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Application and development of the OFIS model within the framework of CityDelta

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Garmisch, 1 June 2004

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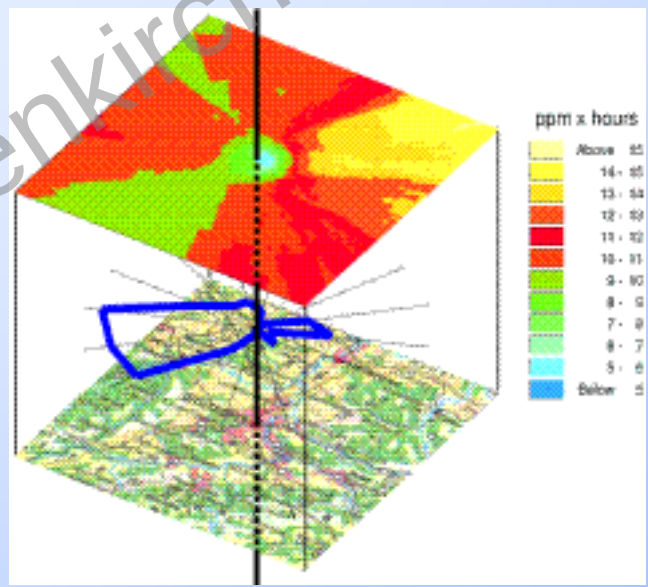
The Ozone Fine Structure (OFIS) model - Model concept (1/2)

The OFIS model was developed in order to

(i) allow authorities to assess urban air quality by means of a fast, simple and still reliable model

(ii) refine a regional model simulation by estimating the urban subgrid effect on pollution levels



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The Ozone Fine Structure (OFIS) model - Model concept (2/2)

Pollutant transport and transformation downwind the city (along the prevailing wind direction) calculated with a 2-layer model.

$$\Delta c_i^1 / \Delta t = K_z (c_i^2 - c_i^1) / dz_1^{\,2} + q_i / dz_1 + R_i (c_1^1, ..., c_n^1) + u (c_i^{u1} - c_i^1) / \Delta x$$

$$\Delta c_i^2 / \Delta t = K_z (c_i^1 - c_i^2) / (dz_2 dz_1) + R_i (c_1^2, ..., c_n^2) + u (c_i^{u2} - c_i^2) / \Delta x +$$
$$(c_i^{bc} - c_i^2) \max\left[0, \Delta H_t / (\Delta t \cdot H_t)\right]$$

C_i: concentration of chemical species i

K_z: vertical turbulent exchange coeff.

q_i : emission rate for species i

R_i : chemical formation or destruction rate for species I

H_t: mixing height

Top of 1st layer = 90 m

2nd layer= mixing height

cell width = city diameter

cell length (Δx) = ~5 km

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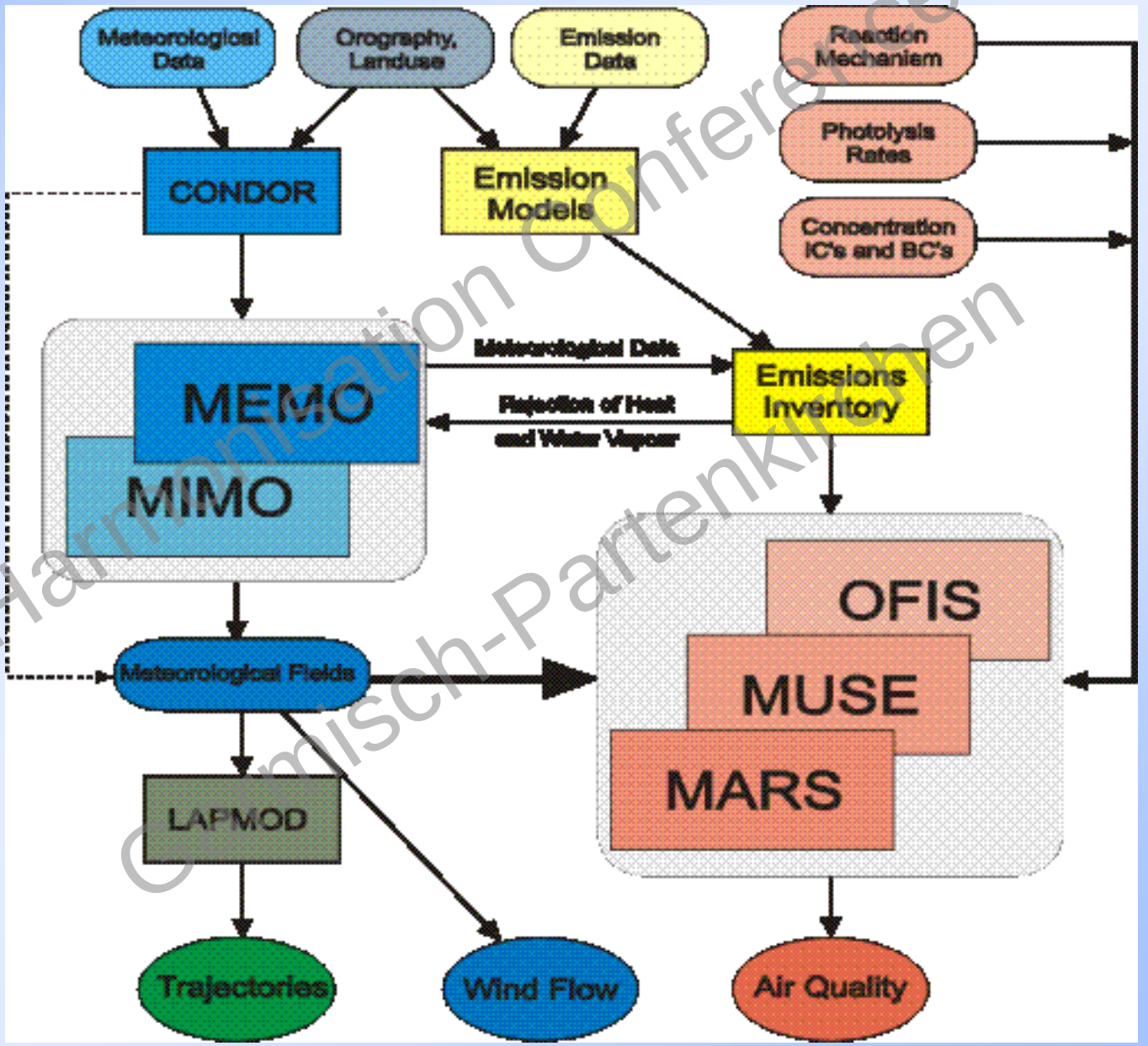
The Ozone Fine Structure (OFIS) model - Model features

- EMEP MSC-W and CBM-IV chemical mechanisms
- Two-mode aerosol module (log-normal distribution) assuming inorganics equilibrium between phases
- Advection discretised using an upwind scheme
- Mixing height and turbulent diffusivity estimated in a vertical column atmosphere/soil radiation budget model.
- Requires a computation time < 4 hours for a full year simulation on a P4 2.0 GHz CPU, being more than 70 times faster than the 3D model MUSE

European Zooming Model (EZM) system



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MUSE

- MUSE belongs to the EZM system
- 3D Numerical Model for the description of the dispersion and chemical transformation of pollutants
- Various chemistry mechanisms (EMEP/RACM/KOREM/CBM-IV)
- Coupled implicit treatment of vertical diffusion & chemistry
- Domain extension: 150×150 km (5km resolution)

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Latest OFIS improvements

- Capability for use of gridded emissions inventories, besides the default disaggregated ones
- 3-hourly values are used for the meteorological and boundary conditions input, performing a 5 hour run for each 3-hour frame
- Aerodynamic resistance approach to parameterise dry deposition for gases and particles
- Use of an appropriate parameterisation for wet removal of gases and particles (Scott, 1979)
- Biogenic emissions calculated according to land use

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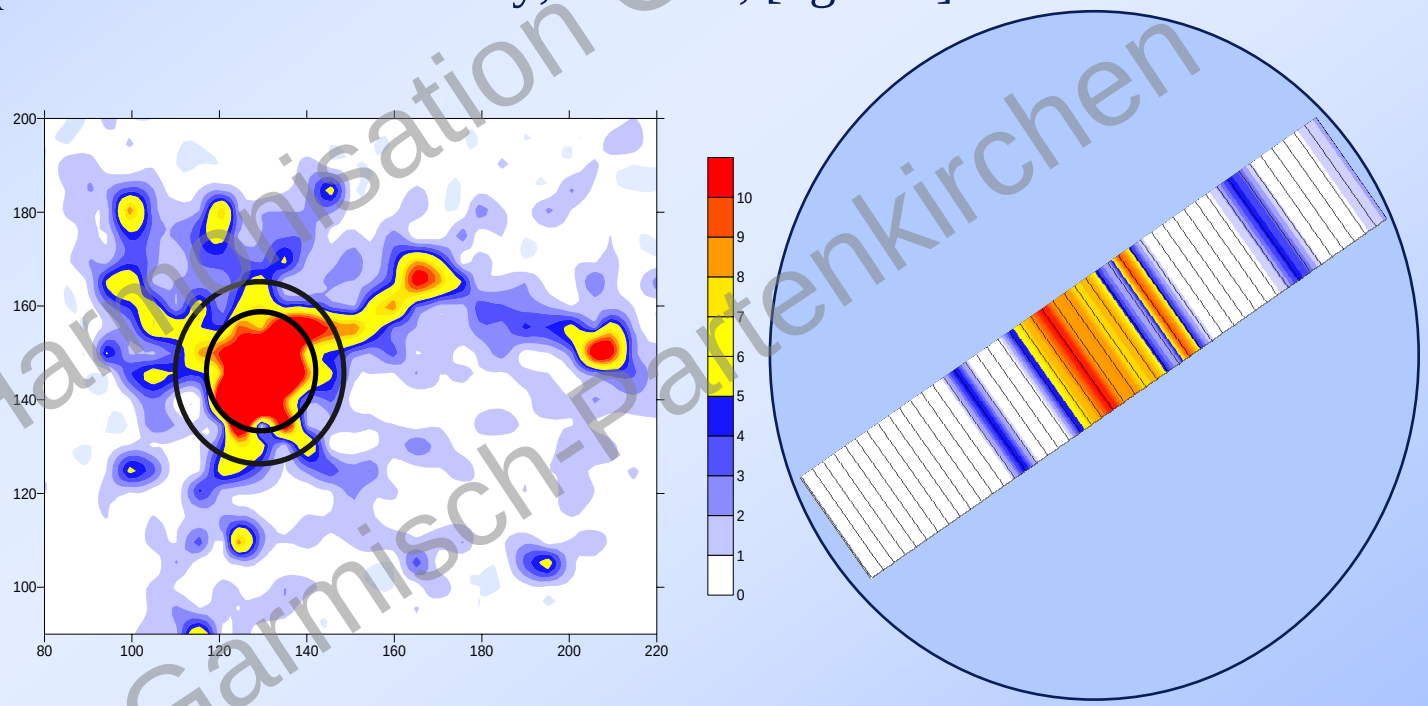
OFIS – Geographical emission distribution used for Milan

NO_x emissions for 5th of May, 8:00 am, [kg/km^2]



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CityDelta Phase II

- Four cities considered (Berlin, Milan, Paris and Prague), domains as in phase I
- Meteorology as in CD phase I
- At the regional scale, revised emission fields with validated gridded distributions of sectoral emissions
- Background boundary conditions for 1999, also for the emission control scenarios
- Base case is 2000 and seven (7) scenarios for 2010 are studied

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Model application

- OFIS was applied to study pollution levels for the cities of Milan, Paris , Berlin and Prague
- Both boundary conditions and emissions data were provided by CityDelta
- Meteorological data used originated from the ALADIN project

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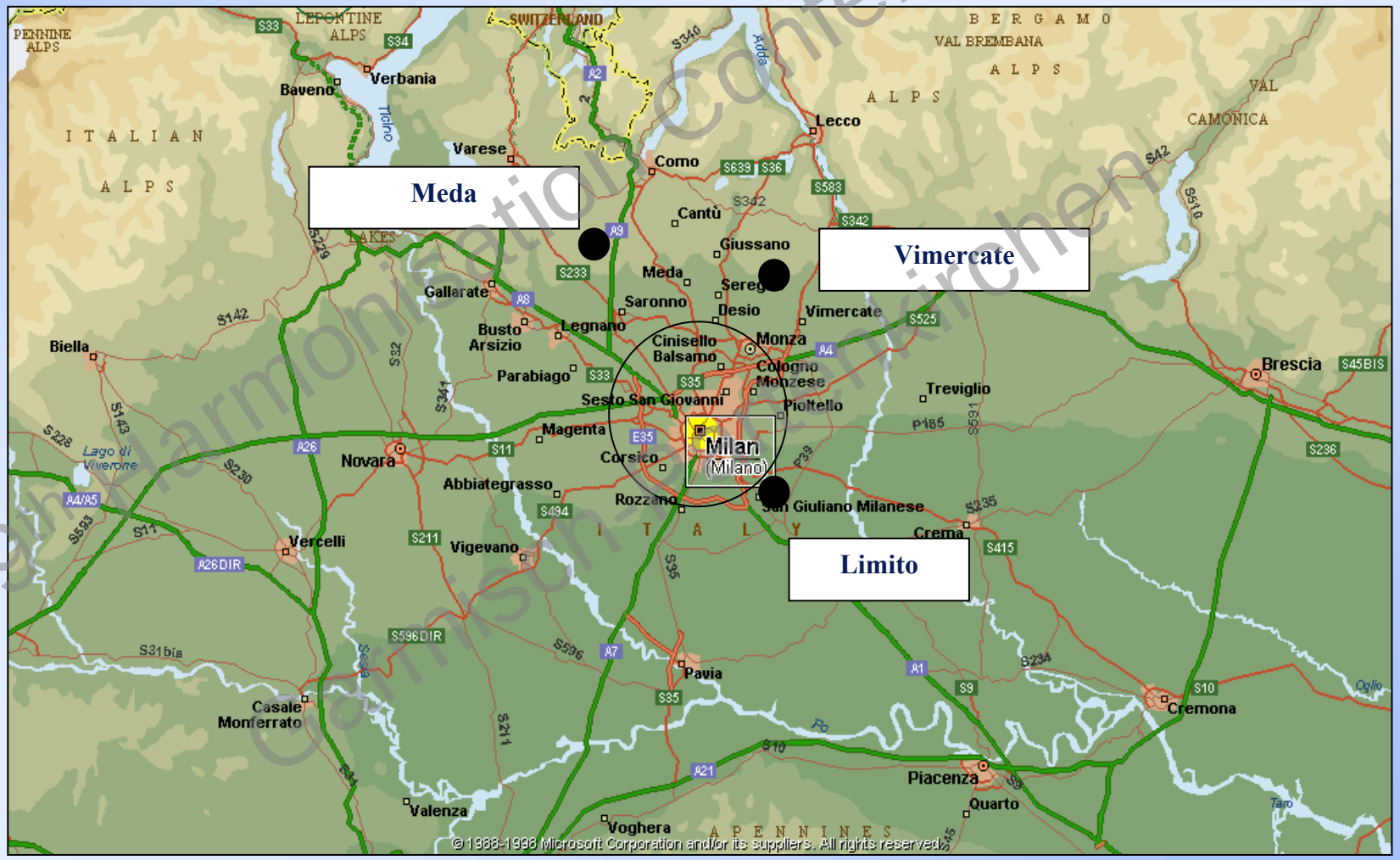
Milan stations



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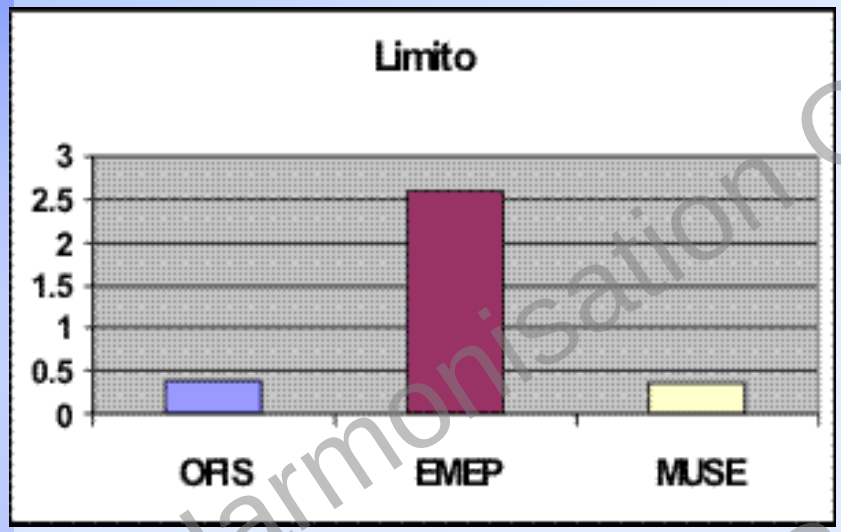
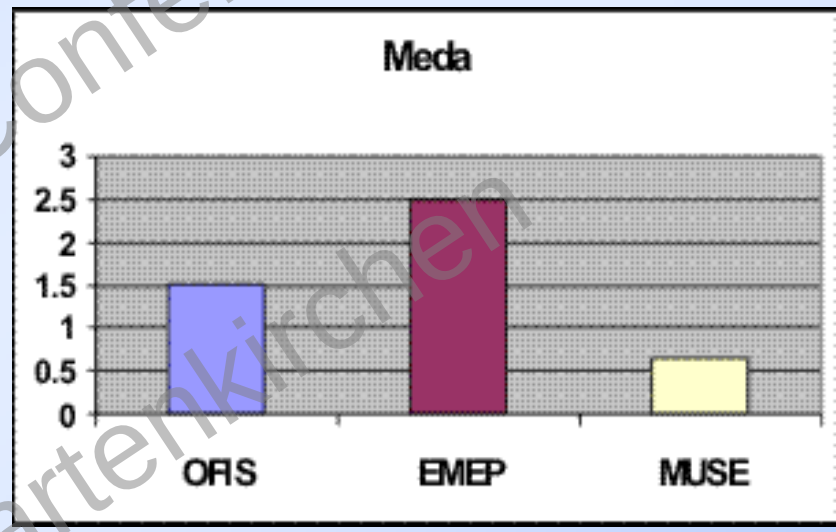
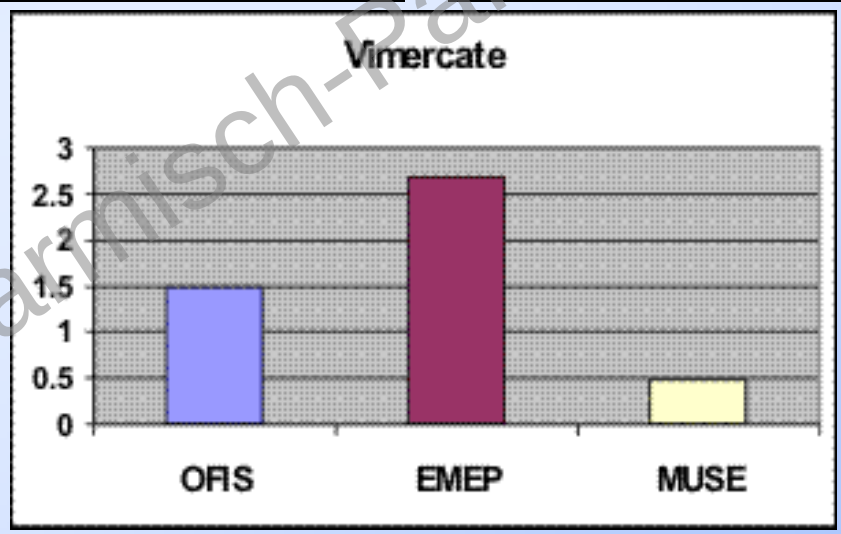
Milan – Comparing OFIS to EMEP and MUSE

NO_2

NMSE







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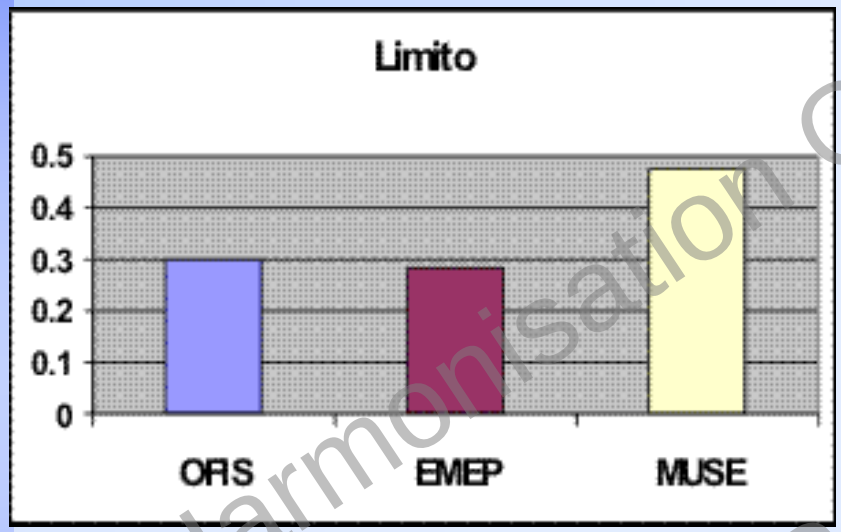
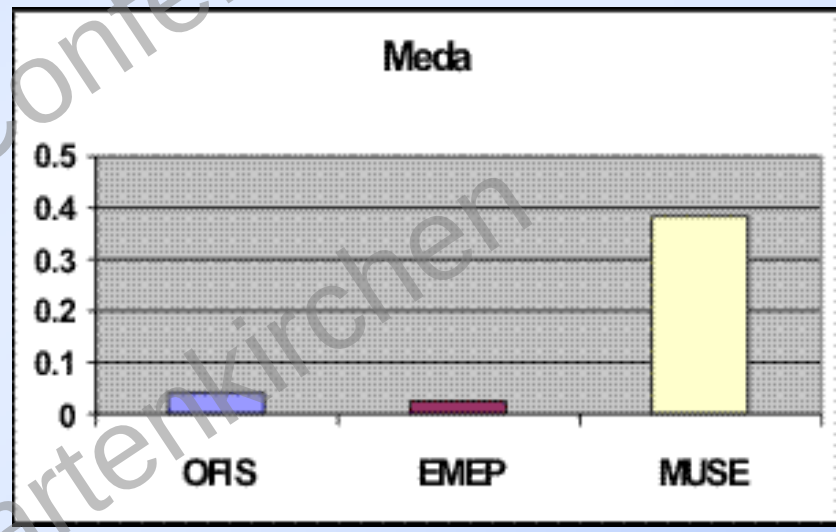
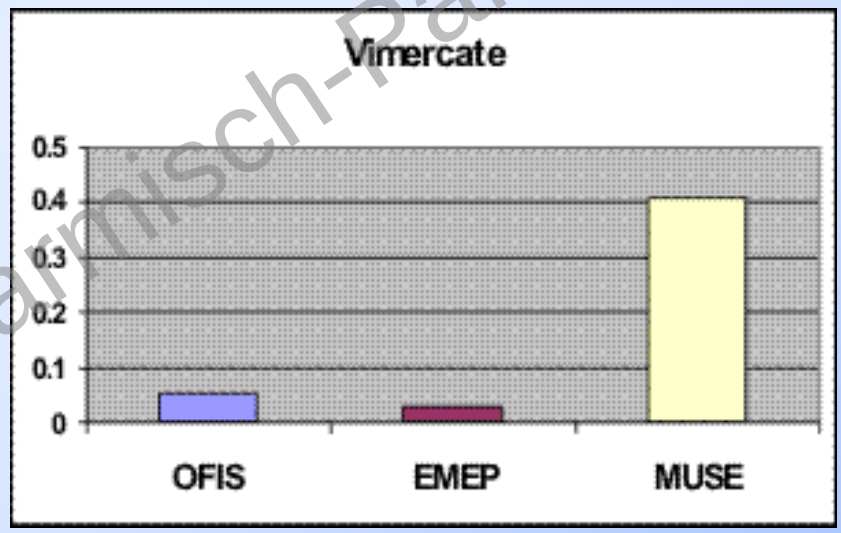
Milan – Comparing OFIS to EMEP and MUSE

NO_2 **Correlation coefficient**







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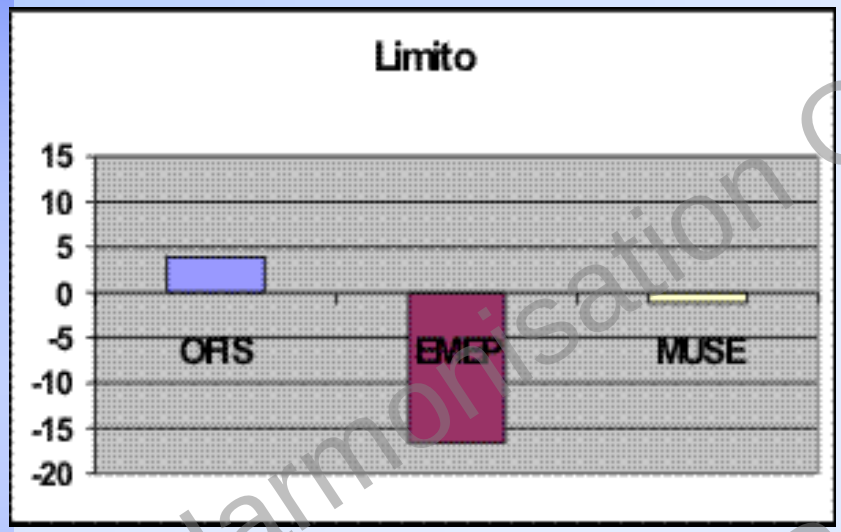
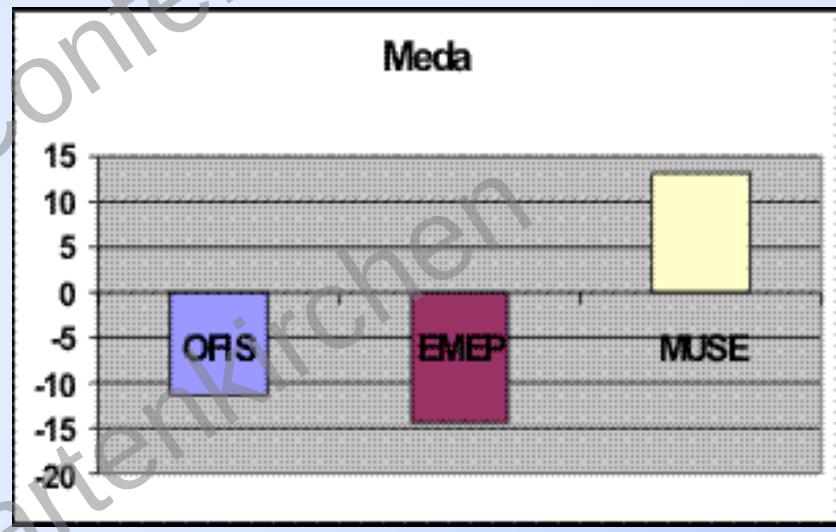
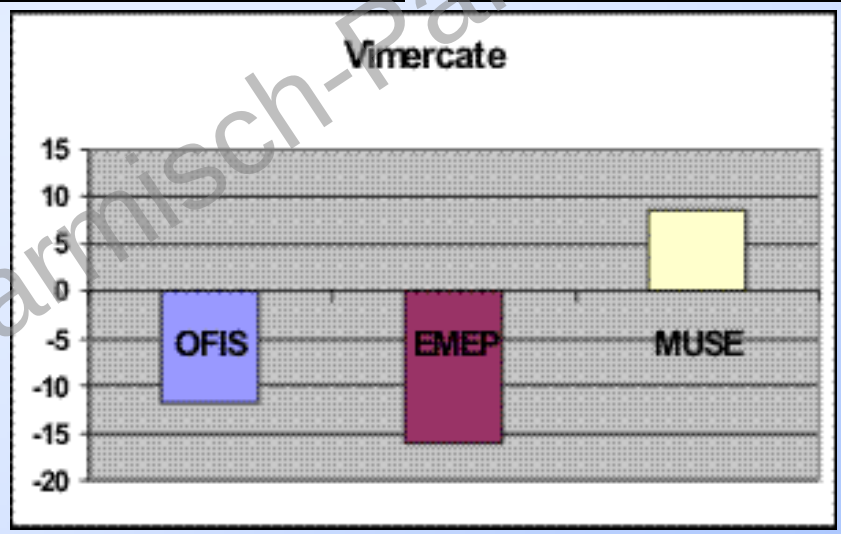
Milan – Comparing OFIS to EMEP and MUSE

NO_2

Bias







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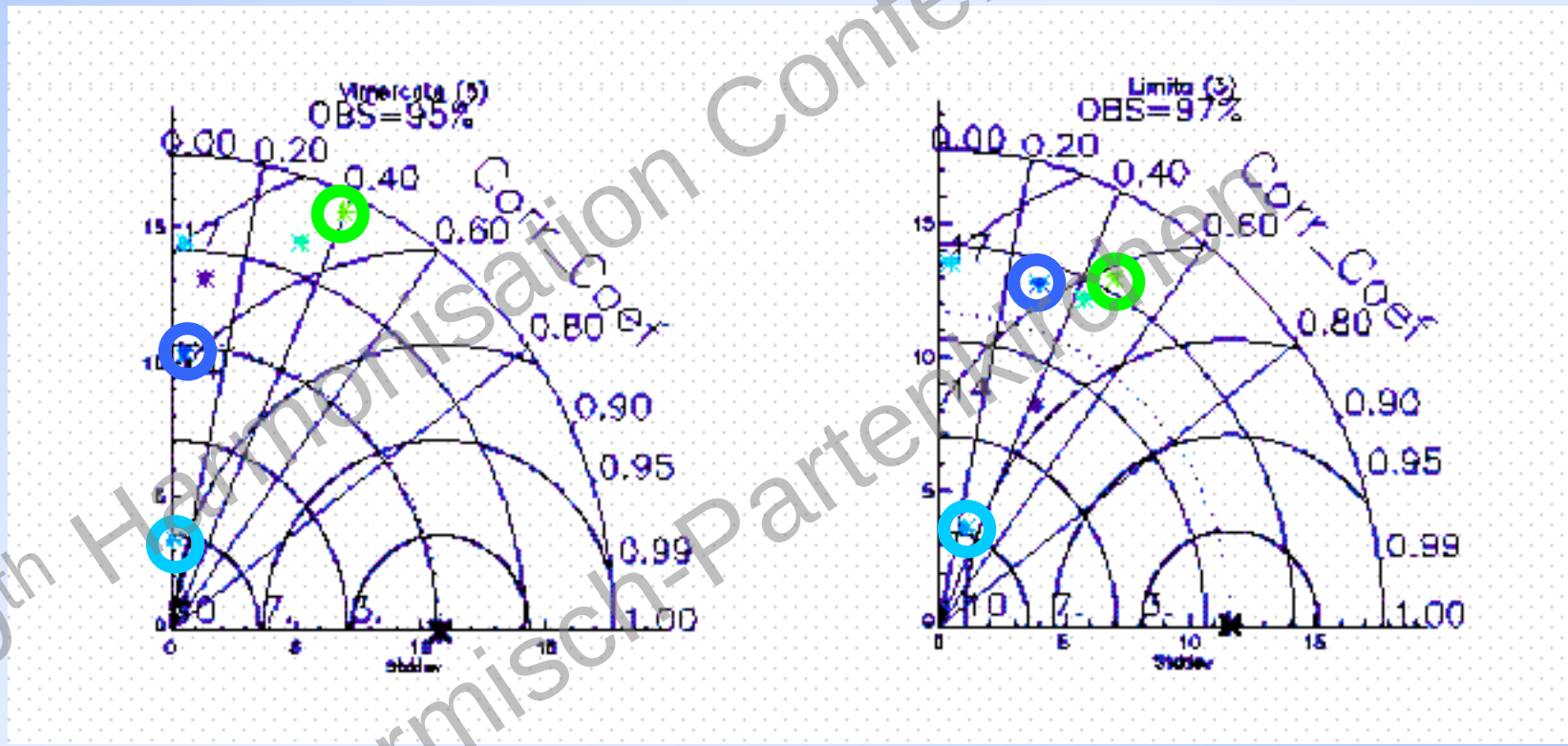
Milan – Comparing OFIS to EMEP and MUSE

NO_2

Taylor diagram



* MUSE
* OFIS
* EMEP

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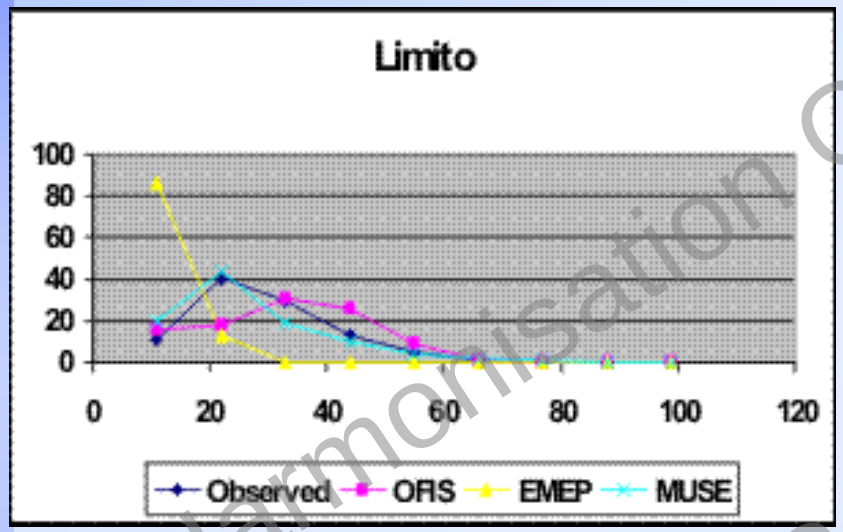
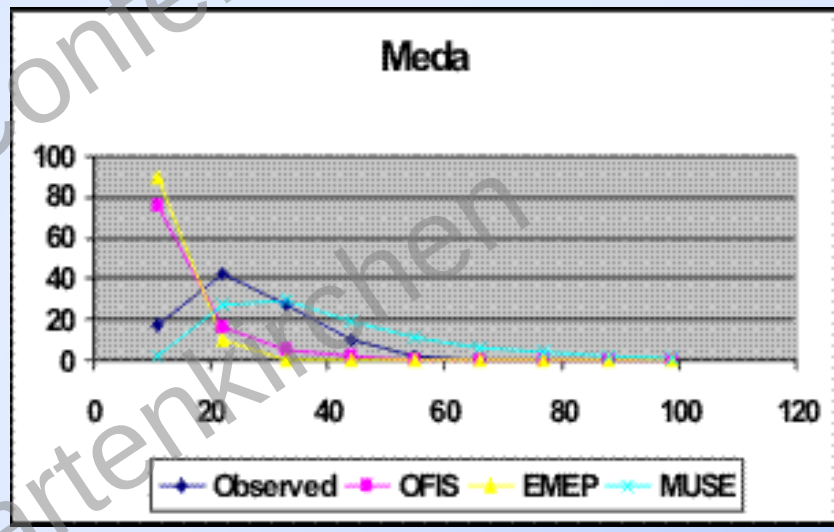
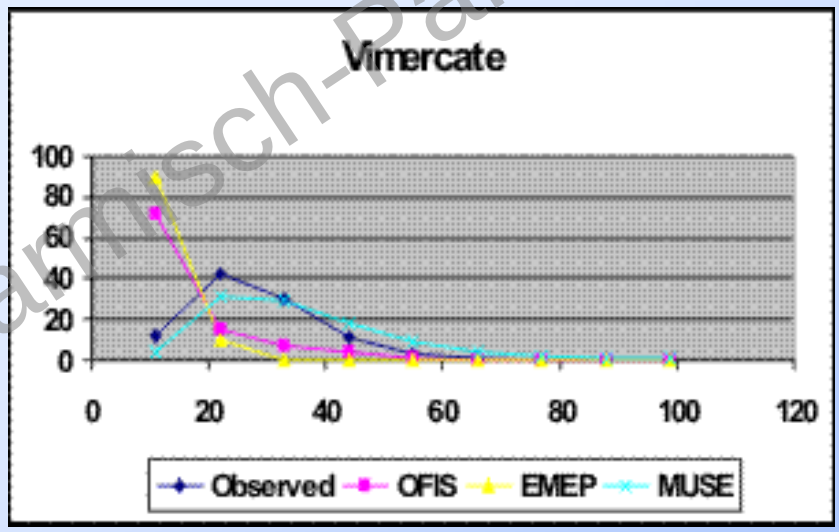
Milan – Comparing OFIS to EMEP and MUSE

NO_2 **Frequencies diagram**







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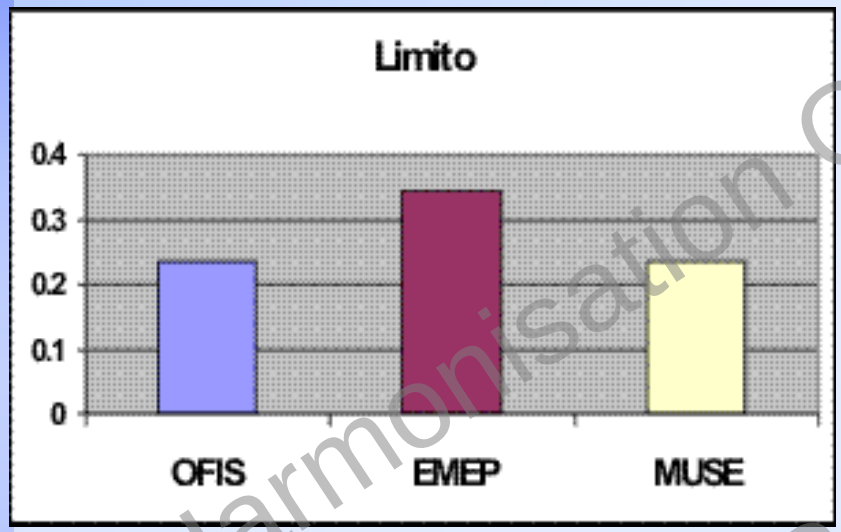
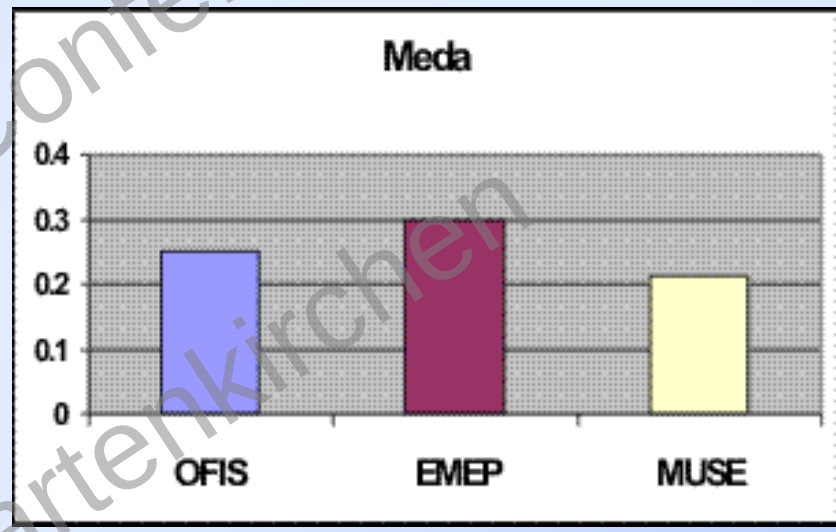
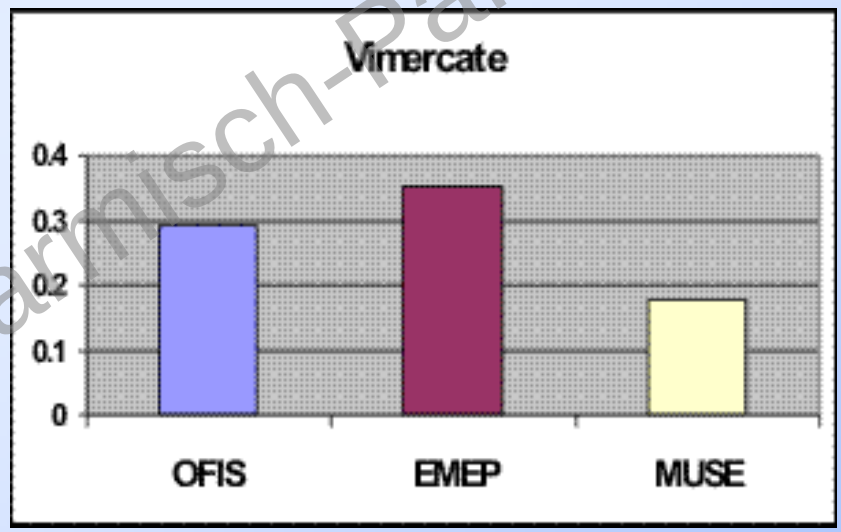
Milan – Comparing OFIS to EMEP and MUSE

O_3

NMSE







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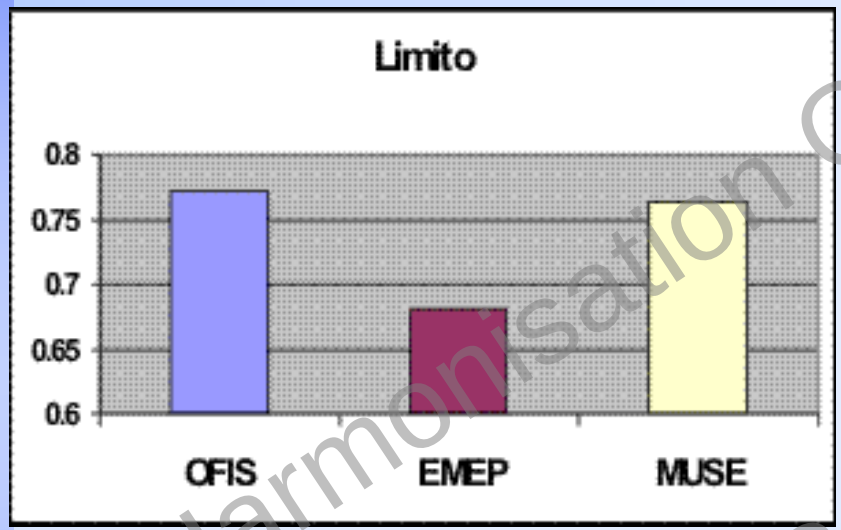
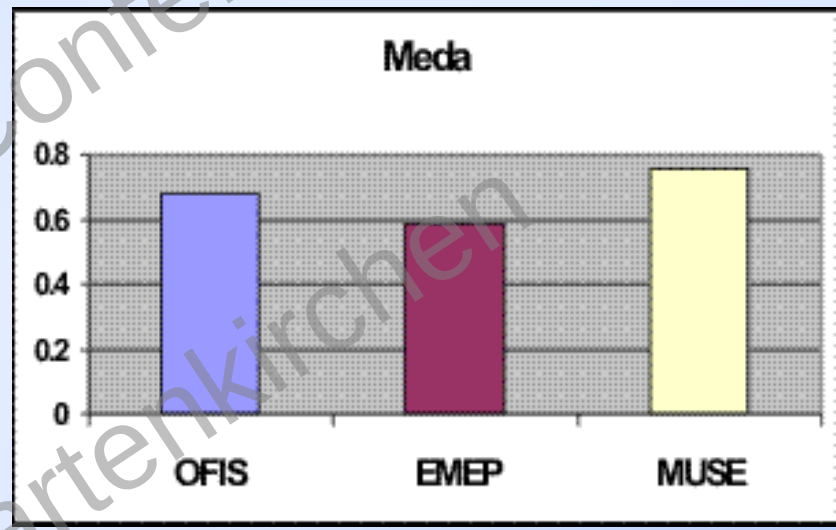
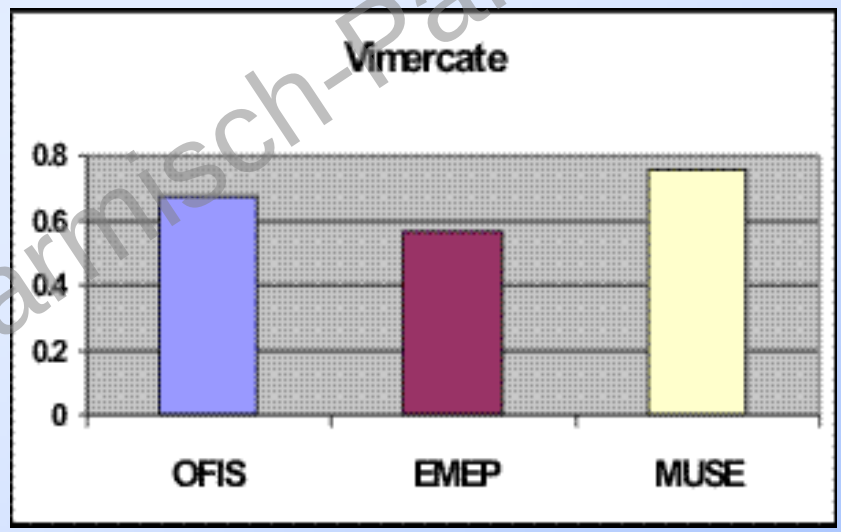
Milan – Comparing OFIS to EMEP and MUSE

O_3 **Correlation coefficient**







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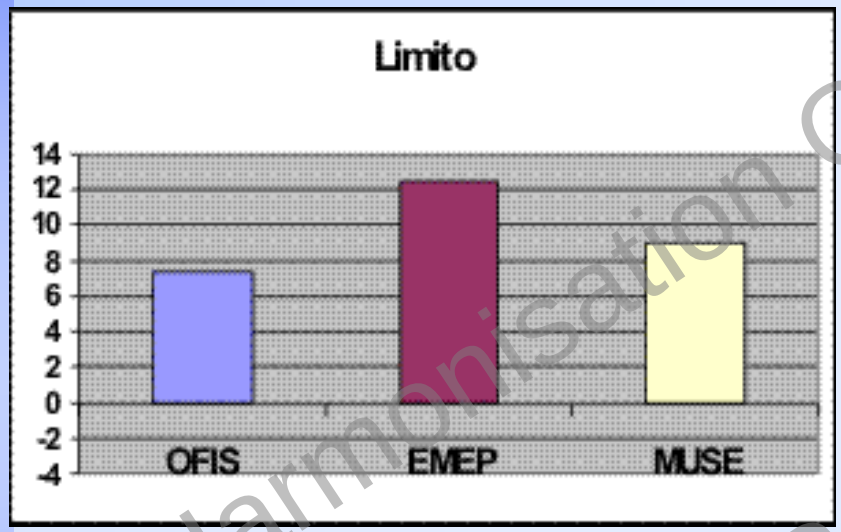
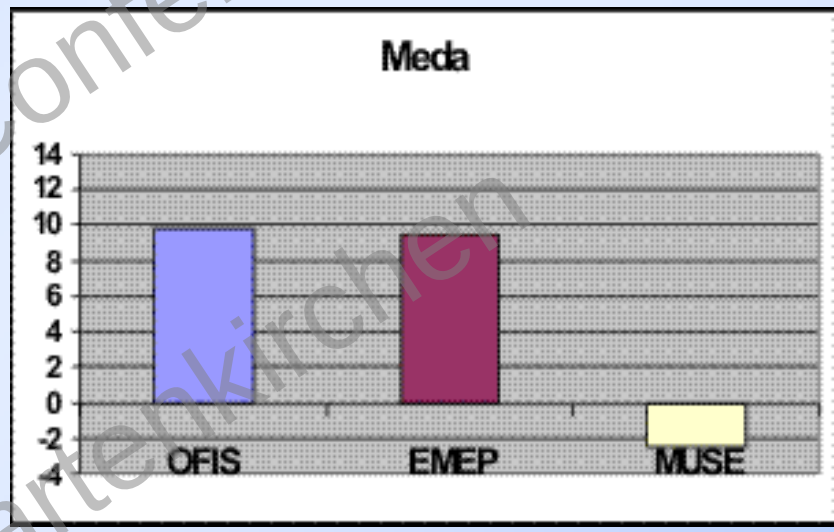
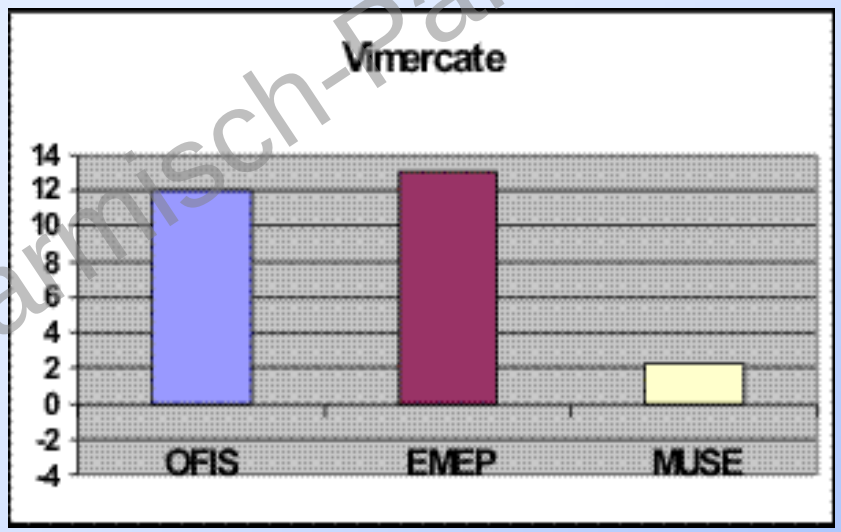
Milan – Comparing OFIS to EMEP and MUSE

O_3

Bias







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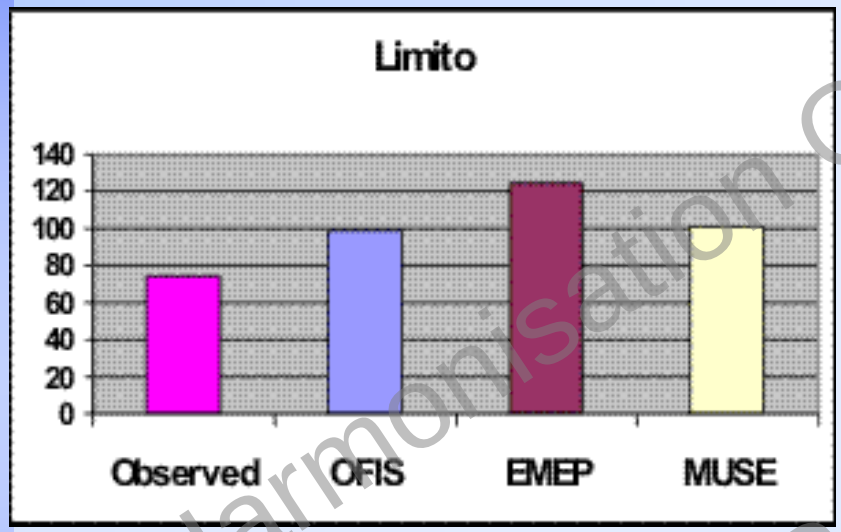
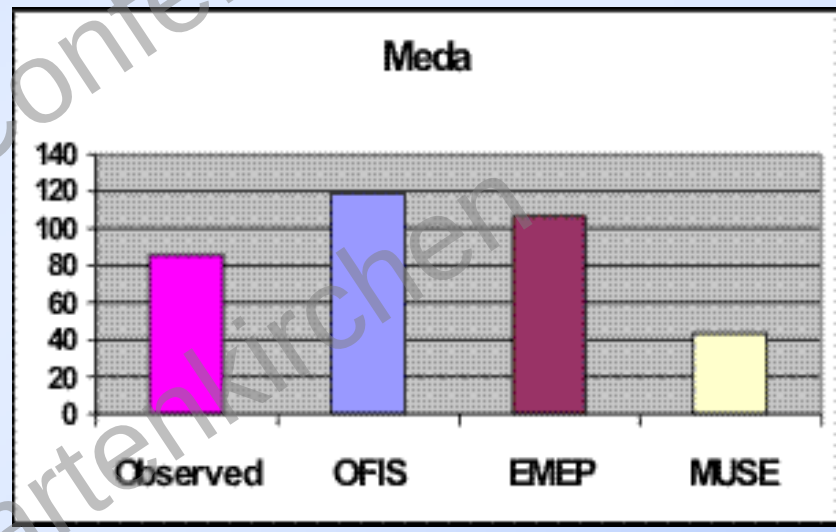
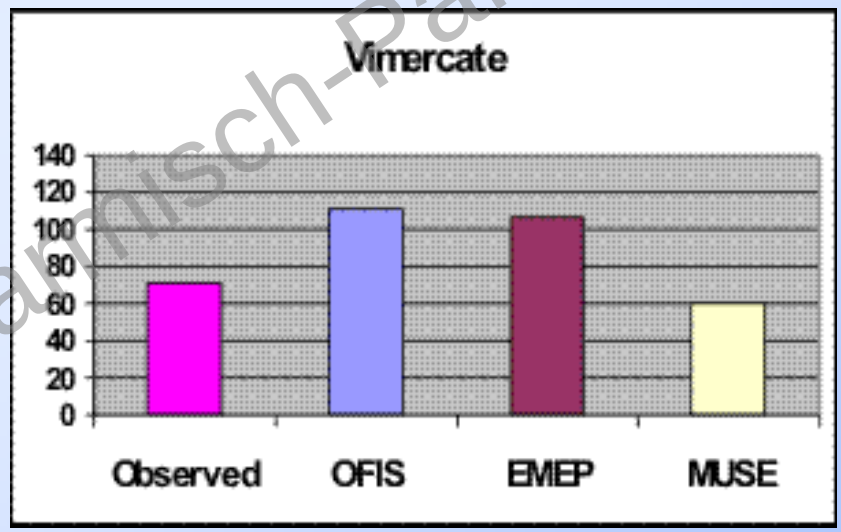
Milan – Comparing OFIS to EMEP and MUSE

O_3 **Exceedance days (120 µg/m^3)**







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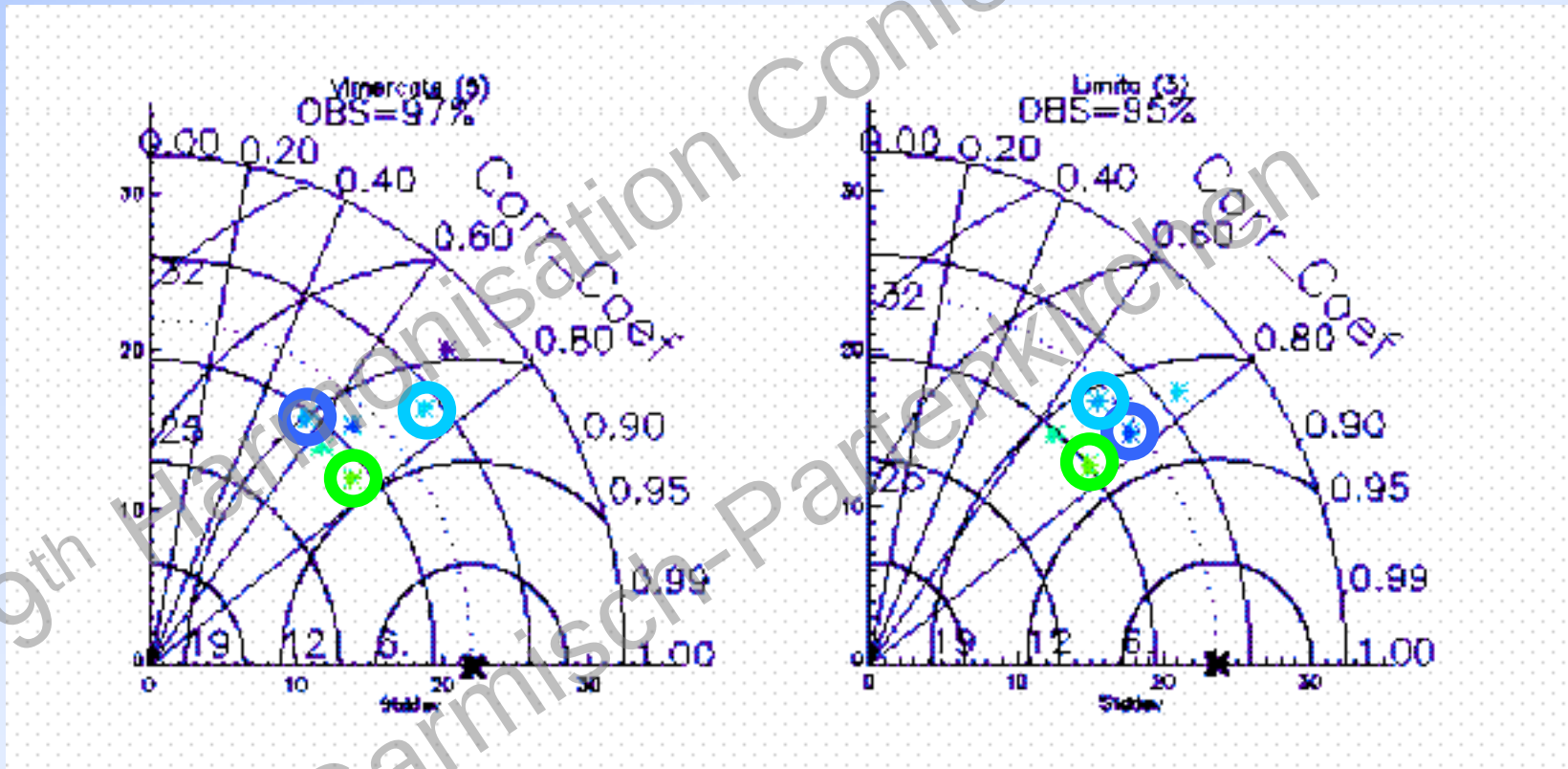
Milan – Comparing OFIS to EMEP and MUSE

O_3 **Taylor diagram**



* MUSE
* OFIS
* EMEP

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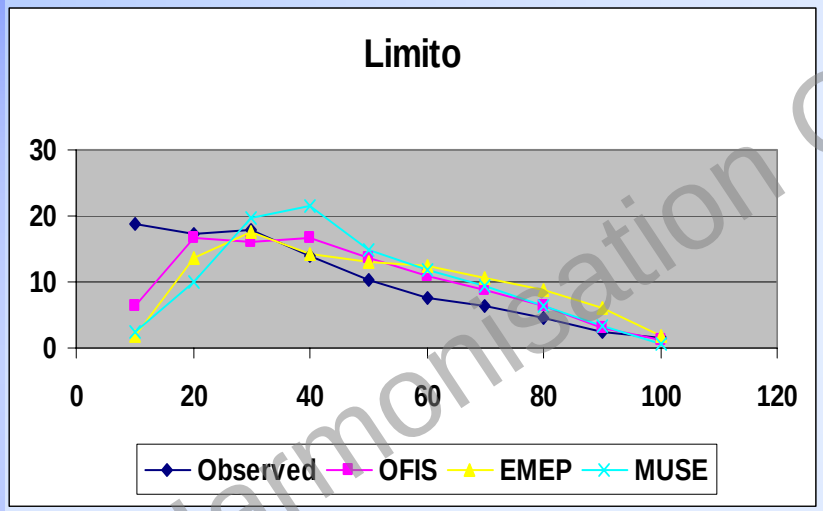
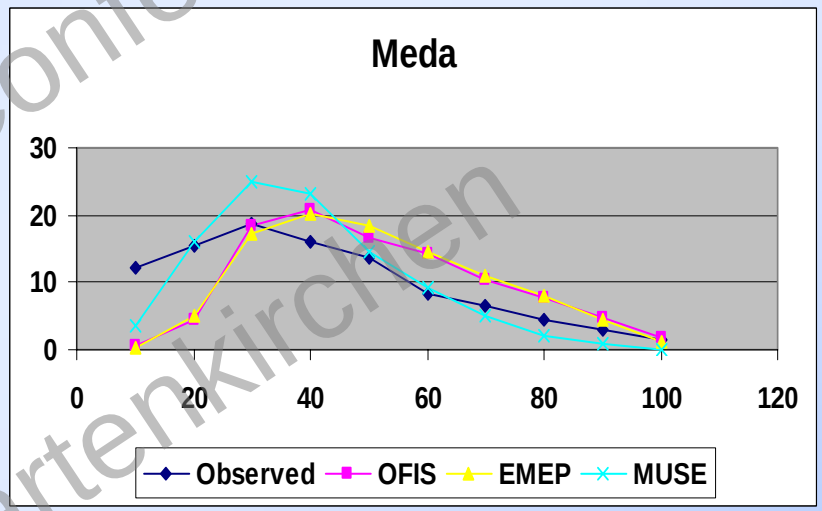
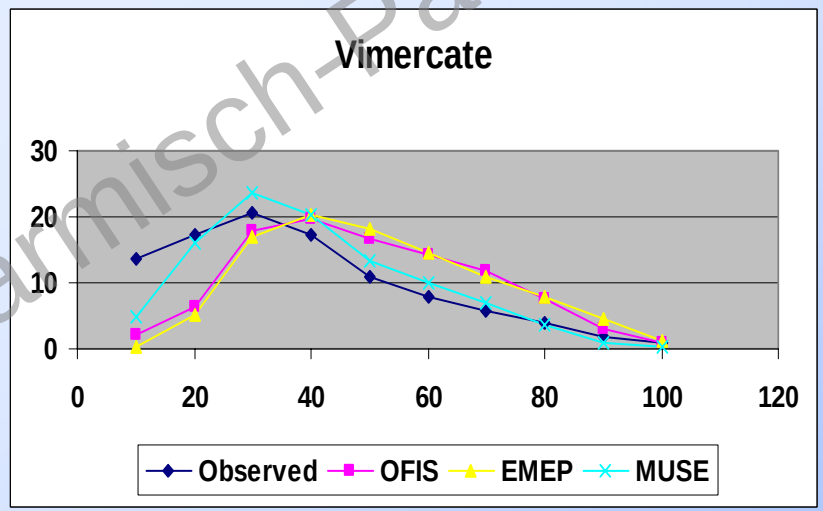
Milan – Comparing OFIS to EMEP and MUSE

O_3 **Frequencies diagram**







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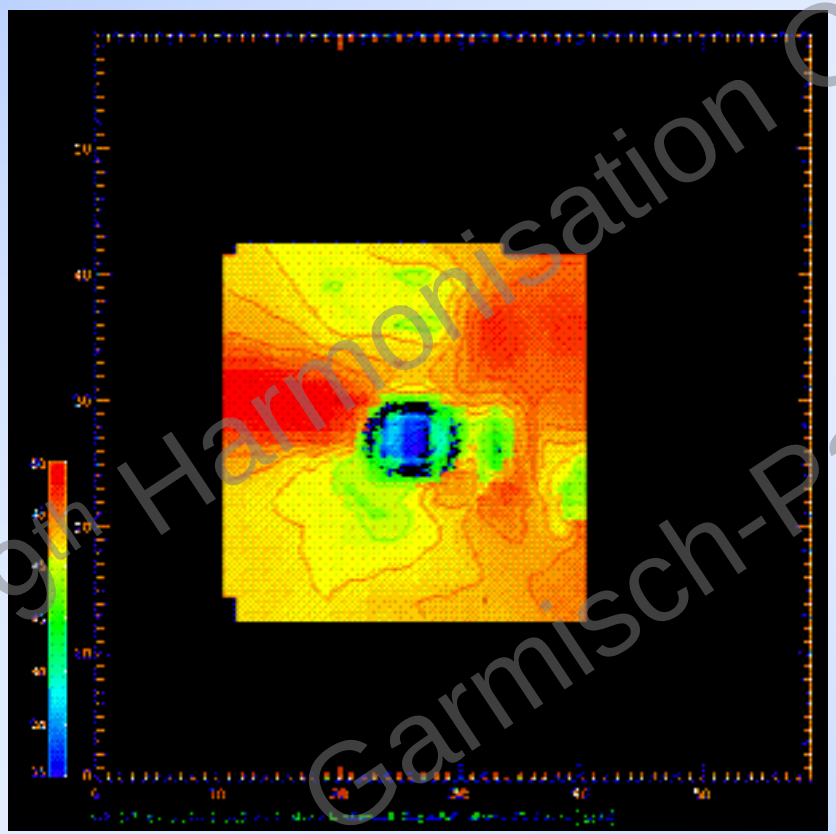
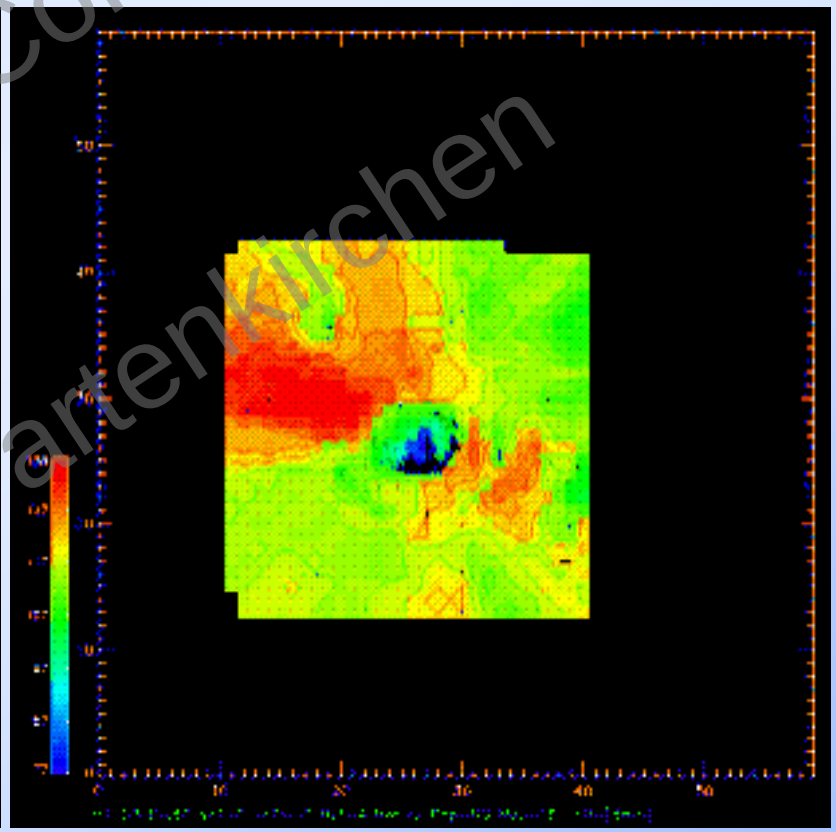
Milan – Spatial distribution of O_3





6-month average

Exceedance days

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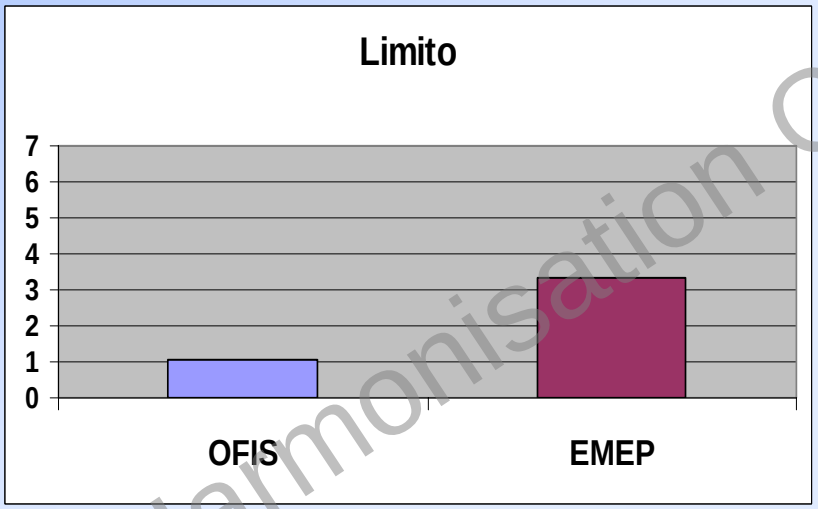
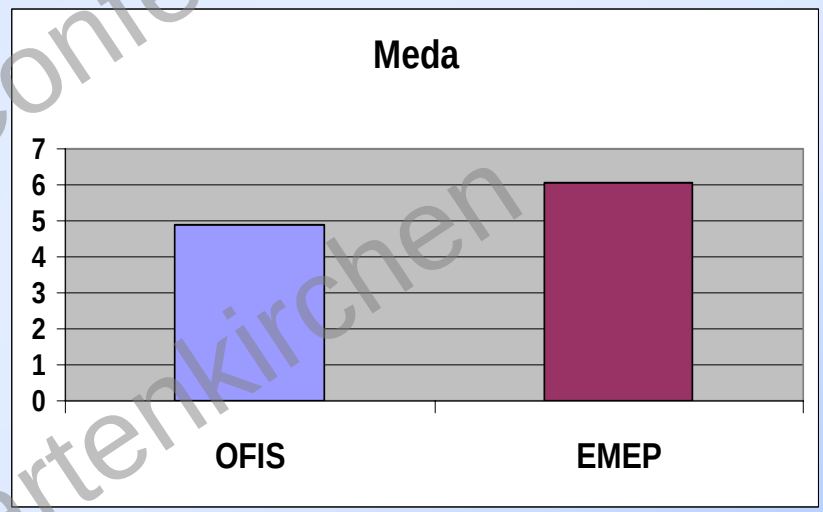
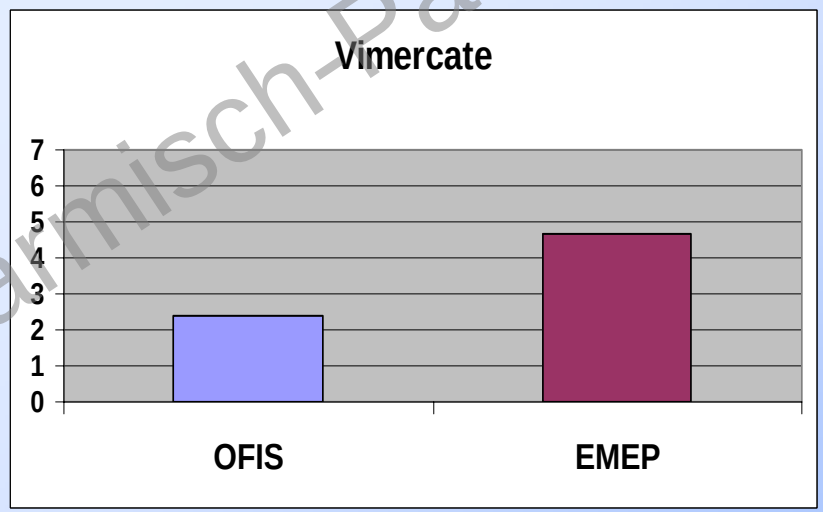
Milan – Comparing OFIS to EMEP

PM_{10}

NMSE







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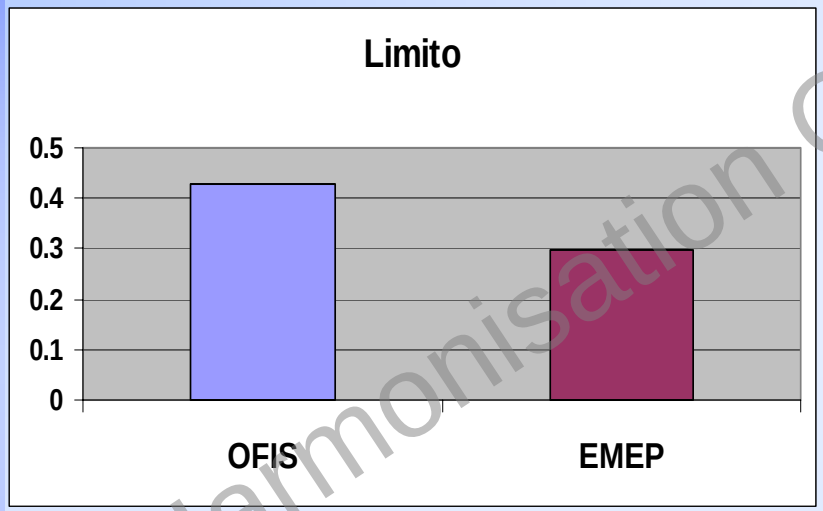
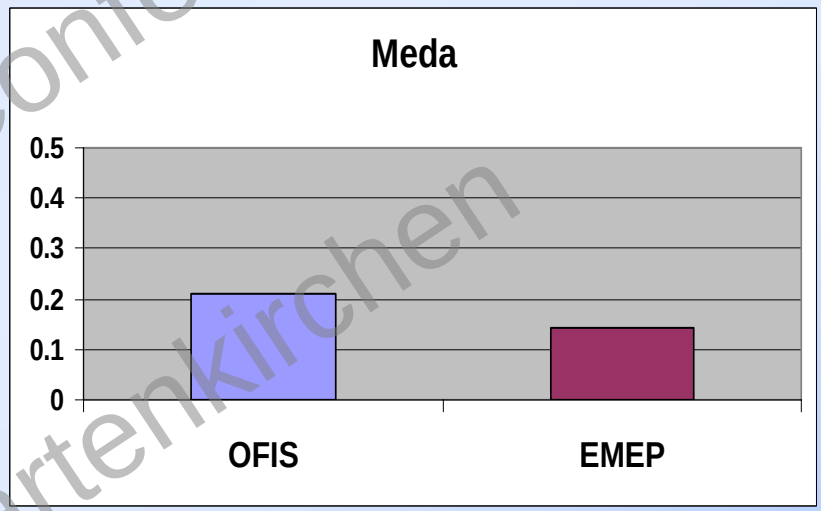
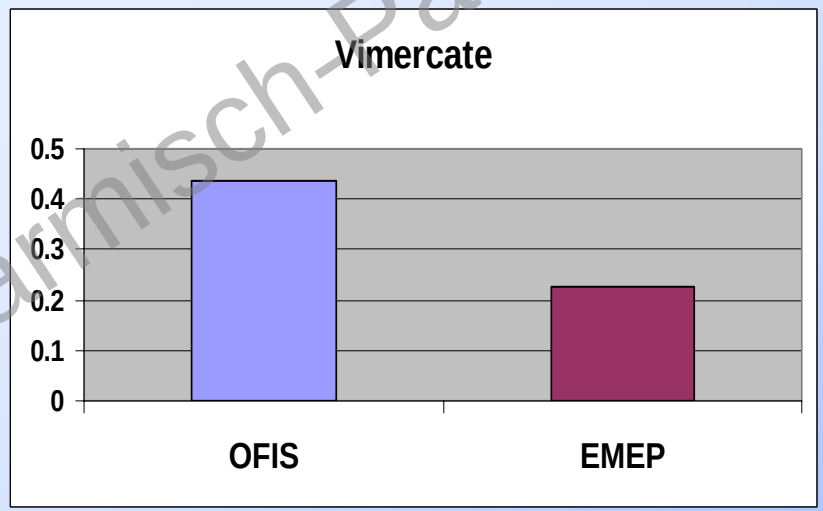
Milan – Comparing OFIS to EMEP

PM_{10} **Correlation coefficient**







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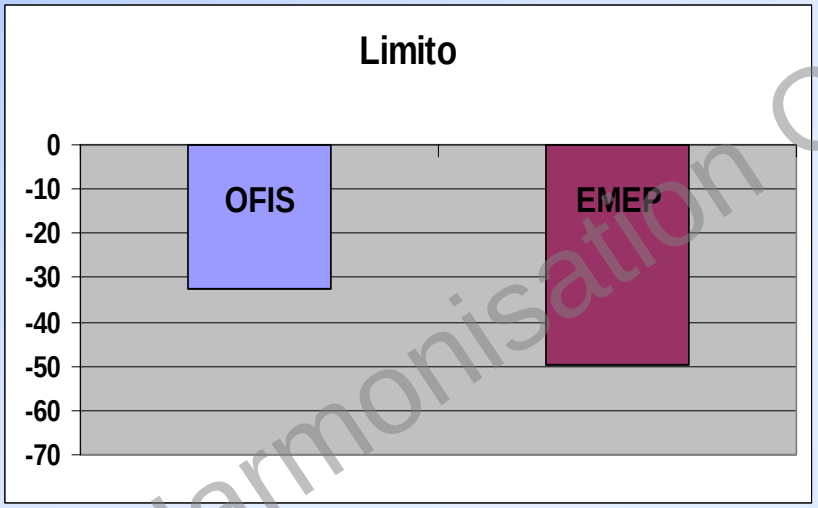
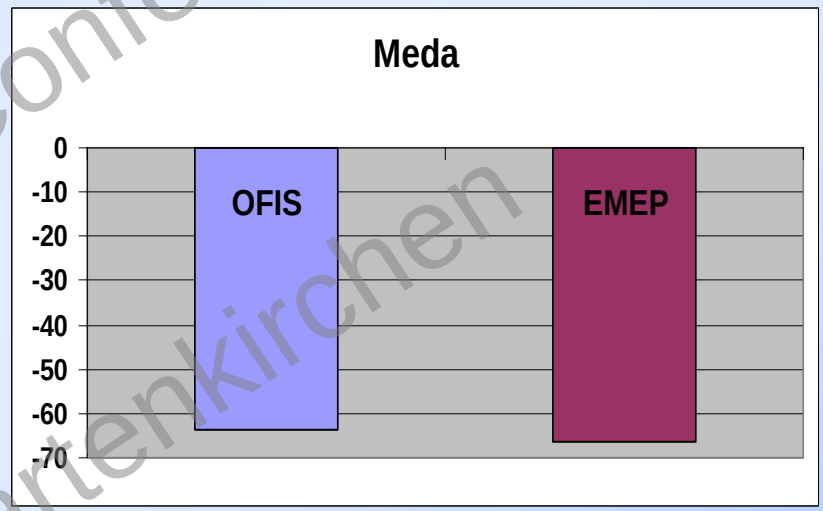
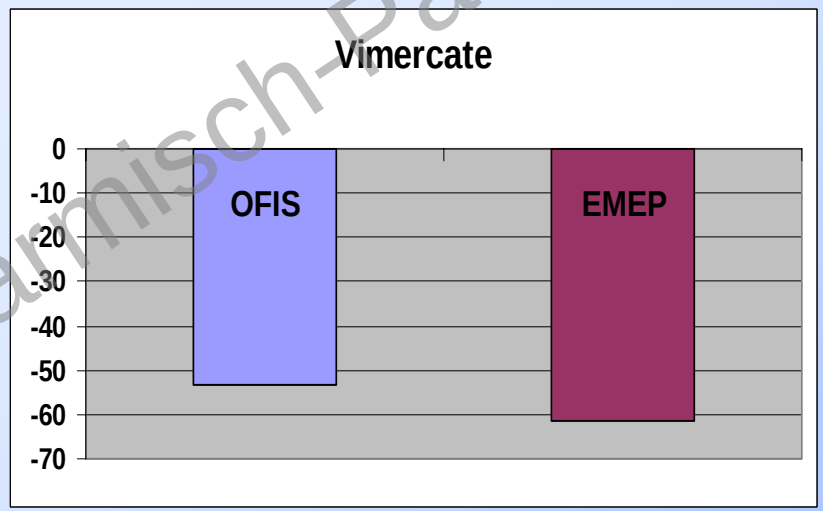
Milan – Comparing OFIS to EMEP

PM_{10}

Bias







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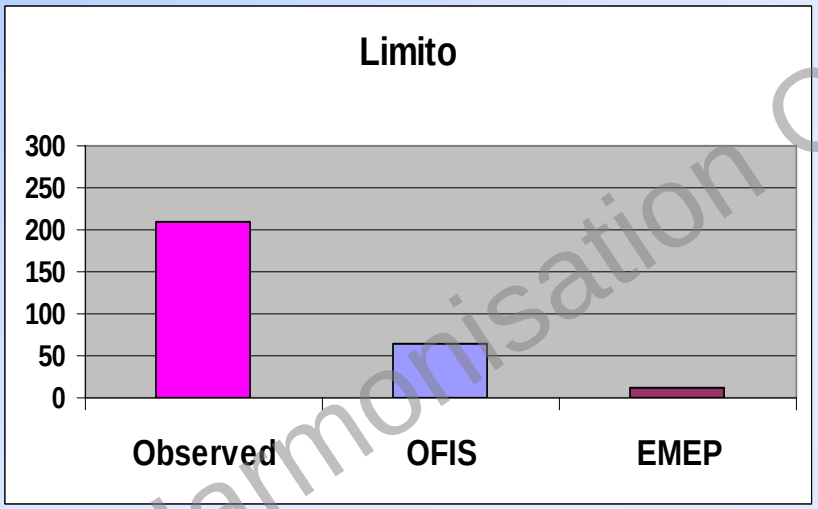
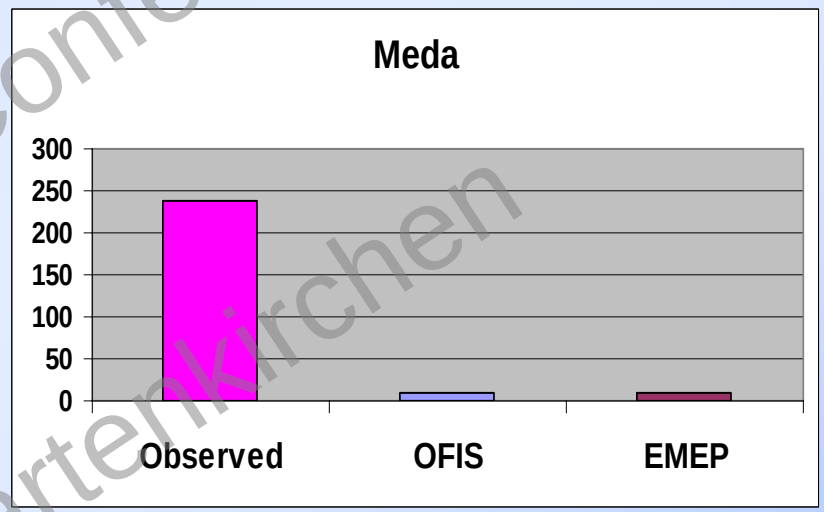
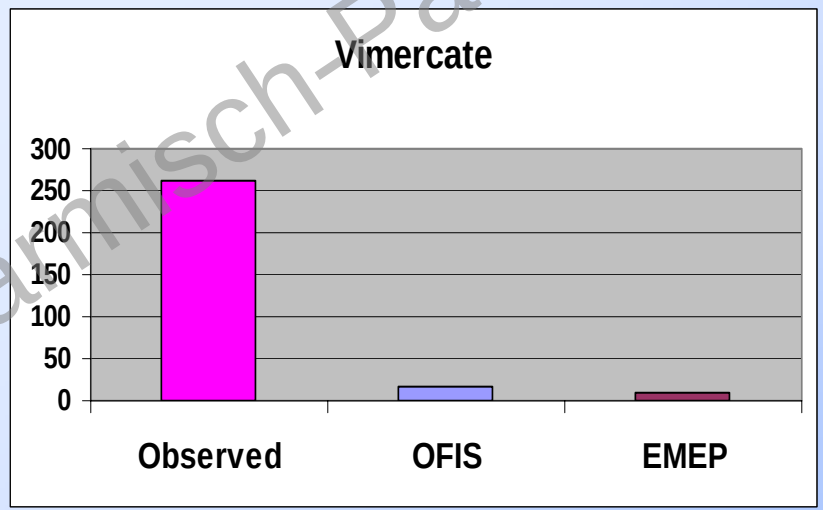
Milan – Comparing OFIS to EMEP

PM_{10} Exceedance days (50 µg/m^3)







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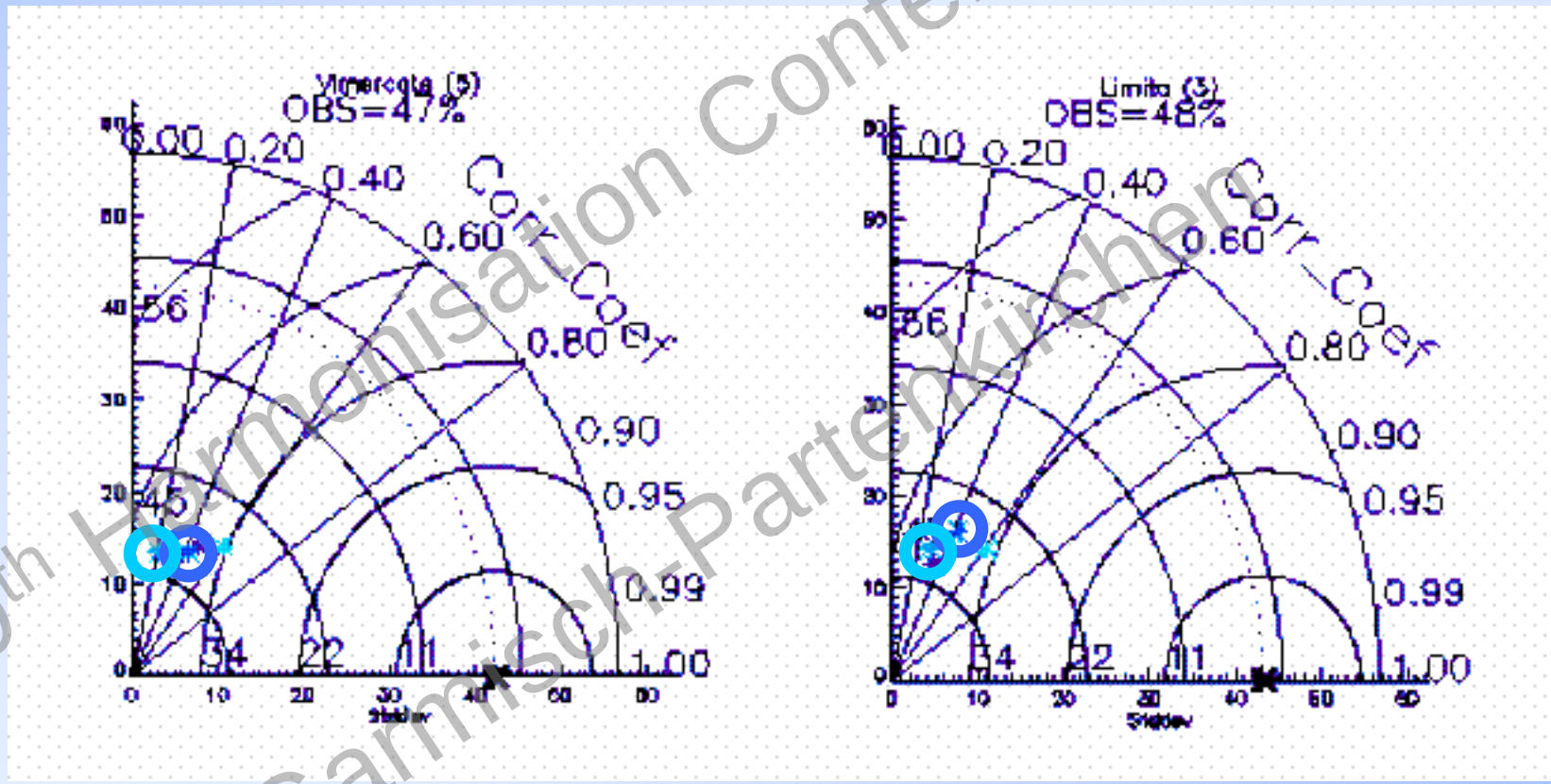
Milan – Comparing OFIS to EMEP

PM_{10}

Taylor diagram



* OFIS
* EMEP

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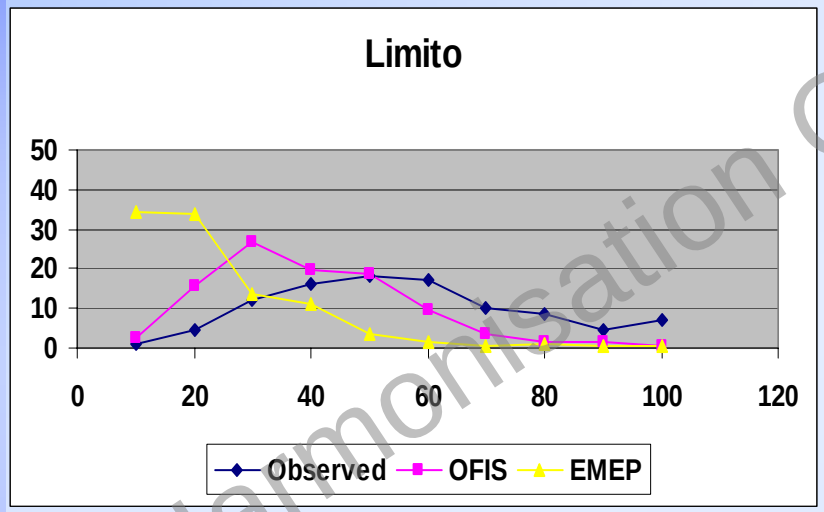
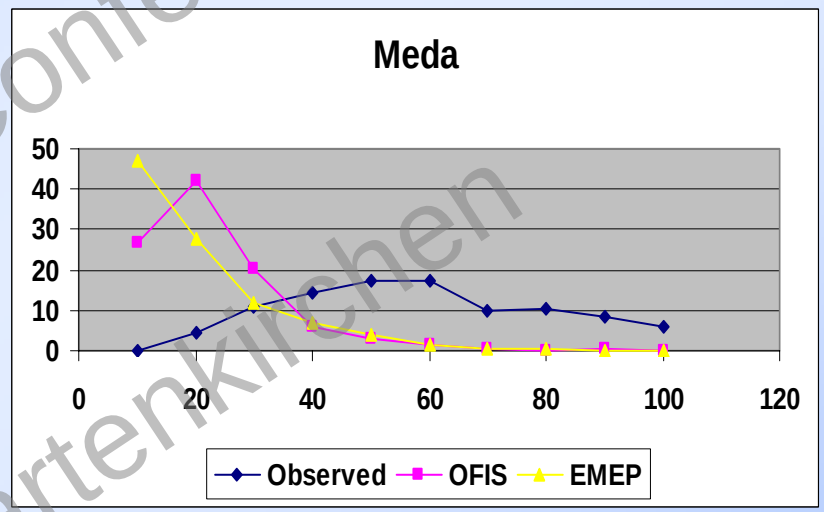
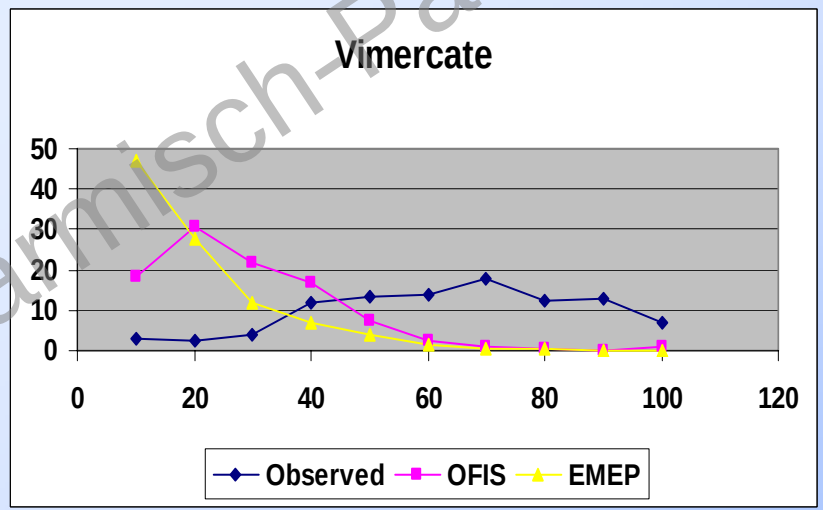
Milan – Comparing OFIS to EMEP

PM_{10} Frequency diagram

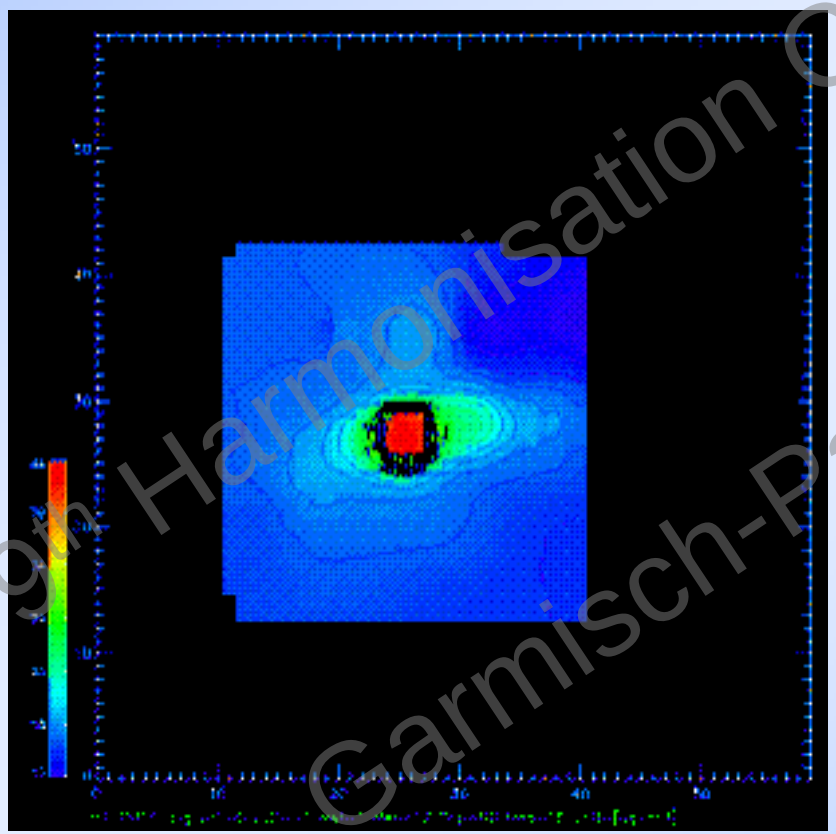


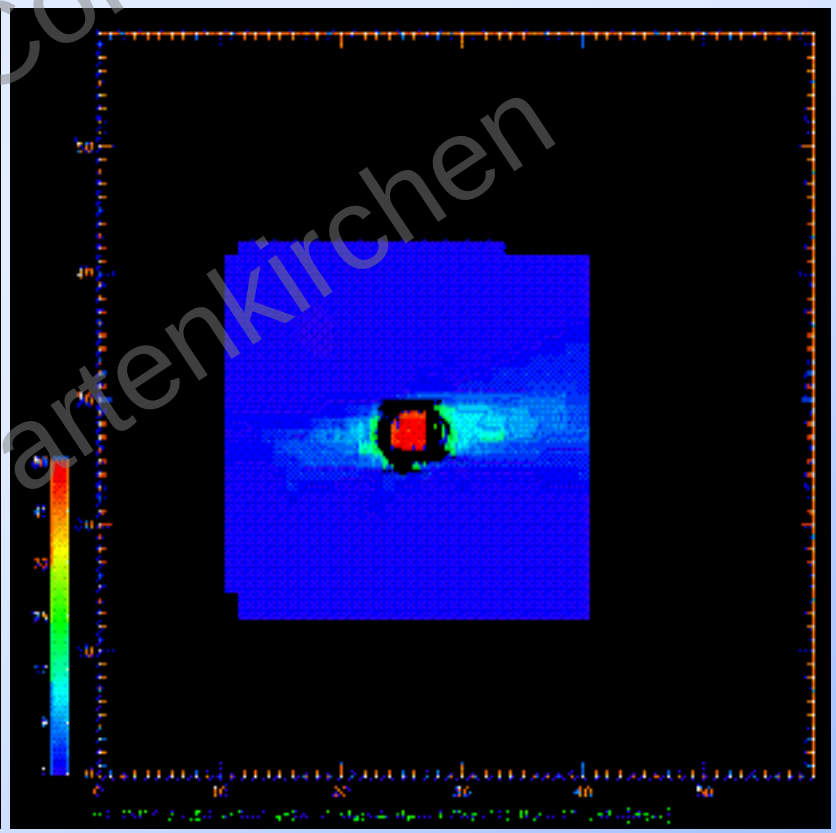




AUT/
LHTEE

Milan – Spatial distribution of PM_{10}





1-year average

Exceedance days

AUT/
LHTEE

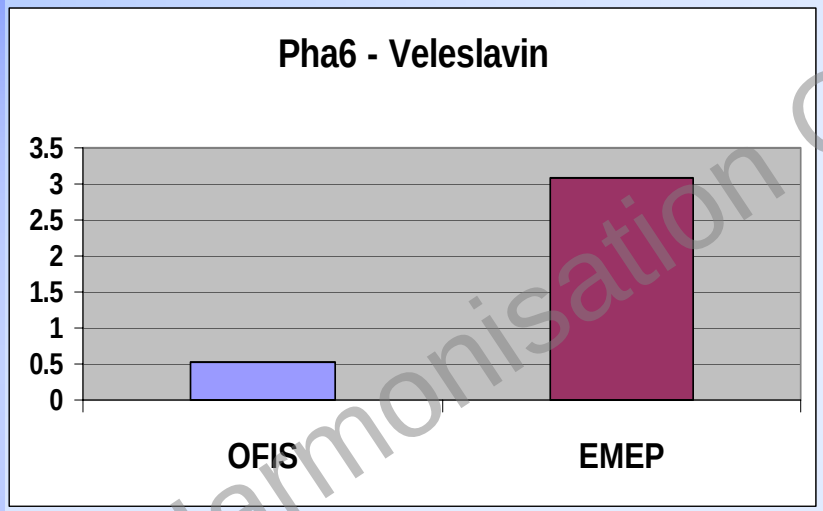
Prague stations

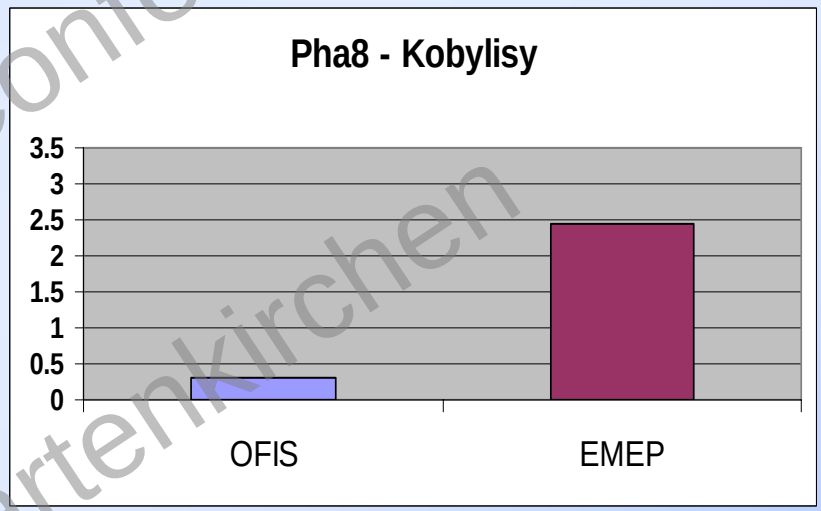
AUT/
LHTEE

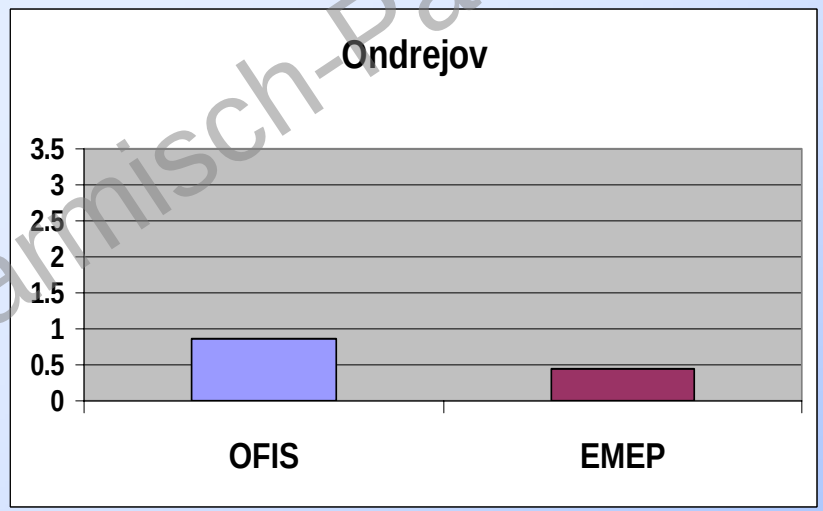
Prague – Comparing OFIS to EMEP

NO_2

NMSE



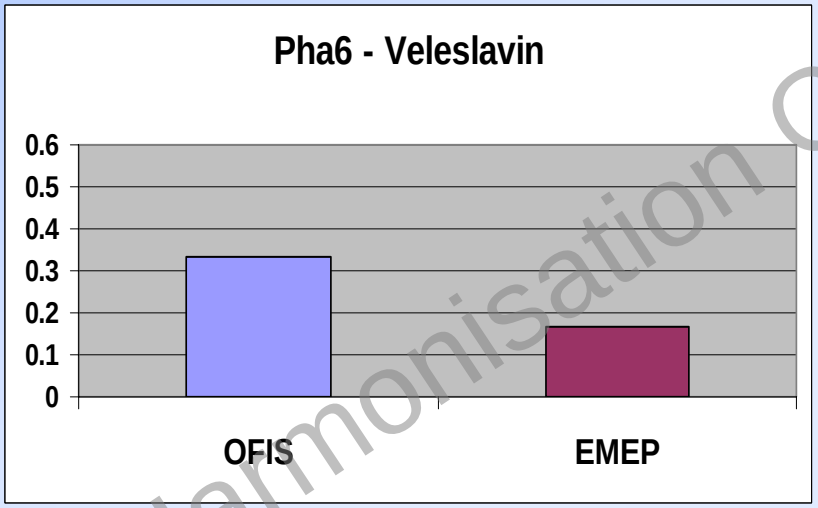


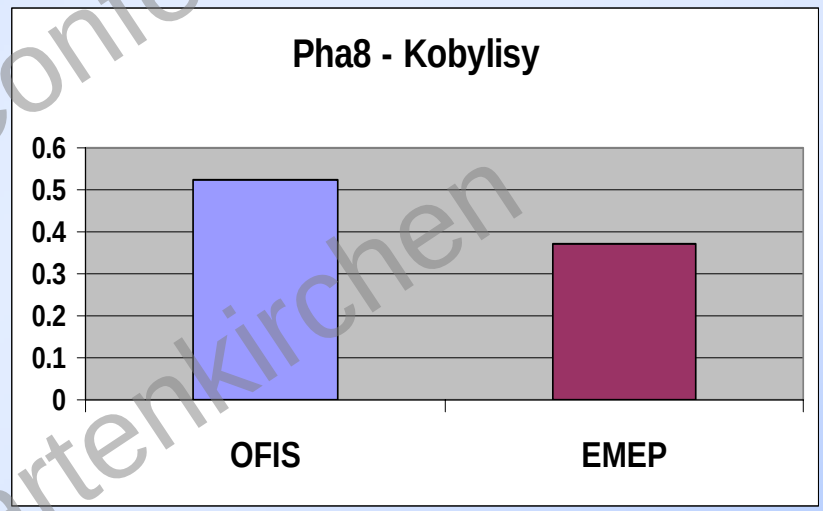


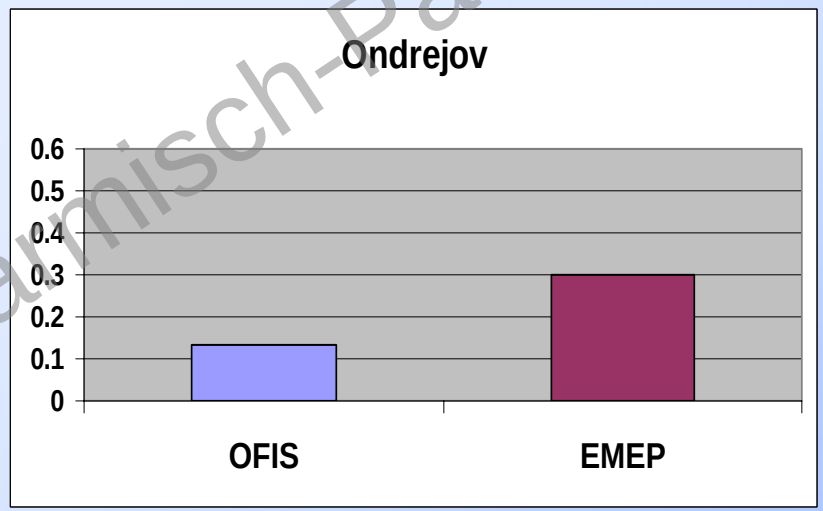
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

NO_2 **Correlation coefficient**



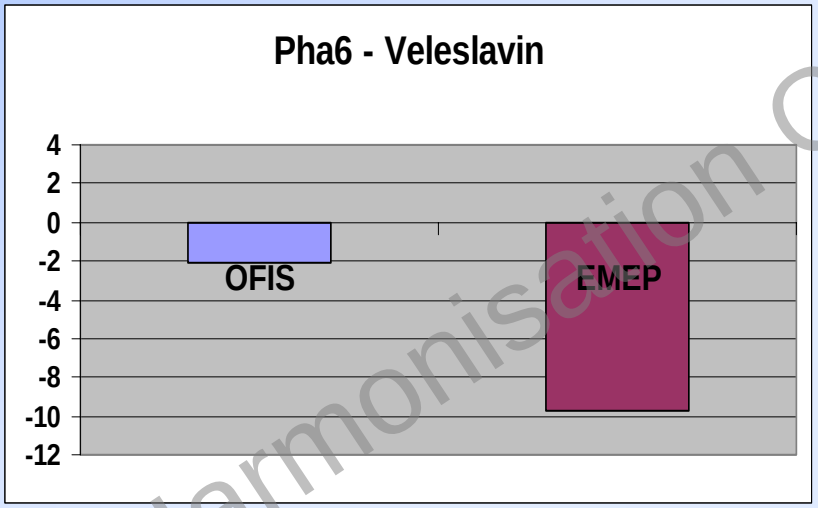


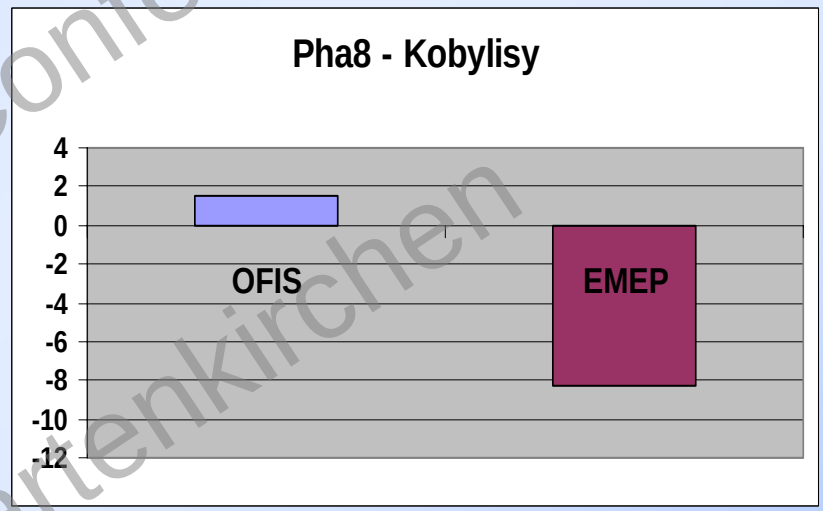


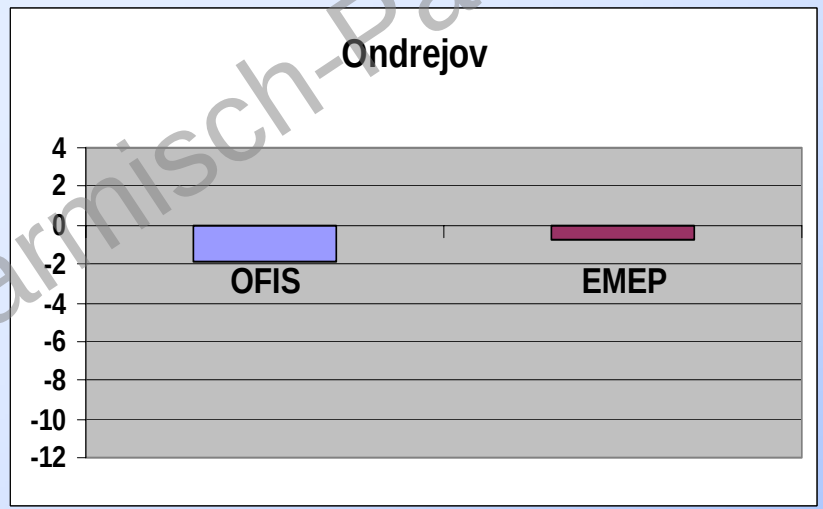
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

NO_2 Bias





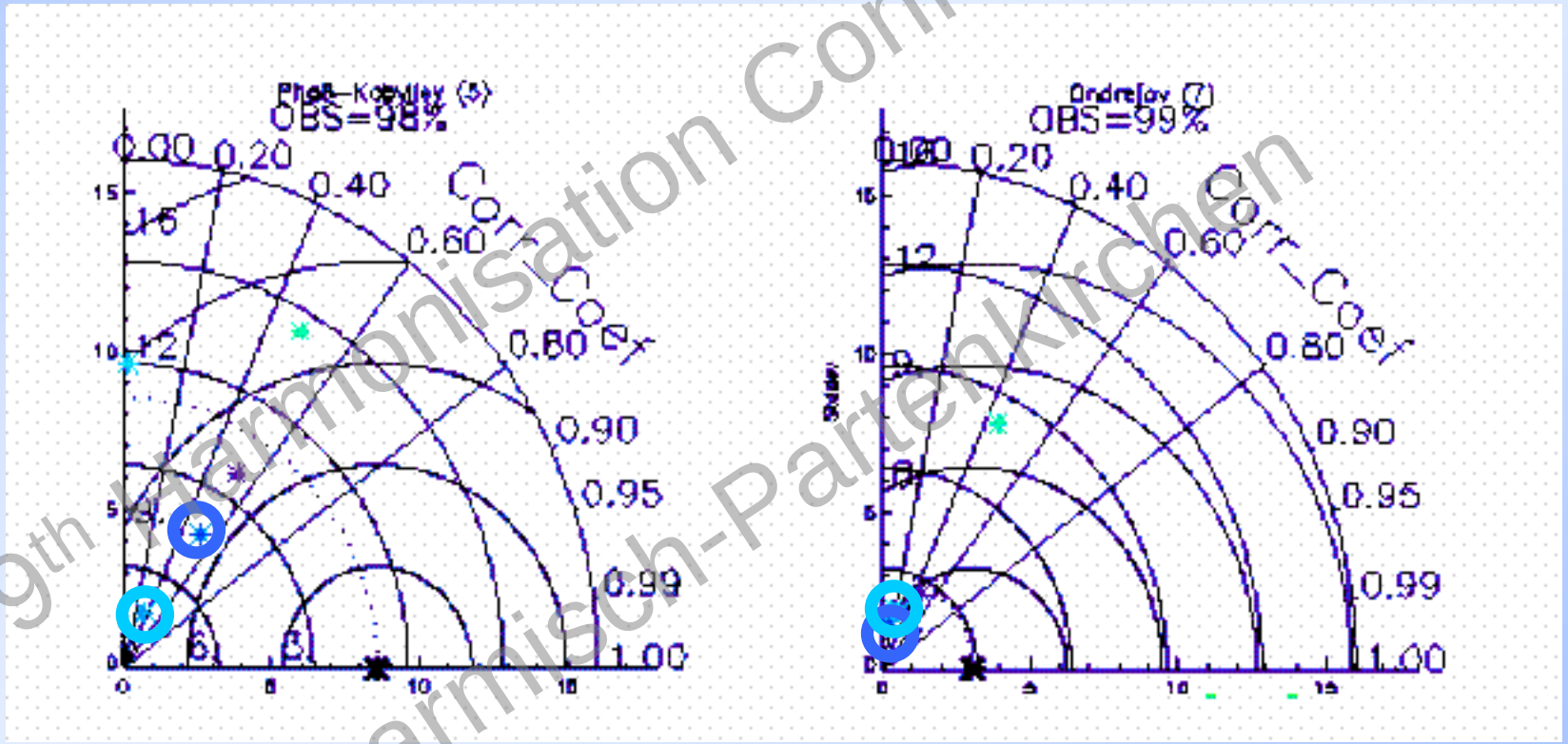


AUT/
LHTEE

Prague – Comparing OFIS to EMEP

NO_2

Taylor diagram

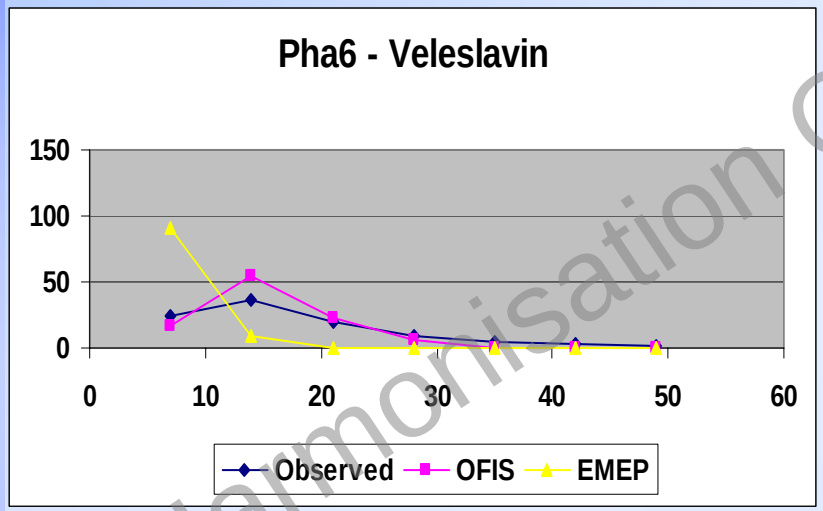


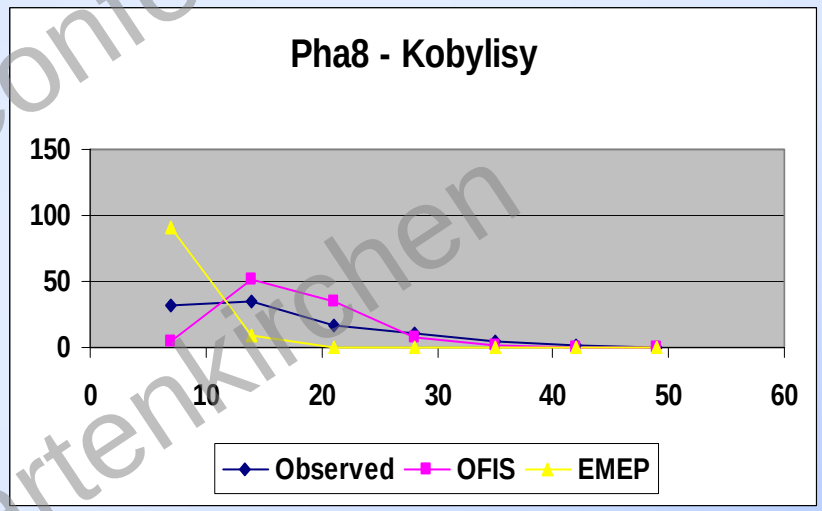
* OFIS
* EMEP

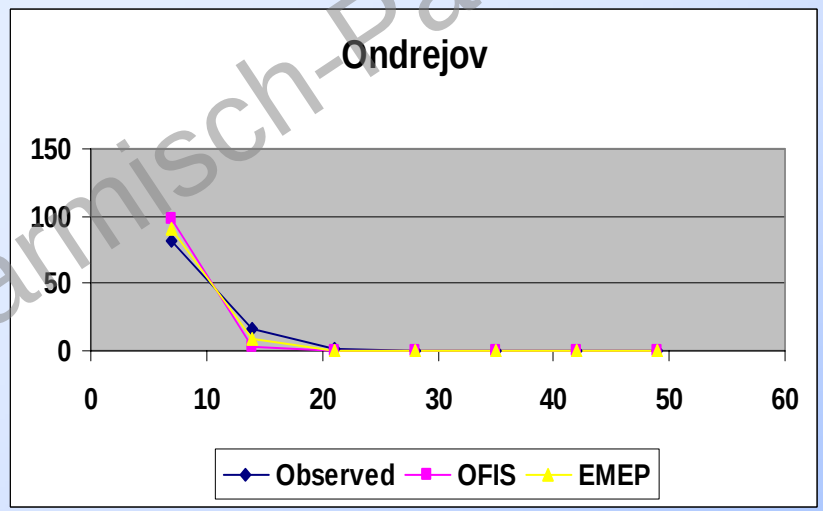
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

NO_2 Frequencies diagram





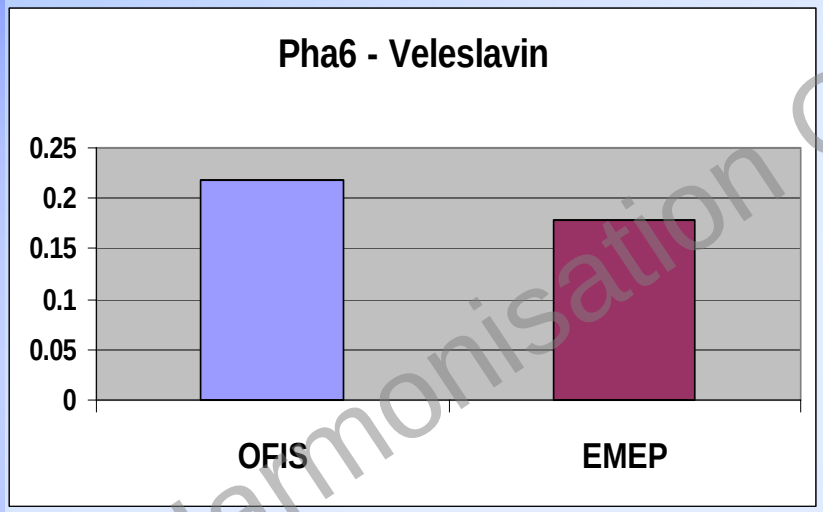


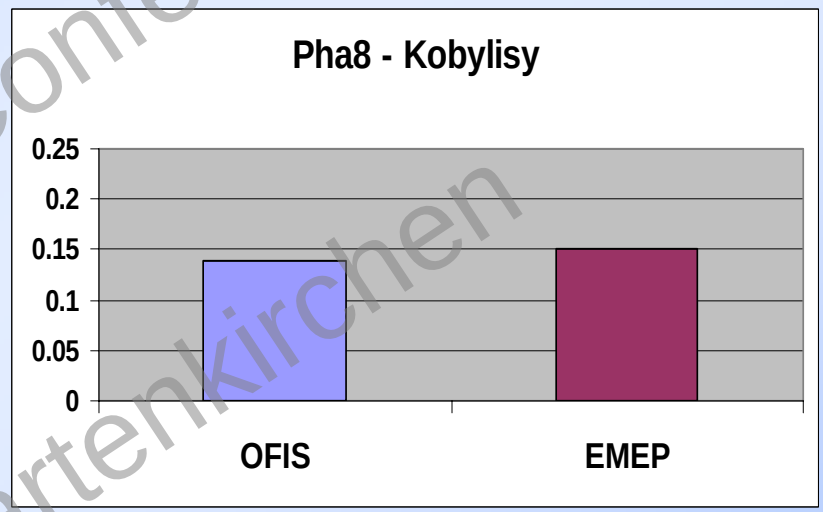
AUT/
LHTEE

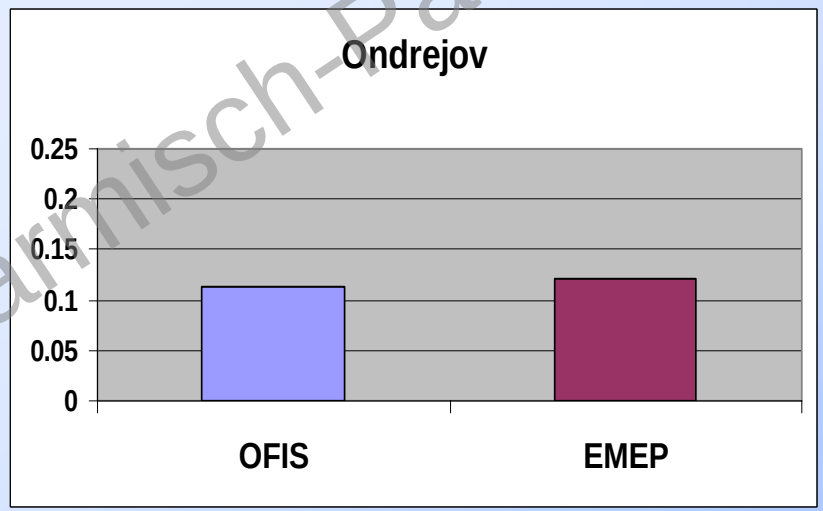
Prague – Comparing OFIS to EMEP

O_3

NMSE



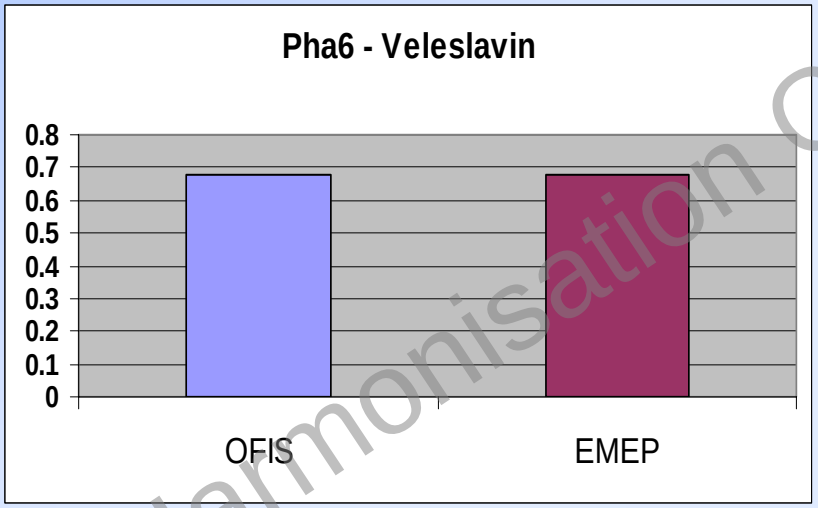


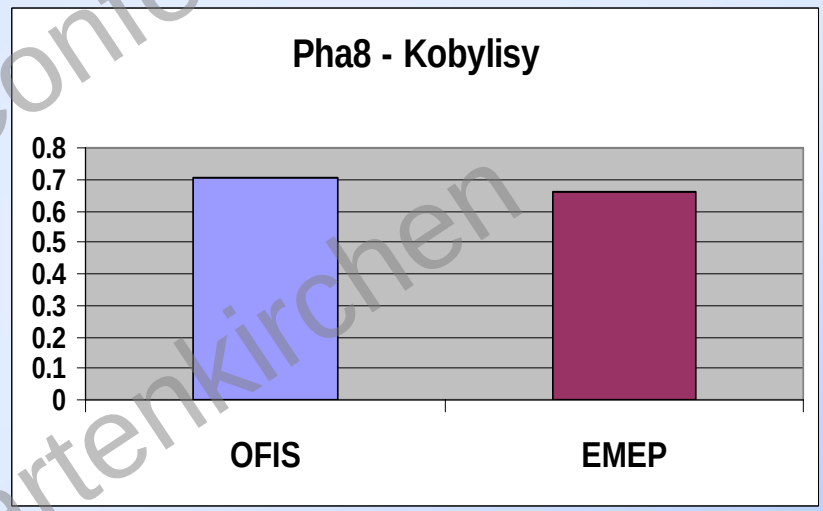


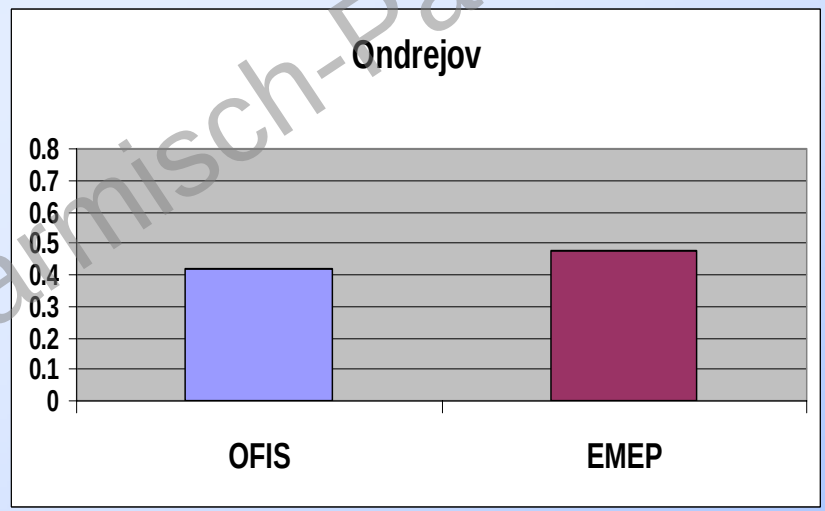
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

O_3 **Correlation coefficient**







AUT/
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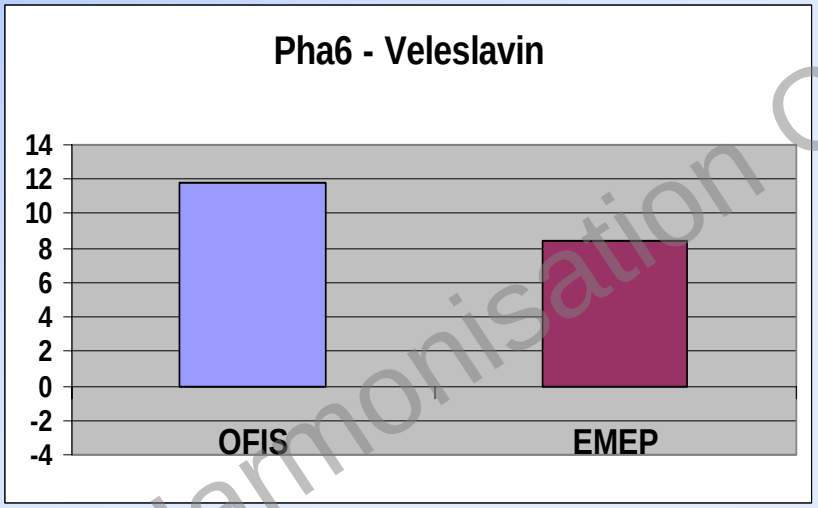
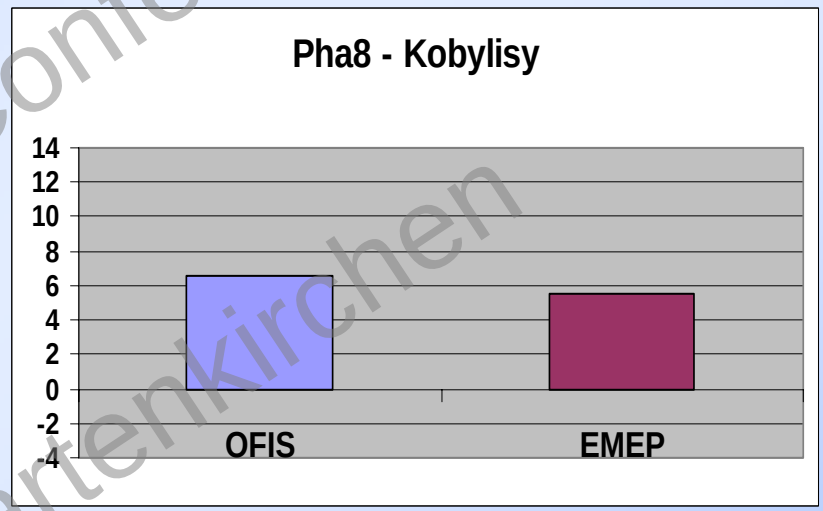
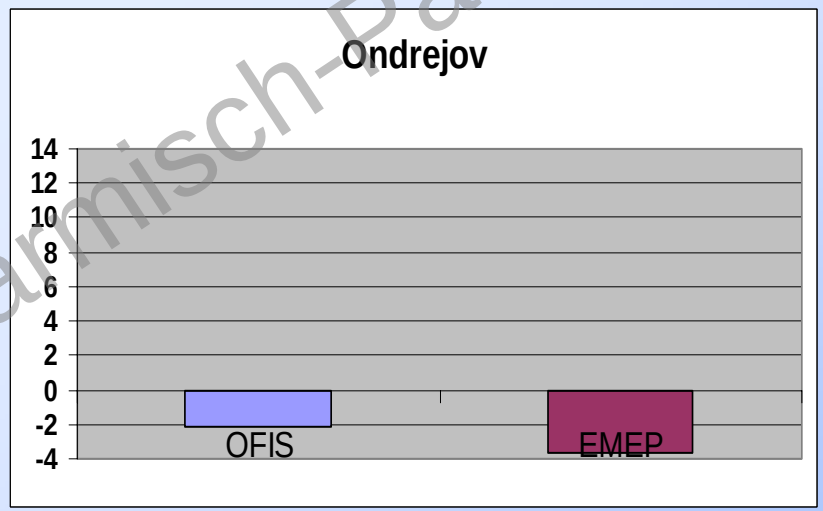
Prague – Comparing OFIS to EMEP

O_3

Bias







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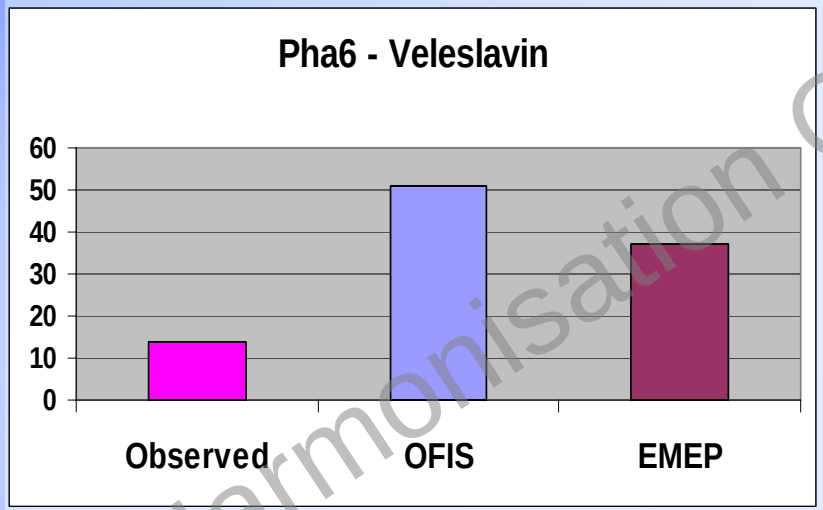
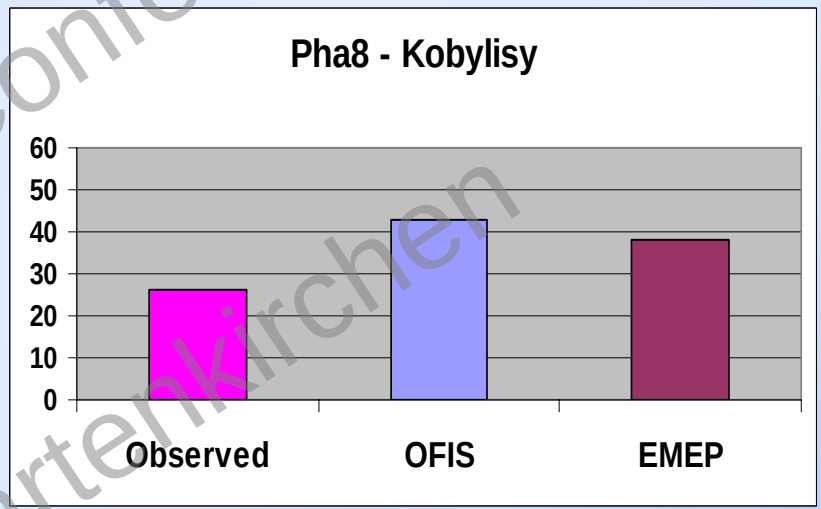
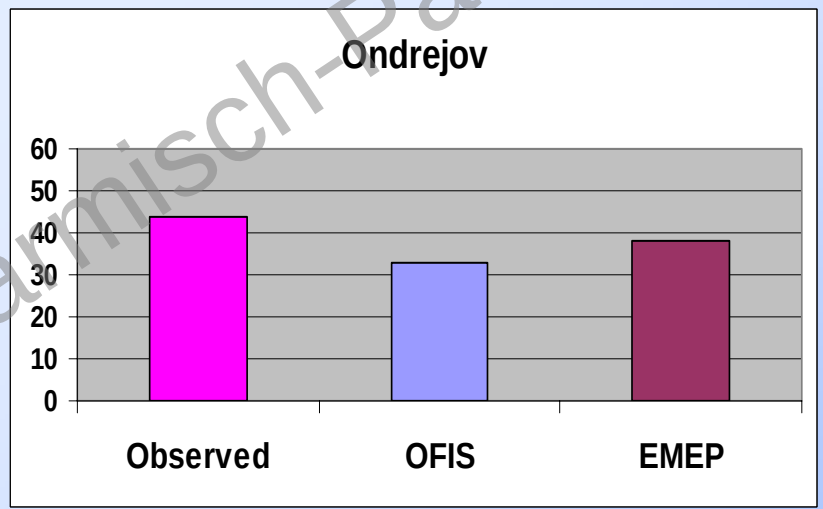
LHTEE

Prague – Comparing OFIS to EMEP

O_3 Exceedance days (120 µg/m^3)





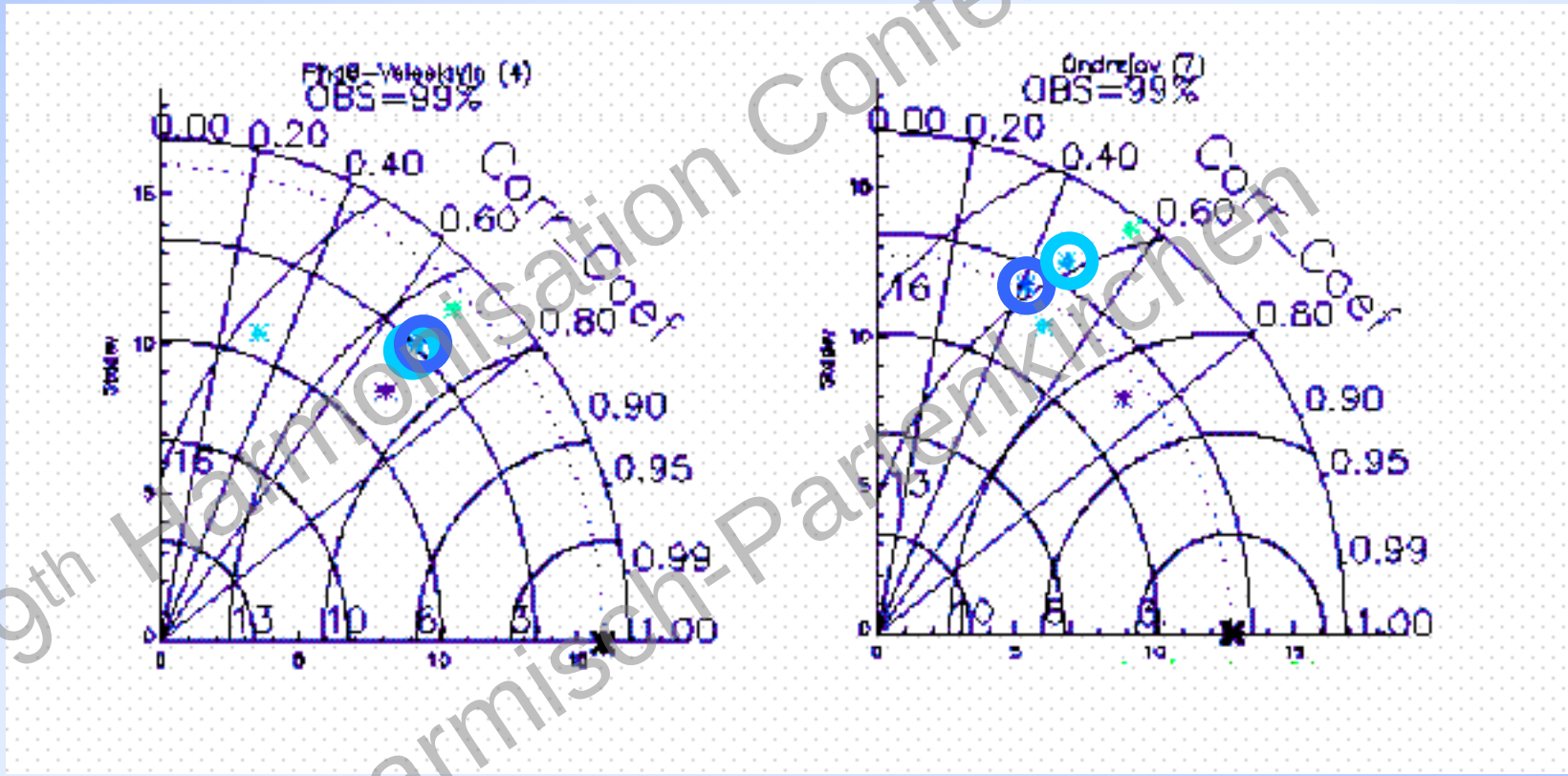


AUT/
LHTEE

Prague – Comparing OFIS to EMEP

O_3

Taylor diagram

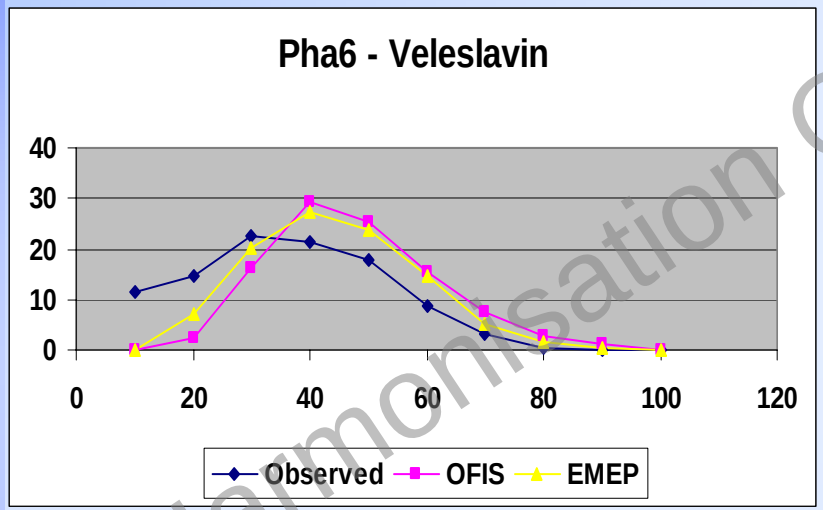


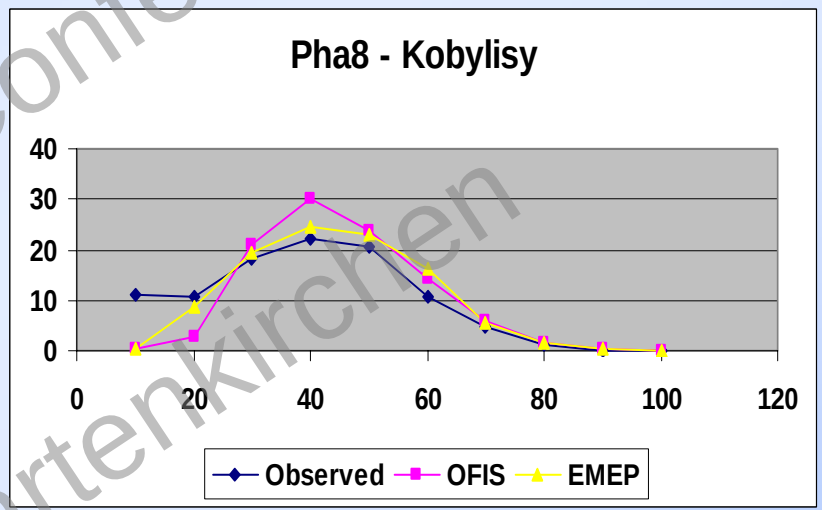
* OFIS
* EMEP

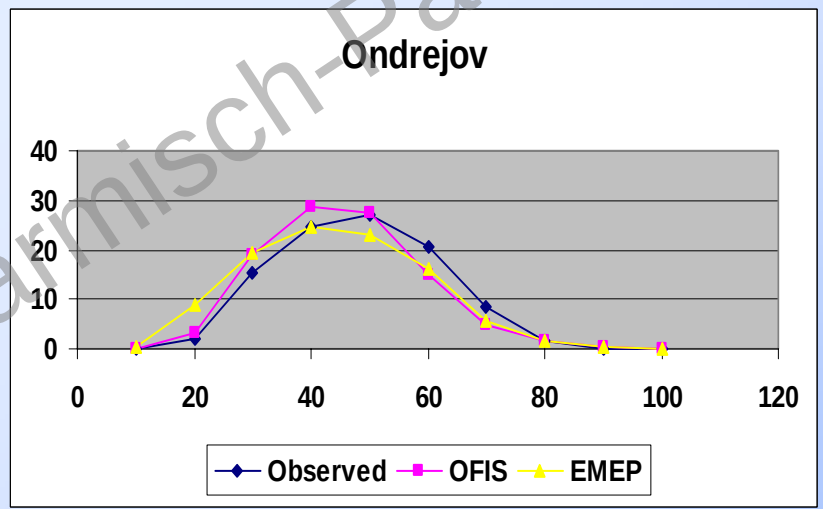
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

O_3 Frequencies diagram

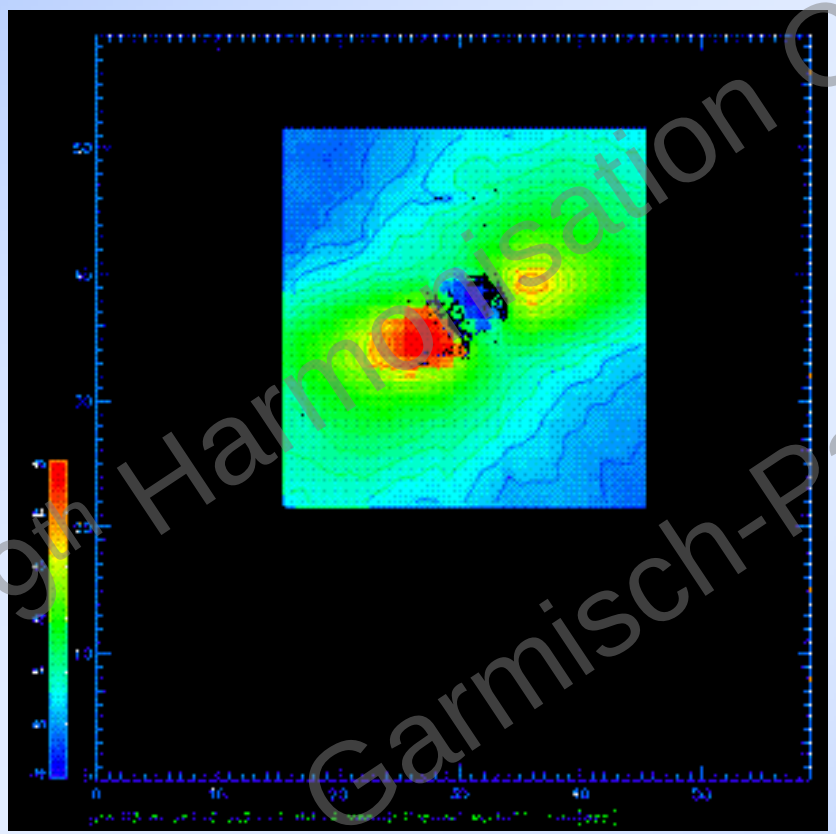


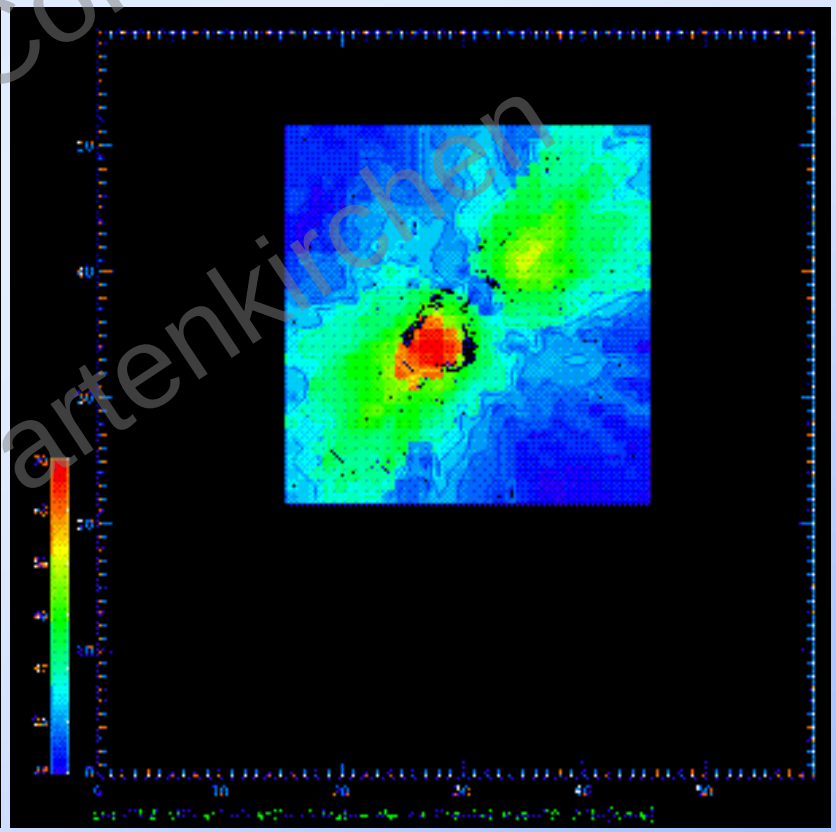




AUT/
LHTEE

Prague – Spatial distribution O_3





6-month average

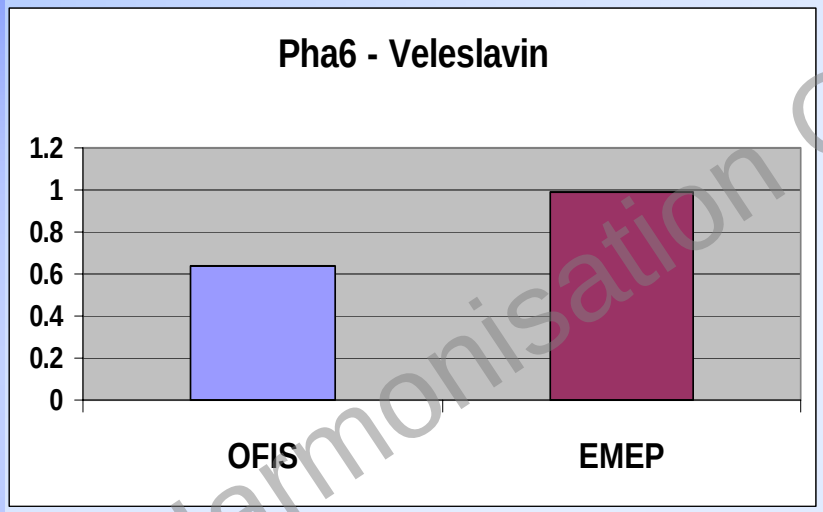
Exceedance days

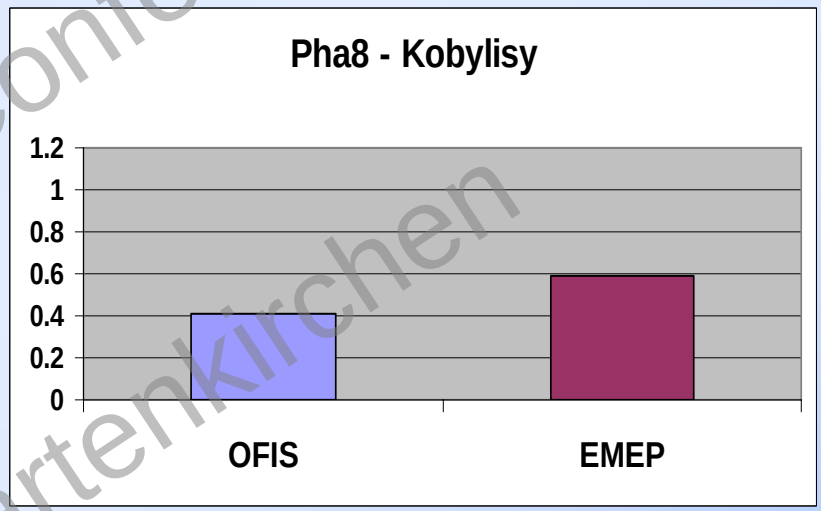
AUT/
LHTEE

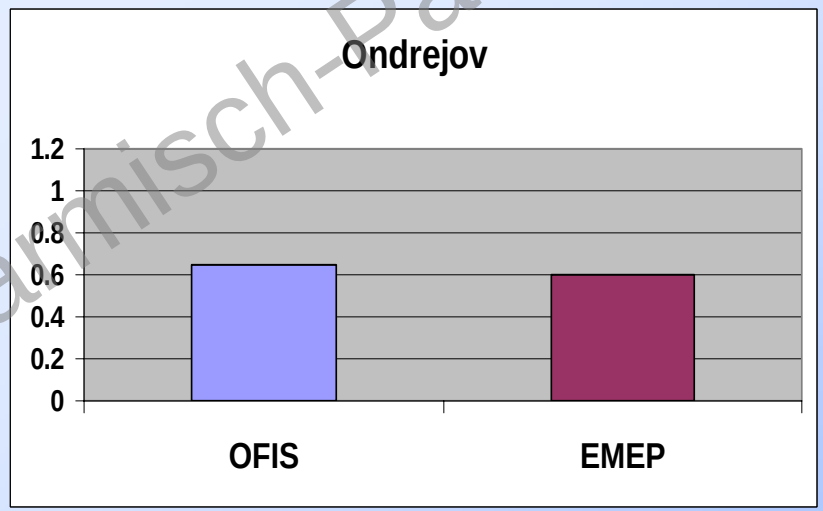
Prague – Comparing OFIS to EMEP

PM_{10}

NMSE



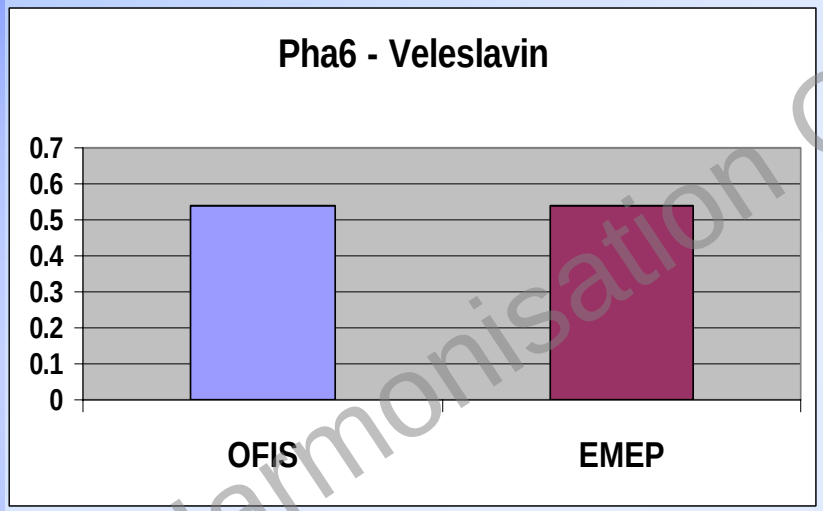


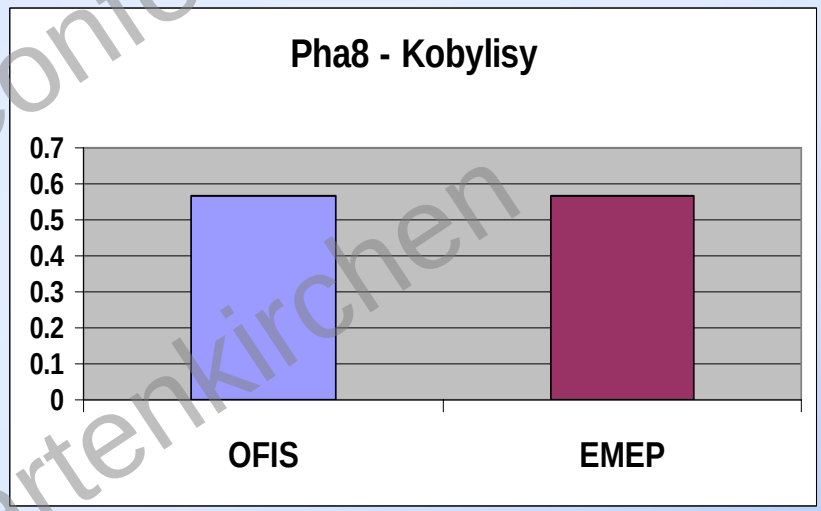


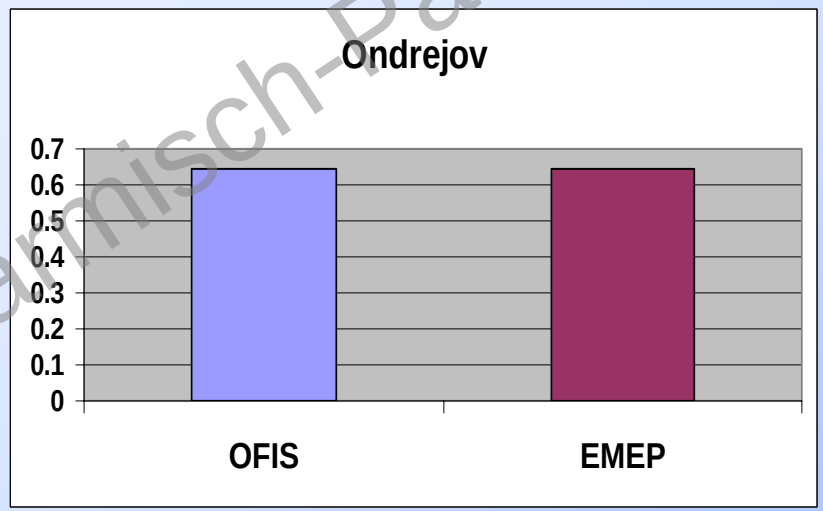
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

PM_{10} **Correlation coefficient**



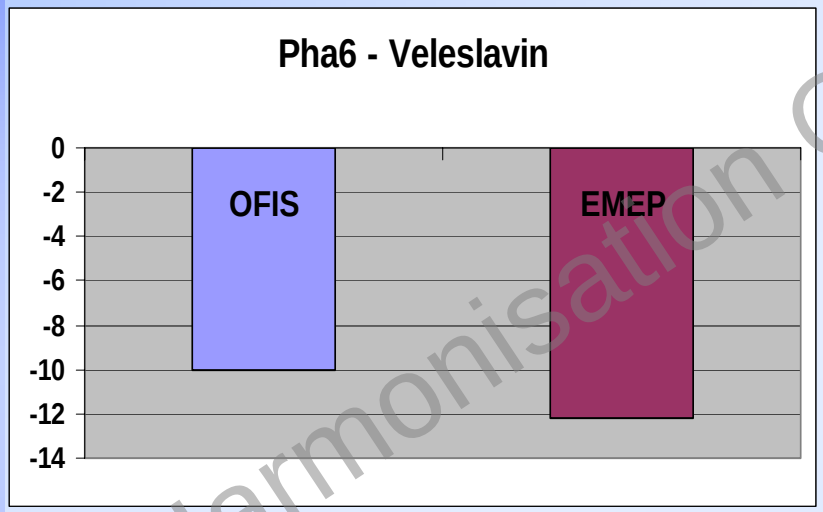


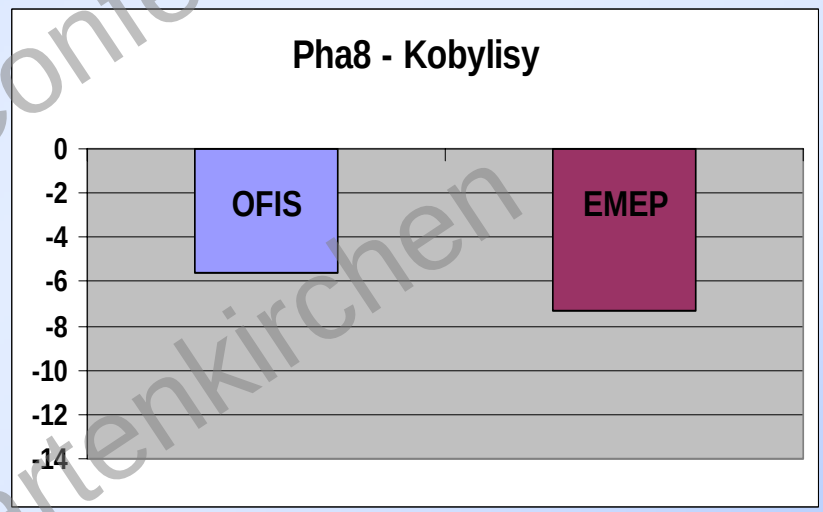


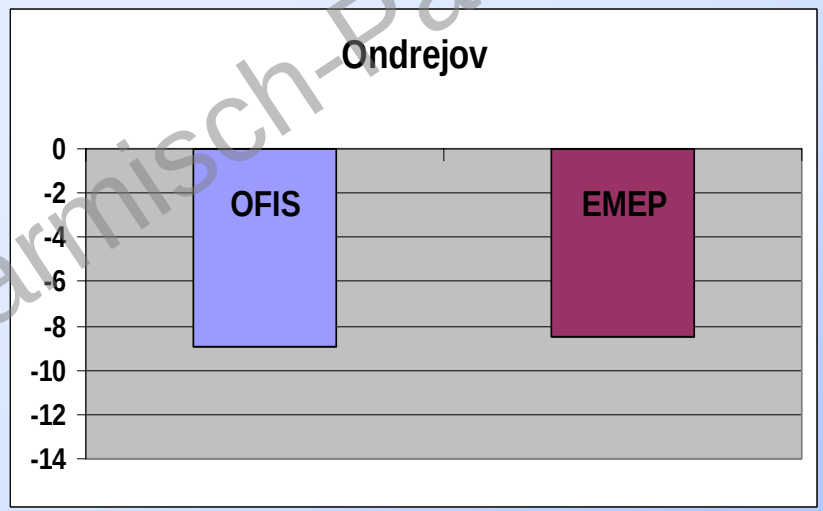
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

PM_{10} Bias



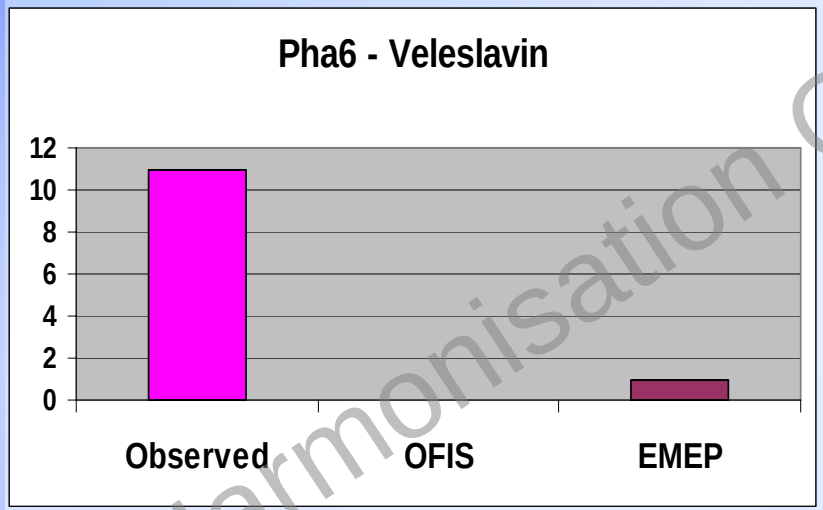


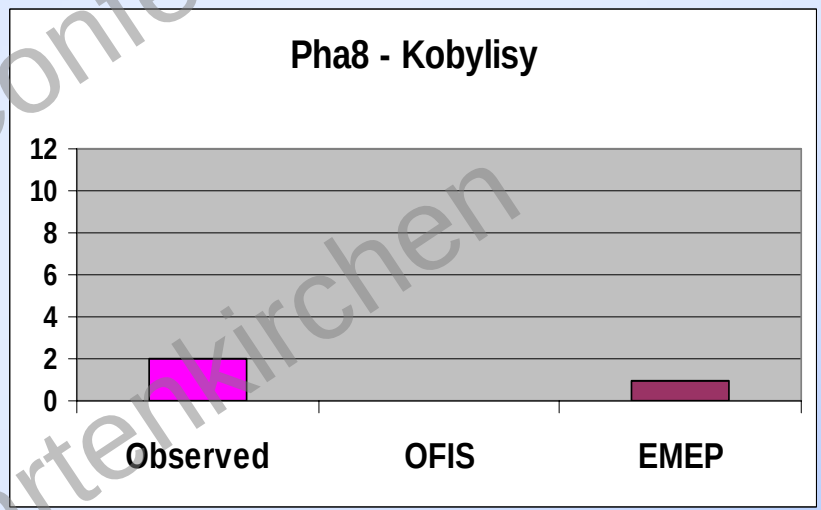


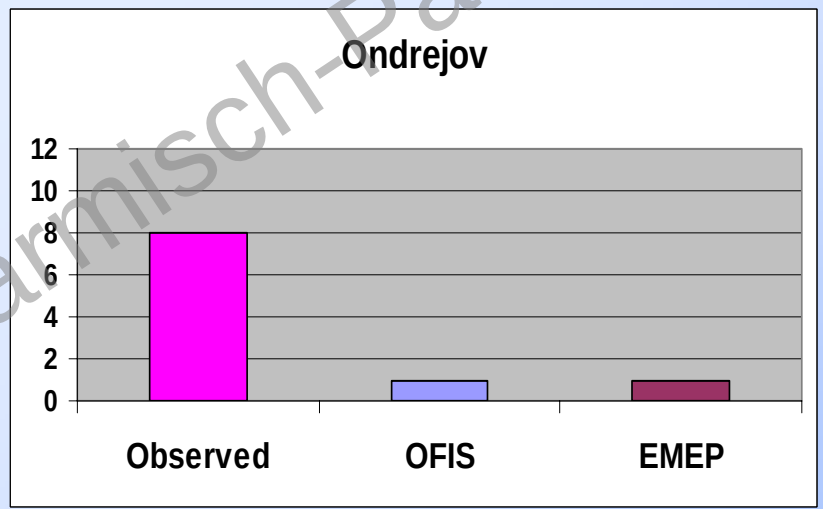
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

PM_{10} Exceedance days (50 µg/m^3)





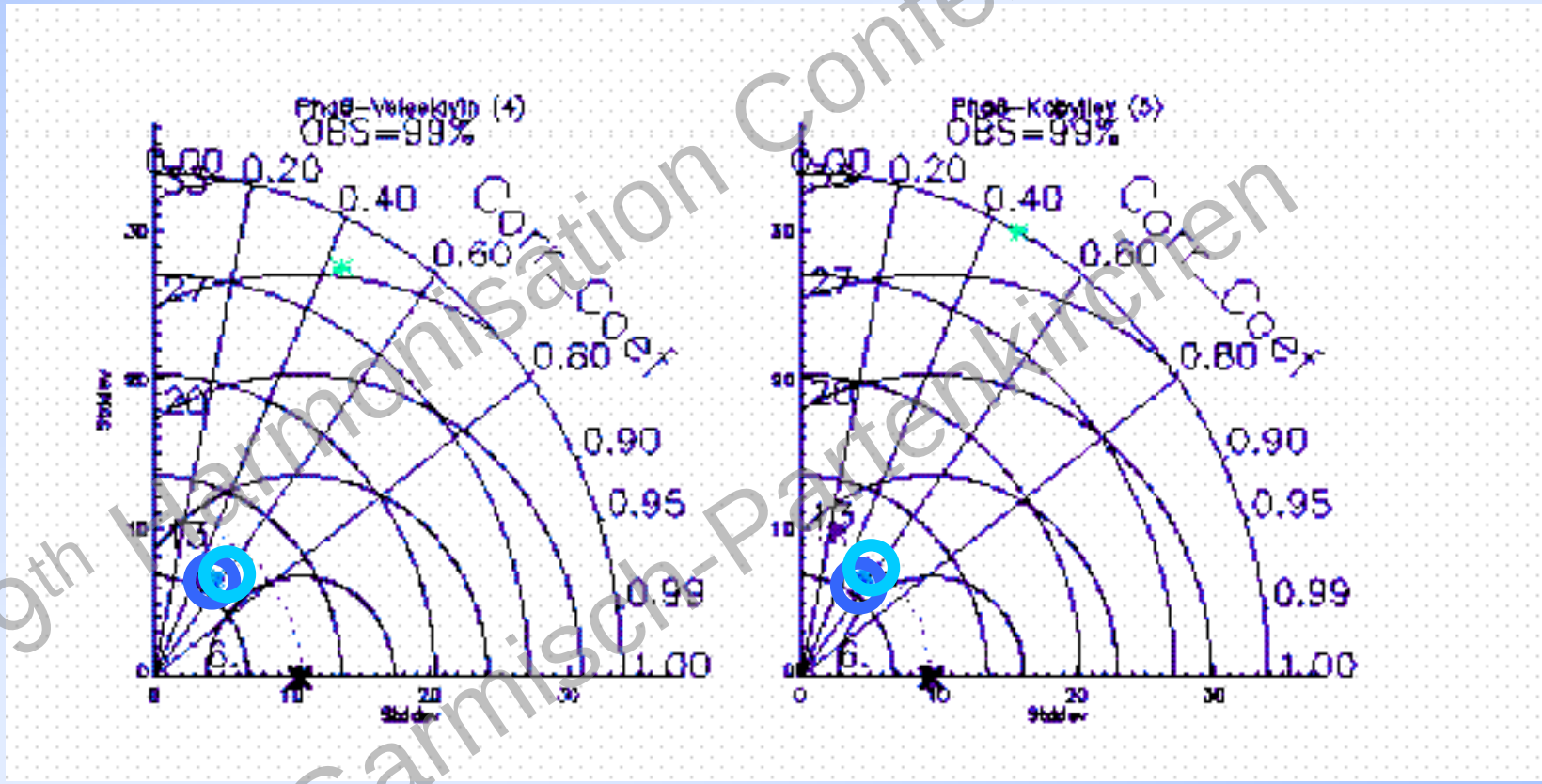


AUT/
LHTEE

Prague – Comparing OFIS to EMEP

PM_{10}

Taylor diagram

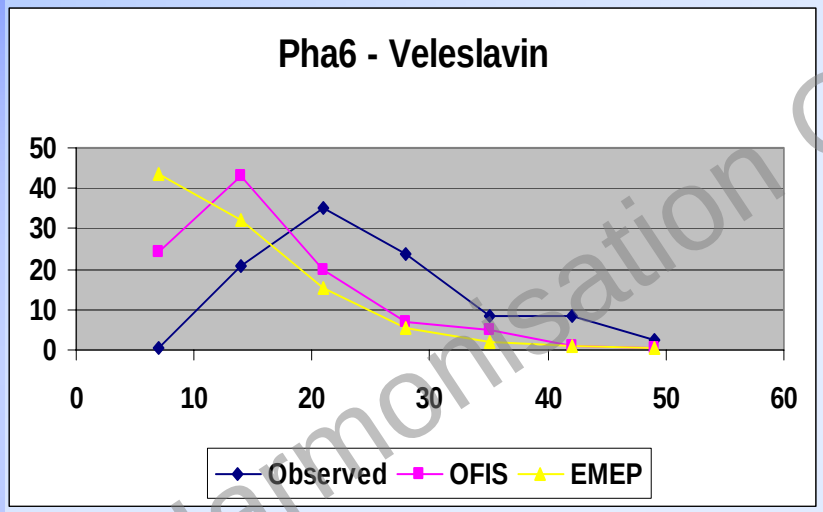


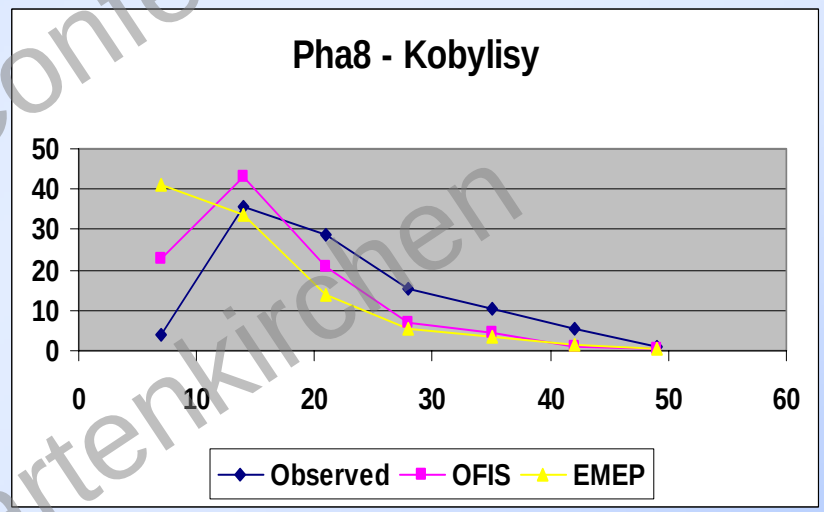
* OFIS
* EMEP

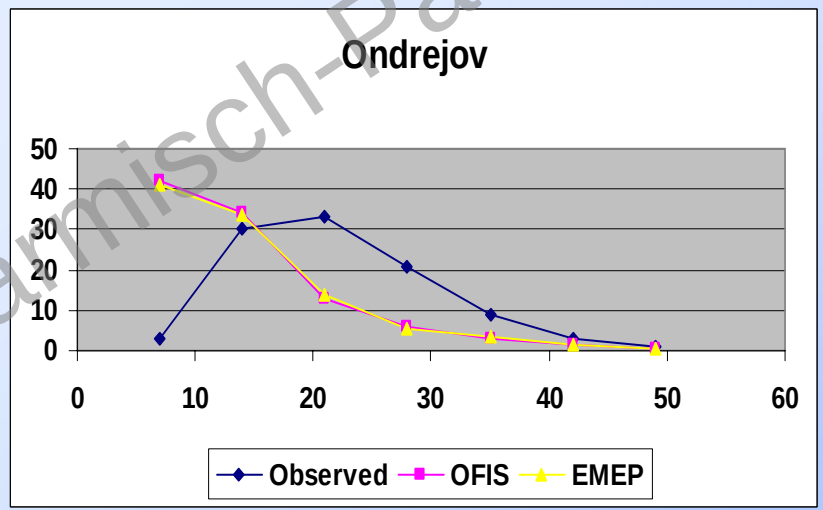
AUT/
LHTEE

Prague – Comparing OFIS to EMEP

PM_{10} Frequencies diagram

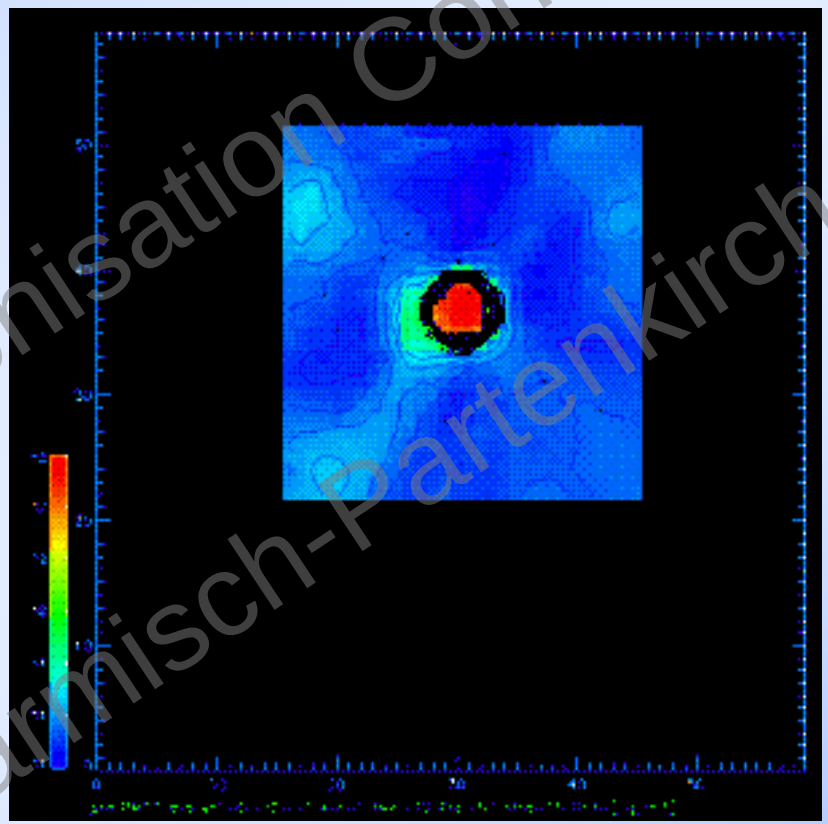






AUT/
LHTEE

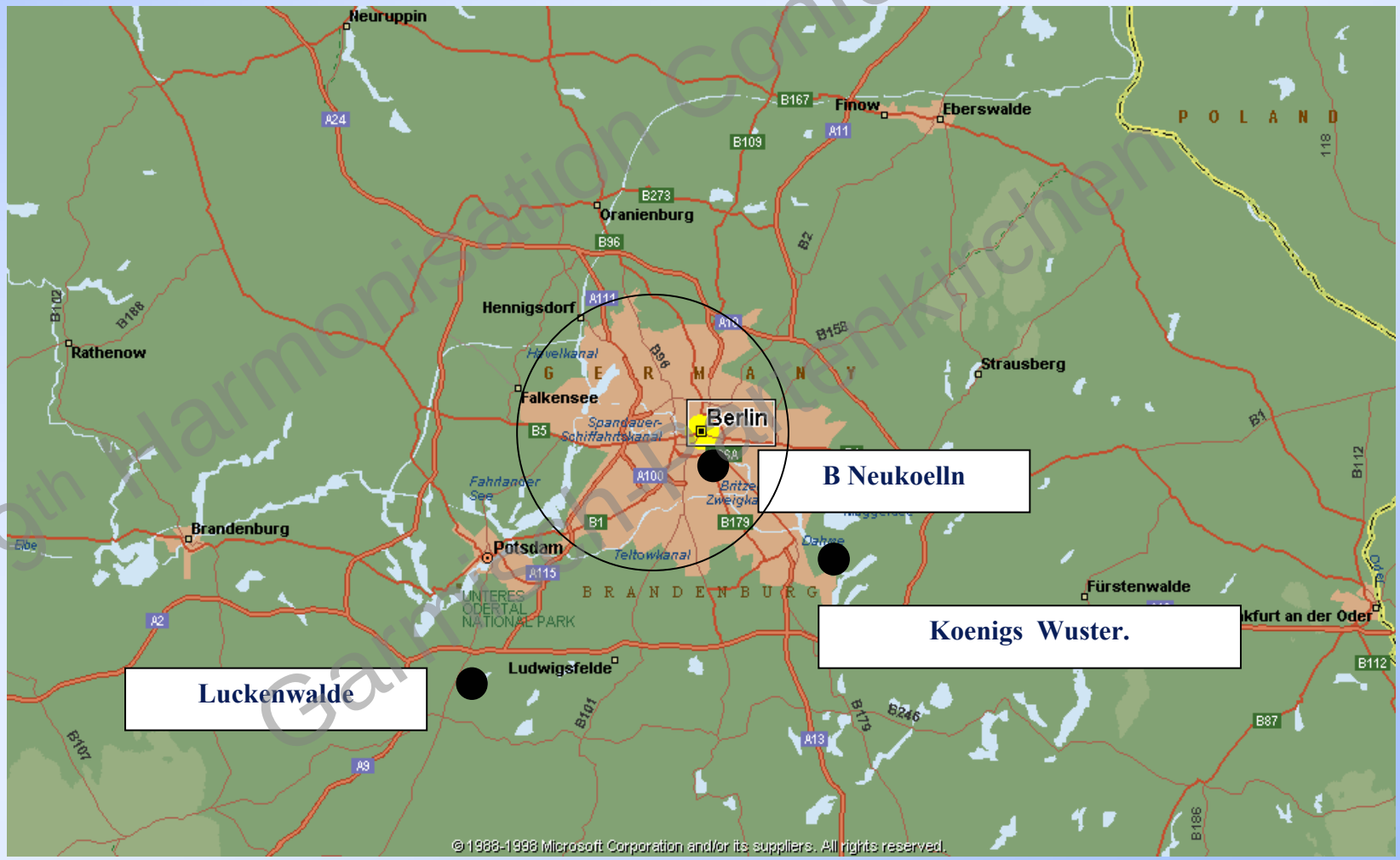
Prague – Spatial distribution PM_{10}



1-year average

AUT/
LHTEE

Berlin stations

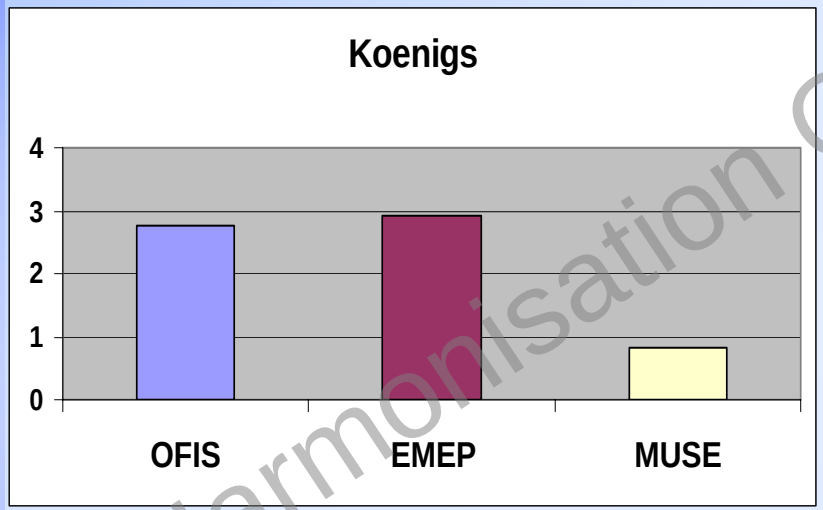


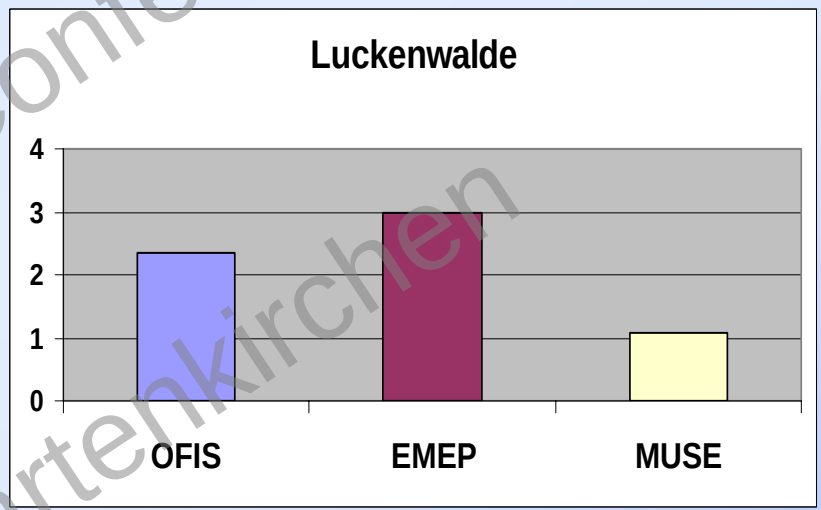
AUT/
LHTEE

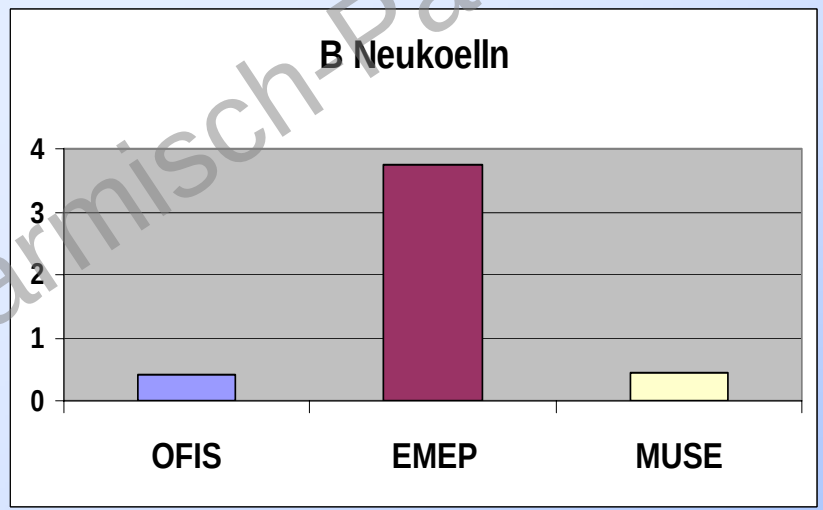
Berlin – Comparing OFIS to EMEP and MUSE

NO_2

NMSE



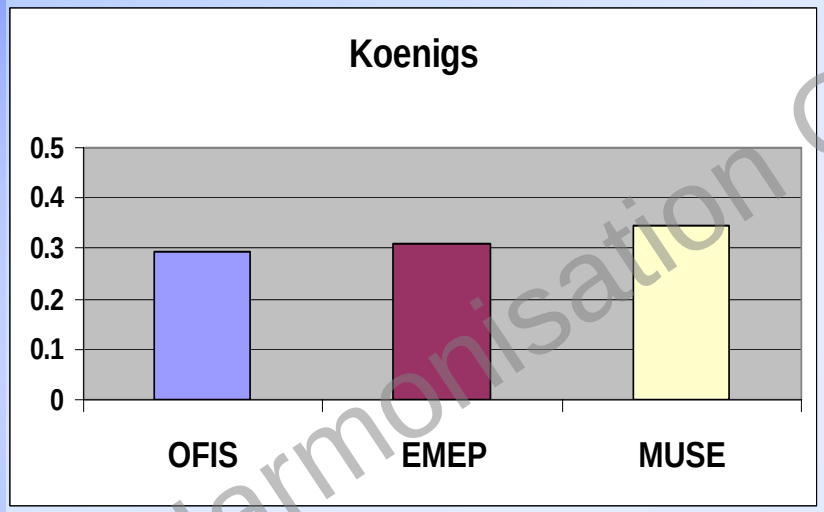


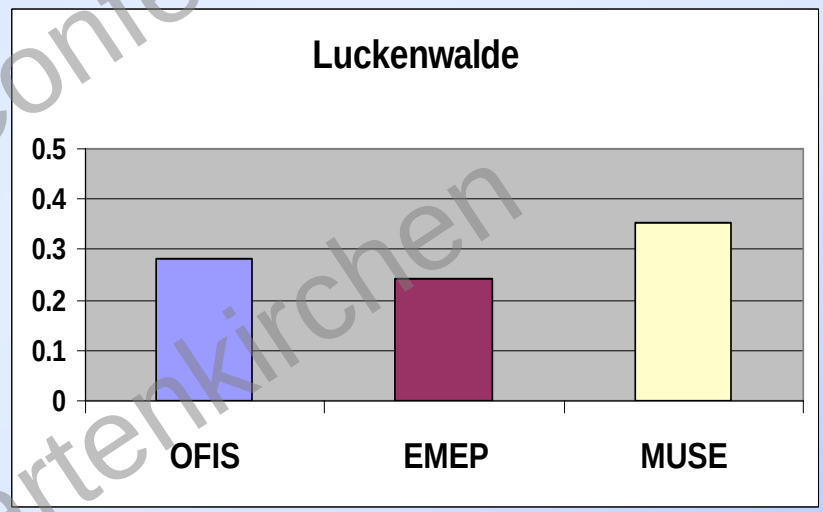


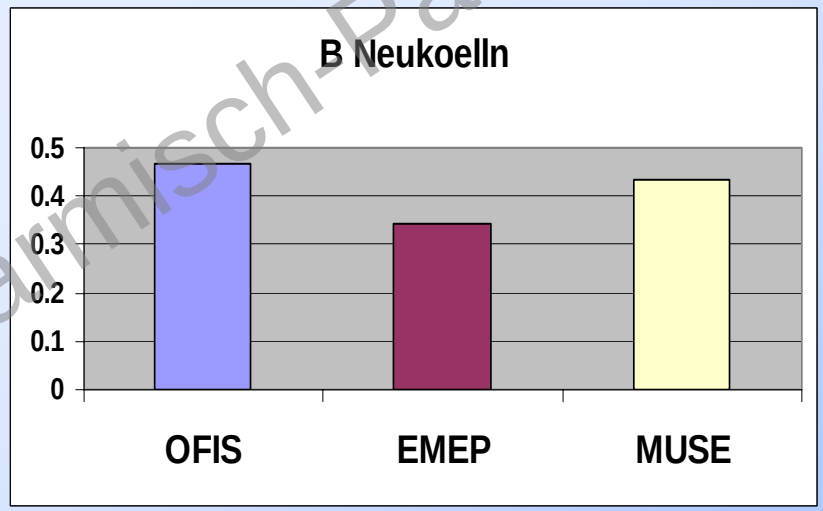
AUT/
LHTEE

Berlin – Comparing OFIS to EMEP and MUSE

NO_2 **Correlation coefficient**

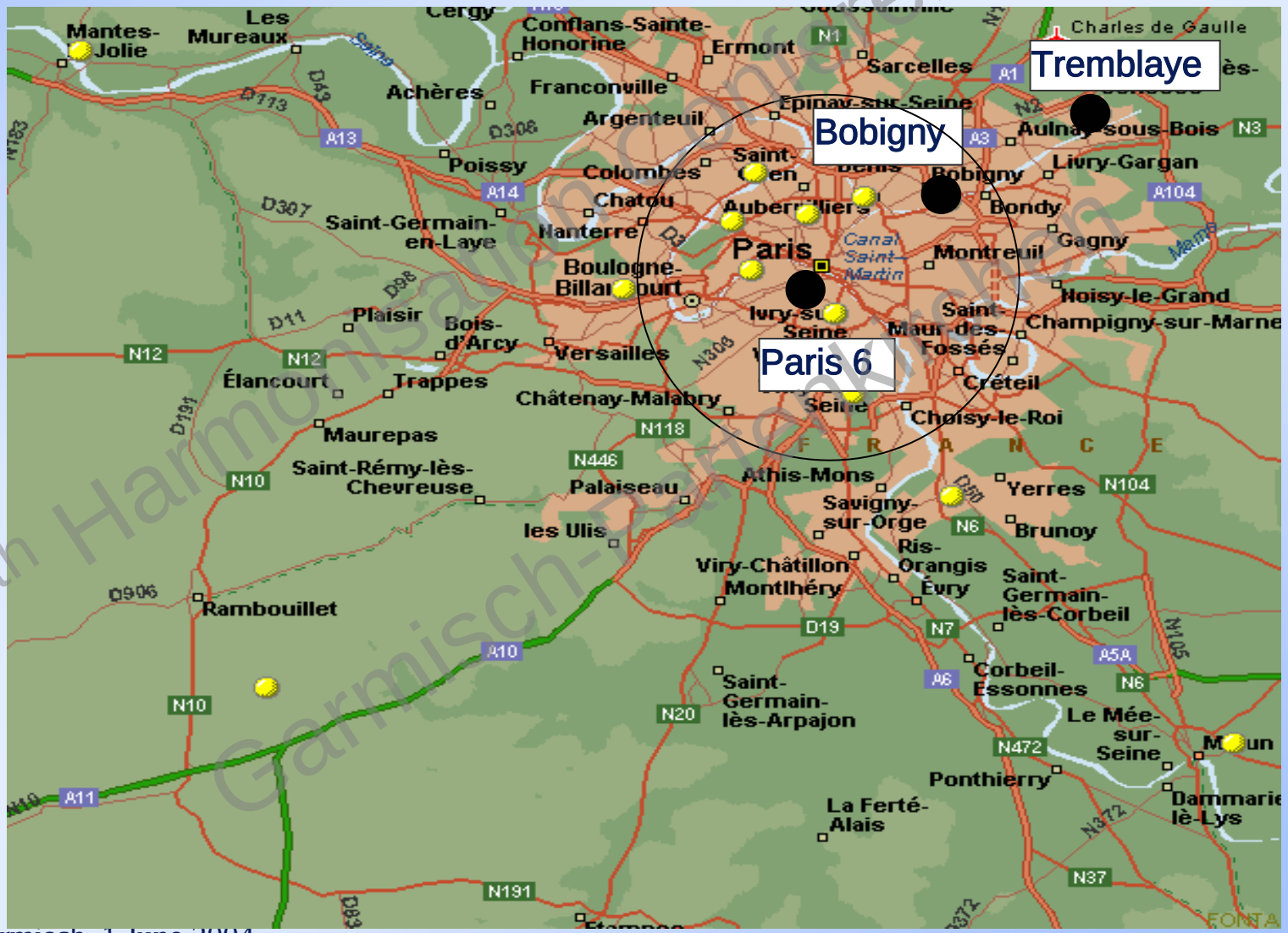






AUT/
LHTEE

Paris stations

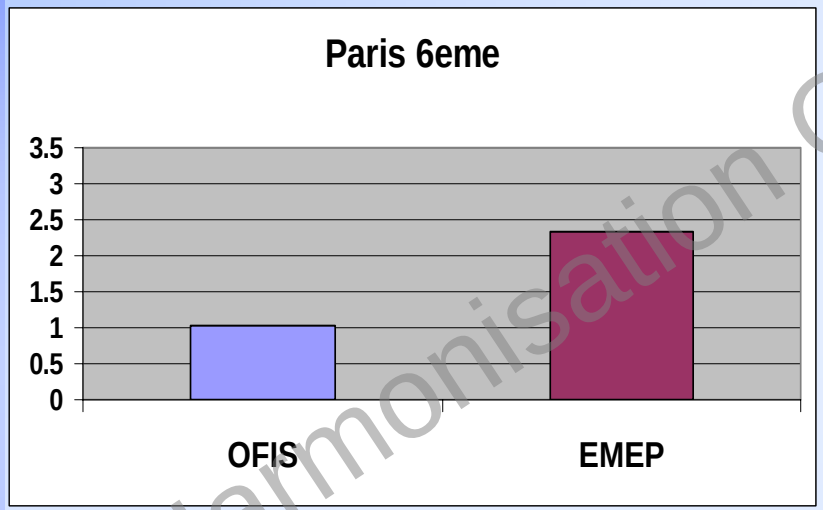


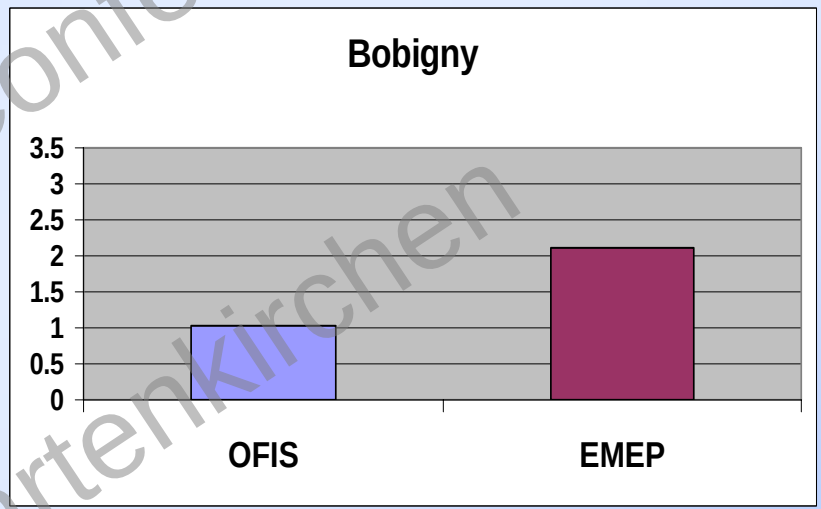
AUT/
LHTEE

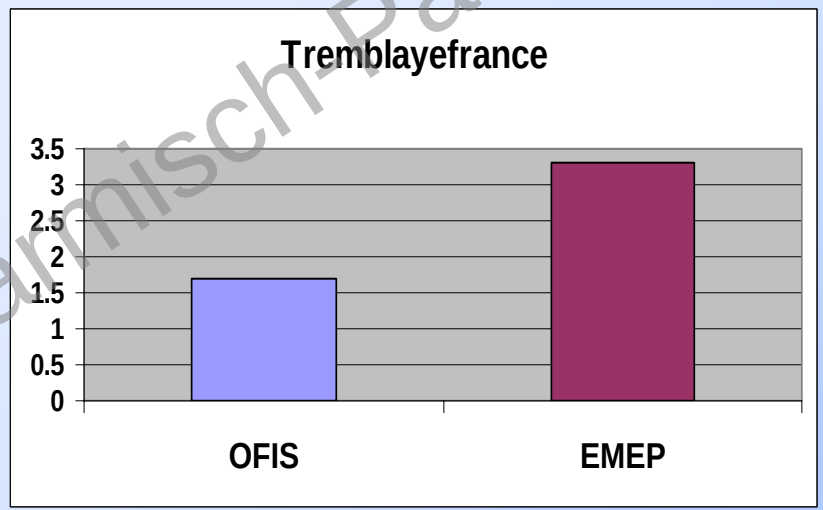
Paris – Comparing OFIS to EMEP

PM_{10}

NMSE



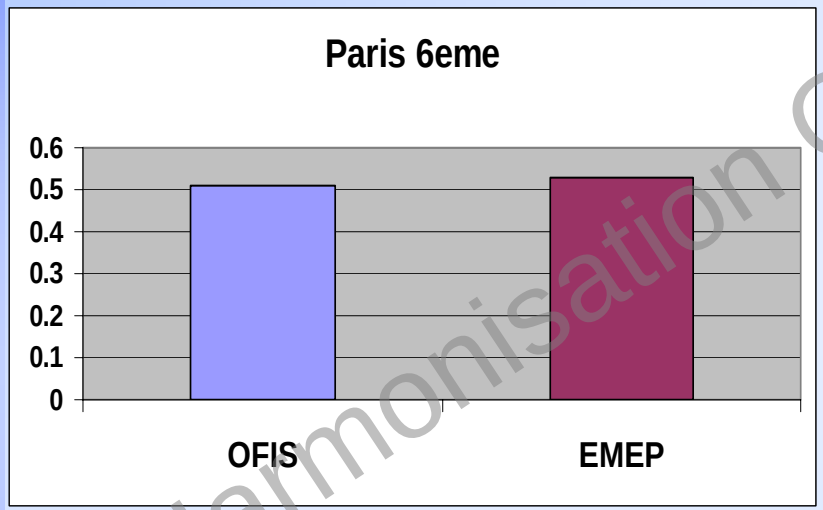


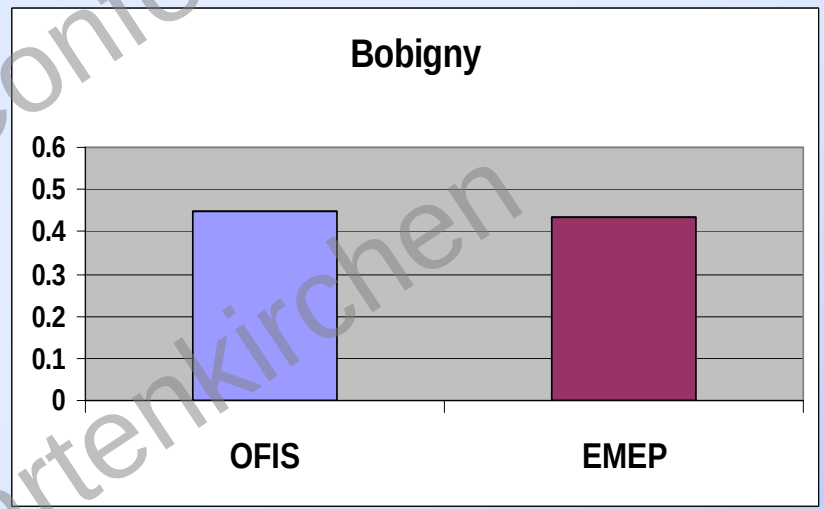


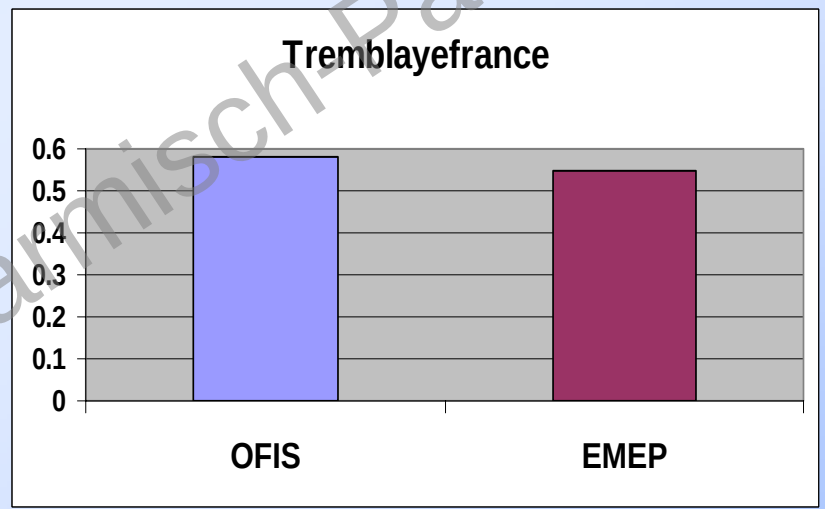
AUT/
LHTEE

Paris – Comparing OFIS to EMEP

PM_{10} **Correlation coefficient**







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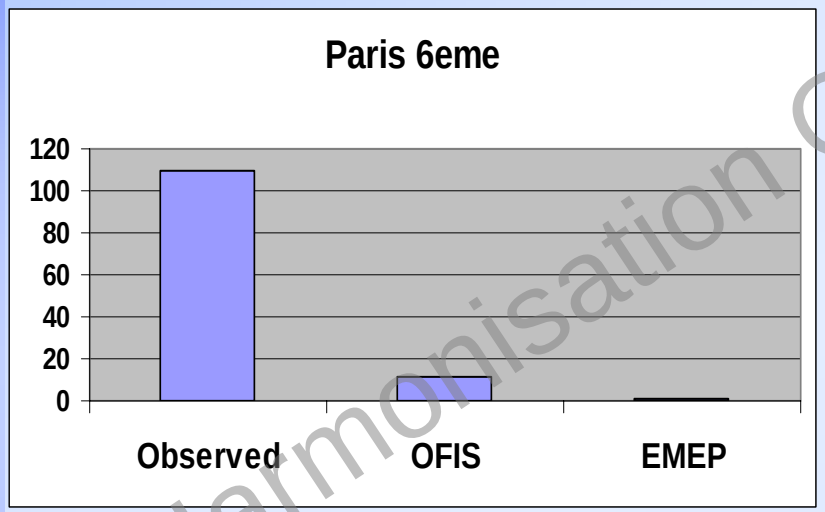
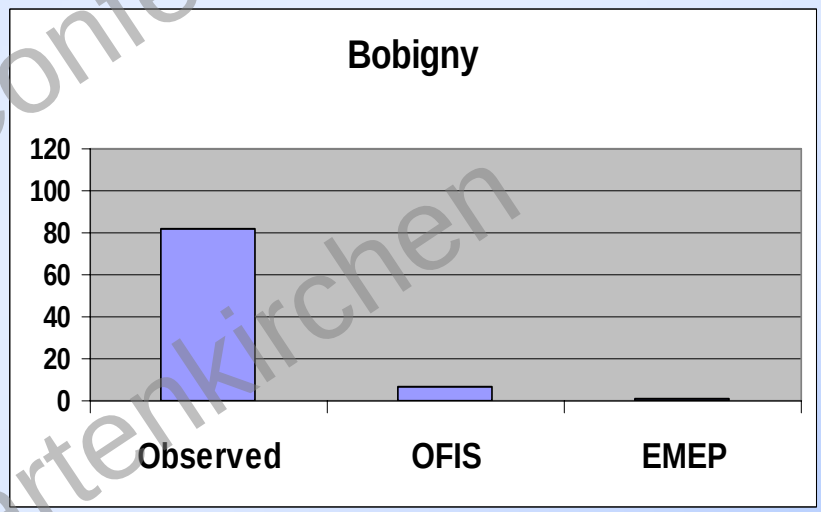
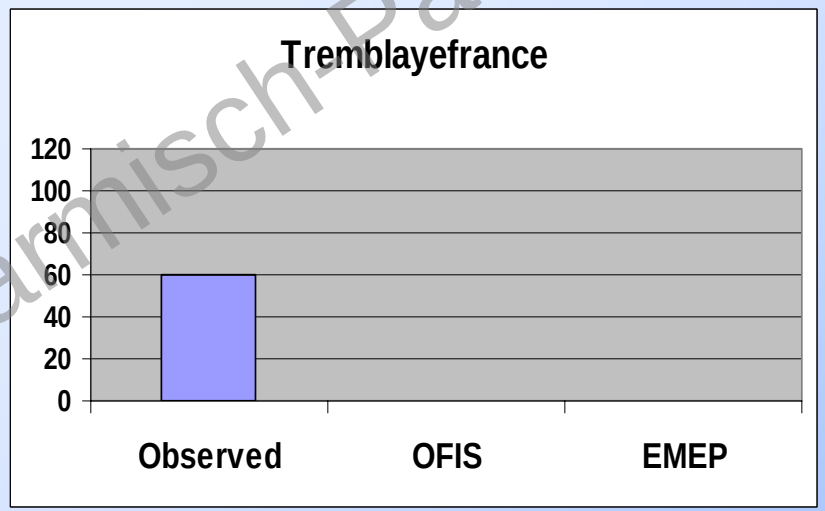
LHTEE

Paris – Comparing OFIS to EMEP

PM_{10} Exceedance days (50 µg/m^3)







Conclusions

- OFIS clearly achieves its goal, i.e., it succeeds in refining regional scale model results
- The effectiveness of OFIS is highest near the city and diminishes with distance
- The performance of OFIS is comparable to that of complex 3D models. However, it is by more than 1 order of magnitude faster
- The combination of a regional scale model and OFIS is an adequate tool for satisfying the needs of the EU Air Quality Framework Directive