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EMME-CARE

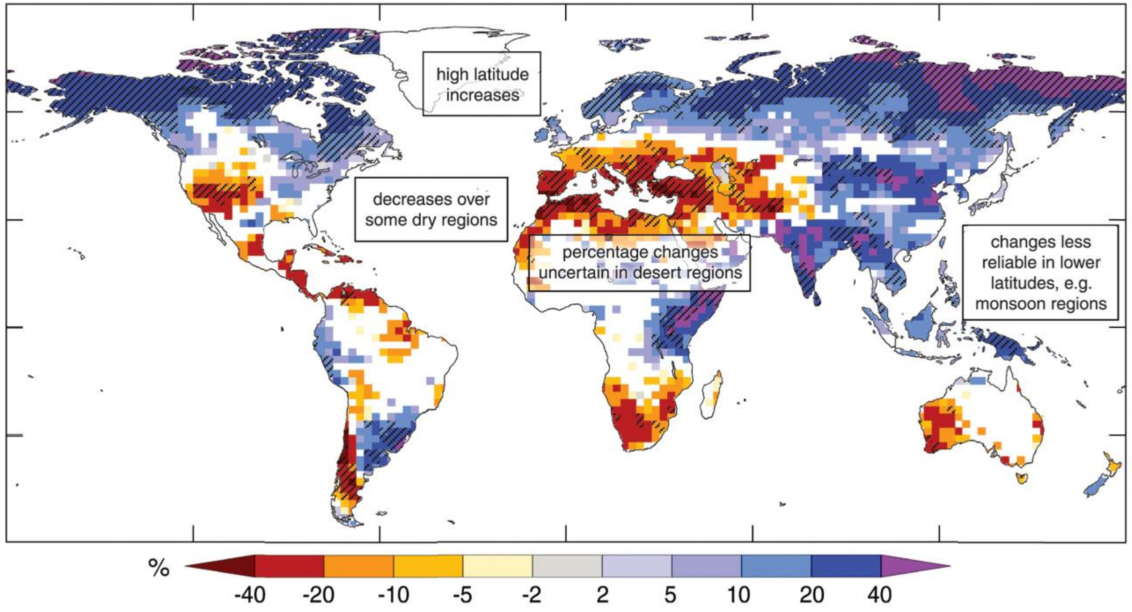
EASTERN MEDITERRANEAN MIDDLE EAST – CLIMATE & ATMOSPHERE RESEARCH CENTRE

ELEMENTAL CARBON CONTRIBUTION TO CLIMATE IN THE EASTERN MEDITERRANEAN AND THE MIDDLE EAST

Jonilda Kushta, G. K. Georgiou, I. Stavroulas, G. Biskos, G. Kouvarakis, Y. Proestos, T. Christoudias, M. Pikridas, N. Mihalopoulos, J. Sciare and J. Lelieveld

Motivation

- EMME region is characterized as a climatically sensitive region
- Investigation of the impact of aerosols on radiation, clouds and precipitation
- Quantify regional climatic forcing of aerosol components



Source: IPCC AR4 Climate Change 2007: Synthesis Report

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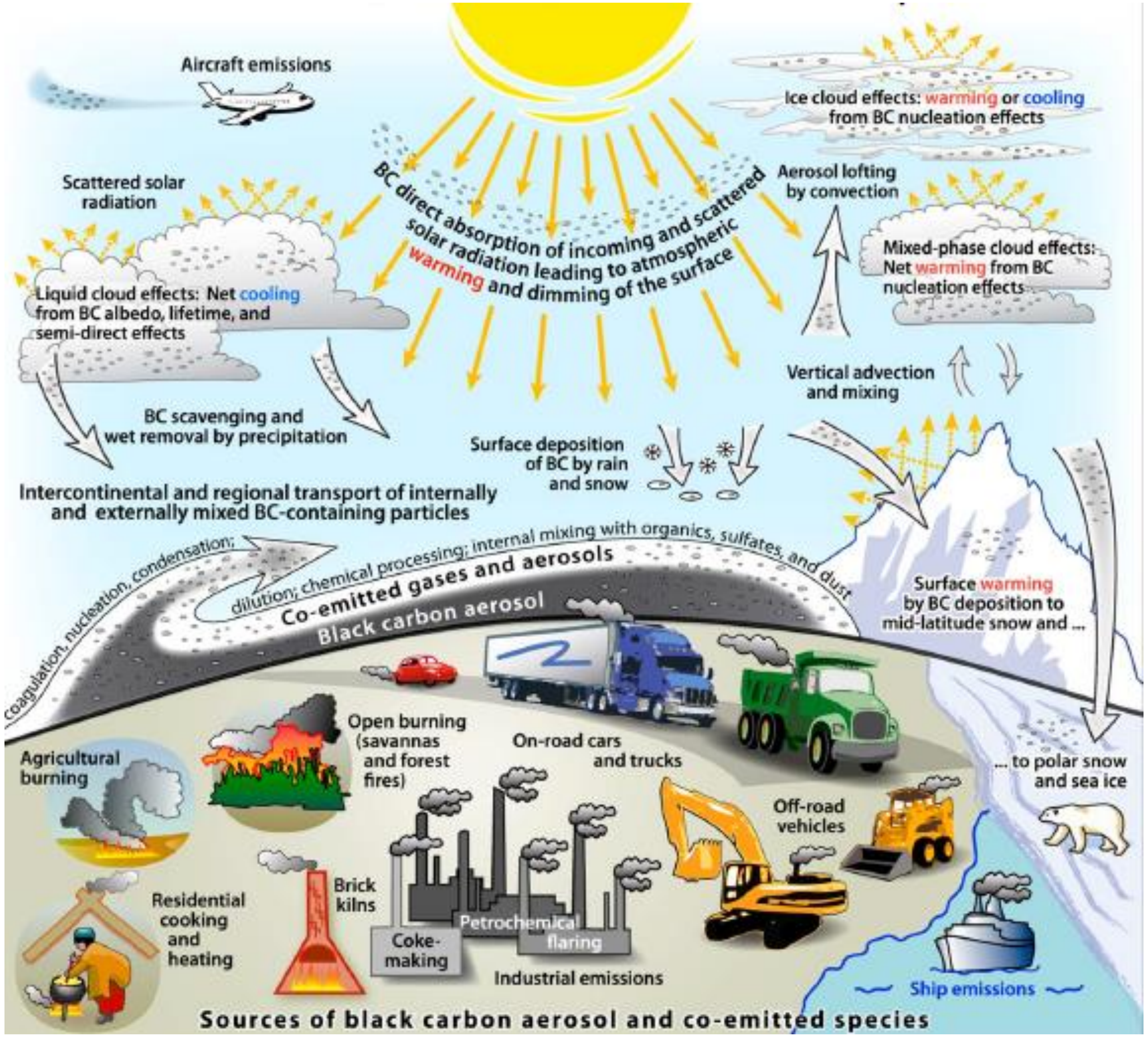
Why look into black carbon?

- ✓ Strongly absorbs visible light (mass absorption cross section of at least 5 m^2g^{-1} at 550 nm (No other substance with such strong light absorption per unit mass is present in the atmosphere in significant quantities).
- ✓ Refractory material (retains its basic form at very high temperatures, with a vaporization temperature near 4000K^o)
- ✓ Insoluble in water, in organic solvents and in other components of atmospheric aerosol with aggregate structure of small carbon spherules.
- ✓ Very low chemical reactivity in the atmosphere (primary removal process is wet or dry deposition to the surface.

BC processes in the atmosphere

Bond et al., 2013



- ✓ A variety of combustion sources, both natural and anthropogenic.
- ✓ Regional and intercontinental transport (only removal process is deposition either through washout or sedimentation) resulting in an average atmospheric lifetime of about 1-2 weeks.
- ✓ Changes in the radiative balance of the Earth due to an increase in absorption of sunlight within the atmosphere.
- ✓ May increase the reflectivity and lifetime of warm (liquid) clouds, causing net cooling, or may reduce cloudiness, resulting in warming.
- ✓ Changes in cloud droplet number and cloud cover in ice and mixed-phase clouds.

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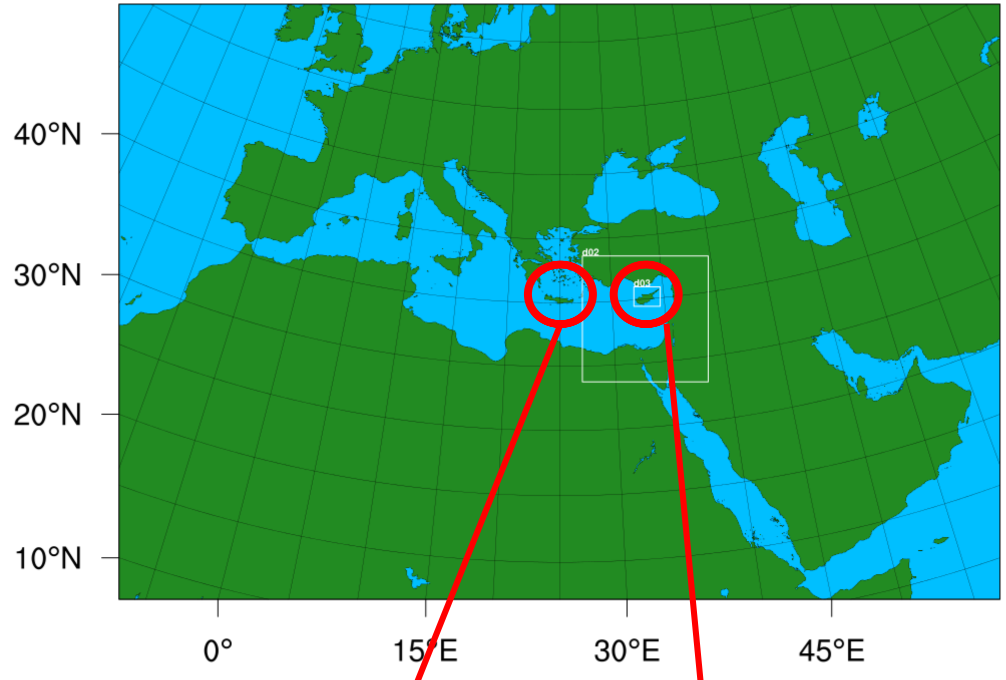
Model and Measurements



- ✓ WRF/Chem 3.9.1 with RACM chemistry for 2015
- ✓ EMISSIONS EDGAR HTAP V2 for NOx, SO_2, NMVOC, CO, primary $PM_{2.5}$ and PM_{10}, Elemental Carbon (estimates 2010) at 0.1°× 0.1°
- ✓ Initial and Boundary conditions from global model (MOZARTv4)
- ✓ Online Dust (GOCART), Sea Salt, Biogenic emissions (MEGAN)
- ✓ Aerosol radiative feedback and prognostic aerosols for cloud droplet activation
- ✓ EMEP Monitoring Network (EC) and BC measurements over Cyprus and Crete

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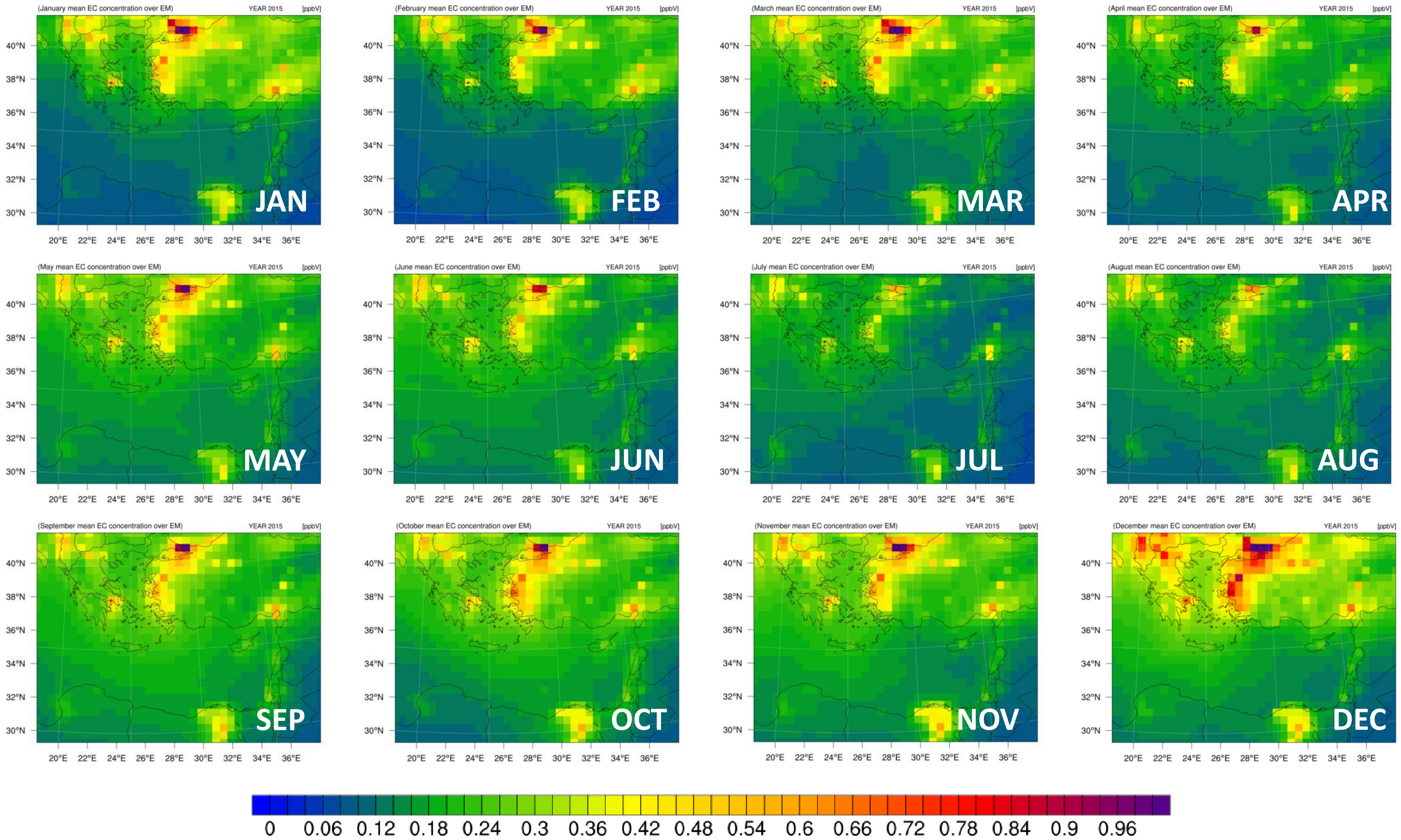
EC Mean Monthly Concentrations



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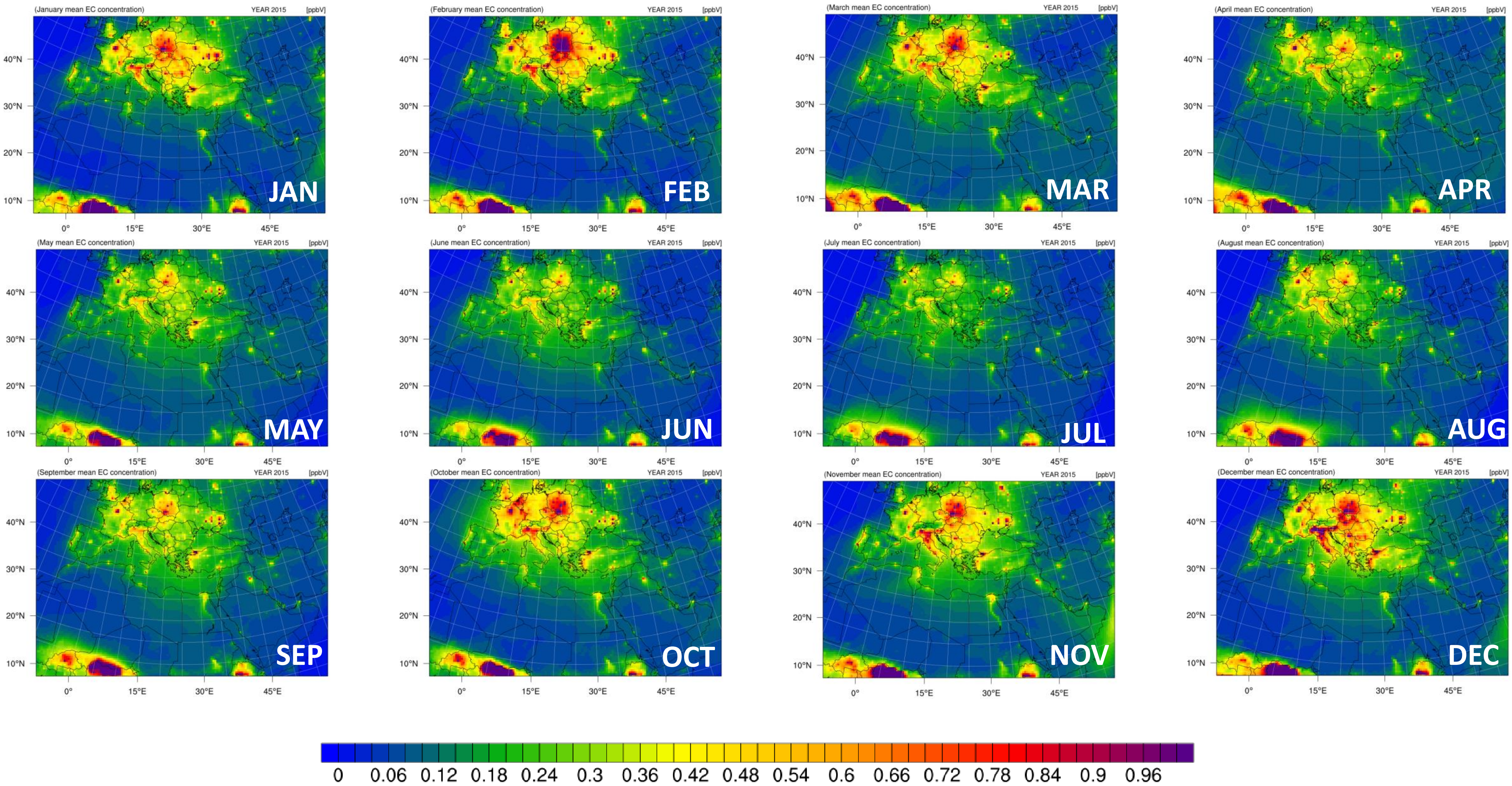
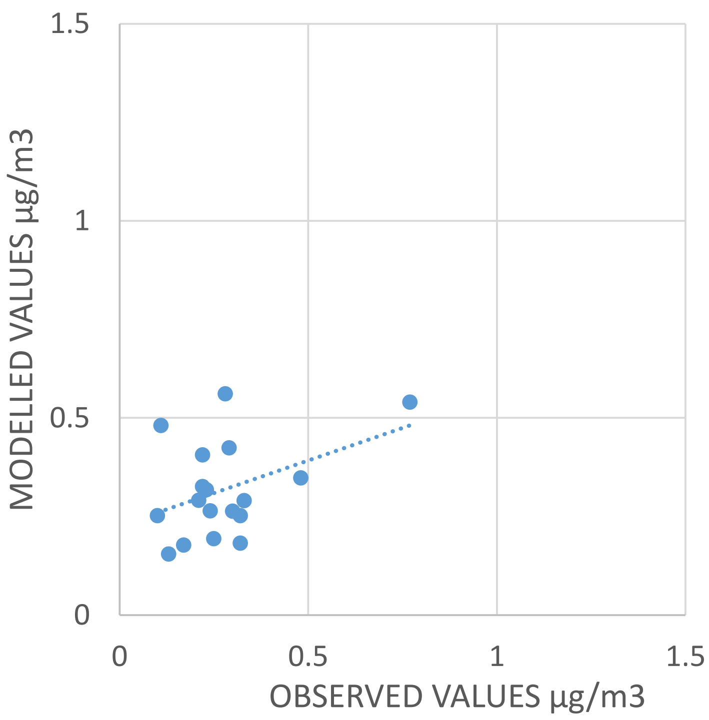
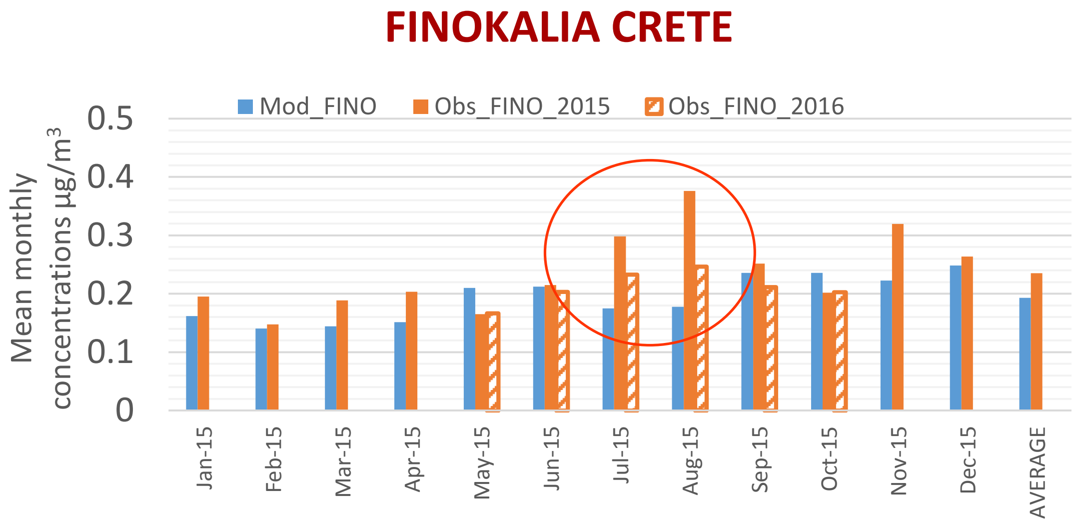
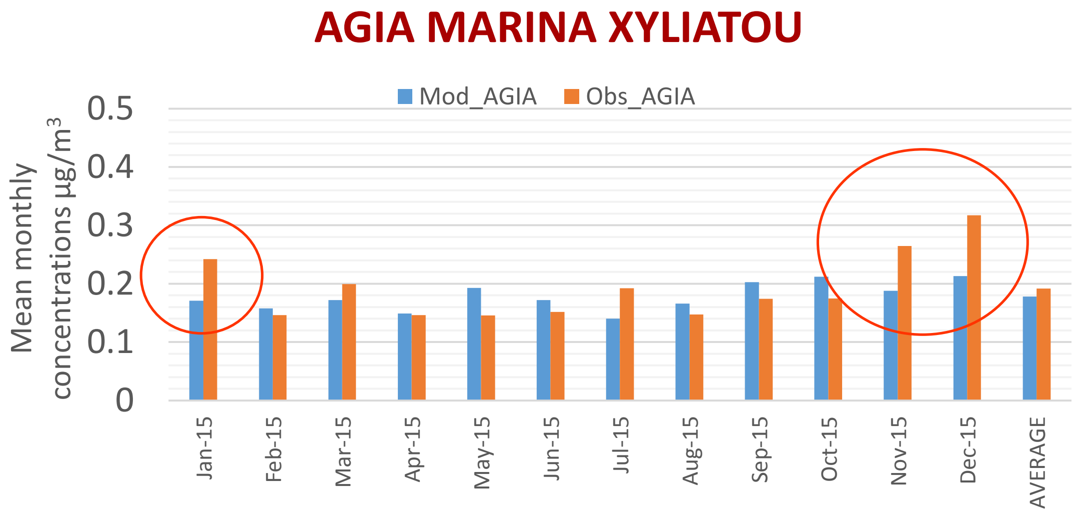
EC Surface concentrations over Europe



Modelled (EC) versus observed EC/BC values







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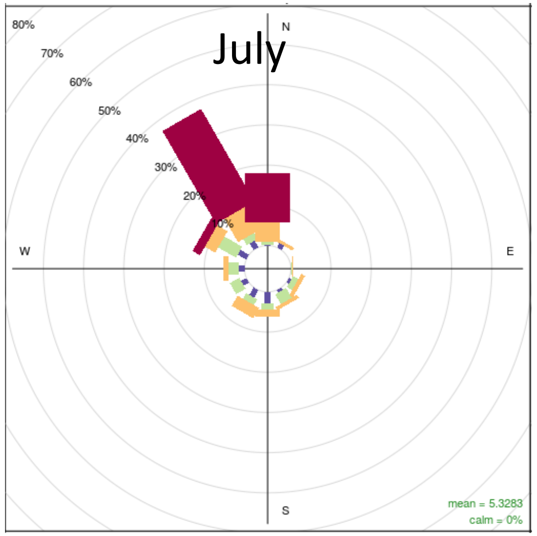
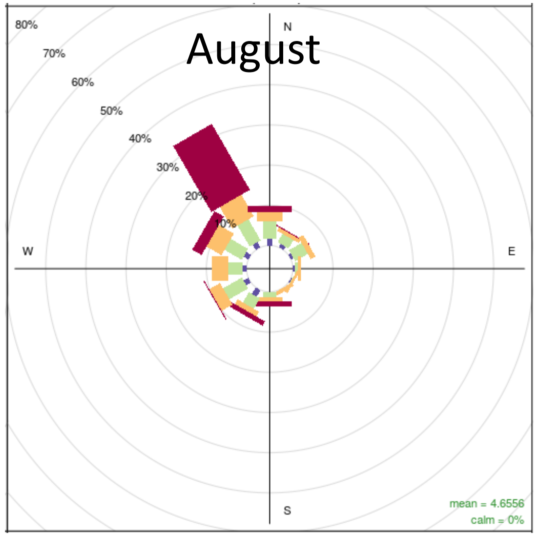
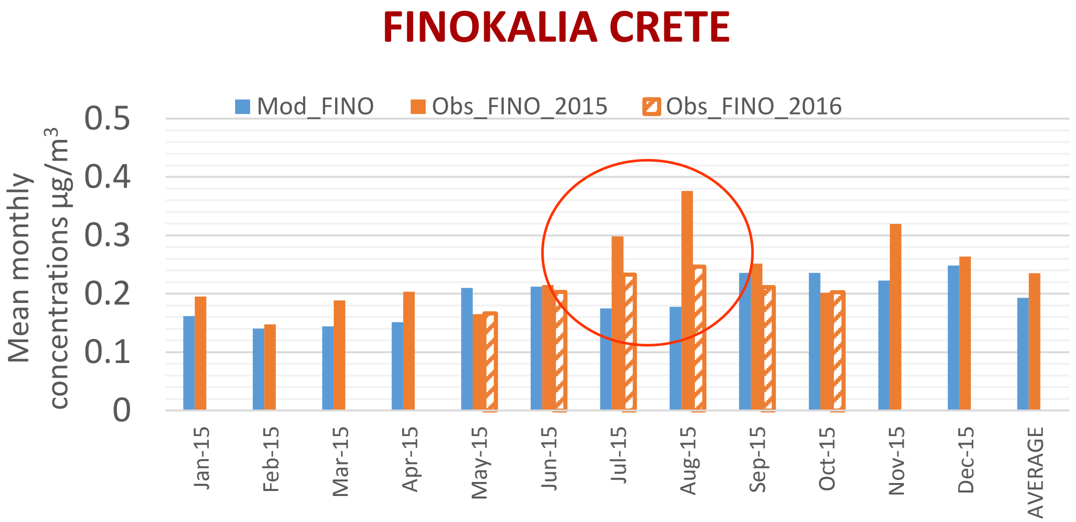
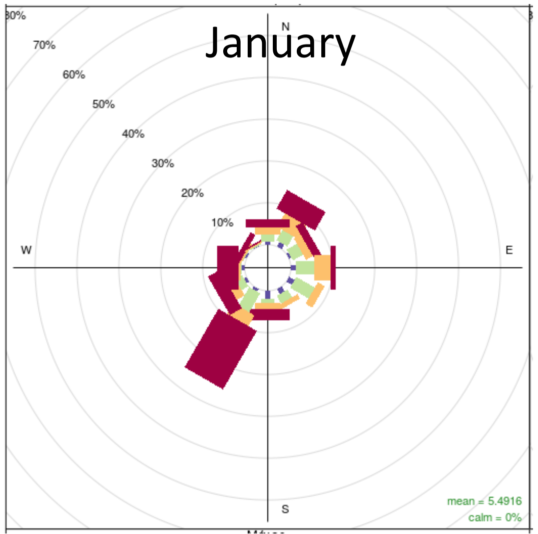
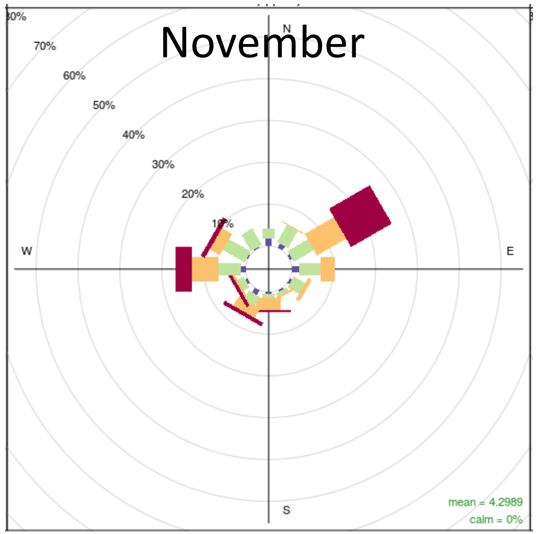
Modelled (EC) versus observed EC/BC values

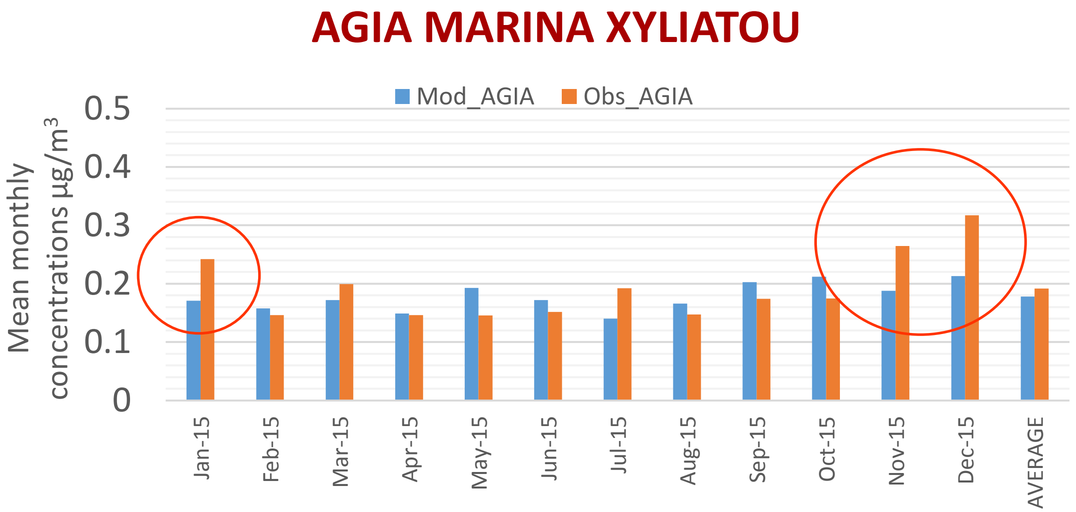












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EC Mean Monthly Columnar Load

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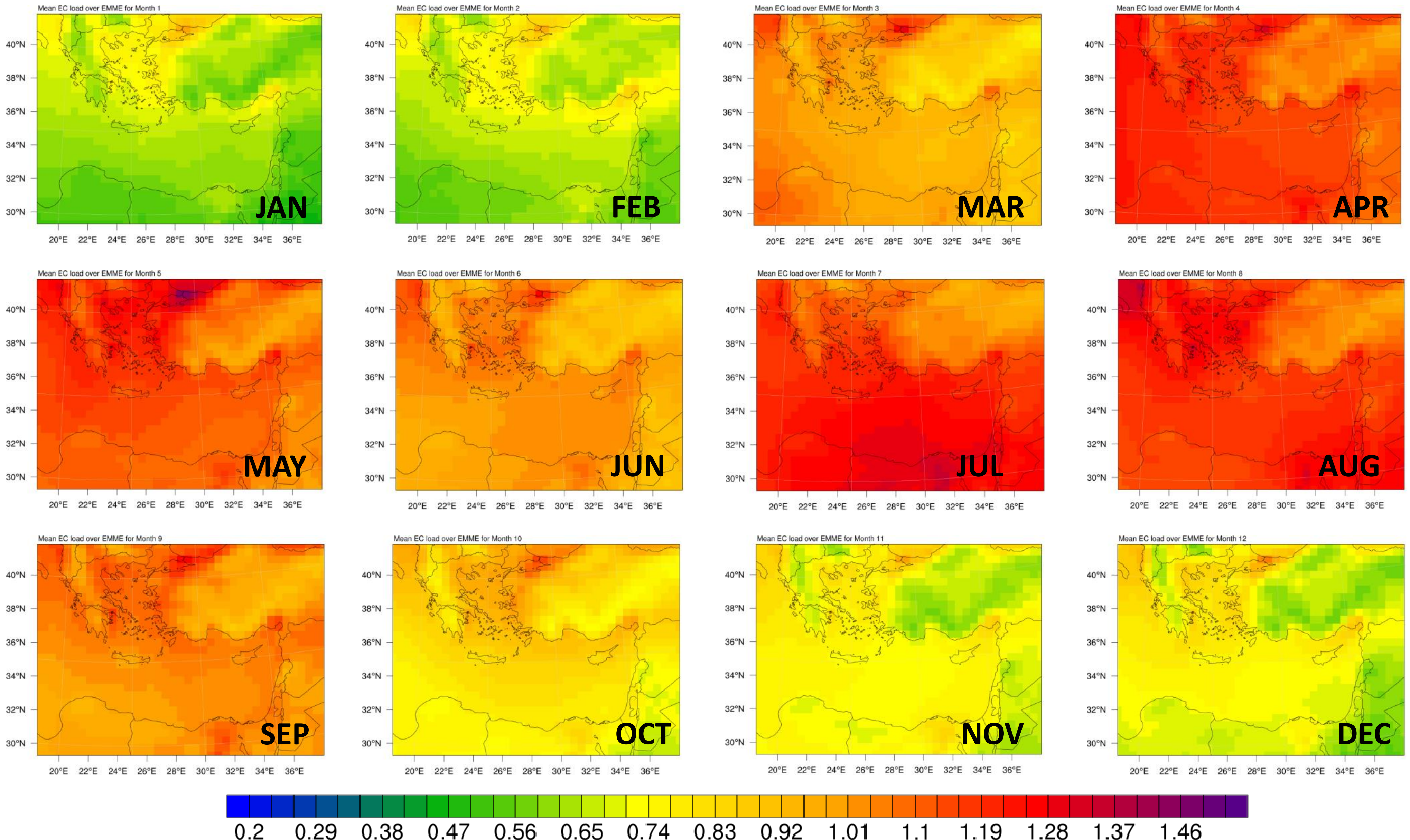

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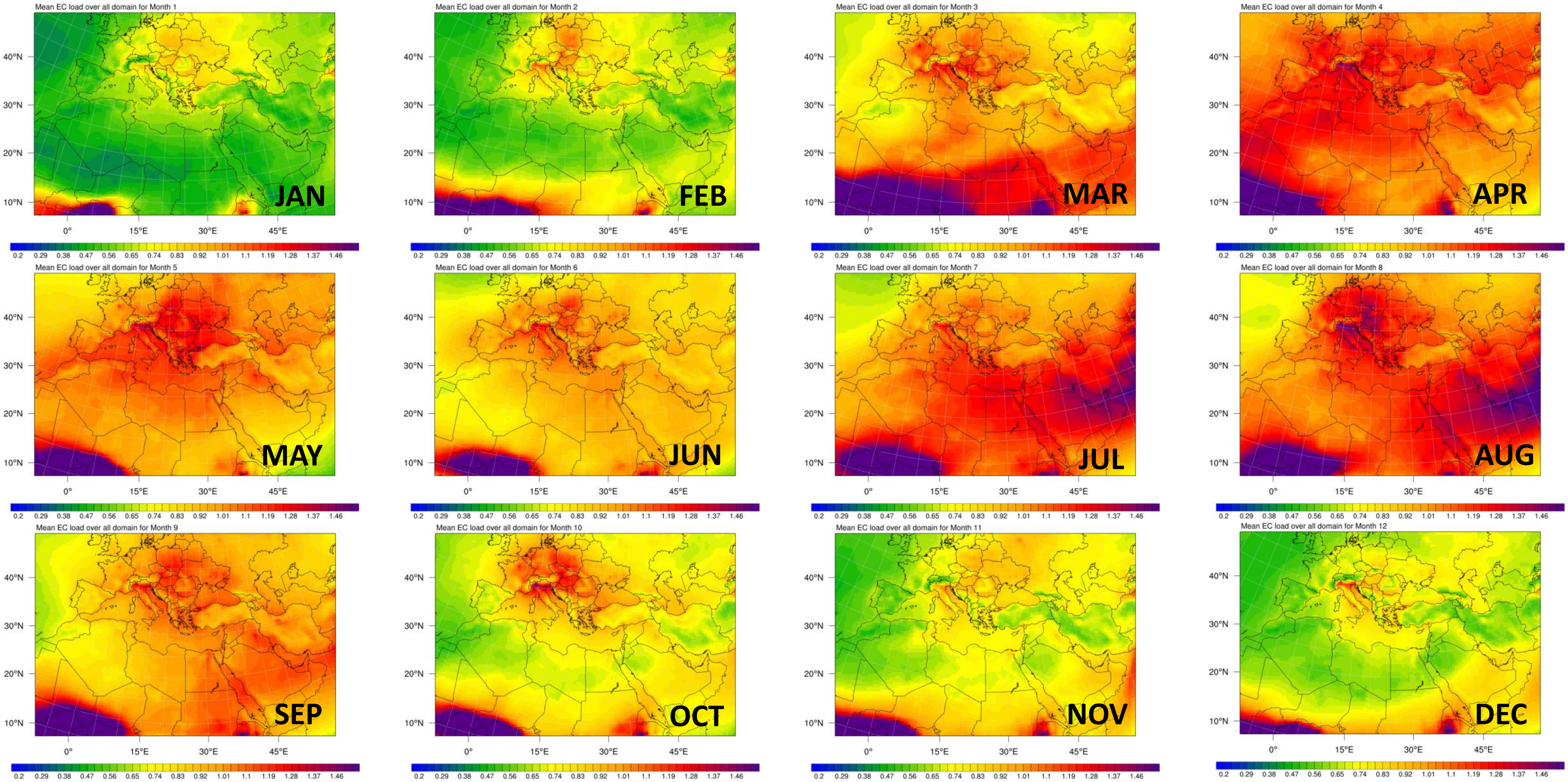
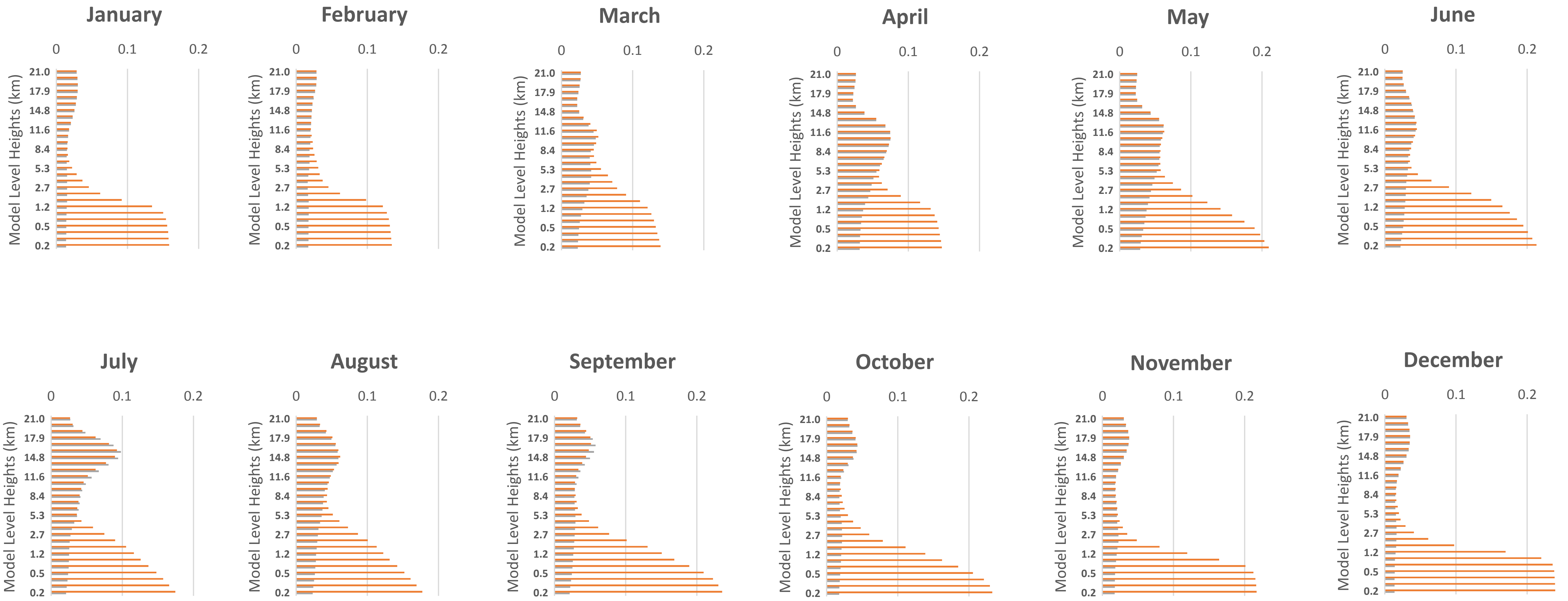
EC Mean Monthly Columnar Load

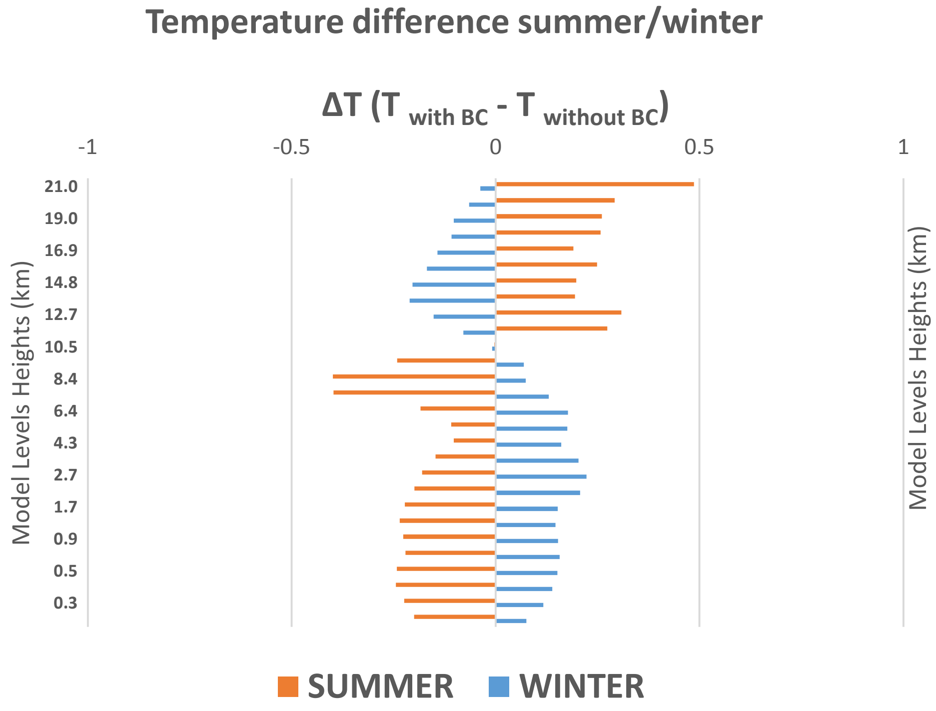
Europe – North Africa – Arabian Peninsula

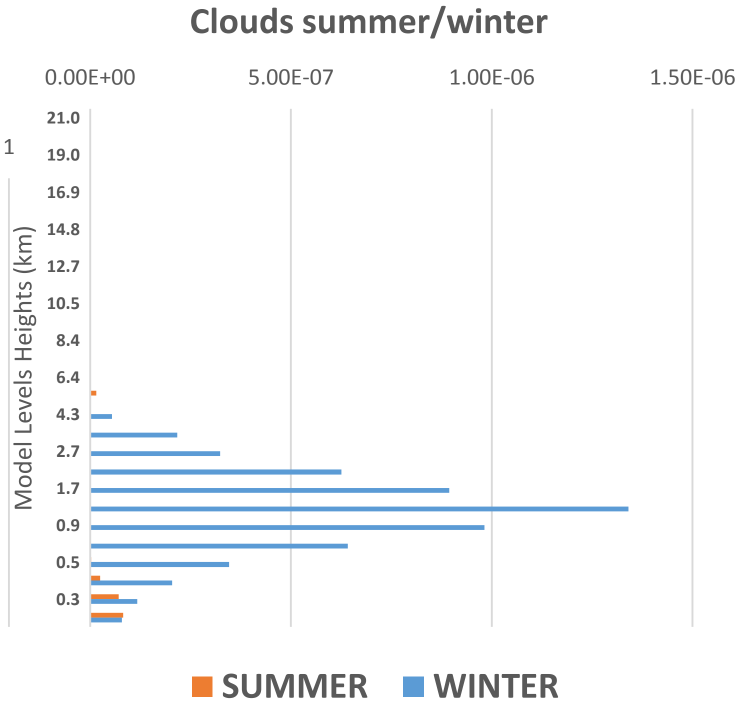


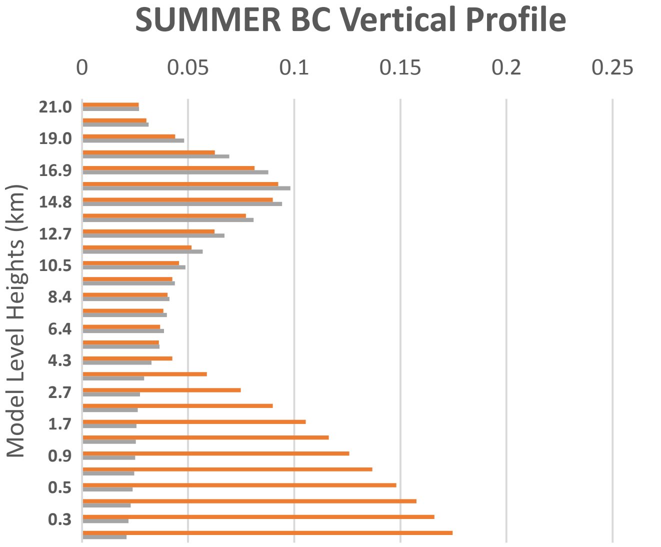
EC vertical profile (concentrations)

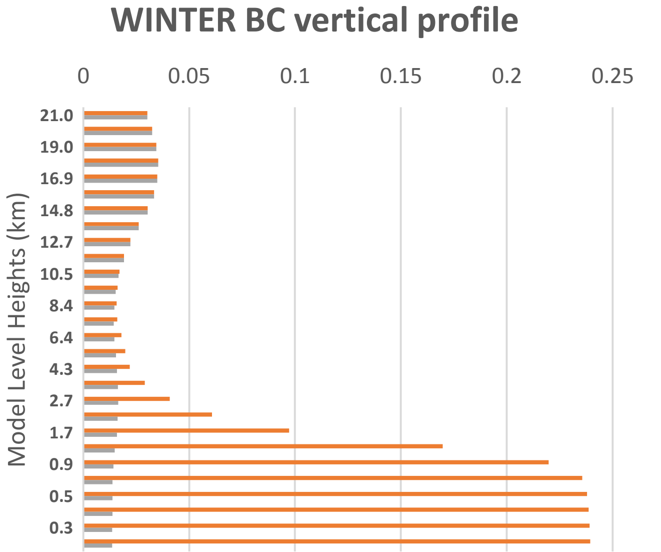


Impact of BC on temperature









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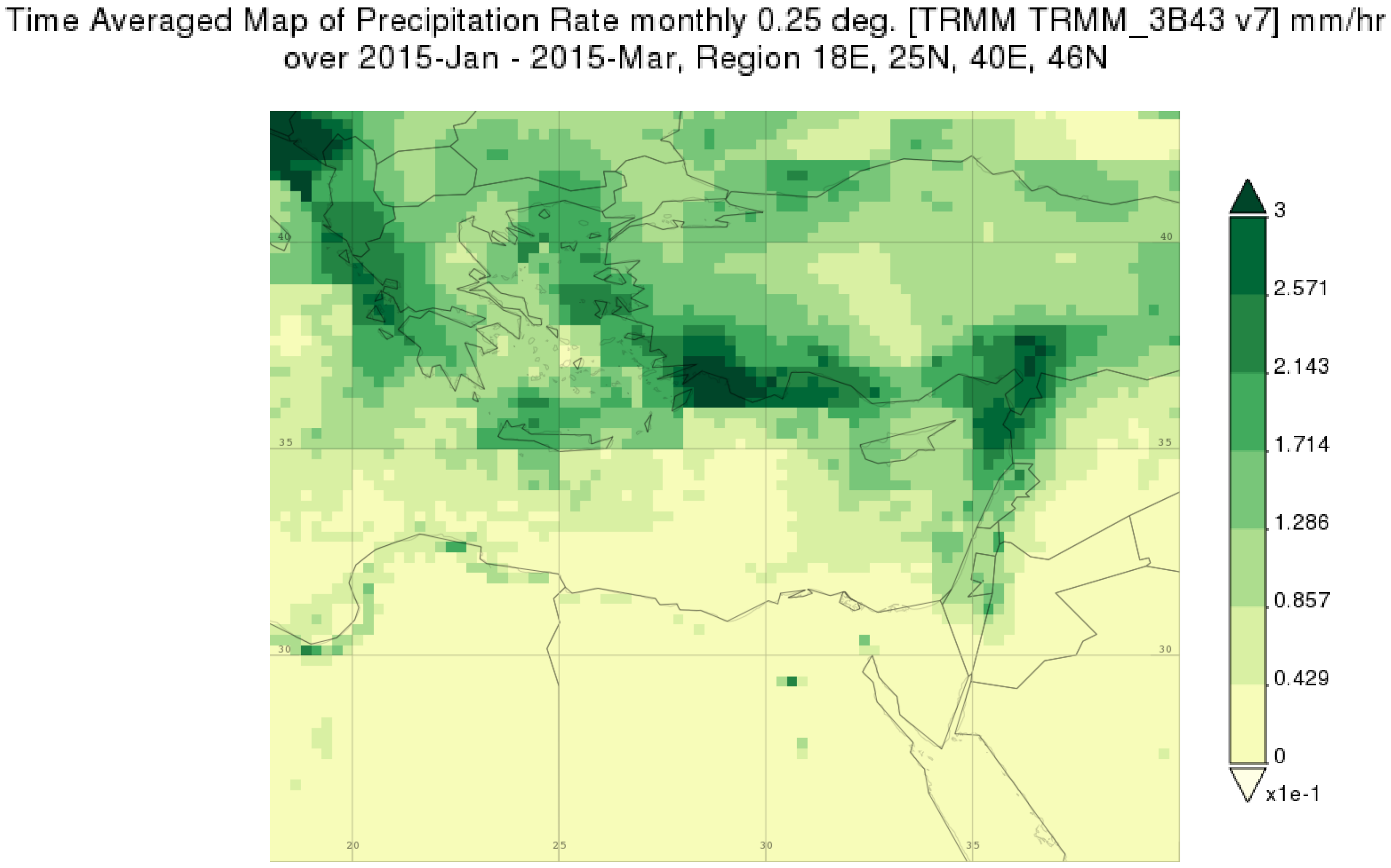
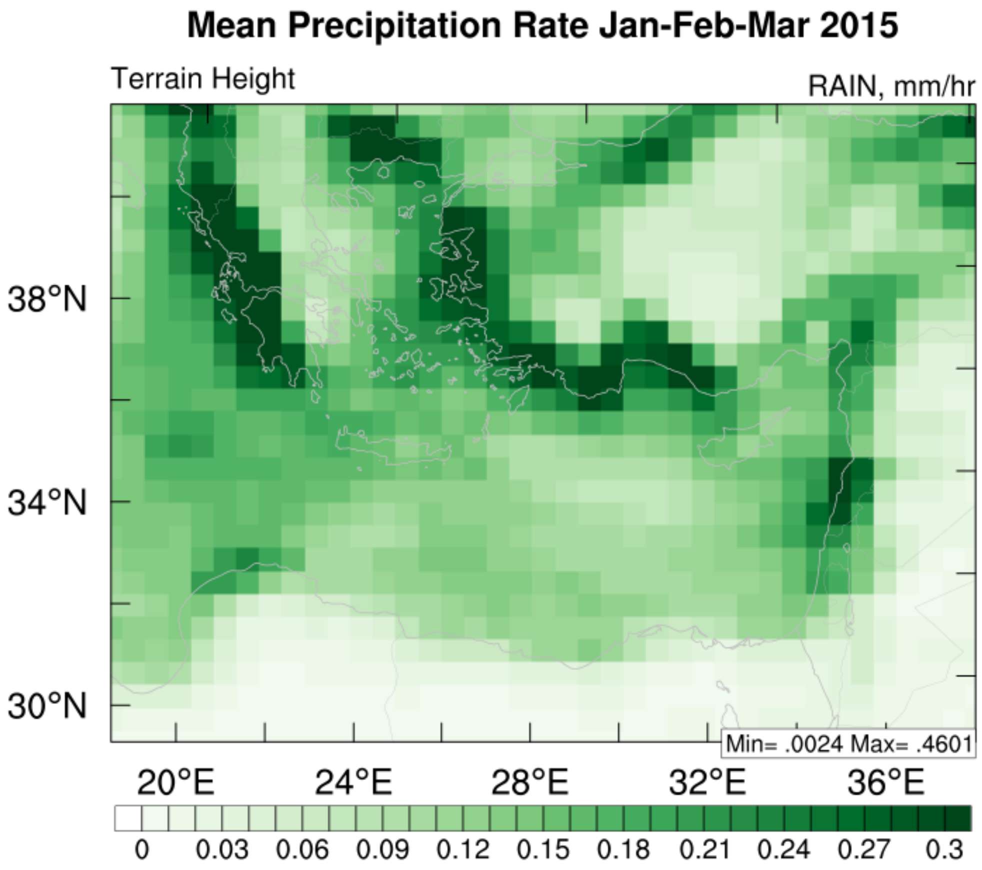
WET SEASON
SATELLITE vs MODEL precipitation rate (mm/hr)





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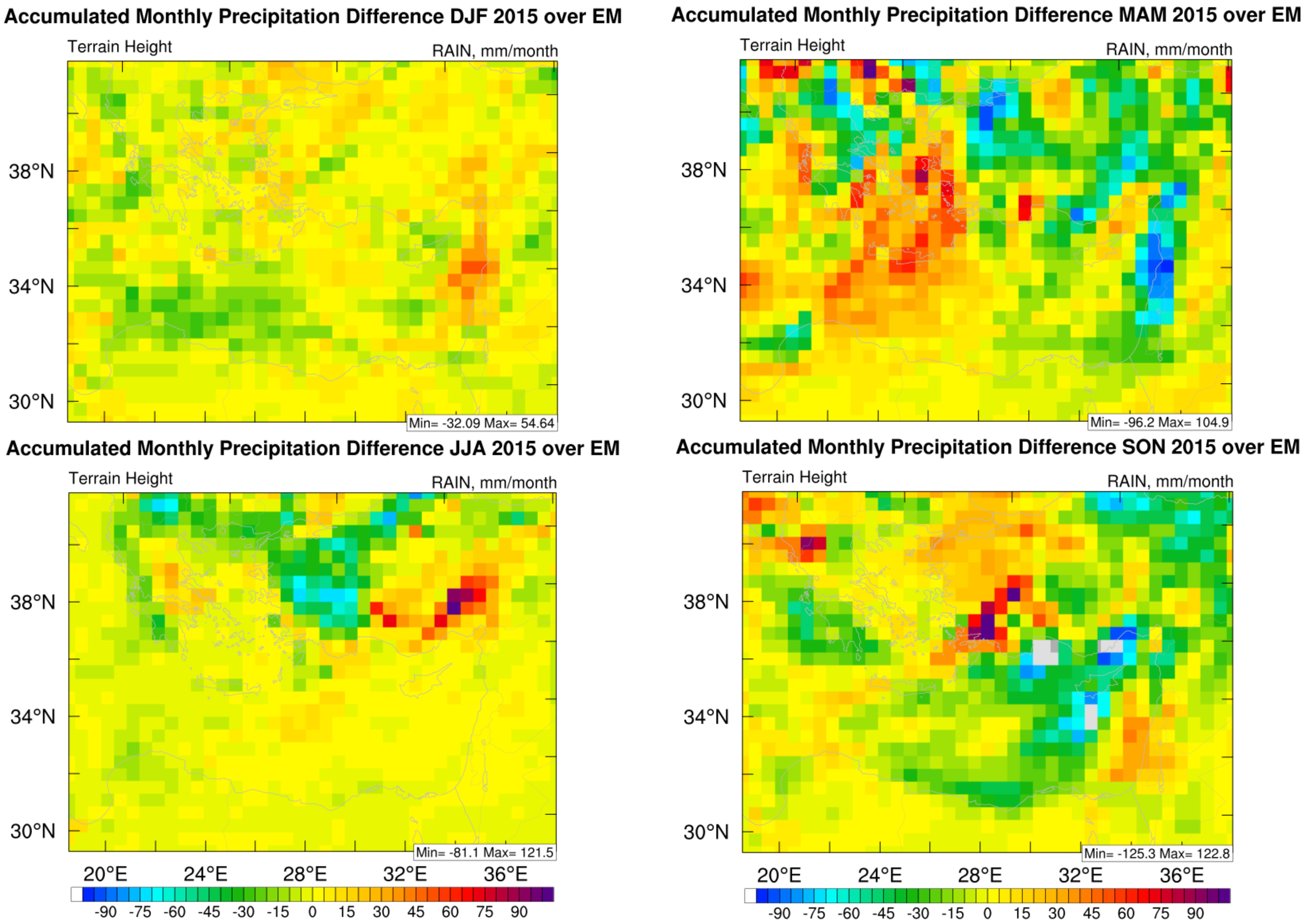
Seasonal Precipitation Difference (mm)



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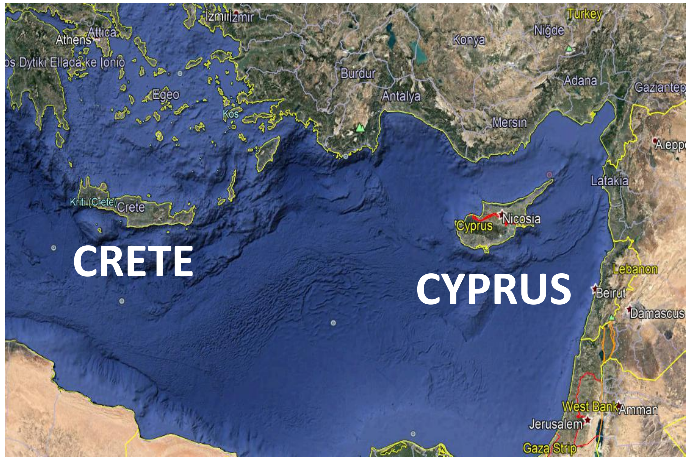
Annual Precipitation Difference



	Total RAIN WITH BC	Total Rain WITHOUT	Cumulus WITH BC	Cumulus WITHOUT	Grid Scale WITH BC	Grid Scale WITHOUT
CRETE	492	448	386	321	106	126
ISRAEL	718	776	614	667	104	106
CYPRUS	529	561	393	430	136	131
ATHENS	382	307	246	207	136	100
ISTANBUL	514	503	136	126	378	378

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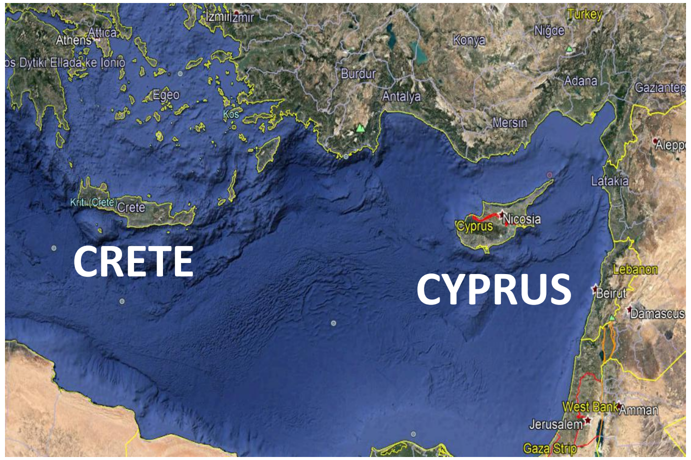
Annual Precipitation Difference



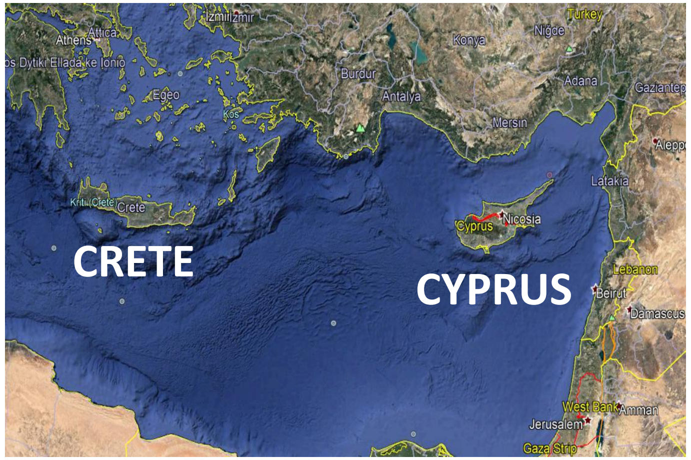
Department of Meteorology

*1960-1990	503
*2000-2010	477

	Total RAIN WITH BC	Total Rain WITHOUT	Cumulus WITH BC	Cumulus WITHOUT	Grid Scale WITH BC	Grid Scale WITHOUT
CRETE	492	448	386	321	106	126
ISRAEL	718	776	614	667	104	106
CYPRUS*	529(-6%)	561	393	430	136	131
ATHENS	382	307	246	207	136	100
ISTANBUL	514	503	136	126	378	378

CY COASTAL	474(-12%)	531	402	432	72(-36%)	99

Annual Precipitation Difference



	Total RAIN WITH BC	Total Rain WITHOUT	Cumulus WITH BC	Cumulus WITHOUT	Grid Scale WITH BC	Grid Scale WITHOUT
CRETE ↑	492 (+9%)	448	386 **+17%**	321	106	126
ISRAEL	718 (-8%)	776	614	667	104	106
CYPRUS ↓	529 (-6%)	561	393 **-10%**	430	136	131
ATHENS	382 (+20%)	307	246	207	136	100
ISTANBUL	514 (2%)	503	136	126	378	378

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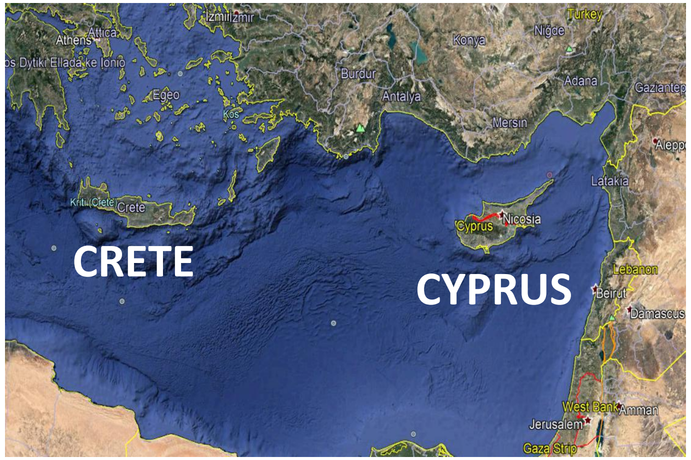
Annual Precipitation Difference



	Total RAIN WITH BC	Total Rain WITHOUT	Cumulus WITH BC	Cumulus WITHOUT	Grid Scale WITH BC	Grid Scale WITHOUT	
CRETE	492	448	386 **+17%**	321	106	126	→ **-19%**
ISRAEL	718	776	614	667	104	106	
CYPRUS	529	561	393	430	136	131	
ATHENS*	382	307	246 **+17%**	207	136	100	→ **+27%**
ISTANBUL	514	503	136	126	378	378	

*1970-2000	389mm

Founda et al. 2016

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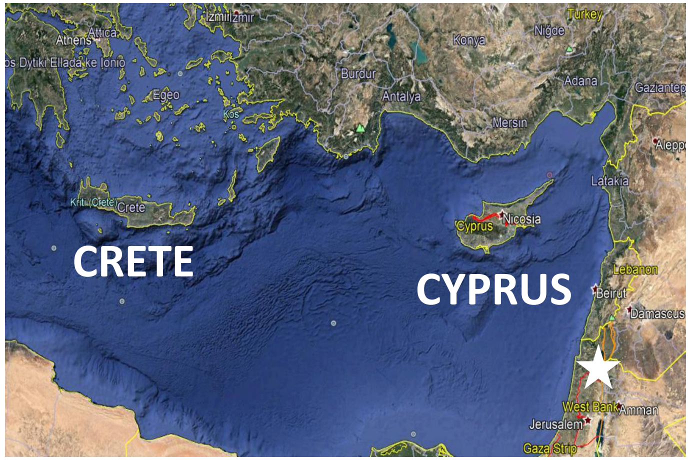
Annual Precipitation Difference



	Total RAIN WITH BC	Total Rain WITHOUT	Cumulus WITH BC	Cumulus WITHOUT	Grid Scale WITH BC	Grid Scale WITHOUT
CRETE	492	448	386	321	106	126
ISRAEL	718	776	614	667	104	106
CYPRUS	529	561	393	430	136	131
ATHENS	382	307	246	207	136	100
ISTANBUL	514	503	136	126	378	378

~0% (ISRAEL)

0% (ISTANBUL)

BC radiative properties
Measurements and model treatment

strong absorption across a wide spectrum of visible wavelengths (wavelength-independent imaginary part k)

R. I. (1.81, 0.79)

…increase of 20–250 % in absorption and a factor of 3–15 in scattering during aging, significantly depending on coating morphology and aging stages…

He et al., 2015

…mass absorption cross section increases by approximately 50% (relative to freshly generated BC) as BC becomes internally mixed with other aerosol chemical component…

Bond et al., 2013

Freshly emitted BC particles are small in diameter and hydrophobic and, therefore, make very poor cloud condensation nuclei. Aging of BC after emission and associated accumulation of soluble mass increases the size and hygroscopicity of the internally mixed BC and enhances its cloud condensation nuclei (CCN) activity (Bond et al., 2013)

Concluding (or opening) remarks

- Elemental carbon can be present at altitudes above 10 km – observational verification of seasonality of inflow from Central Africa and South Asia

- The impact of black carbon on the climate of the EMME region is a combination of the direct effect and alterations in cloud distribution and optical properties with synergetic forcing – global estimates may be over/understatements or of opposite sign

- Impact of BC on temperature and precipitation is determined by the vertical structure of the BC concentrations, proximity to source regions and local features of receptor areas

This work was performed at the Energy, Environment and Water Research Centre at the Cyprus Institute and in close cooperation with national and international governmental and research organizations. Special thanks:

- Department of Labour Inspection for the monitoring data (also responsible for EMEP EC data)
- Department of Meteorology for the meteorological data
- National Observatory of Athens and University of Crete (Mihalopoulos, Nikos; Theodosi, Christina; Kouvarakis, Giorgos responsible for EMEP EC data)