Chemical Weather Forecast for Europe and selected regions - Evaluation and Model Output Statistics

EURAD System

RIU

Hermann Jakobs

Rhenish Institute for Environmental Research at the University of Cologne (RIU), Aachener Str. 209, 50931 Cologne, Germany,
Email: Hermann.Jakobs@eurad.uni-koeln.de, Web: www.riu.uni-koeln.de

Operational Chemical Weather Forecast @ RIU

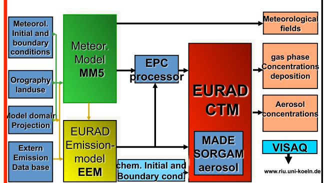
History

Since November 2001 an operational forecast system is running at the Rhenish Institute for Environmental Research at the University of Cologne (RIU) in order to predict the air quality for Europe, Central Europe and some German Federal States. The prediction system is based on the EURAD model (European Air Pollution and Dispersion Model), which is under development at RIU for more than 20 years.

Evaluation and Model Output Statistics

An intensive model evaluation has been carried out for the year 2007, using daily observational data from the German Environmental Agency (UBA). The description and the results of the Model Output Statistics are presented.

The EURAD Model



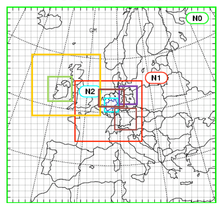
Prediction Variables

Variables: Ozone, NO2, PM10
PM2.5, SO2, CO, Benzene
Air Quality Index

Means: 1h mean, daily mean
Maxima: Max 8h mean, max. 24h mean

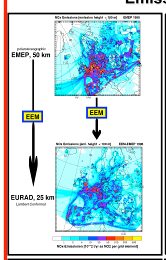
Others: Animations, Time series

Forecast Domains



N0: 125 km Europe
N1: 25 km Central Europe UK – Ireland
N2: 5 km Northrhine-Westfalia Ireland
Lower Saxony
Bavaria

Emissions



Europe: EMEP, TNO
Local: Northrhine-Westfalia, LANUV

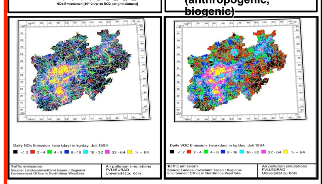
Annual averages projections till 2020

(NOx, SO_2, NH_3, CO, VOC, PM_{10}, $PM_{2.5}$)

Spatial transformation to specific domain (grid)

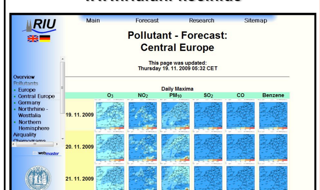
Temporal allocation (Saturday, dunday, workday)

Chemical spilt for VOC (anthropogenic, biogenic)

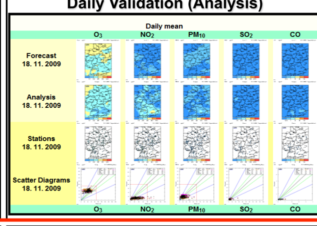


Northrine-Westfalia Emissions

AQ prediction at RIU
www.riu.uni-koeln.de



Daily Validation (Analysis)



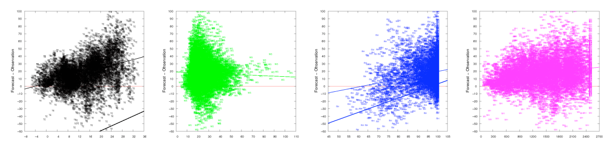
Model Output Statistics

Are there typical forecast errors with respect to meteorological conditions?
Statistics for the year 2007

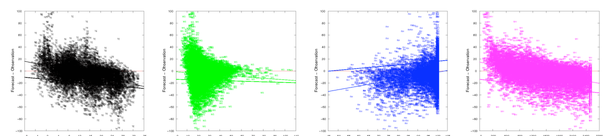
Compare Model error (O_3, NO_2, PM10) to:

- 2m temperature
- 10m horizontal wind speed
- 10m relative humidity
- Atmospheric Boundary Height (ABL)

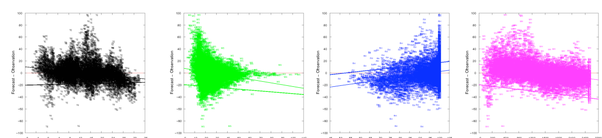
Direct Model Error Ozone



Direct Model Error NO_2



Direct Model Error PM10



vs 2m temperature | vs 10m wind speed | vs 2m re. humidity | vs 2m ABL height

Constituent	2m Temperature	10m Wind	10m Rel.Humidity	ABL
Ozone	+	(-)	+	+
NO_2	-	(-)	+	-
PM10	-	(-)	+	-

Meteorology dependencies of model error (slope)

Model Output Statistics (Multiple Regression)

The relation between the response variable (DMO error) and the dependent variables can be expressed as:

$Y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_p x_{ip} + \epsilon_i$

Where β_j, $j=0,\ldots,p$ are the regression coefficients with i observations and with p co variables. ϵ_i is the residual error. This is a linear system of equations in the form

$\underline{Y} = \underline{X}\underline{\beta} + \underline{\epsilon}$

With

$$\underline{Y} = \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_i \\ \vdots \\ Y_n \end{pmatrix} \in \mathbb{R}^{n\times 1}, \quad \underline{\epsilon} = \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \\ \vdots \\ \epsilon_i \\ \vdots \\ \epsilon_n \end{pmatrix} \in \mathbb{R}^{n\times 1} \text{ and } \underline{\beta} = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_j \\ \vdots \\ \beta_p \end{pmatrix} \in \mathbb{R}^{(p+1)\times 1}$$

The matrix $\underline{X}$ can be written as:

$$\underline{X} = \begin{pmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1p} \\ 1 & x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2p} \\ \vdots & & \vdots & \ddots & & \ddots & \vdots \\ 1 & x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{ip} \\ \vdots & & \vdots & \ddots & & \ddots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nj} & \cdots & x_{np} \end{pmatrix} \in \mathbb{R}^{(n\times(p+1))}$$

As solution of the minimization problem one obtain the vector of the estimated regression coefficients $\underline{b}$

$$\underline{b} = \begin{pmatrix} b_0 \\ b_1 \\ b_2 \\ \vdots \\ b_j \\ \vdots \\ b_p \end{pmatrix} = (\underline{X}^T\underline{X})^{-1}\underline{X}^T\underline{Y}$$

Thus the estimated values for $\underline{Y}$ can be expressed as

$\hat{\underline{Y}} = \underline{X}\underline{b} = \underline{X}(\underline{X}^T\underline{X})^{-1}\underline{X}^T\underline{Y}$

With the knowledge of the estimated regression coefficients of the multivariate regression one can obtain a new estimate for the corrected forecast (DMOE):

$DMOE_i = (F - O)_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + \ldots + b_p x_{pi}$

Where *F* is the forecasted and *O* is the observed value. Or in terms of the selected dependent meteorological variables:

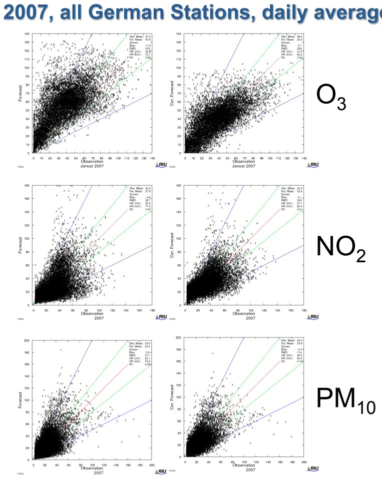
$DMOE_i = (F - O)_i = b_0 + b_1 TEM_i + b_2 WIN_i + b_3 RH_i + b_4 ABL_i$

Where *TEM* is the 2m temperature, *WIN* the 10m wind speed, *RH* the relative humidity and *ABL* the mixing height at the location and time *i*. Thus one can find a new corrected forecast value *Φi*:

$\Phi_i = F_i - (b_0 + b_1 TEM_i + b_2 WIN_i + b_3 RH_i + b_4 ABL_i)$.

Results

Raw forecast <-> MOS correction
2007, all German Stations, daily average



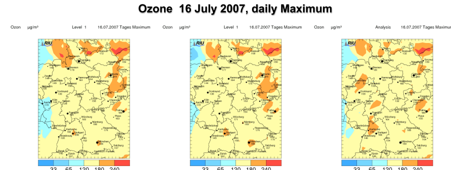
Direct Model Output | Corrected by MOS

Statistical scores for the 2007 evaluation

	Bias		RMSE		HR 20%		HR 50%	
	DMO	MOS	DMO	MOS	DMO	MOS	DMO	MOS
Ozone	16.7	0.7	26.0	16.0	25.8	41.0	70.7	83.2
NO_2	-4.5	0.1	18.9	16.0	30.5	37.1	77.4	82.4
PM10	0.3	-0.1	14.7	13.1	32.1	36.6	79.5	84.0

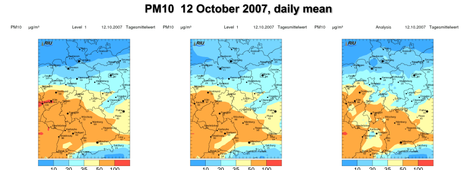
Application of MOS for selected episodes

Ozone 16 July 2007, daily Maximum



Direct Model Output | Corrected by MOS | 2d Var Analysis

PM10 12 October 2007, daily mean



Direct Model Output | Corrected by MOS | 2d Var Analysis

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