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SAND2021-11702C

Sandia National Laboratories

Overview of MACCS Status and Development

PRESENTED BY

J. E. Leute

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY NNSA

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- Current versions
- MACCS background
- MACCS version 4.1 NEW!
- AniMACCS NEW!
- Supporting documents
- Auxiliary files
- Advanced reactor initiatives
- MACCS modernization
- Summary

Current Versions

- MACCS/WinMACCS
  - Current version is v4.1
- SecPop
  - Current version is v4.3.0
  - Will be updated when new US census data is available
- MelMACCS
  - Current version is v2.0.1
  - In the process of re-writing in more modern programming language
- AniMACCS
  - Current version is v1.3

Purpose for MACCS

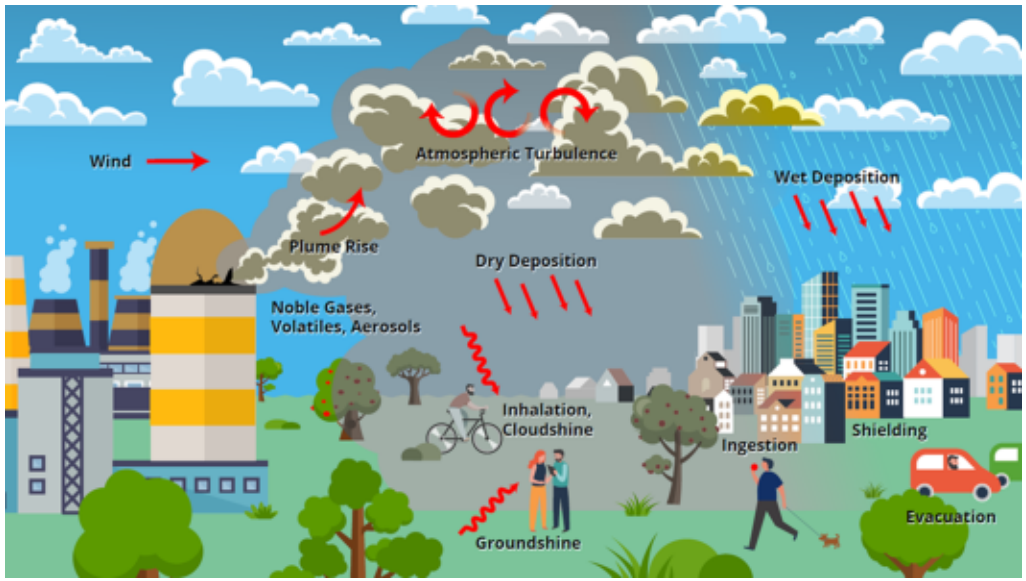
- Created by Sandia to support NRC research and regulatory applications
  - Origins go back to the mid-1970s
- Typically used for prospective analyses, e.g.,
  - Probabilistic risk assessments (NUREG-1150 and NRC's Level 3 PRA)
  - Probabilistic consequence assessments (SOARCA)
  - Cost/benefit analyses (required for environmental analyses in licensing)
- Very versatile with a large set of user inputs
- Intended to run rapidly for PRA applications
  - Large set of weather trials (hundreds or thousands)
  - Significant set of source term categories (ten or twenty) plus additional sensitivity studies

MACCS Lineage

- Calculation of Reactor Accident Consequences (CRAC) Code (1975)
  - Developed for the Reactor Safety Study (WASH-1400)
- CRAC2 (1982)
  - Primarily used in 1982 siting study (NUREG/CR-2239)
- MACCS (MELCOR Accident Consequence Code System) (1990)
  - Primarily used in NUREG-1150
- MACCS2 (1998)
  - Developed to support DOE documented safety analyses of nuclear facilities
- WinMACCS/MACCS (2011)
  - Enhance user friendliness
  - Reduce likelihood of user errors
  - Enable routine examination of uncertainty

Phenomena Treated by MACCS

- Representation of source term
- Atmospheric transport and dispersion
  - Statistical sampling of archived weather data
- Wet and dry deposition
- Exposure pathways to humans
  - Inhalation
  - Cloudshine
  - Groundshine
  - Resuspension
  - Ingestion



- Emergency actions
  - Sheltering
  - Evacuation
  - KI ingestion
  - Relocation
- Long-term remedial actions
  - Decontamination
  - Temporary or permanent interdiction of property
  - Crop disposal
- Economic losses
  - Evacuation and relocation per diem costs
  - Long-term relocation cost
  - Decontamination costs
  - Loss of property use
  - Depreciation during interdiction
  - Property value for permanent interdiction

MACCS Code Modules

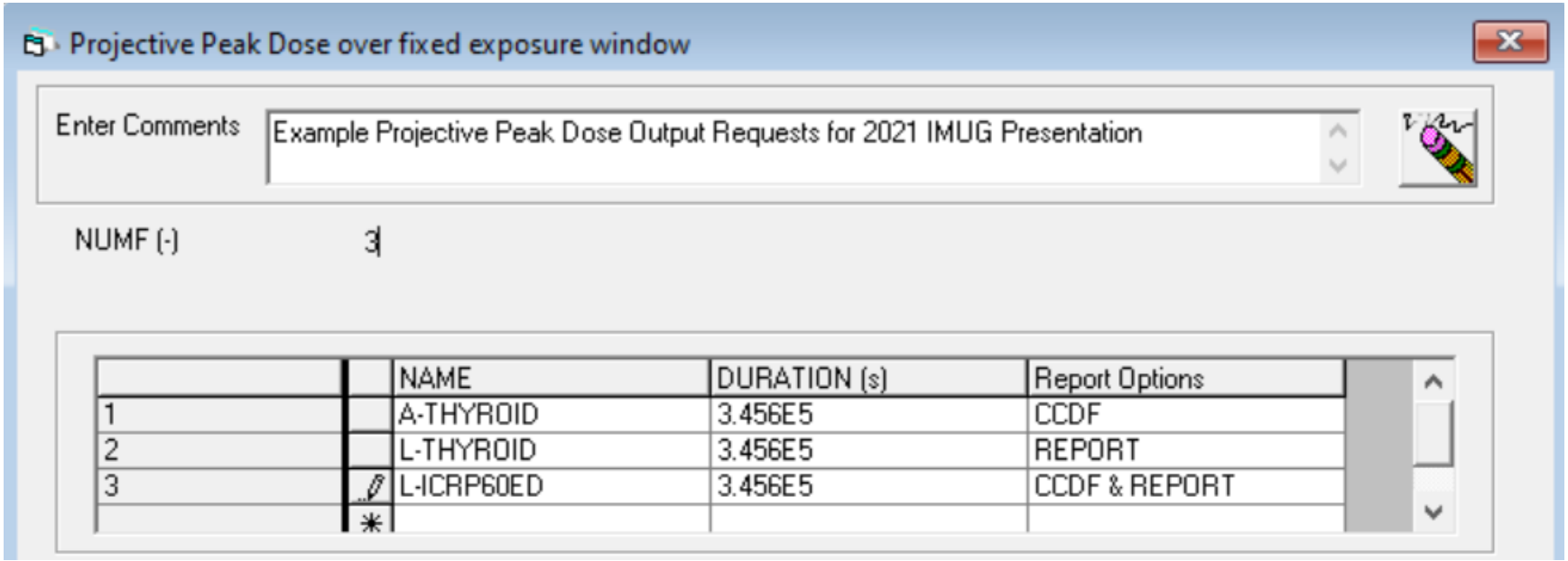
- ATMOS
  - Calculates transient air and ground concentrations
- EARLY
  - Treats emergency phase (up to 40 days, usually one week)
  - Models emergency response actions
  - Estimates doses from exposure pathways
  - Estimates health effects
- CHRONC
  - Treats intermediate phase (up to 30 years, usually one year)
  - Treats long-term phase (up to >300 years, usually 50 years)
  - Estimates long-term doses from exposure pathways
  - Estimates health effects
  - Calculates economic losses

MACCS 4.1 – Released on 30 July 2021!

- Near-field modeling improvements:
  - SAND2020-2609 compared MACCS v3.11.6 to several near-field atmospheric transport and dispersion codes including QUIC, ARCON96, and AERMOD2
  - Concluded MACCS provides a conservatively bounding assessment in the near-field
  - MACCS v4.1 enhancements added for plume meander and trapping and downwash to simulate or bound near-field assessments of other codes
- New projective peak dose output option
- Documentation added to help menu in WinMACCS
- Updates to the RDEIM economic model
- Mixing layer information for each time period
- Time synchronization
- Pop-up window for converting previous version

Projective Peak Dose

- Peak dose over a fixed exposure window
- Helpful for comparison to emergency response guidelines
- Calculated from the time a plume arrives at a grid element to the end of the given time period
- Maximum of the sum of the different plume releases
- User defines to organ dose, duration, and report options



MACCS 4.0 Revolutionary Improvements

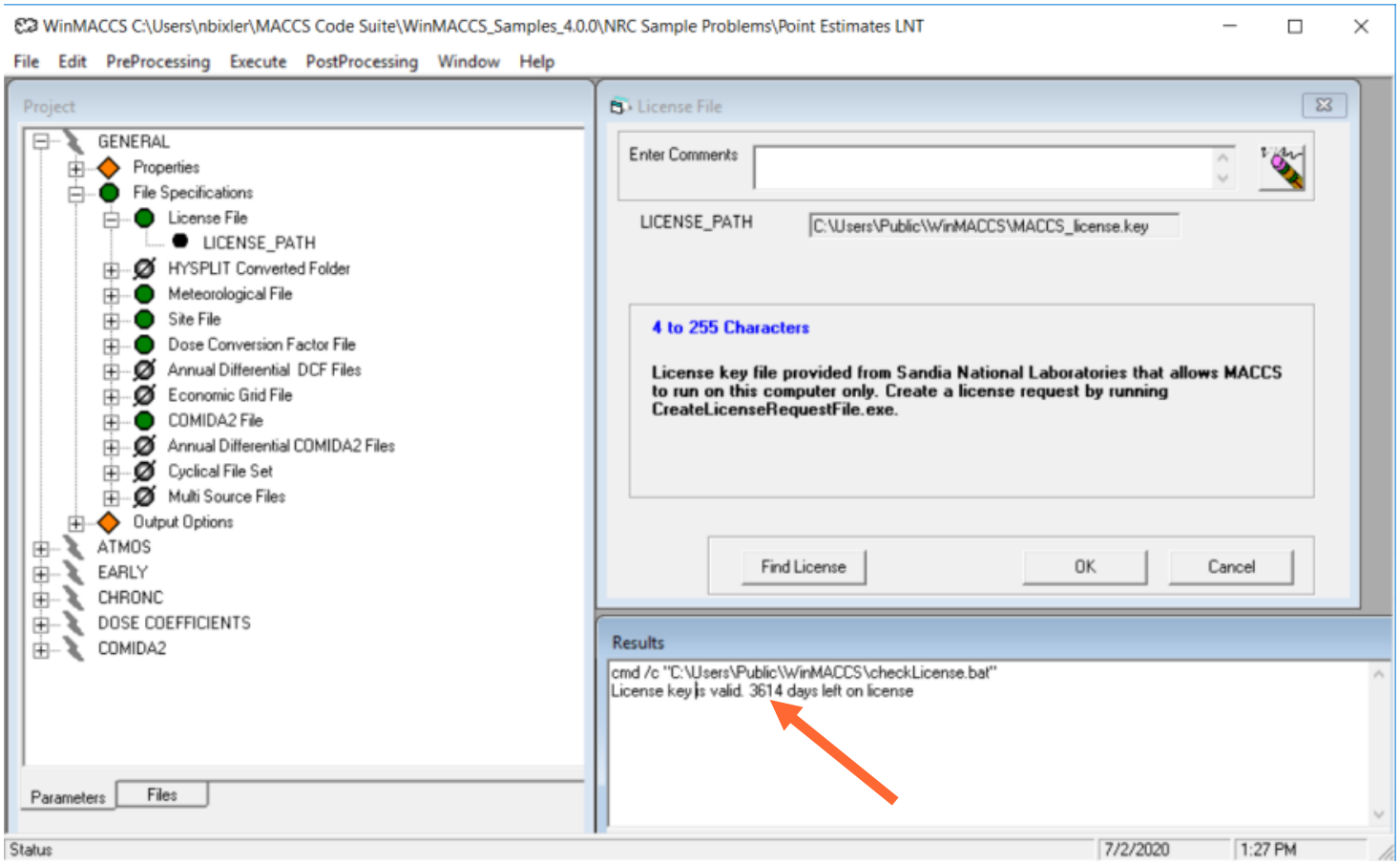
- Optional capability to perform high-fidelity atmospheric transport modeling with HYSPLIT
  - User is responsible for downloading HYSPLIT (from NOAA) and supporting tools (special request to Sandia)
  - Preprocessor steps needed prior to running WinMACCS and MACCS
  - Significantly more computing requirements than the Gaussian model
- Optional state-of-practice, GDP-based model (RDEIM) to account for economic losses (database currently supports contiguous USA)
  - Initially developed prior to 2015
  - Peer review conducted in 2015 led to significant improvements
  - Model was improved and benchmarked between 2015 and 2020
  - Benchmark report published in May 2020
  - Latest version of SecPop supports site data requirements
- Support for special files needed by animation tool, AniMACCS

New Licensing Process

- MACCS 4.0/4.1 contains new licensing features
  - Software is locked to a specific computer
  - Licenses are for one-year duration
- Steps to activate license
  - Run WinMACCS 4.X.0 Setup.exe (no installation key required)
  - Open WinMACCS 4.X.0
    - A popup screen briefly describes the licensing process
    - Readme file provides more details on licensing process
  - Run CreateLicenseRequestFile.exe in folder C:\Users\Public\WinMACCS to create license.request
  - Send a copy of license.request to wg-maccs-entity@sandia.gov
  - Once approved, Sandia sends MACCS_license.key to user
  - License key is linked to WinMACCS

Linking License Key

- File Specifications/License File is used to link MACCS_license.key
- WinMACCS provides the number of days left on license
- User should be proactive in updating license key

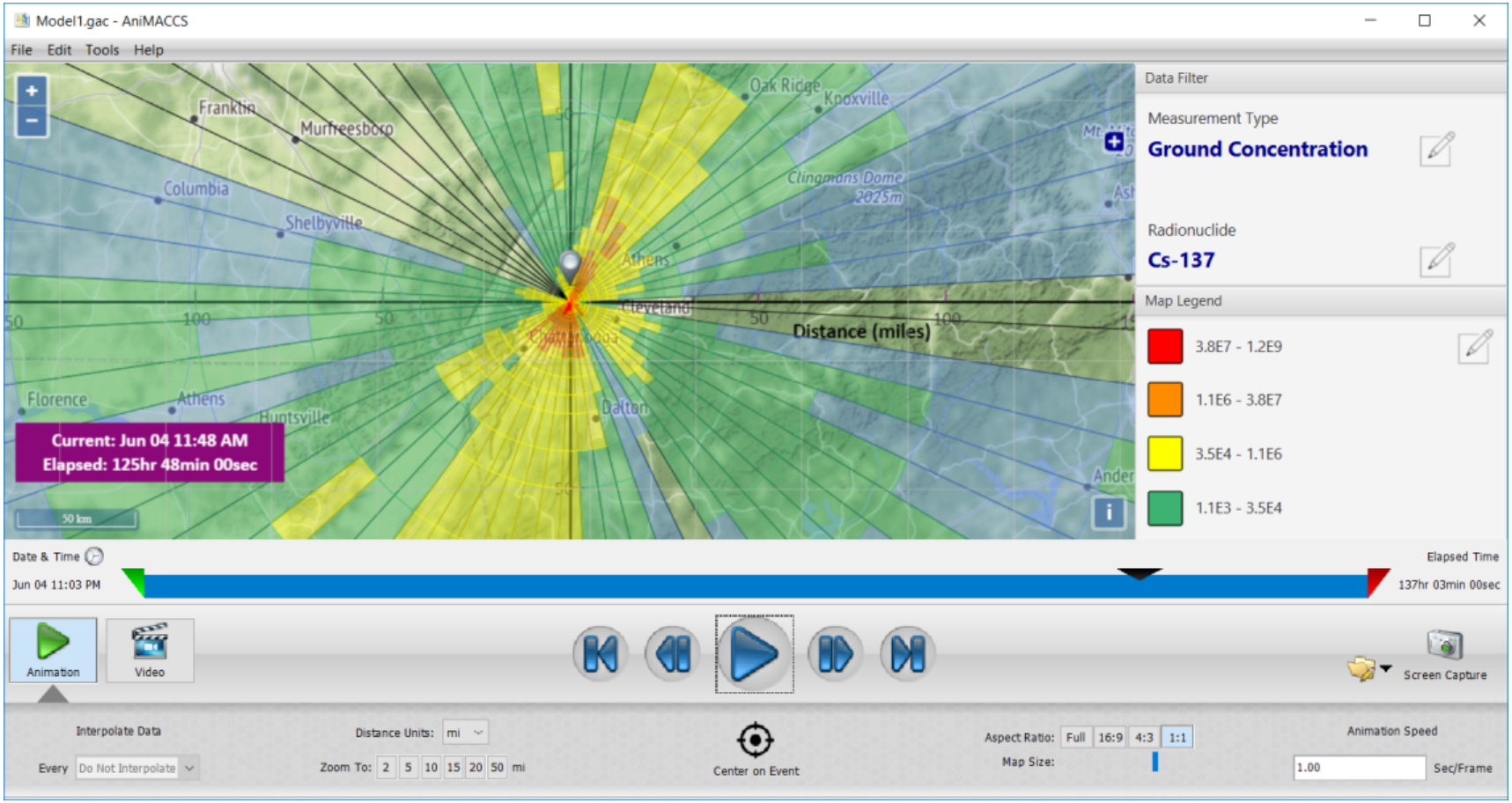


AniMACCS Capabilities

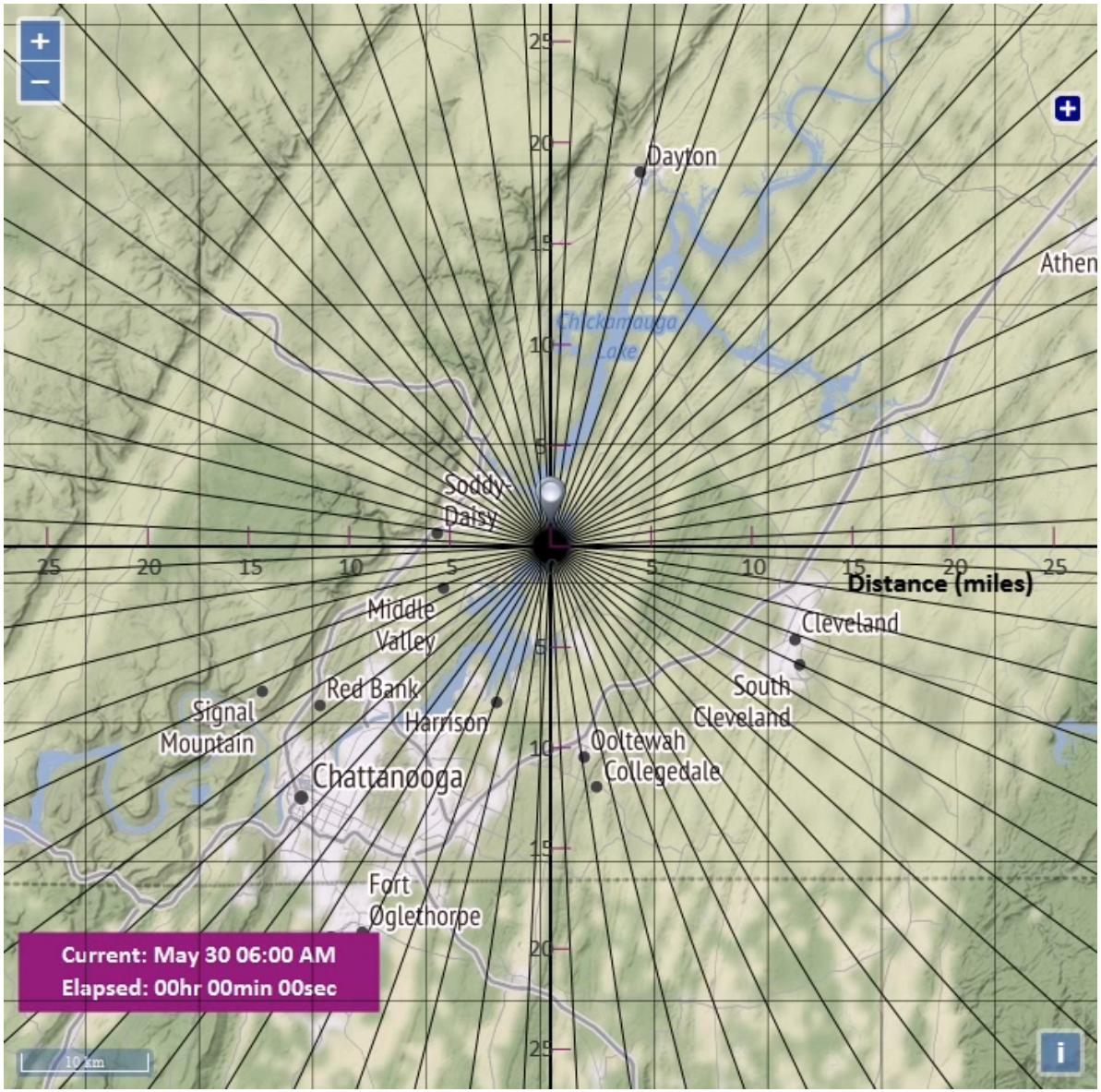
- AniMACCS software released in November 2020
  - Available with MACCS 4.X
  - Can be obtained for a $1000 fee with MACCS 3.X
- Allows MACCS single weather sequence runs to be animated
  - Movement of plume segments for Gaussian model
  - Instantaneous air concentrations (C, Bq/m^3)
  - Time-integrated air concentrations (χ, Bq-s/m^3)
  - Ground deposition (D, Bq/m^2)
- Creates both animations and snapshots

AniMACCS Features

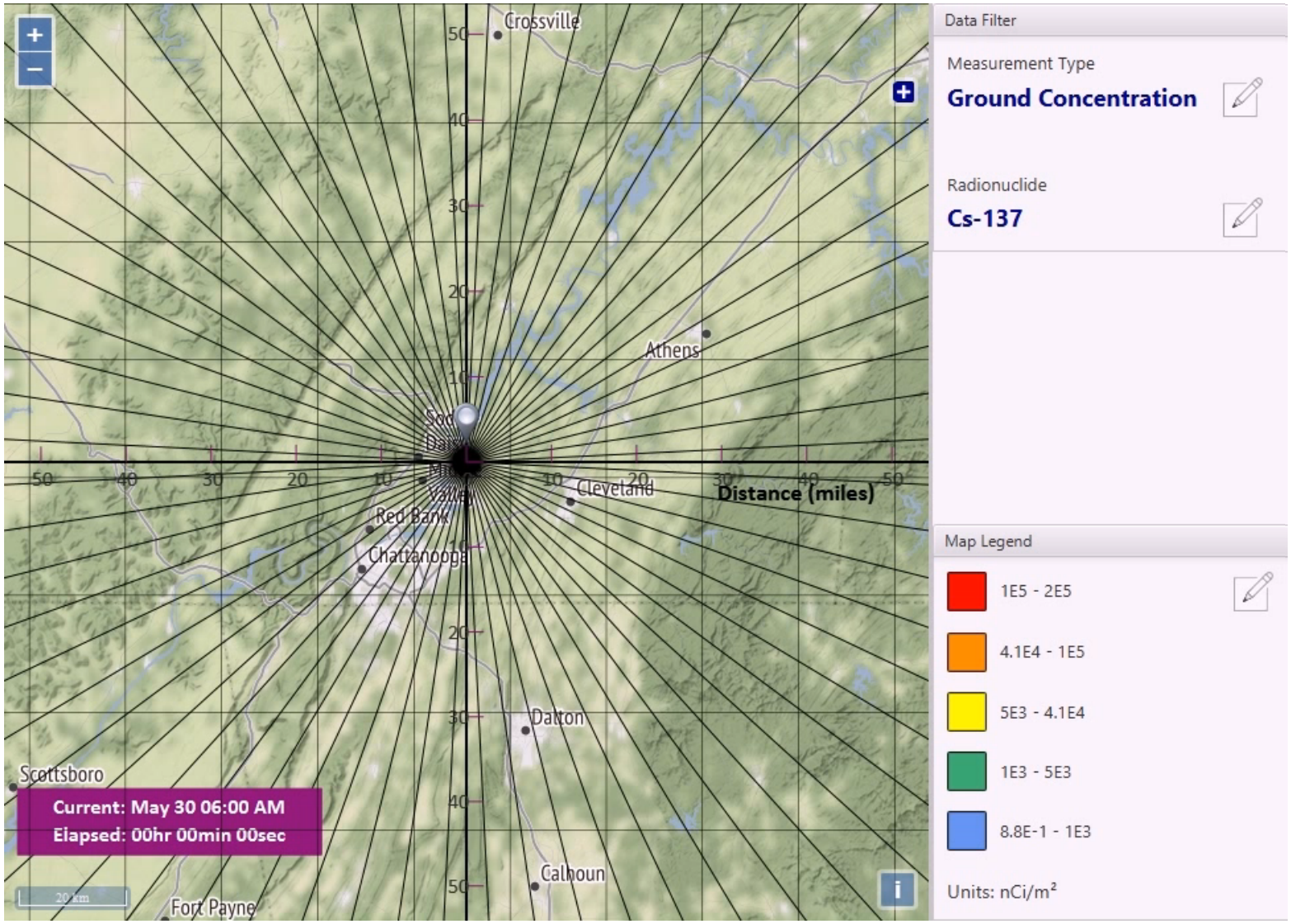
- User can modify
  - Map scale and center
  - Contour colors and isopleth ranges
  - Type of contour and choice of radionuclide
  - Aspect ratio
  - Animation speed for videos
  - Interpolation time of plume movement animations



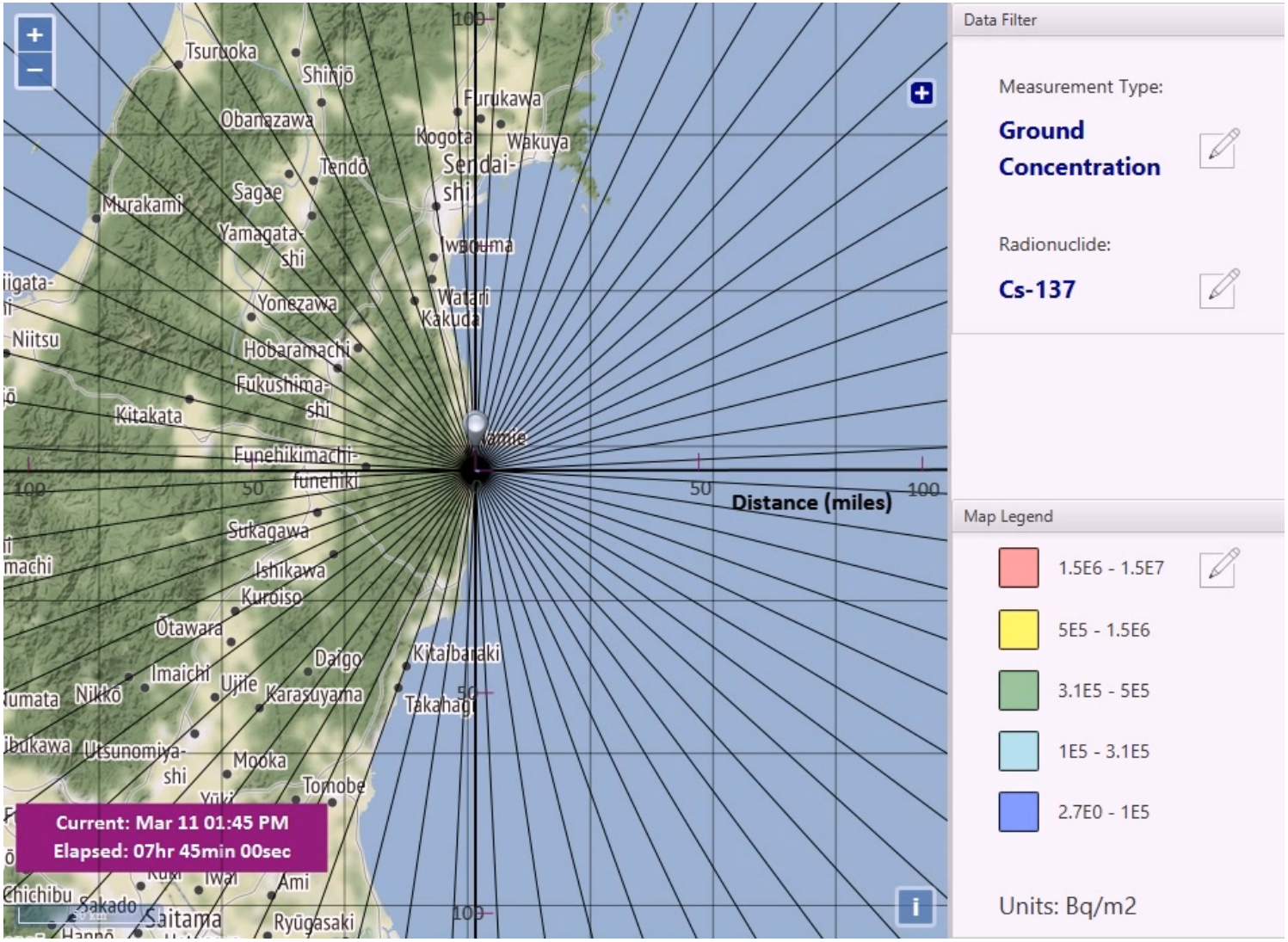
Animation of Plume Segments



Animation of Ground Deposition (Gaussian)



Animation of Ground Deposition (HYSPLIT)



Major Supporting Documents

- MACCS User's Guide and Reference Manual Draft Report (consistent with Version 4.0) (SAND 2021-8998)
- 4.1.0 WinMACCS Enhancements document
- Assessment of the MACCS Code Applicability for Nearfield Consequence Analysis (SAND2020-2609)
- Economic Model for Estimation of GDP Losses in the MACCS Offsite Consequence Analysis Code (SAND2020-5567)
- Complete set of published SOARCA Reports (NUREG-1935 Parts 1&2, NUREG/CR-7110 Vol. 1&2 Rev. 1, NUREG/CR-7155, and NUREG/CR-7245)
- MACCS Theory Manual to be published by 30 September 2021

Auxiliary and Supporting Files

- Dose coefficient (DCF) files for LNT and non-LNT applications
  - FGR-13 (based on FGR-13 using standard radiation weighting factors)
  - FGR-13 Gray Equivalent (Rev. A) (based on FGR-13 using relative biological effectiveness (RBE) factors consistent with FGR-13 cancer induction modeling and with all SOARCA analyses)
- COMIDA2 files to go with each type of dose coefficient file
  - Created with COMIDA2 2.0.0.2
  - Exposure duration (LASTACUM) set to 50 years
- NRC and DOE sample problems
- Tutorials based on NRC sample problems
- Documents to support HYSPLIT applications

Key Advanced Reactors Atmospheric Transport Issues to be Addressed

- Modeling near-field dispersion
  - May be required to estimate doses and other consequences at or just beyond the Exclusion Area Boundary (EAB), which may be very close to the reactor location
  - Examined MACCS against several near-field dispersion codes (SAND 2020-2609)
- Change in the formation of activation products
  - Isotopic inventory, if very different than that of a LWR, may need to be reevaluated to ensure that all important isotopes are included in the analysis
- Change in the chemical form of radionuclides
  - Differences in chemical form are most likely when the oxygen potential within the RCS is substantially different than that of a LWR, where steam is usually the dominant gas-phase component
  - May impact atmospheric transport and require modifications to dose coefficients for internal pathways
- Evolution of deposition behavior
  - May occur either because aerosols are hygroscopic or because some of the radionuclides are chemically reactive and change chemical form
- Cost of decontamination
  - Could be different for advanced reactors if the released isotopes and their unique chemical compositions influence decontamination methods and their effectiveness

MACCS Modernization

- Working collaboratively with the US NRC to determine the future vision for MACCS
- Effectively tackle the consequence analysis challenges of the future
  - Incorporate modern programming languages and techniques
  - Be compatible with modern computing platforms
  - Increased flexibly and modularity
  - Support advanced reactor consequence analysis and future model updates

And we want your feedback!

Please complete survey following IMUG

Summary

- MACCS performs prospective consequence analysis of potential atmospheric releases of nuclear materials
- MACCS 4.1 was just released in July
  - Near-field enhancements
  - Projective peak dose
- Major enhancements in Version 4.0 include
  - Coupling with HYSPLIT to perform high-fidelity ATD modeling
  - A state-of-practice model for economic losses resulting from a nuclear power plant accident (RDEIM)
  - Ability to animate plume segments and air and ground concentrations
- Further updates underway!

List of Acronyms

ATD	Atmospheric Transport and Dispersion
CRAC	Calculation of Reactor Accident Consequences
DCF	Dose Conversion Factor
DOE	Department of Energy
FGR	Federal Guidance Report
GDP	Gross Domestic Product
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory
LNT	Linear No-Threshold
MACCS	MELCOR Accident Consequence Code System
NOAA	National Oceanographic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
PRA	Probabilistic Risk Assessment
RBE	Relative Biological Effectiveness
RDEIM	Regional Disruption Economic Impact Model
SOARCA	State-of-the-Art Reactor Consequence Analyses

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- Support for special files needed by animation tool, AniMACCS

MACCS 4.0 Evolutionary Improvements

- Limits extended on a large set of input parameters
  - Number of output requests for all output types (999)
  - Number of plume segments using multi-source model (9999)
  - Duration of food ingestion with COMIDA2 (50 yr)
- Convenience enhancements added for cyclical file management
  - Network access
  - Reordering capabilities
  - Creates templates on all valid files
  - Allows source term set per realization when running multi-source model
- Simplified method to eliminate quadratic parameters for the linear-quadratic dose-response model
- Qualifiers can be tab-separated in reports to facilitate importing into a spreadsheet
- Input parameters can be exported, including distribution definitions
- Results for each weather trial are used to define quantile results
- Unused correlations are supported