Distribution, optical properties and radiative effect of pollution aerosols in the western Mediterranean basin from TRAQA and SAFMED airborne observations

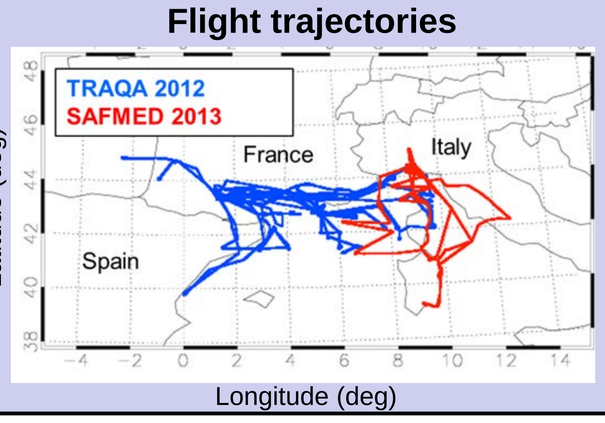
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Campaign overview and measurements: TRAQA (June-July 2012) – SAFMED (July 2013)

Flight trajectories



Research aircraft



Measurements

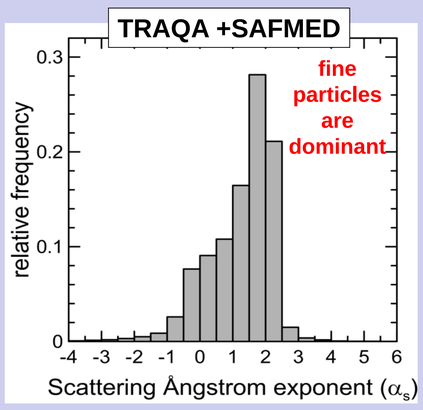


Property measured	Instrument	Particle size range
Aerosol number concentration	CPC	0.004 – 3 µm
Aerosol size distribution	PCASP	0.1 – 3.0 µm
	SkyGRIMM	0.3 – 32 µm
Aerosol scattering coefficient σ_s (450-700 nm)	Nephelometer	<12 µm
Aerosol absorption coefficient σ_a (370-950 nm)	Aethalometer	<12 µm
O_3 and CO mixing ratio	MOZART	-

Spatial and vertical distribution of pollution aerosols in the western Mediterranean

Elevated levels of background pollution throughout the western basin

- Pollution aerosol layers measured up to a distance of ~250 km from the coastline
- Aerosol layers are distributed ubiquitously
- The aerosol concentrations are comparable to those measured in continental urban areas

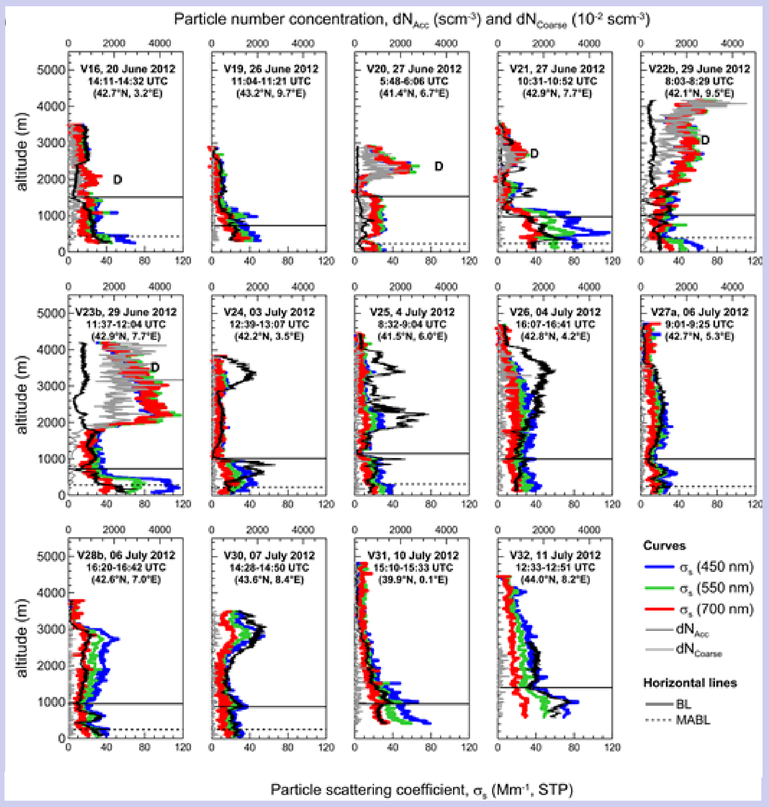


Atmospheric layer	Parameter	TRAQA/SAFMED	Literature over continental Europe
Free troposphere (FT)	dN_{Aitken} (scm^{-3})	0-19250	0-9149
	dN_{Acc} (scm^{-3})	34-3233	0-500
Boundary layer (BL)	dN_{Aitken} (scm^{-3})	4-22471	0-31370
	dN_{Acc} (scm^{-3})	90-3215	0-2000

dN_{Aitken} (0.004-0.1 µm) dN_{Acc} (0.1-1.0 µm)

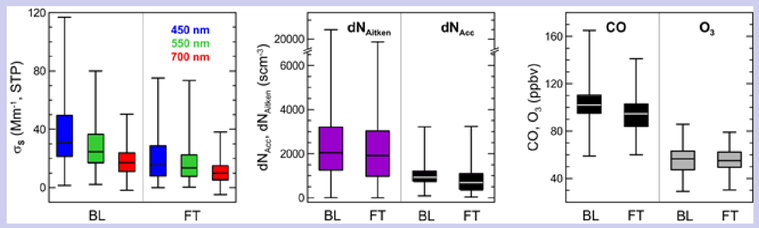
Extension of pollution plumes from the boundary layer to the free troposphere

- Pollution aerosols reach 3000-4000 m in altitude
- Very complex and highly stratified structure



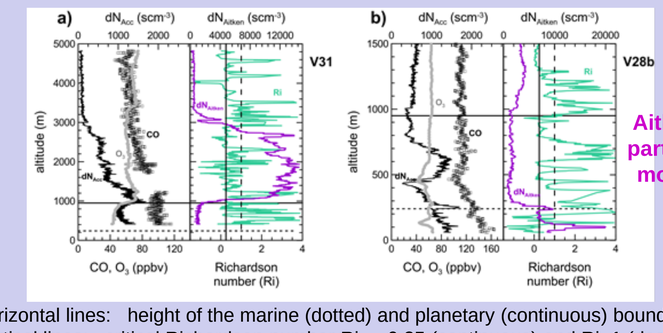
Variability of pollution plume composition indicating diverse air mass sources, histories, and aging times

- Large variability of measured aerosol scattering coefficient and concentration and O_3 & CO plume content



BL= boundary layer FT= free troposphere

- Contribution of ultrafine particles at all altitudes
- These are due to continental or ship emissions, as well as new particle formation (NPF) events

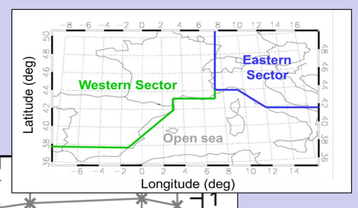


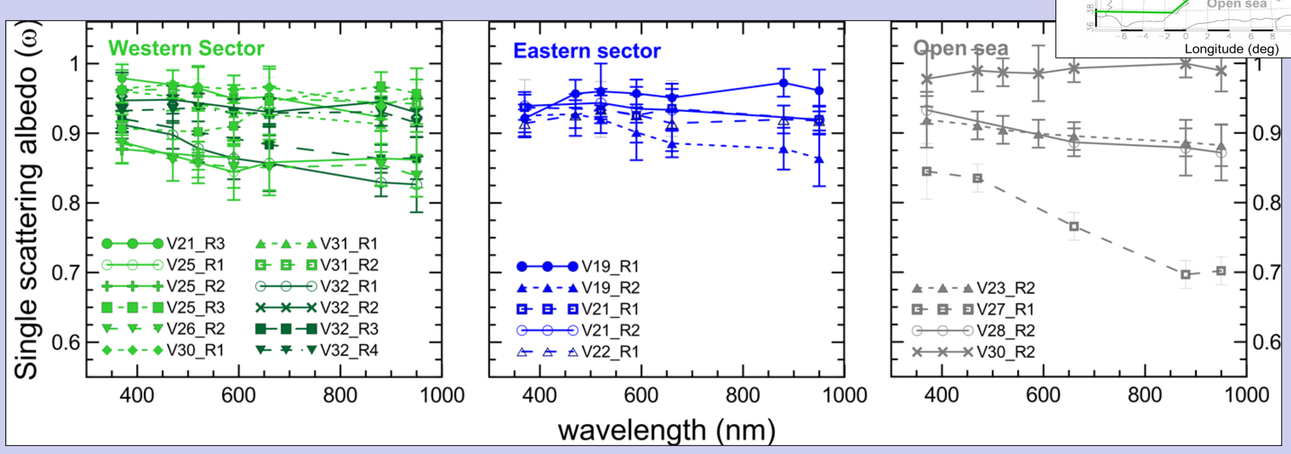
horizontal lines: height of the marine (dotted) and planetary (continuous) boundary layer
vertical lines: critical Richardson number Ri_{crit}=0.25 (continuous) and Ri=1 (dashed)
(Ri<Ri_{crit} indicates favorable conditions for the development of turbulence)

Optical properties and direct radiative effect of pollution aerosols in the western Mediterranean

Large variability of the pollution aerosol single scattering albedo (SSA)

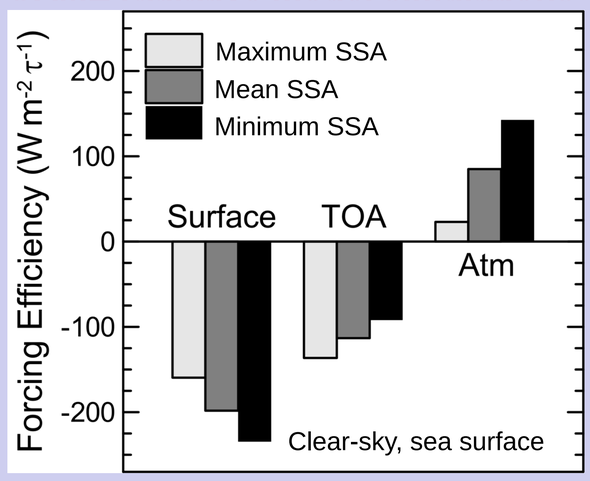
- The SSA varies in the range 0.84-0.98 at 370 nm and 0.70-0.99 at 950 nm
- This variability seems to be independent of the source region, altitude and aging time of the plumes





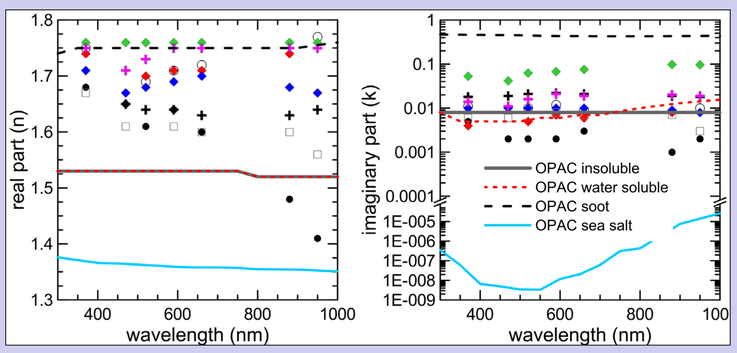
The pollution aerosol shortwave forcing efficiency strongly varies due to the SSA variability

GAME radiative model simulations



Spectral range	0.28-3.0 µm
Solar zenith angle	60°
Albedo of the sea surface	0.009 (0.448 µm) – 0.005 (2.13 µm)
Aerosol optical depth	0.20 (0.55 µm)
Aerosol Ångström exponent	1.5
Aerosol asymmetry factor	0.60 (0.33 µm) – 0.51 (1.5 µm)
Aerosol Single Scattering Albedo (SSA)	
Max	0.98 (330 nm) – 0.99 (1500 nm)
Mean	0.93 (330 nm) – 0.89 (1500 nm)
Min	0.88 (330 nm) – 0.80 (1500 nm)

The SSA variability reflects in a large variability for the complex refractive index for pollution aerosols



Range of variability of the refractive index for pollution aerosols. Data are compared to the refractive indices for single aerosol constituents (OPAC dataset)

The refractive index is obtained by optical closure by combining optical and size aerosol data.

References : Di Biagio, C., et al. (2015), Atmos. Chem. Phys., doi:10.5194/acp-15-9611-2015; Di Biagio, C., et al. (2015), Atmos. Chem. Phys., doi:10.5194/acp-16-10591-2016

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