NATO Science for Peace and Security Series

This Series presents the results of scientific meetings supported under the NATO Programme: Science for Peace and Security (SPS).

The NATO SPS Programme supports meetings in the following Key Priority areas: (1) Defence Against Terrorism; (2) Countering other Threats to Security and (3) NATO, Partner and Mediterranean Dialogue Country Priorities. The types of meeting supported are generally "Advanced Study Institutes" and "Advanced Research Workshops". The NATO SPS Series collects together the results of these meetings. The meetings are co-organized by scientists from NATO countries and scientists from NATO's "Partner" or "Mediterranean Dialogue" countries. The observations and recommendations made at the meetings, as well as the contents of the volumes in the Series, reflect those of participants and contributors only; they should not necessarily be regarded as reflecting NATO views or policy.

Advanced Study Institutes (ASI) are high-level tutorial courses intended to convey the latest developments in a subject to an advanced-level audience

Advanced Research Workshops (ARW) are expert meetings where an intense but informal exchange of views at the frontiers of a subject aims at identifying directions for future action

Following a transformation of the programme in 2006 the Series has been re-named and re-organised. Recent volumes on topics not related to security, which result from meetings supported under the programme earlier, may be found in the NATO Science Series.

The Series is published by IOS Press, Amsterdam, and Springer, Dordrecht, in conjunction with the NATO Emerging Security Challenges Division.

Sub-Series

A.	Chemistry and Biology	Springer
B.	Physics and Biophysics	Springer
C.	Environmental Security	Springer
D.	Information and Communication Security	IOS Press
E.	Human and Societal Dynamics	IOS Press

http://www.nato.int/science
http://www.springer.com
http://www.iospress.nl

Series C: Environmental Security

Air Pollution Modeling and its Application XXI

edited by

Douw G. Steyn
Department of Earth and Ocean Sciences,
The University of British Columbia, Vancouver, BC, Canada

and

Silvia Trini Castelli
Institute of Atmospheric Sciences and Climate National Research Council CNR
Torino, Italy

Springer

Published in Cooperation with NATO Emerging Security Challenges Division

Chapter 99

Improved CTM Boundary Conditions Using DREAM Desert Dust Forecasts: A Case Study over the Po Valley

Claudio Carnevale, Giovanna Finzi, Enrico Pisoni, Marialuisa Volta, Pavel Kishcha, Gabriele Curci, and P. Alpert

Abstract The Po Valley in Northern Italy is frequently affected by high PM10 concentrations, where both natural and anthropogenic sources play a significant role. This work was aimed at giving a proper account of the contribution of Saharan dust to air quality in the Po Valley. This was carried out by improving the boundary conditions of the mesoscale 3D deterministic Transport Chemical Aerosol Model (TCAM) on large-scale transport of Saharan dust, daily predicted over the Mediterranean region. A case study of the integration of the TCAM and DREAM models was implemented over the Po Valley. The results show that the use of improved boundary conditions leads TCAM to better performances, both in terms of correlation and mean errors: TCAM was able to more accurately reproduce high PM10 concentrations observed in the Po Valley during particular dust events.

Keywords Aerosol modeling • Chemical transport model • Saharan dust

99.1 Introduction

As a result of the rather ambitious goal for PM10 fixed by European Directives, the impact of natural sources on the PM10 levels requires deep investigation. In recent years a number of experimental studies have been performed to investigate the

---

C. Carnevale (✉) • G. Finzi • E. Pisoni • M. Volta
Faculty of Engineering, Department of Information Engineering,
University of Brescia, Brescia, Italy
e-mail: Carneval@ing.unibs.it

P. Kishcha • P. Alpert
Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel

G. Curci
CETEMPS, Department of Physics, University of L'Aquila, L'Aquila, Italy
e-mail: gabriele.curci@aquila.infn.it

D.G. Steyn and S. Trini Castelli (eds.), *Air Pollution Modeling and its Application XXI*,
NATO Science for Peace and Security Series C: Environmental Security 4,
DOI 10.1007/978-94-007-1359-8_99,

impact of Saharan dust transport on PM10 levels in the Euro-Mediterranean basin [3, 6, 10]. This work is aimed at evaluating the impact of Saharan dust on PM10 records in the Po Valley. This was carried out by improving the boundary conditions of the mesoscale multiphase Transport Chemical Aerosol Model (TCAM) [1] on large-scale transport of Saharan dust, using DREAM dust concentration computed over the Mediterranean region from the Tel-Aviv University weather research center [4]. In fact, multiphase models, simulating the physical-chemical processes involving secondary pollutants in the troposphere, are key tools to evaluate the effectiveness of emission control strategies and so to improve air quality. Due to the complexity of the phenomena involved in the formation and accumulation of aerosol, these models require very detailed input in terms of meteorological fields, emission sources and boundary conditions. In particular, boundary condition fields give the mesoscale models information about the pollutant fluxes incoming in the domain, assuming a very important role in the correct representation of large scale phenomena like Saharan dust transport.

99.2 TCAM model

TCAM [1] is a 3-D multiphase Eulerian model. It is a part of the Gas Aerosol Modeling Evaluation System (GAMES) [12] which also includes the meteorological pre-processor PROMETEO and the emission processor POEM-PM [2]. TCAM solves time by time a PDE system which describes the horizontal/vertical transport, the multiphase chemical reactions and the gas to particle conversion phenomena using a splitting operator technique. The horizontal transport is solved by a chapeau function approximation and the non linear Forester filter, while the vertical transport PDE system is solved by an hybrid implicit/explicit scheme. The gas chemistry is described by the COCOH97 scheme. The ODE chemical kinetic system is solved by means of the Implicit-Explicit Hybrid (IEH) solver, which splits the species in fast and slow ones, according to their reaction rates. The system of fast species is solved by means of the implicit Livermore Solver for Ordinary Differential Equations (LSODE) implementing an Adams predictor/corrector method in the non-stiff case, and the Backward Differentiation Formula method in the stiff case. The slow species system is solved by the Adams-Bashfort method.

99.3 DREAM Desert Dust Forecasts

DREAM is a model designed to predict the atmospheric cycle of mineral dust aerosol [5, 7]. It solves the Euler-type partial differential nonlinear equation for dust mass continuity. The NCEP/Eta regional atmospheric model drives the aerosol. During the model integration, calculation of the surface dust injection fluxes is made over the model cells declared as deserts. Once injected into the air, dust aerosol is driven by the atmospheric model variables: by turbulence in the early stage of the process when dust is lifted from the ground to the upper levels; by winds in the later phases of the process when dust travels away from the sources; and finally, by thermodynamic processes and rainfall of the atmospheric model and land cover features which provide wet and dry deposition of dust over the Earth surface. A detailed set of eight particle size classes with effective size between 0.1 and 7.1 μm (0.15, 0.25, 0.45, 0.78, 1.3, 2.2, 3.8, and 7.1 μm) is used [4]. At Tel-Aviv University, since the year 2006, DREAM has been producing daily forecasts of 3-D distribution of dust concentrations over the Mediterranean model domain 20°W–45°E, 15°N–50°N with horizontal resolution 0.3° and 24° vertical levels [8, 9] (http://wind.tau.ac.il/dust8/dust.html).

99.4 The Case Study

The impact of the DREAM dust boundary condition has been evaluated for performing a simulation over a Northern Italy domain for the period 15 May–30 June 2007. The TCAM domain (Fig. 99.1a) has been split on a regular horizontal grid with resolution of 10 km, and on 11 terrain following vertical layers ranging from 20 to 4,000 m above ground level. The emission fields were estimated by POEM-PM pre-processor starting from the regional emission inventory collected by ISPRA (Italian Agency for Environmental Protection and Research), while the meteorological fields are computed by means of MM5 model. Two different boundary condition configurations have been tested. In the first case, Chimere CTM [11] simulations have been performed on a European scale domain at an horizontal resolution of $0.5° \times 0.5°$ (Fig. 99.1b) in the frame of QUITSAT project (www.quitsat.it).

The simulation outputs have been interpolated over the bound of TCAM grid and adapted to meet TCAM chemical and size requirements. In the second configuration, the Chimere output has been integrated with the finer resolution outputs of DREAM model ($0.1° \times 0.1°$, Fig. 99.1b). The integration has been performed updating the dust aerosol species in Chimere with DREAM model results, after a spatial and temporal interpolation. The size characterization derived by experimental profiles [3] has been used to characterize DREAM model results. The validation of TCAM simulation results has been performed comparing computed and observed PM10 daily mean concentration in 102 monitoring stations selected to cover all the emission and meteorological regimes of the domain. The use of the DREAM dust forecasts to improve boundary conditions allows TCAM to reach better performances both in terms of normalized mean absolute error (NMAE) and correlation coefficient (Fig. 99.2). In particular, the NMAE shows a significant decreasing due to reduction of the model underestimation and the correlation coefficient median increases with respect to the results computed only with Chimere boundary conditions.

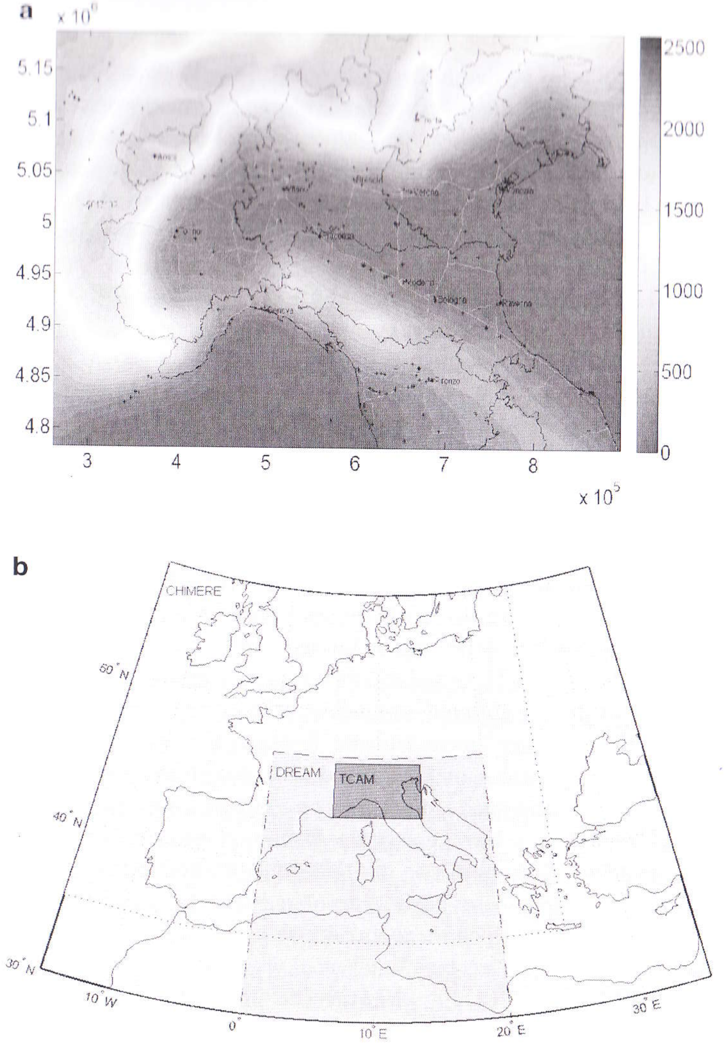

Fig. 99.1 (**a**) TCAM simulation domain topography, and (**b**) TCAM and Chimere domains. The area of DREAM data used is also presented

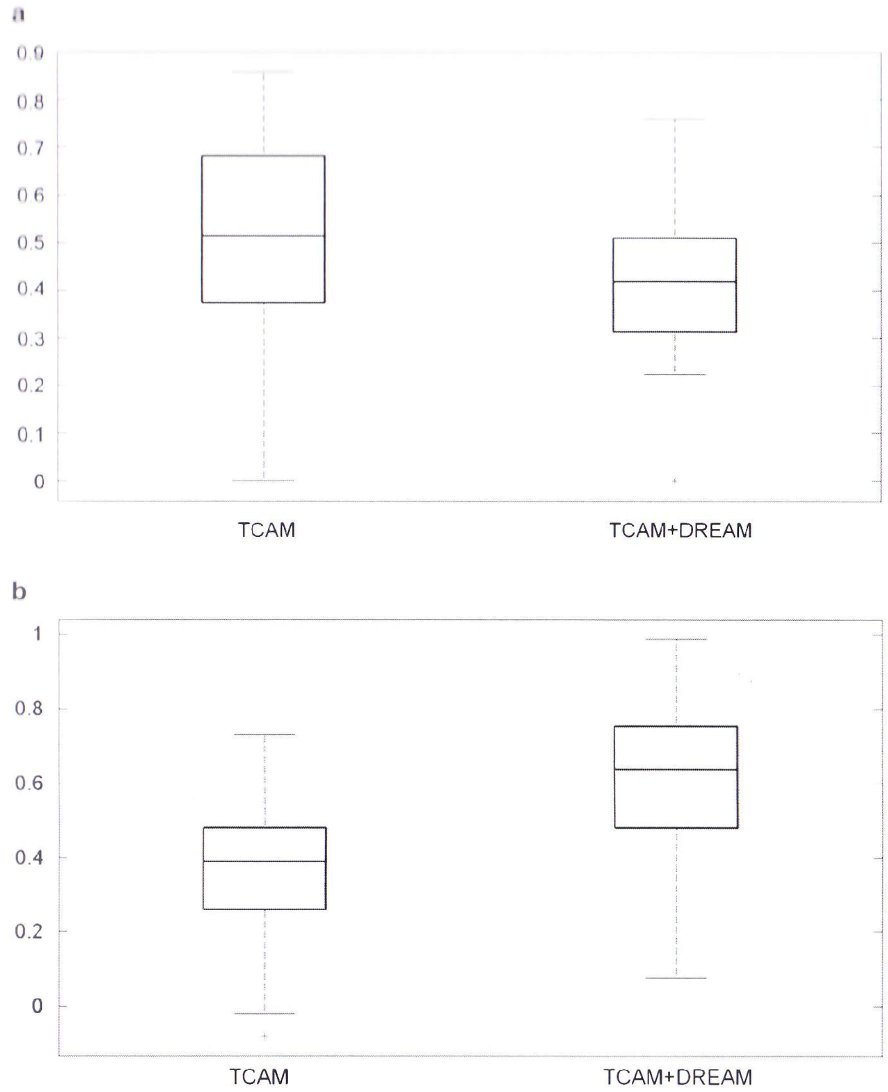

Fig. 99.2 (**a**) PM10 24 h mean NMAE and (**b**) correlation coefficient for the two tested configuration

Acknowledgments The research co-operation between Tel Aviv and Brescia Universities was enhanced and supported by COST ES602 action. The TCAM model simulations have been performed in the frame of the Pilot Project QUITSAT funded by Italian Space Agency.

References

1. Carnevale C, Decanini E, Volta M (2008) Design and validation of a multiphase 3D model to simulate tropospheric pollution. Sci Total Environ 390:166–176
2. Carnevale C, Gabusi V, Volta M (2006) POEM-PM: an emission model for secondary pollution control scenarios. Environ Modell Softw 21:320–329
3. Gobbi GP, Barnaba F, Ammannato L (2007) Estimating the impact of Saharan dust on the year 2001 PM10 record of Rome, Italy. Atmos Environ 41:261–275
4. Kishcha P, Nickovic S, Ganor E, Kordova L, Alpert P (2008) Saharan dust over the Eastern Mediterranean: model sensitivity. Air pollution modelling and its applications XIX. Chapter 4.2, Springer, ISSN: 1874–6519, doi: 10.1007/978-1-4020-8453-9_39, pp 358–366
5. Kishcha P, Alpert P, Shtivelman A, Krichak SO, Joseph JH, Kallos G, Katsafados P, Spyrou C, Gobbi GP, Barnaba F, Nickovic S, Perez C, Baldasano JM (2007) Forecast errors in dust vertical distributions over Rome (Italy): multiple particle size representation and cloud contributions. J Geophys Res 112:D15205. doi:10.1029/2006JD007427
6. Masson O, Piga D, Guarriaran R, D'Amico D (2010) Impact of exceptional Saharan dust outbreak in France: PM10 and artificial radionuclides concentrations in air in dust deposit. Atmos Environ 44:2478–2486
7. Nickovic S, Kallos G, Papadopoulos A, Kakaliagou O (2001) A model for prediction of desert dust cycle in the atmosphere. J Geophys Res 106(D16):18113–18129
8. Papayannis A, Zhang HQ, Amiridis V, Ju HB, Chourdakis G, Georgoussis G, Perez C, Chen HB, Goloub P, Mamouri RE, Kazadzis S, Paronis D, Tsaknakis G, Baldasano JM (2007) Extraordinary dust event over Beijing, China, during April 2006: Lidar, Sun photometric, satellite observations and model validation. Geophys Res Let 34:L07806. doi:10.1029/2006GL029125
9. Perez C, Nickovic S, Baldasano JM, Sicard M, Rocadenbosch F, Cachorro VE (2006) A long Saharan dust event over the western Mediterranean: Lidar, Sun photometer observations, and regional dust modeling. J Geophys Res 111:D15214. doi:10.1029/2005JD006579
10. Rodriguez S, Querol X, Alastuey A, Kallos G, Kakaliagou O (2001) Saharan dust contributions to PM10 and TSP levels in Southern and Eastern Spain. Atmos Environ 35:2433–2447
11. Schmidt H, Derognat C, Vautard R, Beekman M (2001) A comparison of simulated and observed ozone mixing ratios for the summer of 1998 in Western Europe. Atmos Environ 35:6277–6297
12. Volta M, Finzi G (2006) GAMES, a comprehensive gas aerosol modelling evaluation system. Environ Modell Softw 21:587–594

Questions and Answers

A. Kerschbaumer: Have you validate the DREAM model predictions?
C. Carnevale: DREAM has been using for several years for producing operational dust forecasts at two Mediterranean dust prediction centers: at the Barcelona Supercomputer Center, Spain, and at Tel-Aviv University, Israel. Several publications on the DREAM model validation against lidar measurements, AERONET data, and PM10 measurements are available (see e.g. [5, 8, 9]).

S. Finardi: Did you verify if the dust plume trajectory and surface concentration fields produced by TCAM with boundary conditions from DREAM were coincident or similar to those produced by the original dream simulation?
C. Carnevale: The point has been addressed. Our analysis shows that, in the two models, the patterns of dust vertical columns are quite similar, even though sometimes both vertical distributions and ground level concentrations could differ due to different meteorological input.

E. Ferrero: Is it possible to distinguish the particulates coming from dust in the model and in the measurements?
C. Carnevale: In the TCAM model an aerosol chemical species (desert dust) that follow the lifecycle and the dynamics of DREAM boundary conditions is included. Unfortunately, in the measurement a detailed chemical characterization of PM is difficult to achieve and it is only available in a limited number of monitoring stations and days.