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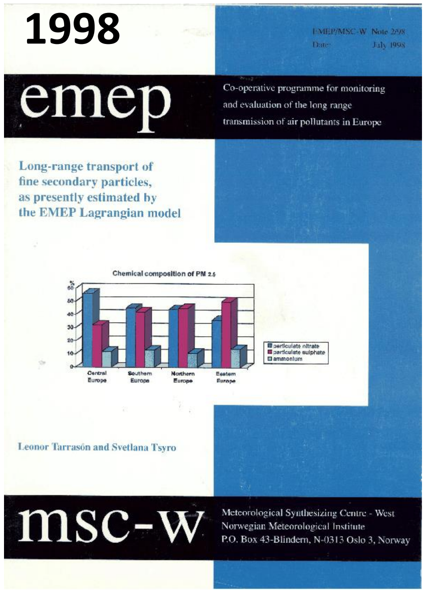
Aerosols
in the EMEP/MSC-W model

EMEP/MSC-W model training course
13 – 14 October 2015

PM history in EMEP

1998



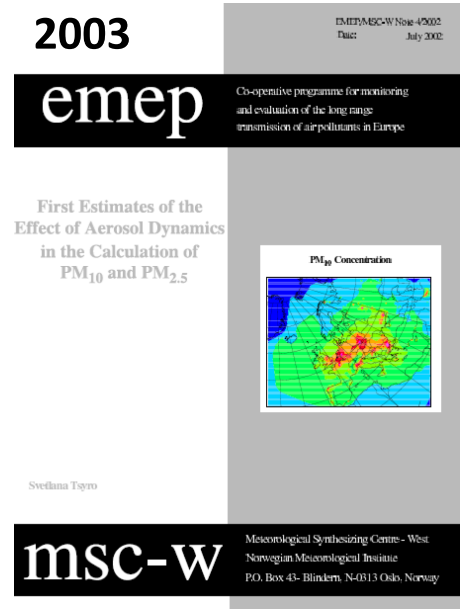
PM expert workshop (2000):

* PPM10 & PM2.5 damage people health

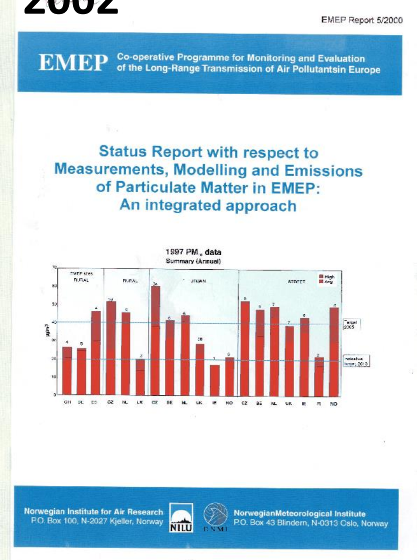
* Can be long-transported

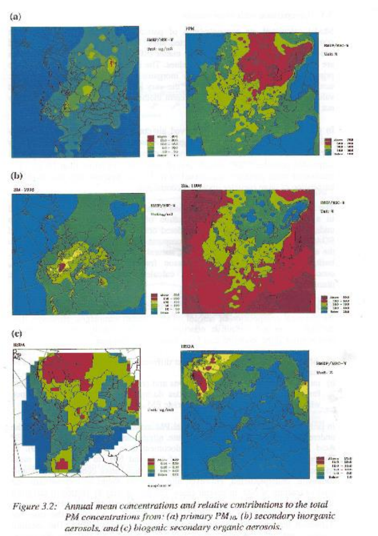
* Unclear which PM characteristics are responsible … mass, number, surface area, chemical composition …

2003



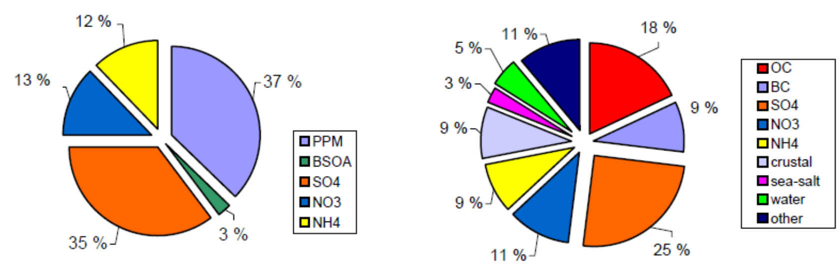
2002





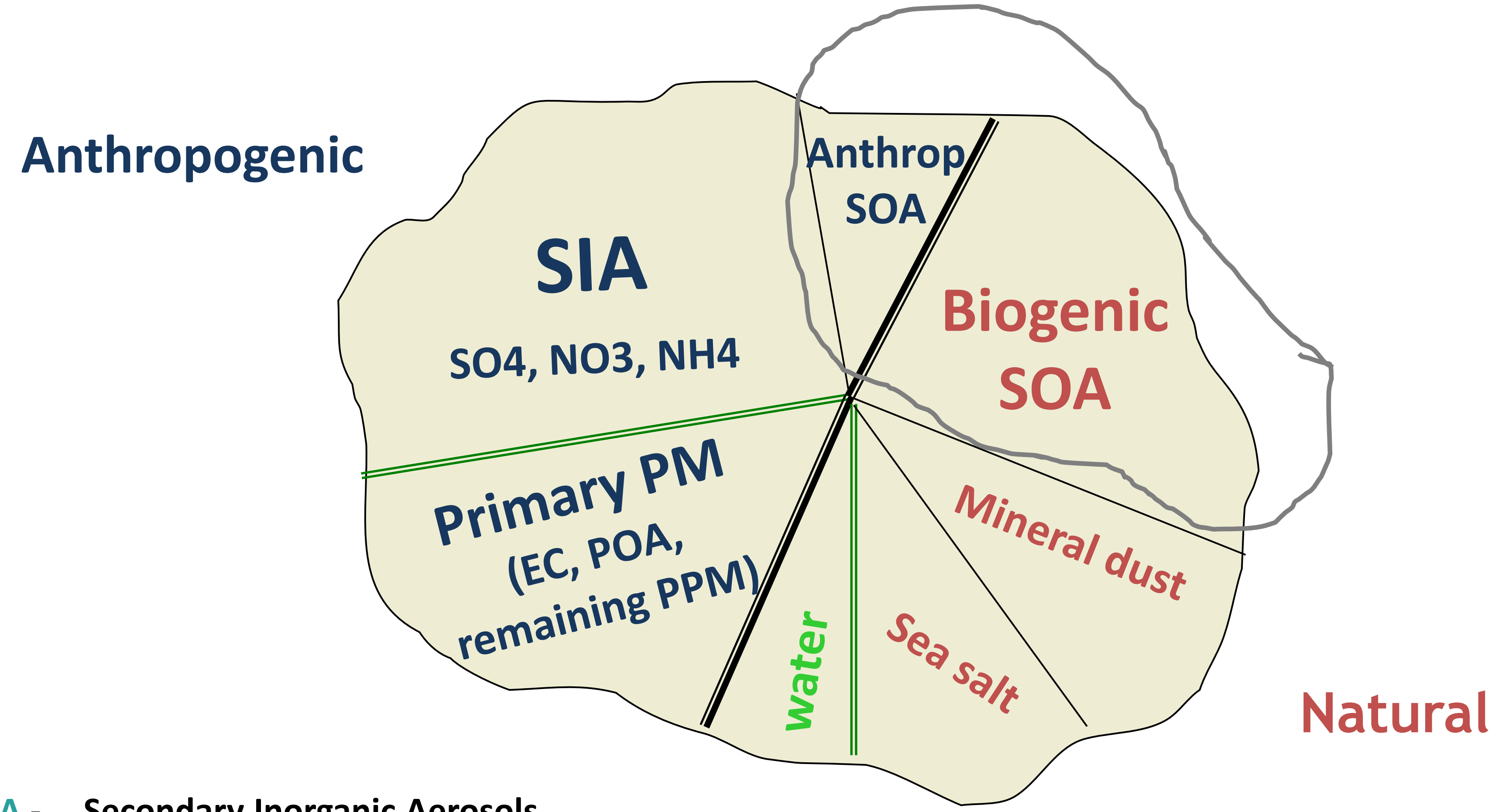
EMEP modelled PM$_{10}$ **Measurements PM**

Helsinki (rural) (Pakkanen et al., 1999)



1998 yearly aver. PM$_{10}$ conc. = 3.5 µg/m^3 Apr-96/Jun-97 aver. PM$_{2.5}$ conc. = 7.8 µg

Atmospheric aerosol



SIA - Secondary Inorganic Aerosols
PPM – Primary Particulate Matter
EC – Elemental Carbon (often **BC** - Black Carbon (absorbing)
POM – Primary Organic Matter (or **POA** - Aerosol)
ASOA/BSOA – Anthropogenic/Biogenic Secondary Aerosol

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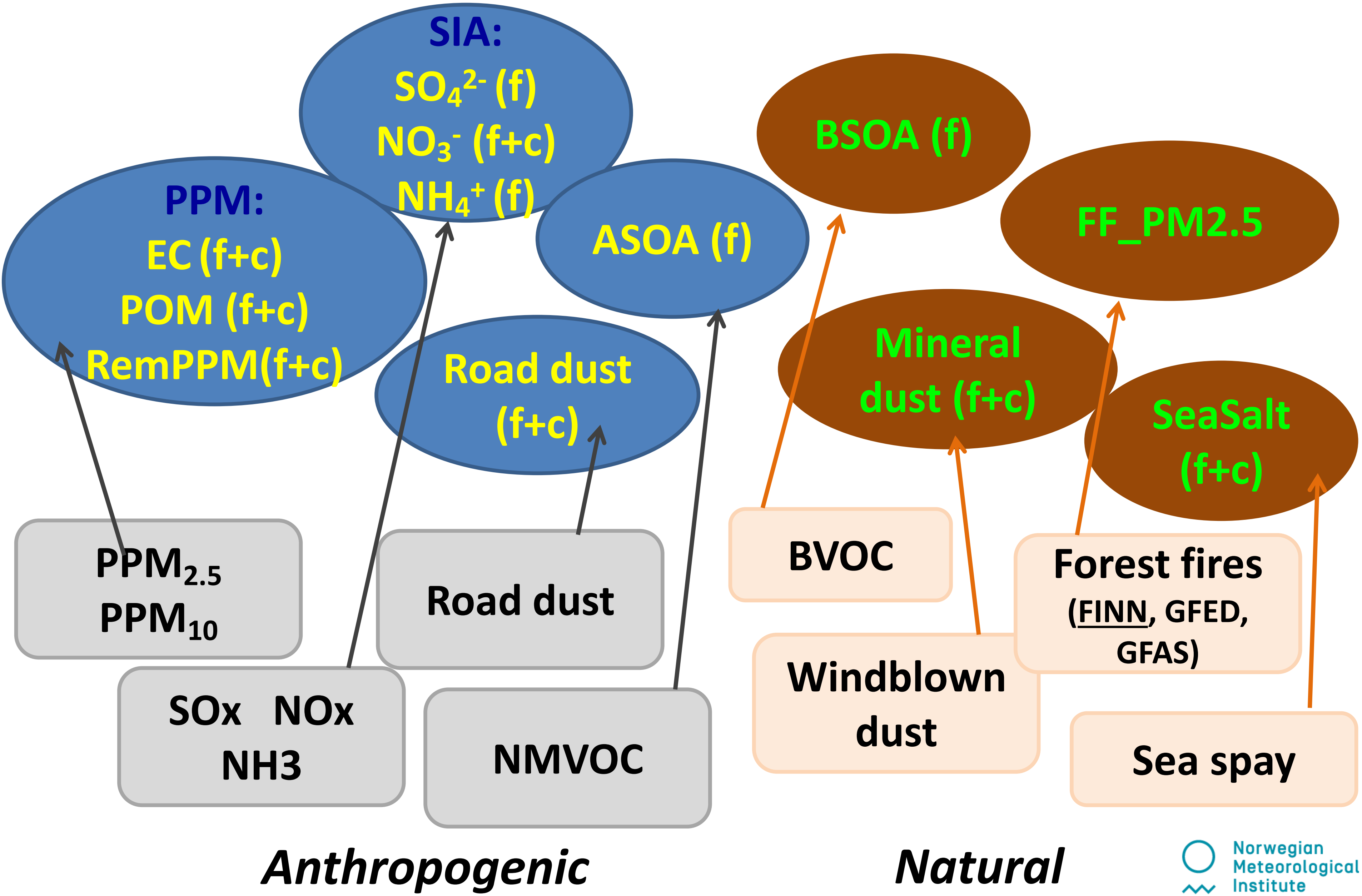
Aerosols and their sources....



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Aerosol formation

Fine	Coarse	Formation	Modules
SO_4^{2-}	-	SO_2 gas/aqueous oxidation **(pH)**	CM_Reactions2.inc
NO_3^-	NO_3^-	Equilibrium (NH_4NO_3) HNO3 -> coarse NO3 (on SS & DUST)	MARS_ml.f90 CM_Reactions2.inc
NH_4^+	-	$(NH_4)_xSO_4$ + Equilibrium (NH_4NO_3)	MARS_ml.F90
EC	EC	PPM fraction (IIASA) EC ageing, Inert	emissplit.specials.pm25 emissplit.defaults.pmco ChemFunctions_ml.f90
POM	POM	PPM fraction (IIASA); Inert	emissplit.specials.pm25 emissplit.defaults.pmco
ASOA	-	VBS approach	My_SOA_ml.f90
BSOA	-	VBS approach	My_SOA_ml.f90
Sea salt	Sea salt	Online; Source function ($u10^3$,Twater)	SeaSalt_ml.f90
Anth. dust	Anth. Dust	Remaining PPM (IIASA) + Road dust	Emissions_ml.f90
Min. Dust	Min. Dust	Windblown (DUST_WB): online, flux(U*, soil moisture, …) Saharan (DUST_SAH) - bound. condition	DustProd_ml.f90 Monthly (EMEP global)
PM water	-	Diagnostic **(SIA)**	MARS_ml.f90

$PM_{2.5}$ and PM_{10}

* Policy relevant metrics (compliance with EU critical values / WHO Air Quality Guidlines)

* Dry mass: parameters PM25 and PM10

* Mass at Rh = 50% and T=20C : PM25_rh50 and PM10_rh50
  for comparison with «standard» gravimetric measurements
  and with critical values

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Output: PM2.5_rh50 and PM10_rh50 (at RelHum=50%)

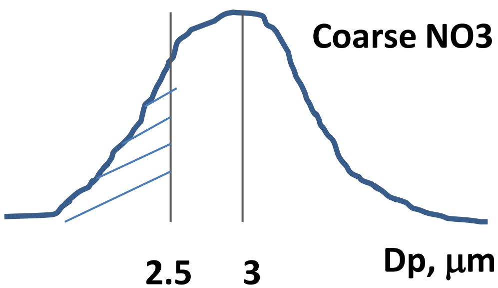
CM_ChemGroups_ml.f90

PMFINE_GROUP = (/ SO4, NO3_F, NH4_F, EC_F_WOOD_NEW, EC_F_WOOD_AGE,
EC_F_FFUEL_NEW, EC_F_FFUEL_AGE, PART_OM_F, REMPPM25, FFIRE_BC,
FFIRE_REMPPM25, SEASALT_F, DUST_ROAD_F, DUST_WB_F, DUST_SAH_F /)

PM10_GROUP = (/ SO4, NO3_F, NO3_C, NH4_F, PART_OM_F, POM_C_FFUEL,
EC_F_WOOD_NEW, EC_F_WOOD_AGE, EC_C_WOOD, EC_F_FFUEL_NEW,
EC_F_FFUEL_AGE, EC_C_FFUEL, REMPPM25, REMPPM_C, FFIRE_BC,
FFIRE_REMPPM25, SEASALT_F, SEASALT_C, DUST_ROAD_F, DUST_ROAD_C,
DUST_WB_F, DUST_WB_C, DUST_SAH_F, DUST_SAH_C /)

Derived_ml.f90

```
select case(nint(AERO%DpgV(2)*1e7))
case(25);    fracPM25=0.37
case(30);    fracPM25=0.27      endselect
```



case ("PM25_rh50")

```
d_2d( n, i,j,IOU_INST) =
    d_2d(ind_pmfine ,i,j,IOU_INST) + d_2d(ind_pmwater,i,j,IOU_INST)
    + fracPM25 * ( xn_adv(iadv_NO3_C,i,j,KMAX_MID) * ug_NO3_C )
    * cfac(iadv_NO3_C,i,j) * density(i,j)
```

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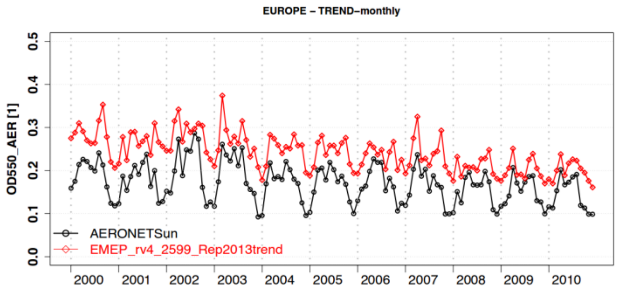
Aerosol extinction & Aerosol Optical Depth (AOD)

Allows model evaluation for aerosol against remote sensing measurements:

- ***AOD from sun-photometers (AERONET) and satellites (global)***
- *Extinction vertical profiles - from LIDARs (Earlinet and satellites)*



Advantages:

- ✓ **Coverage**
- ✓ **Vertical profiles**
- ✓ **Focus on urban pollution (Sentinel satellites/Copernicus)**

AOD_PM_ml.f90

- 3-D aerosol concentrations
- Specific Extinction Efficiencies (Q_i) for the individual aerosol components (OPAC; Hess et al, 1998)
- Effective cross-sections; implicitly accounts for aerosol growth with relative humidity – tabulated based on Chin et al. (2002)

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AOD_PM_ml.f90

calculates 3-D extinction and AOD
for 9 wave lengths (one at time)
for individual aerosol types

---

config_emep.nml

```
'AOD'    ,' ' ,  '350nm','AOD:GROUP','MISC', 4,  AOD_350nm
'AOD'    ,' ' ,  '550nm','AOD:GROUP','MISC', 4,  AOD_550nm
'AOD'    ,' ' ,  '870nm','AOD:GROUP','MISC', 4,  AOD_870nm
---------------------------------------------------------
'SO4'    ,' ' ,  '550nm','AOD:SPEC' ,'MISC',   4,  AOD_SO4_350nm
'DUST'   ,' ' ,  '550nm','AOD:GROUP','MISC', 4,  AOD_DUST_350nm
---------------------------------------------------------
'EXT'    ,'1/m', '350nm','EXT:GROUP','MISC',  3,  EXT_350nm
'EXT'    ,'1/m', '550nm','EXT:GROUP','MISC',  3,  EXT_550nm
```

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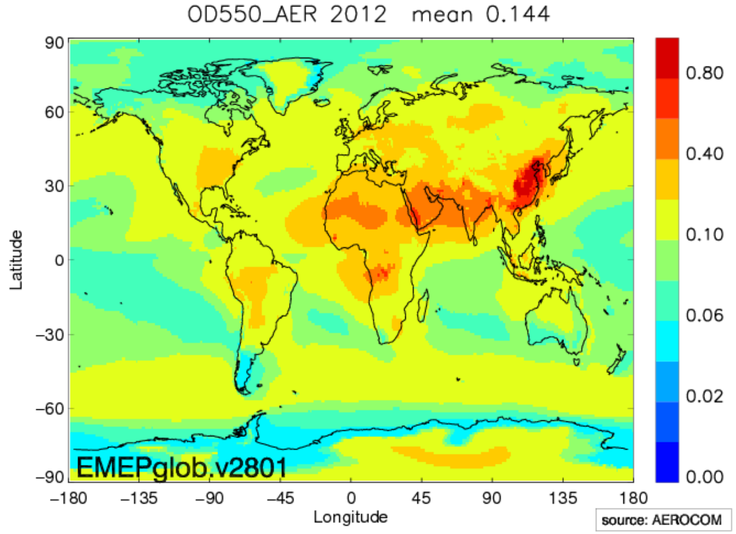
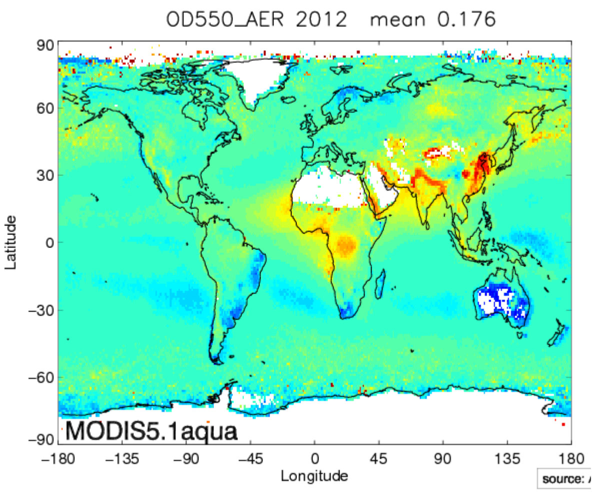
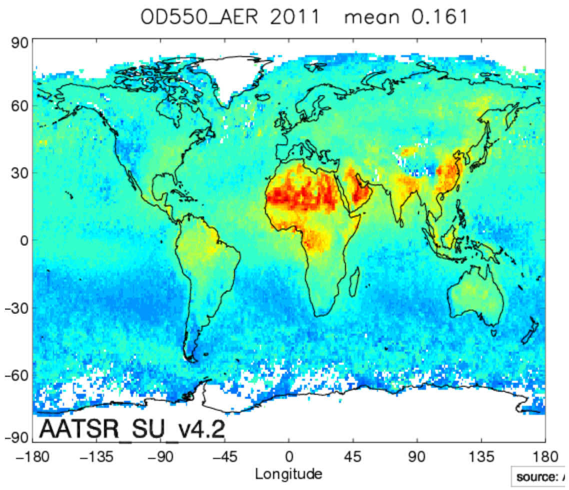
AOD 550nm : EMEP model and satellite data

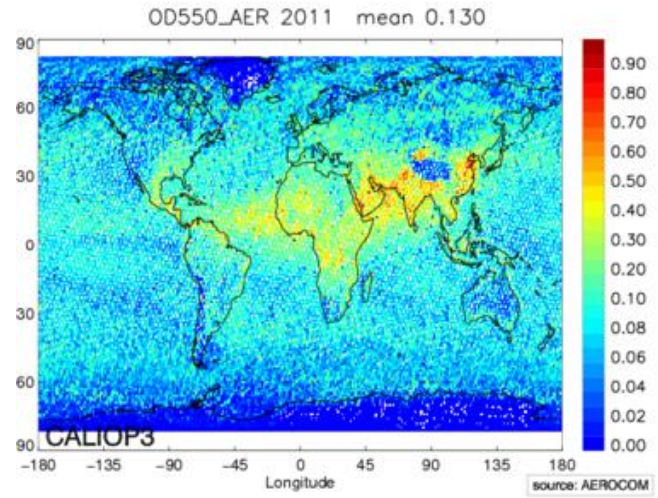




MODIS Aqua



AATSR



CALIOP

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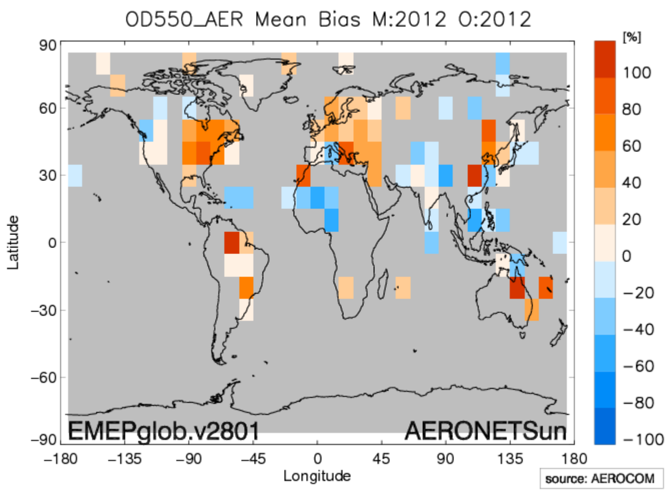
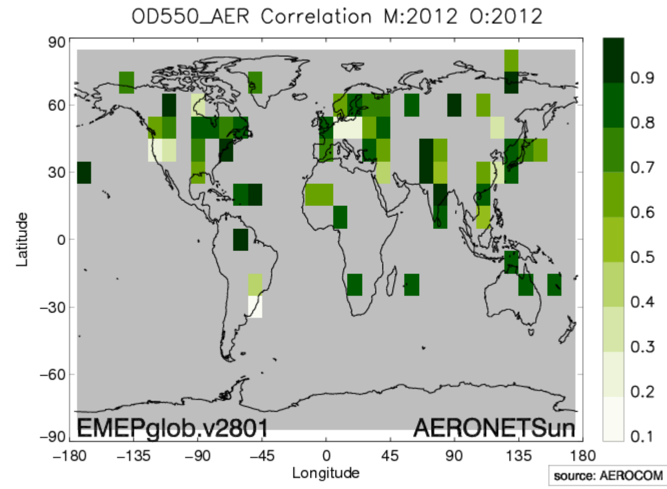
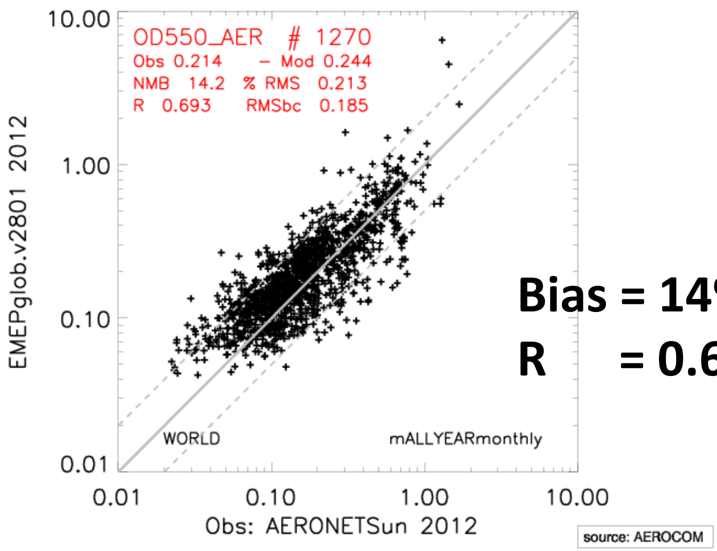
Evaluation of AOD from EMEP model with AERONET data for 2012

Bias



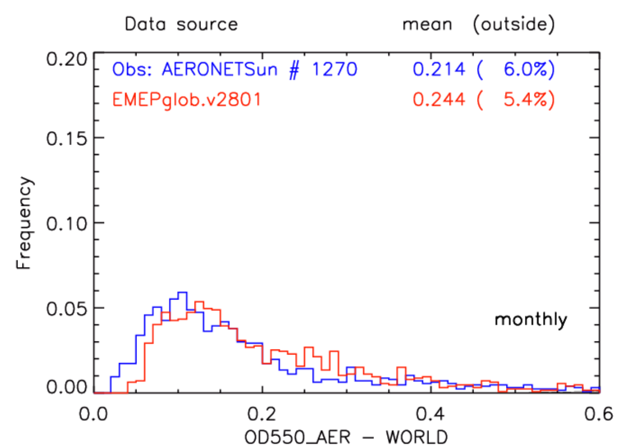
Correlation





Bias = 14%

R = 0.69



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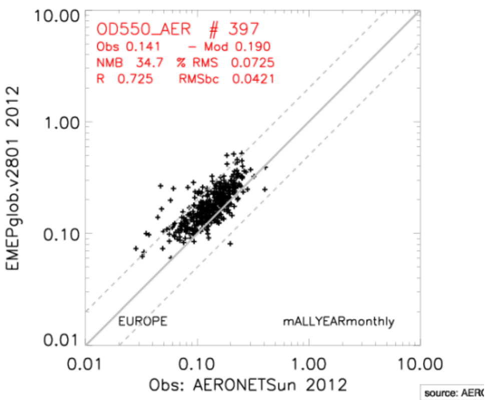
AOD evaluation for different regions: EMEP model vs. AERONET

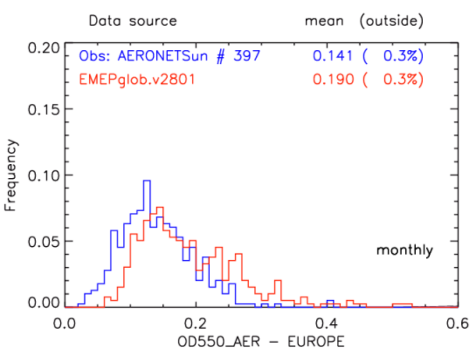
Anthropogenic pollution

Anthropogenic + desert dust

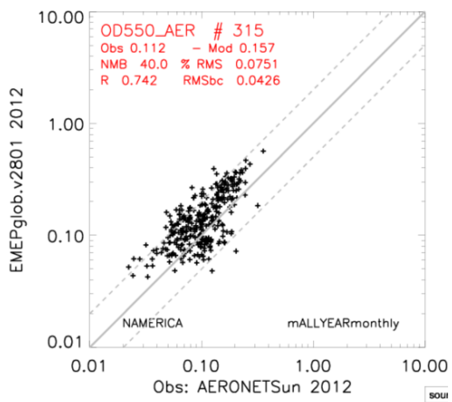
Desert dust

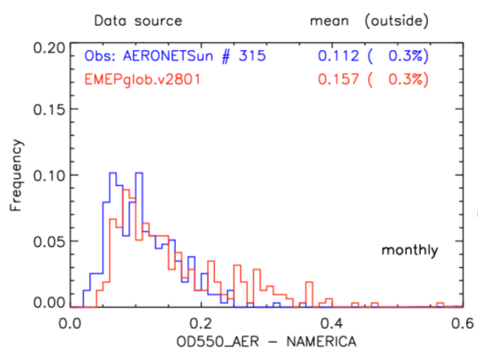
Europe



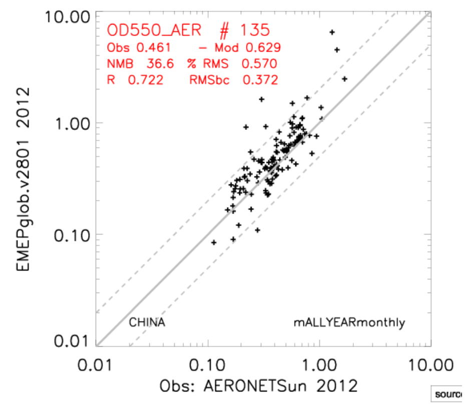


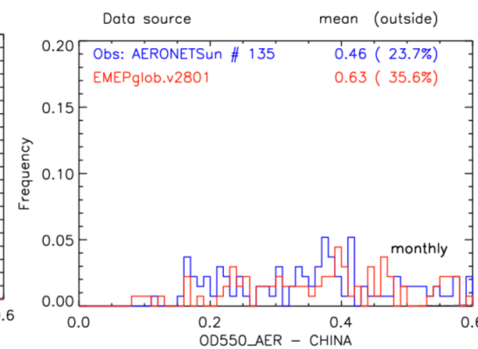
N. America



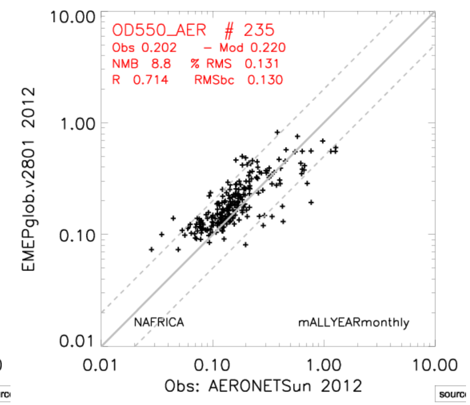


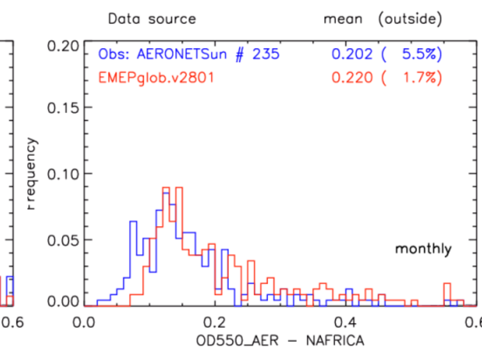
China





N. Africa





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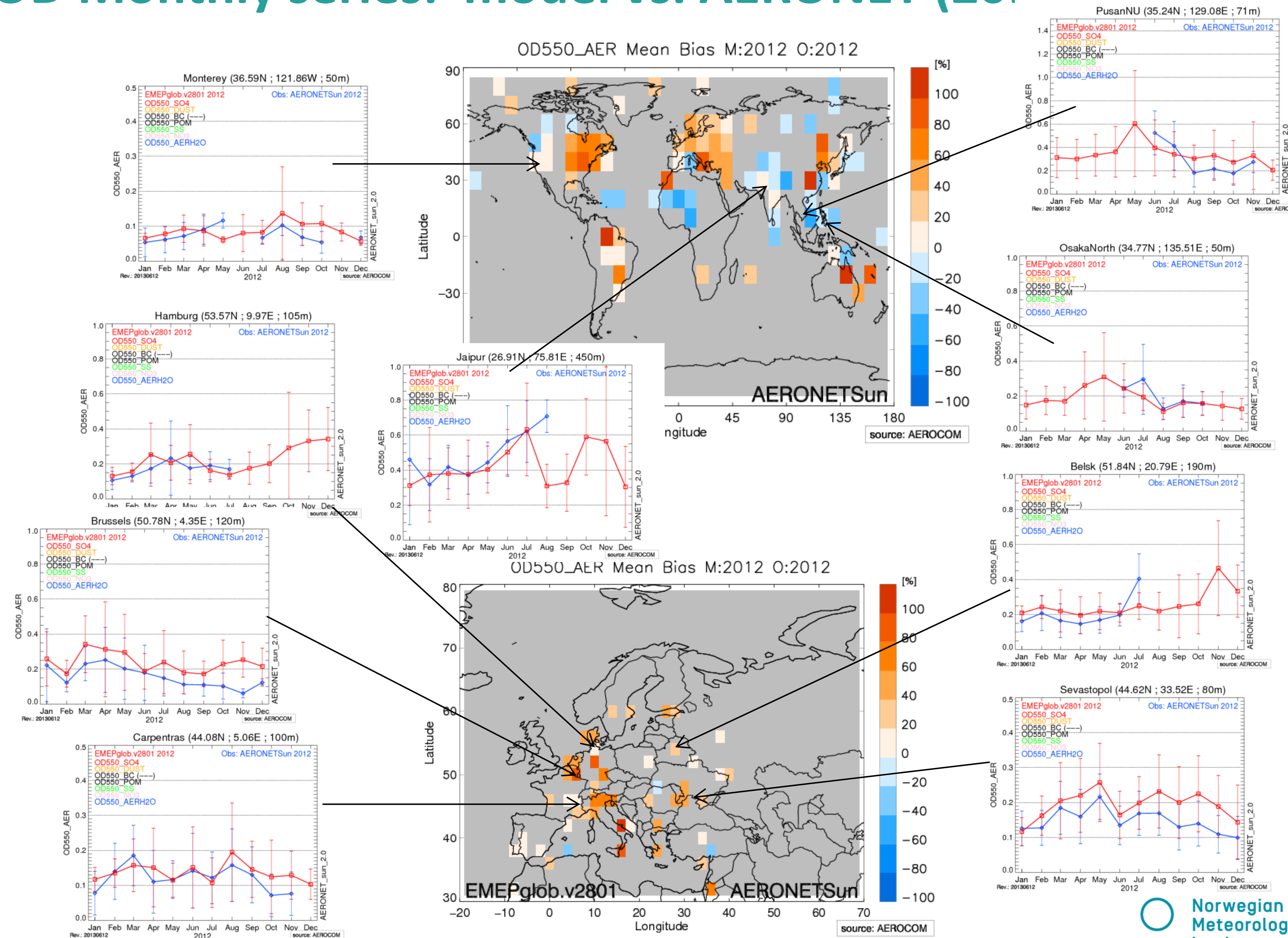
AOD Monthly series: model vs. AERONET (2012)



EMEP vs. AERONET : June-July 2009

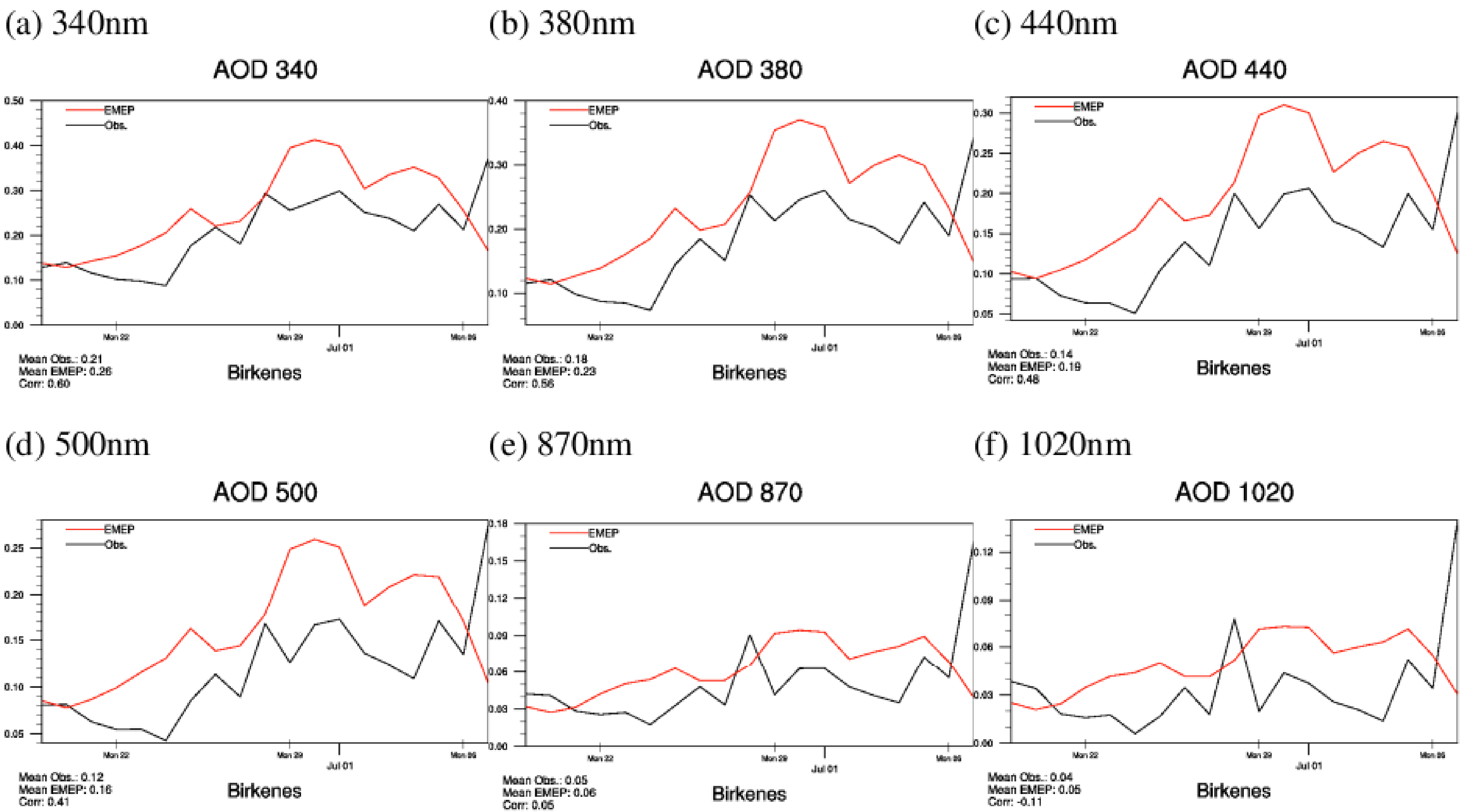
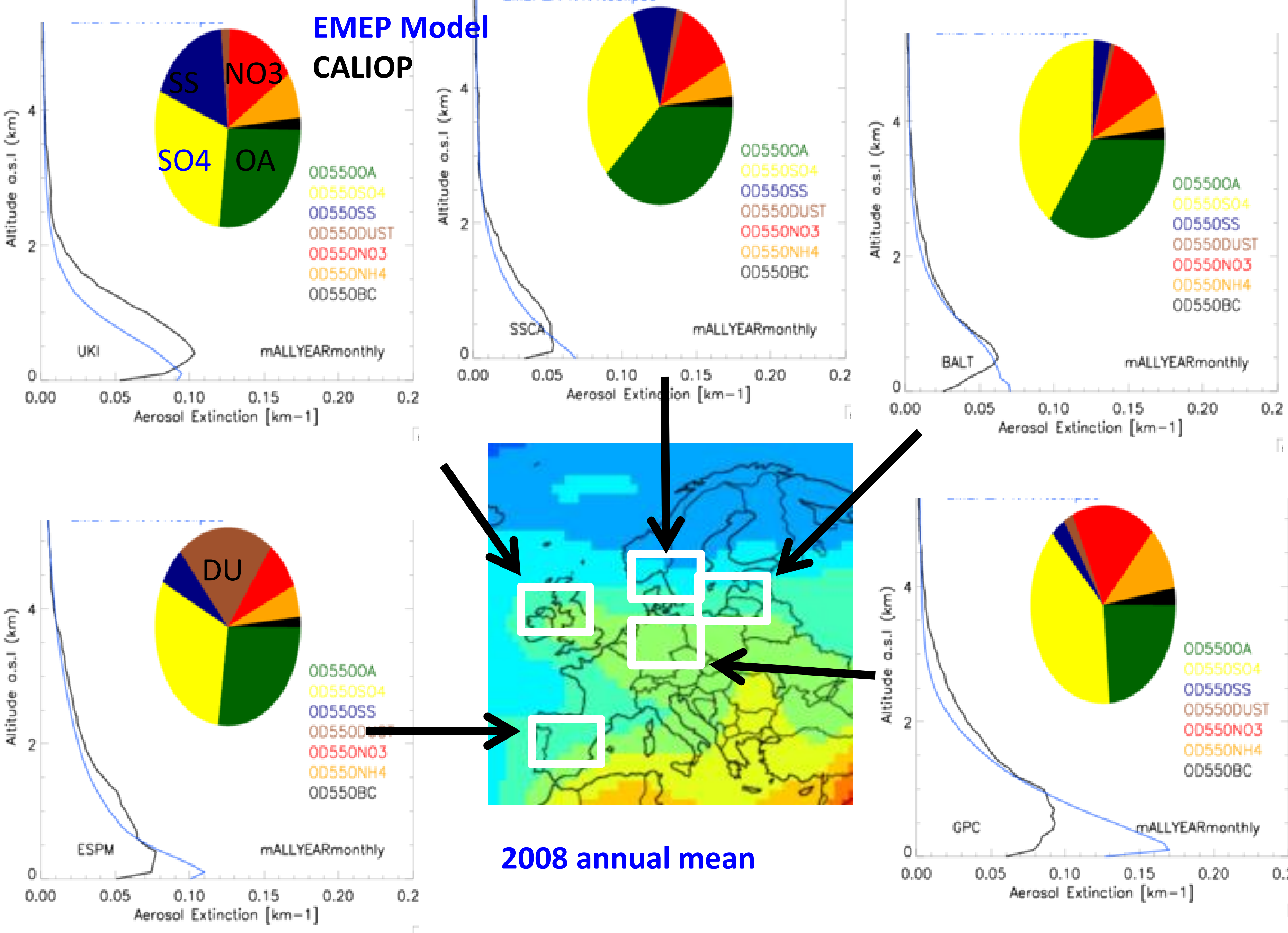


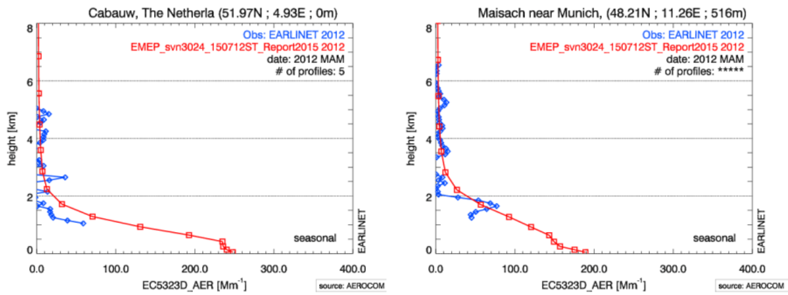
Figure 7: Daily AOD timeseries as modelled and observed at the AERONET site Birkenes (Norway) for the period of 15 June-15 July, 2009.



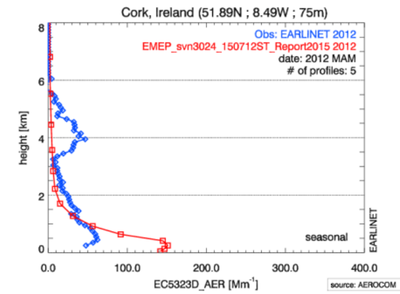
EMEP Model
CALIOP
SS
NO3
SO4
OA
DU
OD550OA
OD550SO4
OD550SS
OD550DUST
OD550NO3
OD550NH4
OD550BC
UKI
SSCA
BALT
ESPM
GPC
mALLYEARmonthly
Altitude a.s.l (km)
Aerosol Extinction [km−1]
0.00
0.05
0.10
0.15
0.20
0.2
0
2
4
2008 annual mean

Extinction vs. Earlinet Lidars

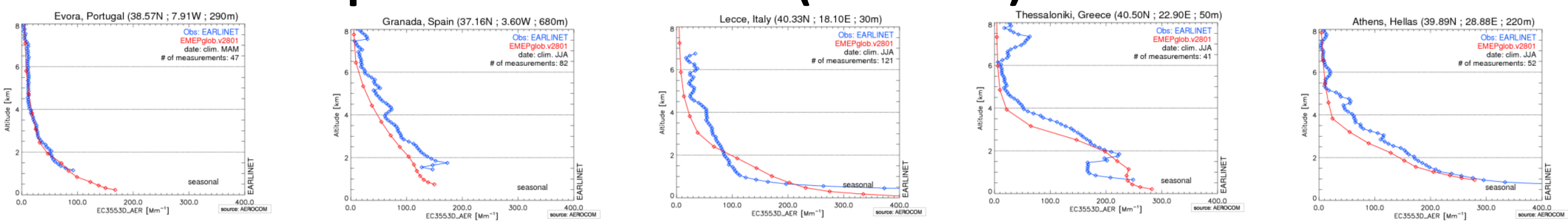
Central Europe



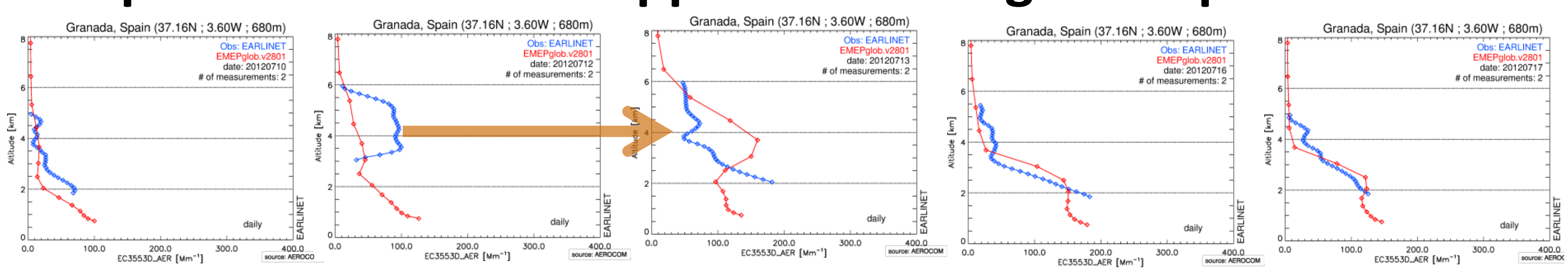
Coastal (Ireland)



Southern Europe: Dust evaluation (seasonal)



Dust episode in Granada: upper level and ground plumes



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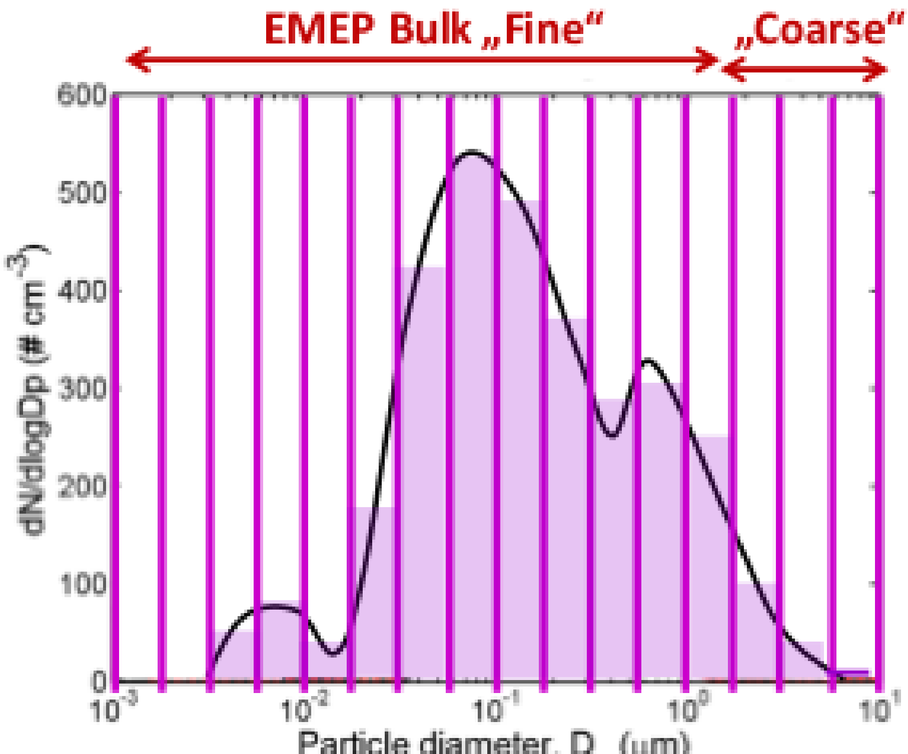
Size-resolved aerosol representation in EMEP-MAFOR

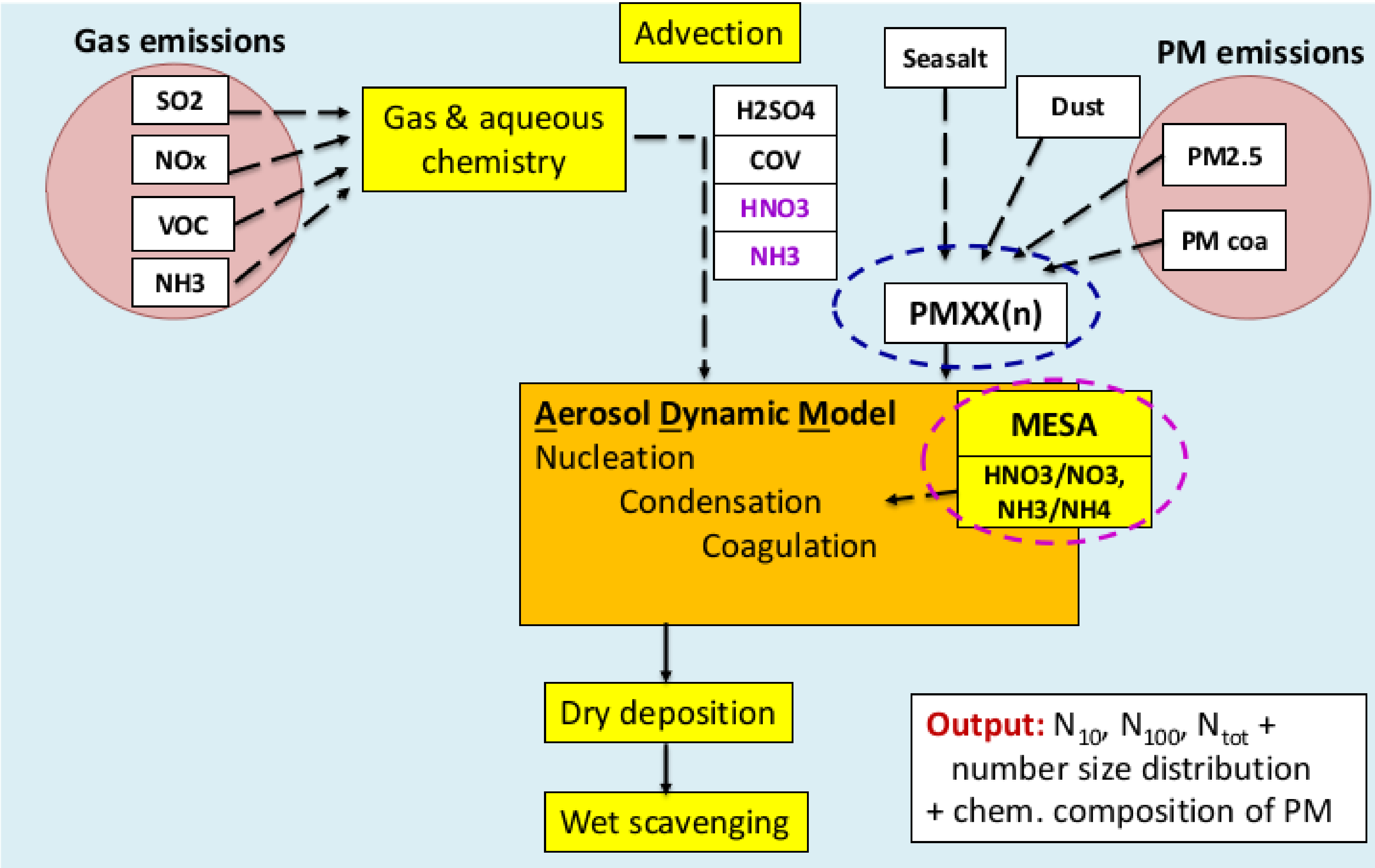
- Health effects (UF particles)
- Radiative effects
- Physically sound description of a number of aerosol processes (interaction with clouds, condensation of semi-volatile gases....)

EMEP – MAFOR model (Karl et al., Tellus, 2011)

- <u>MAFOR aerosol dynamics module</u> solves size distribution of a mixed multicomponent aerosol on a fixed sectional grid (invariable volume)
- Simultaneous and consistent initiation and time integration of particle number and mass concentrations
- Nucleation, coagulation, condensation (H_2SO_4, SV and LV organics) ...
- 16 size sections (1nm – 10 µm), aggregated into 4 modes



EMEP-MAFOR with dynamic SIA



«Golden Day Events» Hyytiälä, 24-30 March 2003

Observations:

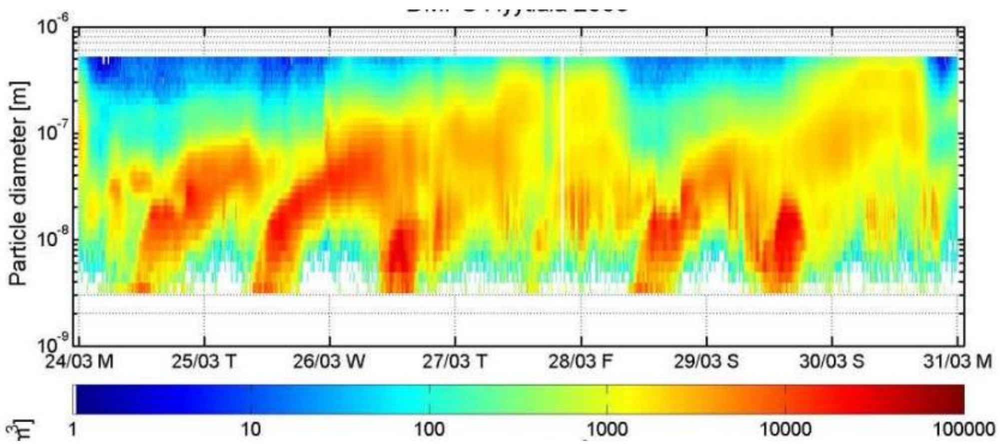
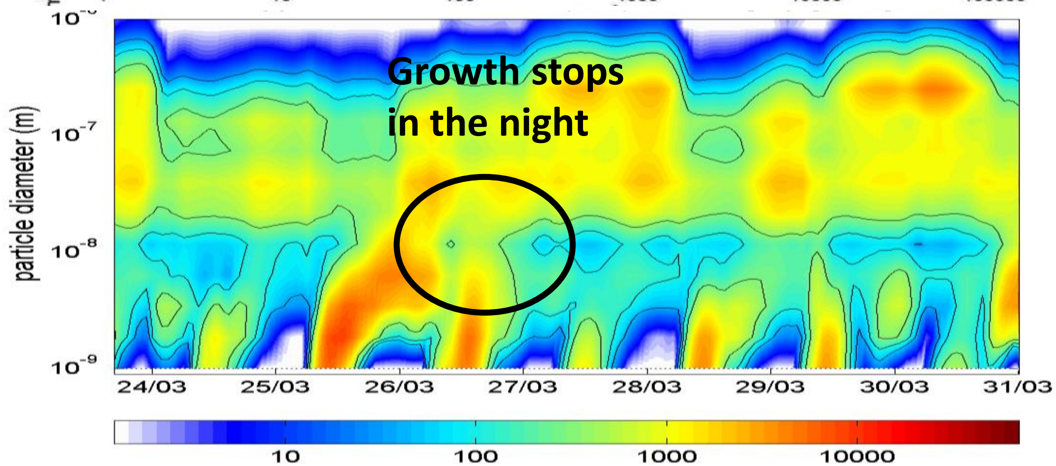


Figure from:
O'Dowd et al.,
ACP, 2009

Model (Ref):



- Missing particle sources (wood burning in winter , agricultural biomass burning in summer)
- SOA from VBS model is currently missing
- Underestimation of 50-200 nm particles in summer at remote sites, possibly due to: 1.Model predicts too many events in summer with too high GR; 2. BVOC chemistry at night identified as possible reason for interruption of particle growth

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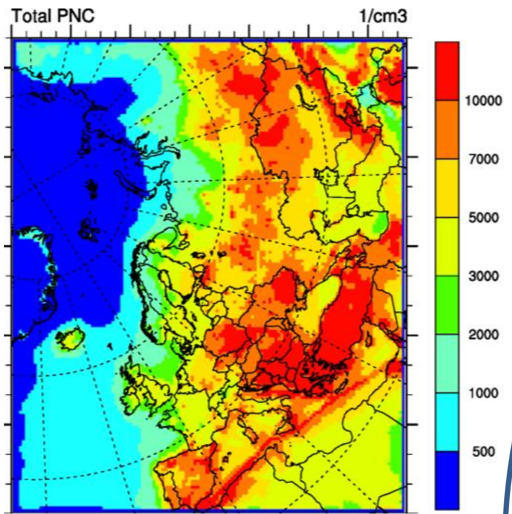
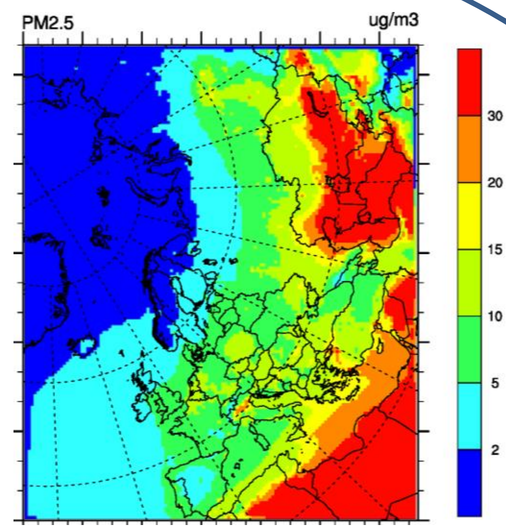
Model: particle number and mass concentrations

2012 mean

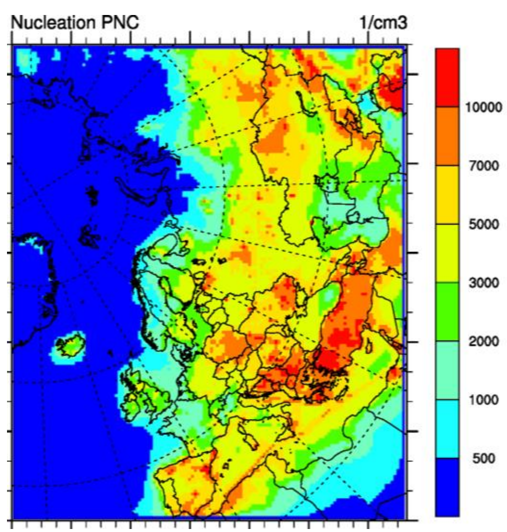
Total PNC



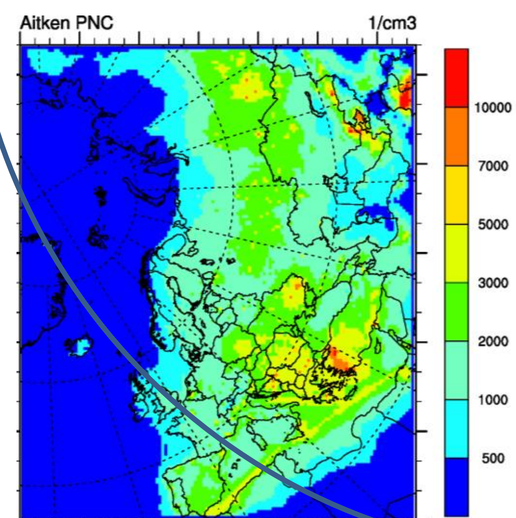
PM2.5



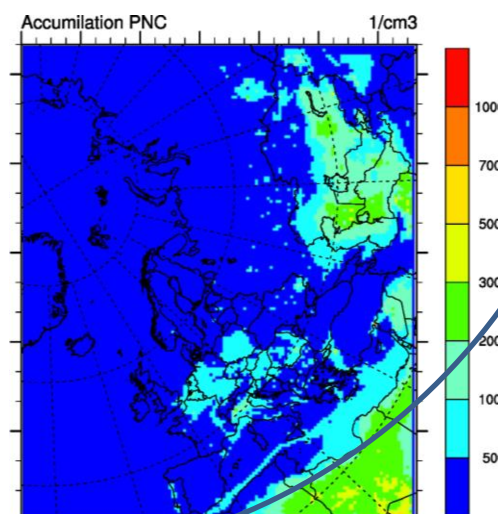
Nucleation PNC



Aitken PNC



Accumulation PNC



EMEP_MAFOR evaluation with measurements:

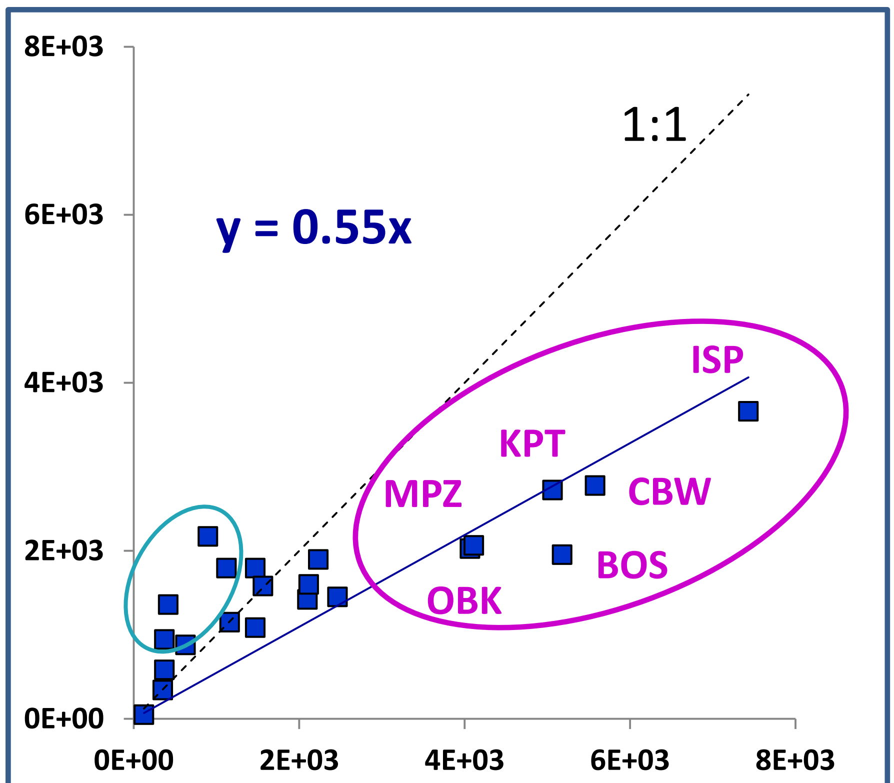
- Asmi et al. Year: 2008 (annual/seasonal PNC & size distribution)
- EUSAAR/ACTRIS/EBAS: Year 2010, dN/dlogDp
- SPC (San Pietro Capofiume): Year 2010, dN/dlogDp
- SmartSMEAR (Hyytiälä) : Summer 2010, VOC, H_2SO_4, OH

Modelled vs. observed total PNC (d>10nm) in 2008

Model compared to measured PNCs:

- Underestimates at polluted sites (C. Europe)
- Quite close at less polluted sites (N. Europe)
- Overestimates at mountain sites

Measurements as in Asmi et al., ACP, 2011



Ny_Alesund2
Pallas
Hyytiala
Birkenes
Aspvreten
Vavihill
MaceHead
Waldhof
Harwell
Finokalia
Zugspitze
Jungfraujoch
Hohenpeissenberg
Puy_deDome
Schauinsland
Mt_Cimone
Melpitz
Kosetice
K_Puszta
Boesel
Cabauw
Ispra

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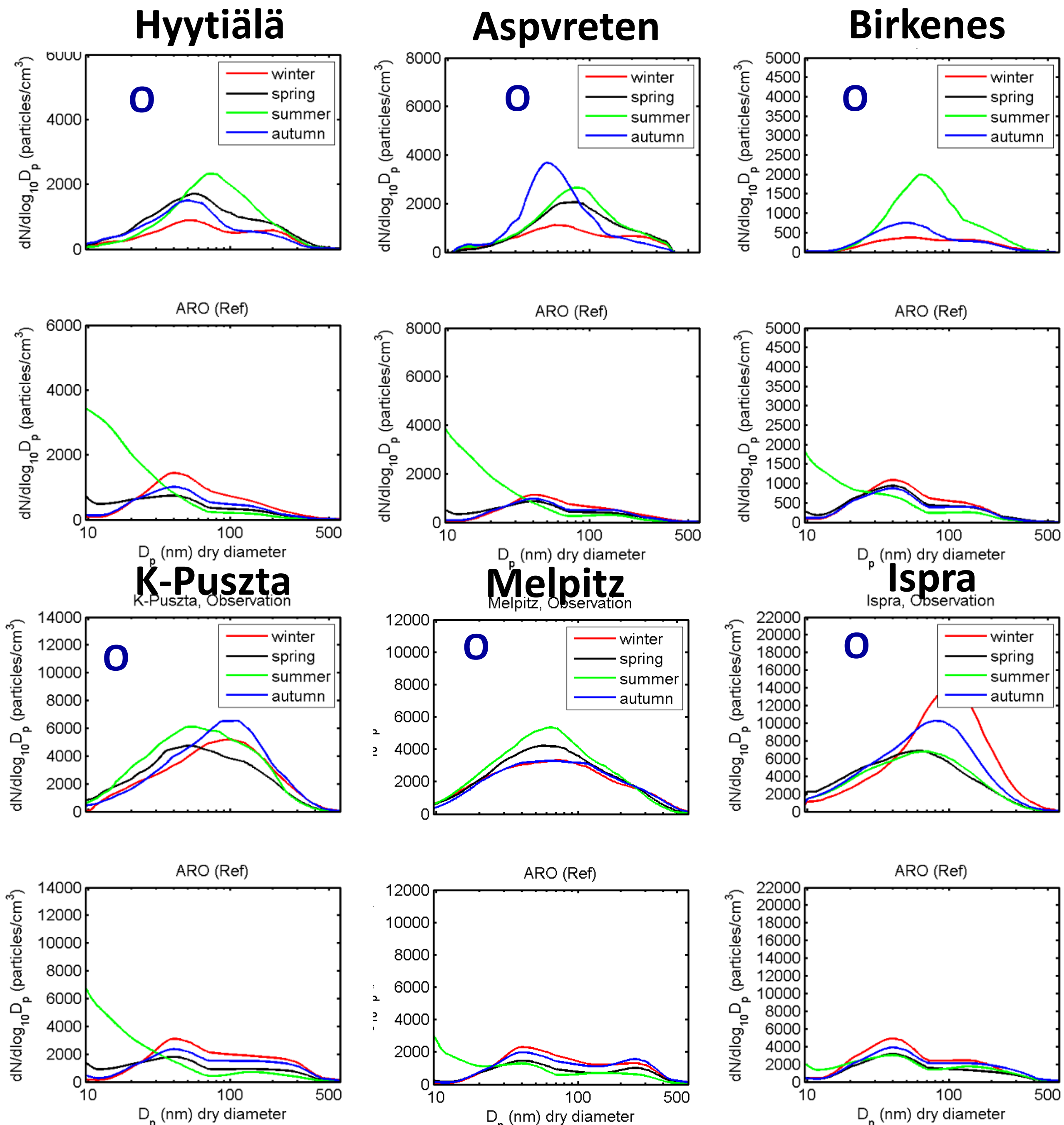
Seasonal median size distribution (2008)



Modelled PNCs compared to the measurements:

- **too low in summer (VBS-SOA and agriculture biomass burning missing)**
- **also low at spring and autumn**
- **In winter: quite close at cleaner sites, but too low at polluted sites (wood burning for residential heating is believed to be underestimated)**

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THE END