RASCAL 4.3

Jeff Kowalczik, USNRC

National REP Conference

Salt Lake City

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

RASCAL

- RASCAL Overview
- RASCAL Program Management
- Updates in RASCAL Version 4.3

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RASCAL Overview

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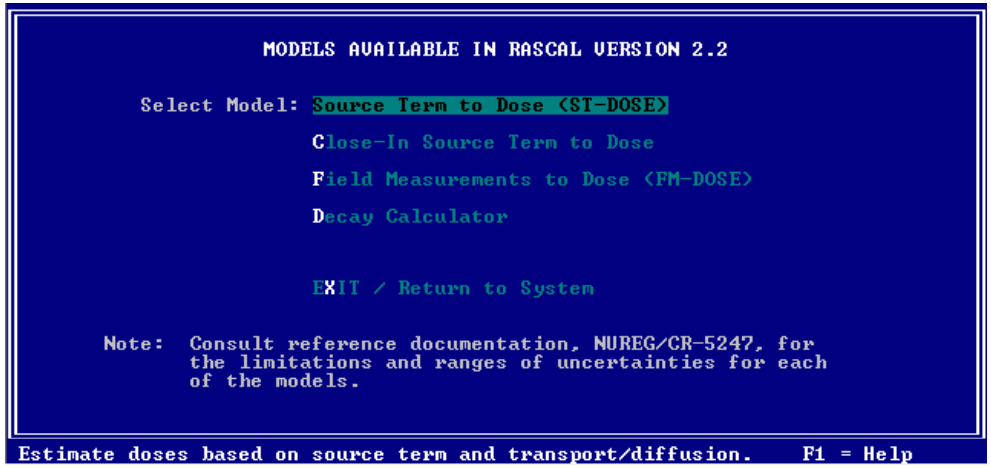
Overview

- Purpose
  - Assists in Protective Action evaluation
- Evaluates releases from:
  - nuclear power plants,
  - spent fuel storage pools and casks,
  - fuel cycle facilities, and
  - radioactive material handling facilities.
- Evaluates atmospheric releases using facility conditions to estimate a source term and dose

Early RASCAL

- Began in late-80s to computerize the hand calculations and paper methods of RTM and NUREG-1228
- RASCAL 2 was DOS-based



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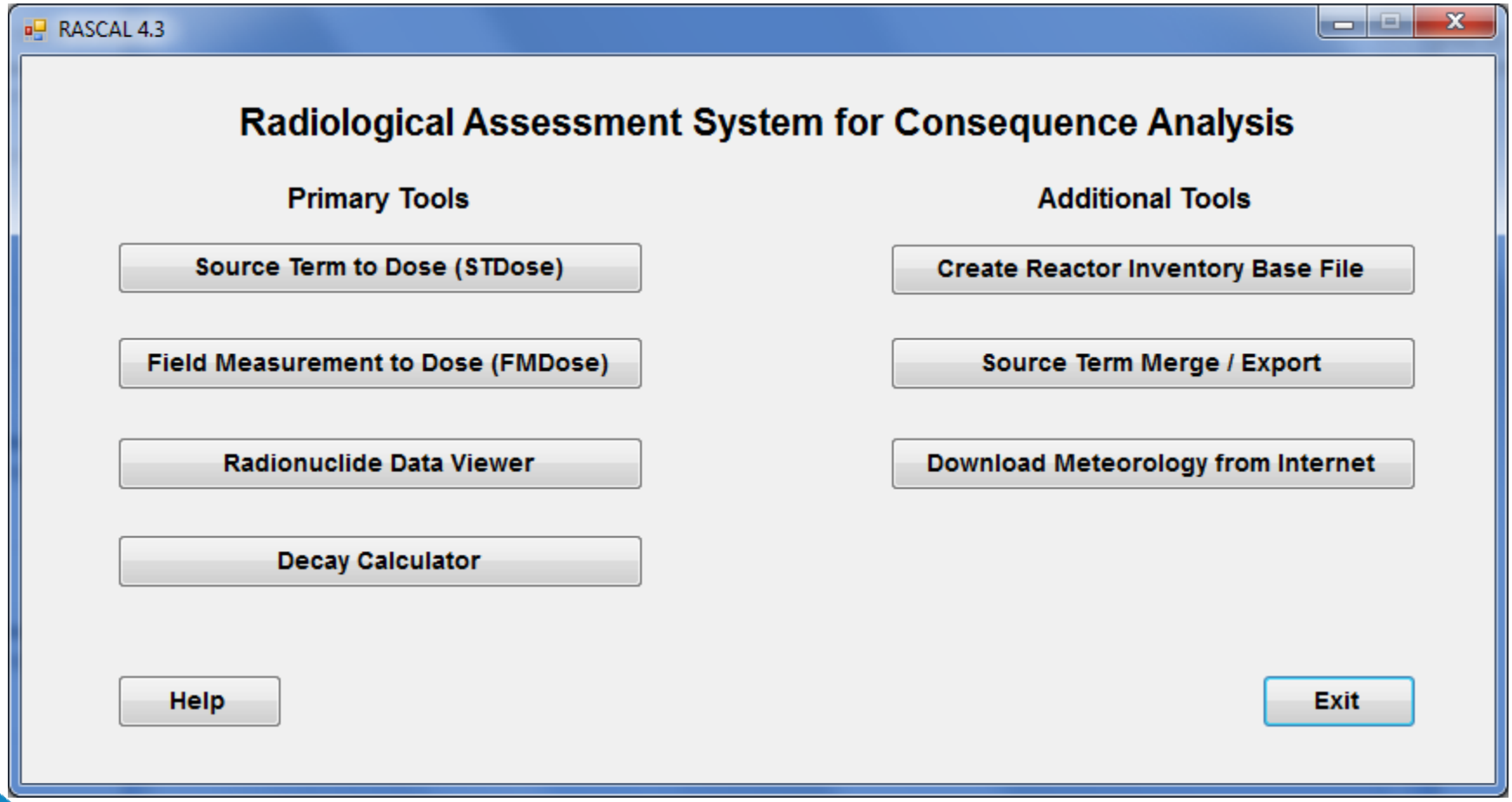
RASCAL Tools



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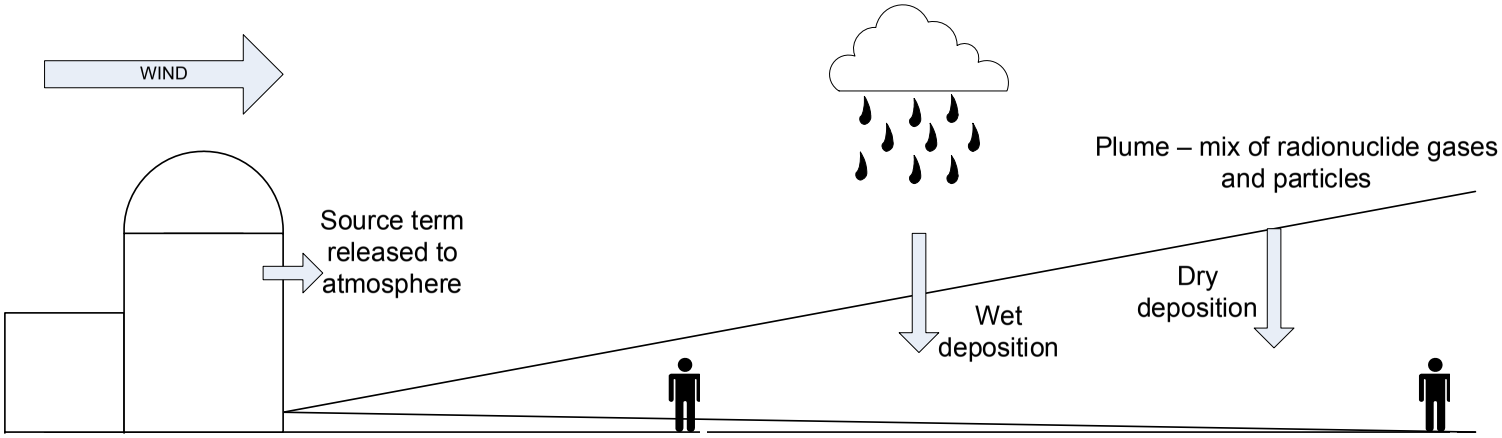
Source Term to Dose

- Calculates source terms from input parameters
- Models atmospheric transport, diffusion, and deposition
- Produces map-based dose projection



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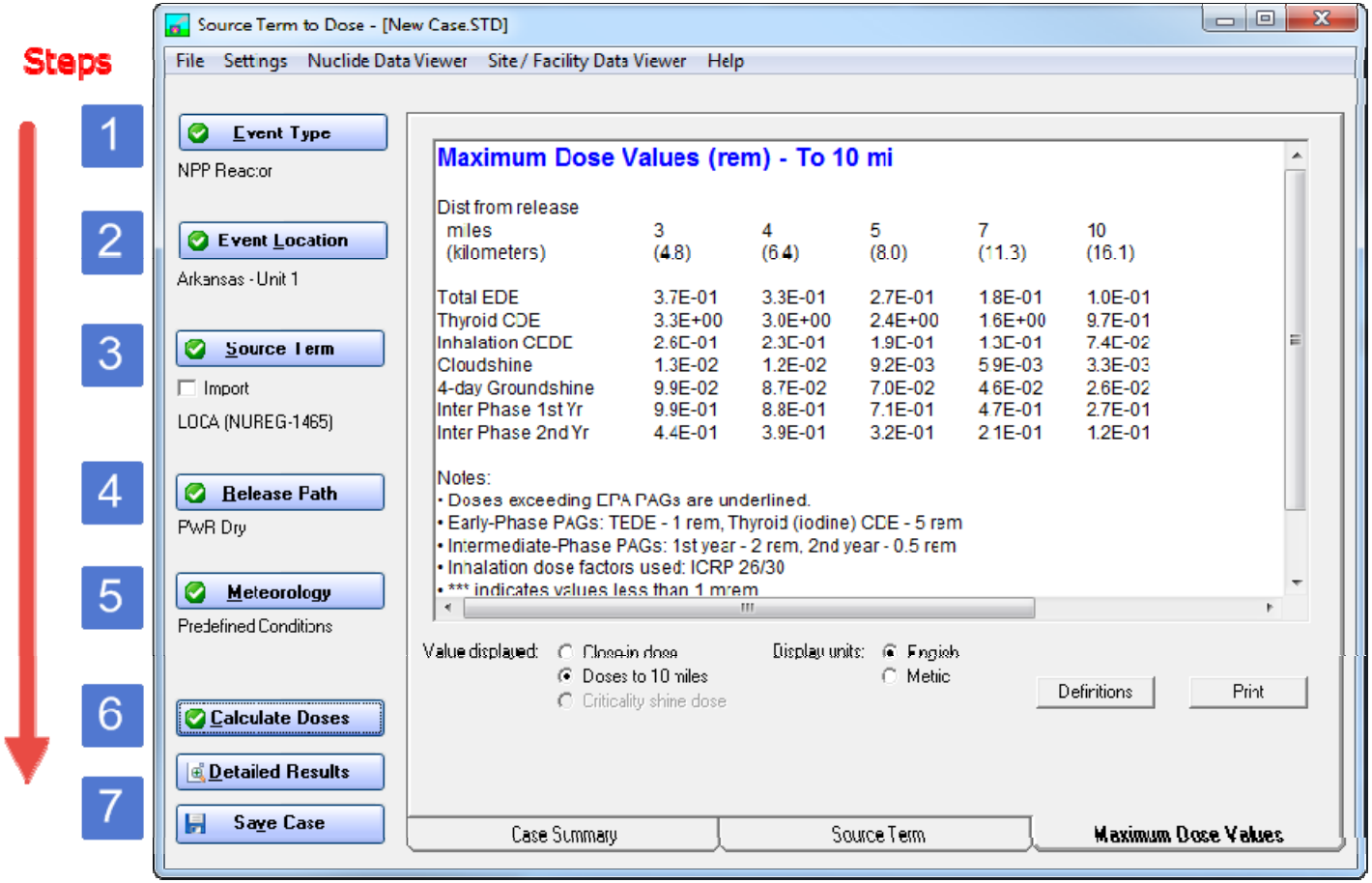
Source Term to Dose - Steps



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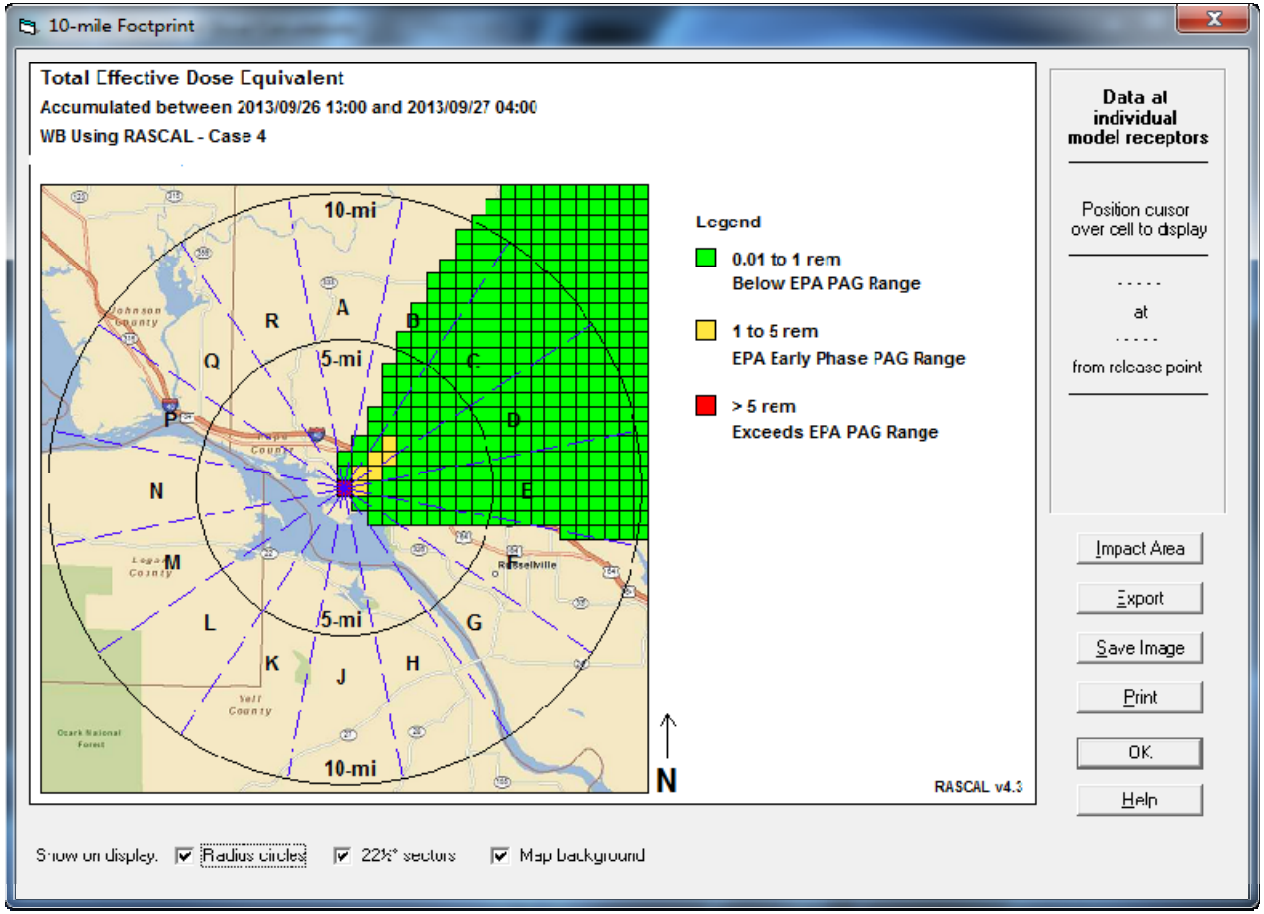
Source Term to Dose - Result



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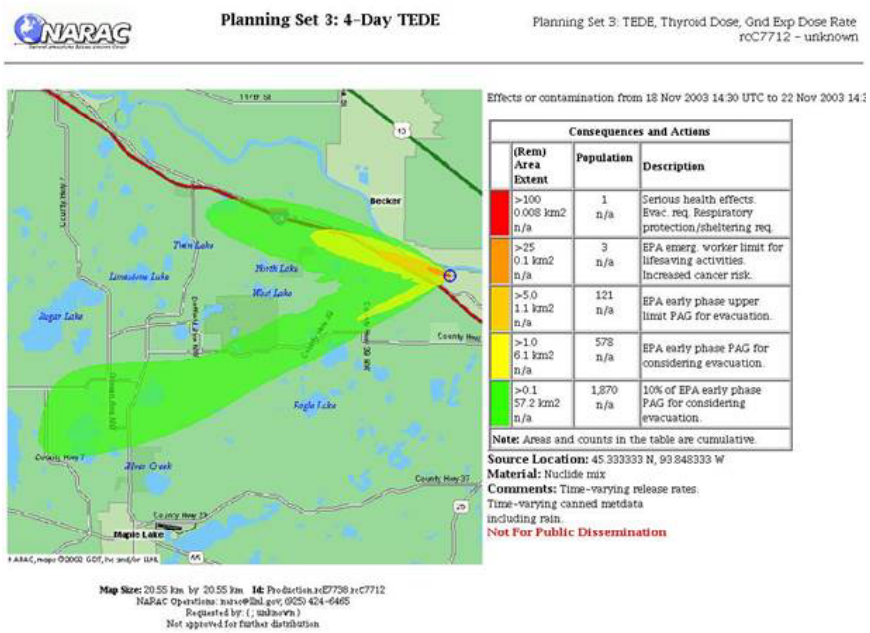
Interagency Modeling

- NRC coordinates with other Federal agencies during response
- Other assessment codes are used to confirm analysis and modeling results



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RASCAL Program Management

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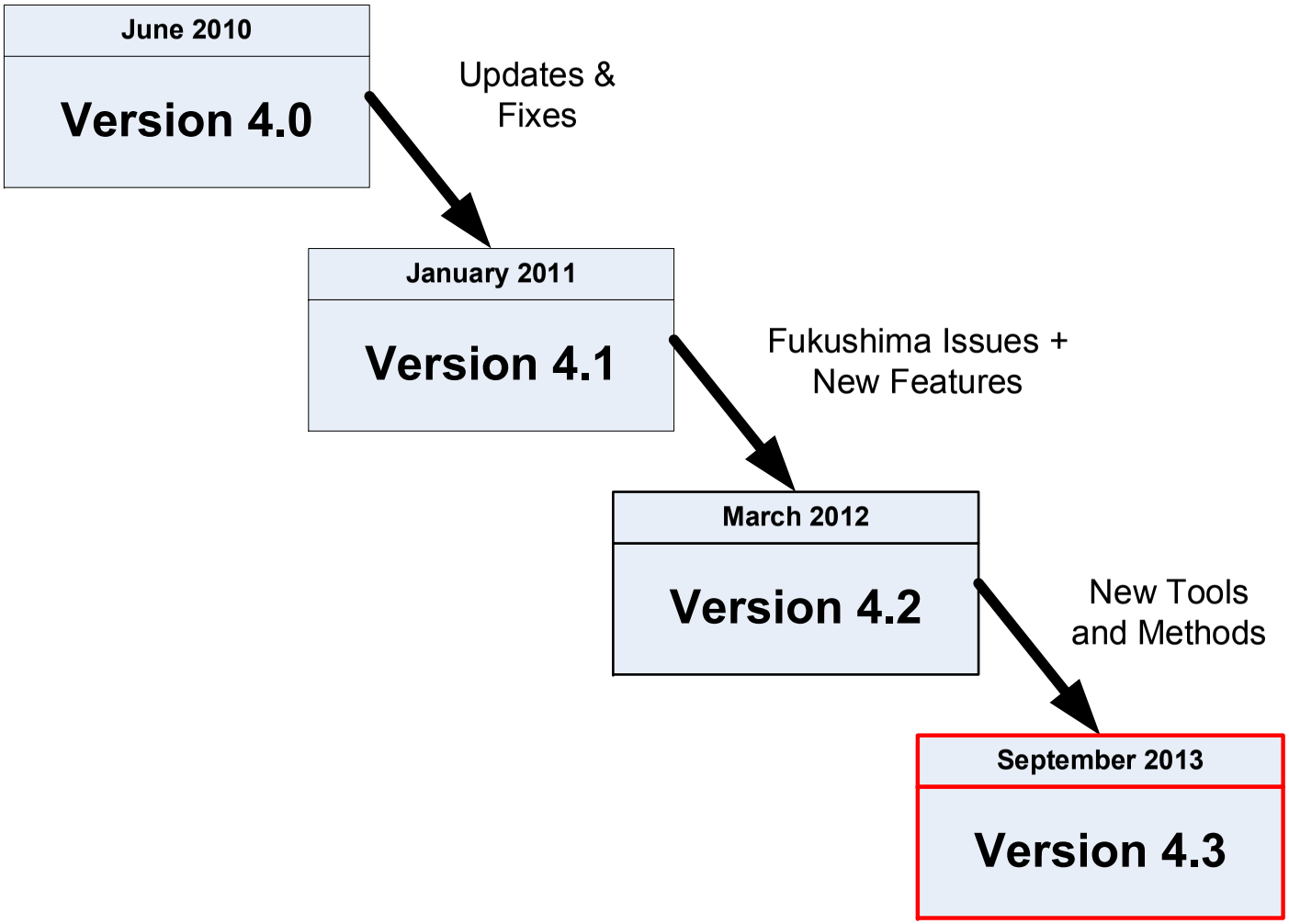
RASCAL Versions



Contributors

- Nuclear Regulatory Commission
  - John Tomon (PM)
  - Tony Huffert
  - Jeff Kowalczik
- Athey Consulting
  - George Athey
- Battelle – Pacific Northwest National Lab
  - Jeremy Rishel
- Ramsdell Environmental Consulting
  - Van Ramsdell

How to Get RASCAL 4.3

- http://www.nrc.gov/about-nrc/regulatory/research/safetycodes/rascal.html
- Distribution
  - Only available from RSICC at ORNL
- Registration
  - All users required to register at RSICC
- Support
  - E-mail to RASCAL_Help@nrc.gov

RASCAL documents

RASCAL 4 Workbook

Updated on a regular basis to capture new exercises and improvements

RASCAL 4: Description of Models and Methods

NUREG-1940

Draft documentation for RASCAL v4.3 can be downloaded from the NRC: Workbook, Technical Supplement, and User Guide

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RASCAL Activities

- **EPRI -** Benchmarking of Emergency Response Dose Projection Software Tools **(***A Fukushima Radiological Assessment Tool Project)*
- ***NEA -*** *WGAMA/WPNEM Task on the International benchmarking project on fast-running software tools used to model fission product releases during accidents at nuclear power plants*
- International Radiological Information Exchange (IRIX) Format – developed by IAEA and being reviewed by U.S. agencies
- Meetings between NRC, DOE, and EPA on dose conversion factors
- **NRC -** Radiation Protection Code Analysis and Maintenance Program (RAMP)

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RAMP

- Computer Code Management Program User Group that will support development and maintenance of radiation/dose assessment codes
  - Streamline updates
  - Incorporate state of the art models
  - Prioritize technical updates
  - Achieve consistency in documentation
  - Implement a software QA program
  - Share costs
  - Implement centralized and consistent management and control structure

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RAMP Codes

RASCAL

VARSKIN

RADTRAD

PIMAL

Rad Toolbox

HABIT

Updates in RASCAL 4.3

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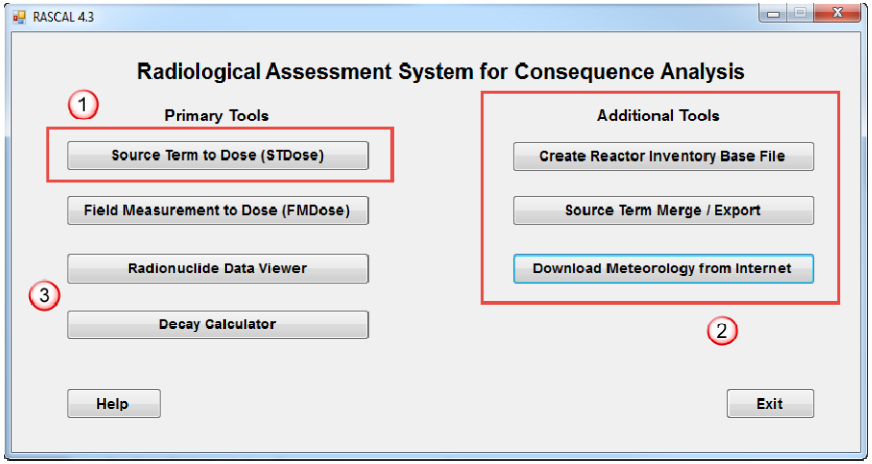
4.3 Overview

- Variety of changes within the Source Term to Dose model
- Three new supporting tools
- No major changes to the other tools: Field Measurement to Dose, Nuclide Data Viewer, and Decay Calculator



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4.3 Source Term Changes

- Long-term Station Blackout (LTSBO)
  - new method
- LOCA
  - updated (previously Time Core Uncovered)
- Coolant Release
  - updated (previously Specified Core Damage Endpoint)
- Pressure / Hole size leak rate model
  - revised method
- Spent fuel drained pool
  - revised method

Source Term

Long-term Station Blackout

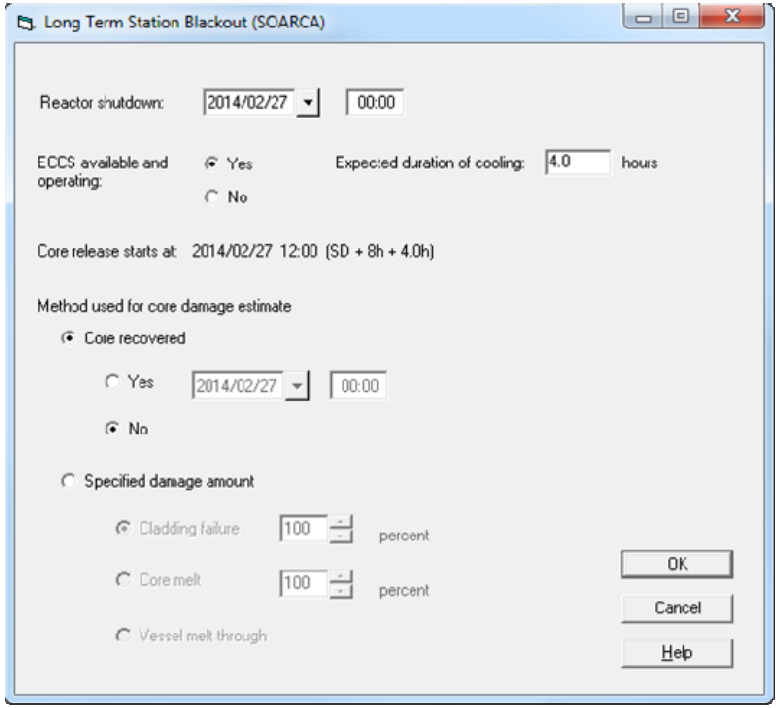
- Based on the LTSBO accident progression as described in the report “Implementation of New Source Term Information for RASCAL,” (Jun et al. 2009) and NUREG-1935, *State-of-the-Art Reactor Consequence Analyses* (SOARCA) Report, (Chang et al. 2012).
- See Section 1.1 of the RASCAL 4.3 Technical Supplement

Source Term

Long-term Station Blackout

- The LTSBO uses the status of core cooling systems, the expected battery life, and the time that it takes for the coolant to boil off to estimate when the core will become uncovered and when the release to the environment will start.

- Adds the option to specify the final damage amount. Code calculates when to recover the core.



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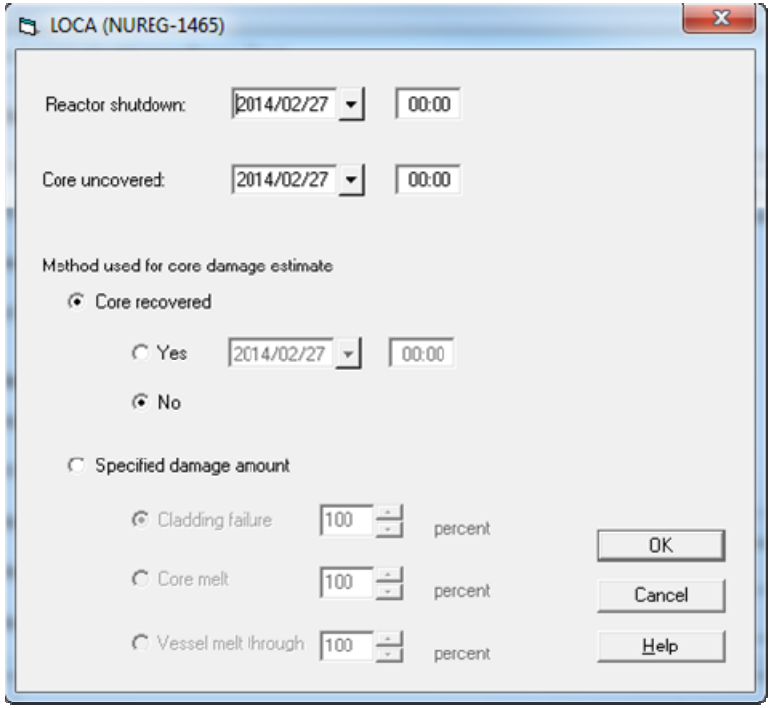
Source Term

LOCA

- The LOCA source term option is the old Time Core is Uncovered option
- Basic method is unchanged from RASCAL 4.2 – same timings and release fractions
- Adds the option to specify the final damage amount. Code calculates when to recover the core



Source Term

LOCA vs LTSBO

- Time delay between the initiating event and the start of the release to the atmosphere
  - LOCA – immediate release
  - LTSBO – release delayed until cooling lost and water boils off
- Differences in release fractions and release timings

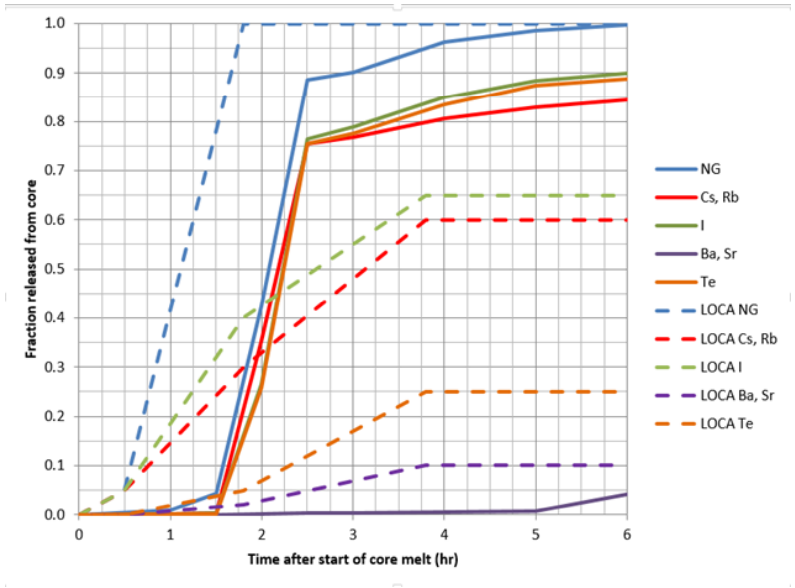
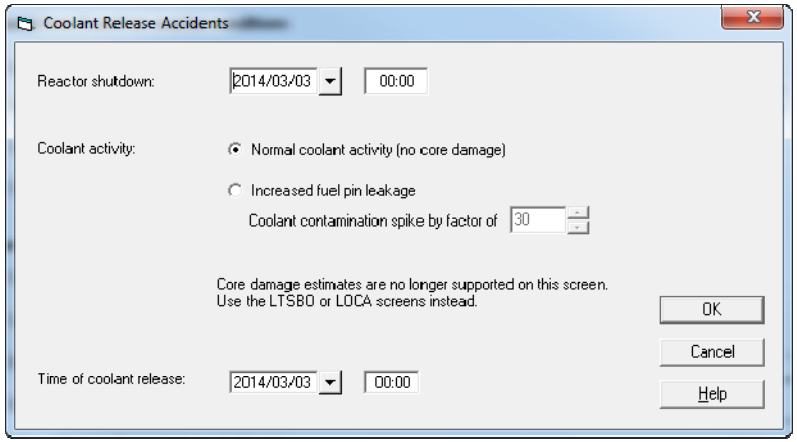


Fig 1-3 of Tech Supp

Source Term

Coolant Release Accident

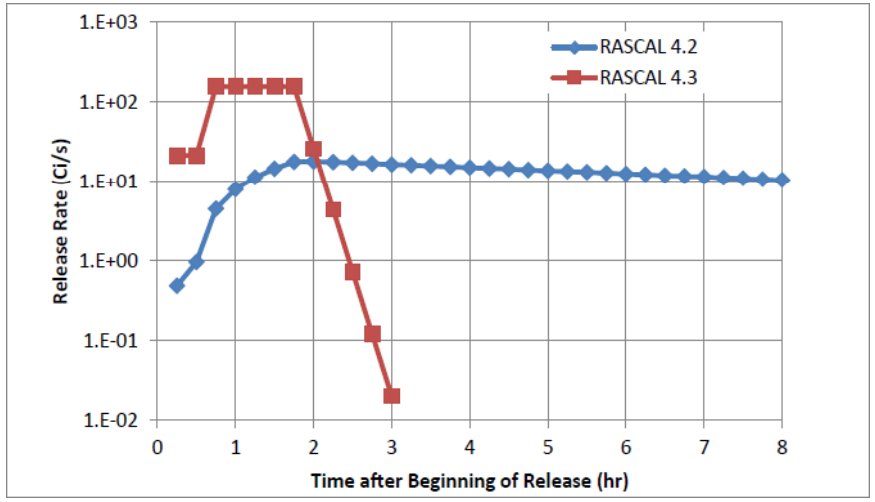
- Previously called Specified Core Damage Endpoint
- Can no longer do cladding failure here. The option to specify the damage endpoint has moved to the LOCA and LTSBO methods
- Option is for normal and spiked coolant only



Source Term

Coolant Release Accident

- Noble gas differences
  - RASCAL 4.2 treated all nuclides in coolant the same and did no decay or ingrowth within the RCS
  - RASCAL 4.3 gets the noble gases out earlier and does include decay and daughter ingrowth in the RCS



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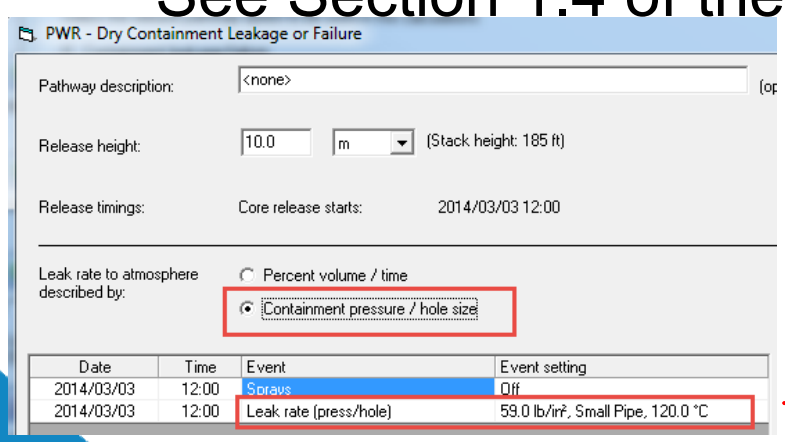
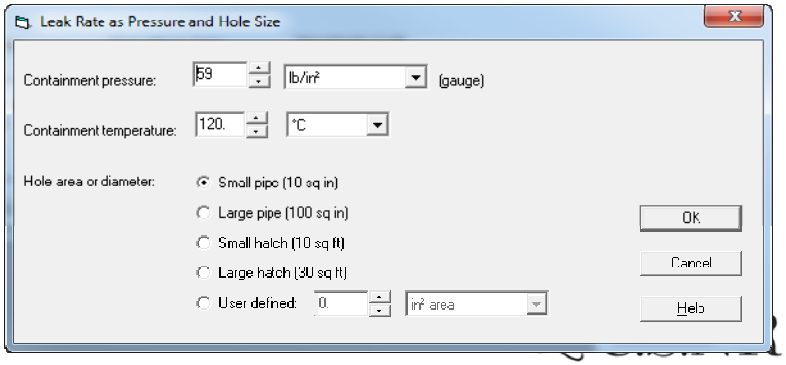
Source Term

Pressure / Hole Size Model

- 4.2 did not model a change in pressure as gases left the containment; required user to enter the pressure decrease
- 4.3 adjusts the pressure automatically
- Now requires containment air temperature and adds some predefined hole sizes
- See Section 1.4 of the Technical Supplement

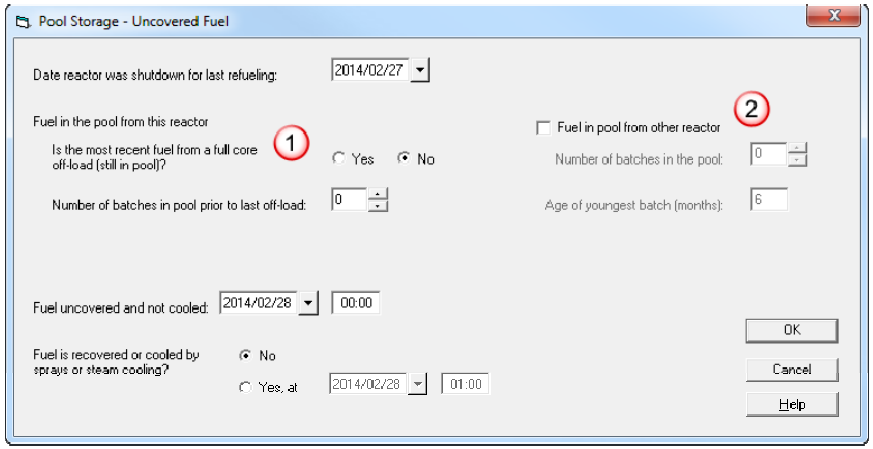




Source Term

Spent Fuel Pool

- Drained pool option has been revised
  - Can now handle full core off-load to the spent fuel pool
  - Can include fuel from another reactor; e.g. shared pool.
- See Section 1.5.1 of the RASCAL 4.3 Technical Supplement



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Radionuclide Activity Balance

- Tracks activity for selected nuclides and nuclide groups from the reactor core and coolant systems through various pathways to the environment.
- Available only for source terms based on reactor conditions
- By time steps for 5 locations and 9 paths
- Final balance shown in source term summary
- Can view and print details
- Discussed in Section 5 of the Technical Supplement

Radionuclide Activity Balance

- Available in 2 locations (summary and detailed)

Source Term

Summary of activity released to atmosphere

	Ci	% of total
Noble gas	1.5E+06	98.5
Iodines	1.3E+04	0.9
Other	1.1E+04	0.7
Total	1.5E+06	100.0

Noble gas / I-131 ratio = 445:1

Approximate activity balance at end of simulation

Core	3.2E+09 Ci
Containment	1.7E+08 Ci
RCS	0.0E+00 Ci
Environment	1.6E+06 Ci

List of all radionuclides released with total activity

Nuclide	Ci	Nuclide	Ci	Nuclide	Ci
Am-241	4.0E-06	La-140	4.9E+01	Sr-92	1.7E+00
Ba-139	5.3E-02	Mo-99	9.0E+02	Tc-99	
Ba-140	5.1E+02	Np-239	3.3E+02	Te-12	
Ce-141	3.5E+01	Pr-143	2.4E-01	Te-12	
Ce-143	1.8E+01	Pr-144	2.7E+01	Te-12	
Ce-144*	2.9E+01	Pu-238	1.8E-05	Te-12	

Display units
English
Metric

View Balance | View Importance

Reactor Activity Balance

Volume activities and activity transfers (all in curies) by model time step for the nuclide(s) selected at left.

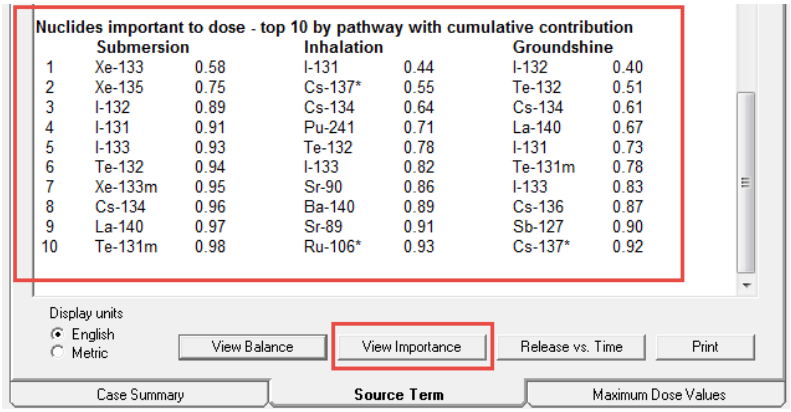
Total
NG
Total I
Kr-85
Xe-135
I-131
I-133
I-135
Cs-134
Cs-137*
Sr-89
Zr-95
La-140

Time (h)	Rx Core	Rx-Cont	Cont	Cont-Env	Env
SD	6.95E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rel Start	5.36E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.25	5.33E+09	4.81E+06	4.26E+06	1.54E+02	1.54E+02
0.50	5.31E+09	4.79E+06	8.08E+06	3.03E+02	4.58E+02
0.75	5.27E+09	2.35E+07	2.87E+07	1.15E+03	1.61E+03
1.00	5.14E+09	1.07E+08	1.23E+08	4.82E+03	6.42E+03
1.25	5.02E+09	1.07E+08	2.09E+08	8.40E+03	1.48E+04
1.50	4.81E+09	1.94E+08	3.48E+08	1.09E+04	2.57E+04
1.75	4.60E+09	1.94E+08	4.61E+08	1.34E+04	3.91E+04

Nuclide Importance

- Evaluates relative nuclide importance for 5 dose pathways and 8 times
- Ranks importance by radionuclide
- 3 outputs
  - Relative importance of TEDE at end of release
  - Relative importance of pathways to TEDE
  - Cumulative importance to dose by radionuclide
- Discussed in Section 6 of the Technical Supplement

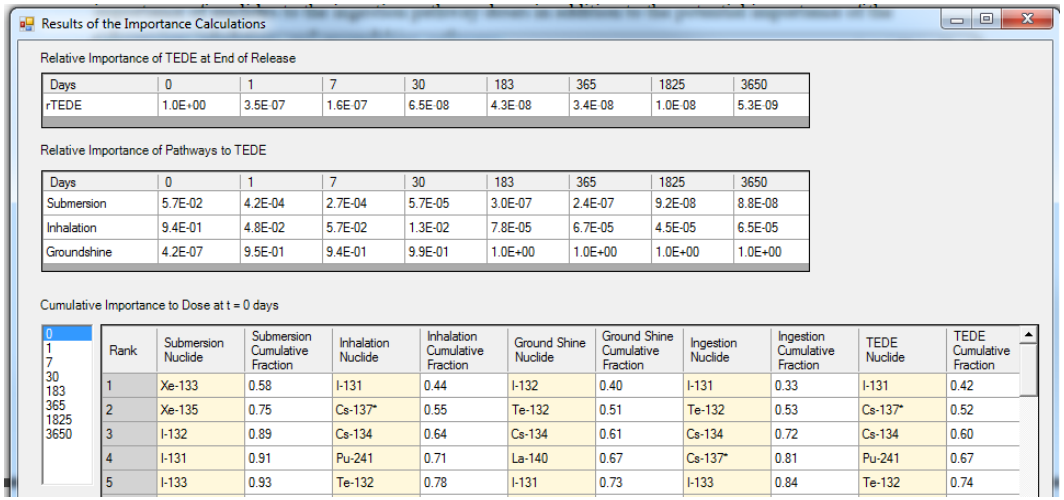
Nuclide Importance - Locations



Nuclides important to dose - top 10 by pathway with cumulative contribution

	Submersion		Inhalation		Groundshine	
1	Xe-133	0.58	I-131	0.44	I-132	0.40
2	Xe-135	0.75	Cs-137*	0.55	Te-132	0.51
3	I-132	0.89	Cs-134	0.64	Cs-134	0.61
4	I-131	0.91	Pu-241	0.71	La-140	0.67
5	I-133	0.93	Te-132	0.78	I-131	0.73
6	Te-132	0.94	I-133	0.82	Te-131m	0.78
7	Xe-133m	0.95	Sr-90	0.86	I-133	0.83
8	Cs-134	0.96	Ba-140	0.89	Cs-136	0.87
9	La-140	0.97	Sr-89	0.91	Sb-127	0.90
10	Te-131m	0.98	Ru-106*	0.93	Cs-137*	0.92

1. Bottom of Source Term Summary (Top 10)



Results of the Importance Calculations

Relative Importance of TEDE at End of Release

Days	0	1	7	30	183	365	1825	3650
rTEDE	1.0E+00	3.5E-07	1.6E-07	6.5E-08	4.3E-08	3.4E-08	1.0E-08	5.3E-09

Relative Importance of Pathways to TEDE

Days	0	1	7	30	183	365	1825	3650
Submersion	5.7E-02	4.2E-04	2.7E-04	5.7E-05	3.0E-07	2.4E-07	9.2E-08	8.8E-08
Inhalation	9.4E-01	4.8E-02	5.7E-02	1.3E-02	7.8E-05	6.7E-05	4.5E-05	6.5E-05
Groundshine	4.2E-07	9.5E-01	9.4E-01	9.9E-01	1.0E+00	1.0E+00	1.0E+00	1.0E+00

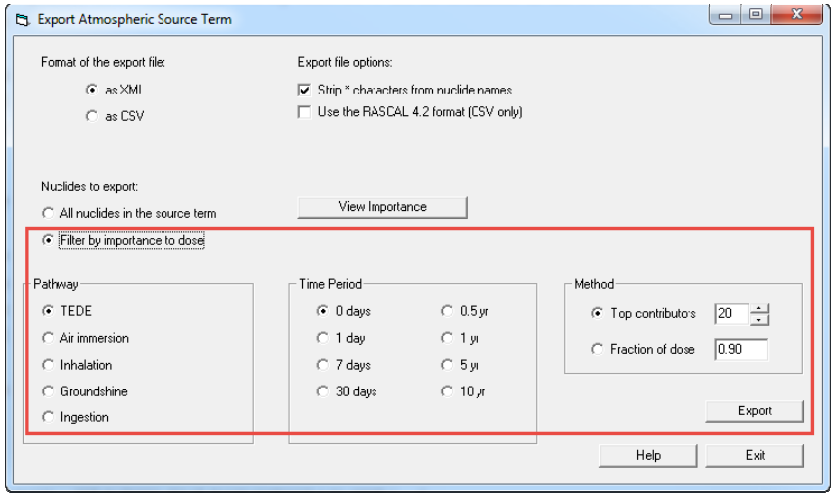
Cumulative Importance to Dose at t = 0 days

0
1
7
30
183
365
1825
3650

Rank	Submersion Nuclide	Submersion Cumulative Fraction	Inhalation Nuclide	Inhalation Cumulative Fraction	Ground Shine Nuclide	Ground Shine Cumulative Fraction	Ingestion Nuclide	Ingestion Cumulative Fraction	TEDE Nuclide	TEDE Cumulative Fraction
1	Xe-133	0.58	I-131	0.44	I-132	0.40	I-131	0.33	I-131	0.42
2	Xe-135	0.75	Cs-137*	0.55	Te-132	0.51	Te-132	0.53	Cs-137*	0.52
3	I-132	0.89	Cs-134	0.64	Cs-134	0.61	Cs-134	0.72	Cs-134	0.60
4	I-131	0.91	Pu-241	0.71	La-140	0.67	Cs-137*	0.81	Pu-241	0.67
5	I-133	0.93	Te-132	0.78	I-131	0.73	I-133	0.84	Te-132	0.74

2. In the Importance Viewer (Details)

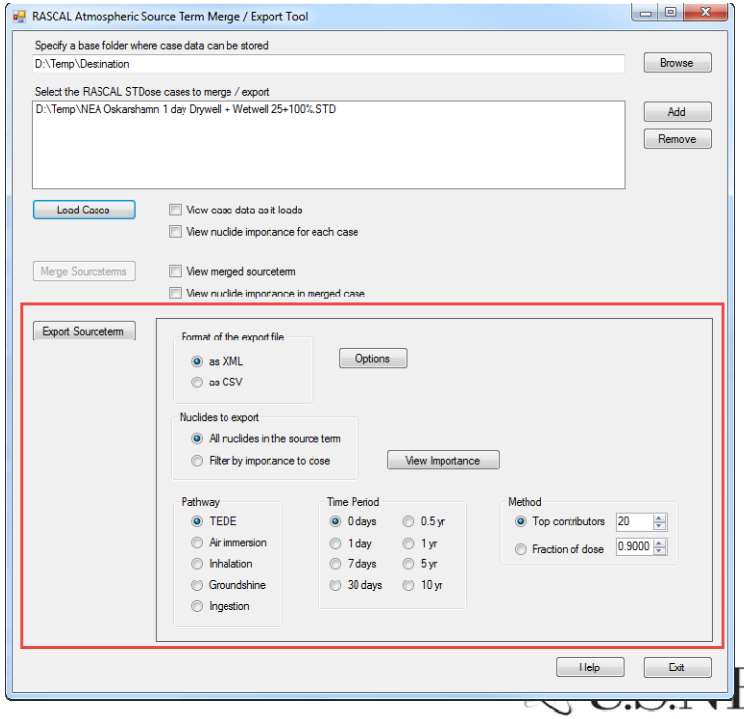
Nuclide Importance - Filters



1. In the source term export

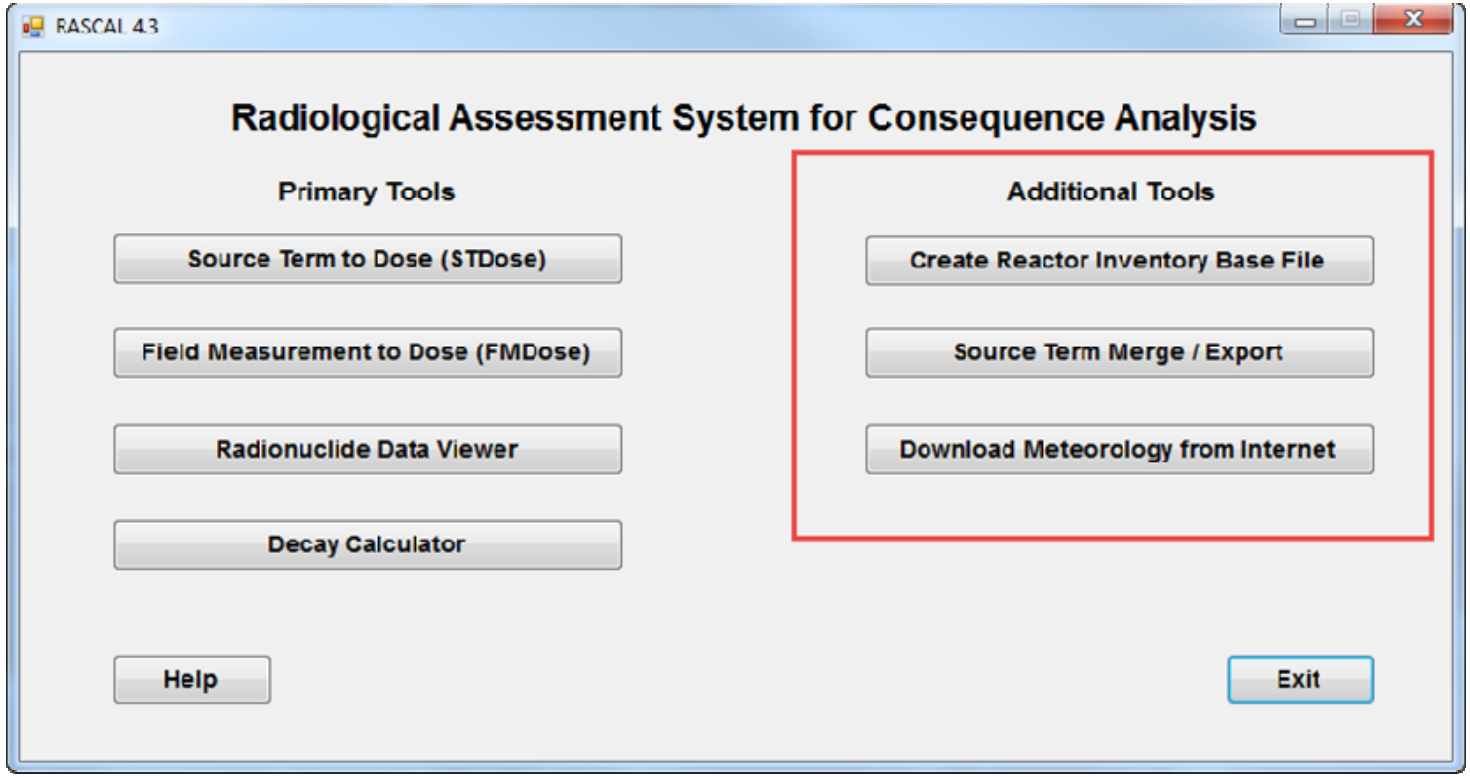
Default setting for NARAC export – TEDE, 0 days, Top 20

2. In the source term merge tool



Additional Tools in 4.3

(STDose support)



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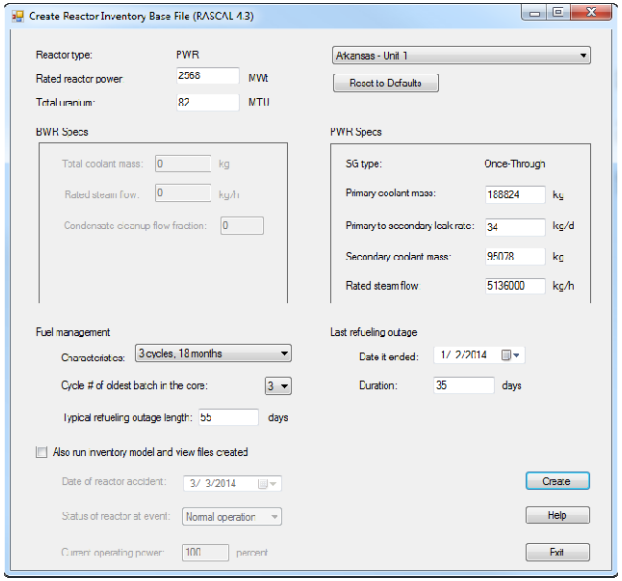
Inventory Tool

- Creates a custom reactor core and coolant inventory
- The default core inventory is based on a single SCALE/ORIGIN run and scaled based on reactor power
- This inventory is also adjusted for burnup by scaling
- Estimates reactor core and coolant nuclide inventories at the time of an accident using reactor specific information on reactor operations prior to the accident
- See Section 4 of the RASCAL 4.3 Technical Supplement

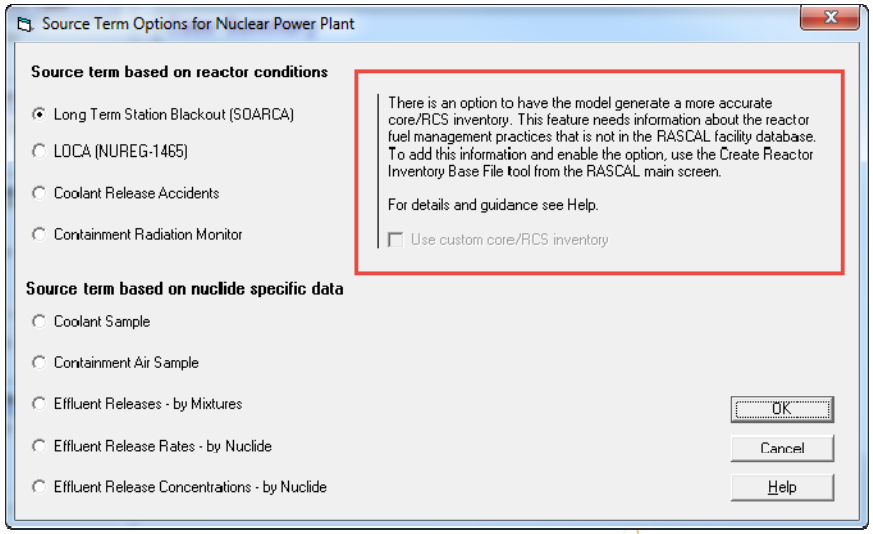
Inventory Tool

- The custom inventory needs to be created only once and can then be optionally used for NPP calculations.



Creates an inventory file specific to the reactor unit.

When an inventory file is available, the option to use it becomes active.



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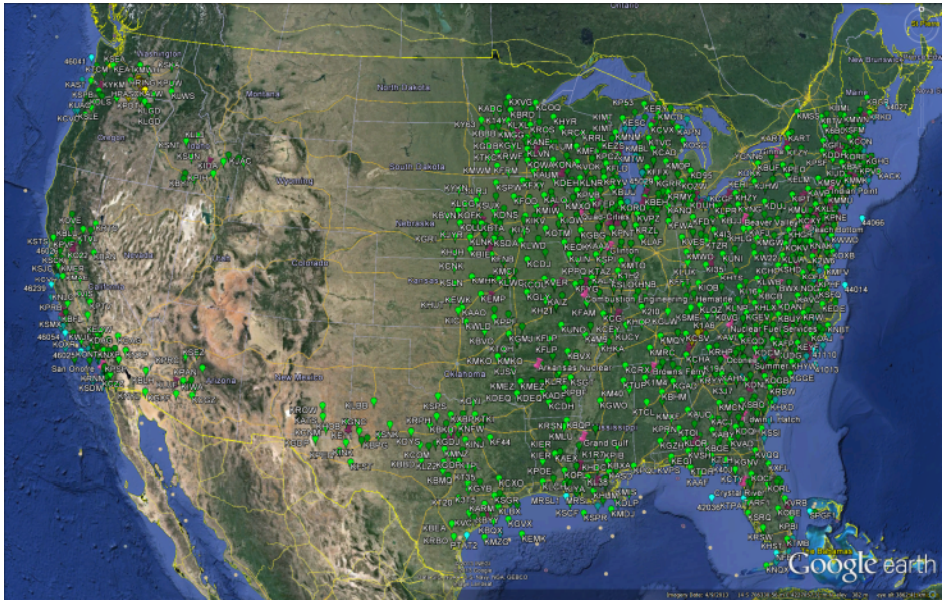
Meteorology Download

- 4.3 includes a tool to download observed and forecast weather data from the internet
- Also includes updated list of sites with supporting weather data



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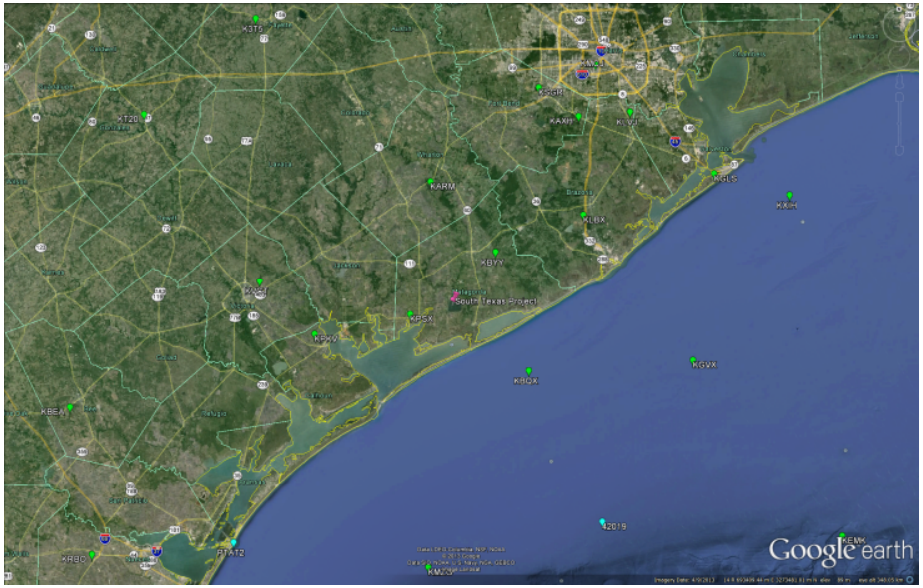
Meteorology Download

- Each site in the facility database now has an expanded list of RASCAL preferred weather stations
- For example, South Texas now includes buoys in the Gulf of Mexico



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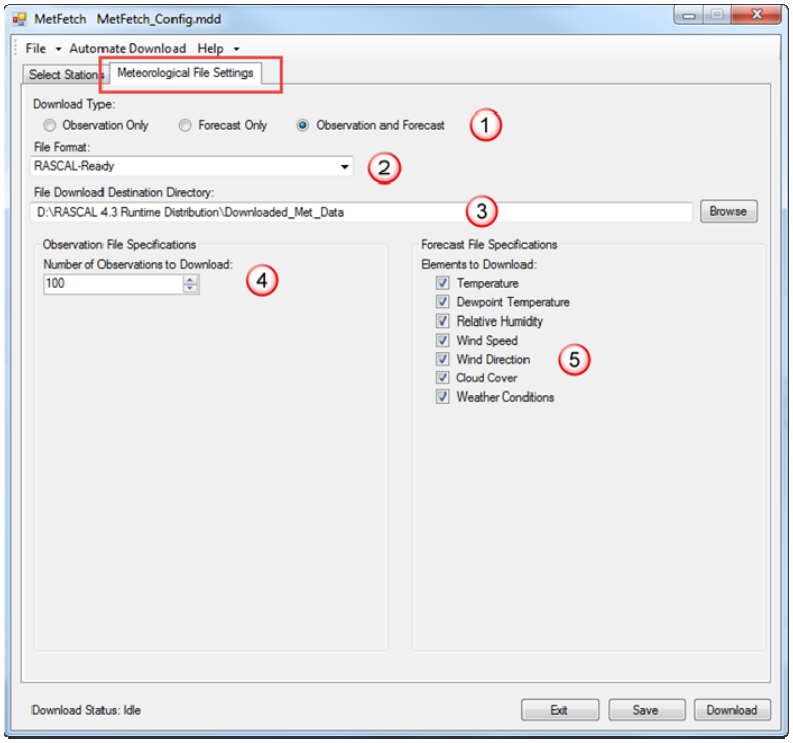
Meteorology Download

- Setup the MetFetch download program by selecting a location and the surrounding weather stations to be used
- Download the observed and forecast data
- In the STDose met processor, retrieve the downloaded data station by station to fill the grids
- Process the data
- Repeat the download as needed; usually once an hour (just after the hour) for observations
- Repeat the creation of the dataset
- See Section 3 of the Technical Supplement and Chapter 6 of the User's Guide

Meteorology Instructions

Configure the MetFetch File Settings

- Want both observations and forecasts
- Format must be RASCAL-Ready to use with models
- Destination must be as shown
- Number controls how far back in time to grab observations
- Want all data elements



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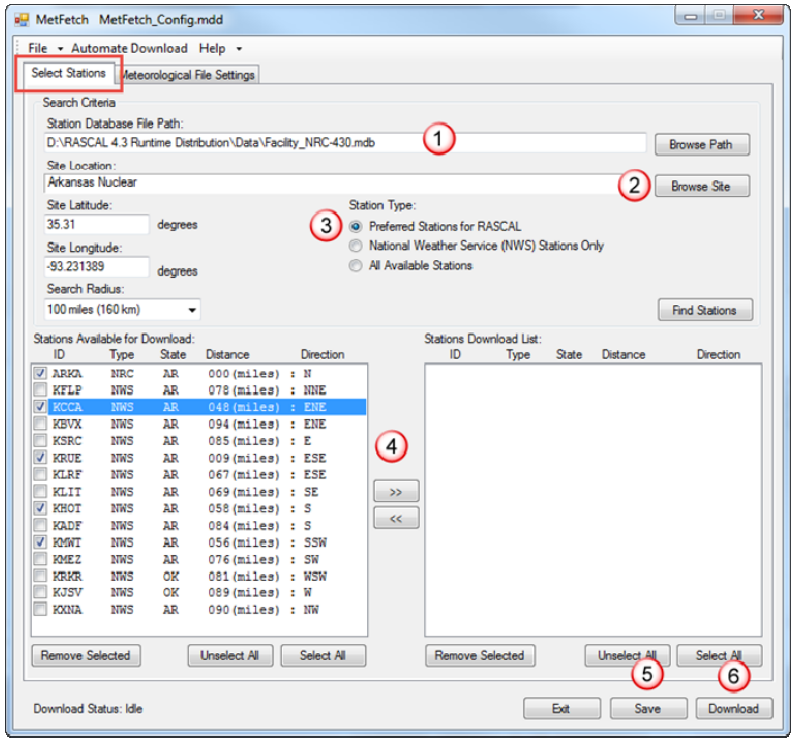
Meteorology Instructions

Configure MetFetch station selection



- Database path should be preset
- Browse to select site or enter latitude and longitude
- Use RASCAL preferred stations; they are already in for defined sites
- Find stations then move ones to be used into right pane
- Save the settings
- Download the data

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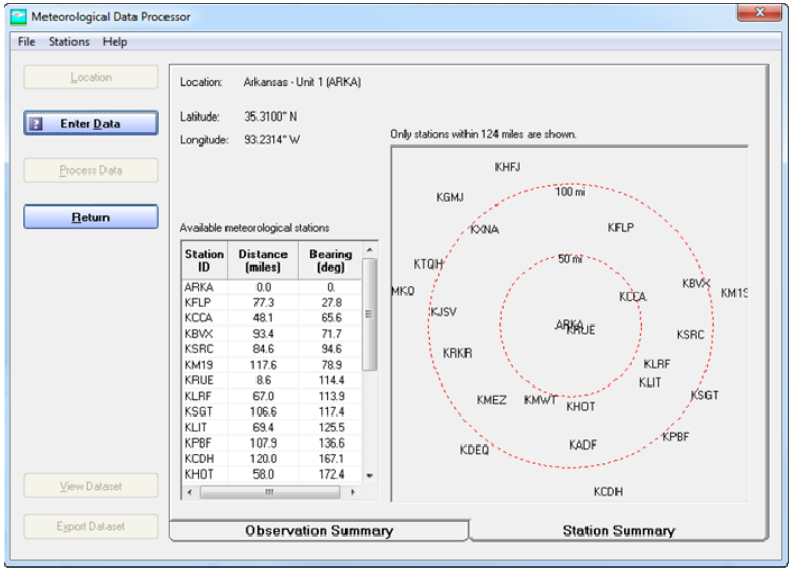
Meteorology Instructions

Use STDose Met data Processor

- The stations shown match those in MetFetch using the “Preferred Stations” option.



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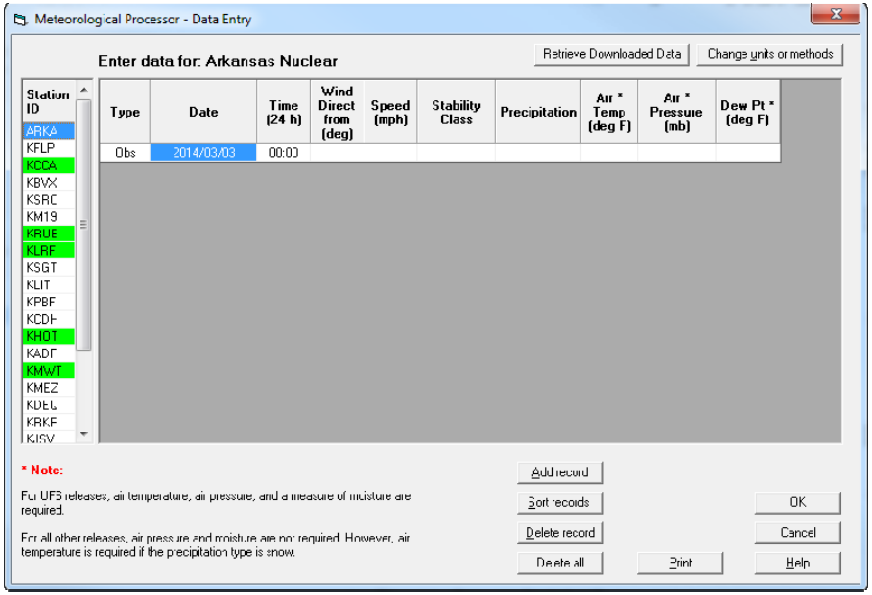
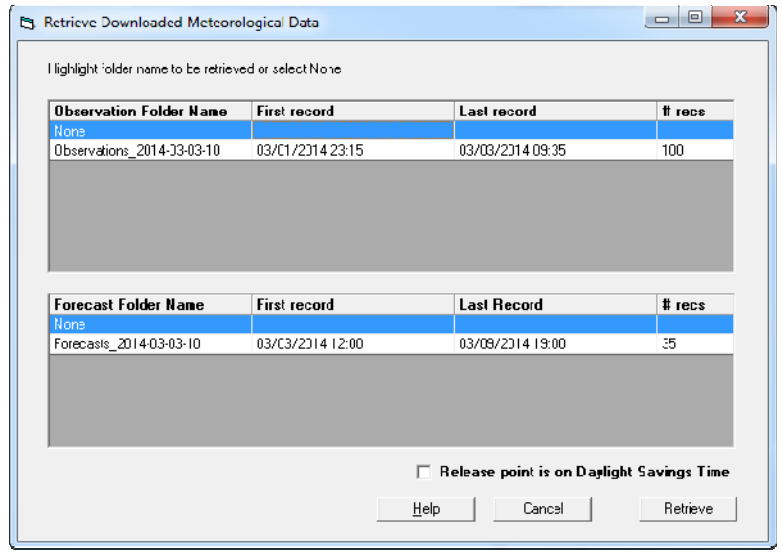
Meteorology Instructions

Available Stations Shown in Green

- The Retrieve Downloaded Data button shows what data can be retrieved.





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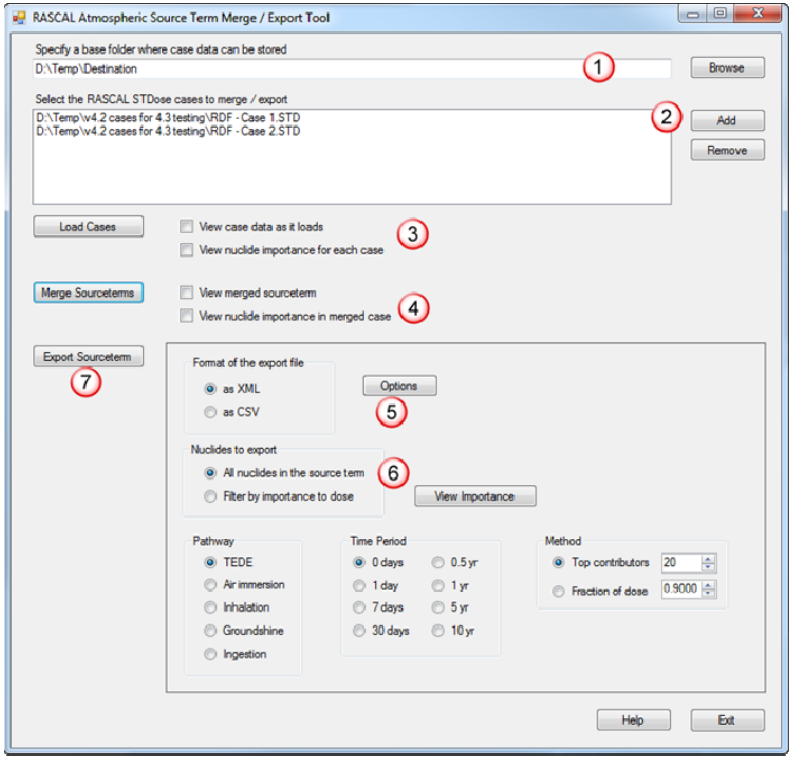
Merge Atmospheric Source Terms Into Single Release

- Tool works with saved STDose cases
- Extracts the atmospheric source term information and merges it together
- Can then export as CSV or XML for use by NARAC or RASCAL
- Importance filtering is available to reduce the size of the radionuclide list
- Provides “a” way to model multi-unit events
- An alternate method is to merge the plumes from separate runs in a GIS

Source Term Merge / Export Tool

- Any temporary folder will work
- Add the STDose cases
- Load the cases; can optionally view data and importance as they load
- If more than 1 case loaded, can merge
- Can export as CSV or XML
- Can optionally filter by importance
- Export the file – can select location



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Other changes in RASCAL 4.3

- Function to allow importing of source terms
- Updated topography and surface roughness data
- Automatic naming of STDose cases
- Calculation of child thyroid dose

Other Changes

Import An Atmospheric Source Term

- Provides a way to:
  - Export a source term, make modification (e.g. apply reductions not modeled in RASCAL), and then import to run calculations
  - Bring in externally created source terms, e.g. manually created in Excel or from other model such as MELCOR
  - Bring in a merged source term

Other Changes

Import An Atmospheric Source Term

- Check the “Import” box under the Source Term button then click the button.
- Browse to select the file to be imported. The file must be in CSV or XML format and meet all the specifications; e.g. 15 minute time step, nuclide names, activity in Ci.
- Click the Import button. Result of the import operation will be displayed.
- The import process completes both the source term and release path steps of problem definition.

Other Changes

Updated Topography & Surface Roughness Data

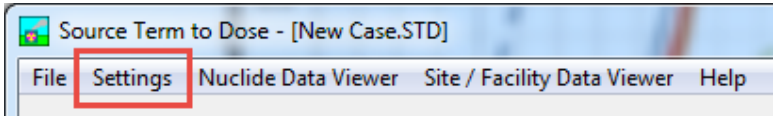
- Topographic data from GTOPO30
- Digital elevation model (DEM) with 30-arc second resolution
- Values not much different but is a referenced source

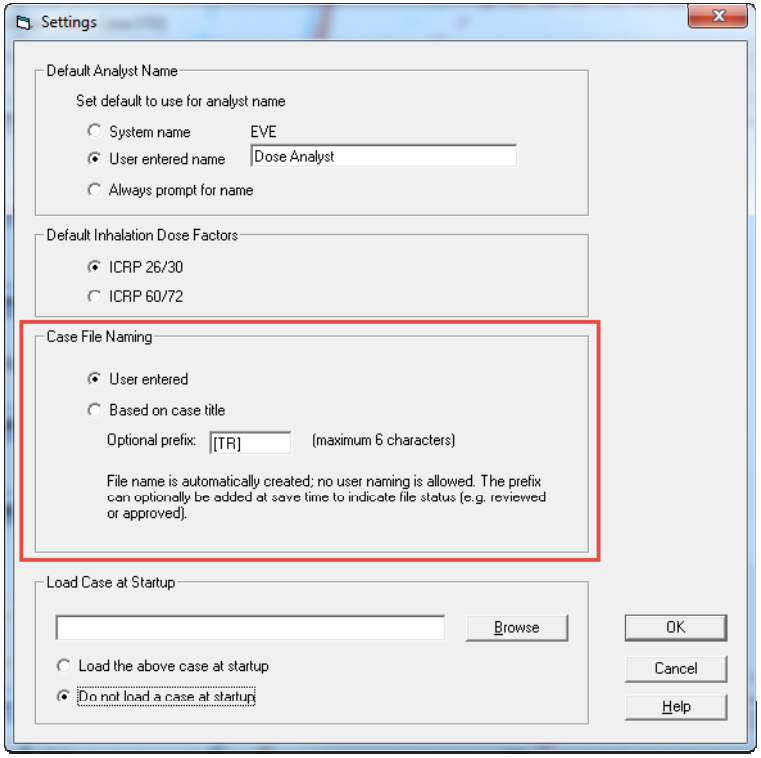
- Surface roughness data from NLCD1992
- National Land Cover Dataset 1992
- Use EPA AERSURFACE method to convert land cover to surface roughness
- Greatly improved; previous models had only 2 classes (land and water)

Other Changes

Automatic Naming of STDose Cases

- The method for naming of STDose case files is set in the Settings screen available from the main menu.





User entered is the old method

Prefix is intended to help designate file status; e.g. TR can represent "technically reviewed"

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Other Changes

Calculation of child thyroid dose

- Child thyroid dose is now calculated when the option to use ICRP 60/72 inhalation dose factors is selected.
- Added to allow the evaluation of recommendations for administration of KI to children
- Based on the dose conversion factors and breathing rate for a 1-year old child
- Calculation is included in both STDose and FMDose
- Based only on exposure to iodine isotopes for consistency with EPA PAG definition
- See Section 2.2 of the Technical Supplement

Review & Questions

- Program Management
- 4.3 Capabilities
- 4.3 Instructions
- Example Problem

Contact Information

Jeff Kowalczik

Emergency Response Coordinator

(301) 287-3755

jeff.kowalczik@nrc.gov

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