4.05 MODA – A HYBRID ATMOSPHERIC POLLUTANT DISPERSION MODEL

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DESCRIPTION OF THE MODA ATMOSPHERIC POLLUTANT DISPERSION MODEL

MODA is a Gaussian-hybrid atmospheric dispersion model, intended for regulatory applications, and designed to meet the following requirements:

- Ability to operate in complex terrain.
- Standard use of a refined description of turbulence.
- Operational efficiency (in terms of both speed and ease to change simulation parameters).
- Ease of integration in modelling interfaces.
- Output compatibility with the widely-used ISC3.

MODA can operate in two modes:

- A standard mode, in which the pollutant dispersion is treated as Gaussian, and
- An advanced mode, in which the hybrid relations are used to compute the pollutant concentrations.

In the standard mode, of special relevance in the context of environmental impact assessment, the pollutant concentration is calculated using two separate sets of relations for stable and convective situations.

Under stable conditions, concentration is modelled as

$$C(x,y,0;Q,h,u)=\frac{Q}{\pi\sigma_y\sigma_z u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right] \qquad (1)$$

where Q denotes the pollutant emission rate (g/s), h the stack tip height above ground (m), and u the wind speed (m/s).

Under convective conditions,

$$C(x,y,0;Q,h,u,z_i)=\frac{q(x,y,0;Q,h,u,z_i)}{\sigma_y u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (2)$$

where

$$q(x,y,0;Q,h,u)=\begin{cases}\dfrac{Q}{\pi\sigma_z}\left\{\exp\left[-\dfrac{1}{2}\left(\dfrac{h}{\sigma_y}\right)^2\right]+\exp\left[-\dfrac{1}{2}\left(\dfrac{2z_i+h}{\sigma_y}\right)^2\right]+\exp\left[-\dfrac{1}{2}\left(\dfrac{2z_i-h}{\sigma_y}\right)^2\right]\right\} & h\le 0.63z_i\\ \dfrac{Q}{\sqrt{2\pi}z_i}\left(1-\beta^2\right)\left[1+\beta^2+2\beta\cos\left(\pi\dfrac{h}{z_i}\right)\right] & 0.63z_i<h\le 1.08z_i\\ \dfrac{Q}{\sqrt{2\pi}z_i} & h>1.08z_i\end{cases} \tag{3}$$

with $\beta=\exp\left[-\dfrac{1}{2}\left(\pi\dfrac{\sigma_z}{z_i}\right)^2\right]$.

In both cases, the wind field is assumed uniform in space, and streamline coordinates are used, so that x represents downwind distance from the source, y the crosswind distance from the source, and z the vertical elevation; the dependence of concentration on downwind distance is indirect, occurring through the horizontal and vertical standard deviations.

Unstable conditions are detected by the decision predicate $H_0=0$. The turbulent sensible heat flux H_0 is read from the meteorological input, along with other turbulence and PBL parameters. At the moment, all of these can be directly measured by surface meteorological stations equipped with an ultrasonic anemometer and running eddy-covariance methods, with the only exception of the mixing height z_i. The latter has been estimated using Gryning-Batchvarova method. For stations where no ultrasonic anemometer still exists, estimation of turbulence parameters can be made by employing similarity relations, provided a minimum instrument set is operating in place.

MODEL VALIDATION

The overall MODA validation is a work in progress, whose final result is expected by end of April 2004.

The result evaluation is currently in progress, and its outcome will be included in the poster.

COMPARISON TO ISC3

MODA (operated in standard mode) has been compared to ISC3 in various natural and artificial situations.

The following graphs illustrate the two models' different behaviour against two artificial cases, differing for stack height (80m in case A, 20m in case B). In both cases, emission is markedly buoyant (release temperature 100 °C). Source position is identical in the two cases, with the single stack placed at the centre of a 10x10km test area. Meteorology is artificially generated, with wind exercising systematically all possible provenance directions; 5 simulated days are present, with an equal occurrence of stable and unstable conditions. The evaluation of concentration difference has been made on a grid of 101 nodes along x axis, and 101 along y axis; only the points where at least one of the ISC3 and MODA concentrations is greater than 0 have been used.

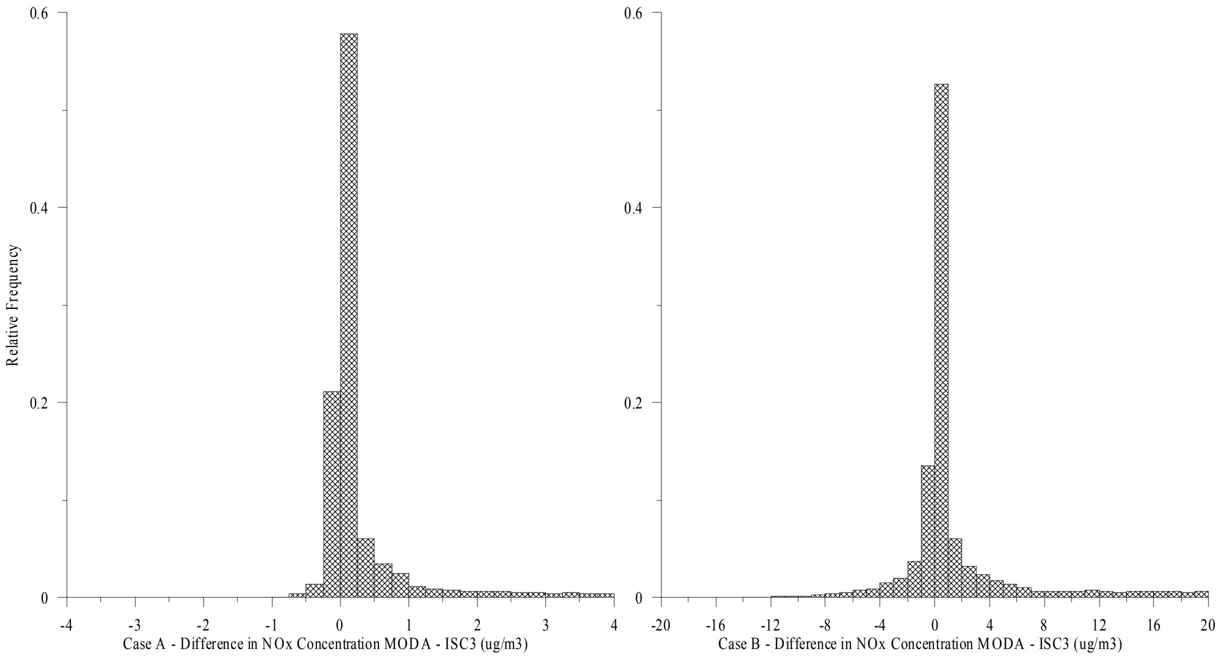

Figure 1. Histograms of the difference between MODA and ISC concentrations

The main statistics associated with the variable $\Delta C = C_{MODA} - C_{ISC3}$ in the two cases are given in table 1:

Table 1. Statistics of $\Delta C = C_{MODA} - C_{ISC3}$

	Case A (Stack tip = 80m)	Case B (Stack tip = 20m)
Number of values	127611	131030
Minimum	-0.7675357	-13.5678
Maximum	43.31969	73.87029
Mean	2.233484	2.8929121
Median	0.00567476	0.01924983
Standard deviation	5.368253	8.283696
Coefficient of variation	2.40353	2.86345
Skewness	3.076	3.318
Kurtosis	53.781	4415.998

In neither case the distribution of variable ΔC appears normal, as suggested by the large values of skewness and kurtosis. Nonetheless, MODA and ISC3 provide comparable values, with a tendency of MODA to overestimate with respect to ISC3, as suggested by both the mean and the median. The actual overestimation amount is greater for the lower stack tip height: this has been traced to the buoyancy parameterization adopted in ISC3, attributing the stack plume under unstable conditions an asymptotic height in excess of 500m in the cases analysed.

EFFECT OF COMPLEX TERRAIN

The maps in figure 1 illustrate the difference between flat and complex terrain MODA runs, any other condition fixed.

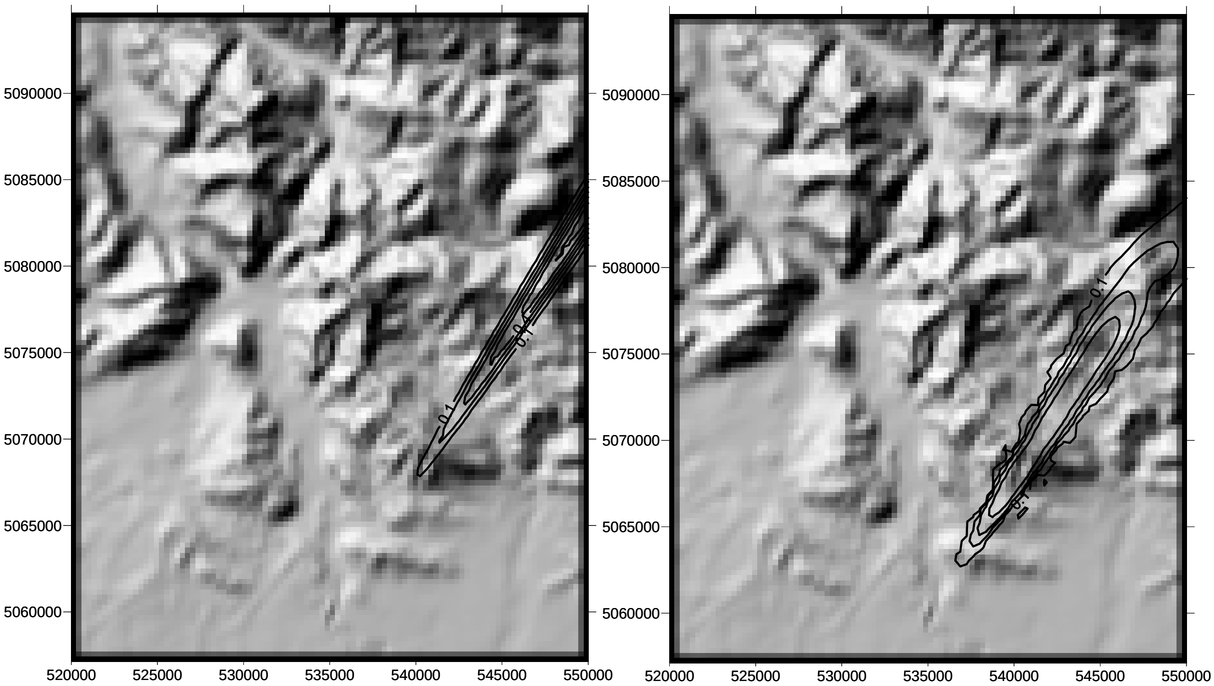

Figure 2. Hourly NO_x concentration map, without (left) and with (right) terrain elevations

The scheme used for modelling concentrations on a complex terrain matches the one adopted by Aermod, based on the decomposition of the plume in a terrain-following and a constant height sub-plumes. The partitioning of concentration between the two plumes is based on current stability, measured on a fine scale by turbulence parameters. Implementation of the critical height and partitioning coefficient computing has been optimised for efficiency, using a linearization of the equations generally used.

Validation of complex terrain data has not yet been done, and is one of the pending development goals in the MODA project.

CONCLUSIONS AND FURTHER PLANNED DEVELOPMENTS

At the date of this abstract's writing, MODA has been confirmed to be a sensible alternative to ISC3 when point sources are considered.

Its main feature, namely the ability to use data from the diffusing advanced meteorological stations, allows to model the effects of PBL turbulence using continuous parameters instead of categorical variables than ISC3.

In the next future, MODA will undergo various planned extensions:

- Ability to use vertical wind profiles (both similarity and measured);
- Extension to coast sites;
- Through testing and validation to European and international data sets.

The authors are evaluating to place the text-interface edition of MODA in the public domain, using a GPL or similar license, so that a large audience is reached and valuable comments can be gathered.

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