ESTIMATION OF BIOMASS BURNING EMISSIONS OVER TURKEY USING SEVIRI FIRE CHARACTERIZATION DATA: THE ANTALYA FIRE, AUGUST 2008

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1. INTRODUCTION

Fire is the main cause of forest destruction in countries of the Mediterranean Basin. Recent studies have also shown that in Europe the fire contribution to $PM_{2.5}$ were comparable with the anthropogenic contribution during recent years (e.g., Sofiev et al., 2009).

For regional air quality modeling purposes, the availability of information on forest fires and their gaseous and aerosol emissions becomes critical for specific regions and seasons. The continuous improvements of air quality models, such as CMAQ (Community Multiscale Air Quality), permit to simulate the chemical composition of the atmosphere at finer resolutions. Therefore also emission inventories must be provided with higher level of detail in terms of both spatial and temporal resolution. In particular forest fire emissions, due to their episodic nature, are characterized by high spatial and temporal variations. In order to better simulate the impact of fire emissions on air quality it is fundamental to better describe the entire evolution of the fires. Satellite observations can provide the needed information both in terms of spatial and temporal resolution. Spinning Enhanced Visible and Infrared Imager (SEVIRI) based Fire Radiative Power (FRP) can be directly linked to the biomass combustion and emissions rate (Wooster et al., 2005) and has sufficient time resolution (15 minutes) to observe the complete fire life cycle and thus capture fires when they reach their peak intensity.

Observed FRP has been successfully used to calculate biomass combusted from wildfires using SEVIRI radiometer onboard the geostationary Meteosat-8 platform in Africa (Roberts et al., 2005) and MODIS data both in Africa and worldwide (Kaiser et al., 2009, 2012).

The EUMETSAT Land SAF Fire Radiative Power and the Wildfire Automated Biomass Burning Algorithm (WF_ABBA) provide operational fire radiative power products based on SEVIRI observations using different algorithms.

In this study we derived emission estimates of the principal pollutants based on these two fire datasets over the East Mediterranean Basin in the beginning of August 2008, when a large forest fire occurred in the province of Antalya (South of Turkey). This emission inventory is compared to other inventories, which are available at larger spatial and temporal resolution, and the impacts of fire emissions on air quality will be investigated through CMAQ air quality modeling simulations.

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2. DATA

The Wildfire Automated Biomass Burning Algorithm (WF_ABBA) is a dynamic contextual algorithm developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison using multispectral GOES data to monitor biomass burning in the Western Hemisphere (Prins & Menzel, 1992, 1994, Prins 2001). Recently a global version of the WF_ABBA (Version 6.5) has been applied to MSG-SEVIRI data. The global geostationary WF_ABBA Version 6.5.006 includes the following:

- Opaque cloud product indicating where fire detection is not possible.
- Fire Radiative Power and Dozier instantaneous estimates of fire size and temperature.
- Meta data on processing region; opaque cloud coverage; block-out zones due to solar reflectance, clouds, extreme view angles, biome type, bad data, etc.
- Fire/meta data mask

The Land SAF FRP PIXEL product is derived every 15 min at the native SEVIRI pixel resolution[1]. The disseminated product includes for each processed pixel, the FRP (MW), the corresponding uncertainty in the FRP retrieval based on the variability of the background radiance estimation, and a confidence measure (representing the level of confidence that the observation is indeed a "true" fire) (Govaerts et al., 2007).

Due to the higher spatial resolution observations and wide usage of the Moderate Resolution Imaging Spectroradiometer (MODIS) active fire products these are taken to be the reference standard against which the SEVIRI FRP product is assessed.

The Global Fire Assimilation System version 1.1 (GFASv1.1) calculates biomass-burning emissions by assimilating Fire Radiative Power observations from the MODIS instruments onboard the Terra and Aqua satellites. It provides daily emissions on a global 0.1° × 0.1° grid.

The comparison of SEVIRI FRP to GFAS emissions should be regarded as a comparison between two independent data sets rather than a validation using a reference data set (EUMETSAT, 2008).

3. METHOD

In order to create a fire emission inventory to use as input of CMAQ model, we started from WF_ABBA and Land SAF FRP product and generated a gridded FRP product at 0.1° × 0.1° resolution containing area integrated FRP totals corrected for partial cloudiness at the grid-cell scale. Then we averaged the gridded FRP over 1 hour time period.

The hourly FRP gridded product was converted to major contaminants emission rate using conversion factors to dry matter combustion rate and emission factors described in Kaiser et al., 2012 (the last ones are based on an updated version of the compilation by Andrea and Merlet (2001)).

The study region (named “Turkey” in the figures and table) is centered within the regular scanning zone of SEVIRI covering the Eastern Mediterranean (from 15ºE to 45ºE longitude and from 32ºN to 50ºN latitude).

4. CASE STUDY (ANTALYA FIRE)

A large forest fire broke out in Turkey’s top tourist province of Antalya on July 31, 2008 (Fig. 1). It burned for 5 consecutive days and destroyed about 4,500 hectares of forestland, 60 homes, dozens of farming buildings, and was occupying at least 2,000 firefighting personnel.

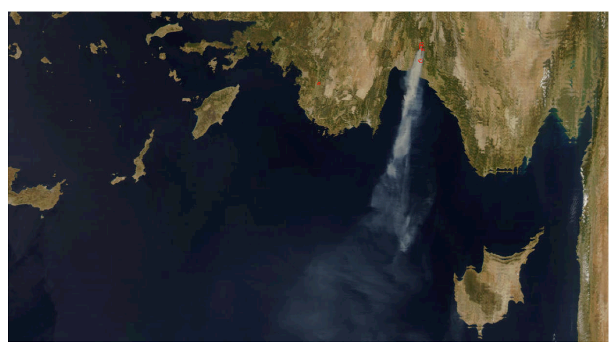

Fig. 1. This image of the Antalya fire was captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Aqua satellite on August 1, 2008.

SEVIRI captured this important biomass-burning episode from the beginning and monitored the entire cycle of the fire. The Antalya fire was an extreme event also in terms of energy output. Fig. 2 shows FRP observed over the study area and over Antalya fire between 30 July 2008 and 6 August 2008. We can notice how the first part of

[1] The SEVIRI sampling distance at the Sub Satellite point is nominally 3 x 3 km. Eastern Mediterranean is centred within the regular scanning zone of SEVIRI, with regional 4x4 km resolution imagery at 15 min intervals

the event (from 31st of July to 3rd of August, 2008) was really intense, reaching FRP values of 8000 MW (for Land SAF FRP product). During this period, it is hypothesized that air pollution levels have increased significantly in the region.

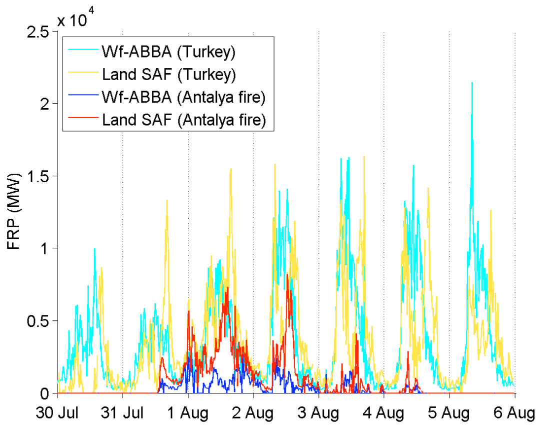

Fig. 2. Total Fire Radiative Power (FRP) detected over Eastern Mediterranean and over Antalya fire between 30 July 2008 and 6 August 2008. The data is derived from the Wf_ABBA and Land SAF products.

5. EMISSION INVENTORY

The hourly and daily average TPM emission rates, integrated over the study area and over the Antalya fire, between the 30th of July 2008 to the 6th of August 2008, are presented in Fig. **3**. They are plotted together with the GFASv1.1 one (in green) over the same areas and time period.

On the entire region, GFASv1.1 emission estimation is sensitively higher than the SEVIRI-based one (WF_ABBA and Land SAF FRP product) while they are comparable on Antalya fire area, where the Land SAF FRP based emission estimations are the highest (Fig. 3 and Tab. 1).

Differences between GFASv1.1 and SEVIRI-based (Wf_ABBA and Land SAF) fire-induced emissions estimates, when they are integrated over the study area, are mainly due to the presence of agricultural waste burning, common this time of the year in Eastern Europe. In fact, SEVIRI coarse spatial resolution causes numerous low intensity fires[2] to escape detection.

On the other hand the impacts of coarse spatial resolution is balanced by the extremely high temporal resolution of the geostationary observations. In fact SEVIRI could capture the complete Antalya fire life cycle that the much higher spatial resolution MODIS instruments on EOS Aqua and Terra could not describe during their four- times per day overpasses.

The two SEVIRI-based FRP products used in this work describe the same fire episode differently (Fig. **1**). The WF_ABBA data leads to lower emission estimates than those generated from Land SAF overall, but they tend to be comparable except on July 31-August 1. Differences between the two algorithms, particularly in their handling of pixel oversampling, could explain why the difference is largest during peak burning.

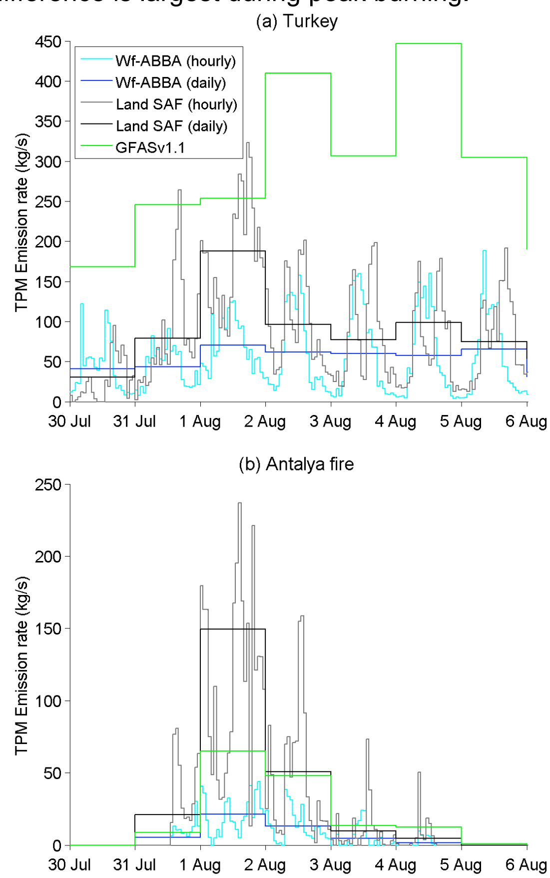

Fig. 3. Total Particulate Matter emission rate observed over Eastern Mediterranean (a) and over Antalya fire (b) from July 30 to August 6, 2008. Cyan and blue line: hourly and daily WF_ABBA FRP derived. Yellow and

2 Minimum FRPs returned by the fire detection algorithm when applied to real SEVIRI Level 1.5 data is of the order of ~ 40 MW (and at extreme ~ 20 MW) at the sub-satellite point. For MODIS, the minimum FRP detection threshold for reliably detected fire pixels is ~ 7-10 MW (EUMETSAT 2008).

red line: hourly and daily Land SAF FRP derived. Green line: GFASv1.1.

Species	Turkey	Antalya Fire
CO	63338.5	8373.4
	102613.0	**40087.6**
	370204.9	27279.7
NMHC	5710.3	466.7
	7645.7	**2234.4**
	37019.9	1513.1
NOx	1782.7	288.3
	3181.0	**1380.1**
	9721.4	942.4
PM2.5	18817.5	2286.9
	29371.4	**10948.5**
	111233.7	7448.2
OC	10394.2	1493.5
	17507.1	**7150.0**
	58115.2	4846.2
BC	1193.8	214.7
	2250.6	**1027.8**
	6267.0	697.5
SO2	300.3	50.8
	548.4	**243.2**
	1586.6	163.2

Tab. 1. Total fire emission estimates of the principal pollutants [tons] in the study area and for Antalya fire from WF_ABBA and Land SAF FRP products and GFASv1.1 during Antalya fire lifetime (July 31 and August 5, 2008). The GFASv1.1 values are underlined below the value for WF_ABBA and Land SAF FRP (in bold) based ones.

An alternative approach to estimate biomass burning smoke aerosols is to directly relate these to FRP, using smoke emission coefficients [kg/MJ] proposed by Ichoku and Kaufman (2005). Specifically, the values we assigned to the main land cover types are: 0.06 kg/MJ for savannah and tropical forest, 0.084 kg/MJ for agriculture, and 0.02 kg/MJ for extra tropical forest.
Tab. **2** shows a significant difference between smoke aerosol emissions evaluated with this approach and with the one described in Kaiser et al., 2012, based on an updated version of the emission factors tabulated in Andreae and Merlet (2001).

	Turkey	Antalya Fire
WF_ABBA	29411.9	3967.1
	158894.5	*10559.1*
Land SAF	48090.6	18992.3
	199287.6	*50551.8*

Tab. 2. Total Particulate Matter estimates [tons] in the study area and for Antalya fire from Wf_ABBA and Land SAF FRP products during Antalya fire lifetime (July 31 and August 5, 2008) using conversion factors and emission coefficients described in Kaiser et al., 2012 (referring to Andreae and Merlet (2001) and Ichoku and Kaufmann (2005) smoke emission coefficients. The estimates based on Ichoku and Kaufmann (2005) are set in italics below the ones referring to Andreae and Merlet (2001).

6. CONCLUSIONS

In this study we used WF_ABBA and Land SAF (MSG-SEVIRI based) FRP products to describe biomass-burning emissions of principal pollutants over the Eastern Mediterranean during a strong wild fire event occurred in the South of Turkey in August 2008. We analyzed the estimates comparing them with the MODIS based GFASv1.1 (Fig. **3** and Tab. **1**).
The SEVIRI based fire emission estimates agree well with the GFASv1.1 ones when they describe the Antalya fire while they tend to be quite lower when integrated on the entire Eastern Mediterranean basin. The presence of low energetic agricultural burning, undetected by SEVIRI because of its coarse spatial resolution, could be the main cause of this difference.
Also the impact of the use of different conversion factors available in literature illustrates the large uncertainties of currently available biomass burning emission estimates (Tab. **2**).

The CMAQ air quality model will be used to estimate the impacts of the Antalya fire on air quality. We are currently performing a set of sensitivity simulations, which will include the newly developed fire emission inventories, based on WF_ABBA and Land SAF, and the GFASv1.1. We will be able then to quantify the impacts of different emission inventories on air quality, and differences due to total emitted amounts, their geographical location, and daily versus hourly emission temporal distribution.

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