NUS National University of Singapore | Singapore Nuclear Research and Safety Initiative

Benchmark Problem Exercise : Consequence Assessment of a Hypothetical Nuclear Power Plant Accident

Singapore Experience with Puff Dispersion Model and Wind Data Inputs

Presented by TAY Bee Kiat; PhD (Atmospheric Sciences)
(co-authors: Harminder SINGH, MUN Cheok Hong, KUAN Say Yong and CHUNG Keng Yeow)
SNRSI NUS, Singapore

Background

- In 2017, a proposal for benchmark problem on consequence management was put up for participation by member states
  - Vietnam and Thailand shared initial outcomes of modelling exercise

- In response to this call, SNRSI would like to share preliminary findings from her technical study on the benchmark problem exercise

ASEAN Network on Nuclear Power Safety Research
Draft No. 1, March 20, 2017

Proposal for Conditions and Timeline of the Benchmark Problem on Consequence Assessment of a Hypothetical Accident in a Virtual Nuclear Power Plant

Participants will perform a consequence assessment of a hypothetical accident in a virtual nuclear power plant under conditions specified below.

Parameters For Comparison in Benchmark Problem Study

Results to be compared

Short-range dispersion

Comparison must be made at some specific distances from the release point. Thailand suggests the comparison at the radius of 5 km, 8 km (5 miles), 10 km, 16 km (10 miles), 20 km and 30 km from the release point of all (16 or 32) directions, since they are distances often set as the boundaries for short-term emergency response, e.g. sheltering or evacuation. Items to be compared are specified below.

- **Air concentration** of the two radionuclides (Bq/m^3) at 1 day, 1 week, 1 month and 1 year after the accident starts,
- **Ground concentration** of the two radionuclides (Bq/m^3) at 1 day, 1 week, 1 month and 1 year after the accident starts,
- Total effective dose equivalent (TEDE; Sv).

Long-range dispersion

- TEDE (Sv) at 50 km, 80 km (50 miles), 100 km, 200 km, 300 km and 500 km of all directions,
- Dispersion pattern (e.g. the direction to which the radionuclide dispersed furthest, the contour of the TEDE),
- Lead time until the radioactive plume reaches the border of the neighboring countries (h).

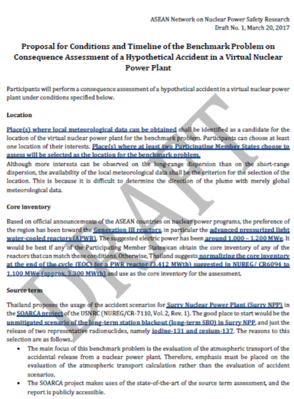
Presentation Overview

Objective : Influence of wind data input on short & long range dispersion outcomes

Location : Virtual NPP at the Ninh Thuan location [1]

Scope of Presentation :

- Source term input (Virtual NPP in Benchmark Problem Exercise)
- Rationale for adopted modelling approach
- Preliminary results
- Future work



ASEAN Network on Nuclear Power Safety Research
Draft No. 1, March 20, 2017

Proposal for Conditions and Timeline of the Benchmark Problem on Consequence Assessment of a Hypothetical Accident in a Virtual Nuclear Power Plant

Participants will perform a consequence assessment of a hypothetical accident in a virtual nuclear power plant under conditions specified below.

Location

Place(s) where local meteorological data can be obtained shall be identified as a candidate for the location of the virtual nuclear power plant for the benchmark problem. Participants can choose at least one location of their interests. Place(s) where at least two Participating Member States choose to assess will be selected as the location for the benchmark problem.
Although more interests can be observed on the long-range dispersion than on the short-range dispersion, the availability of the local meteorological data shall be the criterion for the selection of the location. This is because it is difficult to determine the direction of the plume with merely global meteorological data.

Core inventory

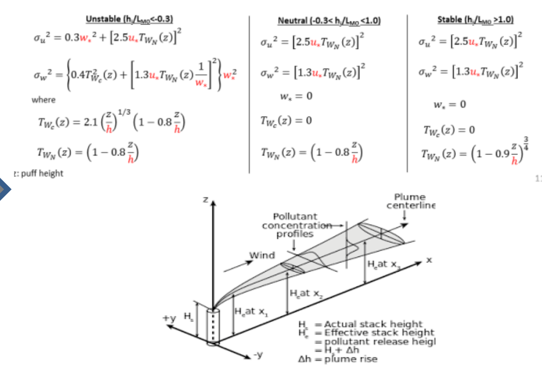
Based on official announcements of the ASEAN countries on nuclear power programs, the preference of the region has been toward the Generation III reactors, in particular the advanced pressurized light water-cooled reactors (APWR). The suggested electric power has been around 1,000 – 1,200 MWe. It would be best if any of the Participating Member States can obtain the core inventory of any of the reactors that can match these conditions. Otherwise, Thailand suggests normalizing the core inventory at the end of the cycle (EOC) for a PWR reactor (3,412 MWth) suggested in NUREG/ CR6094 to 1,100 MWe (approx. 3,300 MWth) and use as the core inventory for the assessment.

Source term

Thailand proposes the usage of the accident scenarios for Surry Nuclear Power Plant (Surry NPP) in the SOARCA project of the USNRC (NUREG/CR-7110, Vol. 2, Rev. 1). The good place to start would be the unmitigated scenario of the long-term station blackout (long-term SBO) in Surry NPP, and just the release of two representative radionuclides, namely Iodine-131 and cesium-137. The reasons to this selection are as follows.

- The main focus of this benchmark problem is the evaluation of the atmospheric transport of the accidental release from a nuclear power plant. Therefore, emphasis must be placed on the evaluation of the atmospheric transport calculation rather than the evaluation of accident scenarios.
- The SOARCA project makes uses of the state-of-the-art of the source term assessment, and the report is publicly accessible.

Proposal



Analysis

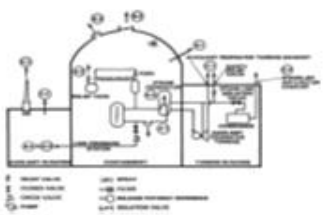
Modelling & Results

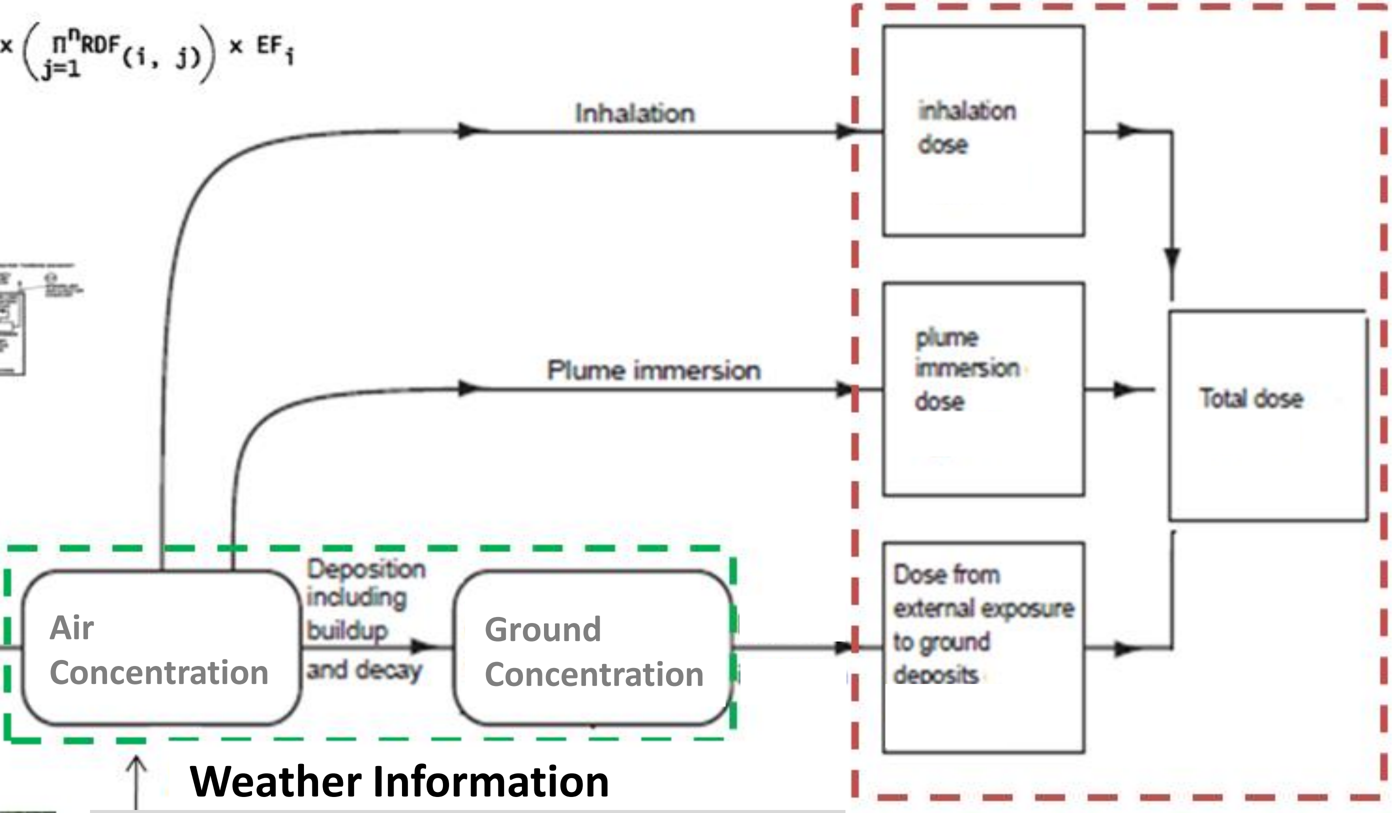
1. One of 2 previously presented locations adopted in the 2017 study on the Benchmark Problem

Key Considerations in SNRSI Dispersion Modelling Approach

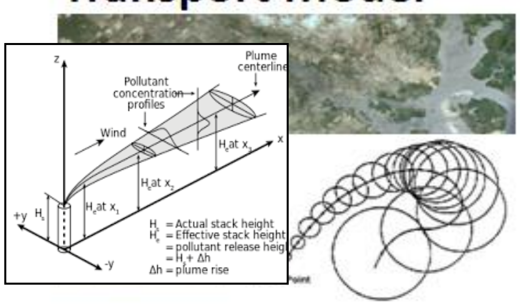
$$\text{Source term}_i = FPI_i \times CRF_i \times \left(\prod_{j=1}^{n} RDF(i,j)\right) \times EF_i$$

(1) Source Term Model





(2) Atmospheric Transport Model



Weather Information

1. **Measurements**
2. **Numerical Weather Prediction (NWP)**

- Using global weather inputs for computation of forecast weather

Weather Information undergoes meteorological pre-processing prior to its use for dispersion modelling

(3) Dosimetry Model

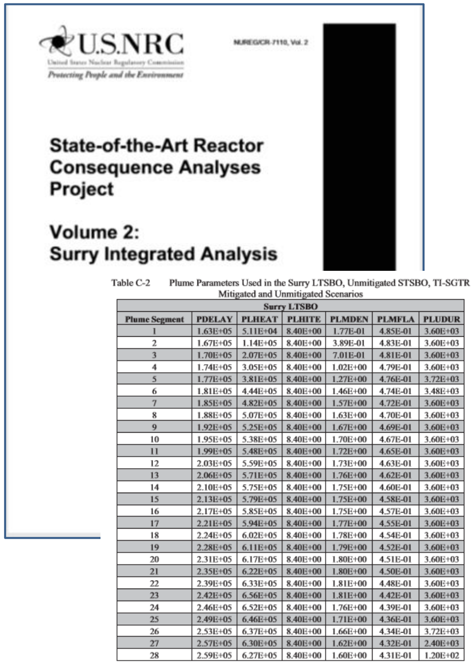
Exposure route	Type	Type of radiation	Types of nuclides	Exposure duration
External Exposure	Cloudshine	Gamma-radiation	All nuclides gas, aerosol	Short term
	Groundshine	Gamma-radiation	Deposited radionuclides, e.g. Cs-137	Long term
Internal Exposure	Inhalation	Alpha, Beta gamma radiation	e.g. I-131, Sr-90	Accumulated dose

Adapted from IAEA (1997)

Selection of Source Term[2]

- Core Inventory:
  - Normalizing the shut-down core inventory (3,412 MW_{TH}) to 3,300 MW_{TH} for Iodine-131 and Caesium-137 radioisotopes
- Accident Scenario:
  - Release fraction is obtained from Surry Nuclear Power Plant unmitigated long term station blackout (NUREG/CR-7110 Volume 2 Rev. 1)
- Release Characteristics:

Release Amount (Bq)	Release Duration	Heat Content	Release Height
• I-131: ~1 x10^{16} Bq (aerosol) • Cs-137: ~ 6 x10^{13} Bq	~26 h	~500 KW	8.4 m



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG/CR-7110, Vol. 2

State-of-the-Art Reactor Consequence Analyses Project

Volume 2:
Surry Integrated Analysis

Table C-2 Plume Parameters Used in the Surry LTSBO, Unmitigated STSBO, TI-SGTR Mitigated and Unmitigated Scenarios

Surry LTSBO						
Plume Segment	PDELAY	PLHEAT	PLHITE	PLMDEN	PLMFLA	PLUDUR
1	1.63E+05	5.11E+04	8.40E+00	1.77E-01	4.85E-01	3.60E+03
2	1.67E+05	1.14E+05	8.40E+00	3.89E-01	4.83E-01	3.60E+03
3	1.70E+05	2.07E+05	8.40E+00	7.01E-01	4.81E-01	3.60E+03
4	1.74E+05	3.05E+05	8.40E+00	1.02E+00	4.79E-01	3.60E+03
5	1.77E+05	3.81E+05	8.40E+00	1.27E+00	4.76E-01	3.72E+03
6	1.81E+05	4.44E+05	8.40E+00	1.46E+00	4.74E-01	3.48E+03
7	1.85E+05	4.82E+05	8.40E+00	1.57E+00	4.72E-01	3.60E+03
8	1.88E+05	5.07E+05	8.40E+00	1.63E+00	4.70E-01	3.60E+03
9	1.92E+05	5.25E+05	8.40E+00	1.67E+00	4.69E-01	3.60E+03
10	1.95E+05	5.38E+05	8.40E+00	1.70E+00	4.67E-01	3.60E+03
11	1.99E+05	5.48E+05	8.40E+00	1.72E+00	4.65E-01	3.60E+03
12	2.03E+05	5.59E+05	8.40E+00	1.73E+00	4.63E-01	3.60E+03
13	2.06E+05	5.71E+05	8.40E+00	1.76E+00	4.62E-01	3.60E+03
14	2.10E+05	5.75E+05	8.40E+00	1.75E+00	4.60E-01	3.60E+03
15	2.13E+05	5.79E+05	8.40E+00	1.75E+00	4.58E-01	3.60E+03
16	2.17E+05	5.85E+05	8.40E+00	1.75E+00	4.57E-01	3.60E+03
17	2.21E+05	5.94E+05	8.40E+00	1.77E+00	4.55E-01	3.60E+03
18	2.24E+05	6.02E+05	8.40E+00	1.78E+00	4.54E-01	3.60E+03
19	2.28E+05	6.11E+05	8.40E+00	1.79E+00	4.52E-01	3.60E+03
20	2.31E+05	6.17E+05	8.40E+00	1.80E+00	4.51E-01	3.60E+03
21	2.35E+05	6.22E+05	8.40E+00	1.80E+00	4.50E-01	3.60E+03
22	2.39E+05	6.33E+05	8.40E+00	1.81E+00	4.48E-01	3.60E+03
23	2.42E+05	6.56E+05	8.40E+00	1.81E+00	4.42E-01	3.60E+03
24	2.46E+05	6.52E+05	8.40E+00	1.76E+00	4.39E-01	3.60E+03
25	2.49E+05	6.46E+05	8.40E+00	1.71E+00	4.36E-01	3.60E+03
26	2.53E+05	6.37E+05	8.40E+00	1.66E+00	4.34E-01	3.72E+03
27	2.57E+05	6.30E+05	8.40E+00	1.62E+00	4.32E-01	2.40E+03
28	2.59E+05	6.27E+05	8.40E+00	1.60E+00	4.31E-01	1.20E+02

2. Taking Reference from Benchmark Proposal (2017)

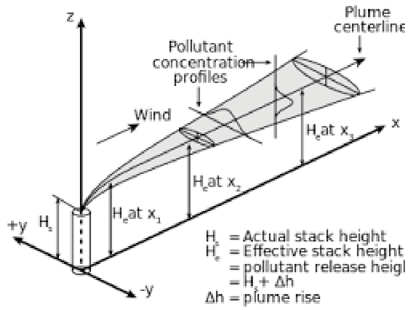
Table C-4 Release Fraction Parameters Used in the Surry LTSBO, Unmitigated STSBO, TI-SGTR Mitigated and Unmitigated Scenarios

Surry LTSBO										
Plume Segment	**Xe**	**Cs**	**Ba**	**I**	**Te**	**Ru**	**Mo**	**Ce**	**La**
1	3.36E-03	3.50E-06	5.31E-07	3.62E-05	5.09E-05	7.77E-08	2.69E-07	1.93E-07	1.21E-08
2	7.20E-03	7.08E-06	1.03E-06	7.43E-05	1.04E-04	1.52E-07	5.22E-07	3.77E-07	2.42E-08
3	1.27E-02	1.17E-05	1.64E-06	1.24E-04	1.75E-04	2.44E-07	8.35E-07	6.06E-07	3.96E-08
4	1.80E-02	1.55E-05	2.17E-06	1.66E-04	2.36E-04	3.18E-07	1.09E-06	7.92E-07	5.28E-08
5	2.24E-02	1.79E-05	2.51E-06	1.94E-04	2.79E-04	3.63E-07	1.23E-06	9.05E-07	6.15E-08
6	2.35E-02	1.76E-05	2.47E-06	1.91E-04	2.78E-04	3.50E-07	1.19E-06	8.74E-07	6.07E-08
7	2.55E-02	1.79E-05	2.52E-06	1.96E-04	2.87E-04	3.50E-07	1.18E-06	8.75E-07	6.20E-08
8	2.59E-02	1.71E-05	2.41E-06	1.88E-04	2.79E-04	3.27E-07	1.10E-06	8.20E-07	5.94E-08
9	2.58E-02	1.60E-05	2.27E-06	1.78E-04	2.66E-04	3.02E-07	1.01E-06	7.57E-07	5.62E-08
10	2.54E-02	1.49E-05	2.12E-06	1.67E-04	2.54E-04	2.76E-07	9.16E-07	6.93E-07	5.27E-08
11	2.50E-02	1.39E-05	1.98E-06	1.57E-04	2.42E-04	2.51E-07	8.29E-07	6.33E-07	4.94E-08
12	2.45E-02	1.29E-05	1.86E-06	1.48E-04	2.32E-04	2.29E-07	7.50E-07	5.79E-07	4.64E-08
13	2.42E-02	1.21E-05	1.75E-06	1.40E-04	2.25E-04	2.10E-07	6.81E-07	5.32E-07	4.38E-08
14	2.34E-02	1.12E-05	1.62E-06	1.30E-04	2.16E-04	1.90E-07	6.09E-07	4.82E-07	4.08E-08
15	2.27E-02	1.04E-05	1.52E-06	1.22E-04	2.09E-04	1.72E-07	5.45E-07	4.37E-07	3.81E-08
16	2.21E-02	9.69E-06	1.42E-06	1.15E-04	2.03E-04	1.56E-07	4.88E-07	3.98E-07	3.59E-08
17	2.16E-02	9.11E-06	1.35E-06	1.09E-04	2.00E-04	1.43E-07	4.40E-07	3.66E-07	3.40E-08
18	2.11E-02	8.57E-06	1.27E-06	1.04E-04	1.98E-04	1.31E-07	3.96E-07	3.36E-07	3.22E-08
19	2.06E-02	8.08E-06	1.21E-06	9.86E-05	1.98E-04	1.20E-07	3.55E-07	3.09E-07	3.07E-08

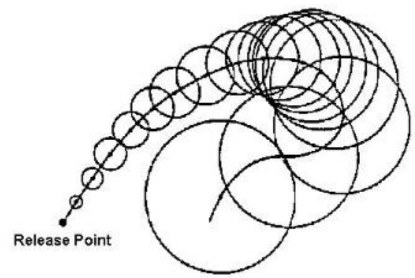
Table 4.0.2 Default (3412 MWth) and Adjusted* (3800 MWth) Shutdown Core Inventory for a PWR Reactor

Isotope	Group	Default Inventory (Ci)	Adjusted Inventory (Ci)
KR-85	1	6.69E+05	7.45E+05
KR-85M	1	3.13E+07	3.49E+07
KR-87	1	5.72E+07	6.38E+07
KR-88	1	7.74E+07	8.62E+07
XE-133	1	1.83E+08	2.04E+08
XE-135	1	3.44E+07	3.83E+07
I-131	2	8.66E+07	9.65E+07
I-132	2	1.28E+08	1.42E+08
I-133	2	1.83E+08	2.04E+08
I-134	2	2.01E+08	2.24E+08
I-135	2	1.73E+08	1.92E+08
CS-134	3	1.17E+07	1.30E+07
CS-136	3	3.56E+06	3.96E+06
CS-137	3	6.53E+06	7.28E+06
RB-86	3	5.10E+04	5.68E+04
SB-127	4	7.53E+06	8.39E+06
SB-129	4	2.67E+07	2.97E+07
TE-127	4	7.28E+06	8.11E+06
TE-127M	4	9.63E+05	1.07E+06
TE-129	4	2.50E+07	2.79E+07

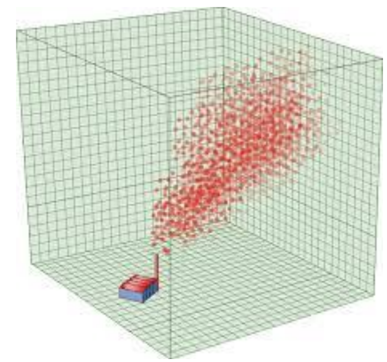
Selection of Dispersion Model



Gaussian Plume Model



Gaussian Puff Model



Lagrangian Particle Model

Gaussian Plume Model

- Fast running
- Assumes a straight wind driving the plume
- Suitable for short range dispersion

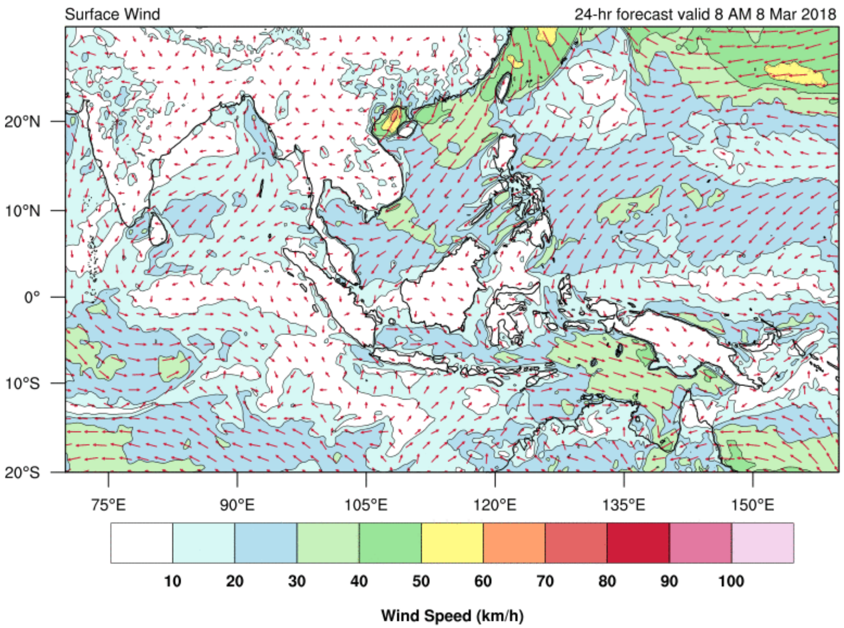
Gaussian Puff Model

- Fast running
- Accounts for spatially varying weather/ wind conditions
- Limited to dispersion in the mesoscale (~100s of km)

Lagrangian Particle Model

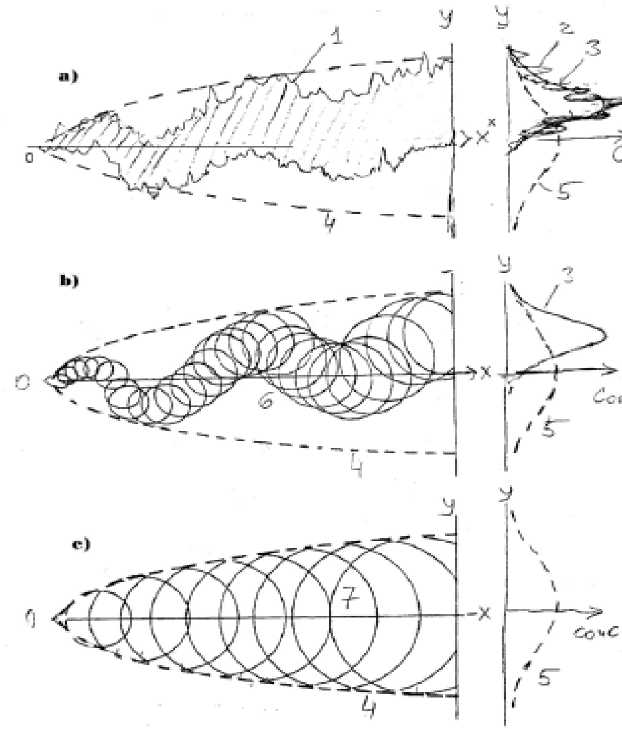
- Takes longer to run relative to Gaussian modelling approaches
- Accounts for spatially varying weather/wind conditions
- Suitable for use in the long range (> 100s km)

Rationale for Selection of Puff Dispersion Model



http://www.weather.gov.sg/weather-marine-surface-wind

Spatially varying wind conditions



"Reality "

Puff (e.g. RIMPUFF, SCIPUFF)

Plume (e.g. HOTSPOT)

Figure 2 Puff simulation atmospheric dispersion. a) Plume behaviour, short term puff simulation, c) long term averaged puff simulation. 1 - instantaneous plume contour, 2 - instantaneous crosswind concentration distribution, 3 - short term averaged crosswind concentration distribution, 4 - long term averaged plume contour, 5 - long term averaged crosswind concentration distribution, 6 - short term averaged puffs, 7 - long term averaged puffs

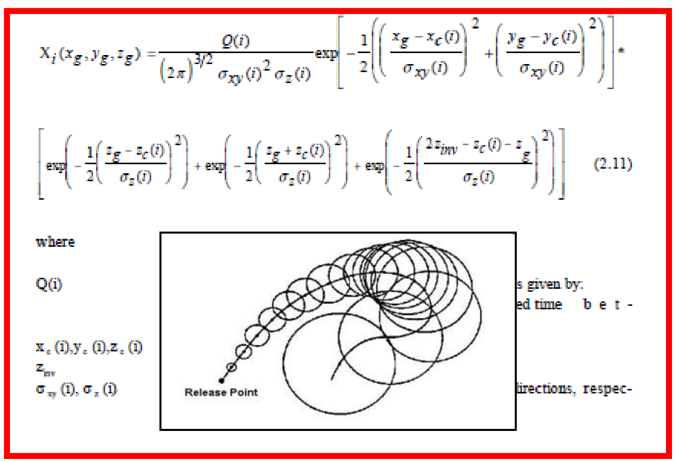
(DTU, 1999)

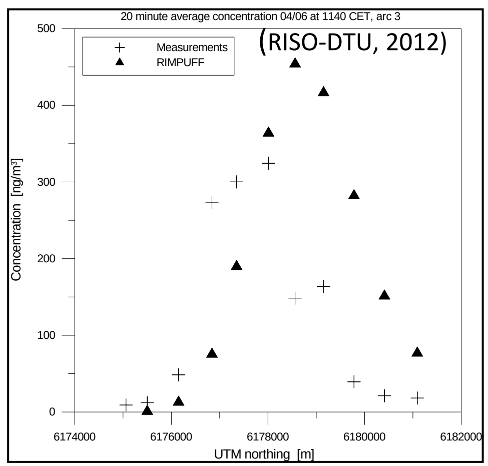
Ability to account for plumes driven by spatially varying wind is important, especially when considering long range dispersion.

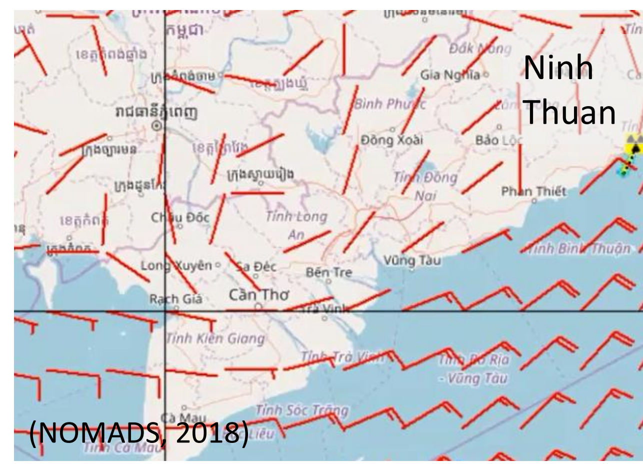
Dispersion Modelling Approach Adopted

- Atmospheric Model - Riso Mesoscale Puff (RIMPUFF) model[3]
  - RIMPUFF model output was compared with field measurements, including data obtained during "Oresund Campaign" an SF_6 release campaign conducted in Denmark (Thykier Nielsen, 2002).

- Numerical Weather Prediction (NWP)/ Gridded Weather Information[4]) at 55 km spatial resolution, 3 hourly temporal resolution



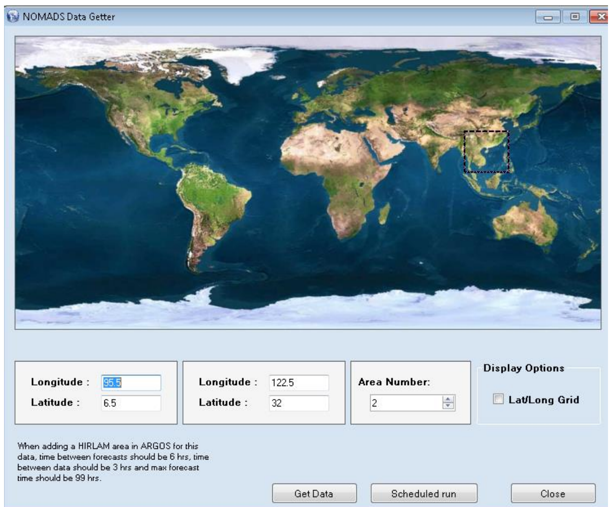




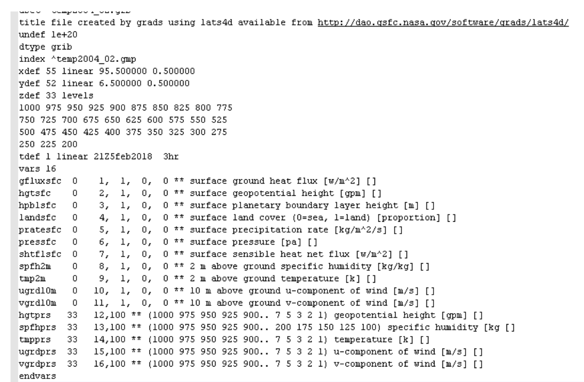
3. RIMPUFF developed by Wind Energy department of DTU. Recommended for use for up to 300km dispersion downwind (http://www.pdc-argos.com/rad-nuc-scenarios.html) Used as key dispersion model in Accident Reporting and Guidance Operating System (ARGOS) was used as a basis of the modelling work (http://www.pdc-argos.com/)

4. NOAA Operational Model Archive and Distribution System (NOMADS NWP Data) in HIRLAM format obtained via the ARGOS weather server (**http://nomads.ncep.noaa.gov/**)

NWP Weather Server



Data Downloaded from ARGOS NOMADS server



```
title file created by grads using lats4d available from http://dao.gsfc.nasa.gov/software/grads/lats4d/
undef 1e+20
dtype grib
index ^temp2004_02.gmp
xdef 55 linear 95.500000 0.500000
ydef 52 linear 6.500000 0.500000
zdef 33 levels
1000 975 950 925 900 875 850 825 800 775
750 725 700 675 650 625 600 575 550 525
500 475 450 425 400 375 350 325 300 275
250 225 200
tdef 1 linear 21Z5feb2018  3hr
vars 16
gfluxsfc  0    1,  1,  0,  0 ** surface ground heat flux [w/m^2] []
hgtsfc    0    2,  1,  0,  0 ** surface geopotential height [gpm] []
hpblsfc   0    3,  1,  0,  0 ** surface planetary boundary layer height [m] []
landsfc   0    4,  1,  0,  0 ** surface land cover (0=sea, 1=land) [proportion] []
pratesfc  0    5,  1,  0,  0 ** surface precipitation rate [kg/m^2/s] []
pressfc   0    6,  1,  0,  0 ** surface pressure [pa] []
shtflsfc  0    7,  1,  0,  0 ** surface sensible heat net flux [w/m^2] []
spfh2m    0    8,  1,  0,  0 ** 2 m above ground specific humidity [kg/kg] []
tmp2m     0    9,  1,  0,  0 ** 2 m above ground temperature [k] []
ugrd10m   0   10,  1,  0,  0 ** 10 m above ground u-component of wind [m/s] []
vgrd10m   0   11,  1,  0,  0 ** 10 m above ground v-component of wind [m/s] []
hgtprs   33   12,100 ** (1000 975 950 925 900.. 7 5 3 2 1) geopotential height [gpm] []
spfhprs  33   13,100 ** (1000 975 950 925 900.. 200 175 150 125 100) specific humidity [kg []
tmpprs   33   14,100 ** (1000 975 950 925 900.. 7 5 3 2 1) temperature [k] []
ugrdprs  33   15,100 ** (1000 975 950 925 900.. 7 5 3 2 1) u-component of wind [m/s] []
vgrdprs  33   16,100 ** (1000 975 950 925 900.. 7 5 3 2 1) v-component of wind [m/s] []
endvars
```

Data converted into HIRLAM file format

Data stored in ARGOS Database

Summary of Modelling Approach & Model Results

Puff Dispersion driven by Northerly winds & NWP:

- **Short Range Dispersion**

(a) Air Concentration & ground contamination

- one day after accident starts,
- Temporal maximum

(b) TEDE (early exposure) at the proposed downwind distances

- For straight wind, downwind is towards the S direction.
- For NWP, downwind is towards the SW direction

Puff Dispersion Driven by NWP:

- **Long Range Dispersion**

- Spatial maximum TEDE (early exposure) at proposed downwind distances,
- Contour of TEDE & lead time

Details of Wind Data Inputs & Puff Model Outputs

<table>
<tr><th>Wind Data</th><th>Short Range Dispersion
(Up to 30 km downwind)</th><th>Long Range Dispersion[5]
(Up to 500 km downwind)</th></tr>
<tr><td>Straight Wind*</td><td rowspan="2">1. Air Concentration (Bq/m^3)
2. Ground Concentration (Bq/m^2)
@ 5km, 8km, 10 km, 16 km, 20 km & 30 km downwind:
• 1 day after release
• Maximum

3. TEDE (Sv), early exposure @ 5km, 8km, 10 km, 16 km, 20 km & 30 km downwind:</td><td>Not Applicable
(Straight wind assessed to be not suitable for long range dispersion)</td></tr>
<tr><td>NWP/
Gridded Wind Information
(31st Jan2018, 0000 UTC to 3rd Feb 2018, 1500 UTC)</td><td>TEDE (Sv) , early exposure @ 50km, 80km, 100 km, 200 km, 300 km & 500[5] km downwind.

Lead-time (h) @ 50km, 80km, 100 km, 200 km, 300 km, 500[5] km downwind.</td></tr>
</table>

NB: Puff Frequency: 5 minutes/ Short Range Grid Resolution: 1 km and Long Range Resolution: 2km/ Flat Terrain

*Weather Condition:
- Winds: Northerly straight wind, 3.78 m/s
- Stability Class: D [6] (Rain not considered)

Summary of Meteorological Data

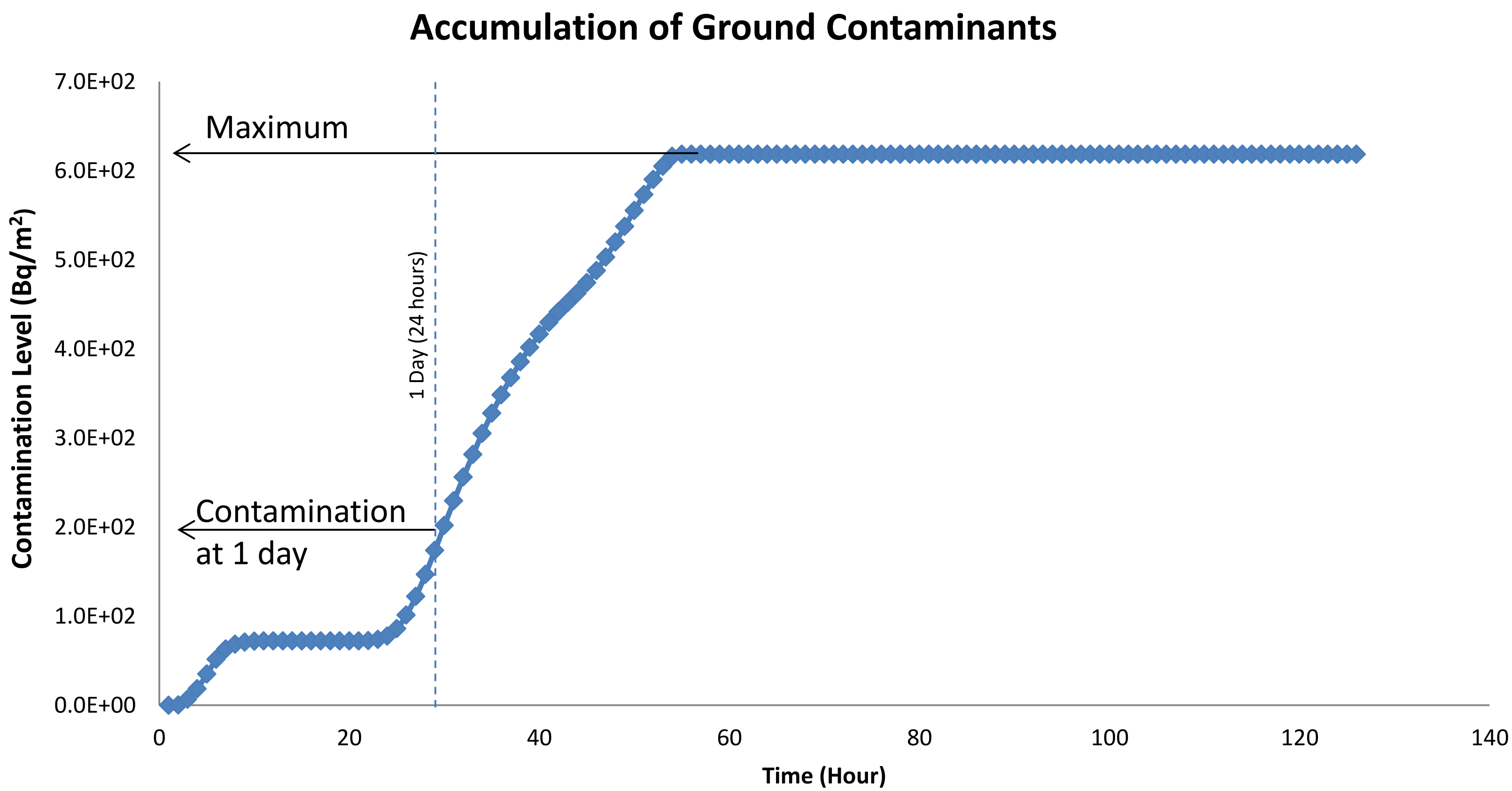
Direction	Stability		Rain (mm/h)		Wind speed (m/s)	
	Vietnam	China	Vietnam	China	Vietnam	China
N	D	E	0.22	0.58	3.78	2.06

5. 500 km is beyond the recommended bounds of RIMPUFF
6. Weather obtained from previous modelling study NPSR (2017)

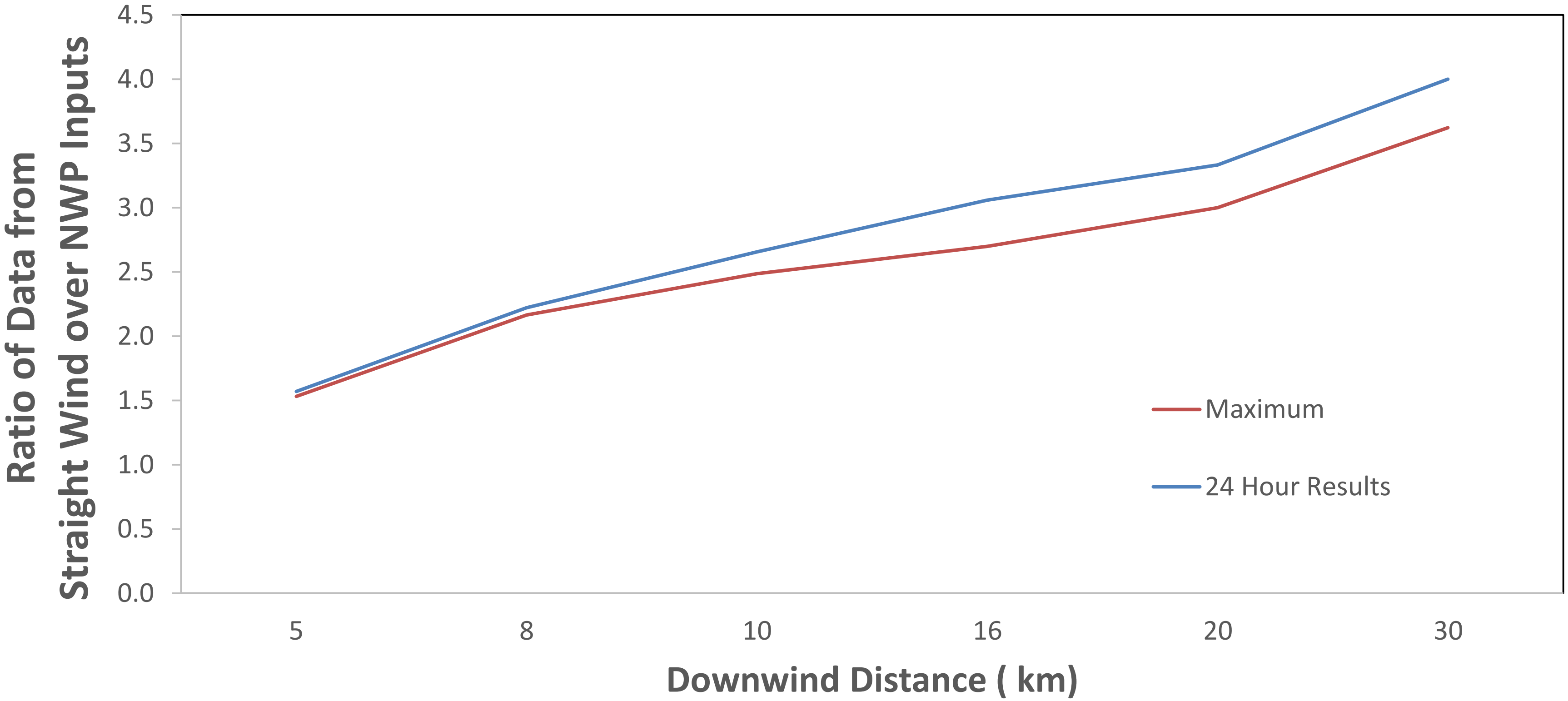
Video of NWP driven Dispersion

To illustrate plume dispersion driven by NWP

Illustration of Temporal Pattern of Cumulative Ground Contamination Levels
(at a given point)



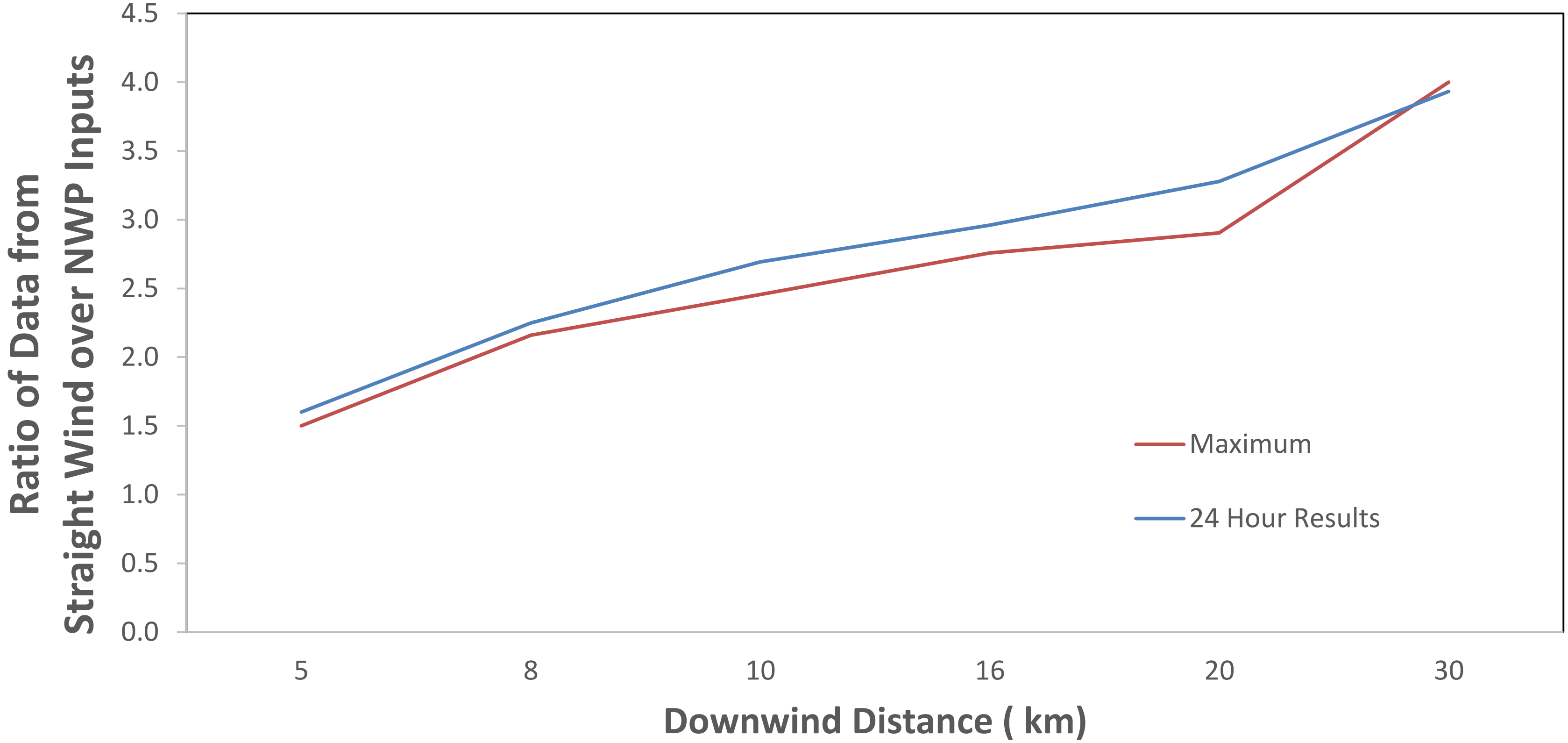
Cumulative Cs-137 Ground Contamination (Bq/m²) Data Short Range Dispersion Preliminary Results (Ia)



Ground Contamination Values (Bq/m²)		5 km		8 km		10 km		16 km		20 km		30 km	
		Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP
	1 day	2.2×10^4	1.4×10^4	1.2×10^4	5.4×10^3	9.3×10^3	3.5×10^3	5.2×10^3	1.7×10^3	4.0×10^3	1.2×10^3	2.4×10^3	6.0×10^2
	Max	2.3×10^4	1.5×10^4	1.3×10^4	6.0×10^3	9.7×10^3	3.9×10^3	5.4×10^3	2.0×10^3	4.2×10^3	1.4×10^3	2.5×10^3	6.9×10^2

* Downwind: For straight wind, downwind is towards the S direction. For NWP, downwind is towards the SW direction.

Cumulative I-131 Ground Contamination (Bq/m^2) Data Short Range Dispersion Preliminary Results (Ib)



Ground Contamination Values (Bq/m^2)		5 km		8 km		10 km		16 km		20 km		30 km	
		Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP
	1 day	3.2×10^6	2.0×10^6	1.8×10^6	8.0×10^5	1.4×10^6	5.2×10^5	7.7×10^5	2.6×10^5	5.9×10^5	1.8×10^5	3.5×10^5	8.9×10^4
	Max	3.3×10^6	2.2×10^6	1.9×10^6	8.8×10^5	1.4×10^6	5.7×10^5	8.0×10^5	2.9×10^5	6.1×10^5	2.1×10^5	4.0×10^5	1.0×10^5

* Downwind: For straight wind, downwind is towards the S direction. For NWP, downwind is towards the SW direction.

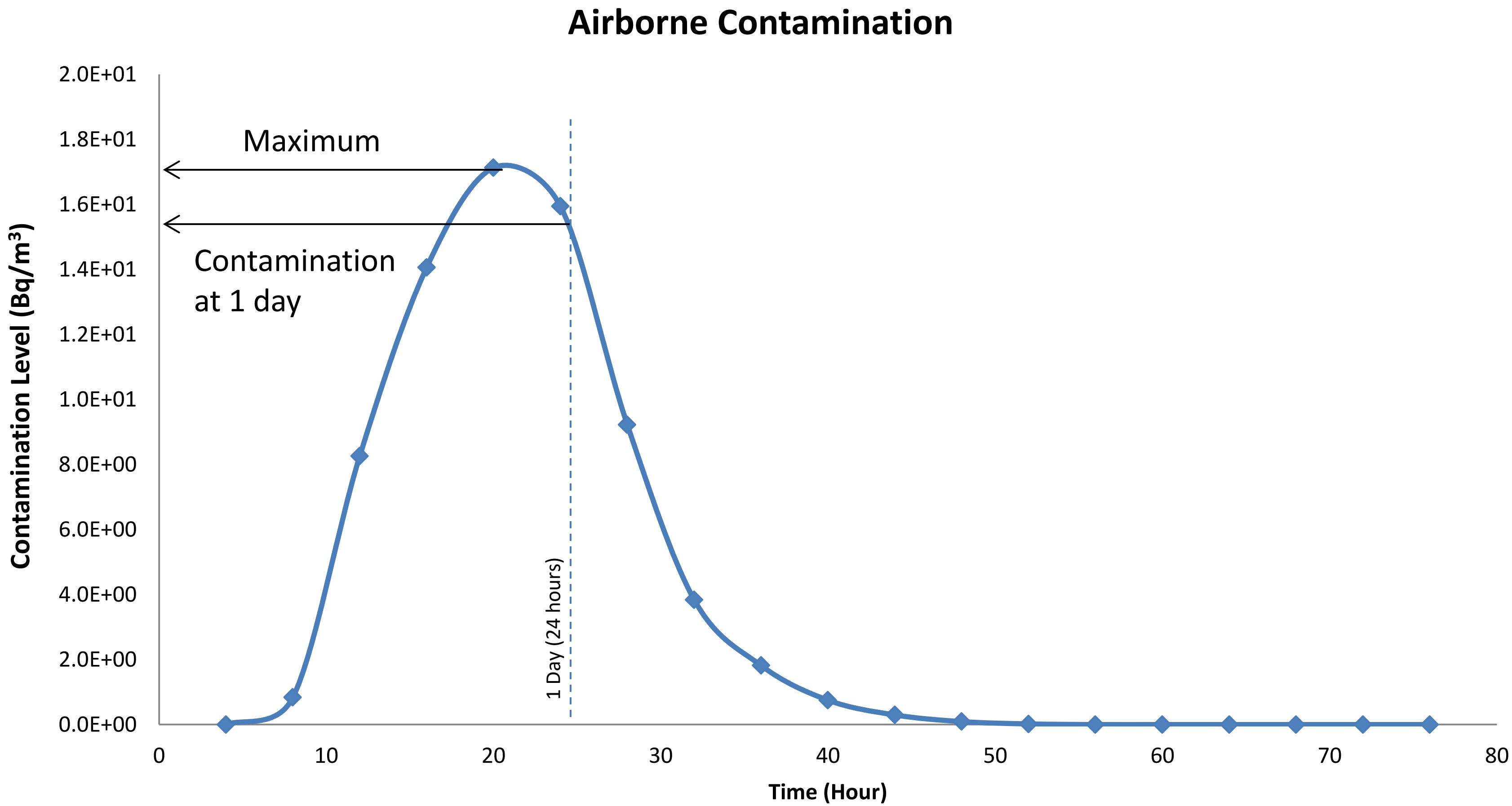
Observations (Ground Concentration)

1. Differing orders of magnitude of results for Cs-137 and I-131 due to different source amounts.

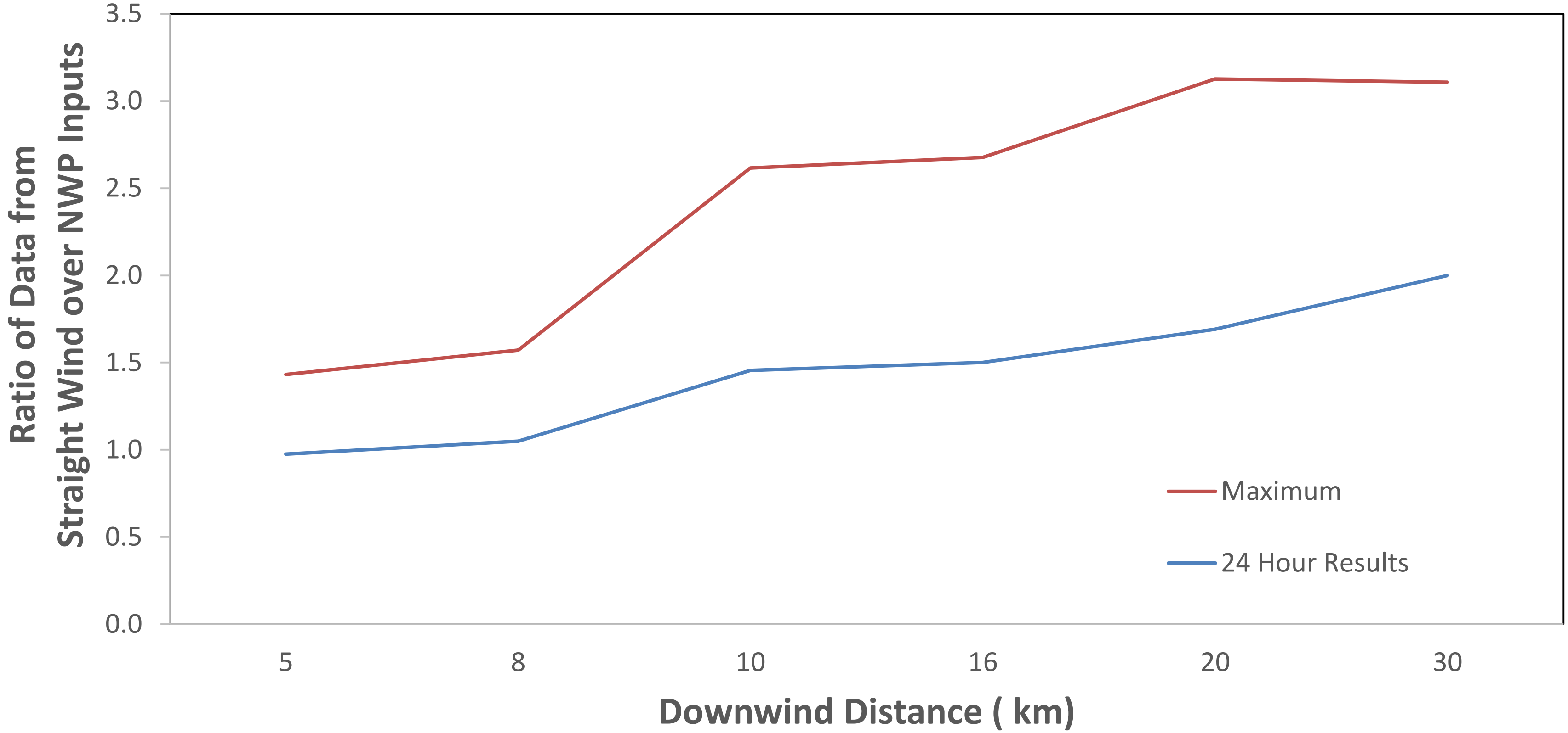
2. Straight wind results consistently more conservative compared with NWP. Both results are within the same order of magnitude (NB: The short range domain (30km) is within a single NWP grid (55 km))

3. Further downwind, the differences between NWP and Straight Wind results increases.

Illustration of Temporal Pattern of Cumulative Air Contamination Level
(at a given point)



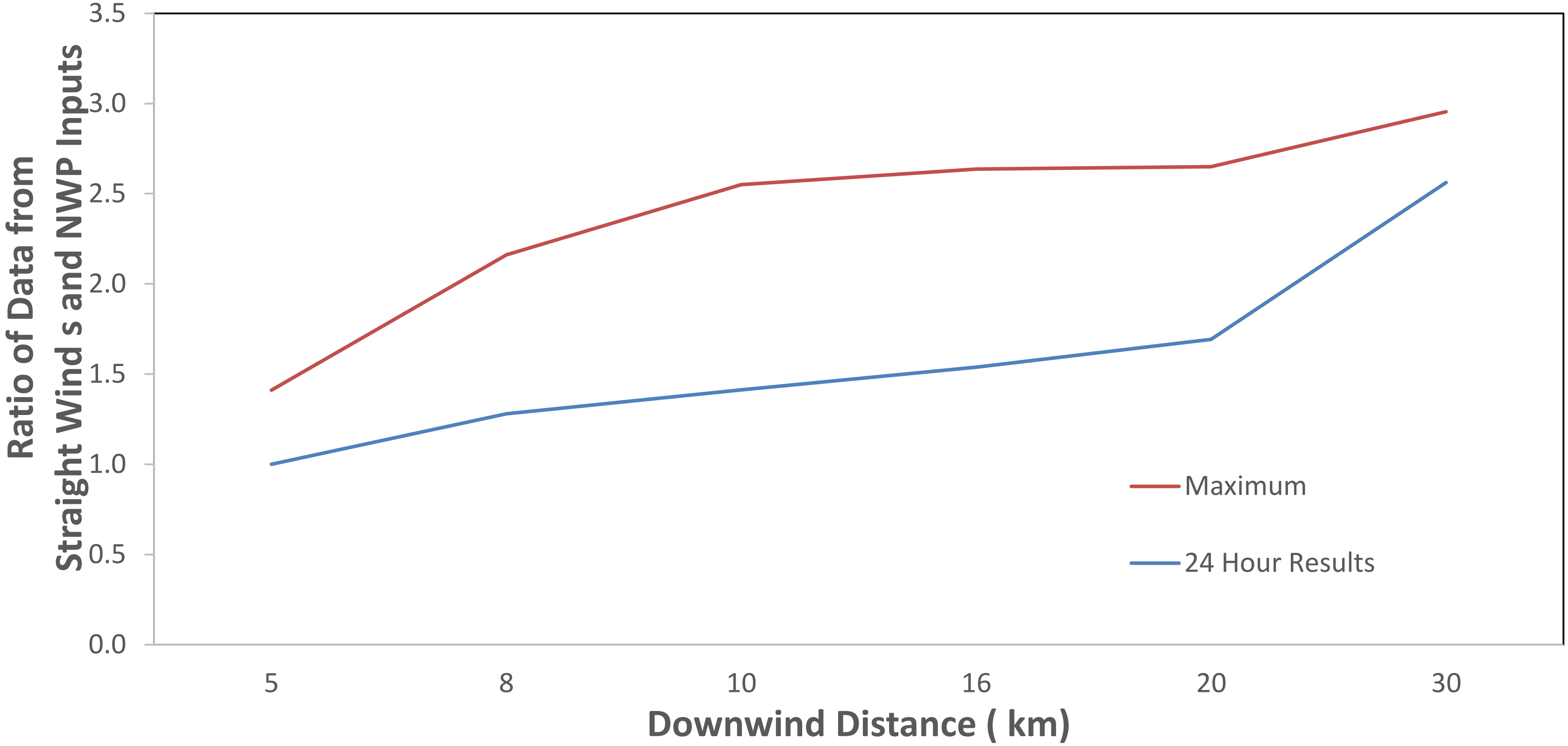
Cumulative Cs-137 Air Contamination (Bq/m^3) Data Short Range Dispersion Preliminary Results (IIa)



Air Contamination Values (Bq/m^3)		5 km		8 km		10 km		16 km		20 km		30 km	
		Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP
	1 day	3.9x10^2	4.0x10^2	2.1x10^2	2.0x10^2	1.6x10^2	1.1x10^2	9.0x10^1	6.0x10^1	7.1x10^1	4.2x10^1	4.8x10^1	2.4x10^1
	Max	7.3x10^2	5.1x10^2	4.4x10^2	2.8x10^2	3.4x10^2	1.3x10^2	1.9x10^2	7.1x10^1	1.5x10^2	4.8x10^1	8.7x10^1	2.8x10^1

* Downwind: For straight wind, downwind is towards the S direction. For NWP, downwind is towards the SW direction.

Cumulative I-131 Air Contamination (Bq/m³) Data Short Range Dispersion Preliminary Results (IIb)



Air Contamination Values (Bq/m³)		5 km		8 km		10 km		16 km		20 km		30 km	
		Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP	Straight Wind	NWP
	1 day	6.0×10^4	6.0×10^4	3.2×10^4	2.5×10^4	2.4×10^4	1.7×10^4	1.4×10^4	9.1×10^3	1.1×10^4	6.5×10^3	7.3×10^3	2.9×10^3
	Max	1.1×10^5	7.8×10^4	6.7×10^4	3.1×10^4	5.1×10^4	2.0×10^4	2.9×10^4	1.1×10^4	2.2×10^4	8.3×10^3	1.3×10^4	4.4×10^3

* Downwind: For straight wind, downwind is towards the S direction. For NWP, downwind is towards the SW direction.

Observations (Air Concentration)

1. Air Concentration (Bq/m^3) levels are 1-2 orders of magnitude lower than that of ground concentration (Bq/m^2)

2. Straight wind results generally more conservative compared with NWP.

3. The difference between Straight Wind results and NWP Wind results increases further downwind.

Prelim Results: Short Range Dispersion Results (III)

TEDE* at given downwind distance (Sv)	Exposure Period	Distance Downwind from Source					
		5 km	8 km	10 km	16 km	20 km	30 km
Straight Wind	1 Day	6.1×10^{-5}	4.6×10^{-5}	3.8×10^{-5}	2.6×10^{-5}	2.1×10^{-5}	1.3×10^{-5}
NWP	1 Day	6.2×10^{-5}	2.6×10^{-5}	1.7×10^{-5}	8.4×10^{-6}	5.8×10^{-6}	3.0×10^{-6}

*Total Effective Dose Equivalent

@ Maximum Total Effective Dose Equivalent

Key Observations :

1. Both cases: monotonically decreasing TEDE values as one goes further downwind.
2. Similar results near the source (5 km).
3. Further downwind (> 5 km), the differences between NWP and Straight Wind results increases.

Prelim Results: Long Range Dispersion Results (I)

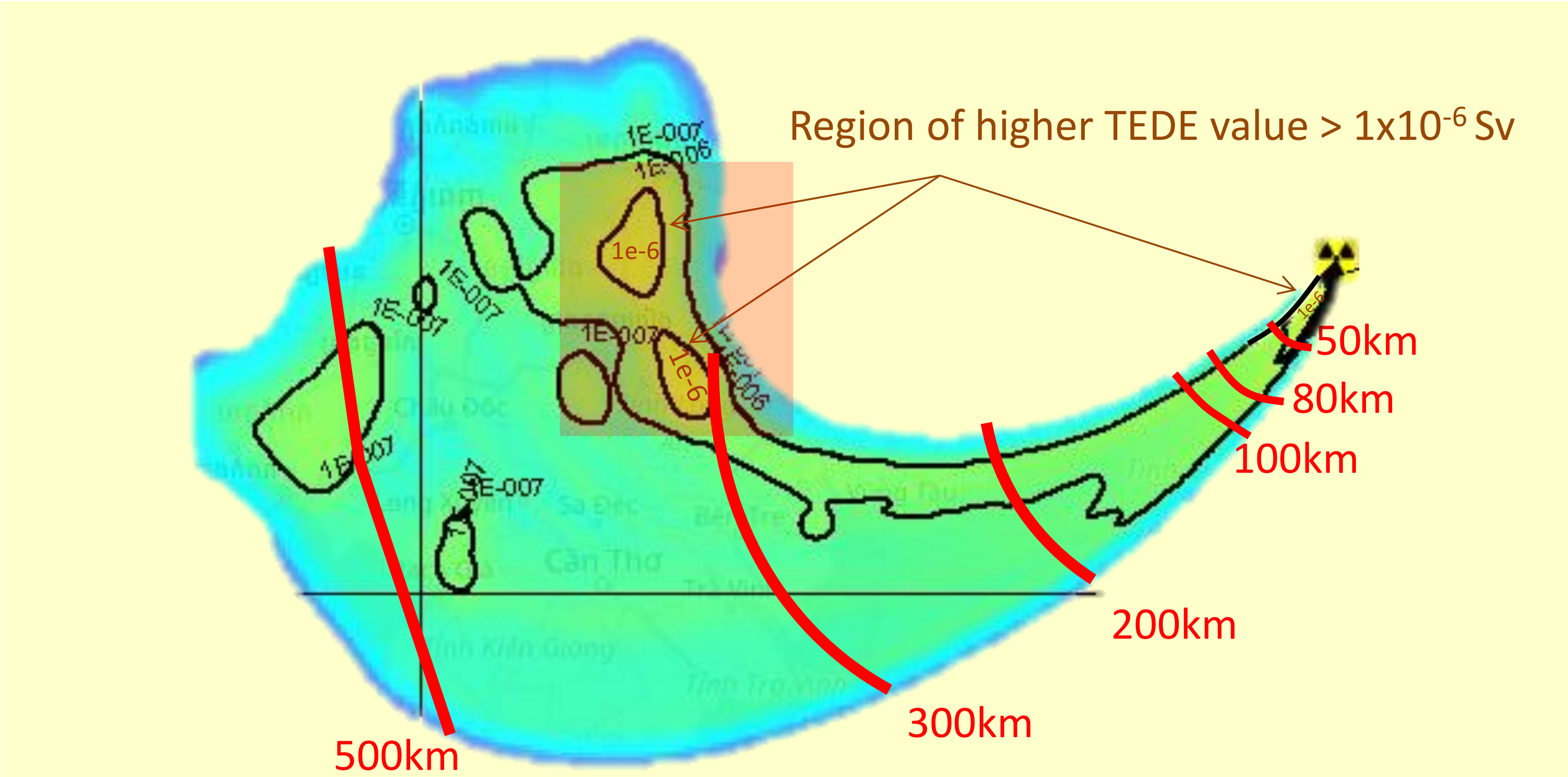


Figure: 1×10^{-6} Sv and 1×10^{-7} Sv TEDE contour plots

Prelim Results: Long Range Dispersion Results (II)

Model Output	Exposure Period	Distance Downwind from Source					
		50 km	80 km	100 km	200 km	300 km	500 km**
Maximum TEDE* at specified Downwind Distance (Sv)	1 Day	1.2×10^{-5}	5.2×10^{-5}	4.0×10^{-5}	1.7×10^{-5}	1.1×10^{-6}	3.0×10^{-5}
Lead-time to Reach the Distance (h)	NA	1.5	2	3.5	5	7.5	18

* Total Effective Dose Equivalent

** Beyond recommended bounds of RIMPUFF

Conclusion

- Short Range: Differences between straight and NWP inputs more pronounced > 5 km downwind

- Long Range: For NWP driven dispersion, plume persistency at 300 km downwind yielded an area with higher ground contamination
  - Due to the change in wind directions that advected the plume upwind

- Need for NWP winds to drive long range dispersion models
  - Validity of NWP obtained weather parameters within SEA requires assessment

- To facilitate modelling results inter-comparison, future modelling work will need harmonized model inputs