

# HOW TO USE SOURCE TERM TO DOSE

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## DO YOU EVEN NEED RASCAL?

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- What is the most recent problem you've had with a power plant?
  - Did you need RASCAL then?
- For all examples in this training:
  - Scenarios justify the use of RASCAL (so you can see how to use the models)
  - We have ability to know all the parameters of the incident
- These might not be true in reality

# WHY ARE YOU USING STDose?



1. Determine possible PARs/PADs in pre-release?
  - No release yet, limited information available
2. Determine bounds of starting release?
  - Release just started. Have clearer understanding of how accident may progress.
3. Determine more detailed dose information?
  - Release ongoing or stopped. Most information available, including some field readings.
4. Compare or verify results.
  - Mostly used for event re-creation or research

## 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]).



## LET'S ASSUME THAT YOUR TASK IS TO DO A PRE-RELEASE ASSESSMENT

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Remember to ask: Do you even need RASCAL?

Before you start RASCAL, familiarize yourself with the area, remembering that your goal is protective actions

- Water: Is the wind blowing toward the ocean?
- Population: Any nearby cities or parks?
- Weather: Based on season and location, what weather is likely in that area?

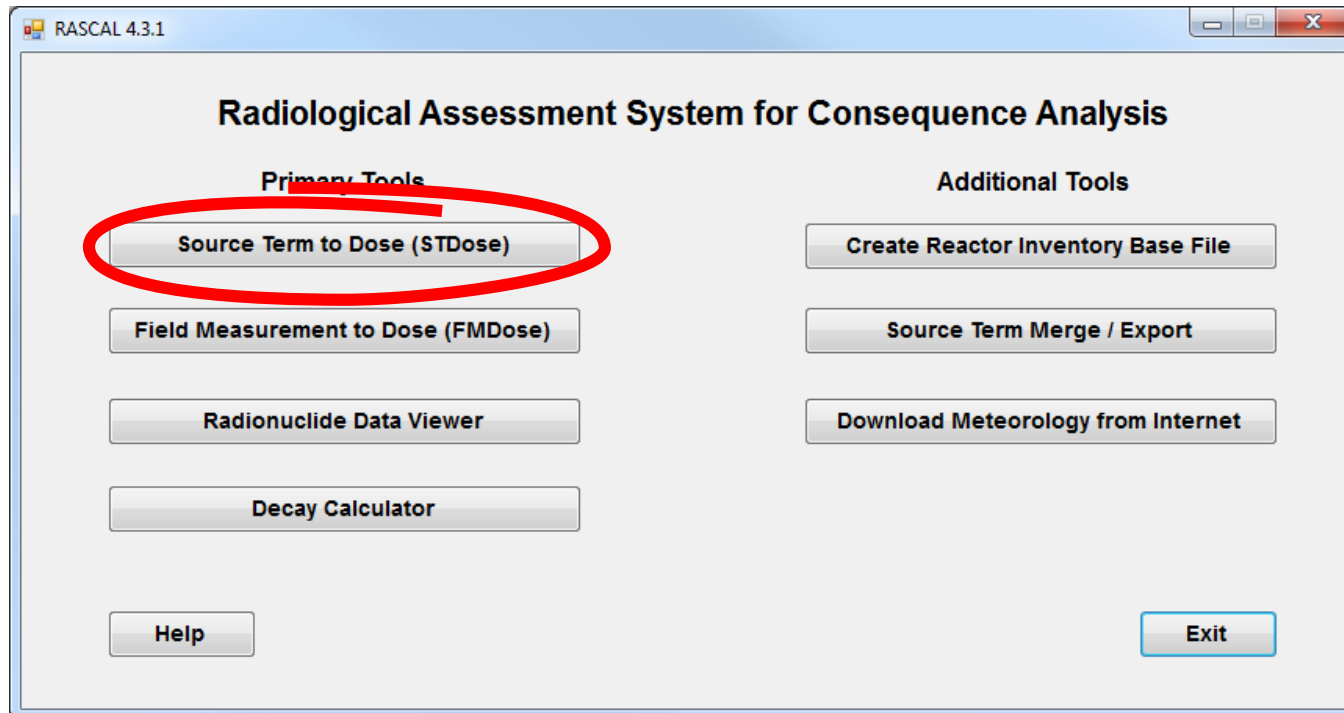
## AS A RASCAL OPERATOR YOUR INITIAL TASK IS TO TAKE INFORMATION AND SET UP A MODELING SCENARIO

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- Where do you get the information:
  - Plant data systems, 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

As time progresses, more information is available

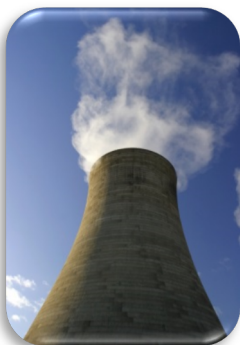
# WHICH TOOL SHOULD BE USED?





**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 the following information: 'Event Type' is 'Nuclear Power Plant'; 'Case description' is 'None'; 'Location' includes 'Name: Arkansas - Unit 1', 'City, county, state: Russellville, Pope, AR', 'Lat / Long / Elev: 35.3100° N, 93.2314° W, 103 m', 'Time zone: Central', and 'Population (2010): 946 / 12,205 / 53,396 (2 / 5 / 10 mi)'. The right pane is titled 'Reactor Parameters' and includes: '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', and 'Design leak rate: 0.20 %/d'. At the bottom of the window, there are two tabs: 'Case Summary' (active) and 'Source Term'.

Step	Value
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

## STATIC INFORMATION ENTERED, NOW FOR ADDITIONAL DYNAMIC CONDITIONS IN SCENARIO

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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.

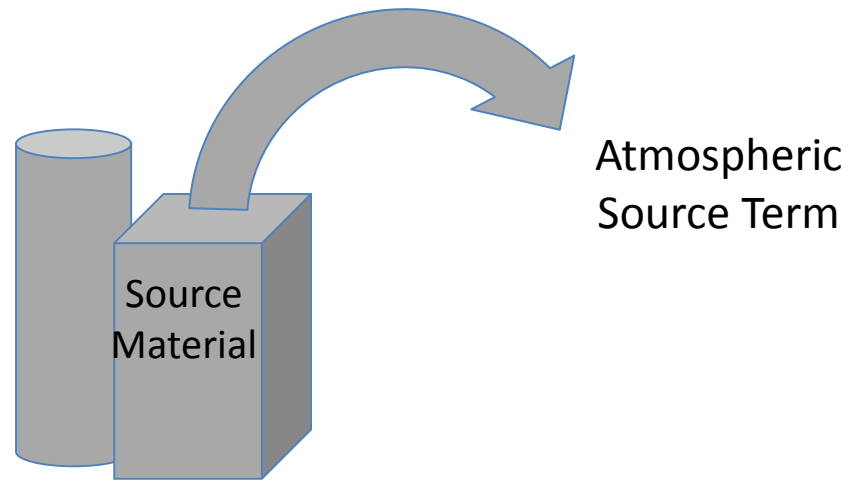


## EACH MODEL REQUIRES ADDITIONAL PARAMETERS

- 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





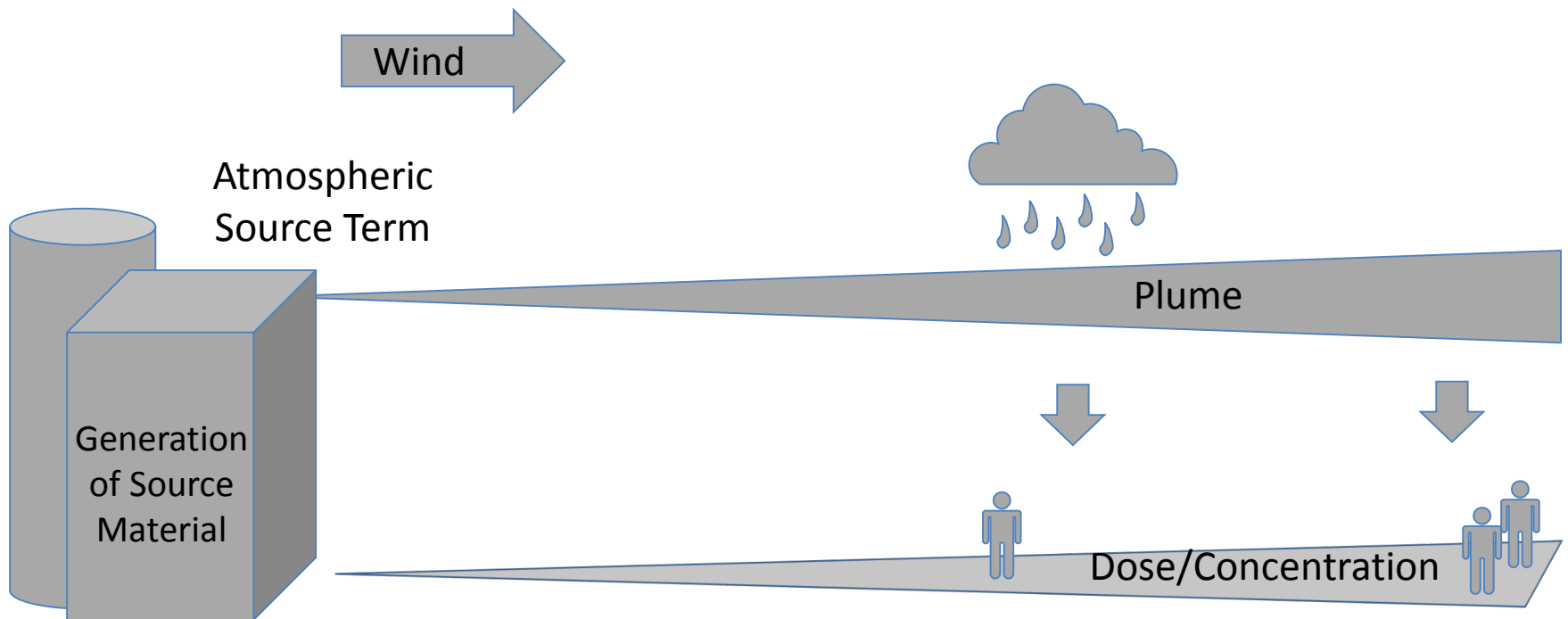
## NOW LET'S INPUT THE RELEASE CONDITIONS SPECIFIC TO A LOCA

- 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 cm<sup>2</sup>)
- 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



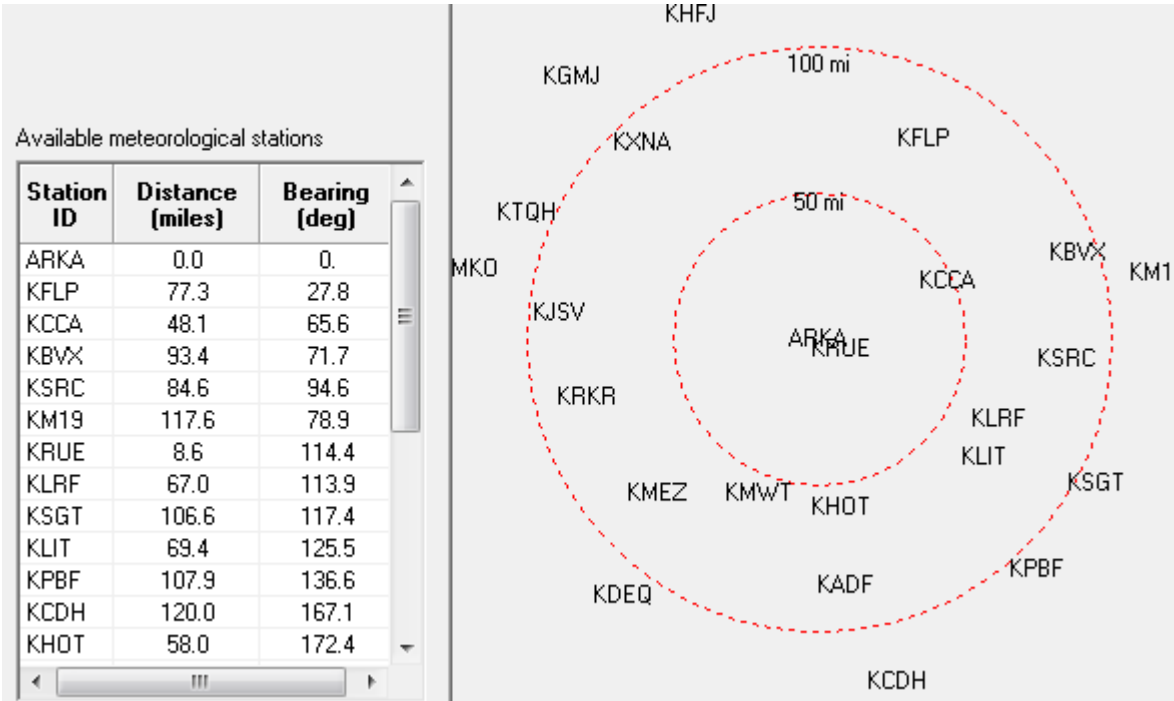
## WEATHER DATA IS MANAGED AS SITE-DEPENDENT FILES

- 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:

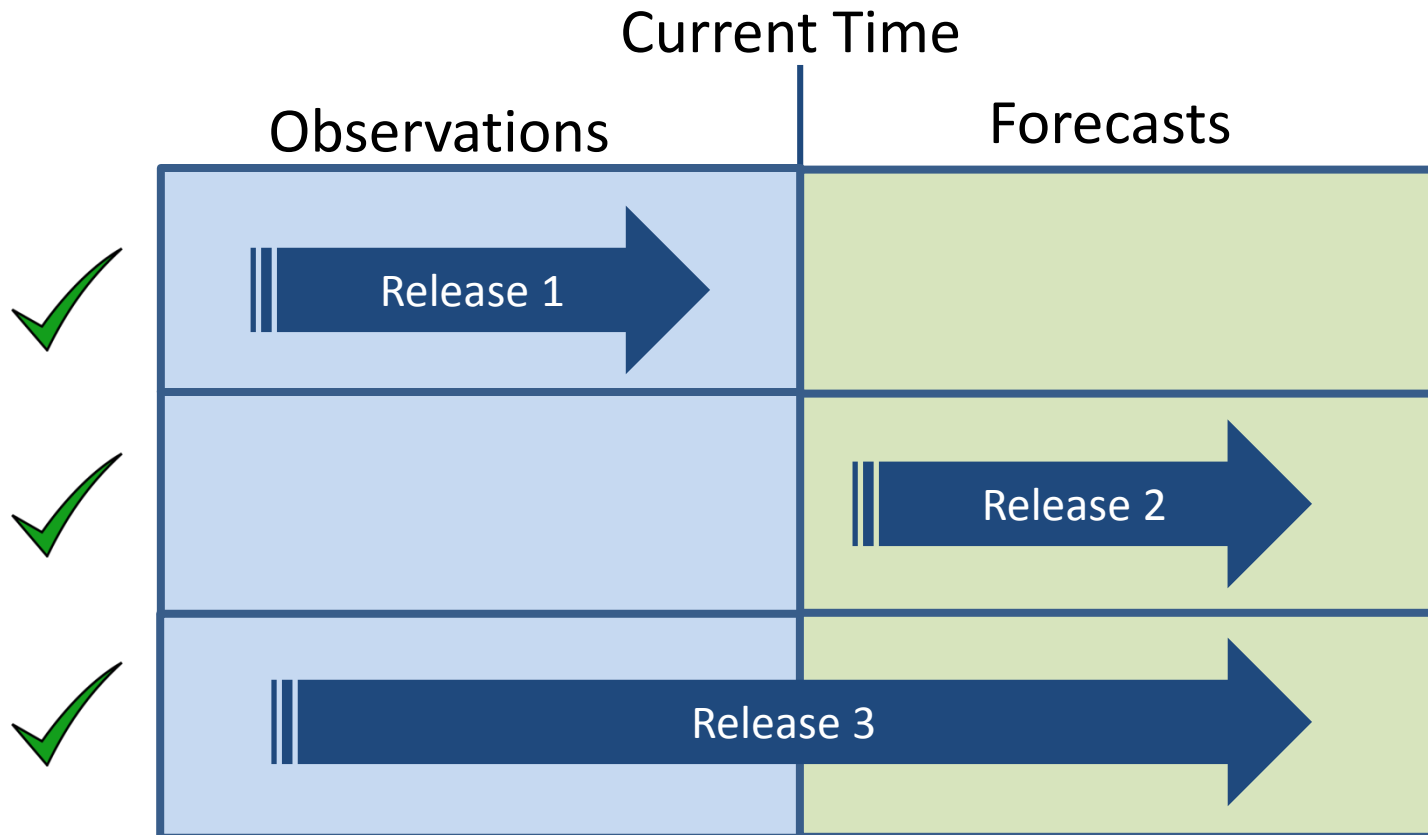
- Type
- Date/Time
- Wind Direction/Speed
- Stability
- Precipitation
- Optional Fields (\*)

[illegible]



**Meteorology**

## RASCAL USES OBSERVED AND/OR FORECAST WEATHER DATA



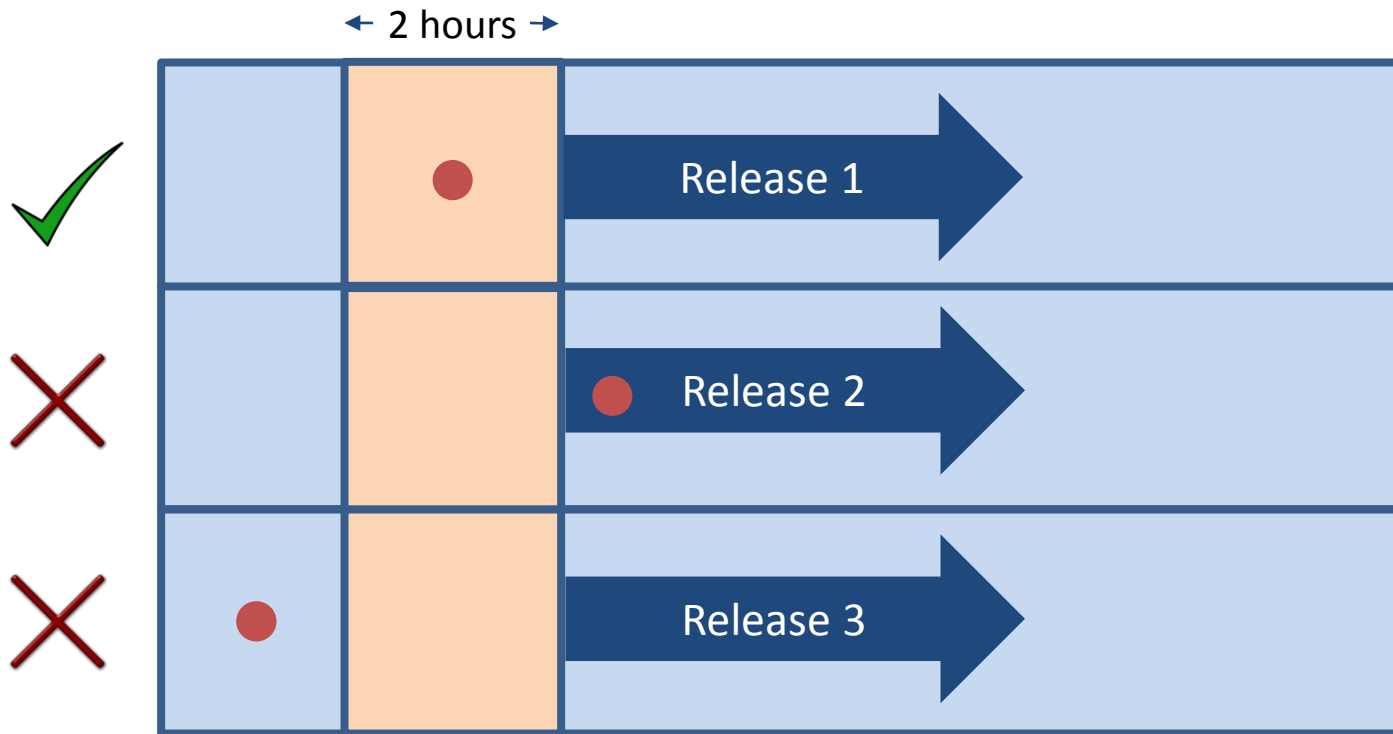
RASCAL can model releases in the past (all observations), in the future (all forecasts), or that span both.





**Meteorology**

## RASCAL CAN RUN WITH A SINGLE WEATHER DATAPoint

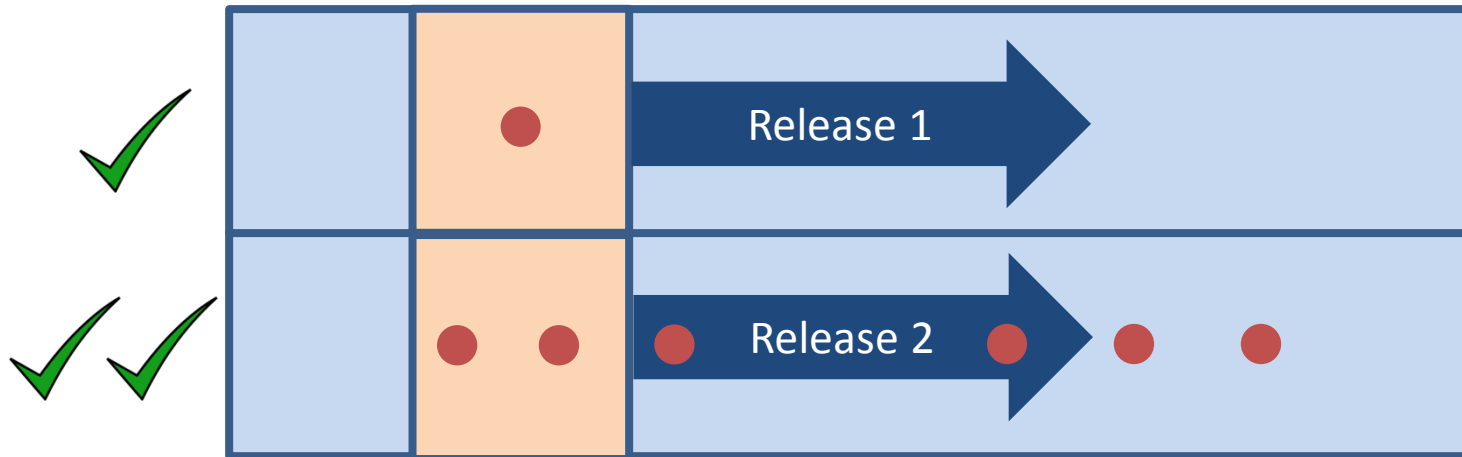


However, the initial meteorological data must fall within 2 hours before the start of the release to the atmosphere. (Release starts at 13:00; must have some meteorology defined within the 11:00 to 13:00 window)



**Meteorology**

## 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.

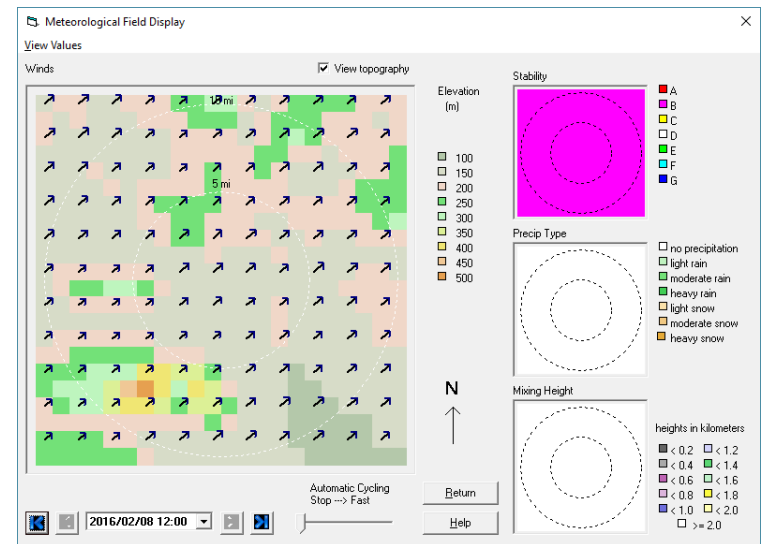
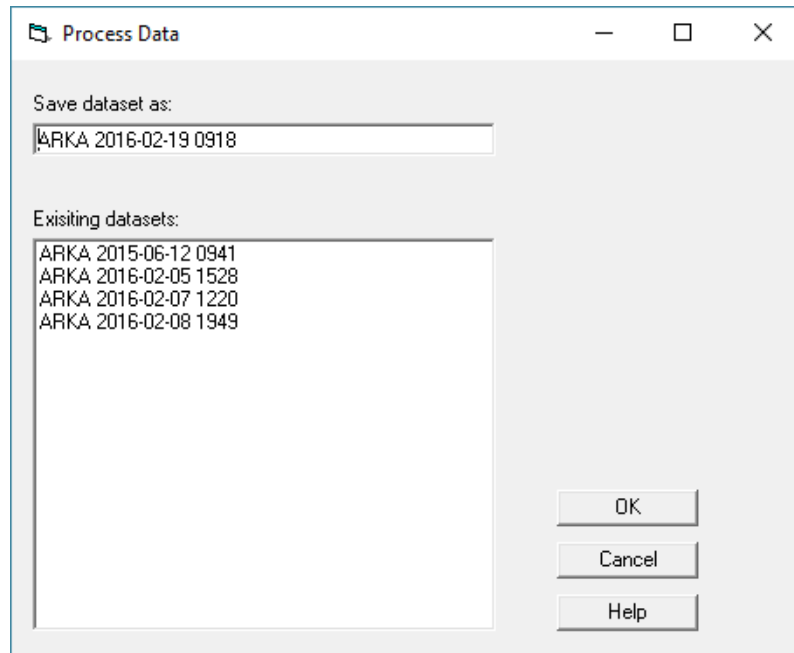
However, our scenario doesn't have additional info like forecasts yet.



## 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

**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:    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
- ☐

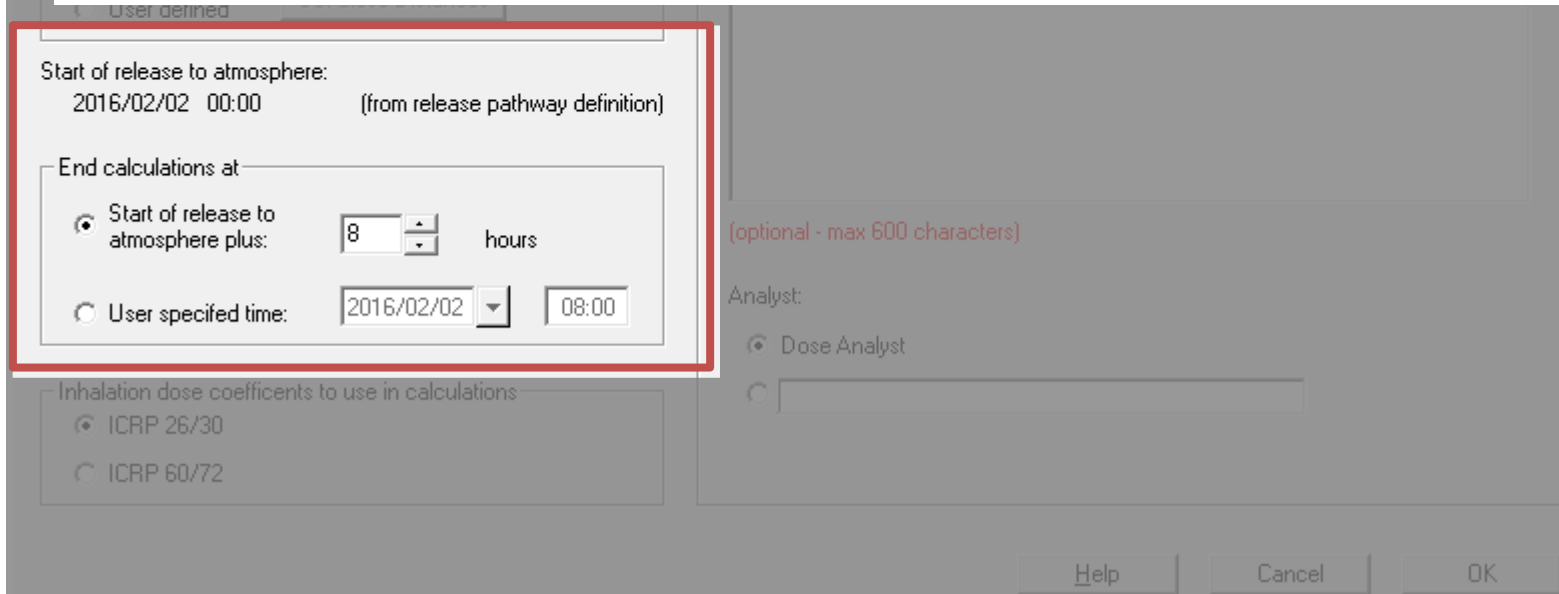
(optional - max 600 characters)

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.

## DEFINE A CALCULATION TIME

- 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)



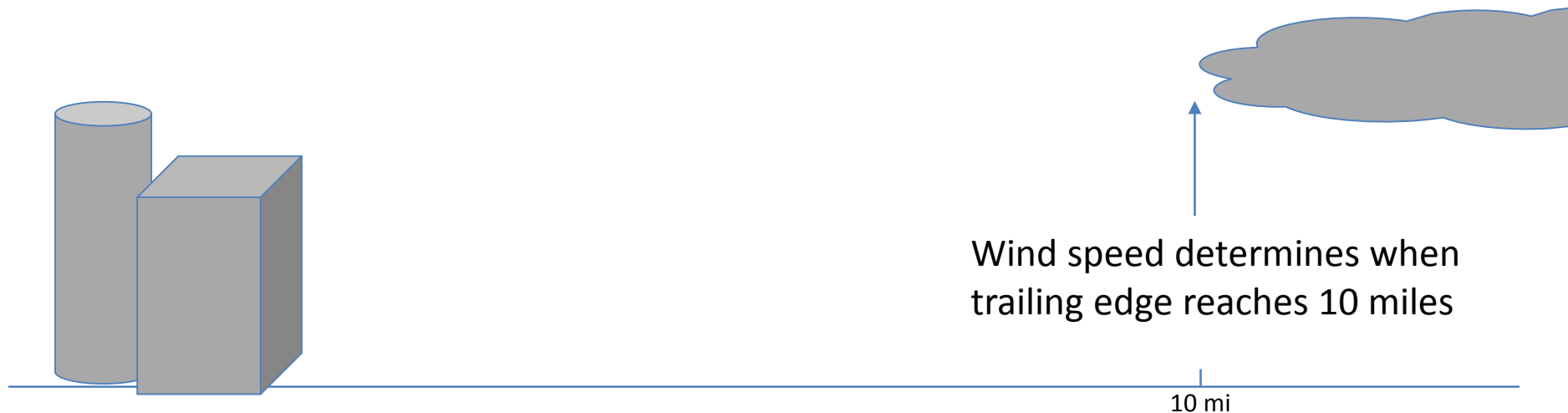
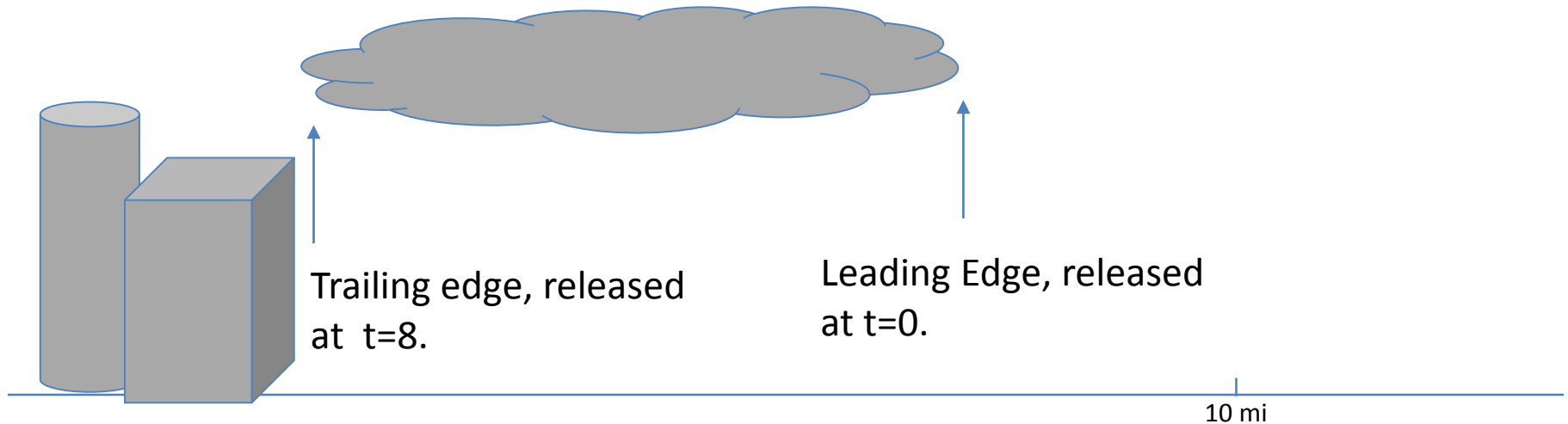
The screenshot shows the 'Define a Calculation Time' dialog box in the RASCAL software. The dialog box is titled 'User defined' and contains the following fields and options:

- 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
- Help**, **Cancel**, and **OK** buttons at the bottom.

Optional text: (optional - max 600 characters)

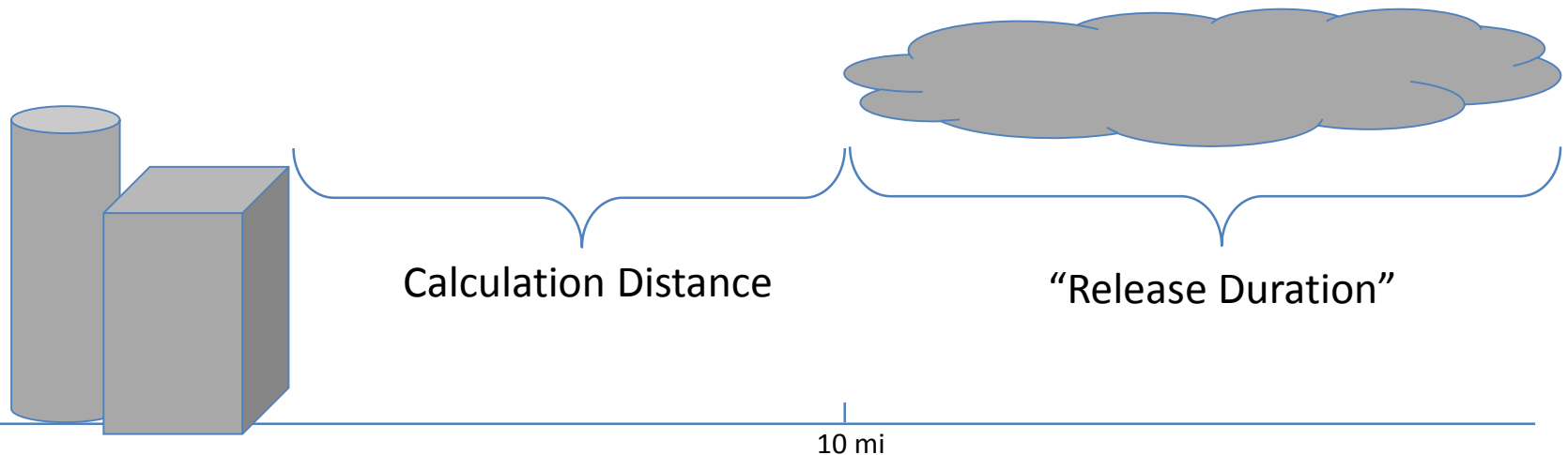
 Calculate Doses

## 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

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- 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

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- 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

Result Type		
<input checked="" type="radio"/> TEDE	<input type="radio"/> Inhalation CEDE	<input type="radio"/> External Gamma Exposure Rate (cloudshine + groundshine)
	<input type="radio"/> Cloudshine Dose	<input type="radio"/> External Gamma + Beta Exposure Rate
	<input type="radio"/> 4-Day Groundshine Dose	<input type="radio"/> Acute Bone Dose Total
		<input type="radio"/> Acute Bone from Inhalation Only
<input type="radio"/> Thyroid CDE		<input type="radio"/> Acute Lung Dose
	<input type="radio"/> Groundshine Dose Over Defined Time Period	<input type="radio"/> Acute Colon Dose
	<input type="radio"/> Ground Concentration - Total	
<input type="radio"/> 1st year Intermediate Phase TEDE	<input type="radio"/> Ground Concentration of: Am-241	
<input type="radio"/> 2nd year Intermediate Phase TEDE	<input type="radio"/> I-131 Air Concentration	
<input type="radio"/> 50 year Intermediate Phase TEDE		

Time Period for Exposure	Display Format	Display Units
<input checked="" type="radio"/> Start of release to end of calculation	<input type="radio"/> From 10-mile calculation	<input checked="" type="radio"/> English
<input type="radio"/> Cumulative over interval	<input type="radio"/> Footprint	<input type="radio"/> SI
From: 2011/01/13 13:00	<input type="radio"/> Numeric table	
To: 2011/01/13 21:00	<input type="radio"/> Special receptors	
	<input type="button" value="Define Receptors"/>	<input type="button" value="Display Result"/>
<input type="radio"/> Rate at single time	<input type="radio"/> From close-in calculation	
2011/01/13 21:00	<input checked="" type="radio"/> Footprint	
	<input type="radio"/> Numeric table	

## DETAILED RESULTS PROVIDE A MULTITUDE OF GRAPHIC AND TABULATED OPTIONS

Result Type

<input checked="" type="radio"/> TEDE	<input type="radio"/> Inhalation CEDE	<input type="radio"/> External Gamma Exposure Rate (cloudshine + groundshine)	<input type="radio"/> Acute Bone Dose Total
<input type="radio"/> Cloudshine Dose	<input type="radio"/> External Gamma + Beta Exposure Rate	<input type="radio"/> Acute Bone from Inhalation Only	
<input type="radio"/> 4-Day Groundshine Dose	<input type="radio"/> Groundshine Dose Over Defined Time Period	<input type="radio"/> Acute Lung Dose	
<input type="radio"/> Thyroid CDE	<input type="radio"/> Ground Concentration - Total	<input type="radio"/> Acute Colon Dose	
<input type="radio"/> 1st year Intermediate Phase TEDE	<input type="radio"/> Ground Concentration of: Am-241		
<input type="radio"/> 2nd year Intermediate Phase TEDE	<input type="radio"/> I-131 Air Concentration		
<input type="radio"/> 50 year Intermediate Phase TEDE			

Time Period for Exposure      Display Format      Display Units

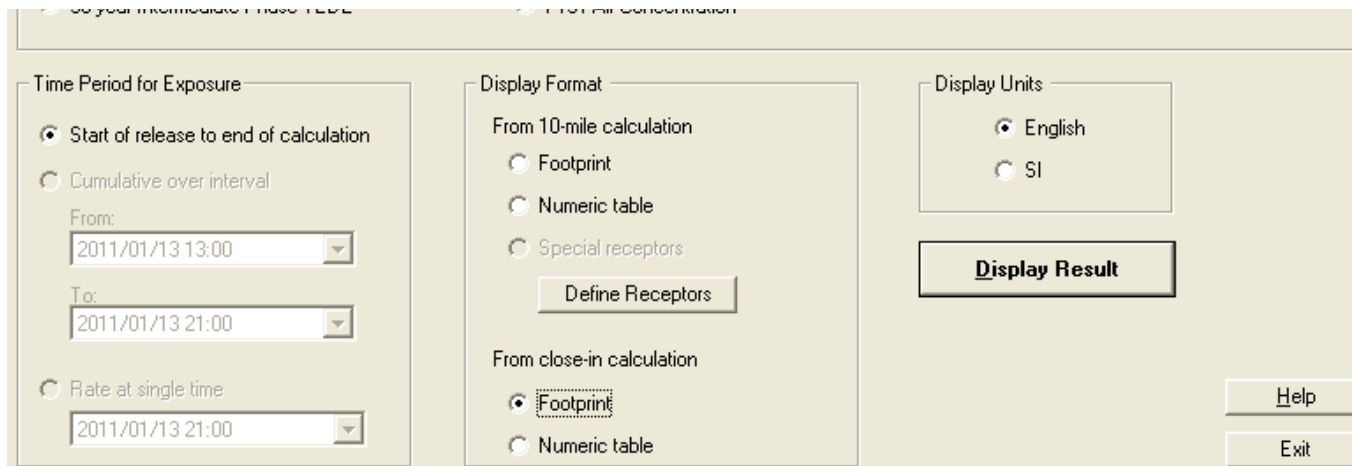
Select a result type to be displayed:

- 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 graphical footprint and tabular format for close-in or far-out distances
- Lastly, select units



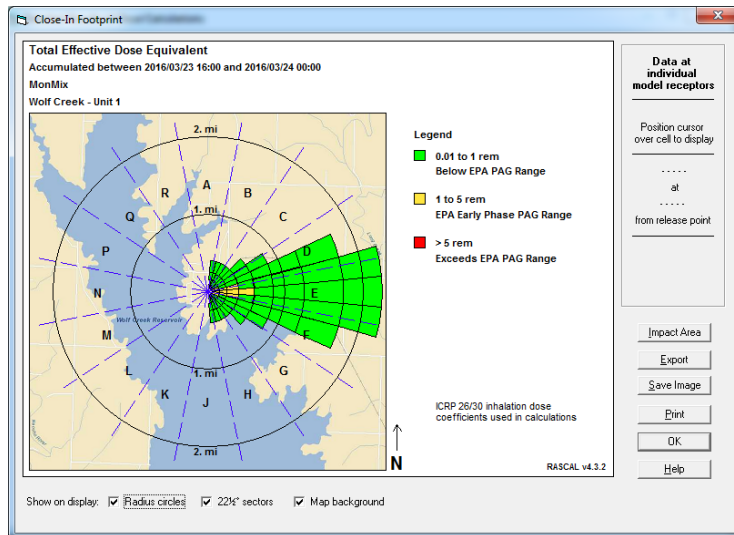
The screenshot displays the 'Detailed Results' configuration window, which is organized into three main sections: 'Time Period for Exposure', 'Display Format', and 'Display Units'. The 'Time Period for Exposure' section on the left offers two radio button options: 'Start of release to end of calculation' (selected) and 'Cumulative over interval'. Below these are 'From' and 'To' time pickers set to '2011/01/13 13:00' and '2011/01/13 21:00' respectively. A third option, 'Rate at single time', is also present with a corresponding time picker set to '2011/01/13 21:00'. The 'Display Format' section in the center provides two sets of options. The 'From 10-mile calculation' group includes radio buttons for 'Footprint', 'Numeric table', and 'Special receptors', with a 'Define Receptors' button below. The 'From close-in calculation' group includes radio buttons for 'Footprint' (selected) and 'Numeric table'. The 'Display Units' section on the right has radio buttons for 'English' (selected) and 'SI'. A large 'Display Result' button is positioned below the units section. At the bottom right, there are 'Help' and 'Exit' buttons.

# DIFFERENCE BETWEEN FOOTPRINT AND TABLE

Footprint provides celled results on map

Table provides numeric values

Both can be exported, map can be queried, table can be filtered



Footprint

The 'Close-In Numeric Table' window displays a table titled 'Total Effective Dose Equivalent (rem)' for the period 'Accumulated between 2016/03/23 16:00 and 2016/03/24 00:00'. The table shows dose values for various distances and bearings from the release point. The table is filtered to show cells with values equal to or greater than 0.0.

Distance		Bearing from release point										
mi	km	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°
0.10	0.16	1.68E-01	2.07E-01	2.57E-01	3.31E-01	4.50E-01	6.12E-01	1.02E+00	1.96E+00	2.67E+00	1.96E+00	1.02E
0.20	0.32	3.39E-02	4.39E-02	7.40E-02	1.06E-01	1.68E-01	2.87E-01	6.80E-01	1.74E+00	2.59E+00	1.74E+00	6.80E
0.30	0.48	1.05E-02	1.44E-02	2.09E-02	3.27E-02	7.36E-02	1.43E-01	4.15E-01	1.26E+00	1.85E+00	1.26E+00	4.15E
0.50	0.80	1.35E-03	1.99E-03	3.25E-03	8.32E-03	1.86E-02	4.88E-02	1.94E-01	7.19E-01	1.15E+00	7.19E-01	1.94E
0.70	1.13	2.05E-04	3.34E-04	7.06E-04	1.47E-03	5.59E-03	1.79E-02	1.03E-01	4.71E-01	7.89E-01	4.71E-01	1.03E
1.00	1.61	1.61E-05	3.14E-05	6.26E-05	1.84E-04	1.05E-03	4.87E-03	4.17E-02	2.57E-01	5.01E-01	2.57E-01	4.17E
1.50	2.41	2.86E-07	6.86E-07	2.34E-06	8.61E-06	8.55E-05	6.23E-04	1.11E-02	1.28E-01	2.76E-01	1.28E-01	1.11E
2.00	3.22	---	---	1.06E-07	5.81E-07	7.42E-06	9.48E-05	3.13E-03	6.51E-02	1.72E-01	6.51E-02	3.13E

ICRP 26/30 inhalation dose coefficients used in calculations

Color all cells with a value equal to or greater than: 0.0

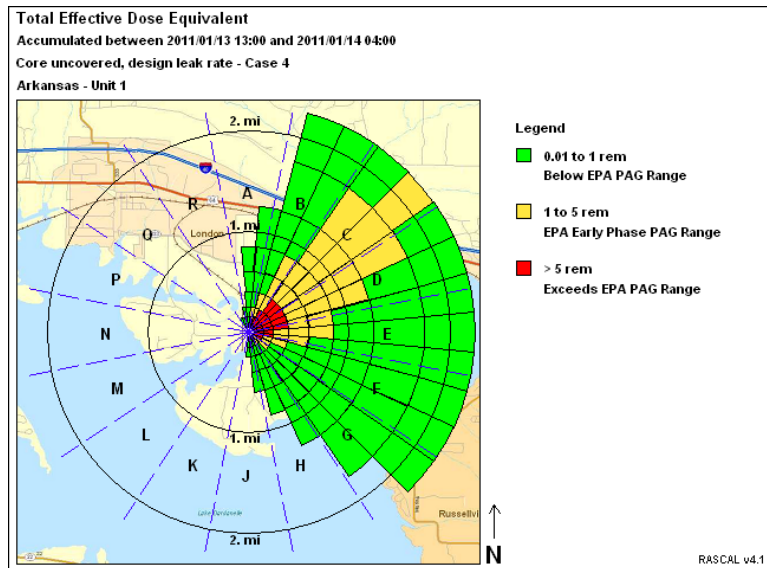
Buttons: Color, Clear Color, Export, Print, OK, Help

Table

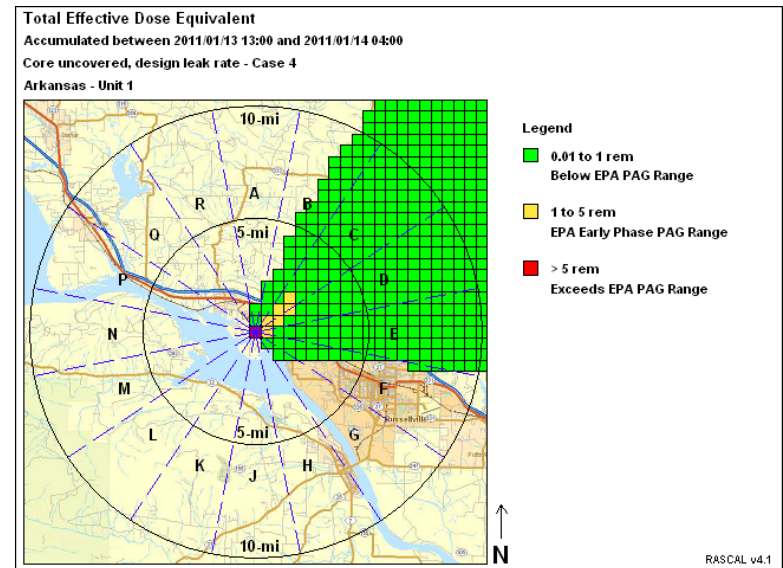
# DIFFERENCE BETWEEN “CLOSE IN” AND “FAR OUT”

Two ATD models are used in the calculations

- Resolution advantages
- Overlap may not line up exactly



Plume Model



Puff Model

## PROBLEM TASK

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- 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 **STD**OSE PARAMETERS CAN HAVE DEFAULTS SET THROUGH THE SETTINGS MENU

