

HOW TO USE SOURCE TERM TO DOSE



**Radiation Protection Code
Analysis & Maintenance
Program (RAMP)**



SCENARIO

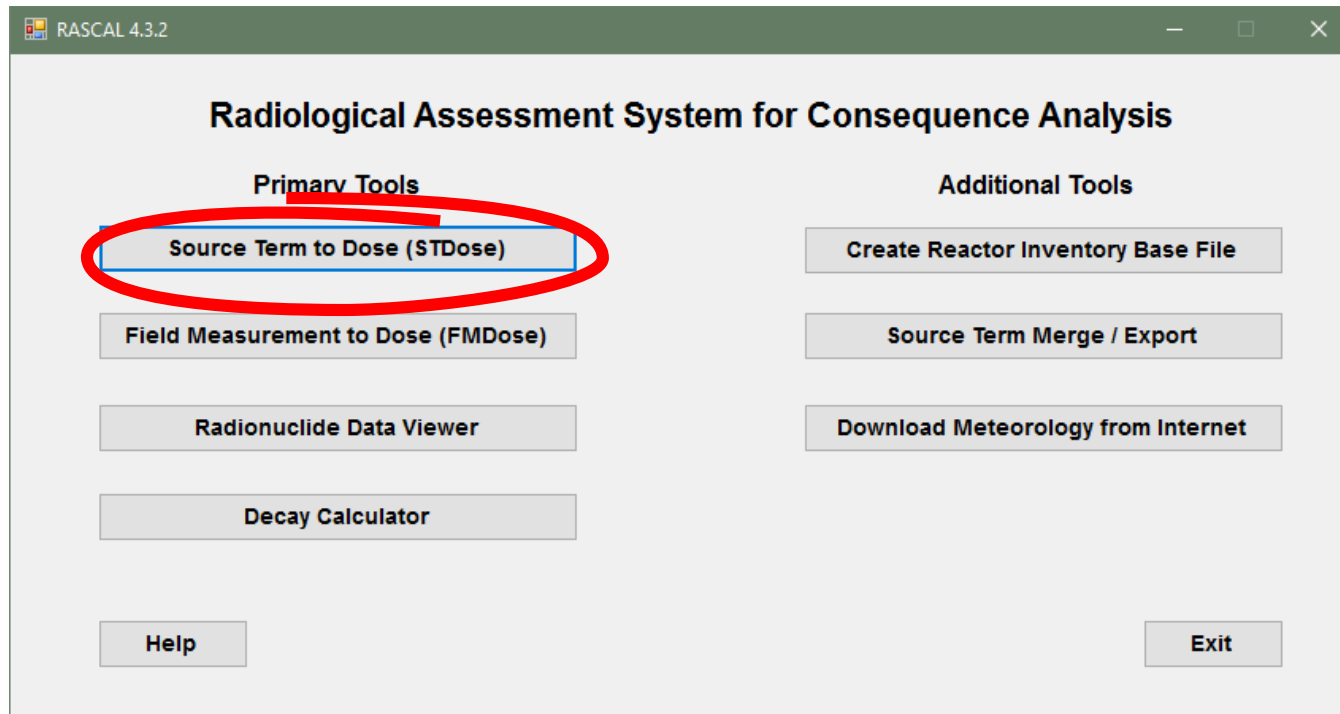
Arkansas Nuclear One, Unit 1 had been operating at full power. At 10:00am local time the reactor tripped due to an earthquake, causing a major rupture in the primary coolant system (loss-of-coolant accident [LOCA]).



WHAT IS BEING ASKED OF YOU?

- Justify PARs/PADs in pre-release?
 - Determine extent of ongoing release?
 - Verify field team readings?
 - Do you even need RASCAL?
-
- Let's assume that your task is to do a pre-release assessment to ensure potential PARs are adequate.

WHICH TOOL SHOULD BE USED TO PERFORM THAT TASK?



BEFORE YOU START RASCAL TAKE A MINUTE TO GET ORIENTED

- Topography
 - Is it flat or hilly?
- Water bodies
 - Any nearby lakes or oceans?
- Population
 - Any nearby cities or parks?
- Weather
 - Based on season and location, what weather is likely in that area?

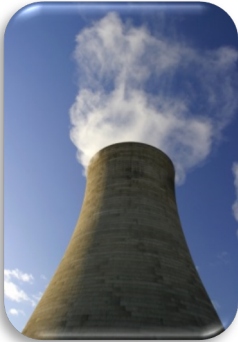
AS A RASCAL OPERATOR YOUR INITIAL TASK IS TO TAKE INFORMATION AND SETUP A MODELING SCENARIO

- Where do you get the information:
 - ERDS, WebEOC, Communicators, etc.
- Translate available data into RASCAL inputs
 - Some data is “static”; enter once
 - Some data is “dynamic” and changes with time as more communications is established and as conditions evolve



Event Type

START BY CLICKING EVENT TYPE



**Nuclear Power
Plant**



Spent Fuel



Fuel Cycle



Other Material

- Select from a list of predefined sites
 - All US facilities (NPPs, Fuel Cycle, Materials)
 - Laguna Verde in Mexico
- Or, define a custom site
 - Need Latitude/Longitude coordinates
 - Does not build in roughness or topography

- The reactor power has units of megawatts thermal (MWt) and is a direct measure of the energy produced by fission. This number is used by the model to determine the fission product inventory in the core.
- The facility database contains the power level at which the reactor is allowed to operate.
- Since reactors generally try to operate at 100% power, change this value only if given data that the reactor has been operating for some time (days) at a lower power.

- Fuel burnup has units of megawatt-days per metric ton of uranium (MWd/MTU) and is a measure of how much fission energy has been produced by the fuel elements that are currently in the core.
- RASCAL uses burnup to adjust core inventory for long-lived radionuclides in the core fuel. A mid-life core value is used as default instead of site-specific values
- The control room can determine the current fuel burnup, although this will not have high priority during an actual emergency. If you have a burnup value – use it, otherwise the default is OK.

THE CASE SUMMARY TAB UPDATES AS INFORMATION IS ADDED

As each step is completed, the input information is added to the case summary displayed

The screenshot displays the 'Source Term to Dose' software interface. The title bar reads 'Source Term to Dose - [STDose Walkthrough - LOCA.std]'. The menu bar includes 'File', 'Settings', 'Nuclide Data Viewer', 'Site / Facility Data Viewer', and 'Help'. On the left, a vertical toolbar contains buttons for 'Event Type', 'Event Location', 'Source Term', 'Release Path', 'Meteorology', 'Calculate Doses', 'Detailed Results', and 'Save Case'. Each button has a green checkmark icon. Below these buttons, the current values for each step are listed: 'NPP Reactor', 'Arkansas - Unit 1', 'LOCA (NUREG-1465)', 'PWR Dry', 'Actual Observations', and 'Calculate Doses'. The main window is divided into two panes. The left pane is titled 'Case Summary' and contains sections for 'Event Type' (Nuclear Power Plant), 'Case description' (None), 'Location' (Name: Arkansas - Unit 1, City, county, state: Russellville, Pope, AR, Lat / Long / Elev: 35.3100° N, 93.2314° W, 103 m, Time zone: Central, Population (2010): 946 / 12,205 / 53,396 (2 / 5 / 10 mi)), and 'Reactor Parameters' (Reactor power: 2568 MWt, Average burnup: 30000 MWd / MTU, Containment type: PWR Dry Ambient, Containment volume: 2.09E+06 ft³, Design pressure: 59 lb/in², Design leak rate: 0.20 %/d). The right pane is titled 'Source Term' and is currently empty. At the bottom, there are two tabs: 'Case Summary' and 'Source Term'.

Step	Value
Event Type	NPP Reactor
Event Location	Arkansas - Unit 1
Source Term	LOCA (NUREG-1465)
Release Path	PWR Dry
Meteorology	Actual Observations
Calculate Doses	

Case Summary

Event Type Nuclear Power Plant

Case description None

Location

Name: Arkansas - Unit 1
City, county, state: Russellville, Pope, AR
Lat / Long / Elev: 35.3100° N, 93.2314° W, 103 m
Time zone: Central
Population (2010): 946 / 12,205 / 53,396 (2 / 5 / 10 mi)

Reactor Parameters

Reactor power: 2568 MWt
Average burnup: 30000 MWd / MTU
Containment type: PWR Dry Ambient
Containment volume: 2.09E+06 ft³
Design pressure: 59 lb/in²
Design leak rate: 0.20 %/d

Case Summary | **Source Term**

STATIC INFORMATION ENTERED, NOW FOR ADDITIONAL DYNAMIC CONDITIONS IN SCENARIO

The licensee believes the core may become uncovered at 13:00 and are unable to activate the containment spray system. They expect the containment to remain intact and any release to the atmosphere will be at the design leak rate.

At 17:00, operators were able to recover the core. Containment remained at high pressure and wasn't reduced until 21:00.



TO CALCULATE THE SOURCE MATERIAL, RASCAL WILL USE A MODEL OR MEASUREMENT

- Long-term Station Blackout (LTSBO)
- Loss of Coolant Accident (LOCA)
- Coolant Release
- Containment Rad Monitor

Models

- Coolant Sample
- Containment Air
- Effluent Release

Measurements

You'll need to pick the best option with the given scenario information.

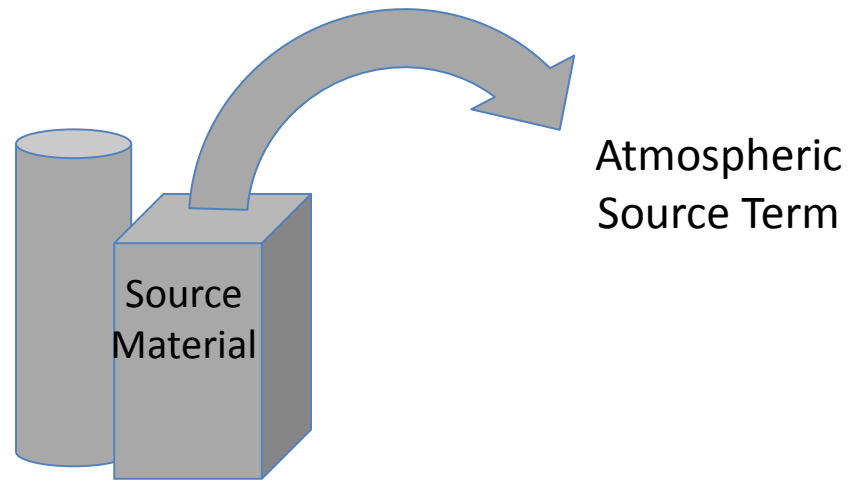


EACH MODEL REQUIRES ADDITIONAL PARAMETERS

- Timing of key events
- Specific reactor conditions
- Measured data
- Specifically for LOCA, required parameters are:
 - Time of reactor shutdown
 - Time core was uncovered
 - Is the core recovered?

RASCAL WILL NEED SOME INFORMATION ON HOW MATERIAL IS RELEASED

- Pathway
 - Determines available release options
- Height
 - Wind speeds change with height
- Reduction
 - Amount of material reduced by decay, holdup, filter, sprays
- Timing
 - Release rates, start and stop



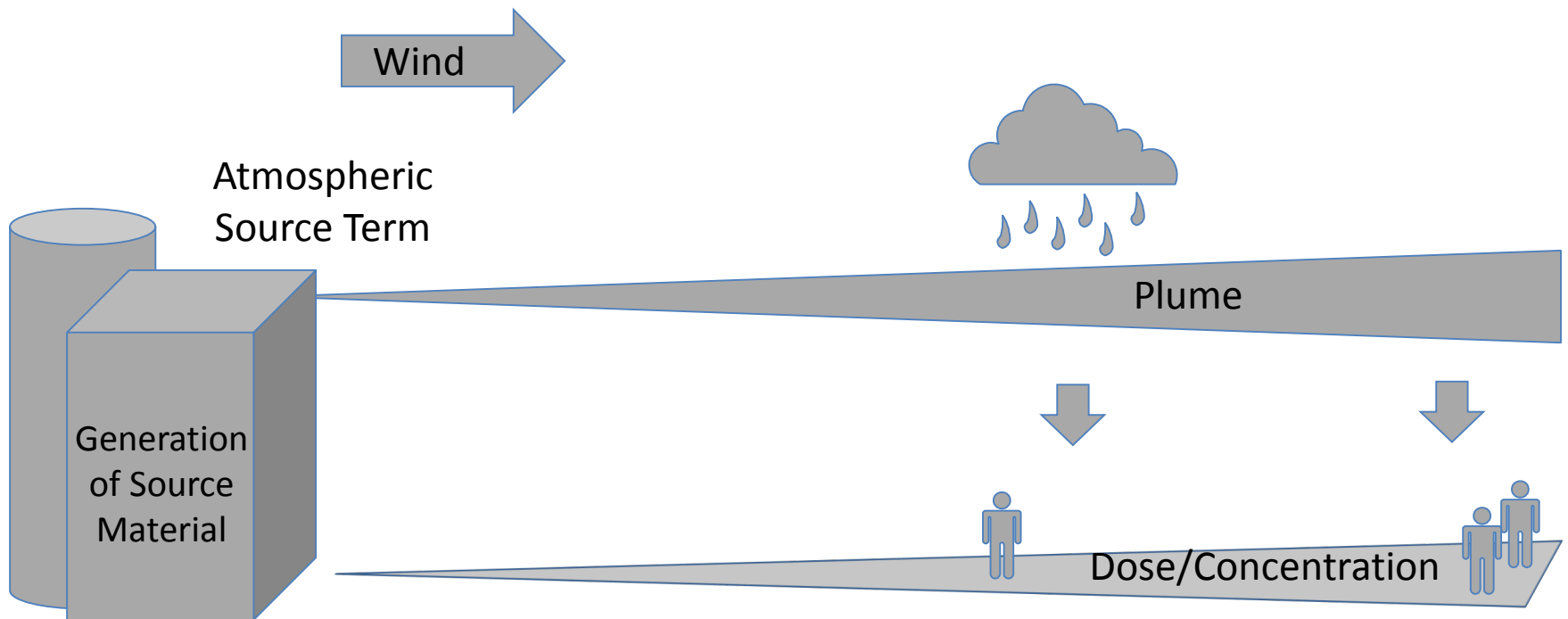
NOW LET'S INPUT THE RELEASE CONDITIONS SPECIFIC TO A LOCA

- Select path of release
 - Containment, Bypass, Steam Generator
- Set height of release
 - 10m is minimum height allowed (ground release)
- Select leak rate type
 - Percent Volume / Time (e.g., 3%/hour)
 - Containment pressure / Hole Size (e.g., 30 psi/2 cm²)
- Define release timeline
 - Used for leak rate and additional conditions
 - Change when conditions warrant



Meteorology

RASCAL NEEDS TO TRANSPORT THIS MATERIAL; WHY DO WE NEED WEATHER DATA?





NOW FOR INPUT OF SCENARIO WEATHER DATA

For this initial run we are going to use weather data such as is usually provided in an exercise – very little, if any, change with time.

Type	Date	Time	Wind Dir (deg)	Wind Spd (mph)	Stability Class	Precip	Air Temp (°F)
Obs	Today	12:00	210	6	B	None	53



THERE ARE 3 METEOROLOGY INPUT OPTIONS

- Actual
 - Enter station observations/forecasts
 - Manual entry or internet download
- Pre-defined (non site-specific)
 - Simple static weather conditions
 - Easy/fast if no meteorological data known, but doesn't include topo/roughness
- Predefined (site-specific)
 - Allows custom creation of likely conditions



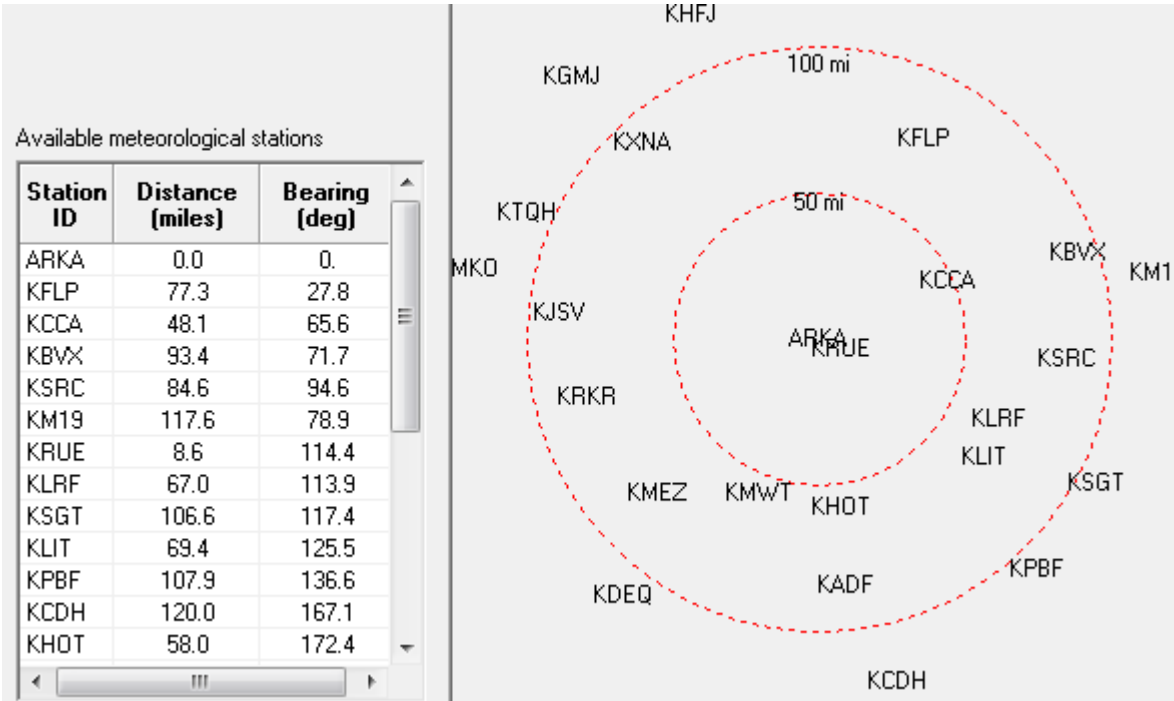
WEATHER DATA IS MANAGED AS SITE-DEPENDENT FILES

- Create New / Edit
- View any previously saved weather files
 - Usable as long as times support scenario

The screenshot shows a software window with two main panels. The left panel, titled 'Dataset Type', contains a radio button labeled 'Actual Observations and Forecasts' which is selected. Below this are four buttons: 'Create New', 'Edit Existing', 'Import', and 'Delete'. The right panel, titled 'Available Datasets', contains a large empty rectangular box, likely intended for a list of saved datasets.

EACH SITE CONTAINS PREDEFINED WEATHER STATIONS

- Table and map show site and surrounding weather stations
- Select stations with plume direction in mind





INPUTTING WEATHER DATA

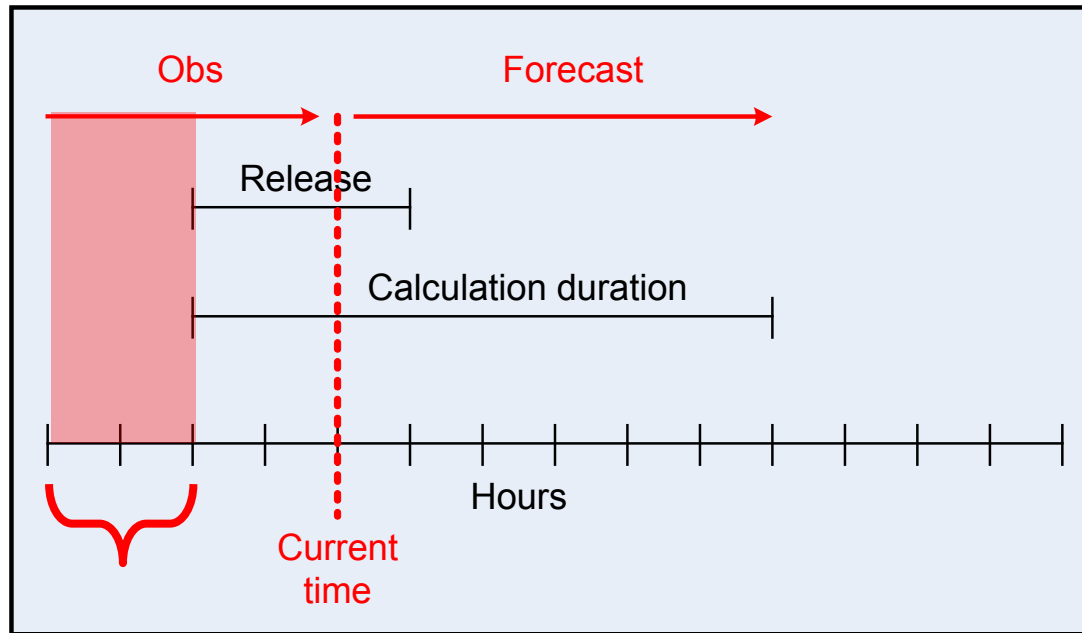
Select weather station on the left to input its data on the right:

- Type
- Date/Time
- Wind Direction/Speed
- Stability
- Precipitation
- Optional Fields (*)

[illegible]



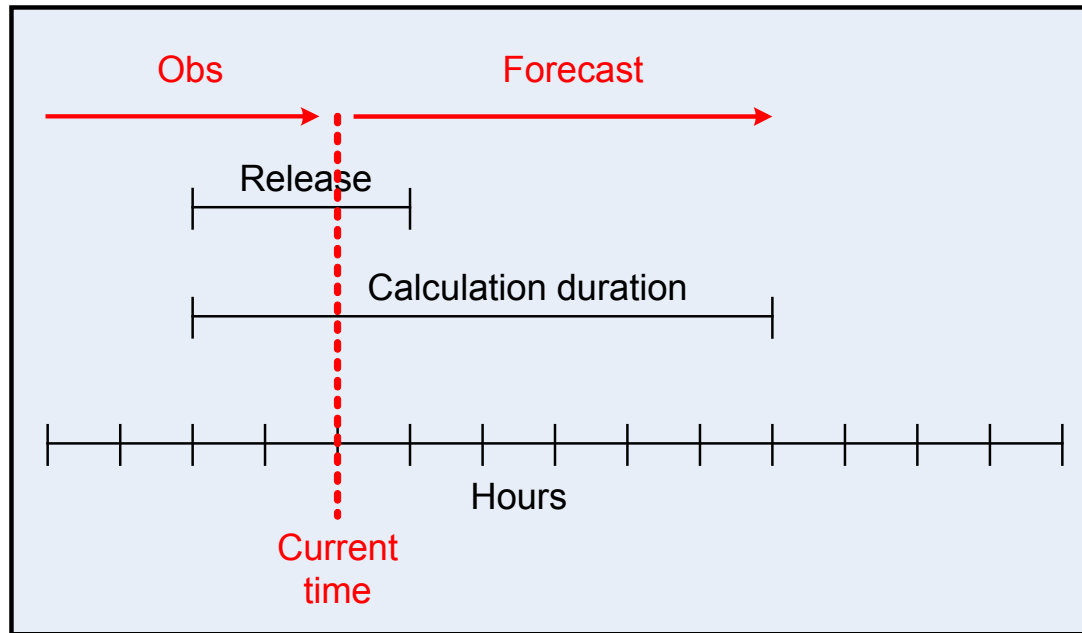
RASCAL CAN RUN WITH A SINGLE WEATHER DATAPoint



However, the initial meteorological data must fall within 2 hours before the start of the release to the atmosphere. (Release starts at 13:00; must have some meteorology defined within the 11:00 to 13:00 window)



ALTHOUGH SINGLE DATAPOINT WEATHER IS POSSIBLE, MORE DATA IS PREFERRED



Important when the release may start in the future or may continue for some period of time. You will likely need both observed and forecast data.

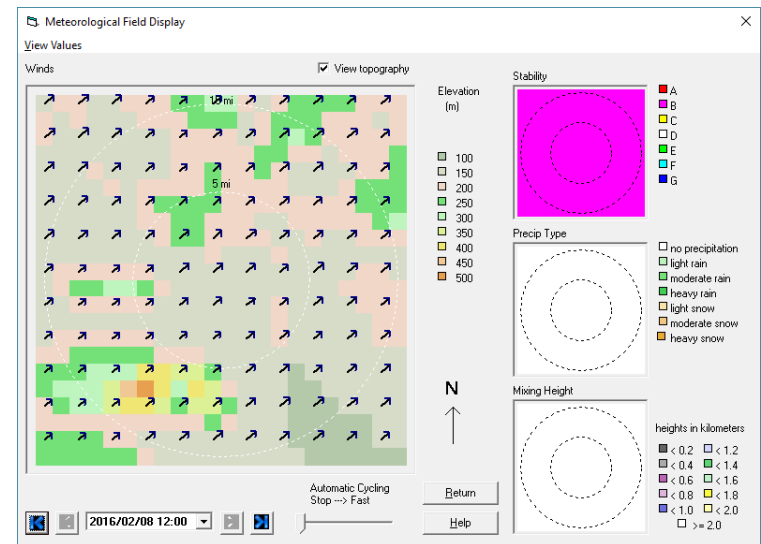
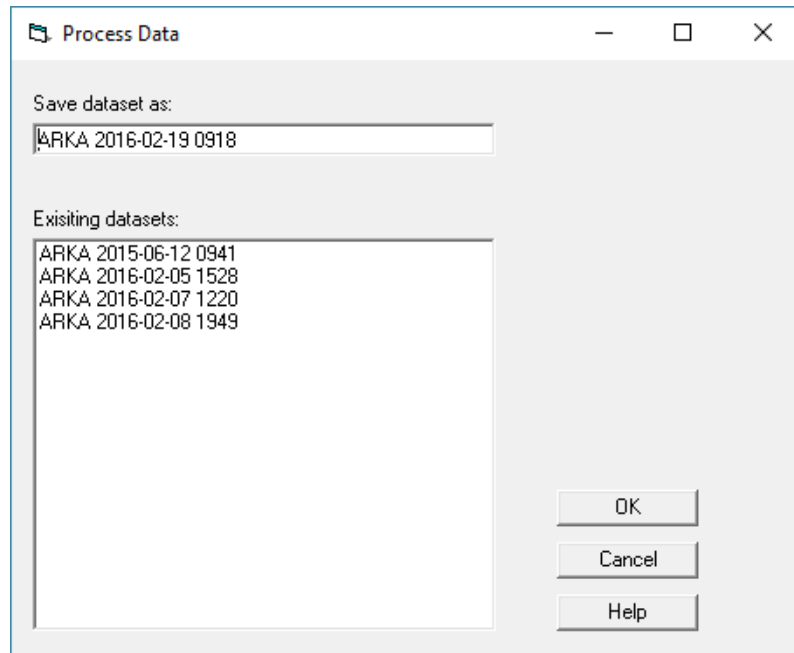
However, our scenario doesn't have additional info like forecasts yet.



Meteorology

RASCAL PROCESSES ALL ENTERED DATA INTO A MERGED GRIDDED FIELD THAT CHANGES OVER TIME

- This named file will show on the main met screen
- Weather details can be viewed if needed (View dataset)



NOTHING HAS BEEN CALCULATED AT THIS POINT. WITH A FEW ADDITIONAL PARAMETERS, RASCAL WILL PERFORM ALL ITS CALCULATIONS

Start the Calculations

Specify options and title for this set of calculations, then OK to begin calculations.

Distance of calculation

- ☒ Close-in + out to 10 miles (16 km)
- ☐ Close-in + out to 25 miles (40 km)
- ☐ Close-in + out to 50 miles (80 km)
- ☐ Close-in + out to 100 miles (160 km)
- ☐ Close-in only

Using close-in distances in miles:
0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0

☒ Defaults

☐ User defined

Start of release to atmosphere:
2016/10/12 13:00 (from release pathway definition)

End calculations at

- ☒ Start of release to atmosphere plus: hours
- ☐ User specified time:

Inhalation dose coefficients to use in calculations

- ☒ ICRP 26/30
- ☐ ICRP 60/72

Case information

Title:

(required - max 45 characters)

Case description:

(optional - max 600 characters)

Analyst:

- ☒ Dose Analyst
- ☐

PICK A DISTANCE TO SET THE CALCULATION AREA

Specify options and title for this set of calculations, then OK to begin calculations

Distance of calculation

- ☒ Close-in + out to 10 miles (16 km)
- ☐ Close-in + out to 25 miles (40 km)
- ☐ Close-in + out to 50 miles (80 km)
- ☐ Close-in + out to 100 miles (160 km)
- ☐ Close-in only

Using close-in distances in miles:
0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0

☒ Defaults

☐ User defined

Start of release to atmosphere:
2016/02/02 00:00 (from release pathway definition)

End calculations at

- ☒ Start of release to atmosphere plus: 8 hours
- ☐ User specified time: 2016/02/02 08:00

Inhalation dose coefficients to use in calculations

- ☒ ICRP 26/30
- ☐ ICRP 60/72

Analyst:

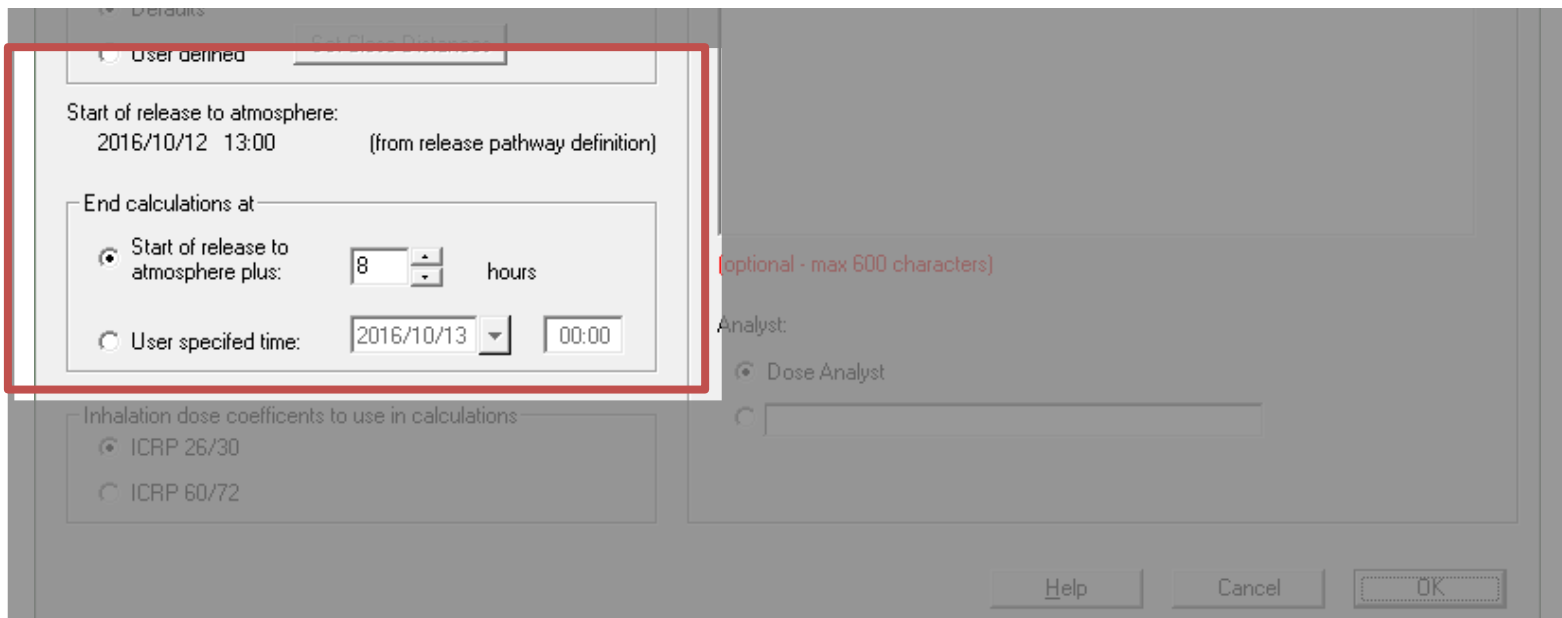
- ☒ Dose Analyst
- ☐

(optional - max 600 characters)

Help Cancel OK

- Shorter distances provide higher resolution
- Rule of Thumb – start on the 10 mile distance. If doses are high at the 10 mi edge, go to 25 miles.

- Duration after the first release to atmosphere that RASCAL terminates the release, plume movement and dose calculations
- If time is set too short, dose may be missed; no disadvantage to going long (except runtime)



Start of release to atmosphere:
2016/10/12 13:00 (from release pathway definition)

End calculations at

☒ Start of release to atmosphere plus: 8 hours

☐ User specified time: 2016/10/13 00:00

Inhalation dose coefficients to use in calculations

☒ ICRP 26/30

☐ ICRP 60/72

Analyst:

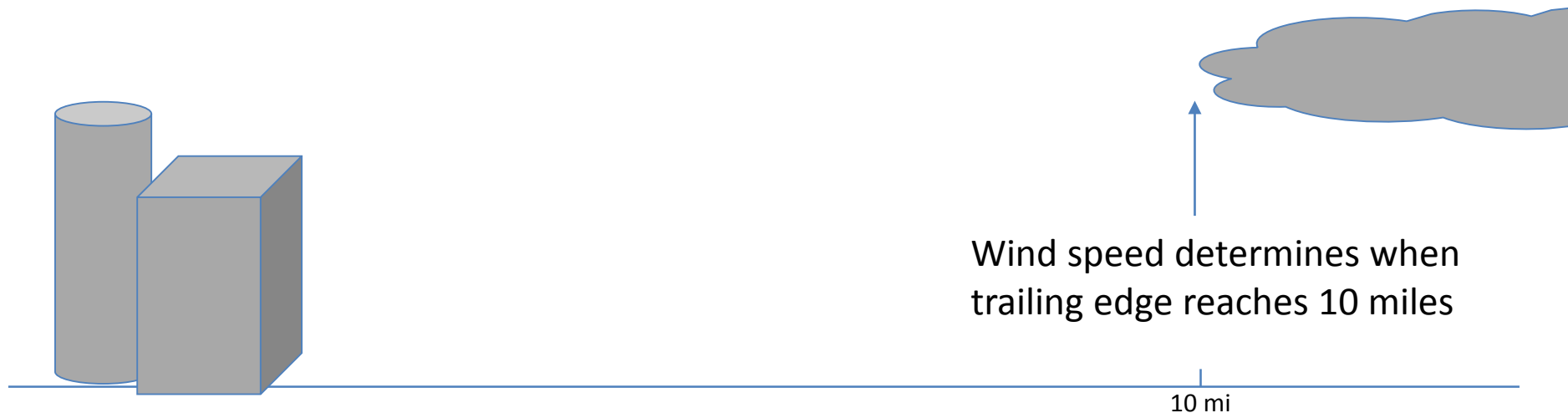
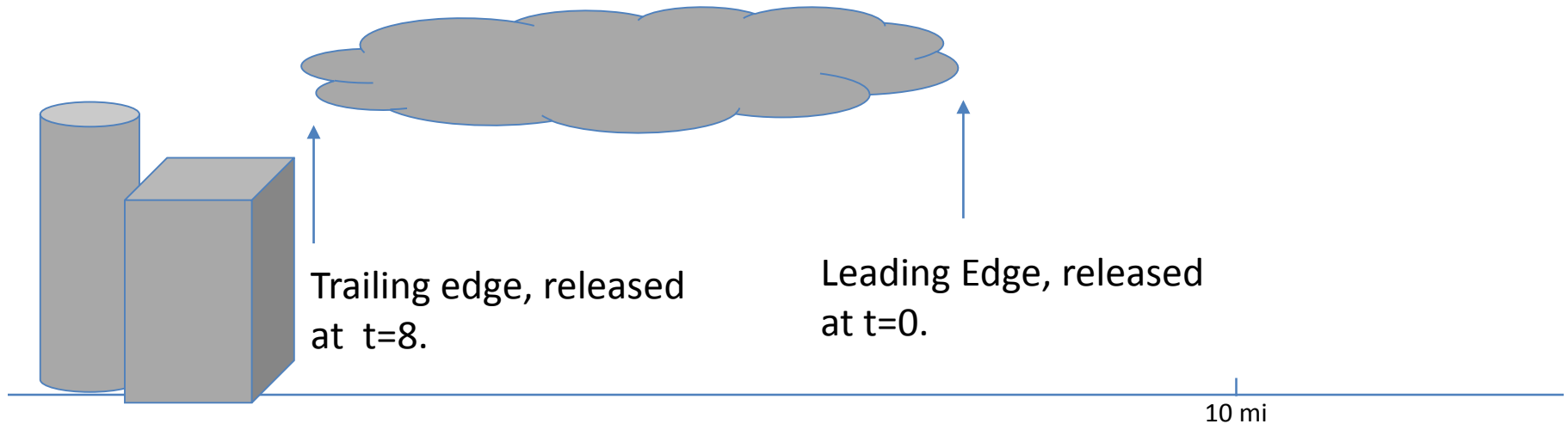
☒ Dose Analyst

(optional - max 600 characters)

Help Cancel OK

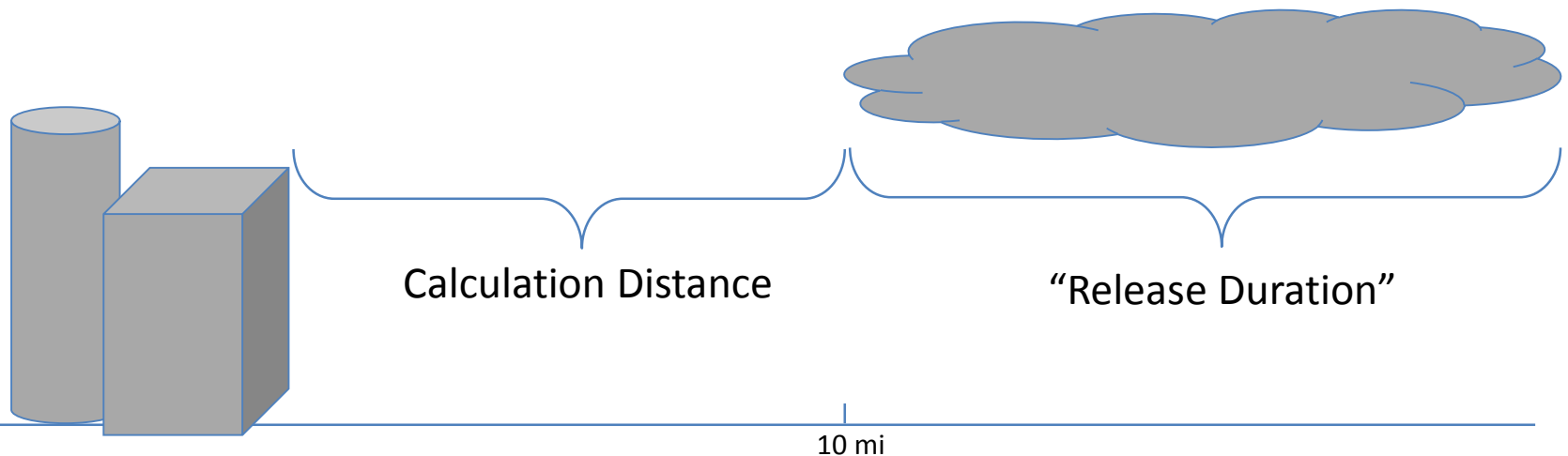
 Calculate Doses

SET CALCULATION DURATION TO ALLOW FOR TRAILING PLUME EDGE TO REACH SET DISTANCE



THERE IS A RULE-OF-THUMB FOR ESTIMATING THE CALCULATION DURATION

$$\text{Calculation Duration} \geq \left(\text{Release Duration} + \frac{\text{Calculation Distance}}{\text{Wind Speed}} \right) \times 1.1$$



For a 8 hour release with 6 mph winds, calculate a duration for 10 miles. What if the doses were high at 10 miles and you needed to increase to 25 miles?

SELECT THE INHALATION DOSE COEFFICIENTS TO BE USED

- ICRP 26/30 vs 60/72
- Currently, NRC and most States use 26/30
- New EPA PAG Manual uses 60/72
- Differences are inclusion of child thyroid CEDE and some minor dose values changes

Specify options and title for this set of calculations, then OK to begin calculations

Distan

Using

Start of

2016

End of

Start of release to atmosphere plus: 8 hours

User specified time: 2016/02/02 08:00

Inhalation dose coefficients to use in calculations

☒ ICRP 26/30

☐ ICRP 60/72

(optional - max 600 characters)

Analyst:

☒ Dose Analyst

Help Cancel OK

ENTER THE CASE INFORMATION

- RASCAL requires a case title
- Description used for justification or special notes; don't need to repeat case info
- Select and/or define an analyst name

Specify options and title for this set of calculations, then OK to begin calculations

Case information

Title:

(required - max 45 characters)

Case description:

(optional - max 600 characters)

Analyst:
☒ Dose Analyst
☐

Help

Cancel

OK

WHAT HAPPENS WHEN THE OK BUTTON IS CLICKED?

- RASCAL calculates the atmospheric source term and runs the ATD models with the given weather
 - You cannot interrupt the calculations
- Once complete, view results tabs at the bottom
 - Case Summary
 - Source Term
 - Maximum Dose Values



AFTER COMPLETING THE CALCULATIONS, SAVE THE CASE

- RASCAL creates a single file
 - Similar to a ZIP file
 - Archives
 - Inputs
 - Results
 - Meteorology data
- Resulting single file can be copied and e-mailed.
- The file can get very large for long calculations.



SOURCE TERM TAB SHOWS DETAILS FOR RELEASE TO ATMOSPHERE

- Summary window
- View Balance
 - Where nuclides are at the end of the simulation
- View Importance
 - What nuclides are contributing the most to dose
- Release vs. Time
 - Displays amount of each nuclide released each 15 minute time step
 - Can be exported

MAX VALUES TABLE SHOWS DOSE SNAPSHOT

- Summary window
 - Doses important for protective actions (TEDE, Thyroid)
 - Underlines doses exceeding PAGs
- Select distance
 - Close in vs selected “far out” model distance

We got a TEDE of 0.1 rem at 2 miles? Which direction is this?



Detailed Results

DETAILED RESULTS PROVIDE A MULTITUDE OF GRAPHIC AND TABULATED OPTIONS

Detailed Results of Dose Calculations

Result Type

- ☒ TEDE
 - ☐ Inhalation CEDE
 - ☐ Cloudshine Dose
 - ☐ 4-Day Groundshine Dose
- ☐ External Gamma Exposure Rate (cloudshine + groundshine)
- ☐ External Gamma + Beta Exposure Rate
- ☐ Acute Bone Dose Total
- ☐ Acute Bone from Inhalation Only
- ☐ Acute Lung Dose
- ☐ Acute Colon Dose
- ☐ Thyroid CDE
- ☐ Child Thyroid CDE
- ☐ Groundshine Dose Over Defined Period
- ☐ Ground Concentration - Total
- ☐ Ground Concentration of:
- ☐ 1st year Intermediate Phase TEDE
- ☐ 2nd year Intermediate Phase TEDE
- ☐ 50 year Intermediate Phase TEDE
- ☐ I-131 Time-integrated Air Concentration

Time Period for Exposure

- ☒ Start of release to end of calculation
- ☐ Cumulative over interval
 - From:
 - To:
- ☐ Rate at single time
 -

Display Format

From 10-mile calculation

- ☐ Footprint
- ☐ Numeric table
- ☐ Special receptors

From close-in calculation

- ☒ Footprint
- ☐ Numeric table

Display Units

- ☒ English
- ☐ SI

DETAILED RESULTS PROVIDE A MULTITUDE OF GRAPHIC AND TABULATED OPTIONS

Result Type

☒ TEDE	☐ Inhalation CEDE	☐ External Gamma Exposure Rate (cloudshine + groundshine)	☐ Acute Bone Dose Total
	☐ Cloudshine Dose	☐ External Gamma + Beta Exposure Rate	☐ Acute Bone from Inhalation Only
	☐ 4-Day Groundshine Dose		☐ Acute Lung Dose
			☐ Acute Colon Dose
☐ Thyroid CDE	☐ Groundshine Dose Over Defined Period		
☐ Child Thyroid CDE	☐ Ground Concentration - Total		
	☐ Ground Concentration of: Am-241		
☐ 1st year Intermediate Phase TEDE			
☐ 2nd year Intermediate Phase TEDE			
☐ 50 year Intermediate Phase TEDE	☐ I-131 Time-integrated Air Concentration		

- Select a result type to be displayed
 - Dose options on left
 - Measurement options in middle
 - Acute options on right

DETAILED RESULTS PROVIDE A MULTITUDE OF GRAPHIC AND TABULATED OPTIONS

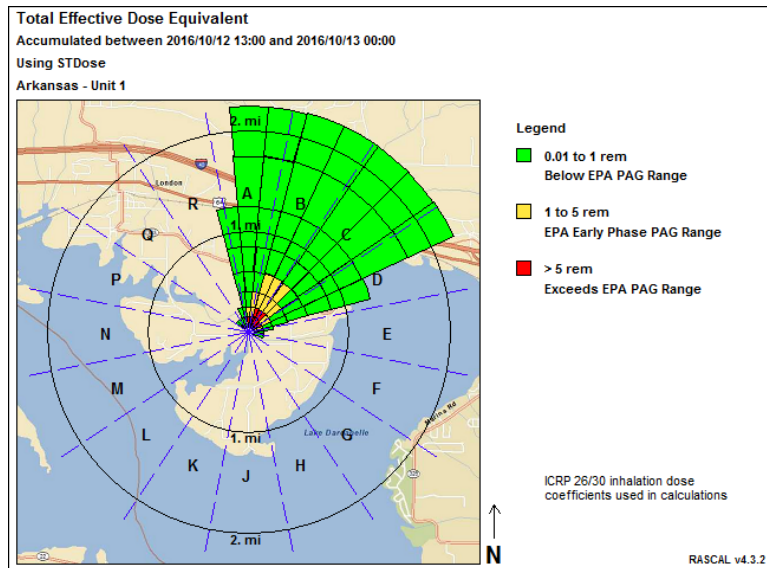
- Time can be set to be cumulative or at a rate
- Select between graphic and tabular format

Time Period for Exposure	Display Format	Display Units
☒ Start of release to end of calculation	From 10-mile calculation	☒ English
☐ Cumulative over interval	☐ Footprint	☐ SI
From: 2016/10/12 13:00	☐ Numeric table	Display Result
To: 2016/10/13 00:00	☐ Special receptors	
☐ Rate at single time	Define Receptors	
2016/10/13 00:00	From close-in calculation	Help
	☒ Footprint	Exit
	☐ Numeric table	

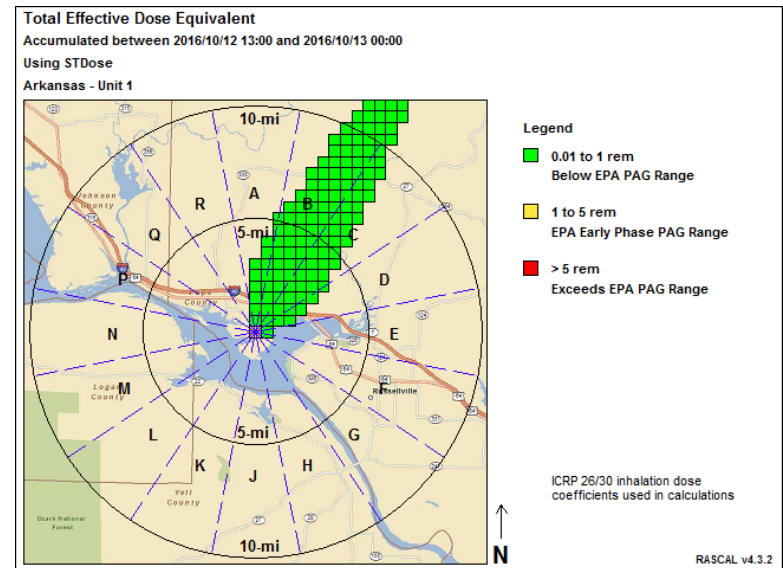
DIFFERENCE BETWEEN “CLOSE IN” AND “FAR OUT”

Two ATD models are used in the calculations

- Resolution advantages
- Overlap may not line up exactly



Plume Model



Puff Model

PROBLEM TASK

- What is the TEDE and Thyroid CDE at 0.2 and at 4 miles?

	Dose at 0.2 miles	Dose at 4 miles
TEDE (rem)		
Adult Thyroid CDE (rem)		

PROBLEM CONCLUSION

	Dose at 0.2 miles	Dose at 4 miles
TEDE (rem)	8.1 rem	0.02 rem
Adult Thyroid CDE (rem)	64 rem	0.15 rem

- Uncertainty in:
 - Source term – extent and timing of core damage
 - Release path – leak rate, reductions, etc
 - Met – uncertainty in forecast and in spatial components
 - Deposition processes – dry and wet
 - People – breathing, moving, sheltering, etc.

A FEW OF THE STDose OPTIONS CAN HAVE DEFAULTS SET THROUGH THE SETTINGS MENU

