ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ

ΕΠΙΧΕΙΡΗΣΙΑΚΑ ΠΡΟΓΡΑΜΜΑΤΑ

«ΑΝΤΑΓΩΝΙΣΤΙΚΟΤΗΤΑ & ΕΠΙΧΕΙΡΗΜΑΤΙΚΟΤΗΤΑ» ΚΑΙ ΠΕΡΙΦΕΡΕΙΩΝ ΣΕ ΜΕΤΑΒΑΣΗ

ΕΘΝΙΚΟ ΣΤΡΑΤΗΓΙΚΟ ΠΛΑΙΣΙΟ ΑΝΑΦΟΡΑΣ
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ΤΙΤΛΟΣ ΠΑΡΑΔΟΤΕΟΥ:

ΔΗΜΟΣΙΕΥΣΕΙΣ, ΠΑΡΟΥΣΙΑΣΕΙΣ ΣΕ ΣΥΝΕΔΡΙΑ

ΔΡΑΣΗ ΕΘΝΙΚΗΣ ΕΜΒΕΛΕΙΑΣ

«ΣΥΝΕΡΓΑΣΙΑ»

ΕΥΡΩΠΑΪΚΗ ΕΝΩΣΗ
ΕΥΡΩΠΑΪΚΟ ΤΑΜΕΙΟ ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ

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η περιφέρεια στο επίκεντρο της ανάπτυξης

ΕΣΠΑ 2007-2013 πρόγραμμα για την ανάπτυξη

Υπουργείο Παιδείας, Δια Βίου Μάθησης και Θρησκευμάτων
ΓΓΕΤ – ΕΥΔΕ-ΕΤΑΚ

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4. ΕΝΕΡΓΕΙΕΣ ΔΗΜΟΣΙΟΤΗΤΑΣ

1. Δελτίο τύπου στον Τοπικό Ραδιοφωνικό Σταθμό VETO της Κοζάνης από την ΑΝΚΟ στις 8 Μαρτίου 2011.

2. Συνέντευξη τύπου στον τοπικό τηλεοπτικό σταθμό FLASH TV της Κοζάνης από την ΑΝΚΟ, στις 14 Μαρτίου 2011.

3. Δημιουργία ιστοτόπου (website): Στα πλαίσια της δημοσιότητας του Έργου και της Διάχυσης των αποτελεσμάτων δημιουργήθηκε ο ιστότοπος του έργου ¨

   http://www2.ipta.demokritos.gr/climaltergr

   Τα δελτία τύπου δίνονται παρακάτω¨

1. **Δελτίο Τύπου στον Τοπικό Ραδιοφωνικό Σταθμό VETO – 8 Μαρτίου 2011**
   Εγκρίθηκε και ξεκινά η υλοποίηση του Έργου «**Μελέτη Κλιματικών Μεταβολών και Ατμοσφαιρικής Ρύπανσης στην Ελλάδα – Εκτίμηση μελλοντικών περιβαλλοντικών και κοινωνικοοικονομικών επιπτώσεων σε τοπικό επίπεδο**» στο πλαίσιο του Προγράμματος «ΣΥΝΕΡΓΑΣΙΑ» της Γενικής Γραμματείας Έρευνας και Τεχνολογίας, με εταίρους το Εθνικό Κέντρο Έρευνας Θετικών Επιστημών «ΔΗΜΟΚΡΙΤΟΣ», ΤΟ Ερευνητικό Ινστιτούτο Χημικής Μηχανικής & Χημικών Διεργασιών Υψηλής Θερμοκρασίας του ΙΤΕ, την Αναπτυξιακή Δημοτική Επιχείρηση Πάτρας, το Σύλλογο «Πάρκο Τήλου και την ΑΝΚΟ.

2. **Συνέντευξη Τύπου στον Τοπικό Τηλεοπτικό Σταθμό Flash TV – 14 Μαρτίου 2011**
   Εγκρίθηκε και ξεκινά η υλοποίηση του Έργου «**Μελέτη Κλιματικών Μεταβολών και Ατμοσφαιρικής Ρύπανσης στην Ελλάδα – Εκτίμηση μελλοντικών περιβαλλοντικών και κοινωνικοοικονομικών επιπτώσεων σε τοπικό επίπεδο**» στο πλαίσιο του Προγράμματος «ΣΥΝΕΡΓΑΣΙΑ» της Γενικής Γραμματείας Έρευνας και Τεχνολογίας, με εταίρους το Εθνικό Κέντρο Έρευνας Θετικών Επιστημών «ΔΗΜΟΚΡΙΤΟΣ», ΤΟ Ερευνητικό Ινστιτούτο Χημικής Μηχανικής & Χημικών Διεργασιών Υψηλής Θερμοκρασίας του ΙΤΕ, την Αναπτυξιακή Δημοτική Επιχείρηση Πάτρας, το Σύλλογο «Πάρκο Τήλου και την ΑΝΚΟ.

   Το έργο έχει ως αντικείμενο την ανάπτυξη μεθοδολογικού πλαισίου για την αποτίμηση της κλιματικής αλλαγής στην Ελλάδα, δίνοντας έμφαση στις κοινωνικές και οικονομικές επιπτώσεις σε τοπικό επίπεδο από τις εκτιμώμενες μεταβολές.

Ερευνητικοί Στόχοι του έργου

Α. Η εκτίμηση με χρήση Παγκόσμιου Κλιματικού Μοντέλου (GISS II' GCM) της μεταβολής του κλίματος το 2050 στον ευρύτερο Ελλαδικό χώρο χρησιμοποιώντας τρία διαφορετικά σενάρια εκπομπών της IPCC (A1B, A2 και A1FI). Οι εκτιμήσεις από τα διαφορετικά αυτά σενάρια θα καθορίσουν τη σχετική αβεβαιότητα των κλιματικών παραμέτρων.

Β. Η χρήση της μεθοδολογίας της δυναμικής τοπικής μείωσης κλίμακας (dynamical regional downscaling) με σκοπό την αύξηση στη διακριτική ικανότητα στον Ελλαδικό χώρο με το μετεωρολογικό μοντέλο μέσης κλίμακας WRF.

Γ. Η χρήση του πλήρους συστήματος GRE-CAPS για τον υπολογισμό των συγκεντρώσεων αερίων και σωματιδιακών ρύπων σε όλη τον πλανήτη, την Ευρώπη και την χώρα μας με υψηλή διακριτικότητα σε συγκεκριμένες περιοχές.

Δ. Η ανάπτυξη μεθοδολογικού πλαισίου αποτίμησης συνεπειών της κλιματικής αλλαγής:

α. Οικονομική ανάλυση

β. Σύνδεση με φυσικές καταστροφές σχετιζόμενες με το κλίμα

γ. Επιπτώσεις στην υγεία από την αλλαγή της ατμοσφαιρικής ρύπανσης και κλίματος

Ε. Η αξιοποίηση των παραπάνω αποτελεσμάτων για τη μελέτη των κοινωνικο-οικονομικών επιπτώσεων λόγω κλιματικής αλλαγής ως παραδείγματα εφαρμογής (case study) τόσο στην ηπειρωτική Ελλάδα (Περιφέρεια Δυτικής Μακεδονίας, Πάτρα και Δυτική Ελλάδα) όσο και στο νησιωτικό χώρο με την παράλληλη διερεύνηση και ανάδειξη κατάλληλων παρεμβάσεων στο υπάρχον παραγωγικό σύστημα.

Βασικό αποτέλεσμα του προγράμματος θα είναι η δημιουργία βάσης δεδομένων για όλη την Ελλάδα με τις μεταβολές των μετεωρολογικών παραμέτρων (θερμοκρασία, βροχόπτωση, χιονόπτωση, νεφοκάλυψη, ταχύτητα ανέμου, ηλιακή ακτινοβολία) καθώς και των συγκεντρώσεων όζοντος και σωματιδίων λόγω της πιθανής μεταβολής του κλίματος, με σκοπό την άμεση χρήση από τοπικούς φορείς (π.χ. τοπική αυτοδιοίκηση, τοπικές αναπτυξιακές οργανώσεις, περιβαλλοντικές οργανικές κτλ) για την εκτίμηση των επιπτώσεων της κλιματικής αλλαγής σε τοπικό επίπεδο και την έγκαιρη λήψη μέτρων προς αποφυγή των συνεπειών.

Η πρόταση θα δημιουργήσει τα πρώτα δεδομένα πολύ υψηλής ανάλυσης για το μελλοντικό κλίμα και ποιότητα του αέρα στην Ελλάδα, χρησιμοποιώντας συζευγμένα μοντέλα για τη δυναμική τοπική μείωση κλίμακας. Τα αποτελέσματα θα συνδεθούν με τις επακόλουθες επιπτώσεις.

Η διάχυση των αποτελεσμάτων αυτών στην επιστημονική κοινότητα και στο ευρύ κοινό θα πραγματοποιηθεί με την δημοσίευση των αποτελεσμάτων σε διεθνή περιοδικά, σε διεθνή συνέδρια και με τη διοργάνωση ημερίδας.

5. ΠΑΡΑΡΤΗΜΑ 1: ΠΕΡΙΛΗΨΕΙΣ ΔΗΜΟΣΙΕΥΣΕΩΝ ΣΕ ΣΥΝΕΔΡΙΑ

Impact of biogenic emissions on $PM_{2.5}$ concentration over Europe

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Keywords: biogenic emissions, particulate matter, Europe
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Natural and biogenic emissions are contributing to atmospheric pollution in addition to anthropogenic emissions. Over 90% of the total Volatile Organic Compounds (VOCs) entering the atmosphere are biogenic (Greenberg et al., 1999), having an important role in regulating the atmospheric composition. The impact of both anthropogenic and biogenic emissions on air quality is very important, as only the anthropogenic part can be influenced by abatement measures. Curci et al. (2009) estimated that biogenic VOC emissions increased on average summer daily ozone maxima over Europe by 5% (2.5 ppbv) using the CHIMERE chemistry-transport model. Sartelet et al. (2012) using the Polyphemus air quality modeling platform estimated that ozone decreased by 10-11% on average over Europe (locally up to 35%) while secondary organic aerosols decreased by 72-88% when removing biogenic emissions. The objective of this study is to estimate the effect of biogenic emissions on $PM_{2.5}$ concentration and chemical composition over Europe.

Meteorological fields are derived using the Penn State/NCAR Mesoscale Model (MM5) (Grell et al., 1994).

Emissions are processed by the Sparse Matrix Operator Kernel Emissions (SMOKE v2.6) Modeling System (http://www.smoke-model.org). The TNO gridded anthropogenic emissions inventory for the year 2006 over Europe in a 0.1 × 0.1 degrees resolution (ftp:// neptunus.tno.nl) is used. The Biogenic Emission Inventory System, version 3 (BEIS3) is used for processing biogenic source emissions (http://www.epa.gov/asmdnerl/biogen.html) using the USGS gridded land use data in 1 Km resolution (http://edc2.usgs.gov/glcc/glcc.php).

The Community Multiscale Air Quality (CMAQ v 4.7) Modeling System with the Carbon Bond mechanism (CB05) (http://www.camx.com/publ/pdfs/ CB05_Final_Report_120805.pdf) is used for the regional air quality modeling (177 × 217 grid cells of 35 km × 35 km, with 14 vertical layers) (Byun et al., 2006).

$PM_{2.5}$ concentrations are simulated with and without biogenic emissions for July, 2006. The effect of the addition of biogenic emissions to anthropogenic ones is computed to reduce the average monthly mean $PM_{2.5}$ concentration over European land by 2% with both positive and negative responses regionally (Fig. 1). The addition of biogenic emissions increases the average monthly mean organic carbon concentration by 14% (Fig. 2) and decreases the monthly mean inorganic component concentrations (SO_4: -6%, NO_3: -4%, and NH_4: -6% on average) due to the reduction in oxidant levels (OH: -30% on average). However, regional changes in inorganic concentrations with both positive and negative responses are simulated.

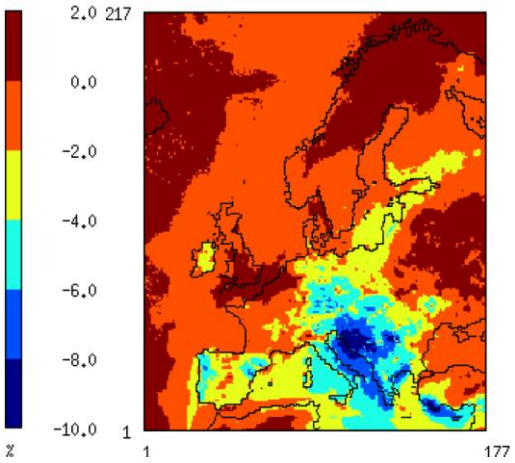

Fig. 1: Average change in $PM_{2.5}$ concentration (%) for July 2006 when biogenic emissions are added to anthropogenic emissions

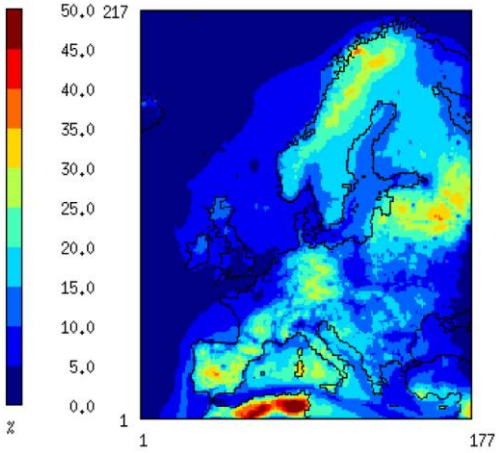

Fig. 2: Average change in OC concentration (%) for July 2006 when biogenic emissions are added to anthropogenic emissions

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The importance of organic compounds for the first aerosol indirect effect: sensitivity to cloud formation parameterizations and meteorological fields.

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Keywords: Aerosol-cloud interaction, CCN, organics, radiative forcing, clouds, modeling.
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Atmospheric aerosols are a focus of attention because of their important impacts on clouds and climate change. Organic aerosols represent an important fraction of tropospheric aerosol; in polluted regions organic aerosols are the second most abundant component by mass of the aerosol burden (Ramanathan et al., 2001). A number of studies have shown that organics play an important role in the aerosol indirect effect (AIE) which is one of the greatest sources of uncertainty in the assessment of anthropogenic climate change. Given that ambient organic aerosols may consist of hundreds of species, their representation in global climate models is typically limited to a few classes; this leads to further challenges in simulating AIE. In addition, much uncertainty also arises from the relationship used to link aerosol with cloud droplet number concentration (CDNC) and the variability in the predicted meteorology that contribute significantly to the differences in predicted AIE between GCM studies. Here it is assessed the importance of organic aerosols for the first AIE under different cloud droplet formation parameterizations and meteorological fields.

For this, the 3D NASA Global Modeling Initiative (GMI) chemical-transport model is used. GMI allows easy interchange of different model components while maintaining all others identical allowing a direct intercomparison of results obtained between alternate representations of aerosol, chemistry and transport processes. CDNC is computed using both empirical correlations (i.e., Menon et al., - LB (2002)), and physically-based parameterizations (i.e., Abdul-Razzak and Ghan - AG (2000), and Fountoukis and Nenes - FN (2005)). Emissions from the IPCC CMIP5 (CMIP) are used. Sensitivities are examined under two meteorological fields (i.e., NASA GEOS4 finite volume GCM (FVGCM) and NASA GEOS1-STRAT (GEOS)) for the same time period. Computed CDNC is used to calculate the effective radius (Re). The CLIRAD-SW solar radiative transfer model is used online to calculate the cloud optical depth (COD) and the shortwave fluxes from the surface to the top of the atmosphere (TOA). COD is calculated as a function of the effective radius. Evaluation of modeling results (i.e., Re, COD) is performed against satellite products from Moderate Resolution Imaging Spectroradiometer (MODIS) platform.

Depending on the combination of meteorological field and cloud scheme used the annual mean CDNC ranges between 63 and 189 cm^{-3} (Figure 1) with larger differences seen over heavily polluted regions (e.g., Europe, China, NE USA), regions affected by long range transport of pollution (e.g., Atlantic Ocean) or by biomass burning (e.g., S. Africa, S. America). Simulations without taking into account organics lead to a reduction in CDNC over S. America and S. Africa that are affected by biomass burning; lower CDNC values are also seen in eastern Asia because of the use of fossil fuels. The impact of organics on the first AIE is mixed: in pristine regions organics increase CCN increasing AIE, while in polluted areas particles grow larger, decreasing CCN and therefore counteracting AIE.

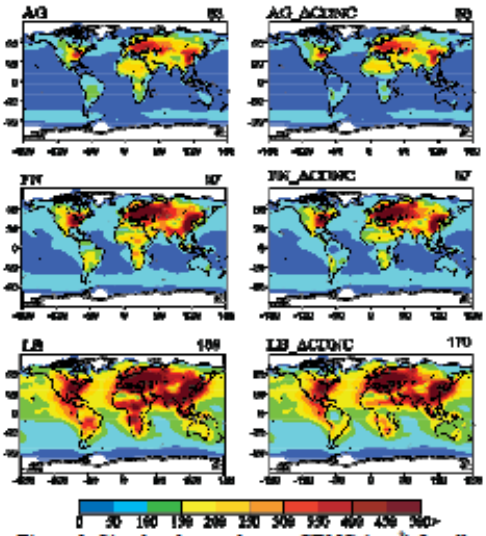

Figure 1. Simulated annual mean CDNC (cm^{-3}) for all droplet formation schemes used under the GEOS meteorological field (right panel) and relative change in CDNC when neglecting organic aerosol, (i.e., $CDNC_{tot}$ – $CDNC_{OC}$) (left panel). Global averages are shown in the upper right hand corner of each panel

This work was supported by the National Strategic Reference Framework (NSRF) 2007-2013 grand No 09SYN-31-667.

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MESOSCALE SIMULATION OF HOT WEATHER EVENTS DURING AUGUST 2012 IN GREECE

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Abstract: Last summer was exceptionally hot in Greece with the highest temperatures occurring during the periods of August 2012, 6-9 and 23-27 and with the Etesian winds being very weak compared to the average statistics, according to the climatology report of the Hellenic National Meteorological Service (HNMS). In this study, the Weather Research and Forecasting (WRF) model has been parameterised at the Environmental research Laboratory (EREL) to simulate the meteorology during the particular periods and compare the model output with observations available from HNMS. The initial and boundary conditions for the WRF model simulations were determined by 6-hourly operational analyses obtained from the National Centres for Environmental Prediction (NCEP) Global Forecasting System (GFS). The simulations were performed in two nested domains, the outer of 15x15 km^2 covering the whole Europe and the inner of 3x3 km^2 including the whole country. The analysis of the results focused on the influence of the complex terrain in reproducing the observed wind pattern and the maximum values of the temperature fields.

Key words: *Hot weather, mesoscale simulation, WRF, Greece.*

INTRODUCTION

As the climate in Greece is predominantly Mediterranean, the summer period is hot and usually dry with temperatures reaching 30 to 35°C but sometimes exceeding the value of 40°C. Variations in the meteorological conditions occur between the summer months because of a cooling northerly wind, known as Etesian, formed more frequently during July and August due to the development of a depression over the Southwest Asia and the extension of the subtropical high pressure system over the eastern Mediterranean (Koletsis, I., et al, 2009). The complexity of the topography of the region causes also variations of particular interest in the climate locally. In this study, the performance of a particular set-up of the Advanced Research Weather (ARW) - Weather Research and Forecasting (WRF) model (Wang, W. et al., 2012) is examined with regard to the temperature and wind fields over Greece in comparison to the observational data from local monitoring stations. More specifically, focus has been placed on the simulation of the meteorological conditions over the whole country during two hot periods of August 2012, 6-9 (period A) and 23-27 (period B).

METHODOLOGY

The ARW-WRF model (version 3.4) has been set-up and parameterized to simulate the three-dimensional meteorological fields. The model is Euler non-hydrostatic, fully compressible, with terrain following coordinates. Simulations were performed for periods A and B in two nested domains following a one-way nesting procedure. The outer domain, d01, included 432 x 432 cells of horizontal resolution 15 x 15 km^2 and the inner domain, d02, comprised 286 x 286 cells of 3 x 3 km^2 horizontal resolution (Fig. 1). In the vertical, 27 unevenly spaced levels were used with the maximum resolution dz of 1500 m at the top of the model (at ~50 mb).

There are several physical parameterization schemes available in the WRF model for the representation of radiative and convective processes, boundary layer, surface temperature and soil moisture and microphysics. More specifically, the following schemes have been selected for this case study: for the microphysics, the WRF single-moment 5-class scheme that allows for

mixed-phase processes (Hong, S. Y., et al., 2004); for the longwave and shortwave radiation, the Rapid Radiative Transfer Model (Mlawer, E. J., et al. 1997) and the Dudhia scheme (Dudhia, J., 1989), respectively; for the land surface model, the Noah Land Surface Model (Mitchell, K., 2005); for the planetary boundary layer, the Yonsei University scheme (Hong, S. Y., et al. 2006 and Hong, S. Y. and S. W. Kim, 2008); for the cumulus parameterization, the Kain-Fritsch scheme (Kain, J.S., 2004). The initial and boundary conditions for the WRF model simulations were determined by 6-hourly operational analyses obtained from the National Centres for Environmental Prediction (NCEP) Global Forecasting System (GFS) valid at 00, 06, 12, and 18 UTC for the two referenced periods A and B. After initialization of the model run, these data were only applied at the boundaries.

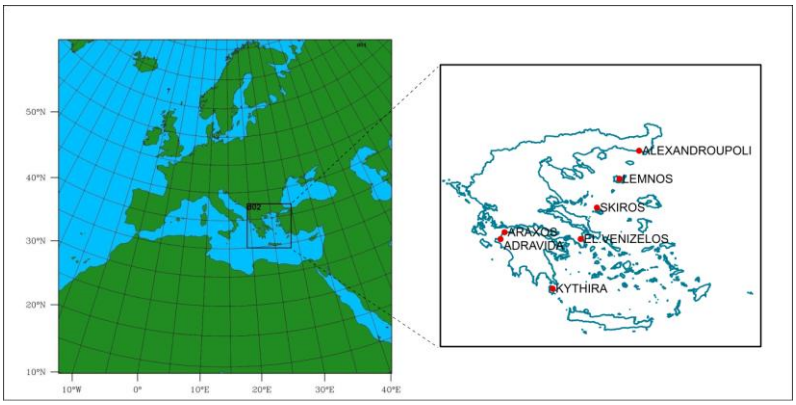

Figure 1. Depiction of the two WRF modeling domains (d01 and d02) and position of observational stations.

RESULTS

The results from the WRF meteorological model runs are presented in this section. The computed near surface temperature T at 2 meters above ground level (T at 2 m a.g.l.) and the wind speed (**v** at 10 m a.g.l.) were compared with meteorological station data. Hourly observational data were available from a number of stations operated by the Hellenic National Meteorological Service (HNMS). The location of the stations is described in terms of latitude and longitude in Table 1.

Table 1. Geographical position of the observational stations.

Station Name	Latitude (deg.)	Longitude (deg.)	Station type
El. Venizelos	23.947315	37.926517	Mainland
Alexandroupoli	25.883333	40.850000	Mainland
Lemnos	25.233333	39.916667	Island
Skiros	24.483333	38.966667	Island
El. Venizelos	23.947315	37.926517	Mainland
Kythira	23.016667	36.283333	Island
Andravida	21.288333	37.923888	Mainland
Araxos	21.423333	38.149722	Mainland

The maximum and the average near surface temperature (T at 2 m) calculated by the model over the two periods A and B are shown in Figures 2 and 3, respectively. Overall, the period A was characterized by higher temperatures than the period B occurring

mainly over a greater area of northern and western parts of the country. The maximum temperatures of up to 40°C were found over several regions of low elevation of the mainland. The urbanized region of Attica (Athens) experienced the highest temperatures in both periods examined in August 2012. The maximum (up to 41.8°C) and the average values (24.0 to 30.7°C) agree well with those of the climatology report of HNMS (HNMS, 2012) for both periods. The comparisons of the hourly average temperature values with the observed ones are shown for periods A and B in Figures 4 and 5, respectively, for four selected stations (due to space limitations). Inspection of the plots reveals that there is no consistent bias of the model with respect to the period studied or the type of the station although in most cases the model seems to underestimate the temperatures at the stations during the day and overestimate them at night hours.

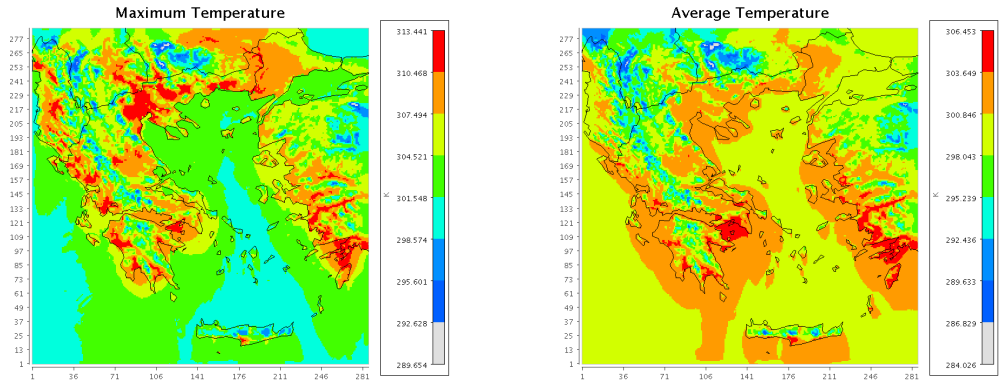

Figure 2. WRF calculated Maximum and Average temperature fields (in K) over period A.

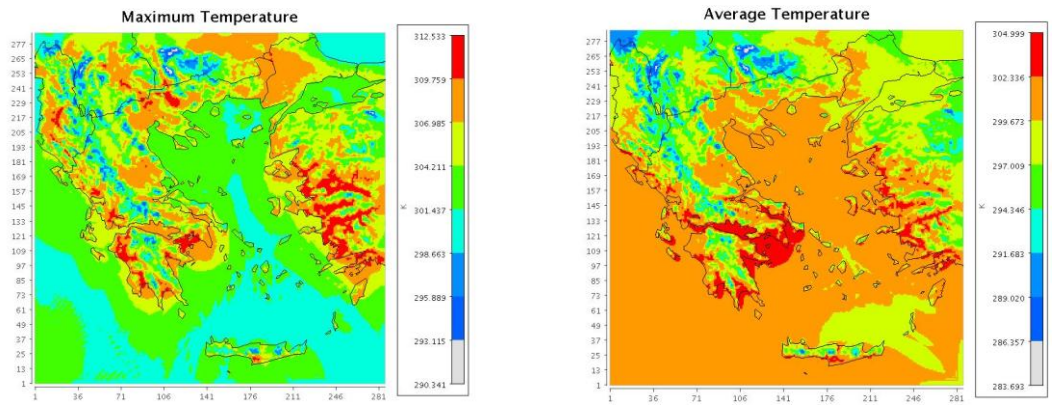

Figure 3. WRF calculated Maximum and Average temperature fields (in K) over period B.

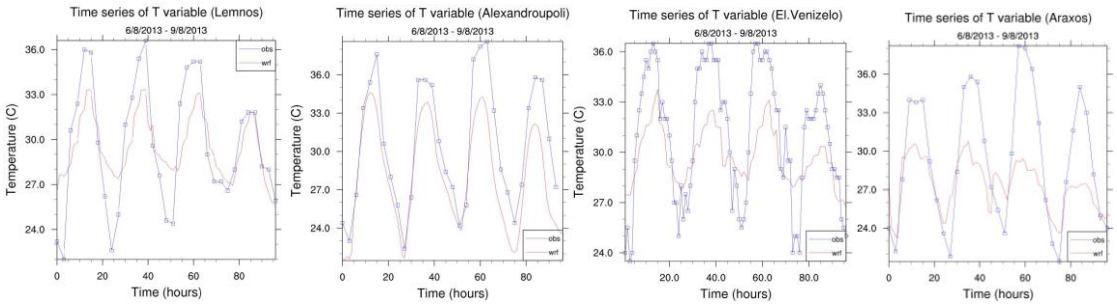

Figure 4. Comparison of WRF calculated temperature with observations at Lemnos, Alexandroupoli, El. Venizelos and Araxos stations during period A.

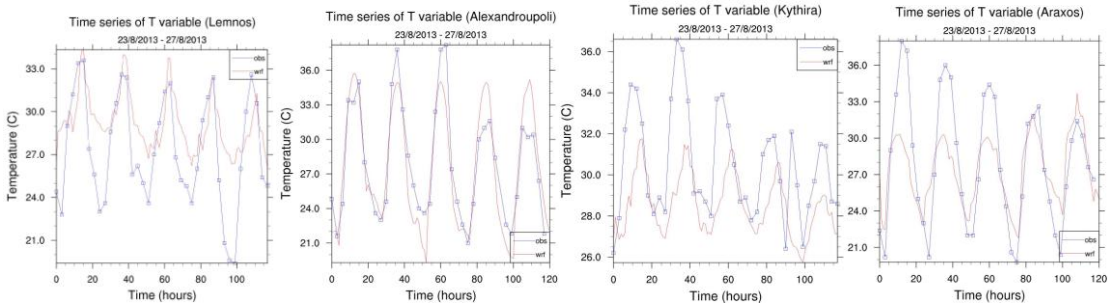

Figure 5. Comparison of WRF calculated temperature with observations at Lemnos, Alexandroupoli, Kythira, and Araxos stations during period B.

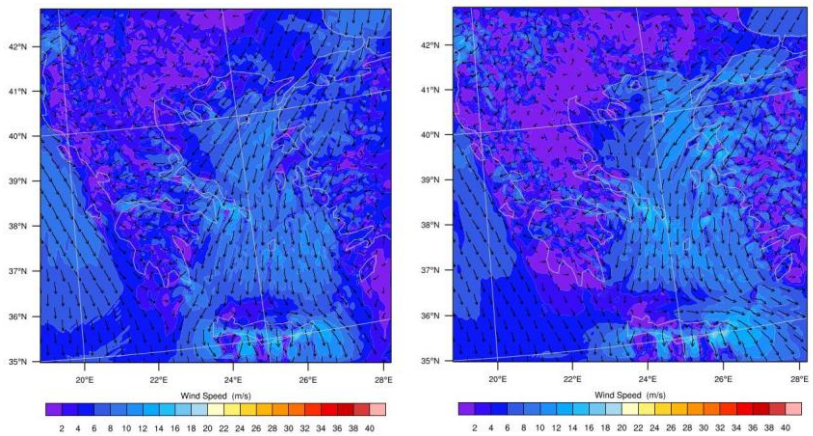

Figure 6. WRF calculated wind velocity fields (10 m a.g.l.) at 0900 UTC (left) and 2100 UTC (right) in August 9, 2012.

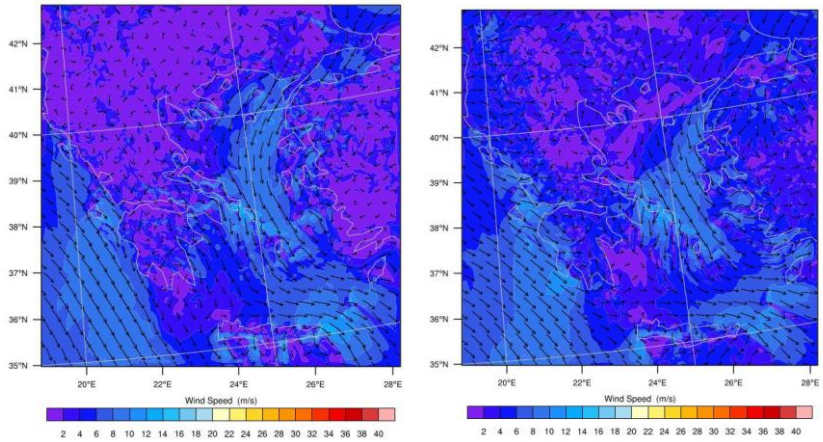

Figure 7. WRF calculated wind velocity fields (10 m a.g.l.) at 0300 UTC (left) and 1200 UTC (right) in August 26, 2012.

The wind velocity fields at 10 meters a.g.l. are shown in Figure 6 at 0900 and 2100 UTC hours for August 9, 2012 (period A). Similarly, but at 0300 UTC and 12 UTC, wind fields are plotted in Figure 7 for August 26, 2012 (period B). The model captures well the northeasterly flow over the Aegean Sea (etesian wind) and the northwesterly wind over the Ionian Sea (in the west). The wind velocity fields have revealed that the etesian winds were weak of comparatively low to medium speeds in the range of 2 – 18 ms^{-1} in agreement with the HNMS report (HNMS, 2012). The winds persisted during the day and night hours and over the whole periods studied in agreement with the HNMS report. The figures show also the funneling effect that is the increase in the wind speed between the straits of the islands. The comparison of the model calculated hourly wind

speed with the observations (Figure 8) yielded a fair agreement with RMSE (root mean square error) values of 3.72 and 4.26, respectively.

Conclusions

This work attempted to test the set up and parameterization of WRF over Greece by studying two rather warm periods in August 2012. Overall, the model produced near surface maximum and average temperature and wind velocity fields were in agreement with the report of HNMS. The model results were compared with observational meteorological data from several monitoring stations. The comparisons revealed a good agreement of the calculated hourly average temperature values and the observed data. Although the model captured well the wind fields and the rather weak northeasterly and westerly flows, the comparison of the hourly wind speed values against the observational data yielded a fair agreement. To improve the calculated wind fields other parameterization schemes will be incorporated. Moreover, the model results will be evaluated for winter cold periods as well.

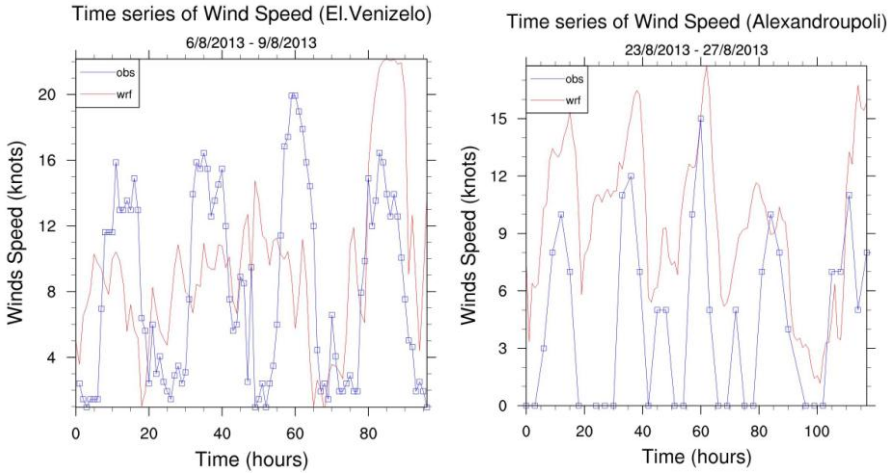

Figure 8. Comparison of WRF calculated wind speed (at 10 m a.g.l.) with observations at El. Venizelos (period A), and Alexandroupoli (period B).

Acknowledgments

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Impact of biogenic emissions on air quality over Europe

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ABSTRACT

The impact of biogenic volatile organic compound (BVOC) emissions on air quality over Europe is assessed for a summer month (i.e., July, 2006) using Models-3 (i.e., CMAQ, MM5, SMOKE) modeling system. The Community Multiscale Air Quality (CMAQ) v4.7 Modeling System with the Carbon Bond mechanism (CB05) is used for the regional air quality modeling. Meteorological fields are derived using the Penn State/NCAR Mesoscale Model (MM5). Emissions are processed by the Sparse Matrix Operator Kernel Emissions (SMOKE v2.6) modeling system for converting the resolution of the emission inventory data to the resolution needed by the air quality model. TNO has provided a gridded anthropogenic emissions database for the year 2006 over Europe in a 0.1 × 0.1 degrees resolution. The Biogenic Emission Inventory System, version 3 (BEIS3) is used for processing biogenic source emissions. Gridded land use data in 1 km resolution provided by the U.S. Geological Survey (USGS), the default summer and winter emission factors and meteorological fields are used to create hourly model-ready biogenic emissions estimates. Results suggest that biogenic emissions increase simulated daily maximum 8 hours ozone average ($Max8hrO_3$) concentrations over Europe by 5.6% for July 2006. BVOC emissions increase $Max8hrO_3$ concentrations more than 5ppbV in a big part of Europe while locally it is more than 10ppbV. Despite the general trend of reduction in $PM_{2.5}$ concentrations (about -2% on average over Europe during July 2006) there are regions where $PM_{2.5}$ concentrations are simulated higher due to BVOC emissions. This is related to the change in $PM_{2.5}$ component concentrations: an increase in organic carbon concentration and a decrease in sulfate concentration are simulated (13.6% and -5.6% on average over Europe during July 2006, respectively) while changes in nitrate concentrations are noted regionally.

This work was supported by the National Strategic Reference Framework (NSRF) 2007-2013 grand No 09SYN-31-667.

Effect of precursor emissions on $PM_{2.5}$ concentrations over Europe

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Keywords: particulate matter, emissions, modeling, Europe
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Atmospheric pollution is a focus of attention because of its important role in many areas including human health (e.g., Seinfeld and Pandis, 2006; Peng et al., 2005). For this reason simulating air and particle concentrations as accurate as possible is fundamental in air quality planning and strategies for attainment of air quality standards. Although simulated meteorology could be compared with observation data spread throughout the domain suggesting the related uncertainties it is very difficult to accurately characterize emissions. Emission inventories are subject to significant uncertainties given that they are based on data sets of limited spatiotemporal coverage and always contain assumptions on interpolation and extrapolation of a limited set of sample data. The objective of this study is to modify appropriately precursor emissions improving air and particle concentrations predictions over Europe.

Meteorological fields are derived using the Penn State/NCAR Mesoscale Model (MM5) (Grell et al., 1994).

Emissions are processed by the Sparse Matrix Operator Kernel Emissions (SMOKE v2.6) Modeling System (http://www.smoke-model.org). The TNO gridded anthropogenic emissions inventory for the year 2006 over Europe in a 0.1 × 0.1 degrees resolution (ftp:// neptunus.tno.nl) is used. The Biogenic Emission Inventory System, version 3 (BEIS3) is used for processing biogenic source emissions (http://www.epa.gov/asmdnerl/biogen.html) using the USGS gridded land use data in 1 Km resolution (http://edc2.usgs.gov/glcc/glcc.php).

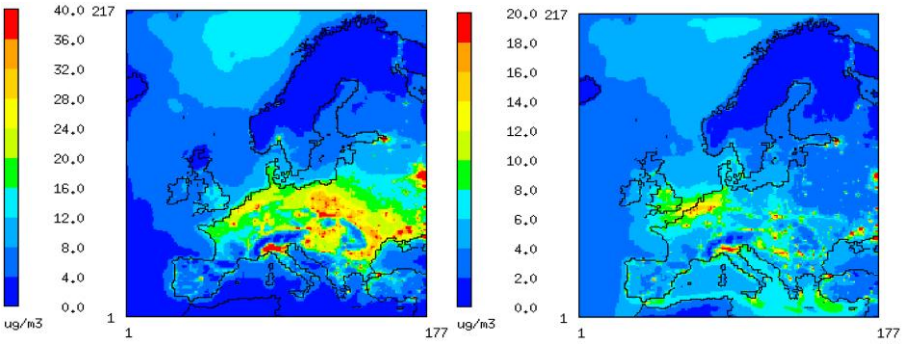
The Community Multiscale Air Quality (CMAQ v 4.7) Modeling System with the Carbon Bond mechanism (CB05) (http://www.camx.com/publ/pdfs/CB05_Final_Report_120805.pdf) is used for the regional air quality modeling (177 × 217 grid cells of 35 km × 35 km, with 14 vertical layers) (Byun et al., 2006).

Emission scaling factors are applied for each country on NO_X, SO_2 and $PM_{2.5}$ emissions due to the significant number of monitoring data throughout the domain for these pollutants based on the country average ratio between observed and predicted concentrations.

Model performance is evaluated using the air quality information system maintained by the European Environment Agency (http://www.eea.europa.eu); a systematic bias for both air (i.e., NO_2, SO_2) and particle (i.e., $PM_{2.5}$) pollutants has been found. Application of scaling factors improves $PM_{2.5}$ and air pollutant model performance although the model still underpredicts $PM_{2.5}$ concentrations; this is related to the uncertain representation of secondary organic aerosol formation (Chen et al., 2005; Kroll et al., 2006).

Elevated $PM_{2.5}$ concentrations up to 40 ug/m^3 during winter are simulated over Europe (Figure 1). NO_3 is dominant during winter in Western Europe and in a few Eastern countries due to the high NO_2 concentrations. OC from biomass burning is a significant contributor in $PM_{2.5}$ components in Eastern Europe. During summer NO_3 is dominant only in regions with elevated NH_3 emissions such as the Netherlands and

Northern Italy. For the rest of the domain SO_4 and OC are significant $PM_{2.5}$ components with SO_4 being dominant in the South and OC in the East.



January, 2006 July, 2006

Figure 1: Daily average ground $PM_{2.5}$ concentrations

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Are indirect forcing estimates sensitive to cloud formation parameterizations, emission scenarios and meteorological fields?

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Keywords: Aerosol-cloud interaction, CCN, radiative forcing, clouds, modeling.
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Aerosol indirect effect (AIE) is one of the greatest sources of uncertainty in the assessment of anthropogenic climate change. Much of this uncertainty arises from the relationship used to link aerosol with cloud droplet number concentration (CDNC). In addition, variability in the predicted meteorology and emission inventories used contribute to the differences in predicted AIE between GCM studies. Here the sensitivity of the first AIE to cloud droplet parameterizations, emission inventories and meteorological fields used is assessed.

The sensitivities are computed with the 3D NASA Global Modeling Initiative (GMI) chemical-transport model. GMI allows easy interchange of different model components while maintaining all others identical allowing a direct intercomparison of results obtained between alternate representations of aerosol, chemistry and transport processes. CDNC is computed using both empirical correlations (i.e., Boucher and Lohmann - BL (1995), Menon et al., - LB (2002)), and physically-based parameterizations (i.e., Abdul-Razzak and Ghan - AG (2000), and Fountoukis and Nenes - FN (2005)). Emissions from the University of Michigan (UoM) and the IPCC CMIP5 (CMIP) are used. Sensitivities are examined under two meteorological fields (i.e., NASA GEOS4 finite volume GCM (FVGCM) and NASA GEOS1-STRAT (GEOS)). Computed CDNC is used to calculate the effective radius (Re). The CLIRAD-SW solar radiative transfer model is used online to calculate the cloud optical depth (COD) and the shortwave fluxes from the surface to the top of the atmosphere (TOA). COD is calculated as a function of the effective radius. Evaluation of modeling results (i.e., Re, COD) is performed against satellite products from Moderate Resolution Imaging Spectroradiometer (MODIS) platform.

Depending on the meteorological field, the emission inventory and the droplet scheme used the annual mean CDNC ranges between 57 and 218 cm^{-3} (Figure 1) with larger differences seen over heavily polluted regions (e.g., Europe, China, NE USA), regions affected by long range transport of pollution (e.g., Atlantic Ocean) and regions affected by biomass burning (e.g., S. Africa, S. America). The droplet scheme used seems to be the most important parameter affecting CDNC followed by meteorology; the sensitivity of CDNC to emission inventories is small. The results for the shortwave cloud radiative forcing and the first AIE are quite similar across the modeling experiments reflecting the main differences seen in CDNC between simulations that use current and preindustrial emissions.

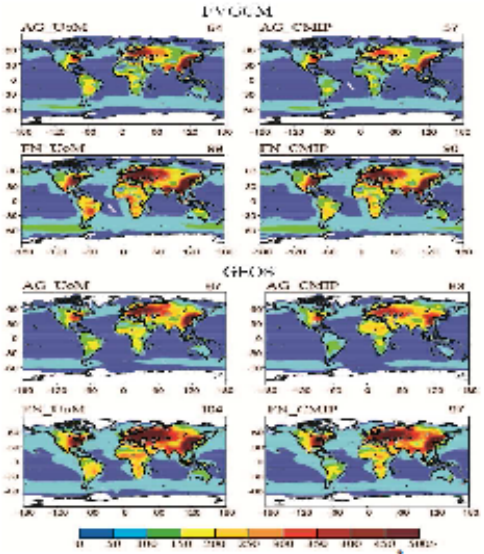

Figure 1. Simulated annual mean CDNC (cm^{-3}) for all emission inventories and meteorological fields used and the schemes of AG and FN. Global averages are shown in the upper right hand corner of each panel

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Impact of biogenic emissions on ozone and fine particles over Europe: Assessing the effect of temperature increase and the role of anthropogenic NOx emissions reduction

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The role of biogenic emissions on ozone and PM2.5 levels over Europe is assessed for July 2006 using the CMAQ modeling system. Biogenic emissions are simulated to increase the daily maximum 8 hour ozone (Max8hrO3) mixing ratios and to decrease PM2.5 average concentrations over Europe. Since climate change will lead to higher temperatures increasing subsequently biogenic emissions, sensitivity analysis to temperature is performed. Higher temperatures suggest an average increase in Max8hrO3 mixing ratios over Europe by about 3% and an average decrease in PM2.5 concentrations by about 6%, related to a temperature increase by 3 K degrees. Temperature increases are simulated, also, to increase the organic part of PM2.5 and to decrease the inorganic one on average over Europe. In order to examine if abatement measures for anthropogenic emissions could offset ozone increases in a warmer environment and their effect on PM2.5 concentrations, simulation with a domain wide reduction of anthropogenic NOx emissions by 10% is performed. This is estimated to reduce Max8hrO3 mixing ratios on average over Europe, however, in VOCs limited areas there is an increase. The reduction in anthropogenic NOx emissions is simulated to reduce PM2.5 concentrations on average over Europe enhancing the reduction simulated in a warmer environment but further modifying PM2.5 component concentrations.

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Assessment of ambient air quality in European countries using CMAQ

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Abstract

Gaseous (i.e., O_3, NO_2, SO_2) and particle (i.e., $PM_{2.5}$) concentrations are estimated over Europe for winter (i.e., January 2006) and summer (i.e., July 2006) months using CMAQ modeling system. Max8hrO_3 concentation during July is simulated up to 75ppbV while a large portion of the domain has values higher than 50ppbV. Higher NO_2 concentrations are simulated over western Europe, northern Italy and the United Kingdom for both seasons (higher concentrations during January compared to July). Elevated SO_2 concentrations are simulated over eastern Europe (higher concentrations during winter). Elevated $PM_{2.5}$ levels are simulated over eastern and western Europe with concentrations up to 30 ug/m^3 during winter. Statistical analysis between observed and predicted concentrations for the European countries found, in general, that NO_2 and $PM_{2.5}$ are underpredicted, SO_2 is overpredicted while Max8hrO_3 is overpredicted for low concentrations and is underpredicted for the higher ones. However, the findings of the current study suggest a number of European countries where observed and predicted concentrations are in good agreement for the pollutants examined here.

Keywords: air quality, ozone, particulate matter, Europe, CMAQ

1. Introduction

Air quality is a focus of attention because of its important role in many areas including human health, atmospheric reactions, acid deposition, and the earth's radiation budget [e.g., 1]. Although air quality management strategies have been applied over recent years to reduce atmospheric pollutant concentrations, ozone and particulate matter pollution are still an issue. For this reason, simulating and forecasting gaseous and particle concentrations as accurately as possible is fundamental in air quality planning for more effective adaptation and implementation guidelines.

Air pollution is not just a local issue since the pollutants released in one country can be transported in the atmosphere, affecting air quality in the nearby countries. As such, several research groups have started simulations of the gaseous and particulate matter

concentrations over the whole of Europe. However, there are a limited number of such studies [e.g., 2,3].

The objective of this study is to simulate gaseous (i.e., O_3, NO_2, SO_2) and particle (i.e., $PM_{2.5}$) concentrations over Europe, and estimating errors and biases between observed and predicted values for European countries with available monitoring data.

2. MATERIALS AND METHODS

Meteorological fields are derived using the Penn State/NCAR Mesoscale Model (MM5) [4]. MM5 is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. Since most meteorological models, such as MM5, are not built for air quality modeling purposes, to address issues related to data format translation, conversion of units of parameters, extraction of data for appropriate window domains, and reconstruction of meteorological data on different grid and layer structures is needed. Meteorology Chemistry Interface Processor (MCIP) [5] is used to provide the meteorological data from the MM5 outputs needed for the emissions and air quality models (177 × 217 grid cells of 35 km × 35 km, with 14 vertical layers).

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3. RESULTS AND DISCUSSION

High ozone conceentrations are predicted in southern Europe where meteorological conditions enhance ozone formation (Figure 1). The daily average maximum 8 hours ozone ($Max8hrO_3$) concentation during July is simulated up to 75ppbV while a large portion of the domain has values higher than 50ppbV. Higher NO_2 concentrations are simulated over western Europe (i.e., Belgium, the Netherlands, Germany, and northern France), northern Italy and the United Kingdom for both seasons. Belgium and the Netherlands have elevated NO_2 values since their small area results in a high emission rate per acre, however, they are not ranked as one of the countries with high NO_X emission rates. Road transport and industry are responsible for the elevated NO_X emissions at northertn Italy, while road and non-road transport energy sector and industry are responsible for the high NO_X emission in the United Kingdom. NO_2 concentrations are higher during January compared to July for two reasons: energy sector and industry emit more NO_X during winter and NO_2 photolysis is unfavorable during winter. Elevated SO_2 concentrations are simulated over eastern Europe, with higher values in Poland and the North Balkan Peninsula. Since power generation and industry are mainly responsible for SO_2 emissions, SO_2 values are very location dependent and also show higher values during winter. Elevated $PM_{2.5}$ levels are simulated over eastern and western Europe (i.e., daily average concentrations up to 30 ug/m^3 during winter).

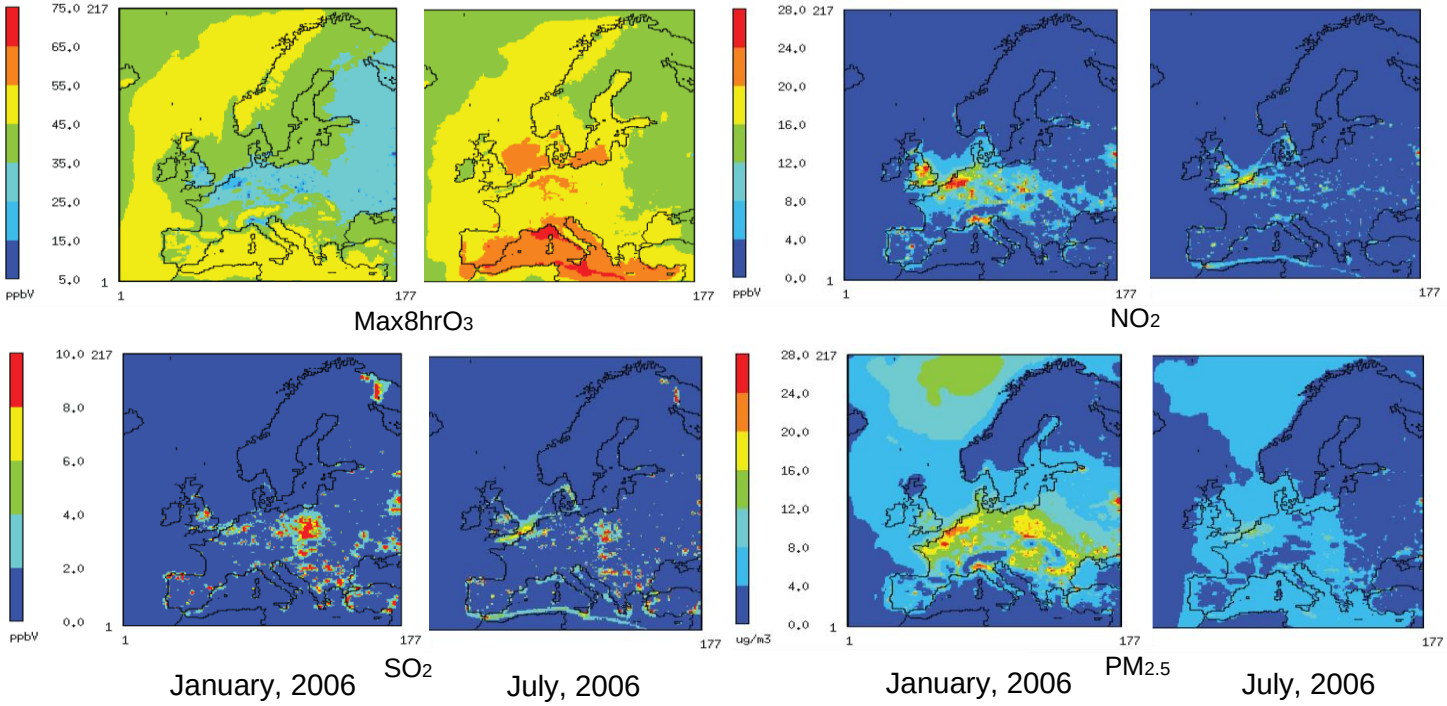

Figure 1: Simulated daily ($Max8hrO_3$, $PM_{2.5}$) and hourly (NO_2, SO_2) average concentrations for January and July of 2006

In order to assess errors and biases between observed and predicted values for European countries we estimate the Mean Bias (M.B.=$\frac{1}{n}\sum_{i=1}^{n}(P_{(i)} - O_{(i)})$) and the Root

Mean Square Error (R.M.S.E.= $\sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_{(i)}-O_{(i)})^2}$) (where P(i) stands for predicted data and O(i) for observed data) for each country using observation data from AirBase, the European air quality database (http://www.eea.europa.eu/data-and-maps/data/airbase-the-europe an-air-quality-database-2).

Mean Bias for Max8hrO_3 concentrations is positive for all countries for January since the model overestimates low concentrations that recorded during winter (Figure 2). The calculated Mean Bias for the majority of the countries is more than 10 ppbV. For many countries (i.e, Bulgaria, Croatia, F.Y.R.O.M., Germany, Hungary, Italy, Lithuania, Luxembourg, the Netherlands, Poland, and the United Kingdom) the calculated Mean Bias is 0±5 ppbV for the summer month while higher positive Mean Bias values are calculated for Ireland, Latvia, Malta, Portugal, and Spain. Higher R.M.S.E. is calculated for the southern European countries compared to the northern European countries for both months. Lower R.M.S.E. is calculated in almost all countries for July compared to January.

Mean Bias for NO_2 values is negative for all countries except Belgium for both months as well as for the Netherlands and the United Kingdom in January with values up to 4.2 ppbV (Figure 3). The largest negative Mean Bias is estimated for Norway (<-15 ppbV) in January while estimates for Spain, Estonia, Denmark, Portugal, Finland, Luxembourg, Poland, Germany, and Latvia along with the United Kingdom, the Netherlands, and Belgium have MB 0±5 ppbV. Austria, F.Y.R.O.M., and

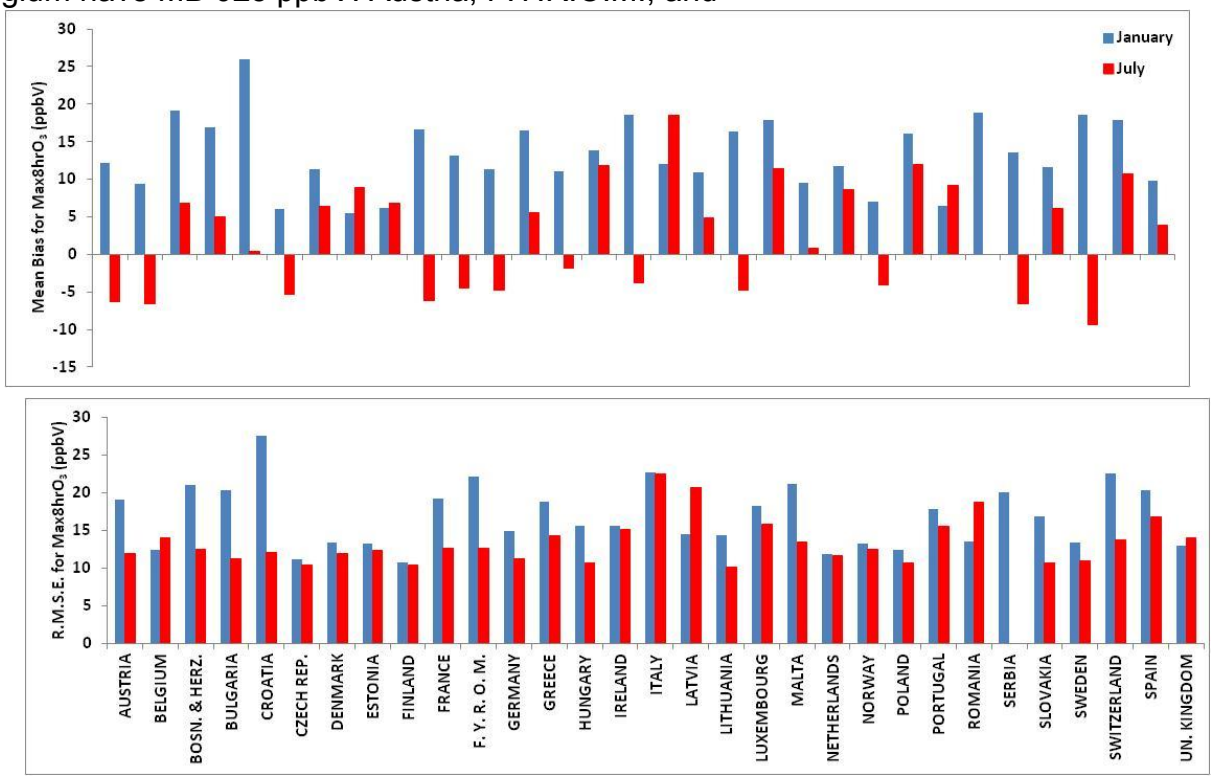

Figure 2: Mean Bias and R.M.S.E. for daily average Max8hrO_3 concentrations for the European countries

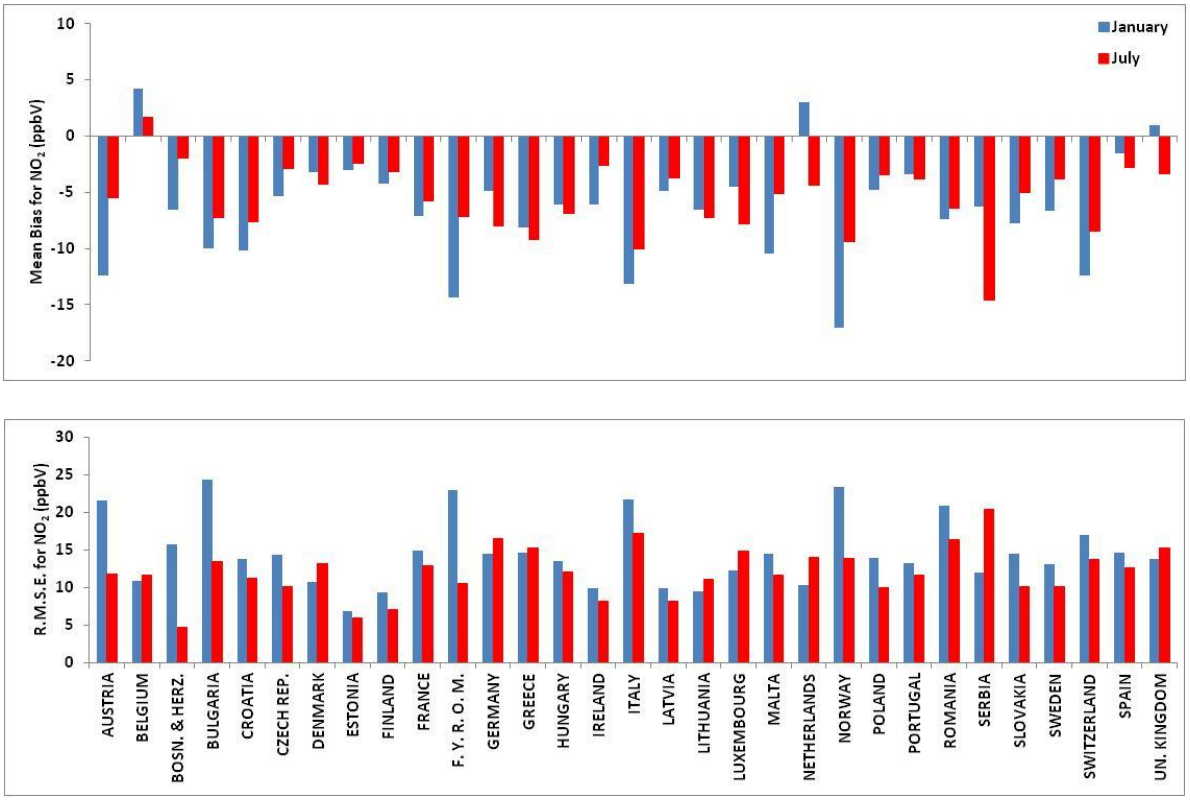

Figure 3: Mean Bias and R.M.S.E. for daily average NO_2 concentrations for the European countries

Norway is estimated to have much higher negative Mean Bias in January compared to July, while Serbia, Germany, and Luxembourg is estimated to have much higher negative Mean Bias in July compared to January. High R.M.S.E. is calculated in Romania, Austria, Italy, F.Y.R.O.M., Norway, and Bulgaria in January while Serbia is estimated to have the highest R.M.S.E. in July.

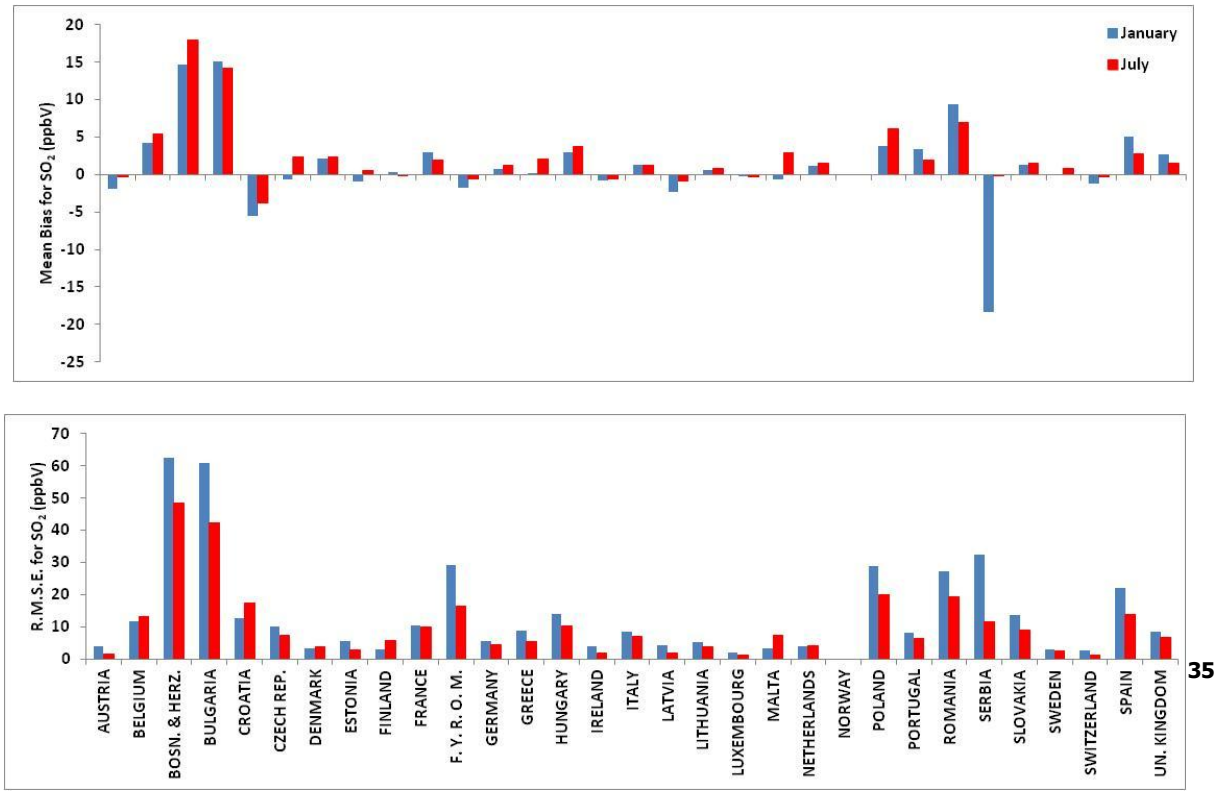

Figure 4: Mean Bias and R.M.S.E. for daily average SO_2 concentrations for the

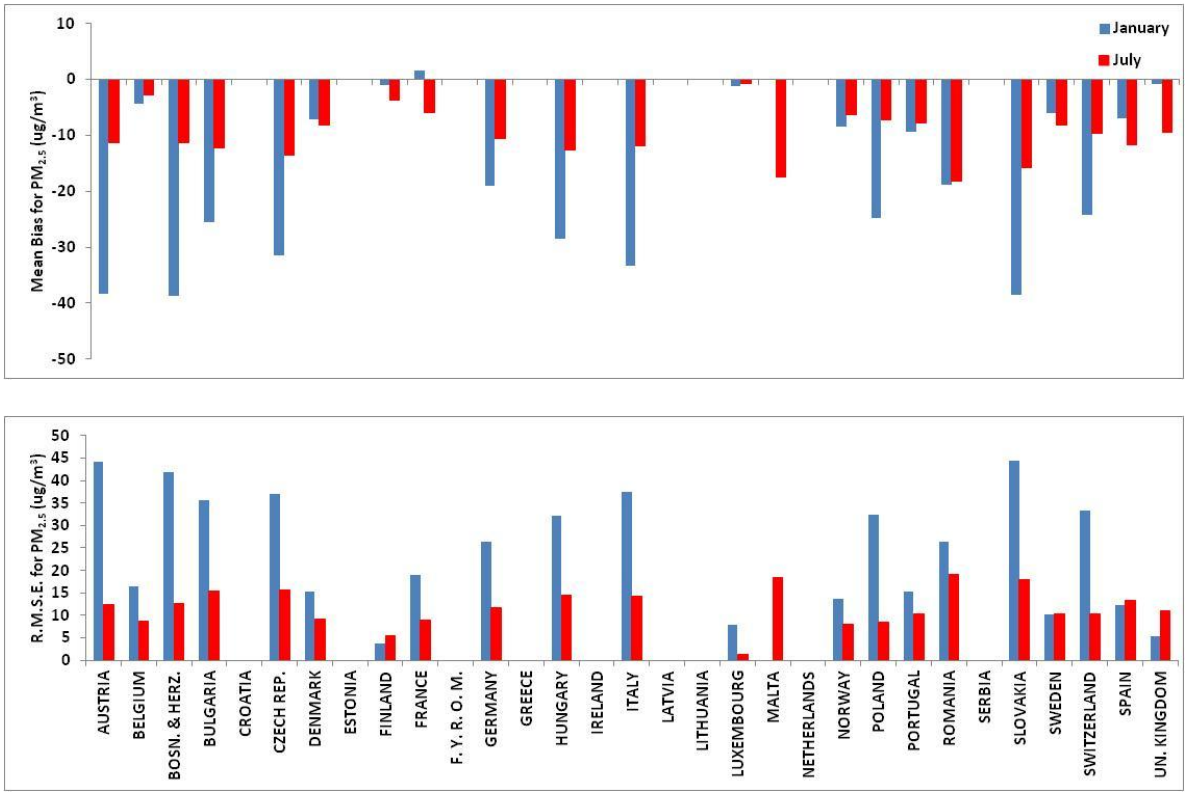

Figure 5: Mean Bias and R.M.S.E. for daily average $PM_{2.5}$ concentrations for the European countries

Mean Bias in SO_2 concentrations is estimated to have both positive and negatives values for both months (Figure 4). The highest positive Mean Bias is calculated for Bulgaria, Bosnia & Herzegovina, and Romania for both months, while the highest negative Mean Bias is calculated for Croatia and Serbia in January and for Croatia in July. More than half of the countries have Mean Bias in the range 0±2 ppbV for both months. There is no significant change in the Mean Bias between the two seasons with the exception of Serbia. High R.M.S.E. is calculated for Spain, Romania, Poland, F.Y.R.O.M., Serbia, Bulgaria and Bosnia & Herzegovina in January, while Poland, Bulgaria and Bosnia & Herzegovina are estimated to have high R.M.S.E. in July. However, results for countries with a very limited number in monitoring stations may not be representative.

Mean Bias for $PM_{2.5}$ concentrations is estimated to be negative for all countries for both months except France in January (Figure 5). The highest (negative) Mean Bias and R.M.S.E. are calculated for Switzerland, Poland, Bulgaria, Hungary, Czech Republic, Italy, Austria, Slovakia, and Bosnia & Herzegovina in January. However, they are much lower in July. The United Kingdom and Finland in January and Luxembourg in July are estimated to have the lowest Mean Bias (i.e., up to -1μg/m^3) as well as the lowest R.M.S.E. (i.e., up to 5.4μg/m^3).

4. CONCLUSIONS

Application of CMAQ modeling system over Europe for January and July of 2006 shows an overestimation trend for low ozone concentrations while the higher ones are

underestimated. However, spatial distribution plots are reasonably estimated (e.g., higher ozone concentrations in southern Europe). Simulated values for NO_2, SO_2, and $PM_{2.5}$ suggest a bias: SO_2 is overestimated while NO_2 and $PM_{2.5}$ are underestimated. However, statistical analysis (i.e., Mean Bias and R.M.S.E.) for each country found that observed and predicted concentrations are in good agreement in a number of countries for both seasons for all pollutants examined here.

Acknowledgments This work was supported by the National Strategic Reference Framework (NSRF) 2007-2013 grand No 09SYN-31-667.

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Modeling air pollution in Europe and the role of anthropogenic and biogenic emissions

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Abstract The objective of this study is to simulate ozone and fine particle concentrations over Europe and to assess the contribution of both anthropogenic and biogenic emissions. Meteorological fields are derived using MM5. TNO has provided a gridded anthropogenic emissions database for the year 2006 over Europe, while BEIS is used for processing biogenic source emissions. Emissions are processed by SMOKE modeling system to convert their resolution to the resolution needed by the air quality model. CMAQ modeling system is used for air quality modeling for July 2006. The findings of the current study suggest that $Max8hrO_3$ is overpredicted for low concentration and is underpredicted for the higher ones while $PM_{2.5}$ is underpredicted. Model application with and without biogenic emissions estimates that the addition of biogenic emissions increases $Max8hrO_3$ concentrations. The relative contribution of biogenic emissions compared to anthropogenic emissions is up to 20%, suggesting and increase in $Max8hrO_3$ concentration up to 12ppbV, locally. The addition of biogenic emissions reduces $PM_{2.5}$ concentrations in a major part of the domain up to about 1 $\mu g/m^3$ suggesting a maximum reduction up to about 10% compared to anthropogenic emissions. However, the addition of biogenic emissions could slightly increase $PM_{2.5}$ concentrations locally.

1 Introduction

Air quality is a focus of attention, because of its important role in many areas, including human health, atmospheric reactions, acid deposition and the earth's radiation budget (e.g., Seinfeld and Pandis 2006, Peng et al. 2005). Although air quality management strategies are applied during the last years in order to reduce atmospheric pollutant concentrations, ozone and particulate matter are still an issue. For this reason simulating and forecasting air and particle concentrations as accurately as possible is fundamental in air quality planning in order to improve policy and decision makers' effectiveness of instructions and regulations.

In addition to anthropogenic emissions, natural and biogenic emissions contribute to atmospheric pollution. Over 90% of the total Volatile Organic Compounds (VOCs) entering the atmosphere are biogenic (Greenberg et al. 1999), having an important role in regulating the atmospheric composition. Understanding the impact of both anthropogenic and biogenic fraction on air quality is very important as only the anthropogenic part can be influenced by abatement measures.

The objective of this study is to simulate ozone and fine particle concentrations over Europe and to assess the contribution of both anthropogenic and biogenic emissions.

2 Data and Methodology

Meteorological fields are derived using the Penn State/NCAR Mesoscale Model (MM5) (Grell et al. 1994). MM5 is a limited-area, nonhydrostatic, terrain-following sigma-

coordinate model designed to simulate or predict mesoscale atmospheric circulation. Since most meteorological models, such as MM5, are not built for air quality modeling purposes, to address issues related to data format translation, conversion of units of parameters, extraction of data for appropriate window domains, and reconstruction of meteorological data on different grid and layer structures is needed. Meteorology Chemistry Interface Processor (MCIP) (Byun et al. 1999) is used to provide the meteorological data from the MM5 outputs needed for the emissions and air quality models (177 × 217 grid cells of 35 km × 35 km, with 14 vertical layers).

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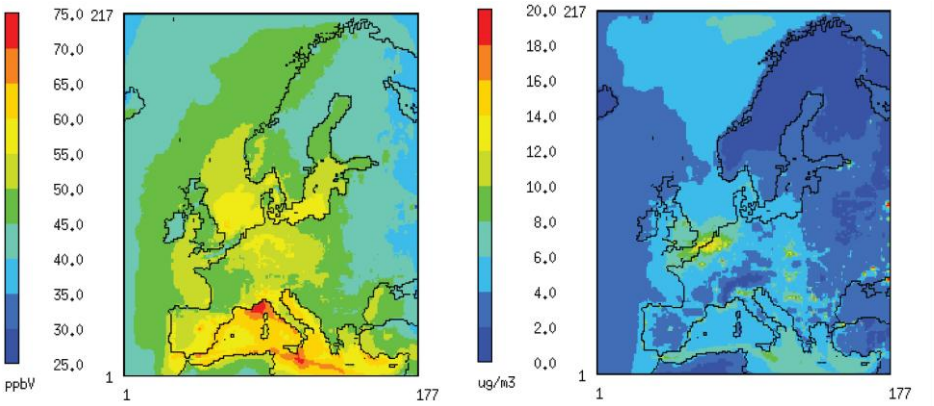
3 Results

High ozone concentrations are predicted in southern Europe where meteorological conditions enhance ozone formation (Figure 1). The daily average maximum 8 hour ozone ($Max8hrO_3$) concentration during July is simulated up to 75ppbV while a large portion of the domain has values higher than 50ppbV. Elevated $PM_{2.5}$ levels (i.e., daily average concentrations up to 20ug/m^3) are simulated over Belgium, the Netherlands and northern Italy. However, high $PM_{2.5}$ concentrations are simulated, locally, in many countries. Nitrate components of $PM_{2.5}$ are dominant in regions with elevated NH_3 emissions (i.e., the Netherlands and northern Italy). For the rest of the domain sulphate components are dominant. Low organic component concentrations are simulated in general; this has been noted in other CMAQ approaches (Foley et al. 2010). Ammonium components of $PM_{2.5}$ follow sulphate and nitrate components distribution, since atmospheric SO_2 is oxidized to sulfuric acid which reacts with ammonia to form ammonium sulfate, while gas-phase NO_X is oxidized to nitric acid which reacts with ammonia to form ammonium nitrate.

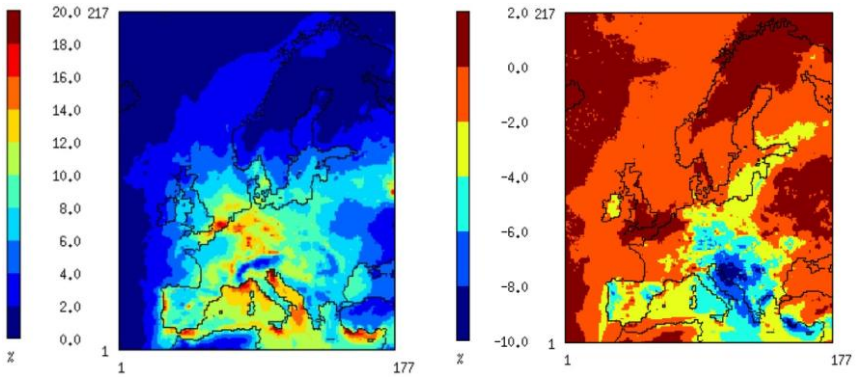


Max8hrO_3 $PM_{2.5}$

Fig 1: Simulated Max8hrO_3 and $PM_{2.5}$ daily average concentrations for July 2006

Model performance for ozone shows a mixed trend: Max8hrO_3 is overpredicted for low concentrations (about 50ppbV) while it is underpredicted for the higher ones. This trend is in agreement with the CMAQ application performed by Appel et al. (2012) for Europe where daytime ozone mixing ratio is overestimated during winter and underestimated during summer months. A bias for $PM_{2.5}$ estimations is noted since $PM_{2.5}$ is underpredicted. The underprediction trend for $PM_{2.5}$ has been also found by Appel et al. (2012) using CMAQ modeling system for Europe.

In order to assess the contribution of both anthropogenic and biogenic emissions on ozone and $PM_{2.5}$ concentrations two sets of simulations are performed, one where only anthropogenic emissions are considered and one where both anthropogenic and biogenic emissions are included. The effect of biogenic emissions is computed as the change between the simulation where both anthropogenic and biogenic emissions are considered and the simulation without biogenic emissions. Anthropogenic emissions play the most important role in ozone concentrations over Europe. However, the impact of biogenic emissions is significant. Since ozone is formed from the photochemical oxidation of VOCs in the presence of nitrogen oxides, the inclusion of Biogenic Volatile Organic Compound (BVOC) emissions enhances its formation. The impact of biogenic emissions on Max8hrO_3 concentrations compared to anthropogenic emissions suggests an increase of about 6% on average over Europe during July 2006 while, locally, it can be up to 23% higher than the solely due to anthropogenic emissions (Figure 2). Anthropogenic emissions play, also, the most important role for $PM_{2.5}$ concentrations over Europe. The addition of biogenic emissions is simulated, here, to reduce $PM_{2.5}$ concentrations by approximately 2% on average over Europe, while over southern Europe the reduction is estimated up to 11% locally. However, there are regions where $PM_{2.5}$ concentrations are simulated to increase with the addition of BVOC emissions, which is related to the change in $PM_{2.5}$ component concentrations. The addition of biogenic emissions increases organic component concentrations of $PM_{2.5}$ due to the higher VOC emissions. Sulphate component concentrations are simulated to be lower over the entire domain when biogenic emissions are added since less sulphuric acid is produced from the oxidation of SO_2 due to OH radical decrease. An increase or a decrease in ammonium nitrate is expected depending on the availability of nitric acid and NH_3 which modifies nitrate component concentrations. Ammonium component concentrations follow the patterns of sulphate and nitrate component concentrations.



Max8hrO_3 $PM_{2.5}$

Fig 2: Relative impact of biogenic emissions compared to anthropogenic emissions (percent) on Max8hrO_3 and $PM_{2.5}$ daily average concentrations for July 2006

4 Conclusions

Application of CMAQ modeling system over Europe for July 2006 using the TNO gridded anthropogenic emissions database for the year 2006 shows an overestimation trend for low ozone concentrations (less than 50ppbV) while the higher concentrations are underestimated. However, spatial distribution plots are reasonably estimated (e.g., higher ozone mixing ratios in southern Europe). Simulated values for $PM_{2.5}$ suggest a bias since $PM_{2.5}$ concentrations are underestimated. Speciated $PM_{2.5}$ component concentrations give low OC concentrations as a result of the uncertain representation of SOA formation.

This work suggests that anthropogenic emissions play the most important role in ozone and $PM_{2.5}$ concentrations over Europe. However, biogenic emissions are simulated to increase substantially ozone, locally, to reduce $PM_{2.5}$ levels and to modify $PM_{2.5}$ component concentrations increasing organic and decreasing inorganic components, on average over Europe.

Acknowledgments This work was supported by the National Strategic Reference Framework (NSRF) 2007-2013 grand No 09SYN-31-667.

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Effects of climate change on air quality in Greece

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Abstract Eastern Mediterranean, from an air quality perspective, is a region of significant concern since particulate matter (PM), ozone and other secondary pollutant levels often exceed air quality limits. In addition, it has been characterized as a "hot spot" area in future climate change projections. In order to assess the effect of climate change on $PM_{2.5}$ concentrations in this area, a coupled global-regional air pollution modeling system (GRE-CAPS) was applied over Europe, focusing on Greece. The GRE-CAPS modeling system consists of three models spanning the global to the regional scale: the GISS II' GCM global CTM with online chemistry, the regional meteorological model WRF, and the regional CTM PMCAMx-2008. We simulated several month-long summertime periods to capture the corresponding variability both for the present (2000s) and the future (2050s) assuming constant anthropogenic pollutant emissions. Different IPCC scenarios for the 2050s were used. Our results show that future $PM_{2.5}$ levels in Greece will change up to several μg m^{-3} due to climate change, although the predicted responses are quite variable in space.

6. ΠΑΡΑΡΤΗΜΑ 2: ΔΗΜΟΣΙΕΥΣΕΙΣ ΣΕ ΠΕΡΙΟΔΙΚΑ