**H14-195**

# OZONE SIMULATIONS WITH ATMOSPHERIC MODELLING SYSTEM OF MINNI PROJECT: A MULTI YEAR EVALUATION OVER ITALY

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**Abstract:**European Community Directive 2008/50/EC attributes a higher role to air quality models in air quality assessment and management, and establish criteria for acceptable model uncertainties or quality objectives as a function of pollutant. This study analyses the capacity of MINNI (Italian Integrated Assessment Modelling System for supporting the International Negotiation Process on Air Pollution and assessing Air Quality Policies at national/local level) atmospheric modelling system to simulate ozone concentrations over Italy for the years 1999, 2003 and 2005, according to the new EU criteria. Surface ozone concentrations over Italy exceed often the thresholds established in EU legislation to protect human health and to prevent damage to ecosystems. The yearly simulations were carried out using the national emission inventories for Italy and EMEP inventories for the other countries included in the computational domain. The meteorological conditions were simulated with RAMS driven by ECMWF initial and boundary conditions. The ozone formation and destruction under different conditions of solar radiation, temperature and chemical composition of atmosphere was computed with the photochemical mechanism SAPRC90. At most of the background stations (rural, urban, suburban) considered in the evaluation, the comparison of simulated and measured ozone concentrations shows a fair agreement between hourly observed and modelled ozone concentrations; furthermore RDE (Relative Directive Error) has values lower than that indicated in the directive. The modelling system exhibits good performance also with respect to other statistical indicators, such as MNBE (mean normalised bias error) which has values laying inside the range proposed in US-EPA's guidelines for an acceptable level of air quality model performance.

***Key words:*** *air quality, MINNI, RDE, FAIRMODE*

## INTRODUCTION

The use of modelling techniques for the assessment of air quality (AQ) in case of pollutants harmful to human health and environment such as ozone ($O_3$) has been suggested fifteen years ago in the European Union Framework Directive on ambient AQ assessment and management (96/62/EC, 1996). Recently, the EC Directive (2008/50/EC, 2008) enhances the role of models in making a cleaner air for Europe and establishes criteria for measuring model performances. For ozone, the Directive set the modelling uncertainties for hourly concentrations at 50%.

$O_3$ concentrations have very high levels over Europe, in particular over Italy, and further increase is expected in spite of reductions of emissions of precursor gases(EEA, 2007). The ozone formation is controlled in a complex way by the changing balance of emitted pollutants and the variability of meteorological conditions and, therefore, only the AQ models can aim to reproduce it.

Few published works report on performance characteristics of the AQ modelling systems for long-term simulations to date.
In this context, the present study is a first step in evaluating the performance of AQ part of MINNI modelling system for year-long simulations over the whole Italian territory, including the islands, Sicily and Sardinia. The evaluation is carried out over three years: 1999, 2003 and 2005 at the same monitoring stations.

## MODEL DESCRIPTION

MINNI (Zanini et al., 2005) is the Italian Integrated Assessment Modelling System for supporting the International Negotiation Process on Air Pollution and assessing Air Quality Policies at national/local level sponsored by the Italian Ministry of the Environment. The MINNI system is composed by an Atmospheric Modelling System (AMS) and the Greenhouse Gas and Air Pollution Interactions and Synergies Model over Italy (GAINS-Italy). The main components of AMS are the meteorological model (RAMS), for simulating the meteorological conditions, and the emission processor (EMMA) and the air quality model (FARM), for simulating the atmospheric chemistry.

The meteorological fields are produced with the meteorological model RAMS (Cotton et al., 2003)which run in a 2-ways nested grid system: the outer grid covering large part of the Central Europe and the Mediterranean Sea, with a resolution of 60kmx60km and an inner grid including the simulation domain with a resolution of 20 km x 20km.

The air quality model FARM (Silibello et al., 2008) is a three-dimensional Eulerian model dealing with the transport and the multiphasechemistry of pollutants in the atmosphere. Gas-phase reactions are described by means of SAPRC-90 chemical scheme (Carter, 1990).

The hourly emissions used by FARM are produced by the emission processor EMMA(EMission MAnager) (ARIA/ARIANET, 2008). This pre-processor split the annual data from the emission inventories by applying daily, weekly and seasonal activity profiles (Monforti and Pederzoli, 2005), gridded spatial proxies and activity-related speciation profiles.

**SIMULATIONS SETUP**

The meteorology and air quality were simulated with the spatial resolution of 20kmx20km and the hourly speciated emissions were prepared for the same horizontal spatial resolution.

The meteorological model (RAMS) used the European Centre for Medium Range Weather Forecast (ECMWF) analysis at 0.5 degrees and 6 h resolution for initial and boundary conditions.

The anthropogenic emission inventories used in this study over Italy were derived from the emissions for major point sources and for the diffuse sources at provincial level (ISPRA, 2000; ISPRA, 2005). These emissions are classified according to activity level CORINAIR/SNAP (CO-oRdinated INformation on the Environment in the European Community AIR / Simplified Nomenclature for Air Pollution). For the anthropogenic sources of other countries included in the simulation domain the EMEP emission inventory was used. The biogenic emissions had also two sources: ISPRA 2000 and 2005 over Italy and a global database (Guenther et al., 2005) for the other countries. The emissions fields also include the maritime activities, the ship emissions on the national and international sources and the port areas. The diffuse emissions and the minor point sources are distributed in the lowest model layers of FARM model (below 50 m) with 80% in the first 20 m above ground. The point sources such as industries, power plants, volcanoes, etc., are treated individually in FARM, considering the plume rise effect.

Initial and boundary conditions for chemical species of FARM model were derived from the simulations of EMEP model at European scale with spatial resolution of 50 km and time resolution of 6 h.

**RESULTS**

From meteorological point of view, the three years simulated have different atmospheric conditions. The temperature anomaly is ca. 0.9$^o$C for 1999, 1.4$^o$C for 2003 and 0.3$^o$C for 2005. The years 2003 and 2005 were characterised by drought conditions during spring and summer. In particular, the climate of 2003 during Northern Hemisphere summer, was exceptionally anomalous throughout the world (Rebetez et al, 2006), withheat wave leading to drought, crop shortfalls, and health crises in several countries (Levinson and Waple, 2004; Ciais et al., 2005). The year 1999 was “normal”, without extreme meteorological conditions, and is often used as reference year in meteorological studies.

The simulated ozone concentrations were compared to data from BRACE (Caricchia et al., 2003; ISPRA, 2010), a national database including information from the main monitoring networks distributed over the country (Fig. 1). The number of ozone monitoring stations had increase substantial from 1999 to 2005, but only 20 background stations had data available according to the requirements of 2008/50/EC Directive for the three years simulated. The analysis is carried out only for these stations since this work aims to compare the evolution of model performances over the years. These stations are located in different areas: 6 rural, 11 urban and 3 suburban.The station codes reported in Fig. 1 are those used by AirBase (the European Air quality dataBase) since AirBase database is largely known.

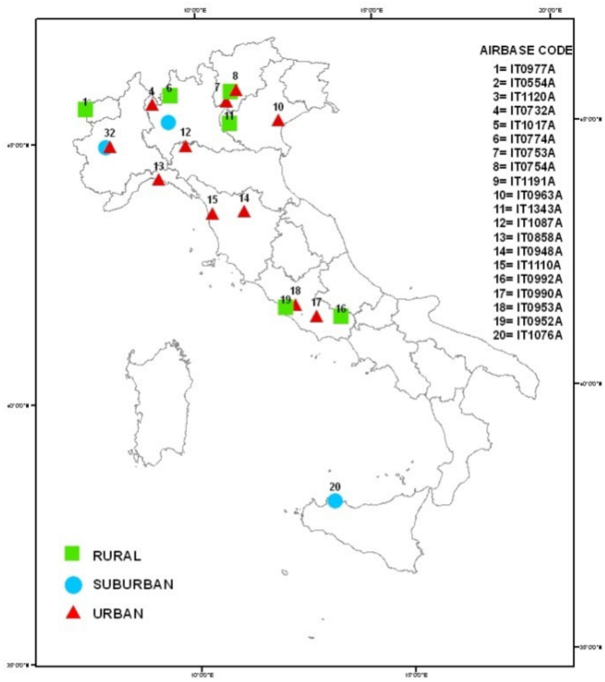


Figure 8. Background ozone monitoring stations.

Fig. 2 shows a comparison between averaged observed and simulated ozone concentrations for background stations located in rural, urban and suburban areas, and a comparison between averaged observed and simulated standard deviations for all stations. For some stations, the observations were lacking according to the Directive request of representative data, therefore the averaged observed concentration and standard deviation are set to zero.

For all years, the agreement between model results and measured data is within 50% model uncertainty requested by the 2008/50/EC Directive. The yearly simulated average ozone concentrations are between 45 and 80 $\mu$g m$^{-3}$ for all the stations while the observed ones vary between 10 and 100 $\mu$g m$^{-3}$. As expected, both model and observations have higher ozone values during the summer (July) than during the winter (January). For July, the monthly averaged ozone concentrations vary from 60 to 105 $\mu$g m$^{-3}$ and from 10 to 45 $\mu$g m$^{-3}$ for January. The best agreement between simulated and observed concentrations is obtained at rural and suburban stations, while the model has a slight tendency for overestimation at urban stations. As already mentioned by Vautard et al. (2007) as a characteristic AQ models feature, the simulated standard deviations are smaller than the observed ones for all three years since the models are still not able to reproduce the daily variability. From the analyses of these statistical indicators, no relevant differences in model performances appear from year to year or from summer (July) to winter (January).

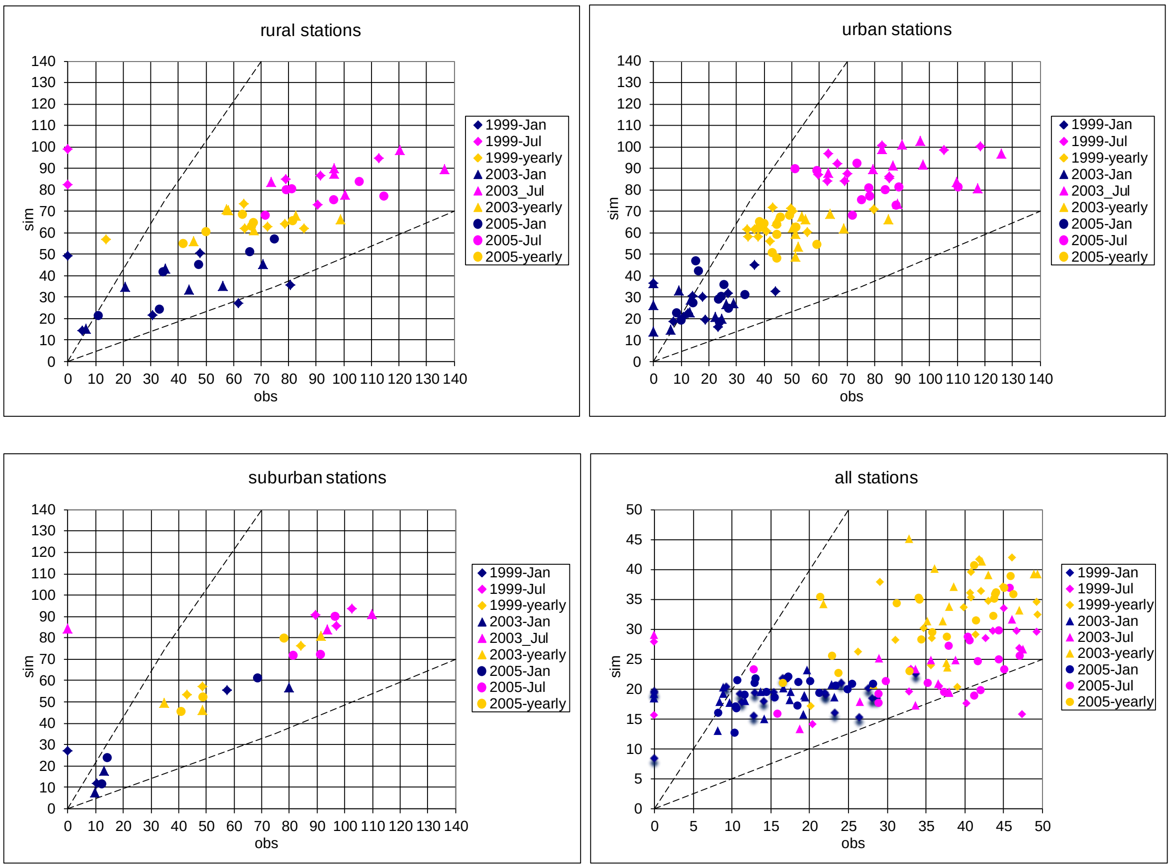


Figure 2. Comparison between averaged observed and simulated ozone concentrations (μg $m^{-3}$) at rural, urban and suburban stations, and comparison between averaged observed and simulated standard deviations at all stations.

Fig. 3 shows the mean normalised bias error (MNBE) at the stations for the three years. When the data available at station were not enough to allow the calculation of the score according to the 2008/50/EC Directive, the bar is missing. For both yearly and monthly MNBE, a substantial decrease is observed at most of the stations from 1999 to 2003 and 2005. One possible explanation is the many progress achieved by the emission inventories in the last years. For 2003 and 2005, the model fulfils US-EPA (US-EPA, 2005) criteria: MNBE is lower than 15% for all the stations. It can be also noted that MNBE has lower values at rural and suburban stations than at urban ones and during summer (July) than during the winter (January).

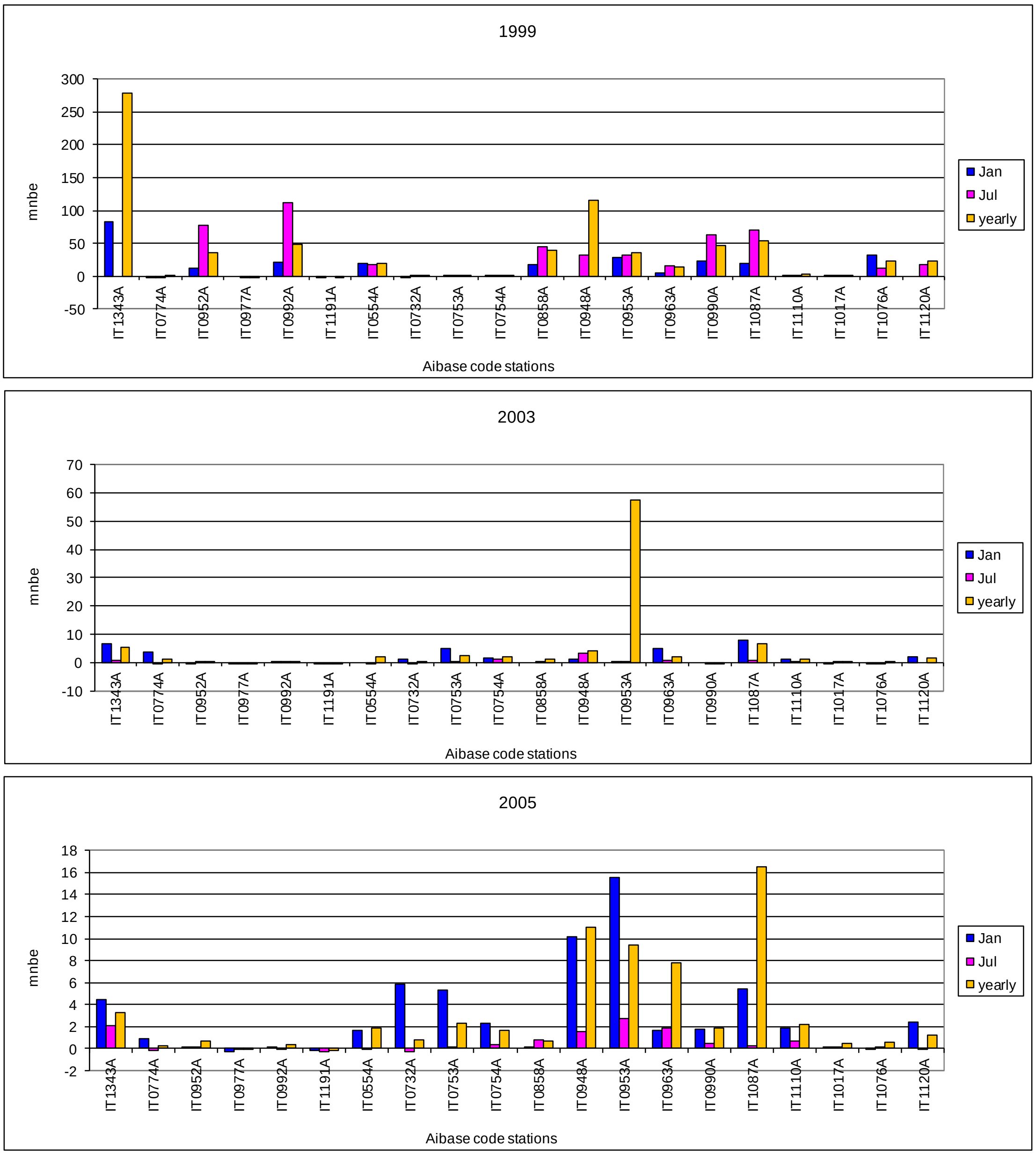


Figure 3. MNBE at Airbase stations shown in Fig. 1 for the years 1999, 2003 and 2005. The stations are in the following order: rural (6), urban (11) and suburban (3).

The Relative Directive Error was computed at each station according to "Guidance on the use of models for the European Air Quality" (2010) and the maximum value found at 90% of the available stations (MRDE) is reported in the Table 1 as a function of station area for the three years. This mathematical formulation of model uncertainty is well below the value of 50 % requested by the 2008/50/EC Directive and shows little variation with the year and the area type where the station is located. According to this statistical score, the model shows similar performances for the years 1999 and 2005, slightly better than the ones for the year 2003.

Table 6. MRDE as a function of station area for the years 1999, 2003 and 2005.

| Year | rural | urban | suburban |
|---|---|---|---|
| 1999 | 19.2 | 13.0 | 15.7 |
| 2003 | 20.5 | 22.7 | 14.8 |
| 2005 | 16.5 | 13.3 | 12.2 |

All the AQ scores investigated in this work show no dependency on station height (not shown here).

**CONCLUSIONS**

This study presents a first multiyear operational evaluation of ozone predictions with the atmospheric modelling system (AMS) of MINNI project over Italy. The comparison of simulated and observed ozone concentrations, and the other statistical scores calculated here shows that the AMS performance characteristics is comparable to that of similar modelling systems exercised in Europe and the values of statistical scores are generally well below the model uncertainty requested by 2006/50/EC Directive. The ability of the modelling system to reproduce ozone concentration also depends on the station area (e.g. suburban, urban, rural), on the period and year considered. This analysis clearly shows an improvement of the model performances in the last years and better performances at rural and suburban stations that at urban ones.

Further investigations will be carried out to understand the dependency of model performances on orography around the station since no clear dependency was found on station altitude.

**ACKNOWLEDGEMENTS**

This work is part of the MINNI (Integrated National Model in support to the International Negotiation on Air Pollution) project, funded by the Italian Ministry for Environment and Territory and Sea and carried out by ENEA.

**REFERENCES**

ARIA/ARIANET, 2008: Emission Manager – Processing system for model-ready emission input - User's guide, Rapport ARIA/2008.99.

Caricchia A.M, L. Merluzzi, A. Scaramella and L. Vaccaro, 2003:La banca dati nazionale di qualità dell'aria. Proc. of 7th National Conference of Environmental Agencies. APAT-ARPAL. ISBN – 88-448-0131-0.

Carter, W.P.L.,1990: A detailed mechanism for gas-phase atmospheric reactions of organic compounds. *Atmospheric Environment*,**24A**, 481-518.

Ciais, P., M. Reichstein, N.Viovy, A. Granier, J. Ogee, V. Allard, M.Aubinet, N.Buchmann, C.Bernhofer, A. Carrara, F.Chevallier, N.De Noblet, A. D. Friend, P. Friedlingstein, T. Grűnwald, B. Heinesch, P. Keronen, A. Knohl, G. Krinner,D. Loustau, G. Manca, G.Matteucci, F. Miglietta, J. M. Ourcival, D.Papale, K. Pilegaard, S. Rambal, G. Seufert, J. F. Soussana, M. J. Sanz, E. D. Schulze, T.Vesala, and R.Valentini, 2005: Europe-wide reduction in primary productivity caused by the heat and drought in 2003, *Nature*, **437**, 529–533.

Cotton, W.R., R.A. Pielke, R.L., Walko, G. E.Liston, C. J.Tremback, H.Jiang, R. L.Mc Anelly, J. Y.Harrington, M. E.Nicholls, G. G. Carrio and J. P. McFadden, 2003: RAMS 2001 current status and future directions. *Meteorology and Atmospheric Physics*,**82**, 5-29.

Council Directive 96/62/EC of the European Parliament and of the Council of 27 September 1996: On ambient air quality assessment and management (The Framework Directive). From the Official Journal of the European Communities, 21.11.1996, En Series, L296/55.

Council Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008: On ambient air quality and cleaner air for Europe (The Framework Directive). From the Official Journal of the European Communities, 11.06.2008, En. Series, L152/51.

Denby B.(ed.), 2010:*Guidance on the use of models for the European Air Quality Directive*. ETC/ACC report Version 6.2.

EEA, 2007: Air pollution in Europe 1990–2004. EEA Report, No. 2/2007.

Guenther A., C. N. Hewitt, D. Erickson,Ray Fall, C. Geron, T. Graedel, P. Harley, L. Klinger, M. Lerdau, W. A. Mckay,T. Pierce, B. Scholes, R. Steinbrecher, R. Tallamraju, J. Taylor and P. Zimmerman, 1995: A global model of natural volatile organic compound emissions, *Journal of Geophysical Research*, **100**, 8873-8892.

ISPRA 2000:http://http://www.sinanet.apat.it/it/inventaria

ISPRA 2005:http://http://www.sinanet.apat.it/it/inventaria

ISPRA, 2010: Annuario dei dati ambientali 2010. ISPRA. ISBN 978-88-448-04843-1.

Levinson D. H. and Waple A. M., 2004: State of the Climate in 2003, B. Am. Meteorol. Soc., 85(6),881–881, doi:10.1175/BAMS-85-6-Levinson.

Monforti, F. and A. Pederzoli, 2005: THOSCANE: A tool to detail CORINAIR emission inventories. *Environmental Modelling and Software*, **20**, 505-508.

Rebetez M., H.Mayer, O.Dupont, D.Schindler, K. Gartner, J. Kropp and A. Menzel, 2006: Heat and drought 2003 in Europe : a climate synthesis,*Ann. For. Sci.*,**63**, 569–577.

Silibello C., G. Calori, G. Brusasca, A. Giudici, E. Angelino, G. Fossati, E. Peroni and E. Buganza, 2008: Modelling of PM10 Concentrations Over Milano Urban Area Using Two Aerosol Modules. *Environmental Modelling and Software*, **23**, 333-343.

U.S. Environmental Protection Agency (US-EPA), 2005: Guidance on the use of models and other analyses in attainament demonstrations for 8-hour ozone NAAQS. EPA Report EPA-454/R-05-002, 128p.

Vautard, R., P.H.J. Builtjes, P. Thunis, C. Cuvelierd,Ã, M. Bedogni, B. Bessagnet, C. Honore, N. Moussiopoulosg, G. Pirovano, M. Schaap,R. Stern, L. Tarrasonj, P. Wind, 2007:Evaluation and intercomparison of Ozone and PM10simulations by several chemistry transport models over fourEuropean cities within the CityDelta project, *Atmospheric Environment*,**41**, 173–188.

Zanini, G., T.Pignatelli, F. Monforti, G. Vialetto, L. Vitali, G. Brusasca, G. Calori, S. Finardi, P. Radice and C. Silibello, 2005: The MINNI project: an integrated assessment modelling system for policy making, MODSIM 2005, Melbourne, In. *Zerger, A. and Argent, R.M. (eds.) MODSIM 2005 Int. Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand*, 12–15 Dec 2005, ISBN: 0-9758400-2-9, pp 2005–2011.