Evaluation of regional climate – air quality simulations over Europe for the period 1996-2006 with emphasis on tropospheric ozone: The impact of chemical boundary conditions

Akritidis D.[1], Zanis P.[1], Katragkou E.[1], Tegoulias I.[1], Poupkou A.[2], Markakis K.[2], Karacostas Th.[1], Pytharoulis I.[1]

1 Department of Meteorology - Climatology, School of Geology, Aristotle University of Thessaloniki, Greece
2 Laboratory of Atmospheric Physics, School of Physics, Aristotle University of Thessaloniki, Greece

1. INTRODUCTION

When using a modelling system to study the effects of chemical boundary conditions on tropospheric ozone, it is essential to evaluate its performance for this period. Several examples of evaluation studies for regional air quality models can be found in the literature (e.g. Vautard et al., 2009: Katragkou et al., 2010: Zanis et al., 2011). In this study a modeling system based on the air quality model CAMx driven off-line by the regional climate model RegCM3 is used for assessing the impact of lateral boundary conditions on tropospheric ozone over Europe for the period 1996-2006. Furthermore, simulated ozone concentrations are compared against measurements from the EMEP network in order to evaluate the modeling system.

2. DATA AND METHODOLOGY

❑ The RegCM3/CAMx modeling system is used in this study to simulate the time period 1996-2006 over Europe with a 50 km x 50 km spatial resolution.
❑ Anthropogenic emissions were processed using the MOSESS emission model (Markakis et al. 2011) and the chemical boundary conditions were obtained from the from the global chemistry climate model ECHAM5-MOZ.
❑ The first run (**clean**) was forced from constant lateral chemical boundary conditions and emissions based on the EMEP emissions of the year 1996, while the second simulation (**run1**) was based on ECHAM5-MOZ chemical boundary conditions and emissions fixed for the year 1996.
❑ The simulated ozone concentrations are compared against measurements from the EMEP network.
❑ We have used in the evaluation analysis only those stations that fulfill the criteria of 75% data availability for near surface ozone, choosing 87 stations from 23 European countries.

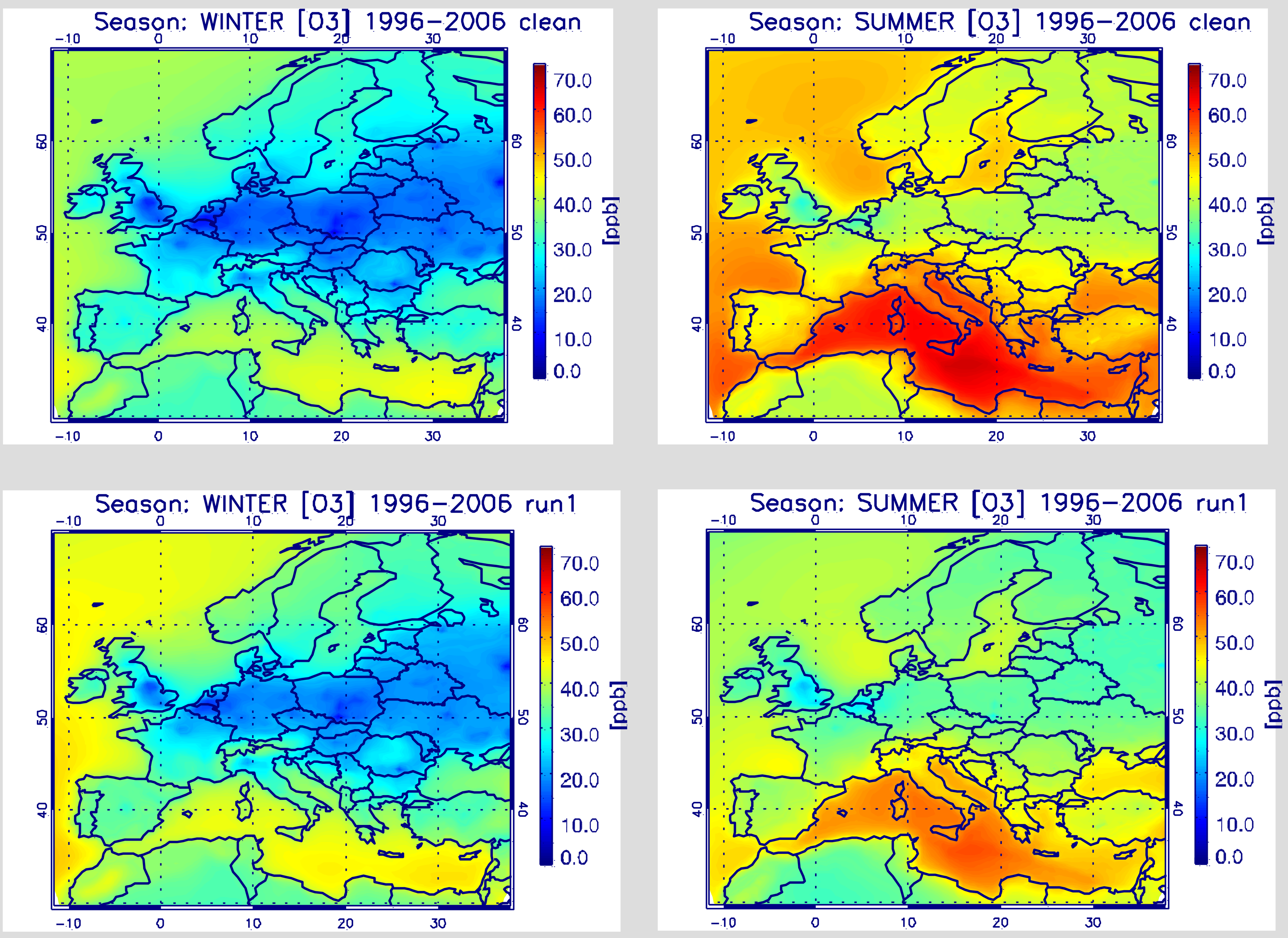

***Figure 1.** Average (1996-2006) surface ozone concentrations for clean and run1 simulation, for the winter and the summer season.*

***Table 1.** Summary statistics of the evaluation metrics based on the comparison of clean and run1 simulated monthly surface ozone concentrations with the observed ozone from the EMEP network over the period 1996-2006.*

	R		MNMB		NSD	
	clean	run1	clean	run1	clean	run1
10%	0.26	0.62	-20.77	-19.99	0.79	0.54
25%	0.50	0.75	-7.41	-5.97	0.99	0.67
75%	0.78	0.84	14.73	15.91	1.27	0.87
90%	0.81	0.86	29.48	29.70	1.40	0.94
min	-0.15	0.31	-43.66	-41.97	0.60	0.35
max	0.85	0.89	79.18	76.23	1.67	1.15
median	0.72	0.81	4.06	4.63	1.14	0.82

3. RESULTS

❑ The different chemical boundary condition forcing resulted in changes of near surface ozone, with an increase ranging between 2 and 5 ppb in winter and a decrease ranging between 2 and 8 ppb in summer (Figure 1).
❑ Visual inspection of Figure 2 shows a good agreement between model and observations at these stations, especially for run1 simulation. For stations located near the north (SE11) and northwest (IE31) boundary of the domain the run1 simulation, unlike clean simulation, is capturing the spring maximum of ozone.
❑ Statistical metrics used for model evaluation are:

Pearson correlation coefficient (R) *Normalized standard deviation (NSD)* *Modified normalized mean bias (MNMB)*

$$R = \frac{\sum (o-\bar{o})(m-\bar{m})}{\sqrt{\sum (o-\bar{o})^2 \sum (m-\bar{m})^2}}$$

$$NSD = \frac{\text{standard deviation of observed values}}{\text{standard deviation of modeled values}}$$

$$MNMB = \frac{2}{N}\sum_{1}^{N}\left(\frac{C_{mi}-C_{oi}}{C_{mi}+C_{oi}}\right)$$

❑ Summary statistics of these metrics for all the stations are presented in Table 1, showing a good agreement between simulated and observed data. In the case of run1 simulation the 75% of the stations have a correlation R>0.75 (R>0.5 for clean simulation) capturing very well the monthly variability of ozone concentrations.

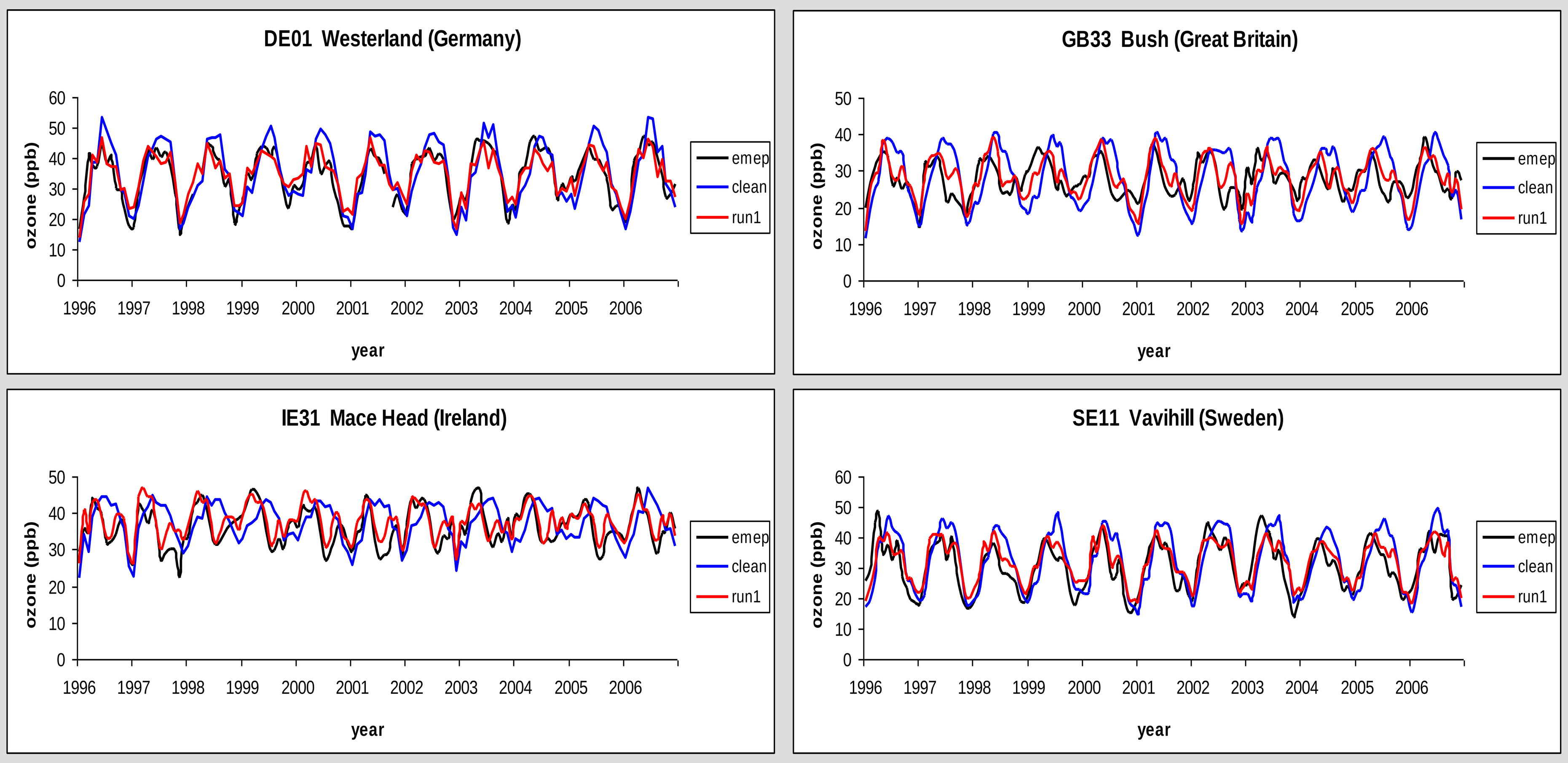

***Figure 2.** Time series of clean (blue line), run1 (red line) and observed (black line) monthly ozone values (ppb) for the following EMEP stations: Westerland (DE01, Germany), Bush (GB31, Great Britain), Mace Head (IE31, Ireland), Vavihill (SE11, Sweden).*

❑ Concerning the amplitude of the ozone bias, a small tendency of model overestimation is found in both simulations (clean and run1) as the median MNMB is 4.06% and 4.63% respectively. For the run1 simulation the 50% of the stations have a MNMB value that range between -5.97% and +15.91%, while for the clean simulation range between -7.41% and +14.73%.
❑ Concerning the NSD metric, for the clean simulation the modeling system seems to overestimate the amplitude of ozone variance (NSD>1 for the 75% of the stations), unlike the run1 simulation where the modeling system underestimates the amplitude of ozone variance (NSD<1 for the 94% of the stations).
❑ In Figure 3 the majority of the points (representing stations) are located above the line, showing that there is a significant improvement in R values between observed and simulated ozone values as a result of the use of chemical boundary conditions from the from the global chemistry climate model ECHAM5-MOZ.

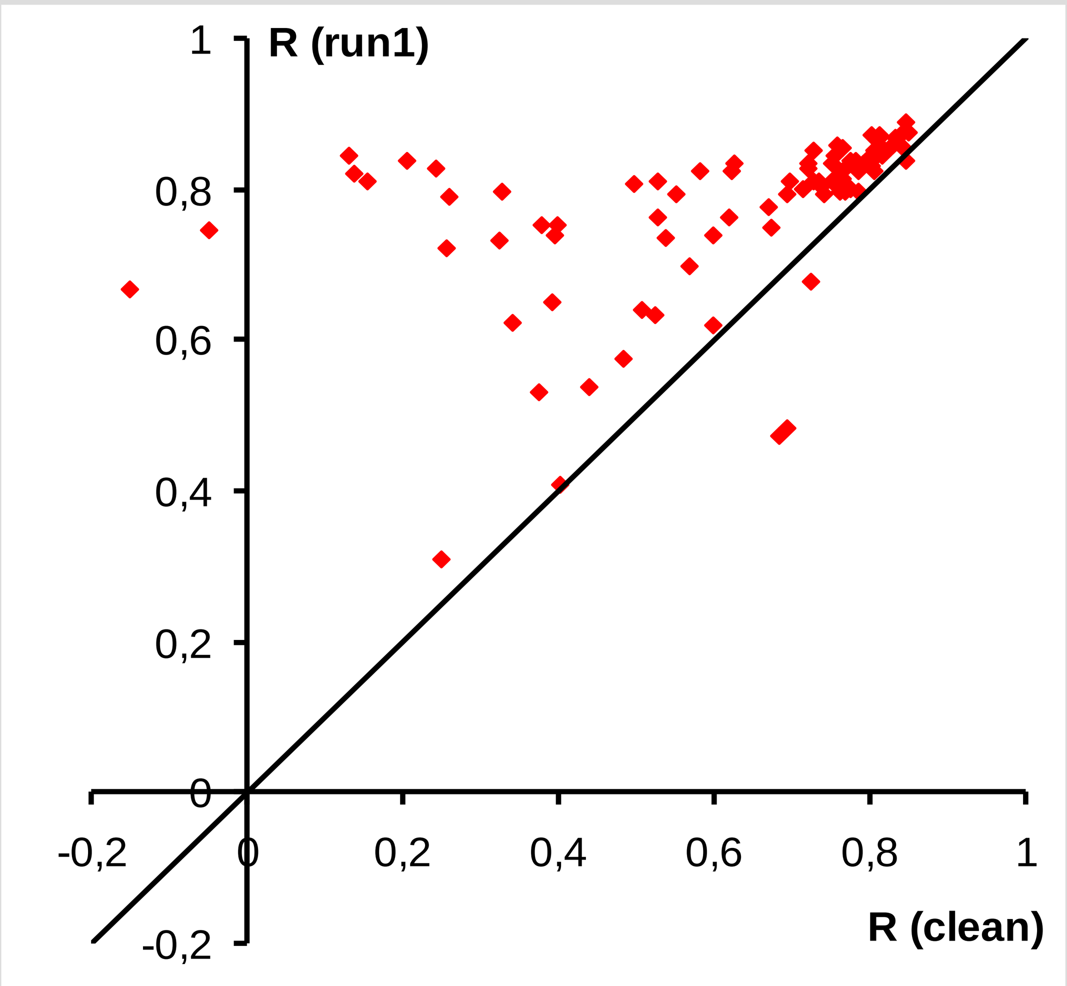

***Figure.3** Comparison between the correlation of run1-emep data and clean-emep data.*

4. CONCLUSIONS

❑ The different lateral boundary conditions forcing resulted in changes of near surface ozone concentrations and variability.
❑ Using lateral boundary conditions obtained from the global chemistry climate model ECHAM5-MOZ (run1), the RegCM3/CAMx modeling system is capturing in a much better way the ozone monthly variability than using constant lateral boundary conditions (clean), especially for stations of northern and northwestern Europe.
❑ Concerning the correlation between simulated and observed monthly ozone values, the run1 simulation exhibits R values greater than the clean simulation for 95% of the stations.
❑ Both clean and run1 simulations show a tendency of model overestimation concerning near surface ozone concentrations, as the MNMB median is 4.06% for clean and 4.63% for run1 respectively.

REFERENCES

Katragkou E., P. Zanis, I. Tegoulias, D. Melas, I. Kioutsioukis, B. C. Krüger, P. Huszar, T. Halenka, S. Rauscher, *Decadal regional air quality simulations over Europe in present climate: near surface ozone sensitivity to external meteorological forcing*, Atmospheric Chemistry and Physics, 10, 11805-11821, 2010

Markakis K., Katragkou E., Poupkou A., Liora N., Giannaros T. and Melas, D., *MOSESS: A new emission model for the compilation of model-ready emission inventories*, Environmental Policy (submitted), 2011

Vautard R., Schaap M., Bergström R., Bessagnet B., Brandt J., Builtjes P.J.H., Christensen J.H., Cuvelier, C. Foltescu V., Graff A., Kerschbaumer A., Krol M., Roberts P., Rouïl L., Stern R., Tarrason L., Thunis P., Vignati E., Wind P., *Skill and uncertainty of a regional air quality model ensemble*, Atmos. Environ.43, 4822e4832, 2009

Zanis P., E. Katragkou, I. Tegoulias, A. Poupkou, D. Melas, *Evaluation of near surface ozone in air quality simulations forced by a regional climate model over Europe for the period 1991-2000*, Atmospheric Environment, 45, 6489-6500, 2011