Usage of the satellite aerosol product SYNAER for regional scale air quality assessments in Europe through EMEP

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Outline

- The Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollution in Europe (EMEP)
- Brief overview of the SYNAER (SYNergetic Aerosol Retrieval) data product
- Validation and usage of satellite based AOD and PM measurements – SYNAER
  - Evaluation of different SYNAER versions
  - Comparison with EMEP surface measurements and EMEP model
  - Examples of SYNAER aerosol type speciation
  - Using data for yearly reporting to EMEP steering body
- Conclusions and recommendations

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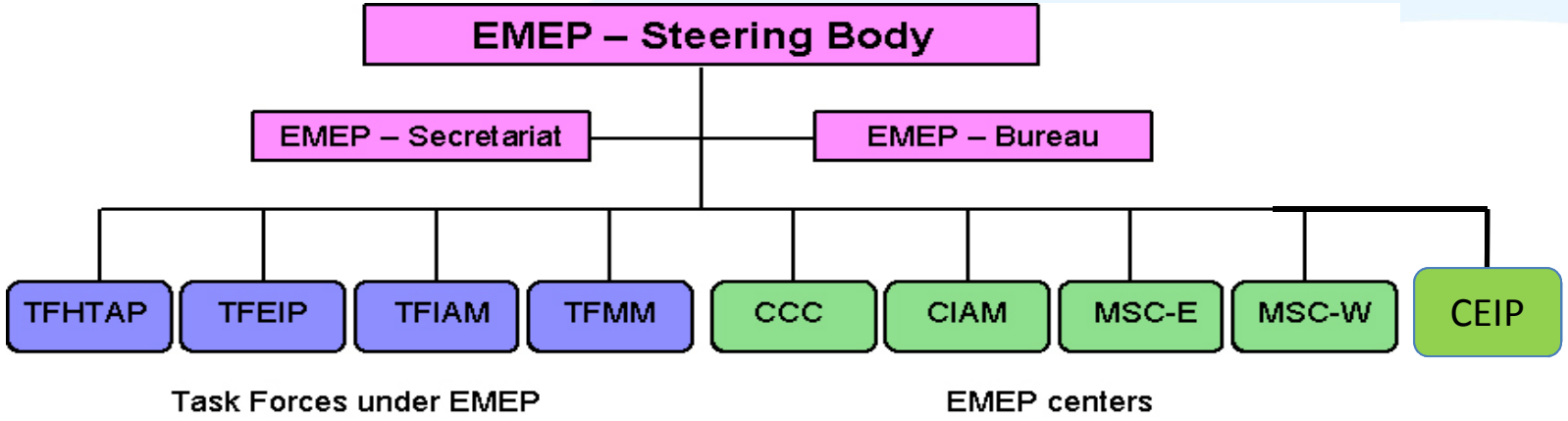
The Convention for Long-Range Transport of Air Pollution



The EMEP program relies on three main elements:

(1) Collection of emission data

(2) Measurements of air and precipitation quality

(3) Modelling of atmospheric transport and deposition of air pollution.

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European Monitoring and Evaluation Programme - EMEP

- Convention on Long-range Transboundary Air Pollution
- Funded through UN-ECE since 1979 - data/stations nationally funded
- http://www.emep.int
- Science-based and policy-driven instrument for international cooperation in
  - Atmospheric monitoring and modelling
  - Emission inventories and projection
  - Integrated assessment to help solve transboundary air pollution problems
- EMEP-CCC (NILU): co-ordination and intercalibration of chemical air quality and precipitation measurements
  - Acid deposition/eutrophication
  - Photochemical oxidants
  - Heavy metals
  - Persistent organic pollutions
  - Fine particulate matter (added in 1998)

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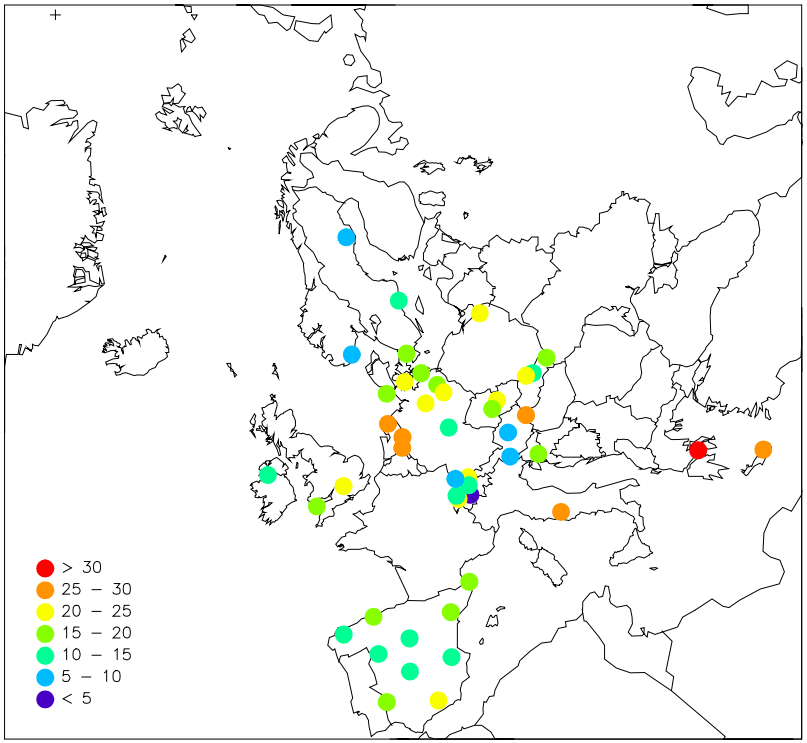
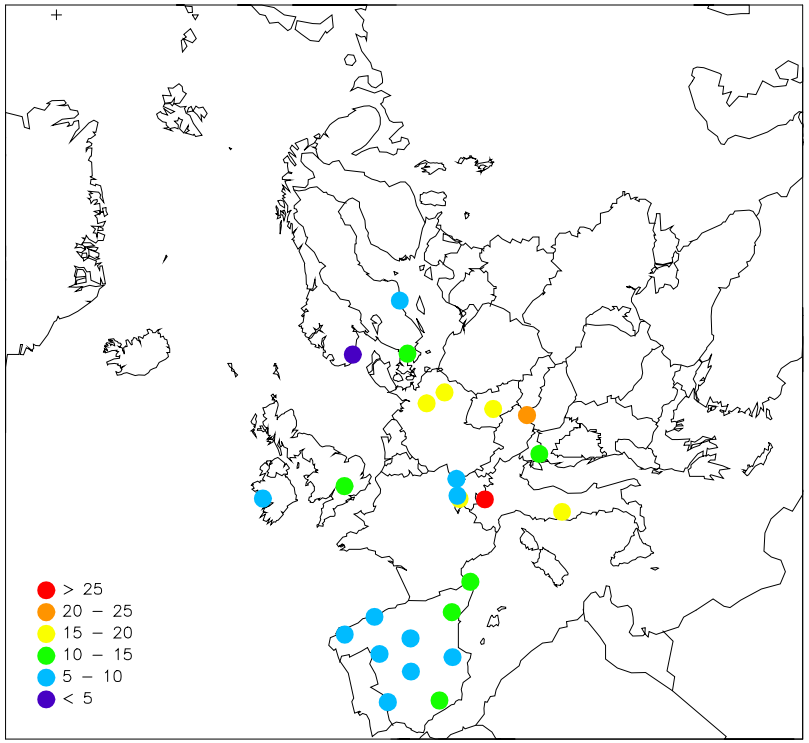
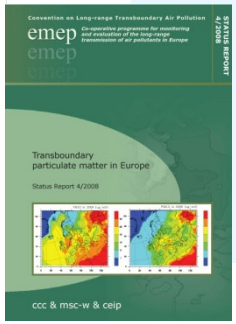
Annual mean surface concentrations of PM_{10} and $PM_{2.5}$ in 2006 (EMEP)







PM_{10} from 47 stations, $PM_{2.5}$ from 25 sites, PM_1 from 5 stations

PM_{10}	CH01: Jungfraujoch	3.3 µg m^{-3}	CY02: Cypriote	33.8 µg m^{-3}
$PM_{2.5}$	NO01: Birkenes	5.0 µg m^{-3}	IT04: Ispra	28.5 µg m^{-3}

EMEP Report, Transboundary particulate matter in Europe Joint CCC, MSC-W and CEIP Status Report 4/2008

Motivation for investigation satellite based measurements

- Data coverage of regular monitoring network not sufficient to answer questions like:
  - *How large is the contribution of intercontinental transport of Air Pollution of regional-scale Air Quality ?*
- In particular in the eastern part of the EMEP region, central Asia and the eastern Mediterranean. Sites in North Africa would be valuable. …. no data over oceans …
- Satellite data are available and should be used?
  - Request for additional data sources such as airborne measurements and remote sensing data
  - **Evaluation of the SYNAER data product for regional air quality monitoring over Europe**

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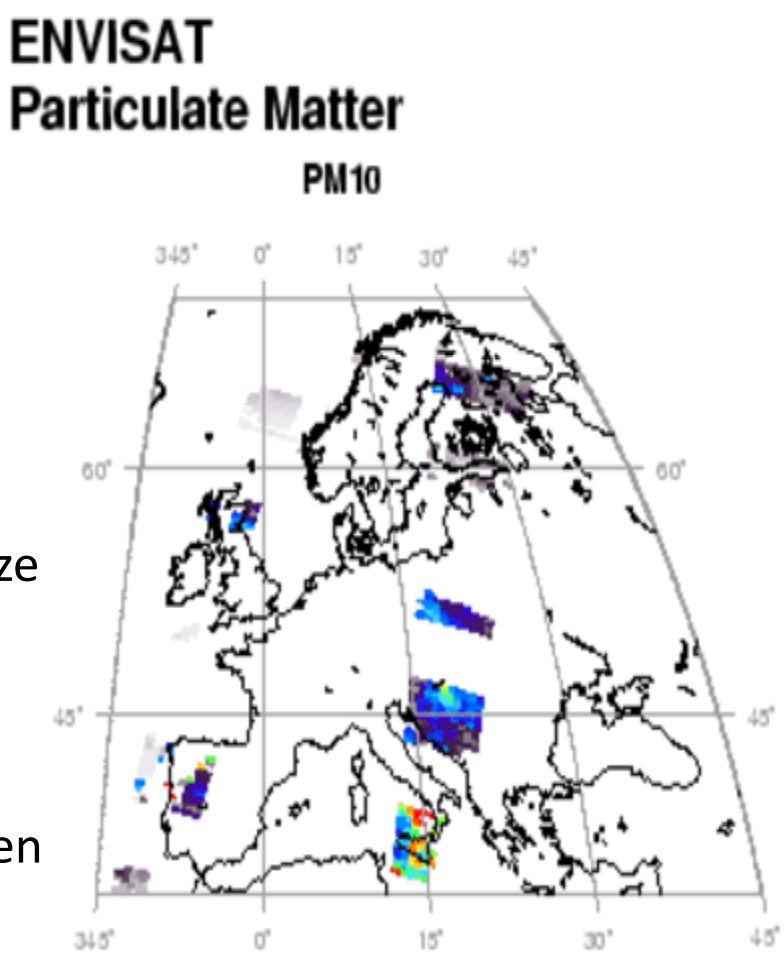
The SYNAER (SYNergetic Aerosol Retrieval) data product

- Provided by DLR through ESA-GSE project PROMOTE “European multi-annual PM record”
- *see Holzer-Popp et al., ACPD, 2008*
- Synergistic retrieval of aerosol properties based AATSR and SCIAMACHY (and ATSR/GOME)
- Radiometer used to estimate AOD as a function of wavelength – information on size distribution
- Spectrometer used to estimate aerosol composition
- Surface levels of PM_{10}, $PM_{2.5}$ and $PM_{0.5}$ given for cloud-free pixels on SCIAMACHY-grid



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SYNAER principle

- **Radiometer** (AATSR: 1x1km^2 pixel size, 7 channels VIS – thermal)
  - Accurate cloud detection and correction
  - Dark field method (670nm land, 870 nm ocean)
  - **Retrieval of AOD and surface albedo for given aerosol type**
  - Repetition for 40 aerosol mixtures
- Coregistration to spectrometer pixels
- **Spectrometer** (SCIAMACHY: 60x30km^2, UV-VIS 0.1 nm)
  - Least square fit of spectra 410-670 nm for 40 aerosol types
  - Using AOD and surface albedo for each type from AATSR
  - **Selection of most plausible aerosol type**
  - Fit quality check

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- **AOD, PM_{10}, $PM_{2.5}$, $PM_{0.5}$, and aerosol type (40 pre-defined mixtures of water soluble, soot, mineral dust and sea salt aerosol)**

Evaluation of SYNAER product

- Compare SYNAER data with EMEP particulate matter (PM_{10}, $PM_{2.5}$, $PM_{1.0}$) and chemical specification
- The EMEP network provides daily (hourly) averaged data , typically for rural background sites
- Compared with satellite 60x30 km^2 “snap-shots” – can this be used to supplement daily averaged data ?
- Focusing on the year 2006 where SYNAER version 1.0, 2.01 and 2.2 are available
  - ERS-2 version (2002): AOD from GOME/ATSR
  - V0.9 (2005): Same as ERS-2 version but with SCIAMACHY/AATSR
  - V1.0 (2006): Sensor-specific adaptations, Addition of $PM_{1.0}$, $PM_{2.5}$ and PM_{10} data assuming constant boundary layer (2km) concentrations
  - V1.8 (2007): Improved dark field methodology, boundary level aerosol profile from EURAD
  - V2.01 (2008): Improved method: Offset to dark field correlation function, improvement of the cloud masking, upgrade of aerosol model
  - V2.2 (2009):

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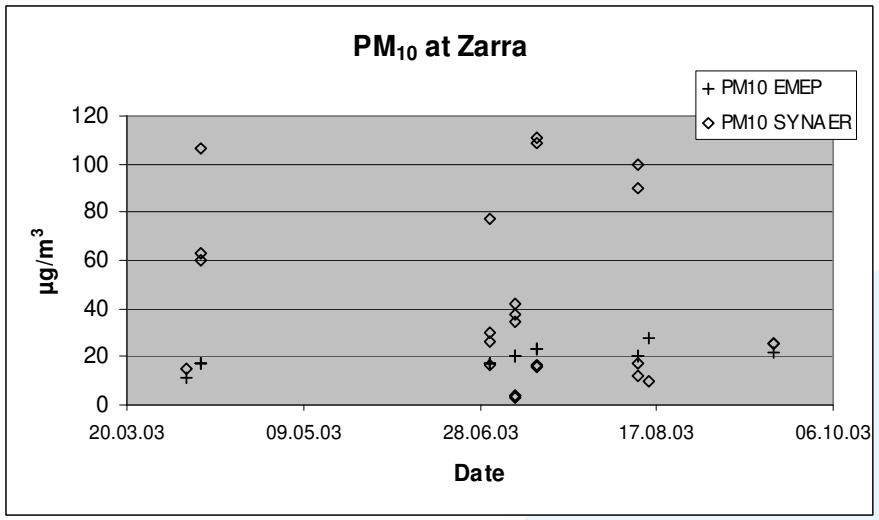

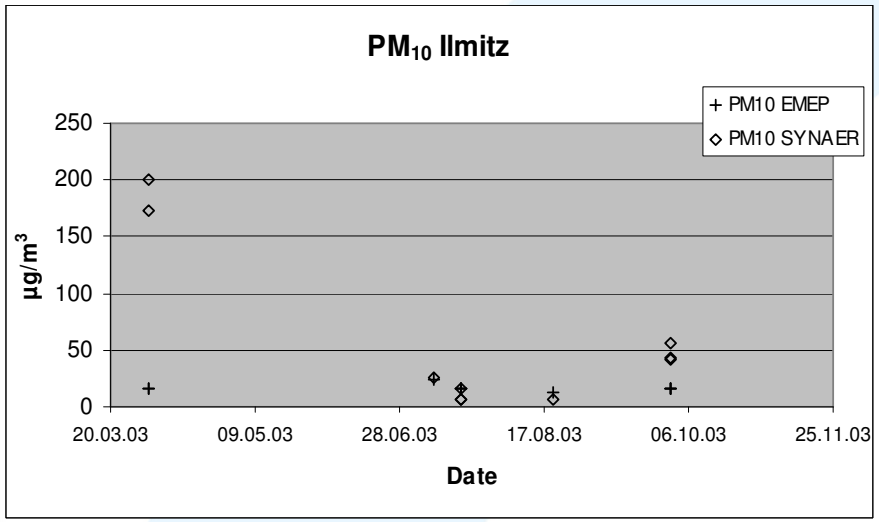

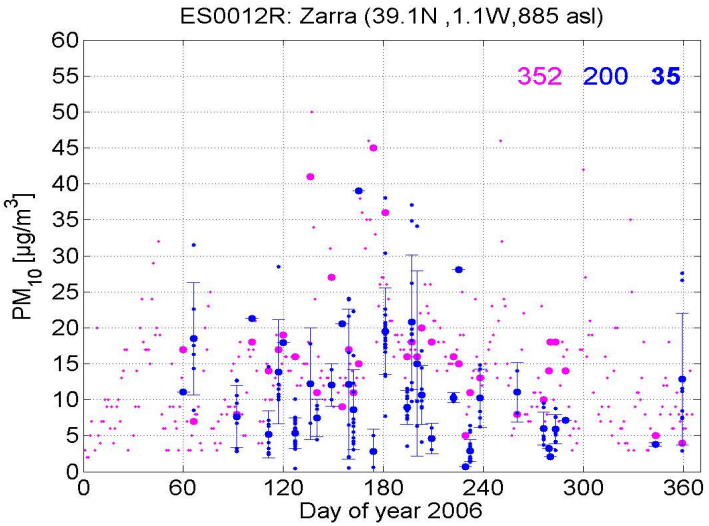

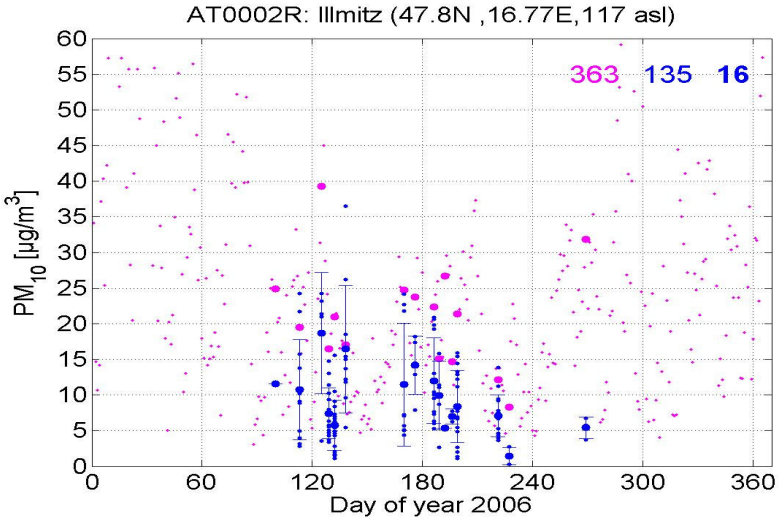

v1.0 from EMEP/CCC-Report 3/2006

overestimation of PM_{10} at Zarra and Illmitz in April

Version 2.2 (prel.)

Underestimation of PM_{10} at Zarra and Illmitz in summer 2006

Bias at Zarra = -23 % , Bias at Illmitz -51%

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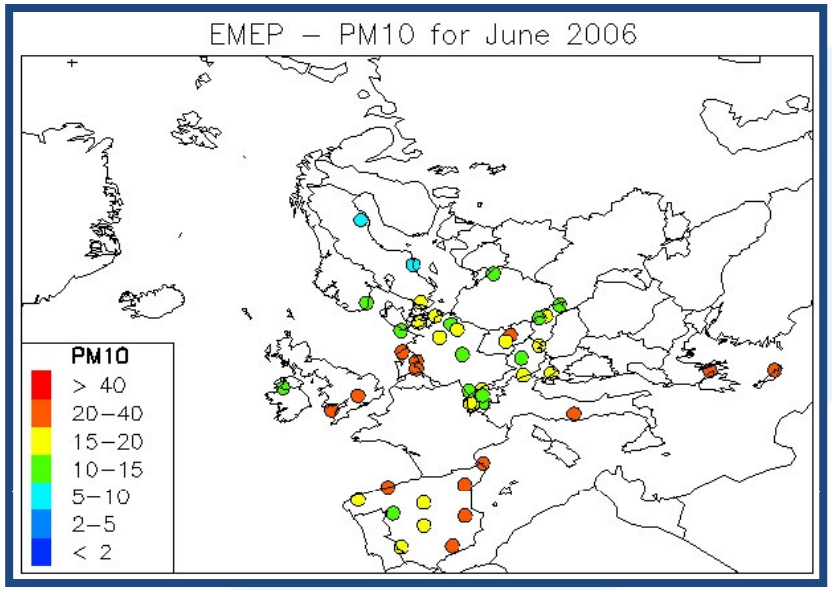
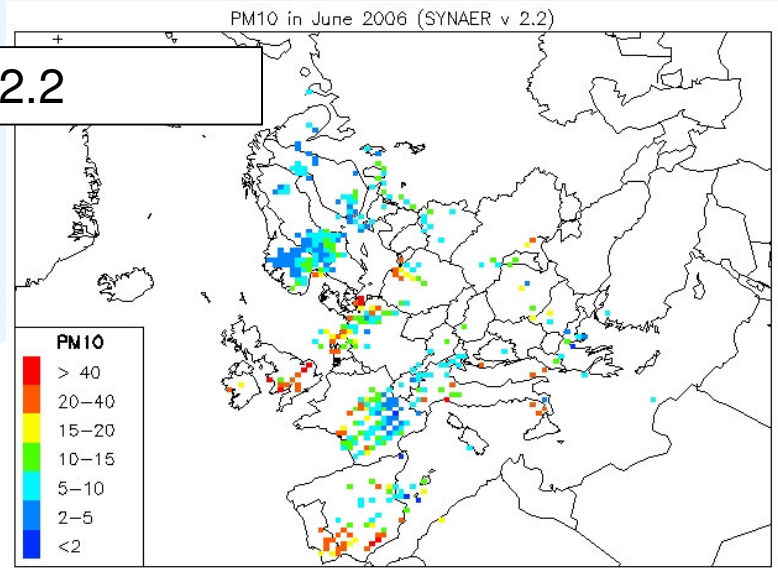
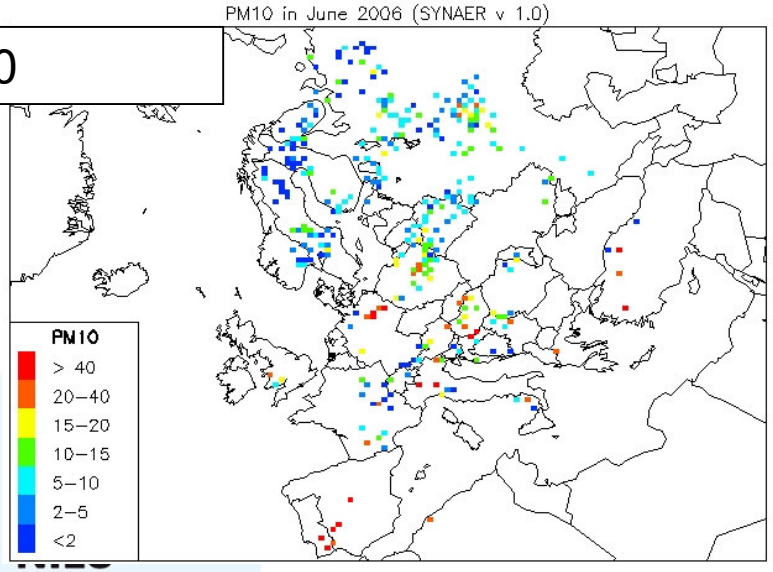
Monthly Means of PM_{10} June 2006 – 3 versions



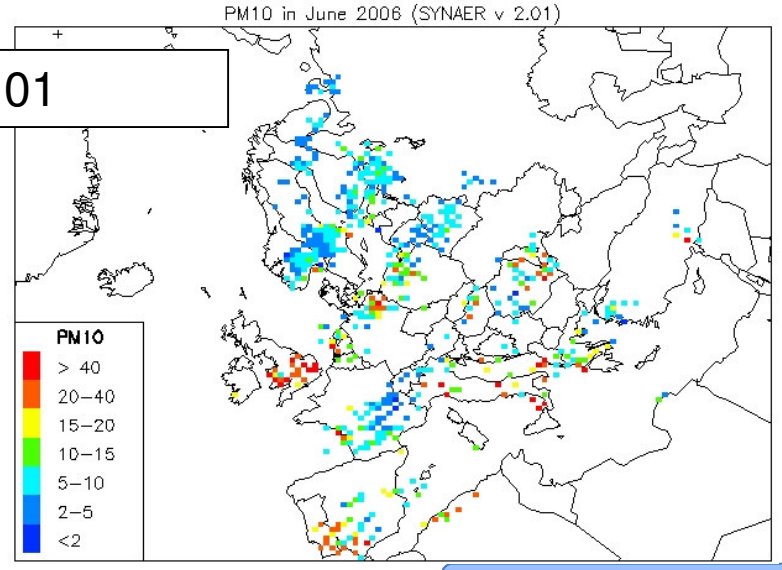
V2.2



v1.0

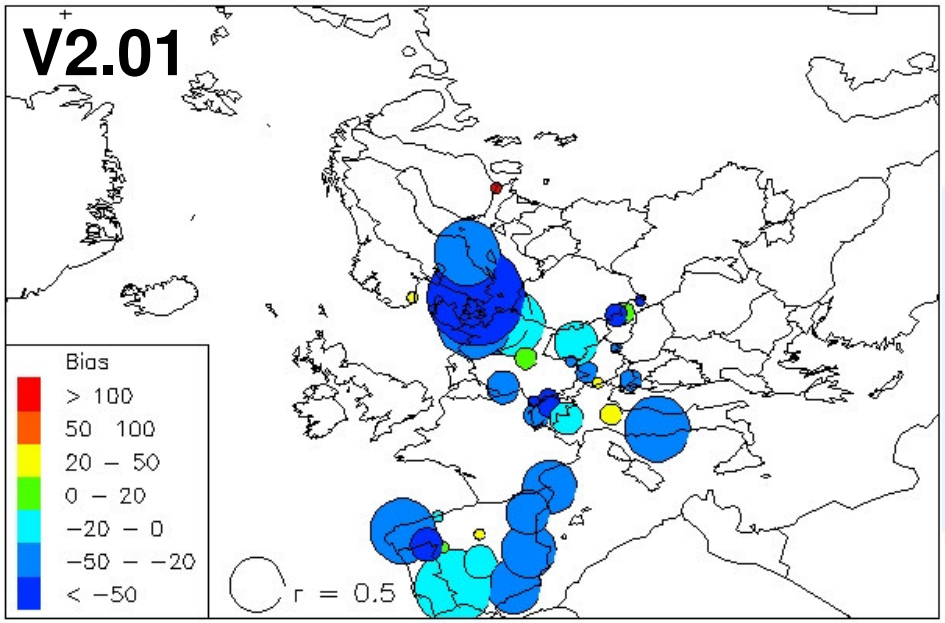


V2.01

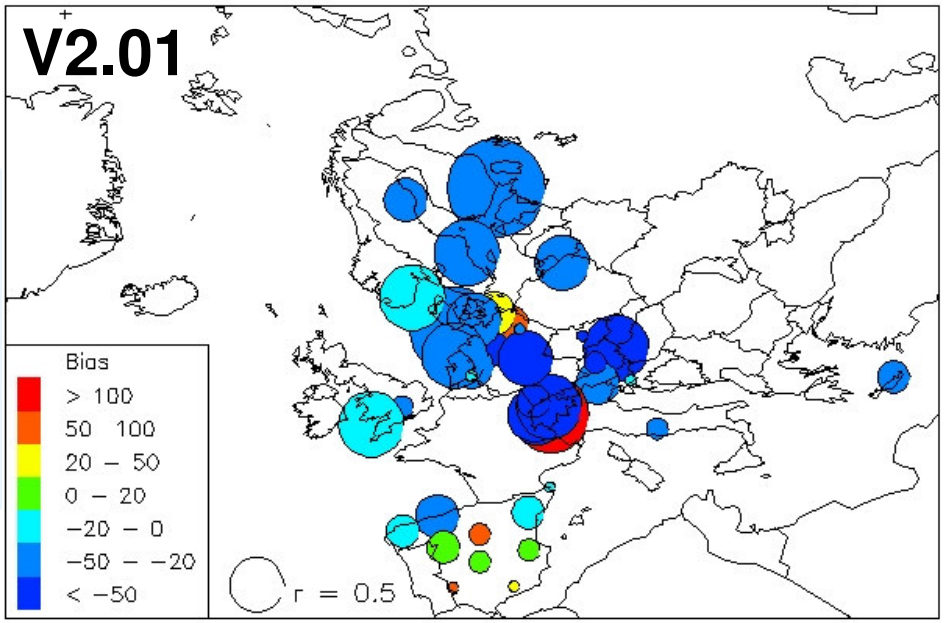


min: 5 data-points in 50x50 km

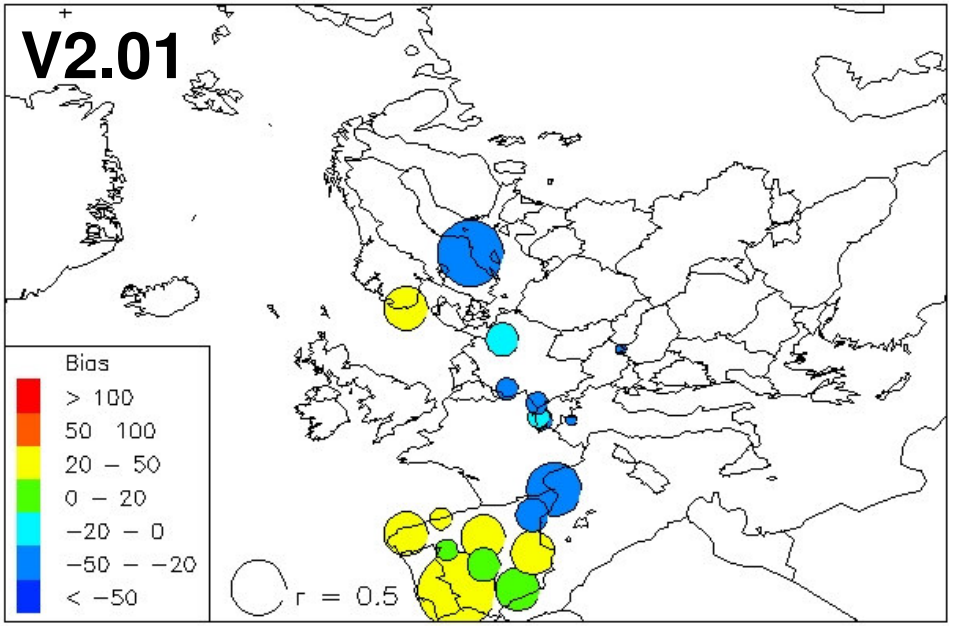
SYNAER–EMEP R & Bias for PM10 in 2003



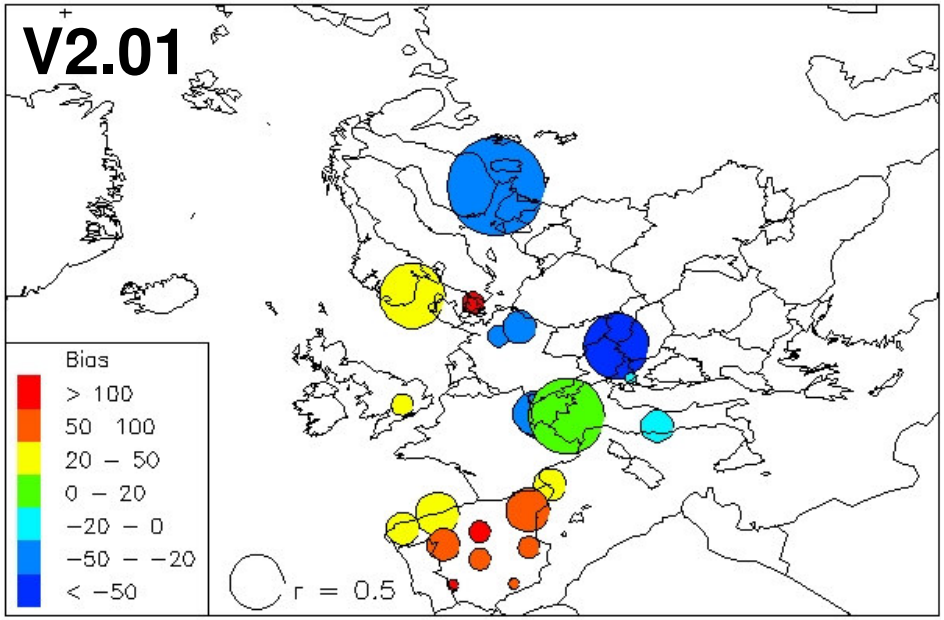
SYNAER–EMEP R & Bias for PM10 in 2006



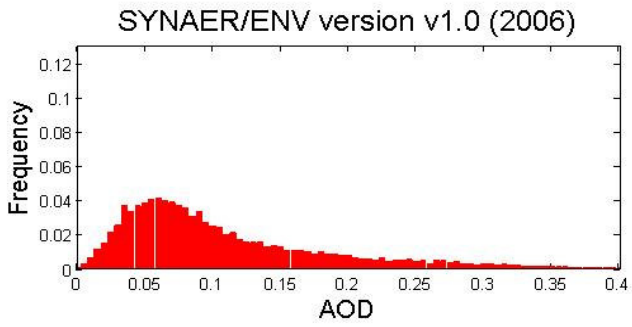
SYNAER–EMEP R & Bias for PM2.5 in 2003

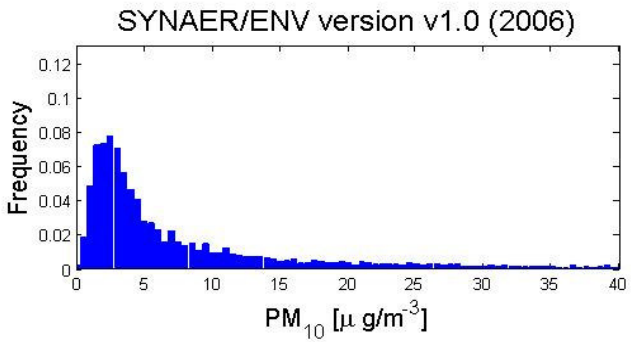


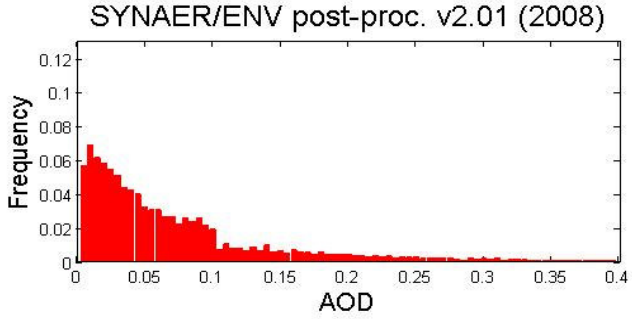
SYNAER–EMEP R & Bias for PM2.5 in 2006

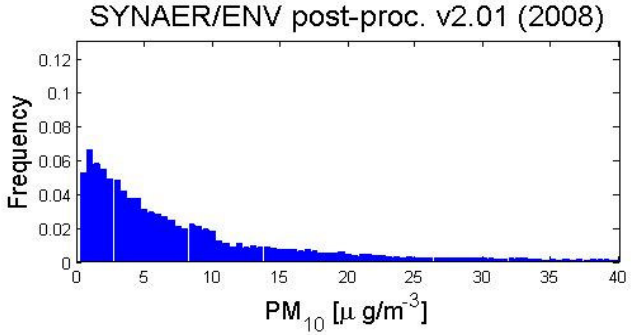


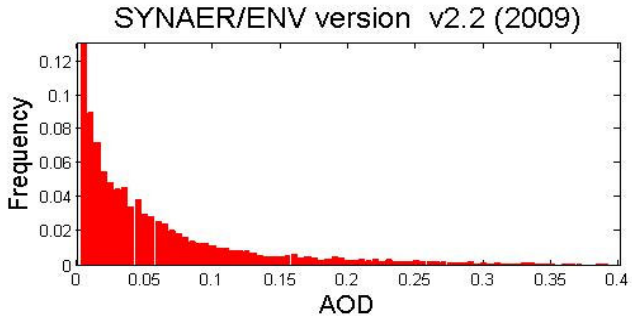
SYNAER/ENV v1.0, v2.01 and v2.2 - data from 2006

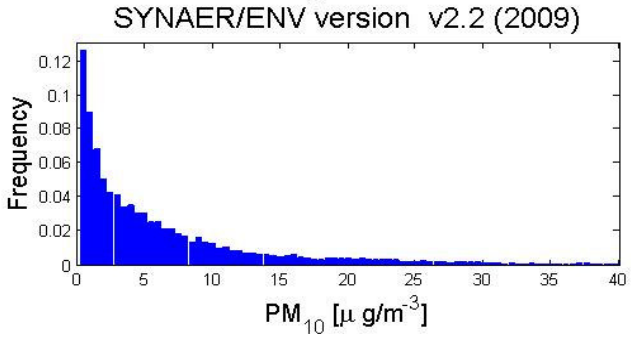












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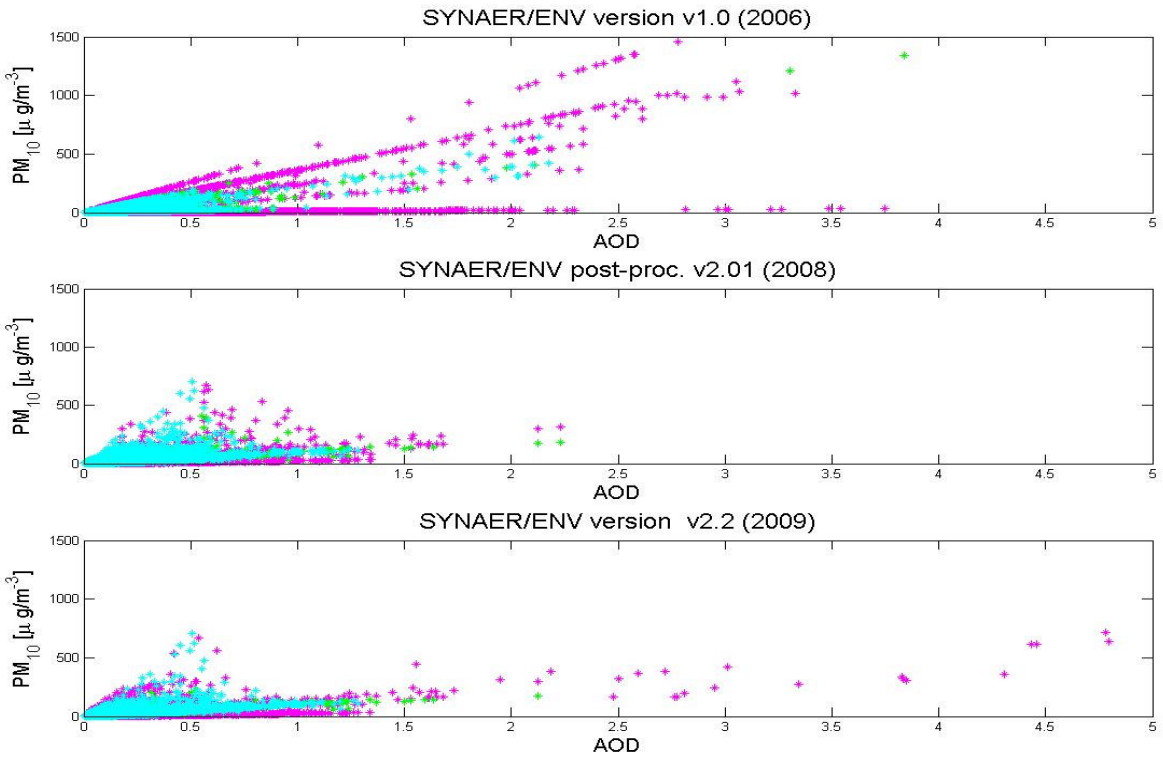
SYNAER/ENV v1.0, v2.01 and v2.2



Selection criteria for good pixel(in v2.01 (2008):

Spectral fit error < 0.025, Cloud fraction < 35%
AOD type ambiguity over bright land albedo < 15%, if estimated AOD error > 0.1
AOD type ambiguity over bright ocean albedo < 5%, if estimated AOD error < 0.05

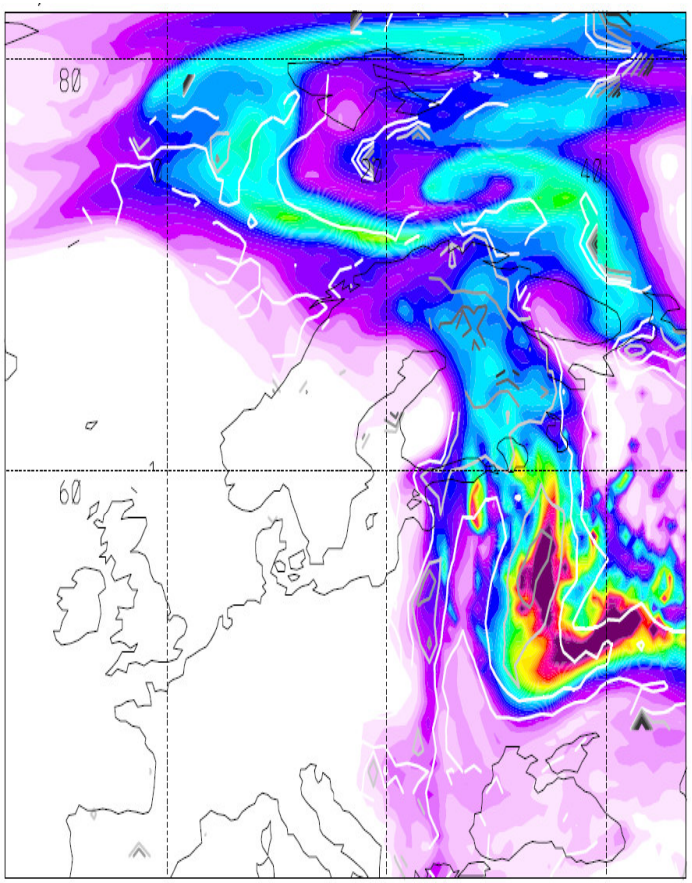
Refined selection criteria for good pixel in v2.2 (2009):

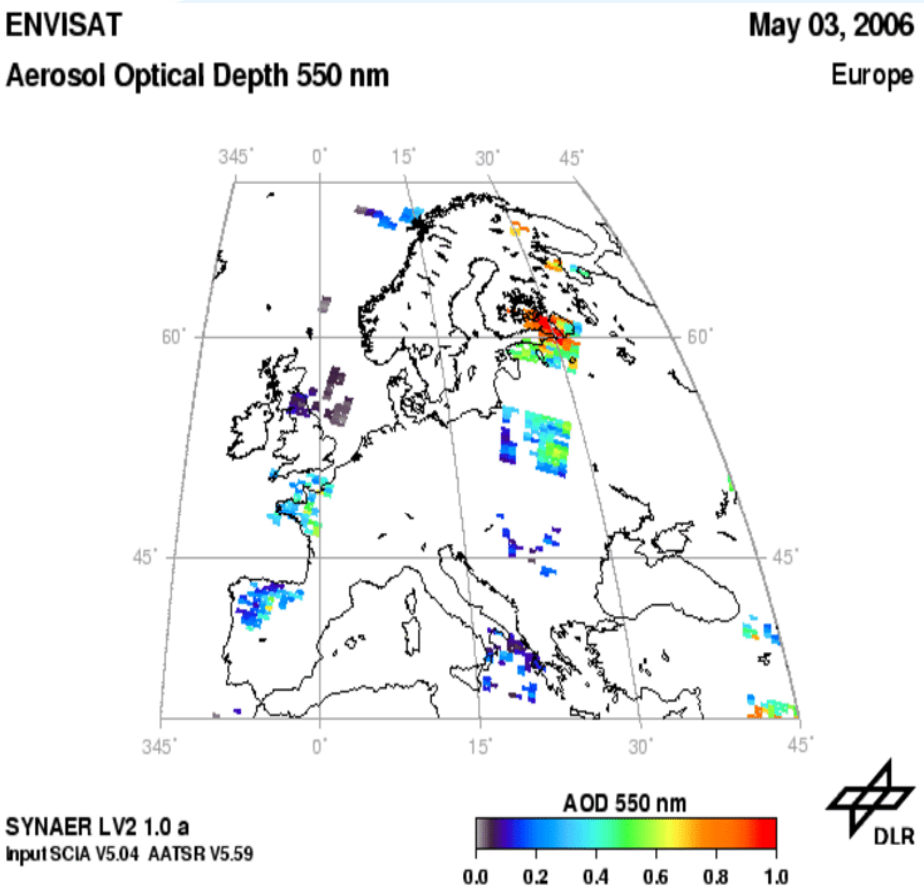
xerr <= 0.02, aod550_error <= 0.14, lalb670 < 25.0 and fcl <0.35

Aerosol speciation information

- Biomass burning and transport event
- Saharan dust and high AOD in N-Norway

Example of SYNAER aerosol speciation





Right: Daily SYNAER results (AOD at 550 nm) from 3 May 2006. Clearly enhanced values over southern Finland can be seen, resulting from agricultural fires in Eastern Europe/western Russia.

Left: Total columns of FLEXPART BB CO tracer at 9–12 UTC for 3 May 2006. Superimposed: 0.3, 0.5, 0.7, 1.0, 1.5, and 2 AOD isolines (white - dark gray) of daily MODIS Terra Level-3. (from Stohl et al, ACP., 2007).

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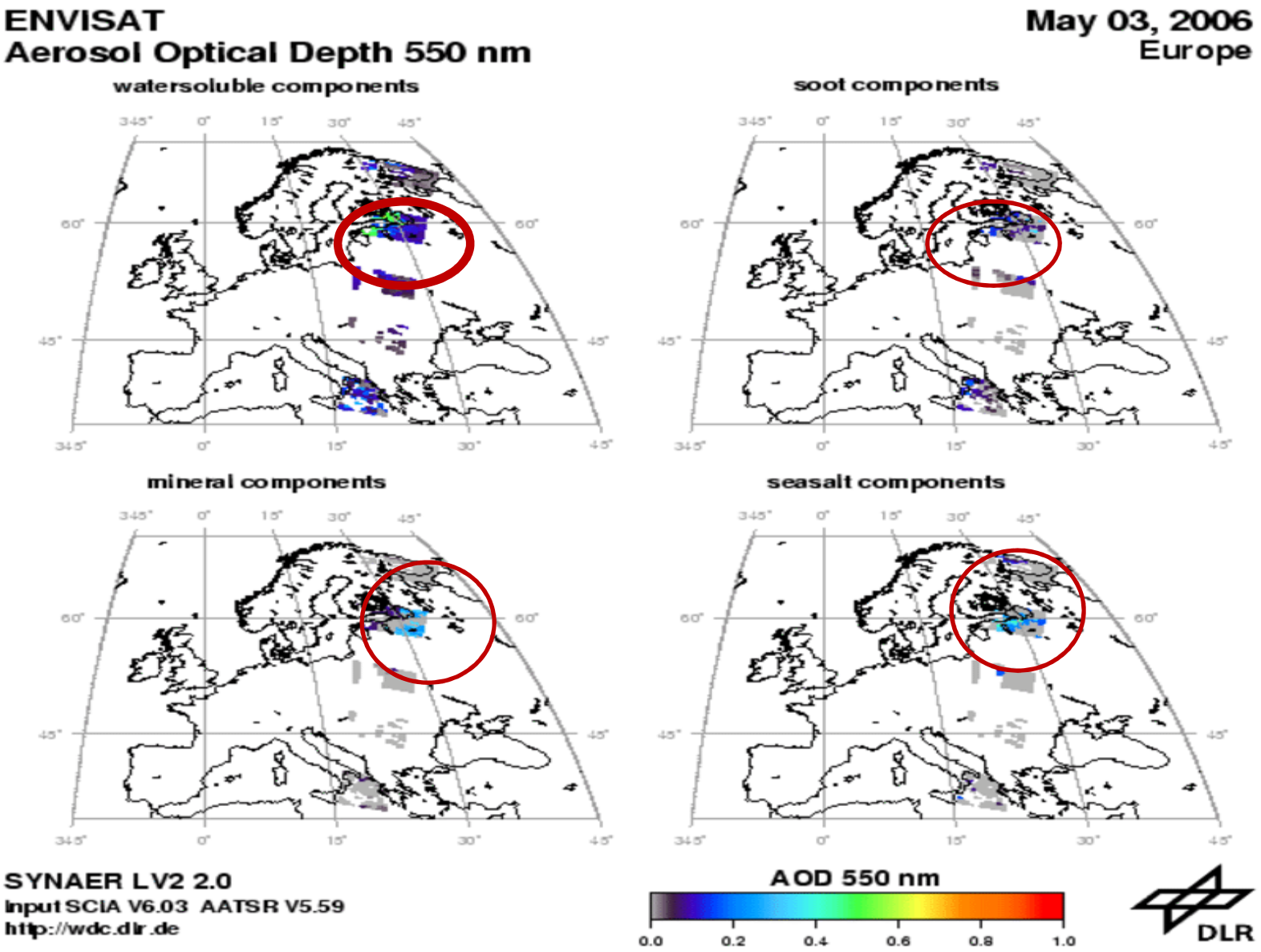
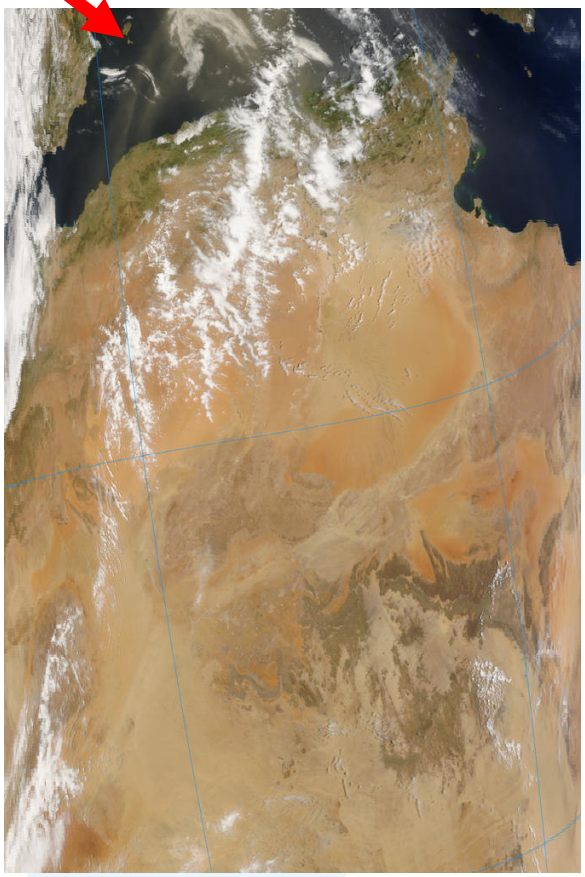
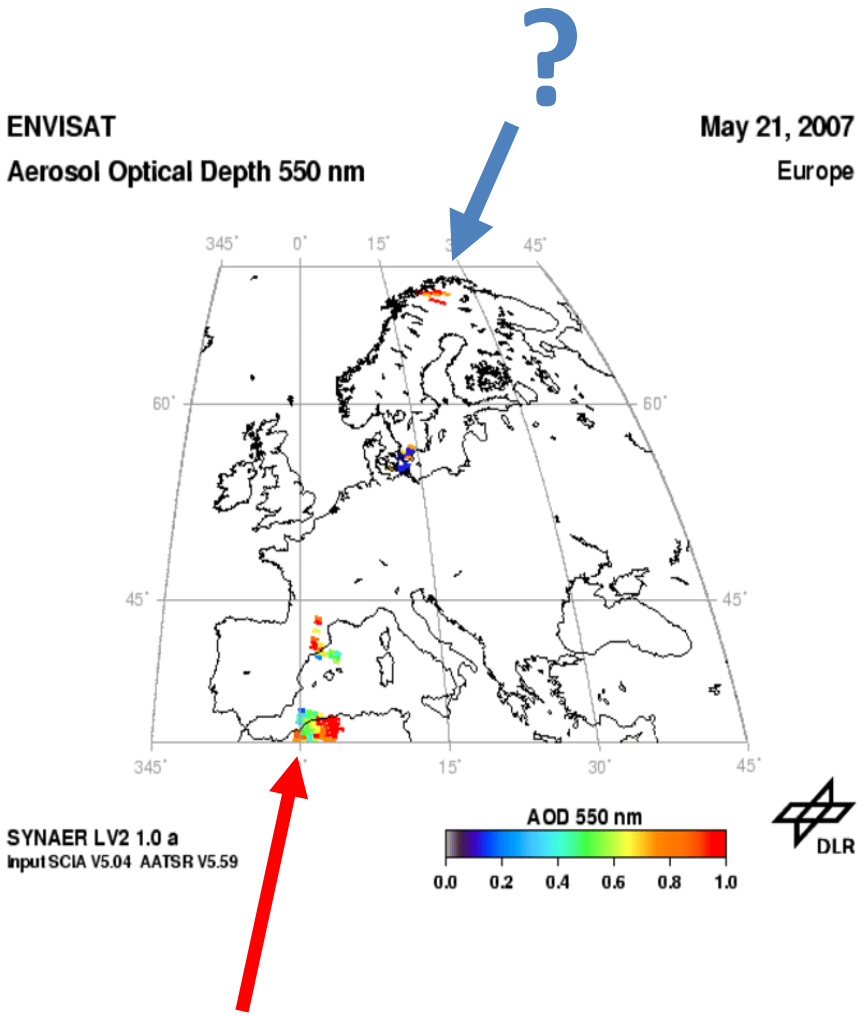
SYNAER aerosol speciation for May 03 2006



SYNAER – Saharian dust outbreak on May 21, 2007



MODIS RGB



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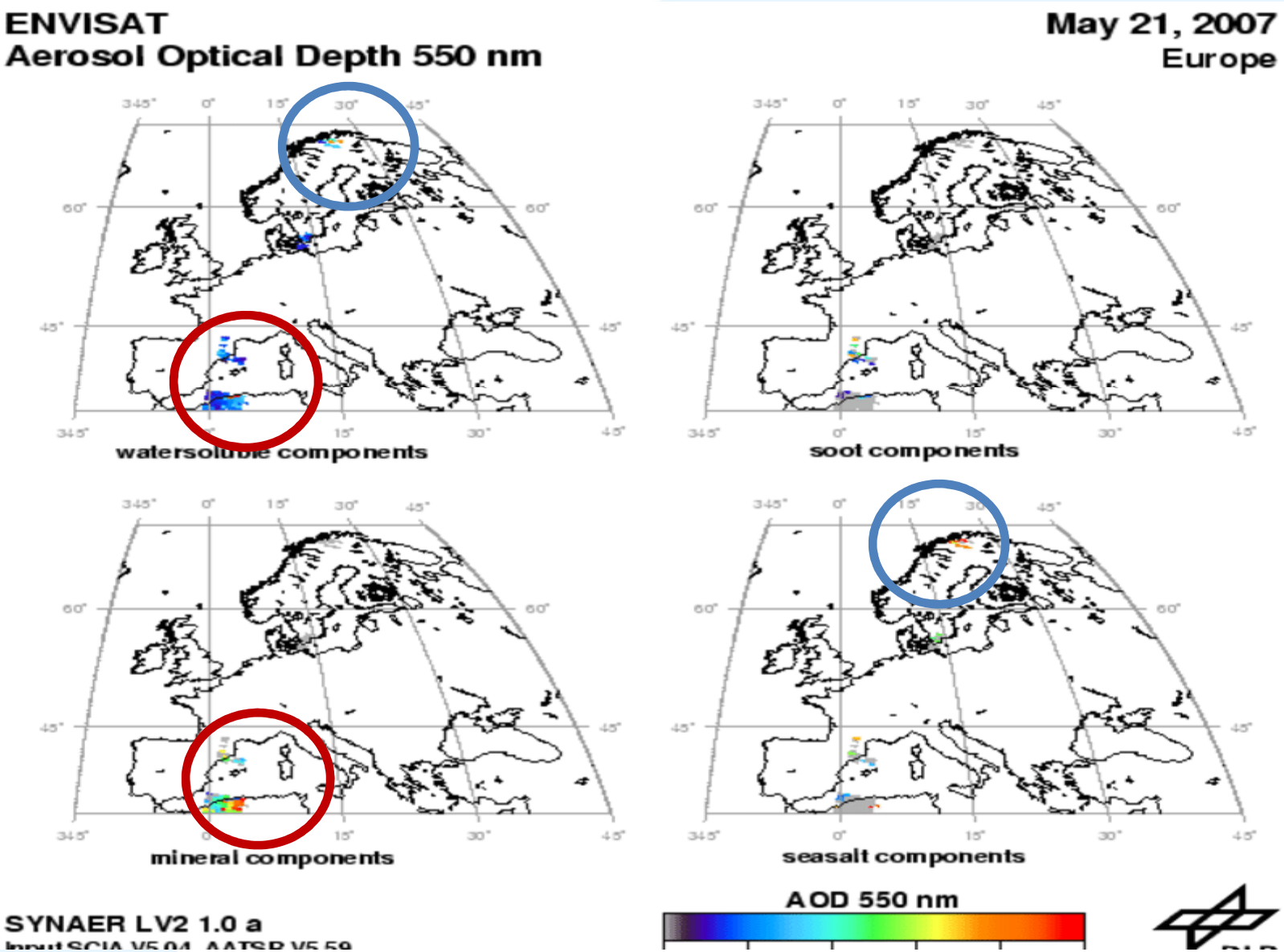
SYNAER aerosol speciation for May 21, 2007



SYNAER-EMEP correlation / bias (v2.2) (prel.!)

- Example comparison at EMEP stations
- SYNAER-EMEP correlation in 2006
- Monthly and summer means 2006 & 2007

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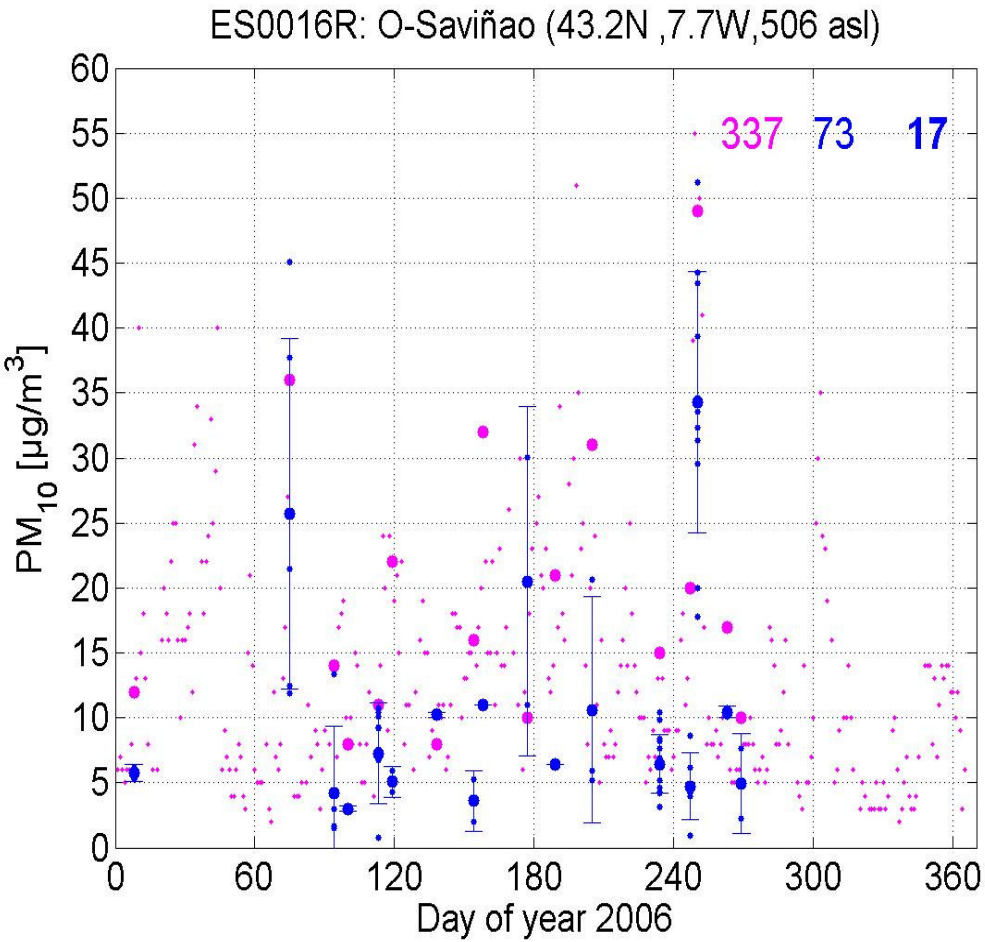

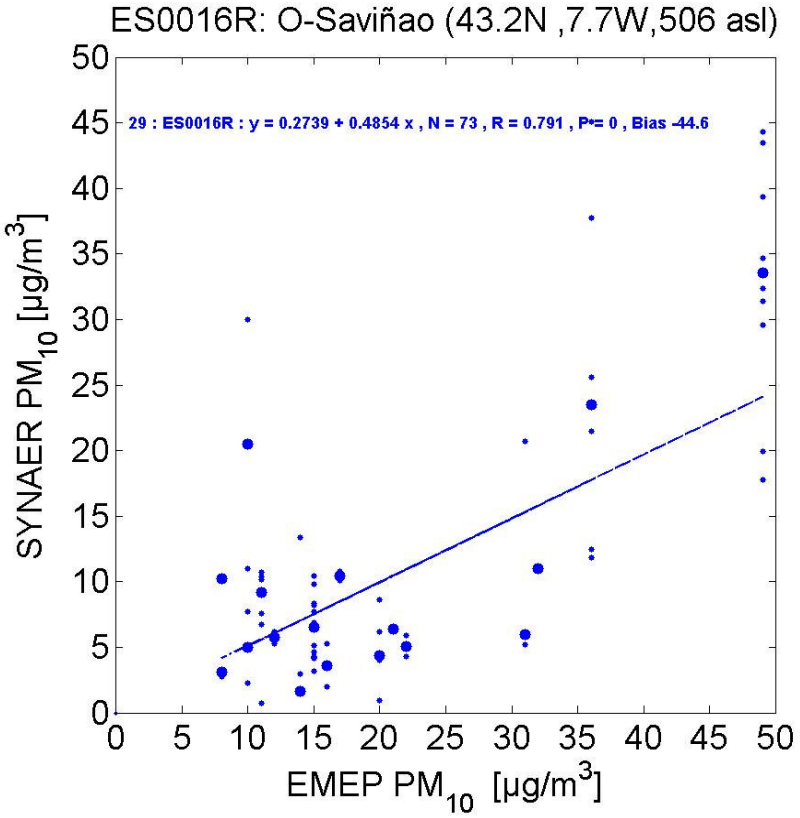

For O-Saviñoa (ES016R), the actual PM_{10} correlation is 0.79 (prev. 0.25) and a bias of -16% (prev. 23%), $PM_{2.5}$ correlation of 0.43 (prev. 0.18) and a bias of –42% (prev. -47%).

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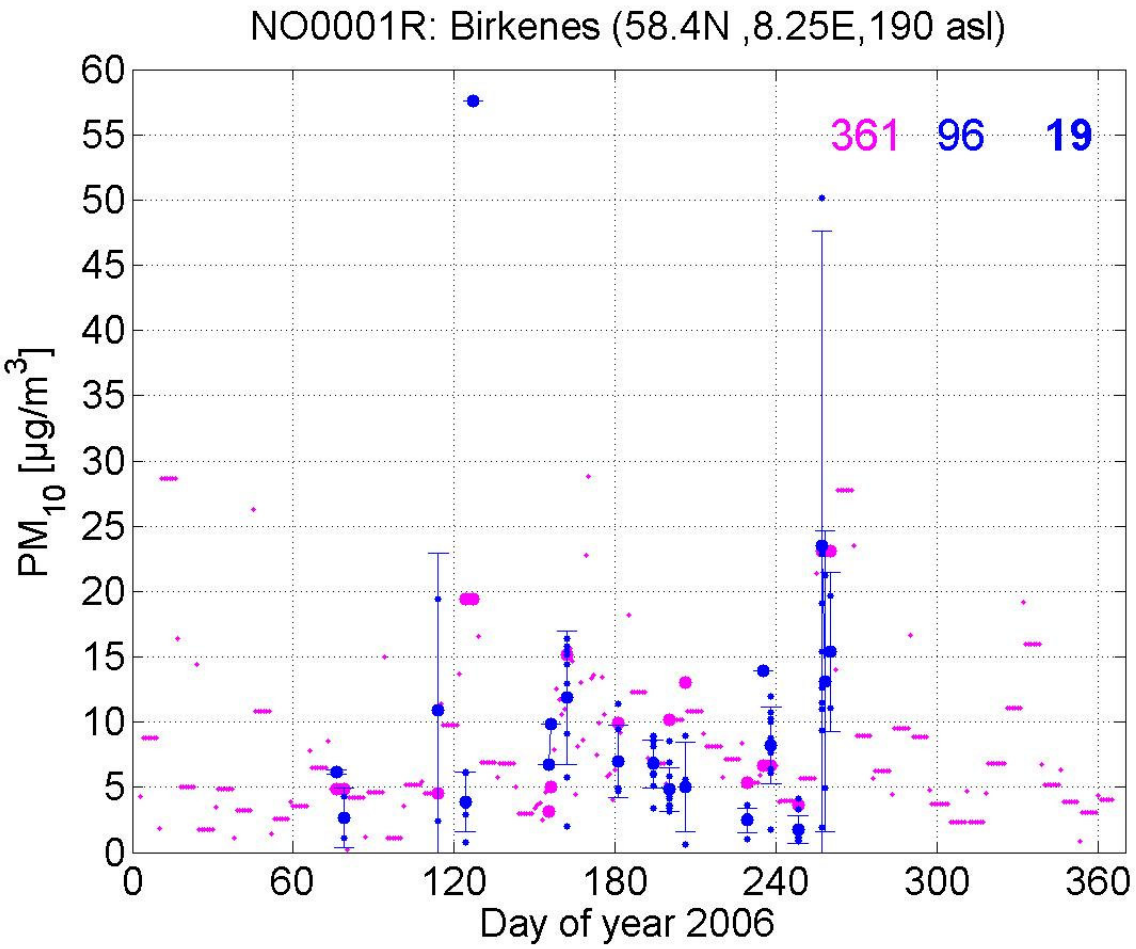

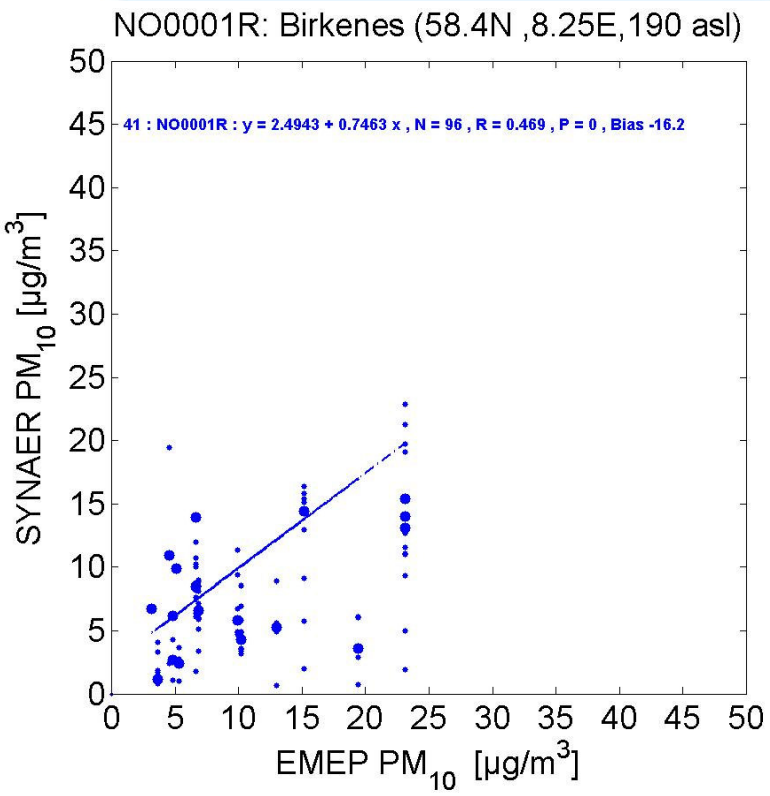

The EMEP filter measurements are performed in a 1-6days cylce

For Birkenes (NO001) we calculate a PM_{10} correlation of 0.47 (prev. negative) and a bias of -16% (prev. +88%), $PM_{2.5}$ correlation of 0.43 (prev. negative) and a bias of –3.7% (prev. +2%).

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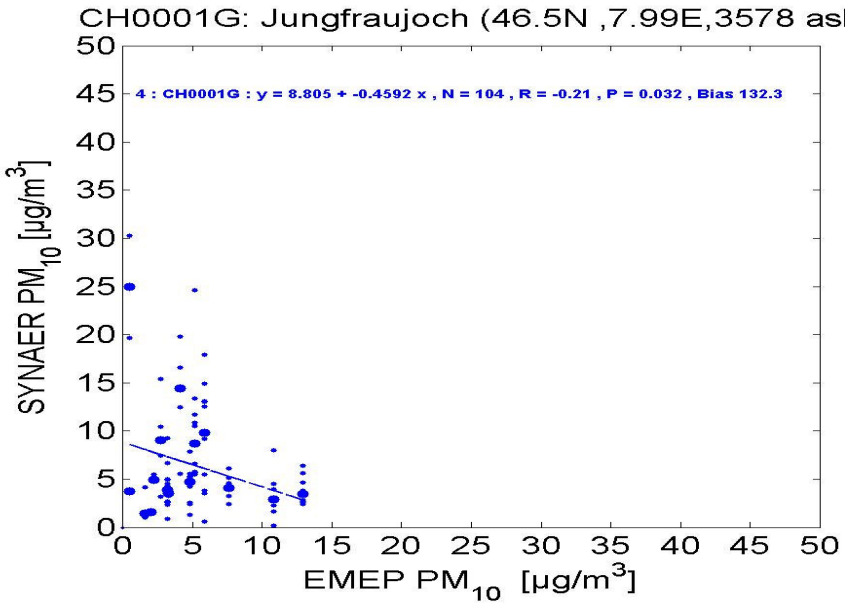
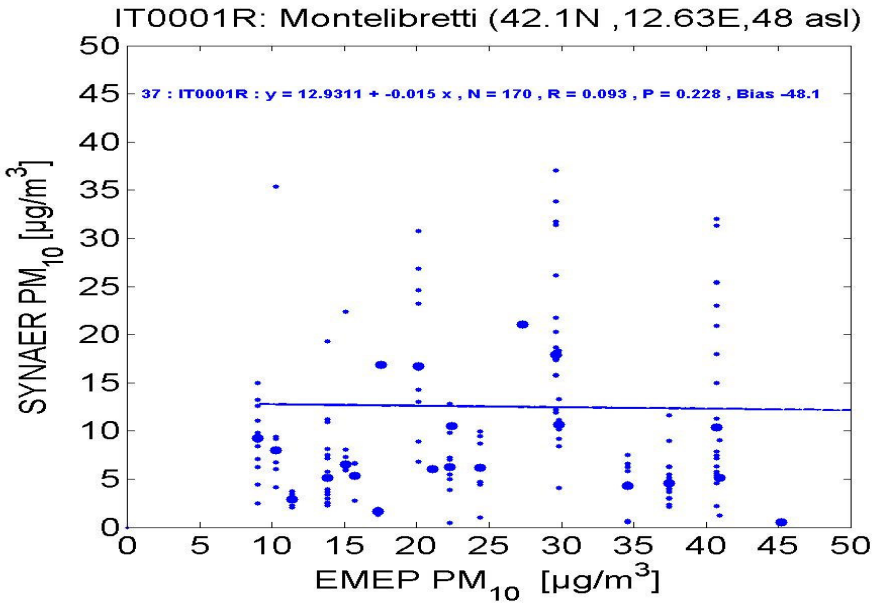
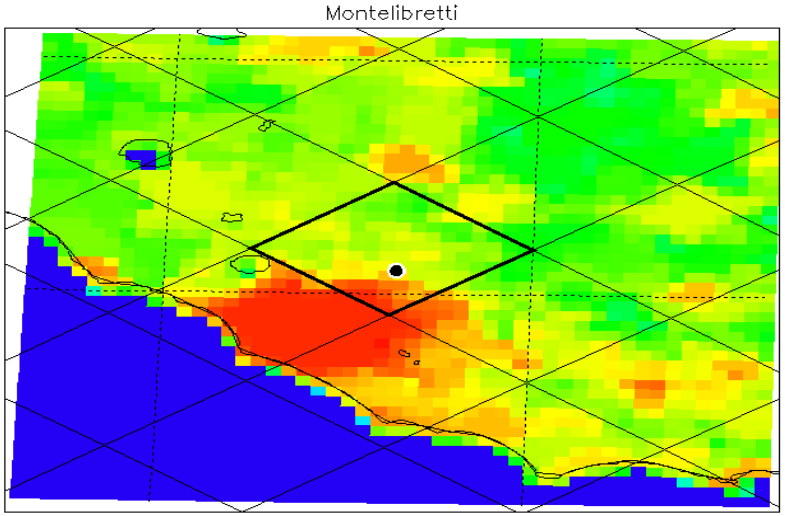
Lack of good correlation: expected ?





Jungfraujoch: high altitude station

Montelibretti: variable population density
land – ocean within 1 degree



from Sverre Solberg (NILU)

SYNAER-EMEP correlation / bias (v2.2) (prel.!)

PM_{10}

significant ($P < 0.05$) and positive correlation at 22 from 49 stations

Station	R	Bias	N_SYNAER
ES0016R	0.79	-45	73
ES0017R	0.69	-19	11
FI0017R	0.68	-19	128
PL0005R	0.53	-26	166
GB0006R	0.53	51	41
DE0001R	0.51	-3	74
CH0004R	0.49	-56	96
NO0001R	0.47	-16	96
NL0009R	0.47	-23	91
GB0043R	0.43	44	64
SE0012R	0.41	-5	98
GB0036R	0.40	-6	126
CH0002R	0.39	-65	92
ES0012R	0.32	-23	200
AT0048R	0.29	-57	87
AT0002R	0.27	-51	135
SE0035R	0.27	-12	82
ES0013R	0.25	-4	149
SI0008R	0.21	-45	162
DE0008R	0.21	-28	119
ES0014R	0.19	-24	138
ES0011R	0.14	49	280

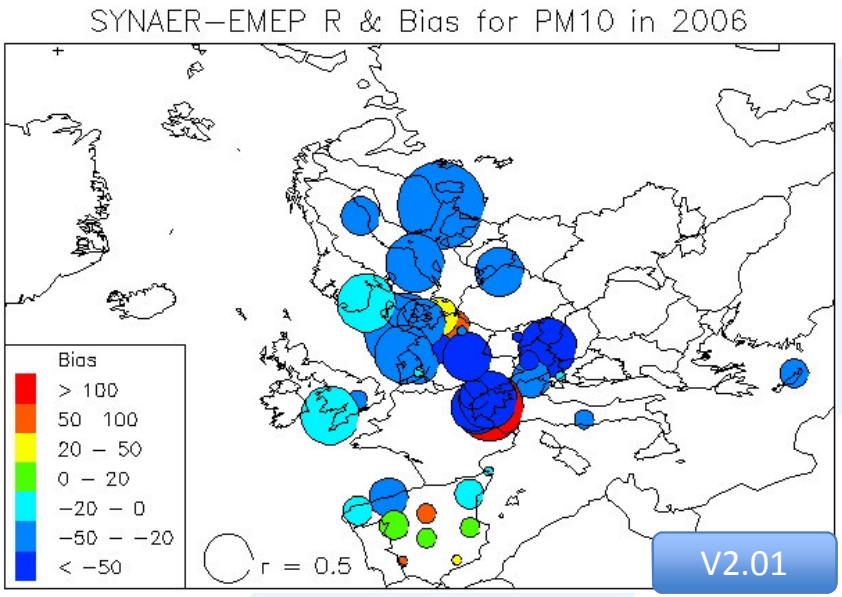
$PM_{2.5}$

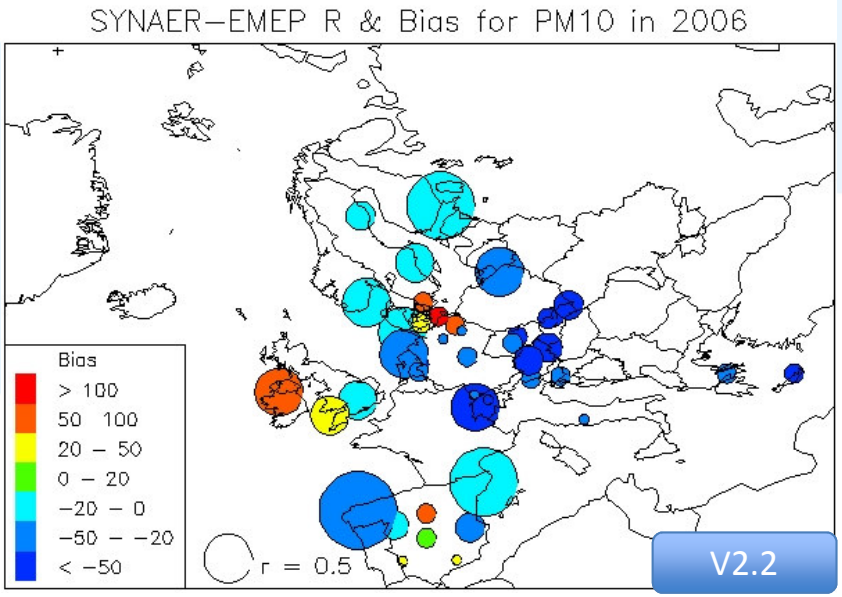
significant ($P < 0.05$) and positive correlation at 17 from 25 stations

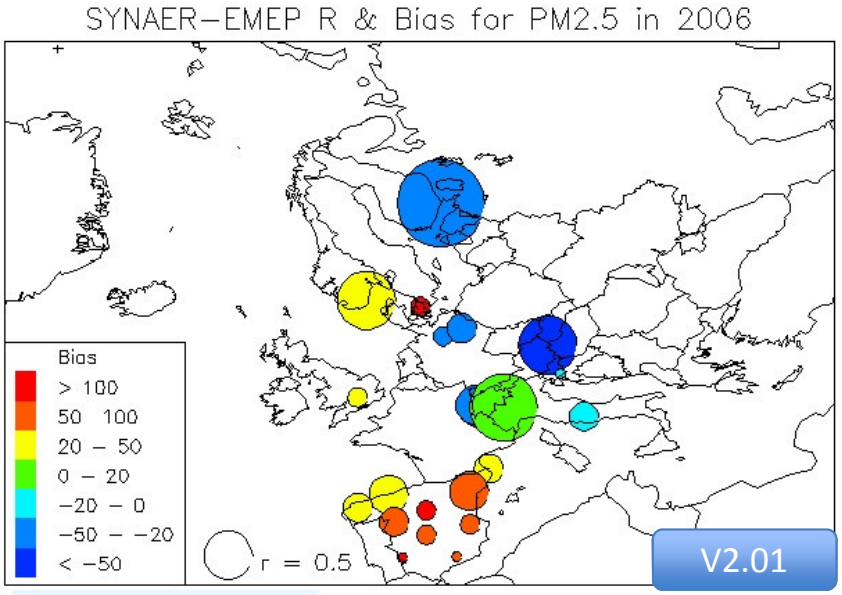
Station	R	Bias	N__SYNAER
ES0016R	0.773	-42.4	73
DE0007R	0.765	31	21
FI0017R	0.726	-35.1	73
SE0012R	0.46	-35.5	49
NO0001R	0.436	-3.7	96
GB0036R	0.435	33.7	126
IE0031R	0.42	47.4	51
ES0012R	0.354	-12.2	192
IT0004R	0.346	-19.8	139
CH0002R	0.333	-55.8	92
CH0004R	0.315	-46.6	96
AT0002R	0.314	-48.9	135
ES0011R	0.286	118.2	317
SE0011R	0.269	37	55
ES0014R	0.203	22.3	119
ES0010R	0.182	3.7	155
ES0007R	0.147	74	280

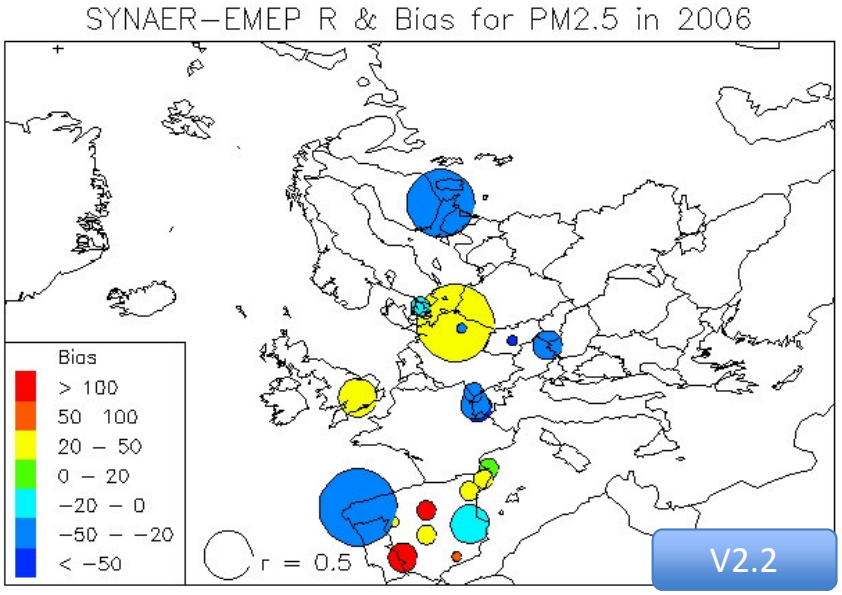
Data from 2006

SYNAER-EMEP correlation/bias (v2.01, v2.2) for data from 2006 (prel.)

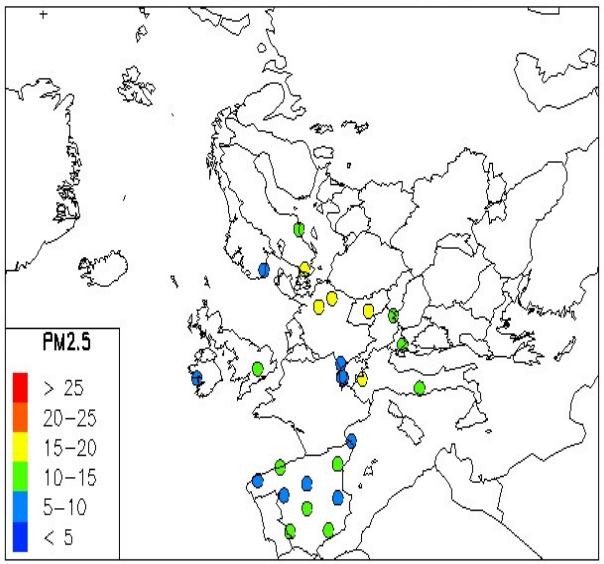


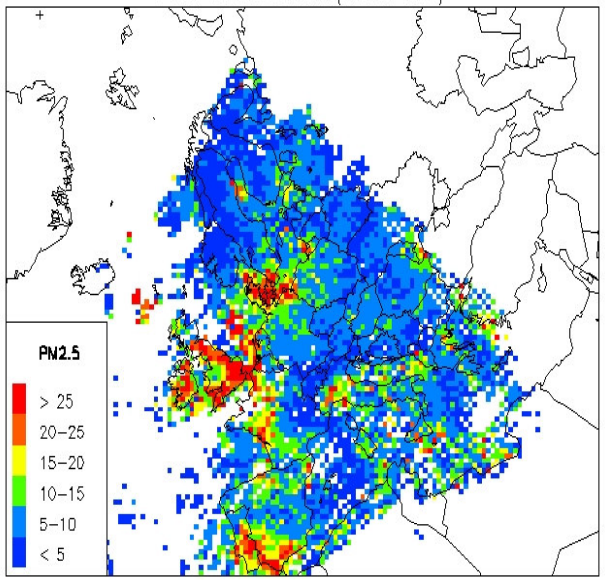


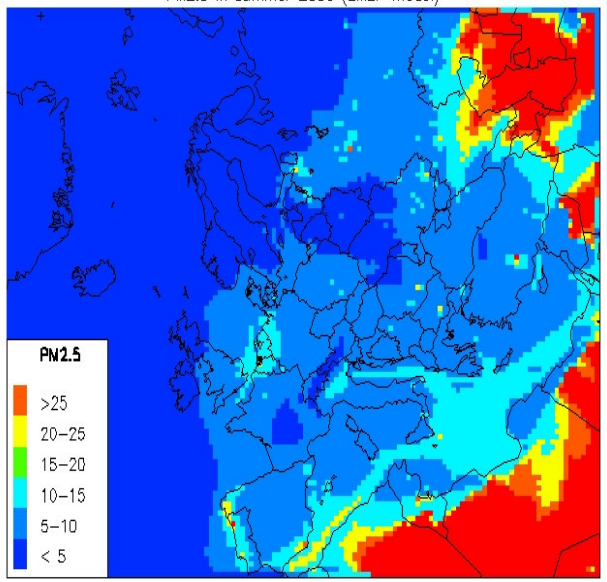


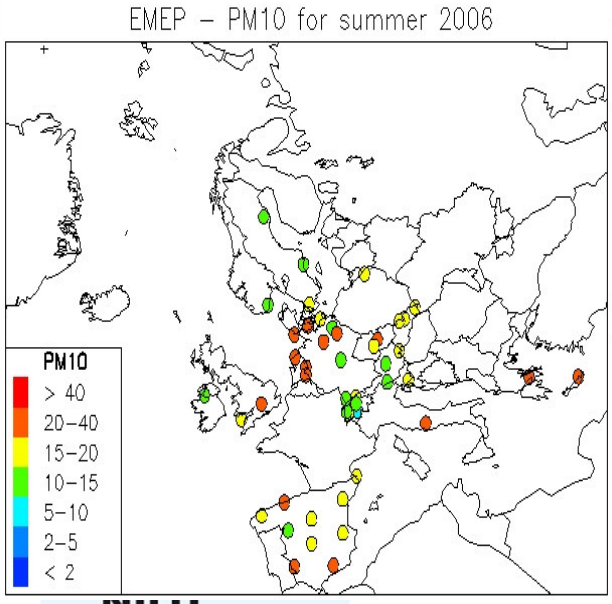


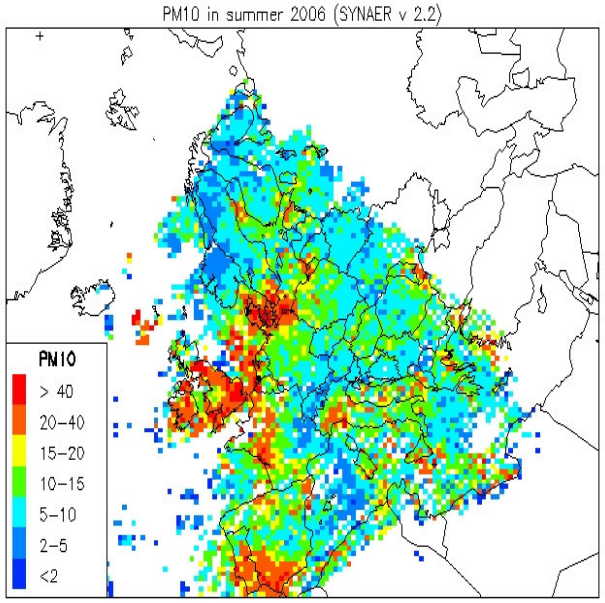
EMEP – SYNAER – EMEP modell – summer 2006

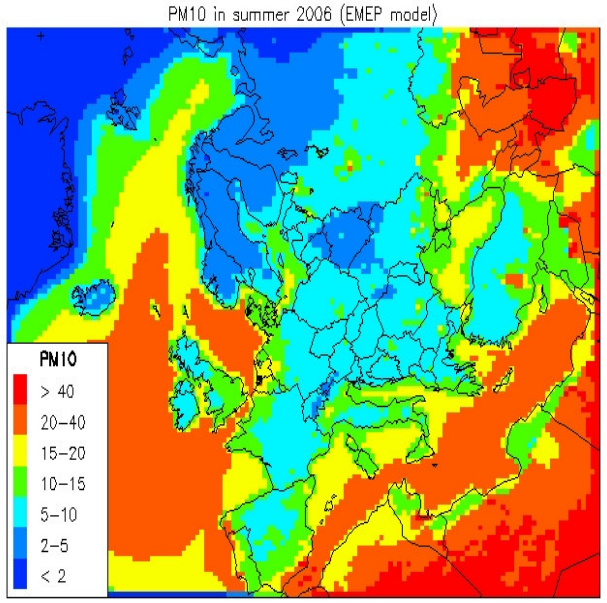












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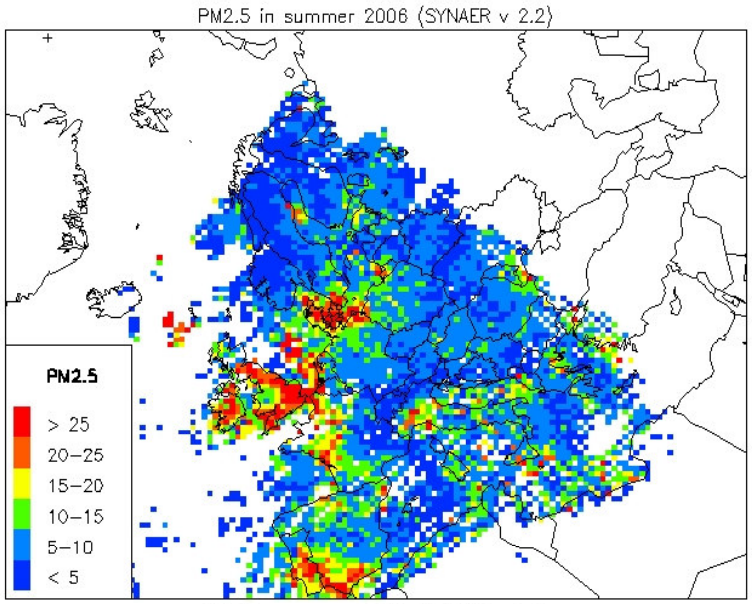
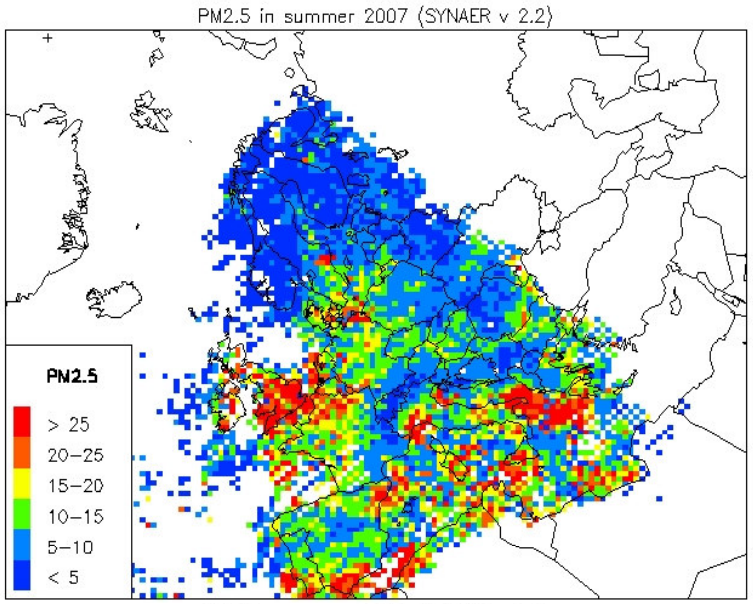
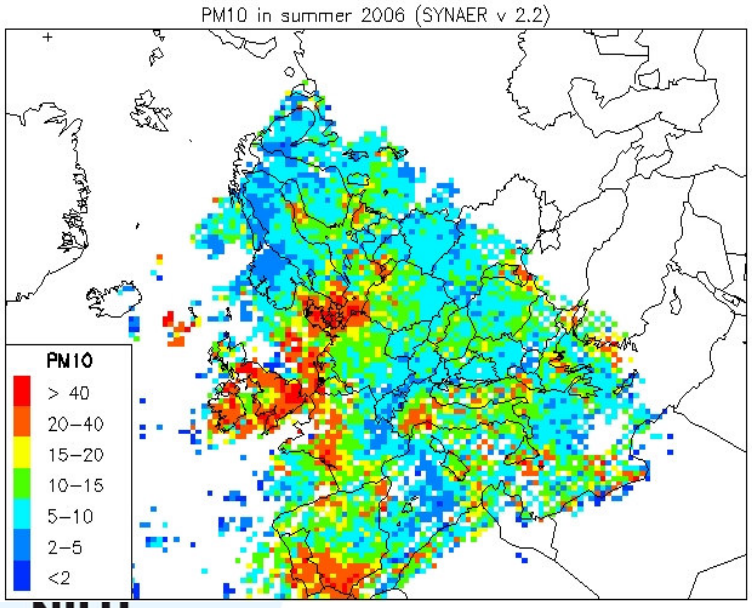
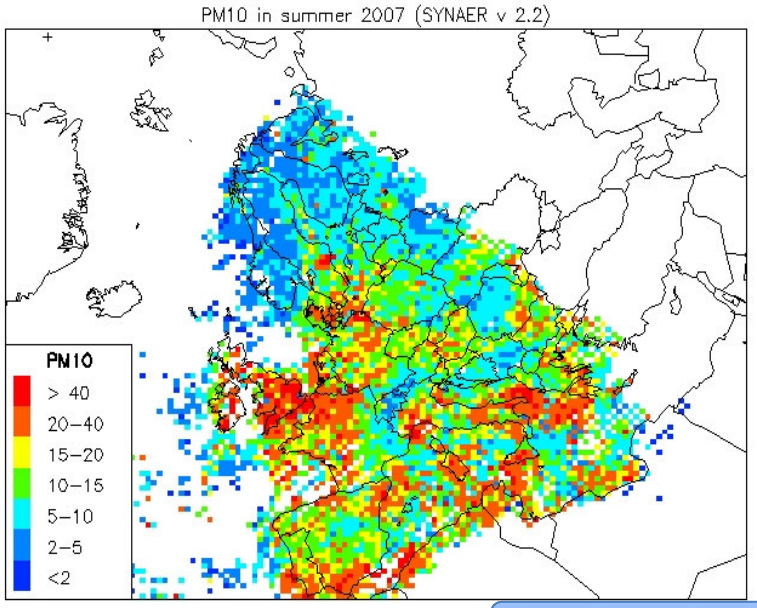
EMEP model

SYNAER-$PM_{2.5}$$PM_{10}$ summer 2006 -2007









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min: 5 data-points in 50x50 km

Towards a conclusion: Our main goal is to use the SYNAER product as supplement for EMEP regional AQ monitoring [not pure validation]

”Opening pandoras box”

How good can you expect satelitte products like SYNAER to get ?

What amount of correlation is already given by AOD-PM correlation ?

How does station representativeness affect the correlation/bias ?

How representative is a satellite pixel for region/site ?

Refinement of ’validation’ approach: 1hour-avg data from EMEP, AIRBASE (?)

aerosol type (use campaign data, EMEP-model)

Need:

Several years of data to estimate product stability (correlations/bias)

Improved temporal coverage / resolution!

[transformation of SYNAER retrieval to GOME-2/AVHRR (METOP)]

More advanced multi-sensor approaches(SYNAER+ IR sensors, profiling info)

Assimilated products

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Conclusions and Recommendations

- SYNAER are complementary to EMEP (remote areas, ocean)
- Clear improvements in performance vs EMEP data from v1.0 to v2.2 due to algorithm development, including better cloud masking and rejection of “bad” pixels over bright albedo sites and where spectral fit and AOD-errors are low
- Aerosol type information is useful for monitoring of special events
- SYNAER now (v2.2) is approaching sufficient quality for operational use for EMEP reporting
- Close interaction between satellite data provider and data user is beneficial – such cooperation should be encouraged by space agencies for current and future missions

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Acknowledgements

Thanks to ESA, Norwegian Space Centre and UN-ECE for funding

Multumesc !

Takk !

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