



Norwegian  
Meteorological  
Institute

# Modeling and measurements of regional PM pollution in Europe.

Jan Eiof Jonson, MET Norway, EMEP/MSC-W

, 20.12.2024

# MET Norway as EMEP/MSC-W

## - what is our role?

- 1979
- 51 Parties

**MSC-W = Meteorological Synthesizing Centre West**, a centre under EMEP in the Convention on Long Range Transport (PM, photo-oxidants, acidifying and eutrophying compounds)

- Assessment of the present air pollution situation
- Input/link to integrated assessment modelling (IIASA/CIAM **GAINS**)
- Scientific analysis & development relevant for air pollution policy



**CEIP**

Centre on  
Emission Inventories and Projections

Direct link to  
emission data

**CCC**

Chemical Coordinating Centre

Direct link to  
measurement data

**MSC-W**

Meteorological Synthesizing Centre  
- West

Direct link to  
model results  
(sulphur, nitrogen,  
ozone, and PM)

**MSC-E**

Meteorological Synthesizing Centre  
- East

Direct link to  
model results (heavy  
metals and POPs)

**CIAM**

Centre for  
Integrated Assessment Modelling

Direct link to  
GAINS-Europe

**TFEIP**

Task Force on  
Emission Inventories and Projections

**TFMM**

Task Force on  
Measurements and Modeling

**TFIAM**

Task Force on  
Integrated Assessment Modeling

**TFHTAP**

Task Force on  
Hemispheric Transport of Air Pollution

If you go to: <https://www.emep.int/>  
you will find more information on the EMEP centres

## EMEP

*The co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (inofficially 'European Monitoring and Evaluation Programme' = EMEP) is a scientifically based and policy driven programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP) for international co-operation to solve transboundary air pollution problems.*

**Five EMEP Centers and four Task Forces undertake efforts in support of the EMEP work plan. We refer to the respective websites for in-depth information:**

# Welcome to HTAP page

The Task Force on Hemispheric Transport of Air Pollution (TF HTAP) is an international scientific cooperative effort to improve the understanding of the intercontinental transport of air pollution across the Northern Hemisphere.

TF HTAP was organized in 2005 under the auspices of the [UNECE Convention on Long-range Transboundary Air Pollution](#) (LRTAP Convention) and reports to the Convention's EMEP Steering Body. However, participation is open to all interested experts, both inside and outside the UNECE region.

► [Read more...](#)

## OPNS

Multi-model experiments to quantify the long-range transport of ozone, particular matter, and the deposition of nitrogen and sulphur

[Read more](#)

## Fires

Towards a multi-model, multi-pollutant study of fire impacts

[Read more](#)

## MCHgMAP

Multi-Compartment Hg Modeling and Analysis Project to support international environmental policy

[Read more](#)

TFHTAP

<https://htap.org/>

This task force should be very relevant also for your region

# MET Norway as EMEP/MSC-W

- Scientific analysis & development relevant for air pollution policy

## Review of the Gothenburg Protocol:

- What are the **trends** in air quality? Do we understand them?
- What is the importance of **condensables**?
- What is the distance to the 2021 **WHO air quality guideline** values?
- What are **projected changes up to 2030** and beyond?
- etc

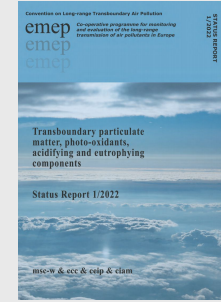
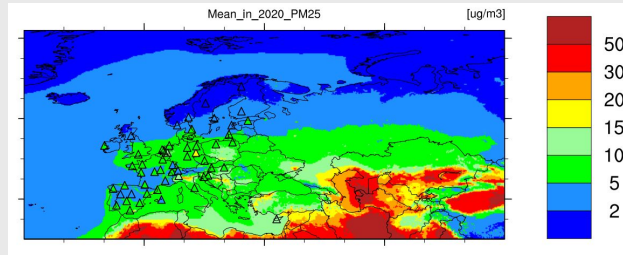
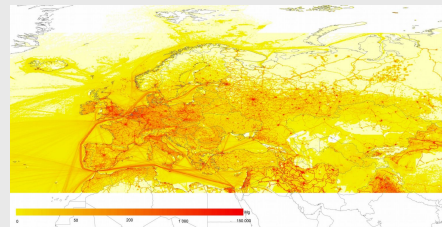
**Gothenburg Protocol:**  
Protocol to Abate Acidification,  
Eutrophication and Ground-level  
Ozone 1999, amended 2012

These ceilings were negotiated on the basis of scientific assessments of pollution effects and abatement options. Parties whose emissions have a more severe environmental or health impact and whose emissions are relatively cheap to reduce have to make the biggest cuts

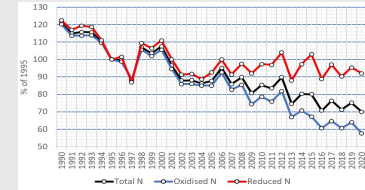
# MET Norway as EMEP/MSW-W

## - what do we do?

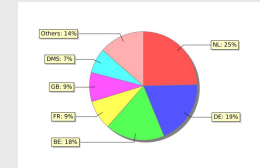
- Assessment of the present air pollution situation every year



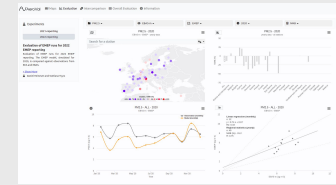
Status reports and reports per country



Regular update of trend data (30 years)  
<https://emep.int/mscw/mscw/moddata.html>



Source receptor matrixes

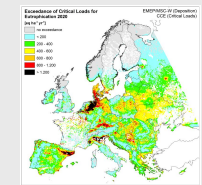


Evaluation  
[https://aeroyal.met.no/evaluation.php?project=emep&exp\\_name=2022-reporting](https://aeroyal.met.no/evaluation.php?project=emep&exp_name=2022-reporting)

All Parties/countries report emissions for NOx, SOx, NH3, NMVOC, CO, PM (gridded) every year

EMEP CTM run and compared to reported observations (triangles)

Use of satellite data, especially for the easternmost part of the region.

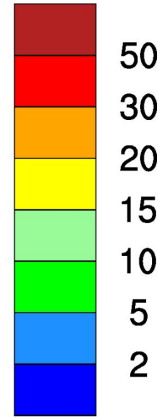
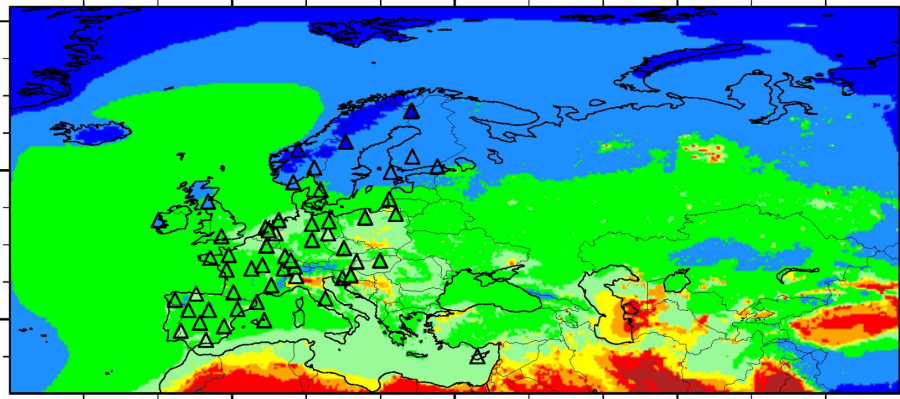


Effects



# PM2.5 concentrations and exceedance days in 2022. Triangles represent measurements

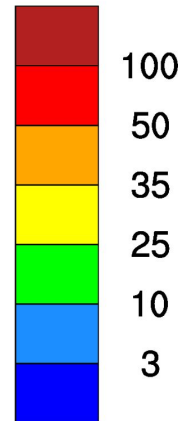
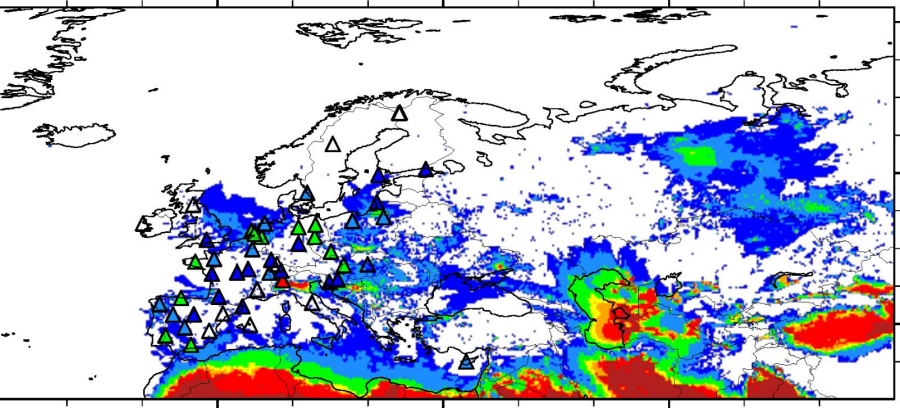
Mean\_in\_2022\_PM25 [ug/m3]



PM2.5 (PM10)  
Annual limits  
In  $\mu\text{g m}^{-3}$

aqg 2005	10 (20)
Aqg 2021	5 (15)

Exceedance\_days\_PM25\_2022 [Ndays]



EU	25 (40)
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(As shown in lower left panel)

# Chemical composition of PM<sub>2.5</sub> in March 2022 at four selected sites:

Overestimation (mainly OM) at PL05 (Poland) and IT4 (Ispra in N. Italy) caused by wildfires.



# National reports: Example from Croatia

HR – Croatia (to itself)

BA – Bosnia and Herzegovina

DE – Germany

HU – Hungary

IT – Italy

PL – Poland

RS – Serbia

Source receptor numbers  
tabulated for all countries in  
annual reports every year.

See

[https://www.emep.int/emep\\_publications.html](https://www.emep.int/emep_publications.html)

For most recent report containing source  
receptor calculations.

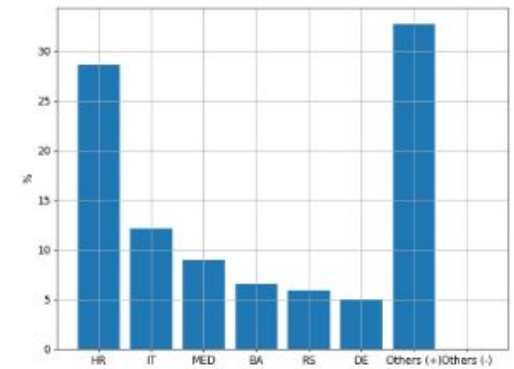
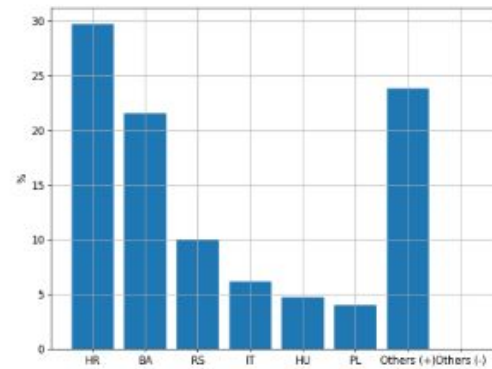


Figure 24: The six most important emitter countries or regions, with respect to their effects on PM<sub>2.5</sub> (left) and PM<sub>coarse</sub> (right) in Croatia that would result from reduction in emissions.

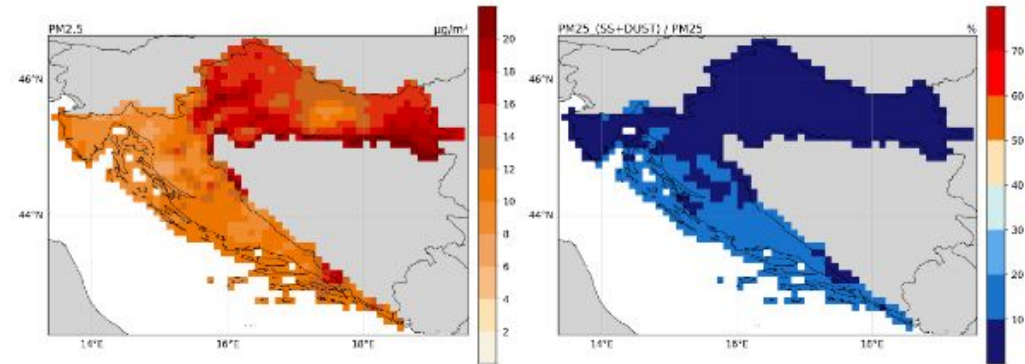
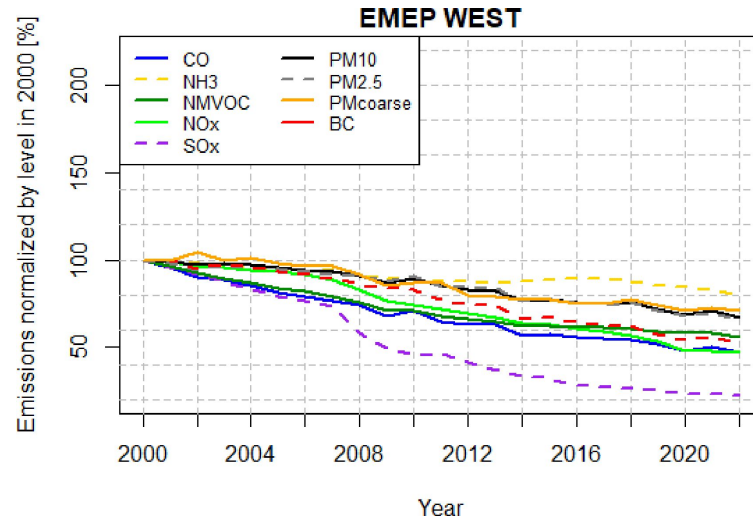
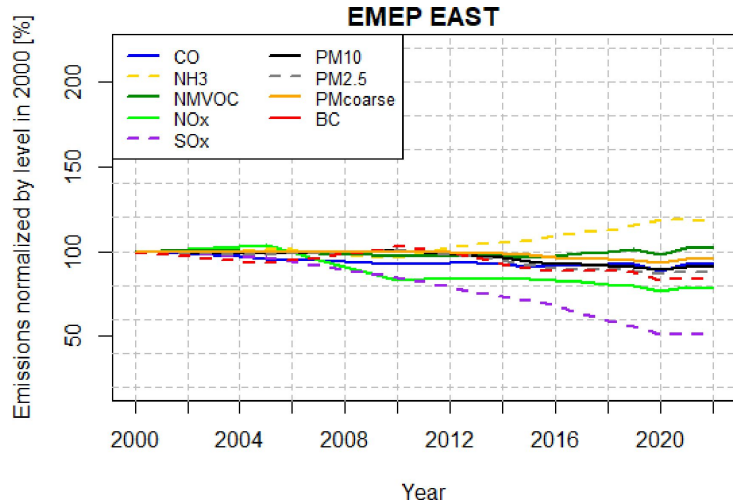


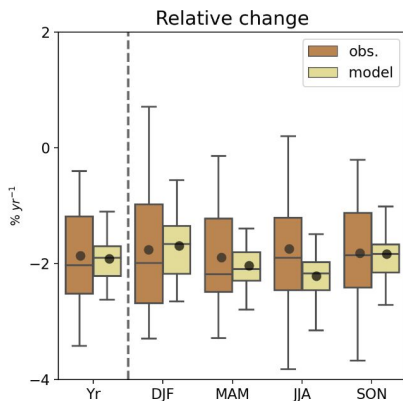
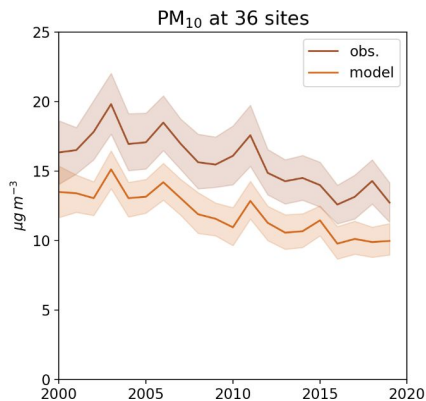
Figure 25: Left: PM<sub>2.5</sub> concentration, and right: fraction of natural contributions of PM<sub>2.5</sub> (sea salt and natural dust) to total PM<sub>2.5</sub> concentration in Croatia. Units:  $\mu\text{g}/\text{m}^3$  (left), % (right).

# Anthropogenic emissions in Europe. How are they changing?



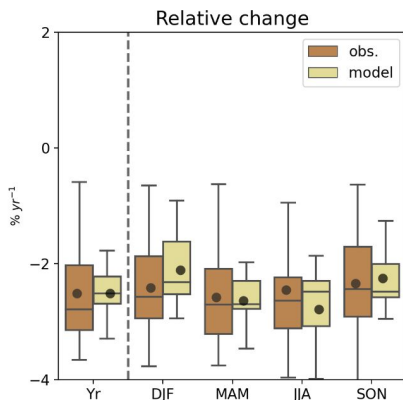
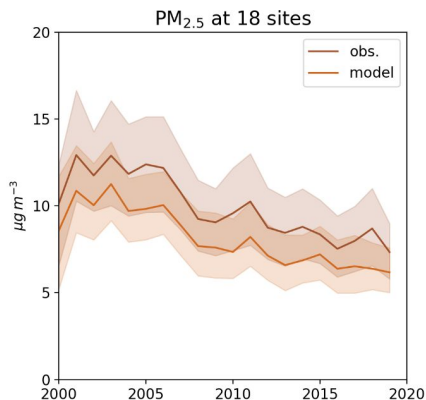
Emissions in western European countries decreasing. Eastern European countries mixed. Emissions in nearby regions (N. Africa and Asia) increasing.

# PM<sub>10</sub> and PM<sub>2.5</sub> 2000-2019



**PM<sub>10</sub>:**  
 Obs: - 35%  
 Mod: - 37%

Reductions in SIA ( $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ) contributed substantially. Considerable reductions in EC and winter time OC (at least in 2010-2019).



**PM<sub>2.5</sub>:**  
 Obs: - 46%  
 Mod: - 48%

Relative trends are well reproduced by the model, although absolute levels and trends are somewhat underestimated (partly due to condensables)

Lower trends in PM<sub>10</sub> than PM<sub>2.5</sub> due to natural contributions to the coarse fraction



# PM<sub>2.5</sub> in Europe in the future

- uEMEP calculations show that in 2015 most of the population in EU, Western Balkan and EECCA live in areas that have PM<sub>2.5</sub> values above current **WHO annual mean guideline values of 5 µg m<sup>-3</sup>**
- By 2030, the Baseline scenario indicates that 75% of the EU population will still be exposed to PM<sub>2.5</sub> levels above 5 µg m<sup>-3</sup> (40% in the 2050 Baseline, 15% in 2050 MFR)
- With baseline scenario less improvements in the PM<sub>2.5</sub> levels for the Western Balkan and EECCA countries. More stringent air quality policies would result in significant reduction of PM<sub>2.5</sub> concentrations. Some EECCA countries are limited in achieving very low PM concentrations by high levels of wind-blown dust.

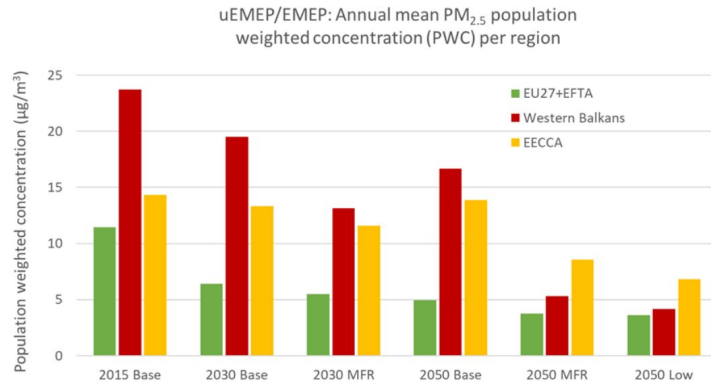


Figure 4.44: Calculated population weighted concentrations (PWC) for the 3 regions and for all scenarios using uEMEP for PM<sub>2.5</sub>.

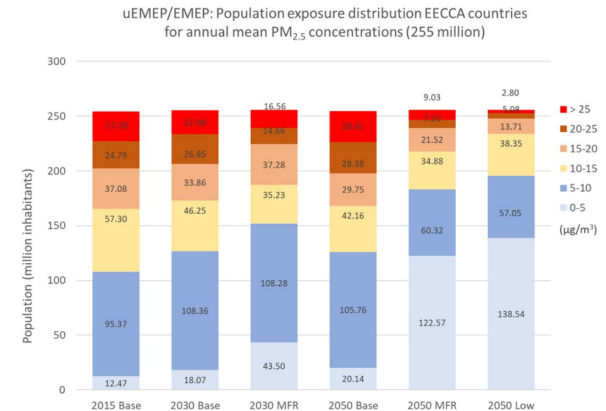


Figure 4.32: EECCA country population exposed to annual mean PM<sub>2.5</sub> concentrations within defined concentration ranges for all scenarios.



# Wildfire emissions

Wildfire emissions fully (or mostly) based on MODIS (Moderate Resolution Imaging Spectroradiometer) on board the National Aeronautics and Space Administration's (NASA) Terra and Aqua

Inventories currently in use in EMEP:

**FINN2.5: Based on MODIS burned area**

FINN2.5 mod 2002 - 2023

FINN2.5 modvrs 2014 -2023

With MODIS supplemented by VIIRS

(the Visible Infrared Imaging Radiometer Suite onboard of Suomi NPP and NOAA-20 satellites)

(FINN1.5 also available)

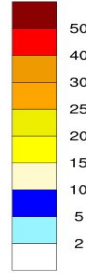
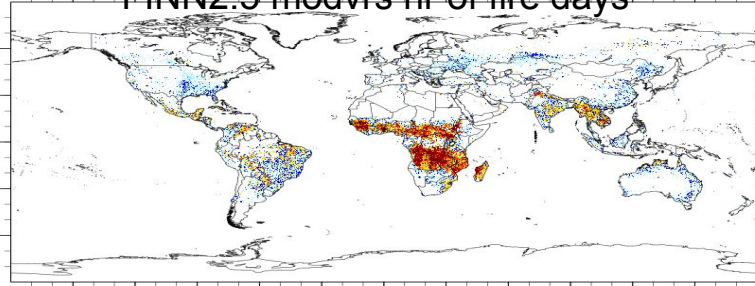
**GFAS: Based on MODIS FRP (Fire Radiative Power in  $W m^{-2}$ )**

Available 2002 - 2023

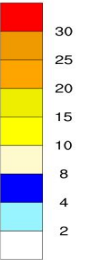
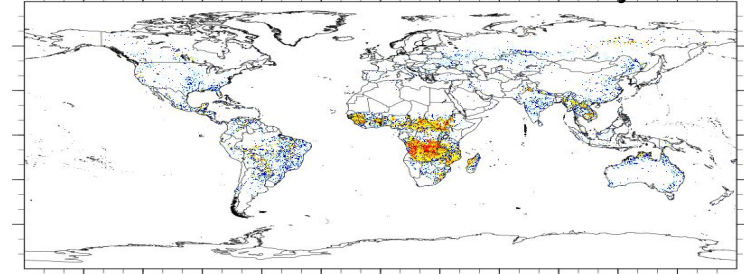
# Where are the fires located in 2021?

Number of fire days on a 0.1 x 0.1 degrees map

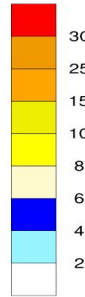
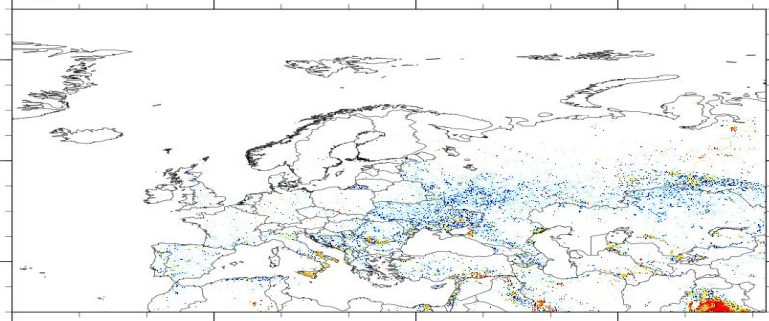
FINN2.5 modvrs nr of fire days



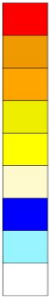
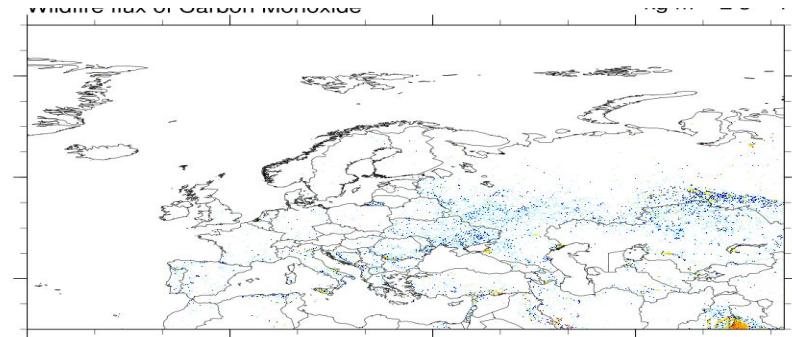
GFAS nr of fire days



ECCA FINN25 modvrs



ECCA GFAS



Number of fires and emissions in the 0.1 x 0.1 degrees global and ECCA grid (ECCA is an extended European domain shown in previous slide.

Note!  
Interannual variability and large differences in inventories.

Modvrs:  
With Visible Infrared Imaging Radiometer Suite (VIIRS)

	Global			EMEP		
	FINN2.5		GFAS	FINN2.5		GFAS
	mod	modvrs		mod	modvrs	
Year 2020						
Nr. fire days <sup>†</sup>	30.81	64.01	21.63	1.07	3.59	1.45
Gg CO (as CO)	548028	696794	265710	15010	21430	9364
Gg NO (as NO)	8074	10285		281	403	
Gg NO <sub>2</sub> (as NO <sub>2</sub> )	21022	23328	79367*	539	772	250*
Gg PM <sub>2.5</sub>	60146	76535	24335	1461	2083	775
Year 2021						
Nr. fire days <sup>†</sup>	29.24	59.91	23.57	0.86	2.95	1.32
Gg CO (as CO)	488154	617719	362376	14511	20977	15558
Gg NO (as NO)	7515	9524		291	424	
Gg NO <sub>2</sub> (as NO <sub>2</sub> )	18531	23328	9247*	536	780	290*
Gg PM <sub>2.5</sub>	54205	68613	29013	1487	2140	1039
Year 2022						
Nr. fire days <sup>†</sup>	28.53	61.79	21.88	1.04	4.18	1.25
Gg CO (as CO)	41812	53219	362376	15782	23820	12673
Gg NO (as NO)	6466	8293		303	472	
Gg NO <sub>2</sub> (as NO <sub>2</sub> )	16218	20578	7195*	547	846	286*
Gg PM <sub>2.5</sub>	45755	58263	21788	1758	2644	986

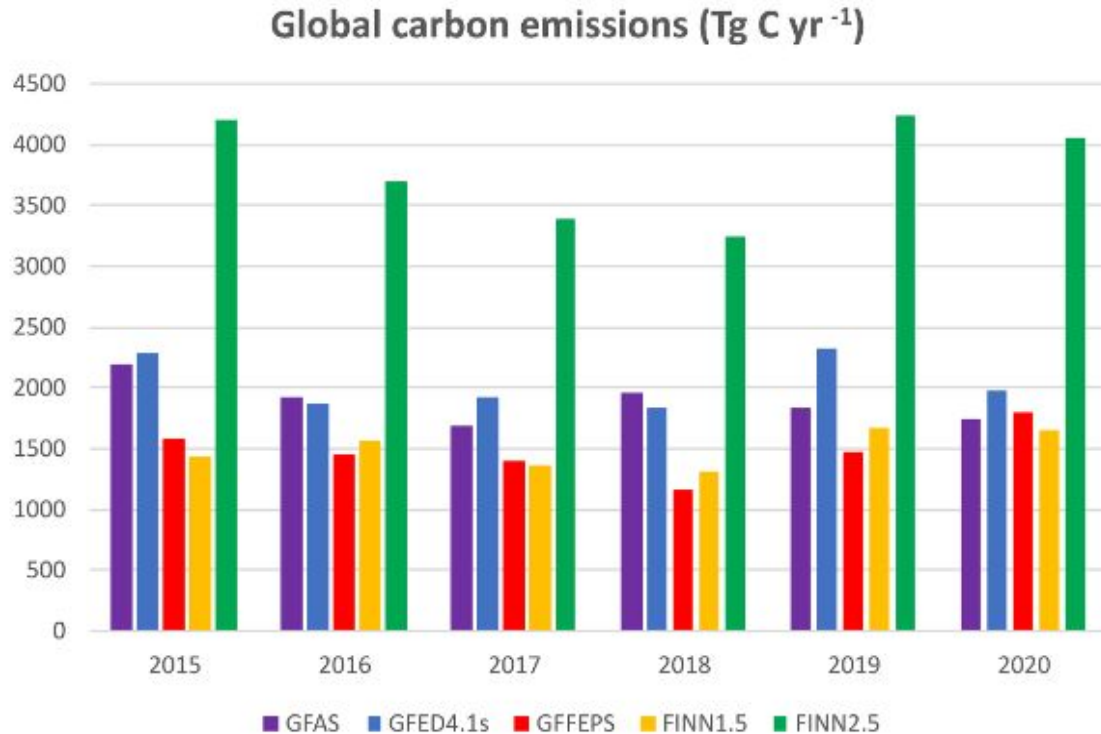
<sup>†</sup> *Devided by 10<sup>5</sup>*

\* *NO<sub>x</sub> as NO<sub>2</sub>*

Wildfire emissions from different inventories.

**NOTE! FINN2.5 is FINN2.5modvrs. FINN2.5mod not as high**

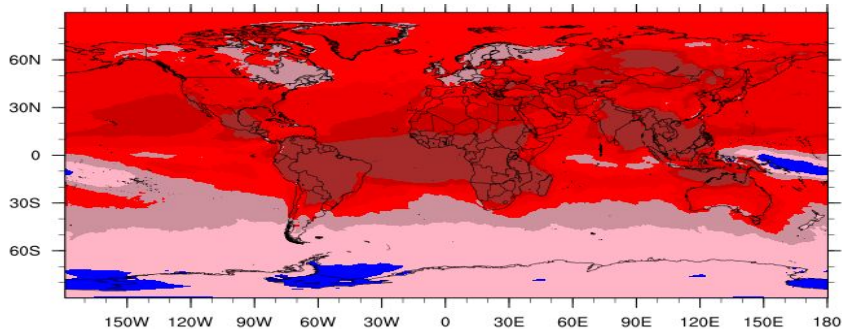
From Anderson et al. (2024) <https://doi.org/10.5194/gmd-17-7713-2024>



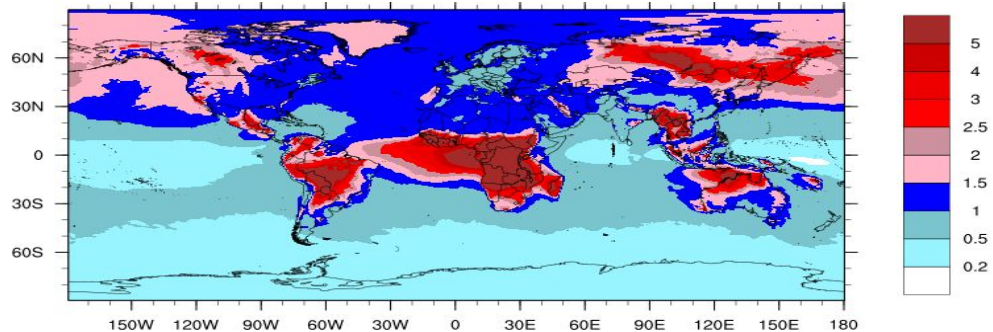
**Figure 11.** Annual carbon emissions (Tg C yr<sup>-1</sup>) of GFFEPS and other global wildfire emissions models included in this study.

# Ozone and PM25 with and without wildfires in 2021

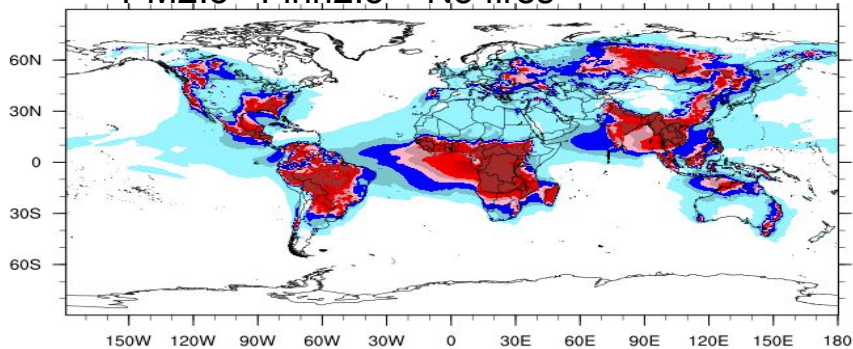
## Ozone Finn2.5 – No fires



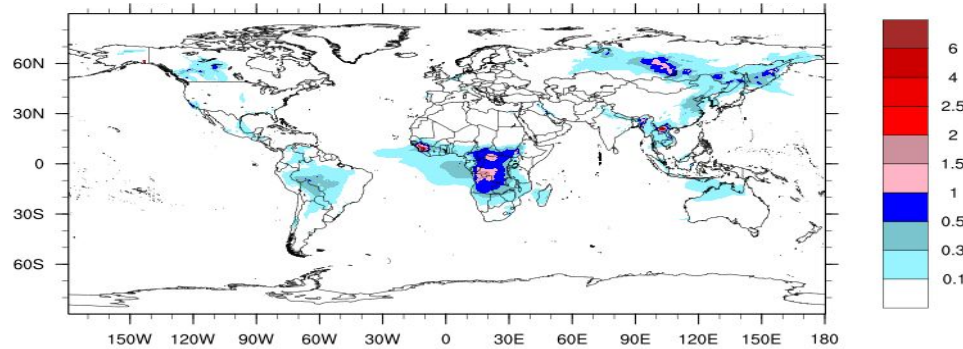
## Ozone GFAS – No fires



## PM2.5 Finn2.5 – No fires



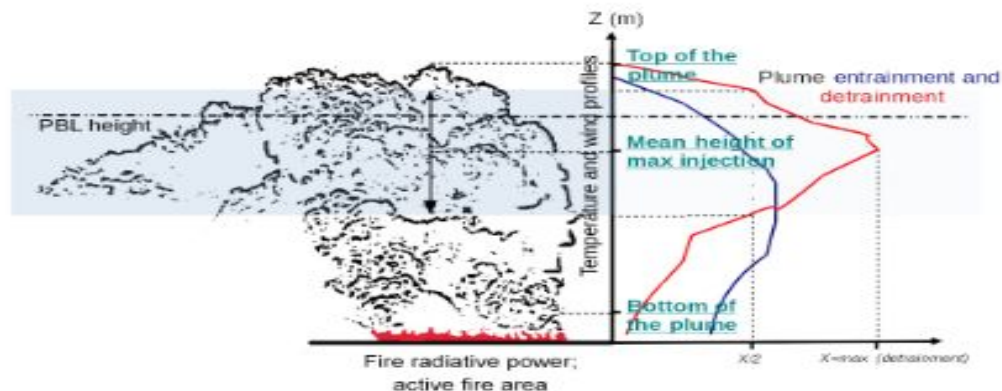
## PM2.5 GFAS – No fires



# GFAS, FINN1.5, FINN2.5 (mod/modvrs)

FINN2.5mod is the default option, but GFAS is also used, in particular for near real time calculations.

Figure from Remy et al. (2017): <https://acp.copernicus.org/articles/17/2921/2017/>



**Figure 1.** Schematic of an algorithm estimating plume injection height parameters. The fire input (fire radiative power and fire area) and the environmental input (temperature and wind profiles) are shown, as well as the possible output of the model: detrainment and entrainment profiles, with the derived quantities (bottom of the plume, top of the plume, mean height of maximum injection), or injection height, usually defined as the top of the plume.

GFAS has daily information on injection height for all years (2000 – present).

Vertical profile of emissions should be implemented in EMEP based on FRP (Fire Radiative Power).

In FINN FRP only provided from 2022 and onwards.

# Fire emissions for a given species calculated as:

E – Emissions of given species

NB! Burned area and FRP are separate MODIS data products

## Finn emissions

$$E = A \times B \times BF \times EF$$

Where:

BA – Area burned

B – Biomass at location

BF – Fraction of Biomass burned

EF – Emission factor for species

## GFAS emissions

$$E = K \times FDM$$

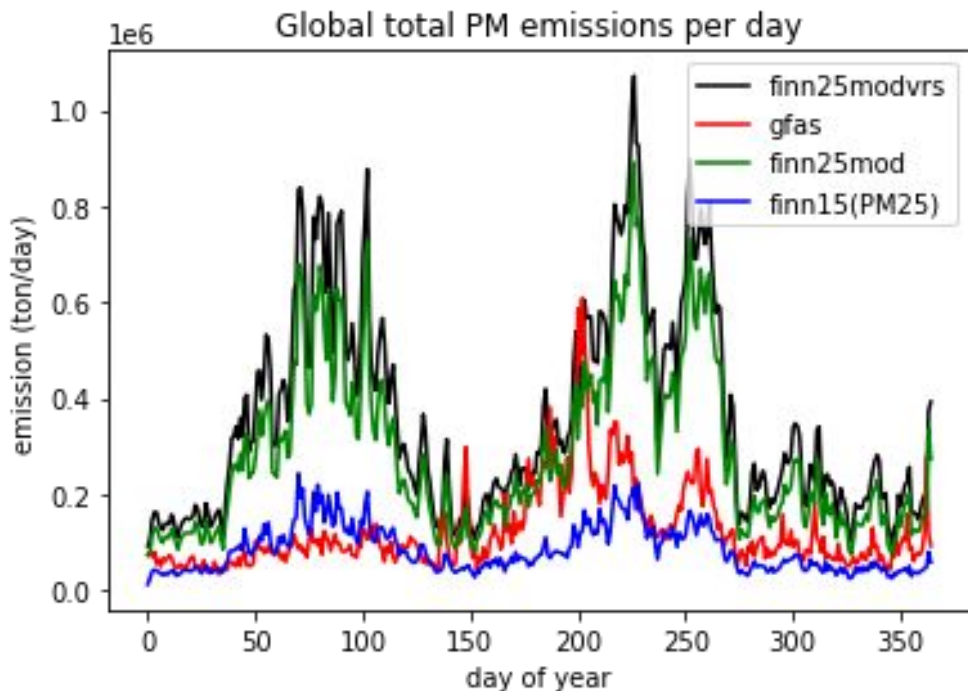
Where:

K – Em. factor

FDM – Dry Matter Comb. rate  
calculated from FRP  
(landcover dependant)

## Time series of global total PM emissions

FINN25 seems to detect more or less the same fire events as FINN15 but with much higher emissions.



Based on 2019 emissions

GFAS:

From Remy et al. (2017):

<https://acp.copernicus.org/articles/17/2921/2017/>

- When used in **C-IFS**, the GFAS emissions of biomass burning aerosols are **scaled by a factor of 3.4**.
- Further in **C\_IFS**: With emissions at the mean height of maximum injection, the **global average for OM and BC scaling factors are 3.0 and 5.9 respectively**, to be compared against values of 3.2 and 6.1 when biomass burning emissions are prescribed at the surface.
- Other models also use a scaling factor for biomass burning emissions, but their **values are different: 1.7 for the Met Office Unified Model limited-area model** configuration over South America

# How are fire emissions treated in the EMEP model now, and what would we like to achieve?

1. As already noted there are options for changing between different emission inventories as FINN2.5 and GFAS (and FINN1.5)
2. As default all forest fire emissions are now distributed evenly within the Planetary Boundary Layer (PBL). Most (order of 85%?) wildfires emit low (within PBL), but is less true at low latitudes).
3. Implementation of a vertical distribution of injection heights in the EMEP model should ideally work independently of emission inventory.

Injection heights can also be estimated from MIRS as shown in later slides

# Alternative injection height

The primary tool for deriving the injection heights comes from the Multi-angle Imaging SpectroRadiometer (MIRS) imagery. MIRS flies onboard the Terra satellite, along with MODIS.

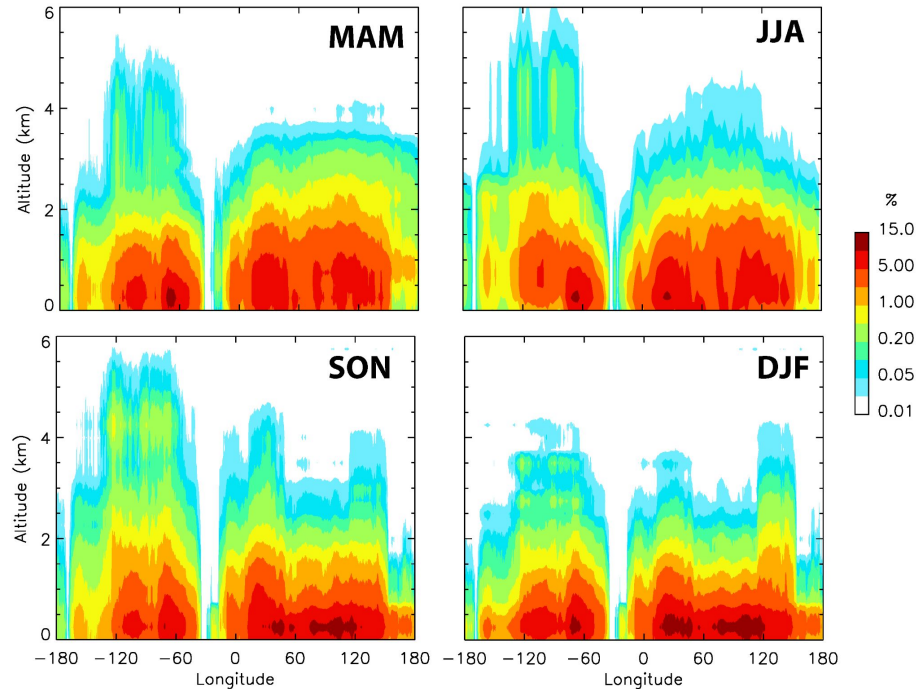
**MIRS: Global coverage takes about 1 week for global coverage, more at lower latitudes.**

From ValMartin et al.  
(2018)

<https://doi.org/10.3390/rs10101609>

Monthly Injection heights  
provided for 2008, 2009 and  
2010

“One size fits all” Injection to  
higher levels episodic. Does  
it make sense to inject all fires  
large and small in the same  
way?



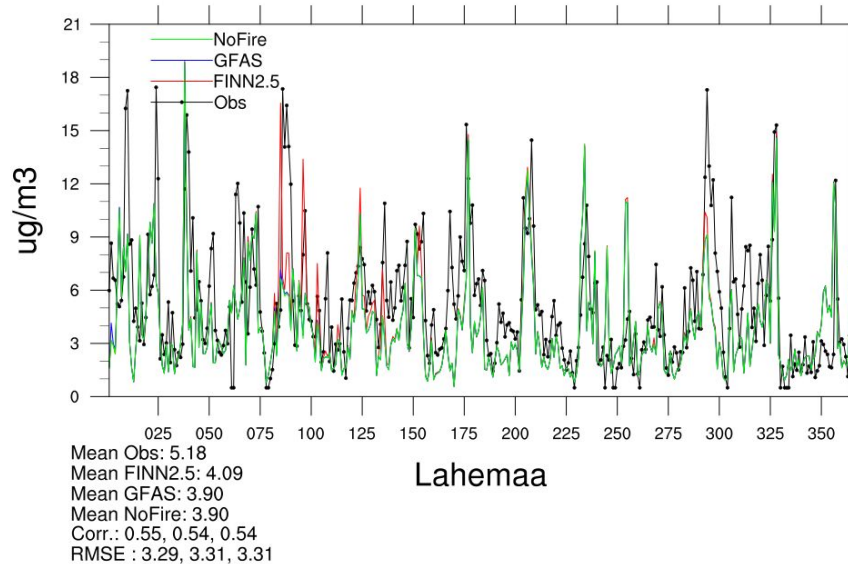
# PM2.5 model versus measurements

## Mixed results

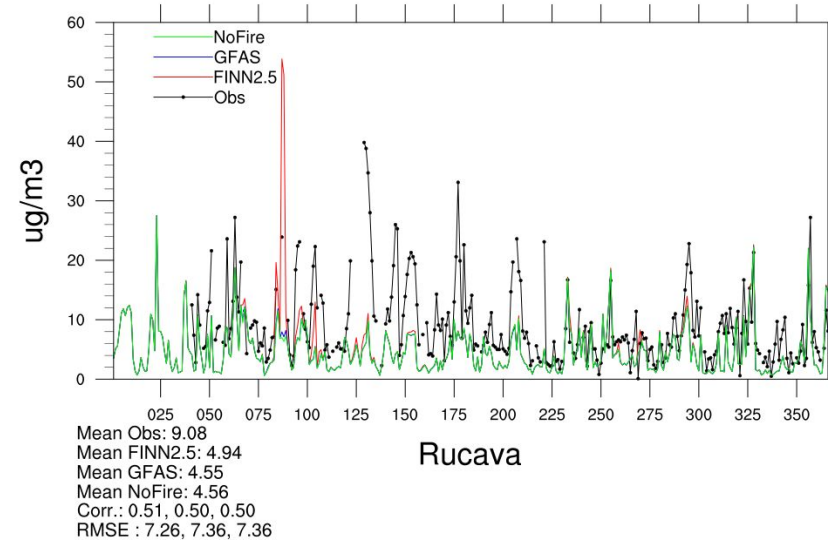
(Unfortunately fewer measurements available in Mediterranean region)

Lahemaa in Estonia, Rucava in Latvia

### PM2.5



### PM2.5



# Concluding remarks

- Air pollution modelling and its integration with integrated assessment has been a successful tool for development of policy in Europe
- Despite the large emission reductions achieved so far, with a generally similar downward trend in pollutant concentrations and depositions, adverse effects on human health, ecosystems and materials continue to occur
- Modelling indicates that exceedances of critical loads and levels (eutrophication,  $O_3$ ,  $PM_{2.5}$  exposure above WHO air quality guideline), even with full implementation of all available technical measures and additional changes will still occur
- Satellite data and data assimilation very useful for model/emission/trends evaluation & analysis, but has been less useful for policy development through e.g. IA or assessment of future scenarios
- Wildfire emission an important source, but with large uncertainties
- Wildfire injection height should be investigated. More important for lower latitudes