

SIERRA Primer

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Purpose / Outline

- **Purpose**
 - To provide an overview of the SIERRA ATD module
- **Outline**
 - SIERRA Background
 - SIERRA ATD Overview
 - Comparison with Legacy Codes
 - Future SIERRA Development

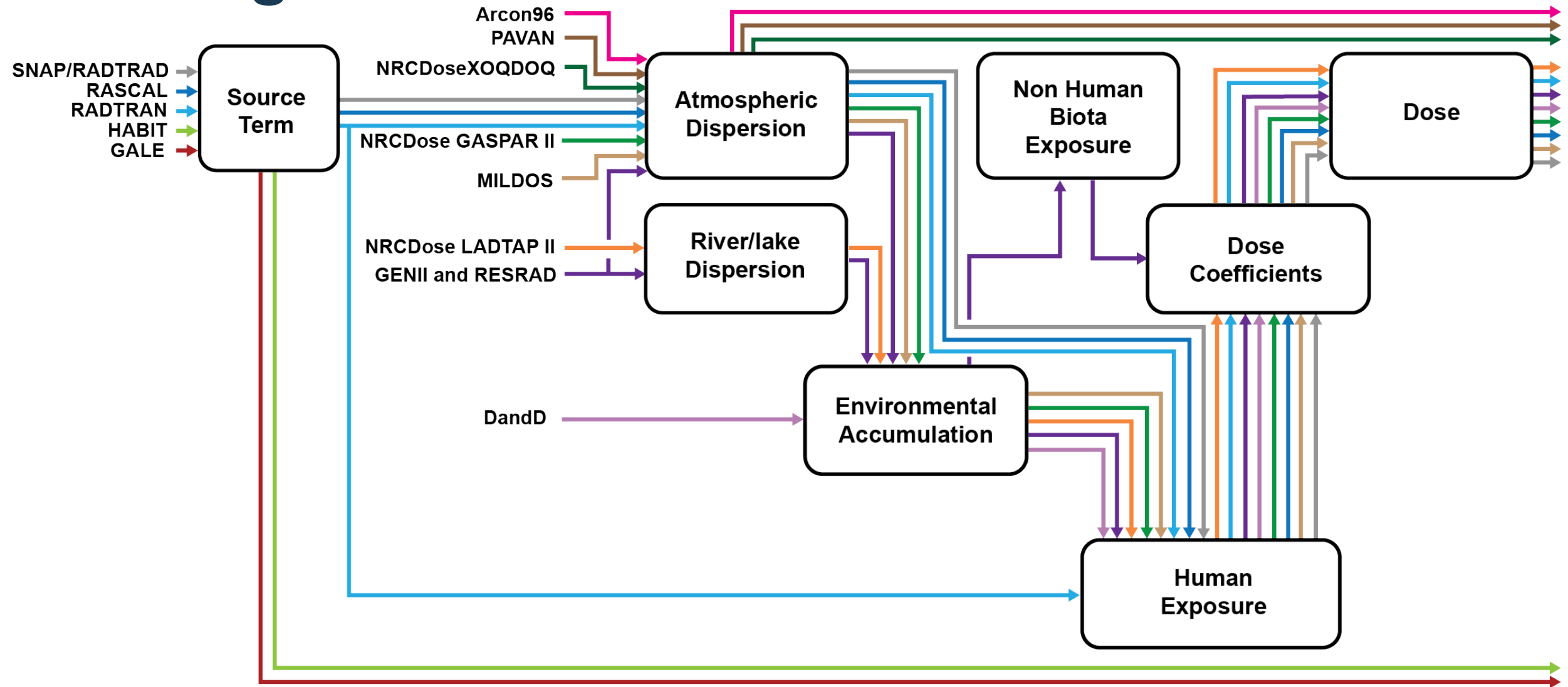
SIERRA ATD updates the RAMP atmospheric codes ARCON, PAVAN, and XOQDOQ while maintaining results in family with those of the legacy codes



SIERRA Overview

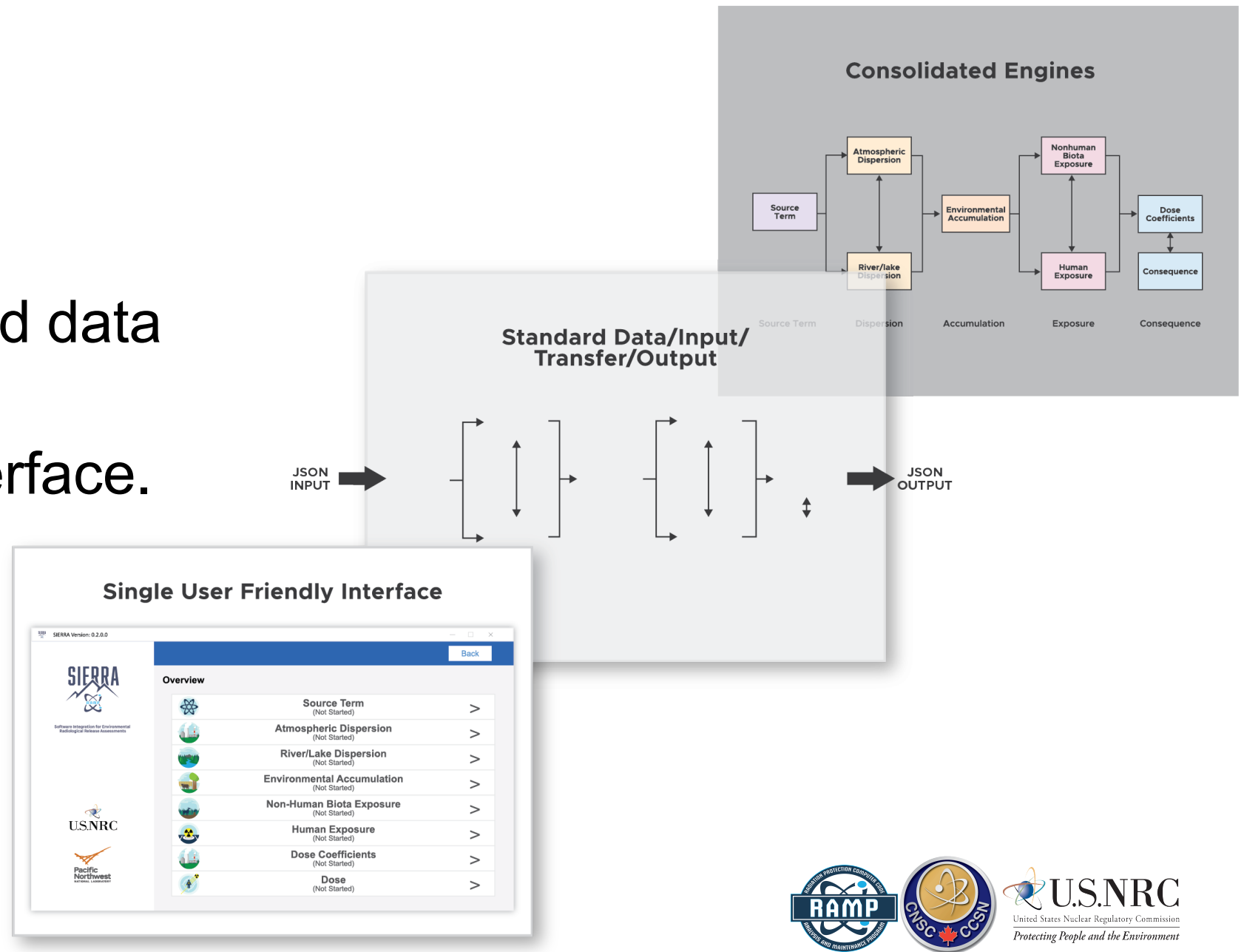


SIERRA: Software Integration for Environmental Radiological Release Assessments



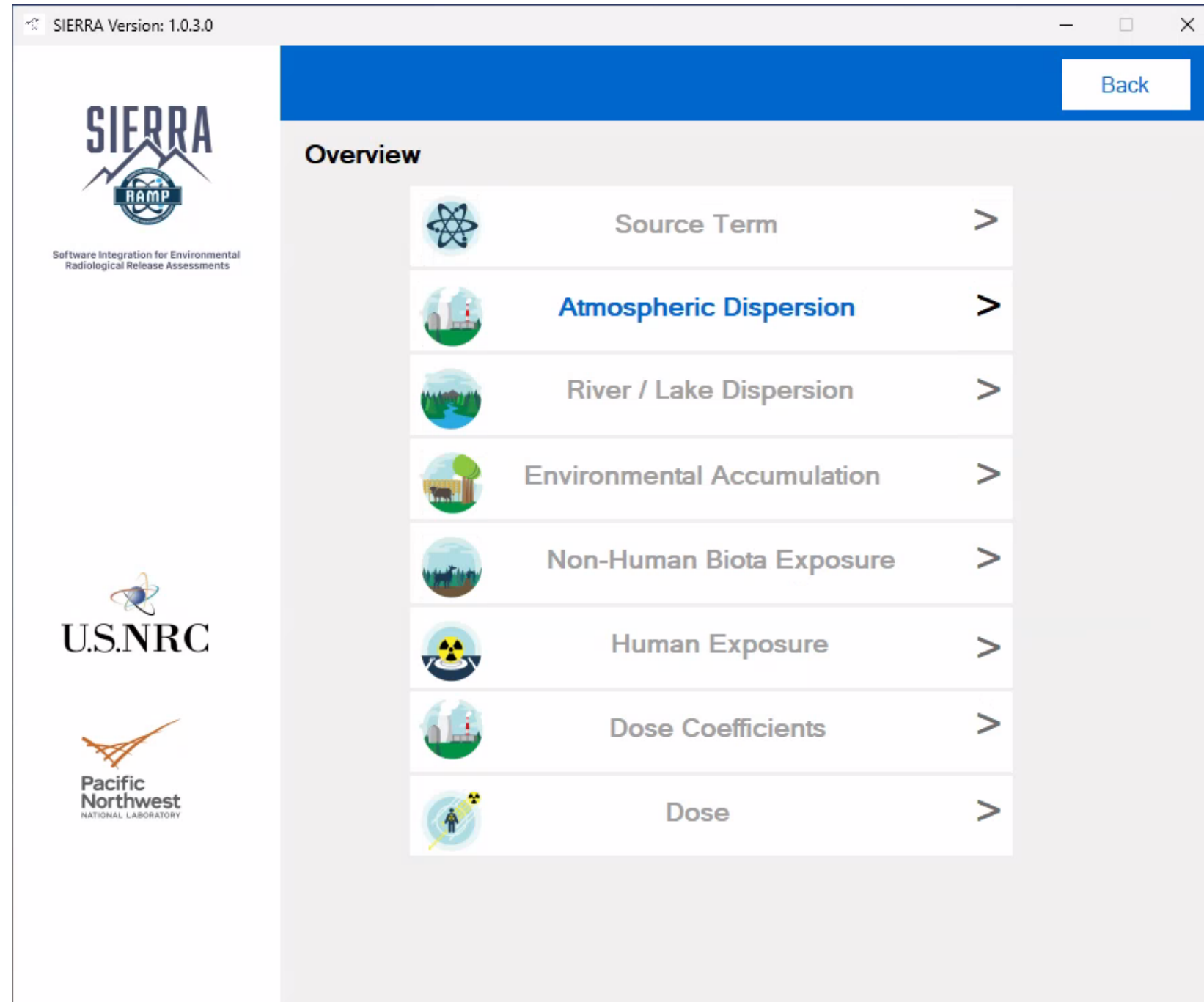
SIERRA Development

- Three Pillars:
 - Create consolidated engines/modules
 - Develop a standardized data transfer schema
 - Build a single user interface.



SIERRA Modules

- An overview of the SIERRA GUI demonstrating the planned modules
- SIERRA ATD is the first module to be released



SIERRA ATD



SIERRA Atmospheric Transport & Diffusion (ATD) Development

- The ATD module was developed :
 - To support a single user interface that allows users to access the functionality of ARCON, PAVAN, & XOQDOQ in a relatively uniform manner
 - To facilitate future development to share data with other modules in SIERRA
 - To allow users to estimate relative concentrations based on **hourly meteorological data for all three codes**
 - To employ a more modern FORTRAN code development practice, which makes the code easier to maintain in the future



SIERRA ATD Assessment Types

Code	ATD Module	NRC Guidance Document	Applicability	Outputs		
				What	Where	When
ARCON	Onsite Control Room DBA Analysis	RG 1.194	Evaluate personnel exposures inside the control room during accidents	χ/Q	Single receptor (Control Room)	Standard Time Intervals
PAVAN	Offsite DBA Analysis	RG 1.143	Offsite consequence at EAB and LPZ for plant design	χ/Q	2 sets of distances (EAB & LPZ)	Standard Time Intervals and Annual
XOQDOQ	Routine Release Analysis	RG 1.111	Annual dose assessment to ensure below threshold limit during normal operations	χ/Q & D/Q	0.5 to 50 mi	Annual averages

Standard Time Intervals:

0-2 hr

2-8 (ARCON), 0-8 (PAVAN) hr

8-24 hr

1-4 day

4-30 day

χ/Q (sec/m³): relative concentration of a radioactive material in air normalized by the release rate

D/Q (1/m²): normalized deposition factor; rate transfer of radionuclides and particulates from the air to the ground (deposition) divided by the release rate



Available Training

- An ATD training was given at the October 2024 RAMP User Meeting
- J Flaherty, PNNL-SA-204862
- <https://ramp.nrc-gateway.gov/codes/sierra-atd/training>

**RAMP Website**
Radiation Protection Computer Code
Analysis and Maintenance Program

[CODES +](#) [MEMBERSHIP +](#) [MEETINGS +](#) [PARTNERS](#) [ABOUT +](#) [CONTACT](#)

Code Menu

- [SIERRA Overview](#)
- [Documentation](#)
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- [Training](#)
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SIERRA ATD

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SIERRA ATD is an atmospheric transport and dispersion code used for analysis in siting, licensing, and environmental reviews.





Overview of Updates from Legacy Codes

- **All Modules**

- Meteorological Data Processing
- Handling of Calm Wind Conditions
- Interpretable Input Files

- **Offsite DBA Analysis (PAVAN) Specific Upgrades**

- GUI!
- Plume rise implementation



Meteorological Data Processing

- Data Comparisons

Code	Meteorological Data Format	Stability Class
SIERRA ATD	Hourly: Reg. Guide 1.23 format	Determined from hourly dT/dz records
ARCON	Hourly: in ARCON format	Provided by inputs
PAVAN	Joint Frequency Distributions (JFD)	
XOQDOQ		

- Reg Guide 1.23 Format (ASCII text data file)
 - 5 header lines (plant name, location, dates, heights of measurements)
 - One record per hour
 - contains data for up to 3 measurement heights, temperature differences, precipitation
 - Special Codes
 - **99999**: indicates lost or missing record
 - **77777** in wind direction: indicates calm

Reg Guide 1.23 Example

This is a combination of Meteorological Station Met Data (1983 - 1987) created by CJF
Met Data was obtained from the Meteorological Tower and Surface Observation Files
Measurement Heights are 15, 61, and 122 meters
Met Variables are Wind Direction and Wind Speed at all Levels as well as Delta - T for Upper - Lower
Conversion to NRC REG1.23 Rev1 Format Using Base File: HMS 8387.met

1

01983 1 100122.0330.0 3.6999.9999.9999.9999.9 61.0330.0 3.6999.9999.9999.9999.9 15.0320.0 2.7999.9999.9999.9999.9 -1.0999.9999.9999.9999.9999.9

2 3 4 5 6 7 8

6 7 8

6 7 8

9

#	Entry	Format	Units	Notes
1	Header	160 characters	—	Must be 5 lines
2	Identifier	4 characters	—	
3	Year	Integer (4 digits)	—	
4	Julian Day	Integer (3 digits)	—	
5	Hour	Integer (4 digits)	—	On 24-hour clock
6	Measurement Height	Floating point (5 characters, 1 digit after decimal)	m	Set for Upper, middle, and lower
7	Wind Direction		°	
8	Wind Speed		m/s	
9	Temperature Difference (Upper – Lower)		°C/100 m	

Treatment of Calm Winds

ATD	ARCON	PAVAN	XOQDOQ
For Control Room: All calms are assigned to the direction to the receptor.	All calms are assigned to the direction to the receptor.	If a WD is provided, use the given WD. If no WD is provided, distribute the calm occurrences by assigning them in proportion to the directional distribution of non-calm winds with speeds less than 1.5 m/s.	If a WD is provided, use the given WD. If no WD is provided, distribute the calm occurrences by assigning them in proportion to the directional distribution of the first non-calm wind speed class.
For Design Basis and Routine Analyses: All calms are distributed equally across all wind directions (WD).		If no WD is provided and there are no winds below 1.5 m/s, distribute the calms equally across all wind directions.	



Interpretable Input Files

SIERRA .json files

```

{
  "release_type": "GROUND",
  "stack_height": 10.0,
  "stack_dia": 0.1,
  "stack_flow": 0.0,
  "stack_terrain": 0.0,
  "stack_heat_emis": 0.0,
  "building_area": 0.0,
  "building_ht": 0.0
},
"receptor_info":

```

```
"prog_defaults_info":
{
  "diffusion_option":1,
  "recirculation_factor_flag":true
}
```

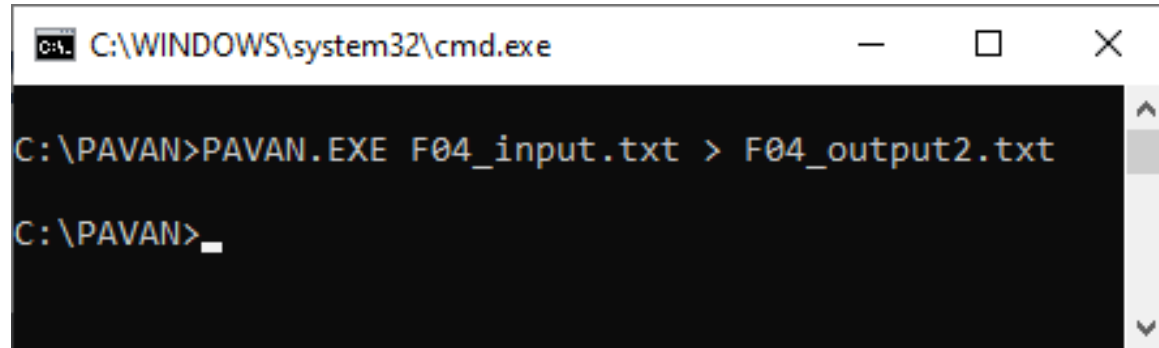
```

1010011101001
NRC NUREG-CR-2919 Test Case 1
5 7 3 5 3 2 0
10 101 2.26 -8 0
0 0 4 4 4 4 4
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
1 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 1
0.5 -100 1 2 4 8 16
100 100 100 100 100 100 100 100 100 100 100 100 100 100 100
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
800 800 800 800 800 800 800 800 800 800 800 800 800 800 800
16 16 16 16 16 16 16 16 16 16 16 16 16 16 16
10000100001000010000100001000010000100001000010000100001000010000
200 200 200 200 200 200 200 200 200 200 200 200 200 200 200
3 3 2
Site Boundary
1 805 1 966 1 1127
Cows
1 1931 8 4989 16 4345
Residences
1 1931 8 6437
Mixed-mode Release - with Purge
10 2 45 40 2000 45 0
A 1 25 4
Ground Level
0 0 30 25 900 10 0
B 0 0 0

```

PAVAN-Specific Upgrades

- 1. PAVAN was only executed via the command line... SIERRA has a GUI



```
C:\WINDOWS\system32\cmd.exe

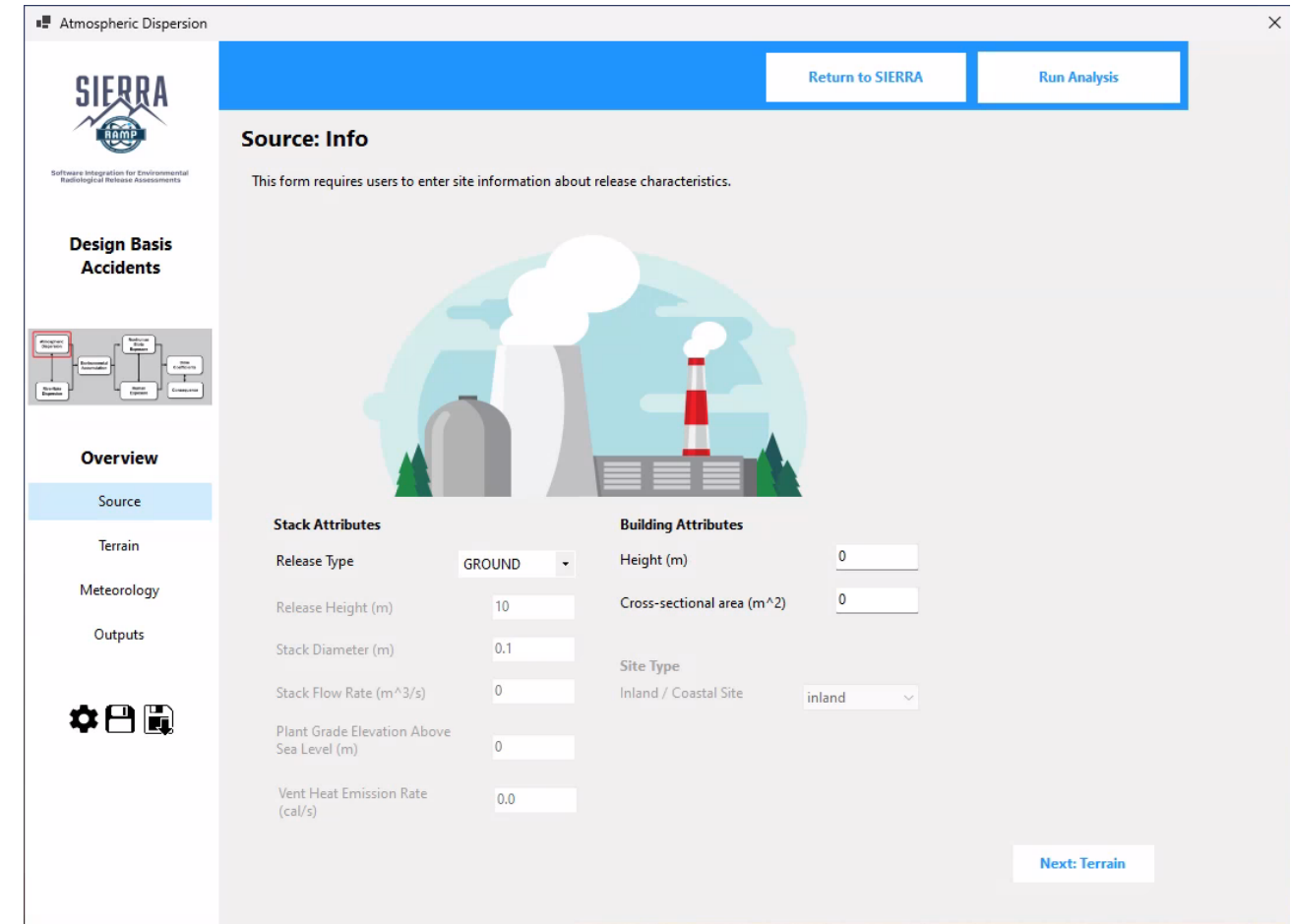
C:\PAVAN>PAVAN.EXE F04_input.txt > F04_output2.txt

C:\PAVAN>_
```

- 2. Plume Rise

Reg Guide 1.145

For those cases in which the applicant can demonstrate that the vertical velocity of effluent plumes from the plant (because of either buoyancy or mechanical jet effects) will be maintained during the course of the accident, this additional velocity may be considered in the determination of the effective stack height (h_e) using the same procedures described in regulatory position 2.a of Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors."



The screenshot shows the SIERRA Design Basis Accidents (DBA) software interface. The main window is titled "Atmospheric Dispersion" and features a sidebar with navigation options: "Source", "Terrain", "Meteorology", and "Outputs". The "Source" tab is selected, displaying a form titled "Source: Info". The form includes a "Return to SIERRA" button and a "Run Analysis" button. Below the buttons is a diagram of a nuclear reactor with a plume. The form contains two columns of input fields: "Stack Attributes" and "Building Attributes".

Stack Attributes	Building Attributes
Release Type: GROUND	Height (m): 0
Release Height (m): 10	Cross-sectional area (m ²): 0
Stack Diameter (m): 0.1	Site Type: Inland / Coastal Site (inland)
Stack Flow Rate (m ³ /s): 0	
Plant Grade Elevation Above Sea Level (m): 0	
Vent Heat Emission Rate (cal/s): 0.0	

At the bottom right of the form is a "Next: Terrain" button.

- In PAVAN, plume rise would have to be calculated independently
- In SIERRA, Reg Guide 1.111 plume rise algorithm is implemented

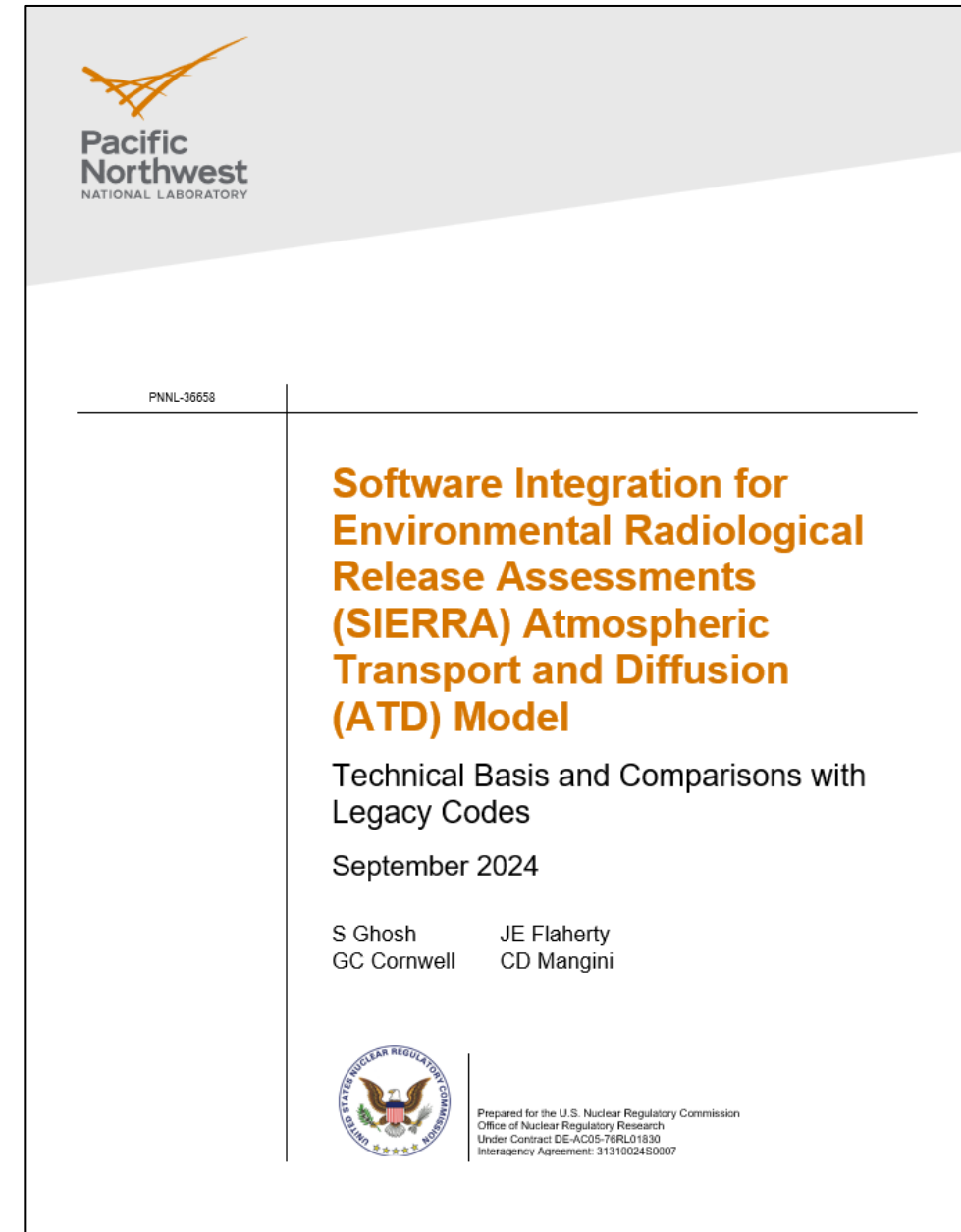


How Does SIERRA ATD Compare with Legacy Codes?



SIERRA ATD Technical Document

- The SIERRA ATD technical basis and comparisons with legacy codes is documented in Ghosh et al. (2024)
 - Comparisons were made with 22 site-specific meteorological datasets that contain 1-5 years of data
 - For each legacy model, a ground (10 m) and elevated (60 m) release case was defined
 - The PAVAN and XOQDOQ JFD files were defined such that the calm wind speeds were assigned a wind direction and distributed uniformly in the first wind speed class
 - Available on the RAMP website



Comparison with Legacy Codes: Metrics Overview

Metric	Description	Target Value	Formula	Notes
Modified Normalized Mean Bias (MNMB)	Average difference normalized by the mean	0%	$MNMB = \frac{100}{n} \sum_i \frac{M_i - O_i}{\frac{1}{2}(M_i + O_i)}$	M_i = ATD result O_i = Legacy result
Factor of 2 (F2)	Percent of ATD results within a factor of 2 of those of the legacy models	100%	$0.5 \leq \text{ATD/Legacy} \leq 2$	
Factor of 5 (F5)	Percent of ATD results within a factor of 5 of those of the legacy models	100%	$0.2 \leq \text{ATD/Legacy} \leq 5$	

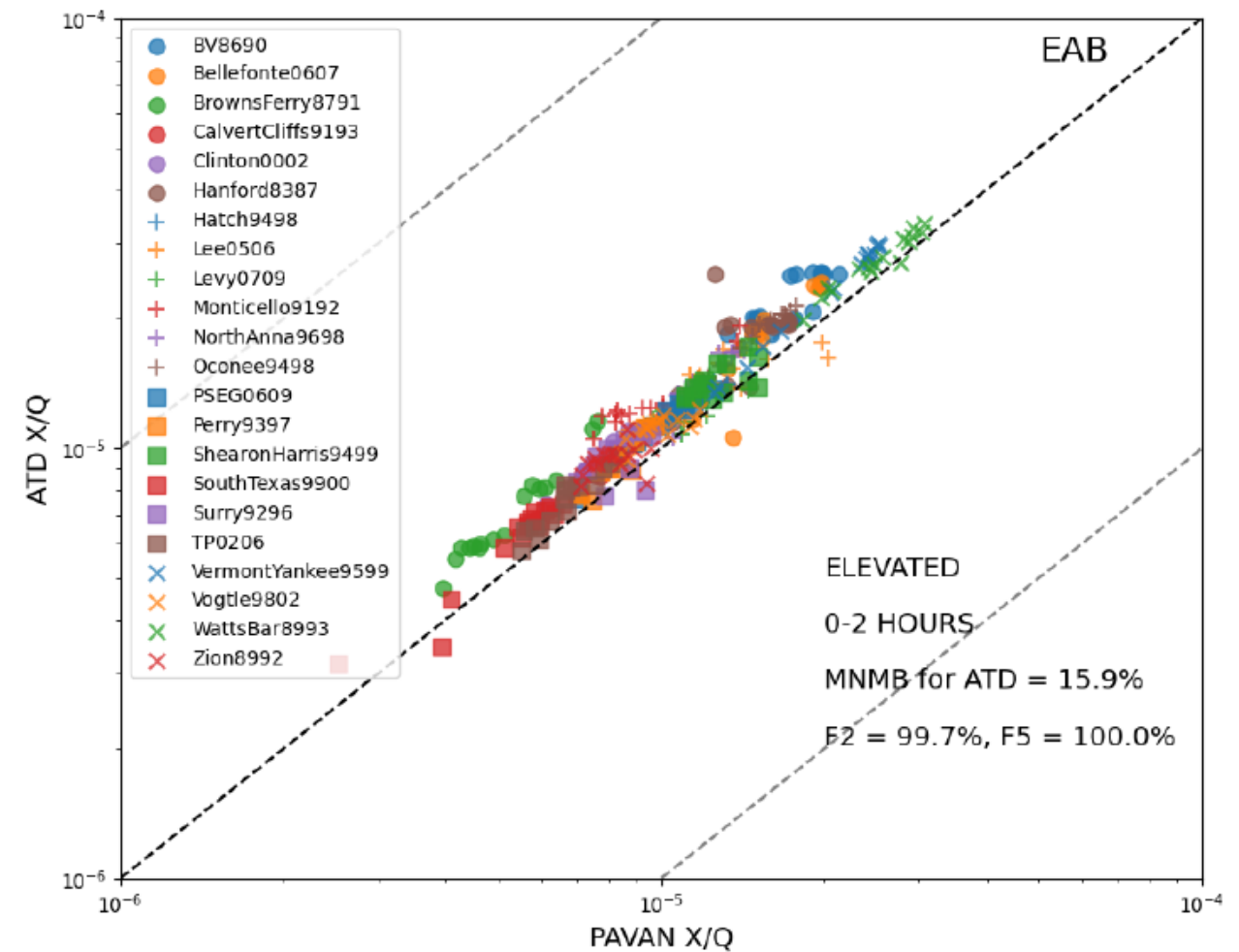
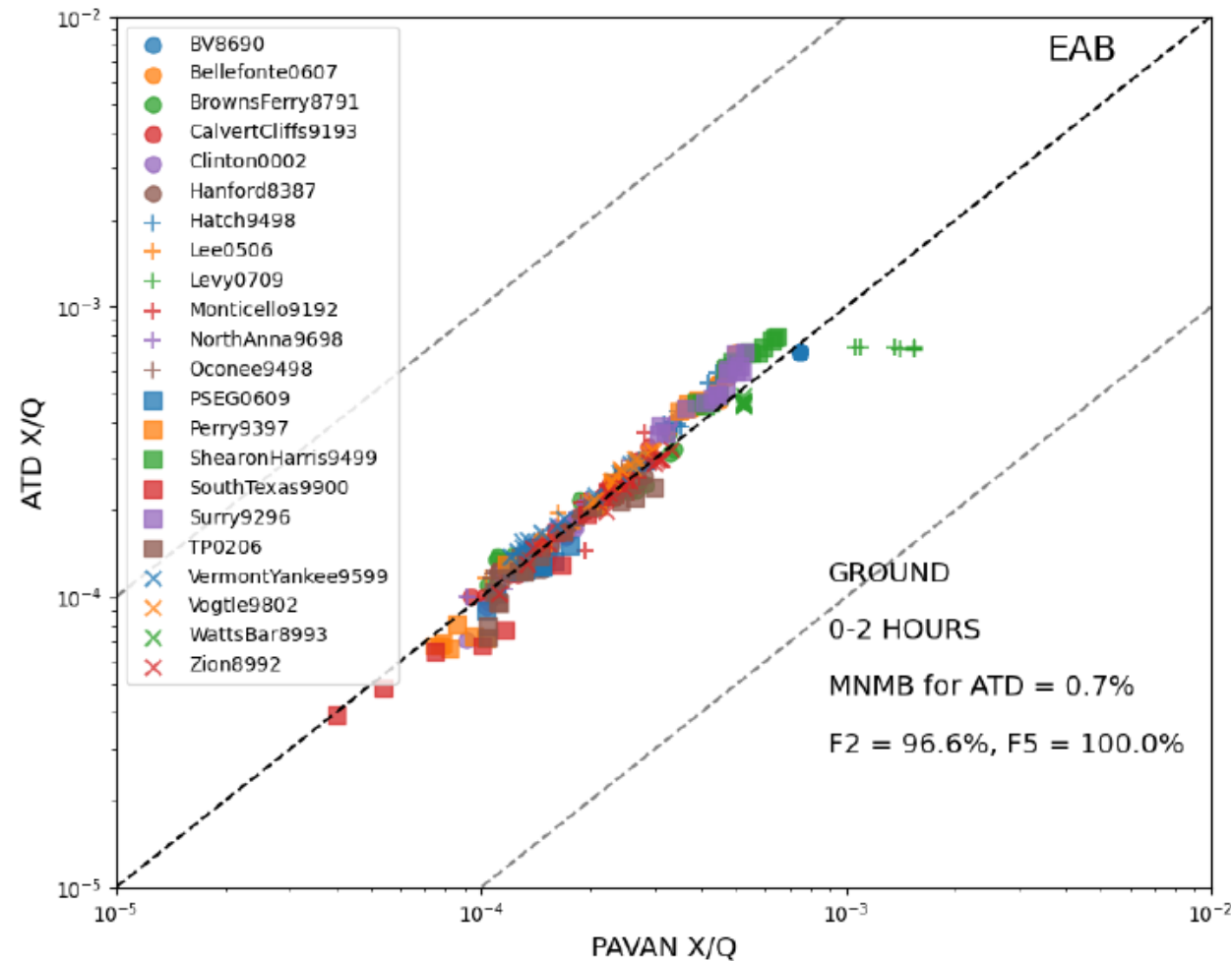
Comparison with Legacy Codes: Results

Legacy Code	Release Type	Result Type	MNMB (%)	F2 (%)	F5 (%)
ARCON	Ground	Standard Averaging Intervals	-0.26	100	100
	Elevated	Standard Averaging Intervals	0.04	100	100
PAVAN	Ground	EAB: 0-2 Hours	0.7	96.6	100
		LPZ: 0-2 Hours	2.4	96.6	100
	Elevated	EAB: 0-2 Hours	15.9	99.7	100
		LPZ: 0-2 Hours	7.5	100	100
	Ground	EAB: Annual Average	5	100	100
		LPZ: Annual Average	5.6	100	100
	Elevated	EAB: Annual Average	-0.5	100	100
		LPZ: Annual Average	1.3	100	100
XOQDOQ	Ground	1 mi: Annual Average	6.3	100	100
		10 mi: Annual Average	1.9	100	100
	Elevated	1 mi: Annual Average	-8.2	100	100
		10 mi: Annual Average	-4.8	100	100

Differences from PAVAN & XOQDOQ can be attributed to statistical processing differences between hourly and JFD data



Comparisons with Legacy Codes – PAVAN & ATD Design Basis Accidents



What's Next?



Upcoming SIERRA Development

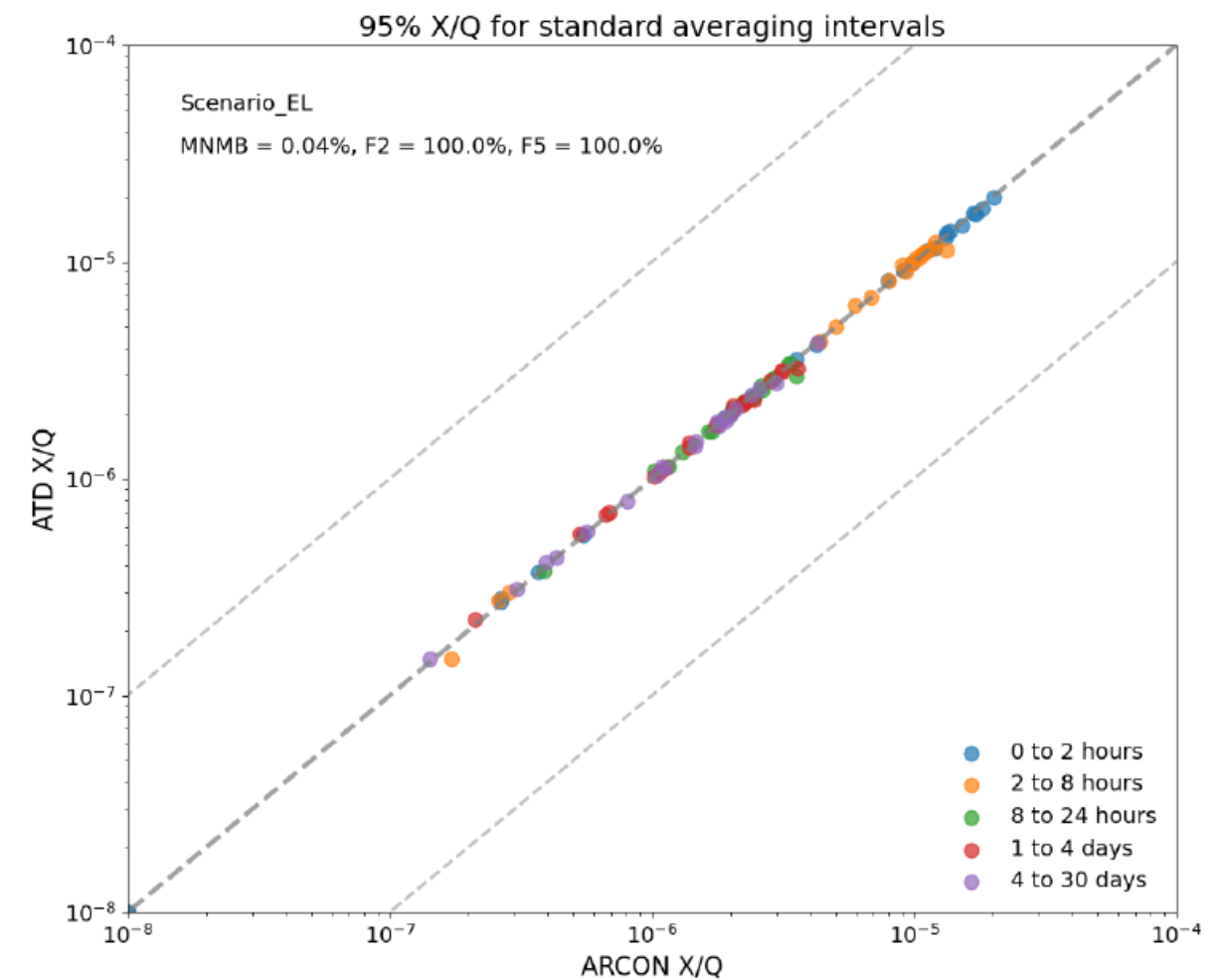
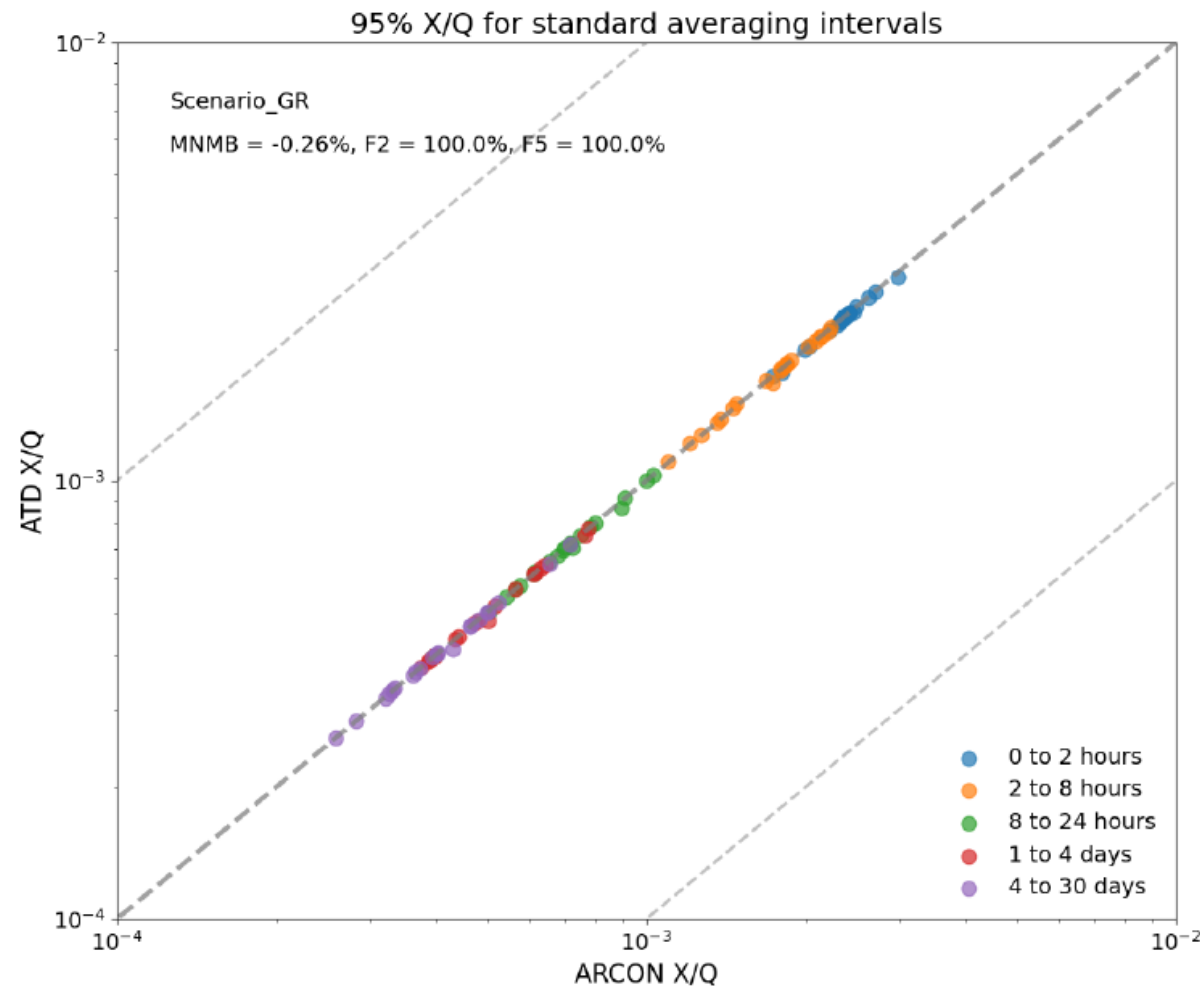
- SIERRA ATD v2.0
 - Includes Reg Guide 1.194 implementation of plume rise (Control Room), ability to run from the command line, various QOL updates, etc.
- SIERRA Source Term
 - Consolidation of GALE into SIERRA
 - Updates for Advanced Reactor Source Terms
- SIERRA Environmental
 - Modernization and consolidation of GASPAR & LADTAP (rest of NRC Dose3) into SIERRA



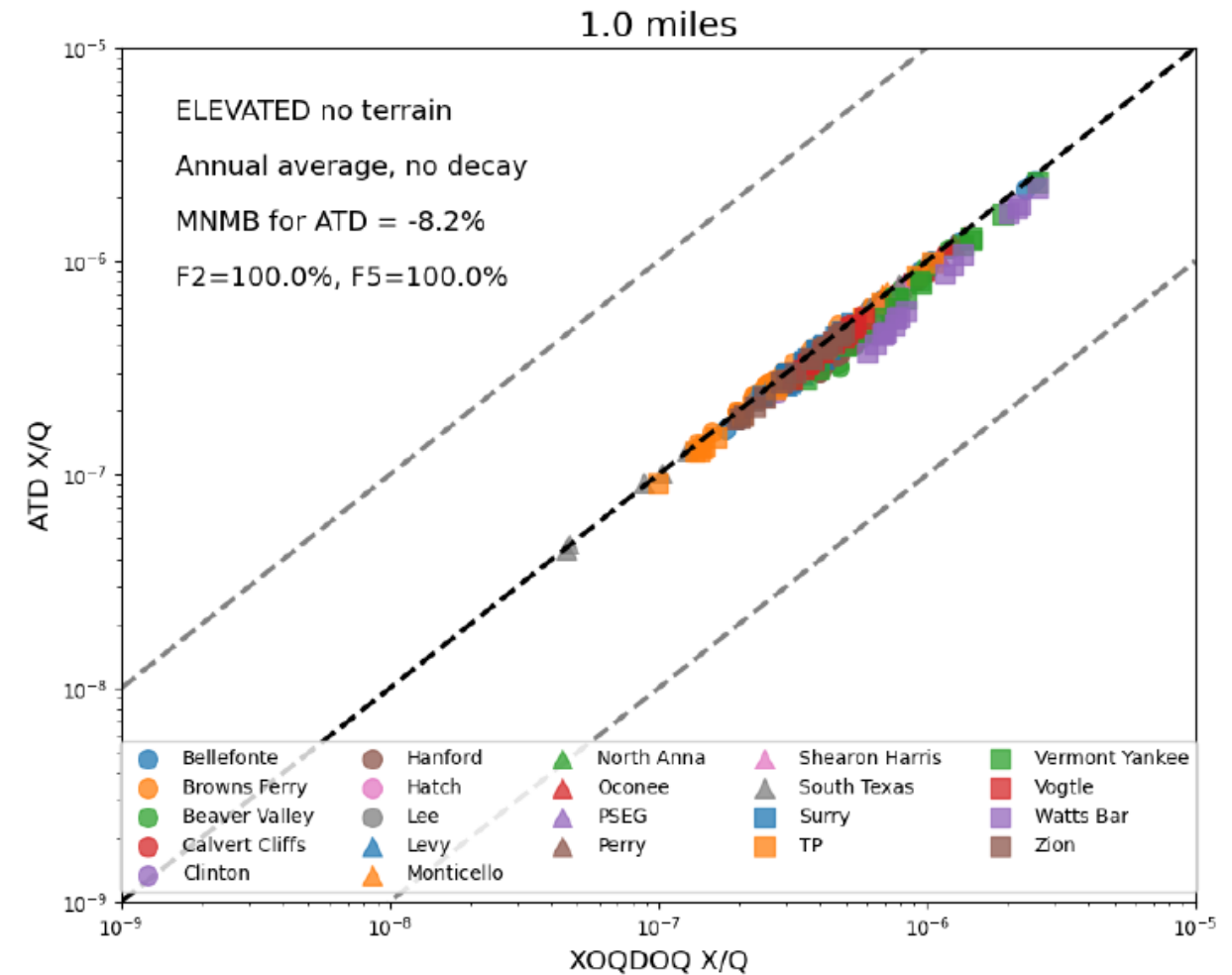
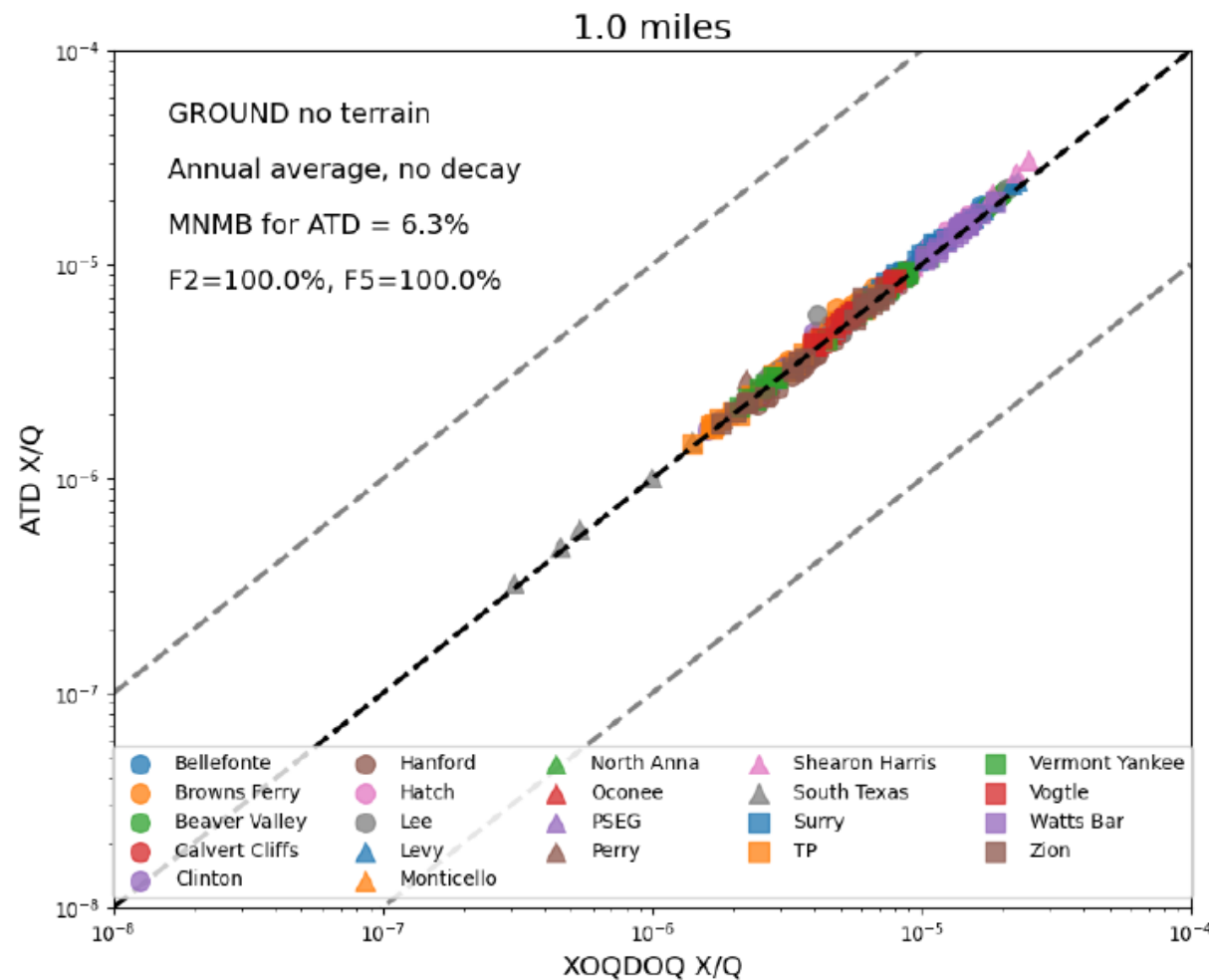
Questions??



Comparisons with Legacy Codes – ARCON & ATD Control Room Analysis



Comparisons with Legacy Codes – XOQDOQ & ATD Routine Analysis



Thank you

