EMME-CARE
EASTERN MEDITERRANEAN MIDDLE EAST – CLIMATE & ATMOSPHERE RESEARCH CENTRE

2021 CLIMATE CHANGE in the Eastern Mediterranean & Middle East 2nd INTERNATIONAL CONFERENCE

Virtual workshop: Climate and Atmosphere Research & Innovation in the Eastern Mediterranean and Middle East
11,12 October 2021

Premature mortality from exposure to ambient PM2.5, black and organic carbon in the EU-27

Niki Paisi, Sourangsu Chowdhury, Jonilda Kushta, George Georgiou, Jos Lelieveld

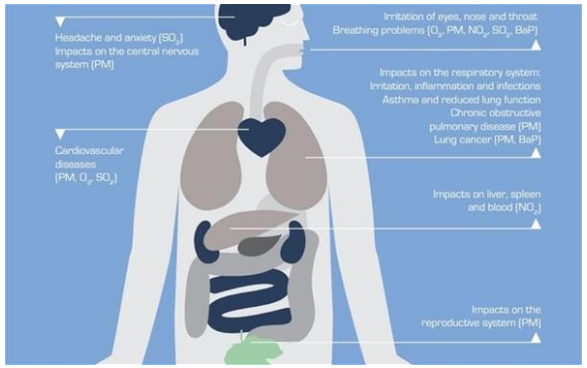
Introduction

- Air pollution is the 4th top risk factor associated with the highest number of deaths worldwide, after high blood pressure, tobacco and dietary risks in 2019 (GBD, 2019)
- Causes comparable losses of healthy life expectancy with that from tobacco smoking (Burnett et al, 2018, Lelieveld et al, 2020)
- Although air pollution in most European countries has decreased over the last decades, it remains above WHO safe limits (OECD, 2020)
- The SE Europe (incl. parts of EMME) is a hot spot of climate change and air pollution

Objectives

- Estimate the premature mortality in the EU-27 which is attributed to outdoor air pollution (PM2.5) using the WRF-CHEM model.

- Estimate the fraction of the premature mortality from carbonaceous components of PM2.5 (BC+OC) taking into account their differential toxicity.



The Weather Research and Forecasting Model coupled with Chemistry (WRF-CHEM)

WRF-CHEM:

Simulates meteorological & chemical processes at the same time (e.g. emission, transport, mixing, chemical transformation of trace gases and aerosols) (UCAR, ACOM)

Application

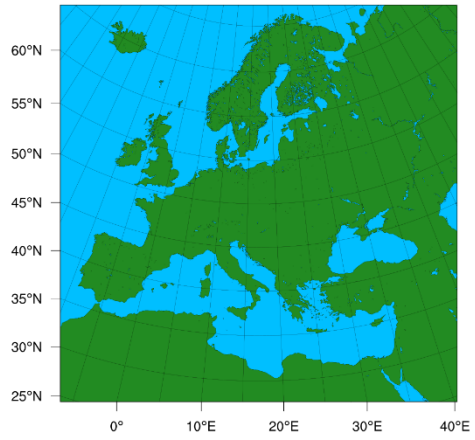
To simulate atmospheric composition over Europe based for the year 2015 focusing on PM2.5 and its carbonaceous components.

Model set-up

- WRF-Chem model version 3.9.1

Initial and boundary conditions	Emissions
Meteorological: Global Forecast System (GFS) (3h, 0.5°×0.5°)	▪ Anthropogenic: EDGAR v.5 global emission inventory (monthly, 0.1°×0.1°)
Chemical: The Global Model for Ozone and Related Chemical Tracers – MOZART (1.89 °×1.89 °)	▪ Biogenic: MEGAN model (online, 0.5°×0.5°)
	▪ Dust: GOCART scheme (online)

- Resolution: 20×20 km
- Domain: Europe
- Chemical mechanism: RACM Chemistry and MADE/VBS aerosols scheme
- Simulation performed at CyI HPC facilities (CYCLONE)



Premature mortality using the **Global Exposure Mortality Model (GEMM)**

$$HR\,(z) = exp\left(\theta \times log\left(\left(\frac{z}{a}\right)+1\right) / \left(1 + exp\left(-\frac{z-\mu}{\nu}\right)\right)\right)$$

(Burnet et al. 2018)

θ, a, μ, ν are the parameters of the fit for the model

$z = \max(0, PM2.5 - 2.4\mu g/m3)$

↓

Gridded annual average concentration of $PM_{2.5}$ for the year 2015

Non-Communicable Diseases and Lower Respiratory Infections (NCD+LRI)

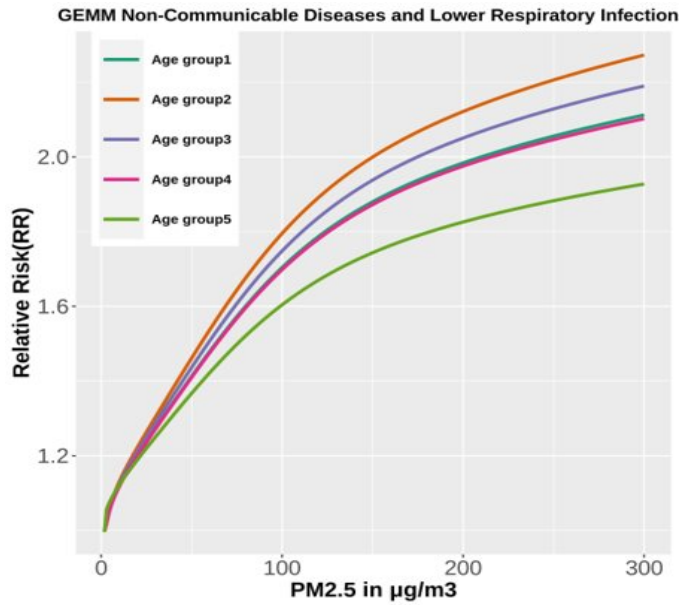
- ❑ Ischemic Heart Disease
- ❑ Stroke
- ❑ Chronic Obstructive Pulmonary Disease
- ❑ Lower Respiratory Infections
- ❑ Lung Cancer

$$Premature\ Mortality_{PM2.5} = BMR \times POP \times (\mathrm{HR} - 1/HR)$$

$$Premature\ Mortality_{PM2.5\ without(BC+OC)} = BMR \times POP \times (HR - \frac{1}{HR})$$

$$\boldsymbol{Premature\ Mortality_{BC+OC} = Premature\ Mortality_{PM2.5} - Premature\ Mortality_{PM2.5\ without(BC+OC)}}$$

Carbonaceous PM2.5 are more toxic than inorganic ones (Lelieveld et. al, 2015)



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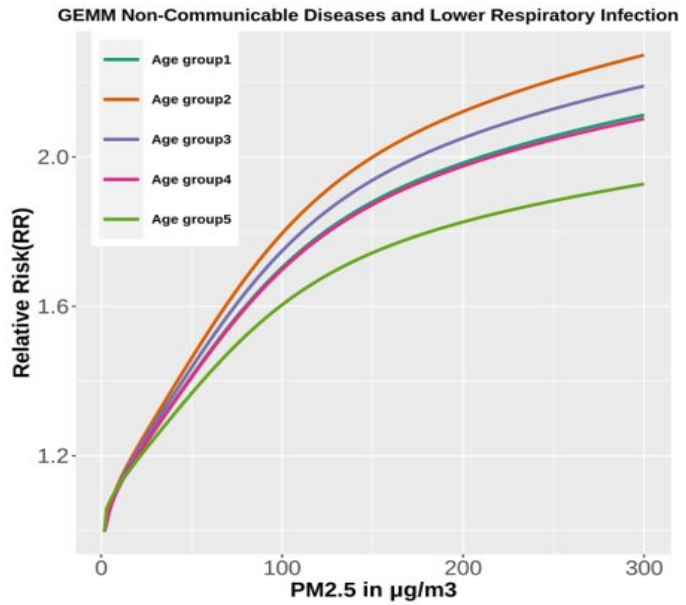

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		Assuming equal toxicity	Assuming BC+OC twice more toxic	Assuming equal toxicity	Assuming BC+OC twice more toxic			
Austria	7300 (6600-8100)	500 (422-513)	1000 (900-1100)	6	13	7.8	10.8	0.9
Belgium	12200 (10900-13400)	600 (570-693)	1300 (1200-1400)	5	11	7.8	15.3	1.2
Bulgaria	9600 (8700-10600)	700 (644-780)	1500 (1300-1600)	7	15	9.4	10.0	1.0
Croatia	4400 (4000-49000)	400 (320-390)	700 (670-800)	8	17	9.8	9.9	1.0
Cyprus	400 (350-500)	31 (27-36)	100 (55-75)	8	15	7.7	6.9	0.5
Czech Republic	11400 (10300-12600)	700 (677-820)	1500 (1400-1700)	7	14	8.9	13.0	1.2
Denmark	4700 (4200-5200)	300 (244-299)	600 (500-600)	6	12	7	11.5	0.9
Estonia	800 (700-900)	100 (124-156)	300 (280-350)	18	39	12.4	6.0	0.9
Finland	1700 (1600-1900)	500 (440-543)	1000 (900-1100)	29	59	10.3	4.3	0.7
France	45000 (40500-49500)	4700 (4270-5180)	10300 (9300-11300)	10	23	10.4	10.5	1.4
Germany	98600 (89100-108100)	4400 (3960-4760)	8900 (8100-9700)	4	9	6	13.3	0.9
Greece	7200 (6400-8000)	800 (700-860)	1700 (1500-1800)	11	23	9.9	7.4	0.9
Hungary	13200 (11900-14400)	1000 (950-1140)	2200 (2000-2400)	8	17	10.4	12.0	1.3
Ireland	1600 (1400-1800)	100 (73-90)	200 (150-190)	5	10	4.3	5.9	0.3
Italy	49700 (44900-54600)	5300 (4820-5820)	11400 (10300-12400)	11	23	12.1	9.6	1.3
Latvia	1900 (1700-2100)	200 (180-220)	400 (370-460)	10	22	9.5	7.6	0.9
Lithuania	3400 (3000-3700)	200 (180-220)	400 (370-450)	6	12	7.4	9.4	0.7
Luxembou	500 (400-540)	29 (25-33)	100 (50-70)	6	13	8.5	13.9	1.2
Malta	170(100-200)	26 (23-30)	100 (50-60)	13	33	12.9	5.9	0.8
Netherlan	16100 (14500-17800)	70 (620-750)	1400 (1300-1500)	4	9	6	15.0	1.0
Poland	41100 (37100-45200)	3000 (2700-3200)	6200 (5600-6700)	7	15	9.4	12.8	1.3
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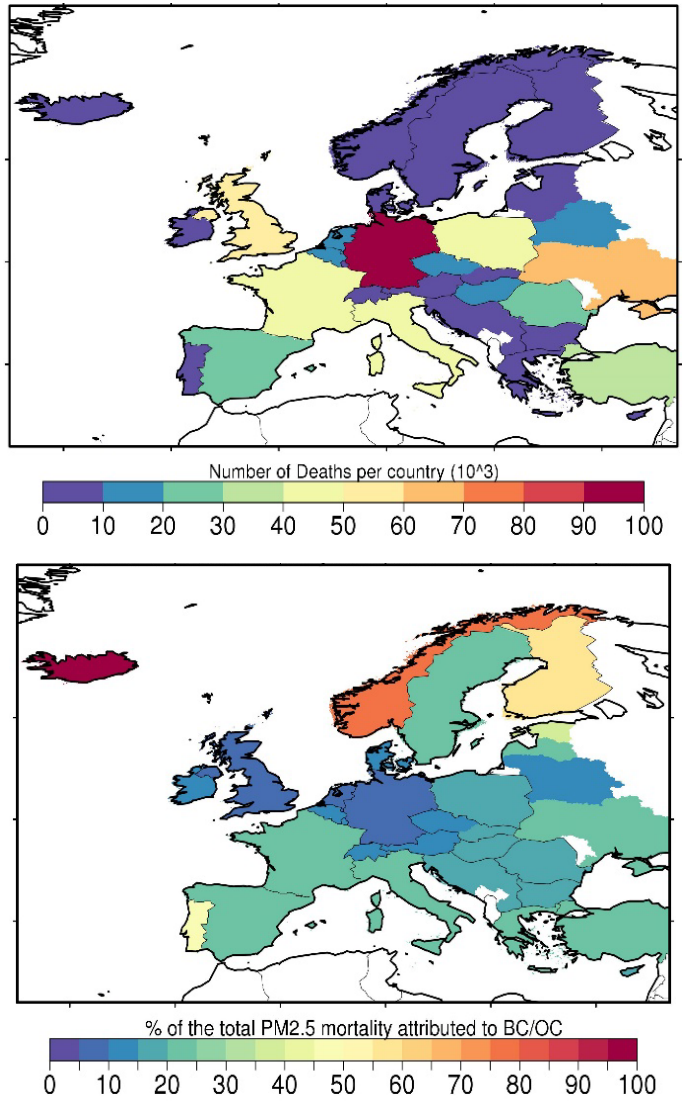
Spain	203000 (18300-22300)	2300 (2100-2600)	5000 (4500-5400)	1	24	8.1	5.5	0.6
Sweden	4200 (3700-4600)	400 (390-480)	900 (800-1000)	10	21	8.4	5.6	0.5
TOTAL	392000 (353000-431000)	31000 (28000-34000)	65000 (58700-71200)	8	17	9.3	9.7	1.0



Excess mortality due to total $PM_{2.5}$ per country for the year 2015 (top panel), and fraction of mortality attributed to black carbon and organic carbon (BC+OC) relative to total $PM_{2.5}$ mortality (bottom panel).

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Country	Excess mortality from PM2.5 total (deaths)	Excess mortality from BC+OC (deaths)		Fraction of excess mortality from BC+OC (% of total)		Fraction of BC+OC in PM2.5 (%)	Pop-weighted-mean PM2.5	Pop-weighted-mean BC+OC
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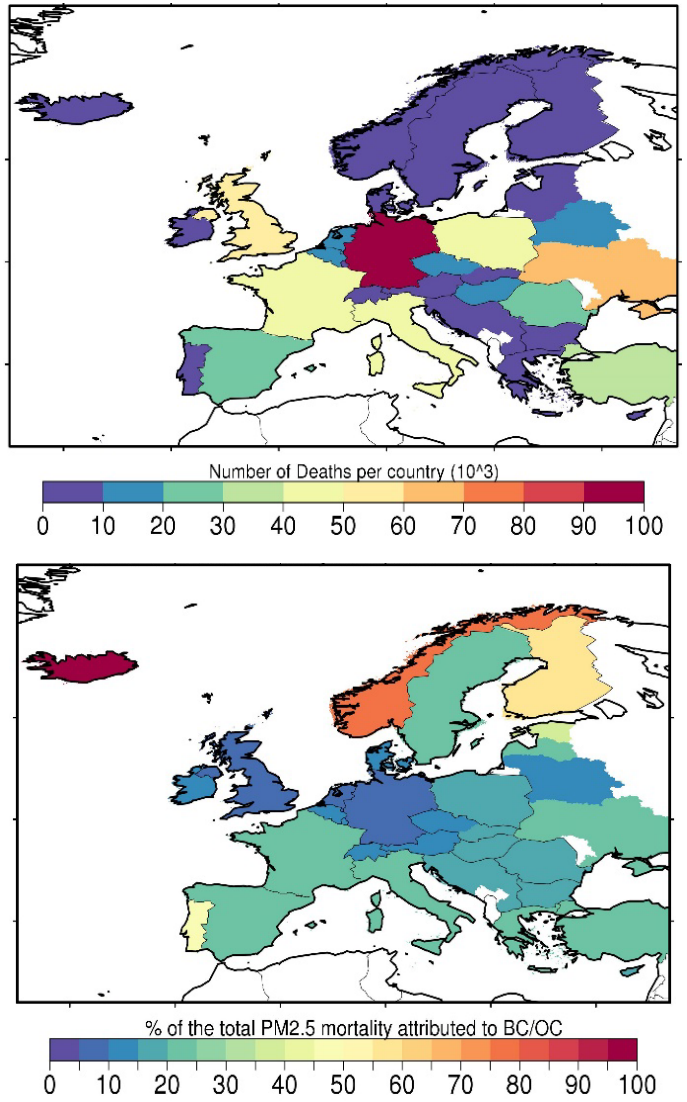

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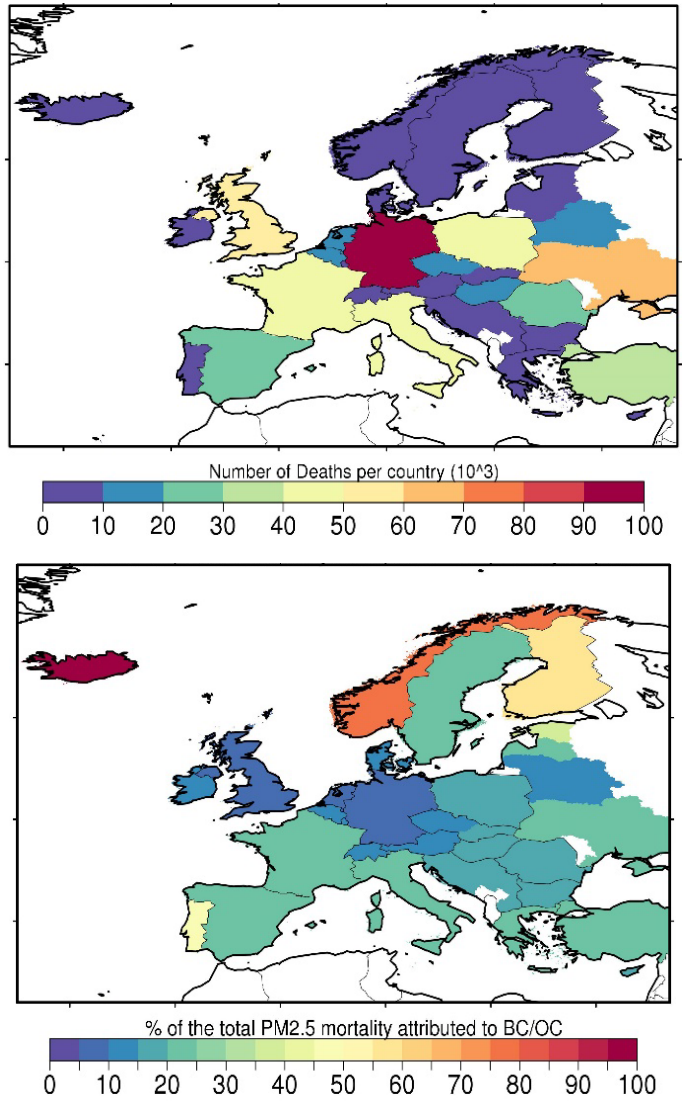

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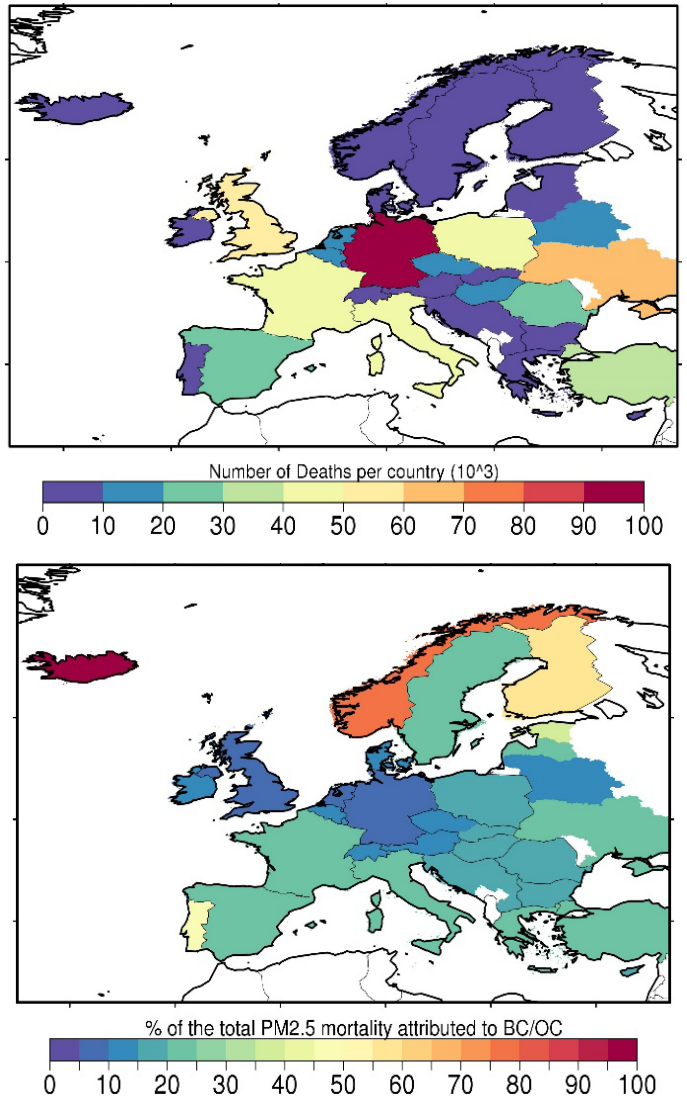
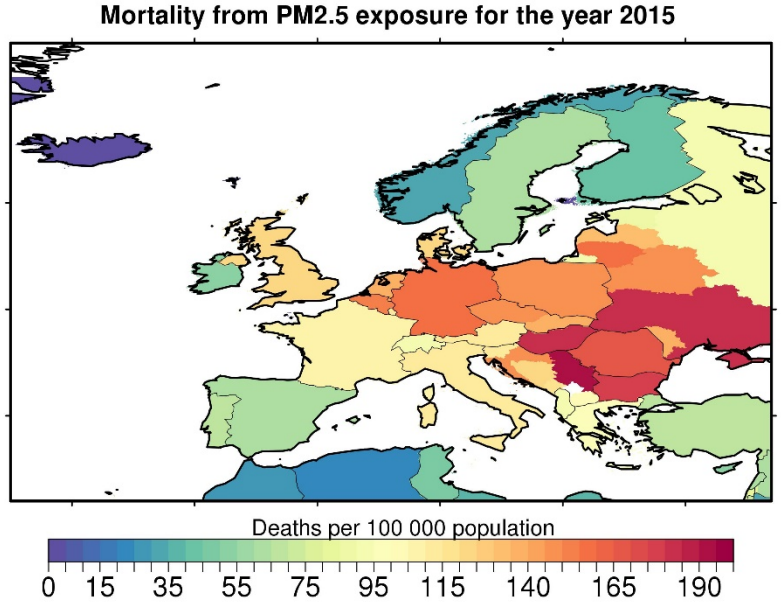
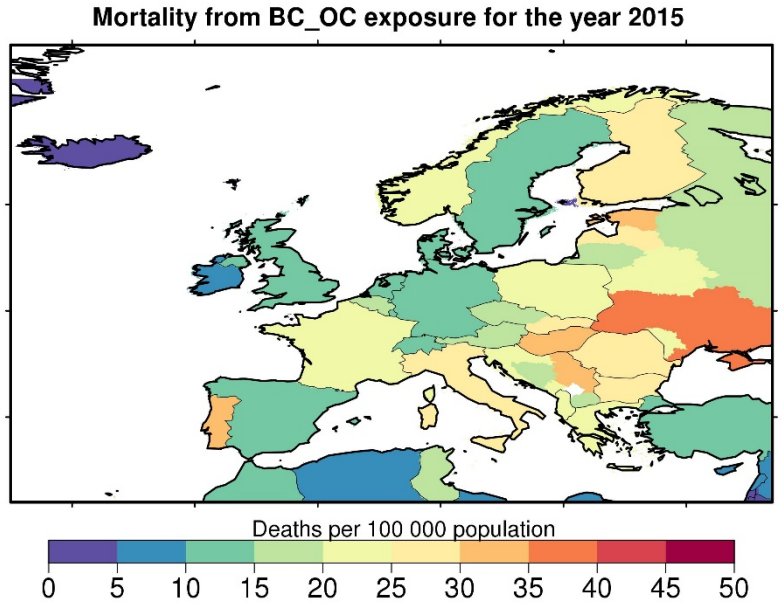
Sweden	4200 (3700-4600)	400 (390-480)	900 (800-1000)	10	21	8.4	5.6	0.5
TOTAL	392000 (353000-431000)	31000 (28000-34000)	65000 (58700-71200)	8	17	9.3	9.7	1.0

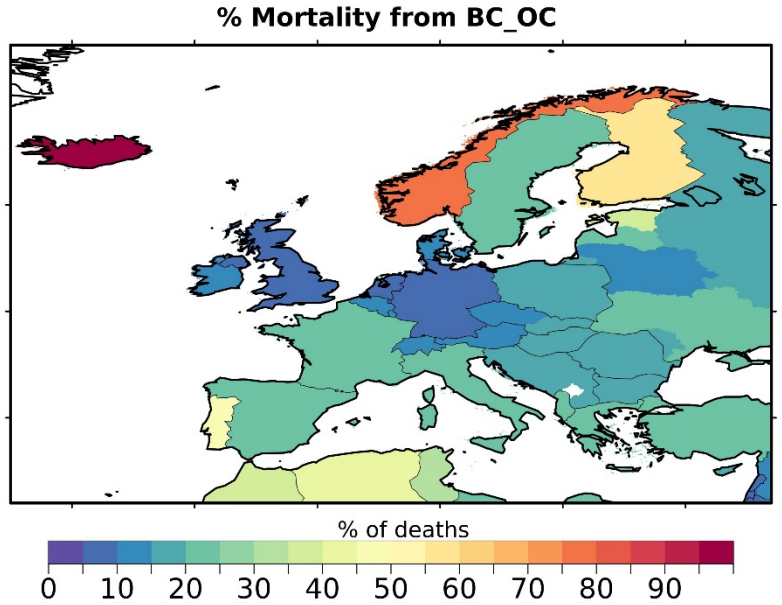


Excess mortality due to total $PM_{2.5}$ per country for the year 2015 (top panel), and fraction of mortality attributed to black carbon and organic carbon (BC+OC) relative to total $PM_{2.5}$ mortality (bottom panel).

Results: Normalized premature mortality estimations







Conclusions

- The toxicity of BC and OC is still not well quantified yet and this affects mortality estimations (Underestimated).
- Our sensitivity analysis shows that the assumption of a doubled toxicity of BC+OC can increase the total premature mortality from PM2.5 by almost 9%.
- Countries with high concentrations of these particles would gain much in terms of health benefits if air pollution mitigation policies would be source specific.

Thank you for your attention

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