# 4.01 DISPERSION MODELLING OF RADIOACTIVE POLLUTANTS: APPLICATION OF THE DETRACT CODE SYSTEM AT THE HANFORD SCENARIO

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## INTRODUCTION

The "Hanford Scenario" refers to an acute accidental release of radioactive $^{131}I$ from the stack of the Hanford (USA) Purex Chemical Separations Plant that occurred between 2 and 5 of September 1963 (BIOMASS, 1999). From the environmental impact point of view it is a very interesting case study for the evaluation of computational systems that simulate the atmospheric dispersion, deposition and passage to food chain of radioactive pollutants. It is a very challenging case too, because of the surrounding topography is complex, while the release is variable in time and lasts for three and a half consecutive days with changing wind direction and atmospheric stability: frequently temperature inversions occur at night and break during the day, resulting in unstable and turbulent conditions.

The available observational data, although not very detailed, are suitable for model validation purposes. They include source term information (released activity as a function of time for the whole duration of the release), meteorological observations (wind speed and direction, temperature, pressure, humidity, solar radiation, atmospheric stability and precipitation) from a number of ground meteorological stations in the greater area and from the meteorological tower at Hanford, and iodine concentrations in air (daily averaged values), in vegetation and milk from a large number of sampling points and farms in the surrounding area.

The DEmokritos TRAnsport code system for Complex Terrain (DETRACT) consists of a topography simulator, a meteorological pre-processor (including a wind field model) and a Lagrangian atmospheric dispersion model. In this article, an application of DETRACT concerning the Hanford scenario for evaluation purposes is presented. The modelling components employed in the particular case are the meteorological pre-processor and atmospheric dispersion model. From the two available operation modes of the Lagrangian model—Gaussian puff and particles—the particles mode results are presented here. The results used for the evaluation purposes were the concentrations of $^{131}I$ in air, and more specifically, the daily averaged and the time-integrated for the duration of the release period values at the available 21 sampling locations in the area surrounding the release point.

## METHODOLOGY

The computational domain for the meteorological pre-processor was selected to include most of the available ground stations around the release location. The horizontal discretisation was 80×80 cells of 5×5 $km^2$. The meteorological domain with the topography, the meteorological stations and the release location is presented in Figure 1. The vertical discretisation consists of 29 cells with dimensions varying from 50 to 500 m, extending up to 10 km in height.

Hourly data of wind velocity, temperature, pressure and atmospheric stability from the ground stations and profiles of wind and temperature from the tower at Hanford have been used by the pre-processor to calculate by interpolation the required 3-dimensional fields for the dispersion model. No precipitation occurred in the area during the release. The required variables that were not included in the observations (e.g., mixing layer height) have been calculated by semi-empirical relations. The time period simulated covered the whole duration of the release from 12:00 of 2/9 to 23:00 of 5/9 local time and the meteorological fields were produced on a hourly basis.

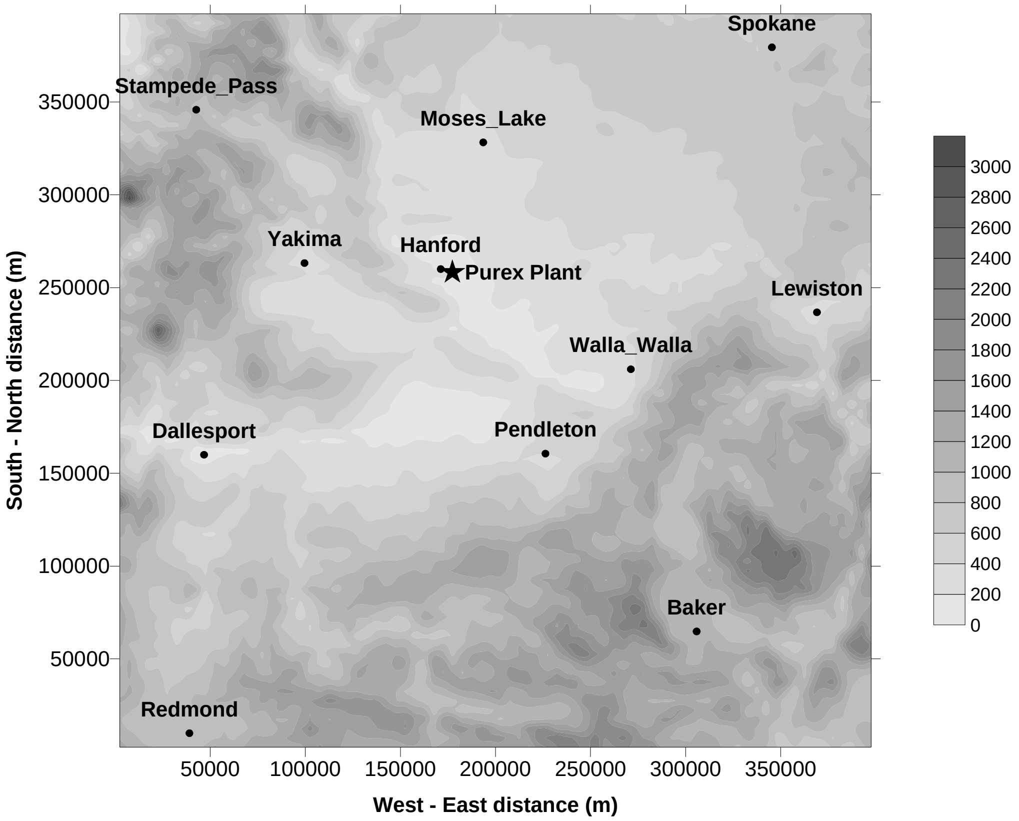


*Figure 1. Computational domain for meteorology, with topography, the meteorological stations (dots) and the release location ("Purex Plant")*

The dispersion calculations have been performed in a domain smaller than the meteorological one, since the available sampling locations cover a more limited area around the plant. The actual time variation of the release has been used, but the modelled released activity was set to 65% of that reported in the scenario, due to the fact that the air samplers used were inefficient in capturing the organic forms of iodine, which consisted 35% of the release (BIOMASS, 1999). The modelled released activity has been distributed to 9270 particles (1 particle per 33 s). The lagrangian model calculated the particles displacement based on random velocities added to the mean wind velocity. More detailed description can be found in Davakis et al. (2001, 2003).The concentrations have been calculated both on a regular grid (42×42 cells of 2×2 $km^2$) and at the sampling locations at 1-hour intervals. Dry deposition of iodine has been taken into consideration. The dispersion calculations lasted for the whole period of the release (12:30 of 2/9 to 23:00 of 5/9 local time).

For model evaluation purposes the calculation results have been compared with the observations, as daily averages and time-integrated values for the period of the release. The daily averages have been selected on the basis of the available measurement data, while the tim-integrated, due to their close relationship with the radiation doses that the population is exposed to. The daily averages have been calculated from the hourly model results at all sampling locations. The time-integrated concentration values are produced directly by the dispersion model. The observed air concentration values during the days previous to the release start have been considered as background values for each station, and therefore have been subtracted from the values observed during the days of the release.

## RESULTS AND DISCUSSION

In Figure 2, the calculated daily averaged concentrations are compared to the observed ones, in the form of a scatter plot. It should be noted that sensors with zero values cannot be plotted on such logarithmic plots.

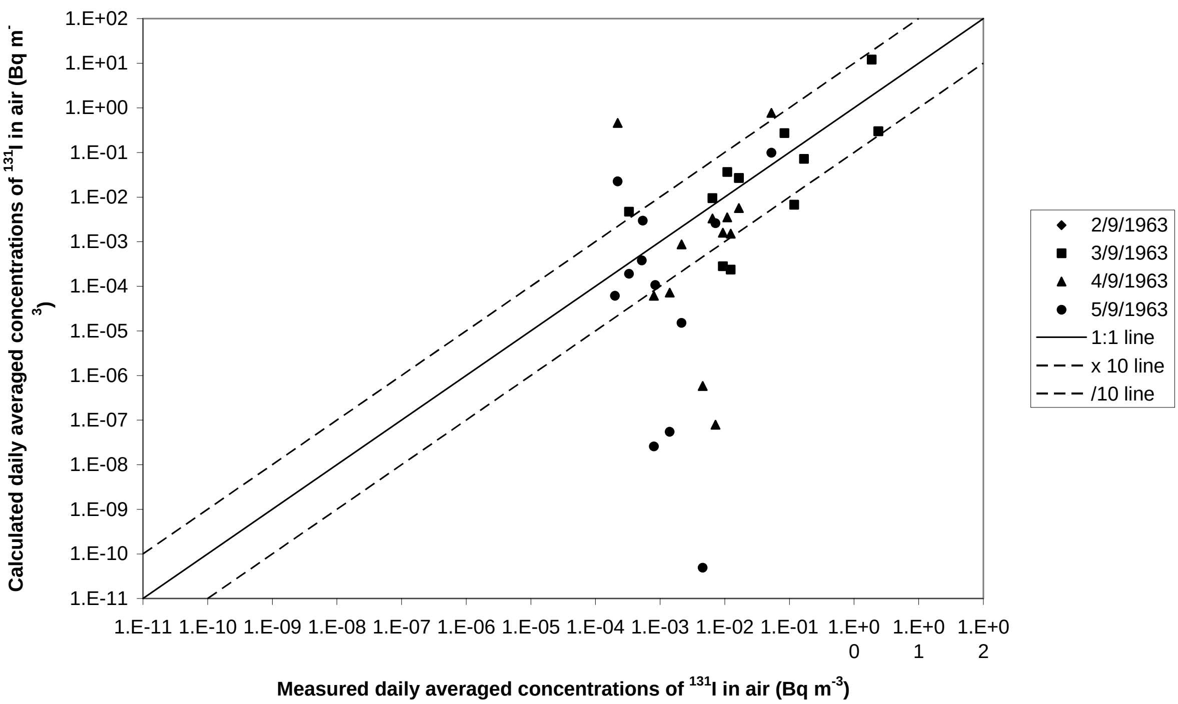


*Figure 2. Scatter plot of calculated vs. observed $^{131}I$ concentrations in air, for each day during the release and for all sensors with non-zero values. Factor-of-10 and 1:1 lines are also drawn.*

In Figure 3 the ratio of calculated to observed daily averaged concentration is presented for all sensors with non-zero values. The sensors are ordered with increasing distance from the release point to detect eventual bias in the model performance.

In Figure 4 the scatter plot presents calculated against observed time-integrated iodine concentrations in air for the time period of the release. The ratios of calculated to observed time-integrated concentrations are plotted in Figure 5, with the respective sensors ordered with increasing distance from the release location.

The factor-of-2, 5 and 10 agreement percentages, between calculated and observed values are included in Table 1. These percentages reflect the number of sensors for which the ratio between model result and observation value lies between 0.5 and 2, 0.2 and 5, 0.1 and 10 respectively. They are commonly used as indicators of model performance. Based on the above, it is concluded that the modelling system DETRACT has performed in a rather satisfactory degree, especially taking into consideration the challenging aspects of the studied case, listed in the introduction of the paper.

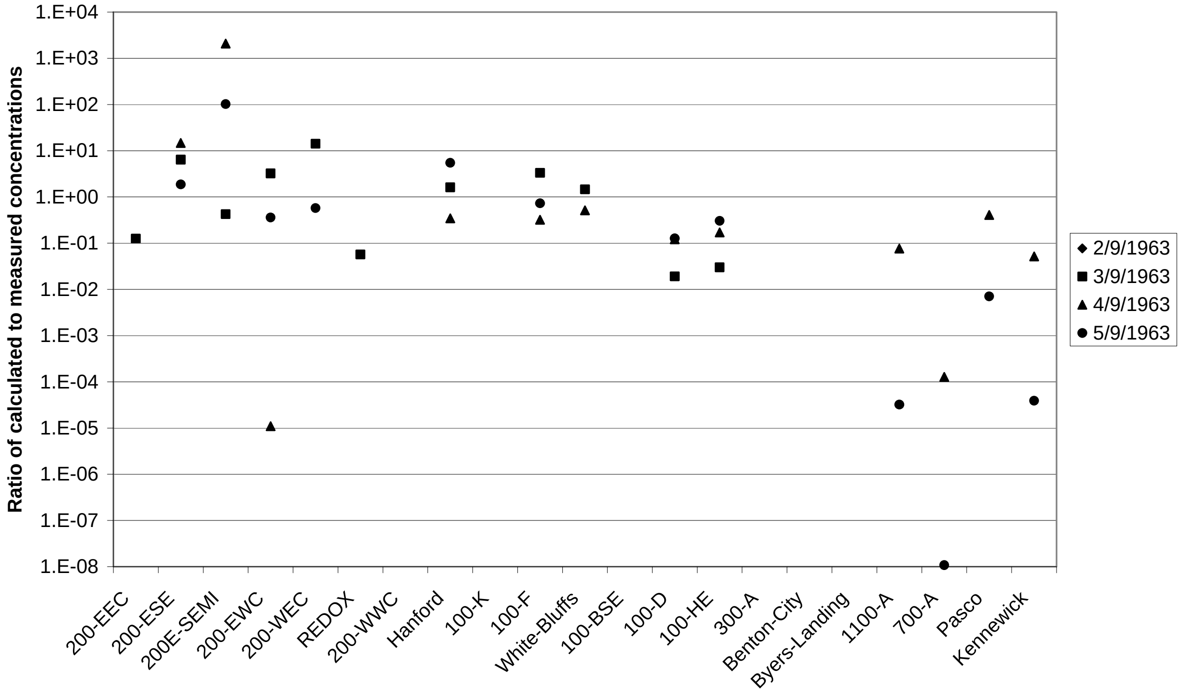


*Figure 3. Ratio of calculated to observed daily averaged concentrations for all days of the release and for all sensors with non-zero values (ordered by increasing distance from the release point).*

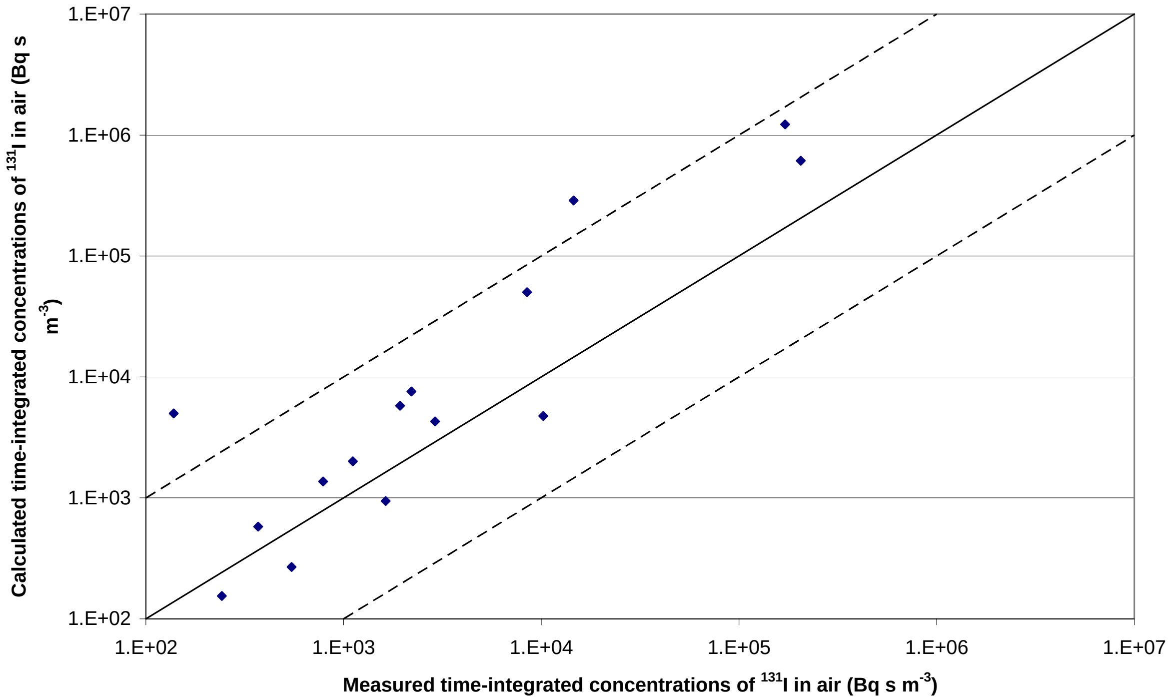


*Figure 4. Scatter plot of calculated vs. observed tme-integrated $^{131}I$ concentrations in air, for each day during the release and for all sensors with non-zero values. Factor-of-10 and 1:1 lines are also drawn*

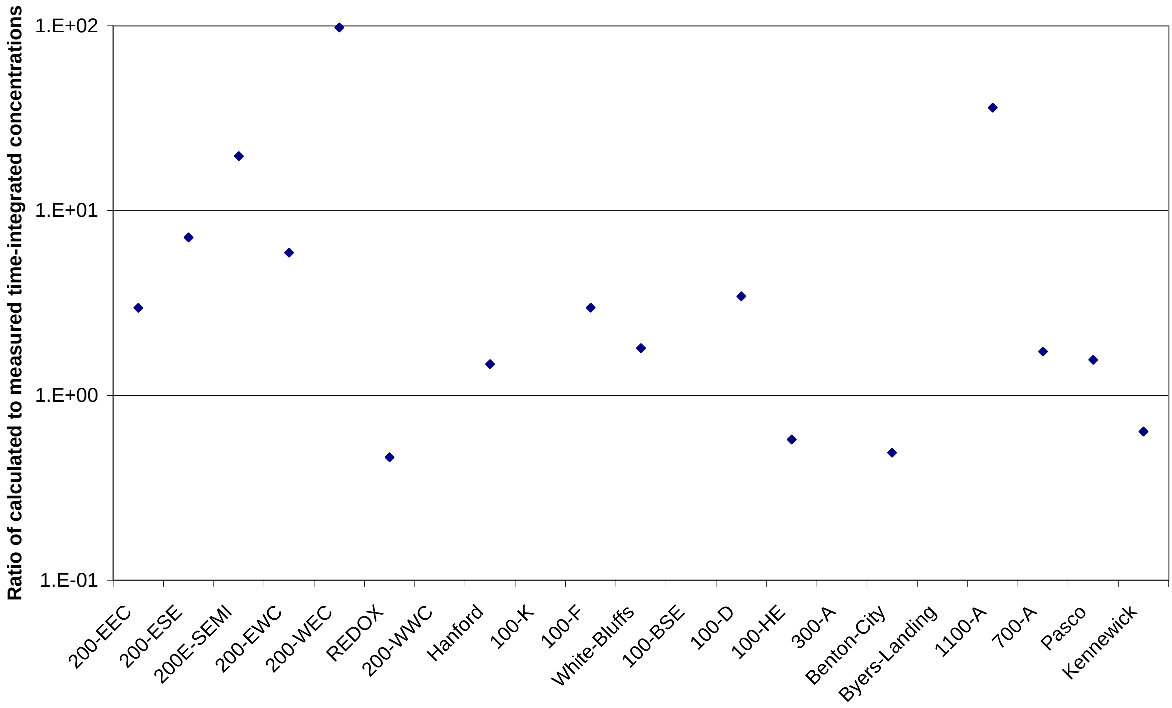


*Figure 5. Ratio of calculated to observed time-integrated concentrations for the period of the release and for all sensors with non-zero values (ordered by increasing distance from the release point).*

*Table 1. Agreement between calculated and observed concentration values*

| | Factor-of-2 | Factor-of-5 | Factor-of-10 |
|---|---|---|---|
| Daily averaged concentrations | 17% | 40% | 57% |
| Time-integrated concentrations | 37.5% | 68.8% | 85.7% |

The high values the statistical indices for the level of agreement concerning the time-integrated concentrations, indicate that DETRACT is a tool suitable to be used within computing systems evaluating the environmental impact of accidental releases to the atmosphere, and designed to evaluate the radiation doses to which the population is exposed due to atmospheric dispersion of radio-nuclides.

## REFERENCES

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