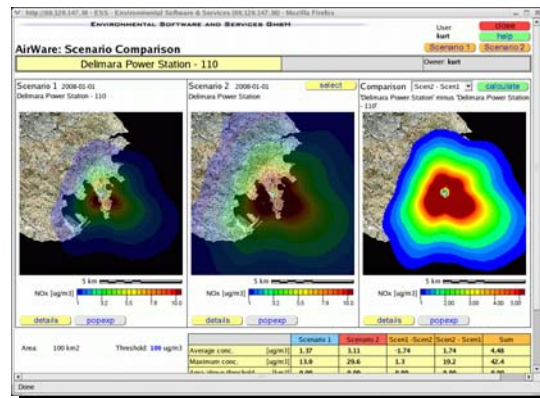
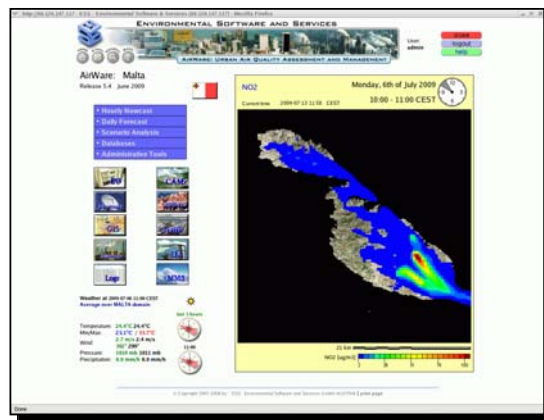


# AIR DISPERSION MODELS OF NO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, METALS AND BENZO-A-PYRENE FROM DELIMARA POWER STATION

The proposed model solution for the dispersion modeling around the Delimara Power Stations (current and projected future emissions for a 144 MW upgrade) will use a system of several interlinked, cascading and nested grid models to cover the necessary combinations of spatial and temporal resolutions for regulatory compliance (2008/50/EC and 2004/107/EC).

The proposed model system (part of an AirWare demo configured for Malta within the framework of EUREKA E! 3266 WEBAIR) ) includes:

- MM5 for the calculation of detailed, distributed (hourly, one km resolution) local meteorology, re-analysis run from NCEP GFS data sets, that include local meteorological data for data assimilation (objective methods);
- CAMx, nested grid Eulerian model including PM<sub>10</sub>/PM<sub>2.5</sub>, at hourly resolution for larger local domains (all of Malta, larger domain with both of the Power stations, interaction between Delimara and Marsa); CAMx will be run on an annual basis (hourly time step, 250 m resolution, and for several most common/worst case episodes of 5 days each at 100 m resolution);
- AERMOD, regulatory Gaussian model, with arbitrary spatial resolution (possible display resolution on a regular grid down to 5 m or any number of arbitrarily located simulated monitoring points) but based on the assumption of a homogeneous and constant wind field for each run assumed to be in steady state; for a wind speed of 3 m/s, this makes a model domain to about 6 km downwind feasible for an assumed 1 hour averaging period; AERMOD can be run for annual results (on an hourly basis, i.e., 8,760 hourly model runs per year) to compute the averaging periods necessary (see Table 1 below based on 2008/50/EC Annex XI, and <http://ec.europa.eu/environment/air/quality/standards.htm> and follow-up: [http://ec.europa.eu/prelex/detail\\_dossier\\_real.cfm?CL=en&DossierId=193497](http://ec.europa.eu/prelex/detail_dossier_real.cfm?CL=en&DossierId=193497) for PM<sub>10</sub>, PM<sub>2.5</sub>, benzene and lead and other metals regulated.



Particulates (PM 10) in AERMOD (current release version 09292) can be represented by either

- Specifying up to 20 particulate size categories defined by average diameter, mass fraction and density;
- Defining the mass fraction below 2.5 micron, and the mean diameter in this class.

Please note that the particle size distribution definitions can be made independently for each PM10 source.

Substance	Averaging period
Sulphur dioxide	One hour, one day
Nitrogen dioxide	One hour, calendar year
Benzene	Calendar year
PM 10	One day
PM 2.5	Three year average
Lead, As, Cd, Ni	Calendar year
PAH	Calendar year

- INPUFF, a dynamic combined Lagrangian and Gaussian plume model with arbitrary resolution (down to 5 m) which depends, however, on the detail of the (diagnostic) wind field interpolation between 2 min, output time steps from MM5, interpolation from the 3 km resolution to 5 m, based on a roughness characteristics of surface, and a 30m spatial resolution DEM. INPUFF is run with a 1-5 minute output time step for short episode of 24 hours max, e.g., for the representation of highly transient meteorological conditions (sea breeze) or changing emission conditions (boiler startup phase). INPUFF can also be used for mobile sources such as large ships, entering, berthing for loading, and leaving a harbor.
- TIMES, a 3D CFD code for selected episodes, can be run at 5 m resolution with fully 3D representation of building obstacles and corresponding 3D wind field calculations.



1. Simple, intermediate and complex terrain, including over stretches of sea.

The proposed models cover the entire range from simple topography and roughness based characterization of turbulence to a prognostic (MM5), and diagnostic (AERMET, high-resolution interpolation for INPUFF) to fully 3D CFD (Computational Fluid Dynamics) representations. Please note that these representation are not independent from spatial and temporal resolution of the respective models. Terrain representation uses either the (interpolated where necessary) 30 m horizontal resolution DEM based on ASTER satellite data (<http://free-gis-data.blogspot.com/2009/04/aster-global-digital-elevation-model.html>),

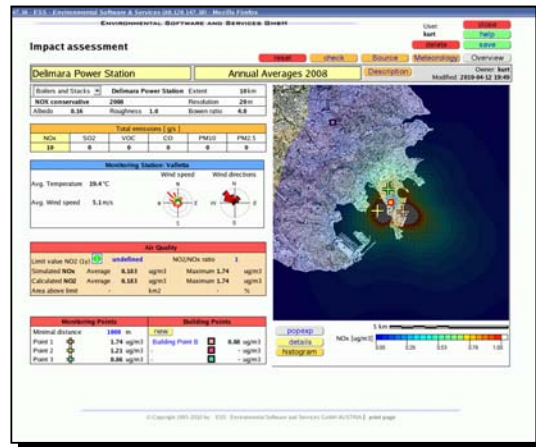
or a detailed 3D representation of the power plants immediate surrounding with 3D building representation derived from a minimally 1:5,000 local city map and estimated building height for the CFD near-field model.

2. The ability to use real-time meteorological data and ambient (background) pollutant concentrations for prediction of emissions.

All models can be run both with historical and re-time data; however, to obtain the long-term aggregation periods (e.g., for particulates with semi-annual and annual averages), the use of historical data is mandatory.

3. Continuous release modeling (depending on inputting of stack height, plume parameters, temperature, etc.).

All models either use dynamic emission data (stack measurements) or generate dynamic, time-variable emission in a pre-processor emission model using patterns (for monthly, daily, and hourly variations), e.g., for traffic emissions. Please note that while INPUFF and the CFD code can process dynamic emission down to 2 minute time steps, CAMx and AERMOD use hourly averages.



4. Screening of continuous or single releases in simple or complex terrain.

The models are run for arbitrary periods, and can represent continuous, time variable, or PUFF (highly transient or mobile) type of release. Please note that the Gaussian model AERMOD assumed constant emissions (as well as meteorological parameters) for each steady-state solutions; interpreted to represent hourly “episode”, the emission can vary on an hourly basis for consecutive runs of 24 hours a day, or 24\*365 hours for an annual run. All models but AERMOD use 3 D wind fields at various resolutions. AERMOD uses optional terrain corrections based on the AERMAP pre-processor. Mobile sources in PUFF are available for the representation of ships in and out of the harbor, or airplanes starting and landing at the nearby airport.

5. Industrial source complex modeling.

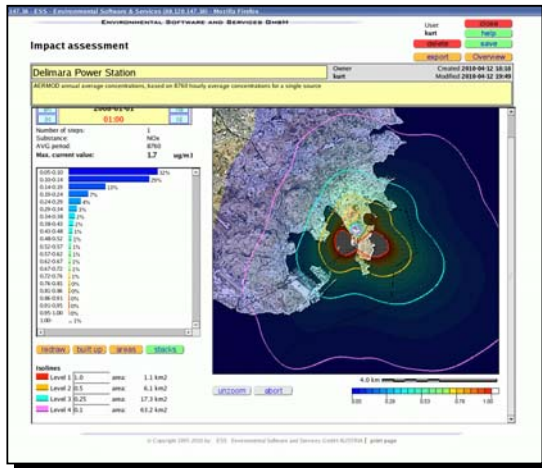
The models use either

- PIG (point in grid) complex elevated point source representations (CAMx);
- The full complement of stack related parameters and processes such as stack height, flue gas exit velocity and temperature, wakes and downwash;
- A fully 3D wind field:
  - diagnostically interpolated from the prognostic 3D model MM5
  - Calculated at 5 m resolution with the CFD code. Please note that this very high resolution, the CFD model requires

- A correspondingly detailed terrain characterization in 3D including building obstacles;
- Considerable computational resources; on an 8 core dual-processor, 3GHz 64 bit server, a model domain of 1 km<sup>2</sup> at a resolution of 5m can be simulated at approximately 0.5 real-time, i.e., to simulate a 24 hour period (internal computation time step about 10 sec) will require 10-12 hours of CPU time.

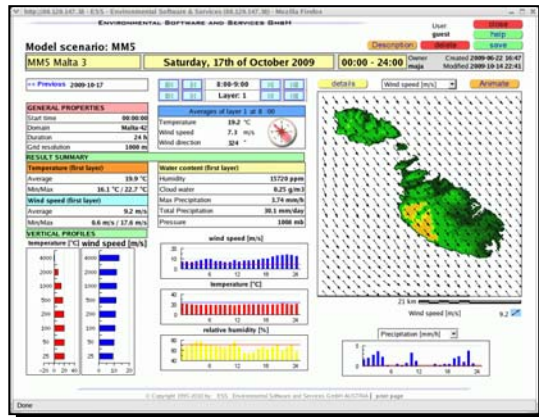
## 6. Graphics system for illustration of modeling results.

Model results are generated in graphical and numerical/tabular format as well as optional animations in mpg format. Graphical display uses color coded (with user defined ranges and colors) overlays (translucent or opaque, user defined iso-lines, numerical data at user defined points (building-points of arbitrary height (flag height), or as a spatial overlay of concentration over specific land use classes (e.g., built-up area for population exposure calculation with a user defined threshold).



## Models to be used:

- MM5: Dynamic 3D meteorological data are calculated using PSU/NCAR mesoscale model (known as MM5). MM5 is a limited-area, non-hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. The model is supported by several pre- and post-processing programs, which are referred to collectively as the MM5 modeling system. The MM5 modeling system software is mostly written in Fortran, and has been developed at Penn State and NCAR as a community mesoscale model with contributions from users worldwide. (Reference: <http://www.mmm.ucar.edu/mm5/mm5-home.html>) MM5 output is generated in three levels of grid nesting to a 3 km, hourly resolution that is further interpolated diagnostically for use CAMx down to a resolution of 1 km (standard), and possibly down to 100m.
- CAMx: The **C**omprehensive **A**ir quality **M**odel with **e**xtensions (CAMx) is an Eulerian photochemical dispersion model that allows for an integrated *one-atmosphere* assessment of gaseous and particulate air pollution (ozone, PM-2.5, PM-10, air toxics, mercury) over many scales ranging from sub-urban to continental. It is



designed to unify all of the technical features required of state-of-the-science air quality models into a single system that is computationally efficient, easy to use, and publicly available. The model code has a highly modular and well documented structure which eases the insertion of new or alternate algorithms and features. CAMx simulates the emission, dispersion, chemical reaction, and removal of pollutants in the troposphere by solving the pollutant continuity equation for each chemical species (I) on a system of nested three-dimensional grids. The Eulerian continuity equation describes the time dependency of the average species concentration (cI) within each grid cell volume as a sum of all of the physical and chemical processes operating on that volume. The governing equations are expressed mathematically in terrain-following height (z) coordinates. It considers a horizontal wind vector, net vertical entrainment rate, multiple vertical layers, atmospheric density, and turbulent exchange (or diffusion). The terms on the right-hand side represents horizontal advection, net resolved vertical transport across an arbitrary space- and time-varying height grid, and sub-grid scale turbulent diffusion. Chemistry is treated by simultaneously solving a set of reaction equations defined from specific chemical mechanisms. Pollutant removal includes both dry surface uptake (deposition) and wet scavenging by liquid precipitation (rain). CAMx can be used reliably to a resolution of 1000 m, in special cases to 100 m.

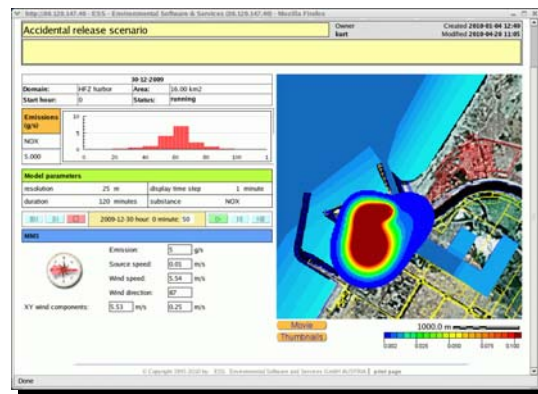
Current release: 5.10 <http://www.camx.com/over/camx51.php>

Version 5.10 provides the following additional capabilities and features over previous versions:

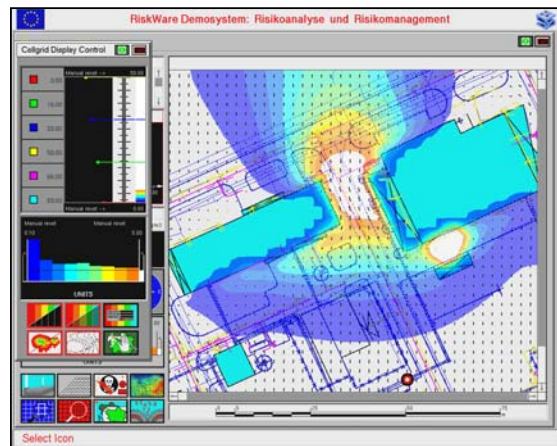
- The Euler-Backward Iterative (EBI) chemistry solver replaces the CMC fast chemistry solver. EBI provides improved accuracy with similar speed compared to the CMC solver.
- The High-order Decoupled Direct Method (HDDM) for source sensitivity has been added as a new Probing Tool. The DDM probing tool is retained as a separate option. HDDM provides both first and second order sensitivity coefficients for initial and boundary conditions, emissions, and reaction rate constants, leading to more accurate estimates of model response to large changes in input parameters.
- The Asymmetric Convective Mixing Algorithm, Version 2 (ACM2) has been added as a new vertical diffusion option and can be used as an alternative to the original K-theory approach. Meteorological interface programs (e.g., MM5CAMx, WRFCAMx, and RAMSCAMx) have been updated to include an option to generate vertical diffusivities for ACM2. ACM2 works with all probing tools except Process Analysis IPR.
- The Reactive Tracer Chemical Mechanism Compiler (RTCMC) has been added as a new RTRAC option. The CAMx Reactive Tracer (RTRAC) Probing Tool can be used to simulate reactive tracers, such as air toxics. The RTCMC is a new front-end to RTRAC that reads (and solves) a user-defined chemical mechanism for reactive tracers. The RTCMC permits much more complex tracer chemistry than RTRAC.
- Radical concentrations can now be output to the CAMx average file for subsequent analysis or use. Previously, only "state" species names in the CAMx chemistry parameters file could be selected for output. CAMx now allows mechanism-specific (CB4, CB05, or SAPRC99) radical concentrations to be output to the same files.
- Deposited amounts of OSAT/PSAT source apportionment tracers can now be written to a new OSAT/PSAT deposition output file, similar to the core model deposition file. A new flag is available in the SA section of the CAMx namelist control file to turn on deposition output of tracers.

- AERMOD, USEPA preferred/recommended regulatory model, see: [http://www.epa.gov/scram001/dispersion\\_prefrec.htm](http://www.epa.gov/scram001/dispersion_prefrec.htm)  
AERMOD is a steady-state Gaussian plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. The American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC) was formed to introduce state-of-the-art modeling concepts into the EPA's air quality models. Through AERMIC, a modeling system, AERMOD, was introduced that incorporated air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.  
There are two input data processors that are regulatory components of the AERMOD modeling system: AERMET, a meteorological data preprocessor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP, a terrain data preprocessor that incorporates complex terrain using Digital Elevation Data. As of December 9, 2006, AERMOD is fully promulgated as a replacement to ISC3,

- INPUFF is a Gaussian (dynamic, non-steady state) puff model for moving or stationary point sources with strongly variable or intermittent release characteristics, or transient weather (wind field) conditions like in mountainous or coastal locations (sea breeze). INPUFF that simulates the atmospheric dispersion of neutrally buoyant or buoyant chemical releases. A series of evolving (Gaussian) puffs are transported in a wind field in a Lagrangian approach. The model accounts for point sources and a release duration that is either finite or continuous. INPUFF can account for plume rise, due to buoyancy and momentum, as well as stack tip downwash. INPUFF allows the user to specify the location and dimension of a receptor grid where concentration estimates will be calculated downwind of the release. Concentration estimates are based upon the Pasquill-Gifford dispersion coefficients with modifications to account for initial dispersion and buoyancy-induced dispersion (if applicable) and a user-specified averaging time.  
[http://www.ofcm.gov/atd\\_dir/pdf/inpuff.pdf](http://www.ofcm.gov/atd_dir/pdf/inpuff.pdf)



- TIMES, fully 3D computational fluid dynamic (CFD) code for very high resolution, near field calculations in complex terrain with 3D obstacles. TIMES was developed in collaboration with the Polish Academy of Sciences (Holnicky 1978) and the Institute for Mathematical Modeling of the Russian Academy of Sciences within the EUREKA project E!1388 AIDAIR (Suzan, 2006).



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