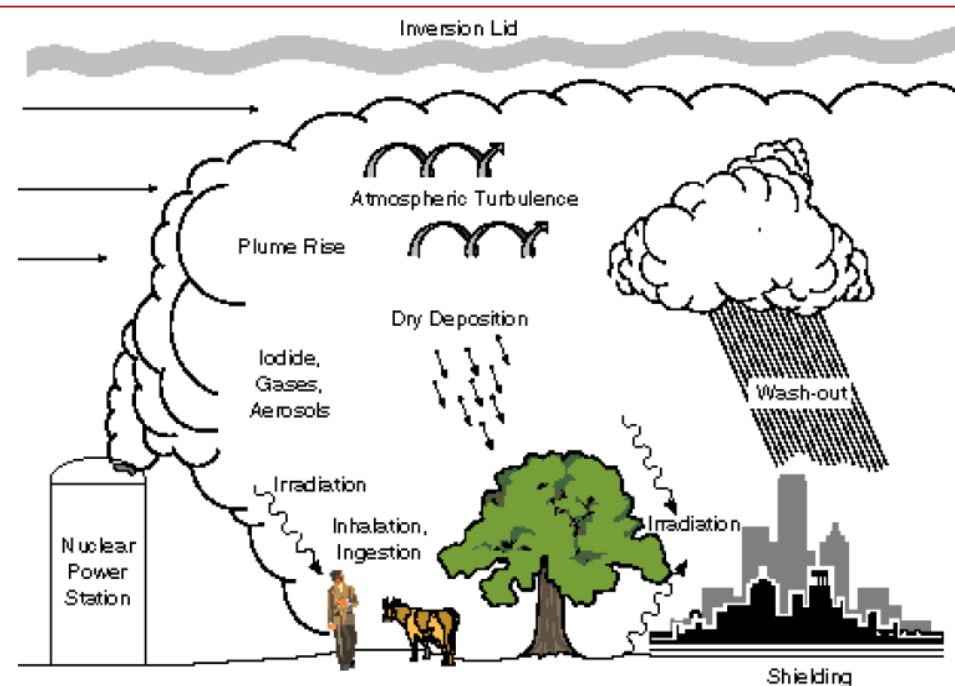


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# MACCS Overview

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Salmon Haq, US Nuclear Regulatory Commission

Presented at the 9<sup>th</sup> International MACCS Users Group Meeting, Sept. 14 - 15, 2017



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# Outline

- MELCOR Accident Consequence Code System (MACCS) overview and historical background
- Improvements in the most recent versions
- New models being developed
- Improvements in preprocessor codes
- Summary

# MACCS Models and Capabilities

- Models treat
  - Atmospheric transport and deposition onto the ground
  - Statistical effect of variability in weather
  - Dose pathways for cloudshine, groundshine, inhalation, ingestion, and deposition onto skin
  - Protective actions during emergency, intermediate, and long-term phases
- Calculates offsite consequences
  - Doses
  - Health effects
  - Economic costs
  - Land contamination





# History of NRC Consequence Code Development

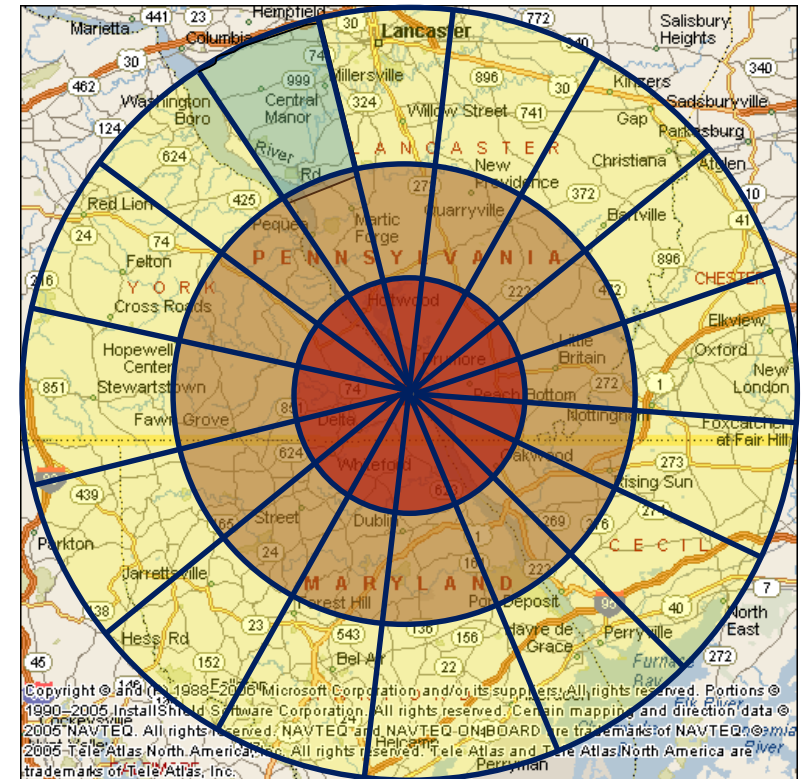
- MACCS is the NRC tool used to evaluate the offsite consequences of hypothetical radioactive releases into the atmosphere
- Evolved from codes going back to the 1970s
  - Calculation of Reactor Accident Consequences (CRAC)
    - Reactor Safety Study (WASH-1400)
  - CRAC2
    - 1982 Siting Study
  - MACCS2 v1.13.1
    - NUREG-1150
  - MACCS v2.4 – 3.10
    - Security Studies
    - State-of-the-Art Reactor Consequence Analyses (SOARCA) (NUREG-1935, /CR-7110)
    - Peach Bottom, Surry, and Sequoyah Uncertainty Analyses (drafts)
    - Spent Fuel Pool Consequence Study
    - BWR Mark I and II Containment Venting Study
    - Level-3 PRA

# Improvements In MACCS 3.9 (9/14)

- Flexible capability to define the location of cohorts
- Keyhole evacuation model
- Tracking population movement
- Resizable parameter input screens
- Choice of units
- Improvements in reporting options
- Change-card paradigm for cohorts eliminated
  - Auto-propagation of cohort values added to facilitate conversion
- Upper limits increased
  - Up to 150 chemical groups
  - Up to 500 plume segments

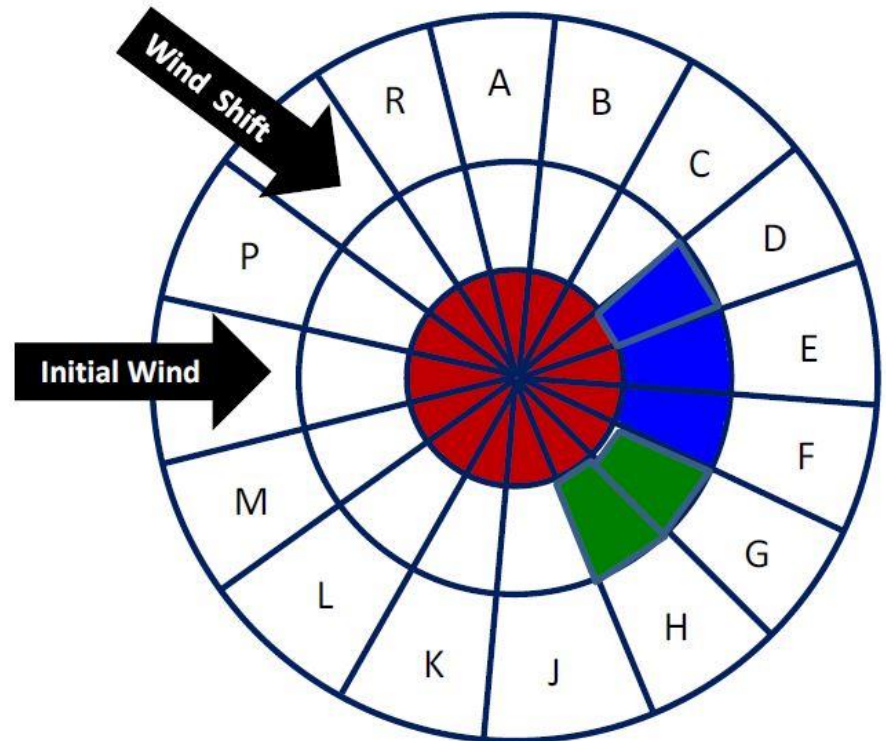
# Added Flexibility in Defining Cohorts

- The user can locate cohorts in regions anywhere within MACCS grid
  - Feature was supported previously, but not user friendly
  - Map layer can be used to facilitate cohort locations
- E.g., regions might represent
  - Emergency Planning Zone (EPZ) 
  - Shadow evacuation 
  - No evacuation 
  - Special facility 



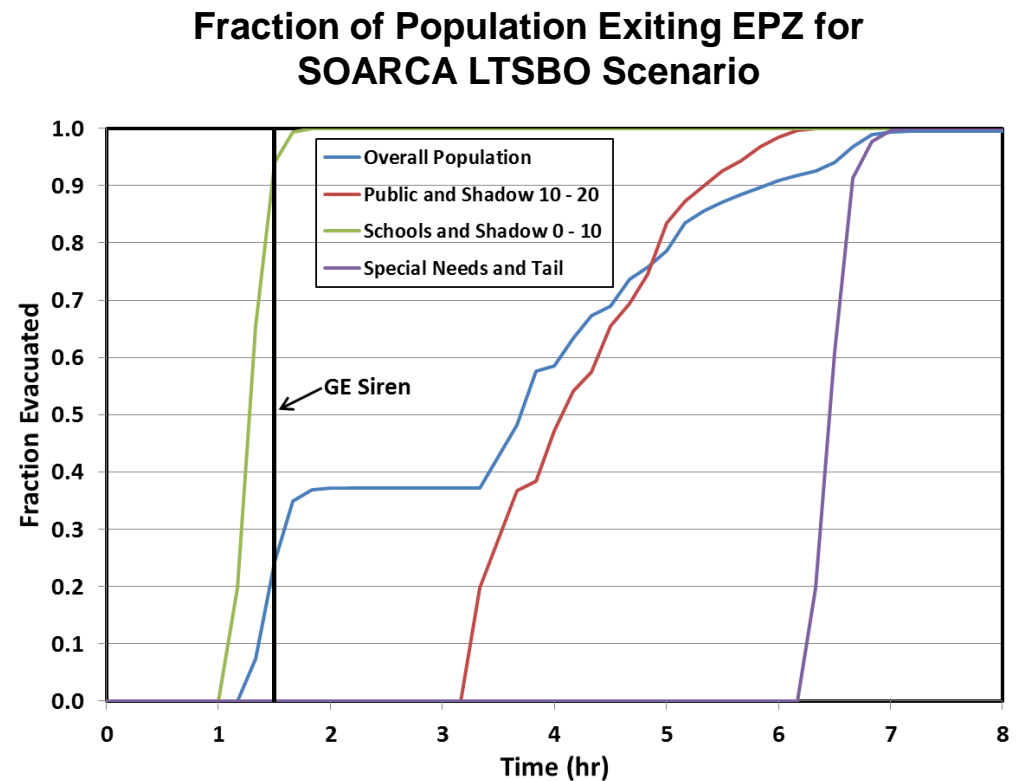
# Keyhole Evacuation Model

- Keyhole consists of
  - A central circular region
  - An pie-shaped outer region
- User defines initial dimensions of keyhole
- Shift in wind direction causes pie-shaped region to expand
- Model allows for foreknowledge of weather (forecasting)



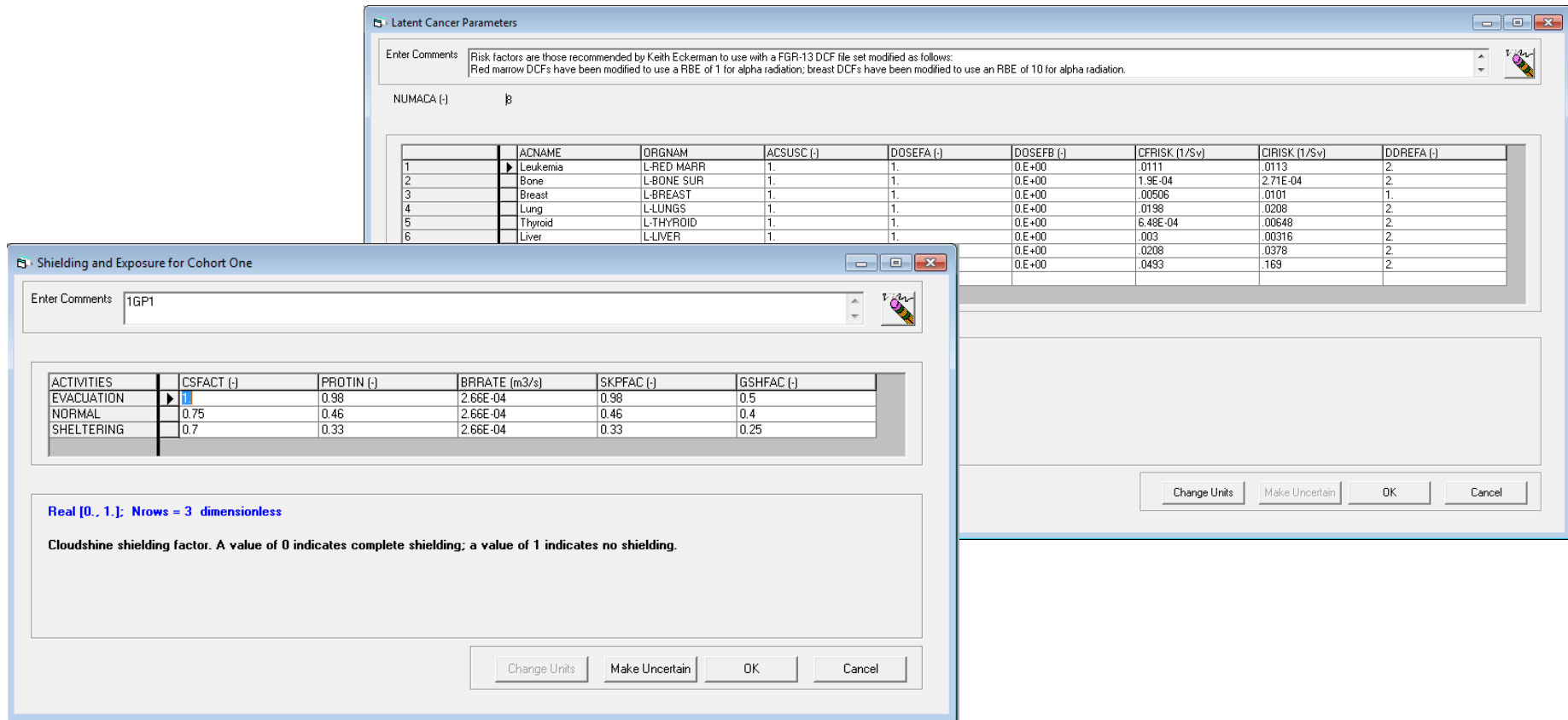
# Tracking Population Movement

- The timing of evacuating cohorts crossing boundaries can be evaluated to verify consistency with the Evacuation Time Estimate (ETE)
- Overall timing of the entire population can also be evaluated





# Resizable Parameter Input Screens



**Latent Cancer Parameters**

Enter Comments: Risk factors are those recommended by Keith Eckerman to use with a FGR-13 DCF file set modified as follows:  
Red marrow DCFs have been modified to use a RBE of 1 for alpha radiation; breast DCFs have been modified to use an RBE of 10 for alpha radiation.

NUMACA (-) 8

	ACNAME	ORGNAM	ACSUSC (-)	DOSEFA (-)	DOSEFB (-)	CFRISK (1/Sv)	CRISK (1/Sv)	DDREFA (-)
1	Leukemia	L-RED MARR	1.	1.	0.E+00	.0111	.0113	2.
2	Bone	L-BONE SUR	1.	1.	0.E+00	1.9E-04	2.71E-04	2.
3	Breast	L-BREAST	1.	1.	0.E+00	.00506	.0101	1.
4	Lung	L-LUNGS	1.	1.	0.E+00	.0198	.0208	2.
5	Thyroid	L-THYROID	1.	1.	0.E+00	6.48E-04	.00648	2.
6	Liver	L-LIVER	1.	1.	0.E+00	.003	.00316	2.
					0.E+00	.0208	.0378	2.
					0.E+00	.0493	.169	2.

**Shielding and Exposure for Cohort One**

Enter Comments: 1GP1

ACTIVITIES	CSFACT (-)	PROTIN (-)	BRRATE (m3/s)	SKPFAC (-)	GSHFAC (-)
EVACUATION	1.	0.98	2.66E-04	0.98	0.5
NORMAL	0.75	0.46	2.66E-04	0.46	0.4
SHELTERING	0.7	0.33	2.66E-04	0.33	0.25

Real [0., 1.]: Nrows = 3 dimensionless

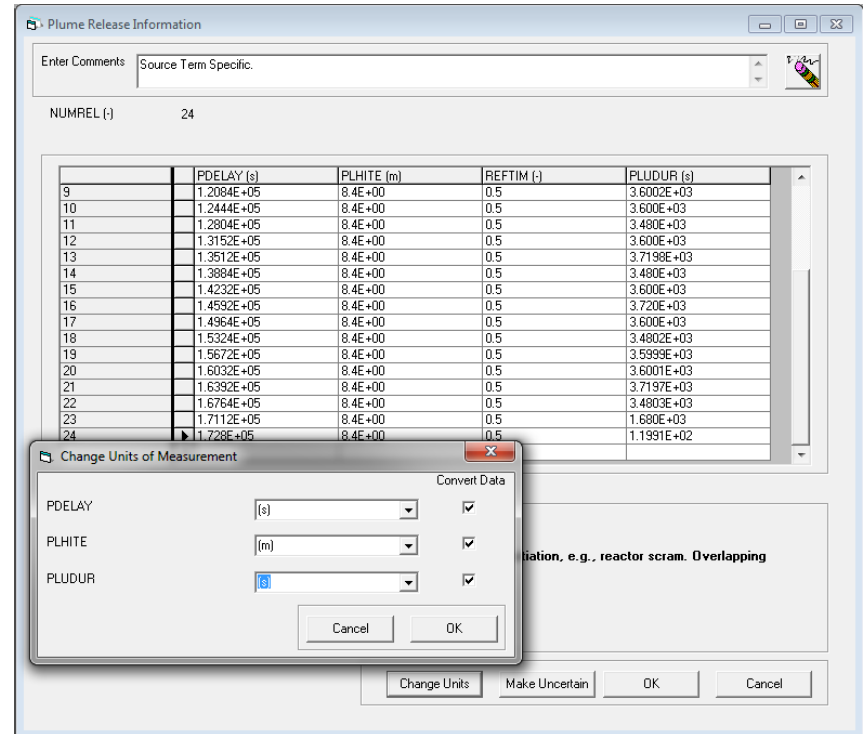
Cloudshine shielding factor. A value of 0 indicates complete shielding; a value of 1 indicates no shielding.

Buttons: Change Units, Make Uncertain, OK, Cancel

- Screens can be expanded to view all parameters at once

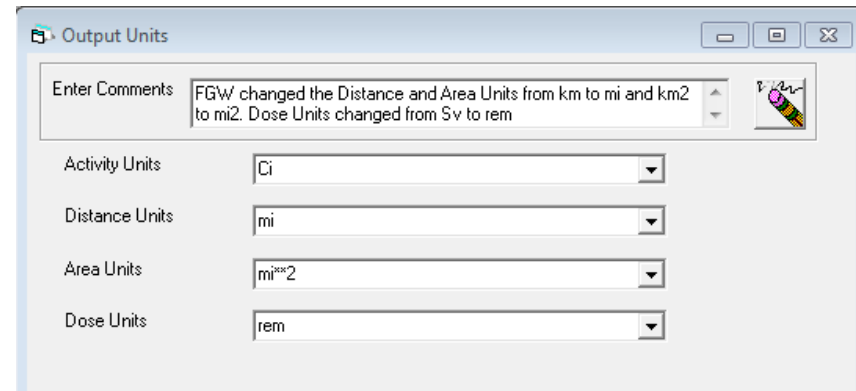
# Choice of Units

- WinMACCS input units can be chosen for most dimensional parameters, e.g., time can be specified in seconds, minutes, hours, days, or years
- MACCS output units can be chosen for activity, distance, area, and dose



The 'Plume Release Information' dialog box shows a table of release data. The 'Change Units of Measurement' sub-dialog is open, allowing users to select units for PDELAY, PLHITE, and PLUDUR. The 'Convert Data' checkbox is checked for all three parameters.

	PDELAY (s)	PLHITE (m)	REFTIM (-)	PLUDUR (s)
9	1.2084E+05	8.4E+00	0.5	3.6002E+03
10	1.2444E+05	8.4E+00	0.5	3.600E+03
11	1.2804E+05	8.4E+00	0.5	3.480E+03
12	1.3152E+05	8.4E+00	0.5	3.600E+03
13	1.3512E+05	8.4E+00	0.5	3.7198E+03
14	1.3884E+05	8.4E+00	0.5	3.480E+03
15	1.4232E+05	8.4E+00	0.5	3.600E+03
16	1.4592E+05	8.4E+00	0.5	3.720E+03
17	1.4964E+05	8.4E+00	0.5	3.600E+03
18	1.5324E+05	8.4E+00	0.5	3.4802E+03
19	1.5672E+05	8.4E+00	0.5	3.5999E+03
20	1.6032E+05	8.4E+00	0.5	3.6001E+03
21	1.6392E+05	8.4E+00	0.5	3.7197E+03
22	1.6764E+05	8.4E+00	0.5	3.4803E+03
23	1.7112E+05	8.4E+00	0.5	1.680E+03
24	1.728E+05	8.4E+00	0.5	1.1991E+02



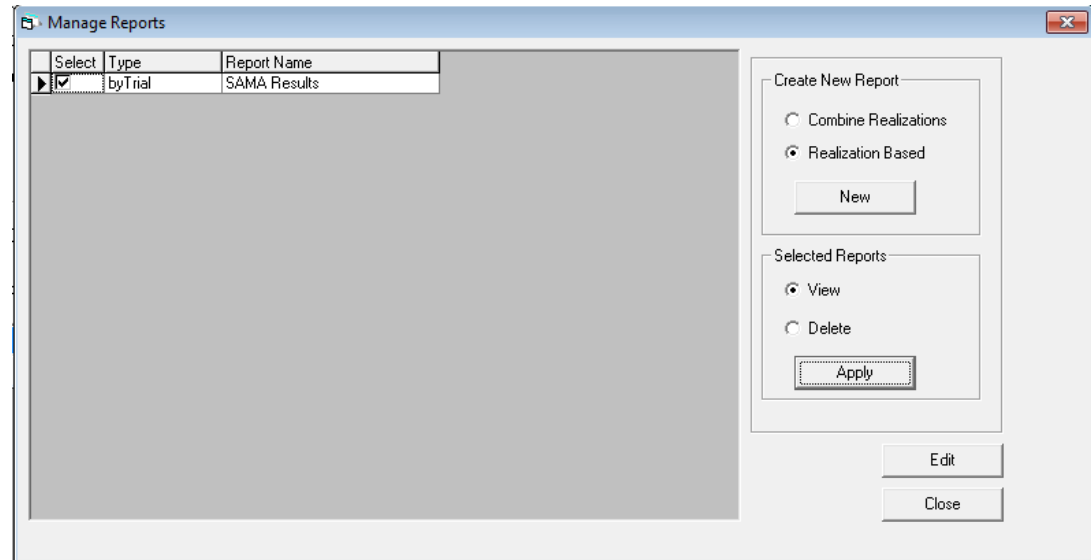
The 'Output Units' dialog box shows the following settings:

- Activity Units: Ci
- Distance Units: mi
- Area Units: mi<sup>2</sup>
- Dose Units: rem

Comments: FGW changed the Distance and Area Units from km to mi and km<sup>2</sup> to mi<sup>2</sup>. Dose Units changed from Sv to rem

# Reporting Options

- Reports can be created, e.g., with just the most essential results



SAMA Results.txt - Notepad

File Edit Format View Help

Report based on Project C:\Users\nbixler\winMACCS Projects\VEGP Base Case 08 18 14\VEGP Base Case 08 18 14.mxd  
winMACCS Version 3.9.1 SVN:2188  
Report based on MACCS version 3.9.0.6  
First binary file date/time stamp 09/04/2014 14:56  
9/5/2014 10:30:44 AM

Population Dose (rem)	Evacuation overall	L-ICRP60ED [0.,15.](mi)	5th Quantile	10th Quantile	50th Quantile	90th Quantile	95th Quantile	99th Quantile	99.5th Quantile	Peak Concentration	Peak Probability	
Peak Trial	Probability Non-zero	Mean	5th Quantile	10th Quantile	50th Quantile	90th Quantile	95th Quantile	99th Quantile	99.5th Quantile	Peak Concentration	Peak Probability	
Realization 1	1.E+00	1.207E+04	2.331E+03	3.613E+03	1.077E+04	2.028E+04	2.158E+04	2.493E+04	2.653E+04	3.317E+04	1.332E-04	2.15E+02

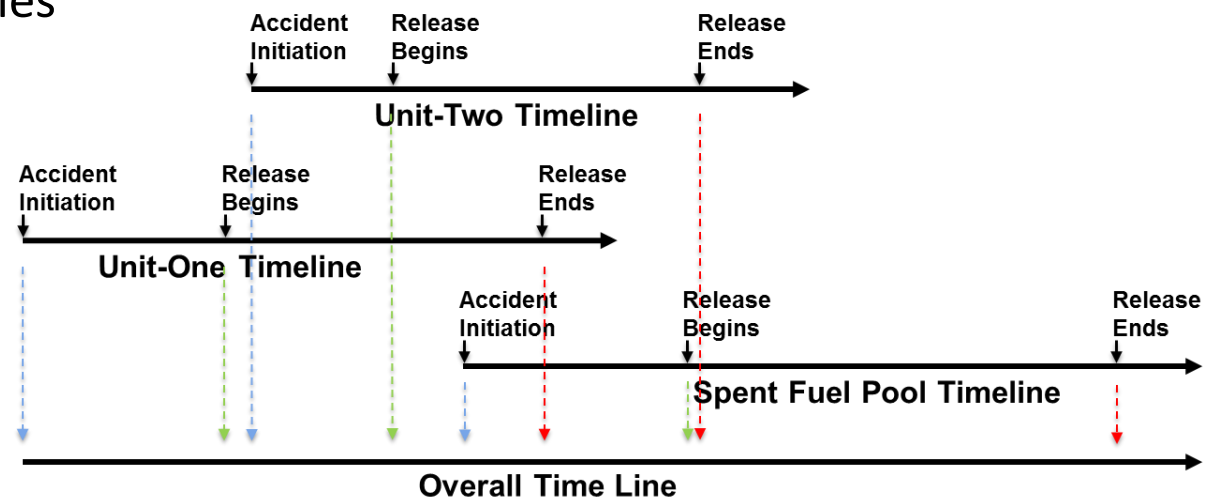
Total Economic Costs (\$)	Evacuation CHRONC [0.,30.](mi)	5th Quantile	10th Quantile	50th Quantile	90th Quantile	95th Quantile	99th Quantile	99.5th Quantile	Peak Concentration	Peak Probability		
Peak Trial	Probability Non-zero	Mean	5th Quantile	10th Quantile	50th Quantile	90th Quantile	95th Quantile	99th Quantile	99.5th Quantile	Peak Concentration	Peak Probability	
Realization 1	1.E+00	4.849E+07	2.099E+06	5.499E+06	3.344E+07	1.067E+08	1.203E+08	1.59E+08	1.793E+08	2.345E+08	7.583E-04	2.30E+02

# Improvements In MACCS 3.10 (5/15)

- Multi-source releases (requires MelMACCS 2.0.0 or newer)
- Extended durations
  - Alarm time (30 day)
  - Delay to release (30 day)
  - Emergency phase (40 day)
- User-defined dose projection periods for emergency and intermediate phases (previously duration of phase)
- Detailed output for people affected by countermeasures by phase
- Increase in weather hours read from file from 120 to 1200
- User-defined return time for evacuees unaffected by release (previously duration of emergency phase)

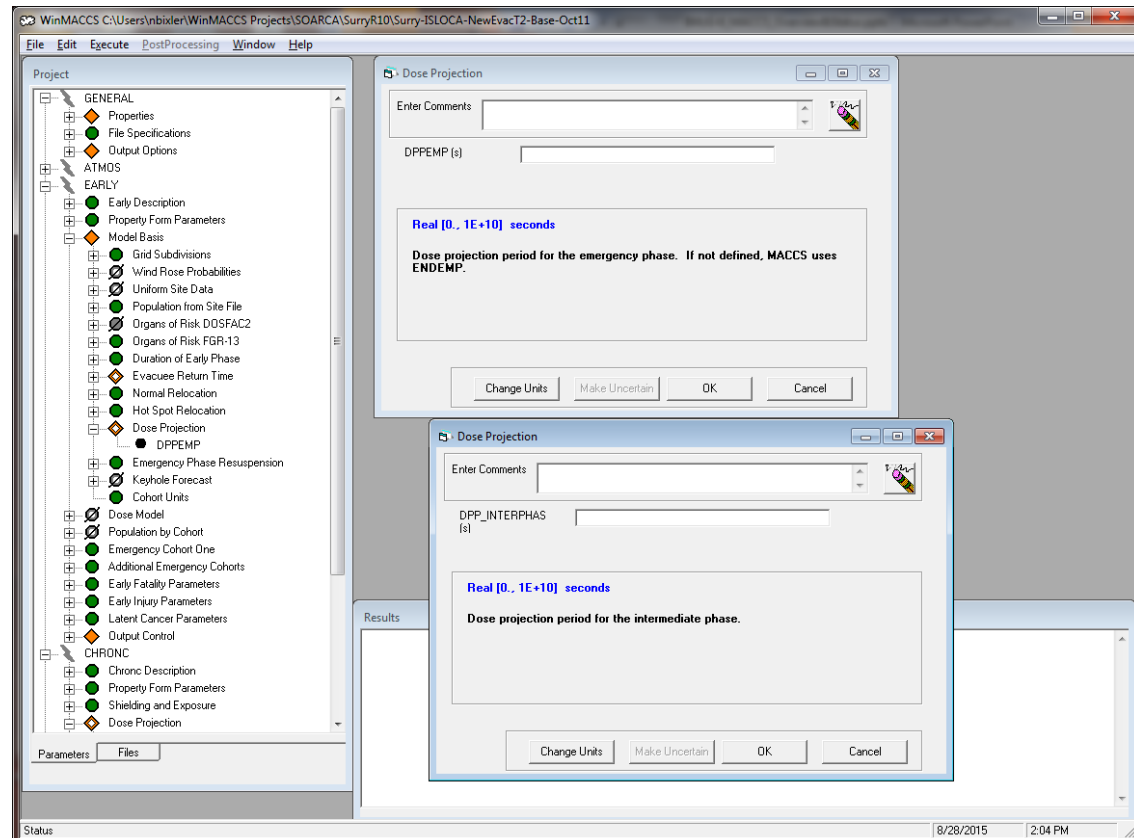
# Multi-Source Release Model

- Allows releases from multiple units with independent
  - Accident initiation times
  - Release time line
  - Isotopic inventories
- Allows releases from a spent fuel pool with multiple rings (cooling times) with independent
  - Release time line
  - Isotopic inventories



# User-Definable Dose Projection Periods

- User-definable dose projection periods for
  - Emergency phase
  - Intermediate phase
- Long-term phase model previously supported a user-definable dose projection period



# Detailed Output for People Affected by Countermeasures

- EVACUATED & RELOCATED PEOPLE 0-50.0 mi
  - EVACUEES NOT AFFECTED BY PLUME
  - EVACUEES AFFECTED BY PLUME
  - NORMAL EMERGENCY PHASE RELOCATION
  - HOTSPOT EMERGENCY PHASE RELOCATION
  - INTERMEDIATE PHASE RELOCATION
  - LEVEL 1 DECONTAMINATION RELOCATION
  - LEVEL 2 DECONTAMINATION RELOCATION
  - LEVEL 3 DECONTAMINATION RELOCATION
  - DECONTAMINATION+INTERDICTION RELOC
  - CONDEMNATION RELOCATION

# Fixes In MACCS 3.10.1.2 (9/16)

- Latitude and longitude are input as decimal degrees
- An error in the evaluation of time traveling through a grid element with network evacuation was corrected
- An error in centerline dose introduced in MACCS 3.10.0 was corrected
- A discrepancy between the input and output values of day and hour for a weather trial was corrected
- Two bugs in the implementation of the keyhole evacuation model were corrected



# Future Improvements (Version 3.11)



- Probable release by end of calendar year
- Significant improvements and corrections
  - OALARM can be defined for each cohort.
  - Dosimetry – all organs and tissues supported in dose coefficient file can be used to estimate doses and health effects.
  - Limit on number of early and latent health effects is increased.
  - Limits on decontamination costs is increased.
  - Executable is 64 bit instead of 32 bit to eliminate insufficient memory errors.
  - A bug limiting emergency-phase dose projection period to the duration of the emergency phase has been corrected.

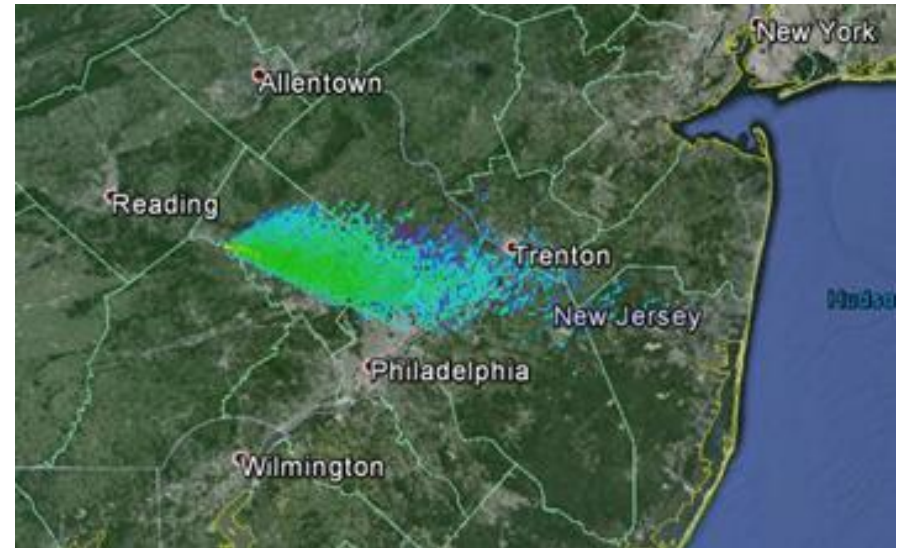
# Future Improvements (Version 4.0)

- Alternative atmospheric transport model (HYSPLIT) to evaluate special issues
  - Gaussian puff model
  - Lagrangian particle tracking model
- Alternative economic model to evaluate GDP losses
  - Based on input-output economic model
  - Uses modified REAcct code developed by NISAC for DHS
- Animation capability

# New Optional Atmospheric Transport Model

- Background

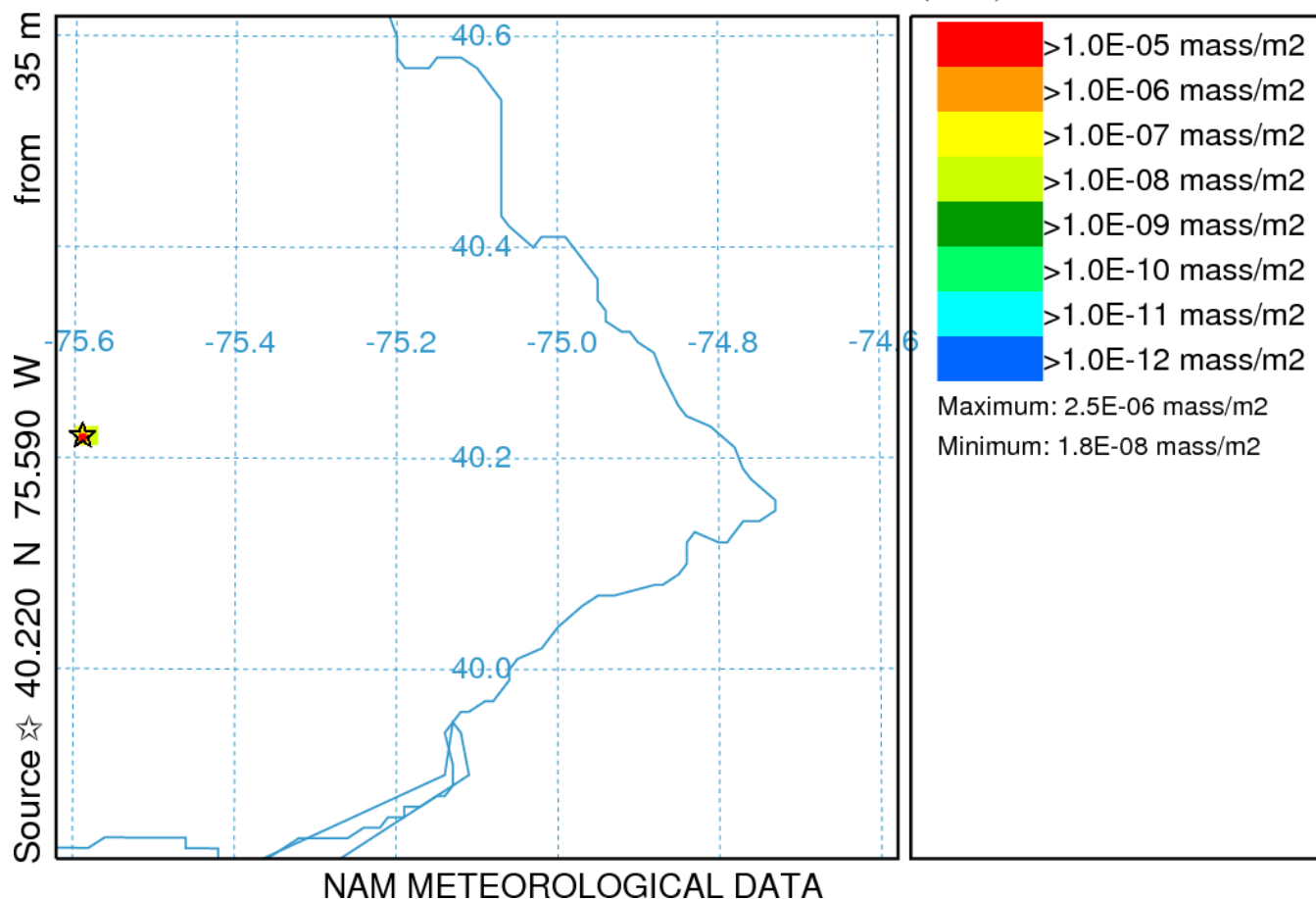
- Original model in MACCS is simple and fast, the Gaussian plume segment model
- Significant improvements in modeling capabilities have been made over the past 15 years.
- Code comparisons have demonstrated that results are within a factor-of-2 of the best model from NARAC.
- Occasionally, questions arise about the adequacy of the Gaussian plume segment model for specific situations.
- Sandia is developing a new atmospheric transport model to directly address these questions.



# New Optional Atmospheric Transport Model (Cont'd)

## NOAA HYSPLIT MODEL

Deposition (mass/m<sup>2</sup>) at ground-level  
Integrated from 1500 26 Nov to 1505 26 Nov 11 (UTC)  
SUM Release started at 1500 26 Nov 11 (UTC)



# Steps Required to Run New Atmospheric Transport Model

- Download and store one or more years of transient, gridded weather data
  - Requires about 1TB per year of 12-km NAM data
- Perform normalized atmospheric transport calculations with HYSPLIT for a site (release from a specific latitude, longitude at several elevations)
  - Requires several days on a cluster of 100 processors
- Convert HYSPLIT output to MACCS grid
  - Requires about 10 minutes on a desktop computer
  - Creates 50 to 100 MB of intermediate data
- Run MACCS to estimate consequences
  - Requires an order-of-magnitude more CPU time to run MACCS

# Alternative GDP-Based Economic Consequence Model

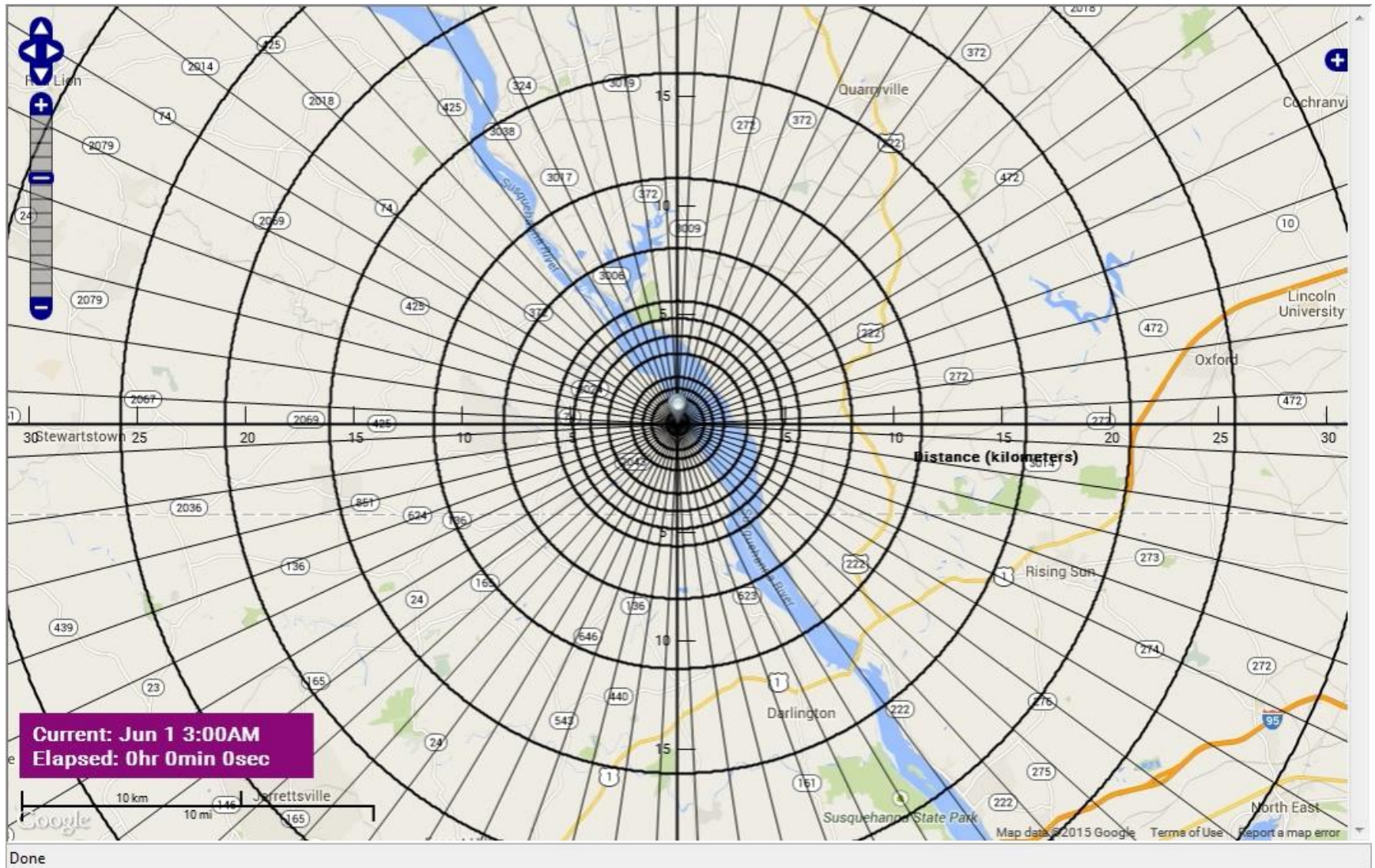
- Based on standard input/output theory developed by Leontief
- Created from REAcct model developed by Sandia for DHS
- GDP losses include direct, indirect, and induced
  - Total GDP losses are sums of net value added over industrial sectors at the national level
  - Direct losses are from loss of production in the directly affected area
  - Indirect losses account for losses outside affected area from sales of intermediate goods to affected area
  - Induced losses account for loss of spending by unemployed workers

# Comparison of Economic Losses

Cost Model	GDP and Tangible Wealth Model
Evacuation/relocation costs	Evacuation/relocation costs
Long-term relocation	Long-term relocation
Decontamination costs	Decontamination costs
Expected return on investment	GDP losses, including direct, indirect, and induced
Depreciation on property improvements	Depreciation on property improvements
Value of condemned property	Value of condemned property
Disposal of contaminated crop and dairy products	

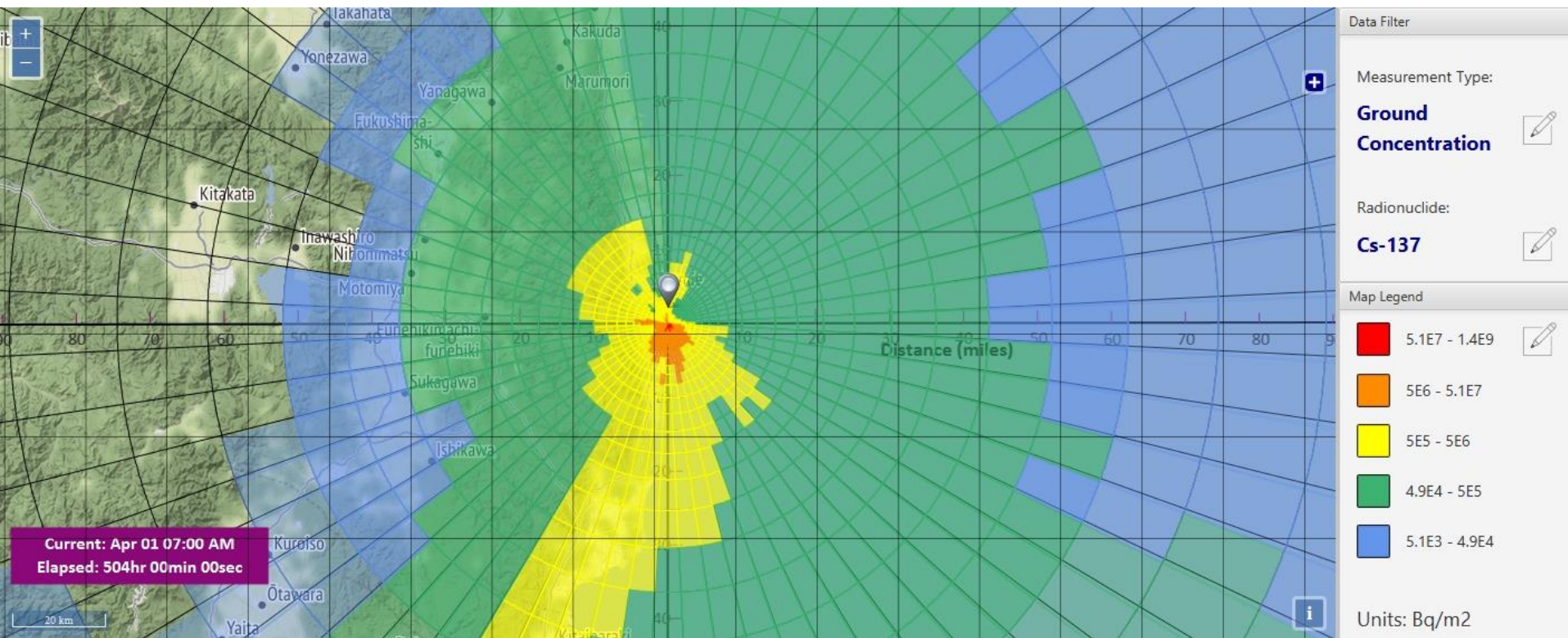


# Animation of Plume Segments

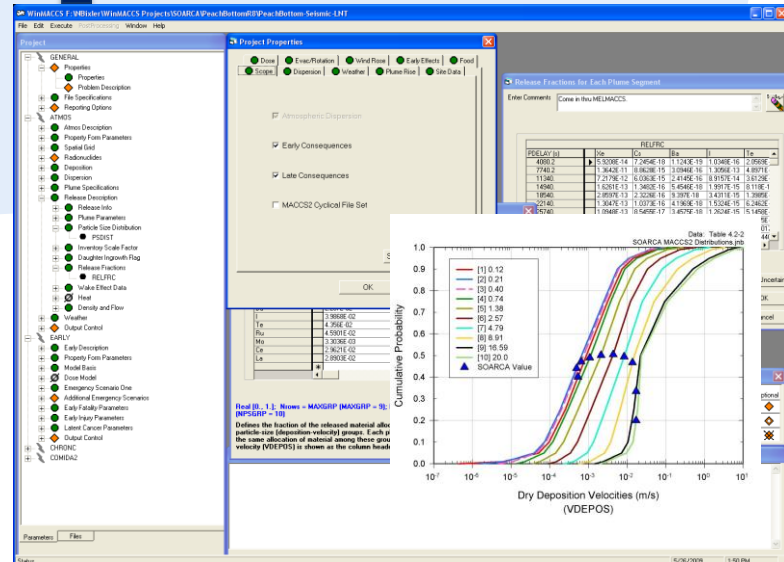
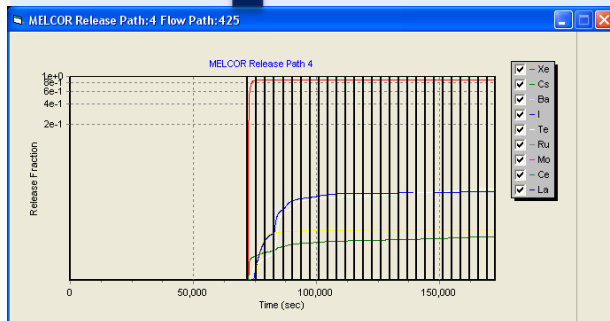
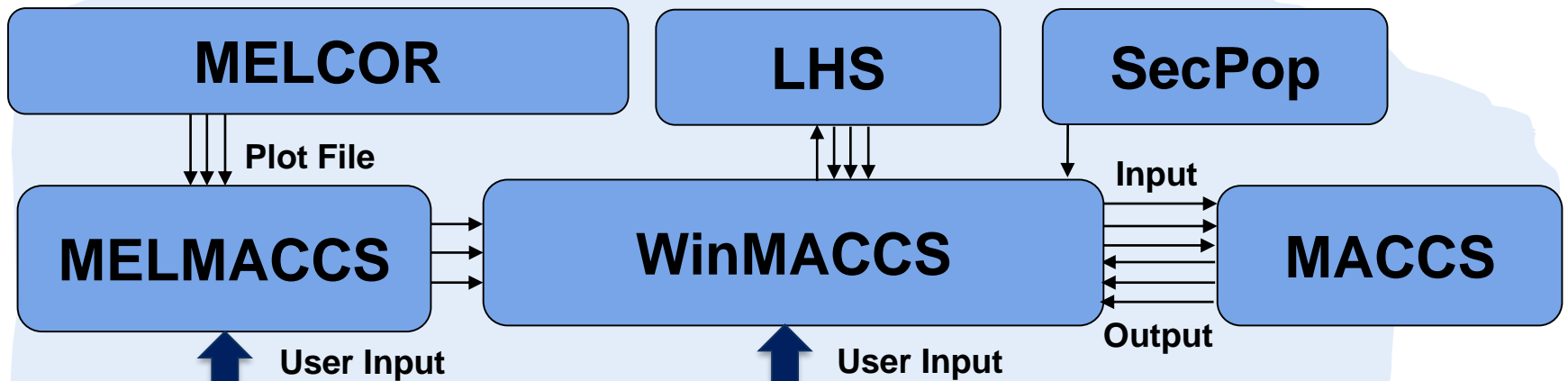




# Ground Concentration Isopleths



# Typical WinMACCS Calculation Framework

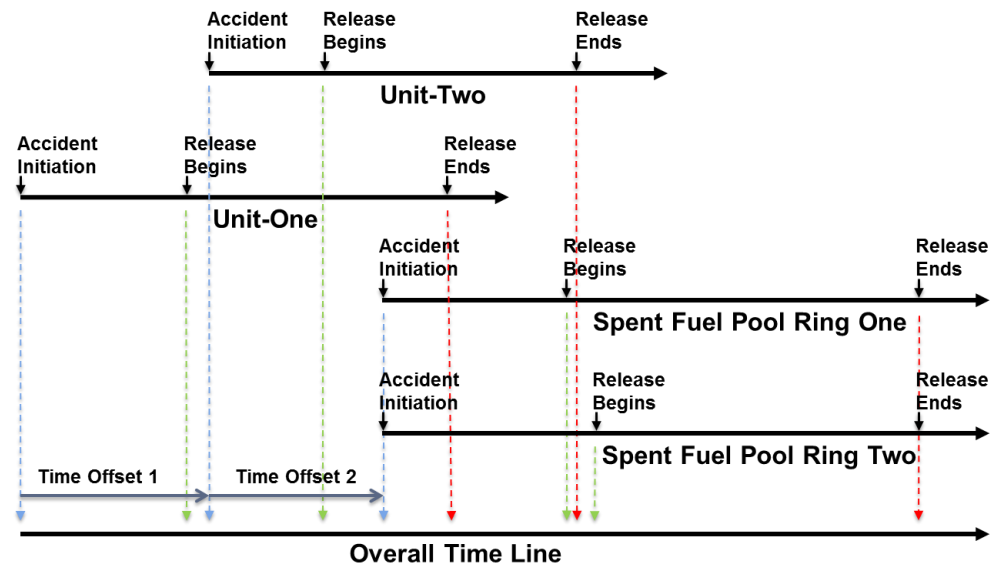
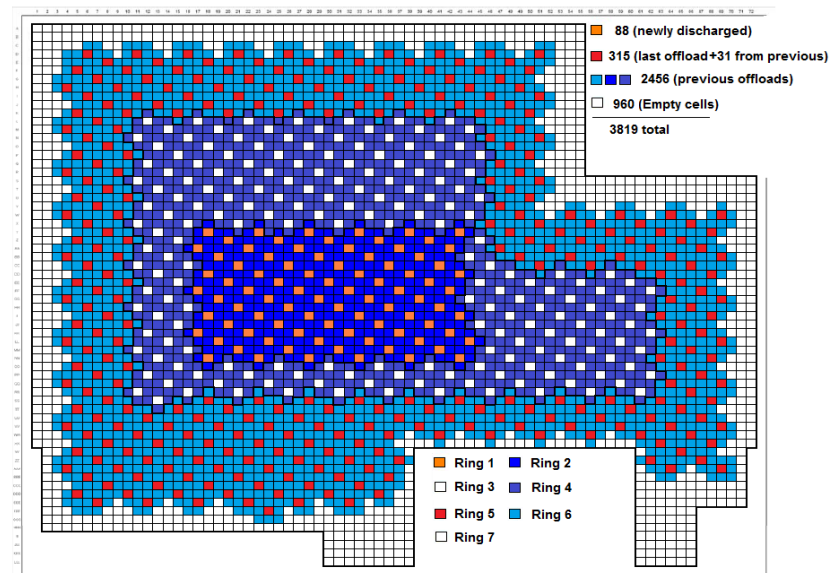


# MACCS Preprocessors

- MelMACCS
  - Extracts and processes source-term data from MELCOR plot files
- SecPop
  - Evaluates census, land use, and economic data for a MACCS site file
- COMIDA2
  - Evaluates dose coefficients for the food pathway

# MelMACCS Status

- MelMACCS 2.0.1 released in July 2016
  - User-definable fission product inventories
  - Support for multi-unit source terms
  - Support for multi-ring spent fuel pool source terms



# SecPop Status

- SecPop 4.2.0 released in October 2013
  - Uses 2010 census data
  - Allows 16, 32, 48, or 64 compass sectors
  - Uses a smart algorithm for defining economic regions
  - Supports alternative economic model development
  - Supports Windows 7 operating system
- SecPop 4.3.0 released in September 2014
  - A bug related to the calculation of farm fraction was fixed
  - The first three economic regions are automatically assigned as follows:
    - Region 1 is the exclusion area – population and economic values are zero
    - Region 2 – no land area
    - Region 3 – no census blocks
- 2012 economic data released July 2016

# Summary

## Recently added modeling options

- Multi-source releases
- Multiple-age fuels in spent fuel pool
- User-defined dose projection periods
- Detailed countermeasure output

## Ongoing improvements are addressing

- Complete set of organs and related cancer types
- Alternative models for atmospheric transport and economic analysis
- Estimation of GDP losses with optional economic model
- Animation of plume segments and isopleths

# List of Acronyms

- CRAC            Calculation of Reactor Accident Consequences
- DHS            Department of Homeland Security
- MACCS        MELCOR Accident Consequence Code System
- NAM            North American Mesoscale Forecast System
- NISAC        National Infrastructure Simulation and Analysis Center
- PRA            Probabilistic Risk Assessment
- REAcct        Regional Economic Accounting tool
- SecPop        Sector Population, Land Fraction, and Economic Estimation Program
- SOARCA       State-of-the-Art Reactor Consequence Analyses