9th International Conference on Air Quality – Science and Application 2014

Satellite based mapping of Particulate Matter

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DLR

Motivation

Environmental Agencies have the duty to monitor particulate matter

EU directive 2008/50/EC:

per station and year only 35 days allowed
with an exceedance over 50 µg/m3 in daily mean PM10

annual mean of PM10 must not exceed 40 µg/m3

Continuous measurements of particulate matter conducted by regional authorities

disadvantages:

- no comprehensive information
- no discrimination of aerosol compounds (anthropogenic, natural)

➢ Satellite based mapping of particulate matter as complementary monitoring product

Content

- satellite retrieval of aerosols
- AOD-PM conversion
- MODIS col. 6 results
- SYNAER results
- Summary

Satellite retrieval of aerosols

- Polar orbiting satellite

~3 orbits overpass Europe per day

- Radiometer measurements in VIS, NIR and SWIR
- Cloud correction
- Knowledge about contribution of surface reflectance
- LUT approach to get AOD

- SYNAER uses addionally onboard spectrometer measurements identifying aerosol type

Satellite retrieval of aerosols

- Polar orbiting satellite

~3 orbits overpass Europe per day

- Radiometer measurements in VIS, NIR and SWIR (~1km resol)
- Cloud correction
- Knowledge about contribution of surface reflectance
- LUT approach to get AOD

- SYNAER uses addionally onboard spectrometer measurements identifying aerosol type (40x80km resol for MetOp GOME-2)

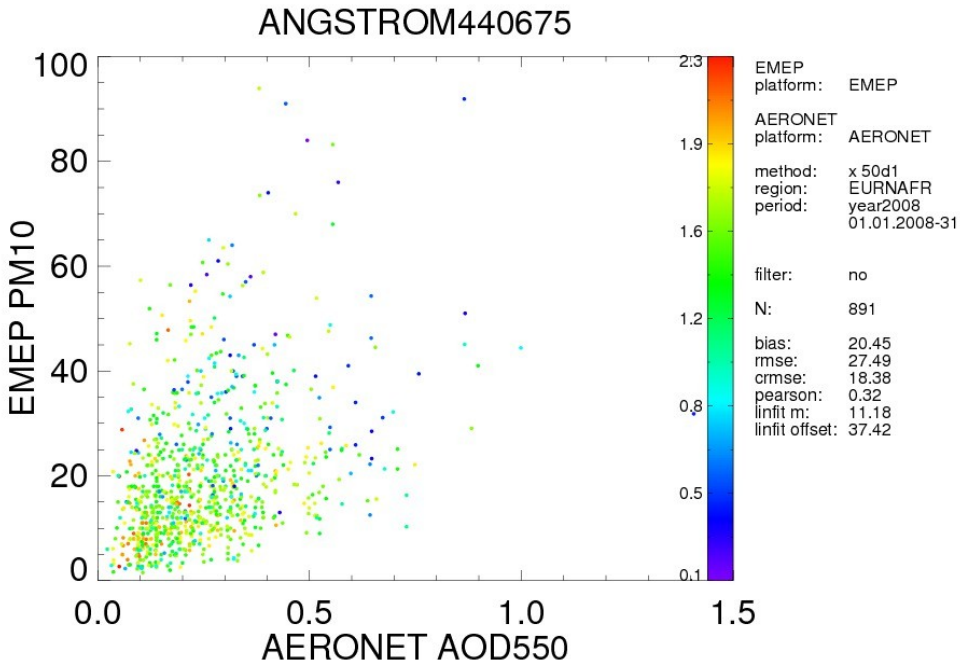
AOD-PM conversion

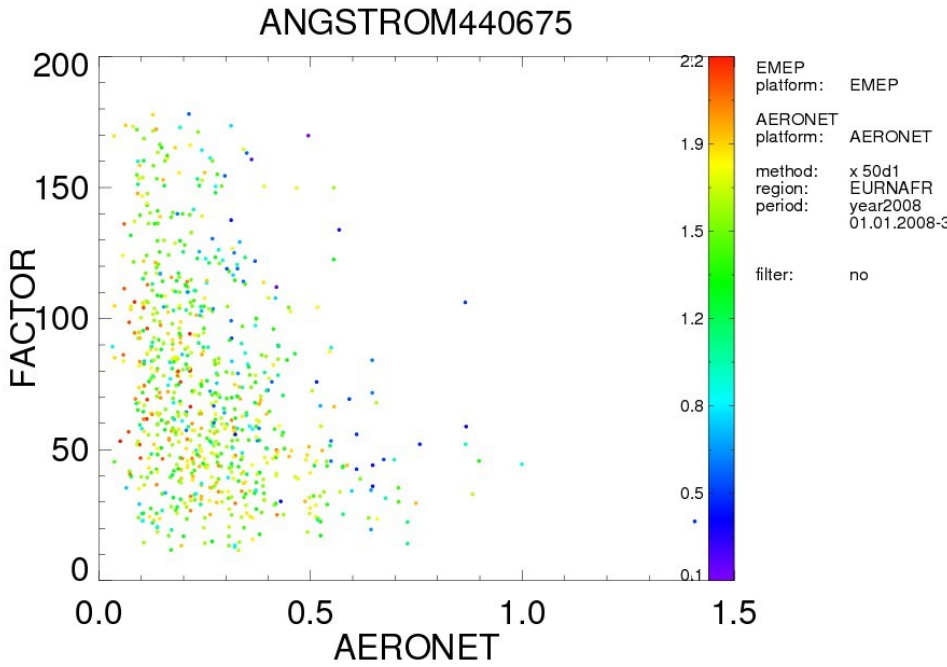
Mostly linear relationship used

$$PMX_{ground} = A \bullet AOD_{satellite}$$

Factor A retrieved by regional fit with groundbased data

AOD-PM conversion





aerosol components

Component	Species	Complex refract. Index at 550 nm	Mode radius [μm]	Stand. Dev. of size distribution	Particle density [g/cm^3]	Extinction coefficient for 1 particle per cm^3 at 550 nm [km^{-1}]	Single scattering albedo at 550 nm	Literature source
WASO, RH=70%	Sulfate/ nitrate	1.53–0.0055 i	0.028	2.24	1.33	7.9 e-6	0.981	Hess et al., 1998
INSO	Mineral dust, high hematite content	1.53–0.008 i	0.471	2.51	2.0	8.5 e-3	0.73	Hess et al., 1998
INSL	*Mineral dust, low hematite content*	*1.53–0.0019 i*	*0.471*	*2.51*	*2.0*	*8.5 e-3*	*0.891*	*Dubovik et al., 2002*
SSAM, RH=70%	Sea salt, accumulation mode	1.49–0 i	0.378	2.03	1.2	3.14 e-3	1.0	Hess et al., 1998
SSCM, RH=70%	Sea salt, coarse mode	1.49–0 i	3.17	2.03	1.2	1.8 e-1	1.0	Hess et al., 1998
BISO	*Biomass burning soot*	*1.63–0.036 i*	*0.0118*	*2.0*	*1.0*	*1.5 e-7*	*0.698*	*Dubovik et al., 2002*
DISO	*Diesel soot*	*1.49–0.67 i*	*0.0118*	*2.0*	*1.0*	*7.8 e-7*	*0.125*	*Schnaiter et al., 2003*
MITR	Transported minerals, high hematite content	1.53–0.0055 i	0.5	2.2	2.6	5.86 e-3	0.837	Hess et al., 1998
MILO	*Transported minerals, low hematite content*	*1.53–0.0019 i*	*0.5*	*2.2*	*2.6*	*5.86 e-3*	*0.93*	*Dubovik et al., 2002*

AOD-PM conversion

Knowledge of Aerosol Mixture

- optical properties: extinction α
- microphysical properties: number distribution (r_g, σ_g), density ϱ, mixture of components

Assumption

- vertical well mixed within boundary layer (H)

$$A = f(r_g, \sigma_g, \varrho, \alpha, H)$$

$$PMX_{ground} = A \bullet AOD_{satellite}$$

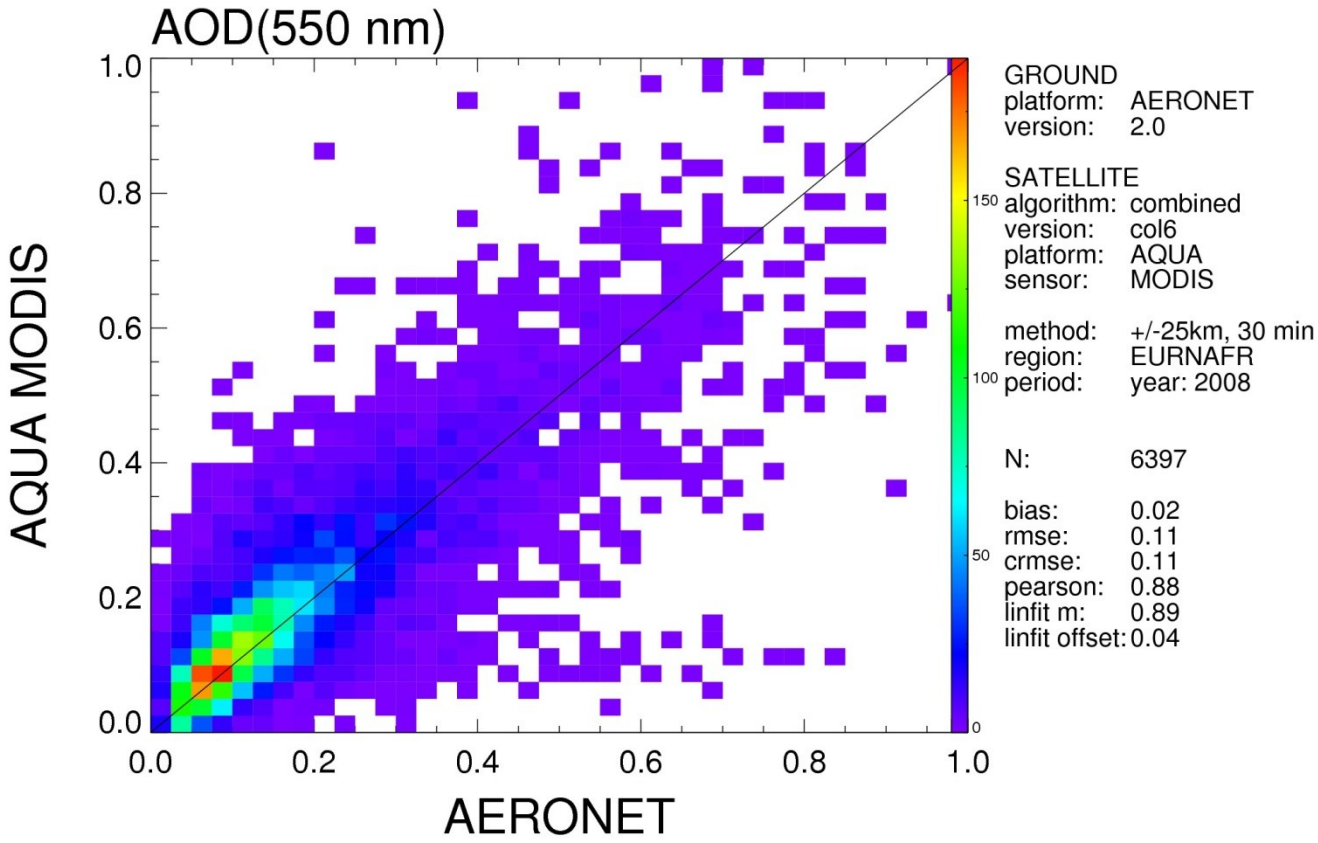
AOD-PM conversion

Mapping for PM 2.5 and PM 10 on annual basis

Counting for

- Missing data due to clouds
- Retrieval results based on limited dark fields
- Relatively big pixel size

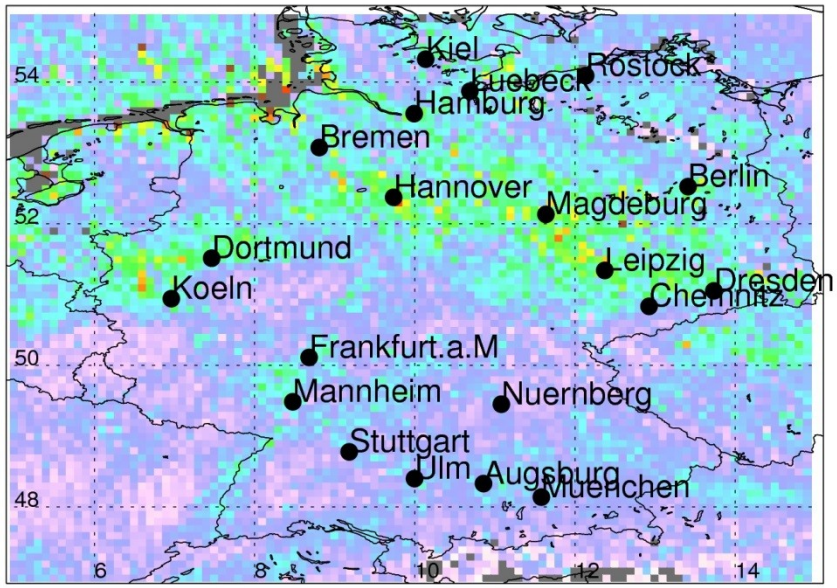
Example: MODIS col. 6



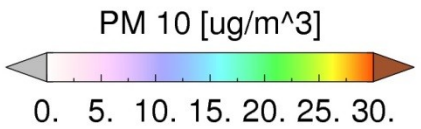
MODIS/AQUA
PM 10

year 2008
Germany

Mix 1
pure water soluble
factor: 83.1



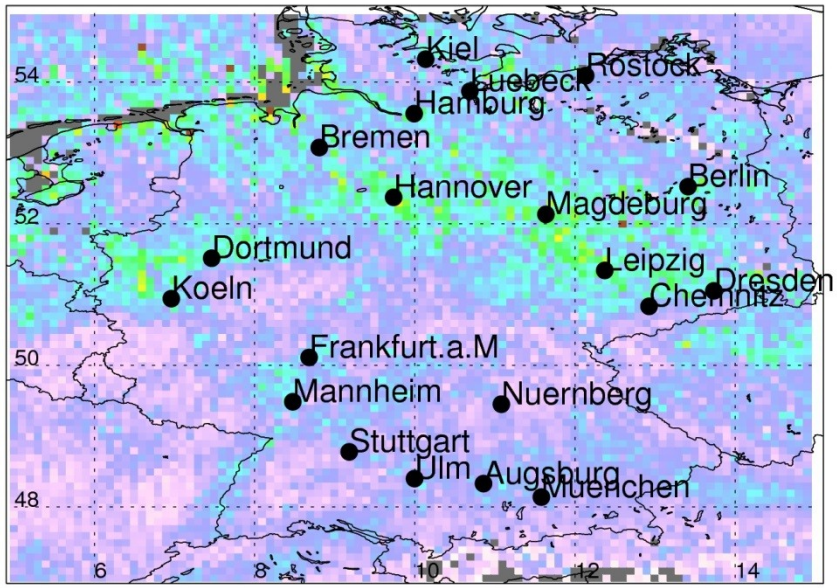
col.6, combined
grid 0.10



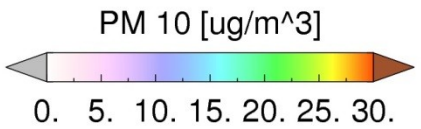
MODIS/AQUA
PM 10

year 2008
Germany

Mix 10
polluted water soluble
factor: 74.1



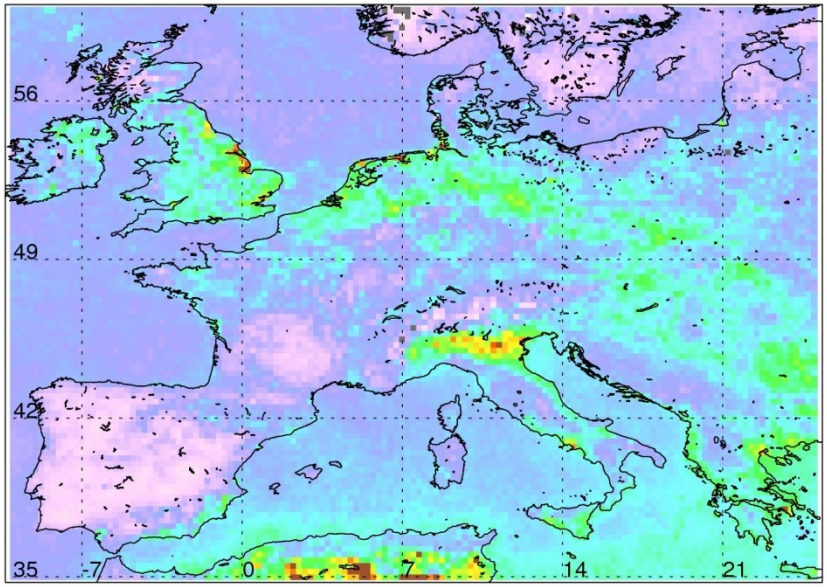
col.6, combined
grid 0.10



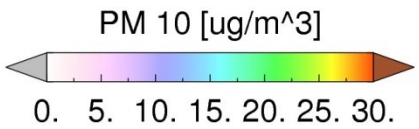
MODIS/AQUA
PM 10

year 2008
europe

Mix 1
pure water soluble
factor: 83.1



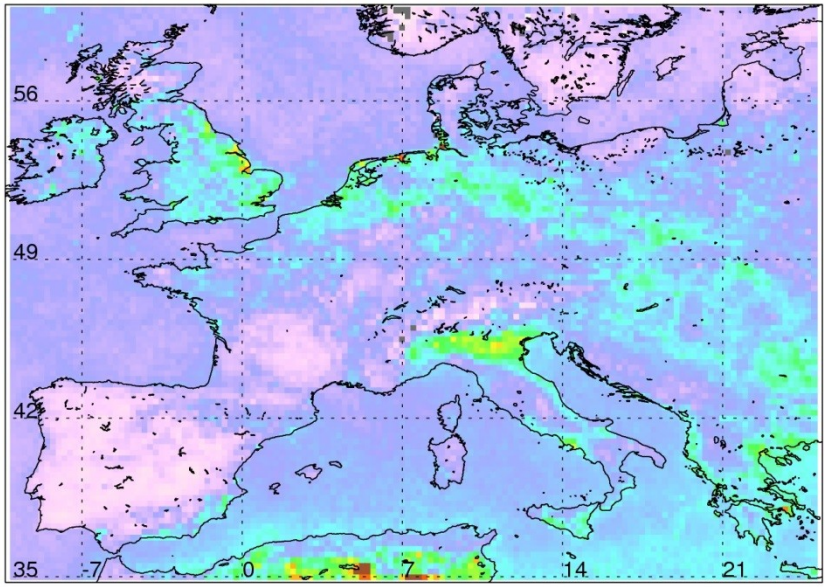
col.6, combined
grid 0.25



MODIS/AQUA
PM 10

year 2008
europe

Mix 10
polluted water soluble
factor: 74.1



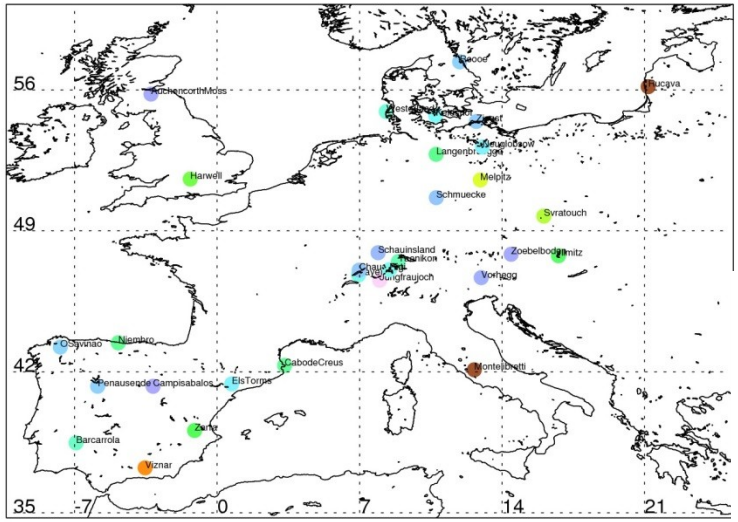
col.6, combined
grid 0.25

PM 10 [ug/m^3]

0. 5. 10. 15. 20. 25. 30.

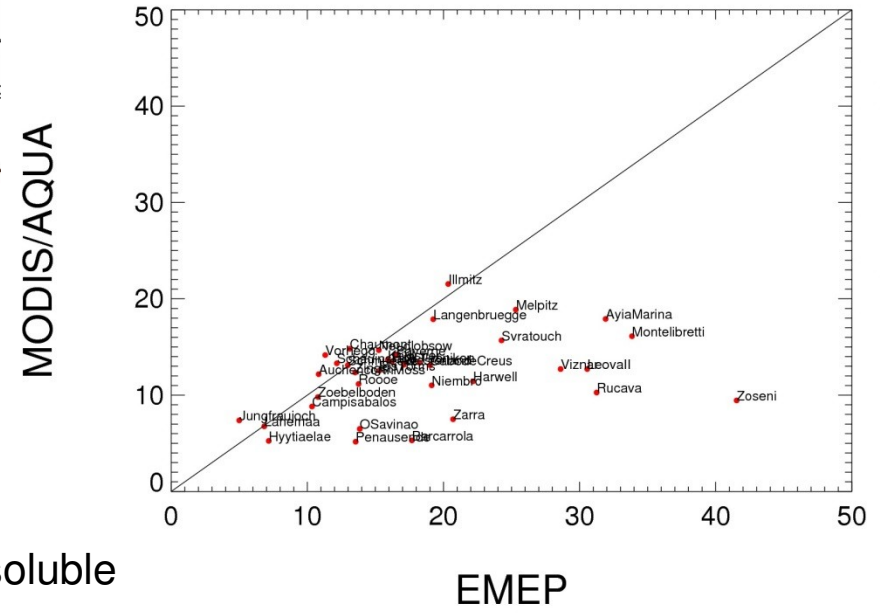
EMEP
PM 10

year 2008
europe



PM 10 [ug/m^3]

year 2008
mean



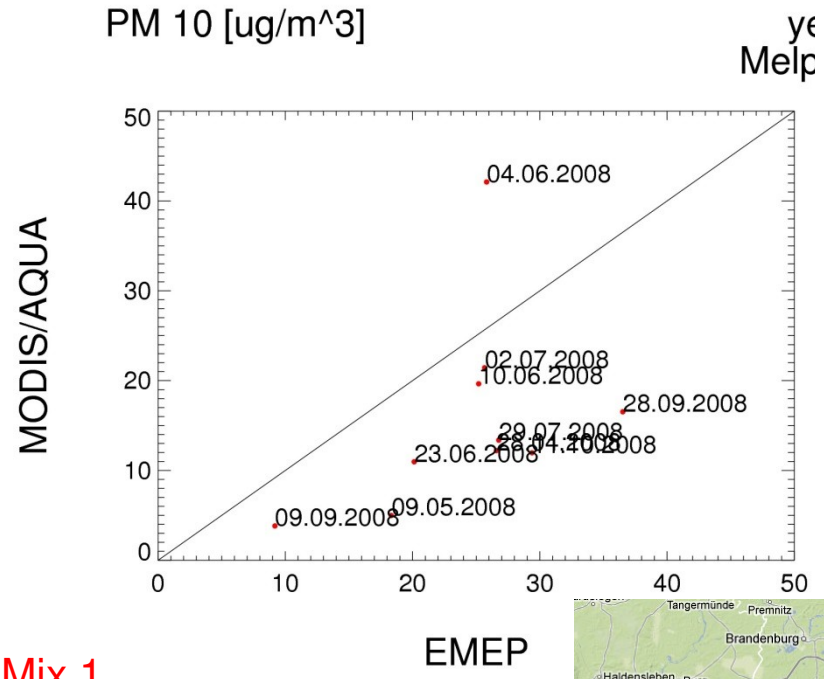
SATELLITE
platform: AQUA
sensor: MODI
version: col.6
algorithm: combi

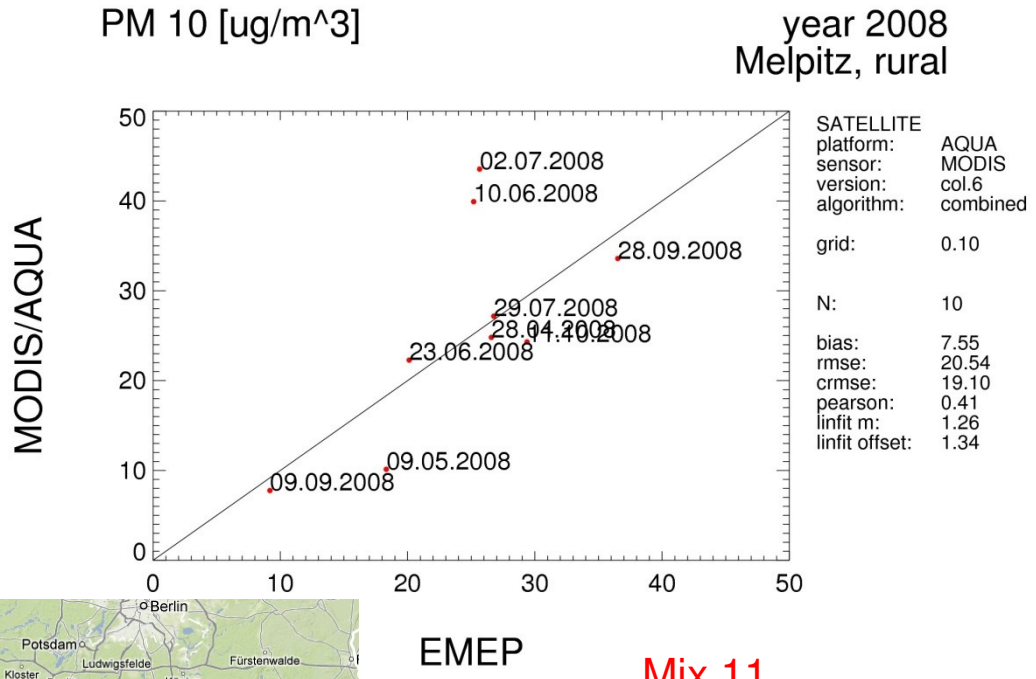
grid: 0.25

N: 36

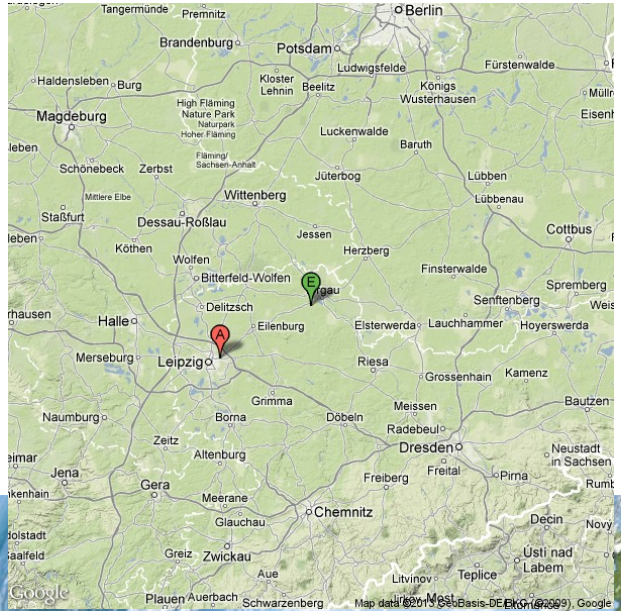
bias: -6.06
rmse: 9.77
crmse: 7.67
pearson: 0.35
linfit m: 0.17
linfit offset: 9.10

Mix 1
pure water soluble
factor: 83.1



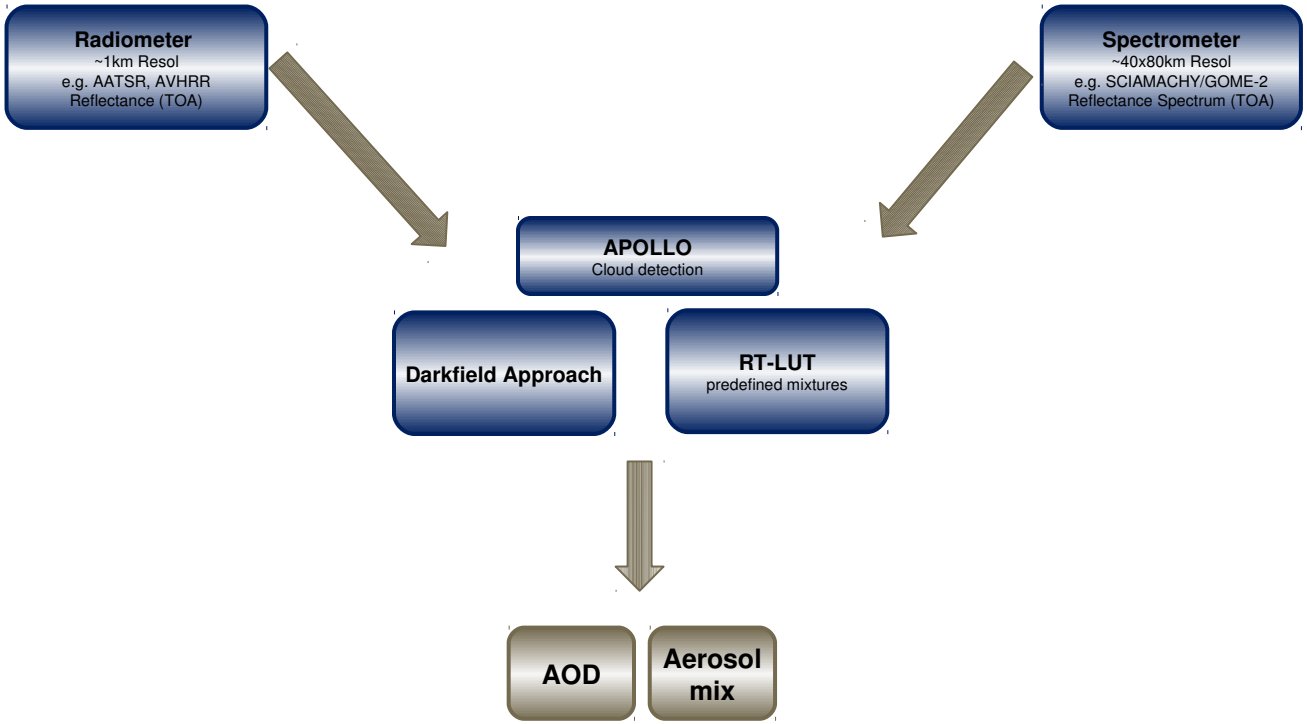


Mix 1
pure water soluble
factor: 83.1



Mix 11
polluted continental
factor: 170

Aerosol Retrieval SYNAER



AOD-PM conversion

Knowledge of Aerosol Mixture

- optical properties: extinction α
- microphysical properties: number distribution (r_g, σ_g), density ϱ, mixture of components

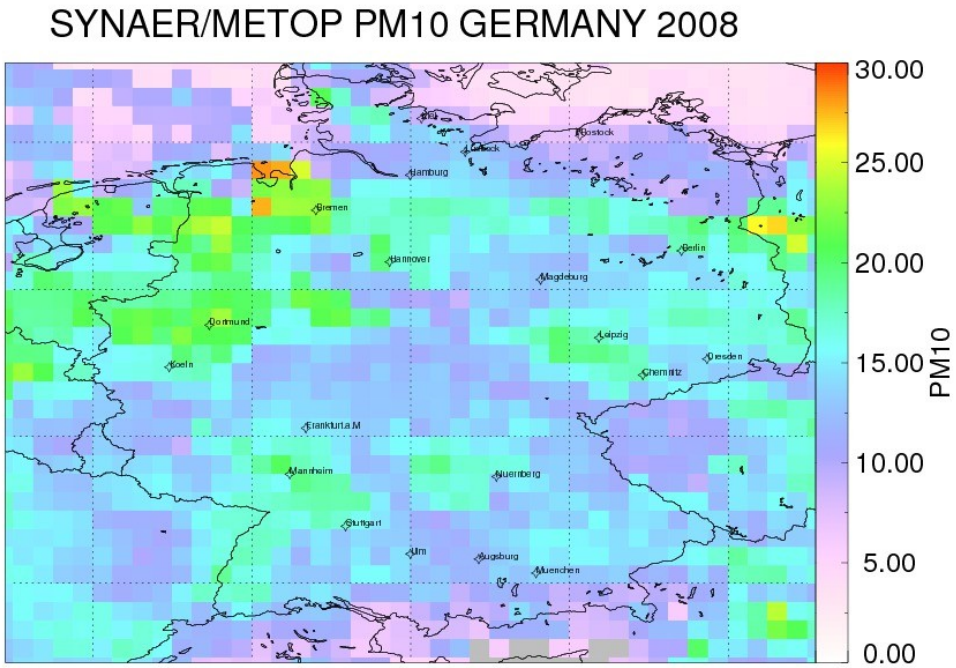
Assumption

- vertical well mixed within boundary layer (H)

$$a = f(r_g, \sigma_g, \varrho, \alpha, H)$$

$$PMX_{ground} = a \bullet AOD_{satellite}$$

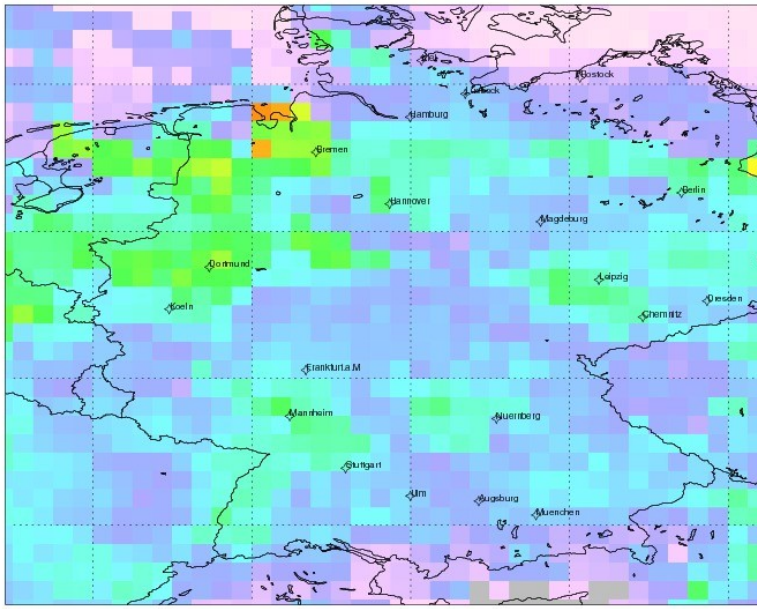
MetOp product Particulate Matter



annual mean Particulate Matter [ug/m3]

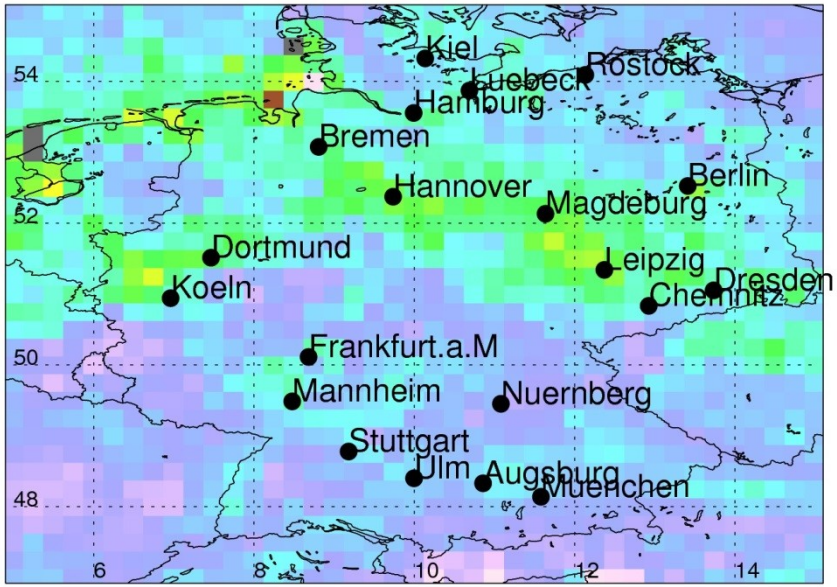
MetOp product Particulate Matter

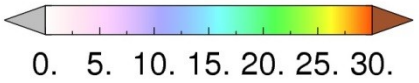
SYNAER/METOP PM10 GERMANY 2008



annual mean Particulate Matter [ug/m3]

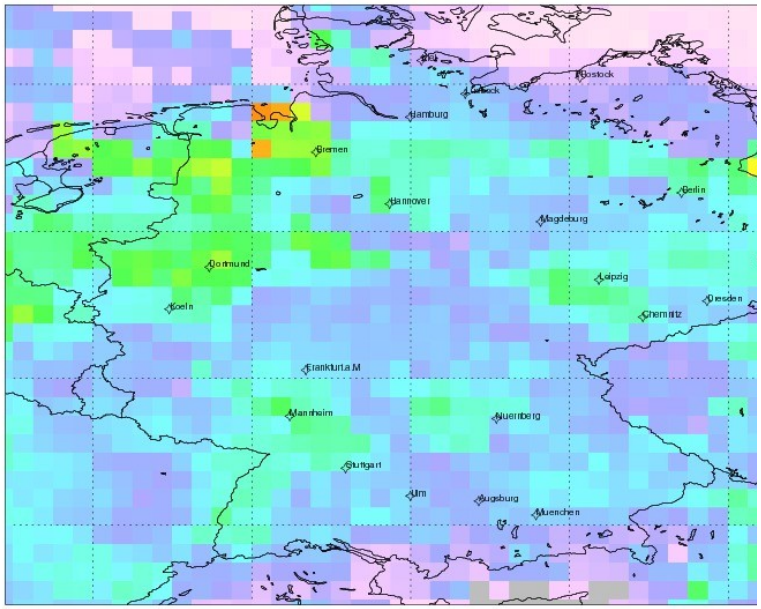
MODIS col.6 Mix 1





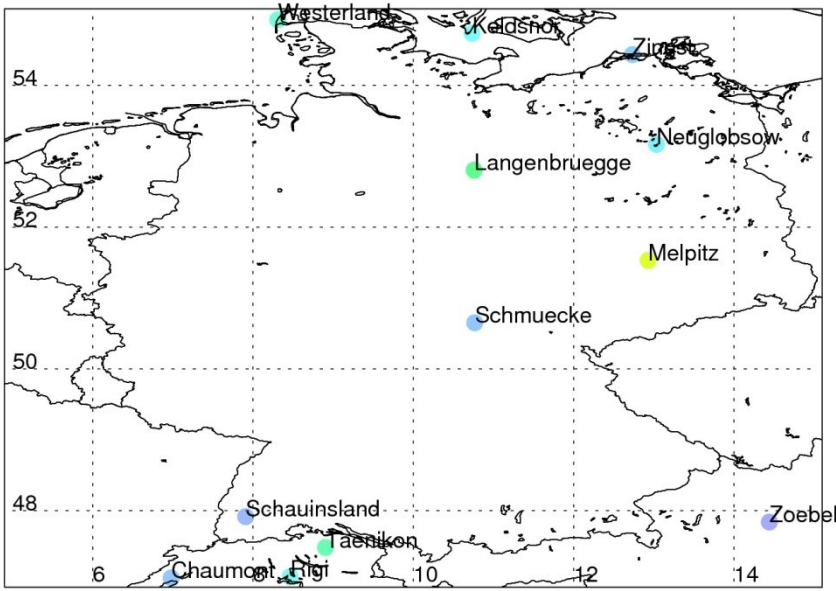
MetOp product Particulate Matter

SYNAER/METOP PM10 GERMANY 2008



annual mean Particulate Matter [ug/m3]

EMEP

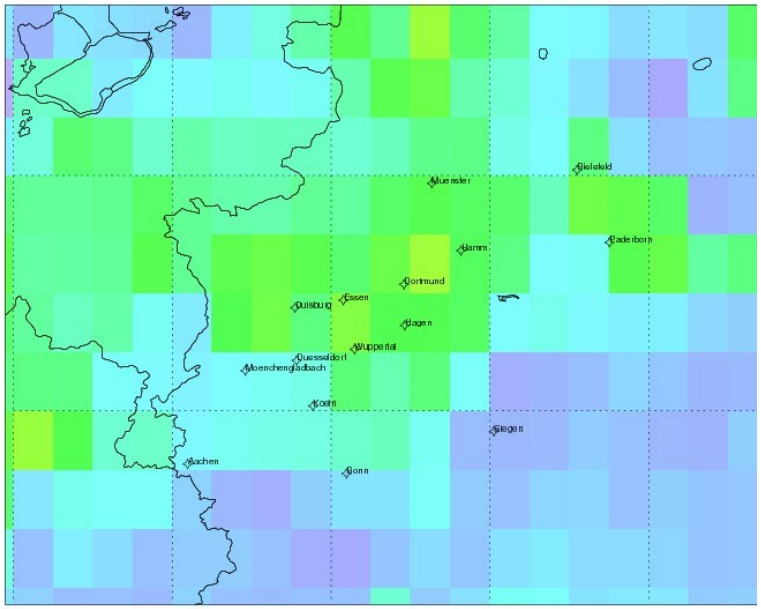


PM 10 [ug/m^3]

0. 5. 10. 15. 20. 25. 30.

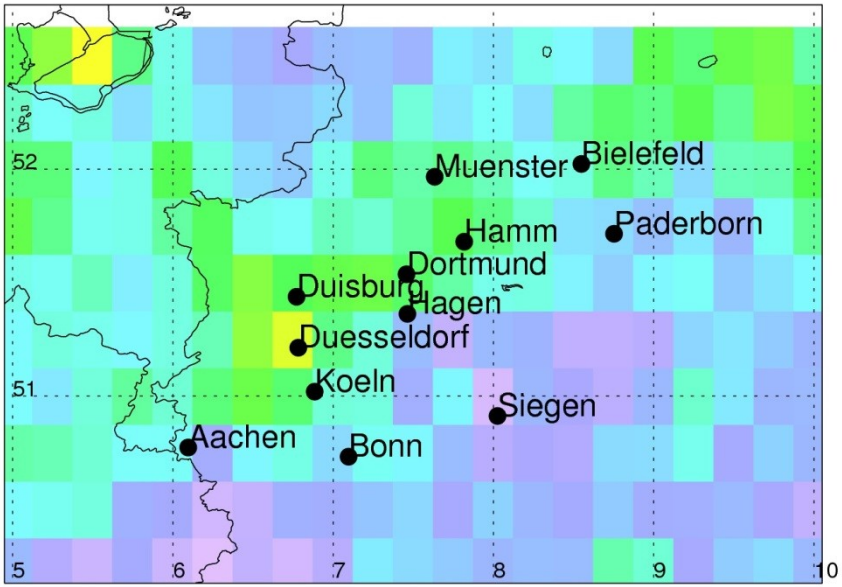
MetOp product Particulate Matter

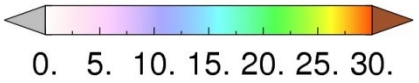
SYNAER/METOP PM10 NRW 2008



annual mean Particulate Matter [ug/m3]

MODIS col.6 Mix 1

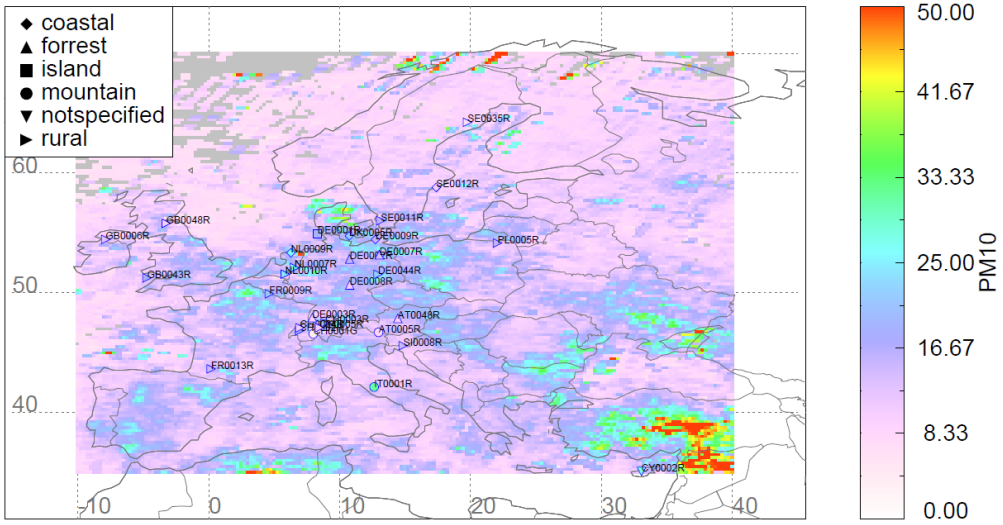




Envisat product Particulate Matter

PM 10

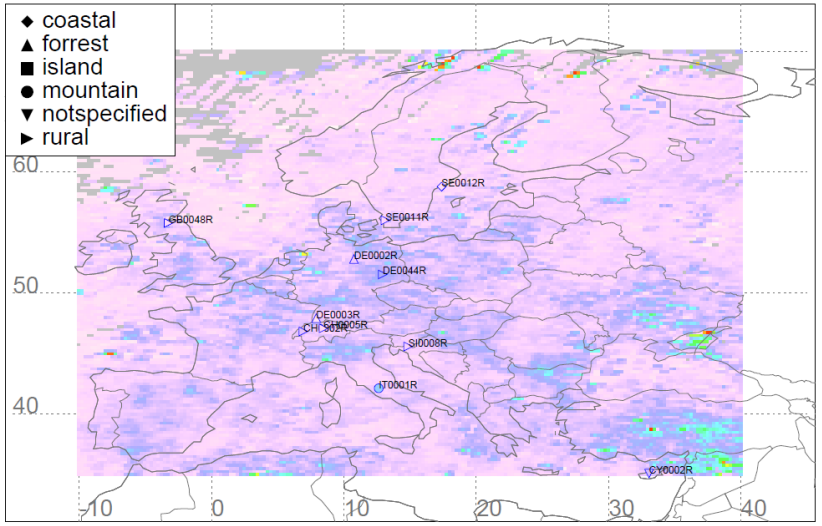
SYNAER/ENVISAT + EMEP PM10 EUROPE 2007



annual mean Particulate Matter PM10 [ug/m3]
SYNAER retrieved PM10

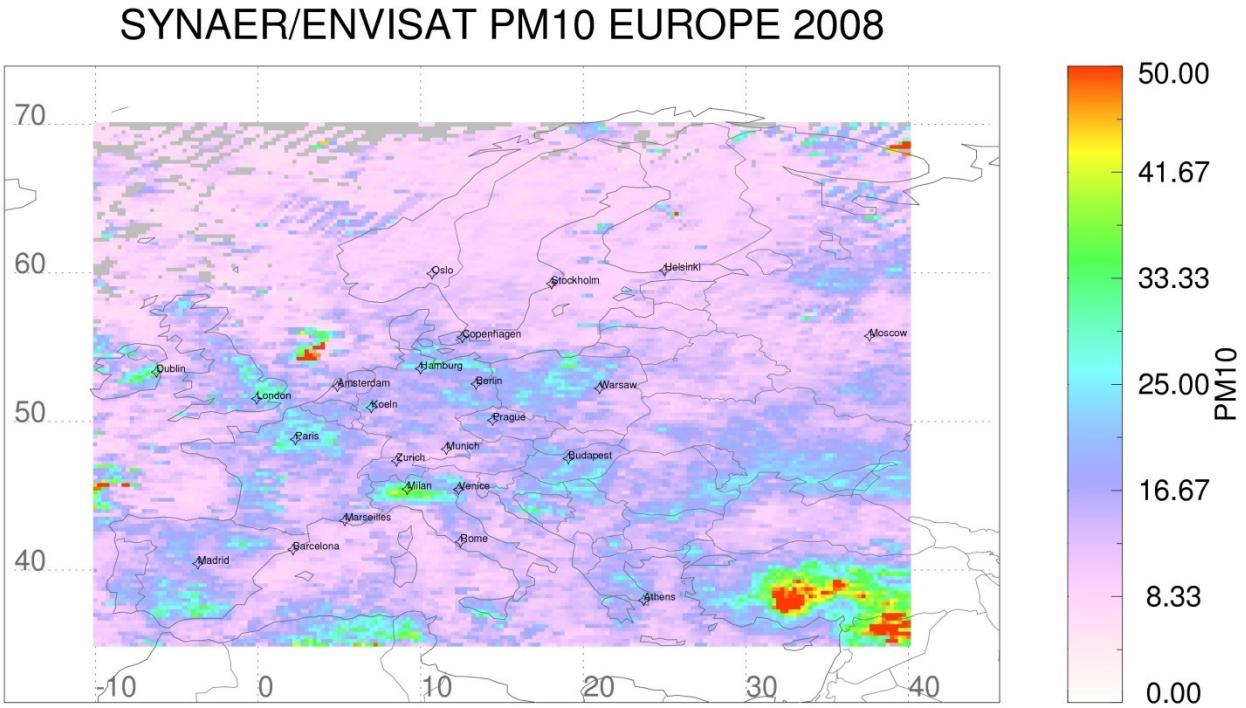
PM 2.5

SYNAER/ENVISAT + EMEP PM2.5 EUROPE 2007



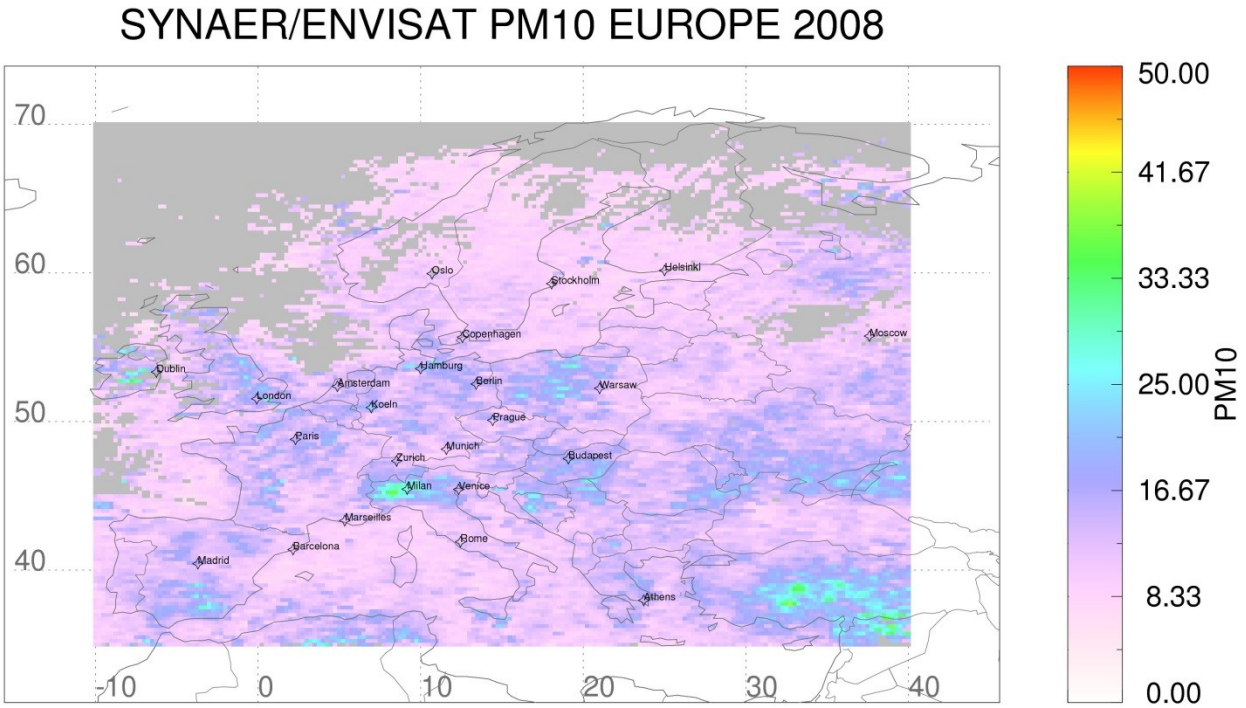
annual mean Particulate Matter PM2.5 [ug/m3]
SYNAER retrieved PM2.5

Envisat product Particulate Matter



annual mean Particulate Matter PM10 [ug/m3]
SYNAER retrieved PM10

Envisat product Particulate Matter



annual mean Particulate Matter PM10 [ug/m3]
SYNAER LOCAL retrieved PM10

Summary

- simple physical conversion from AOD to PMx
- dependent on aerosol mixture
- assumption of well mixed boundary layer
- method not restricted to single region – independent product

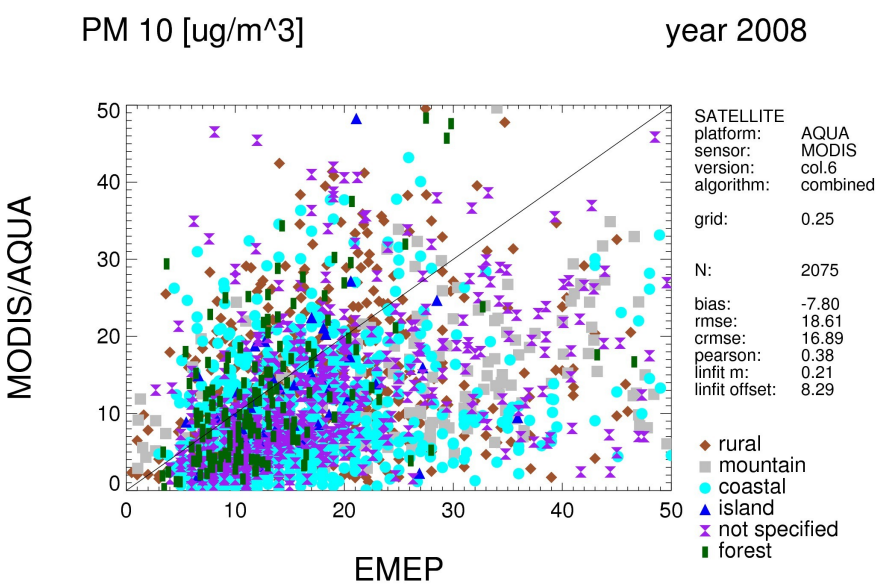
- daily product difficult due to missing AOD caused by clouds, limited darkfields

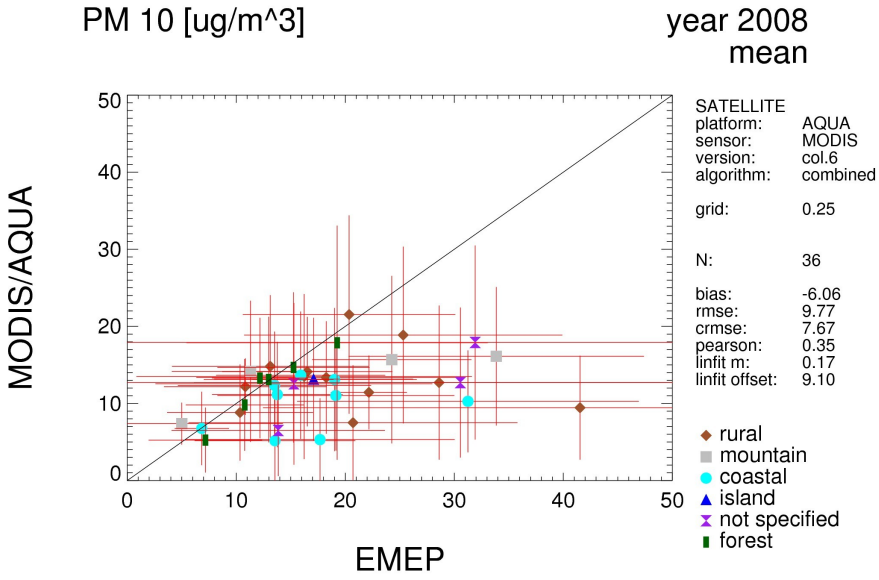
- annual mean product of particulate matter
  with lower RMSE than daily product
- local PM load by separating aerosols originated from natural and anthropogenic sources

complementary information on regional air quality

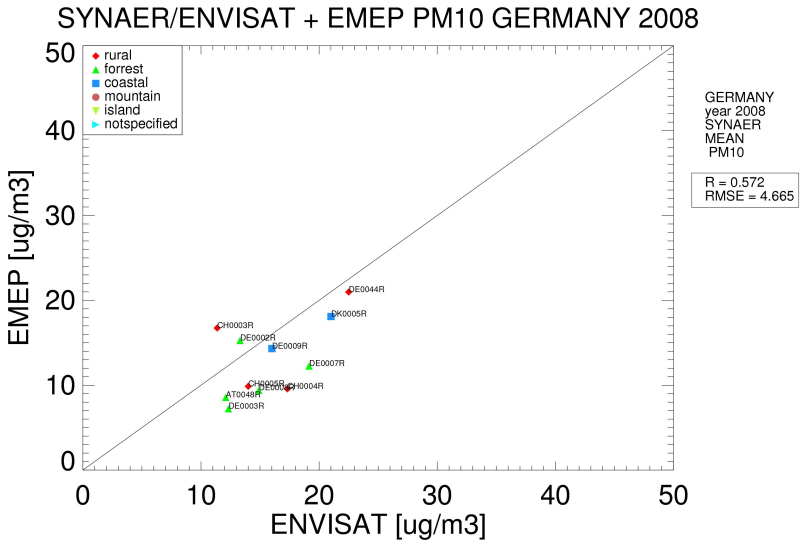
Thank You !

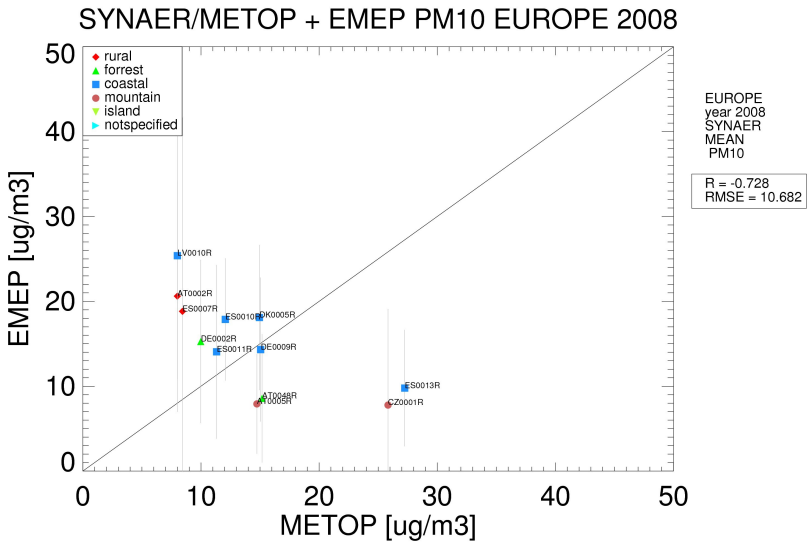
Daily versus annual mean product



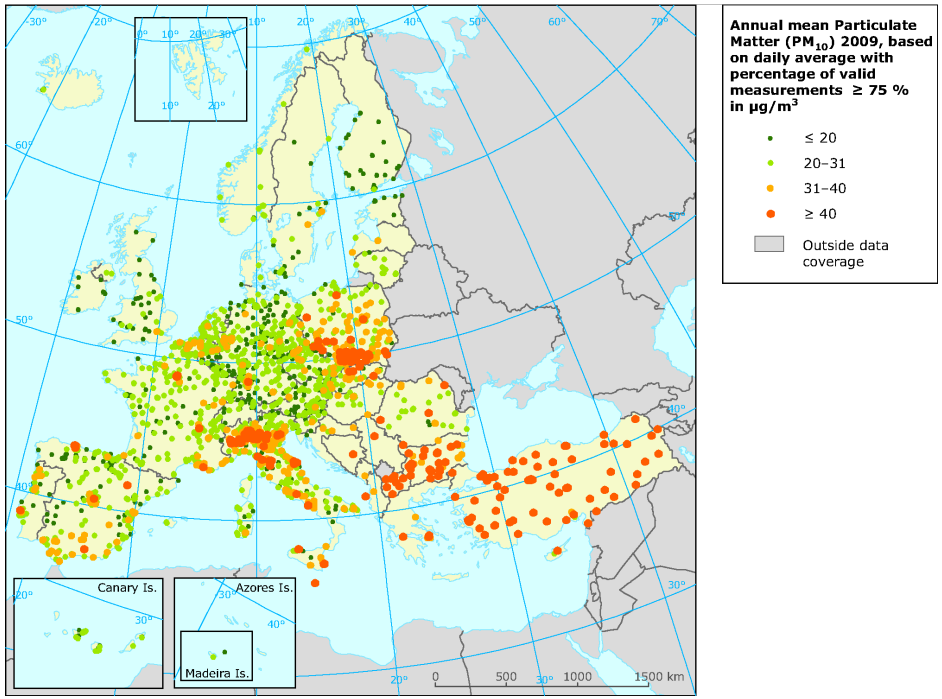


Daily versus annual mean product

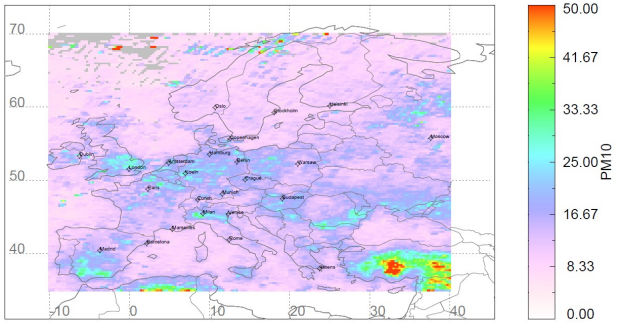




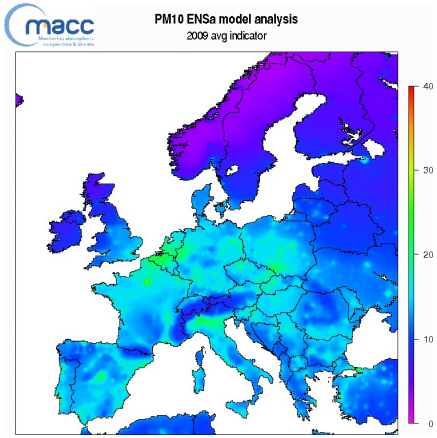
High concentrations



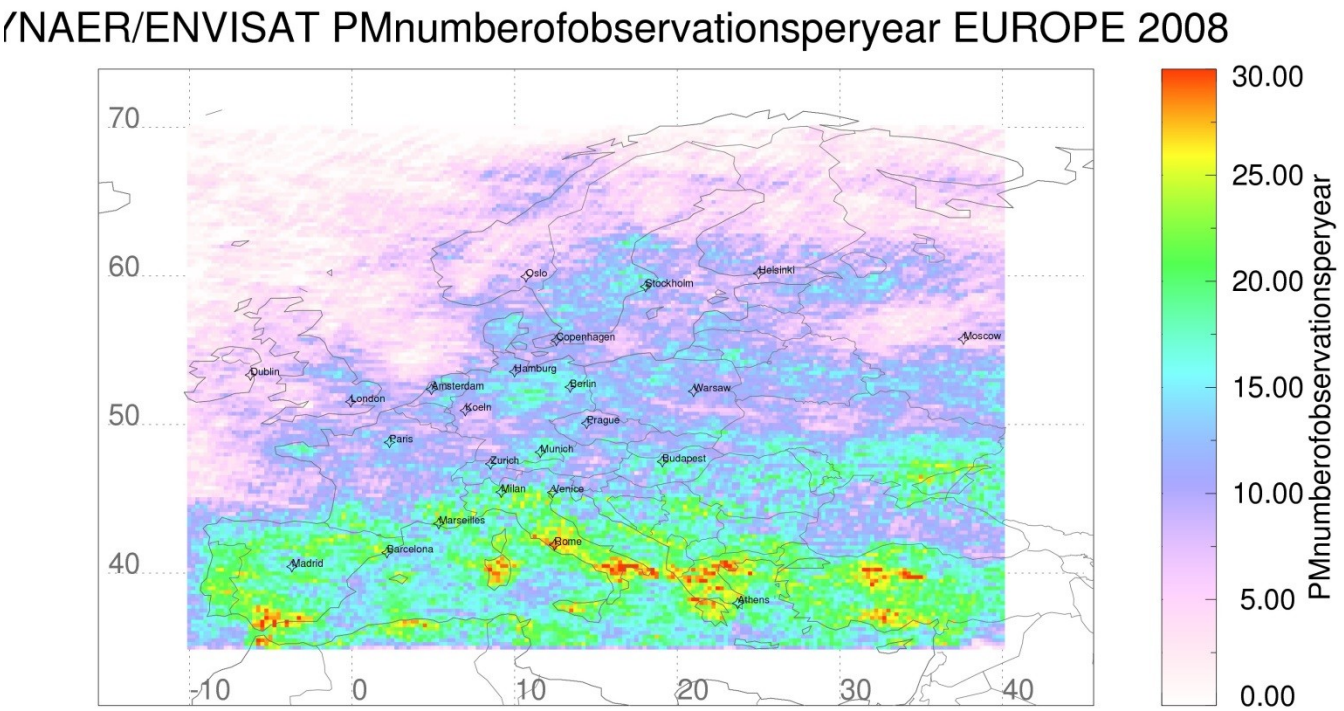
SYNAER/ENVISAT PM10 EUROPE 2009



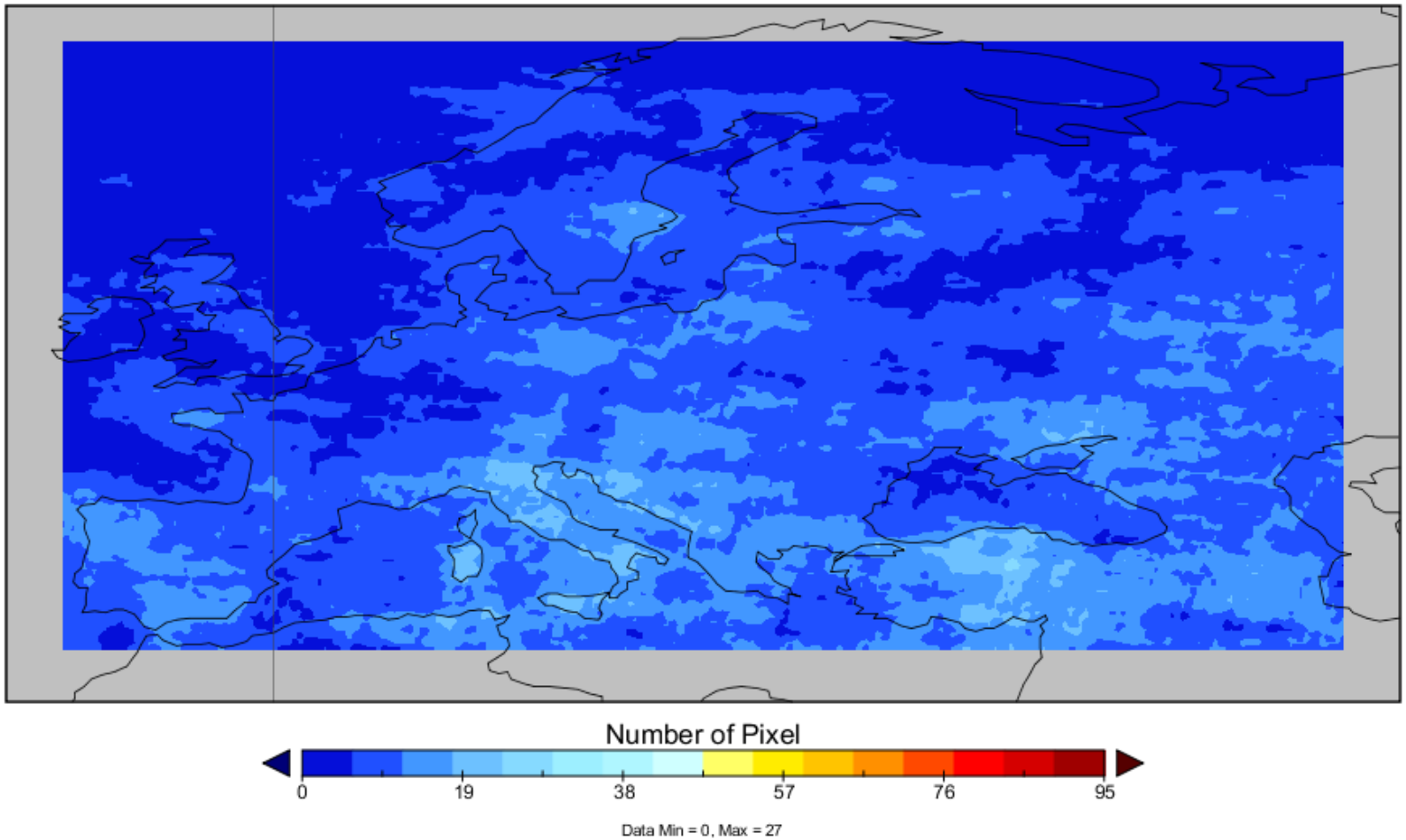
annual mean Particulate Matter PM10 [ug/m3]
SYNAER retrieved PM10



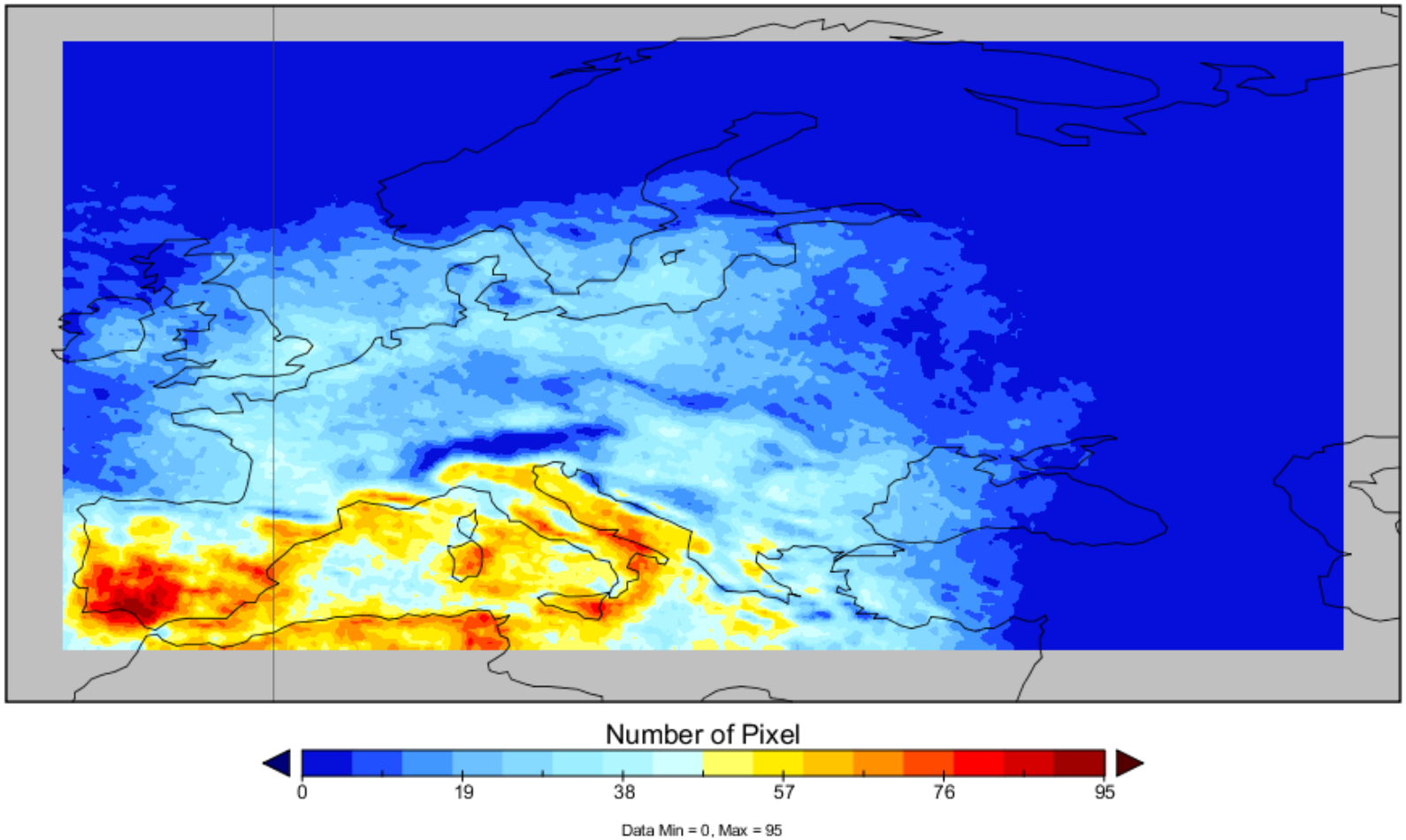
Envisat number of pixel



Number of available Pixel in 2008 for SYNAER 2.2 ENVISAT

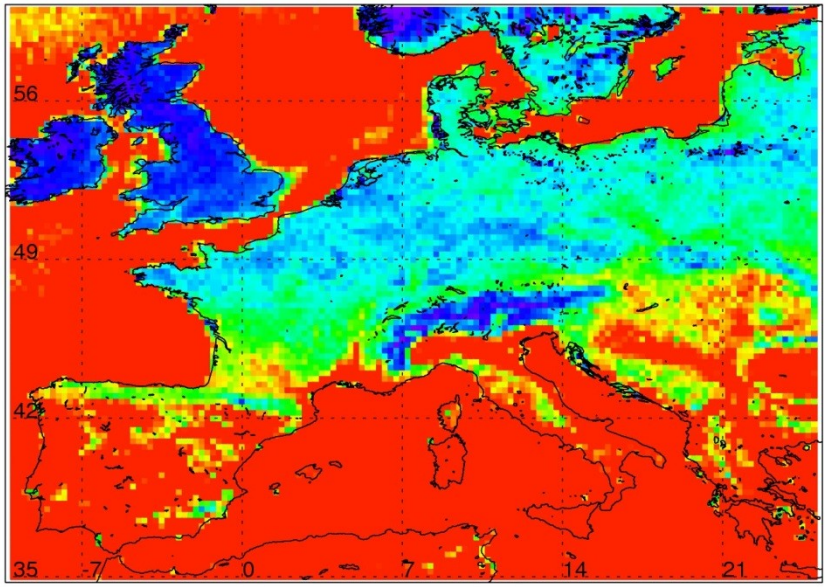


Number of available Pixel in 2008 for SYNAER 0.9L MetOp



MODIS/AQUA
number of measurements

year 2008
europe



col.6, combined
grid 0.25