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Modeling area, line and point sources for ISC model: methodology, computer interface and case studies

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ABSTRACT

In the paper a methodology for preparing air pollutant emissions to input for Environmental Protection Agency Industrial Source Complex model will be presented. The methodology used for emission inventory preparation at local level is first introduced. The inventory introduce point, linear/nodal and diffuse sources, a methodology to disaggregate the diffuse sources emissions on grid and a methodology for disaggregate the emissions on hourly basis.

Next a specific computer tool to interface emission inventory data base with ISC model will be introduced.

Finally a lot of case studies will be discussed.

INTRODUCTION

Industrial Source Complex dispersion model[1] from United States Environmental Protection Agency (US EPA) has been widely used in the last year in Italy for local air quality management and for environmental impact analysis.

In the frame of preparation of an Air Quality Management Plan the use of the model is inserted in the following activities:

- emissions inventory,
- use of models to estimate emissions in particular topics (road transport, airports, forests, ports and navigation lines, forest fires),
- air quality and meteorological data analysis,
- emissions projection without emissions reduction measures,
- classification of territory and analysis of priority in remediation actions,
- planning of measures to reduce emissions,
- definition of scenarios of reduction,
- emissions projection in plan scenarios,
- use of air quality dispersion and photochemical models in the actual situation and in future with and without plan application.

In the case of environmental impact analysis the use of the model is inserted in the following activities:

- emissions inventory in the *"ante operam"* scenario, also with use of models in particular topics (road transport, airports, forests, ports and navigation lines, forest fires),
- meteorological data analysis for input to dispersion model,
- use of dispersion model in *"ante operam"* scenario,
- comparison between air pollutants monitored concentrations and model results for model validation,
- evaluation of the emission of the project (plant, transport infrastructure, landfill, etc.) at project year (*"post operam"* scenario),
- emissions projection of existing sources at project year (*"post operam"* scenario),
- use of dispersion model in *"post operam"* scenario.

Usually, for planning purpose, the model was used in its *long term* option to evaluate the average pollution on selected areas. However, in some cases, also the *short term* behaviours of pollution can be of interest; in these cases the short term model was been used.

In the following the preparation of emissions for modelling, the user interface with the model and some case studies are discussed.

EMISSIONS INVENTORY

The emission inventory activity in Italy started in 1980 at a national level[2] and has been applied at the local level since 1990[3]. The preparation of air pollutants emissions inventories allows characterization of the different role played by the various emission sources and consequently represents a basic tool to define criteria for air quality management plans[4]. A recent paper reports a balance of air quality management activities in Italy[5].

Sources categories

The nomenclature used at the local level follows the guidelines of the European Commission CORINAIR working group[6]. CORINAIR nomenclature includes about 200 activities grouped in 11 groups:

- Combustion in energy and transformation industries (stationary source),
- Non-industrial combustion plants (stationary sources),
- Combustion in manufacturing industry (stationary sources),
- Production processes (stationary sources),
- Extraction and distribution of fossil fuels and geothermal energy,
- Solvent and other product use,
- Road transport,
- Other mobile sources and machinery,
- Waste treatment and disposal,
- Agriculture,
- Other sources and sinks .

The sources are generally split in four categories: main point sources, minor point sources, area sources and linear/nodal sources. The fixed sources for which the total annual emissions of one pollutant is larger than a fixed threshold value (Table 1), are considered main or minor point sources. Linear/nodal sources correspond to the main communication ways (roads, rivers, railways, and seaways) and nodes (ports, airports) and generally all the highways, all the main extra-urban roads and all the main ports and airports are included. All the other sources are defined as area sources.

Table 1: Thresholds for Main and Minor point Sources

Pollutant	Minor point sources	Main point sources
Carbon Monoxide	50 t/year	250 t/year
Other main pollutants	5 t/year	25 t/year
Heavy metals	50 kg/year	250 kg/year

Actual and future emissions evaluation

For main point sources, information is gathered through a questionnaire that allows collection of general data (identification, location, etc.), structural data (stacks and units characteristics) and quantitative data (pollutant concentrations at the stacks, pollutant emissions, actual production, fuel consumptions). For minor point sources information is gathered through a simplified questionnaire with general data, pollutant emissions and actual production.

Area sources (for instance, domestic solvent use and natural sources) are evaluated on a geographical basis, inside each municipal administrative unit, using statistical or survey data on suitable activity indicators (for example: paint consumptions, fuel consumptions) and emission factors.

Within the realization of the air quality management plan, the projections of emissions of air pollutants are carried out[7]. Future area and line emissions are evaluated from emission at base year, projection parameter for activity indicator and projection parameter for emission factor. For point sources, future emissions are as in area and line case but projection parameter for the specific unit of a single facility, are also used where applicable.

Representation of the sources for the model

In the last years, the US EPA ISCLT dispersion model[1] is used in actual situation, for comparison with air quality network data, and in future situations, with and without plan measures, to evaluate the effect of the actions[8].

The methodology for preparing air pollutant emissions to input for EPA ISC model was developed, improved and tested in different applications. The methodology is based on the different modeling of Main Point sources, Minor Point sources, not elevated area sources (traffic, agricultural, ..), elevated area sources (residential combustion, industrial, …). For all sources except Main Point Sources, a lot of default parameters (dimensions, heights, etc.) are introduced.

The model receives (Table 2) as input the different sources of atmospheric pollution inside the areas:

- main point sources, modeled giving in input to the model, besides the emissions, the physical characteristics of the emissions themselves (height of the release, temperature of gases, speed of gases, inside diameter of the stack);
- minor point sources, modeled as 50 m x 50 m squared area sources and height 10 m;
- low line/nodal sources (line/nodal sources of road transport CORINAIR group), modeled as 1 km x 1 km squared area sources with height 0,5 m;
- high line/nodal sources (line/nodal sources of other mobile sources CORINAIR group), modeled as 1 km x 1 km squared area sources with height 10 m;
- low area sources (area sources of the following CORINAIR groups: extraction and distribution of fossil fuels and geothermal energy, road transport, other mobile sources and machinery, waste treatment and disposal, agriculture), modeled as area source on a 1km x 1km grid with height 0,5 m;
- high area sources (area sources of the following CORINAIR groups: non-industrial combustion plants, combustion in manufacturing industry, production processes, solvent and other product use, other sources and sinks), modeled as area source on a 1 km x 1 km grid with height 10 m.

Table 2: Sources categories model representation

Source category	Geographical representation	Physical representation
main point sources	point	specific of source
minor point sources	50 m x 50 m squared area	height 10 m
low line/nodal sources	1 km x 1 km squared area	height 0,5 m
high line/nodal sources	1 km x 1 km squared area	height 10 m
low area sources	1 km x 1 km squared area	height 0,5 m
high area sources	1 km x 1 km squared area	height 10 m

Geographic representation of sources

Main point sources are singularly located on territory with plant coordinates. Minor point sources are located, by means of coordinates, at 50 m x 50 m squared areas. Line/nodal sources are allocated to the 1 km x 1 km grid on the basis on topological consideration.

Area emissions are allocated on a square grid mesh with the methodology of proxy variables. When municipal value is known, it is distributed on the square grid mesh according to the two following cases:

- the data to be distributed is an extensive variable and it is proportional to coverage of a thematism on single mesh (for example: urban zones); in this case the weight of the mesh coverage on total municipal coverage is utilized;
- the data to be distributed is an intensive variable and depends on the presence of the activity estimated at municipal level on the single mesh (for example the presence of a small industry); in this case the weight of the mesh activity on total municipal activity, is utilized.

The emissions on mesh k are obtained as:

$$E_{ik} = \Sigma_j \left(E_j P_{lkj} / \Sigma_k P_{lkj}\right)$$

where: i, activity; j, municipality; k, mesh; l, proxy variable appropriate to activity i; E_j, total emission; P_{lkj}, value of the proxy variable.

Example of proxy from CORINE Land Cover are: urban; agricultural; industrial and commercial; modeled artificial; mining, permanent crops, arable land, deciduous forests; coniferous forests; airports; landfills.

Temporal Disaggregation

Annual emissions are at first evaluated. Once annual emissions have been evaluated, to allow the application of short term diffusion model to study short-time pollutant dispersion, it is necessary to obtain an estimate of their hourly, monthly and daily distribution. For main point sources temporal disaggregation may be evaluated directly at the plant. Other sources disaggregation is estimated through the use of corrective factors that have a similar rule of the proxy variable in the case of spatial distribution (for example: typical working hours, wintertime, temperature, monthly selling of fuels, etc.).

SOFTWARE

The computer interface to ISC models is integrated in the computer models system AIR SUITE developed by Techne consulting. In the following a brief description of the system is reported as an introduction to ISC model interface.

Air suite software

The air suite system schema is reported in Figure 1. The information system has been implemented on a network of Pentium computers with large extended RAM running Windows NT, Oracle or Access, Arc View or MapInfo, and Statistica.

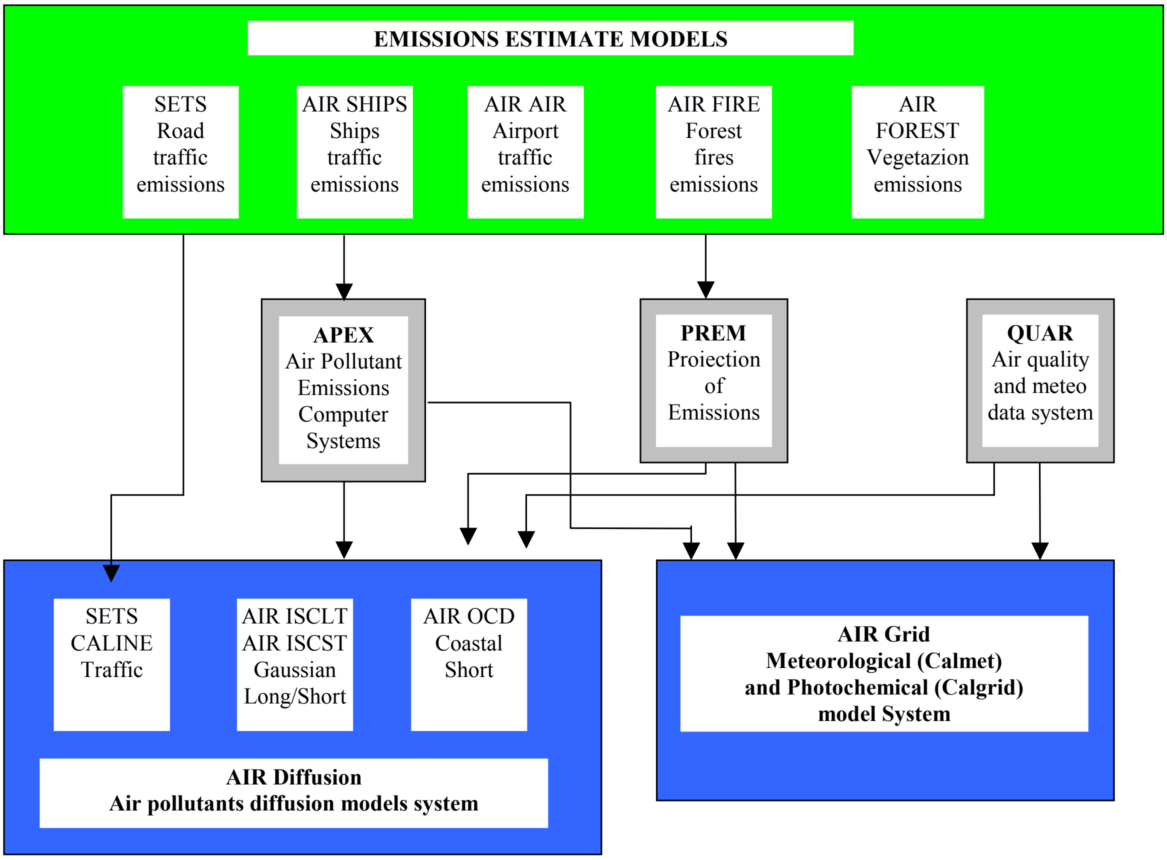

Figure 1: Structure of information system for air quality management planning

The following tools are contained in the information system:

- *APEX*, air pollutant emissions computer system, in Windows/ORACLE environment[9,10,11,12,12,13]; the system contains an emission factors data base and tools and data to estimate grid and municipal emissions from more aggregated data[14], the system uses Arc View or MapInfo for thematic map;

- software models[13], in Windows/ ACCESS environment, interfaced with the *APEX* system in an unique environment: *SETS*, for road traffic; *AIR AIR*, for airports; *AIR FOREST*, for forest; *AIR SHIPS*, for ports and navigation lines *AIR FIRE*, for forest fires
- PREM[13], a software model for emissions projections and to evaluate emission control measures in Windows/ORACLE environment: the system contains a socioeconomic projection factors database, a technologic projection factors database and some tools to project emissions; integrated with the *APEX* system;
- QUAR, a computer system for air quality data management and analysis; *QUAR* is developed in Windows/ORACLE environment and use Statistica software to analyze data and ArcView or MapInfo for thematic map;
- SETS/D, a computer interface to SETS and CALINE4 models to evaluate air pollution dispersion near a road;
- AIR_ISC, a computer interface to ISC Long Term and ISC Short term integrating data coming from APEX and QUAR computer systems;
- AIR OCD, a computer interface to OCD model integrating data coming from APEX and QUAR computer systems;
- AIR_GRID, a computer interface to CALMET and CALGRID models integrating data coming from APEX and QUAR computer systems.

AIR_ISC interface

In Figure 2 is reported the flux of information in the ISC interface.

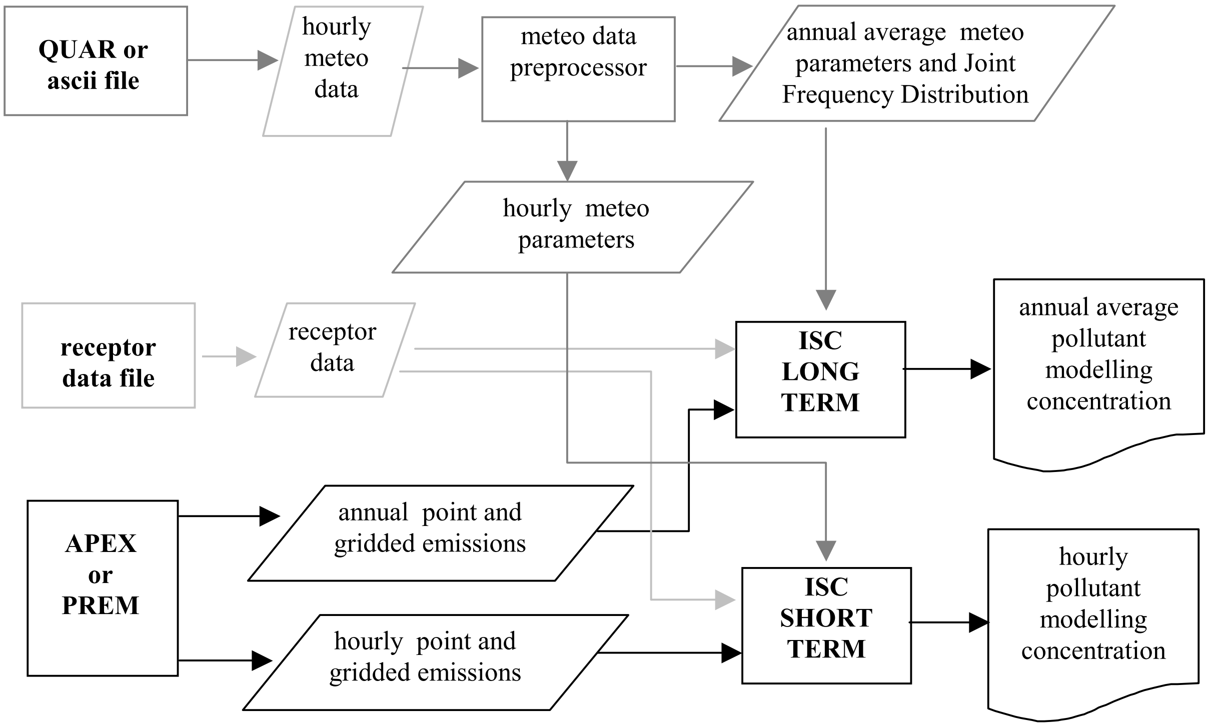

Figure 2 - ISC Long Term interface information flux

The interface is developed in Windows environment with object-oriented Visual Basic language and is available with ORACLE (as regard emission inventory and meteorological data) and ACCESS (as regard model parameters) database. An application in the model environment is called simulation and each model consists in a lot of simulation.

In Figure 3 an example of interface to Long Term version is reported. The computer interface is designed to manage:

- simulation (each application of the model characterized by associated emissions, meteo and receptors scenario);
- emissions scenario (a specific extraction from emissions database or from emissions projections database for a given area);
- meteorological scenario (meteorological data from QUAR or ASCII file);
- receptors scenario (a selection of receptors defined by the user);
- alphanumerical output (show the model outputs);
- maps (gridded Mapinfo or Arcview maps or Surfer isolines).

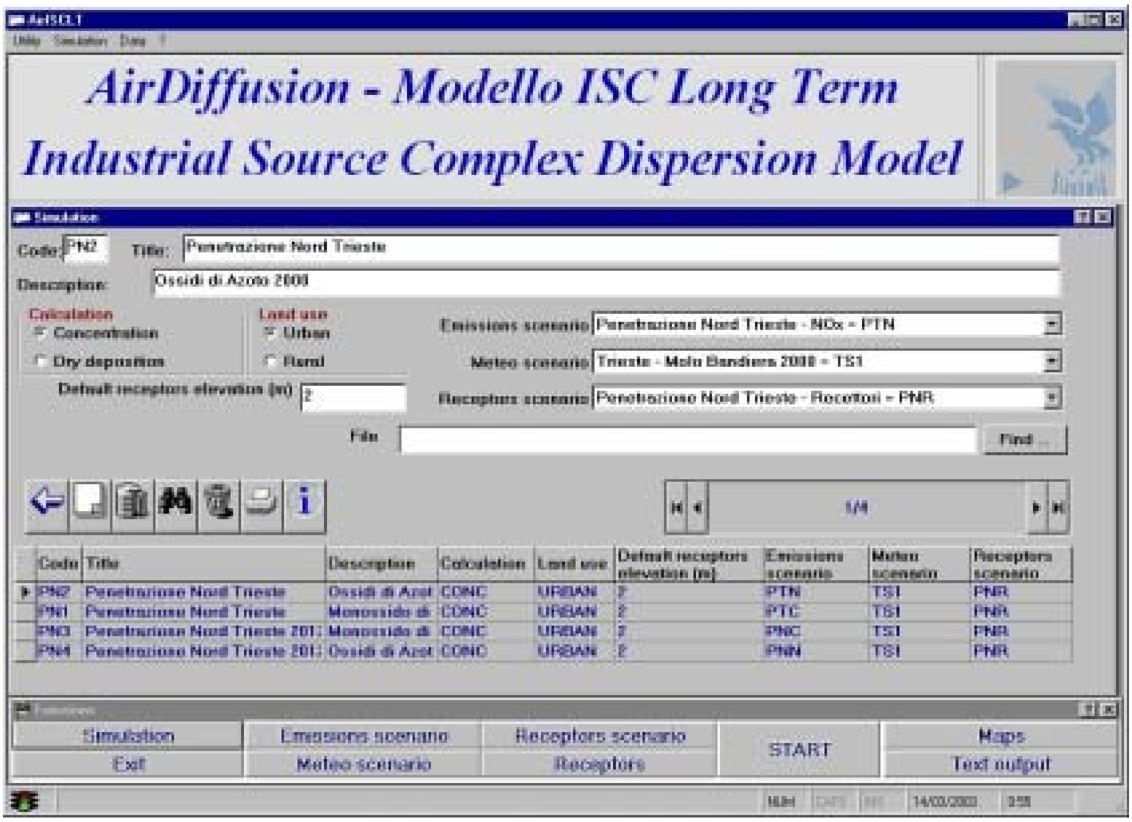

Figure 3 - AIR ISCLT system: principal menu

MODEL PERFORMANCE EVALUATION

The results of the model are valued on 1 km x 1 km squared grid. Besides the concentrations have been valued in an area of ray 20 meters around the air quality monitoring station specifying the height of the receptors on the level of the ground.

To evaluate the accuracy of the model the following statistical indicators[16] can be used:

- Normalized mean standard error $NMSE=\langle (C_s-C_m)^2\rangle/\langle C_s\rangle*\langle C_m\rangle$
- Fractional Bias $FB=2\ (\langle C_s\rangle-\langle C_m\rangle)/(\langle C_s\rangle+\langle C_m\rangle)$

where C_s is the model concentration and C_m the air quality monitoring station concentration.

CASE STUDIES

The model was widely used at local level in the frame of environmental impact analysis and at regional level in the frame of emissions inventories and air quality management plans. The meteorological data are elaborate from the data of the meteorological stations. The results of model application will be presented and discussed comparing data with monitoring by means of statistical indicators, in the Long Term case.

In Table 3 an example of application of the model in Trento region air quality planning is reported; in Figure 4 an example of maps for Friuli Venezia Giulia Region is reported.

Table 3: Example of ISCLT model results for Trento Region case study

Monitoring station	Measured data µg/m^3		Model computed data µg/m^3					
	2000		2000		2015 do nothing		2015 plan preparatory study	
	SO_2	NO_2	SO_2	NO_2	SO_2	NO_2	SO_2	NO_2
Trento – Gardolo	7	49	3	44	2	20	2	18
Trento – Porta Nuova	4	60	6	44	5	24	4	20
Trento – S. Chiara	6	41	6	43	5	25	4	21
Trento – Via Veneto	7	45	6	46	5	25	4	21
Grumo S. Michele	5	44	3	57	2	26	2	22
Borgo Valsugana	4	33	3	22	3	17	3	17
Rovereto – Posta	6	40	11	43	10	23	9	22
Rovereto – Benacense	5	50	12	45	11	24	9	24
Riva del Garda	7	42	12	49	11	34	10	31

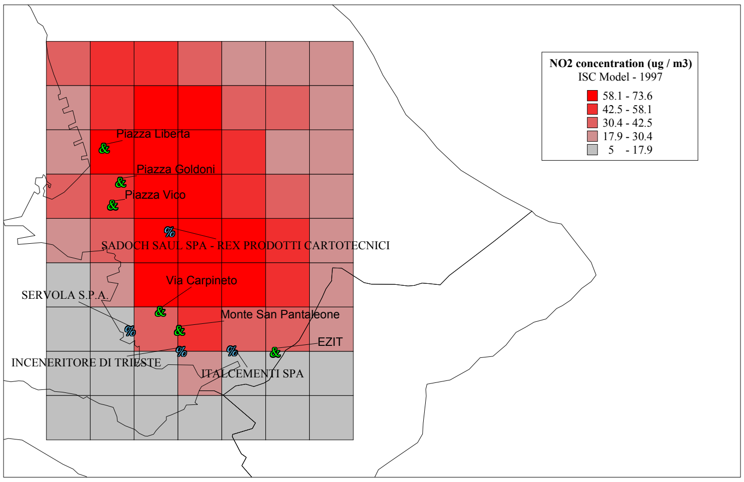

Figure 4: Example of map of ISCLT model computed Nitrogen oxides concentration for Friuli-Venezia Giulia Region case study

In Table 4 computed indexes are reported for selected pollutants and networks. In all the areas examined, the comparison, with statistical indexes, between the data calculated by the model and the values detected by the stations shows that the model can, in the long term, reconstruct the concentrations of air pollutants and can be efficiently used in air quality planning. In the 1995 case the model use only area (0.5 high sources) and point (stacks height) sources while in 2000 case the methodology of the present paper was used. A significant improvement for nitrogen oxides can be noted.

Table 4: Model performance indexes

Index	Trento network 1995		Trento network 2000		Test	
	SO_2	NO_2	SO_2	NO_2	Perfect	Good
NMSE	0.1	0.2	0.36	0.04	0	<1.0
FB	-0.2	-0.2	0.19	-0.03	0	0.5<FB<0.5

CONCLUSIONS

In the paper methodology, computer interface and case studies for modeling area, line and point sources for ISC model are discussed. The results of the case studies shown as a better representation of sources emissions from air pollutants emissions inventory can significantly improve model results, particularly in complex areas with pollutants emissions from multiple sources categories.

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