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OFFLINE COUPLING AND VERIFICATION OF THE UNIFIED EMEP MODEL AND WORKETA MODEL

"Offline" povezivanje unificiranog EMEP modela i WorkETA modela

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Abstract: In this paper the offline coupling of the Unified EMEP (European Monitoring and Evaluation Programme) model and WorkETA model was presented. For that purpose the meteorological driver was developed to supply the Unified EMEP model with input data from WorkETA model. To examine the use of the new driver, the Unified EMEP model was run from April to December 2005. The monthly and daily concentration of NO_2, SO_2 and SO_4^{2-} obtained by using WorkETA driver was compared to measured values and to those obtained from the input data from parallel version of HIRLAM (High Resolution Limited Area Model), PARLAM-PS model. The analysis shows that the use of the new meteorological driver has more influence on the concentration of SO_4^{2-} than on the concentration of NO_2 and SO_2.

Key words: EMEP model, offline coupling, meteorology driver

Sažetak: U ovom radu je predstavljeno tzv. "offline" povezivanje unificiranog EMEP modela i WorkETA modela. Kako bi se omogućilo korištenje rezultata WorkETA modela kao ulaz u unificirani EMEP model, razvijen je meteorološki preprocesor. Preprocesor je testiran simulacijom unificiranog EMEP modela, pomoću meteoroloških polja iz WorkETA modela, za razdoblje od travnja do prosinca 2005. Dobivene mjesečne i dnevne koncentracije NO_2, SO_2 i SO_4^{2-} su uspoređene s izmjerenim koncentracijama kao i koncentracijama dobivenim iz paralelne verzije HIRLAM, PARLAM-PS modela. Analiza je pokazala da korištenje novog preprocesora ima veći utjecaj na koncentraciju SO_4^{2-} nego na koncentraciju NO_2 i SO_2.

Ključne riječi: EMEP model, "offline" povezivanje modela, meteorološki preprocesor

1. INTRODUCTION

The concentration of chemical compounds in both the atmosphere and chemical transport models is in a close relationship with the meteorology processes. In the paper by Solazza et al., 2012, it was shown that bias in meteorology driver is one of the factors that influence most of the error in regional air quality models. Moreover, the influence of meteorology parameters becomes important by increasing spatial/temporal resolution of the model (Nasstrom et al., 1998). There are two different ways of coupling numerical weather prediction (NWP) models and atmospheric chemical transport models (ACTM). The first one is offline coupling of NWP model and ACTM where the ACTM uses data from NWP model prepared by a meteorological preprocessor (driver) within a limited period of time, without feedback between ACTM and NWP model such as the Unified EMEP (European Monitoring and Evaluation Programme) model (Simpson et al., 2012) and LOTOS-EUROS model (Schaap et al., 2008). This type of coupling has low computational costs, it uses data from operational NWP model, and it is suit-

able for operational chemical weather forecast. Another one is an online coupled model where the ACTM model uses NWP data at each time steep including a feedback mechanism between processes in ACTM and NWP model such as WRF-Chem model, RegCM-Chem4, Enviro-HIRLAM etc. (e.g. Baklanov et al. 2010). The offline coupled models are more suitable for ensembles, operational activates and air quality management. The online coupled models have the same physical parameterizations, no interpolation in space and time and have the capacity to consider gaseous and aerosols forces on atmospheric processes. The Unified EMEP model (Simpson et al. 2012) has been widely used for air quality policies in Europe since the late 1970s. Meteorological fields for forcing the Unified EMEP model are originally provided by using PARLAM-PS model (Bjorge and Skalin 1995; Berge and Jakobsen 1998; Lenschow and Tsyro 2000). This NWP model is a dedicated version of the HIRLAM (HIgh Resolution Limited Area Model) and its architecture is accommodated with architecture of the Unified EMEP model. The operational Unified EMEP model has a coarse spatial resolution (50 km). Such resolution is appropriate for analyzing transboundary processes over Europe. However, the application of the Unified EMEP model on a much finer spatial resolution is essential. Consequently, such application of the Unified EMEP model requires the adaptation of meteorological driver. Recently, such drivers have been developed for EMEP4UK (EMEP for the United Kingdom) (Vieno et al. 2009) and EMEP4HR (EMEP for CROATIA) (Jeričević et al. 2007; Kraljević et al. 2008; Prtenjak et al. 2009) models. Meteorological drivers use meteorological fields from the Weather Research and Forecast model (WRF) and ALADIN NWP model, respectively. The optimal way for national meteorology institutes that need to run the Unified EMEP model in finer resolution for their own air quality policy is usage of meteorological fields already produced by operational weather forecast model. Accordingly, all efforts invested in coupling widely used NWP models and the Unified EMEP model can be seen as very beneficial. The NCEP's (US National Center for Environmental Prediction) WorkETA (Janjic 1984; Mesinger et al. 1988) prognostic system is broadly used as an operational forecasting system on national level. The aim of this work is to examine the performance of the Unified EMEP model when meteorological inputs created by WorkETA model outputs are used.
Going in that direction, we have made a procedure for the spatial interpolation of the meteorological fields of WorkETA model grid to the Unified EMEP model grid. The Unified EMEP model uses a polar-stereographic projection true at 60°N and sigma vertical coordinate, while WorkETA model uses the transformed latitude-longitude coordinate system and eta or sigma as a vertical coordinate. Let us note that the transformed latitude-longitude coordinate system has singularity at poles. Consequently, the official domain of the Unified EMEP model cannot be entirely covered by the domain of the WorkETA model. However, the application of the Unified EMEP model at country level is not an important drawback to our approach. The application of the Unified EMEP model on finer resolution for East Balkan region is still not possible due to the lack of appropriate gridded emissions. Therefore, we used the Unified EMEP model with horizontal resolution as in vr_3 version, i.e. 50 km.

The Unified EMEP model was first run with the standard meteorology inputs produced by PARLAM-PS model, followed by the Unified EMEP model run with meteorological fields produced by WorkETA model simulation (Section 2). Finally, NO_2, SO_2 and SO_4^{2-} surface concentrations, simulated in these ways, were compared to each other and against the data observed within EMEP measurement network to do the model evaluation with the meteorology fields from the WorkETA model (Section 3).

2. METHODS AND MATERIALS

To provide the metrological input data for the Unified EMEP model, WorkETA model was run for the period from April to December 2005. The center of WorkETA domain was at 21°E i 45° N and included 101x101 horizontal grids with resolution 0.5° and 50 vertical sigma levels. The time step was 180 s. The 6-hour NCEP (*National Centers for Environmental Prediction*) analysis was used as input data for initial and boundary conditions. NCEP analysis was not available for the period from January to March 2005 and the WorkETA model was not run in this period. The model was run for 24 forward and the meteorology fields on every 3 hours were interpolated from WorkETA to the Unified EMEP model domain used in this paper (Figure 1). The interpolation was done first in horizontal plain and after that in vertical direction. For horizontal interpolation the bilinear interpolation was used, except for the precipitation where the so-called zero interpolation was used (the nearest-neighbor estimator) (Kruizing and Yperlan 1977). In vertical direction "spline" interpolation was used.

The latitude-longitude coordinate system used in WorkETA model has singularity at the pole and it is the reason why the WorkETA model cannot provide meteorology inputs for the whole EMEP domain, as it was mentioned before. For the Unified EMEP simulation we used the part of the official domain that covers almost whole Europe (Figure 1). The Unified EMEP model was run with input parameters from WorkETA and PARLAM-PS model. After preparing meteorology inputs the Unified EMEP model was run first with standard inputs obtained from PARLAM-PS model and after that with inputs obtained from WorkETA model. Standard EMEP horizontal model resolution, 50 x 50 km, and 20 sigma vertical model levels were used for simulations. The EMEP gridded emissions for 2005 were used (www.ceip.at). The run time period was from April to December 2005 with time step of 1200 s. The Unified EMEP model was not run for the period from January to March because of the missing of WorkETA run for the same period that was already explained. This is the reason why further analyses were done only in one winter month, December.

The monthly surface concentrations of NO_2, SO_2 and SO_4^{2-} obtained from the two models simulations were compared to each other and to the measured concentration from EMEP stations network at the considered model domain. Those compounds were used because of their life time 1 to 3 days for NO_2, SO_2 and about one week for SO_4^{2-}. This was the best compromise because their life spans are

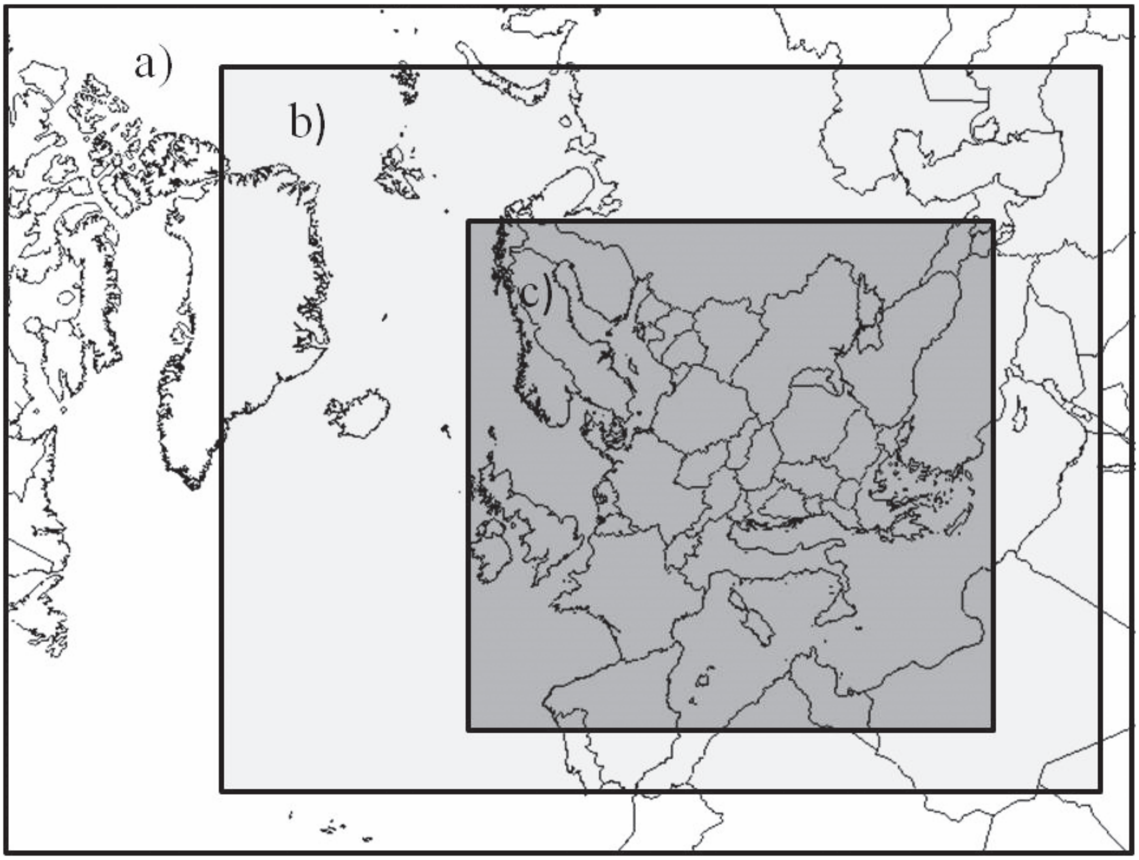


Figure 1. EMEP domain: a) expanded domain, b) official domain and c) domain used in this paper.

Slika 1. Domena modela EMEP: a) proširena domena, b) uobičajena domena i c) domena korištena u radu.

short/long enough to represent local and non-local meteorology influence. Also, the NO_2, SO_2 are gases and SO_4^{2-} is a particle. SO_4^{2-} concentration depends on the long-range transport of gaseous precursors and processes in their origin. The EMEP stations network has good spatial and temporal resolutions. Data sets from that network are well documented, quality controlled and suitable for comparing to model results (Topçu et al. 2002; Mihailovic and Alapaty 2007; Mihailovic et al. 2009; Calvo et al. 2010). All the details on measurement techniques, the location of stations and data sets can be found at http://www.nilu.no/projects/ccc/emepdata.html. In this study, we used daily surface concentration measurements of NO_2 (μg N m^{-3}) and SO_2 (μg S m^{-3}) at stations AT0002R, DE0001R and CZ0001R for the year 2005. The surface concentration measurements of SO_4^{2-} (μg S m^{-3}) at stations CZ0001R and DE0007R were used. Details about those stations are given in Table 1. The monthly surface concentration of the same compounds was used from all EMEP stations inside the model domain taking care that some of the mountain stations and some stations in the North Sea shipping area were excluded. At the mountain stations and some stations in the North Sea shipping area, the high discrepant between modeled and measured data is due to the coarse horizontal model resolution and the shipping emission path because the high concentrations are horizontally diffused over a large area (Jericevic at al., 2010). The relative differences (*rd*) between averaged monthly meteorology parameters obtained using WorkETA and PARLAM-PS model were calculated as:

$$rd = \frac{(mpp - mpe)}{0.5 \cdot (mpp + mpe)} \tag{1}$$

where *mpp* and *mpe* are averaged monthly meteorology parameters provided by PARLAM-PS and WorkETA model, respectively. The obtained average monthly concentrations were compared to the measured one using statistic quantities BIAS and RMSE:

$$BIAS = \left(\frac{\overline{M} - \overline{O}}{\overline{O}} \right) \cdot 100\% \tag{2}$$

$$RMSE = [\sum_{i=1}^{N_s} (M_i - O_i)^2 / N_s]^{1/2} \tag{3}$$

where M_i and O_i denote modeled and observed average monthly concentrations, N_s is the number of stations, while over bar indicates average monthly concentration for all the stations.

3. RESULTS

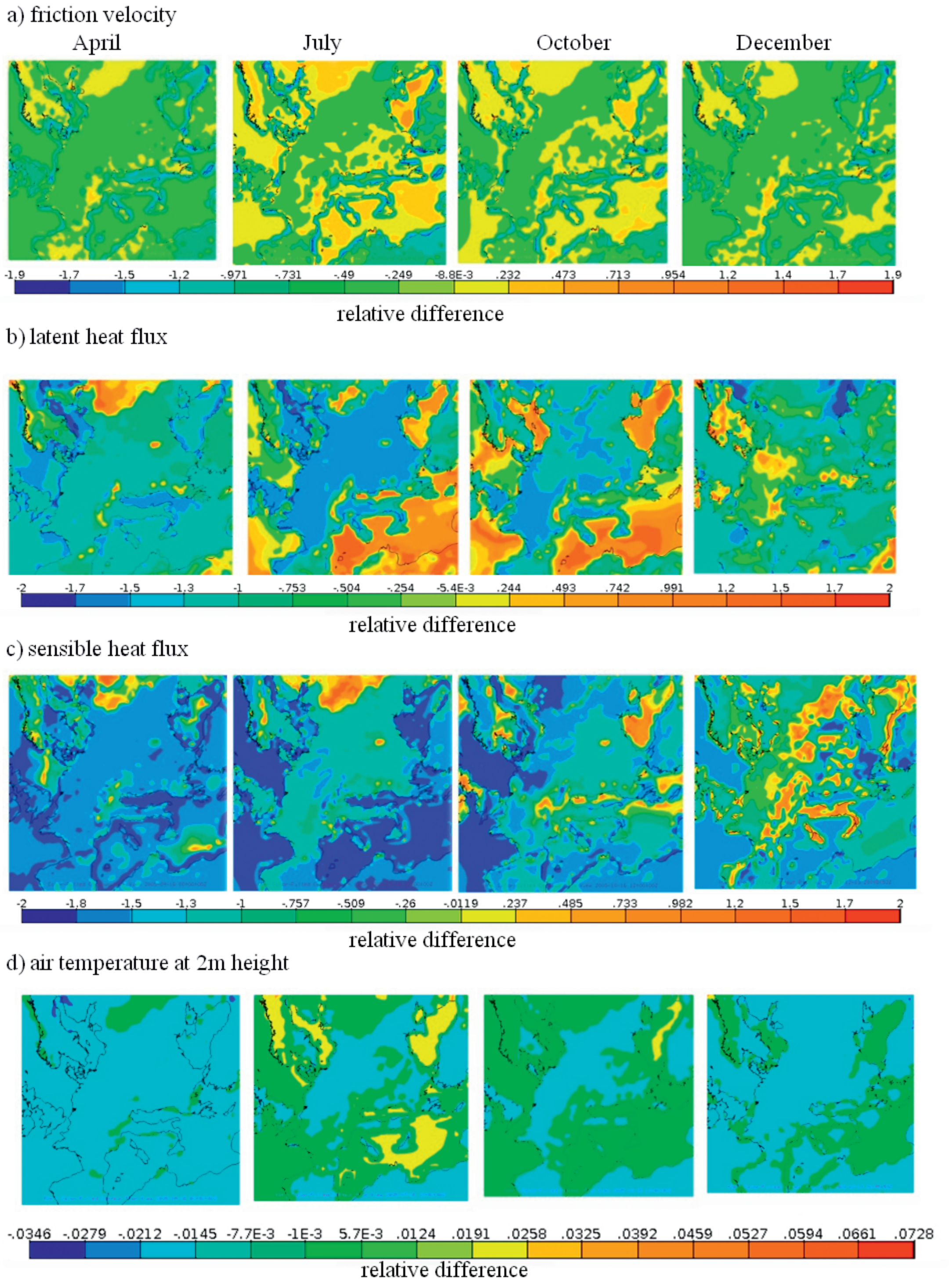
The meteorology parameters influence dispersion and transformation of chemical compounds in the atmosphere. The compound dispersion depends on wind and atmospheric stability. The meteorology parameters that influence the transformation of the compounds are not the same for every compound. The most important meteorology and chemistry interactions were summarized in Baklanov et al. 2014. The meteorology parameters and their main purpose in the Unified EMEP model were presented in Simpson et al. 2012. The interaction between the meteorological parameters and the atmospheric chemistry in the models was predefined and was not changed due to the change in the meteorology driver. When the meteorology driver was changed all input meteorology parameters were changed

Table 1. Details about the location and altitude of stations used in this paper

Tablica 1. Podaci o mjernim postajama korištenim u radu

Station	Location	Altitude	Compounds
AT0002R (Illmitz, Austria)	47º 46'N, 16º 46'E	117 m	NO_2, SO_2
DE0001R (Westerland, Germany)	54º 56'N, 08º 19'E	10 m	NO_2, SO_2
CZ0001R (Svratouch, Czech Republic)	49º 44'N, 16º 02'E	737 m	NO_2, SO_2, SO_4^{2-}
DE0007R (Neuglobsow, Germany)	53º 09'N, 13º 02'E	62 m	SO_4^{2-}

more or less at the whole domain at a particular time. Identification of the meteorology parameter whose increase/decrease influences the increase/decrease of particular compounds concentration is very complicated and the relationship between them is not always straightforward. For example, the decrease of wind speed near emission source tends to accumulate compound and the concentration increases, but at the distance from the source the concentration decreases. The detailed analysis of meteorology influence on the concentration of compounds and the identification of the most influenced meteorology parameters and their interaction are not the main goal of this work. Only the difference in



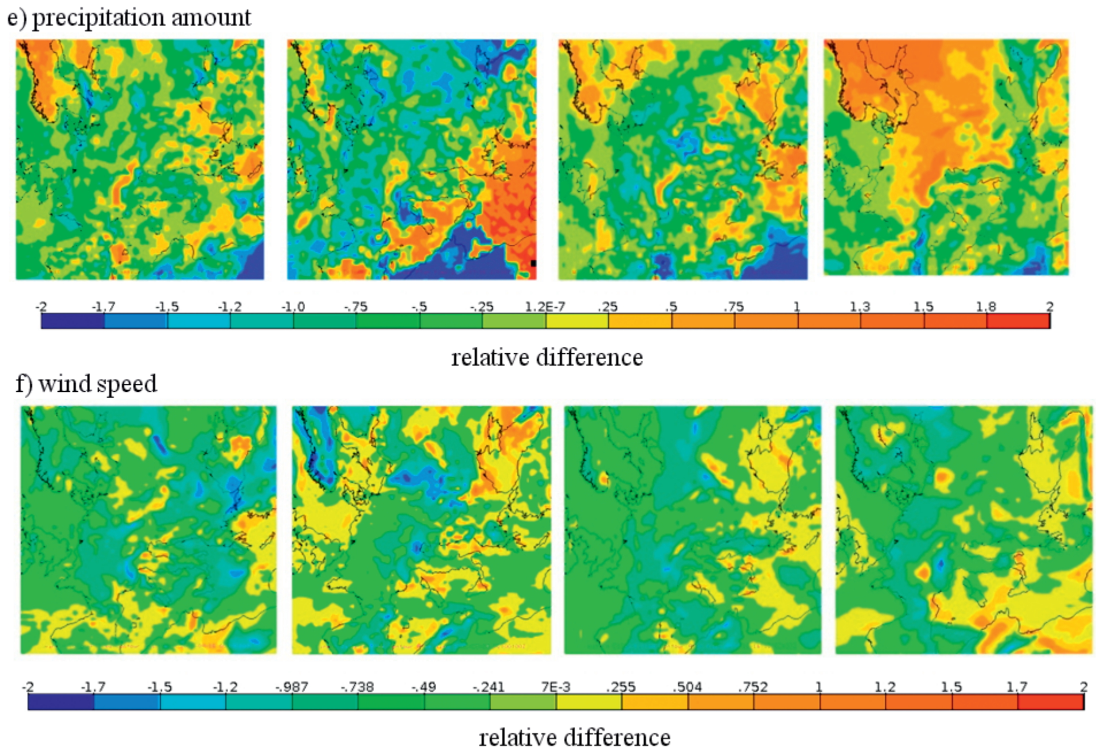


Figure 2. Relative difference between average monthly meteorology parameters: a) friction velocity, b) latent heat flux, c) sensible heat flux, d) air temperature at the height of 2 m, e) precipitation amount and f) wind speed obtained by PARLAM-PS and WorkETA model.

Slika 2. Relativna razlika između srednjih mjesečnih meteoroloških veličina: a) brzina trenja, b) tok latentne topline, c) tok osjetne topline, d) temperata zraka na 2 m visine, e) količina oborine i f) brzina vjetra dobivenih pomoću PARLAM-PS i WorkETA modela.

meteorology parameters and concentration due to the change of meteorology driver will be analyzed. For that purpose the relative differences in some average monthly meteorology parameters provided by WorkETA and PARLAM-PS driver that influenced advection (wind speed at lowest model level, here after just wind speed), atmospheric stability (sensible heat flux and air temperature at the height of 2 m), wet/dry deposition (precipitation amount and latent heat flux), both deposition and stability (friction velocity) (Figure 2) and relative differences in NO_2, SO_2 and SO_4^{2-} concentration in April, July, October and December (Figure 3) were presented. The differences between the meteorology parameters provided by WorkETA and PARMAM-PS driver come from the different formulation of NWP model dynamic and parameterization of physical processes in models. The friction velocity provided by WorkETA model is always higher over coastal lines and lower over mountains than friction velocity provided by PARLAM-PS model (Figure 2a). The latent heat flux provided by WorkETA model is lower than latent heat flux provided by PARLAM-PS model over sea and higher over land in July and October (Figure 2b). In April and December the latent heat flux provided by WorkETA model is higher over the domain except in the central Europe and Scandinavia than latent heat flux provided by PARLAM-PS model. The sensible heat flux provided by WorkETA model is higher than sensible heat flux provided by PARLAM-PS model over the whole domain except over land in December (Figure 2c). The air temperature at the height of 2 m provided with WorkETA model is higher or similar to that provided by PARLAM-PS model in the whole domain (Figure 2d). The differences between precipitation (Figure 2e) and wind speed provided (Figure 2f) by WorkETA and PARLAM-PS model do not have a pattern. The biggest difference in precipitation (Figure 2e) provided by WorkETA and PARLAM-PS model is in December when the amount of precipitation provided by WorkETA model was much lower over the east and the north parts of Europe.

The concentrations of NO_2 (Figure 3a) and SO_2 (Figure 3b) were lower when the Unified EMEP model was run with meteorology parameters provided by WorkETA driver than when they were provided by PARLAM-PS model in most parts of the domain. The big difference in sensible heat flux could be one of the most important reasons for the change in NO_2 and SO_2 concentration since atmospheric stability and vertical transport are mostly driven by this flux. In April, July and October, the SO_4^{2-} concentration obtained by using WorkETA driver in some parts of the domain is lower and in some parts is higher than the concen-

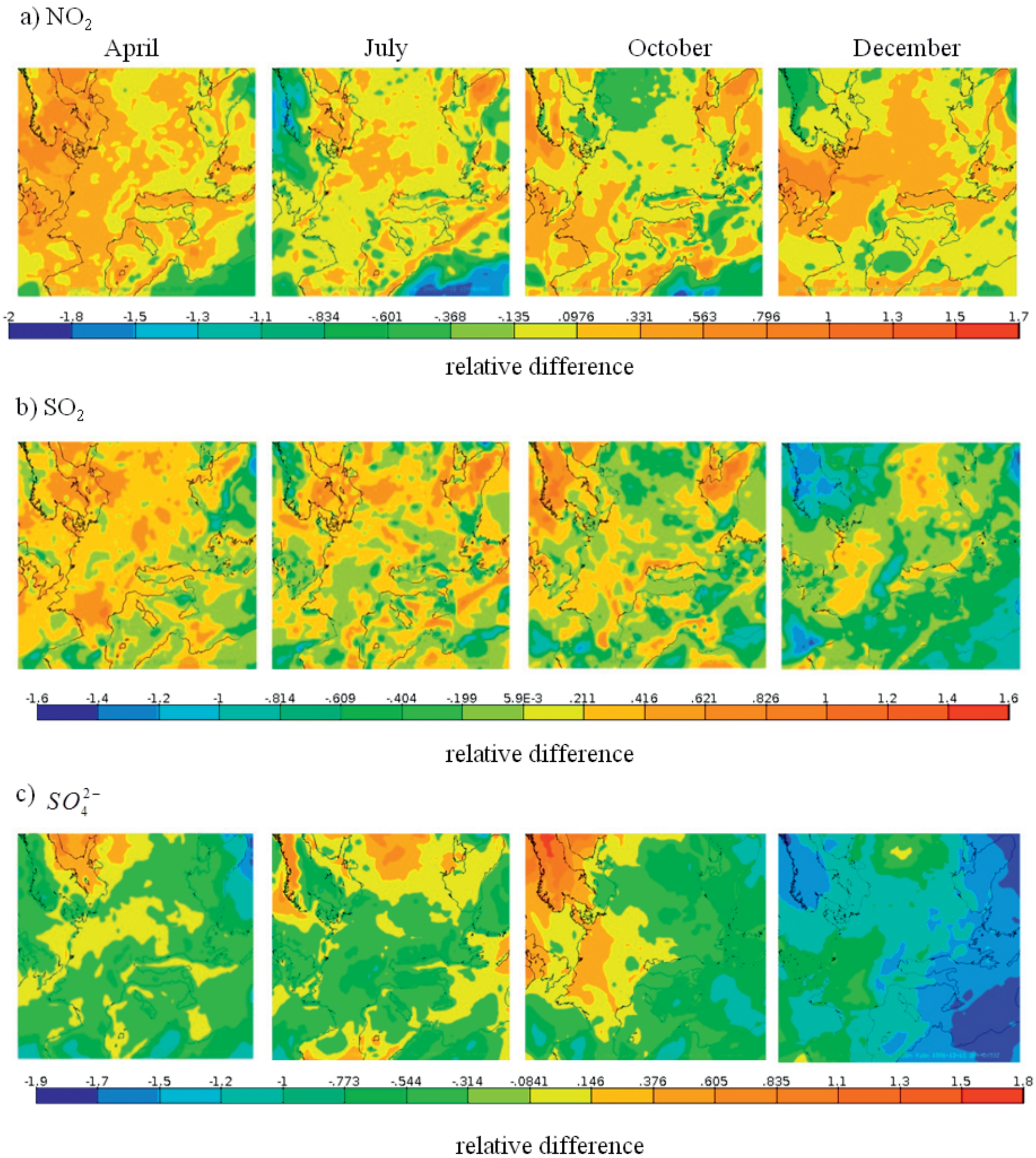


Figure 3. Relative differences between average monthly concentration of NO_2 (a), SO_2 (b) and SO_4^{2-} (c) obtained by using the Unified EMEP model with input data provided by WorkETA and PARLAM-PS driver.

Slika 3. Relativne razlike između srednjih mjesečnih koncentracija NO_2 (a), SO_2 (b) and SO_4^{2-} (c) dobivenih pomoću unificiranog EMEP modela s WorkETA i PARLAM-PS preprocesorom.

tration obtained by PARLAM-PS driver. In December, the amount of precipitation in WorkETA model was much lower than amount of precipitation in PARLAM-PS model. The decrease in the amount of precipitation decreases wet deposition rate which influences the increase in the concentration of compounds. This parameter, among other parameters, leads to the higher concentration of SO_4^{2-} (Figure 3c) in December when the meteorology parameters from WorkETA model were used.

To evaluate the use of WorkETA and PARLAM-PS meteorology fields as input data in the Unified EMEP model with measurements on EMEP stations, we used statistical quantities: BIAS and RMSE (figures 4-5, respectively). The statistical quantities, spatial BIAS and spatial RMSE for all analyzed stations within the domain were calculated for the average monthly concentrations of NO_2, SO_2 and SO_4^{2-}. It is very important to note that BIAS calculated by Eq.2 is an average measure for the whole domain and it does not necessarily mean that the BIAS is positive or negative in every part of the domain. Very often the BIAS is positive in some parts of the domain and negative in other parts. There is no difference between BIAS of NO_2 concentration obtained by the two different meteorological drivers and measured ones (Figure 2). The situation with the BIAS of SO_2 is similar to the BIAS of NO_2 concentration, except in the summer months when the difference between BIAS is articulated (Figure 4). The average concentration of SO_4^{2-} in the domain was always lower than the measured one when the meteorology inputs from WorkETA model were used (Figure 4). There is no difference in the spatial RMSE values for NO_2 and SO_2 concentration in the domain (Figure 5). The spatial RMSE of SO_4^{2-} concentration in the domain obtained by meteorology inputs from WorkETA model was lower for July, August and December than those obtained by PARLAM-PS meteorology driver (Figure 5). The effect of the three meteorology drivers (PAR-

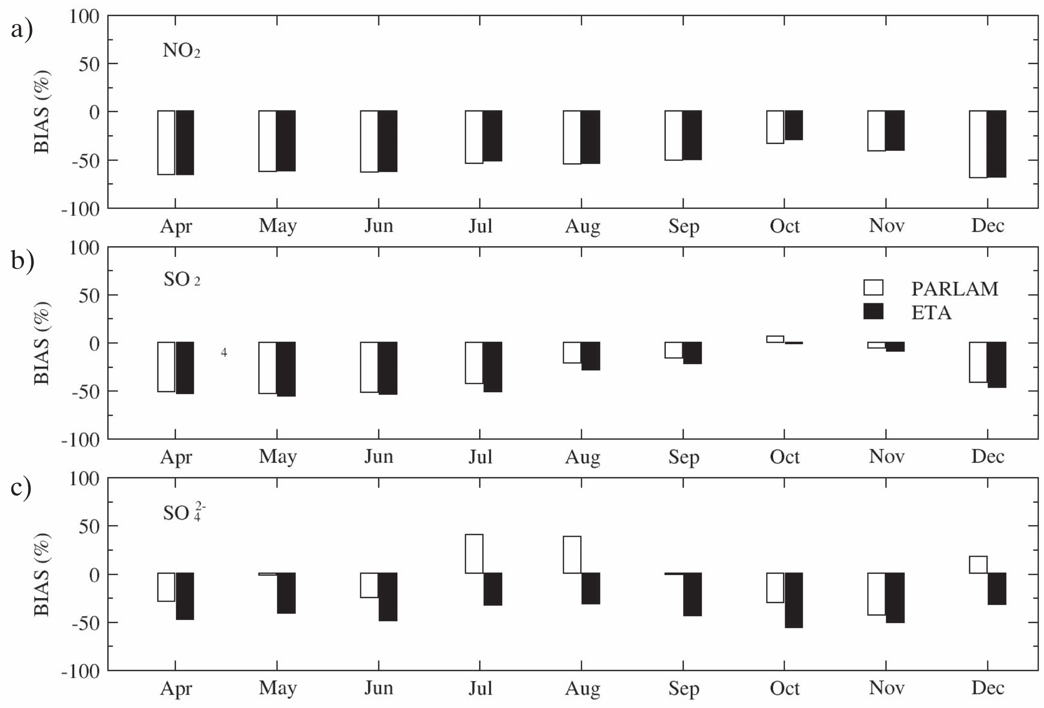


Figure 4. The average monthly BIAS (%) for the observed and modeled concentration of NO_2 (a), SO_2 (b) and SO_4^{2-} (c) with the meteorological inputs from WorkETA and PARLAM-PS driver used in the Unified EMEP chemical model.

Slika 4. Srednja mjesečna pogreška (%) između opaženih i modeliranih koncentracija NO_2 (a), SO_2 (b) i SO_4^{2-} (c) dobivenih pomoću WorkETA i PARLAM-PS preprocesora u unificiranom EMEP modelu.

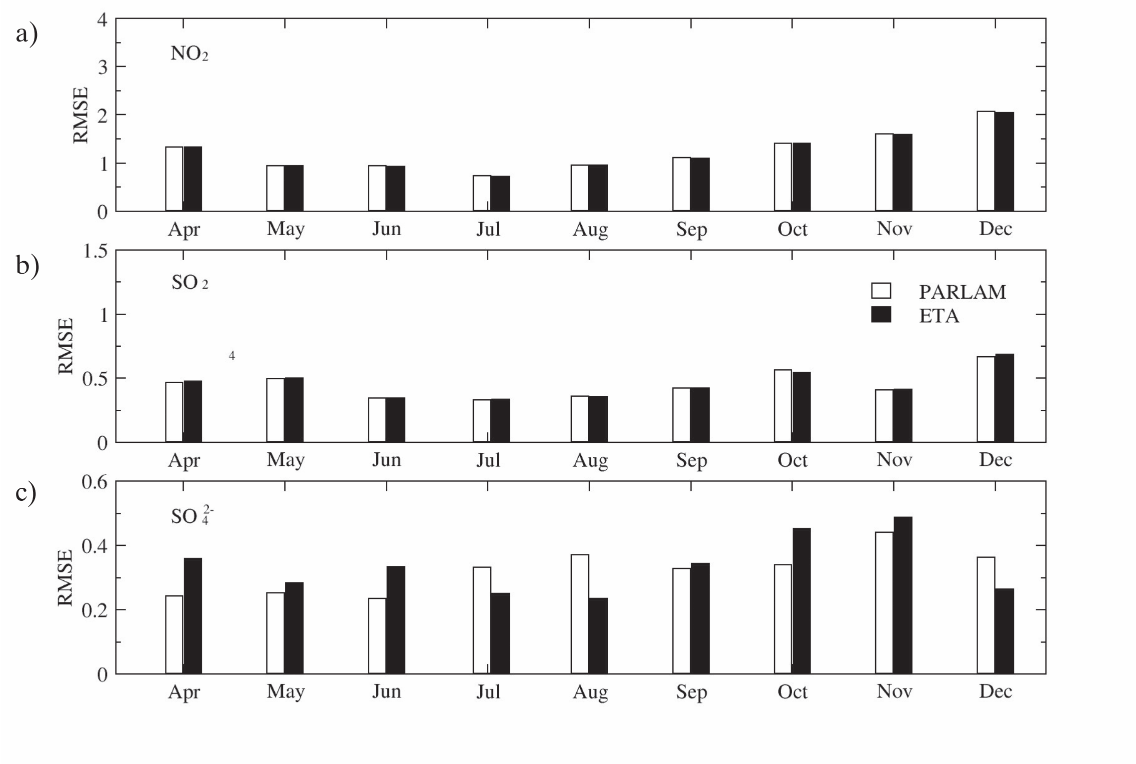
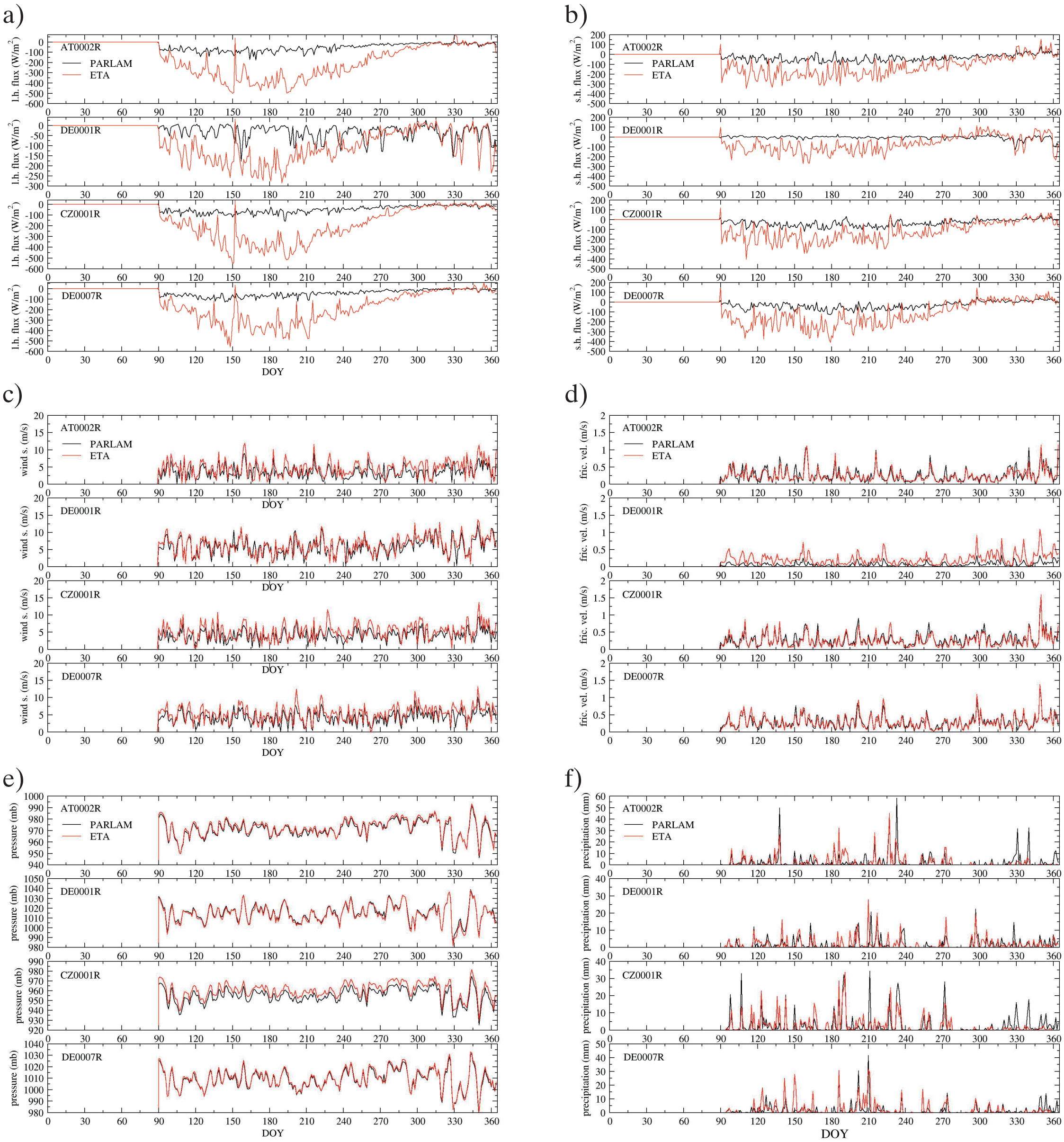


Figure 5. The average monthly RMSE for the observed and modeled concentrations of NO_2 (a), SO_2 (b) and SO_4^{2-} (c) with the meteorological inputs from WorkETA and PARLAM-PS drivers used in the Unified EMEP chemical model.
Slika 5. Srednji mjesečni RMSE opaženih i modeliranih koncentracija NO_2 (a), SO_2 (b) i SO_4^{2-} (c) pomoću meteoroloških ulaznih veličina iz WorkETA i PARLAM-PS preprocesora u unificiranom EMEP modelu.

LAM-PS, HIRLAM version 7.1 and ECMWF models) on sea salt concentration which among other inorganic aerosols alters the distribution of SO_4^{2-} was studied in the work of Tsyro et al., 2011. They showed that the use of HIRLAM-v7.1 and ECMWF (European Centre for Medium-Range Weather Forecasts) improved the prediction of sea salt concentration in the Unified EMEP model.

In addition to average monthly NO_2, SO_2 and SO_4^{2-} concentrations, some changes in the daily concentration of NO_2, SO_2 and SO_4^{2-} obtained by using different meteorological drivers at stations which are shown in Table 1 are also presented (Figure 6). At the same stations the meteorology parameters (friction velocity, wind speed and direction, surface pressure, latent and sensible heat flux, air temperature at the height and precipitation amount) obtained by using two meteorology drivers are also provided (Figure 7). In the summer period, the daily values of sensible and latent heat fluxes (Figure 6a,b) at considered stations were higher when the WorkETA model was used than when the PARLAM-PS model was used. The wind speed provided by WorkETA model at four stations was lower than wind speed provided by PARLAM-PS model (Figure 6c). The DE0001R station is on the cost of the Baltic Sea and the friction velocity calculated by WorkETA model, as it was expected from previous discussion, was higher (Figure 6d) than those obtained by using PARLAM-PS driver. The CZ0001R station is a mountain station and surface pressure calculated by WorkETA model had higher values then those calculated with PARLAM-PS model (Figure 6e). The surface pressure affects the air density which plays a role in the deposition process. At four stations the amount of precipitation calculated by PARLAM-PS model is slightly higher than the amount on those calculated by WorkETA model (Figure 6f). That is emphasized at CZ0001R station during the colder part of the year. These changes in the meteorology parameters imply changes in the concentration of NO_2, SO_2 and SO_4^{2-} at discussed stations. The NO_2 (Figure 7a) and SO_2 (Figure 7b) concentrations were lower when



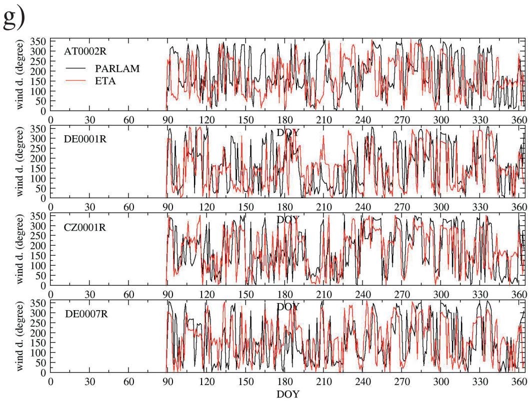
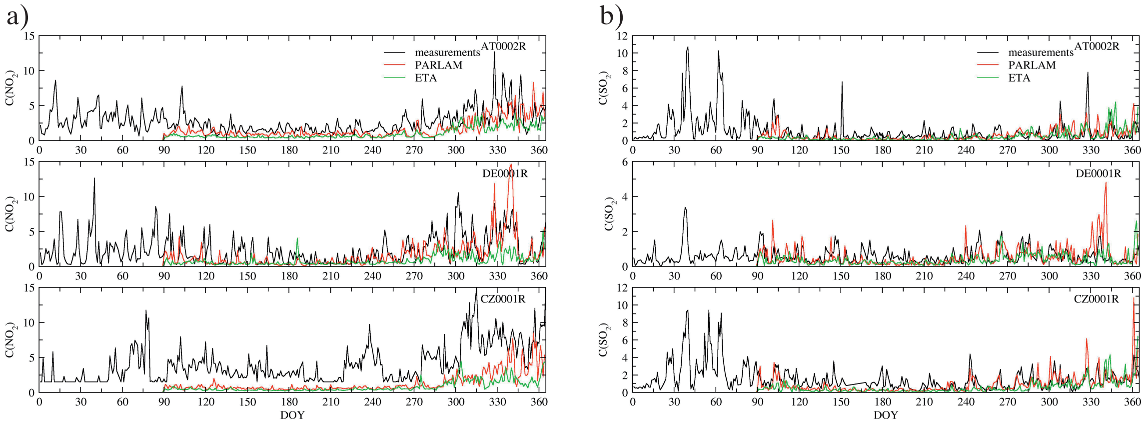


Figure 6. Relative difference between daily meteorology parameters a) latent heat flux, b) sensible heat flux, c) wind speed, d) friction velocity, e) surface pressure, f) precipitation amounts and g) wind direction obtained by using PARLAM-PS and WorkETA model at stations AT0002R, DE0001R, CZ0001R and DE0007R. The time is shown on the x-axis as the day of the year (DOY).

Slika 6. Relativna razlika između dnevnih vrijednosti meteoroloških veličina a) tok latentne topline, b) tok osjetilne topline, c) brzina vjetra, d) brzina trenja, e) prizemni tlak, f) količina oborine i g) smjer vjetra dobivenih pomoću PARLAM-PS i WorkETA modela na mjernim postajama AT0002R, DE0001R, CZ0001R i DE0007R. Na x-osi vrijeme je prikazano kao redni broj dana u godini.

the WorkETA driver was used than when the PARLAM-PS driver was used at AT0002R, CZ0001R and DE0001R stations. In summer, the unstable atmosphere influenced with high heat flux obtained by using WorkETA driver provides intensive vertical mixing and lower concentration of compounds near the ground. This could explain the lower concentration of NO_2 and SO_2 when the WorkETA driver was used in summer. In winter, the wind speed and direction plays a more important role. The SO_4^{2-} concentration (Figure 7c) at the two stations mostly depends on precipitation amount and wind direction. The difference in SO_4^{2-} concentration when two different meteorological drivers were used is due to the differences in amount precipitation and wind direction obtained by a different meteorology driver.

The comparison of daily NO_2, SO_2 and SO_4^{2-} concentrations obtained by using WorkETA and PARLAM-PS driver with measured concentration at AT0002R, CZ0001R, DE0001R and DE0007R was also done (Figure 7). The RMSE, correlation coefficient and average annual concentration are in Tables 2-4. The RMSE as a good measure of model accuracy calculated for NO_2, SO_2 and SO_4^{2-} at chosen stations when WorkETA driver was used was lower or similar to RMSE calculated when PARLAM-PS driver was used. The average annual NO_2, SO_2 and SO_4^{2-} concentrations obtained by using WorkETA driver were lower than those measured at the same stations. The better correlation of the measured daily NO_2, SO_2 and SO_4^{2-} concentrations and those obtained by using PARLAM-PS driver at analyzed stations is due to the model ability to produce the measured peaks when meteorology parameters from this driver were used. We supposed that this is due to the difference in wind speed and lower amount of precipitation given by WorkETA model during the colder part of the year at the analyzed stations.



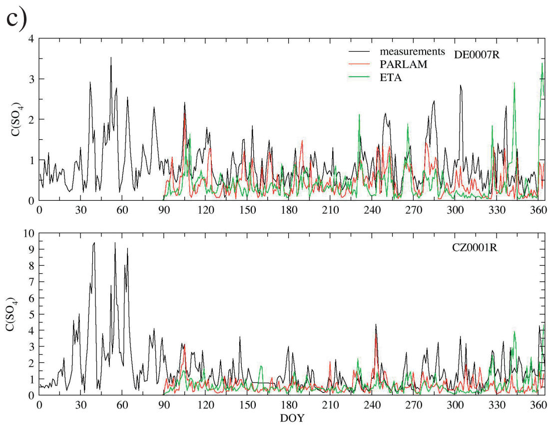


Figure 7. Relative difference between the daily concentration of a) NO_2, b) SO_2 and SO_4^{2-} c) obtained by using PARLAM-PS and WorkETA model at stations AT0002R, DE0001R, CZ0001R and DE0007R. The time is shown on the x-axis as the day of the year (DOY).

Slika 7. Relativna razlika između dnevnih koncentracija a) NO_2, b) SO_2 and SO_4^{2-} c) dobivenih pomoću ulaznih meteoroloških veličina iz PARLAM-PS i WorkETA modela na postajama AT0002R, DE0001R, CZ0001R and DE0007R. Na x-osi vrijeme je prikazano kao redni broj dana u godini.

Table 2. RMSE, the corelation coefficient and the average annual concentration of NO_2 (μg N m^{-3})

Tablica 2. RMSE, koeficijent korelacije i srednja godišnja koncentracija NO_2(μg N m^{-3})

Station	RMSE/Corelation coefficient		Average		
	PARLAM-PS	WorkETA	Measurements	PARLAM-PS	WorkETA
AT0002R	1.75/0.55	1.12/0.57	2.54	1.61	1.00
CZ0001R	2.00/0.59	2.07/0.62	2.27	1.69	0.85
DE0001R	3.70/0.58	2.00/0.44	4.37	1.33	0.80

Table 3. RMSE, the corelation coefficient and the average annual concentration of SO_2 (μg S m^{-3})

Tablica 3. RMSE, koeficijent korelacije i srednja godišnja koncentracija SO_2 (μg S m^{-3})

Station	RMSE/Corelation coefficient		Average		
	PARLAM-PS	WorkETA	Measurements	PARLAM-PS	WorkETA
AT0002R	0.79/0.49	0.64/0.23	0.75	0.57	0.47
CZ0001R	1.01/0.53	1.03/0.40	1.23	0.94	0.59
DE0001R	0.62/0.34	0.65/0.39	0.59	0.57	0.37

Table 4. RMSE, corelation coefficient and the average annual concentration of SO_4^{2-} (μg S m^{-3})

Tablica 4. RMSE, koeficijent korelacije i srednja godišnja koncentracija SO_4^{2-} (μg S m^{-3})

Station	RMSE/Corelation coefficient		Average		
	PARLAM-PS	WorkETA	Measurements	PARLAM-PS	WorkETA
DE0007R	0.54/0.38	0.45/0.32	0.84	0.44	0.39
CZ0001R	0.99/0.38	1.04/0.32	1.23	0.61	0.62

4. CONCLUSION

To test the use of the WorkETA outputs as the Unified EMEP model inputs the Unified EMEP and WorkETA model were coupled. The new meteorological driver was developed for that purpose. The meteorology parameters such as friction velocity, latent and sensible heat flux, precipitation and wind speed provided by WorkETA model were differing from those provided by PARLAM-PS model at whole domain. The average monthly sensible and latent heat fluxes from WorkETA driver were higher from those obtained by PARLAM-PS model during the warmer part of the year. The friction velocity provided by WorkETA model was higher at coastlines than those provided by PARLAM-PS model. The significant difference in precipitation provided by the two models was observed in December. The higher instability in PBL is the consequence of higher sensible and latent heat fluxes in summer and during such condition vertical mixing is more intensive and the surface concentrations of NO_2 and SO_2 are much lower. The lower amount of precipitation, especially in December, increase wet deposition which decreases SO_4^{2-} concentration. Analyses of some daily values of meteorology parameters and NO_2, SO_2 and SO_4^{2-} concentration at the chosen stations also show that concentration of NO_2 and SO_2 is in correlation with meteorology parameters which influence the stability of planetary boundary layer (PBL) and advection, while concentration of SO_4^{2-} correlated with wind (advection) and amount of precipitation (wet deposition). The peaks in measured daily concentration of NO_2, SO_2

and SO_4^{2-} could not be captured when the WorkETA driver was used probably due to the differences in advection and atmospheric stability. The spatial BIAS and RMSE for the average monthly NO_2 and SO_2 concentration modeled by using two drivers and measured are the same. The spatial RMSE of SO_4^{2-} concentration in the domain obtained when WorkETA driver was used was lower for July, August and December than those obtained by PARLAM-PS meteorology driver. The daily NO_2, SO_2 and SO_4^{2-} concentrations obtained by using the two drivers were lower than the measured concentration The result of the comparison of the concentration obtained by the two drivers, WorkETA driver with PARLAM-PS driver, and the measurements indicate that in some situations one model is better than the other whereas in some others, it is the other way around. Still, the differences are not emphasized and the developed WorkETA meteorological driver can be used for preparing meteorological input data for the Unified EMEP model.

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