A VALIDATION EXERCISE ON THE SAFE-AIR VIEW SOFTWARE

F. D' Alberti [1], *F. d' Amati* [1], *E. Canepa* [2], *G. Triacchini* [3]
[1] NDFM Unit, Joint Research Centre of the European Commission - Ispra, Italy
[2] INFM - Department of Physics, University of Genova, Italy
[3] Catholic University of Brescia, Italy

INTRODUCTION

Safe-Air View *(Triacchini G. et al., 2004)* is a software for the prediction of the air and ground contamination following an accidental release of radionuclides into the atmosphere, and it is used at the Joint Research Centre in Ispra (JRC), Italy, as a decision support tool for the management of nuclear emergencies. Safe-Air View implements the SAFE_AIR I code *(Canepa E. et al., 1999)* to calculate the atmospheric dispersion of the emitted contaminants. An evaluation on the SAFE_AIR I code had already been carried out *(Canepa E. et al., 2000, Canepa E. and Builtjes P. J. H., 2001)*. The present paper presents a validation exercise on the Safe-Air View software, with the purpose to identify the role of some functions of the SAFE_AIR I code that have been parameterized within the software in order to render it simpler and faster in emergency situations. The validation exercise has considered three well known tracer experiments: Copenhagen, Indianapolis and Kincaid. The data sets related to these experiments are all included in the Model Validation Kit *(Olesen H. R., 1994)*.

METHODS AND INSTRUMENTS

The Safe-Air View software has been implemented in the simulation of some tracer experiments by means of different configurations, with the aim of estimating the performances for configurations that are more input demanding with respect to the one used at the JRC Ispra, assumed as a reference. *Table 1* shows the software configurations used in the present validation exercise.

SAFE-AIR VIEW CONFIGURATION	DESCRIPTION
Safe- Air View (A)	The wind data come from one only meteorological station. The mixing height value is suggested by the software. This configuration corresponds to the one used at the JRC Ispra.
Safe- Air View (B)	Compared with (A) configuration, the mixing height value calculated by the software is replaced by the observed value provided by the data sets.
Safe- Air View (C)	Compared with (B) configuration, the wind field has been calculated using another meteorological station, besides the one already introduced into simulations of (A) and (B) configurations.
Safe- Air View (D)	Compared with (C) configuration, the wind field has been calculated by introducing the entire wind profile from a meteorological tower, measured at 10, 30, 50 and 100 meters above the ground level, rather than the wind data measured only at 10 meters above the ground level.

Table 1 – Safe-Air View configurations applied in the present validation exercise.

The software evaluation has been carried out by means of quantitative and qualitative analysis tools included in the Model Validation Kit. Further performance indices, such as WNNR and NNR *(Poli A. A. and Cirillo M. C., 1993)*, have been derived. *Table 2* summarizes the performance indices used in the present validation exercise.
The present exercise has considered maximum arcwise and crosswind integrated concentrations; all concentrations have been normalized by emission. For synthesis reasons, most of the statistics related to crosswind integrated concentrations are not reported in the present paper.

INDEX	MEANING
MEAN	Average of the observed, or modeled, concentrations.
SIGMA	Standard deviation of the observed, or modeled, concentrations
BIAS	Difference between the average of the observed and modeled concentrations.
FB	Fractional Bias: shows how large is BIAS in relation to the average of observed and modeled concentrations. FB ranges between -2 and +2. For a perfect model, FB = 0
FS	Fractional Sigma: shows how large is the difference between the standard deviations of observed concentrations and the modeled concentrations, with respect to their average. FS ranges between -2 and +2; For a perfect model FS = 0
COR	Linear correlation factor between observed and modeled concentrations. COR ranges between -1 and +1. For a perfect model, COR = +1.
NMSE	Normalized Mean Square Error: gives a global estimation of the model performances. NMSE ranges from zero to infinity; NMSE is equal to zero for a perfect model.
WNNR	Weighted Normalized mean square error of the Normalized Ratios: shows the model ability to provide good estimates of the concentration peaks. WNNR ranges from zero to infinity and its best value is zero.
NNR	Normalized mean square error of the distribution of Normalized Ratios: is analogous to NMSE, but it is independent from the data set, and it attributes the same weight to model errors in estimating both maximum and minimum concentrations. NNR ranges from zero to infinity and its best value is zero.
FA2	Fraction of modeled concentrations within a factor 2 from the observed ones. FA2 ranges between 0 and 1. For a perfect model, FA2 = 1.

Table 2 – Performance measures used in the present validation exercise.

VALIDATION AND RESULTS

The results of the validation exercise, grouped by tracer experiment, are reported and interpreted in the following paragraphs.

Copenhagen

Safe-Air View has been used in the simulation of the experimental Copenhagen campaign by means of (A) and (B) configurations.

Table 3 presents the results of the quantitative analysis. Scenarios like Copenhagen are well simulated by Safe Air View, as shown by FB and FA2 values. Since the plume rise has been negligible in Copenhagen tracer experiment, the simulation of this phenomenon is not relevant.

	MEAN	SIGMA	BIAS	NMSE	COR	FA2	FB	FS	WNNR	NNR
Perfect model	632.66	450.25	0.00	0.00	1.000	1.000	0.000	0.000	0.00	0.00
Safe- Air View (A)	784.22	537.07	-151.56	0.38	0.672	0.783	-0.214	-0.176	0.45	0.25
Safe- Air View (B)	786.12	535.39	-153.47	0.37	0.682	0.783	-0.216	-0.173	0.43	0.25

Table 3 – Copenhagen tracer experiment. Statistics for maximum arcwise concentrations (normalized with emission); unit, 10^{-9} s m^{-3}; 23 observations.

Indianapolis

Safe-Air View has been used in the simulation of the experimental campaign of Indianapolis by means of (A), (B) and (C) configurations.

Table 4 presents the results of the quantitative analysis: the indices values are comparable with those derived from other model evaluations (Luhar A. K. and Hurley P. J., 2002).

Safe-Air View tends to underestimate the observed concentrations. As shown in the box plots in *figure 1*, this behavior is associated to stable atmospheric conditions that do not allow the plume to reach the ground. The use of a sigma function involving a greater vertical dispersion under stable conditions may ensure a better accuracy of the modeled concentrations. The underestimation is shown even in neutral conditions: this is due to the variability of meteorological conditions during release/monitoring cycles in the Indianapolis tracer experiment, as neutral conditions often represent a transition phase between stable and unstable conditions. Therefore Safe-Air View faces difficulties in predicting exact ground level concentrations under variable meteorological conditions.

	MEAN	SIGMA	BIAS	NMSE	COR	FA2	FB	FS	WNNR	NNR
Perfect model	353.81	221.25	0.00	0.00	1.000	1.000	0.000	0.000	0.00	0.00
Safe- Air View (A)	237.60	248.75	116.21	1.15	0.248	0.340	0.393	-0.117	1.68	1.39
Safe- Air View (B)	237.94	248.67	115.87	1.15	0.248	0.340	0.392	-0.117	1.68	1.39
Safe- Air View (C)	210.61	225.84	143.20	1.39	0.166	0.347	0.507	-0.021	2.00	1.54

Table 4 – Indianapolis tracer experiment. Statistics for maximum arcwise concentrations (normalized with emission); unit, 10^{-9} s m $^{-3}$; 430 observations.

Moreover, Safe-Air View can not estimate if the thermal discontinuity is strong enough to confine the plume under the mixing height: thus, it is assumed that the buoyant plume can totally penetrate the thermal discontinuity. This assumption is correct for many atmospheric conditions, but it can bring an underestimation of the concentrations at the ground level.
Finally, the software performances for (C) configuration suggest the need of caution when wind data are derived from more than one meteorological station: according to the position, the elevation, the presence of buildings and the orography, meteorological stations data may affect the accuracy of the wind field derived for the entire domain.

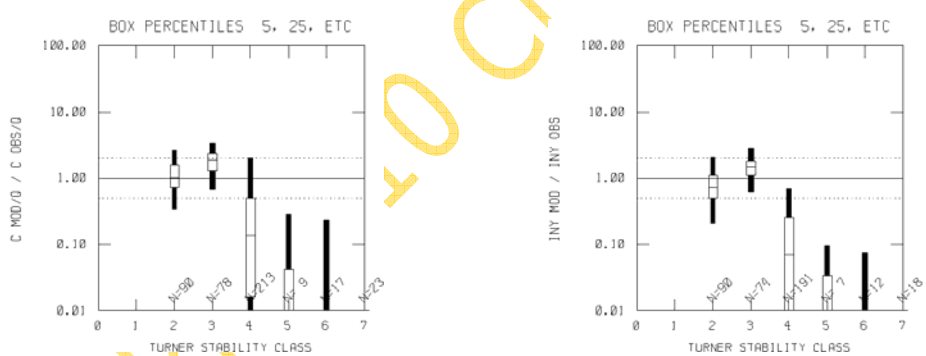

Figure 1 – Indianapolis tracer experiment, (B) configuration. Ratio of modeled/observed concentrations analysed in terms of atmospheric stability classes (numbers 1.....7 correspond to the scale A…,G, for maximum arcwise concentrations (left) and integrated crosswind concentrations (right). The boxes indicate percentiles 5, 25, 50, 75 and 95.

Kincaid

Safe-Air View has been used in the simulation of this campaign by means of (A), (B), (C) and (D) configurations. *Table 5* presents the result of the quantitative analysis. As shown by the FA2 and NNR values, the software performances are slightly better than those obtained in the simulation of the Indianapolis tracer experiment.
The box plots in *figure 2* show the ratio of modeled/observed concentrations as function of the distance from the source, for (B) and (C) configurations. The high plume rise causes the underestimation of concentrations in proximity of the release.
The initialization of the wind field by means of data from two meteorological stations has reduced the performances, as already observed in the simulation of the Indianapolis tracer experiment: this confirms therefore the importance of properly choosing the meteorological stations for the initialization of the wind field. In the Kincaid scenario simulation, the station

used in (D) configuration is far from the release source: as a result, it is not useful for a realistic simulation of the wind field.

	MEAN	SIGMA	BIAS	NMSE	COR	FA2	FB	FS	WNNR	NNR
Perfect model	54.34	40.25	0.00	0.00	1.000	1.000	0.000	0.000	0.00	0.00
Safe- Air View (A)	34.89	31.50	19.45	1.52	0.044	0.385	0.436	0.244	2.19	0.99
Safe- Air View (B)	36.33	32.27	18.00	1.47	0.035	0.408	0.397	0.220	2.10	0.94
Safe- Air View (C)	43.74	40.82	10.59	1.52	-0.064	0.382	0.216	-0.014	2.25	1.16
Safe- Air View (D)	39.67	41.22	14.66	1.59	0.033	0.343	0.312	-0.024	2.46	1.35

Table 5 – Kincaid tracer experiment. Statistics for maximum arcwise concentrations (normalized with emission); unit, 10^{-9} s m $^{-3}$; 338 observations.

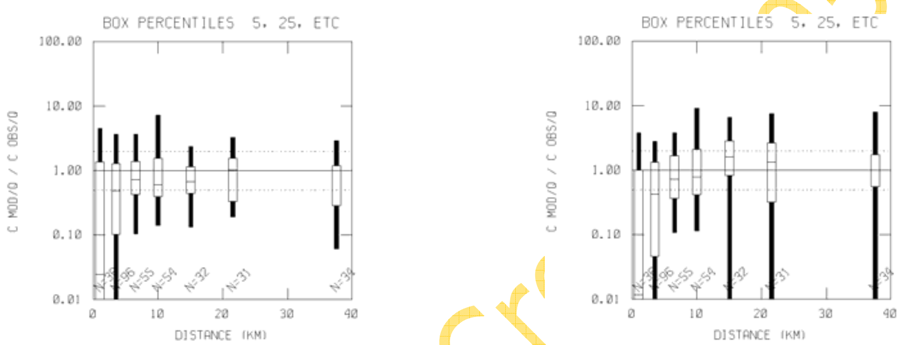

Figure 2 – Kincaid tracer experiment, configurations (B) on the left and (C) on the right. Ratio of modeled/observed concentrations as a function of distance from emission source, for maximum arcwise concentrations. The boxes indicate percentiles 5, 25, 50, 75 and 95.

CONCLUSIONS

The NNR and FA2 performance indices are useful to set the performances obtained through each configuration. Better performances correspond to better NNR and FA2 values: according to this criterion the chart list shown in *table 6* has been derived. The following considerations can be drawn:

- Safe-Air View has achieved the best performances in the simulation of the Copenhagen tracer experiment: in this case accuracy and precision of the modeled concentrations have the highest values.
- The simulation of Indianapolis and Kincaid tracer experiments has not produced as good results: in both the cases accuracy and precision of the modeled concentrations cannot be judged satisfactory.
- The type (B) configurations guarantee generally better performances. However, the difference of performances between (A) and (B) configurations is reduced.
- (C) and (D) configurations give the worst performances.

Therefore, the Safe-Air View software guarantees a good accuracy and precision in predicting ground level concentrations for release scenarios similar to the Copenhagen one. This kind of scenario is characterized by an elevated source, absence of significant obstacles on the surrounding territory, constant meteorological conditions and not elevated plume rise.

Where the complexity of the scenario grows, such as in Indianapolis and Kincaid tracer experiments, the software performances get worse: in these conditions an underestimation is generally observed, and about a third of modeled concentrations is within a factor two of the observed concentrations.

The cause of most of the observed discrepancies resides in the parameterization of the SAFE_AIR I code as implemented in the Safe-Air View software. In fact, the user cannot act on the calculation method for the plume rise, on the interaction between plume rise and thermal discontinuity, and on the sigma function: this prevents the calibration of the software to get optimal results in some release scenarios.

Tracer experiment	Configuration	Arcwise maximum concentrations		Crosswind integrated concentrations	
		NNR	FA2	NNR	FA2
Copenhagen	Safe- Air View (B)	0.25	0.783	0.10	0.957
Copenhagen	Safe- Air View (A)	0.25	0.783	0.11	0.957
Kincaid	Safe- Air View (B)	0.94	0.408	-	-
Kincaid	Safe- Air View (A)	0.99	0.385	-	-
Kincaid	Safe- Air View (C)	1.16	0.382	-	-
Kincaid	Safe- Air View (D)	1.35	0.343	-	-
Indianapolis	Safe- Air View (B)	1.39	0.340	1.47	0.365
Indianapolis	Safe- Air View (A)	1.39	0.340	1.47	0.362
Indianapolis	Safe- Air View (C)	1.54	0.347	1.67	0.327

Table 6 – Chart list of the Safe-Air View performances, for data set and configuration.

In practical cases, Safe-Air View is applied to various release scenarios that are similar to the Indianapolis one. Therefore, the results of the present exercise suggest that an optimization of the Safe-Air View software may be possible, introducing the possibility for the user to customize certain parameters that at the moment are frozen within the software.

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