danger estimations using the pine tree as a generalized type of biomass fuel. It only utilizes meteorological parameters taking into consideration the fuel humidity and the wind to estimate the fire behavior.

Moriondo et al., (2006) used the FWI to calculate how the fire danger might evolve in the Mediterranean. They used the meteorological outputs of the Hadley Centre Regional Circulation Model (HadRM3P) to calculate the FWI for two future climate IPCC scenarios, A2 and B2.

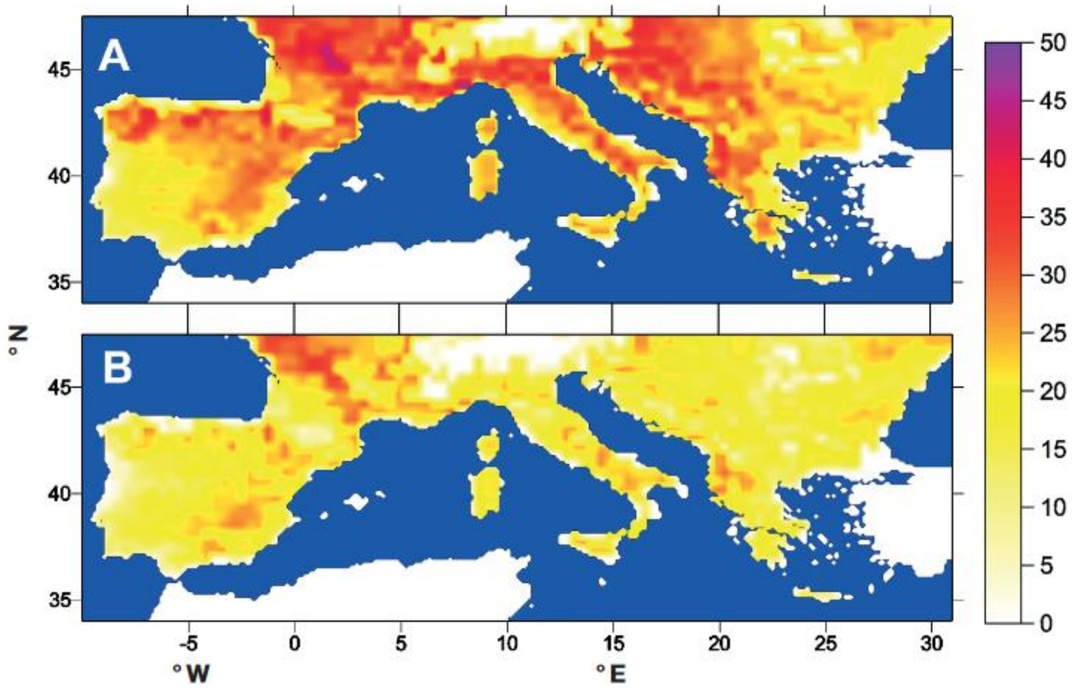


Figure 13: Percent changes in mean season FWI for a) A2 scenario and b) B2 scenario (Moriondo et al., Fig. 3, 2006).

The researchers found a general increase of the FWI in the region, an increase in days with FWI > 45 and an increase of events where the FWI > 45 for 7 consecutive days. The fire danger seems to be affected by the increase in the number and length of seasons with fire risk. They also found that the biggest increase in fire danger was observed in areas where forest cover is high.

Chapter 3: Data and Analysis

Chapter 3: Data and Analysis

3.1 Data

The NRT ECMWF uses estimations from the Global Fire Assimilation System (GFAS), which in turn converts Fire Radiative Power estimation from the Terra and Aqua satellites, which carry the MODIS instrument, into smoke constituents. However satellite daily observations have many missing values as the satellites orbit around the earth and thus can't measure all of the earth's surface. The missing values are filled by progressing in time the previous day's Fire Radiative Power estimations until an observation is obtained, this means that the GFAS's estimations are kept unchanged during the forecasting which results in an overestimation of the fire duration and in turn an overestimation of the total fire emissions (Giuseppe et al; 2016).

The station data that will be used from the AERONET are available in a lot of different formats. Each station has remote sensing instruments that measure optical, microphysical and radiative properties of aerosols, after the measurements a retrieval algorithm is applied to produce the final product. Currently AERONET has three different versions of data, in this research the most recent will be used. The data are also given in three different levels.

Level 1.0: These are the final products from the algorithm however they have not been cloud-screened.

Level 1.5: The data have been cloud-screened in this level.

Level 2.0: The data have been cloud-screened and have been manually inspected.

The best possible quality data are Level 2.0 data but these take approximately 12 months to get published while Level 1.0 and Level 1.5 are published near real time. When the Level 2.0 data are available they will be used otherwise Level 1.5 will be used.

3.2 Matching wavelengths

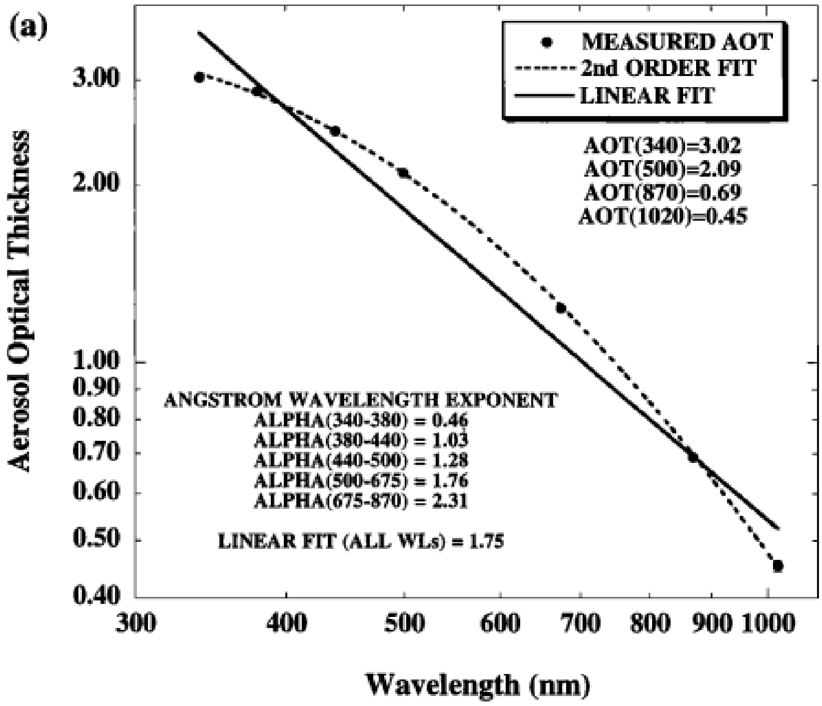
When trying to compare AOD from the ECMWF NRT data to AOD from the AERONET stations it's important to have same wavelengths in order to compare them. This can be achieved by a formula proposed by Eck et al; 1999. According to the paper if we have two AOD at certain wavelengths (λ_1, λ_2) we can compute the AOD at a wavelength (λ_3) where $\lambda_1>\lambda_3>\lambda_2$ with the following formula:

$$AOD(\lambda_3) = AOD(\lambda_1) * (\lambda_3/\lambda_1)^{-\alpha}$$

Where α is the Angstrom exponent and can be computed with the following formula:

$$a = -\frac{\ln(AOD(\lambda_1)/AOD(\lambda_2))}{\ln(\lambda_1/\lambda_2)}$$

This formula as was noted by the paper authors depends on the Angstrom component which depends on the particle radius of each aerosol. This effectively means that the formula is more effective on certain wavelengths.



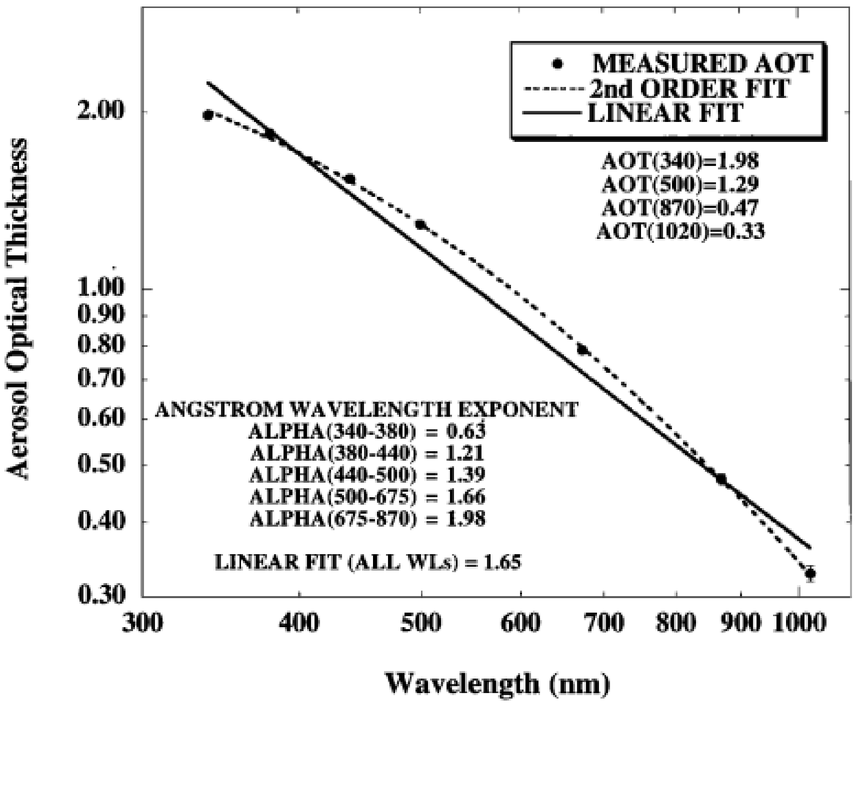
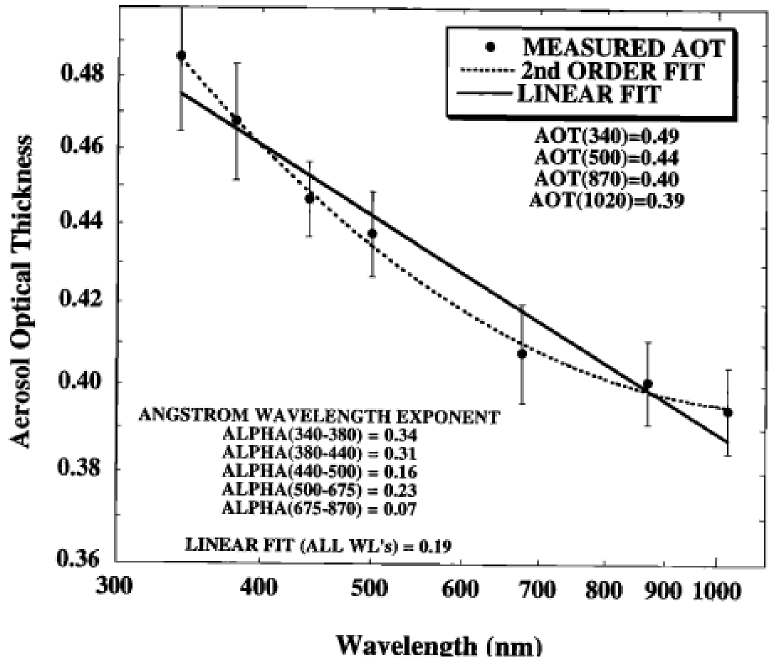


Figure 14: Spectral variation of measured AOD from AERONET for biomass burning aerosols in Concepcion, Bolivia on 24/08/1998 (top) and in Mongu, Zambia on 01/09/1997 (bottom). Linear fit and second order polynomial fit of the values are shown (Eck et al; 1999, Fig. 1.a (top), Fig. 3 (bottom)).

It's apparent from fig.1 that the formula performs best for biomass burning aerosols, which are the ones that interest the current research, in a wavelength around 400nm. It's also important to note that the 400nm wavelength perform best for dust aerosols. This is very important because the Mediterranean region has Saharan dust outbreaks frequently.



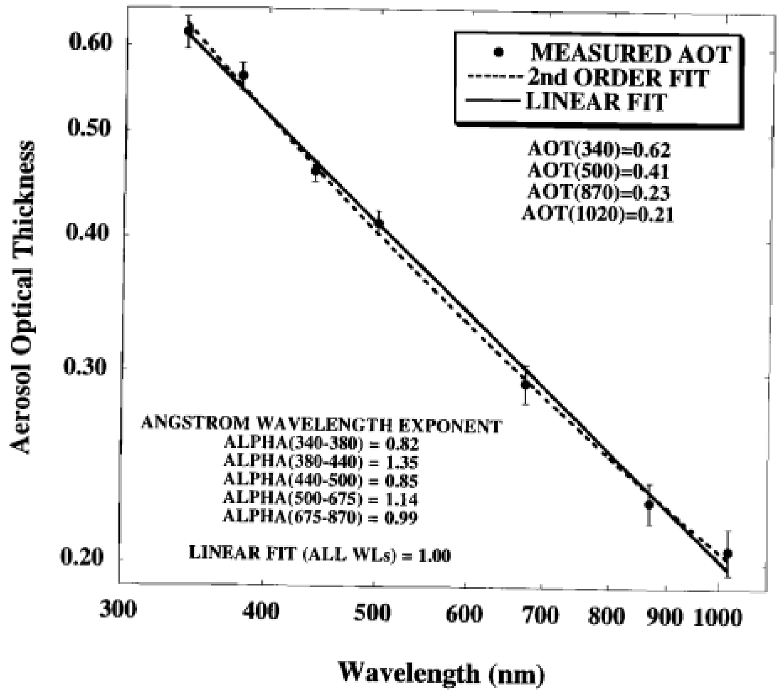


Figure 15: Same as Figure 1 but for desert dust aerosols at Dalanzadgad, Mongolia on 18/04/1998 (top) and at Bahrain on 05/08/1998 (bottom) (Eck et al; 1999, Fig.10, Fig.12).

In order to test the method the formula will be used in the Evora station on already existing data. The Evora station has data for wavelengths in 1020nm, 870nm, 675nm, 500nm, 440nm and 340nm, so the formula will be applied in the 500nm and 340nm to calculate the 440nm data. The calculated data will be compared to the real data in the period of the fire.

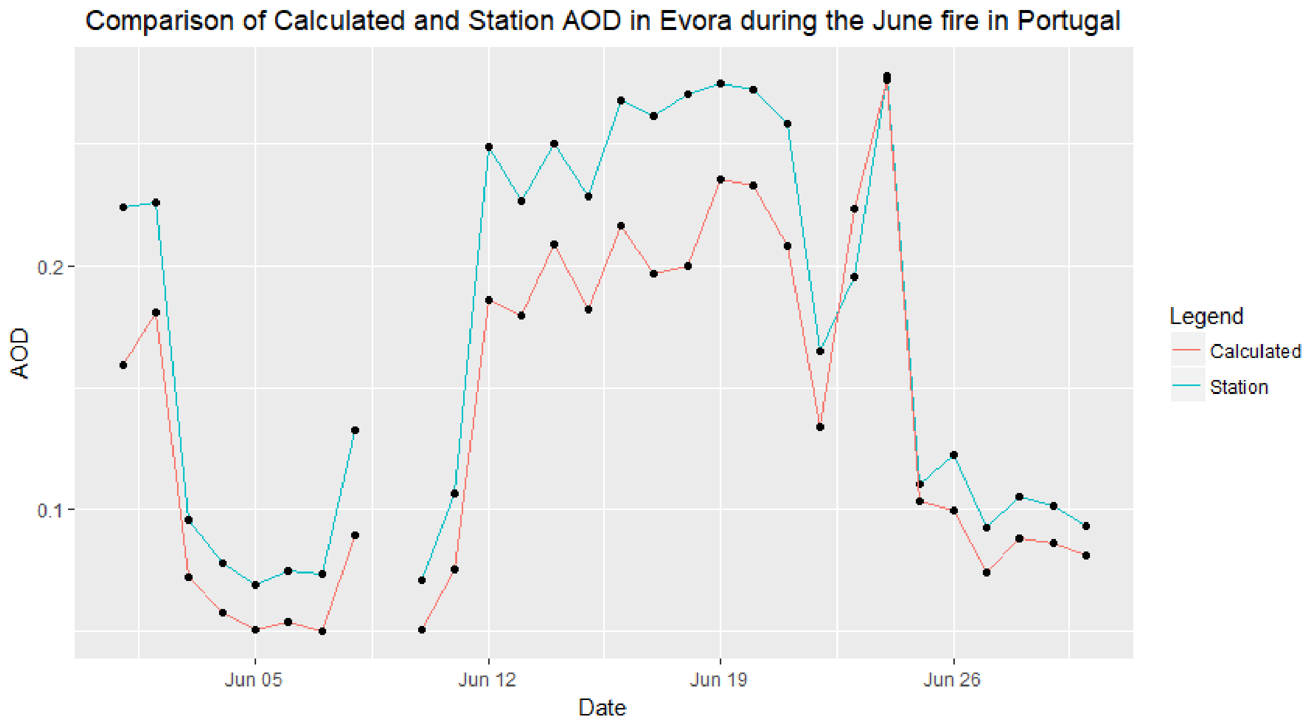


Figure 16: Evora station data from AERONET on June, 2017. Calculated AOD at 400nm (red) using values from AOD at 340nm and AOD at 500nm, compared to real station data (blue).

The fire lasted between 17 and 24 of June and during this period as is obvious from the figure the formula was underperforming in the first days of the fire while on the last days it performed very well. However the RMSE for the whole period was 0.0454 which is quite small.

For the final comparison, the AODs provided from ECMWF are at 1240nm, 865nm, 670nm, 550nm, and 469nm. From the paper mentioned previously (Eck et al; 1999) the wavelengths must be calculated around 400nm in order to be accurate but it’s impossible to calculate the AOD at 400nm since there is no AOD lower than 469nm in the data provided. This means that the station data from AERONET must be calculated at 469nm, to do this the 500nm and 400nm AODs will be used.

Chapter 4: Results

Chapter 4: Results

4.1 Portugal-June 2017

First the maps from WORLDVIEW will be presented to find the sources of the fire. From the maps it seems that the fire was most intense during 18-20 of June.

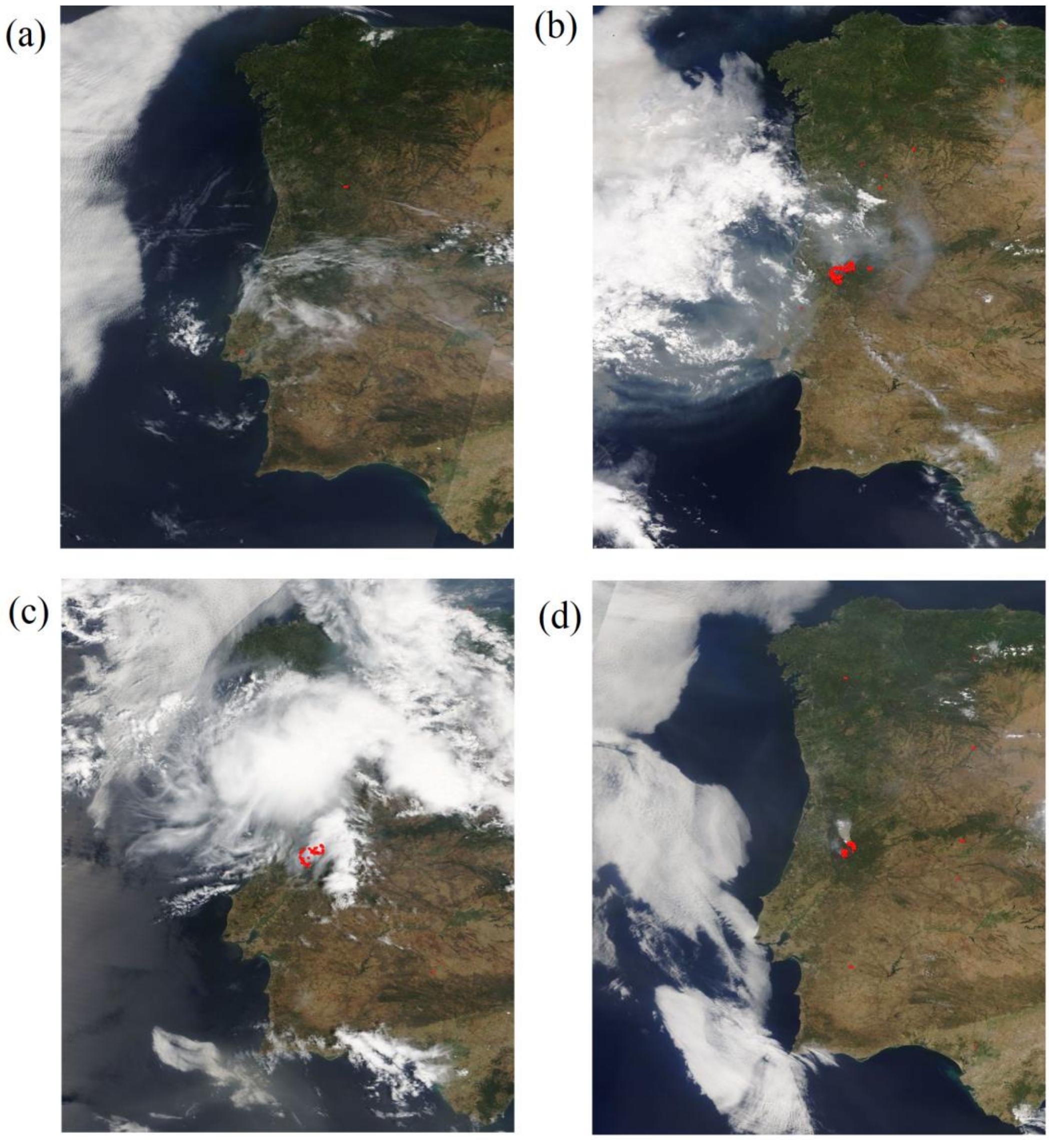


Figure 17a: Satellite imagery with fire anomalies (red dots). a) – d) is 17-20 June.

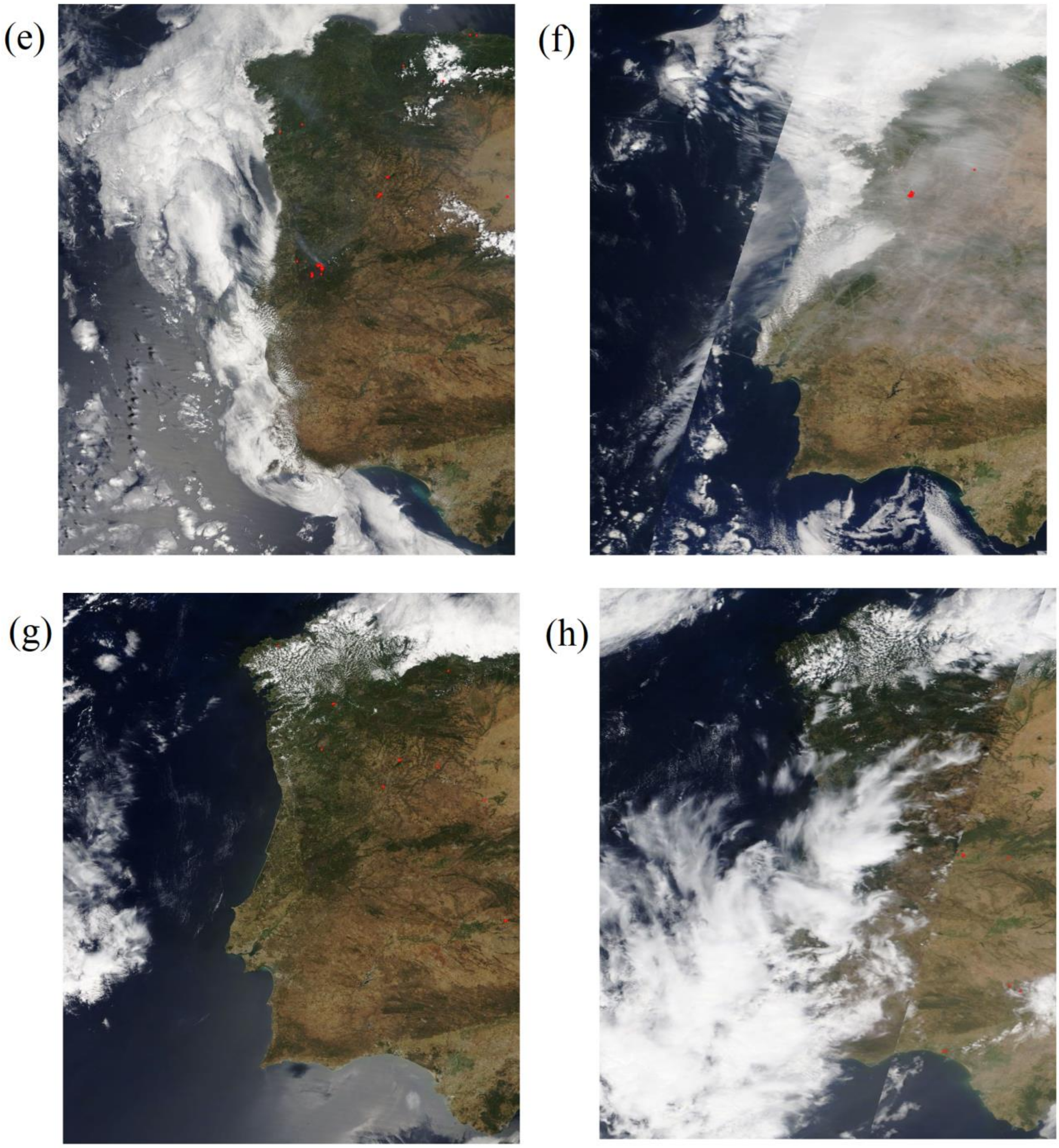


Figure 17b: Satellite imagery with fire anomalies (red dots). e) – h) is 21-24 June.

Smoke can be seen from the satellite images throughout 17-21 of June. Next trajectories will be calculated for all the days. The trajectories will be used as a guide to choose stations as was also mentioned previously.

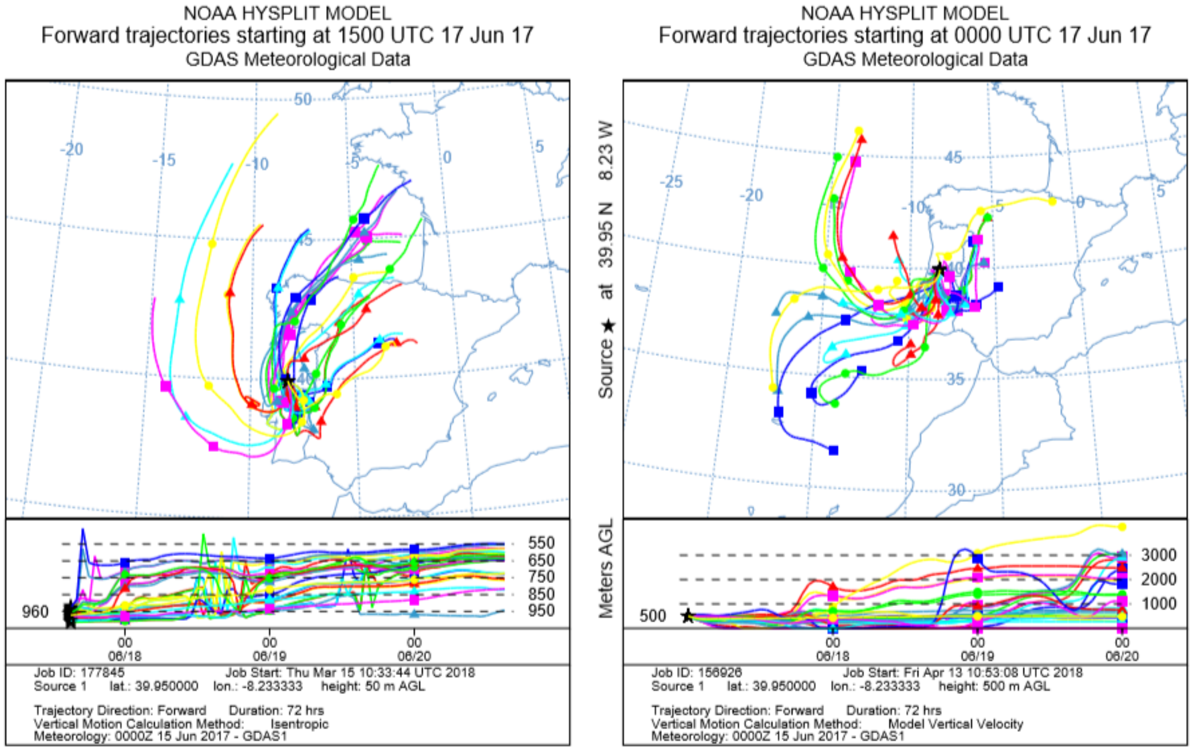


Figure 18a: HYSPLIT trajectories from the source of the fire at the surface (left) and at 500m (right).

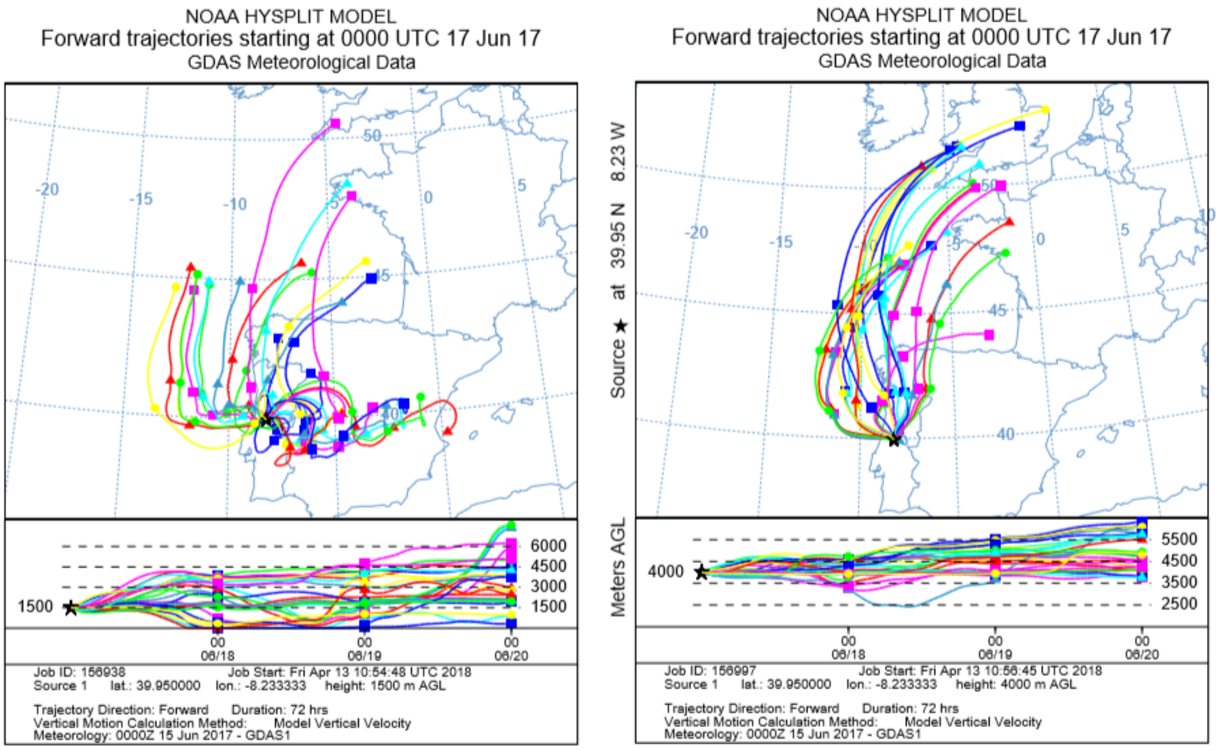


Figure 18b: HYSPLIT trajectories from the source of the fire at 1500m (left) and at 4000m (right).

From the trajectories it seems that the smoke's plume covered the northern part of Portugal and Spain mainly. The trajectory at 4000m also covers some of England and France but for this research stations from Portugal and Spain will be analyzed.

Name	Longitude	Latitude	Elevation	Level	Country
Evora	-7,912	38,568	293	1.5	Portugal
Cabo da Roca	-9,498	38,782	136	2.0	Portugal
Madrid	-3,724	40,452	680	2.0	Spain
Valladolid	-4,706	41,664	705	2.0	Spain
Zaragoza	-0,882	41,633	250	1.5	Spain
Badajoz	-7,011	38,883	186	2.0	Spain

Table 1: List of AERONET stations that will be used for analysis

Figure 19: Map of AERONET stations that will be used for analysis.

All of the stations overlap with the trajectories, however there is a lack of stations in the northern Portugal region. The ECMWF data will be compared with the actual station data after they have been bilinearly interpolated to the station location.

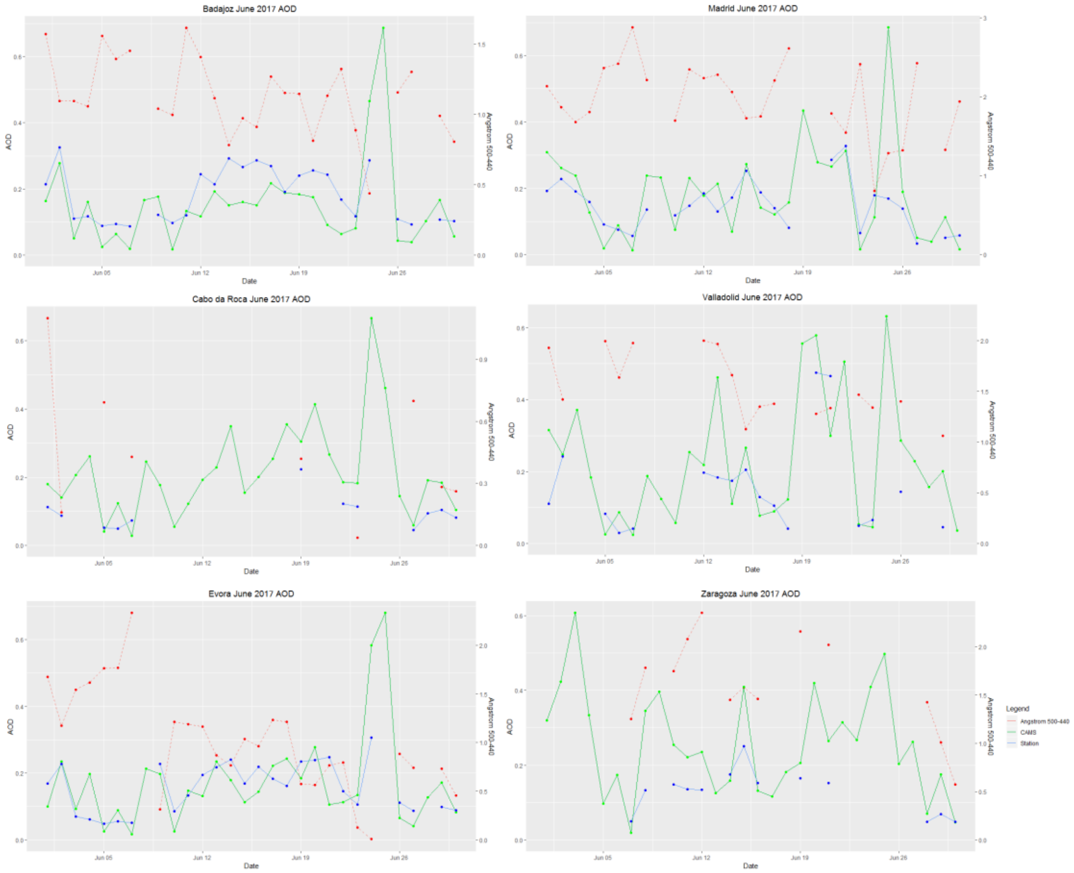


Figure 20: Comparison of AOD of a collection of AERONET stations and interpolated ECMWF data.

Despite the missing data from a lot of the stations it's obvious that CAMS data slightly overestimate the AOD at the days of the fire. The only large loss that is recorded is during 24-26 of June which is technically after the fire has been extinguished. These losses can be mainly seen in the Madrid and Evora stations. In addition the Angstrom exponent seems to dip during the days of the big overestimations which indicates an increase in the average size of aerosols above the station. In general the model performs well during the days of the fire with the exception of 24-26 of June which from the worldview maps is technically not in the day of the fires.

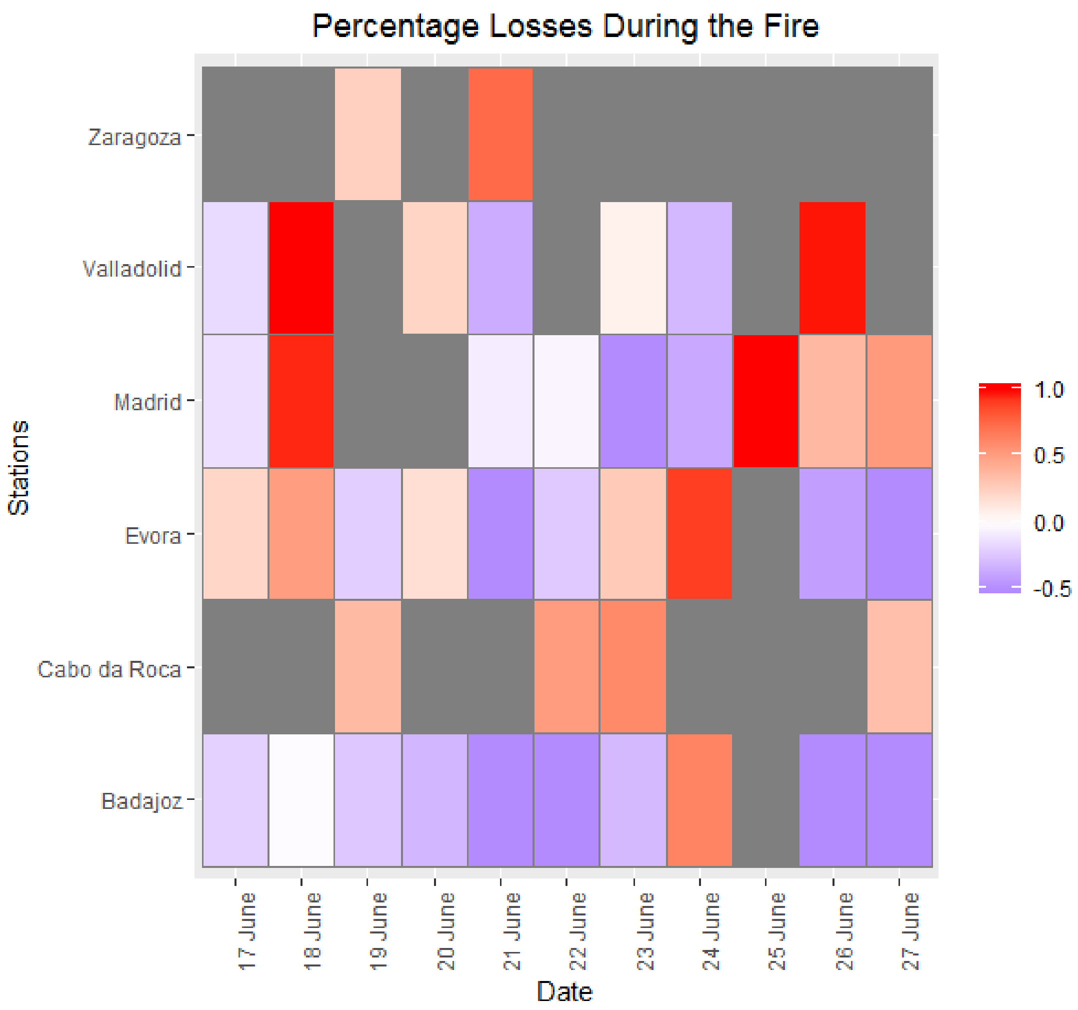


Figure 20b: Percentage losses per station per day.

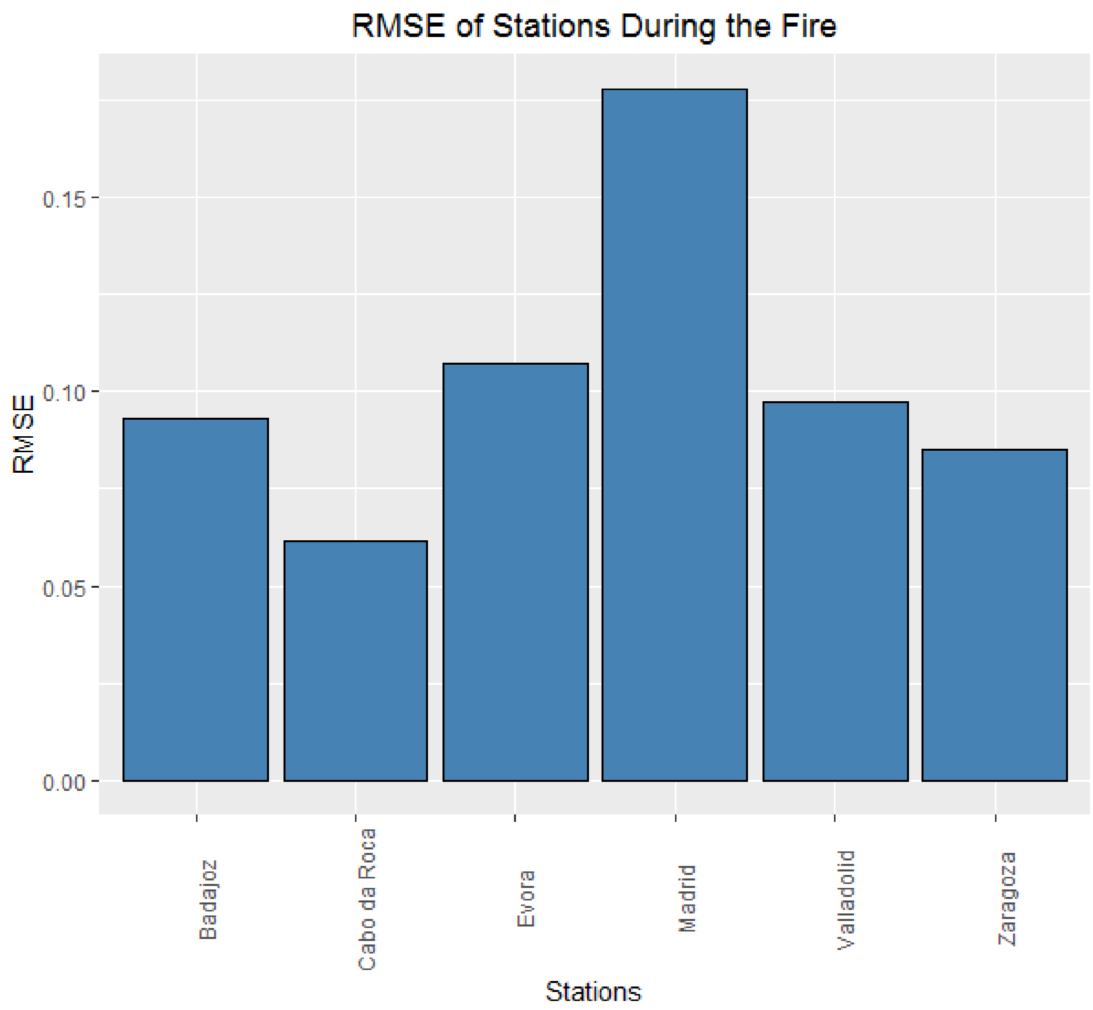


Figure 20c: Total RMSE of each station during the fire

To further investigate the reason for the high losses during the last days of the fire one must break down the AOD contributions from each aerosol. This will give insight as to what atmospheric composition does the ECMWF model consider over the stations. After the data are bilinearly interpolated they will be plotted to find the atmospheric composition during the days of the big losses. Data from total AOD, Organic Matter, Black Carbon, Sea Salt and Dust are given by the ECMWF.

Figure 21: Breakdown of the contribution of each aerosol to the total AOD at 550nm above the AERONET stations.

During the days of the fire the aerosol composition seems to be mainly organic matter dominated, these are generally the days where the model performed well. However the actual AOD values are not particularly large in the real data, in the breakdown of each aerosol's contribution according to the ECMWF the organic matter AOD is not large in the days of the fire either. The only time where there is a large spike in the organic matter AOD is at the Evora station on the 26 of June. However Aeronet data does not support such a spike. In addition in the Worldview maps there are no fire anomalies during those days. Dust in the beginning of June can also be seen in the Worldview maps especially in the south-western part of the Iberian peninsula. It's worth looking into the volume distribution that is provided by Aeronet and compare it to the model data.

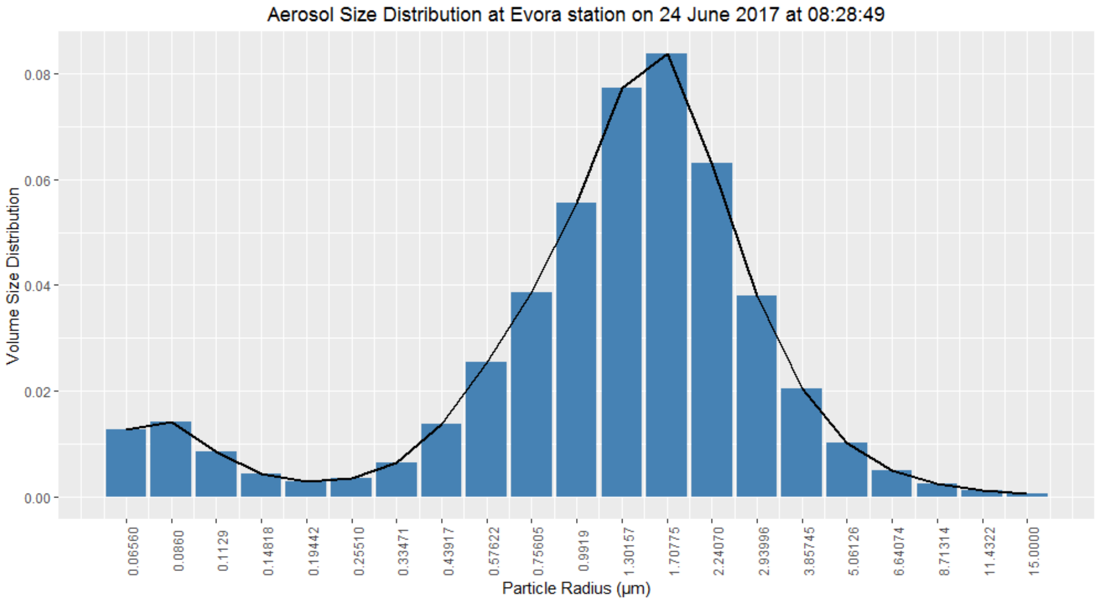


Figure 22a: Aerosol size distribution on 24 of June 2017

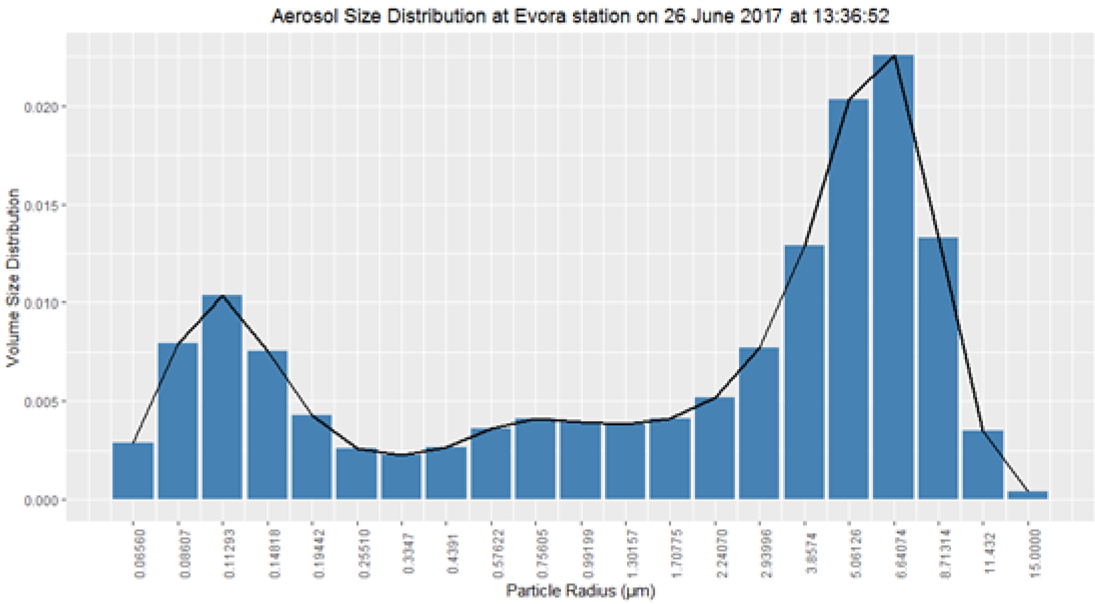


Figure 22b: Aerosol size distribution on 26 of June 2017

In both days coarse mode aerosols dominate the distribution, unfortunately there are no data in the rest of the stations that are also recording large aerosol increases according to the model data. This data further confirms that the model mistakenly simulates organic matter aerosols above the stations.

Next, maps of each Aerosol contributing to the AOD according to the ECMWF will be constructed to further analyze the air composition above stations during the days of the fire.

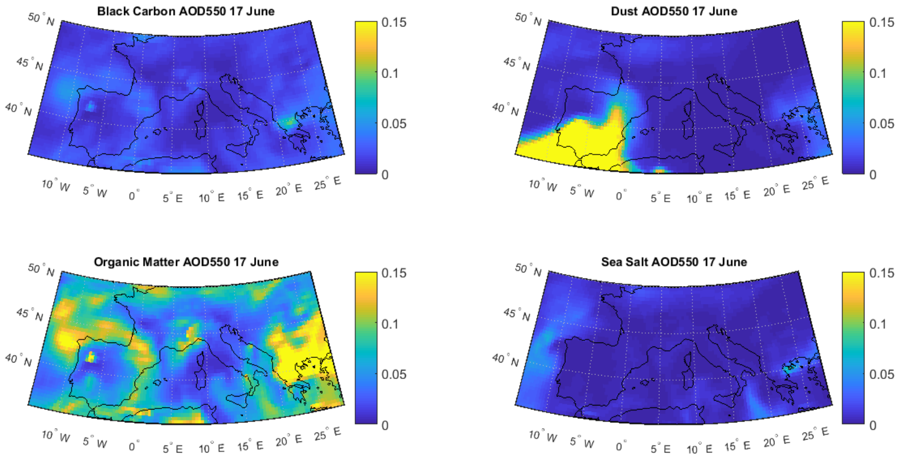


Figure 23a: AOD at 550nm for each of the AOD components provided by the ECMWF in 17 of June.

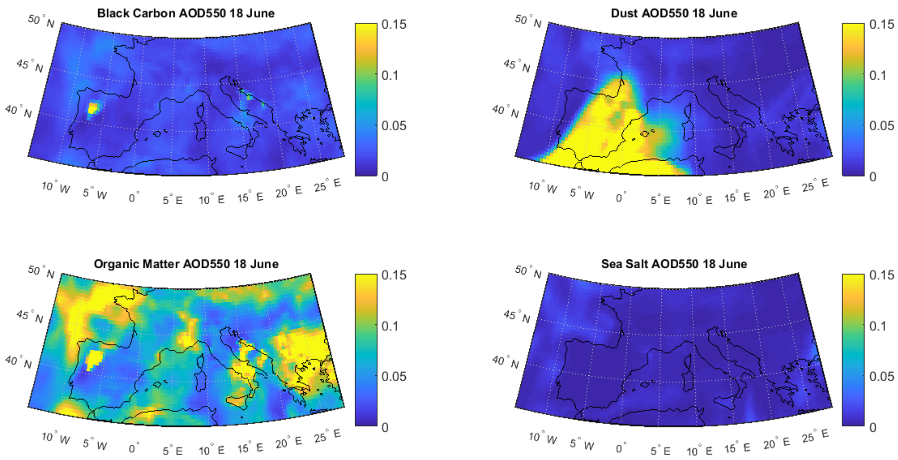


Figure 23b: Same as fig.23a but in 18 of June.

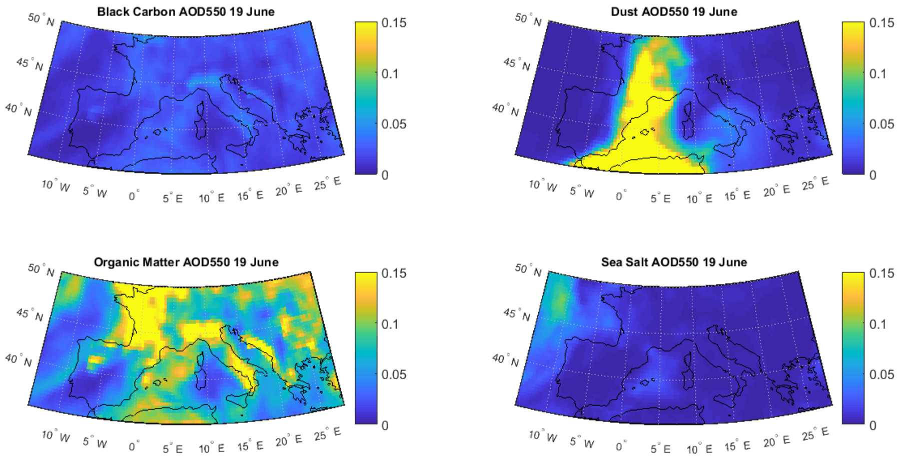


Figure 23c: Same as fig.32a but in 19 of June.

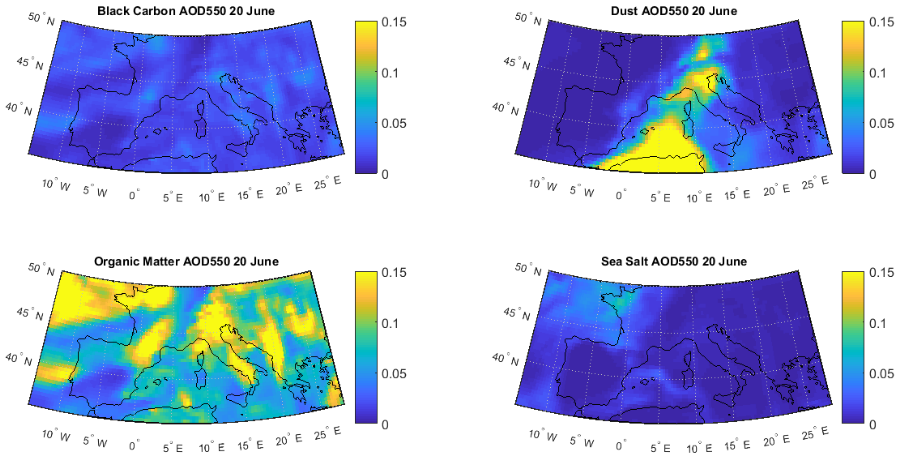


Figure 23d: Same as fig.23a but in 20 of June.

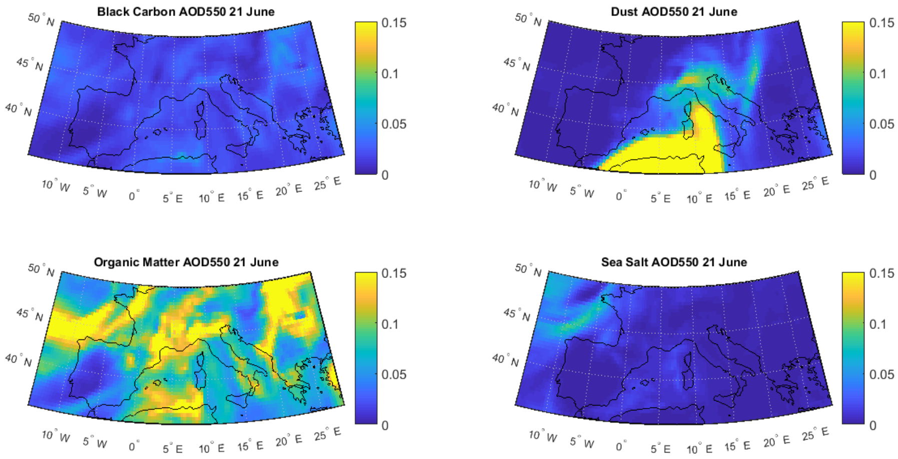


Figure 23e: Same as fig.23a but in 21 of June.

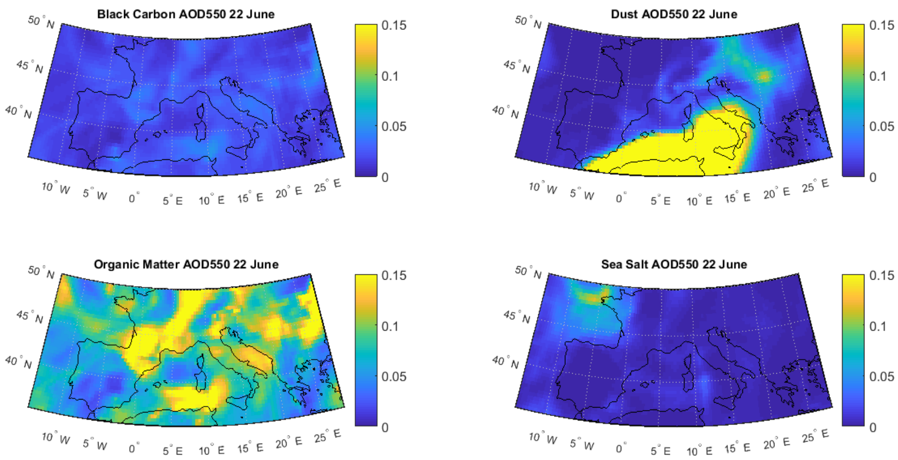


Figure 23f: Same as fig.23a but in 22 of June.

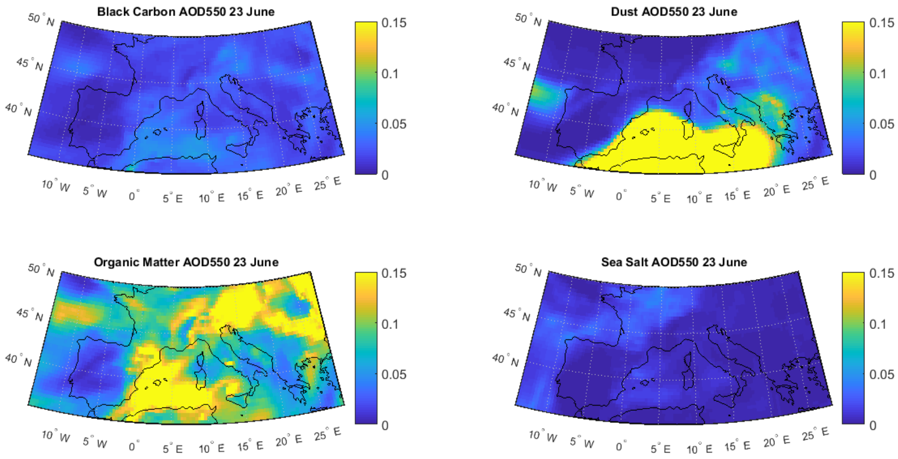


Figure 23g: Same as fig.23a but in 23 of June.

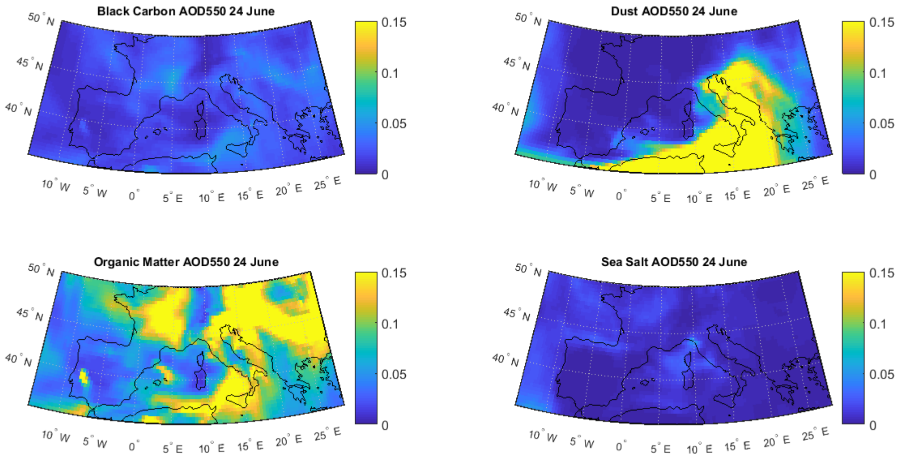


Figure 23h: Same as fig.23a but in 24 of June.

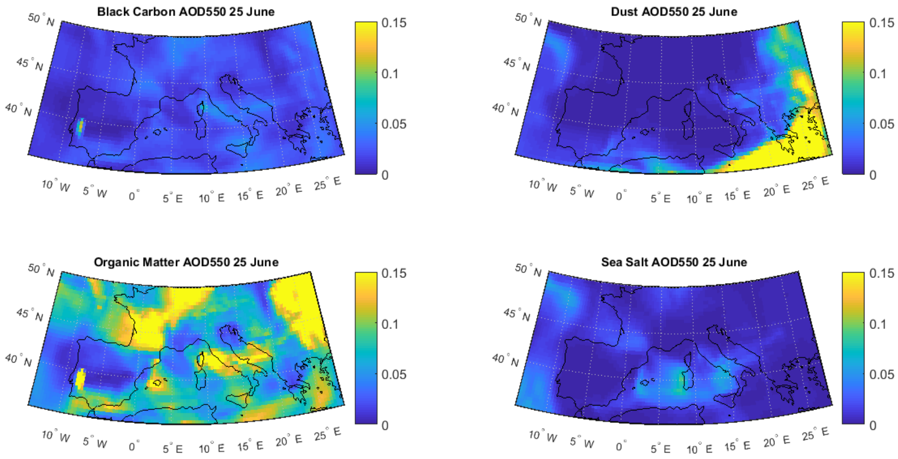


Figure 23i: Same as fig.23a but in 25 of June.

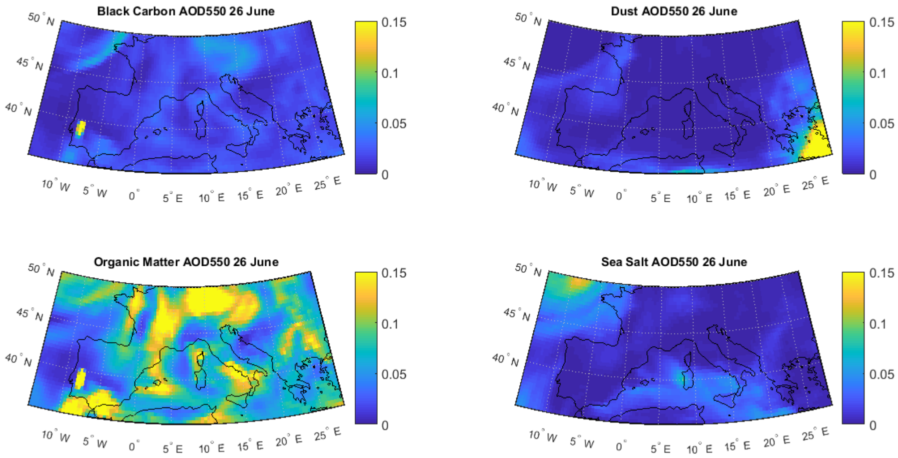


Figure 23j: Same as fig.23a but in 26 of June.

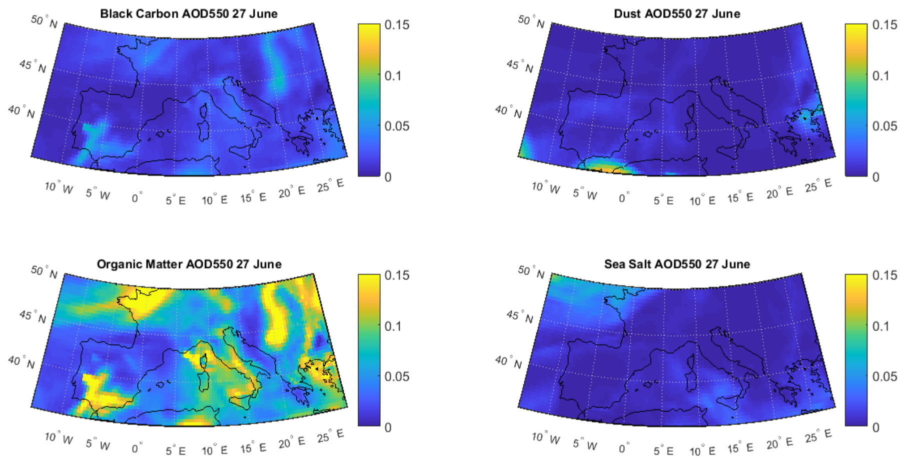


Figure 23k: Same as fig.23a but in 27 of June.

During the beginning of the fire some dust seems to appear in the area that later gets shifted eastwards. Next during the fire from the organic matter and the black carbon AOD it's obvious that CAMS simulates the fire well. However during the days of the big losses another fire seems to be recorded and virtually no dust in all southern Europe. The supposed fire, extrapolating from the organic matter and black carbon AOD that are recorded is as big as the one during 19 of June. However from the Worldview maps there is no such fire recorded. This can be an error due to missing data, meaning that there were no data to inform the model that the fire has been extinguished.

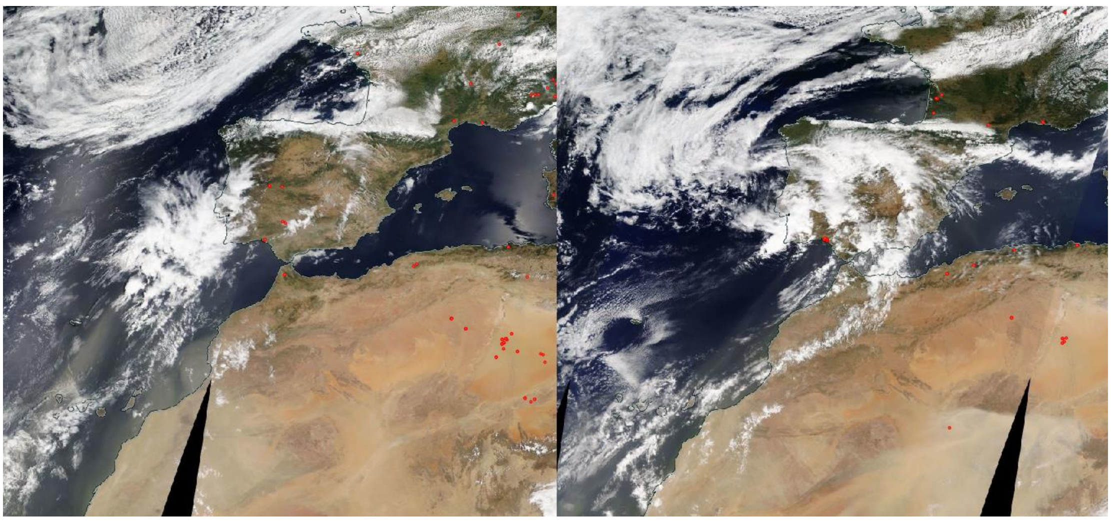


Figure 24: Worldview maps with fire anomalies during 24 of June (left) and 25 of June (right).

4.2 Portugal-October 2017

Next it's interesting to compare this wildfire with the Portugal wildfire in October of the same year. During that fire hurricane Ophelia fanned flames and dust in a north-eastern trajectory causing the fire to spread into northern Spain. As a result the UK and France were impacted since aerosols from the area got transported. This is particularly interesting for the purpose of this research as it's interesting to see if the model can interpret correctly such a complex aerosol transport event. Next, maps for thermal anomalies will be produced from WORLDVIEW.

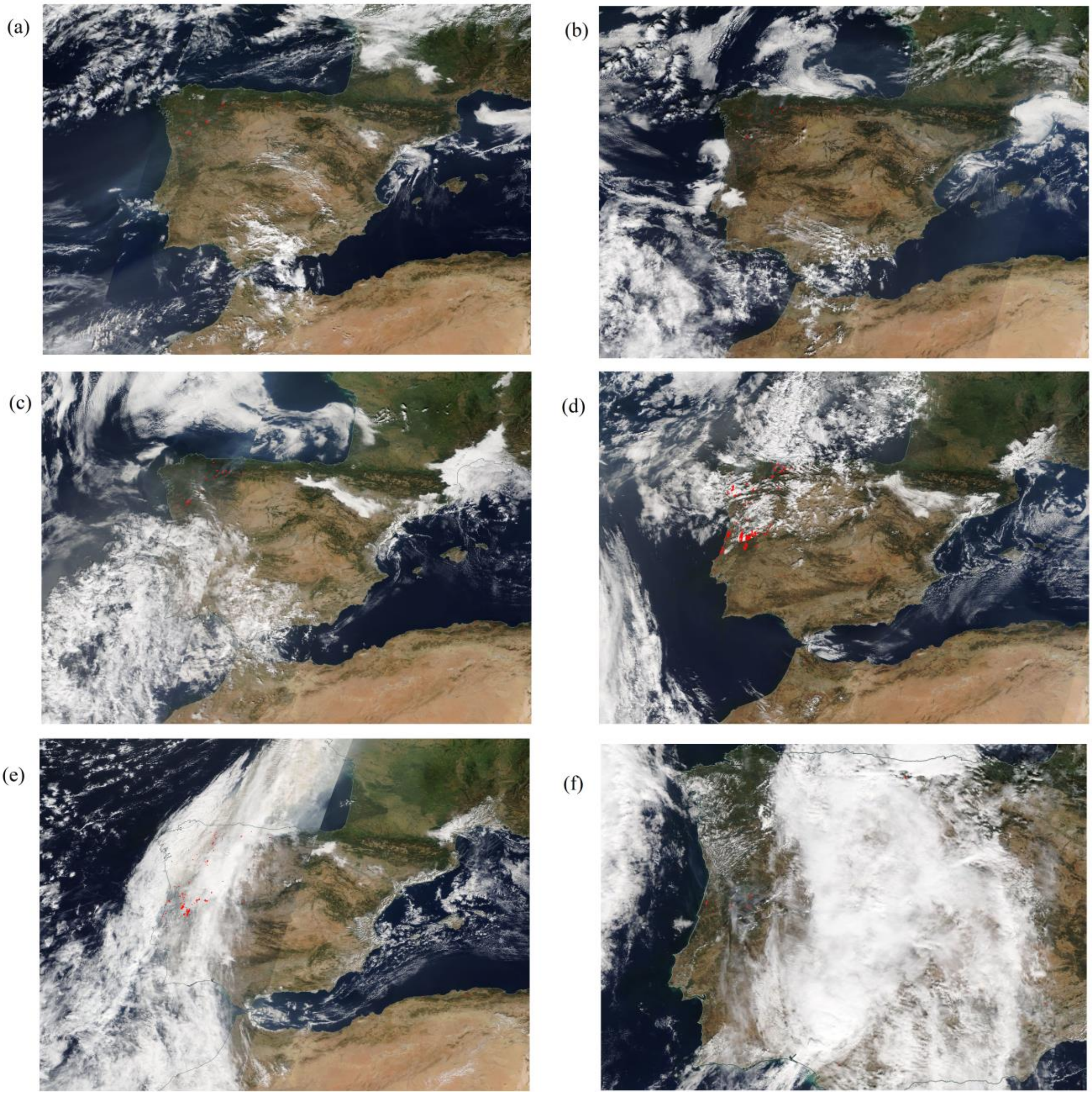


Figure 25: Thermal anomalies from WORLDVIEW from 12/10/2017-17/10/2017 (a-f).

From the figure we can see the exact days where hurricane Ophelia influenced the wildfire, in 14/10/2017 one can see that the fire was contained in the northern part of Portugal, while in 15/10/2017 the fire has spread further in both the south and the north-eastern part of the peninsula. In order to then make trajectories, since the fire spread in essentially two parts, two point will be used as starting points for the trajectories.

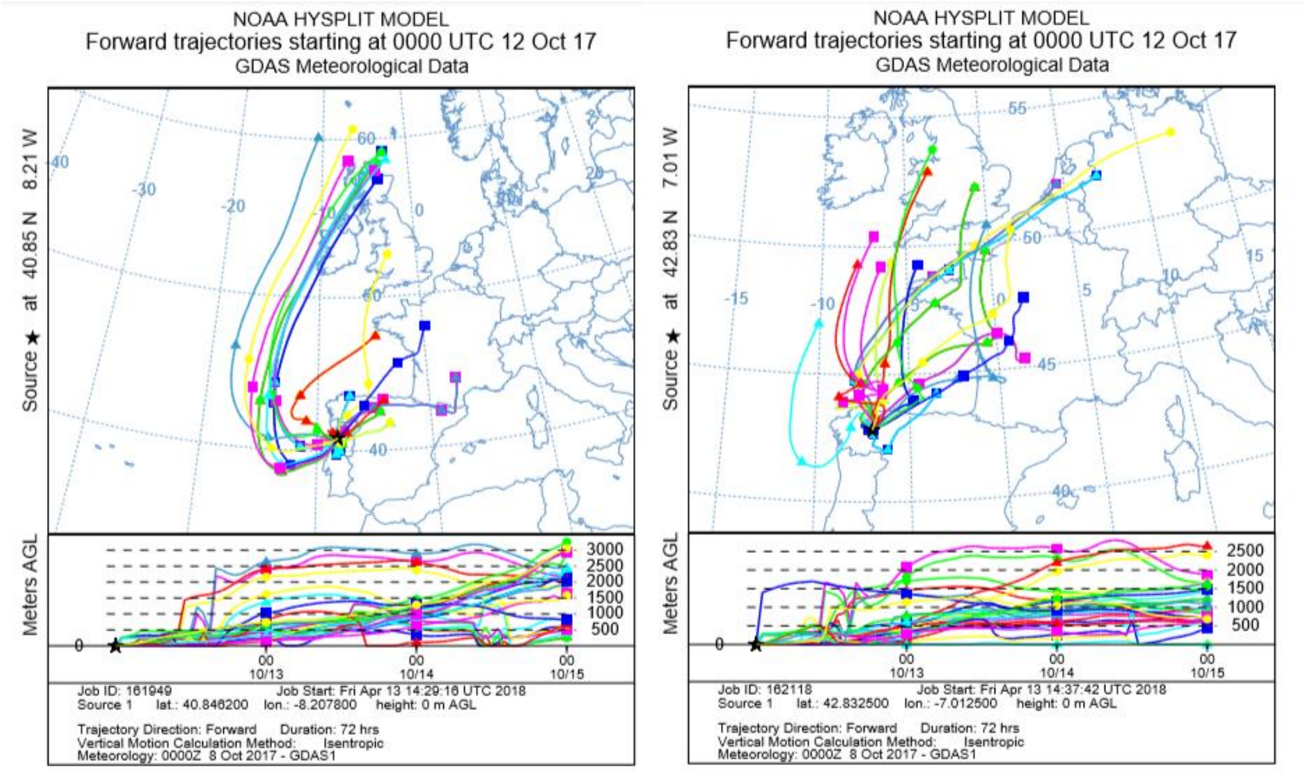


Figure 26a: Trajectories for 12-17/10/2017 for the two points of the fire at the surface level.

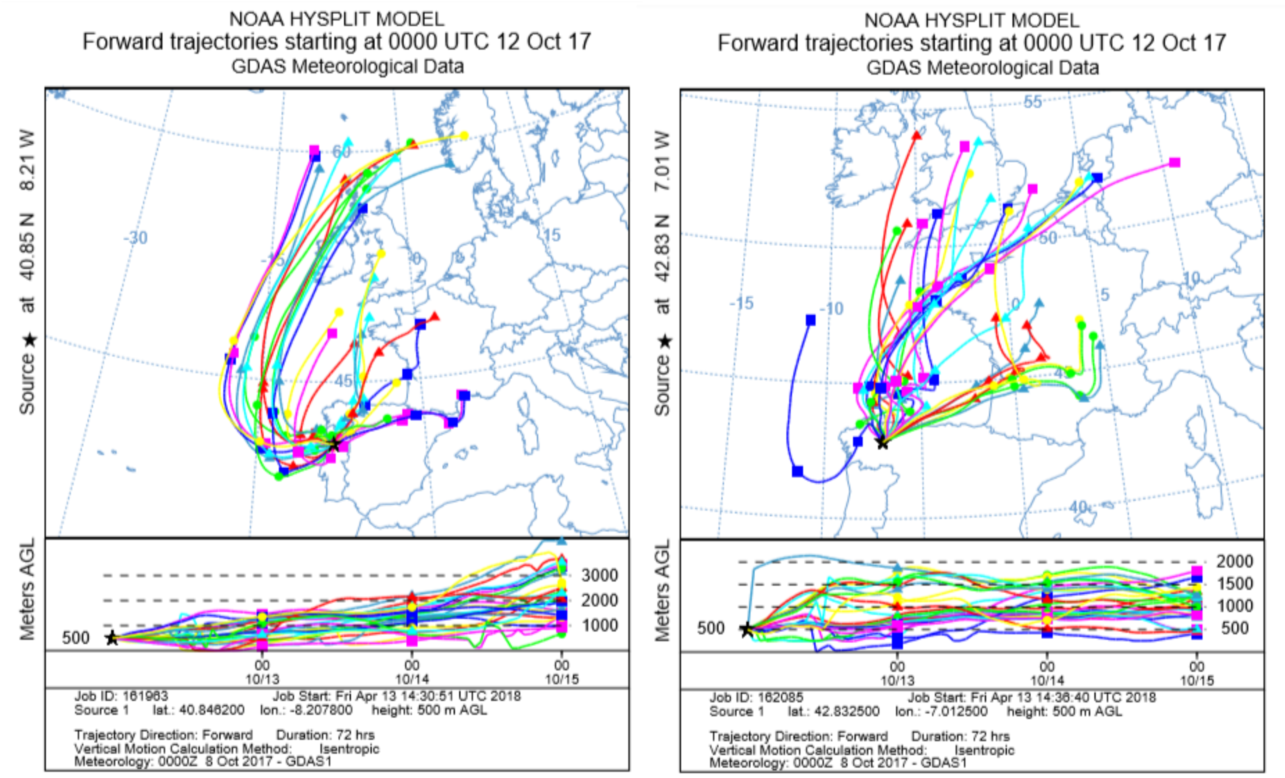


Figure 26b: Same as fig.a but at 500m

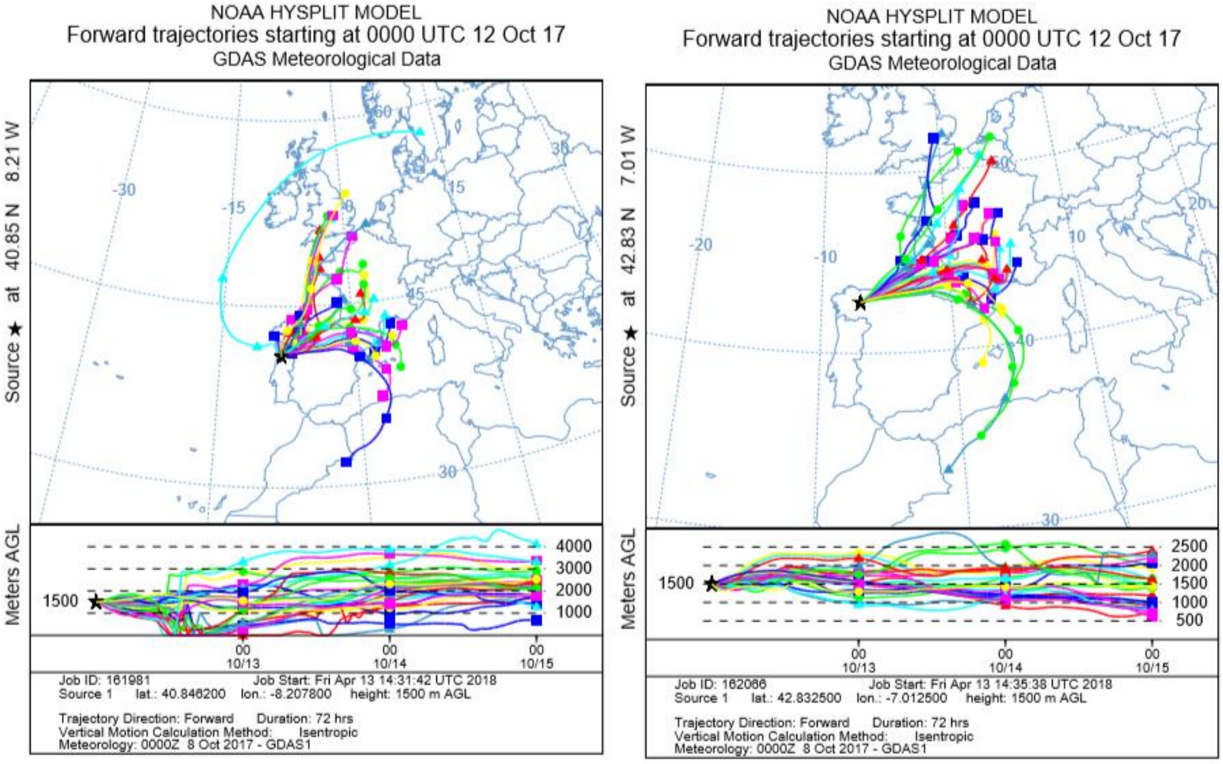


Figure 26c: Same as fig.a but at 1500m.

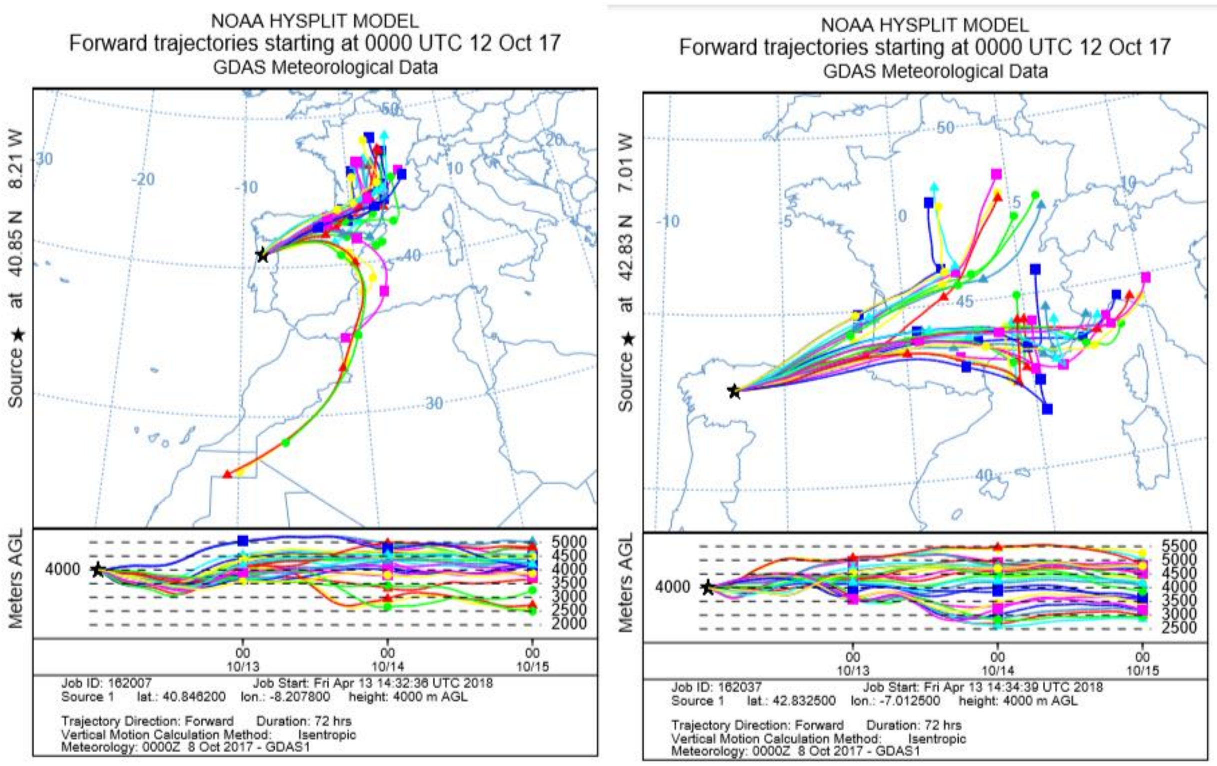


Figure 26d: Same as fig.a but at 4000m

The area of impact for this fire is particularly large. Portugal, France, Britain and Ireland have been impacted. The next step will be to choose stations from these countries. However unfortunately there are no stations in the UK and Ireland with sufficient data during the period that is studied.

OHP_OBSERVATOIRE	5,710	43,935	680	1.5	France
Paris	2,333	48,867	50	1.5	France
Toulon	6,009	43,136	50	2.0	France
Toulouse_MF	1,374	43,573	160	2.0	France
Evora	-7,912	38,568	293	1.5	Portugal
Cabo_da_Roca	-9,498	38,782	136	1.5	Portugal
Madrid	-3,724	40,452	680	2.0	Spain
Palencia	-4,516	41,989	750	2.0	Spain
Valladolid	-4,706	41,664	705	1.5	Spain
Zaragoza	-0,882	41,633	250	1.5	Spain

Table 2: AERONET stations used to study the October wildfire in Portugal.

Figure 27: Map of AERONET stations that will be used for analysis.

There are a lot more stations in this wildfire than the previous. The plethora of stations will help better understand the spatial extent of the fire.

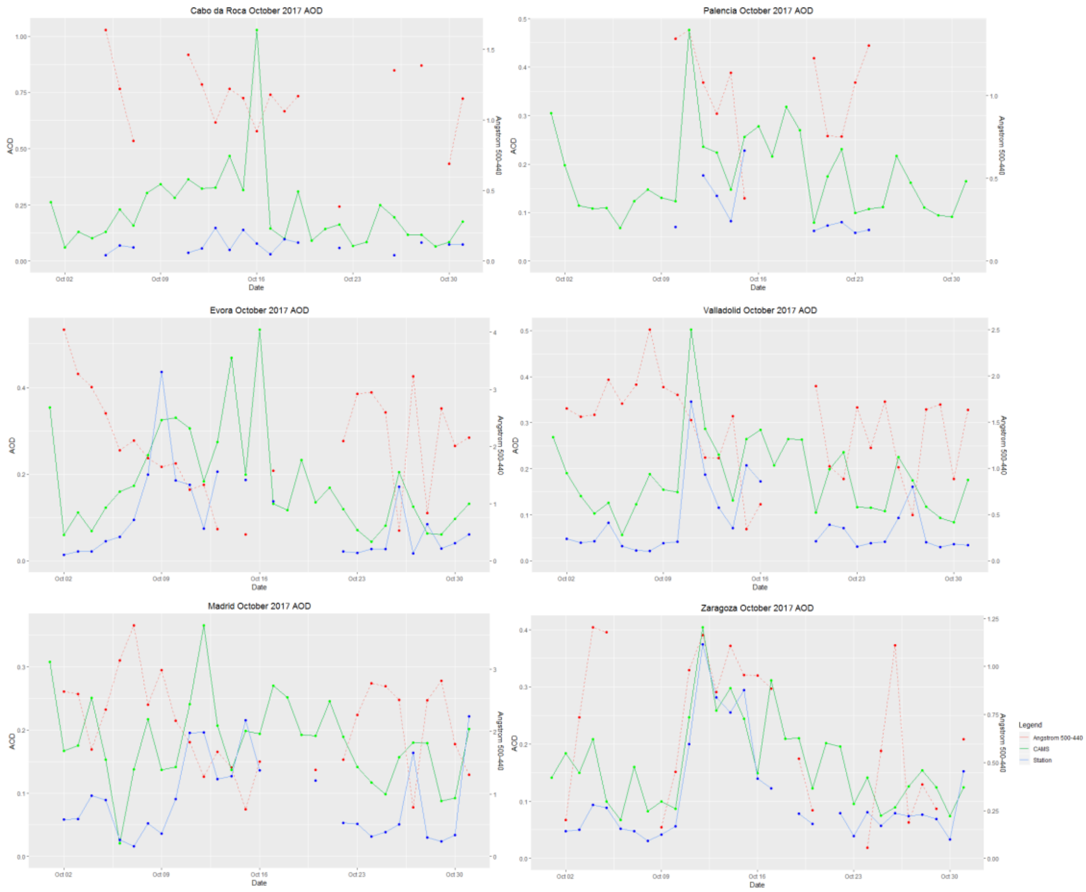


Figure 28a: Comparison of AOD of a collection of AERONET stations in Portugal and Spain and interpolated ECMWF data.

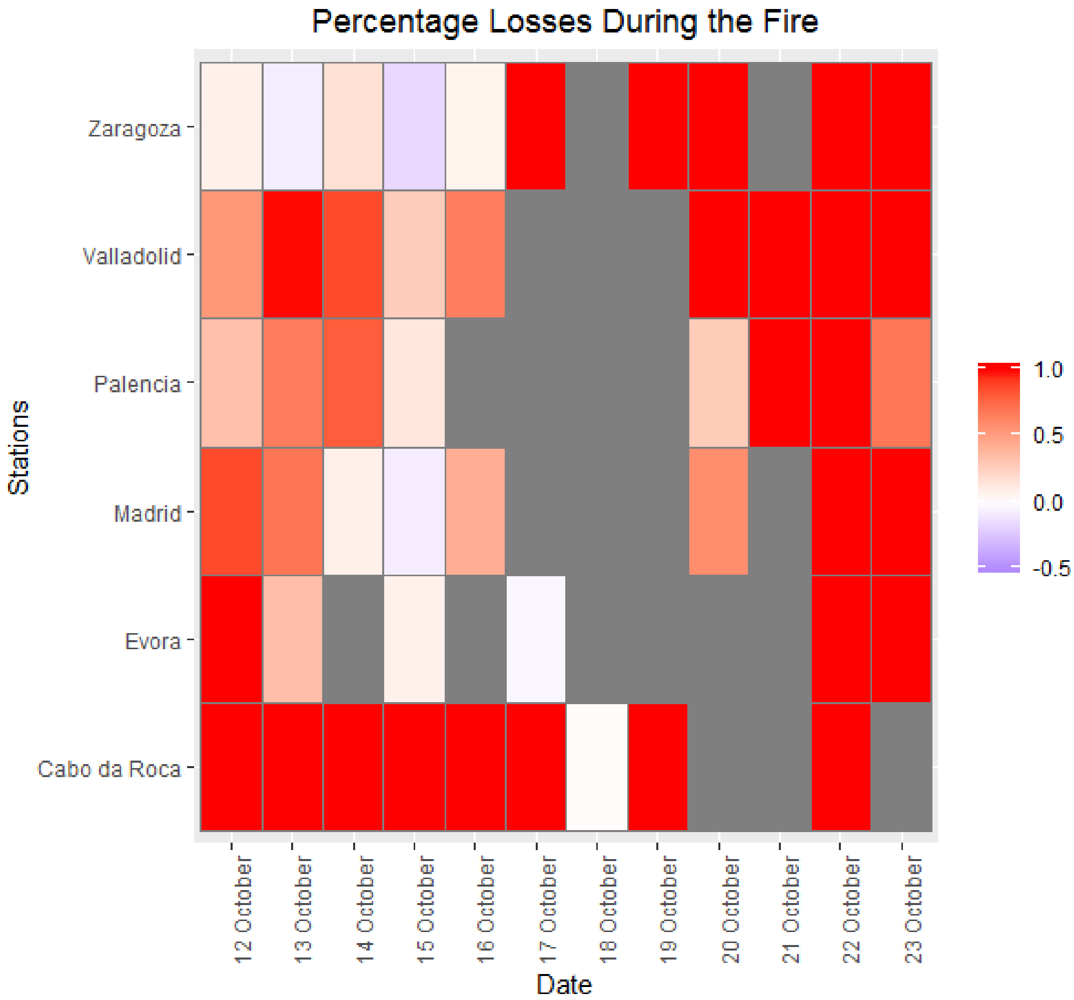


Figure 28b: Percentage losses for AERONET stations in Portugal and Spain.

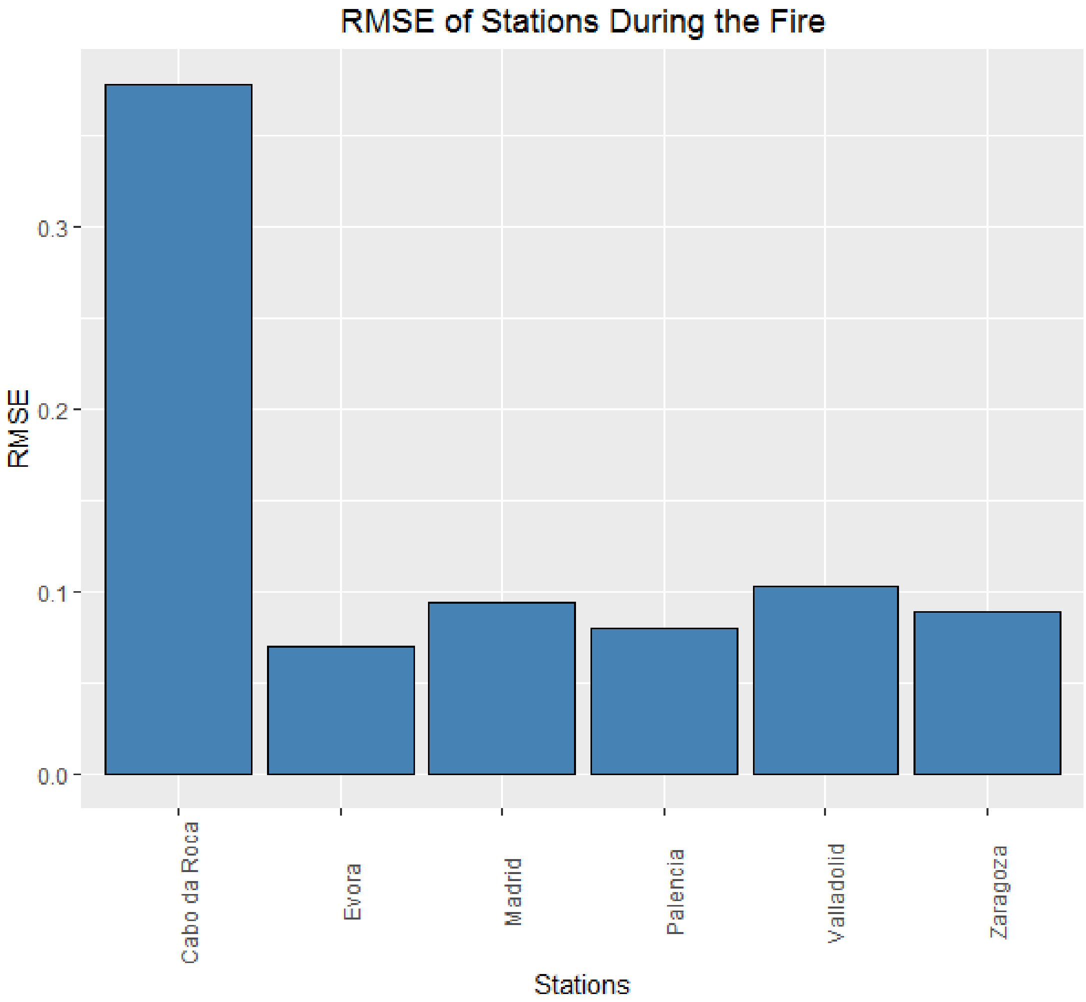


Figure 28c: Total RMSE of AERONET station during the day of the fire in Portugal and Spain.

Figure 29a: Comparison of AOD of a collection of AERONET stations in France and interpolated ECMWF data.

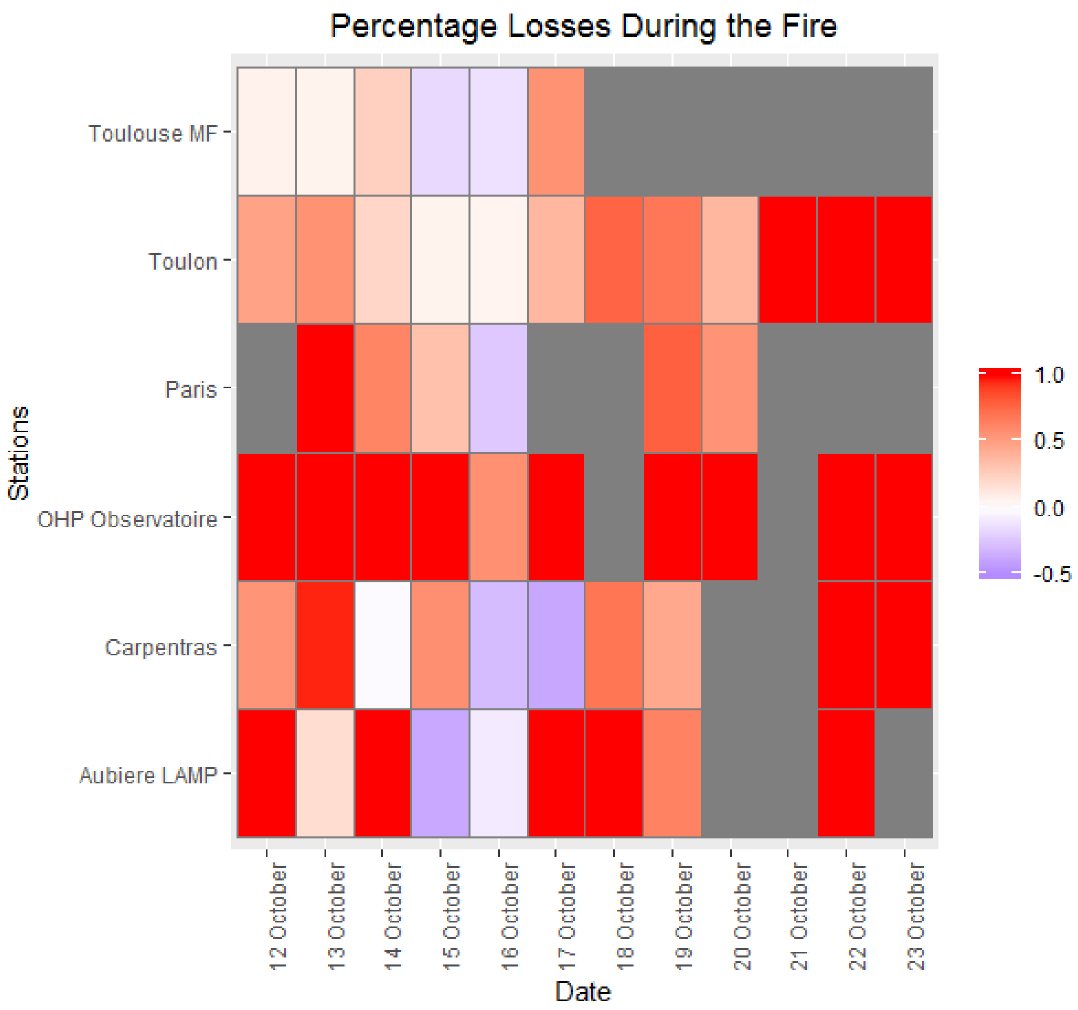


Figure 29b: Percentage losses for AERONET stations in France.

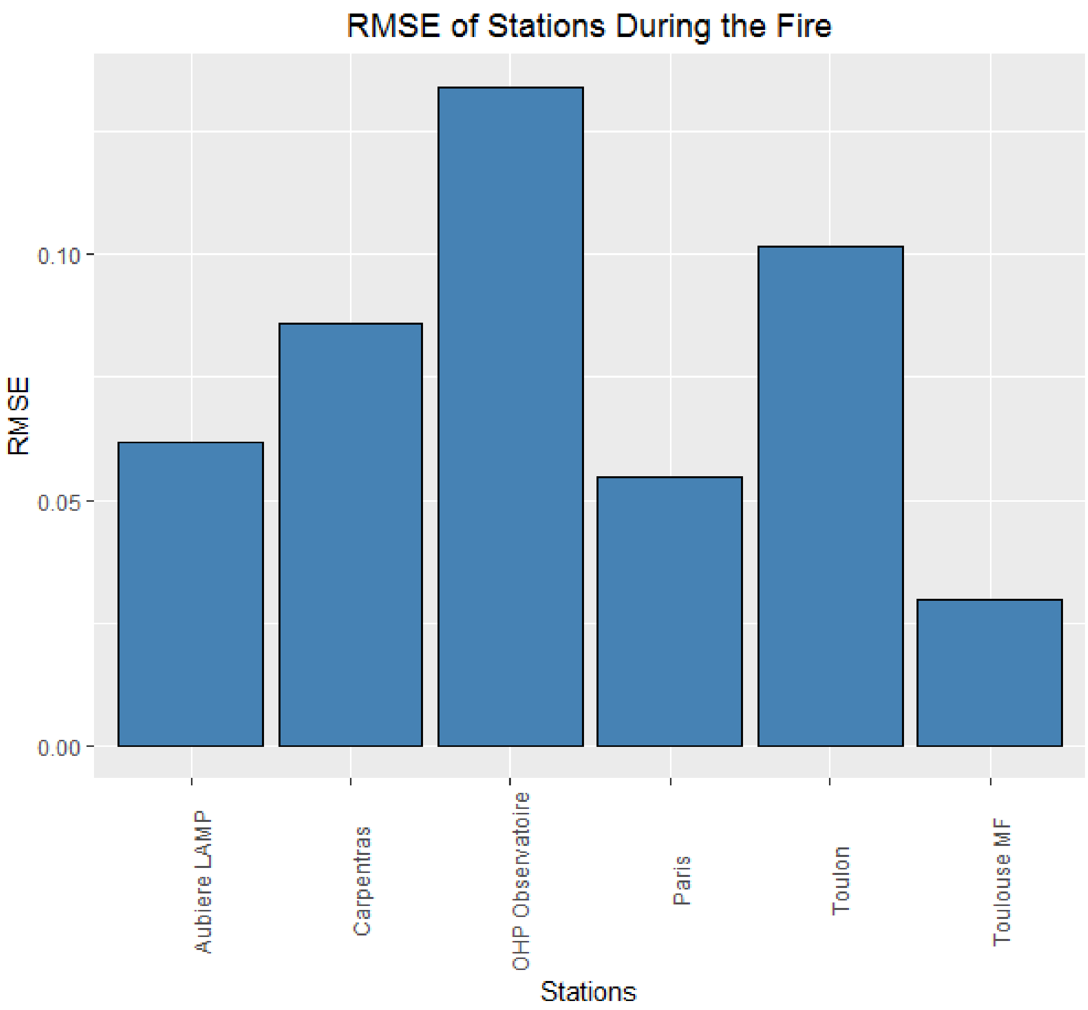


Figure 29c: Total RMSE of AERONET station during the day of the fire in France.

The model seems to simulate the peak at the days of the fire very well, with the model having slight overestimations. In only three stations the model performs badly, Cabo da Roca, Madrid and OHP Observatoire. Cabo da Roca is located southern of Evora, OHP Observatoire is located in the southern part of France and Madrid is located in central Spain. In these station the Aeronet data indicate that they didn't get affected by the fire. In Madrid's case particularly the real data show a smaller peak than the model data, while the other two stations seem to be not affected at all.

After the first peak a second one is recorded after 15-16 of October, this is due to hurricane Ophelia affecting the region. Unfortunately during those days there are a lot of missing data. From the few instances that exists the overestimations are bigger, however no conclusion can be drawn.

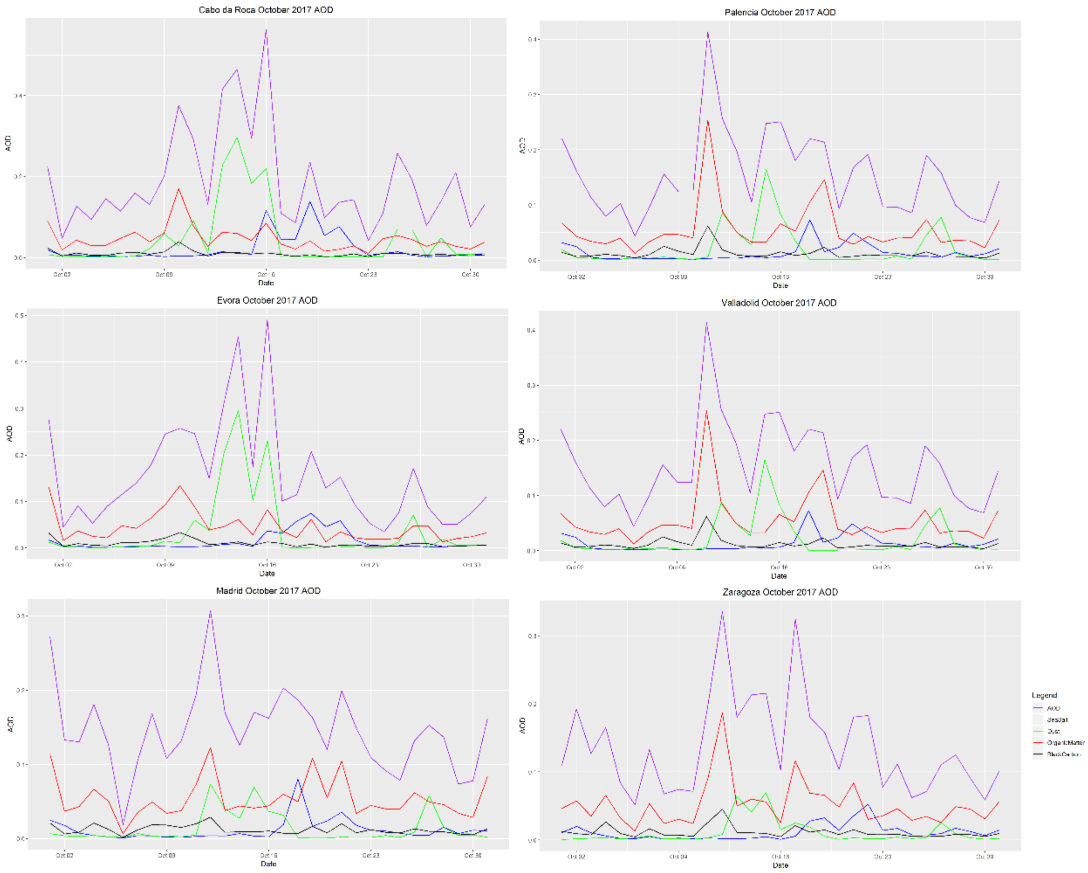


Figure 30a: Breakdown of the contribution of each aerosol to the total AOD at 550nm above the AERONET stations in Portugal and Spain.

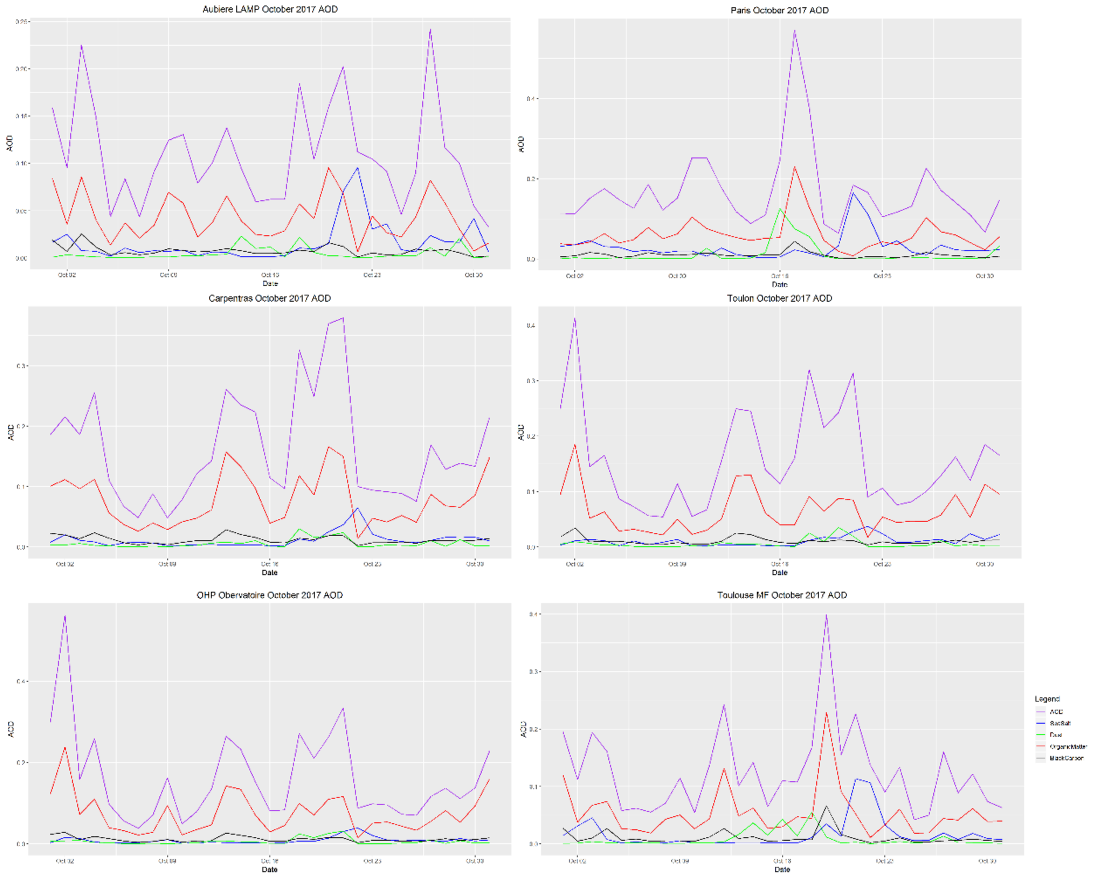


Figure 30b: Breakdown of the contribution of each aerosol to the total AOD at 550nm above the AERONET stations in France.

In Portugal and Spain the first peak seems to be consistent among all stations, and it's mainly organic matter dominated, this is where the model performs the best. In the days that hurricane Ophelia affected the region dust is the dominant aerosol for stations in the Iberian peninsula. In France dust does not contribute to the total AOD during hurricane Ophelia, rather organic matter aerosol gets transported the most. The inversion datasets unfortunately there aren't any data for the Cabo da Roca station which is the worst performing, however there are data for the Madrid station and the OHP Observatoire station.

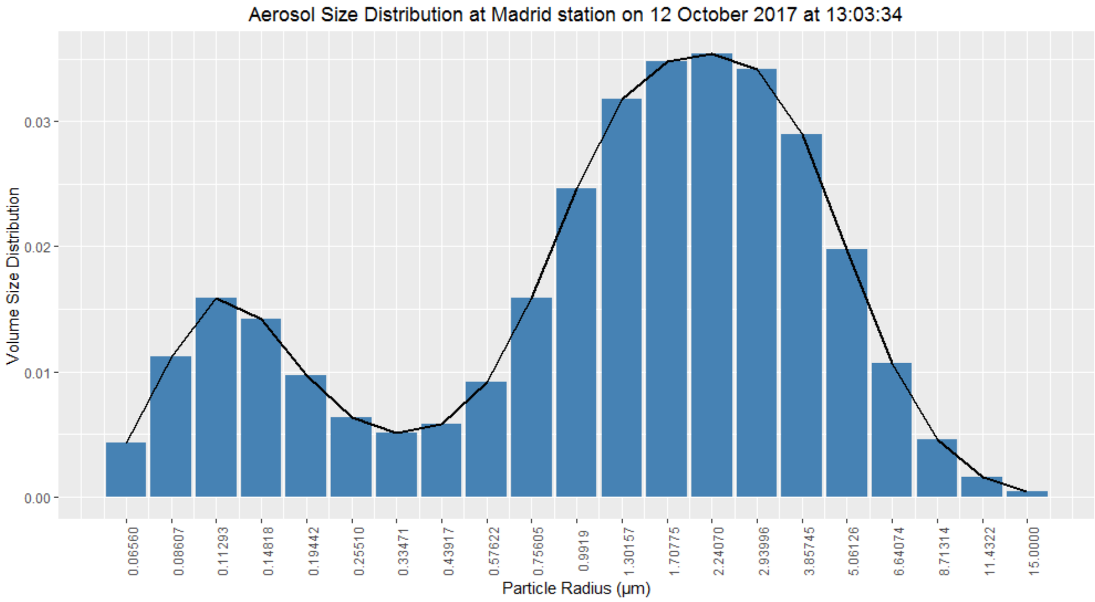


Figure 31a: Aerosol size distribution on 12 of October 2017

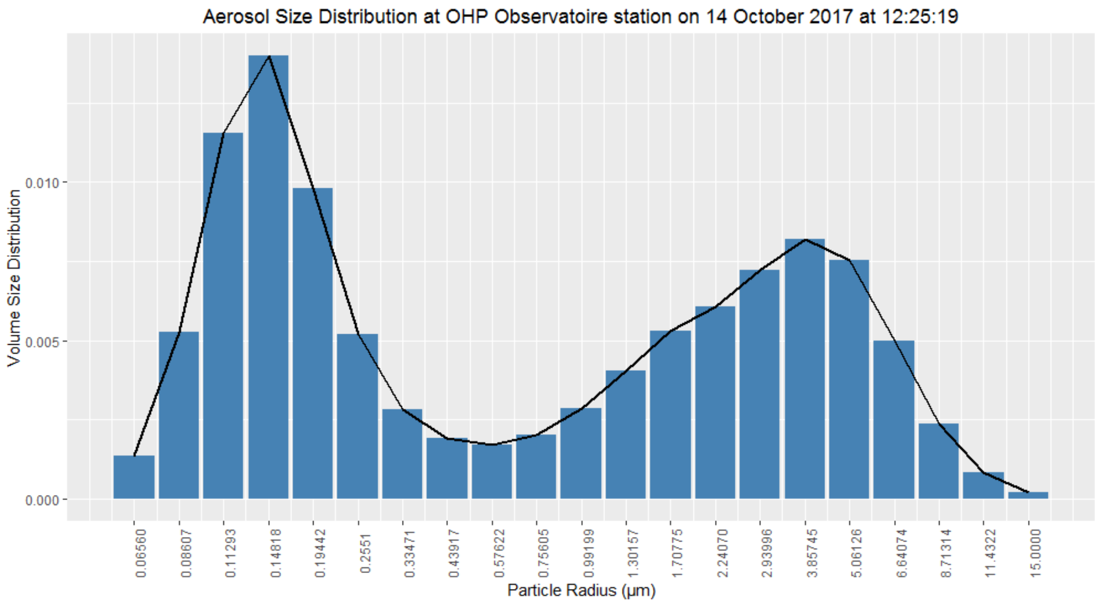


Figure 31b: Aerosol size distribution on 14 of October 2017

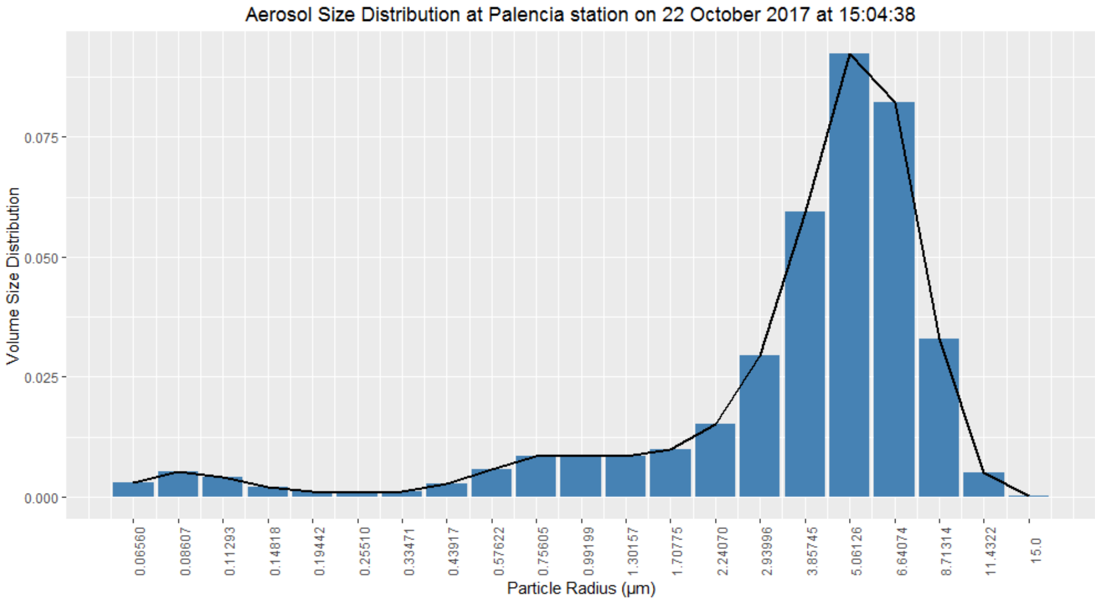


Figure 31c: Aerosol size distribution on 22 of October 2017

At the Madrid station the coarse mode aerosols are more common than fine mode in the distribution. The model also showed a similar mixture of both organic matter aerosols and dust aerosols. Similarly at the Palencia station the volume distribution shows only coarse mode aerosols while in the model there was organic matter and sea salt AOD contributing. Sea salt aerosol is included in the coarse mode aerosols so the overestimations can be due to the organic matter aerosol the model has simulated. At the OHP Observatoire the volume distribution data show general fine mode particle dominance which is aligned with the model data. This means that the overestimations are probably due to the amount of aerosols the model simulates to have been transferred.

Next maps will be produced for each of the AOD's that are considered in the plots to identify the air composition above the whole region during the days of the fire.

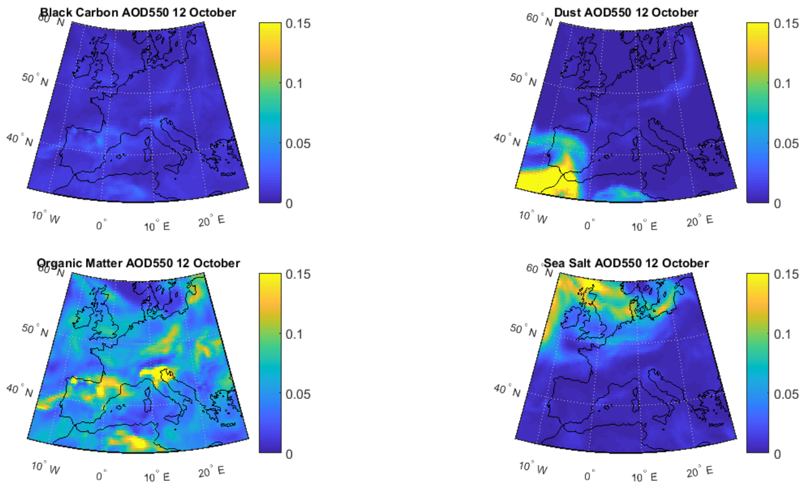


Figure 32a: AOD at 550nm for each of the AOD components provided by the ECMWF in 12 of October.

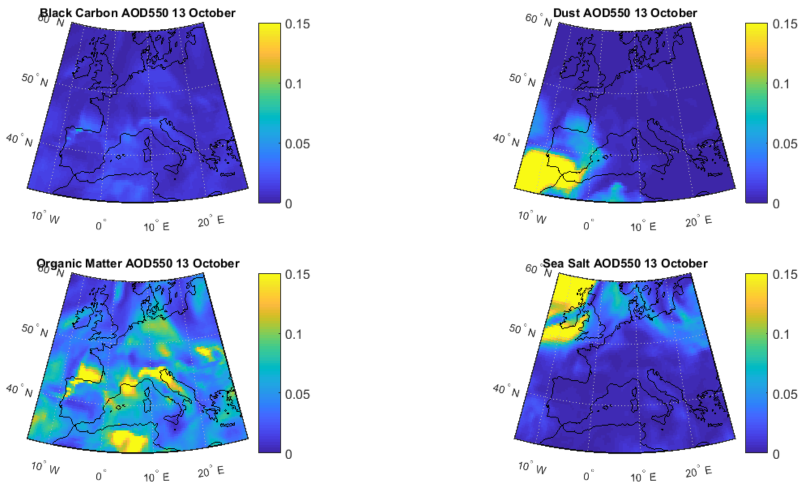


Figure 32b: Same as figure 32a but for 13 of October.

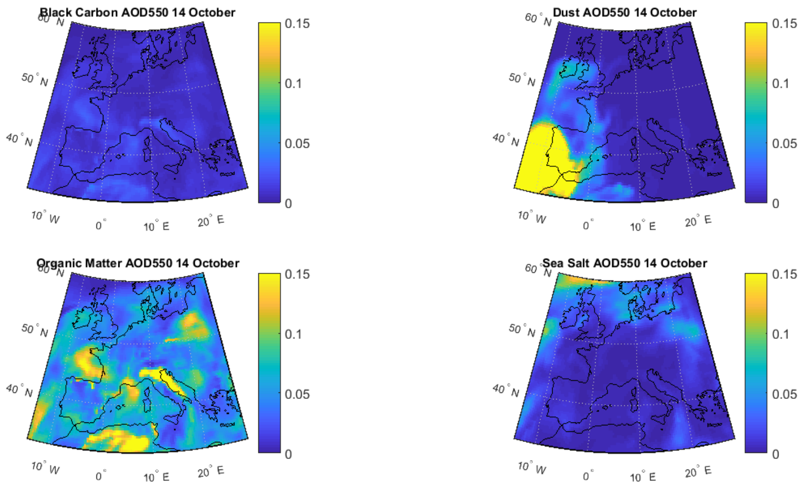


Figure 32c: Same as figure 32a but for 14 of October.

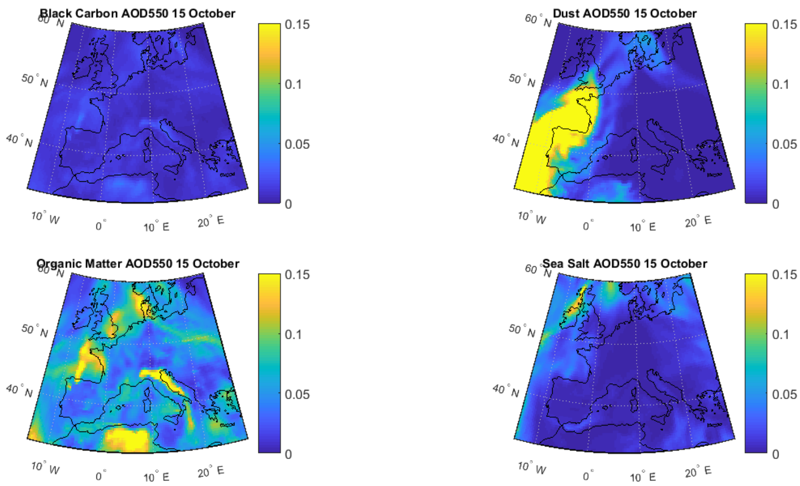


Figure 32d: Same as figure 32a but for 15 of October.

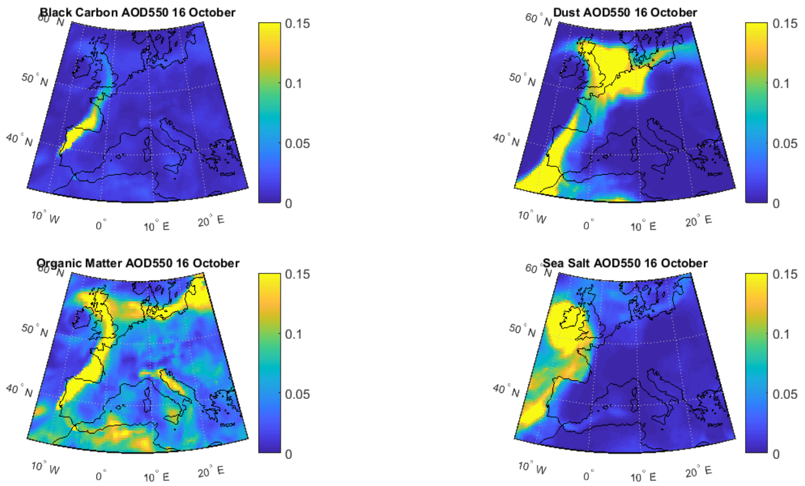


Figure 32e: Same as figure 32a but for 16 of October.

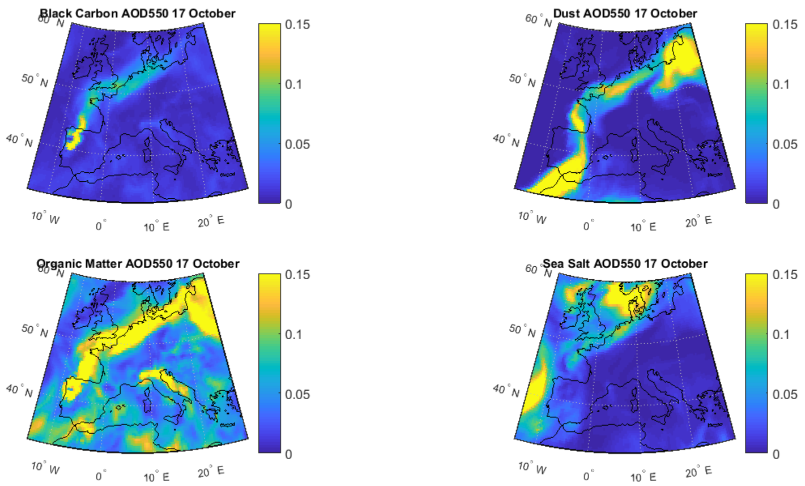


Figure 32f: Same as figure 32a but for 17 of October.

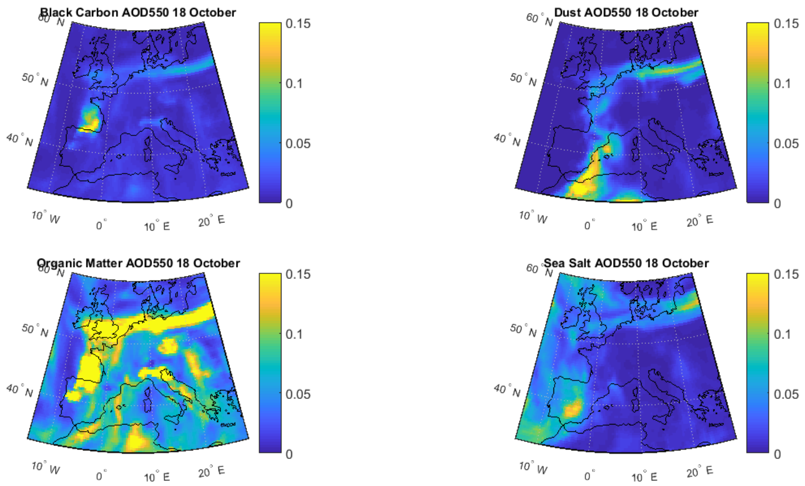


Figure 32g: Same as figure 32a but for 18 of October.

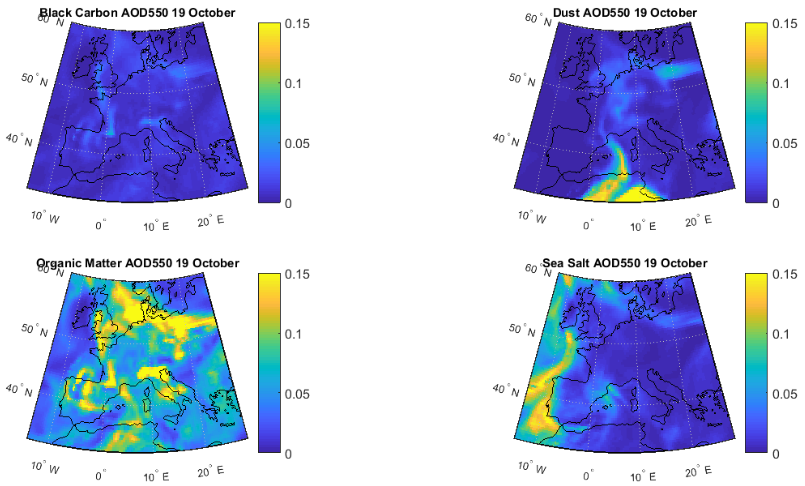


Figure 32h: Same as figure 32a but for 19 of October.

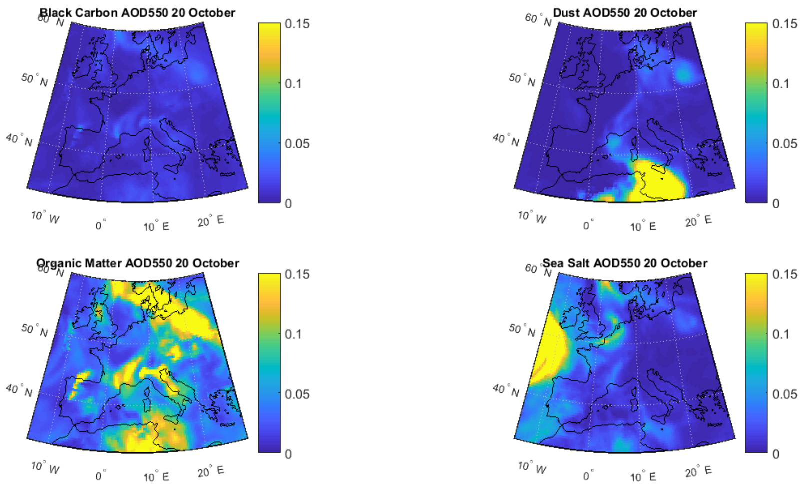


Figure 32i: Same as figure 32a but for 20 of October.

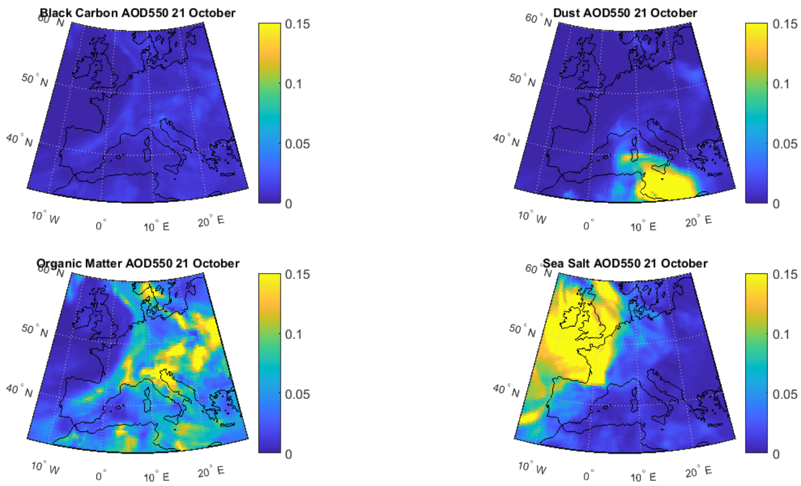


Figure 32k: Same as figure 32a but for 21 of October.

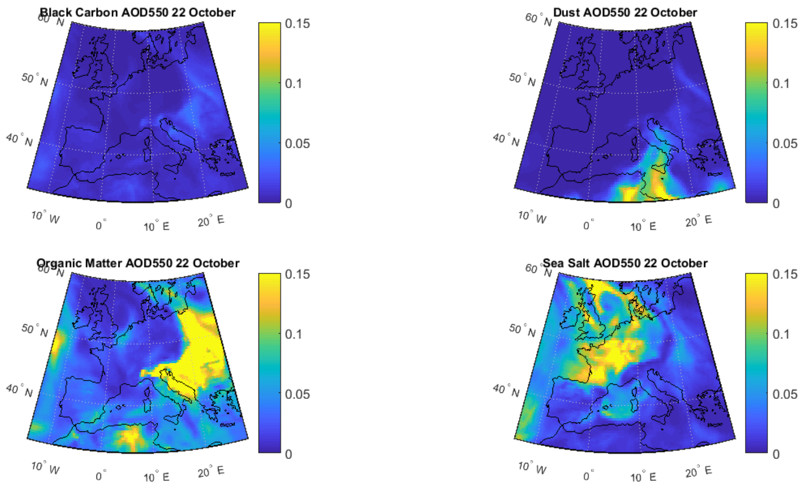


Figure 32k: Same as figure 32a but for 22 of October.

The results seem to confirm the previous figures. The model simulates the fire and hurricane Ophelia correctly, however in the Southern part of Iberian peninsula the model simulates dust aerosol, which can be the cause of the overestimations in the Cabo da Roca station. However at the Madrid station there are coarse mode particles which indicate that there was dust in the Iberian peninsula. In the Worldview maps there are some traces of aerosols, however these results are not robust as there are no inversion data from Aeronet. At the Palencia station the model did simulate correctly the shift from organic matter aerosol to sea salt aerosol but apparently it left small amounts of organic matter aerosol at the area where in the volume distribution there are virtually no fine mode particles. At the OHP Observatoire and at the Madrid station inversion data show a mixture of coarse and fine mode particles to which the model data agree. This practically means that the overestimations are due to an overestimation of one or both of the aerosols.

4.3 Athens-August 2017

The next fire that will be studied is a smaller scale fire in north-eastern Athens during August 2017. When compared to the fires in Portugal this one is much smaller and lasted for about a day, only a fraction of the previous fires. The reason for analyzing such a smaller event, is to identify how the model performs in both large-scale and small-scale events. Furthermore there are some similarities in the aerosol climatology of Portugal and Greece. Both have dust-storms during the summer and spring, but Greece being farther away from Africa gets influenced much less.

Figure 33: Thermal anomalies from WORLDVIEW from 13/08/2017-15/08/2017 (a-c).

From the WORLDVIEW maps one can see that the fire started on the 13/08/2017 but it really intensified on 14/08/2017. The next step is to create HYSPLIT trajectories from 14/08/2017 and find stations in the general direction of the trajectories.

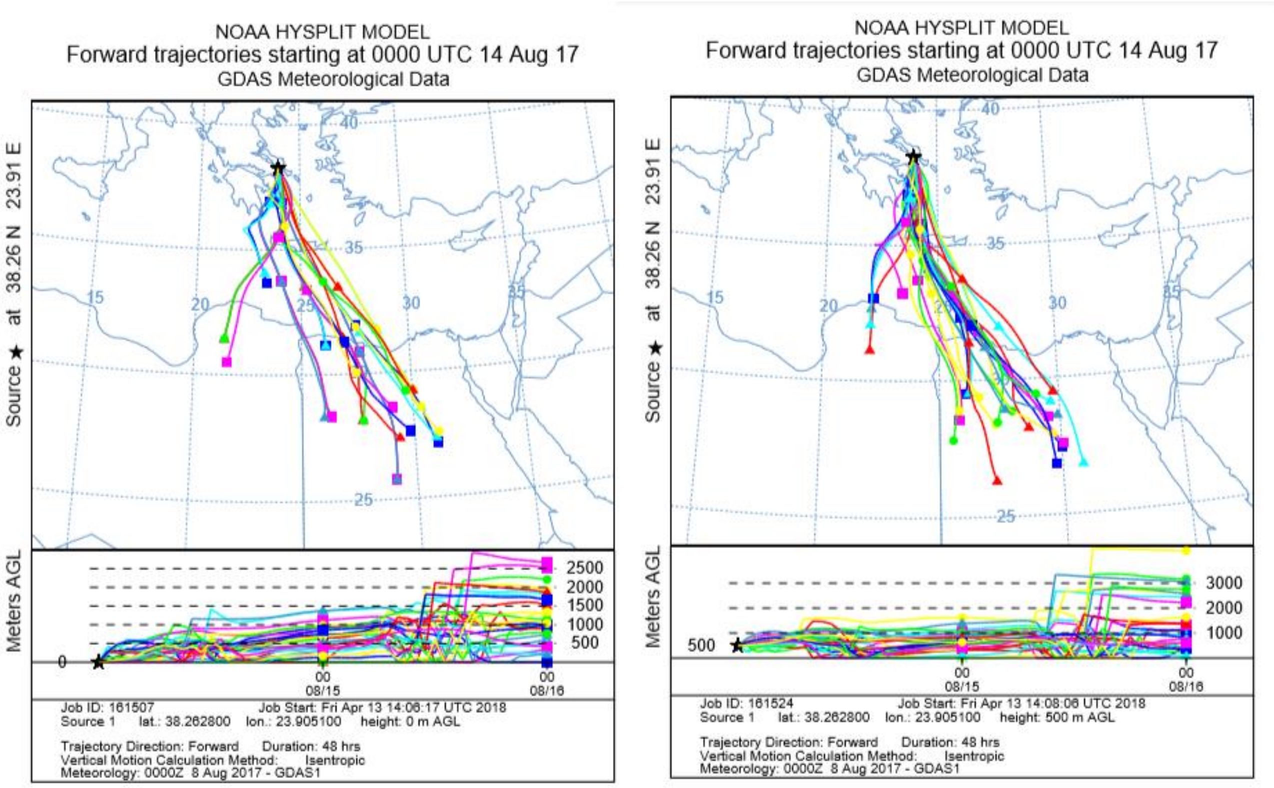


Figure 34a: Trajectories for 14/08/2017 for the fire at the surface (left) and at 500m (right).

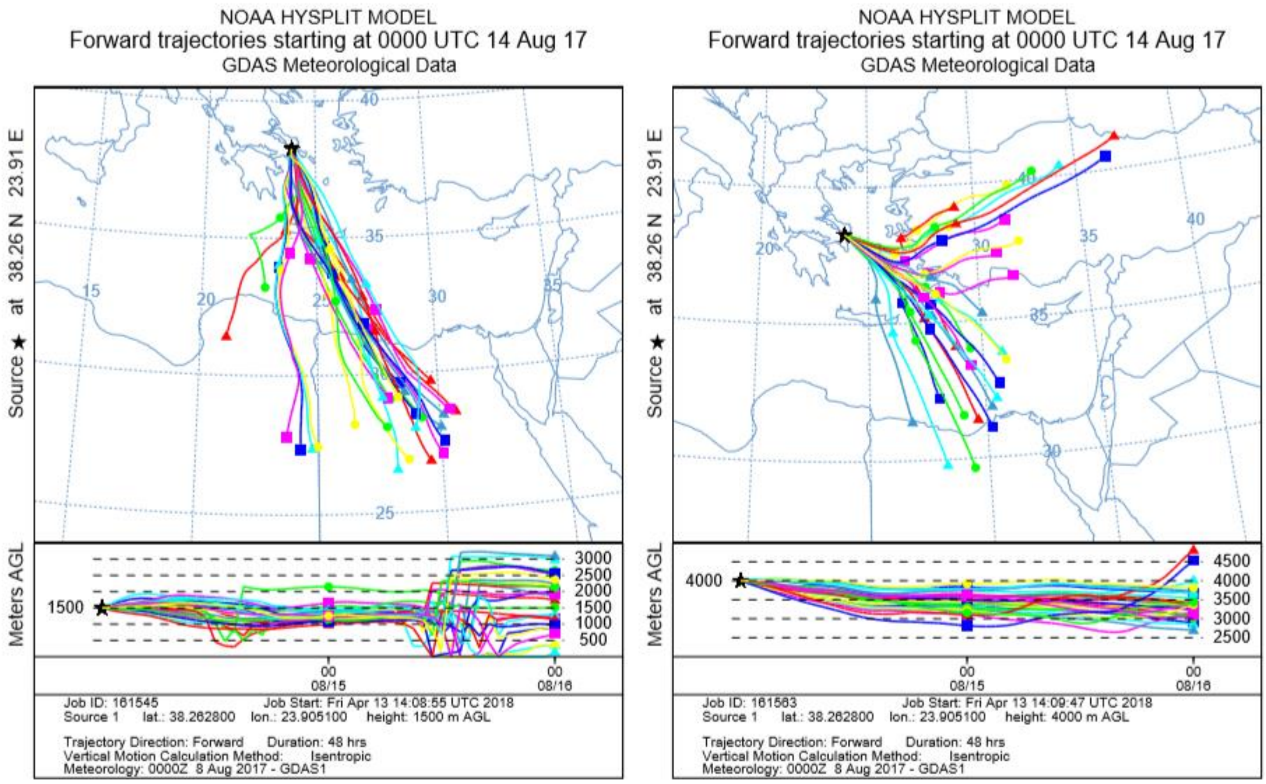


Figure 34b: Trajectories for 14/08/2017 for the fire at 1500m (left) and at 4000m (right).

All trajectories point to the south making dust transport impossible. Thus the stations will be probably evaluated on the increase of organic matter AOD alone.

Name	Longitude	Latitude	Elevation	Level
ATHENS-NOA	23.775	37.988	130	2.0
Finokalia-FKL	25.670	35.338	233	2.0

Table 3: AERONET stations that will be used for the evaluation.

Figure 35: Map of AERONET stations that will be used for analysis.

This event doesn't have as many stations as the other events. However the two stations are well located on top of the generally simple trajectory of this fire. One is very close to the event (ATHENS-NOA) and the other station is in the island Crete (Finokalia-FKL) which is one of the farthest points of the trajectory.

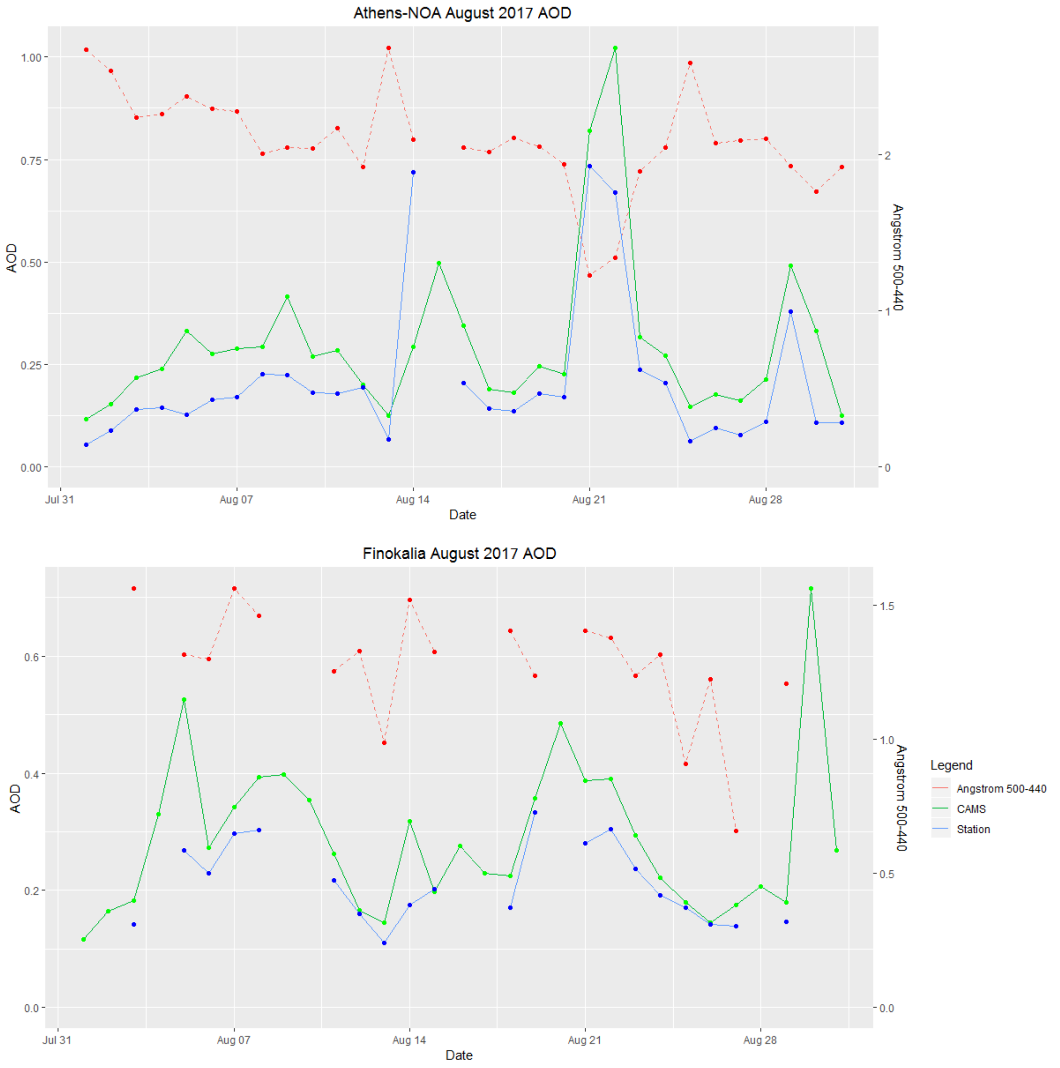


Figure 36a: Comparison of AOD of a collection of AERONET stations in Greece and interpolated ECMWF data.

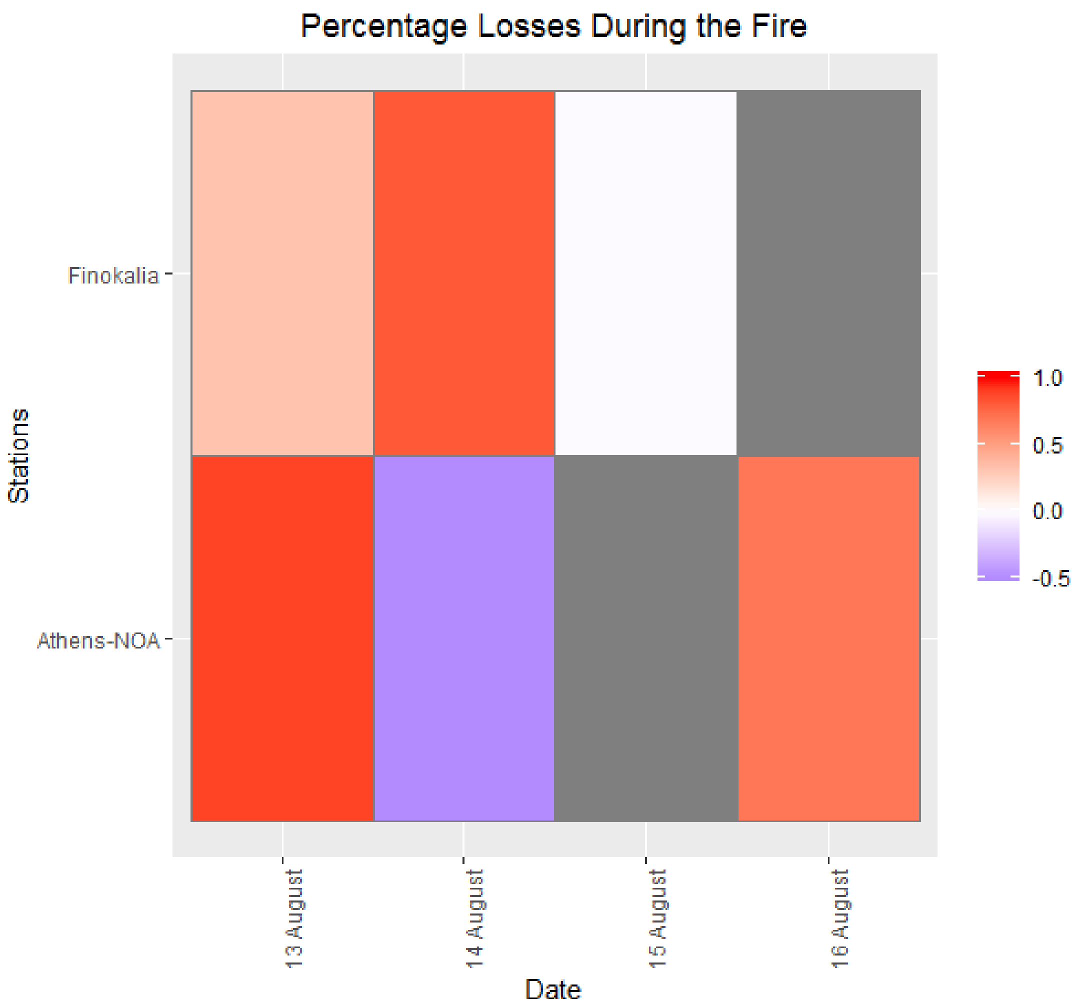


Figure 36b: Percentage losses of stations during the days of the fire

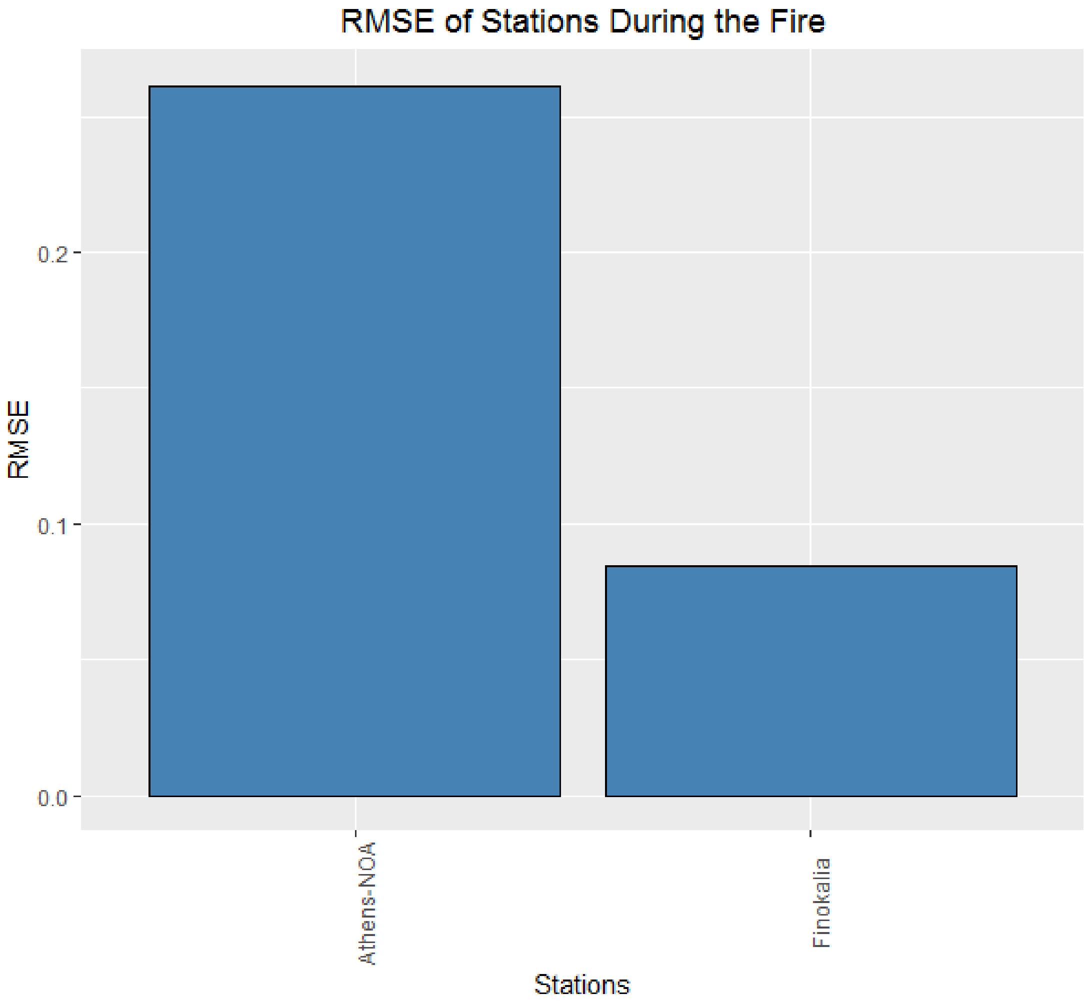


Figure 36c: RMSE of AERONET stations during the fire.

In the Athens-NOA station this is an underestimation by the model, the first time that this happens in the stations that have been studied. In the ECMWF data the AOD starts increasing later in the Athens station which can be the cause of the overestimation. In the Finokalia station the model seems to overestimate the AOD.

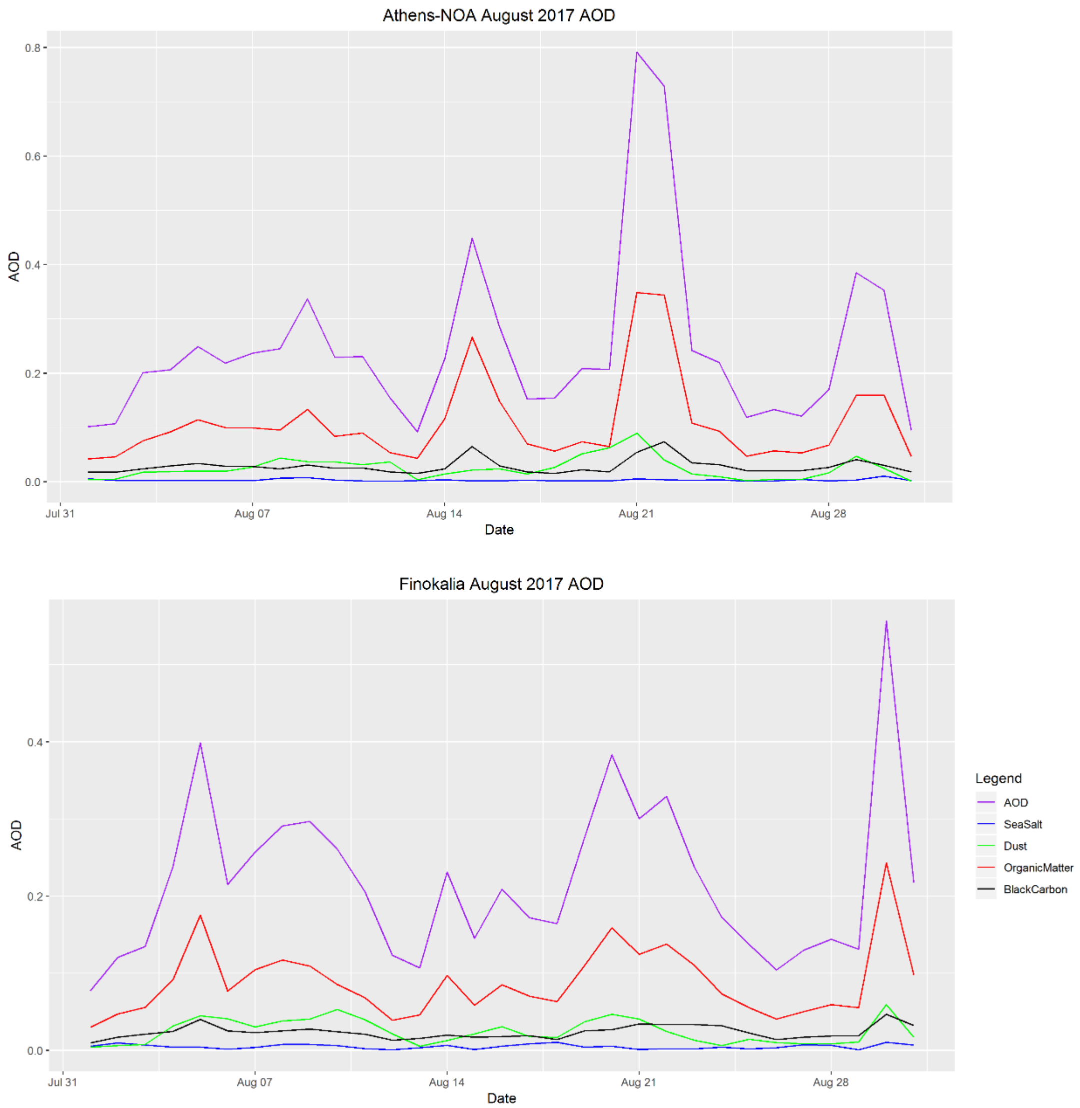


Figure 37: Breakdown of the contribution of each aerosol to the total AOD at 550nm above the AERONET stations in Greece.

As expected due to the wind regime during the fire there was no significant contribution from dust, thus the increase in the AOD seems to be because of the increase in organic matter. In the Finokalia station the peak that is simulated is much smaller in the real data.

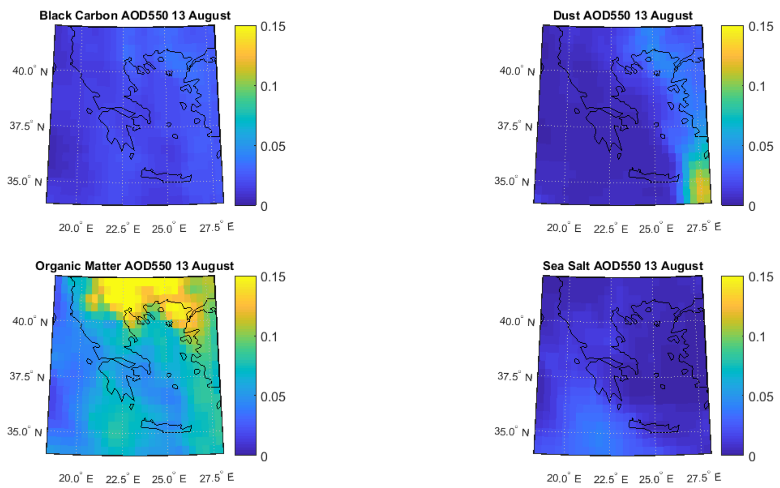


Figure 38a: AOD at 550nm for each of the AOD components provided by the ECMWF in 13 of August.

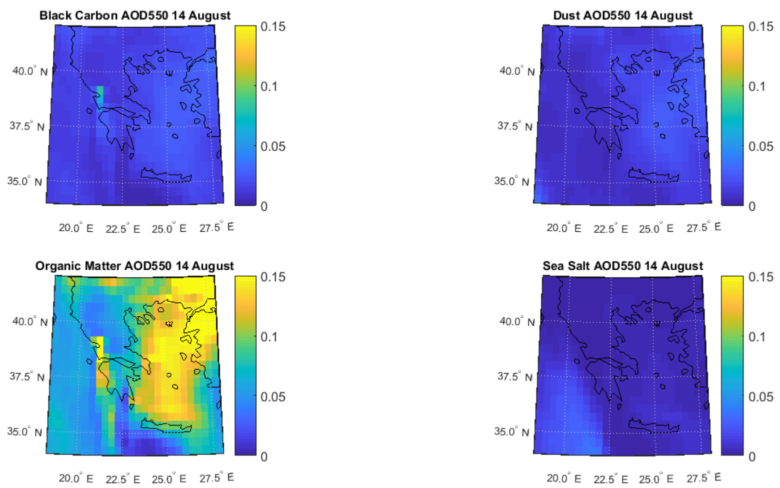


Figure 38b: Same as figure 38a but for 14 of August.

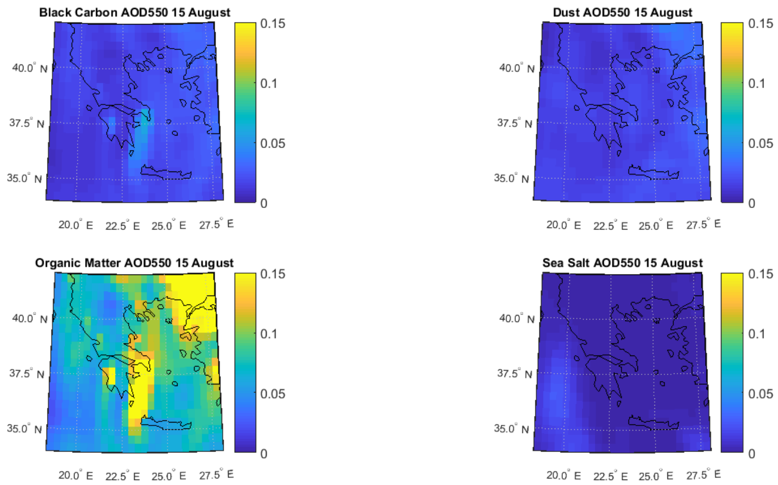


Figure 38c: Same as figure 38a but for 15 of August.

In the ECMWF data there seems to be a fire recorded in the central western Greece that never existed, there is also the possibility that this is some organic matter emissions from fire events northern of Greece that the simulation calculated to have been transported there. This can be seen by the patterns in both Organic Matter AOD and Black Carbon AOD, however since there are no stations in the area, no conclusion can be drawn.

4.4 Sweden-July 2018

The fire in Sweden occurred throughout the summer of 2018, and peaked in July. In this research the fires that occurred during 21-31 of July will be studied. The fires were 'caused by an intense heat storm which was one of the worst Sweden has ever experienced causing July to be the hottest July on record. The fires were really extinguished at the end of July due to the first intense rain. This fire is by far the longest in period when compared to the rest of the events, and the only one located in Scandinavia.

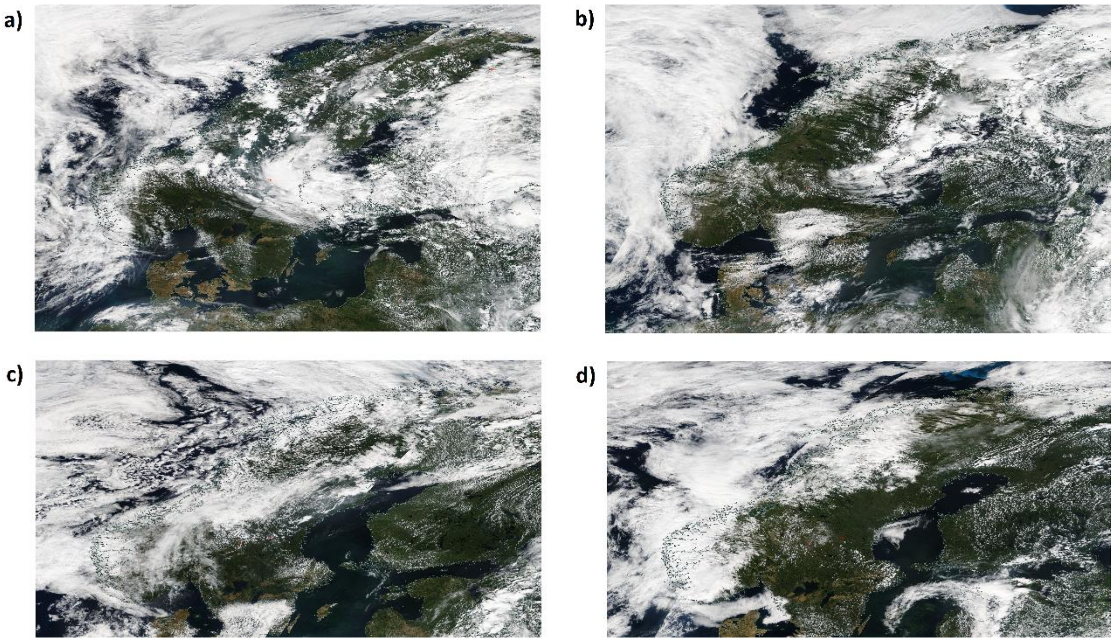


Figure 39a: Thermal anomalies from WORLDVIEW from 21/07/2018-24/07/2018 (a-d).

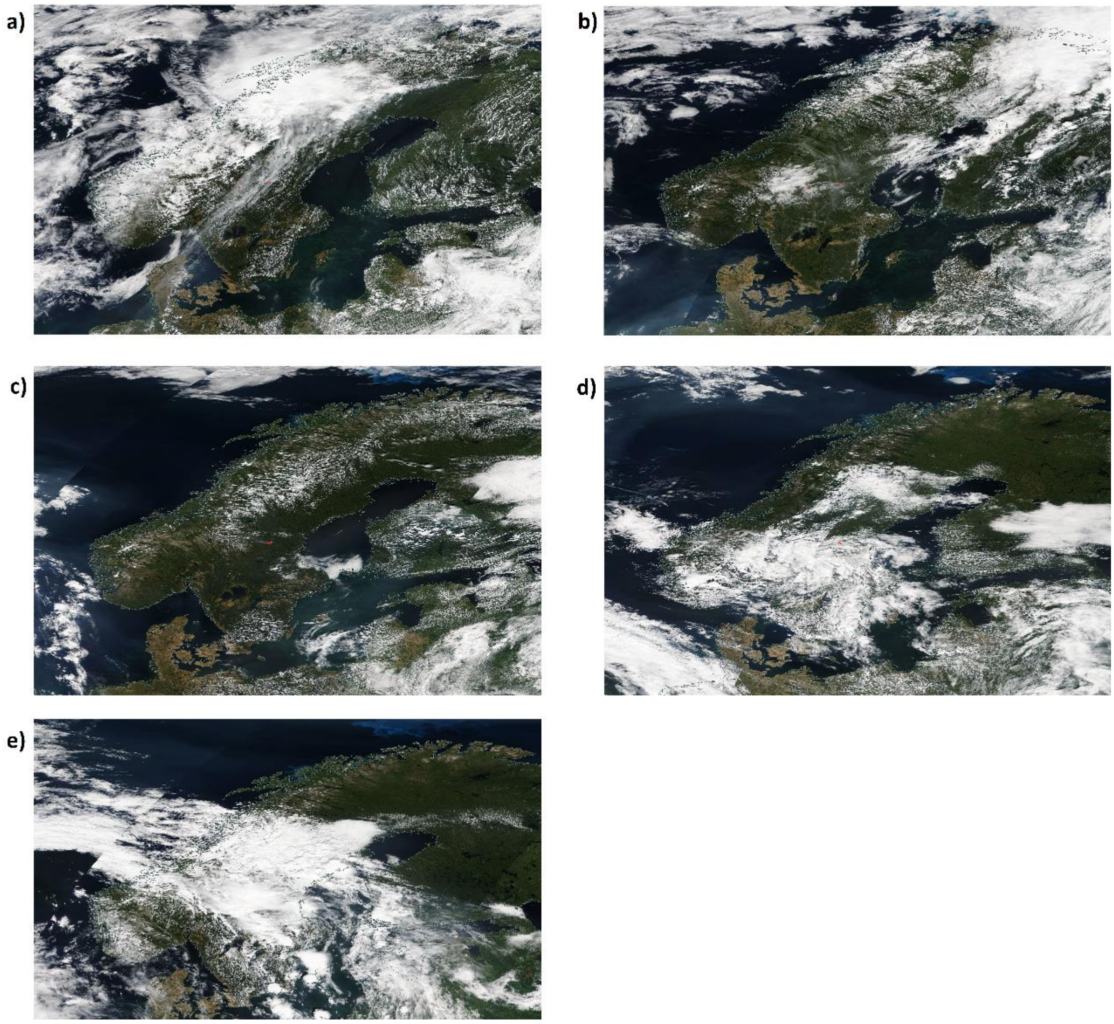


Figure 39b: Thermal anomalies from WORLDVIEW from 25/07/2018-29/07/2018 (a-e).

From these figures there seems to be fire anomalies consistently through-out the time period until they eventually die out in 29 of July. In 23 of July the fire anomalies seem to be most intense.

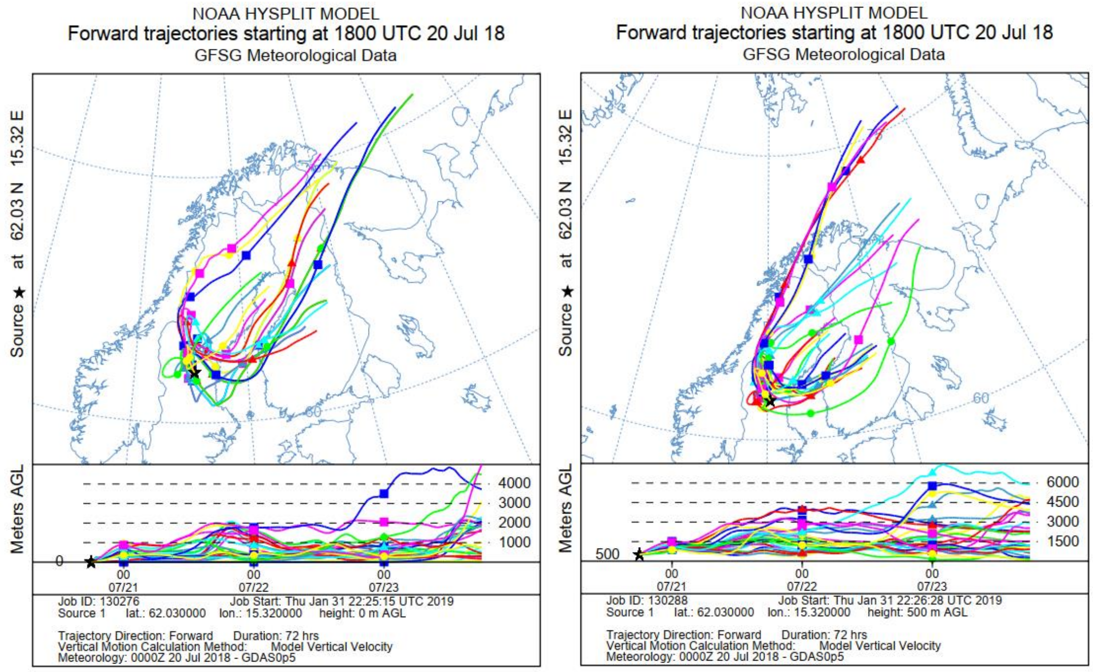


Figure 40a: Trajectories for 20/07/2018 for the fire at the surface (left) and at 500m (right).

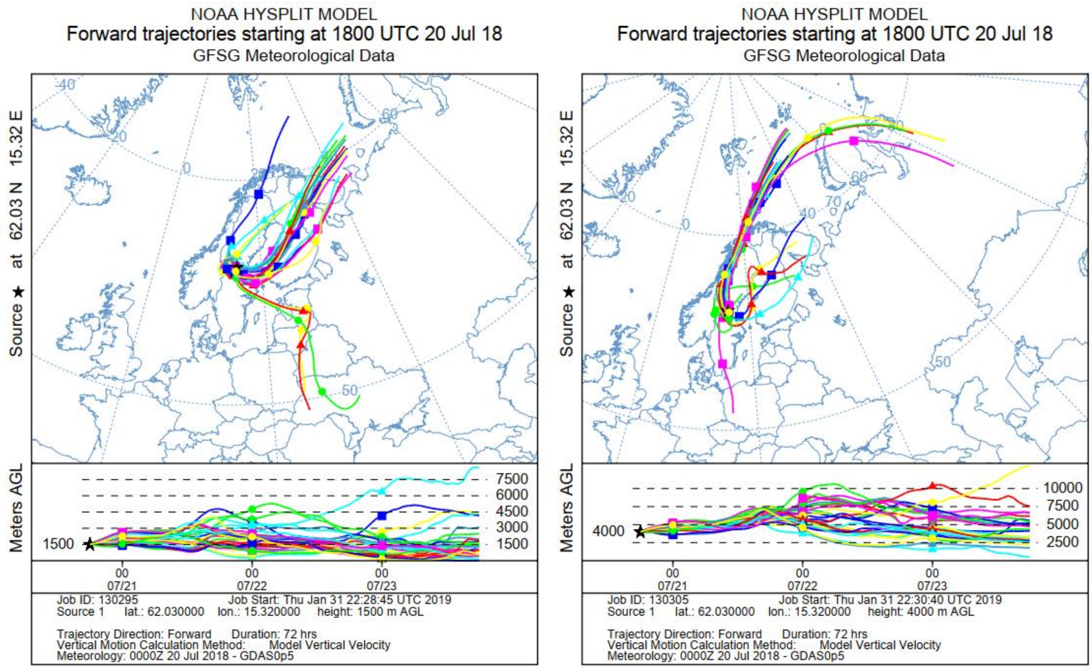


Figure 40b: Trajectories for 20/07/2018 for the fire at 1500m (left) and at 4000m (right).

The wind direction during the days of the fire pushed the aerosols towards Finland. The stations were chosen in Finland because there were no stations in Sweden.

Name	Longitude	Latitude	Elevation	Level
Helsinki	24,961	60,204	52	1.5
Hyytiala	24,296	61,846	191	1.5
Kuopio	27,634	62,892	105	1.5
Sodankyla	26,63	67,367	184	1.5

Table 4: Aeronet stations used in the Evaluation

Figure 41: Map of AERONET stations that will be used for analysis.

It is unfortunate that there are no stations in Sweden but these stations will give a good picture of how the model performs. It's worth noting that Scandinavian countries have very different aerosol climatology when compared to the Mediterranean countries. The Mediterranean is a crossroads of different types of aerosols which creates a very complicated climatology making it even more difficult to simulate while Scandinavian countries have a much simpler aerosol climatology.

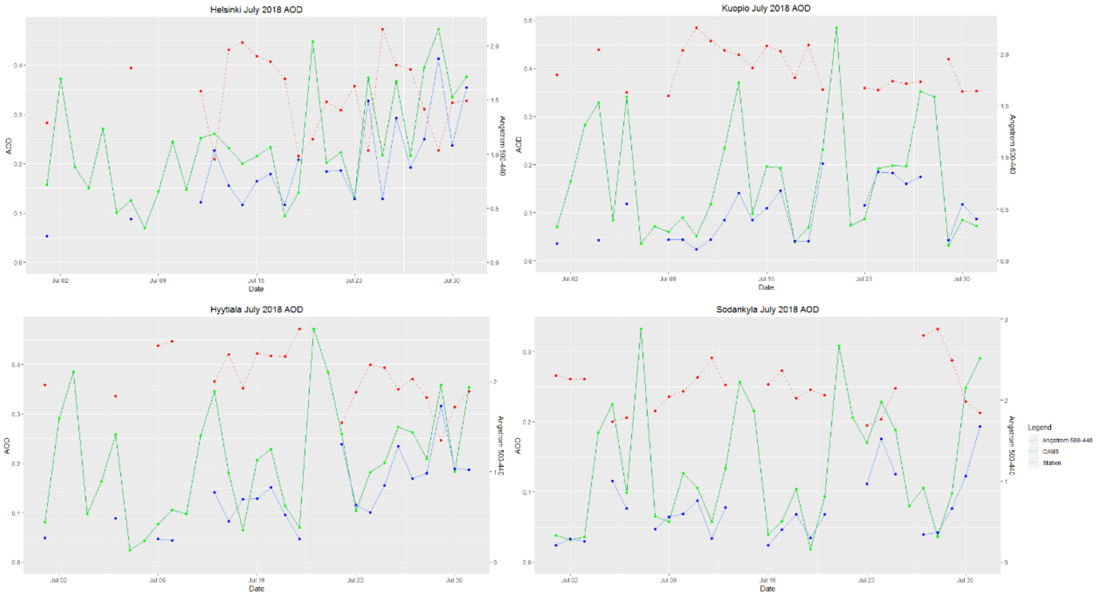


Figure 42a: Comparison of AOD of a collection of AERONET stations in Finland and interpolated ECMWF data.

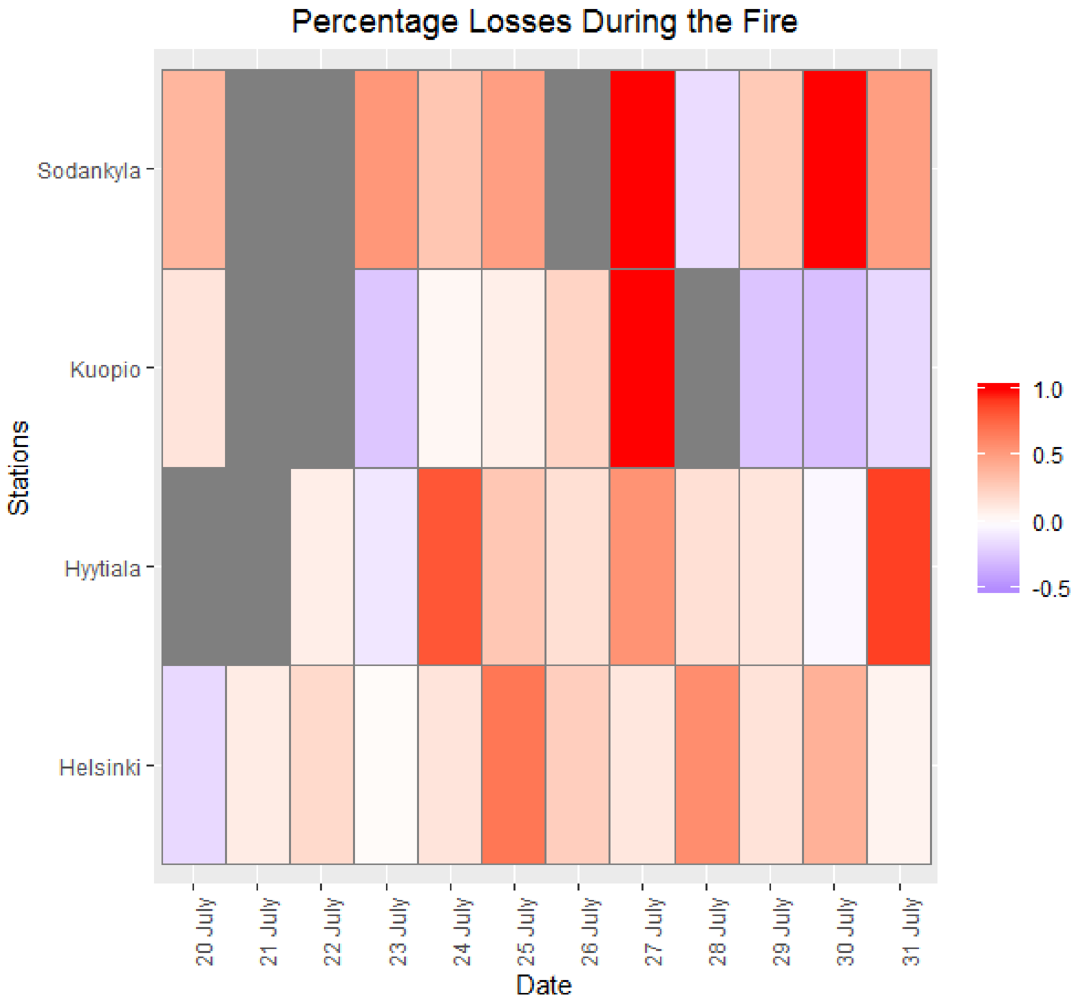


Figure 42b: Percentage losses of stations during the days of the fire

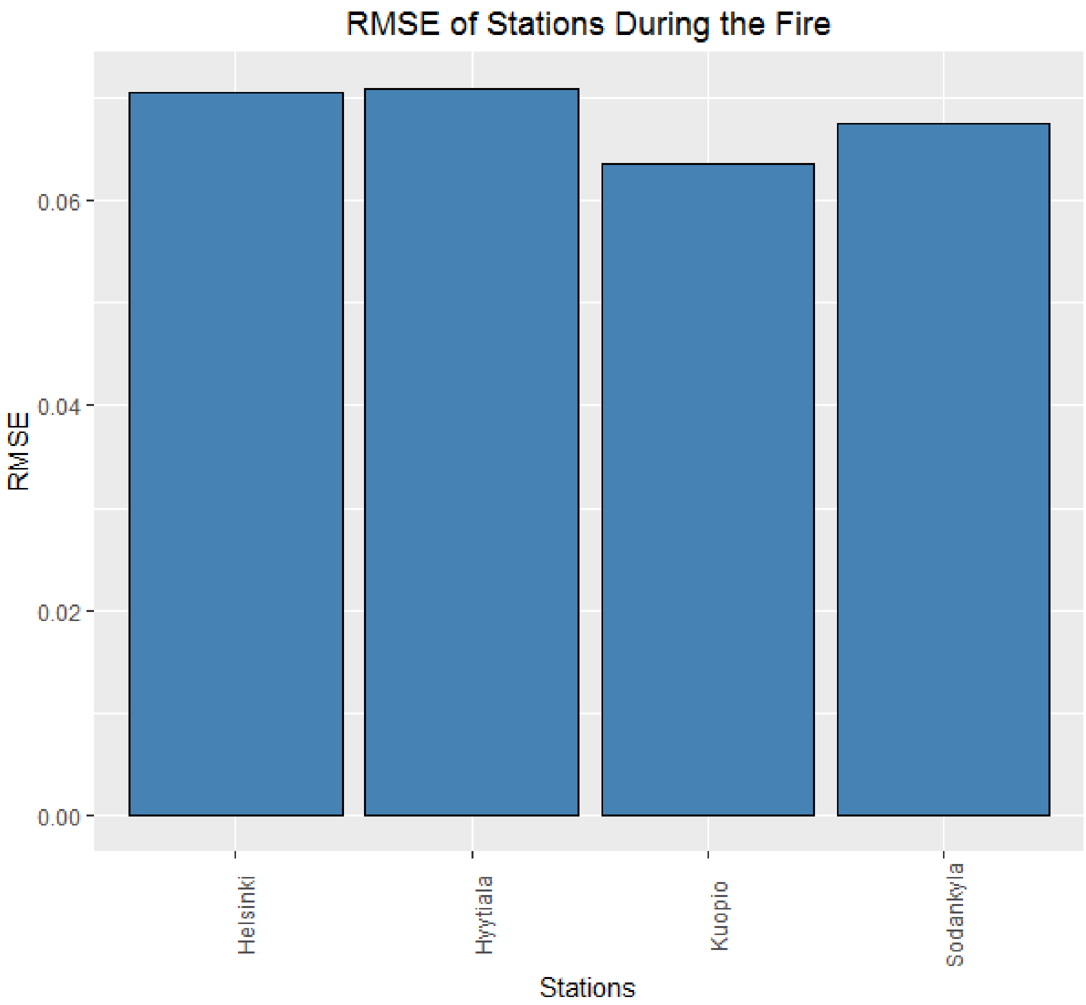


Figure 42c: RMSE of AERONET stations during the fire.

The stations seem to be missing data during the peaks that are recorded by CAMS, especially the peak at 21 of July. In the rest of the data the model performs well, it only generally overestimated the data across all stations. This can also be seen in the average RMSE which is less than 0.07 in all stations, and from the figure it is obvious that the losses are consistent in all stations.

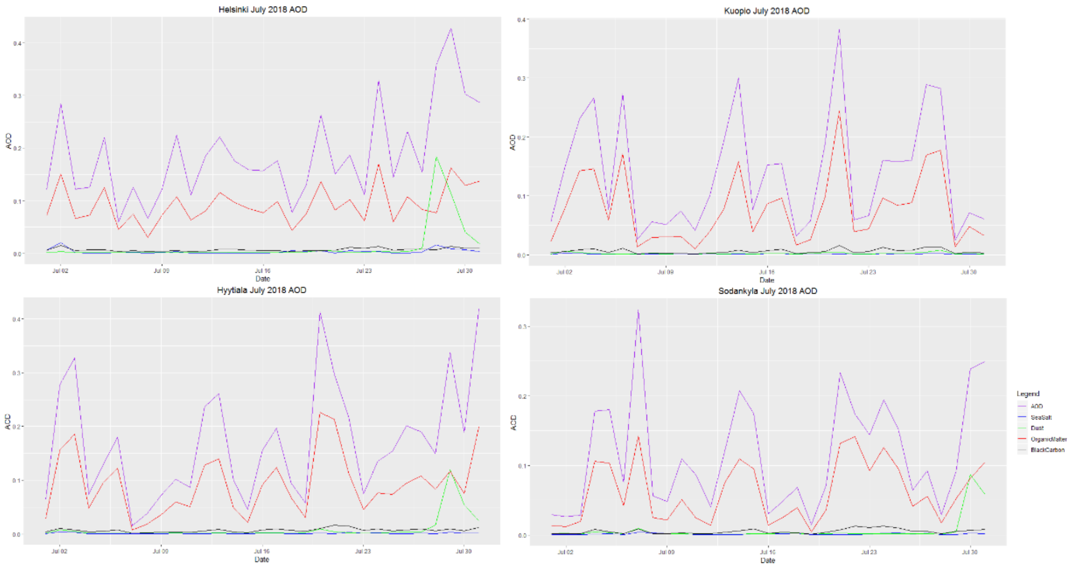


Figure 43: Breakdown of the contribution of each aerosol to the total AOD at 550nm above the AERONET stations in Finland during July.

The AOD movements are completely explained by organic matter aerosol, as expected. This is far different than the fires in Portugal where there was a mix of different aerosols. After the days of the fire, during 29 and 30 of July some dust aerosol was recorded in the stations which is very unusual given the latitude of the stations. Luckily the inversion datasets have data for the given days.

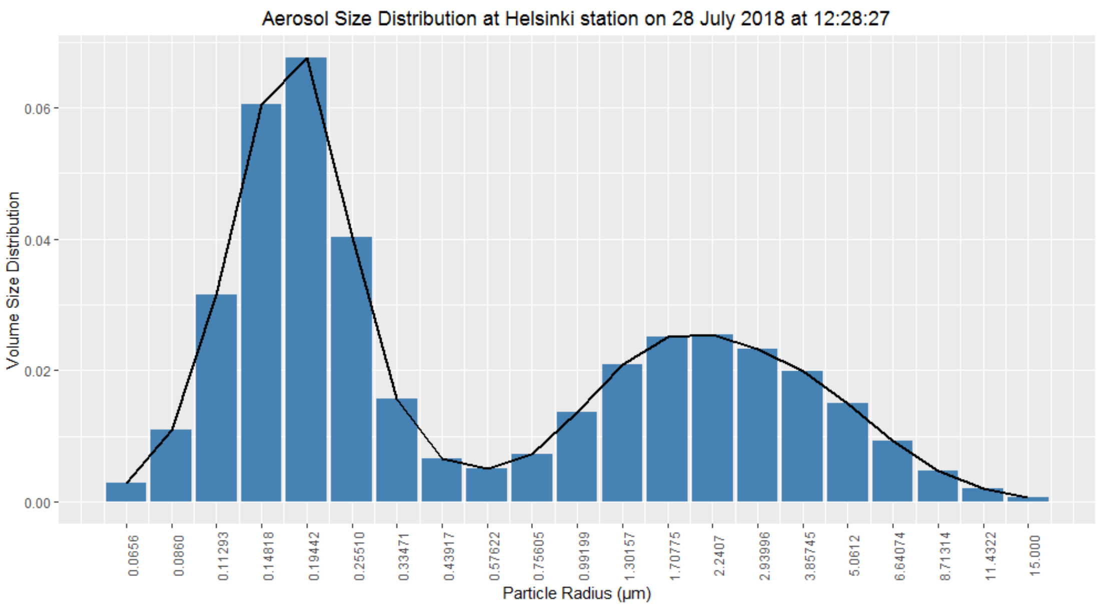


Figure 43a: Volume size distribution on 28 July at Helsinki station.

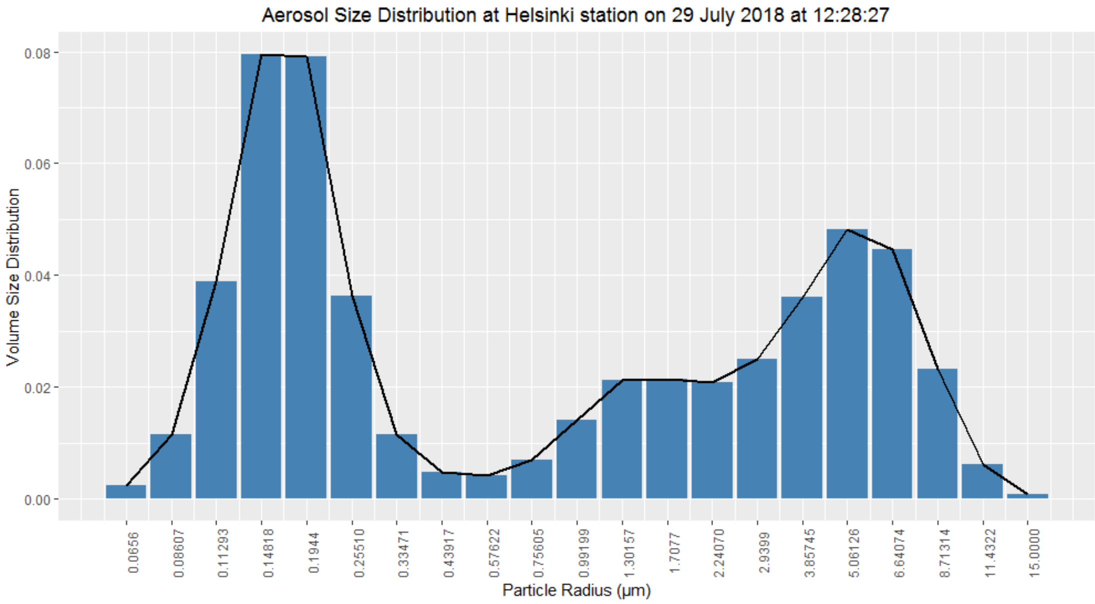


Figure 43b: Volume size distribution on 29 July at Helsinki station.

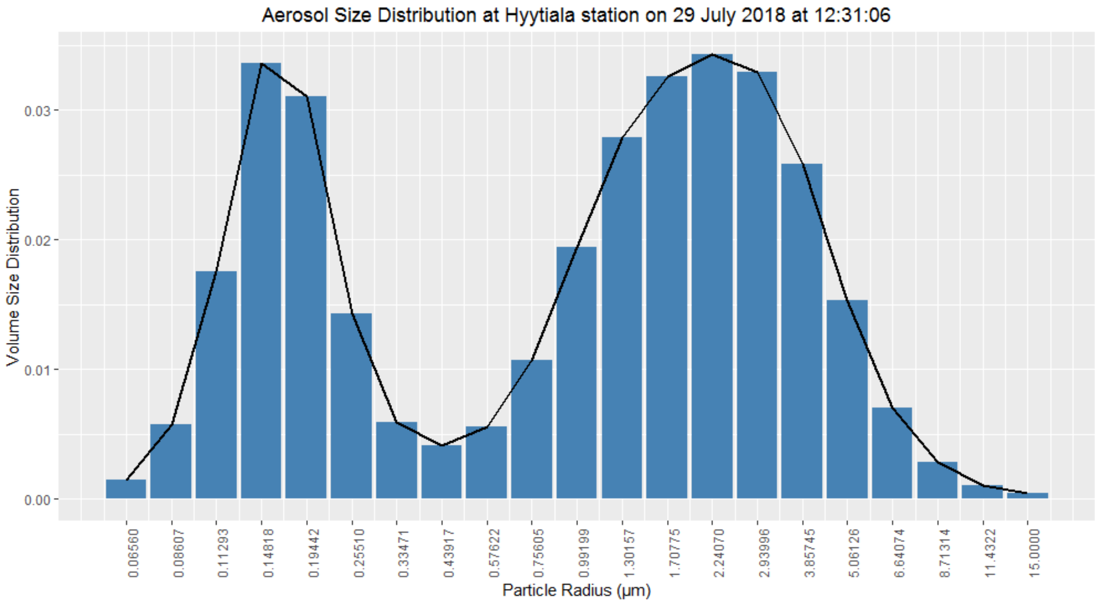


Figure 43c: Volume size distribution on 29 July at Hyytiala station.

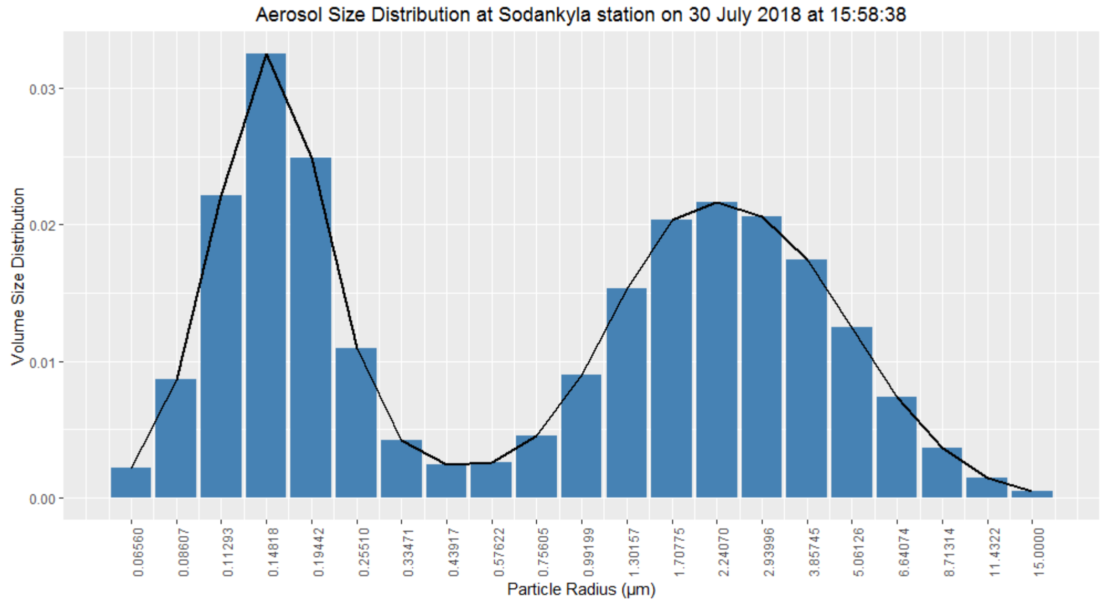


Figure 43d: Volume size distribution on 30 July at Sodankyla station.

It seems that the model correctly predicted the dust aerosol because in every station there are coarse mode aerosols. At the Helsinki station more coarse mode aerosols are on 29 of July than 28 of July in contrast with the model data where at 28 there is a peak of dust aerosol.

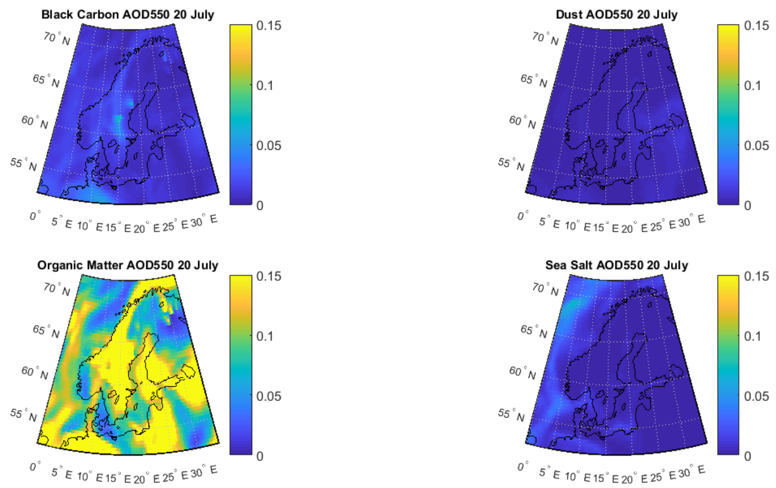


Figure 44a: AOD at 550nm for each of the AOD components provided by the ECMWF in 20 of July.

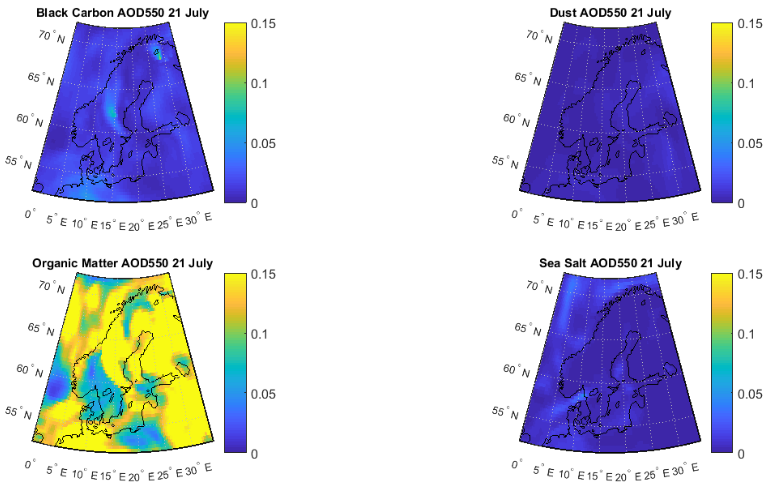


Figure 44b: Same as figure 44a but for 21 of July.

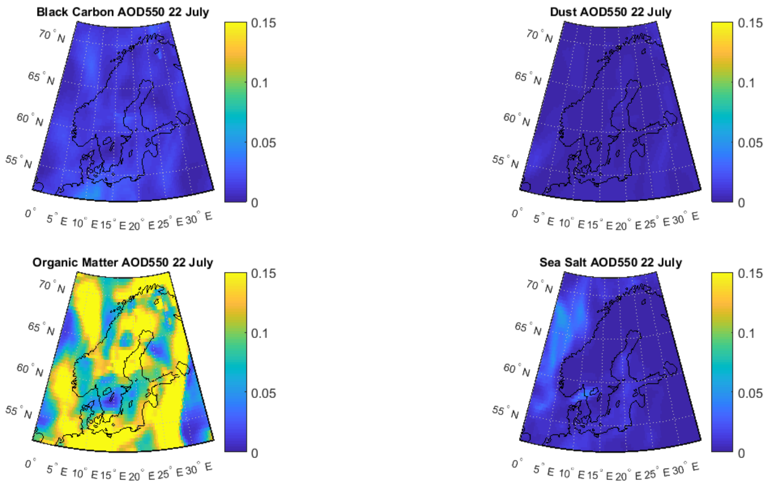


Figure 44c: Same as figure 44a but for 22 of July.

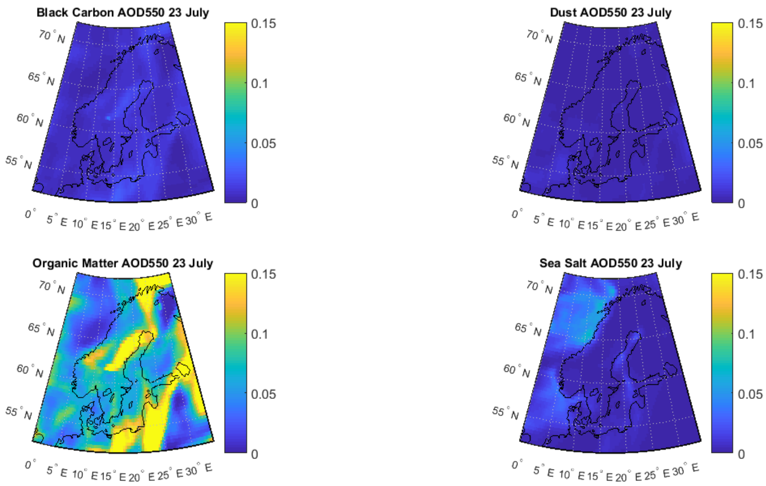


Figure 44d: Same as figure 44a but for 23 of July.

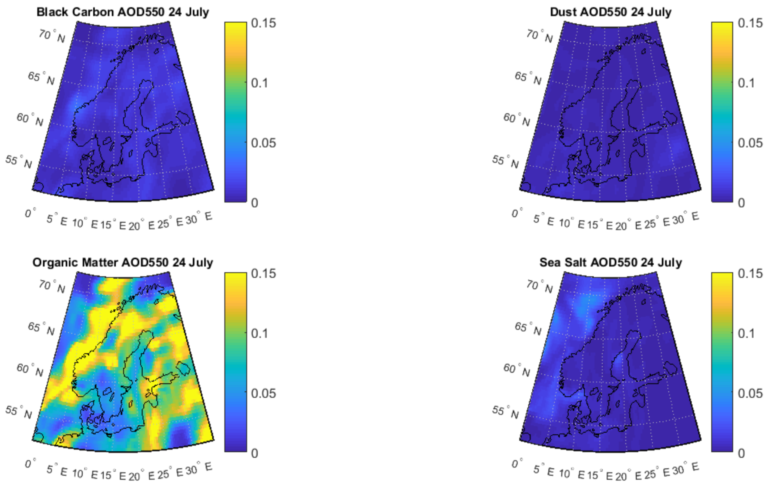


Figure 44e: Same as figure 44a but for 24 of July.

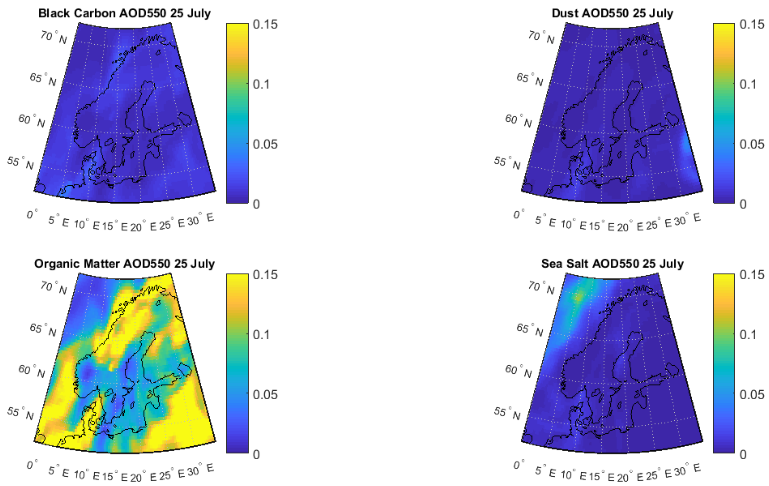


Figure 44f: Same as figure 44a but for 25 of July.

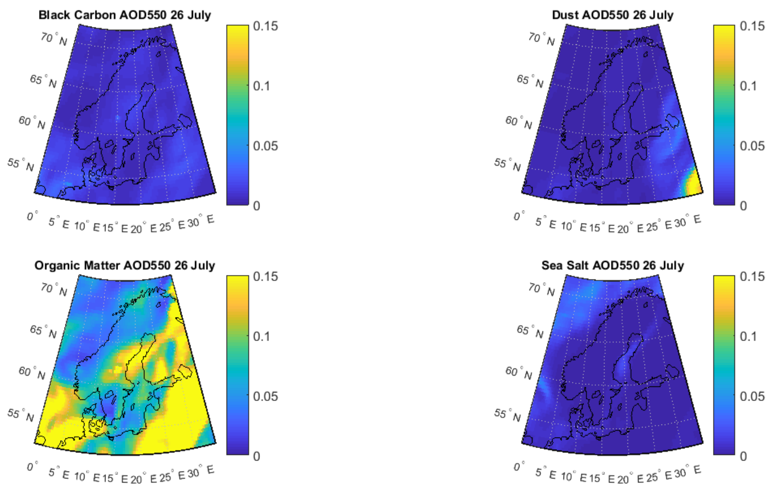


Figure 44g: Same as figure 44a but for 26 of July.

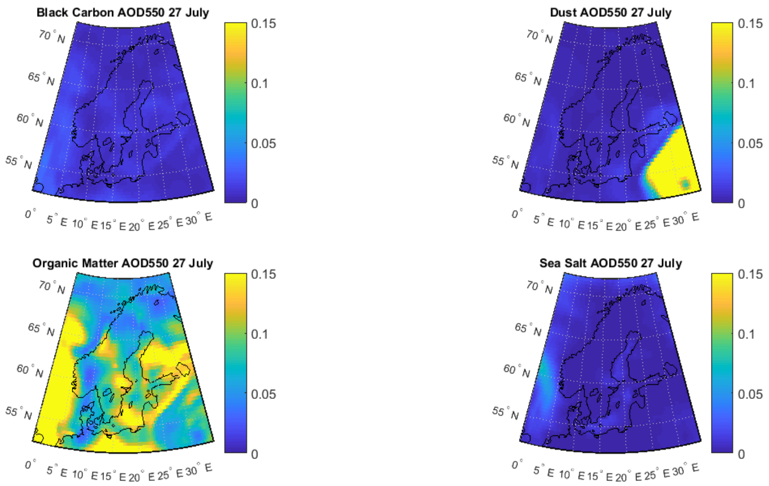


Figure 44h: Same as figure 44a but for 27 of July.

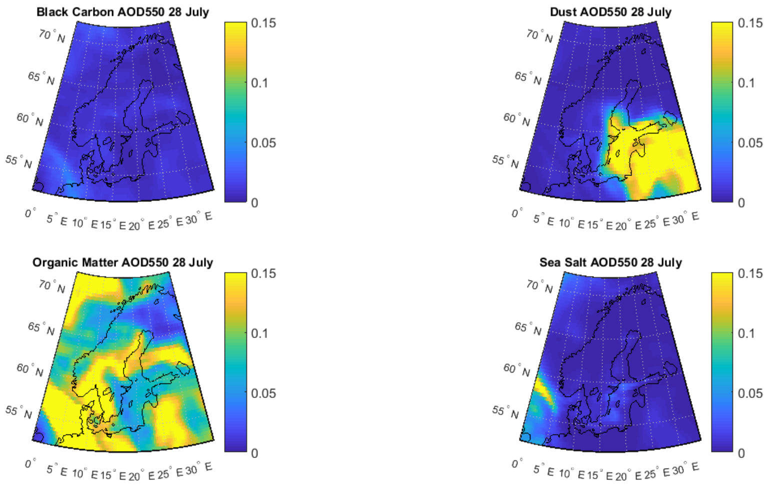


Figure 44i: Same as figure 44a but for 28 of July.

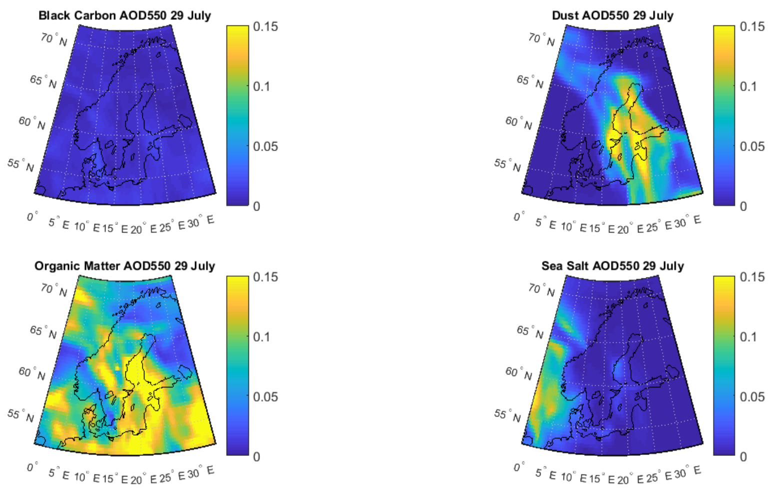


Figure 44j: Same as figure 44a but for 29 of July.

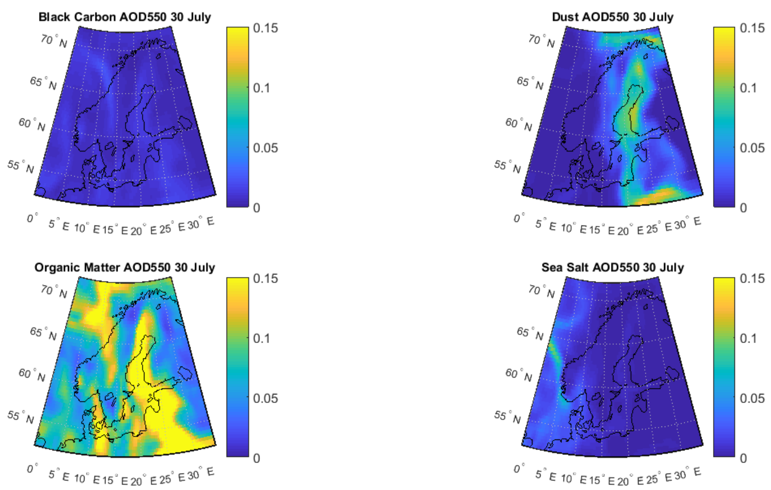


Figure 44k: Same as figure 44a but for 30 of July.

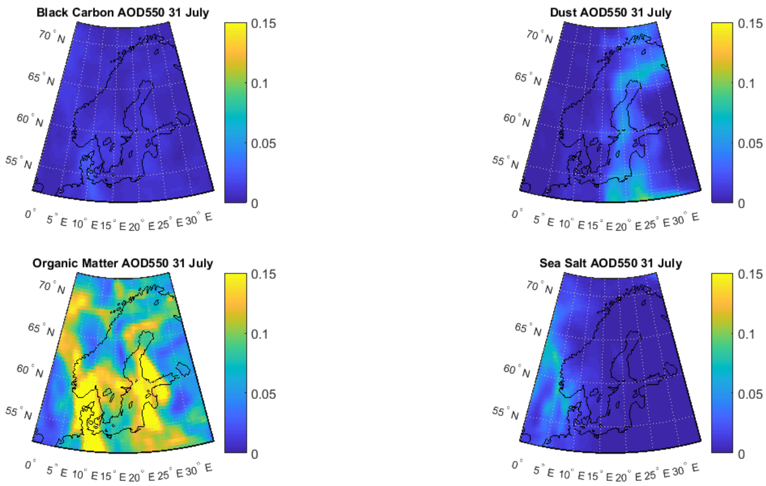


Figure 44l: Same as figure 44a but for 31 of July.

In the first days mapped the fires seemed to be more intense until 28-29 of July when the die down. During 28-30 a dust seems to be transported from the south east which is confirmed by the previous figure.

Chapter 5: Conclusions

Chapter 5: Conclusions

In this study four fires where considered, the first three in the Mediterranean and in the same year, while the fourth was in Sweden which has radically different aerosol climatology. The Mediterranean is a region where multiple aerosols get mixed which makes it a particularly hard region to simulate, while Scandinavian countries have very simple aerosol regimes. The first two fires were in Portugal, and in the second event a hurricane hit the shores of Portugal influencing the direction of the fire as well as its intensity. The third event was the smallest event studied and the shortest in duration, while the event in Sweden was the longest of all the events, and the main reason that it was chosen was due to the radically different aerosol climatology of the region which allowed a comparison to be made with the rest of the fires studied.

During all the events it seems that the models generally overestimate the emissions. The biggest differences can be interpreted as missing data from GFAS. The complex nature of the aerosol regime seems to further complicate the simulations as the transportation of all the different aerosols must also be calculated. The wind regime during the days of the fire is also important as it determines the aerosol transport.

In the June event in Portugal the model accurately predicts a mixed environment where dust and organic matter aerosol are present. However during the last days of the event the model simulates large amounts of organic matter and black carbon AOD, which causes large overestimations. It was furthered confirmed that there isn't organic matter in the area by inversion data and WORLDVIEW maps where no fire or heat anomalies are present. The inversion data clearly show a coarse mode dominance during the days of the overestimations while in the maps from the model the dust that was present in the region throughout the days of the event is shifted eastward. This false event can actually just be missing data that were falsely simulated forward by previous observations where a fire actually existed, when finally the model takes data it is informed that the fire has ended and stopped stimulating it.

In the October event the situation was more complex due to hurricane Ophelia. Unfortunately there were a lot of missing data precisely the day the hurricane hit the shores of Portugal. In general the model performed well despite the very complex event. In Madrid and OHP Observatoire the model overestimates the data however the breakdown of each aerosol agrees with the inversion dataset which means that either one or both of the aerosols are overestimated. In the Palencia station the inversion data show no fine mode aerosols and while the model simulates the change from organic matter aerosols to sea salt aerosols, it leaves a small amount of organic matter aerosols that cause the overestimations/ Unfortunately in the Cabo da Roca station that recorded the biggest losses and in most stations during the hurricane Ophelia there are a lot of missing data and no conclusion can be made.

In contrast to the events in Portugal the third event that was studied was a much smaller event in Greece. This event has some distinct differences between the Portugal events. Even though Greece is in a similarly complex region in terms of aerosol climatology, the event was much smaller, and due to the wind regime during the fire, dust aerosols didn't affect the simulation, however because the fire emissions didn't leave Greece's borders there are only two stations available. In that event the station that was closest to the fire actually was underestimated by the model while the station that was farther away was overestimated. This is the only station in all the events where the AOD was underestimated. In the maps produced by the model data the model seems to have simulated another fire in the north western part of Greece while in the Worldview maps no such event exists. But one of the main problems is that the fire seems to begin a day later. This again can be interpreted as a lack of GFAS data.

The last event was in Sweden and it was chosen because of how radically different the aerosol climatology is. Sadly there were no station very close to event however the stations that were studied recorded very small losses. This also an event where the losses where uniform across all stations. During the end of the fire the dust that was simulated by the model is also correct according to the inversion data. When comparing the events it's safe to say that the fires in Sweden were simulated most accurately.

In conclusion:

- The model seems to generally overestimate the AOD from the fire.

- Overestimations occur commonly due to the spatial extent and amount of organic matter AOD.
- A complex wind and aerosol regime further complicate the simulation making the biases greater.
- Predictions in smaller scale fires are also more accurate than larger scale ones.
- On two occasions large amounts of organic matter were simulated in areas where no event existed.
- Large overestimations or underestimations of AOD are usually linked to missing GFAS data. As was seen in Greece if there are no GFAS data the simulation cannot start. While in Portugal if the fire stops during a time where there are no GFAS data the model continues to simulate based on previous data.

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