Model evaluation of RIMPUFF within complex terrain using an ^{41}Ar radiological dataset

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Nuclear-based science benefiting all Australians

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INTRODUCTION

- The newly updated atmospheric dispersion model RIMPUFF from Risø – DTU in Denmark is evaluated using routine releases of ^{41}Ar from the former HIFAR research reactor located at ANSTO, Sydney, Australia.
- Complex topography around HIFAR causes challenging meteorological conditions for emergency response models in terms of predicting dispersion where wind shear, local terrain slope flows and strong inversions frequently occur.
- The main objective is to 1. determine whether the model can provide emergency personnel with a high-resolution radiological plume in complex terrain, and 2. predict the timing and location of the maximum dose rate.

DATA AND METHODOLOGY

Site description and dataset

- 3 Meteorological stations (model input): 00 (up to 49m), 01, 02 (see **Figure 1**).
- 4 Environmental Gamma Radiation stations (receptors): MG, WS, BT, BR deployed as a perimeter 5km from the HIFAR reactor.
- 16 cases of 15-min measured ^{41}Ar data: Nov/Dec 2002, June/July 2003 (covering different stability conditions).

Map 1: 25m resolution land-use | Map USGS: 1km resolution land-use

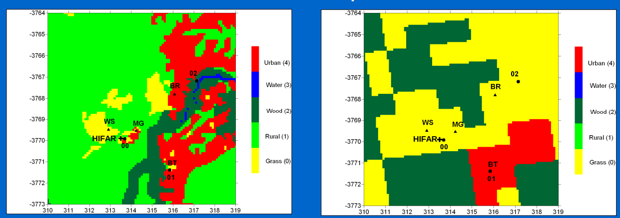


***Figure 1:** Left: 25m resolution land use map (Map 1). Right: 1km resolution land-use map (USGS)*

Dispersion Model

- RIMPUFF is a rapid operational puff diffusion code, developed for real-time simulation of atmospheric dispersion during nuclear accidents.
- A recently **modified puff growth parameterisation scheme** is used with a similarity scaling method and two different wind interpolation schemes: 1. inverse square distance (r^{-2}) and 2. the flow model LINCOM based on weighted sum of measured winds.
- 91 x 91 grid points, 100m x 100m grid size with inputs: 15-min averaged source data from a 23m tall stack and 15-min averaged met-data from stations 00 and 01.

RESULTS AND DISCUSSION

- Different **stability calculation methods** available in RIMPUFF identified limitations with net radiation data and station 00 temperature data at 2m. These measurements were withheld from the model runs.
- Meteorological data at station 02 located at the valley floor is controlled by **local terrain features** where katabatic winds are observed due to drainage of cooler air into the sloping terrain. Including this station in the wind model LINCOM's weighted sum based calculation leads to poor results and therefore station 02 is not used.
- The **wind shear** between stations 00 and 01 in **Figure 2** causes the weighted sum method of LINCOM to incorrectly predict the plume direction. The inverse square method over-predicts however it produces a more accurate wind field.
- Variations in the user defined **surface roughness** parameter produced large differences in the dose rate calculation – Case 4 in **Figure 3** shows variations of 0.005m to 1.0m can result in a 30-min difference in peak arrival time and more than a doubling in dose rate.

R^{-2} parameterisation | LINCOM wind flow model

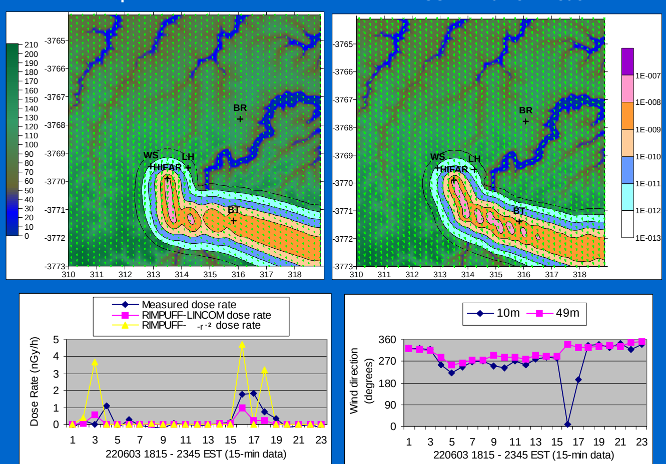


Figure 2: Above: Concentration contour plots for Case 2 at BT (22/06/2003 2200 EST) using r^{-2} (Left) and the wind flow model LINCOM (Right). Below: Dose rate and wind direction plots.

- In most cases the model prediction was closer to the observations when the higher resolution **land-use map** data was used however the results vary between Map 1 and Map 2 depending on the location of the receptor station (see **Figure 3**).
- Results indicate that inclusion of more **land-use categories** than the present 5 and thereby a better resolved surface roughness pattern might improve the code. Figure 3 shows good results for USGS but overall it is found to be out of date and not at a suitable resolution for such short range dispersion.

Surface roughness varied | Land-use map varied

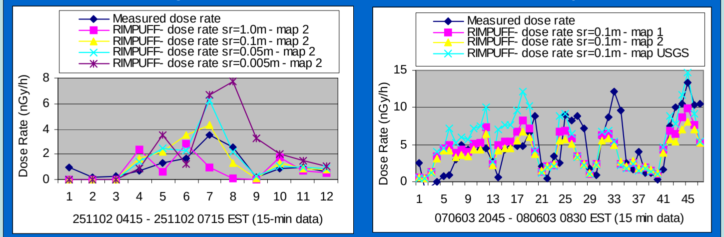


***Figure 3:** Dose rates for Case 4 at BT with specified surface roughness varied for met-station 00 (Left), and for Case 15 at MG where land use maps are varied (Right)*

- **Scatter plots** in **Figure 4** show receptor BT has the best performance with ratios falling mostly within a factor of 2 and generally during neutral conditions or slightly unstable with constant wind direction. BT over-predicts during stable conditions with low wind speeds.
- The closest receptors WS and MG generally under-predict during neutral conditions however with a few large over and under-predictions, commonly during large vertical wind shears with low wind speeds at the time of the peak.
- The smallest sample size for receptor BR meant all cases under-predicted for neutral conditions and constant wind direction.
- The **quantile-quantile plot** shows good correlation up to 5nGy/h and slightly under-predicting but then over-predicting for all large dose rates.

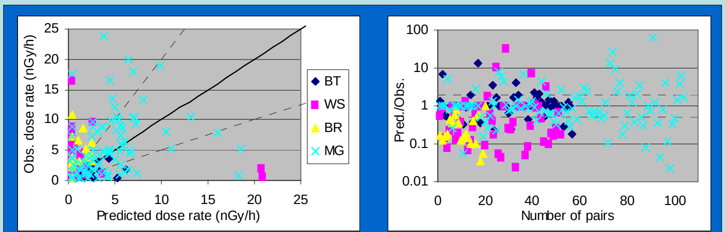
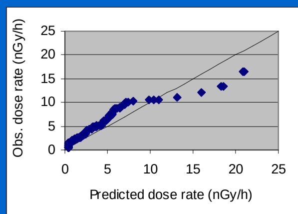


Figure 4:
Top Left: Scatter plot of observed to predicted pairs.
Top Right: Residual plot of predicted/observed ratios.
Bottom: Quantile-quantile plot of separately ranked observed and predicted pairs.



Black diagonal line is 1-1 and dotted lines represent within a factor of 2.

- **Statistical analyses** reveal RIMPUFF's performance for receptor station BT is very good as it satisfies the Model Acceptance Criteria for the stringent test of **pairing in space and time**. Receptor MG with the largest sample size satisfies all of the criteria except NMSE or VG due to the large over and under-predictions.

***Table 1:** Statistical measures from the BOOT software*

Receptor St. (cases)	NMSE	FA2	FB	VG	MG
(median)	3.97	0.524	0.096	5.37	1.42
BT (56)	1.18	0.75	-0.187	1.67	0.96
WS (52)	9.24	0.385	0.179	15.2	2.39
BR (20)	3.48	0.15	1.225	26.5	5.12
MG (105)	2.54	0.543	-0.013	4.42	1.07

CONCLUSIONS

- RIMPUFF mostly under-predicted during neutral conditions but was found to over-predict often during very stable conditions with low wind speeds.
- Particularly difficult cases were characterised by vertical wind shear near the reactor for low wind speeds blowing towards the nearby receptor WS. Results were shown to improve when upper level wind data at 49m were used however observations at even higher levels for input would enable the model to provide better predictions of wind shear.
- The model is very sensitive to inputs such as surface roughness, land-use and vertical profiles of meteorological data.
- RIMPUFF produces most accurate dose rate predictions at the ANSTO site when using the r^{-2} model for wind data interpolation, surface roughness at met-station 00 defined as 0.1m and a high resolution land-use and topography map is preferred when using a high resolution wind and dispersion code.