Overall Project Objectives

1. Estimate Biomass Burning emissions over Eastern Mediterranean Basin during a large fire event (Antalya fire, August 2008)

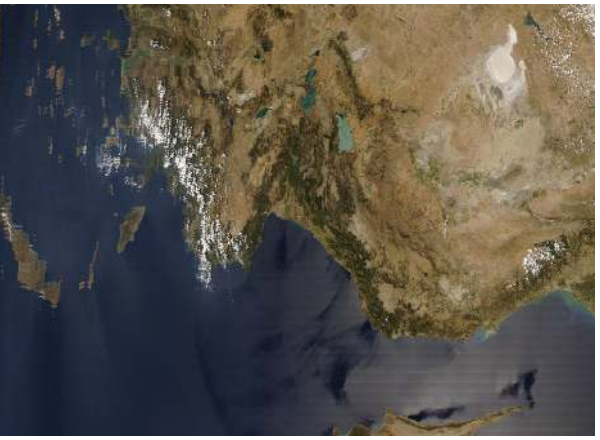
1. Simulate the selected fire emission episode with the meteorological model WRF and the regional air quality model CMAQ

Requirements on Fire Emission Product

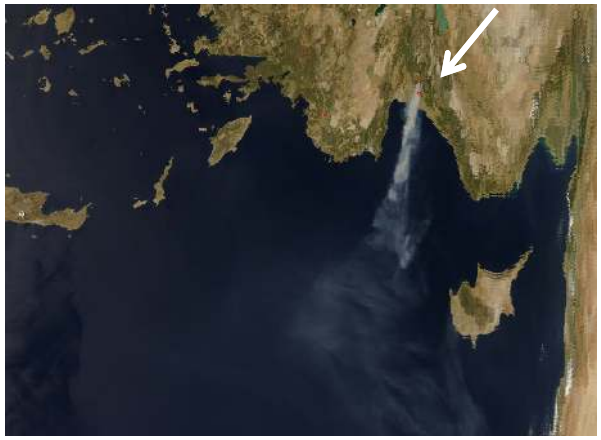
- 10 km resolution over Eastern Mediterranean Basin
- Hourly time resolution
- Injection height profile estimates

Case Study (Antalya Fire)

Aqua/MODIS 07/31/2008 10:45 UTC



Aqua/MODIS 08/01/2008 11:30 UTC



Terra/MODIS 08/02/2008 08:55 UTC

Terra/MODIS 08/03/2008 09:40 UTC

Terra/MODIS 08/04/2008 08:45 UTC

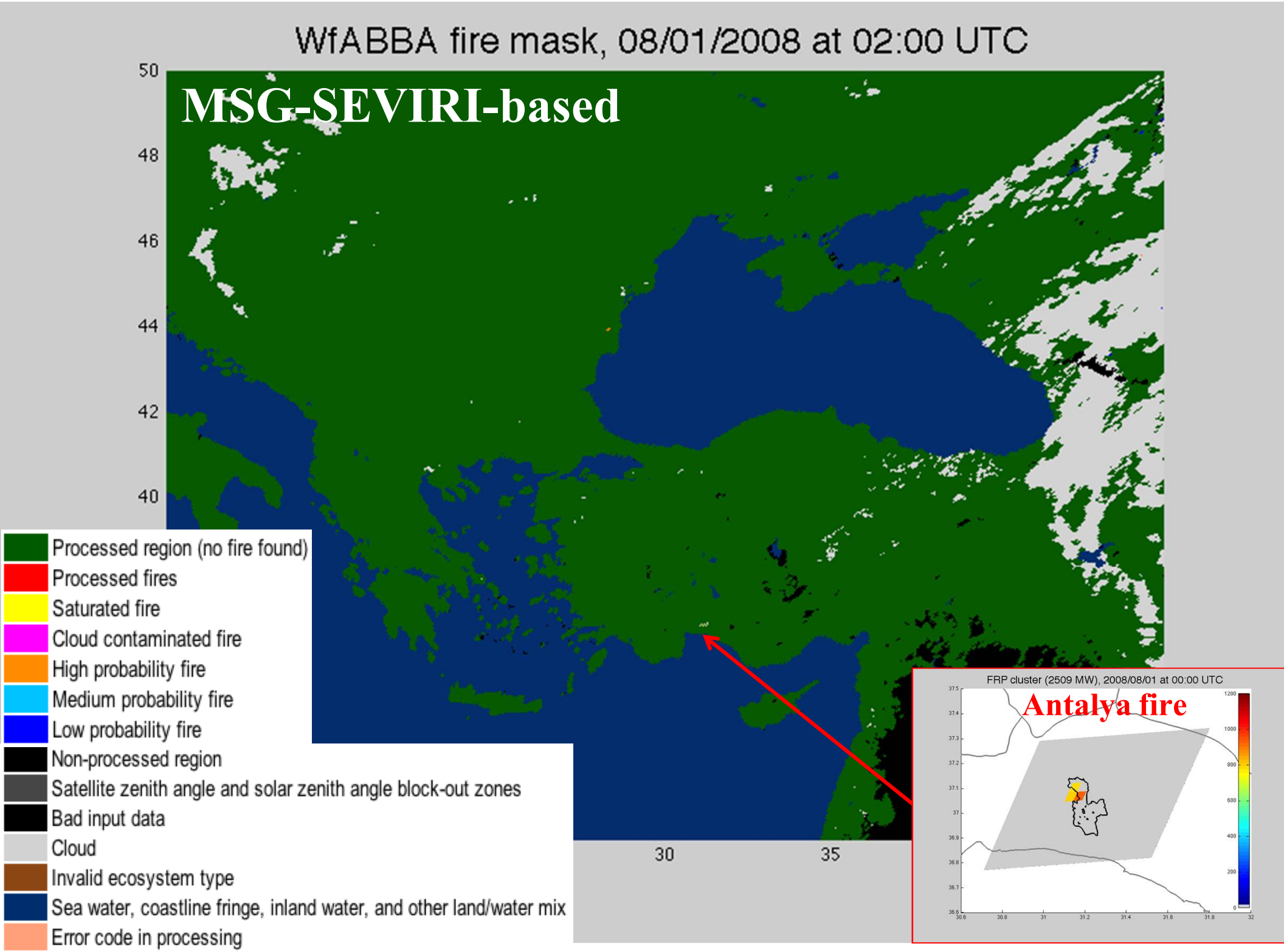
Aqua/MODIS 08/05/2008 11:05 UTC

Location: province of Antalya (Manavgat and Serik towns)

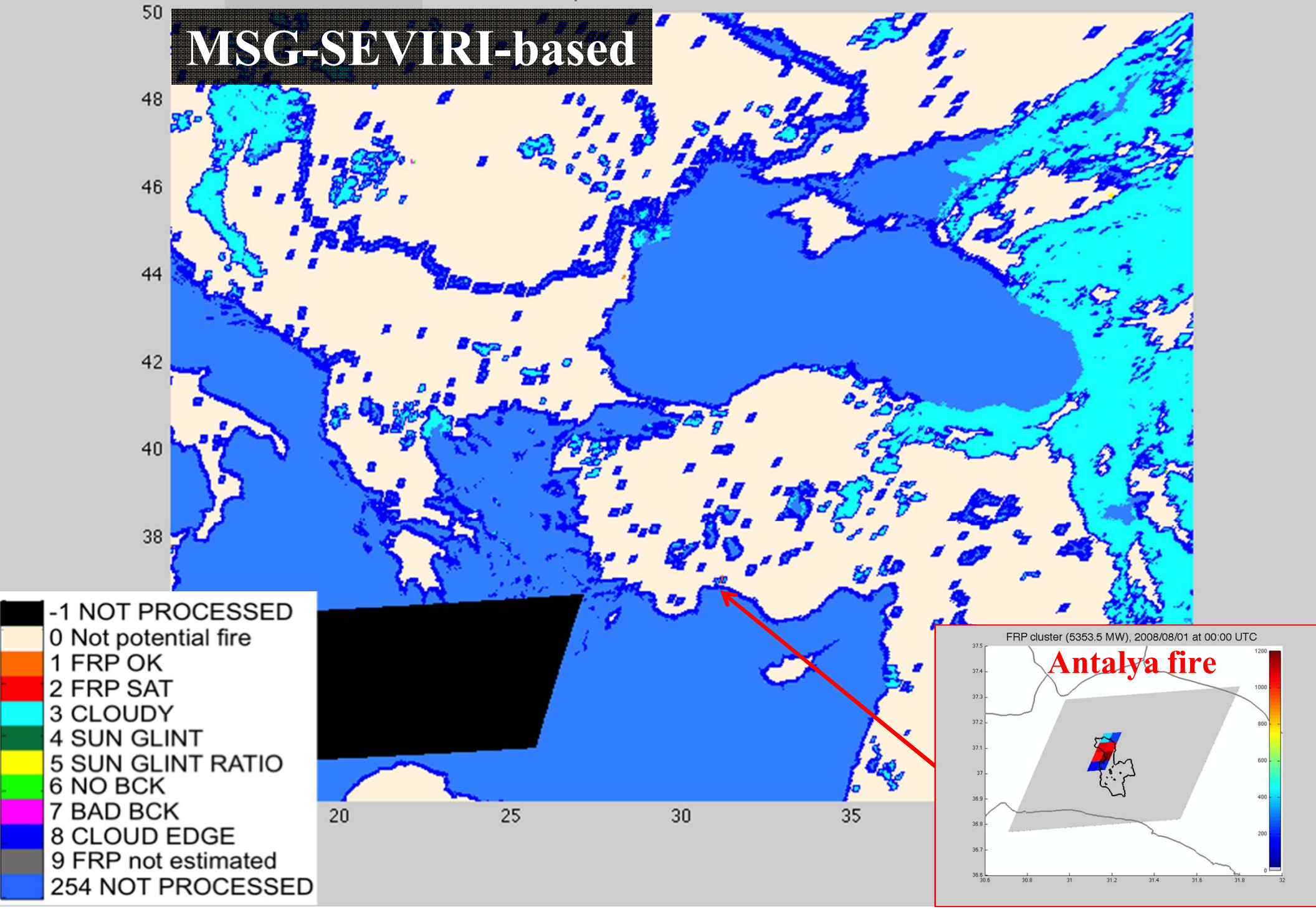
Time: 31/07/2008 – 05/08/2008

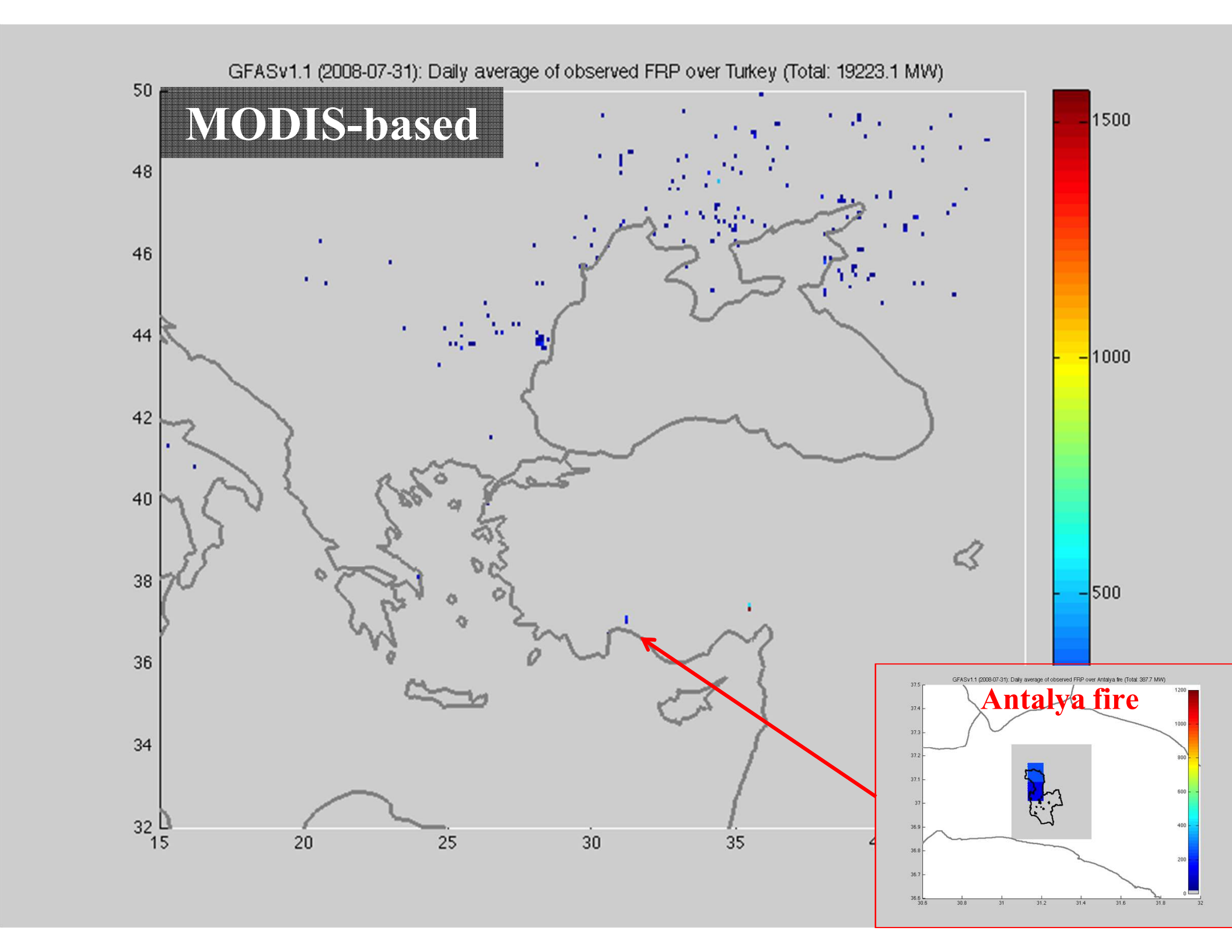
Cost:

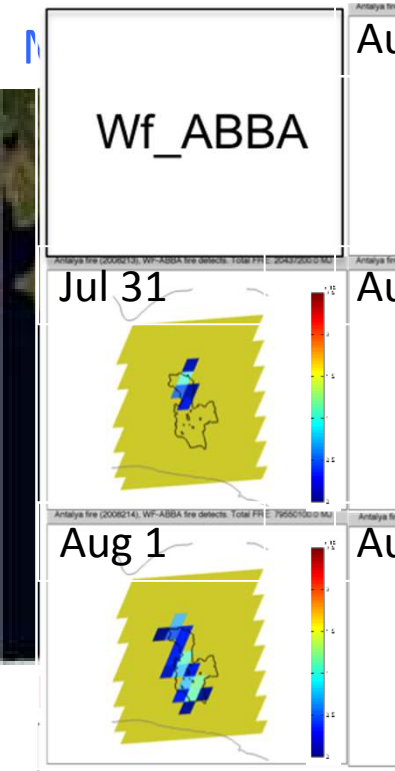
- 4500 hectares of forest land
- 60 homes
- Dozens of farming buildings
- 2000 fire fighting personnel


WfABBA fire mask, 08/01/2008 at 02:00 UTC
MSG-SEVIRI-based
50
48
46
44
42
40
30
35
Processed region (no fire found)
Processed fires
Saturated fire
Cloud contaminated fire
High probability fire
Medium probability fire
Low probability fire
Non-processed region
Satellite zenith angle and solar zenith angle block-out zones
Bad input data
Cloud
Invalid ecosystem type
Sea water, coastline fringe, inland water, and other land/water mix
Error code in processing
FRP cluster (2509 MW), 2008/08/01 at 00:00 UTC
Antalya fire

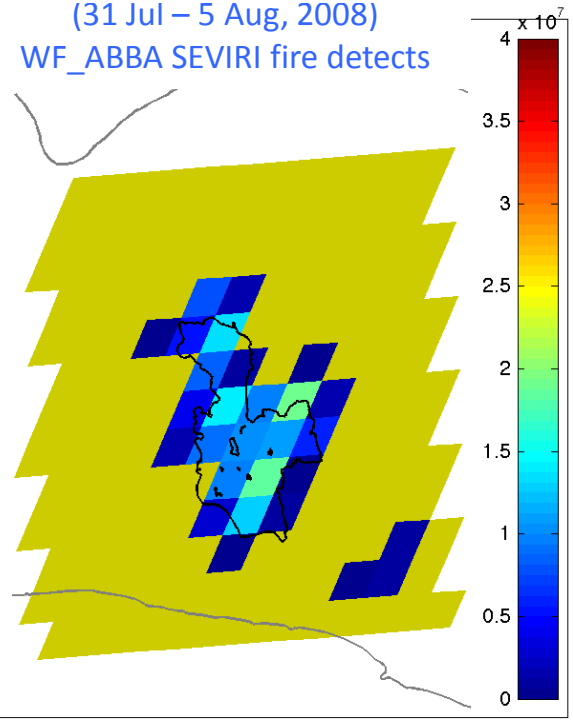
Land SAF fire mask, 08/01/2008 at 02:00 UTC



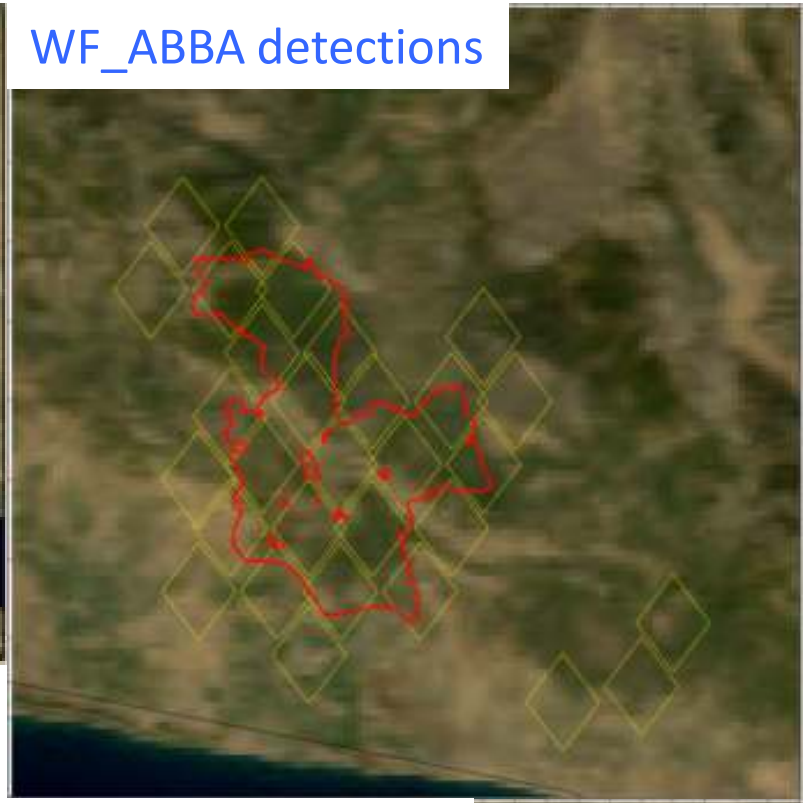

GFASv1.1 (2008-07-31): Daily average of observed FRP over Turkey (Total: 19223.1 MW)
MODIS-based
50
48
46
44
42
40
38
36
34
32
15
20
25
30
35
1500
1000
500
GFASv1.1 (2008-07-31): Daily average of observed FRP over Antalya fire (Total: 387.7 MW)
Antalya fire

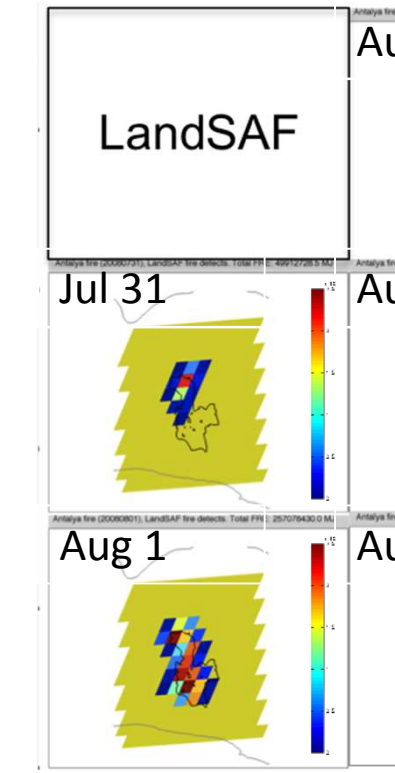


Radiative Energy (MJ) from Antalya fire
(31 Jul – 5 Aug, 2008)
WF_ABBA SEVIRI fire detects

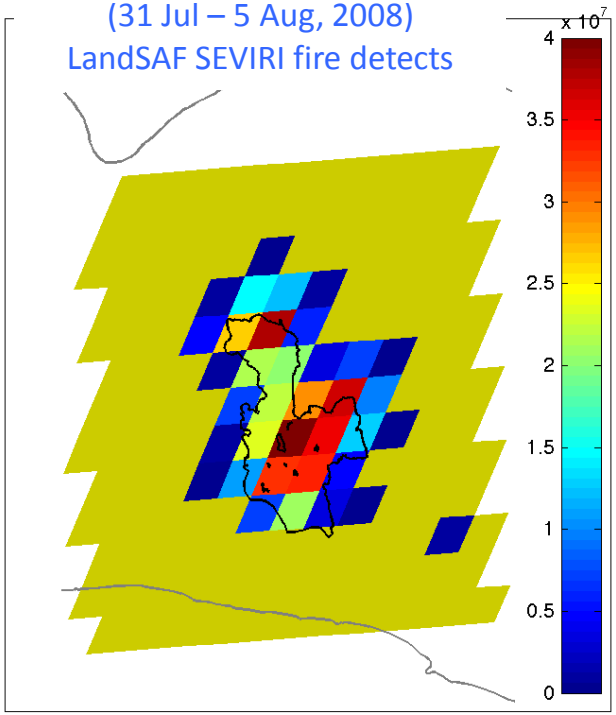


WF_ABBA detections

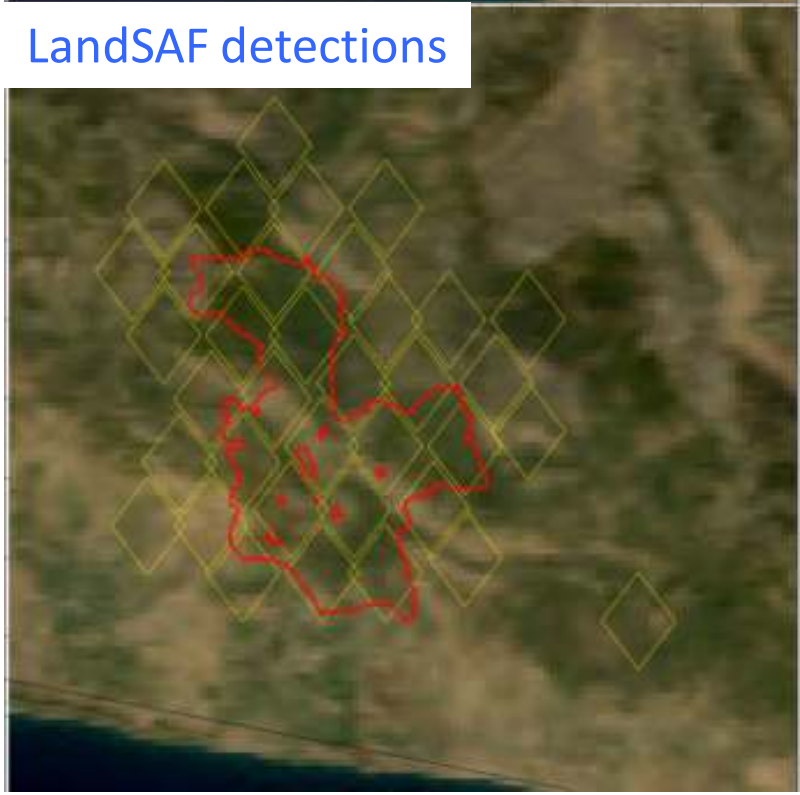


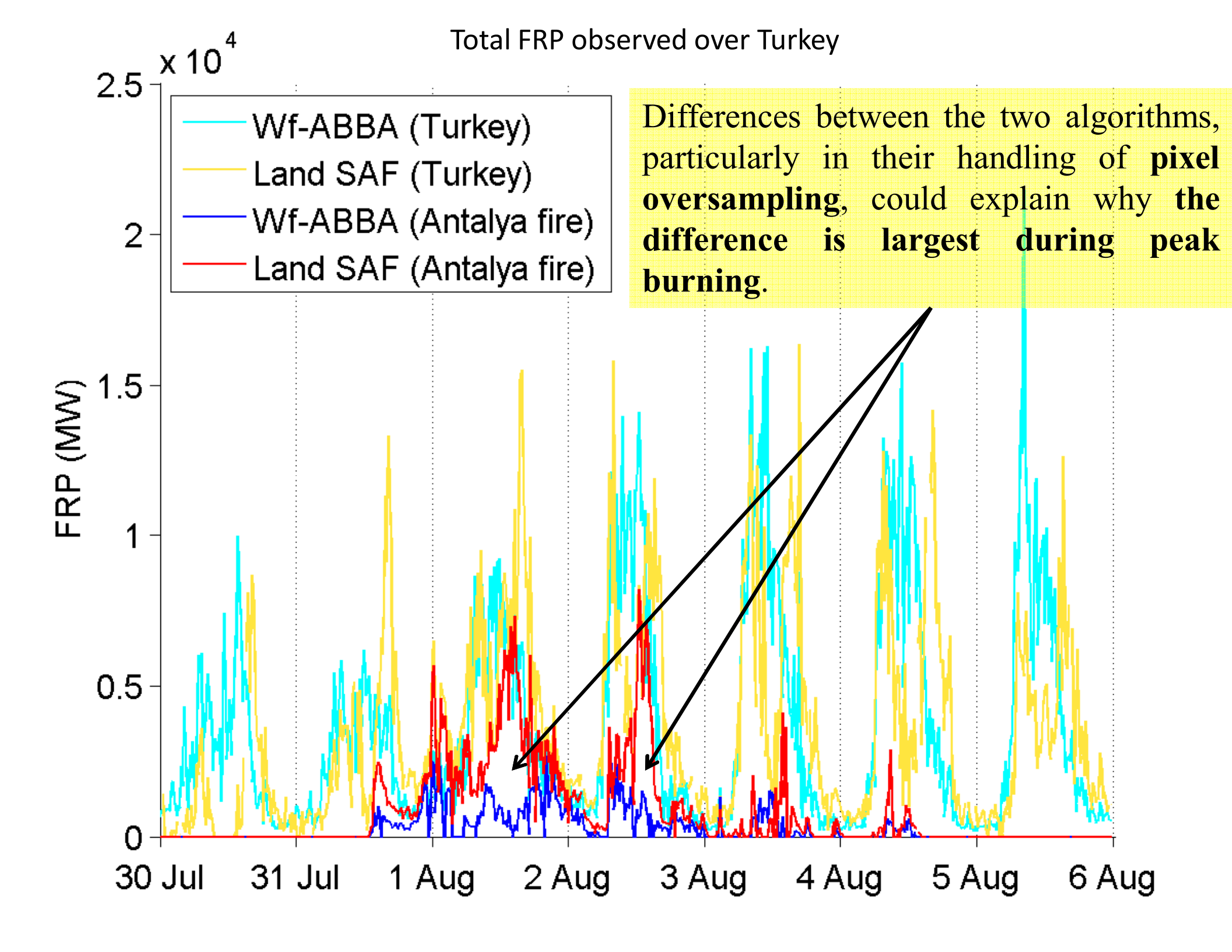


Radiative Energy (MJ) from Antalya fire
(31 Jul – 5 Aug, 2008)
LandSAF SEVIRI fire detects



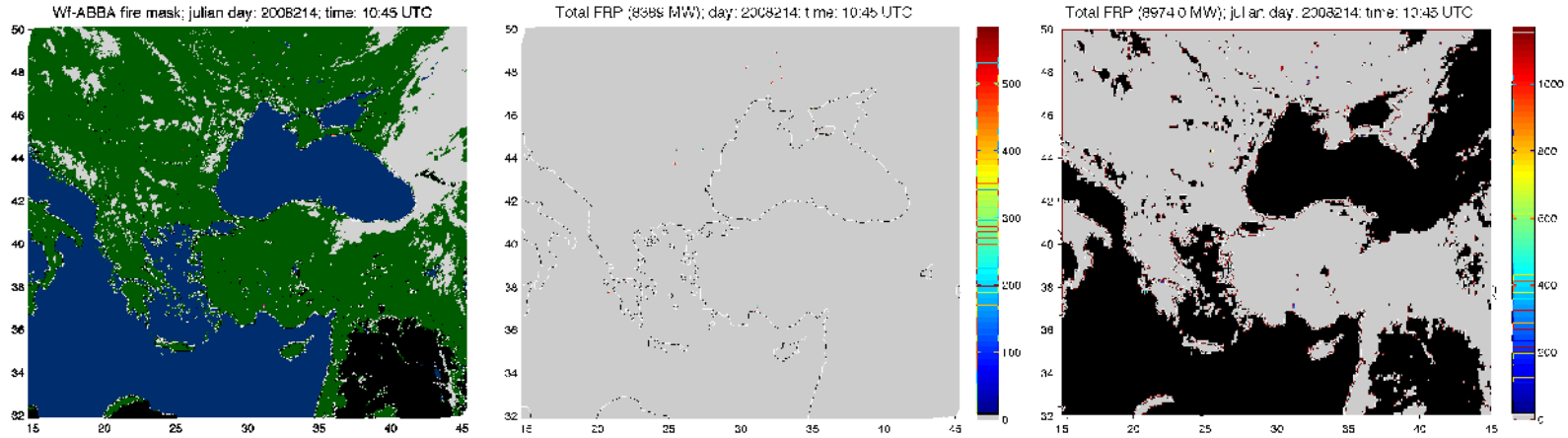
LandSAF detections




Total FRP observed over Turkey
x 10^4
2.5
2
1.5
1
0.5
0
FRP (MW)
Wf-ABBA (Turkey)
Land SAF (Turkey)
Wf-ABBA (Antalya fire)
Land SAF (Antalya fire)
Differences between the two algorithms, particularly in their handling of **pixel oversampling**, could explain why **the difference is largest during peak burning**.
30 Jul
31 Jul
1 Aug
2 Aug
3 Aug
4 Aug
5 Aug
6 Aug

Processing steps to derive Antalya fire emissions from FRP Pixel product as input to CMAQ model

1. Grid FRP PIXEL product to 0.1x0.1 deg grid and correct for cloud cover
2. Average over 1 hour

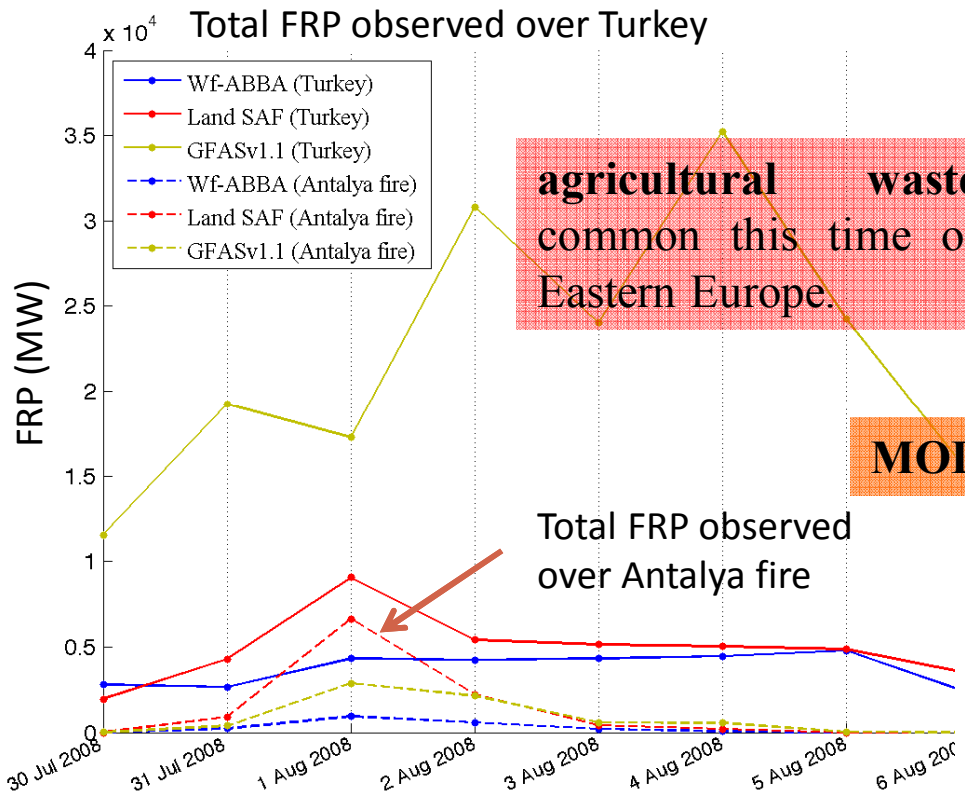


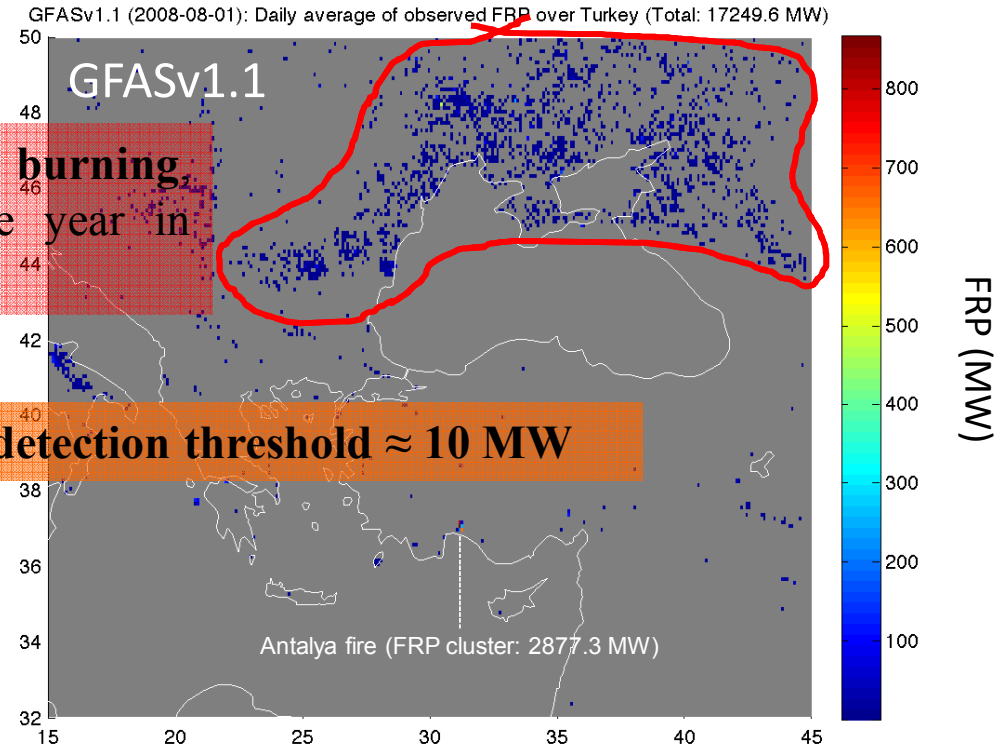
Gridded FRP product at 0.1° × 0.1° resolution containing area integrated FRP totals corrected for partial cloudiness at the grid-cell scale.

1. Injection height (Sofiev et al., 2012): $$H_p = \alpha H_{abl} + \beta FRP'^{\gamma} e^{-\delta N'^2_{FT}}$$

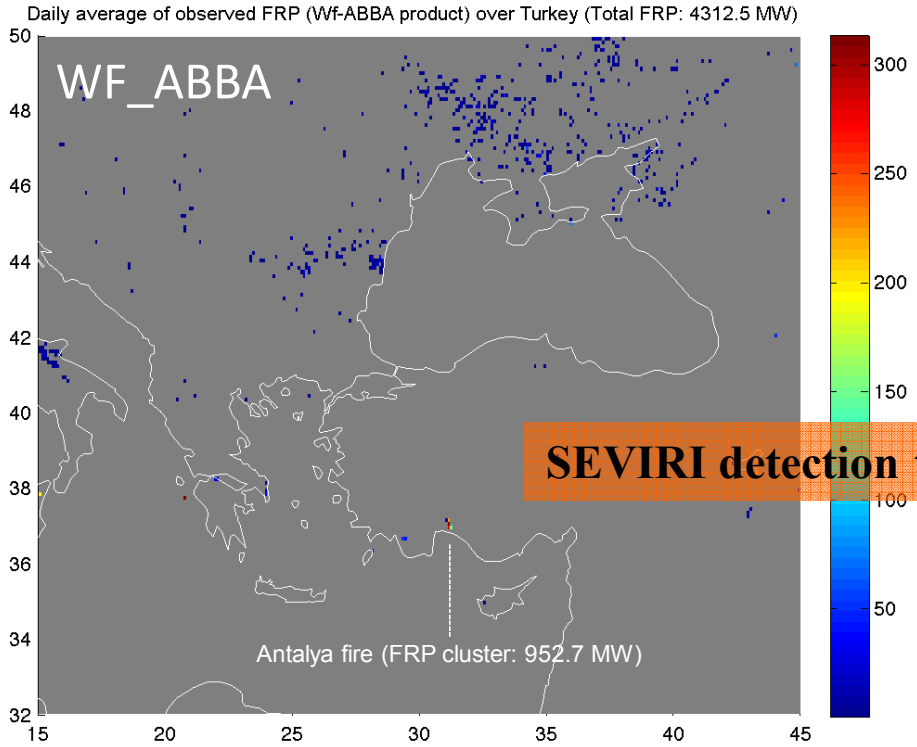
   Where H_{abl} is the atmospheric boundary layer height , N_{ft} is the Brunt-Vaisalia frequency for free troposphere (from WRF and MCIP model) and , α, β, γ, δ, parameters defining the dependence on stability in Free Troposphere (Sofiev et al, 2012)

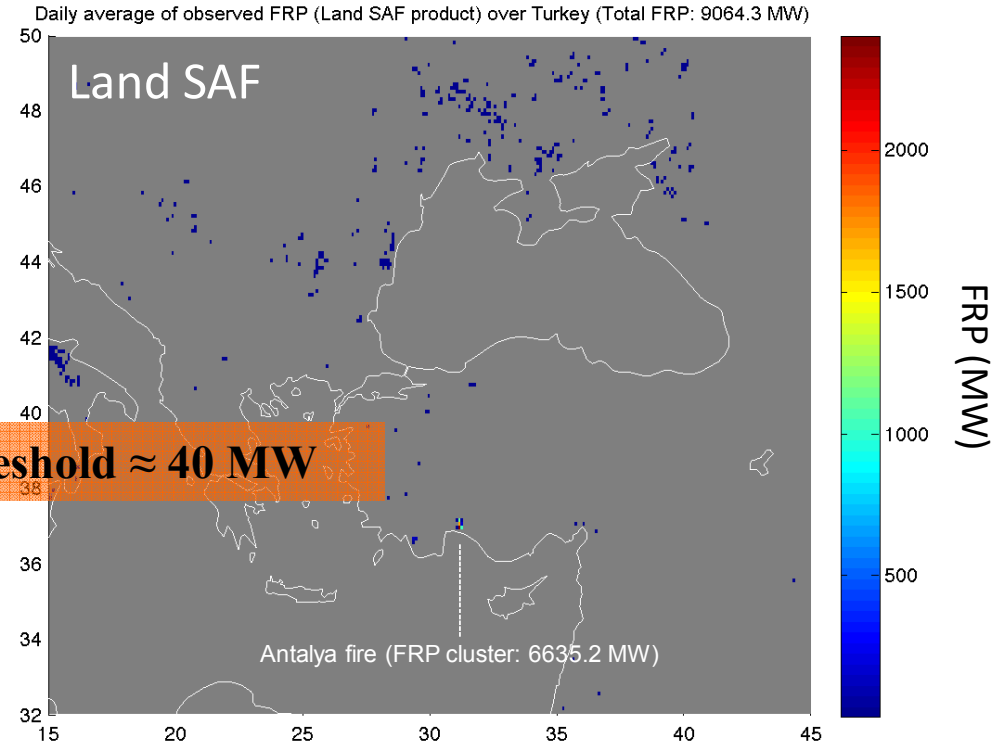
2. Convert to trace gasses and aerosols emission rate (kg/s) with emission factors based on a combination of Andreae and Merlet (2001).





MODIS detection threshold ≈ 10 MW





SEVIRI detection threshold ≈ 40 MW

Conversion to Emission (Kaiser et al. 2012)

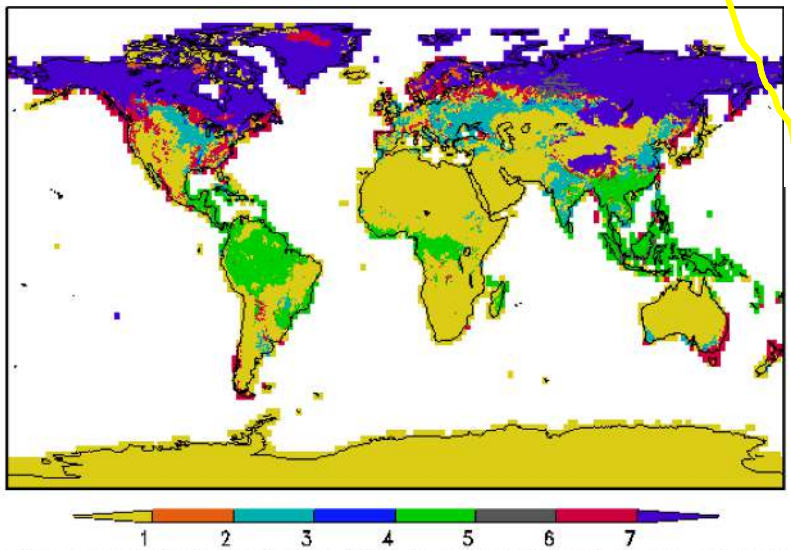
$$\textbf{Emission rate}_{i,k}\ (\text{kg/s}) = \textbf{ß}_{k} * \textbf{FRP}\ (\text{MW}) * \textbf{Ef}_{i,k}\ (\text{g/kg})$$

Emission rate$_{i,k}$: emission rate for species i and for land cover class k

ß$_k$: conversion factor for land cover class k

FRP : Fire Radiative Power

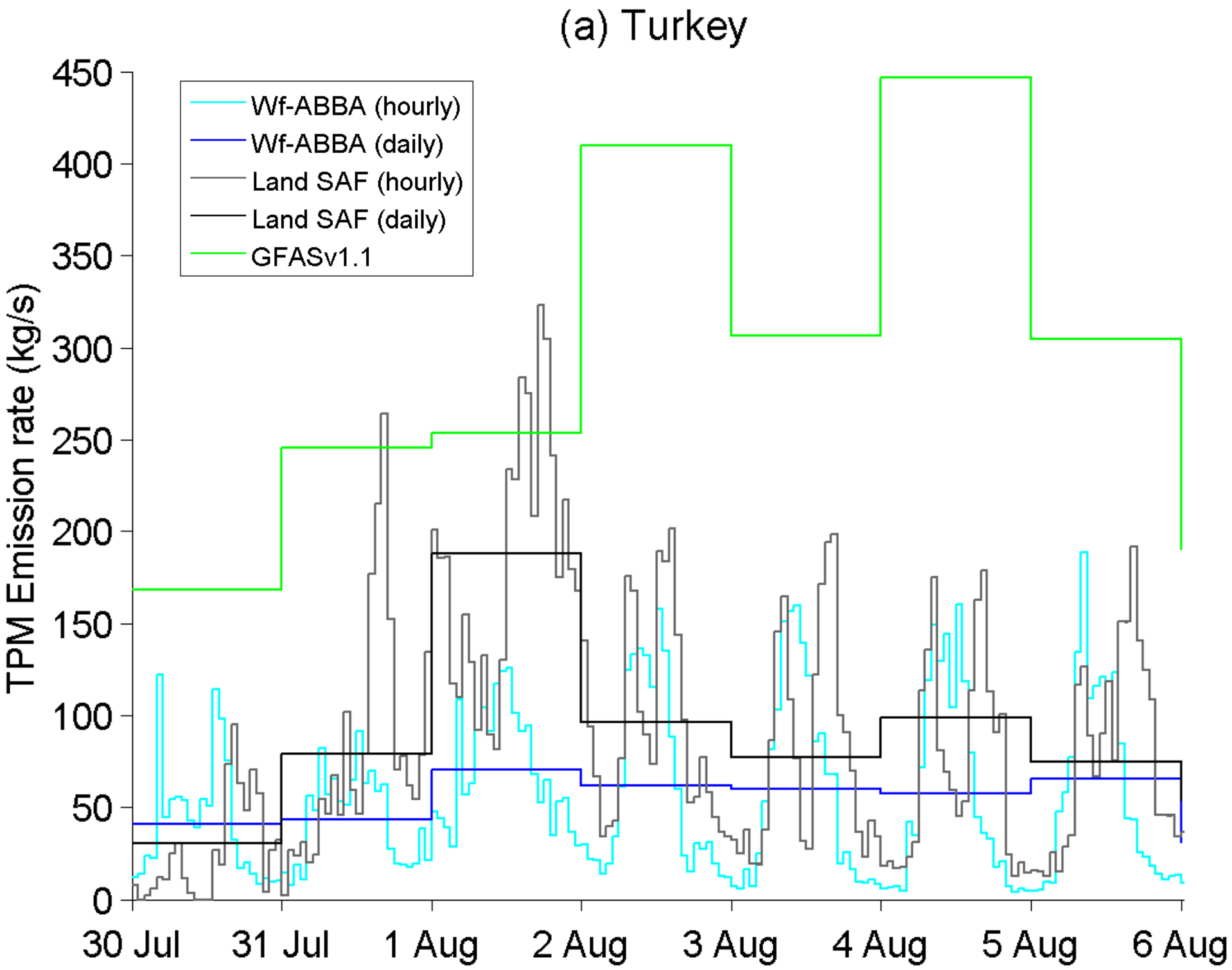
Ef$_{i,k}$: emission factor for species i and for land cover class k

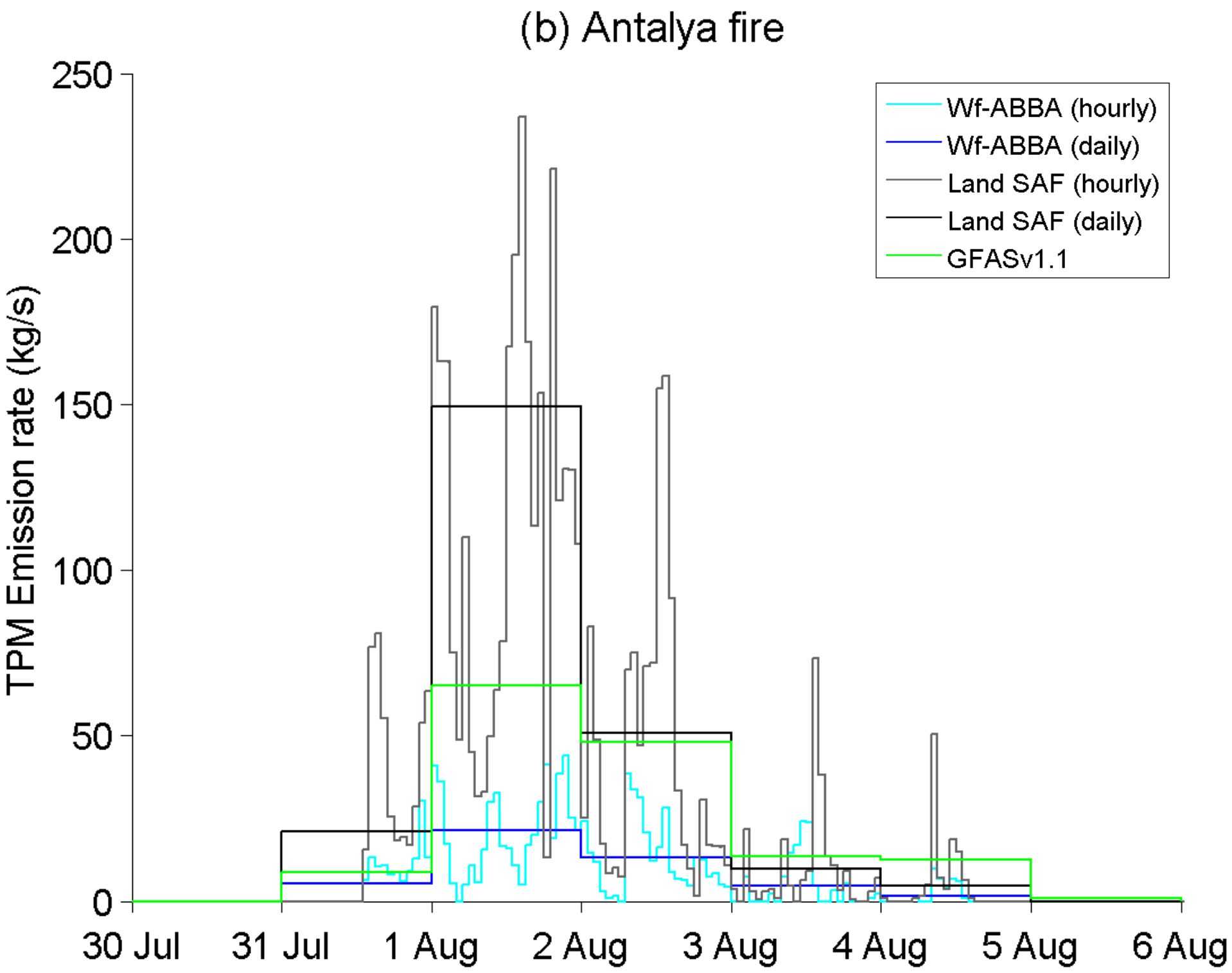


Species	SA	TF	EF	AG	PEAT
CO_2	1646	1626	1572	1308	1703[g]
CO	61	101	106	92	210[g]
CH_4	2.2	6.6	4.8	8.4	20.8[g]

land cover class	abbrev.	conv. factor
savannah	SA	0.78
savannah with organic soil	SAOS	0.26
agriculture	AG	0.29
agriculture with organic soil	AGOS	0.13
tropical forest	TF	0.96
peat	PEAT	5.87
extratropical forest	EF	0.49
extratropical forest with organic soil	EFOS	1.55

Emission of particulate matters have been boosted by a factor of 3.4 according to Kaiser et al. 2012


(a) Turkey
Wf-ABBA (hourly)
Wf-ABBA (daily)
Land SAF (hourly)
Land SAF (daily)
GFASv1.1
TPM Emission rate (kg/s)
0
50
100
150
200
250
300
350
400
450
30 Jul
31 Jul
1 Aug
2 Aug
3 Aug
4 Aug
5 Aug
6 Aug


(b) Antalya fire
TPM Emission rate (kg/s)
250
200
150
100
50
0
30 Jul
31 Jul
1 Aug
2 Aug
3 Aug
4 Aug
5 Aug
6 Aug
Wf-ABBA (hourly)
Wf-ABBA (daily)
Land SAF (hourly)
Land SAF (daily)
GFASv1.1

WRF-CMAQ Model Simulations:

Episode: July 30 – August 6, 2008

Coarse Domain: 30 km resolution covering all Europe to provide boundary conditions for the Eastern Mediterranean:

- **Ref30**: fire emi. GFAS1.0 (daily), 30 km x 30 km
- **Nofire30**: without fire emi., 30 km x 30 km

Fine Domain: 10 km resolution covering the Eastern Mediterranean

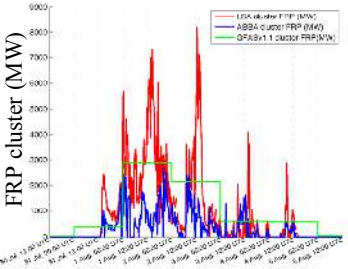
- **Ref10**: fire emi. GFAS1.1 (daily), 10 km x 10 km (IC/BC from Ref30)
- **LandSAF**: fire emi. LandSAF (hourly), 10 km x 10 km (IC/BC from Ref30)
- **WF_ABBA**: fire emi. WF_ABBA (hourly), 10 km x 10 km (IC/BC from Ref30)
- **Nofire10**: without fire emi., 10 km x 10 km (IC/BC from Nofire30)

CMAQ FIRE :

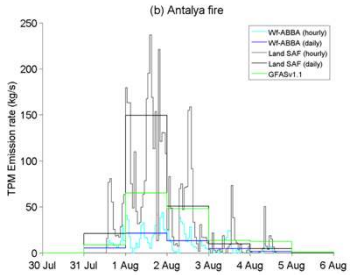
- **Ref30 (GFASv1.0)**
- **Ref10 (GFASv1.1)**
- **LandSAF**
- **WF_ABBA**

CMAQ BASE :

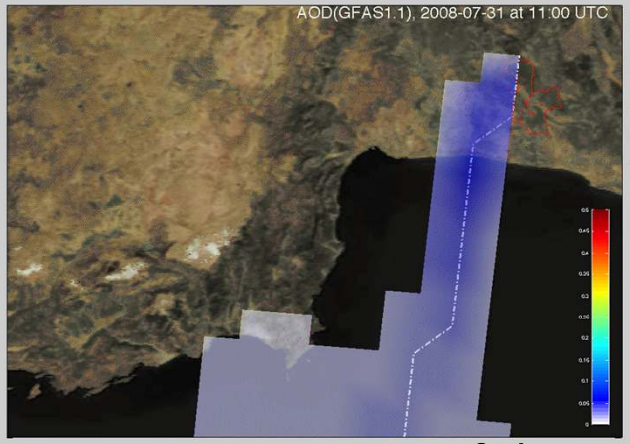
- **Nofire**

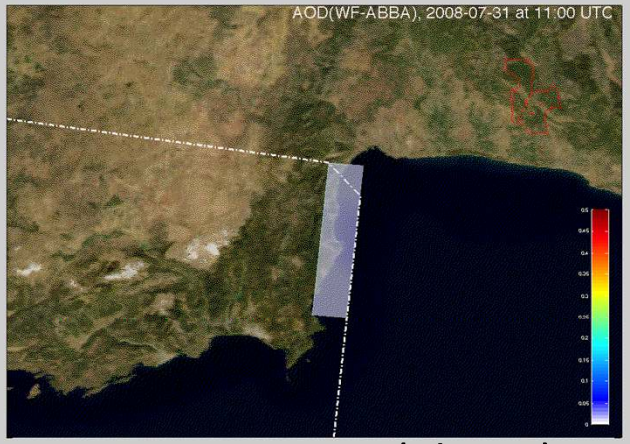


Emission inventory

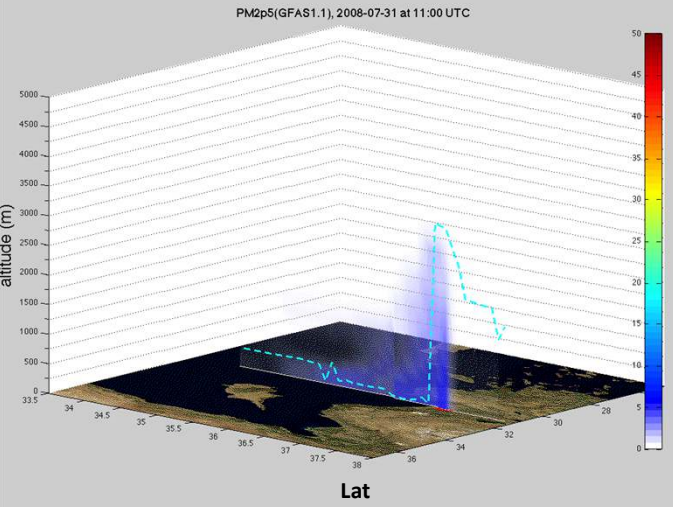


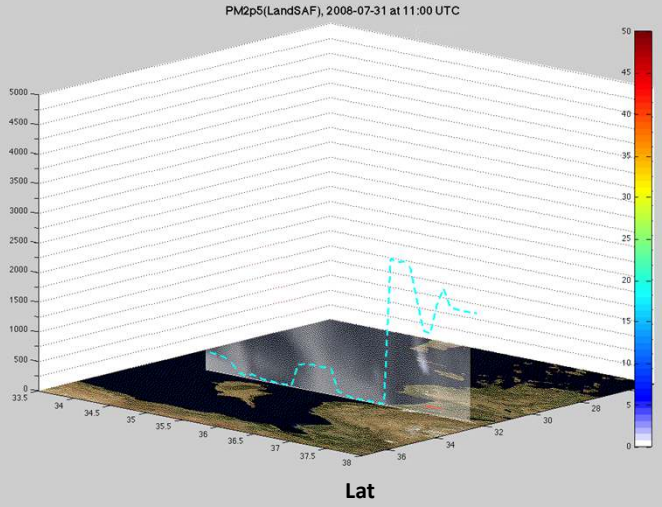
CMA Q

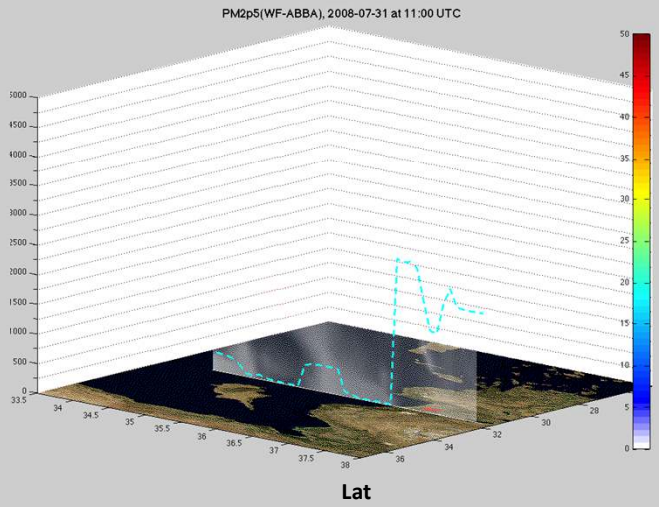




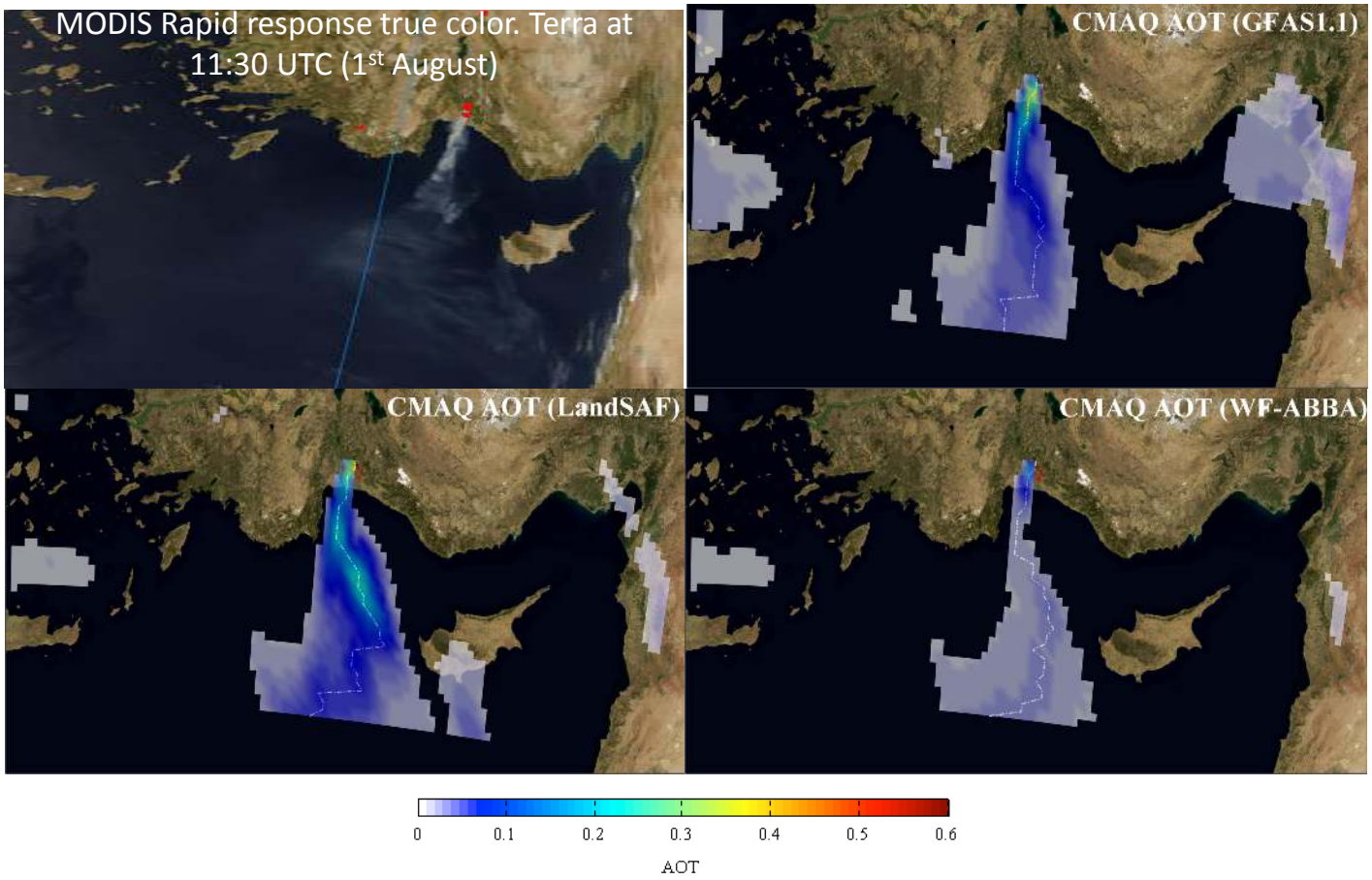
PM2.5: cross section of the PM2.5 simulated concentration across the maximum AOD (above)



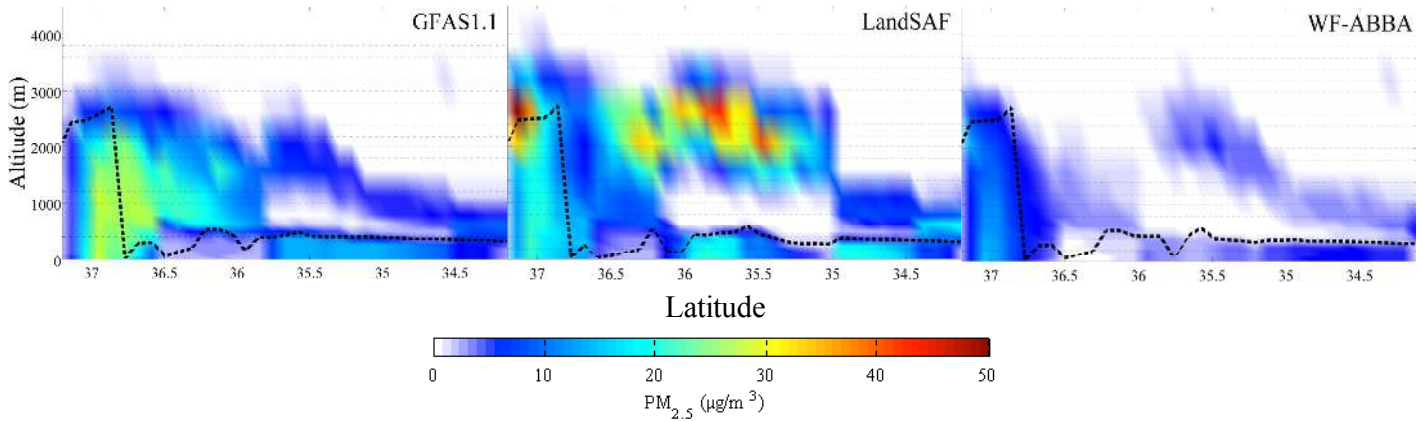




Aug 1st, 11:00 UTC

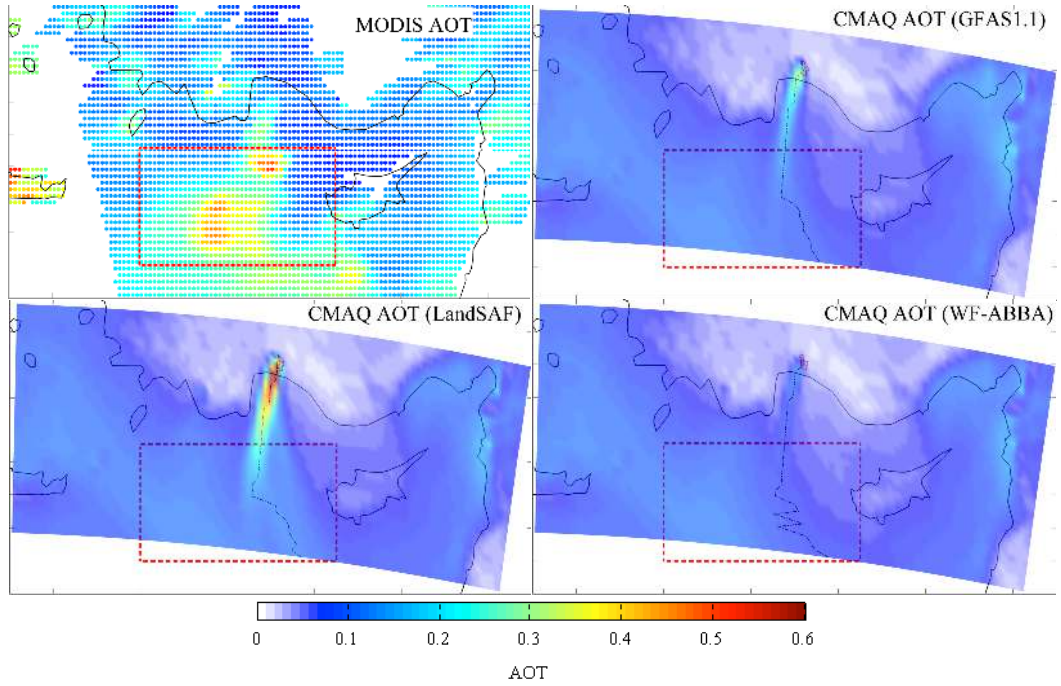


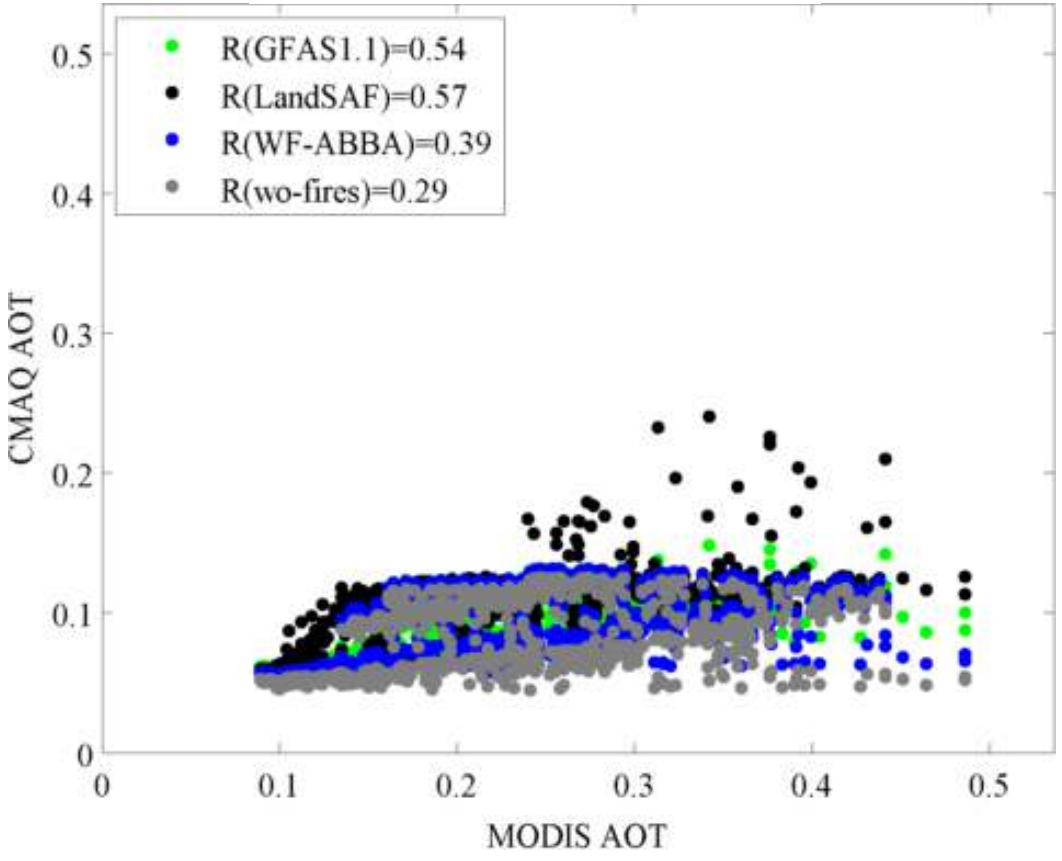
PM2.5: cross section of the PM2.5 simulated concentration across the maximum AOT (above)



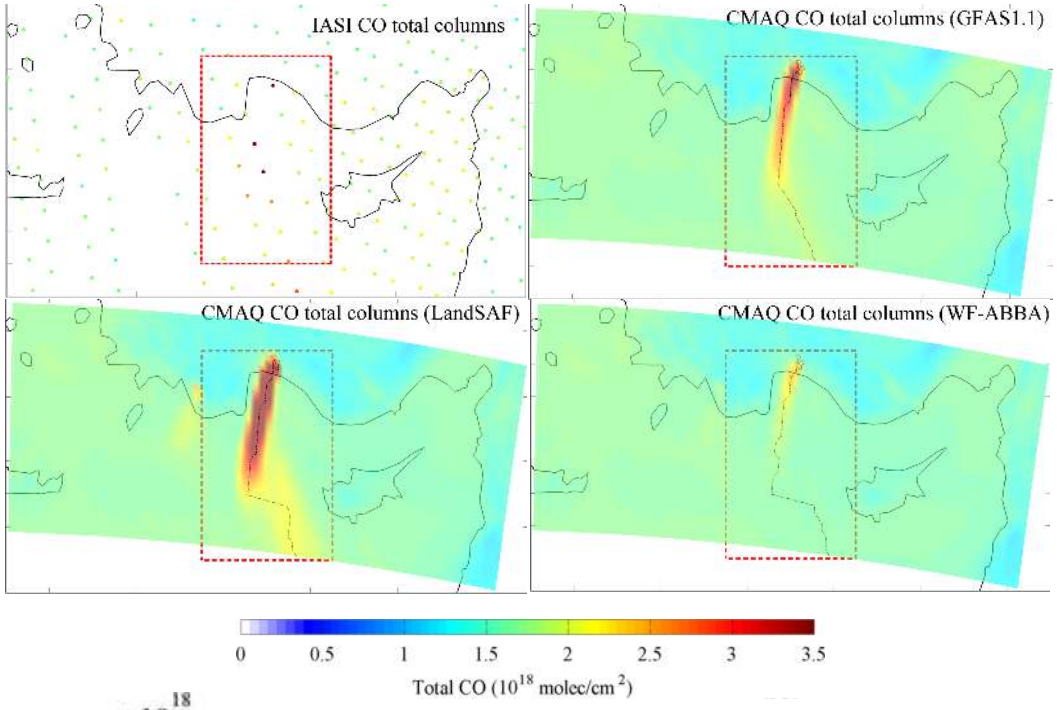
---- PBL

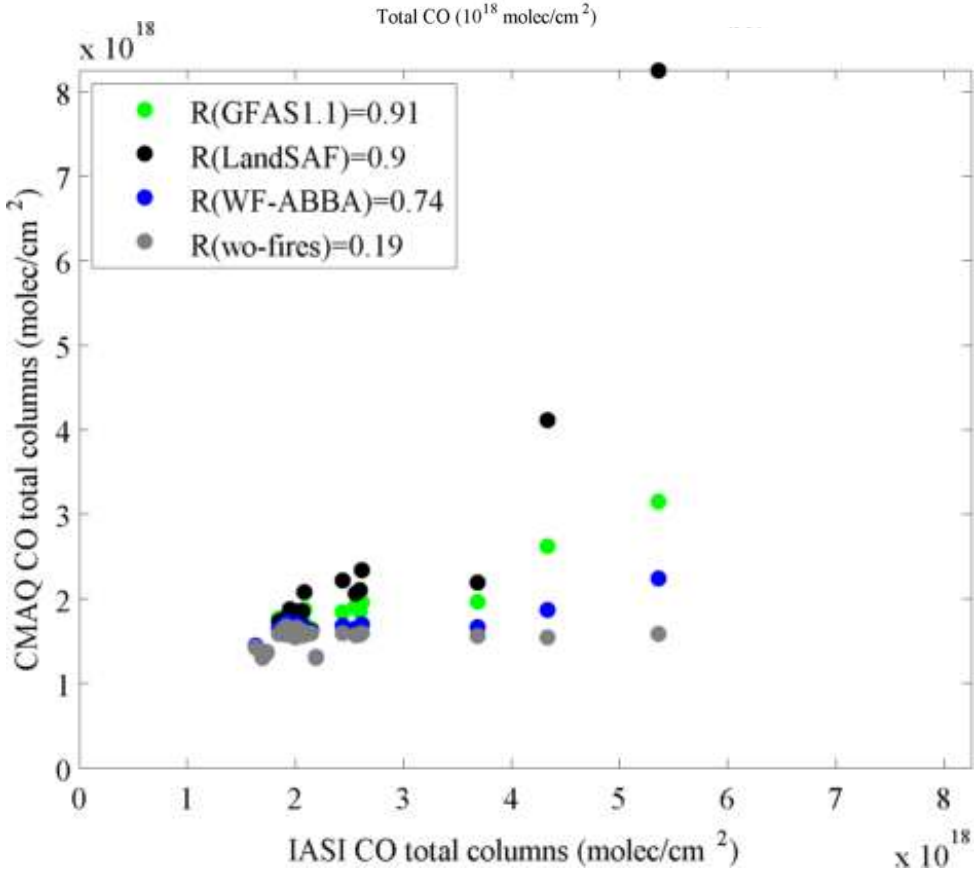
Aug
1st


MODIS AOT
CMAQ AOT (GFAS1.1)
CMAQ AOT (LandSAF)
CMAQ AOT (WF-ABBA)
0
0.1
0.2
0.3
0.4
0.5
0.6
AOT

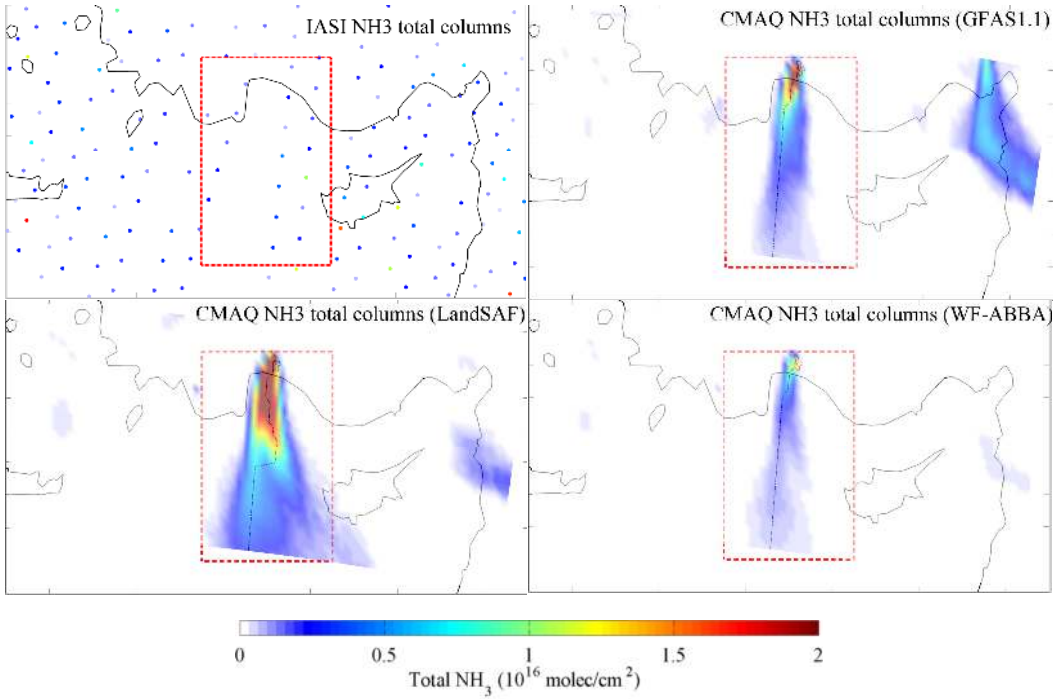

R(GFAS1.1)=0.54
R(LandSAF)=0.57
R(WF-ABBA)=0.39
R(wo-fires)=0.29
CMAQ AOT
MODIS AOT
0
0.1
0.2
0.3
0.4
0.5

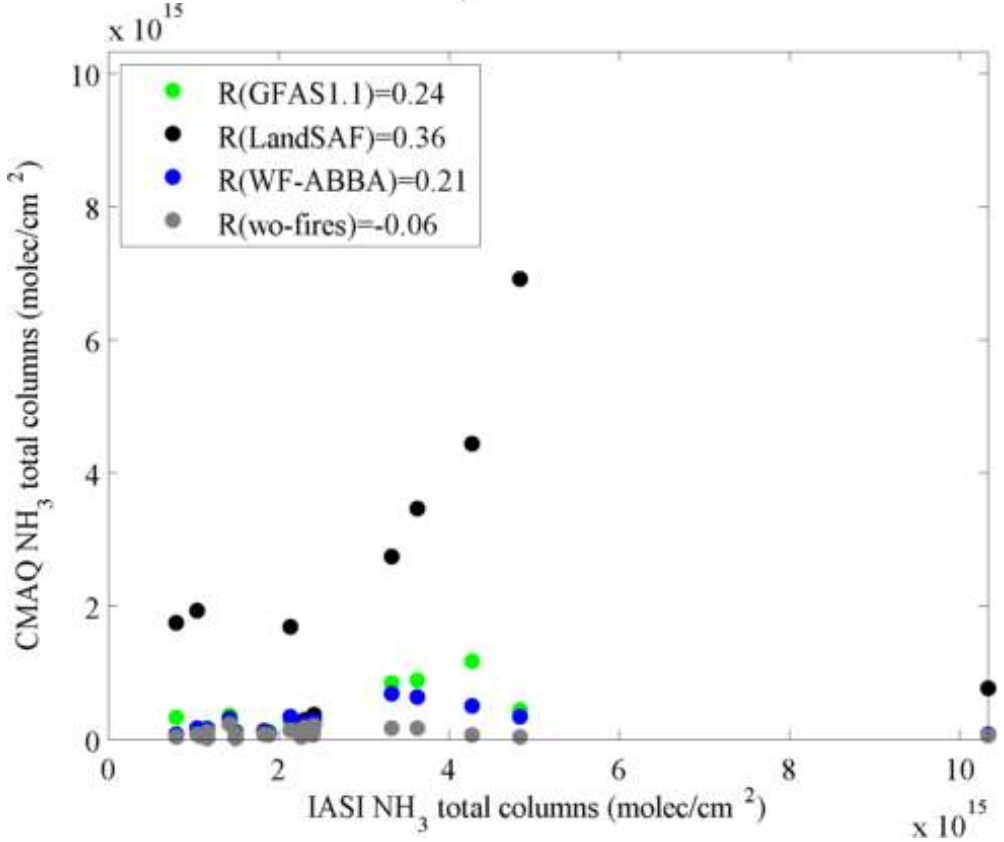
Aug 1st PM


IASI CO total columns
CMAQ CO total columns (GFAS1.1)
CMAQ CO total columns (LandSAF)
CMAQ CO total columns (WF-ABBA)
0
0.5
1
1.5
2
2.5
3
3.5
Total CO (10^18 molec/cm^2)


x 10^18
R(GFAS1.1)=0.91
R(LandSAF)=0.9
R(WF-ABBA)=0.74
R(wo-fires)=0.19
CMAQ CO total columns (molec/cm^2)
IASI CO total columns (molec/cm^2)
x 10^18

Aug 1st AM


IASI NH3 total columns
CMAQ NH3 total columns (GFAS1.1)
CMAQ NH3 total columns (LandSAF)
CMAQ NH3 total columns (WF-ABBA)
0
0.5
1
1.5
2
Total NH3 (10^16 molec/cm^2)


x 10^15
R(GFAS1.1)=0.24
R(LandSAF)=0.36
R(WF-ABBA)=0.21
R(wo-fires)=-0.06
CMAQ NH3 total columns (molec/cm^2)
IASI NH3 total columns (molec/cm^2)
x 10^15

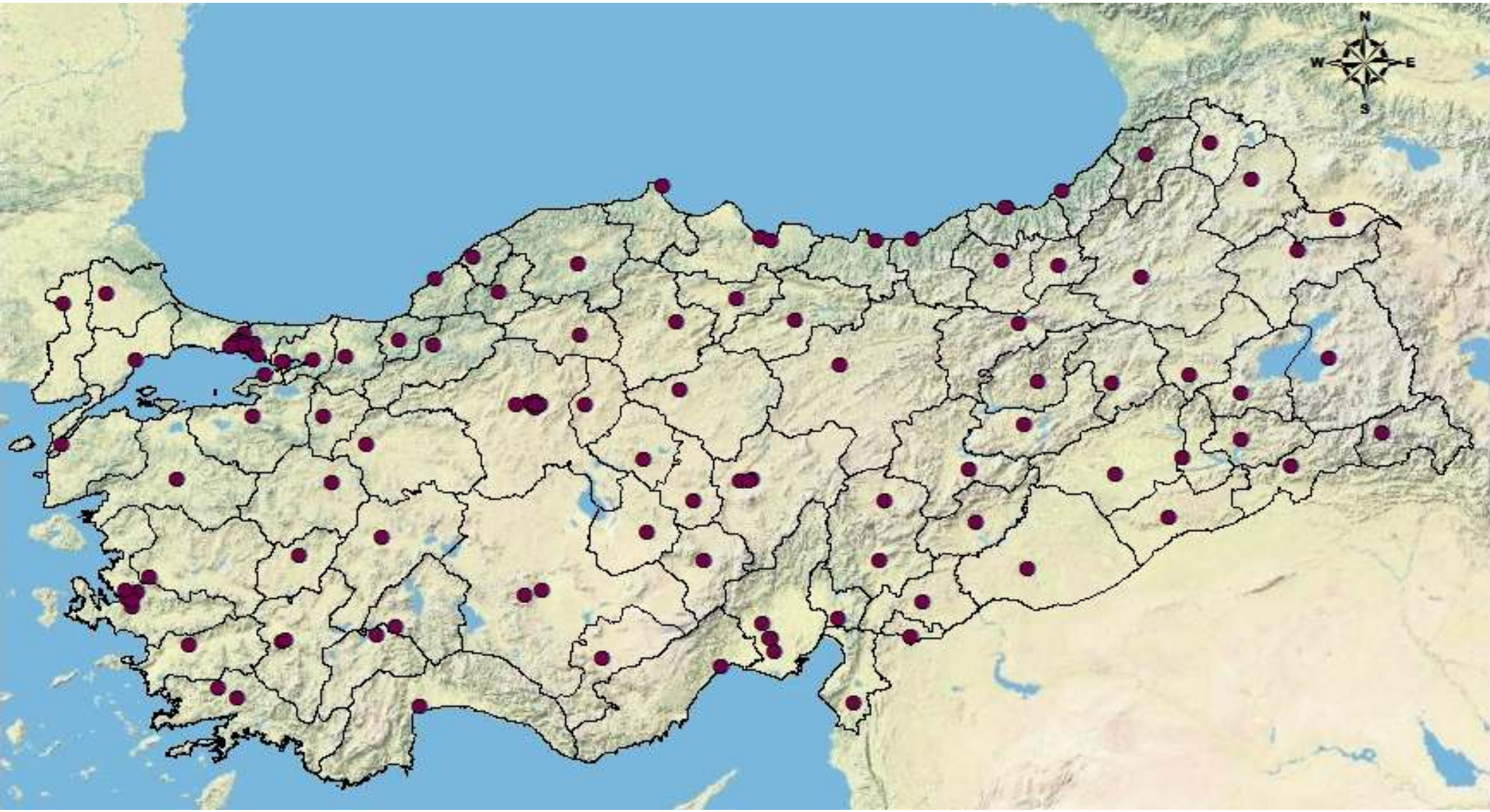
Conclusions

-The SEVIRI based fire emission estimates agree with the GFASv1.1 ones when they describe the Antalya fire; providing a refined description of Antalya fire in terms of temporal behavior.

-GFAS1.1 provides us a better understand of fire emission impact on air quality over the Eastern Mediterranean Basin (agricultural burning in Eastern Europe).

-Good agreement between the simulated CO total columns and the IASI measurements.

Air Quality ground station in Turkey



What FRP is (by definition)

FRE and its time derivative FRP are by definition related to the temperature and size of a fire:

$$FRP = A \sigma T^4$$

where A is the area burning, σ is the Stephan-Boltzman Constant, and T is the temperature of the fire. The typical unit of FRP is Watts (J/s) and FRE is Joules.

What FRP is (by approximation)

This relationship allows approximation of FRP:

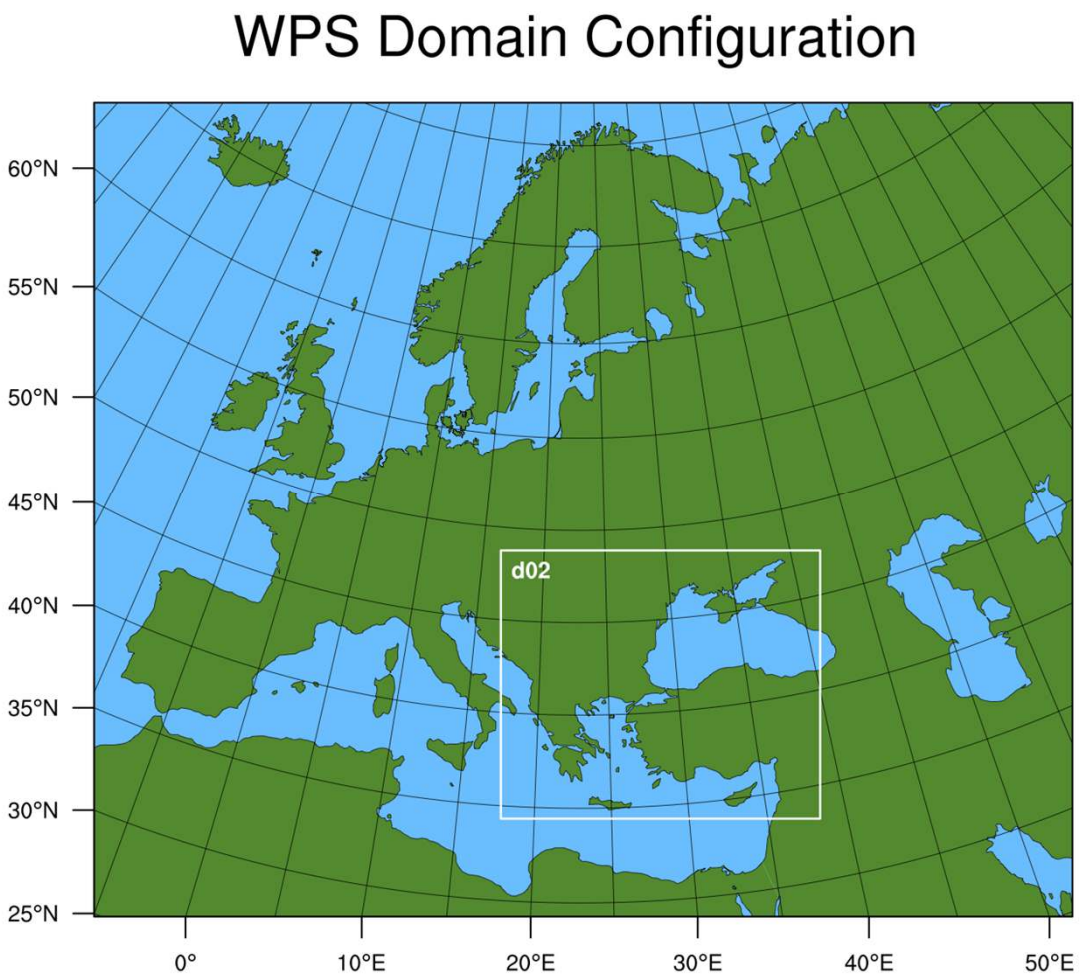
$$R_4 = aT^4$$

where R_4 is the radiance at ~4 μm, a is a curve-fitting constant, and T is the fire temperature. This relationship is only valid for 600K < T < 1400 K and fires are assumed to emit as gray-bodies. The "radiance method" FRP looks like:

$$\mathbf{FRP = A_{pixel}\ \sigma\ (R_{4,fire} - R_{4,background})/a}$$

Which utilizes the difference between the fire pixel radiance and the background radiance. A_{pixel} is the area of the satellite pixel.

WRF-CMAQ Model Simulations:



WRFv3.3
D01: 188x156 cells, 30 km
D02: 184x154 cells, 10 km

37 sigma layers, from surface to 10 hPa

IC/BC, nudging on temp, wind and moisture:
The National Centers for Environmental Prediction (NCEP) Final Analyses (FNL) data of 1 x 1

CMAQv4.7.1
CB05 chemical mechanism
AERO5 aerosol scheme
IC/BC monthly mean MACC-IFS-MOZ (fbov)
Anthropogenic Emissions: TNO/MACC_2005
Biogenic Emissions: MEGANv2.10