Usage of Satellite Aerosol Information for Environmental Reporting

SYNAER data applied for regional scale air quality assessments in Europe through EMEP

Kerstin Stebel, Aasmund Fahre Vik, Ann-Mari Fjæraa and Mona Johnsrud, NILU, Kjeller, Norway

Thomas Holzer-Popp, Marion Schroedter-Homscheidt and L. Klüser, DLR, Wessling, Germany

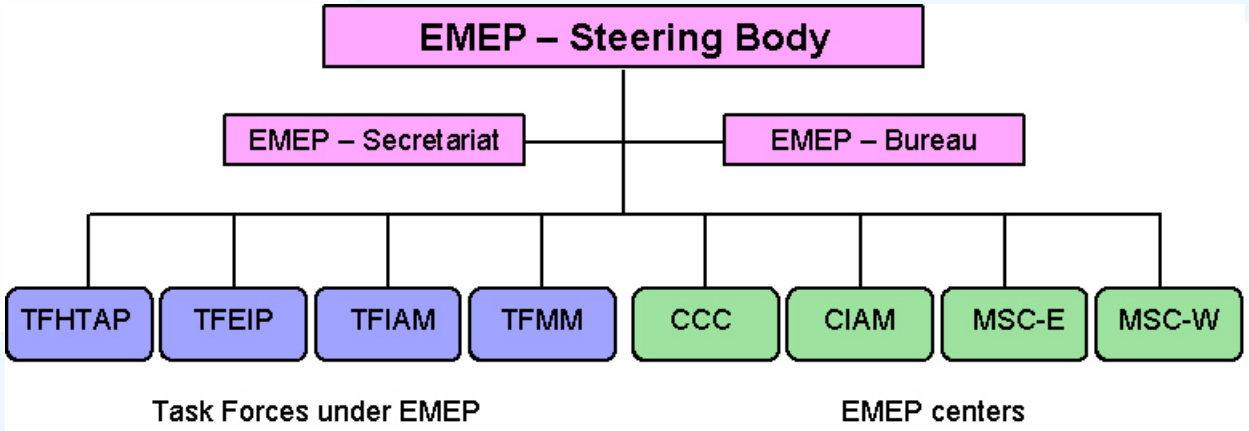
NILU

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
  - Validation against EMEP surface measurements and EMEP model
  - Use and validation of aerosol speciation information
  - Using data for yearly reporting to EMEP steering body
- Conclusions and recommendations

NILU

The Convention for Long-Range Transport of Air Pollution



The EMEP programme 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.

NILU

European Monitoring and Evaluation Programme - EMEP

- **Convention on Long-range Transboundary Air Pollution**
- **Funded through UN-ECE since 1979**
- **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)**

NILU

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

NILU

EMEP monitoring strategies

- *The 4th draft of* **EMEP monitoring strategy 2010-2019**

  EMEP observations should contribute to the Global Earth Observation System of Systems (GEOSS). EMEP observations and monitoring sites are particularly well suited to serve as complementary sources of data to air- and space borne remote sensing instrumentation, and it is expected that satellite data will towards the end of the coming strategic period provide essential information to address the air pollution situation across the EMEP domain. The capabilities of remote sensing capacities will still strongly rely on reliable data for calibration and validation which EMEP observations partly will offer.

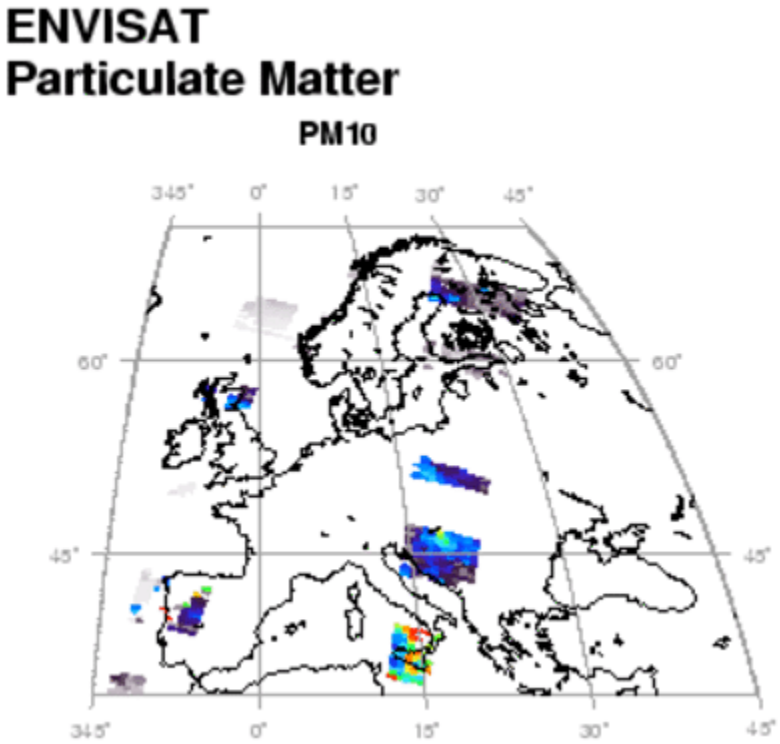
- **EMEP monitoring strategy and measurement programme 2004-2009**

  … In the future, remote sensing from satellites might become an integral part of a network where ground-based stations and remote sensing complement each other. …

NILU

The SYNAER (SYNergetic Aerosol Retrieval) data product

- The SYNAER 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
  - Spectrometer used to estimate aerosol composition
  - Surface levels of PM10, PM2.5 and PM0.5 given for cloud-free pixels on SCIAMACHY-grid



NILU

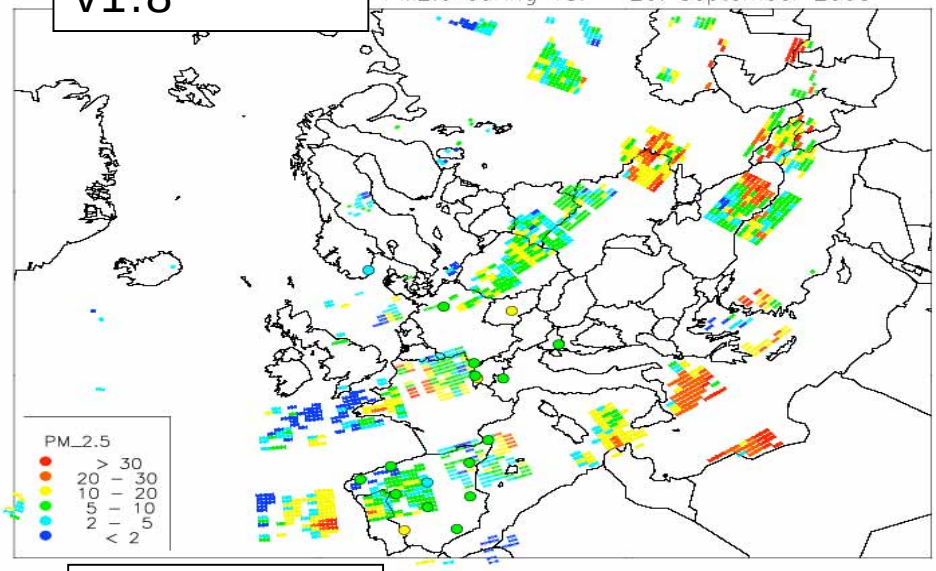
Evaluation of SYNAER product

- Compare SYNAER data with EMEP particulate matter (PM_{10}, $PM_{2.5}$, $PM_{1.0}$) and chemical specification
- The EMEP network provides daily averaged data, typically for rural background sites
- Compared with satellite 60x30 km2 “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): Refined criteria for selection of good/bad pixel - currently being produced by DLR and validated by NILU

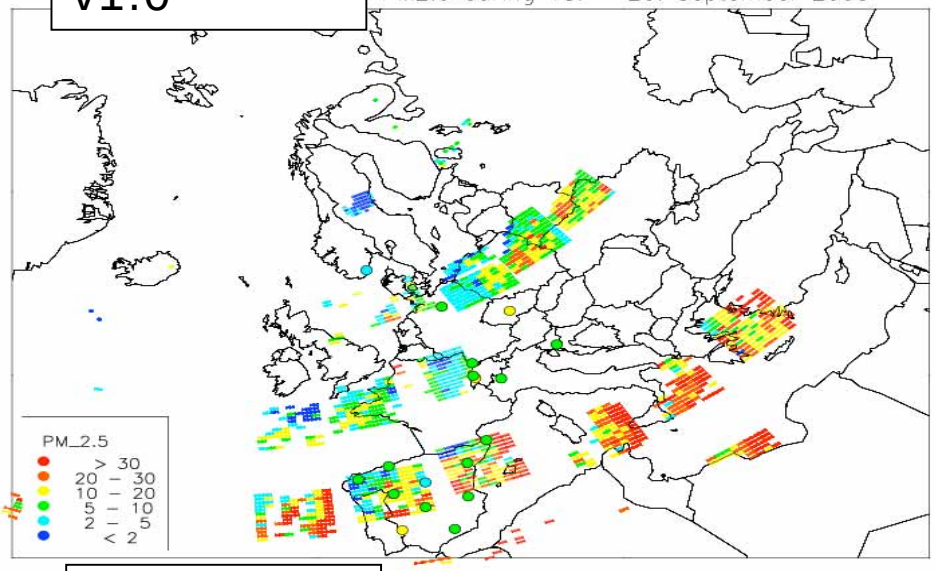
NILU

SYNAER v1.8 vs v1.0 (&EMEP)

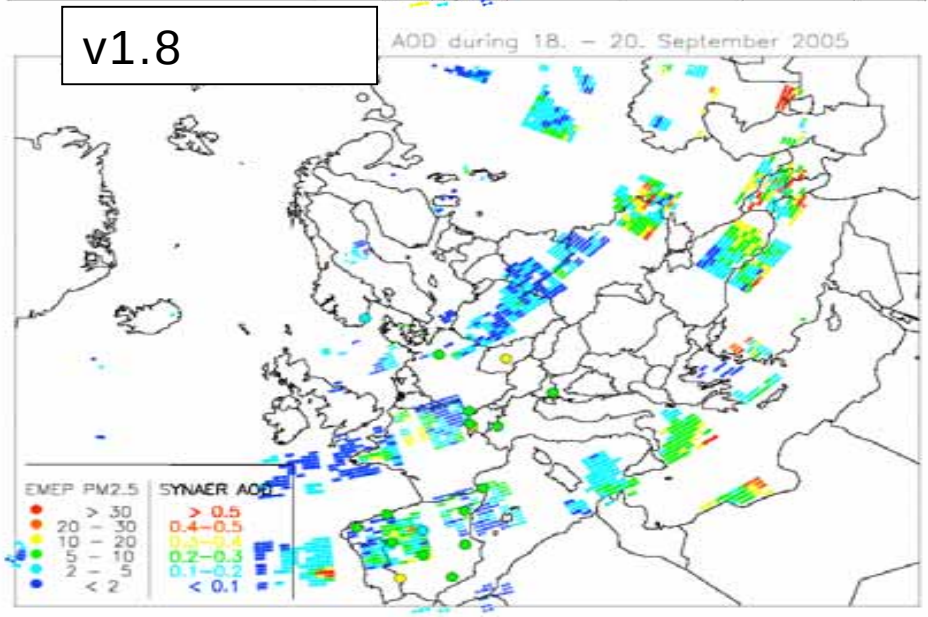
v1.8



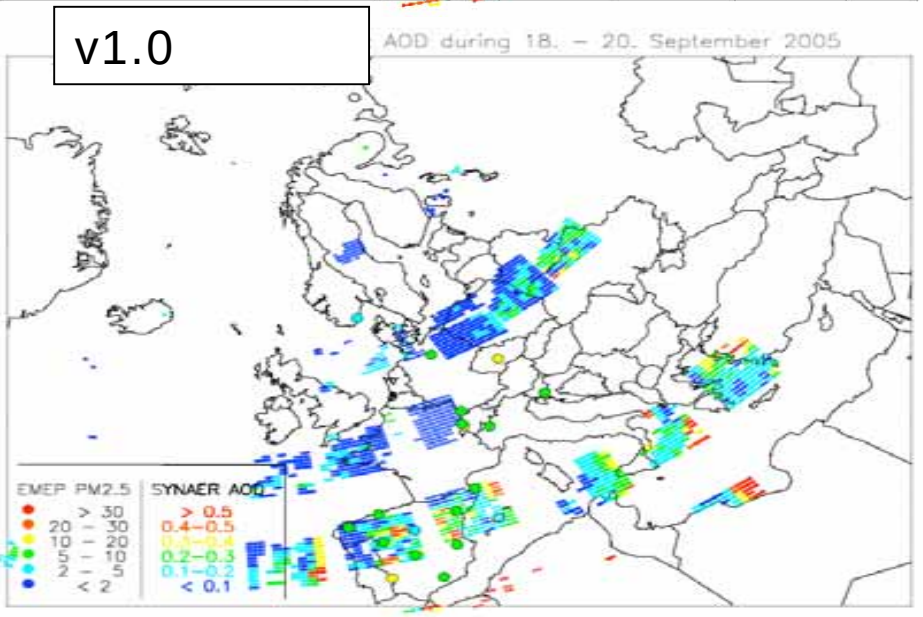
v1.0

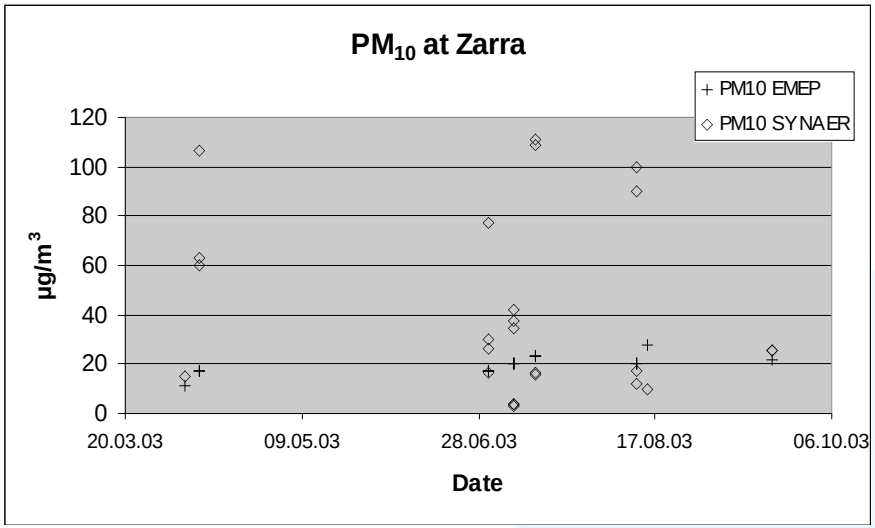


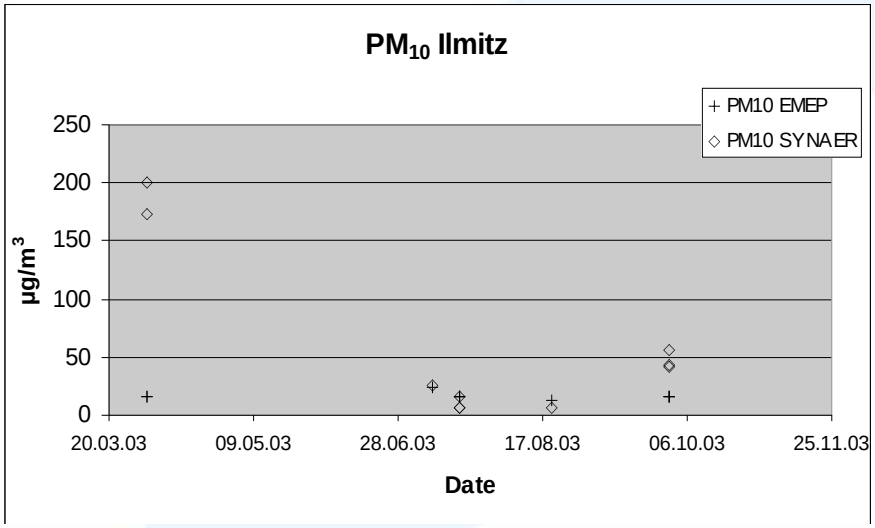
v1.8

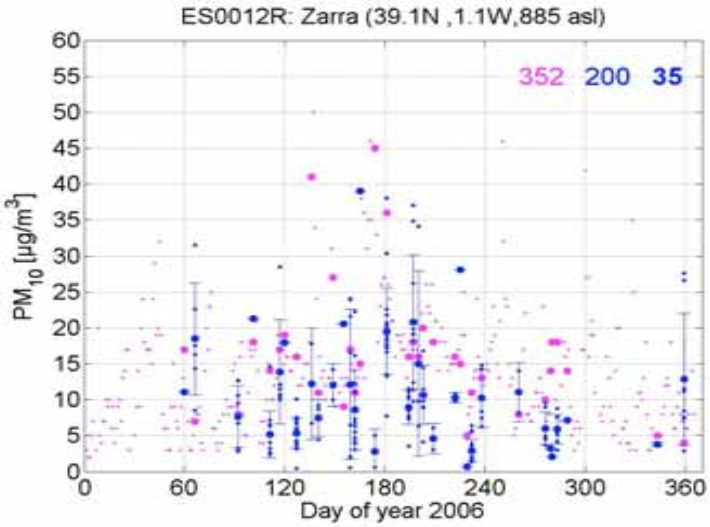


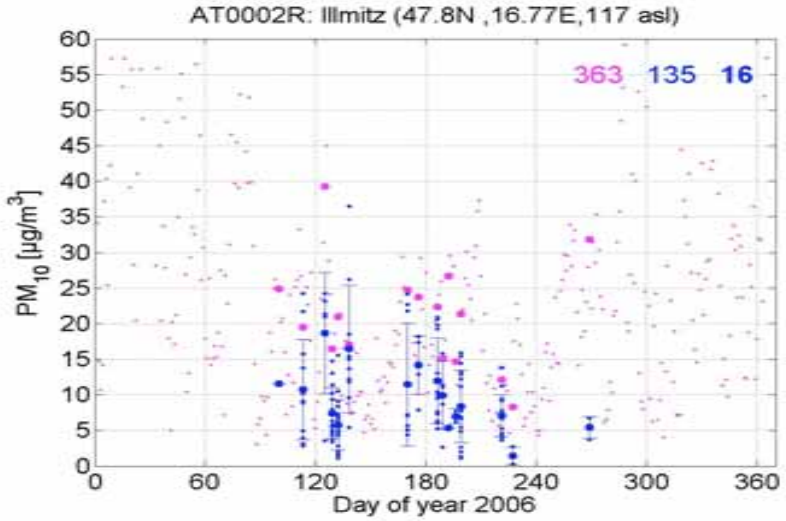
v1.0











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

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

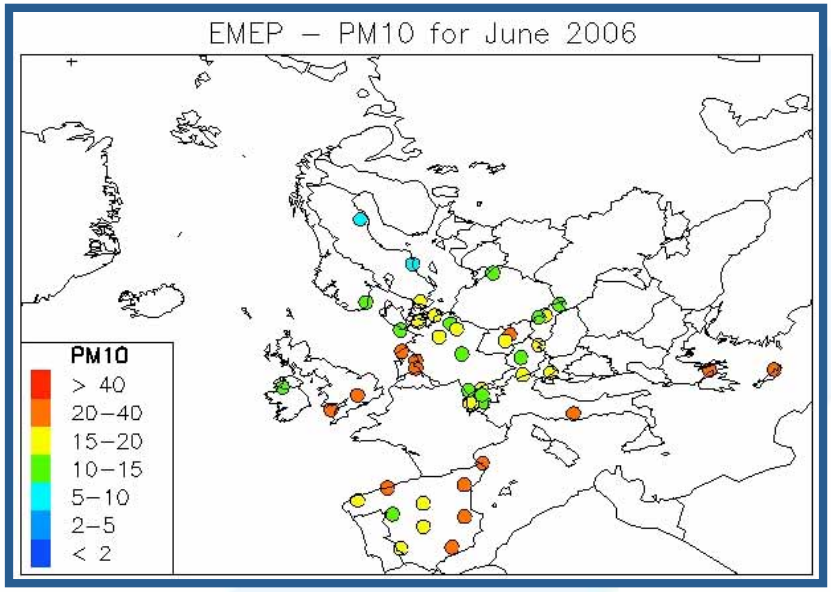
Version 2.2 (prel.)

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

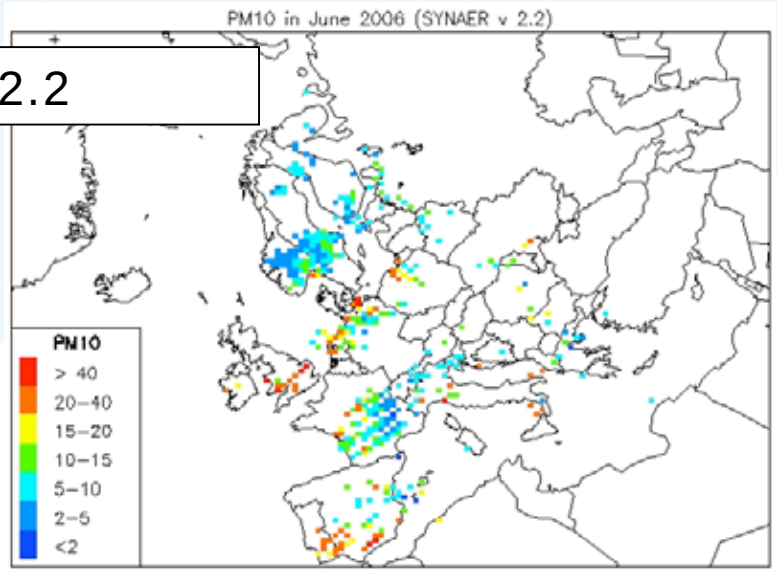
Bias at Zarra = -23 % , Bias at Illmitz -51%

NILU

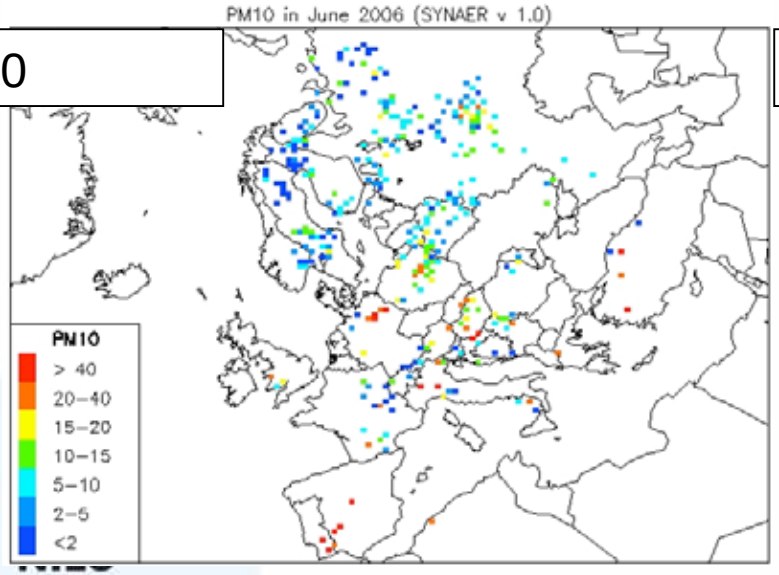
Monthly Means of PM_{10} June 2006 – 3 versions



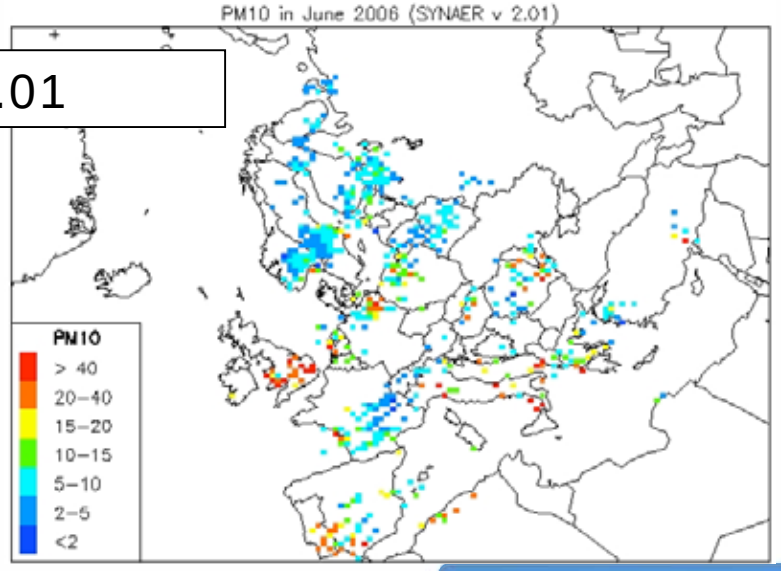
V2.2



v1.0

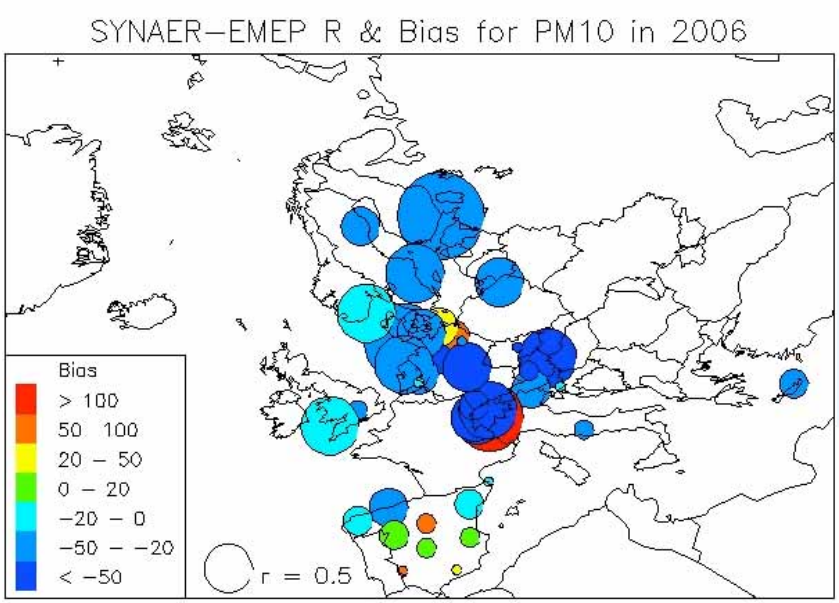


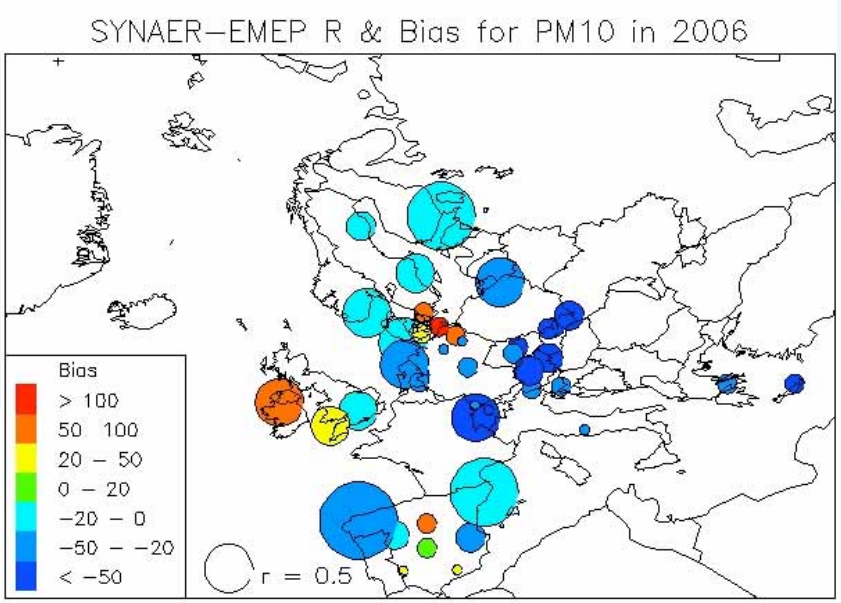
V2.01

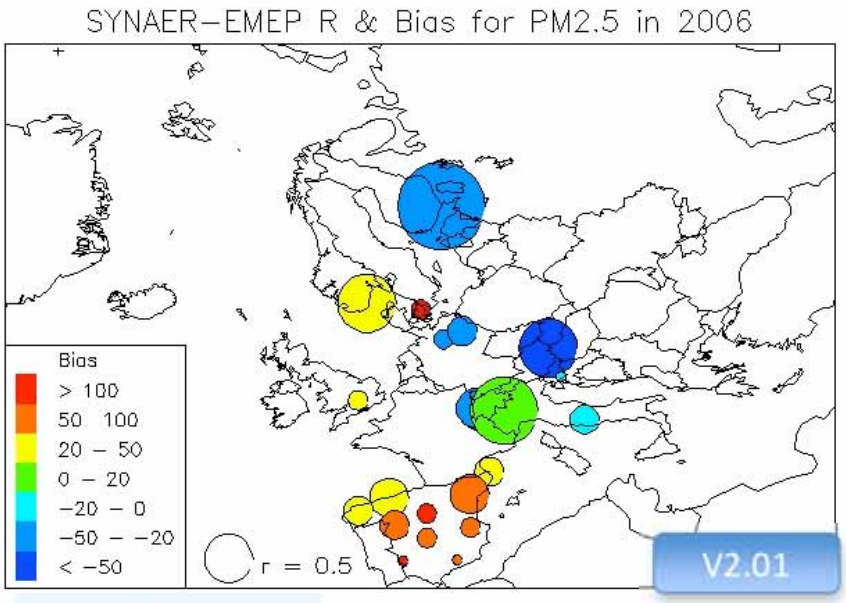


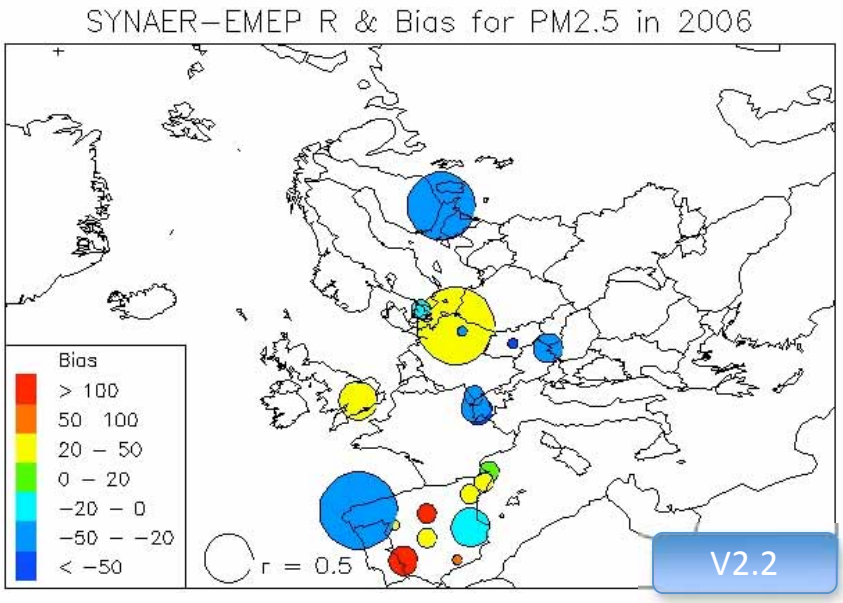
min: 5 data-points in 50x50 km

SYNAER-EMEP correlation/bias (v2.01, v2.2) (prel.!)

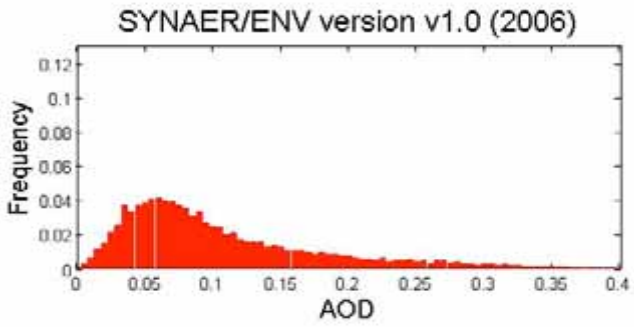


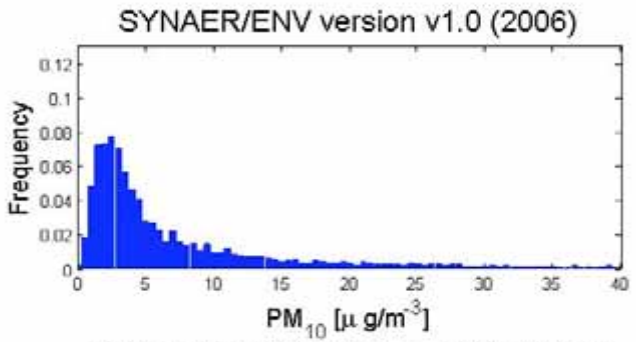


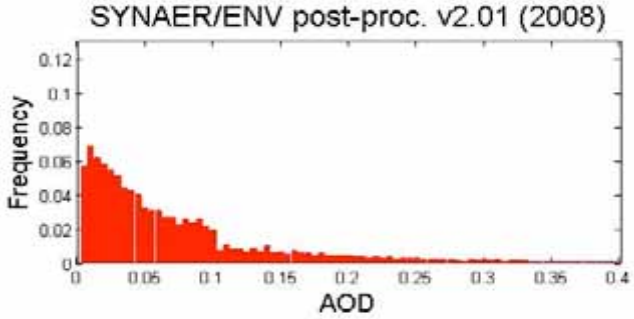


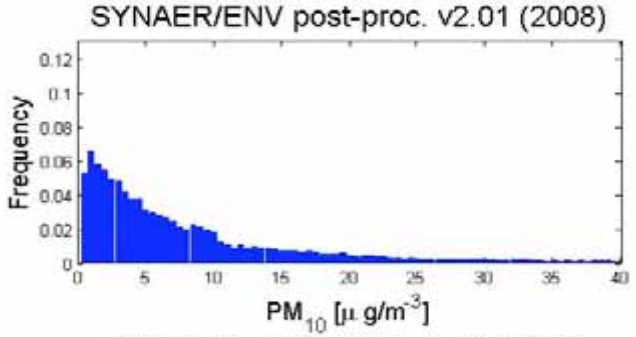


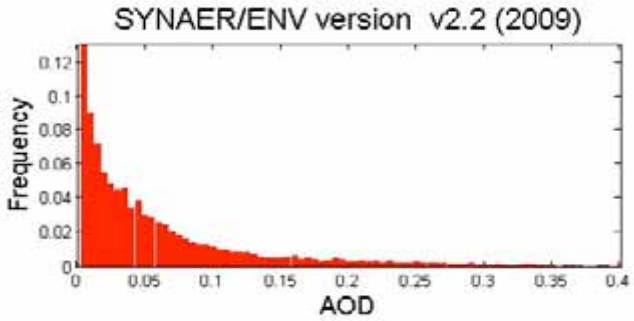
SYNAER/ENV v1.0, v2.01 and v2.2 -the same raw-data from 2006

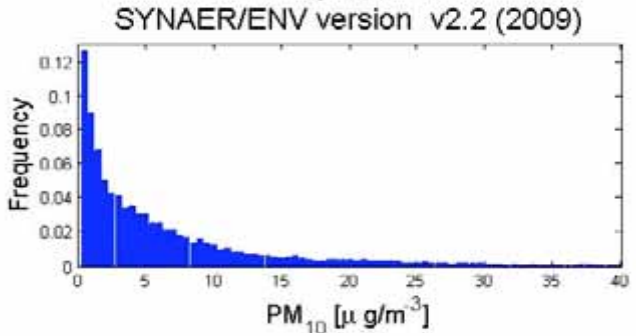






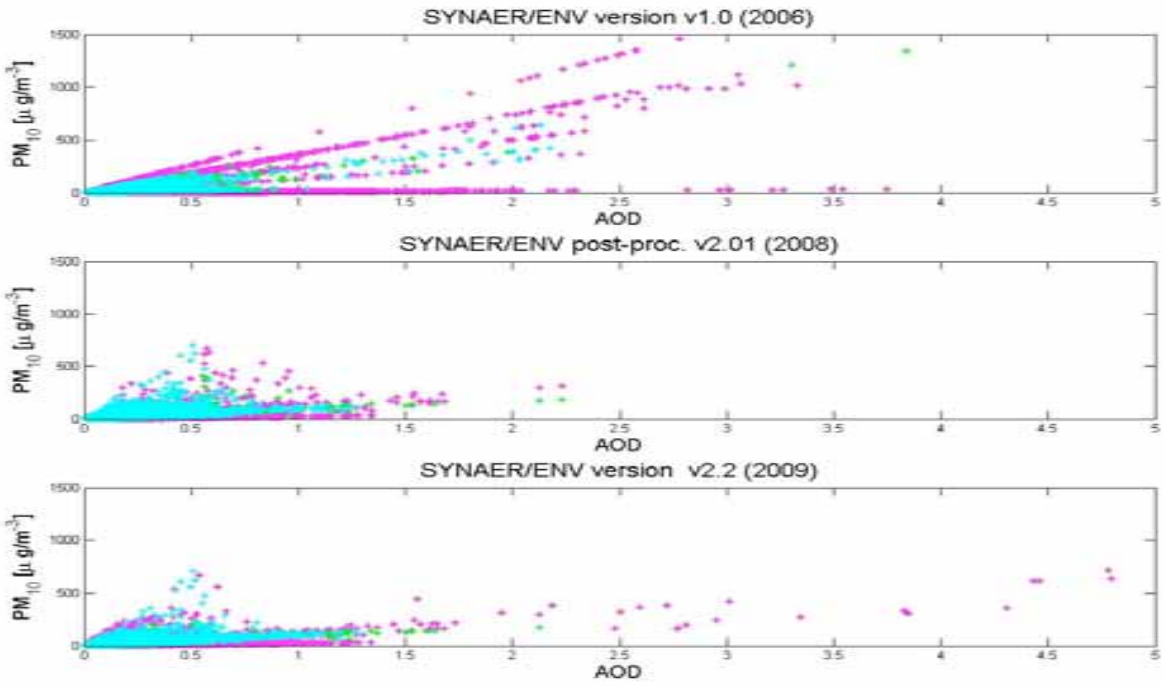






NILU

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

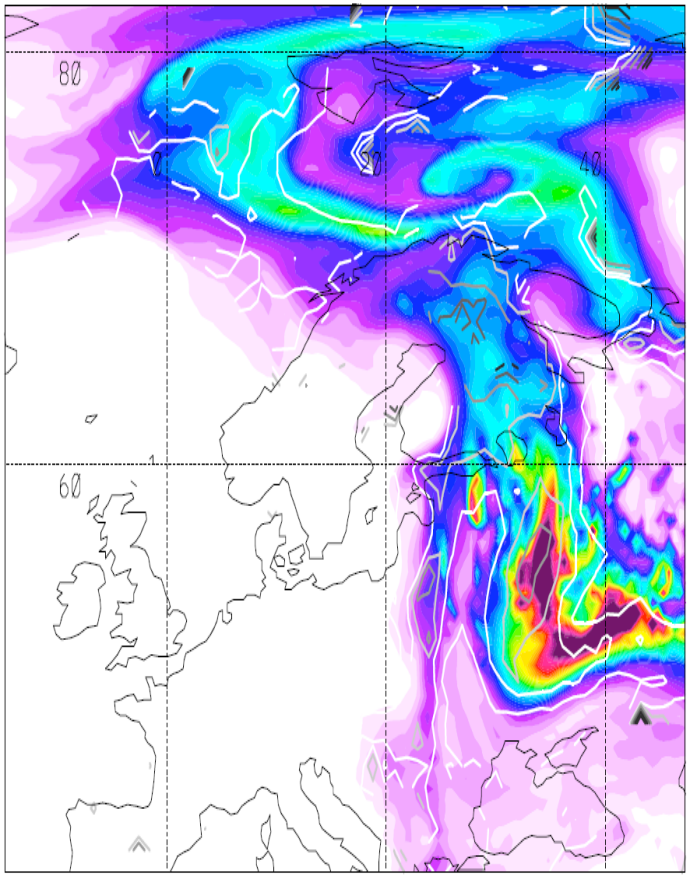
Refined selection criteria for good pixel in v2.2 (2009): xerr <= 0.02, aod550_error <= 0.14, lalb670 < 25.0 and fcl <0.35

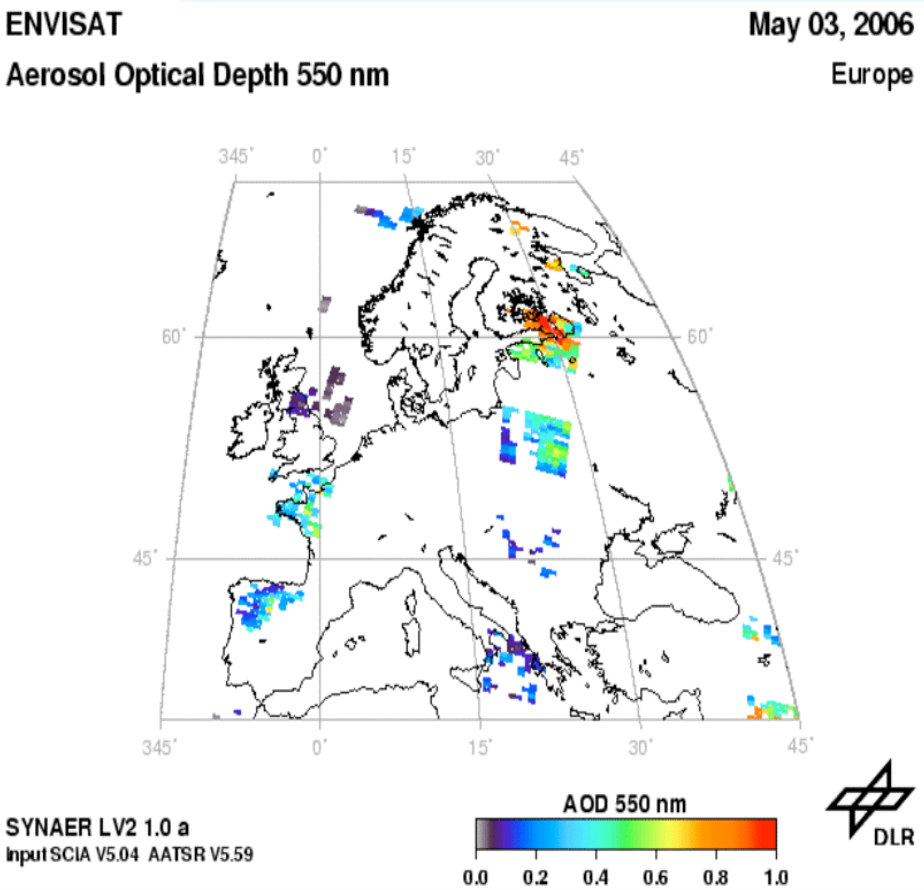
Aerosol speciation information

- Biomass burning and transport event
- Saharan dust storm and possible transport to Norway

NILU

Example of SYNAER aerosol speciation



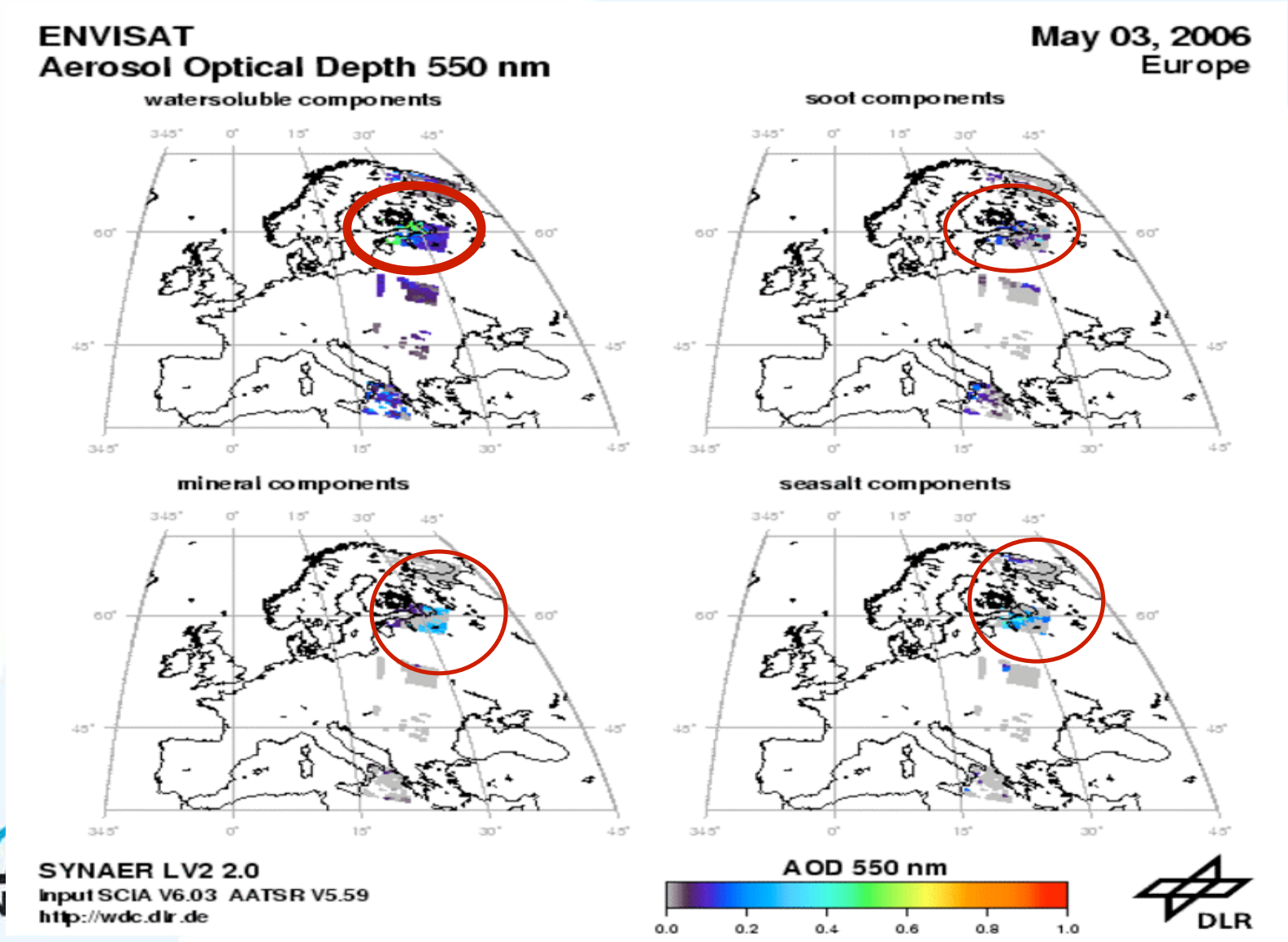


Right: Daily SYNAER results (AOD at 550 nm) from 3 May 2006. Clearly enhanced values over southern Finland can be seen, resulting from agricultural fires in Eastern Europe/western Russia.

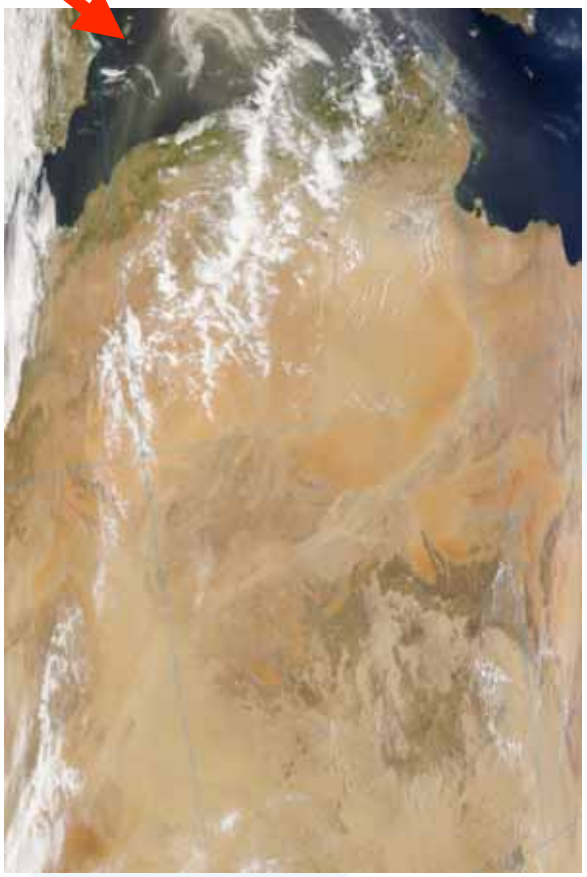
Left: Total columns of FLEXPART BB CO tracer at 9–12 UTC for 3 May 2006. Superimposed: 0.3, 0.5, 0.7, 1.0, 1.5, and 2 AOD isolines (white - dark gray) of daily MODIS Terra Level-3. (from Stohl et al, ACP., 2007).

NILU

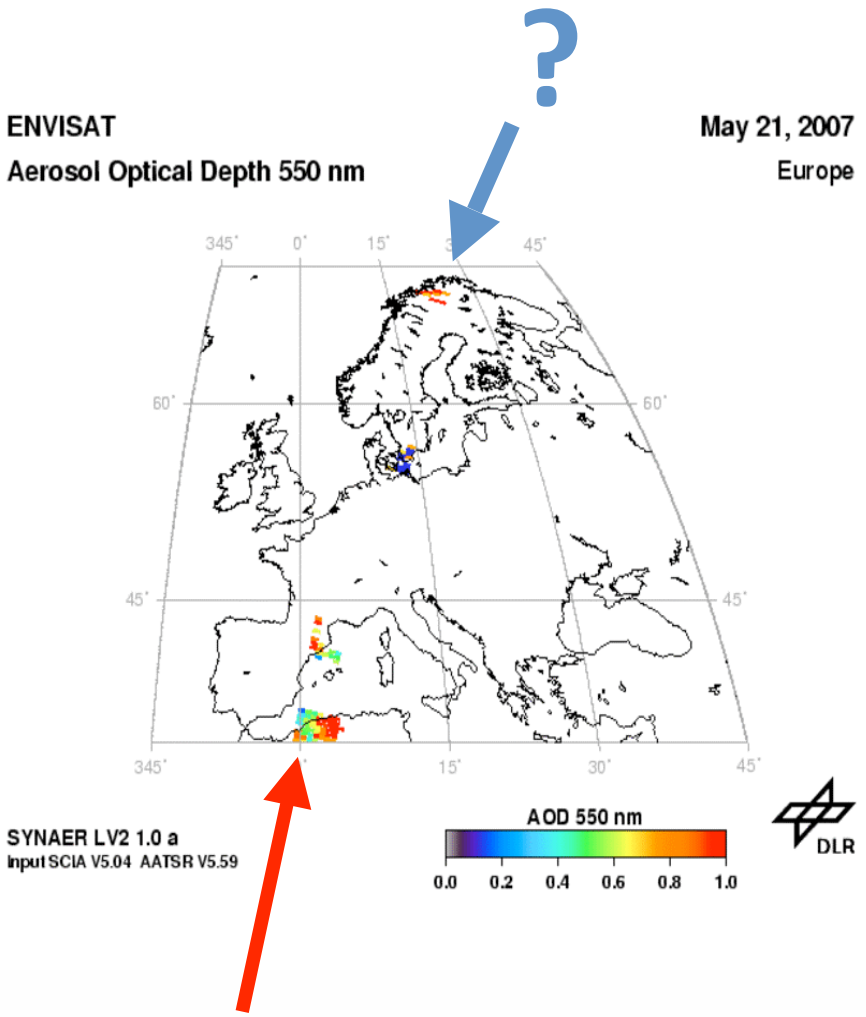
SYNAER aerosol speciation for May 03 2006



SYNAER – Saharian dust outbreak on May 21, 2007

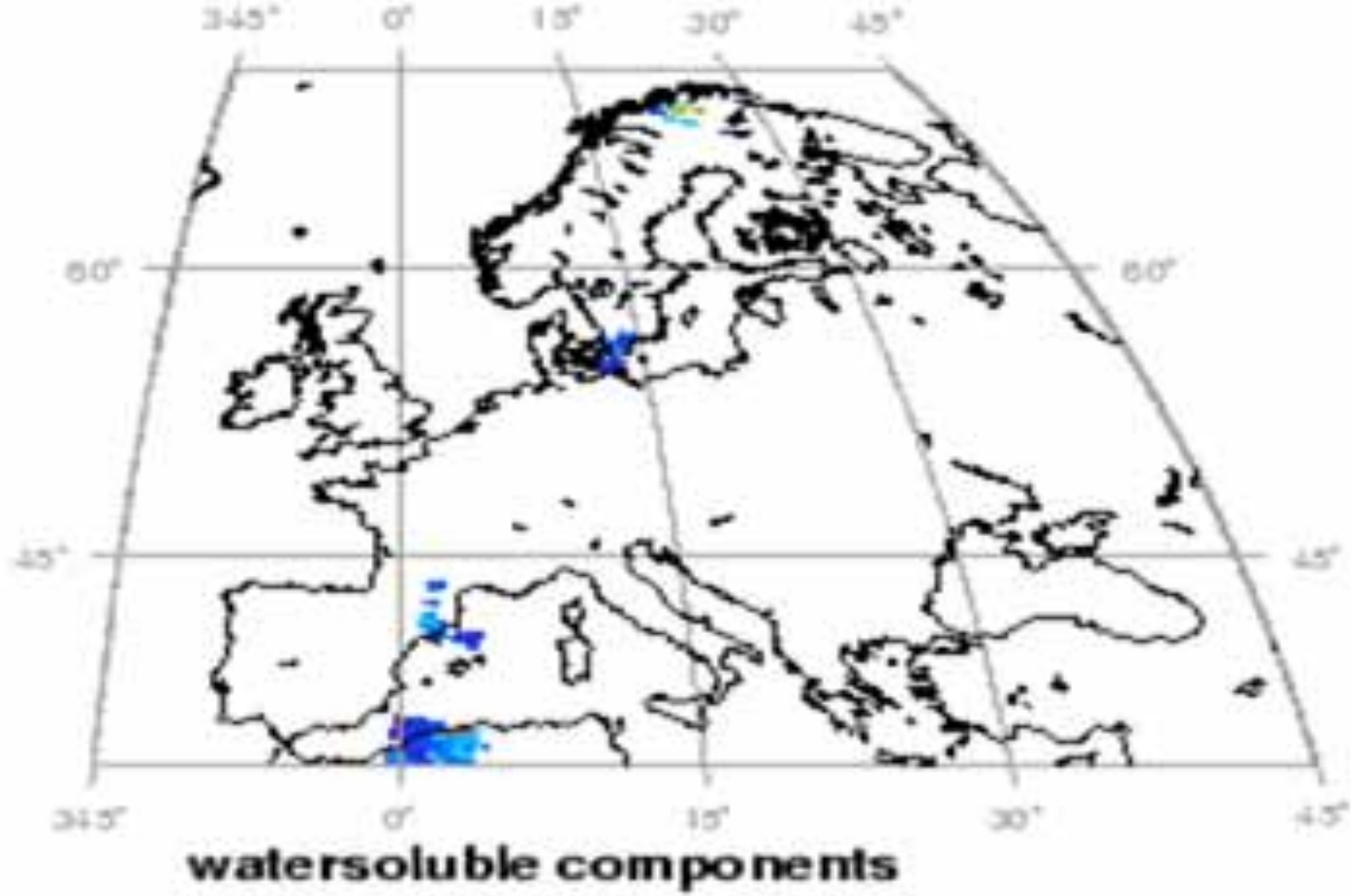


MODIS RGB

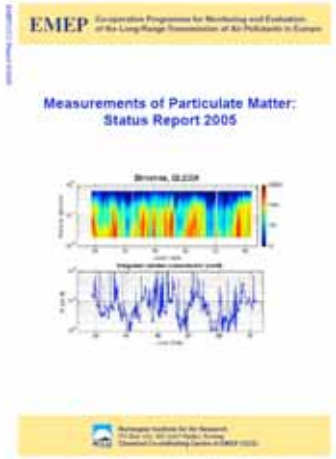


NILU

SYNAER aerosol speciation for May 21, 2007



Reporting to EMEP steering body

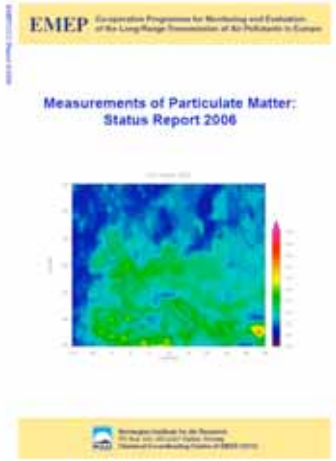


- Chapter 6. European aerosol optical depth measurements from ground and space (2005)

  ATSR-2 retrieved spatial distribution of aerosols over Europe

  Synergetic ENVISAT aerosol optical depth and type

  Satellite part written mainly by data provider: AOD + early type classification



- Chapter 6. European aerosol measurements from space (2007)

  Aerosol Optical Depth over Europe in 2003 as observed from AATSR

  Particulate matter in Europe as obs. with SCIAMACHY + AATSR in the SYNAER retrievals

  Vertical profiling of aerosols

  Early user driven validation of SYNAER products

Reporting to EMEP steering body

- Chapter 6. Remote sensing (2008)

  Implementation of AOD calculations in the EMEP model

  Modelled AOD results and MODIS data

  Use of SYNAER satellite data for aerosol monitoring in Europe

  Implementation of satellite-type-products (AOD) in EMEP model

  More advanced user validation of SYNAER

- Chapter 6 – Plan for 2009

  Integrated assessment of MODIS/AERONET, EMEP model and SYNAER data

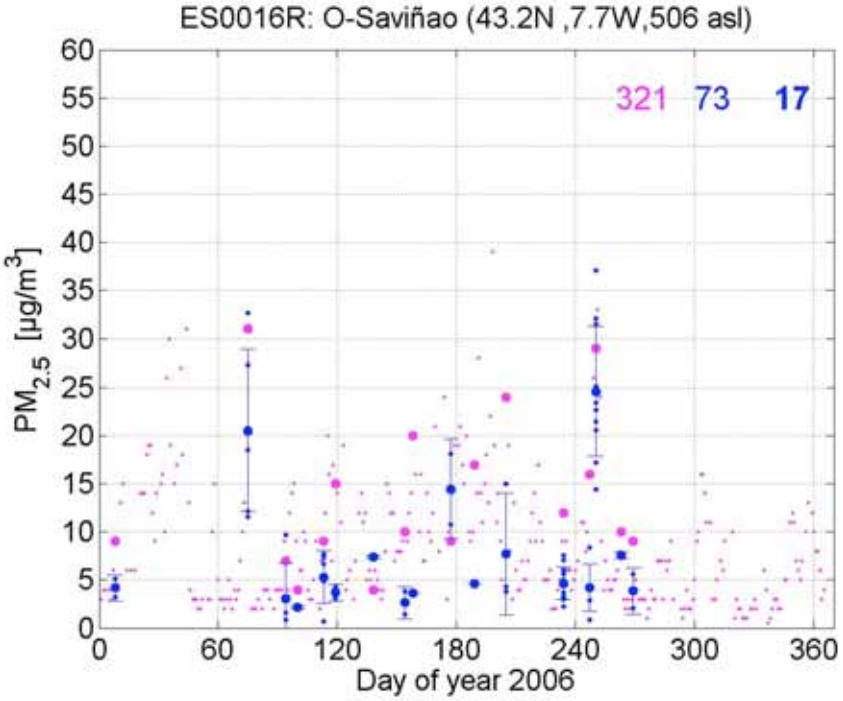
  Towards active use, assimilation of earth observation data/products

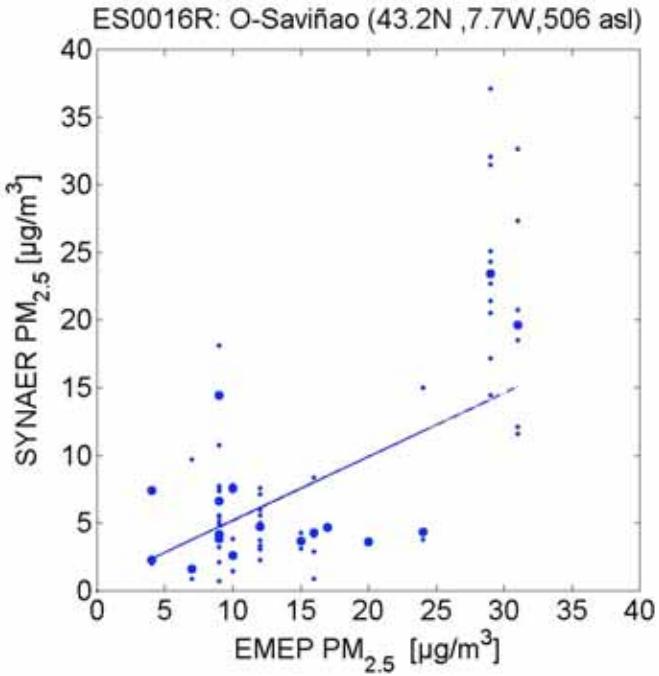
NILU

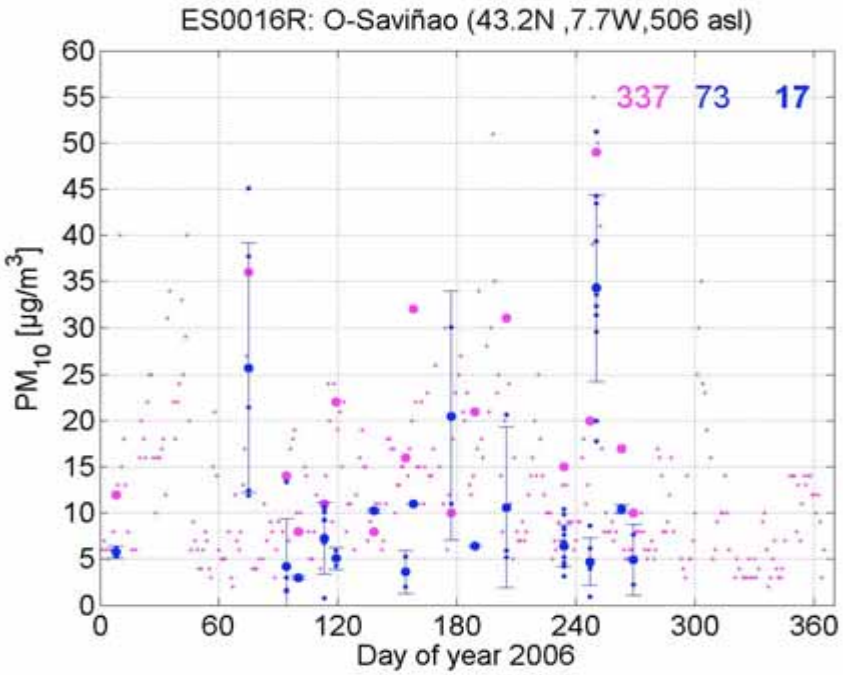
Reporting to EMEP steering body 2009

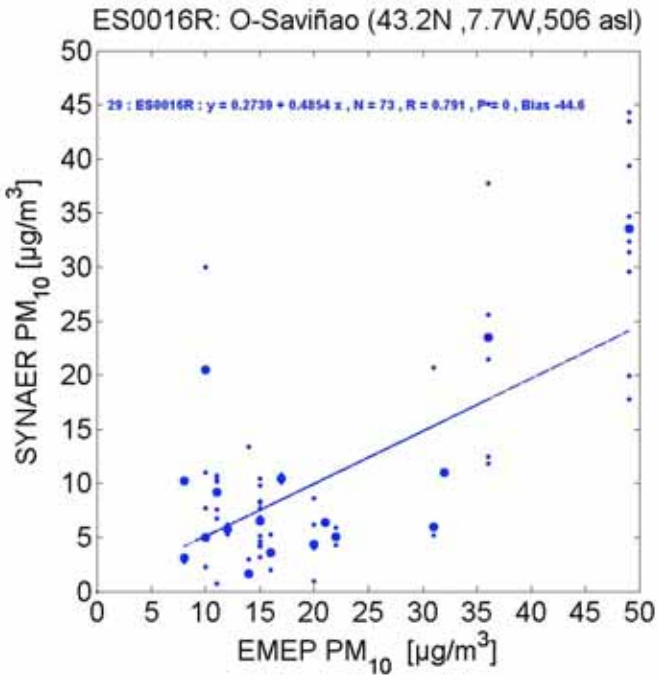
- Presentation of SYNAER v2.2 data for 2006 and 2007
- Validation against EMEP surface data and EMEP model output
  - For individual stations – timeseries
  - Annual and seasonal averages

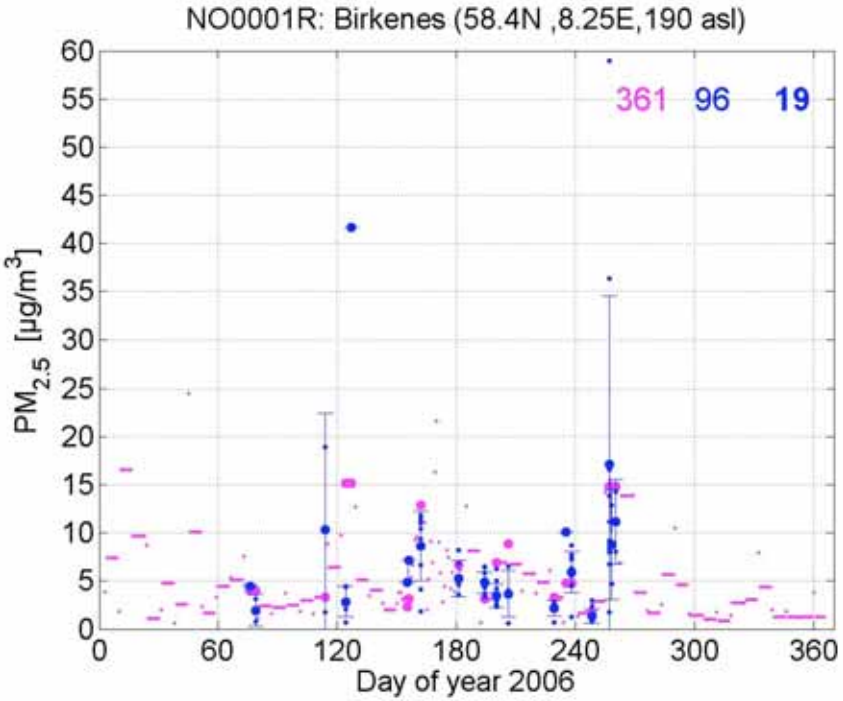
NILU

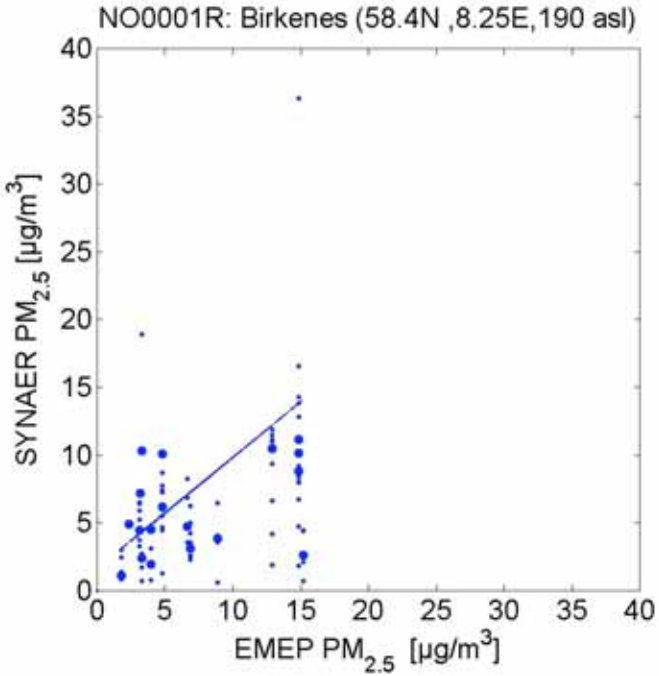

ES0016R: O-Saviñao (43.2N ,7.7W,506 asl)
321 73 17
PM2.5 [µg/m3]
Day of year 2006

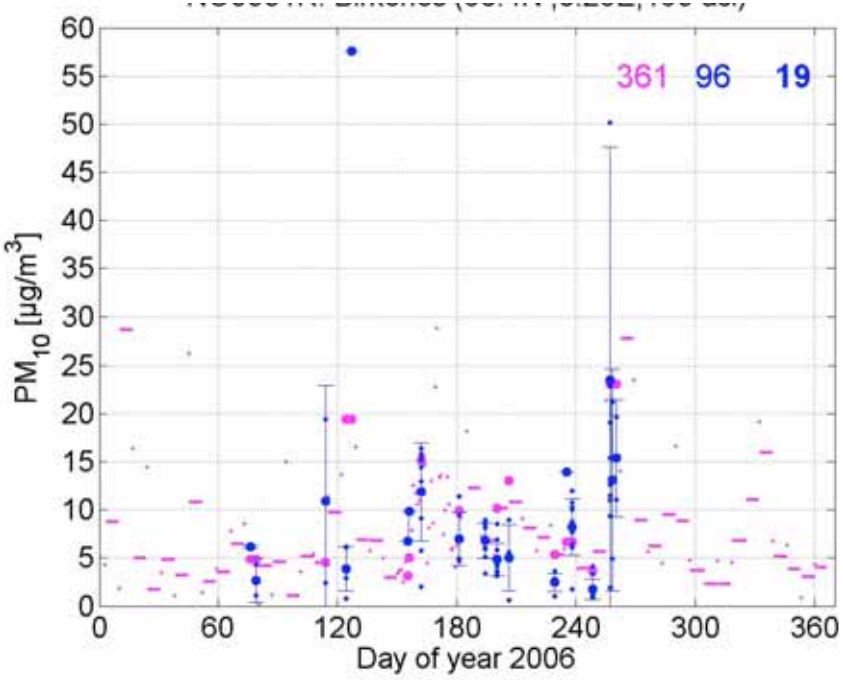

ES0016R: O-Saviñao (43.2N ,7.7W,506 asl)
SYNAER PM2.5 [µg/m3]
EMEP PM2.5 [µg/m3]

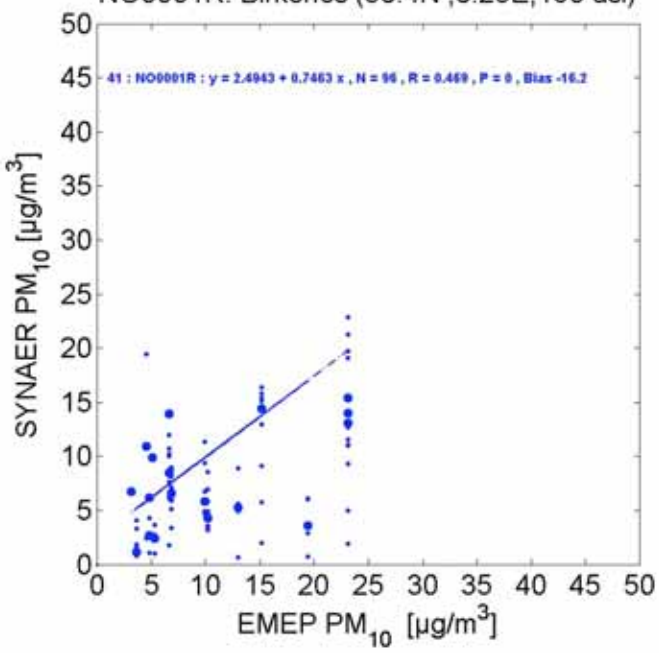

ES0016R: O-Saviñao (43.2N ,7.7W,506 asl)
337 73 17
PM10 [µg/m3]
Day of year 2006


ES0016R: O-Saviñao (43.2N ,7.7W,506 asl)
29 : ES0016R : y = 0.2739 + 0.4854 x , N = 73 , R = 0.791 , P= 0 , Bias -44.6
SYNAER PM10 [µg/m3]
EMEP PM10 [µg/m3]

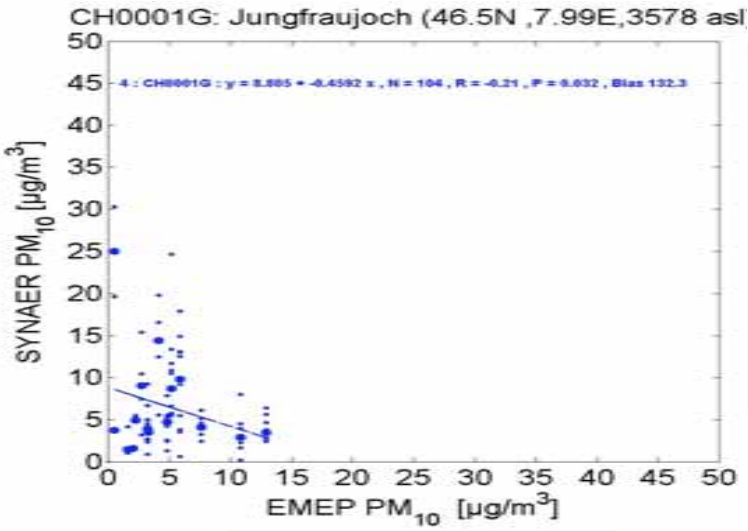

NO0001R: Birkenes (58.4N ,8.25E,190 asl)
361 96 19
PM2.5 [µg/m3]
Day of year 2006

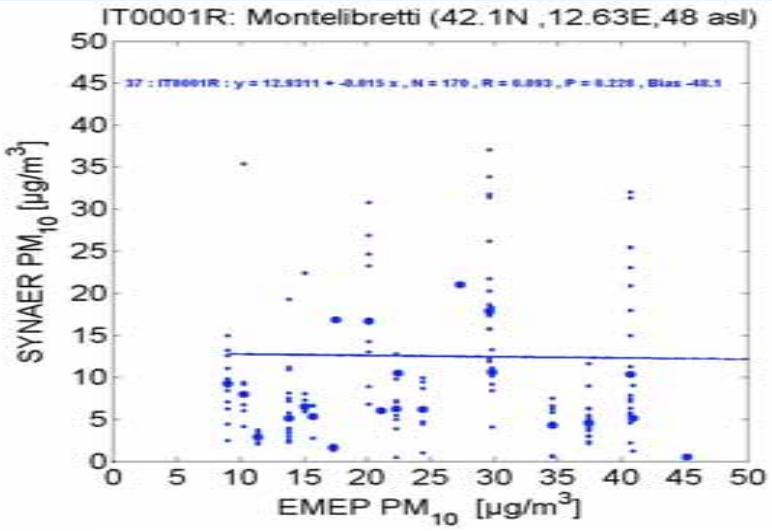

NO0001R: Birkenes (58.4N ,8.25E,190 asl)
SYNAER PM2.5 [µg/m3]
EMEP PM2.5 [µg/m3]


361 96 19
PM10 [µg/m3]
Day of year 2006


NO0001R: Birkenes (58.4N ,8.25E,190 asl)
41 : NO0001R : y = 2.4943 + 0.7463 x , N = 96 , R = 0.469 , P = 0 , Bias -16.2
SYNAER PM10 [µg/m3]
EMEP PM10 [µg/m3]

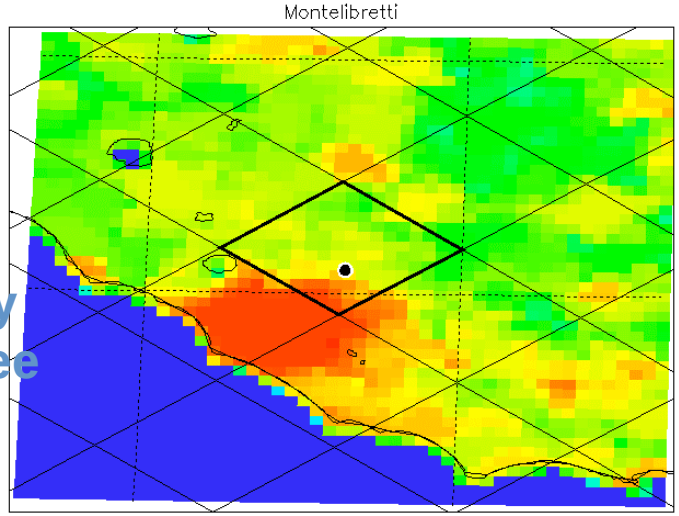
Expected lack of good correlation





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

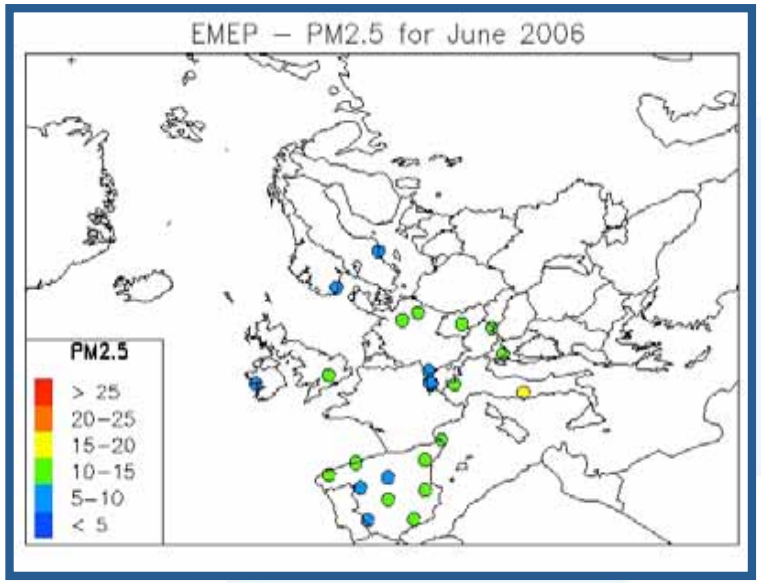
$PM_{2.5}$

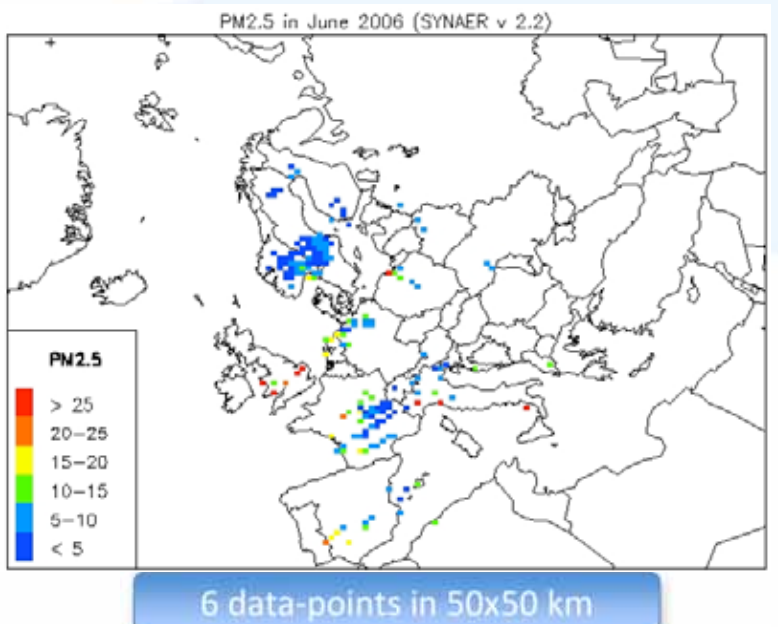
significant ($P < 0.05$) and positive correlation at 17 from 25 stations

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

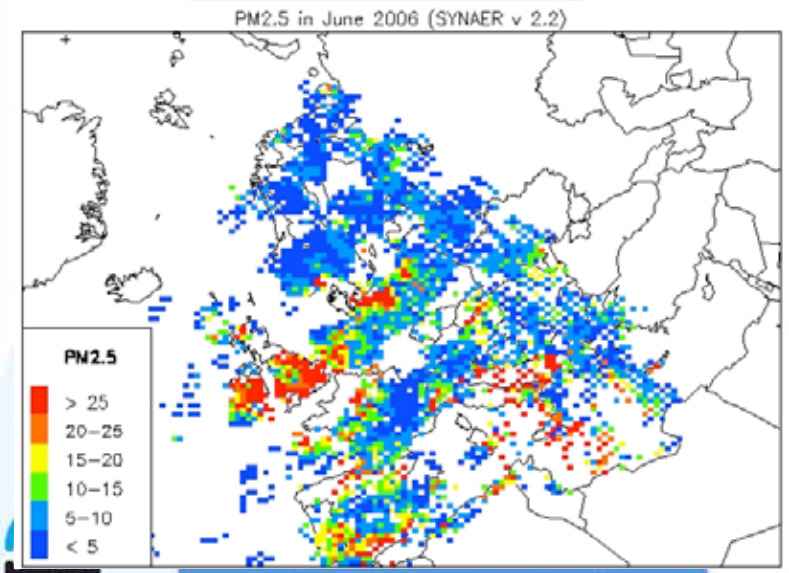
NILU

Monthly Means of $PM_{2.5}$ - min data for averages

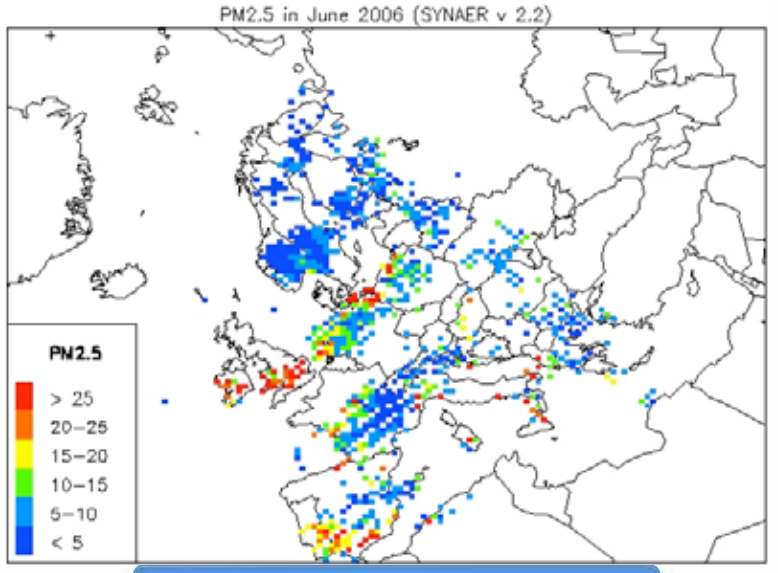




6 data-points in 50x50 km



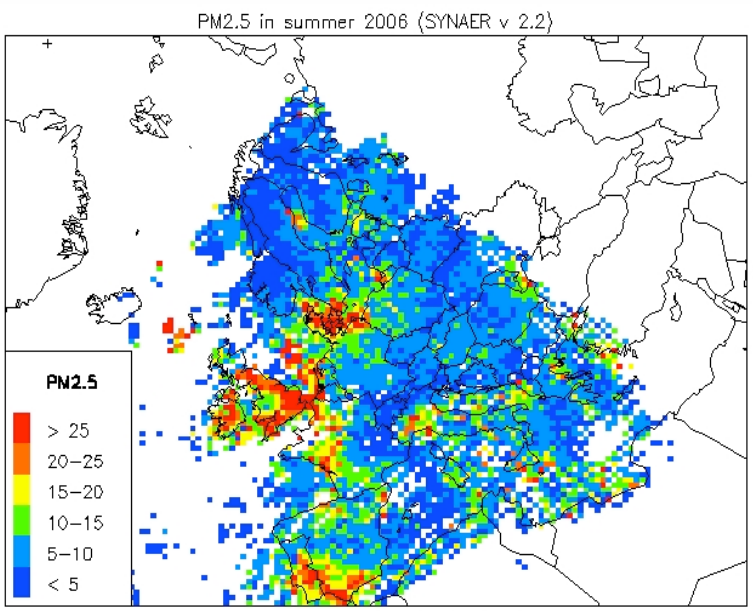
2 data-points in 50x50 km

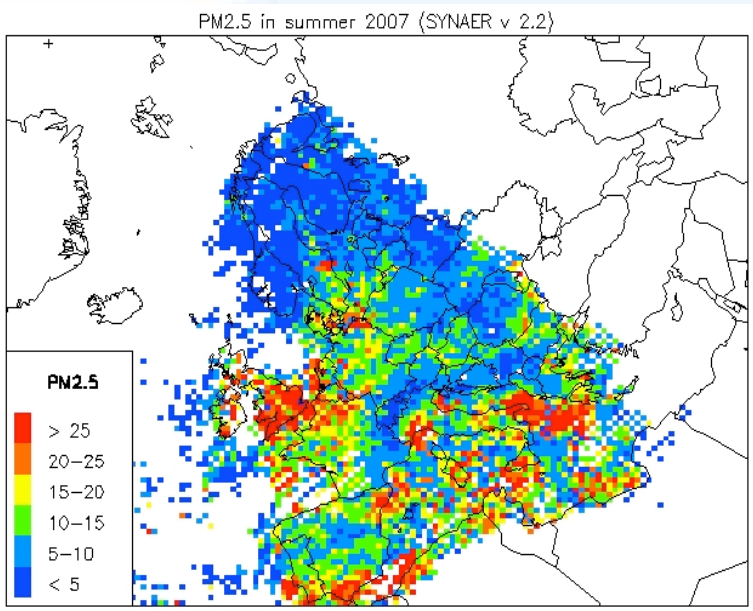


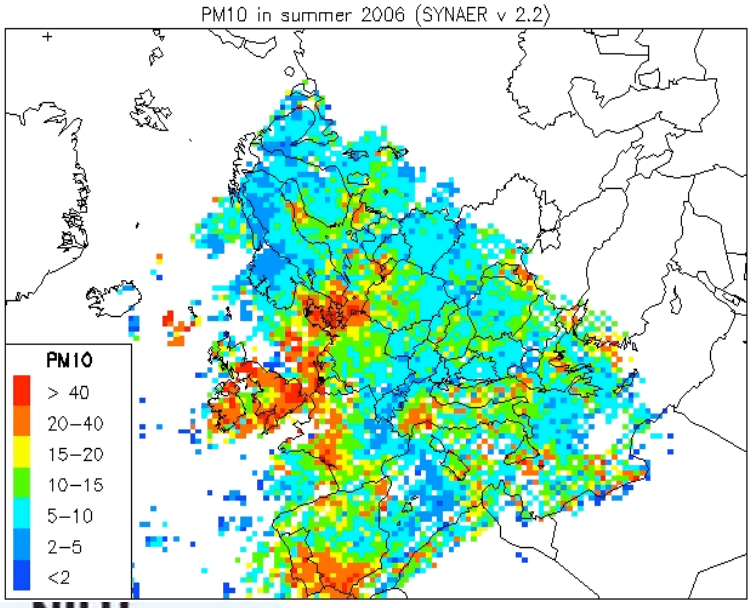
4 data-points in 50x50 km

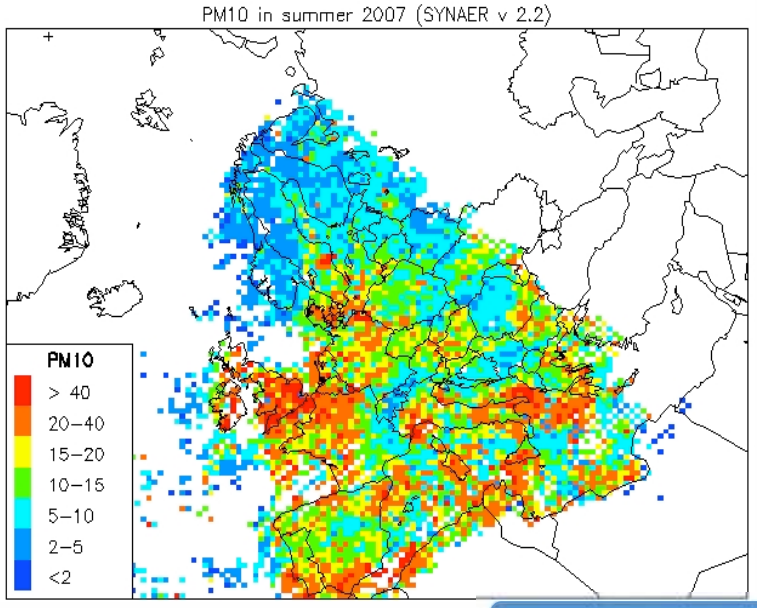
NILU

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





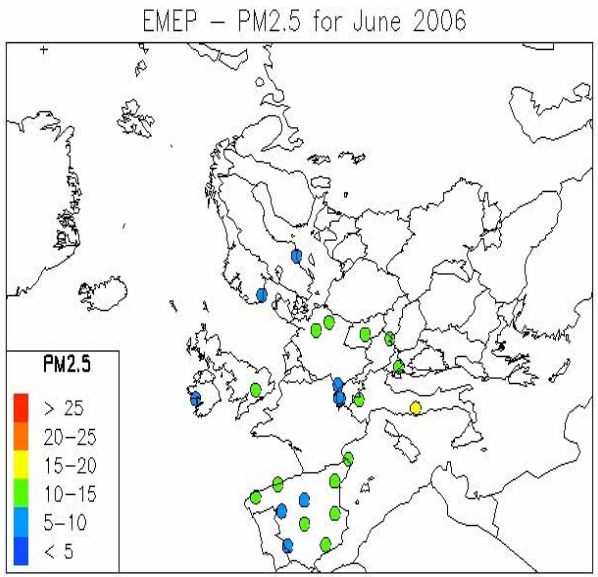


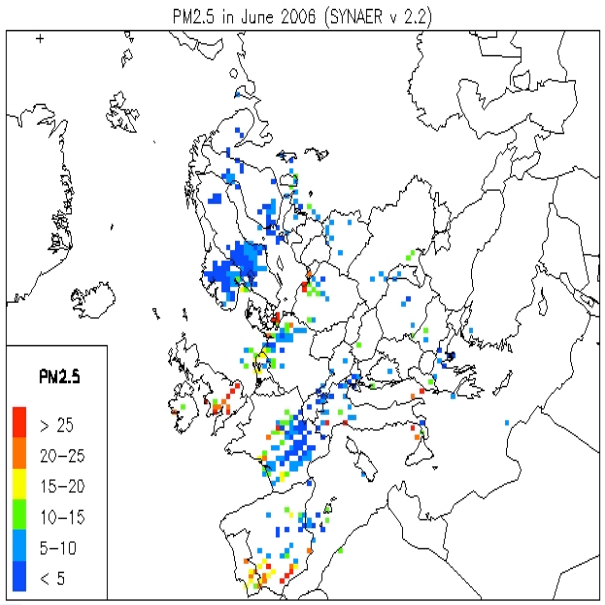


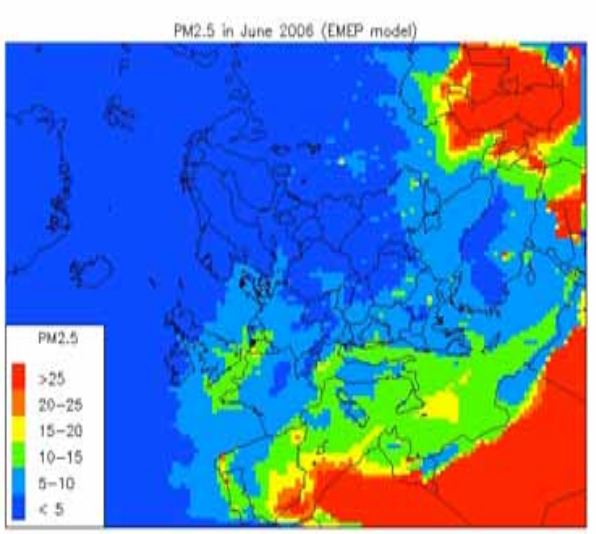
NILU

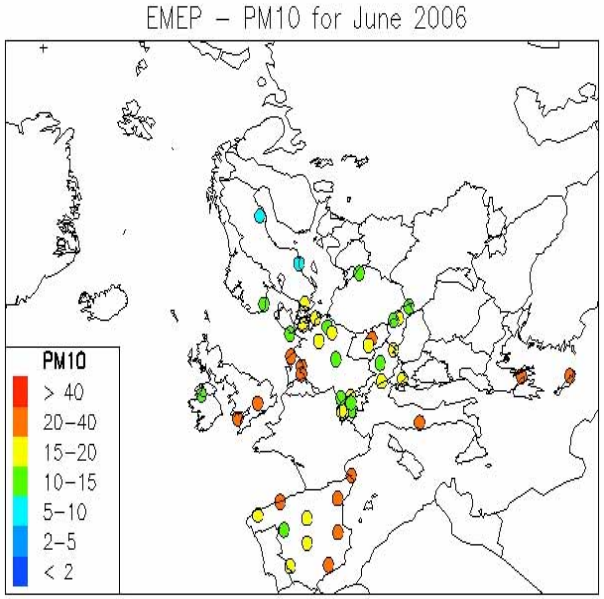
min: 5 data-points in 50x50 km

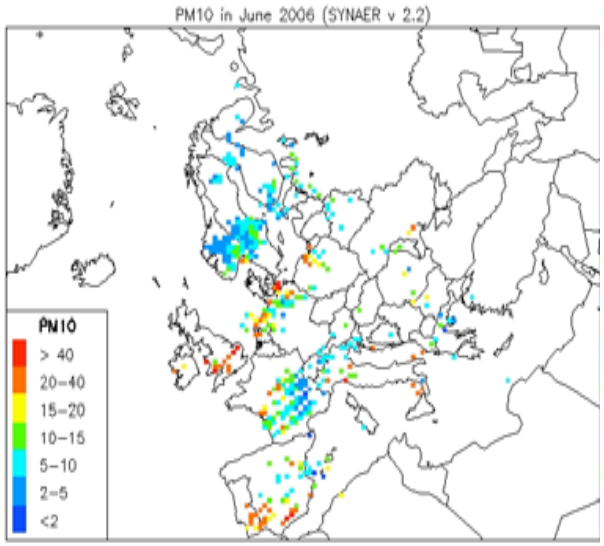
Monthly Means of $PM_{2.5}$ and PM_{10} – June 2006

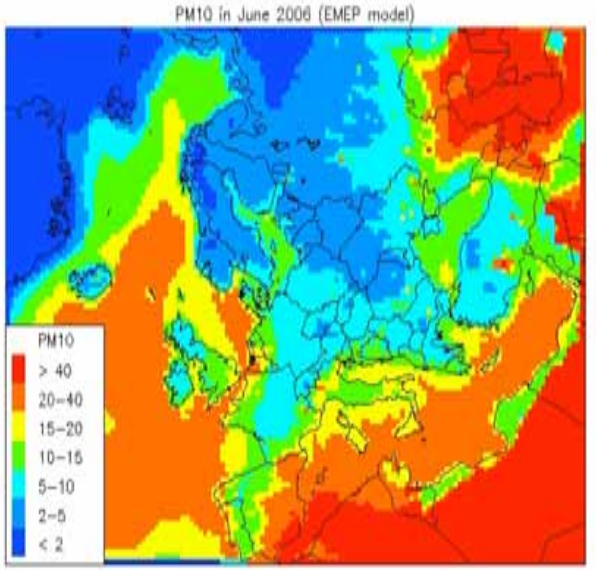










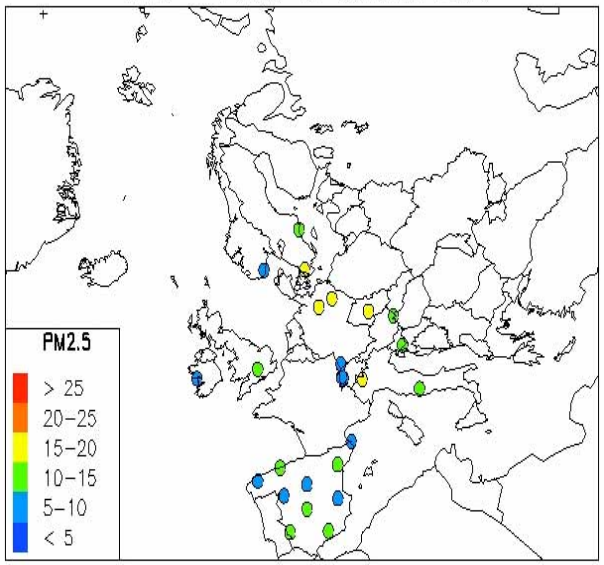


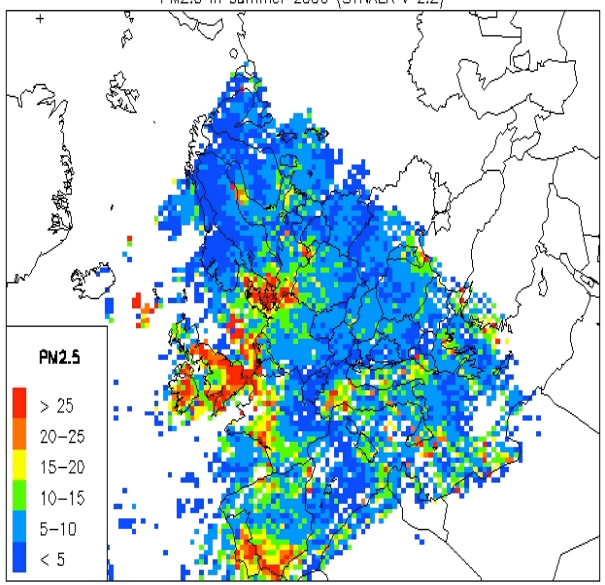
min: 5 data-points in 50x50 km

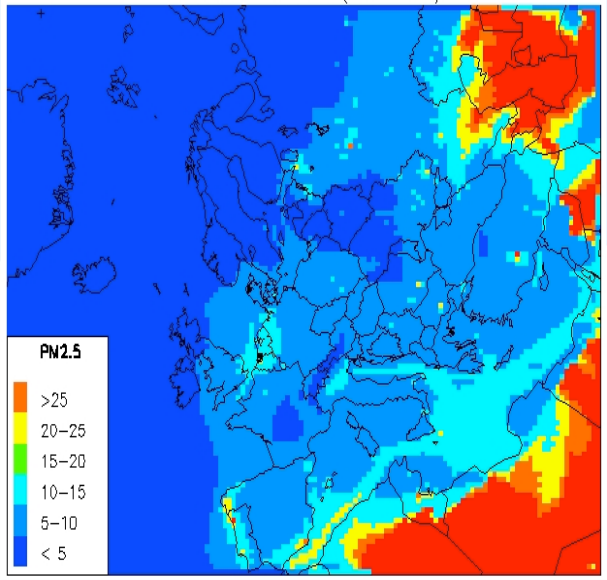
EMEP model data: S. Tsyro, met.no

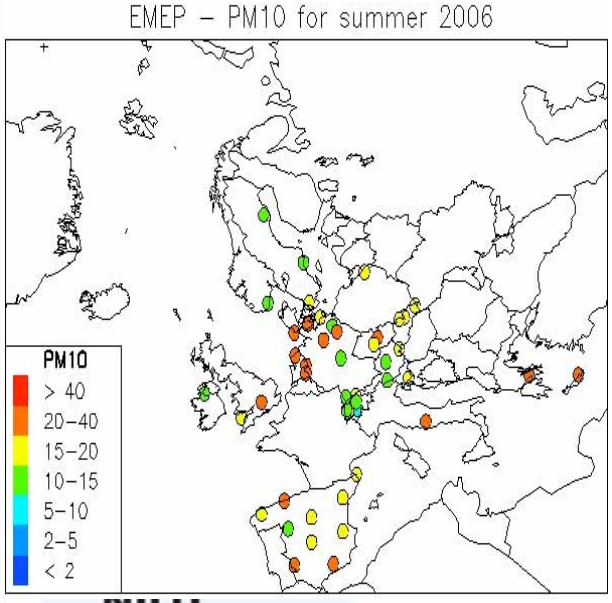
NILU

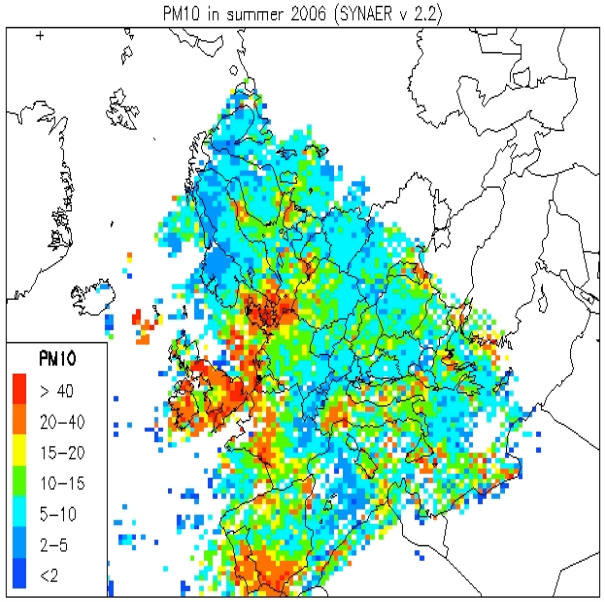
EMEP – SYNAER – EMEP modell – summer 2006

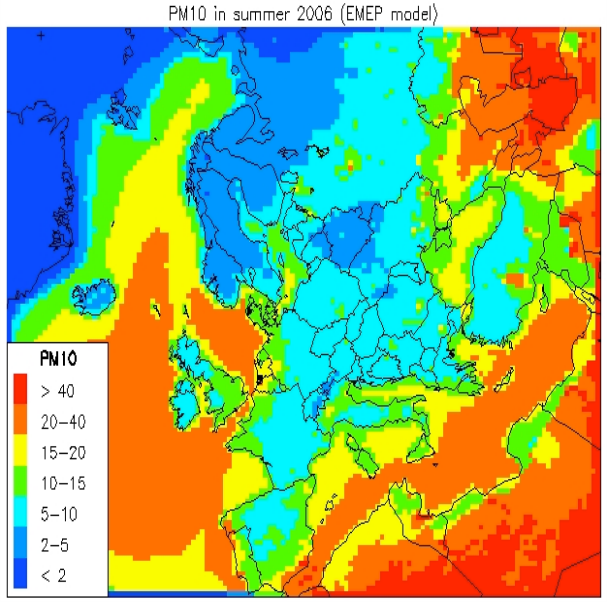








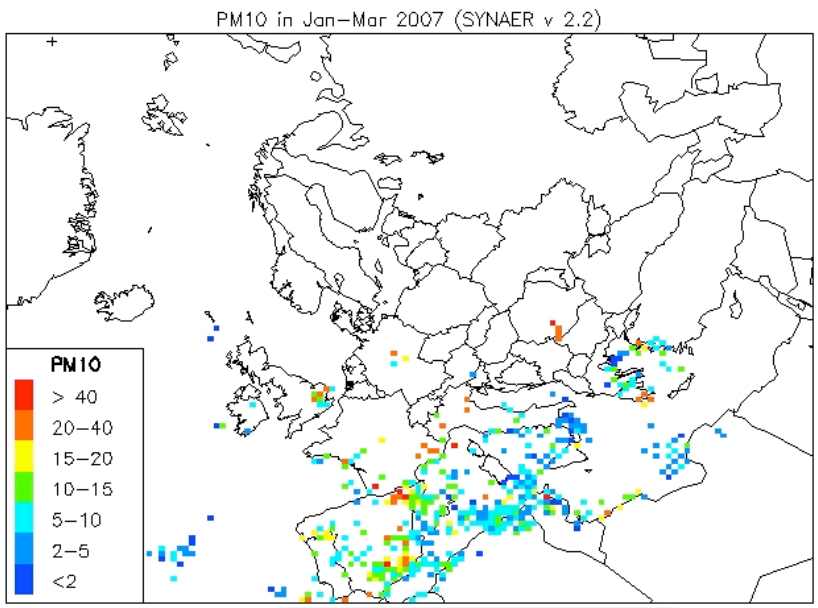


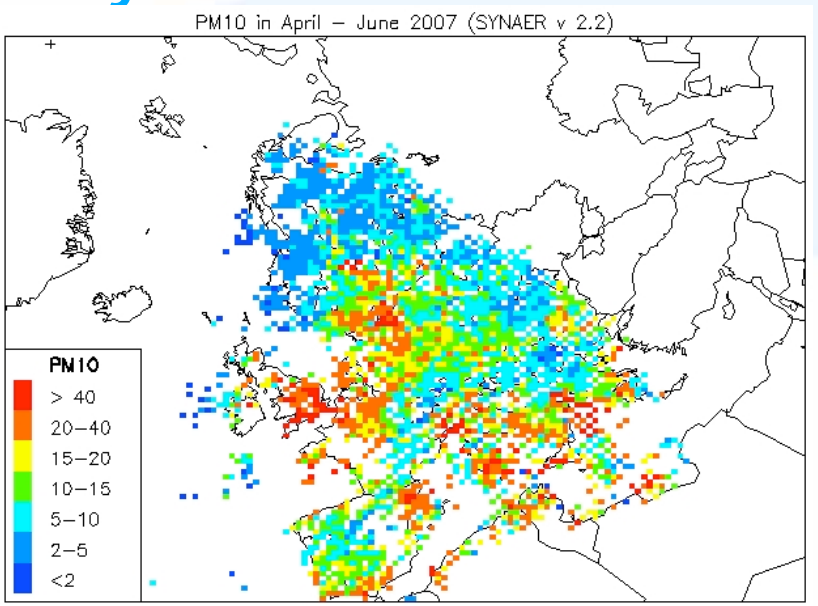


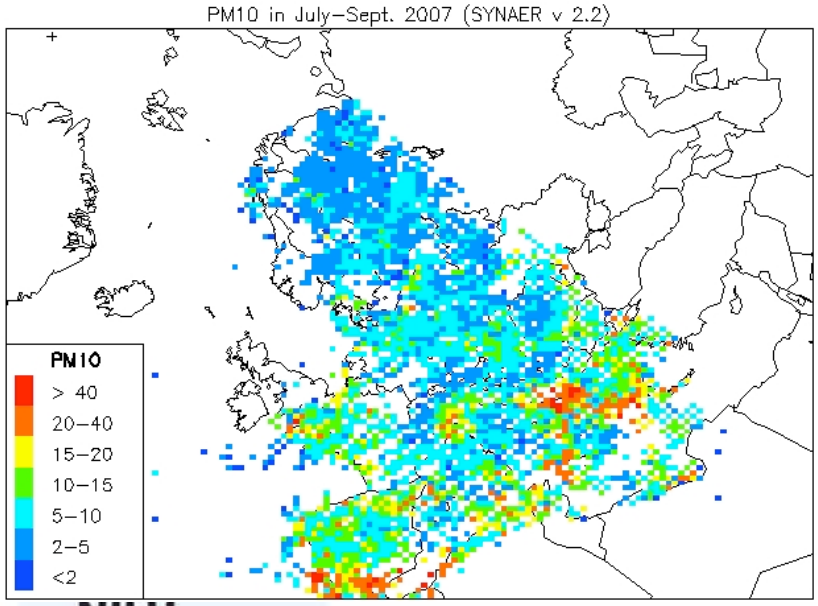
NILU

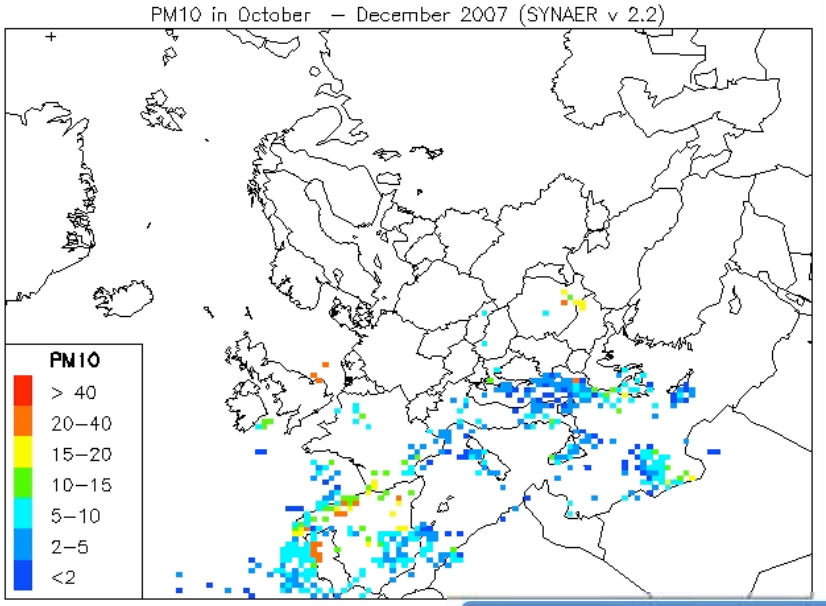
EMEP model data: S. Tsyro, met.no

SYNAER v2.2 for 2007









NILU

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) [autumn 2009]

Future:

- Better data coverage !
- More advanced multi-sensor approaches(SYNAER + IR sensors, profiling info)
- Assimilated products

NILU

Conclusions and Recommendations

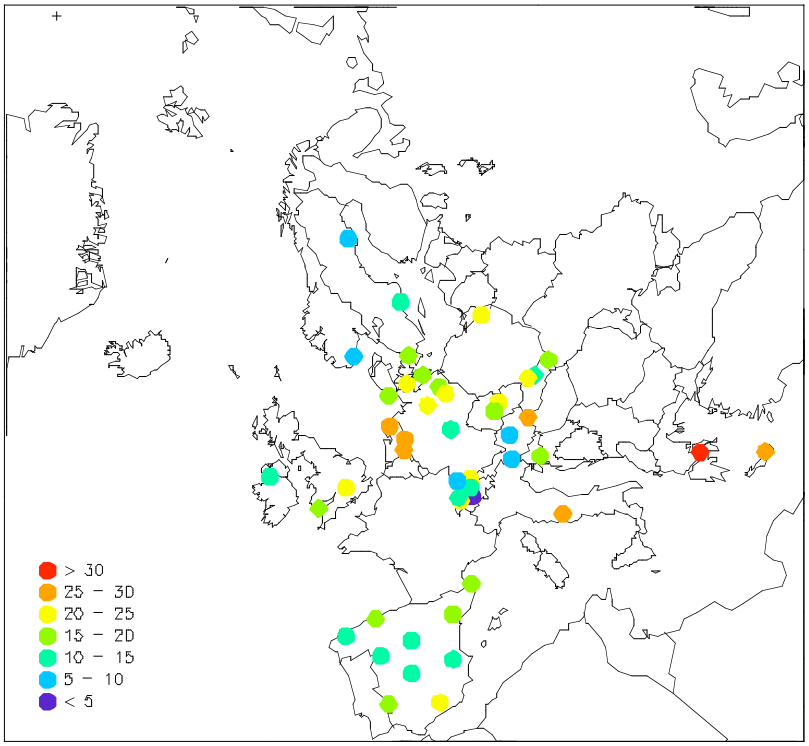
- SYNAER are complementary to EMEP (remote areas, ocean)
- Clear improvements in performance vs EMEP data from v1.0 to v2.2 due to:
  - Vertical aerosol distribution from EURAD
  - Proper cloud masking
  - Proper rejection of “bad” pixels over bright albedo sites and where spectral fit and AOD-errors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

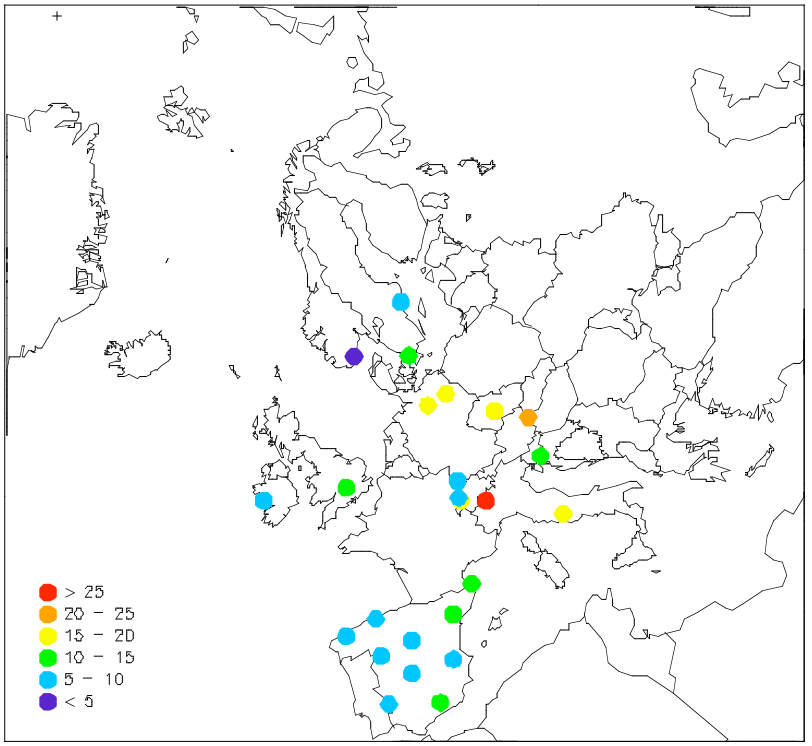
NILU

Acknowledgements

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

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





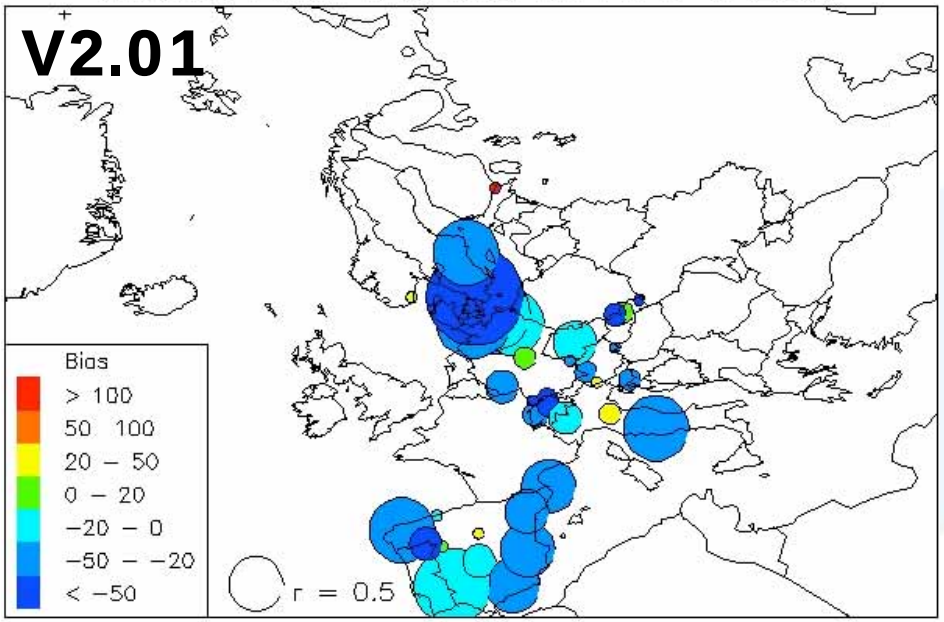
PM_{10} from 47 stations, $PM_{2.5}$ from 25 sites, PM_1 from 5 stations

PM_{10} CH01: Jungfraujoch 3.3 µg m^{-3} CY02: Cypriote 33.8 µg m^{-3}

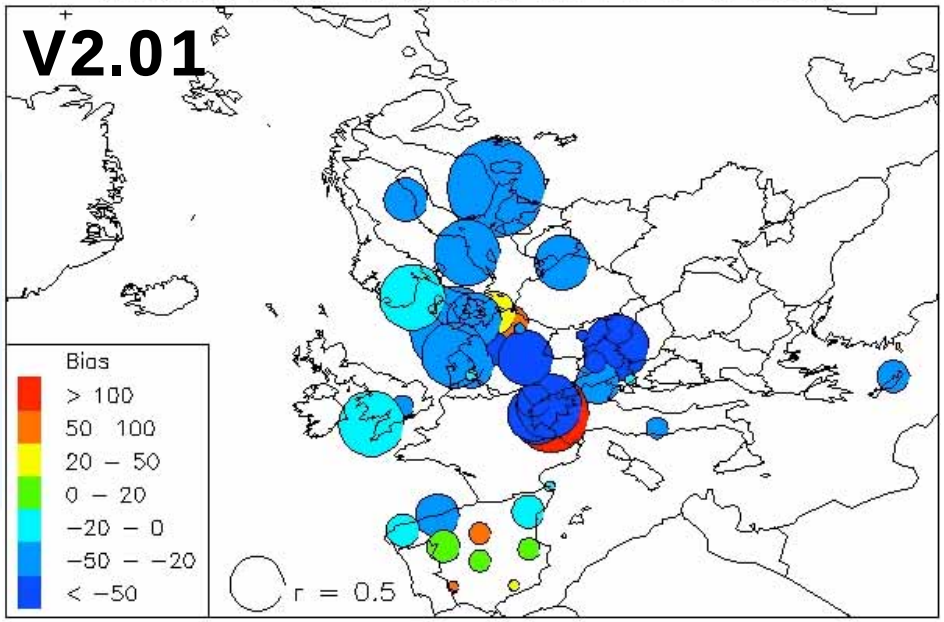
$PM_{2.5}$ NO01: Birkenes 5.0 µg m^{-3} IT04: Ispra 28.5 µg m^{-3}

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

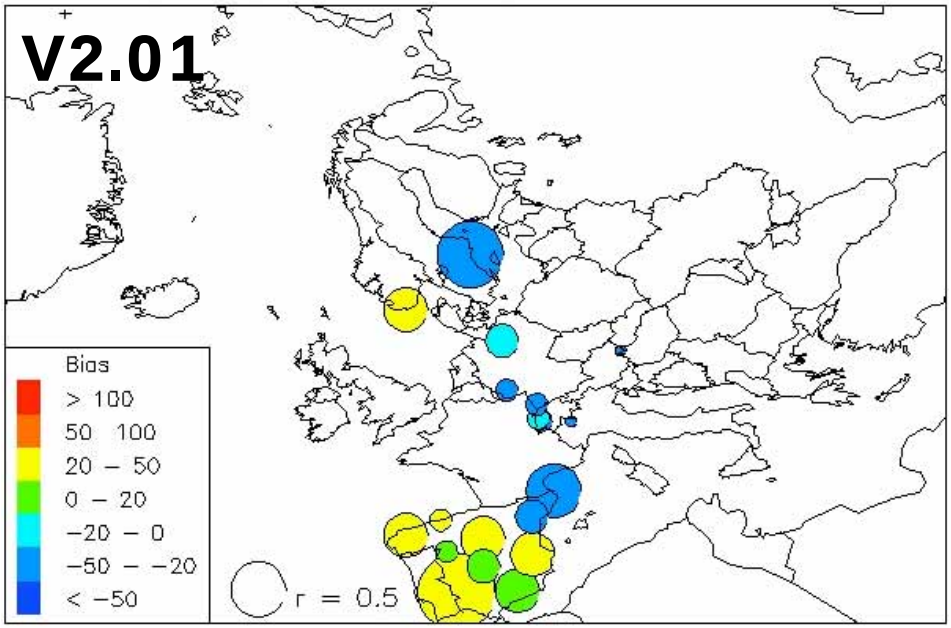
SYNAER–EMEP R & Bias for PM10 in 2003



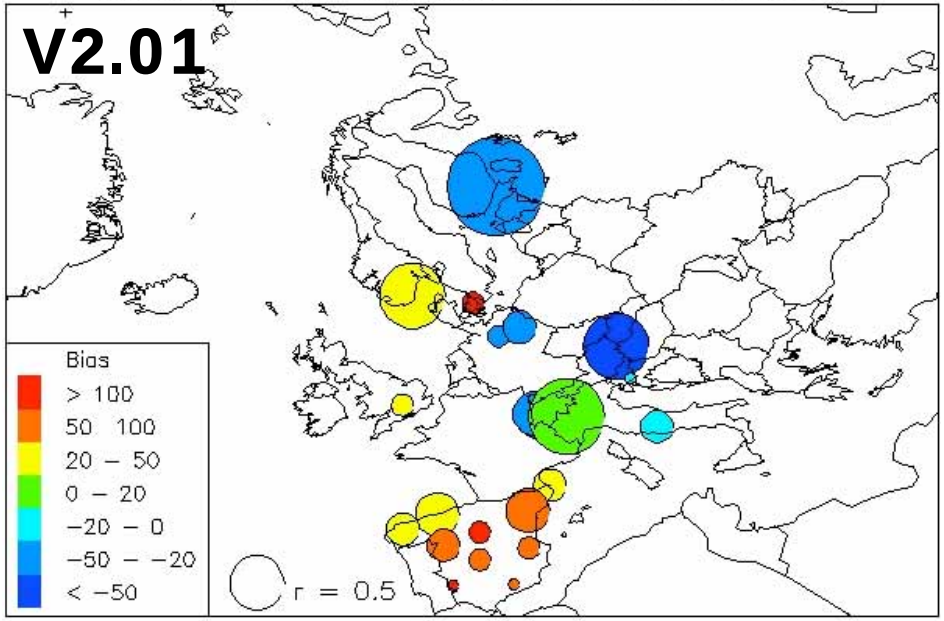
SYNAER–EMEP R & Bias for PM10 in 2006



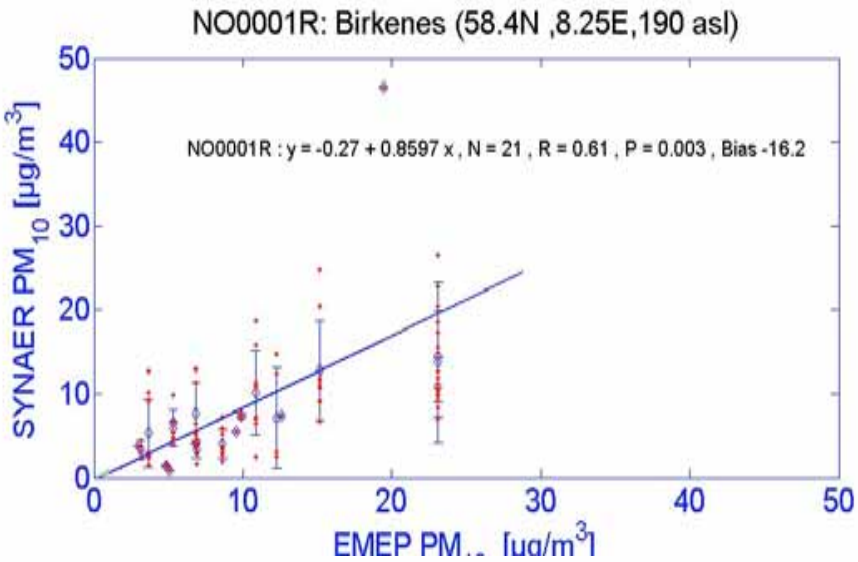
SYNAER–EMEP R & Bias for PM2.5 in 2003

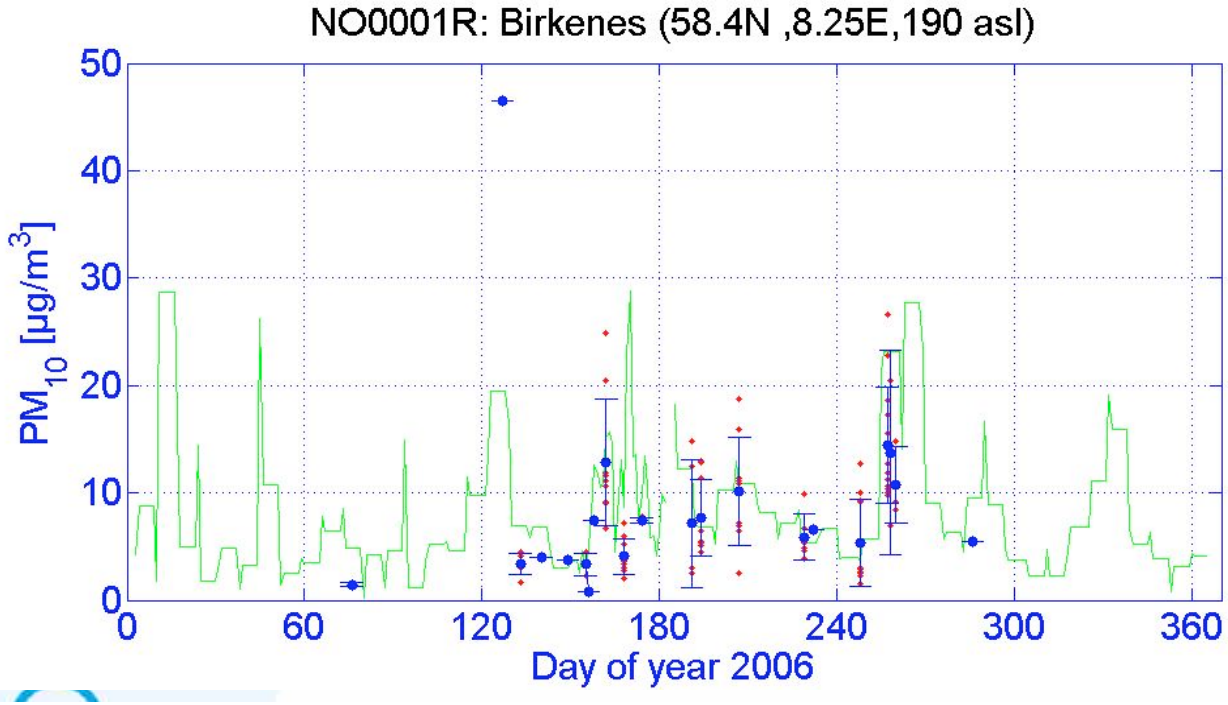


SYNAER–EMEP R & Bias for PM2.5 in 2006



SYNAER v2.01 & EMEP PM_{10}





Timeseries (lower panel) and correlation (upper right panel) of SYNAER & EMEP PM_{10} for the Birkenes station in 2006. The EMEP filter measurements are performed in a 1-6days cylce

ONLY FOR INFO - - strange - ?