



# ASEAN NPSR Benchmark Problem Assessment

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# 1. Introduction- About Us

- Singapore Nuclear Research & Safety Initiative (SNRSI)
- Established on 22 Apr 2014
- Three research focus areas
  - Nuclear Safety Analysis
    - Atmospheric dispersion study
    - Simulation studies – pressurized water reactors
    - Safety analysis of newer reactors that are inherently safe.
  - Radiochemistry
    - Accurate and quick measurement of radioactivity
  - Radiobiology
    - Effects of low-dose radiation on human health
    - Develop expertise in dose assessment.

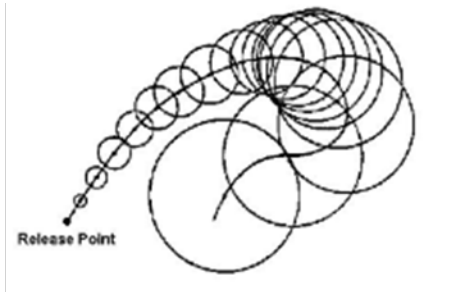


# Background

- 2017- Proposal for benchmark problem on consequence management
  - Vietnam and Thailand shared initial outcomes of modelling exercise
  
- 2018- Continuation of the benchmark problem on consequence management
  - Presentation from four countries on the proposed benchmark problem
  - Definition of initial conditions based on accident scenario from the SOARCA project of the USNRC(USA Nuclear Regulatory Commission)

# Background

- Further Discussion was done beyond since the 2<sup>nd</sup> meeting
- Participants include, Thailand, Singapore & Vietnam
- Cases pertaining to the benchmark problem have since been revised.
- SNRSI would like to share the findings from our technical study on the benchmark problem exercise.

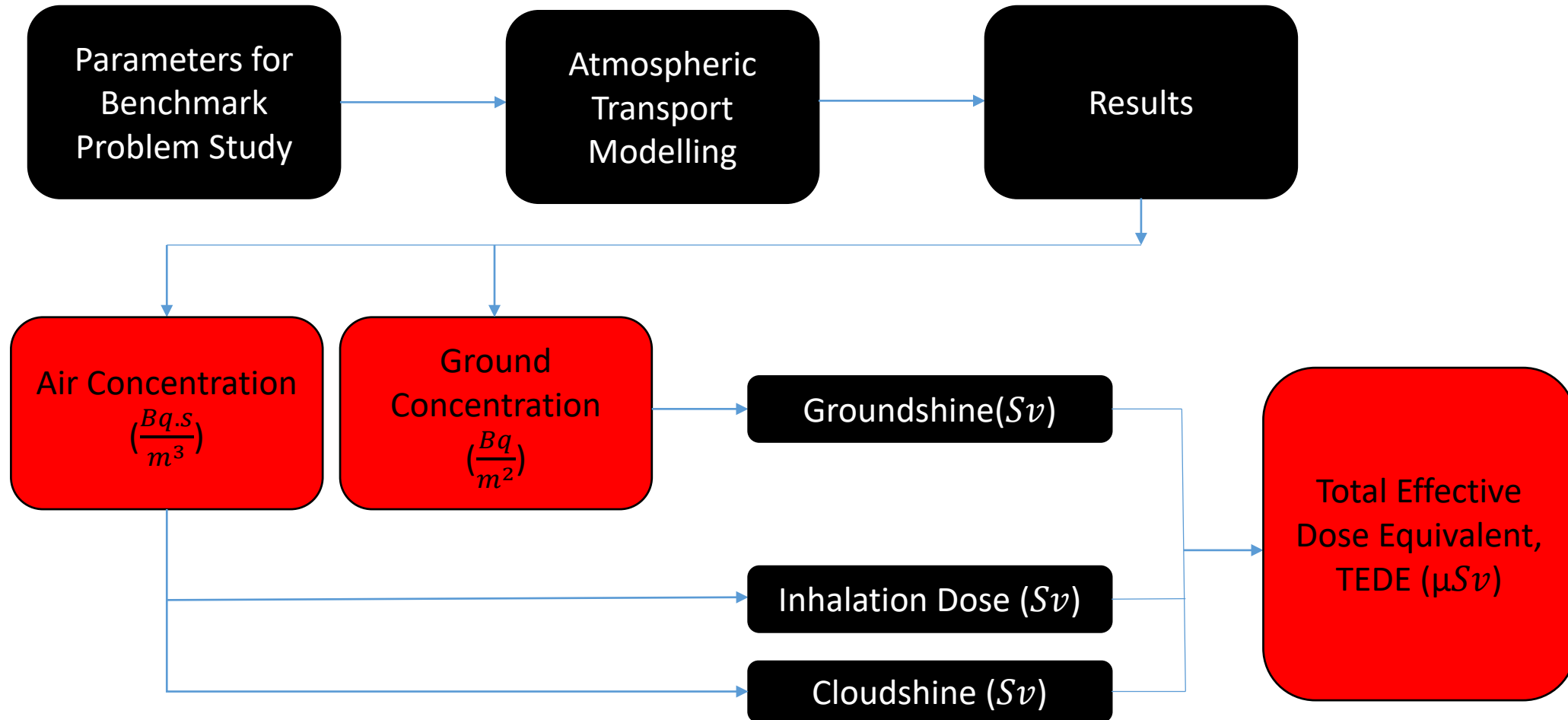


## Gaussian Puff Model

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

- ARGOS-PDC
- Utilize Numerical Weather Prediction(NWP) from USA NOAA ( 55 km spatial resolution & 3 hourly temporal resolution)
- Riso Mesoscale Puff (RIMPUFF) model
- Excel at short term accidental release of airborne materials into atmosphere
- Part of ARGOS2000 Decision Support System as well as the RODOS system

# SNRSI's Approach



## 2. Results NPP1 & NPP2

Results to be compared are:

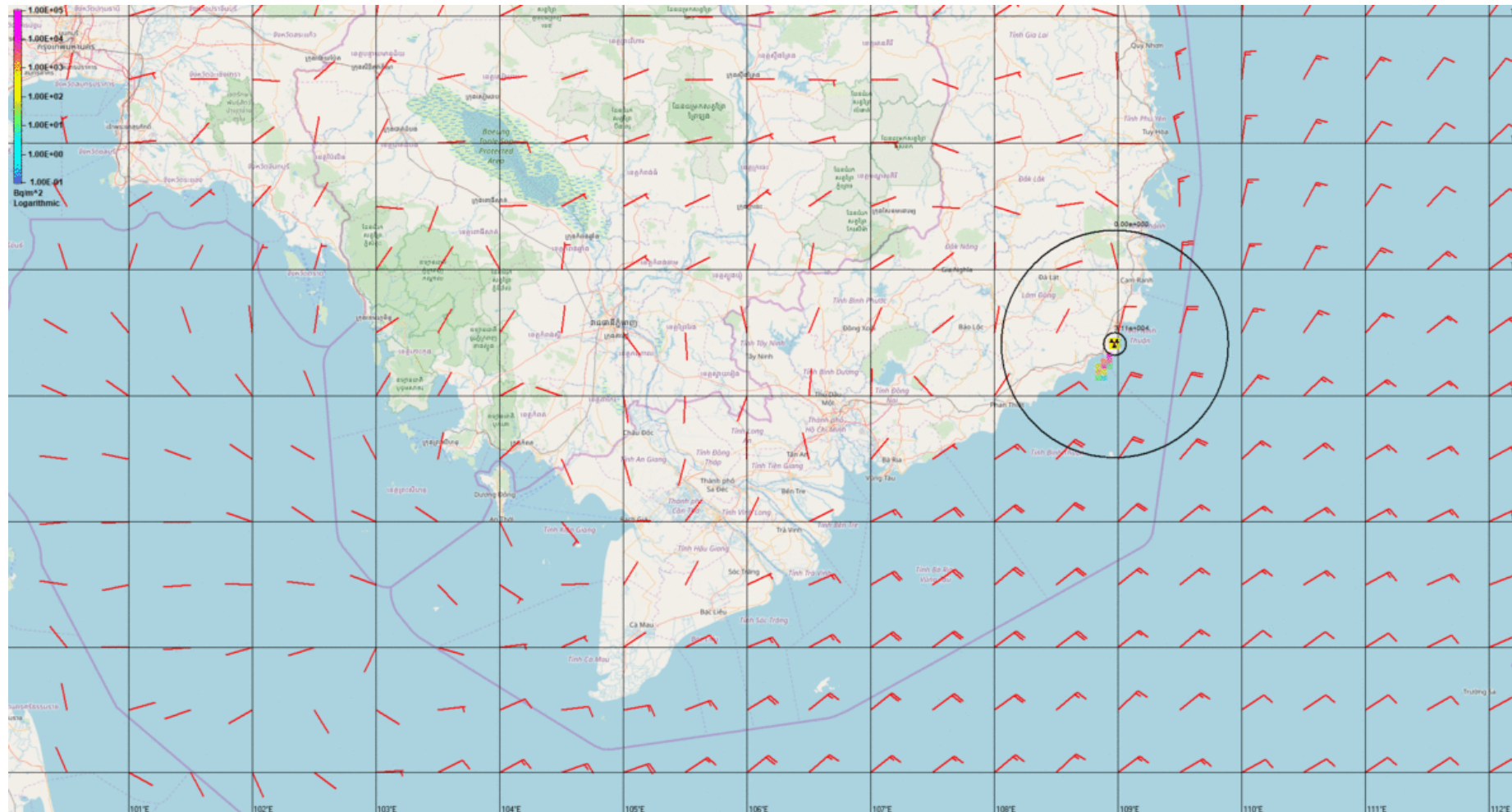
- Distribution maps of the following values at 1 day from the release starting time
  - *Time-integrated air concentration ( $\frac{Bq.s}{m^3}$ )*
  - *Ground concentration ( $\frac{Bq}{m^2}$ )*
  - *Time-integrated exposure dose in terms of TEDE ( $\mu Sv$ )*
- *1-day TEDE exposure extent for 1  $\mu Sv$  (defined as the furthest distance to which the specified TEDE is extended to)*
- *Air concentration ( $\frac{Bq.s}{m^3}$ ), ground concentration ( $\frac{Bq}{m^2}$ ) at 1 day from the release starting time at 10 / 100 km*

# Parameters for Benchmark Problem Study

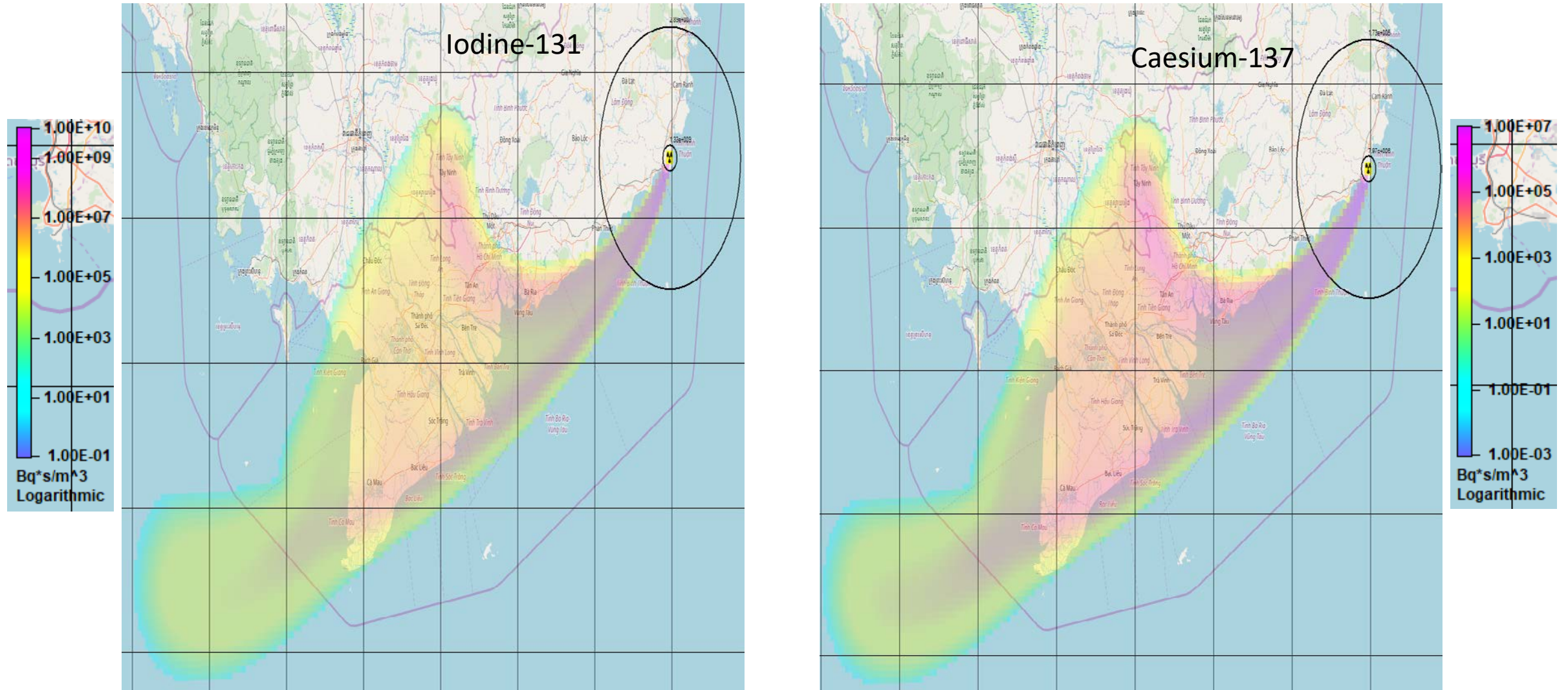
## Release Characteristics

- Locations
  - Ninh Thuan 1 Nuclear Power Plant (11°24'48"N 108°58'29"E)
  - Fangchenggang Nuclear Power Plant (21°40'15"N 108°33'30"E)
- Representative radionuclides
  - I-131: for the evaluation of short-term consequences
  - Cs-137: for the evaluation of long-term consequences
- Release amount (total release amount for the whole period)
  - Cs-137:  $6 \times 10^{13}$  Bq
  - I-131:  $1 \times 10^{16}$  Bq (aerosol only)
- Release starting time
  - Ninh Thuan 1 Nuclear Power Plant: January 31, 2018 at 00:00 (GMT+8)
  - Fangchenggang Nuclear Power Plant: January 18, 2018 at 15:00 (GMT+8)
  - Fangchenggang Nuclear Power Plant: November 25, 2018 at 00:00 (GMT+8)
- Release period: 26 hours (constant rate)
- Release height: 10 meters
- Heat content: 500 kW (to calculate plume rise)

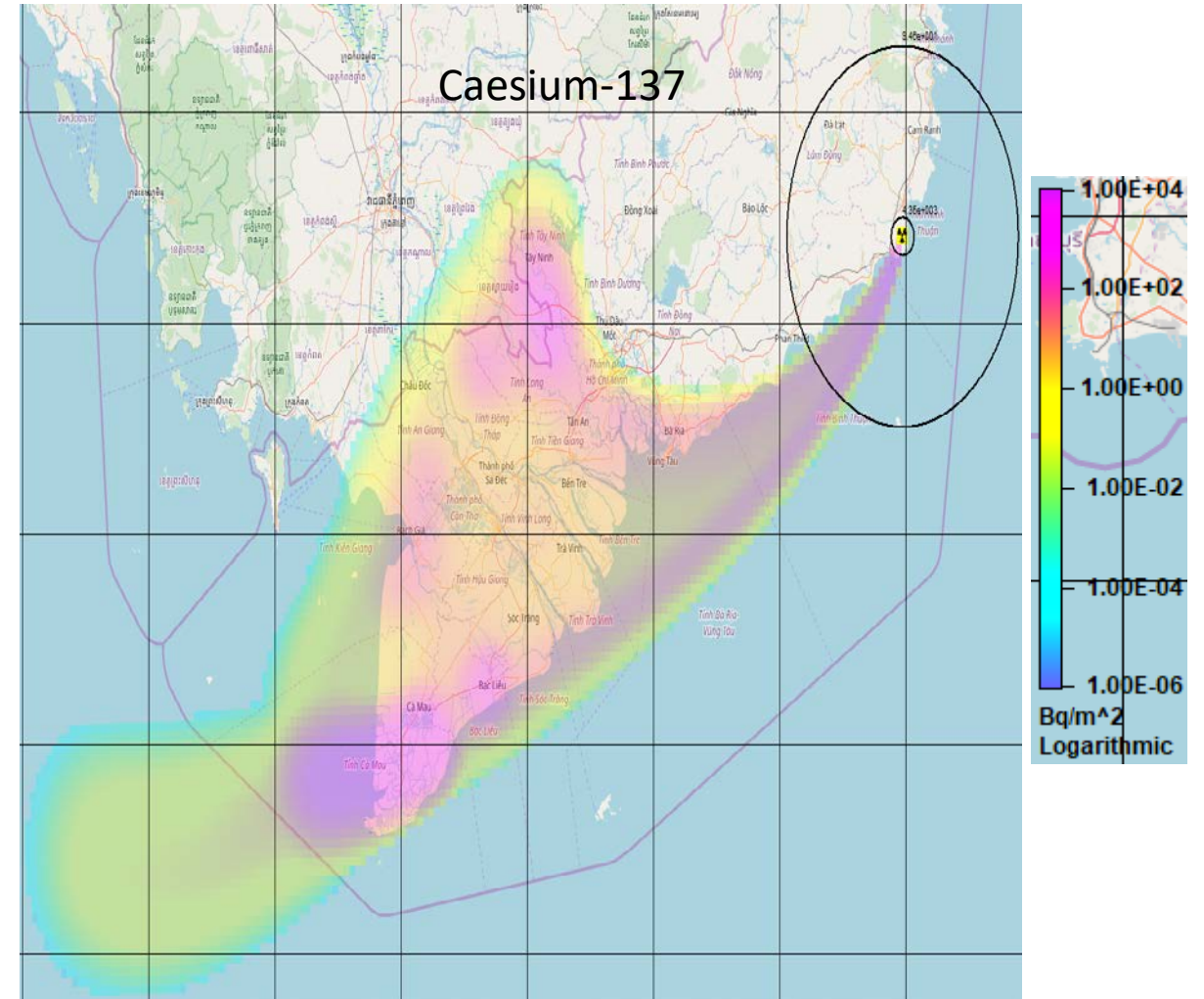
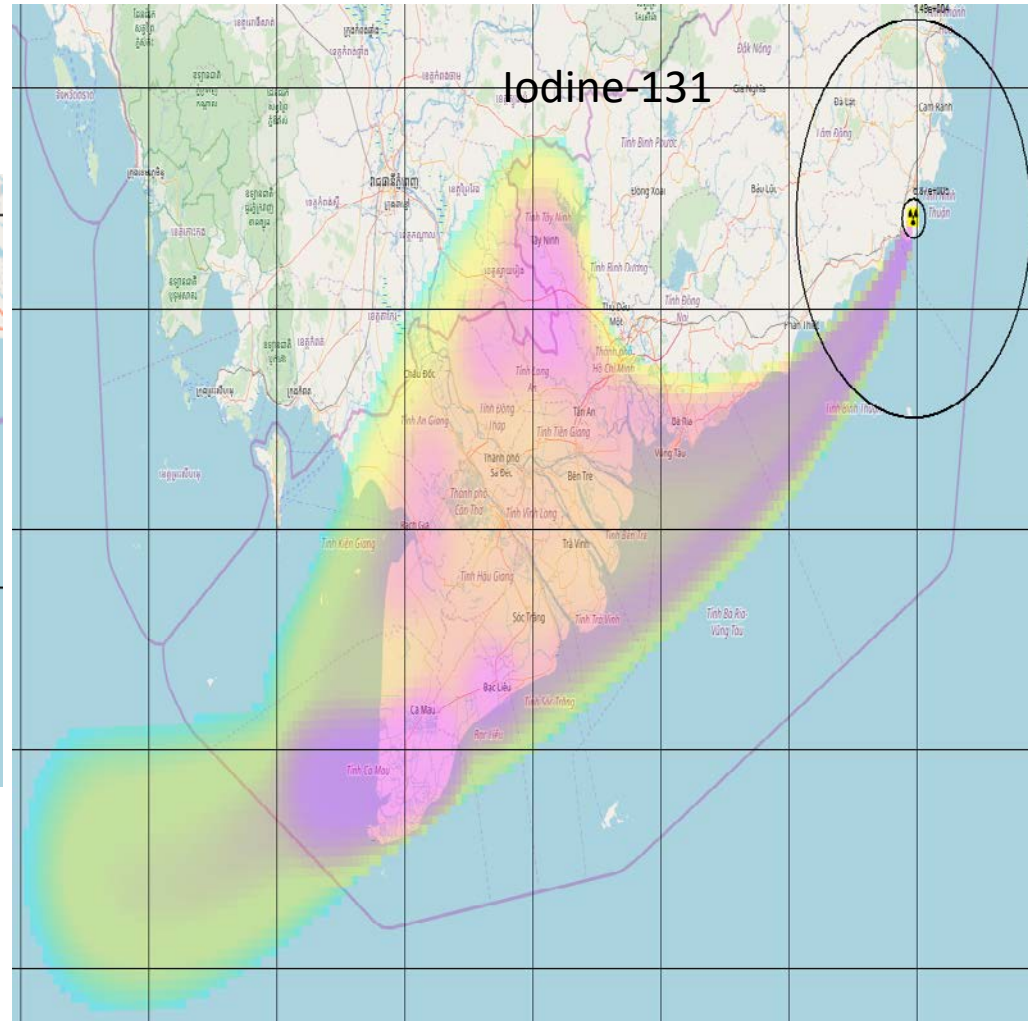
# 2018 Benchmark Problem: NPP1 31<sup>th</sup> Jan



# Air Concentration after 24 hours



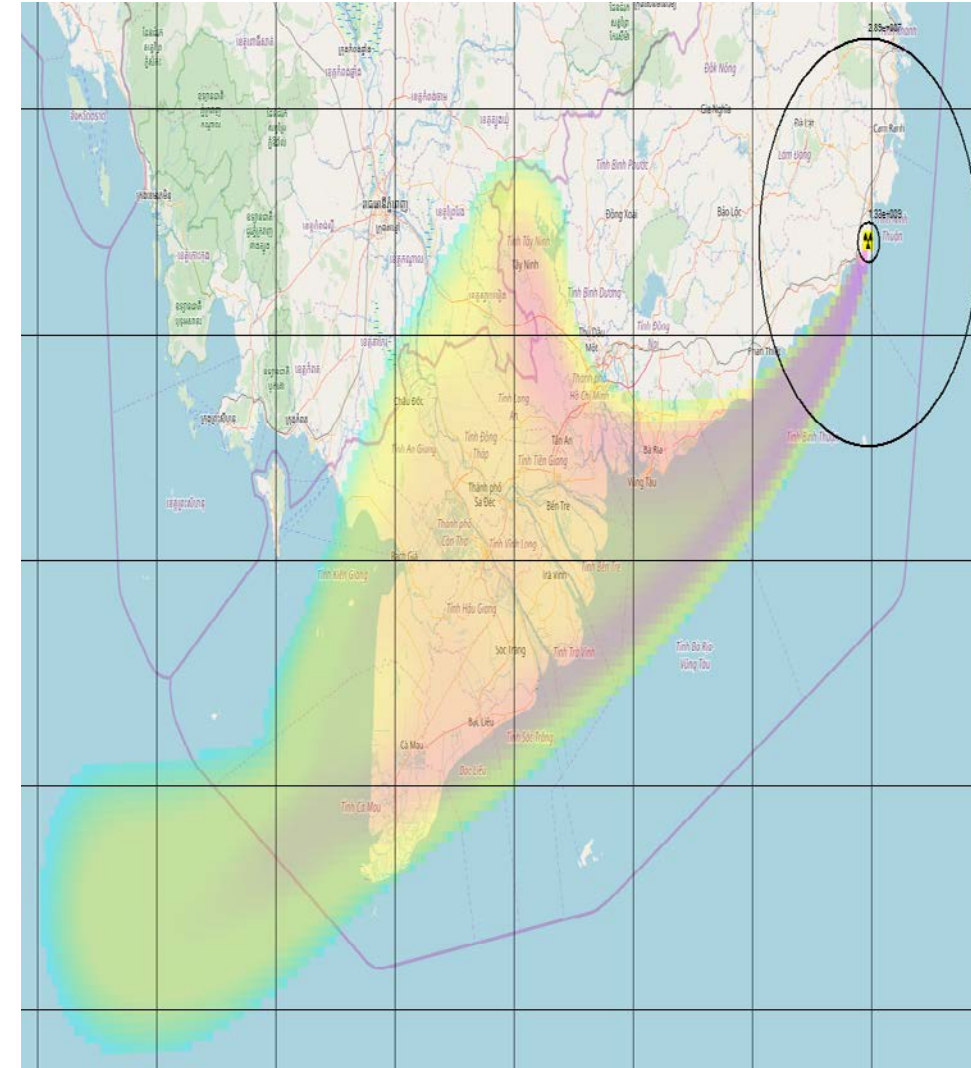
# Ground Concentration (1 day)



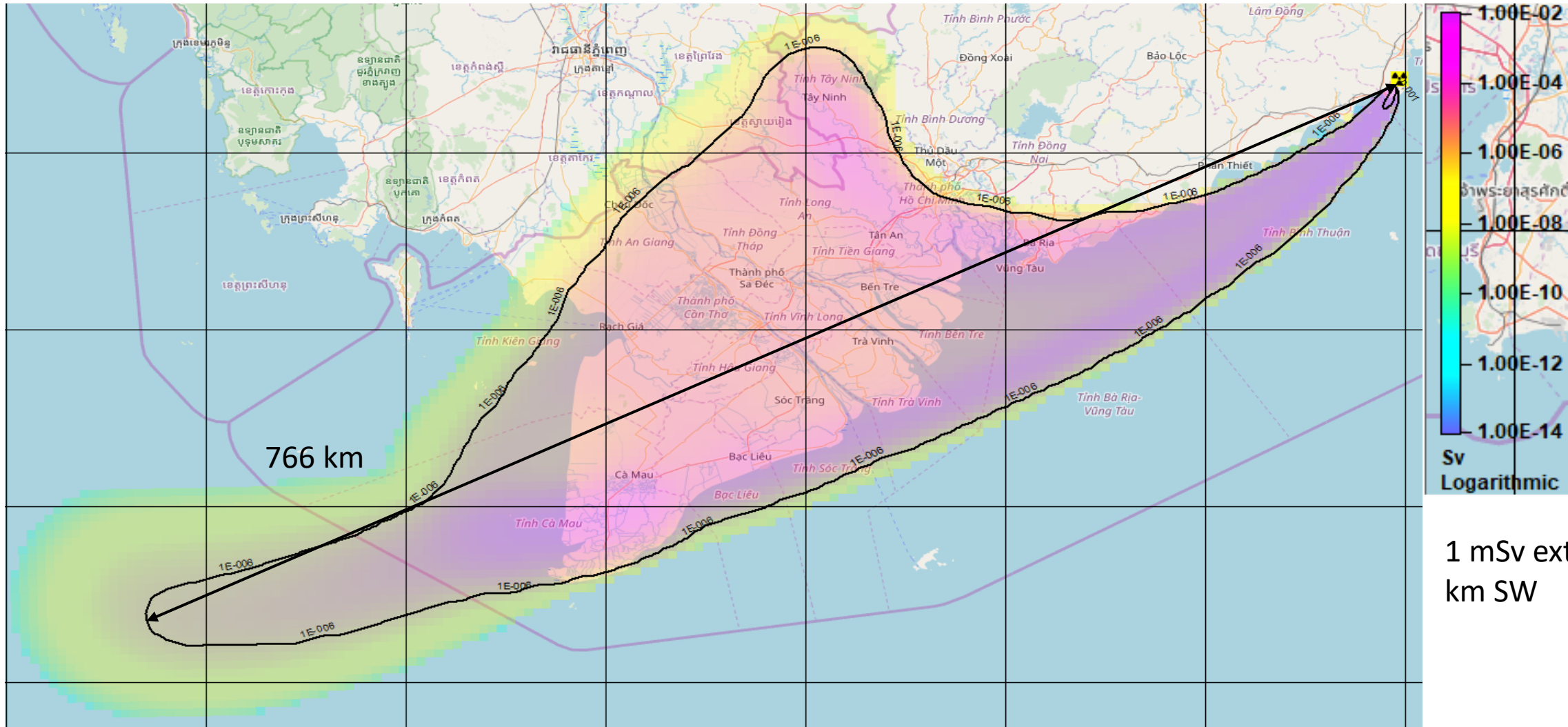
# NPP1

In Southwest direction

		10 km	100 km
Air Conc $(\frac{Bq.s}{m^3})$	I-131	1.33E9	2.89E7
	Cs-137	7.97E6	1.73E5
Ground Conc $(\frac{Bq}{m^2})$	I-131	6.87E5	1.49E4
	Cs-137	4.35E3	9.46E1



# 1 Day TEDE (Adults) exposure extent for $1\mu\text{Sv}$

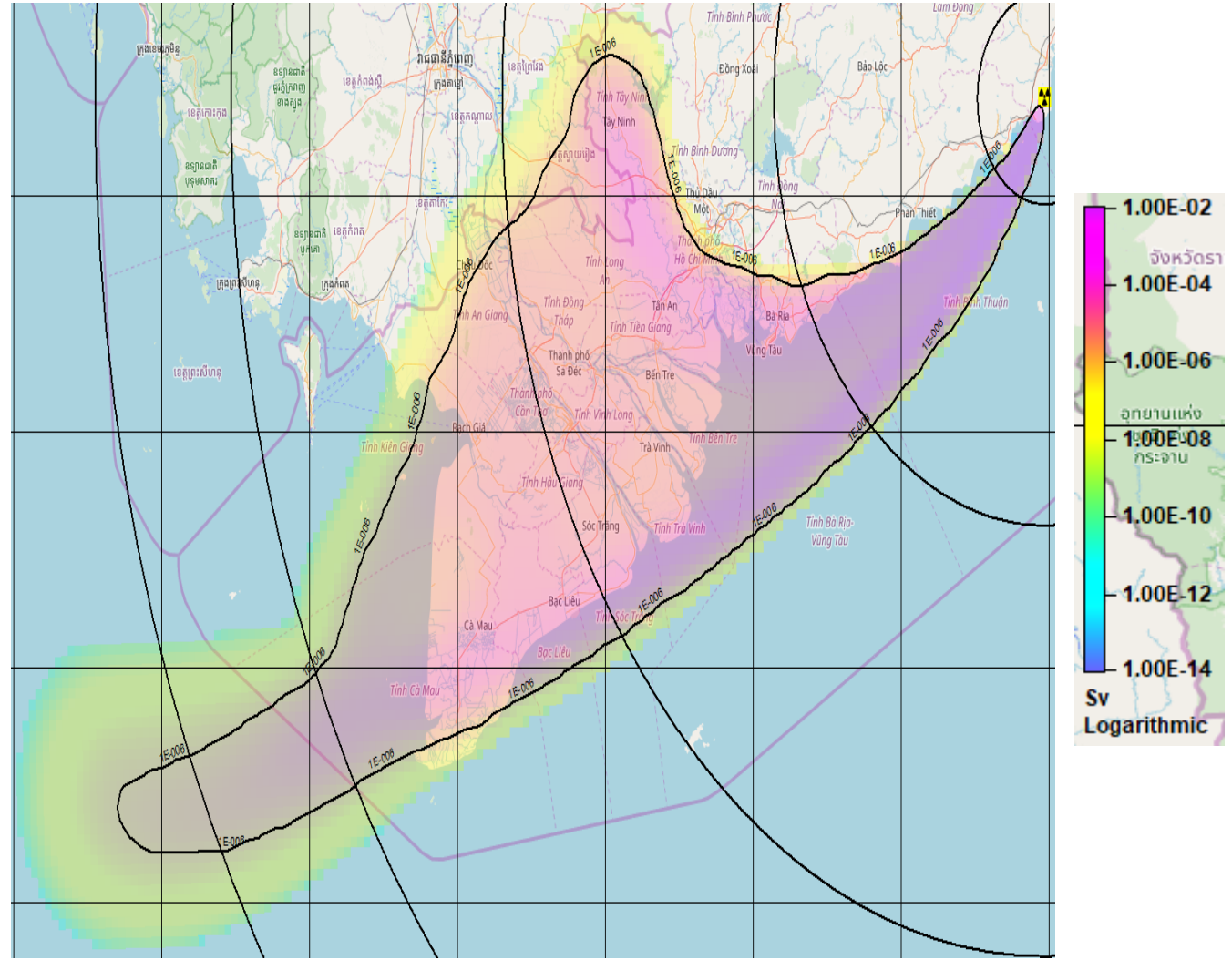


1 mSv extend 20 km SW

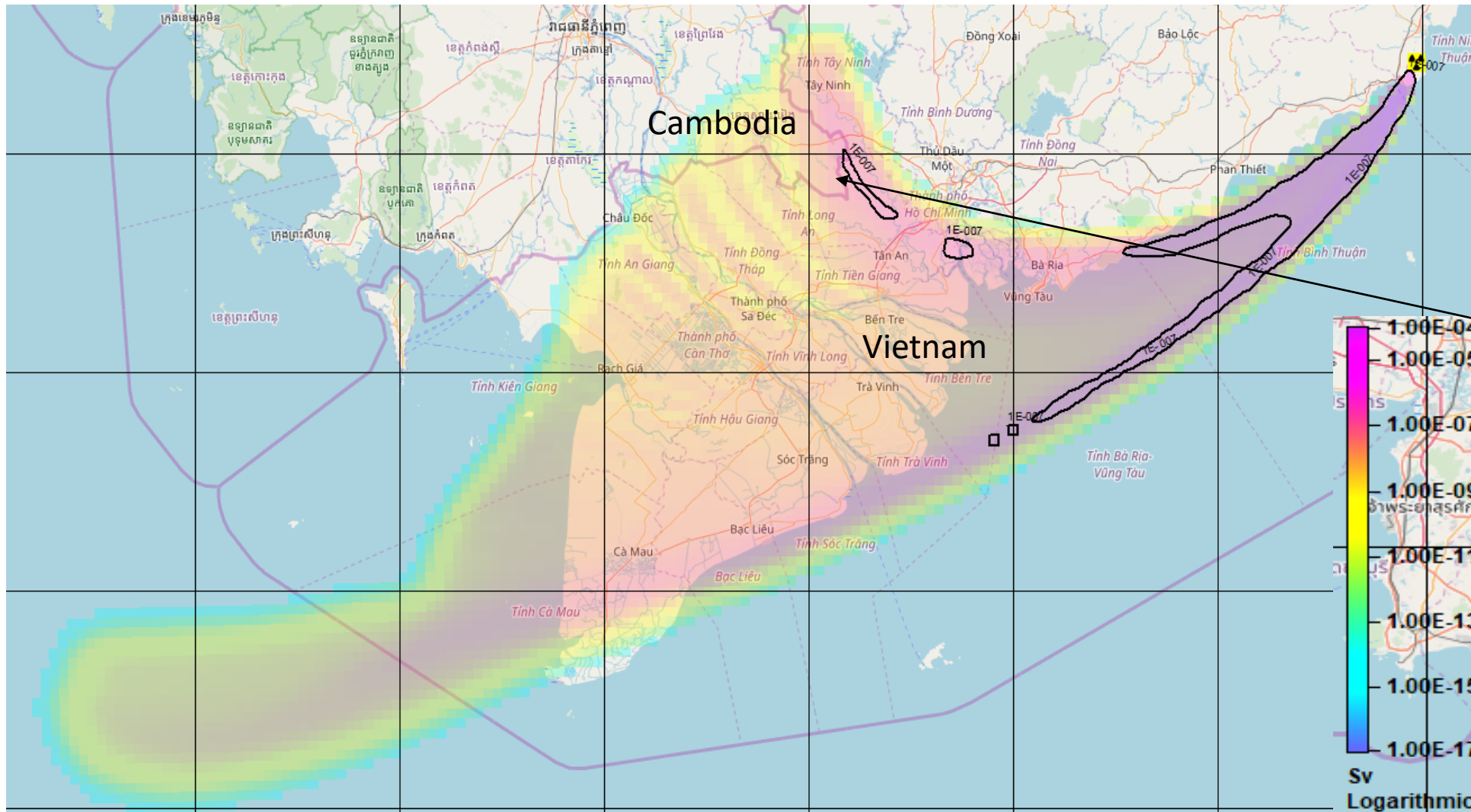
Contour (km)	TEDE value ( $\mu Sv$ )
50	340
200	53
400	36
600	9.7
700	2.5

TEDE gradually decreases as the distance from source increases.

\*Contours represent the magnitude of doses within the  $1\mu Sv$  isocurve.



# Lead time analysis (NPP1, Cloudshine)

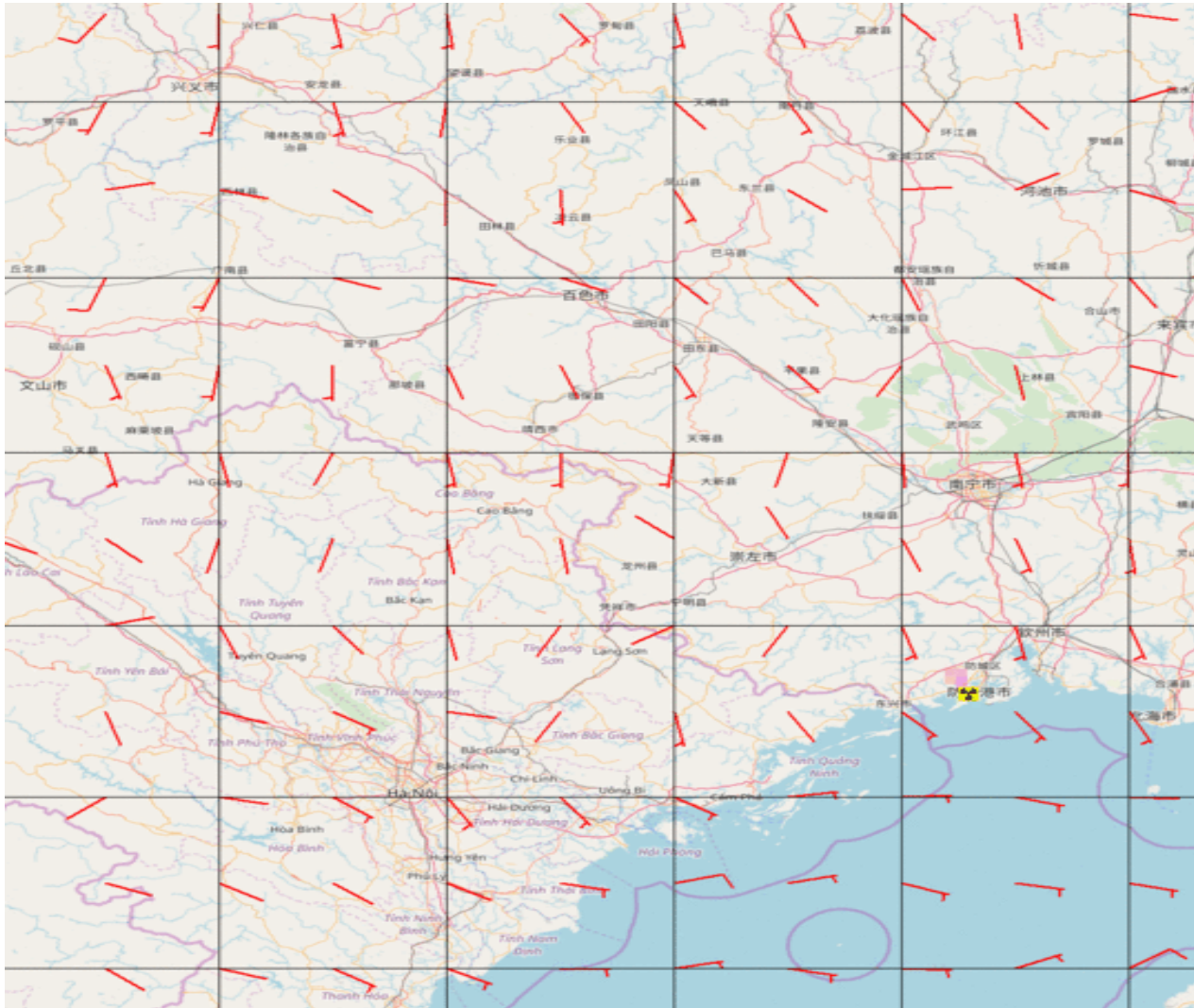


How long before the plume reaches Cambodia border?  
21 hours

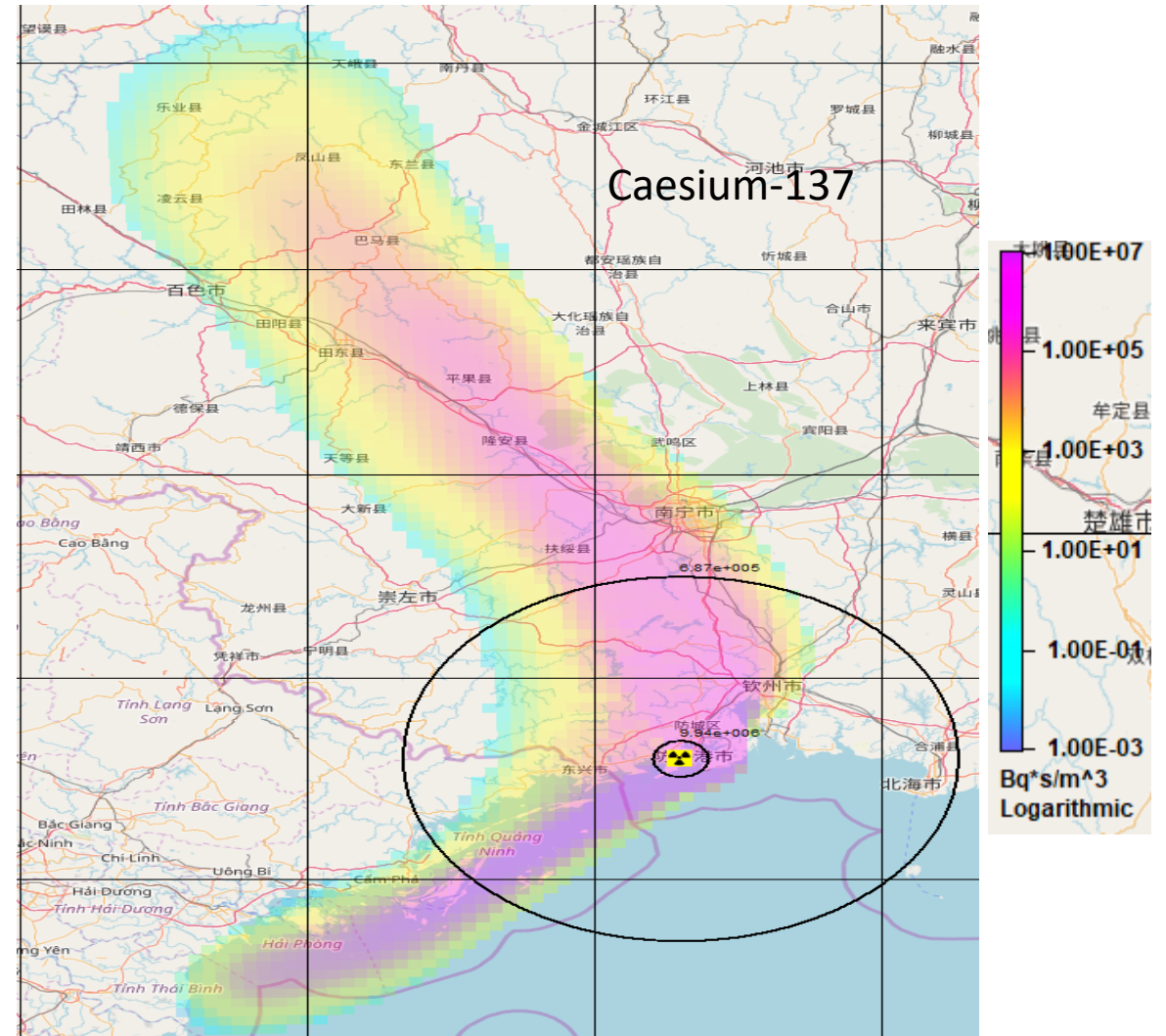
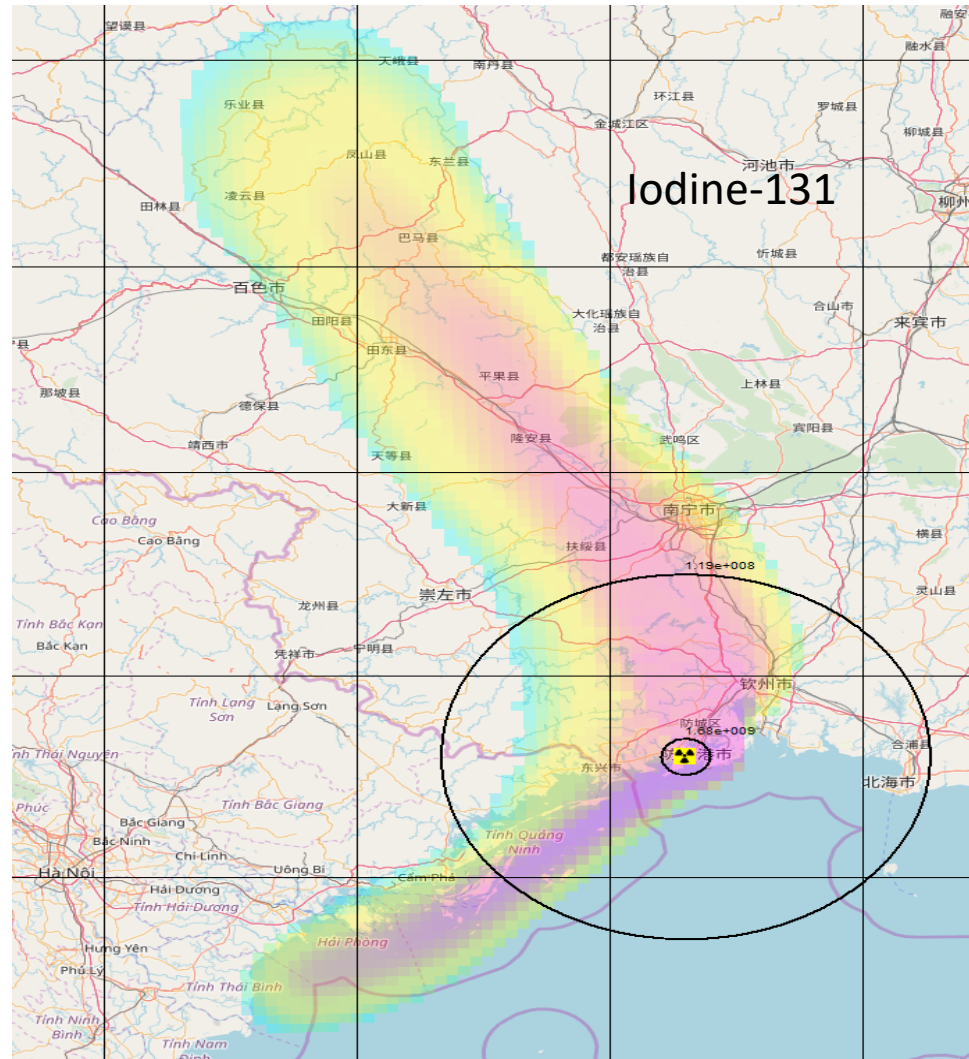
Background dose  $\approx$   
 $0.1\mu Sv$  or  $1 \times 10^{-7} Sv$

May not be able make significant detection as the doses are lower than background in that area

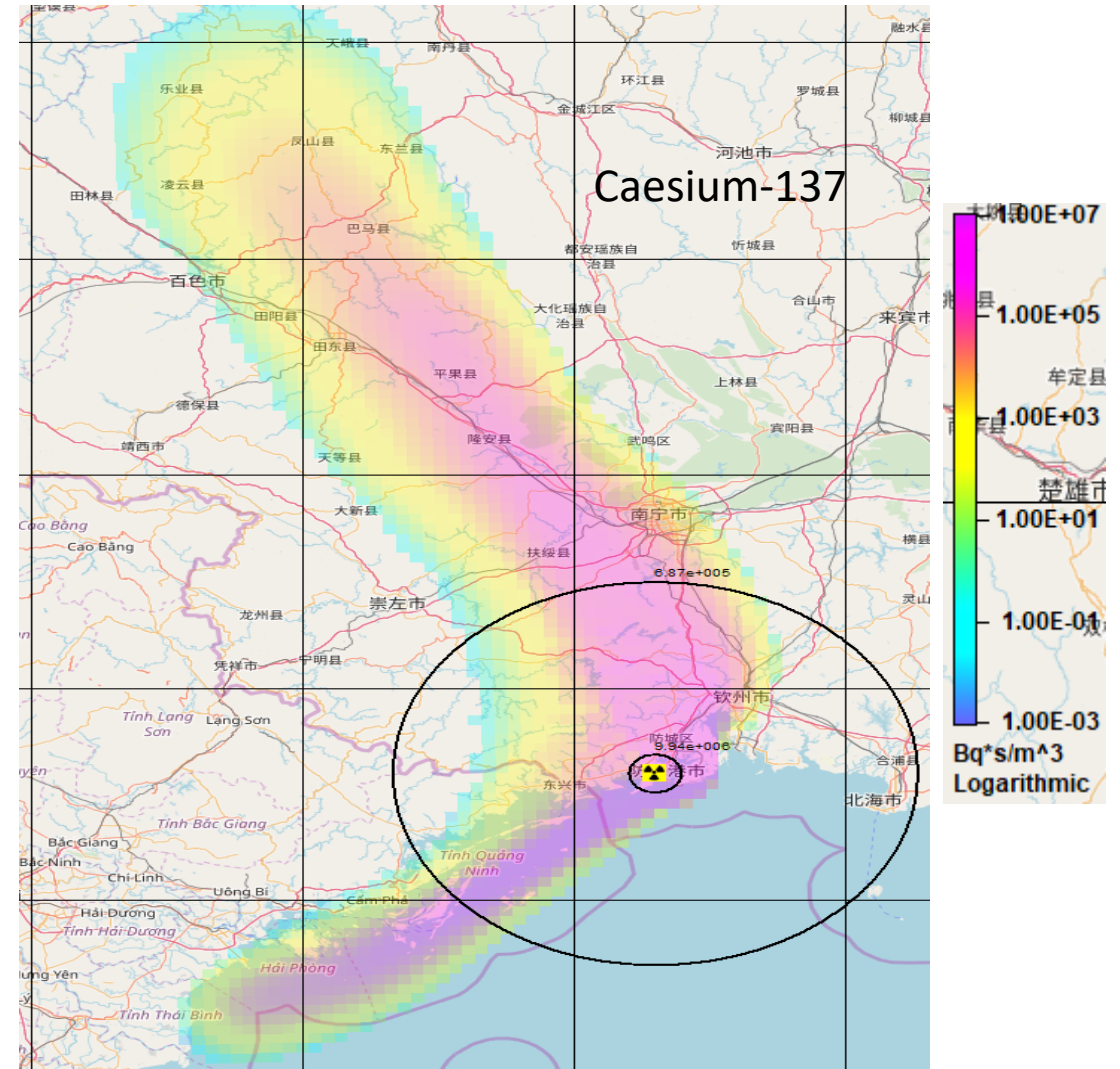
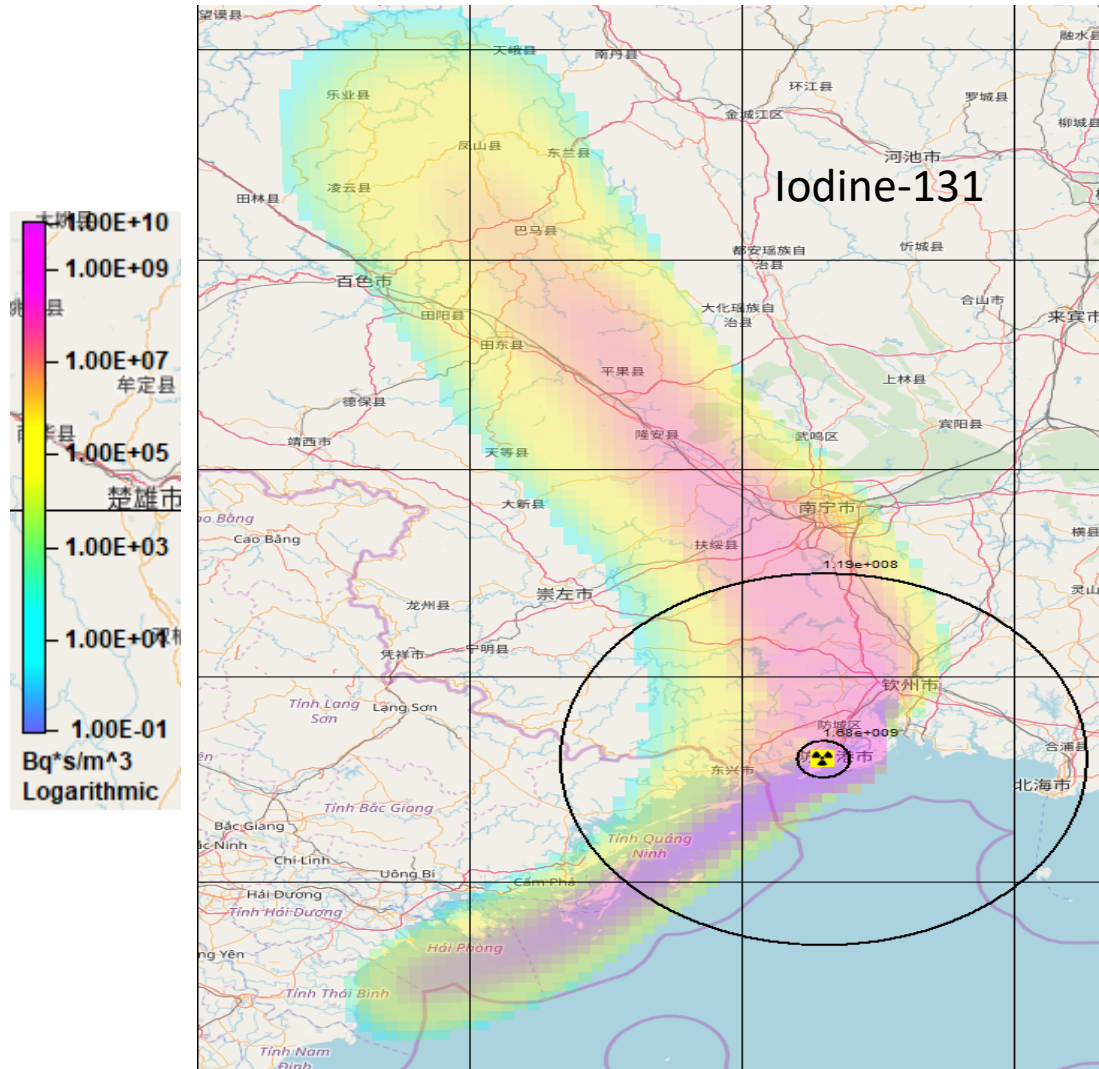
# 2017 Benchmark Problem: NPP2 18<sup>th</sup> Jan



# Air Concentration after 24 hours



# Ground Concentration after 24 hours



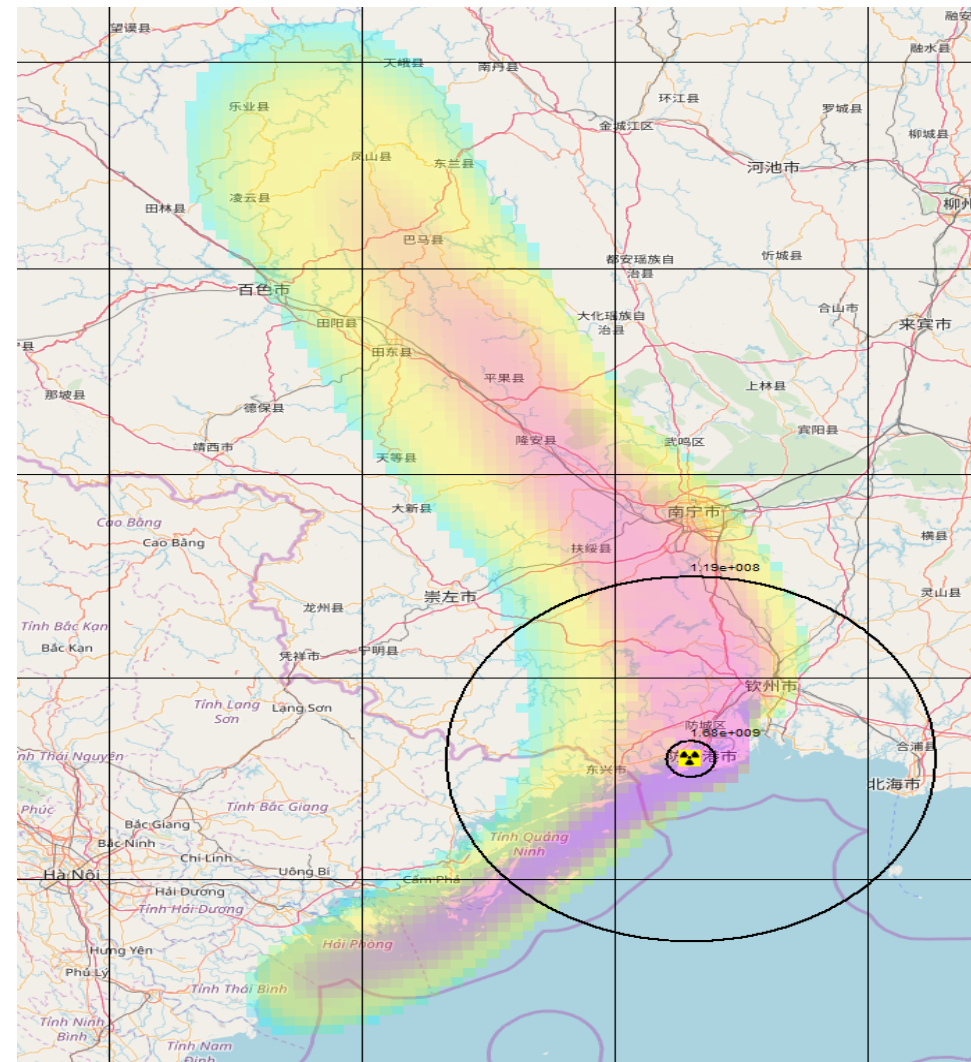
# (NPP2 Jan 18)

## In Northwest direction

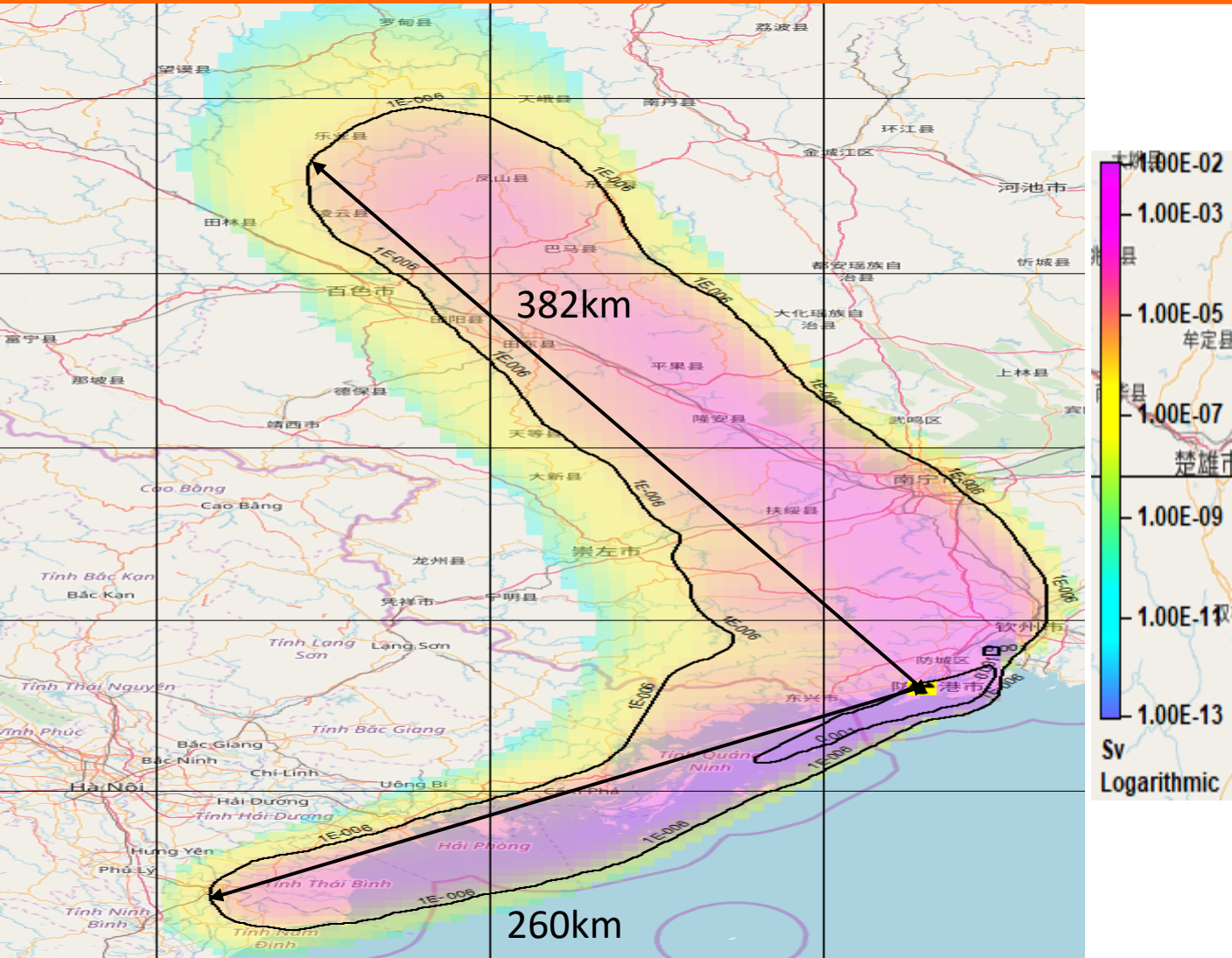
		10 km	100 km
Air Conc $\left(\frac{Bq.s}{m^3}\right)$	I-131	1.06E8	1.87E7
	Cs-137	2.81E4	2.39E4
Ground Conc $\left(\frac{Bq.s}{m^2}\right)$	I-131	2.50E3	5.59E2
	Cs-137	3.33E2	5.82E1

## In Southwest direction

		10 km	100 km
Air Conc $\left(\frac{Bq.s}{m^3}\right)$	I-131	1.72E9	8.49E7
	Cs-137	1.02E7	4.95E5
Ground Conc $\left(\frac{Bq.s}{m^2}\right)$	I-131	8.54E5	5.48E3
	Cs-137	5.23E3	2.63E2



# 1 Day TEDE (Adults) exposure extent for $1\mu\text{Sv}$



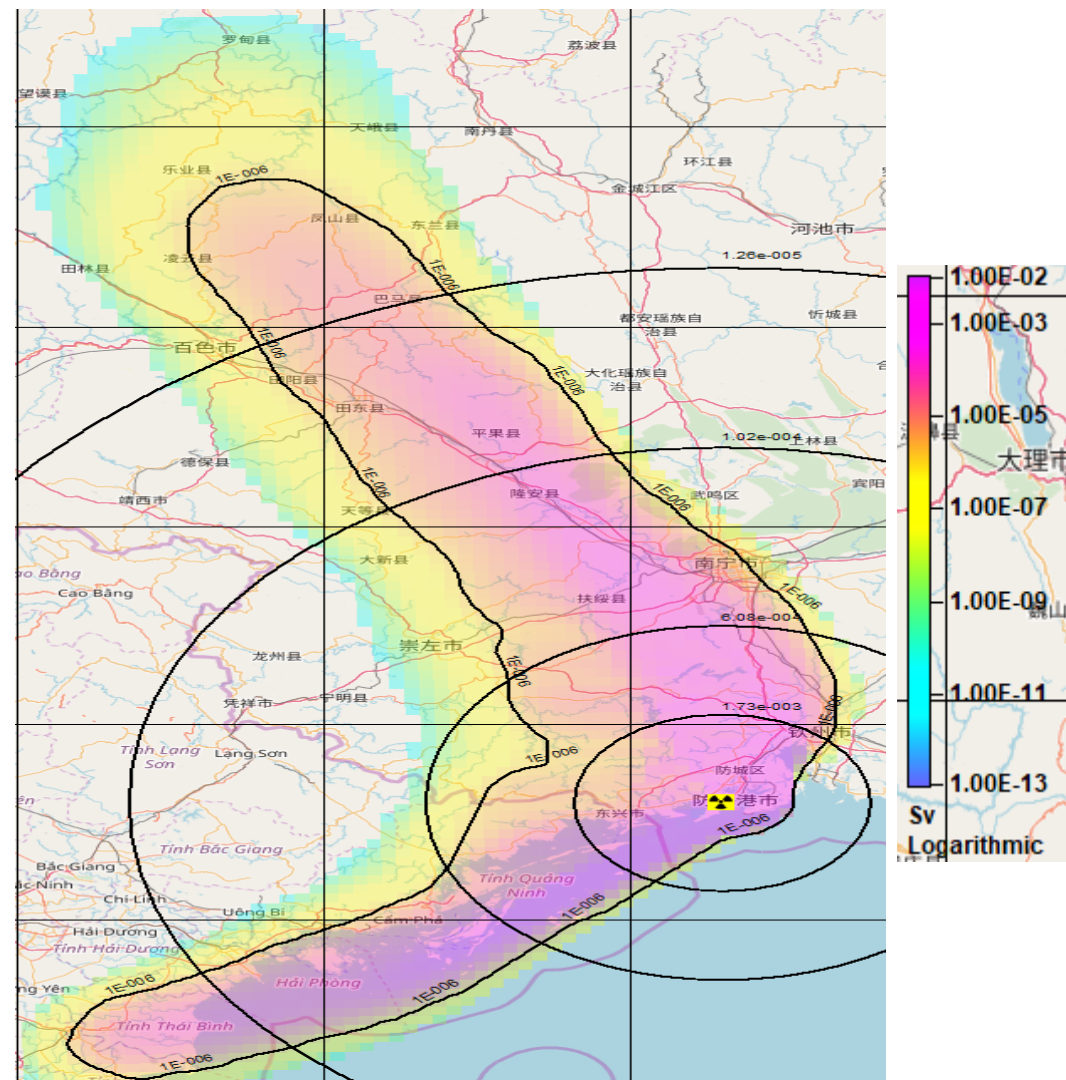
As the plume spreads in North-West and South-West directions, 2 different distances from source are labeled

1 mSv – 70 km from source (SW)  
25 km from source (NE)

Contour (km)	TEDE value ( $\mu Sv$ )
50	1730
100	608
200	102
300	13

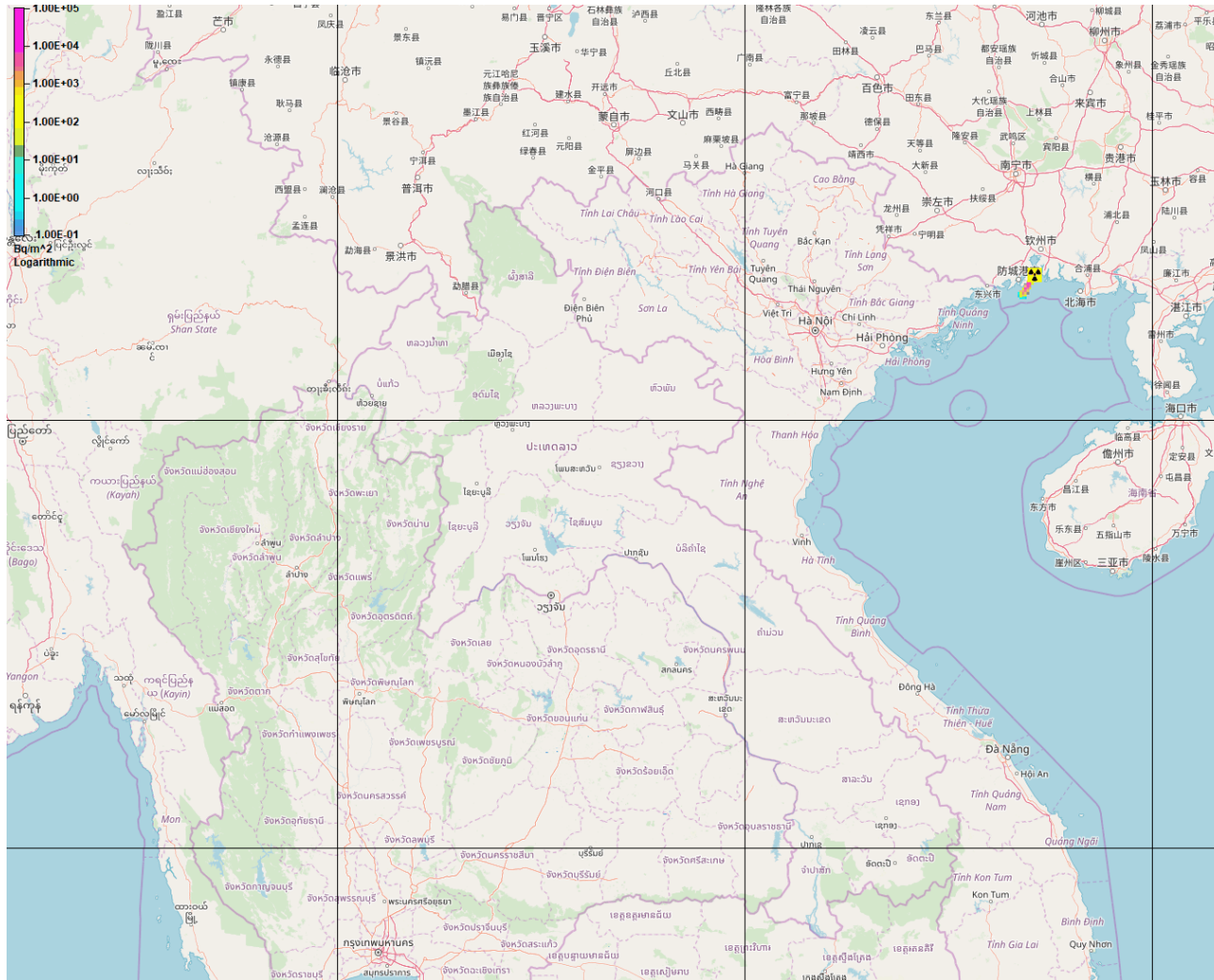
TEDE gradually decreases as the distance from source increases.

\*Contours represent the magnitude of doses within the  $1\mu Sv$  isocurve.

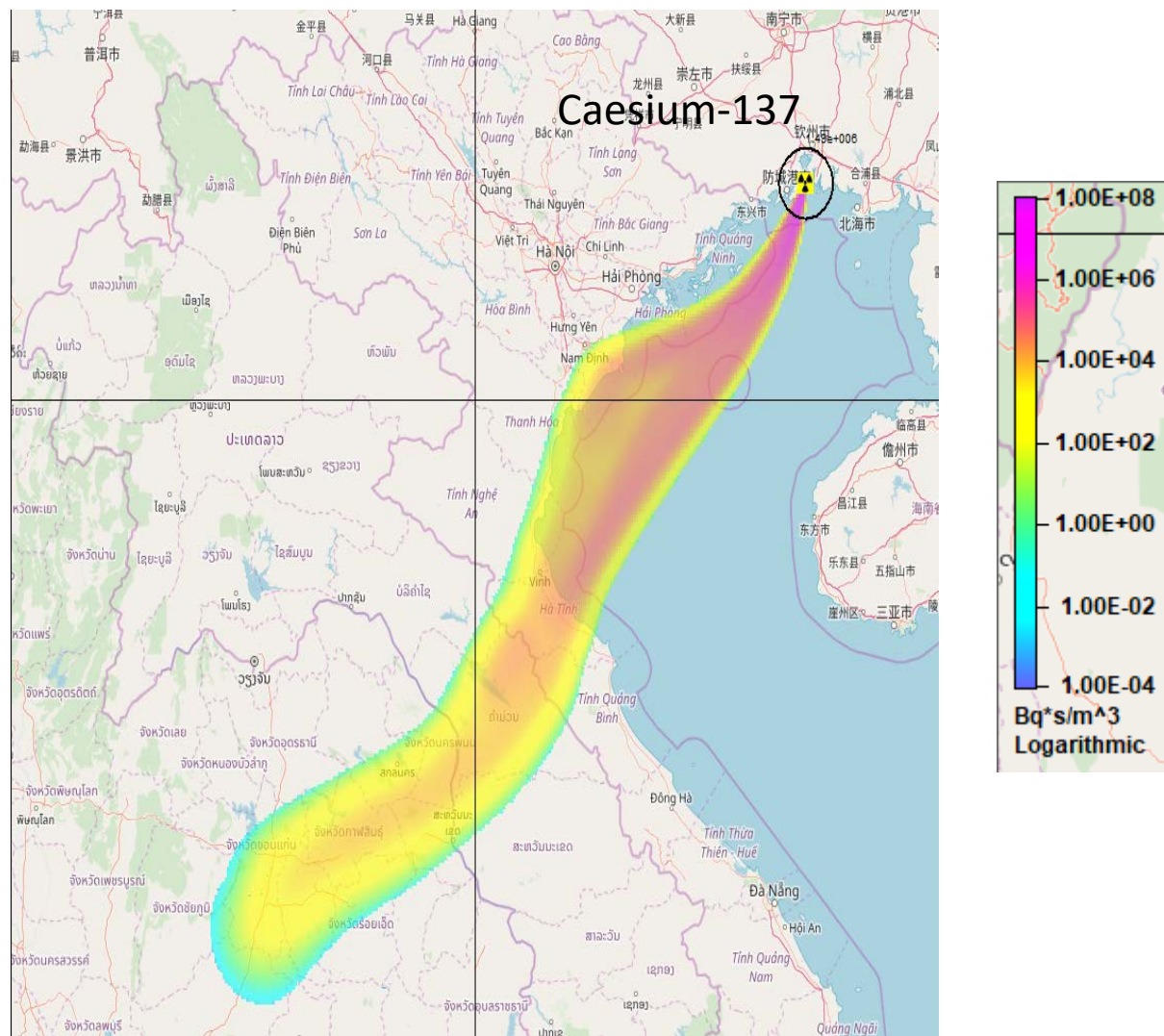
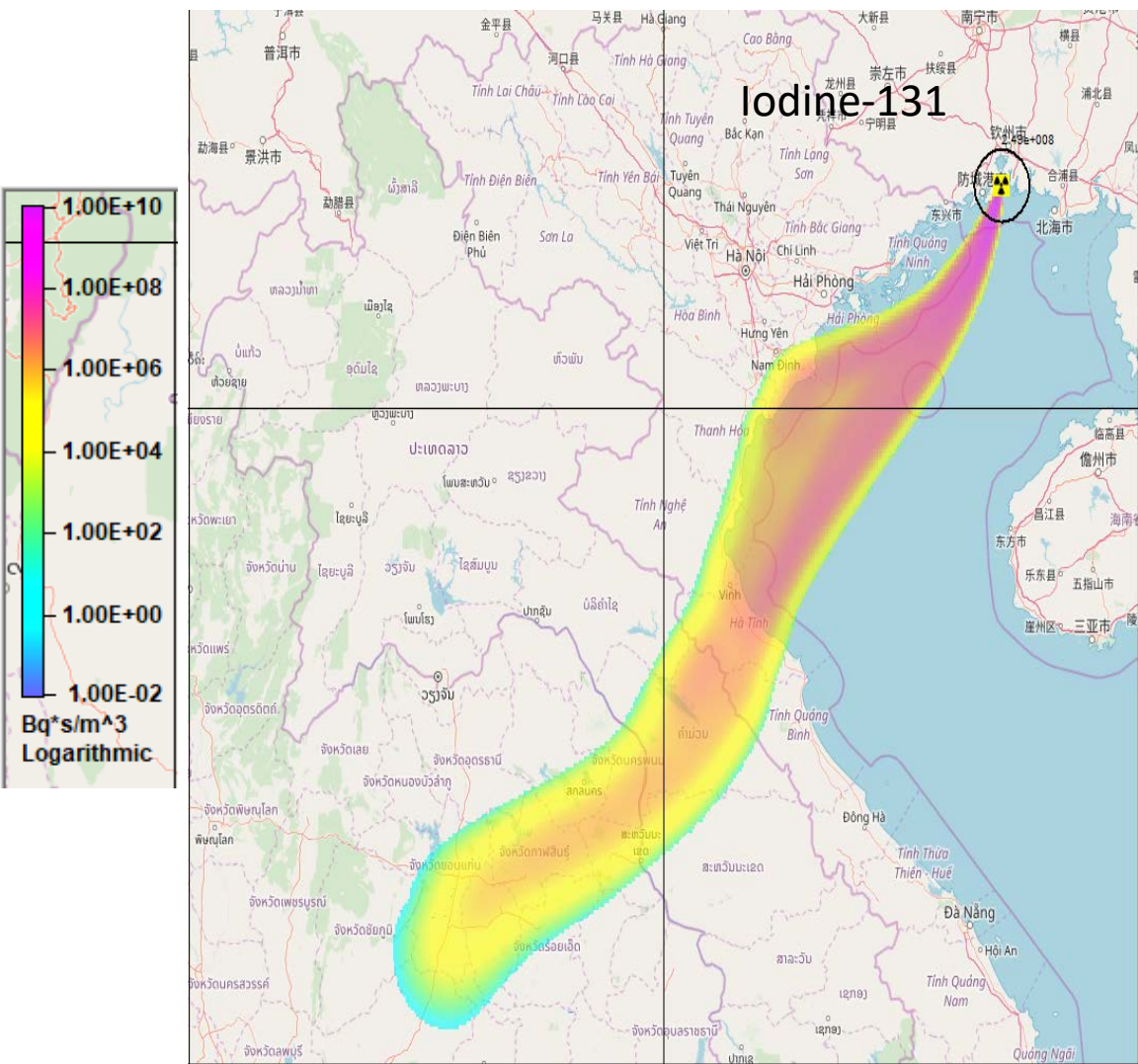




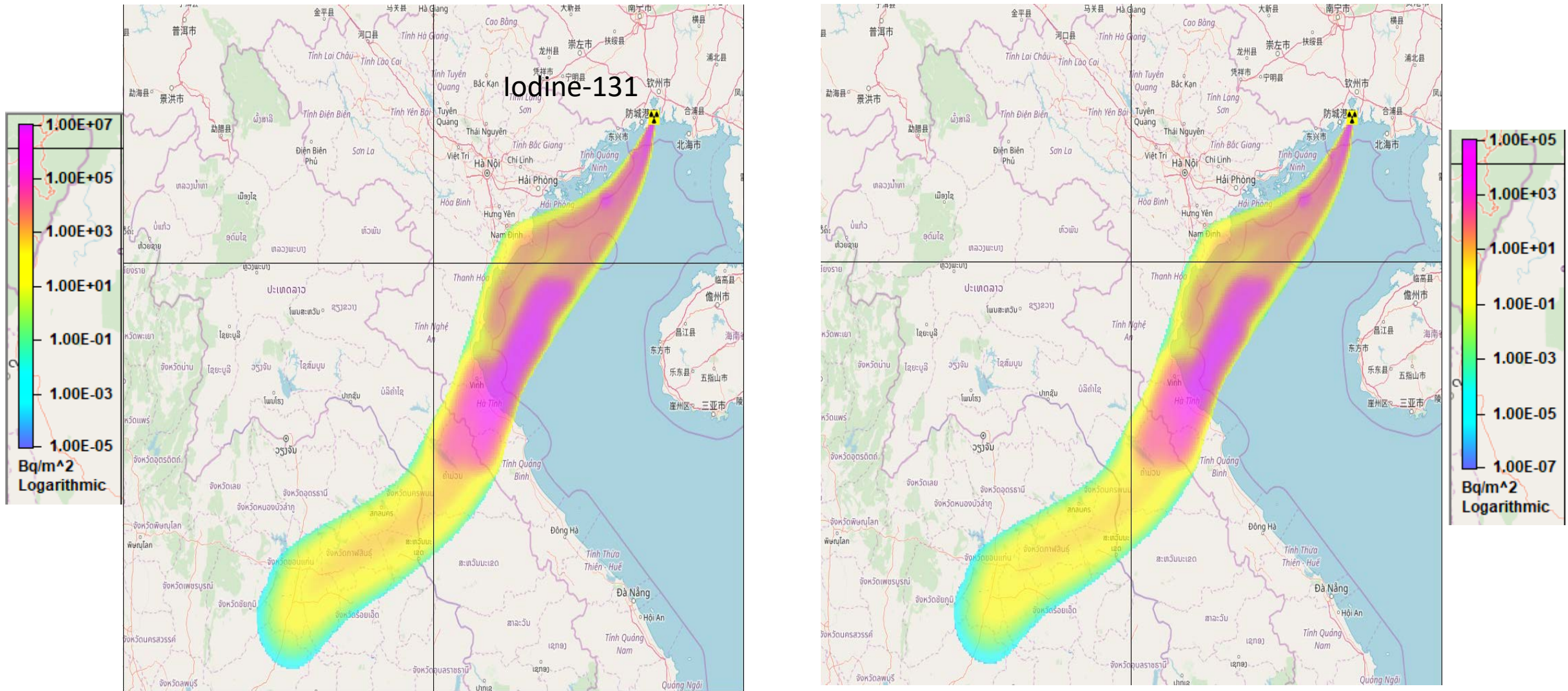
# 2018 Benchmark Problem: NPP2 25<sup>th</sup> Nov



# Air Concentration after 24 hours

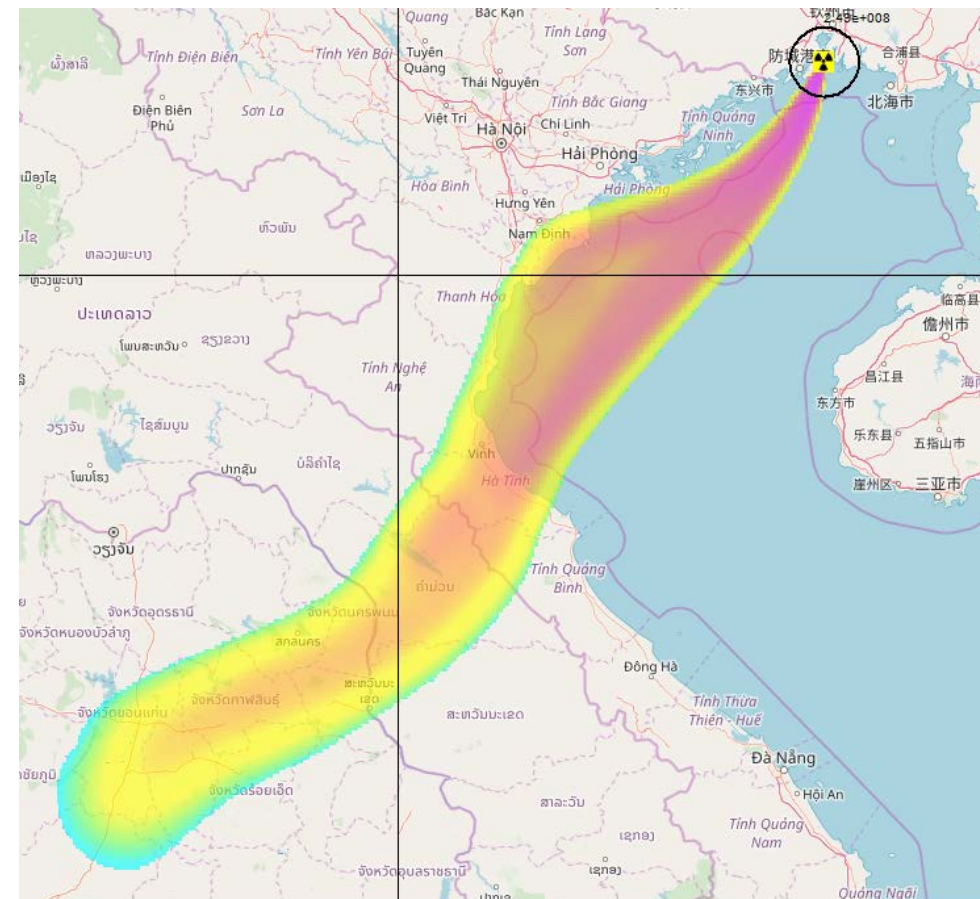


# Ground Concentration after 24 hours

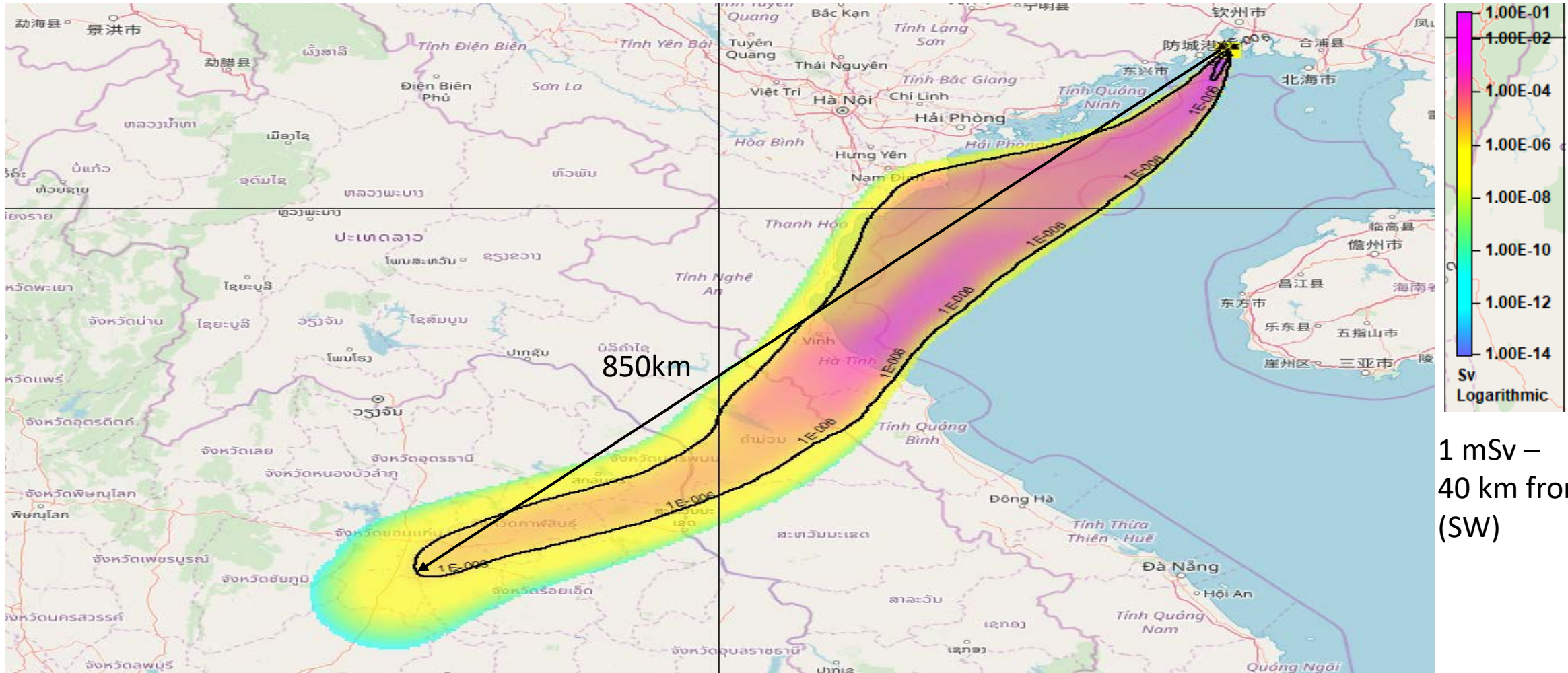


In Southwest direction

		10 km	100 km
Air Conc $\left(\frac{Bq.s}{m^3}\right)$	I-131	1.75E9	3.34E7
	Cs-137	1.04E7	2.00E5
Ground Conc $\left(\frac{Bq.s}{m^2}\right)$	I-131	9.45E5	1.82E4
	Cs-137	5.83E3	1.12E2



# 1 Day TEDE (Adults) exposure extent for $1\mu\text{Sv}$

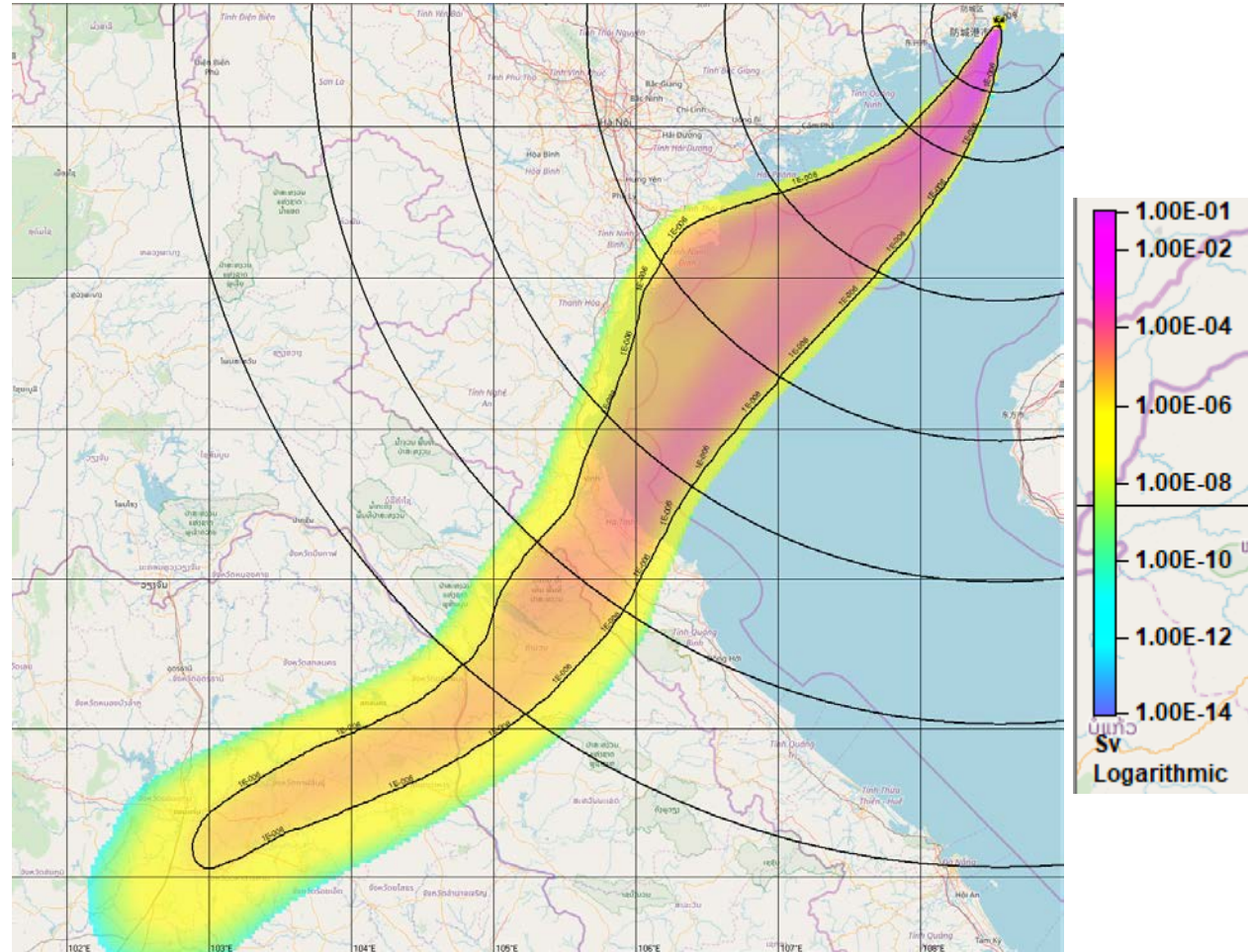


1 mSv –  
40 km from source  
(SW)

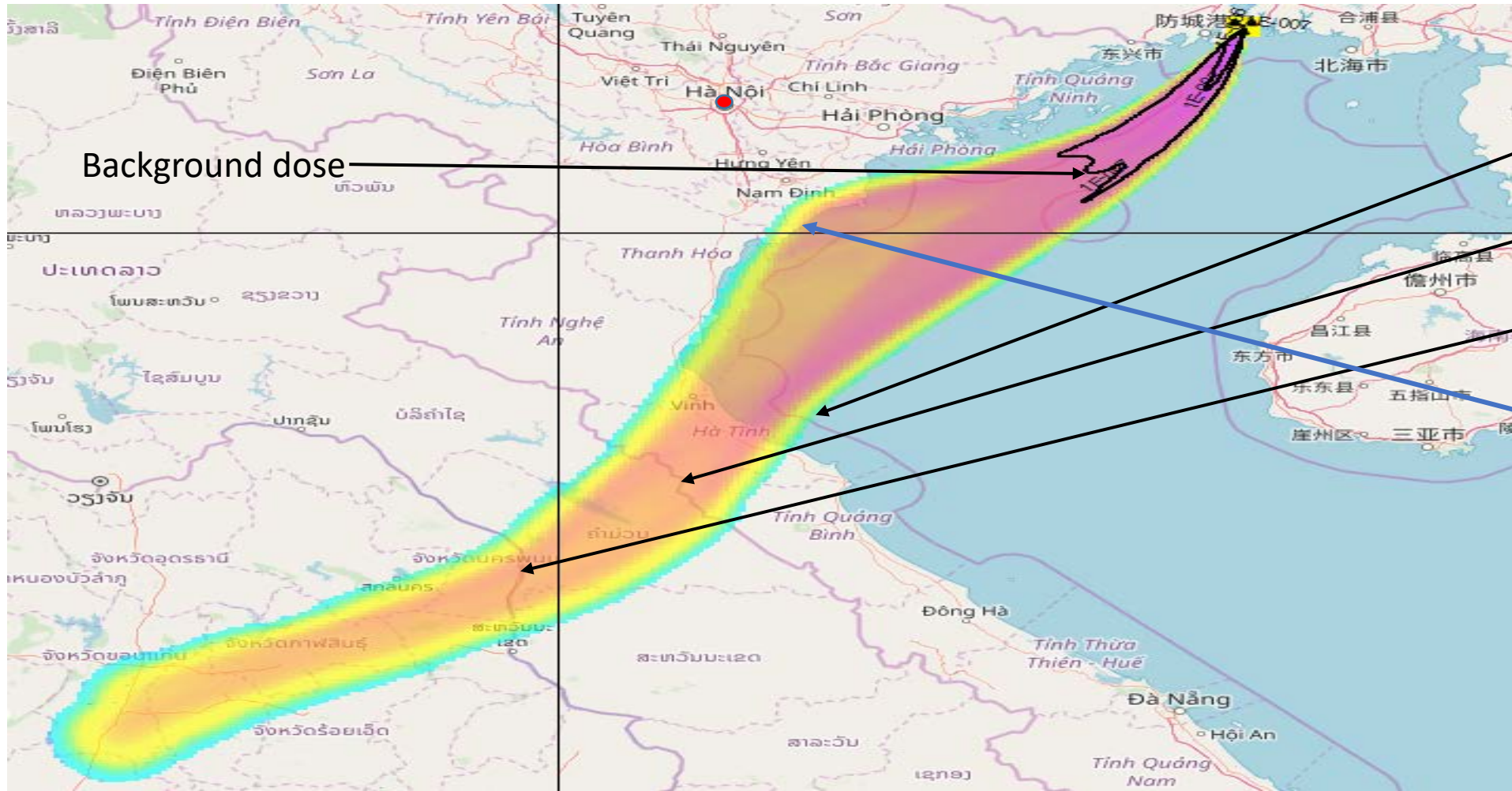
Contour (km)	TEDE value ( $\mu\text{Sv}$ )
50	620
100	170
200	44
300	38
400	40
500	12
600	4

TEDE gradually decreases as the distance from source increases.

\*Contours represent the magnitude of doses within the  $1\mu\text{Sv}$  isocurve.



# Lead time analysis (NPP2 Jan 25, Cloudshine)



How long before the plume reaches respective border?

Reaches Vietnam in 12hours.

Reaches Laos in 13hours.

Reaches Thailand in 17hours.

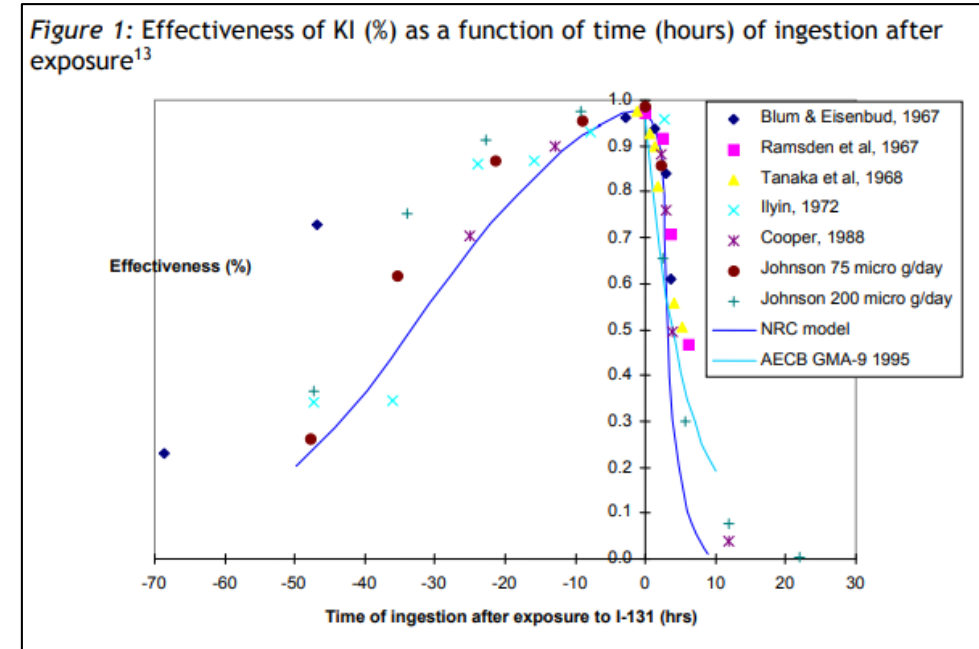
Change in direction in 22 hours

Background dose  $\approx 0.1\mu Sv$  or  $1 \times 10^{-7} Sv$

May not be able make significant detection as the doses are lower than background in that area

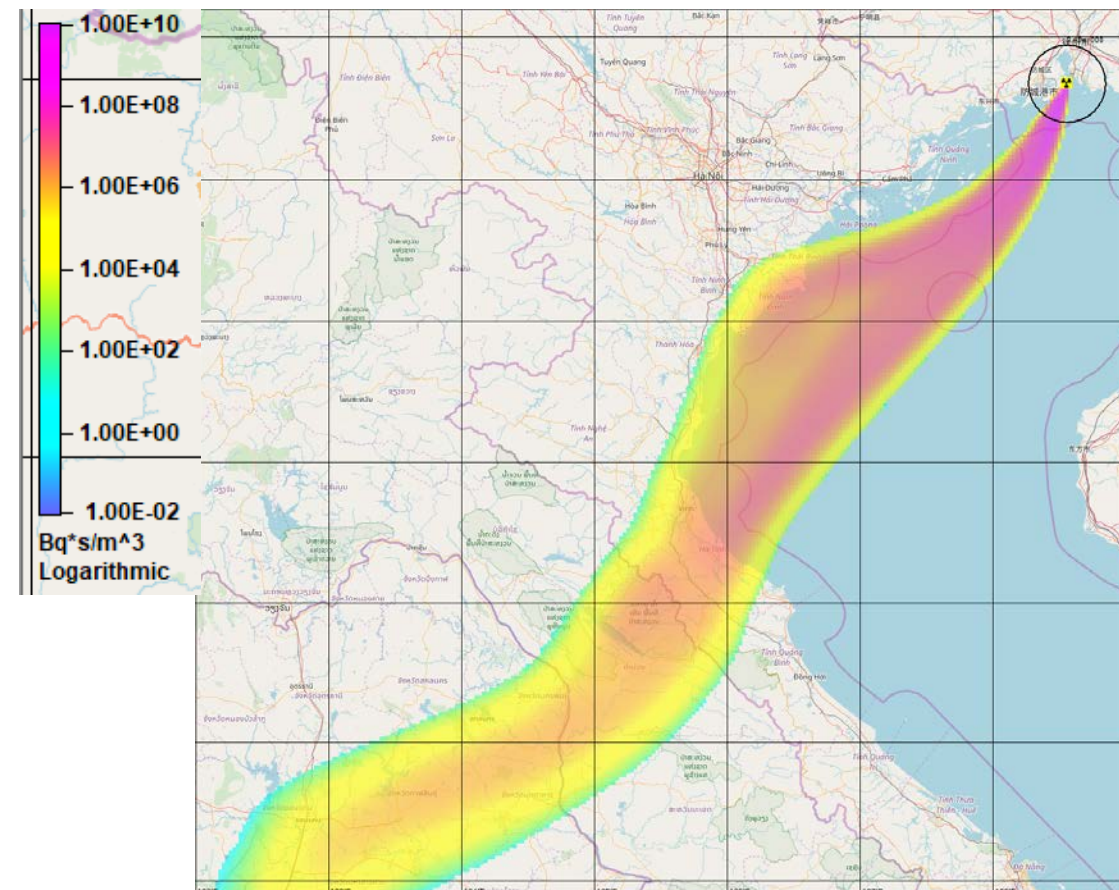
# Observations

- Iodine concentration and administration of iodine pills
- IAEA advises for administration of Iodine Thyroid Blocking (ITB) when projected equivalent dose to the thyroid exceeds 50mSv.
- ITB is ideally administered two to six hours before exposure if not ideally within three hour after first exposure
- Imperative to look at dispersion patterns and results for prediction

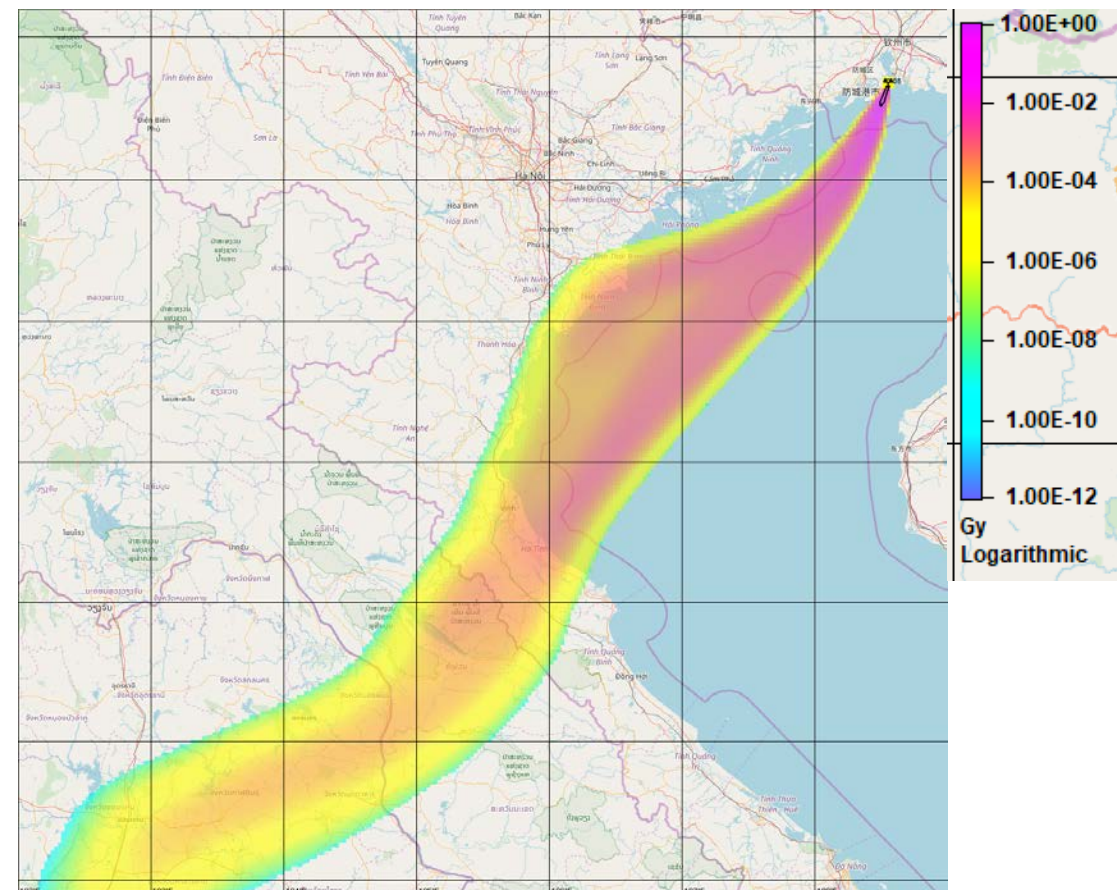


# Observations & Analysis

## Air concentration



## Thyroid dose



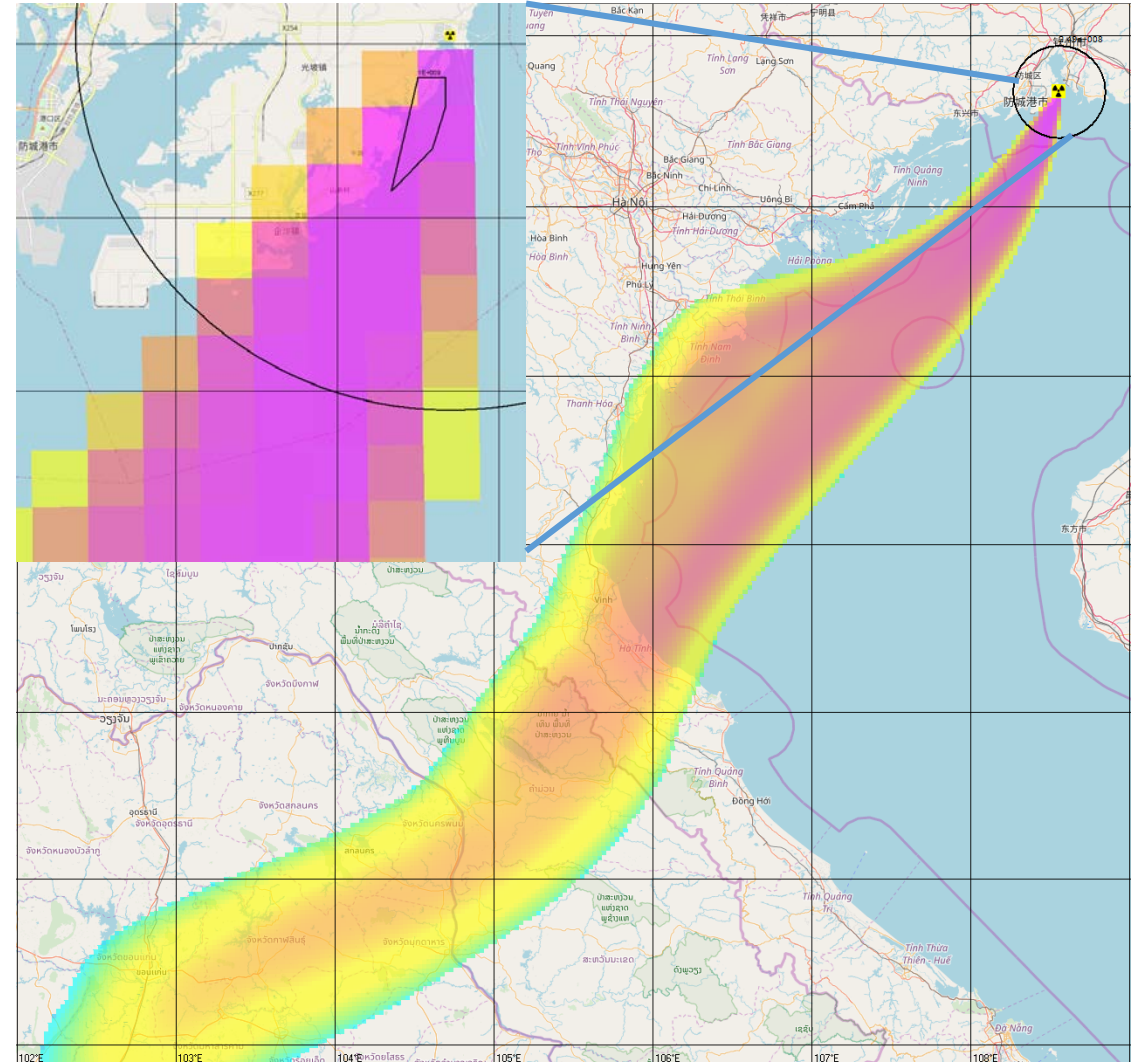
# Observation & analysis

Air concentration  $\longrightarrow$  Thyroid dose

$$C_{intg} = \frac{D_{thy}}{TDF * I * E_i(50)}$$

- $C_{intg}$  Time integrated air concentration
- $D_{thy}$  Thyroid dose
- TDF Thyroid Dose Factor (5)
- I Inhalation
- $E_i(50)$  Committed Effective dose coefficient(adult)

Therefore for 50mSv guideline:  $C_{intg} = 10^9 \text{ Bq*s/m}^3$   
Results obtained are less than the guideline at 10km



## Concluding Remarks

- Differing orders of magnitude of results for Cs-137 and I-131 due to different source activity
- Lower air and ground concentrations at further distances from source due to dispersion.
- 1-day TEDE with  $1\mu Sv$  values at hundreds of kilometers from source while  $1mSv$  are much less than 100 km from the source
- Dispersion direction in the NPP2 cases (18<sup>th</sup> Jan and 25<sup>th</sup> Nov 2018) varied significantly due to seasonal weather patterns.