Transforming Meteorological Data Processing for Air Quality Modeling

Management Performance Hub Data Day

April 30, 2026

Presentation Roadmap

Why This Matters

The Old World

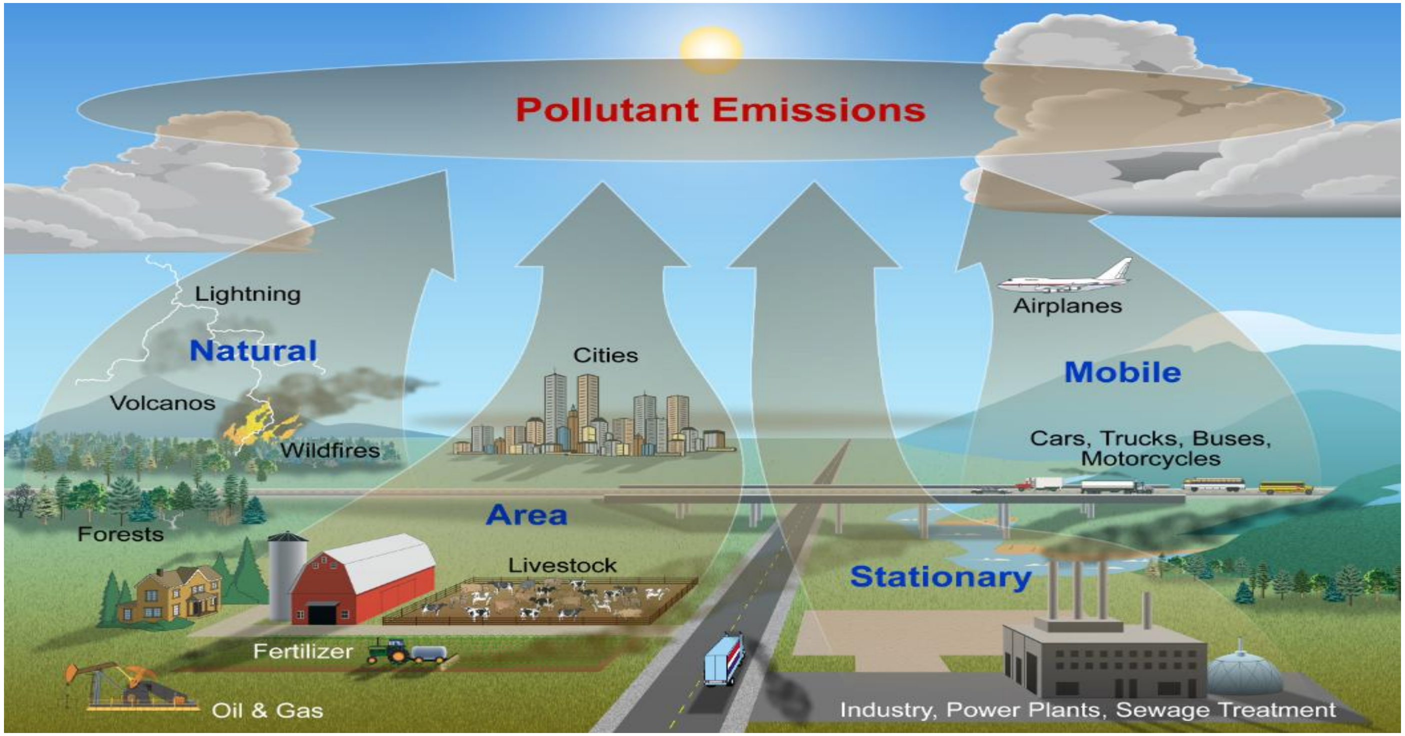
The Transformation

The New Workflow

What Comes Next

Why This Matters

Visual Depiction of Air Pollution Plumes



Source: National Park Service

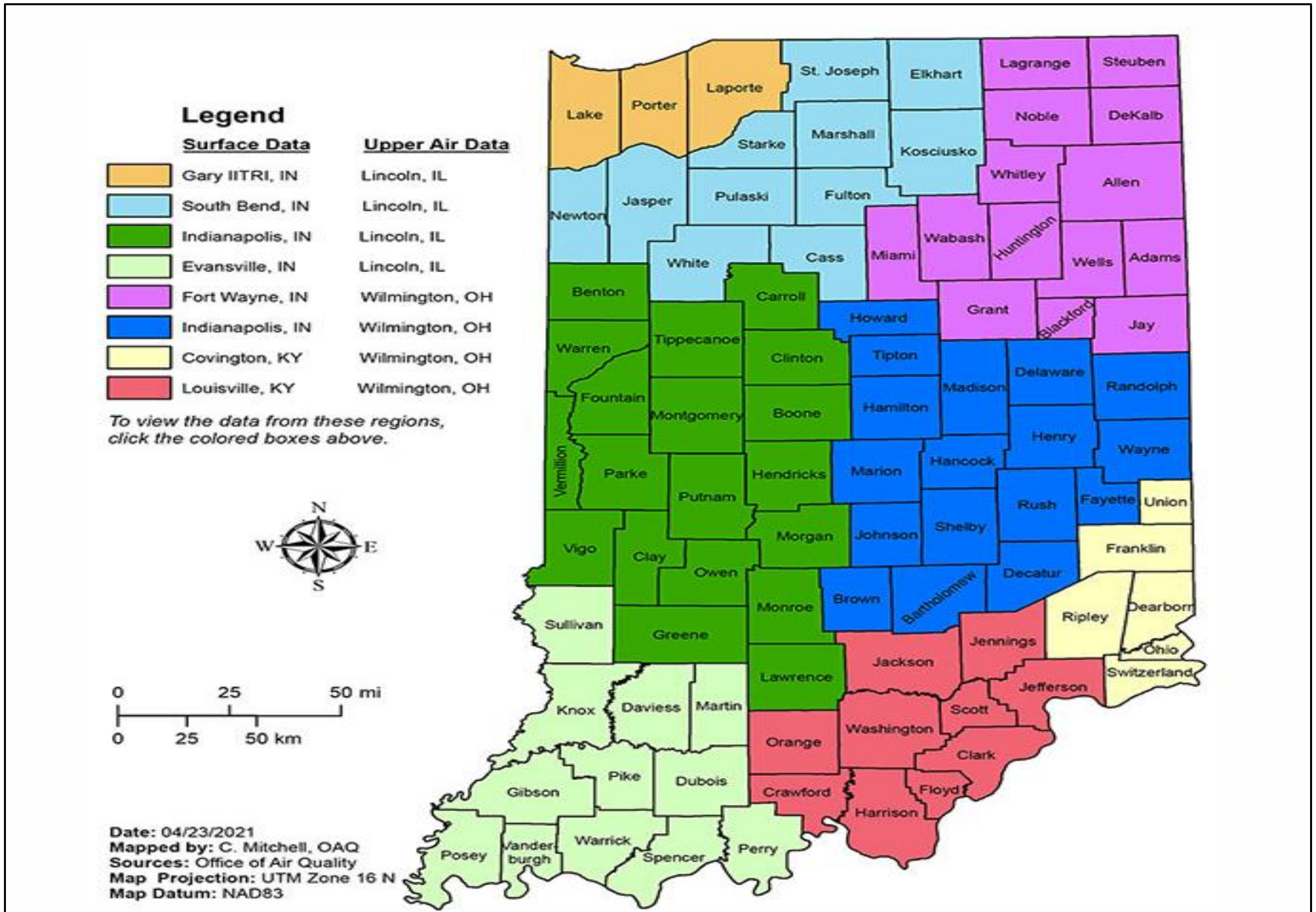
What This Data Supports

- State air-quality regulatory modeling
- Air permit evaluations
- EPA-approved dispersion modeling
- Analysis of thousands of meteorological hours each year

Why Accuracy Matters

- Meteorological inputs drive credible air quality modeling results
- Errors can distort dispersion outcomes
- Modeling supports permitting, compliance, and public health

Where We Process Meteorological Data and Why It's Needed



Core Data Inputs

- Surface and upper-air observations
- High-frequency wind data
- Land-cover information
- Local climate and precipitation records

Modeling Tools We Use

- What is AERMET?
  - AERMOD Meteorological Preprocessor
- What is AERMOD?
  - American Meteorological Society / Environmental Protection Agency Regulatory Model
  - US EPA's primary regulatory dispersion model

What does AERMET do?

- A preprocessing tool that prepares weather data for AERMOD
- Converts raw meteorological data into the specialized format AERMOD needs
- Provides wind, temperature, turbulence, cloud cover, and other atmospheric parameters

What does AERMOD do?

- Predicts how pollutants travel once released into the atmosphere
- Incorporates emissions data, stack characteristics, local terrain, and meteorological conditions
- Estimates pollutant concentrations that could be experienced at ground level

The Old World

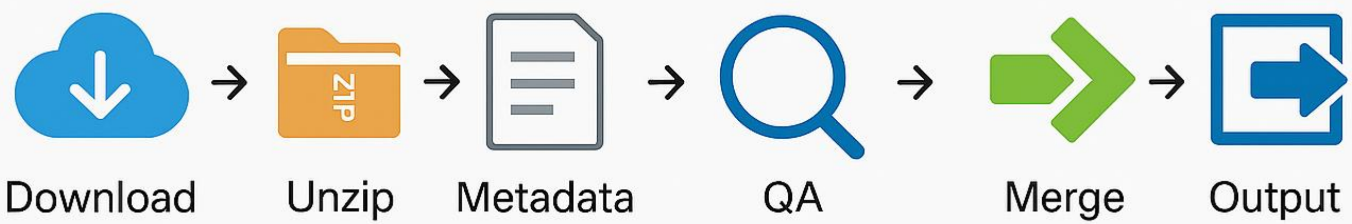
Why Modernization Was Needed

- Manual downloads from multiple, unlinked data sources
- Heavy spreadsheet work and manual file merging
- High potential for QA/QC errors
- ~8 hours of processing per site (plus one site requiring extra steps)

What the Old Tools Looked Like

- Multiple AERMET runs
- Manual merging
- GUI heavy workflow
- Snow cover spreadsheet, etc.

Legacy Meteorological Data Workflow:
Why It Needed Change



Pain Points

- Manual renaming and file handling
- Complex snow cover logic
- Multiple data sources – high error risk
- QA/QC delays – slow turnaround

The Transformation

From Idea to Automation

- AI reviewed the 64-page manual process and identified automation opportunities using Python
- Team prototyped a hybrid process using Python; later adopted an R-based workflow after collaborating with other states
- Human review ensured compliance with EPA modeling guidance
- Iterative refinements with staff and AI support accelerated development

Six Sigma Waste Analysis

- Overproduction: Redundant runs
- Overprocessing: Manual file handling
- Defects: Manual snow cover calculations
- Waiting: QA delays
- Automation opportunities exist for all

SMART Goals

- Specific: Implement protocol
- Measurable: 50% pilot, 90% full
- Achievable: Existing tools
- Relevant: Compliance
- Time-bound: May 2026

Project Objectives

- Reduce manual effort
- Improve QA/QC transparency
- Maintain compliance
- Institutionalize workflow
- Achieve >90% time savings

Project Scope

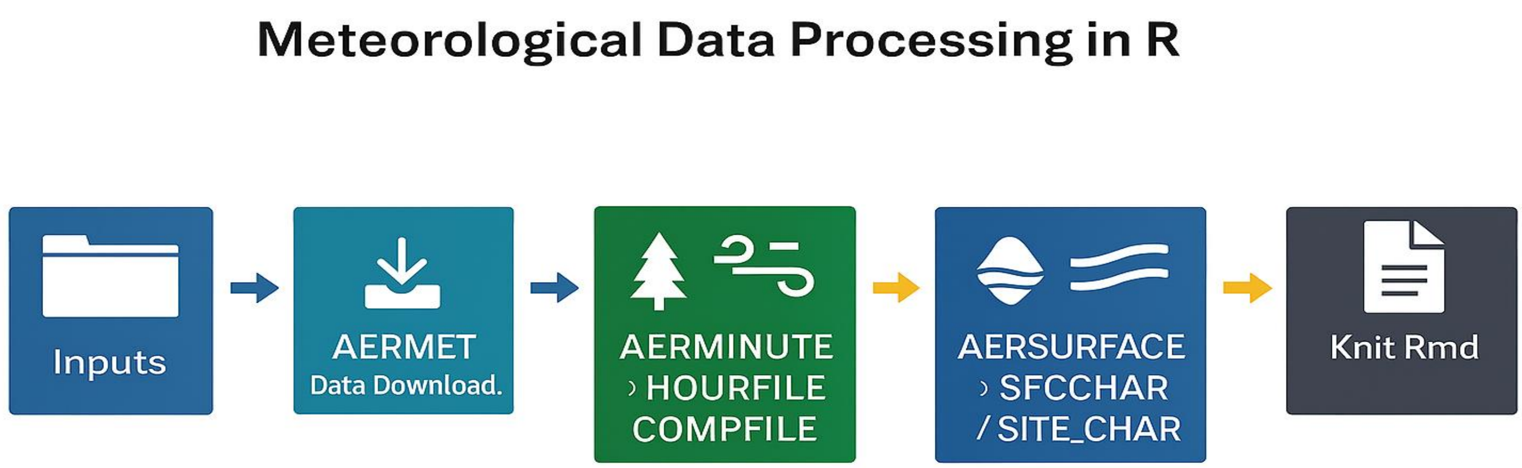
- In-Scope: Hybrid/fully automated workflow, QA/QC logs, SOPs, training, historical data
- Out-of-Scope: Routine ops, software procurement
- Deliverables: SOPs, workflow docs, QA/QC records
- Success: >90% time savings, EPA-ready docs
- Achieved by using existing resources

Key Features

- Centralized metadata system
- Automated retrieval for NWS sites
- Dedicated onsite workflow for Gary IITRI
- Full-year automated testing for every site
- Batch processing capability for multi-site runs
- Integrated QA/QC
- No additional costs were incurred

New Workflow

Final Automated Workflow



Bringing the new automated process to life

Now that we've shown how the data is processed, let's look at how this data is used.

Initial Data Download

- Script downloads all required datasets for a full year
- Includes surface, upper-air, wind, precipitation, snow cover, and land-cover data
- User only selects the year to process

Manual Processing Eliminated Through Automation

	Win SNOW	Win nosnow	Bowen Spring	Ratios Summer	Fall
Wet	0.5	0.42	0.24	0.32	0.42
Average	0.5	0.75	0.37	0.52	0.75
Dry	0.5	1.99	1.12	1.45	1.99

Albedo

Win SNOW	Win nosnow	Spring	Summer	Fall
0.56	0.18	0.15	0.19	0.19

Import	Cut / paste functions
Export	Cut / paste values

Sector	Roughness Winter	Spring	Summer	Fall	SNOW-covered roughness Winter
1	0.031	0.041	0.178	0.174	0.015
2	0.03	0.041	0.142	0.134	0.015
3	0.2	0.024	0.03	0.027	0.012
4	0.019	0.023	0.031	0.028	0.011
5	0.02	0.024	0.032	0.028	0.011
6	0.019	0.022	0.029	0.026	0.011
7	0.018	0.022	0.028	0.024	0.01
8	0.046	0.06	0.18	0.172	0.025
9	0.039	0.051	0.204	0.202	0.02
10	0.033	0.044	0.187	0.183	0.016
11	0.036	0.049	0.194	0.189	0.018
12	0.026	0.037	0.13	0.123	0.013

Snow Cover Days

	Jan	Feb	Dec
2011	24	23	4
2012	10	5	5
2013	9	8	9
2014	27	28	0
2015	17	26	0
2016	5	2	16
2017	0	2	12
2018	18	6	0
2019	18	8	3
2020	3	12	2
2021	3	26	2
2022	9	20	5

Remember : Formulas for February need to be checked for leap days

SITE_CHA	1	1	0.290	1.557	0.031
SITE_CHA	1	2	0.290	1.557	0.03
SITE_CHA	1	3	0.290	1.557	0.2
SITE_CHA	1	4	0.290	1.557	0.019
SITE_CHA	1	5	0.290	1.557	0.02
SITE_CHA	1	6	0.290	1.557	0.019
SITE_CHA	1	7	0.290	1.557	0.018
SITE_CHA	1	8	0.290	1.557	0.046
SITE_CHA	1	9	0.290	1.557	0.039
SITE_CHA	1	10	0.290	1.557	0.033
SITE_CHA	1	11	0.290	1.557	0.036
SITE_CHA	1	12	0.290	1.557	0.026
SITE_CHA	2	1	0.451	0.477	0.031
SITE_CHA	2	2	0.451	0.477	0.03
SITE_CHA	2	3	0.451	0.477	0.2
SITE_CHA	2	4	0.451	0.477	0.019
SITE_CHA	2	5	0.451	0.477	0.02
SITE_CHA	2	6	0.451	0.477	0.019
SITE_CHA	2	7	0.451	0.477	0.018
SITE_CHA	2	8	0.451	0.477	0.046
SITE_CHA	2	9	0.451	0.477	0.039
SITE_CHA	2	10	0.451	0.477	0.033
SITE_CHA	2	11	0.451	0.477	0.036
SITE_CHA	2	12	0.451	0.477	0.026
SITE_CHA	3	1	0.15	0.24	0.041
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SITE_CHA	3	3	0.15	0.24	0.024
SITE_CHA	3	4	0.15	0.24	0.023
SITE_CHA	3	5	0.15	0.24	0.024
SITE_CHA	3	6	0.15	0.24	0.022
SITE_CHA	3	7	0.15	0.24	0.022
SITE_CHA	3	8	0.15	0.24	0.06

Cut and paste Precipation VALUES only

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2011	1.8	3.21	3.03	5.3	10.17	3.25	0.98	3.37	4.76	3.81	6.09	3.77
2012	3.09	2.01	2.9	1.29	1.06	0.65	4.35	3.51	3.61	3.31	0.6	2.2
2013	3.43	1.86	2.34	7.1	2.94	5.91	3.68	5.08	1.89	3.66	1.46	2.86
2014	2.59	3.49	1.9	3.99	4.57	5.81	2	6.04	4.9	2.78	3.05	1.72
2015	2.23	1.54	2.07	3.28	5.01	11.98	5.97	3.57	3.03	1.43	2.13	4.15
2016	1.62	1.43	3.96	3.05	4.13	5.44	1.12	3.06	5.44	3.65	2.16	2.31
2017	4.71	1.76	3.81	3.95	9.22	7.31	4.36	3.16	1.67	2.24	5.49	1.01
2018	1.25	4.37	2.84	2.25	3.31	6.02	3.05	7.77	1.65	3.46	3.86	2.94
2019	2.12	2.43	3.95	5.55	3.82	2.74	3.31	4.35	2.59	3.69	1.65	2.83
2020	4.07	2.04	3.23	2.28	3.68	1.97	5.25	2.67	3.33	4.55	2.9	1.27
2021	1.87	1.57	2.69	2.95	4.67	5.91	5.59	2.46	3.78	7.31	1.07	4.27
2022	0.83	2.94	3.18	2.54	3.07	3.26	6.34	3.26	1.96	1.74	1.9	2.57
2023	2.75	4.16	4.86	1.96	4.06	1.39	5.28	2.48	1.63	3.44	0.64	1.69
2024												

Cut and paste %ile VALUES only

70%ile	2.759	2.576	3.257	4.071	5.019	5.473	5.44	4.066	3.828	3.653	2.973	2.839
30%ile	1.849	1.51	2.133	2.329	3.238	3.257	2.957	2.979	1.726	1.871	1.991	1.884
	1.849	1.51	2.133	2.329	3.238	3.257	2.957	2.979	1.726	1.871	1.991	1.884
	2.759	2.576	3.257	4.071	5.019	5.473	5.44	4.066	3.828	3.653	2.973	2.839

Things that may change from year to year

Wet / Dry / Average months
Snow Cover Days and winter functions
February Days

WET

SITE_CHA	1	1	0.290	0.443	0.031	SITE_CHA
SITE_CHA	1	2	0.290	0.443	0.03	SITE_CHA
SITE_CHA	1	3	0.290	0.443	0.2	SITE_CHA
SITE_CHA	1	4	0.290	0.443	0.019	SITE_CHA
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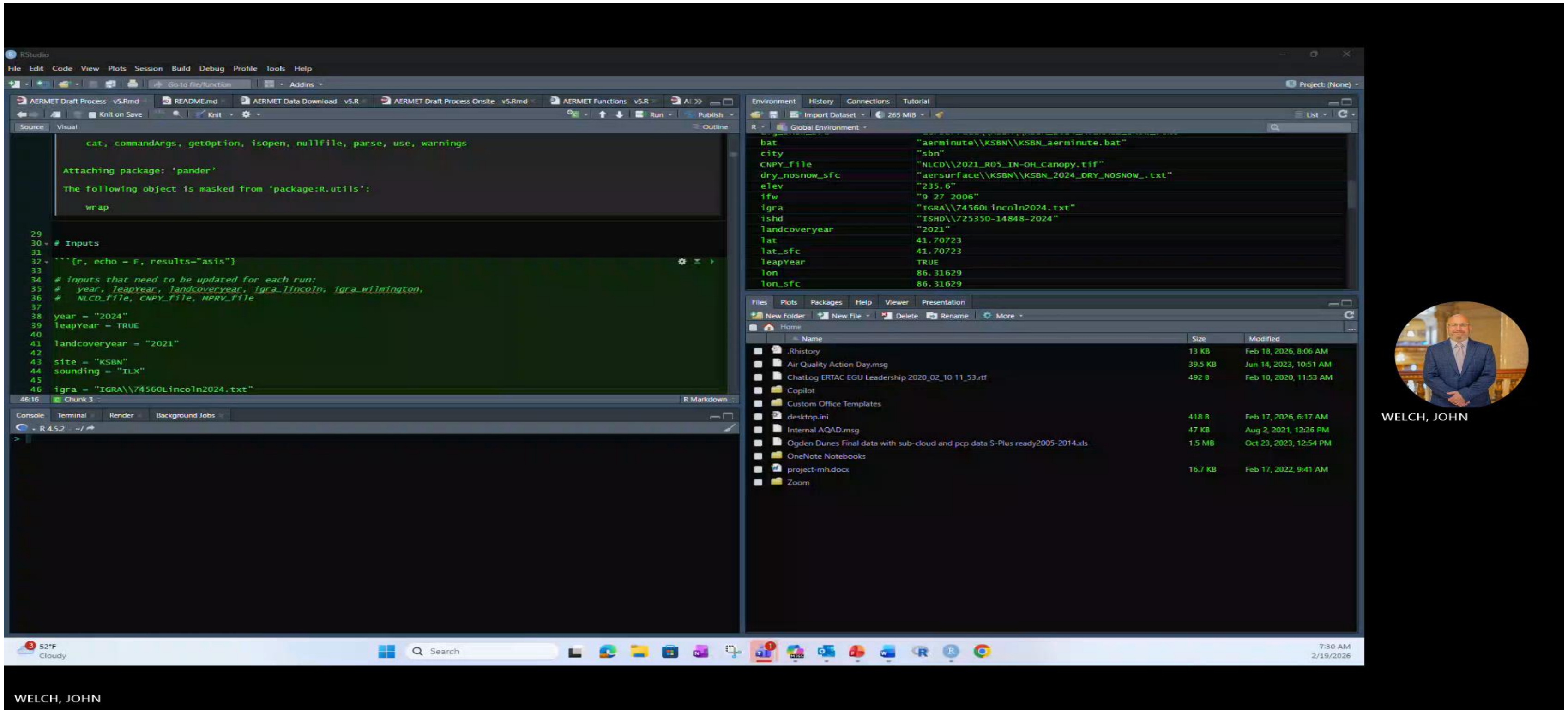
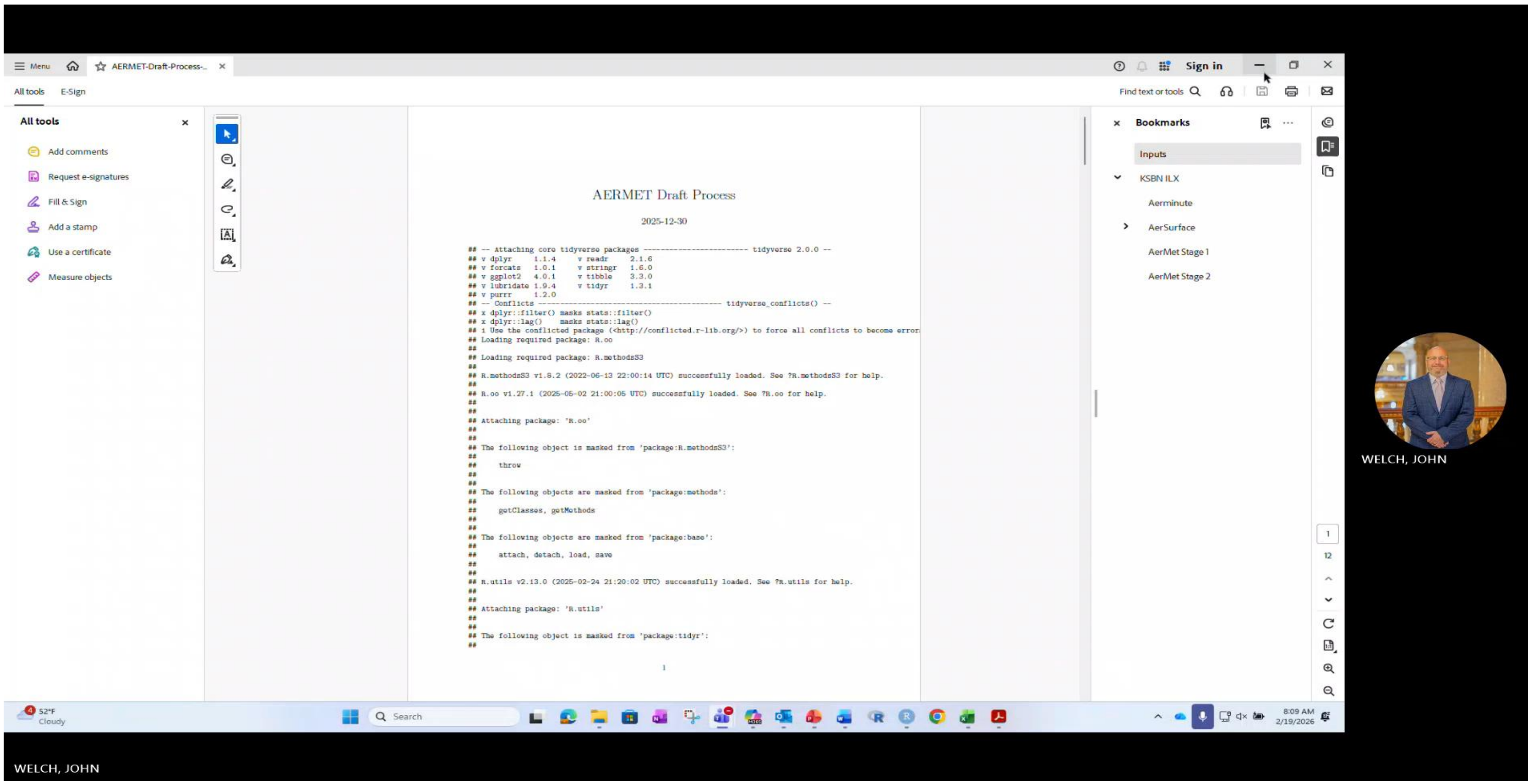
EVV | EVVb | FWA | CVG | IND | Ceilometer | SBN | SDF | GYY | EVVbave | INDave | SBNave | Sheet8 | +

Automation in Action:

South Bend Example



QA/QC Log Output

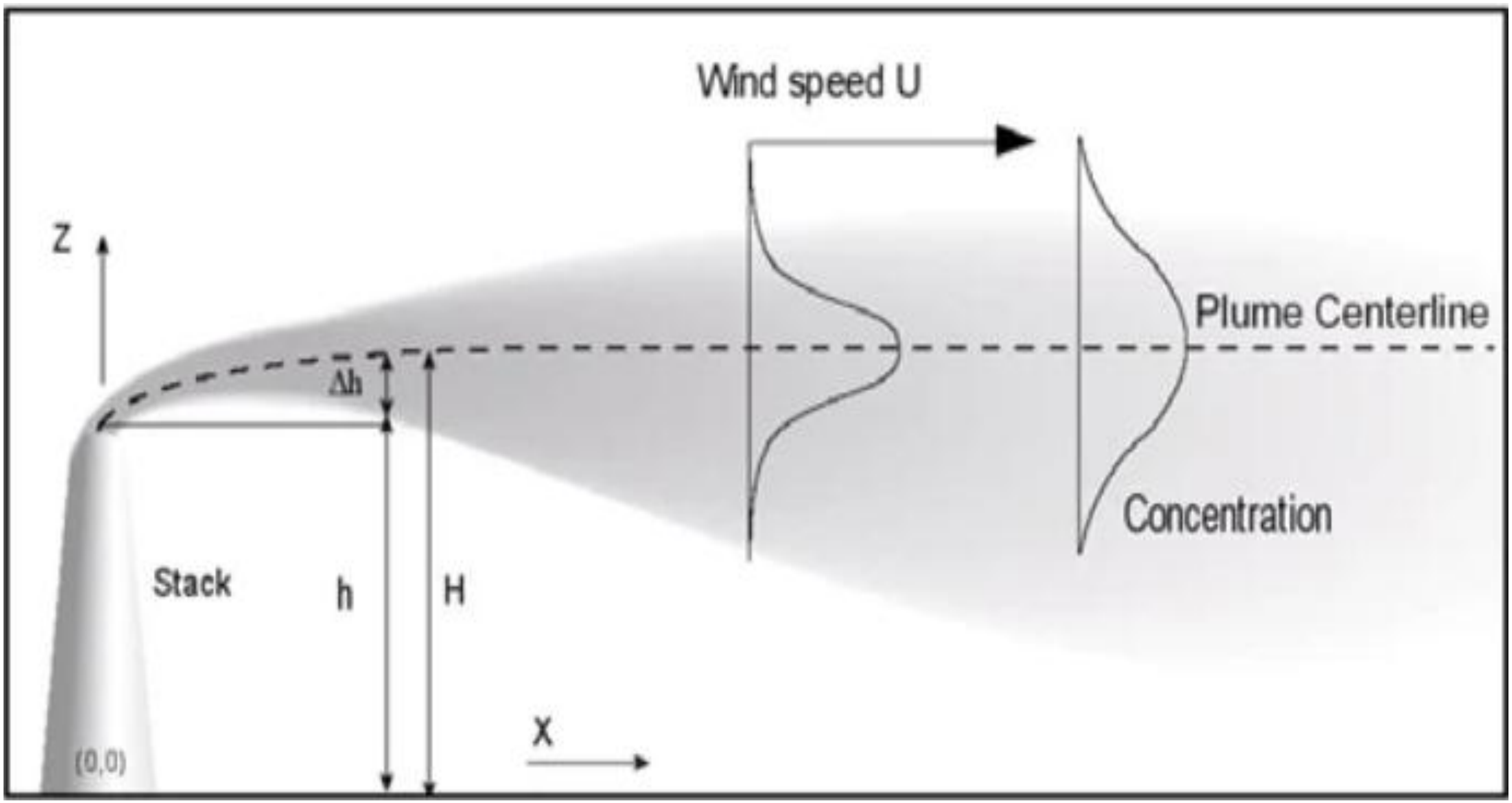


Protocol Development

- User guide created for non-R users
- Code fully documented and tested by multiple staff
- Updates will follow future EPA changes

We've processed the meteorological data—now what?

Data Inputs Used In AERMOD



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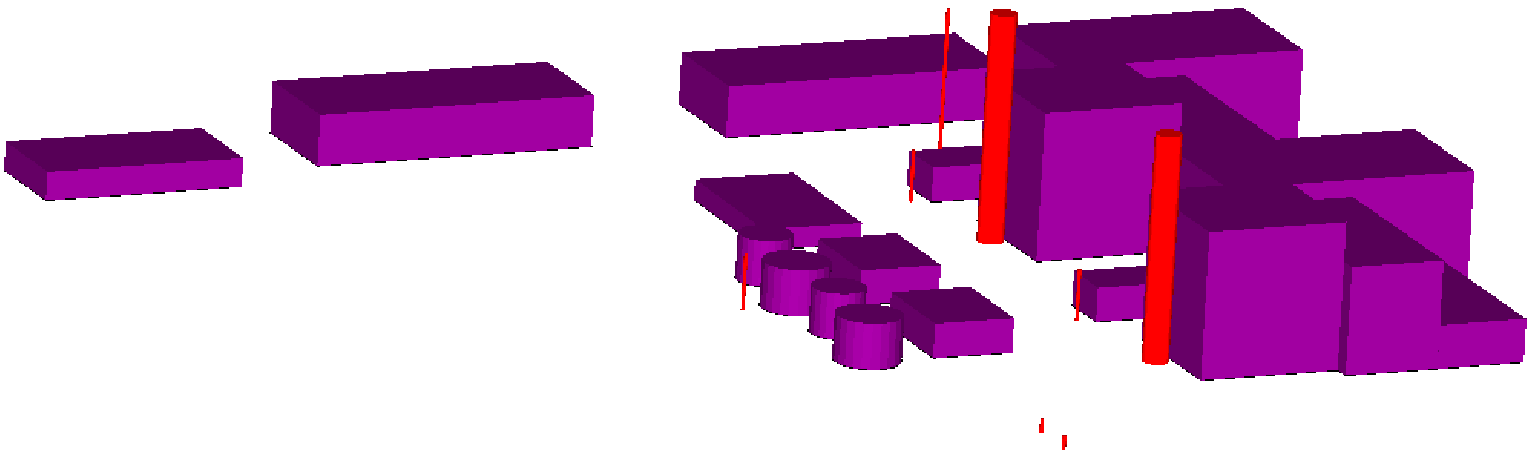

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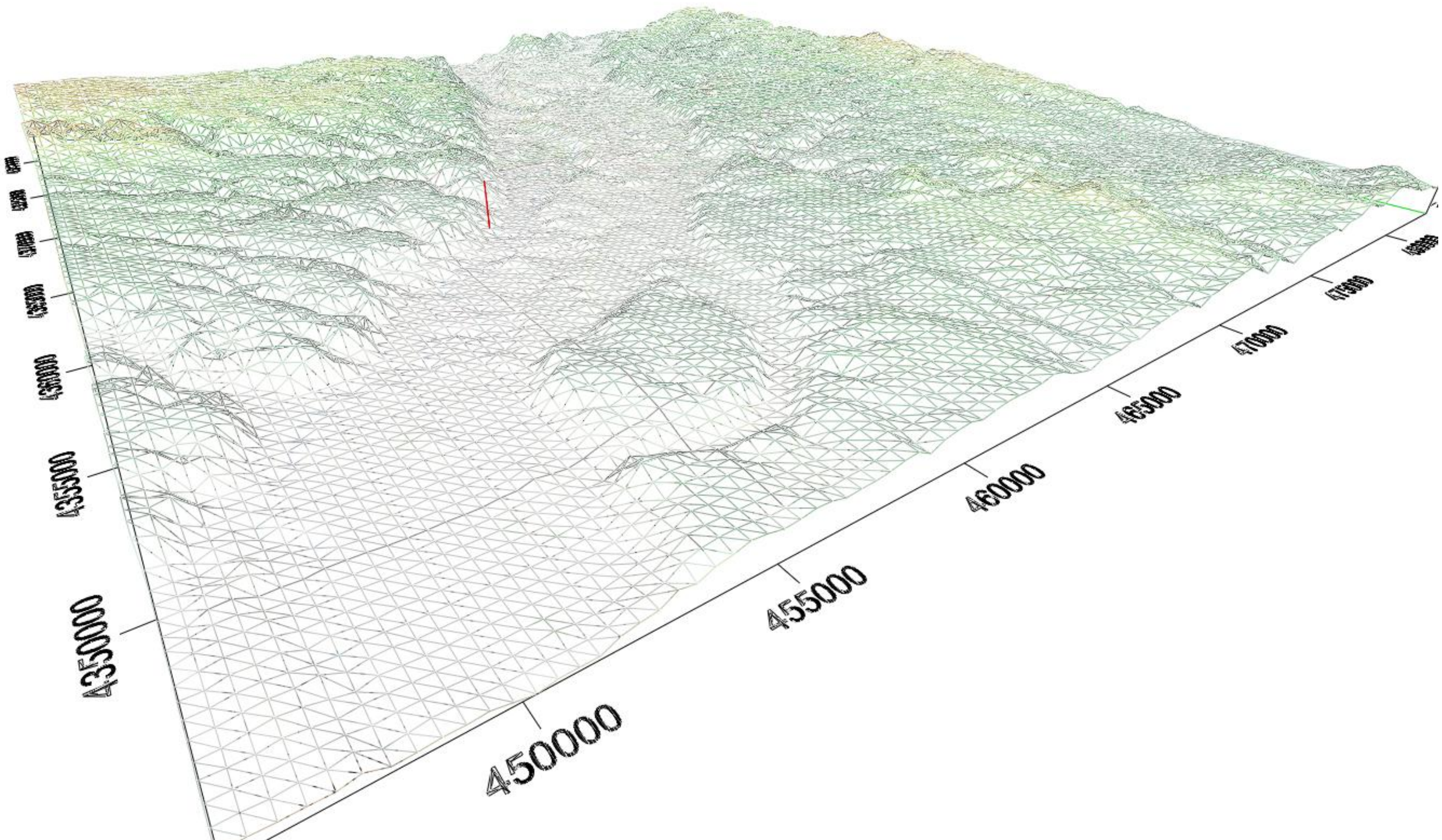

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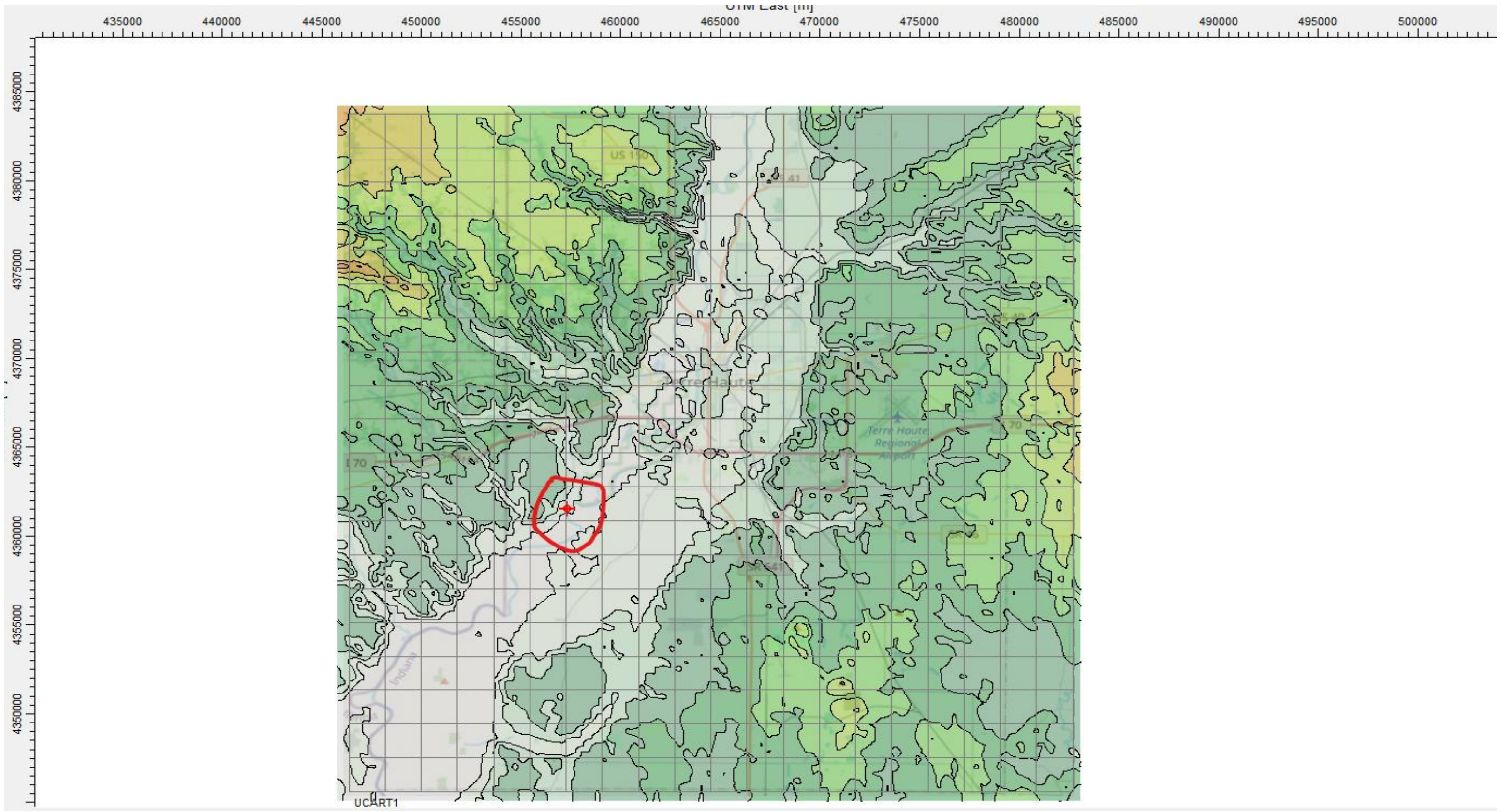
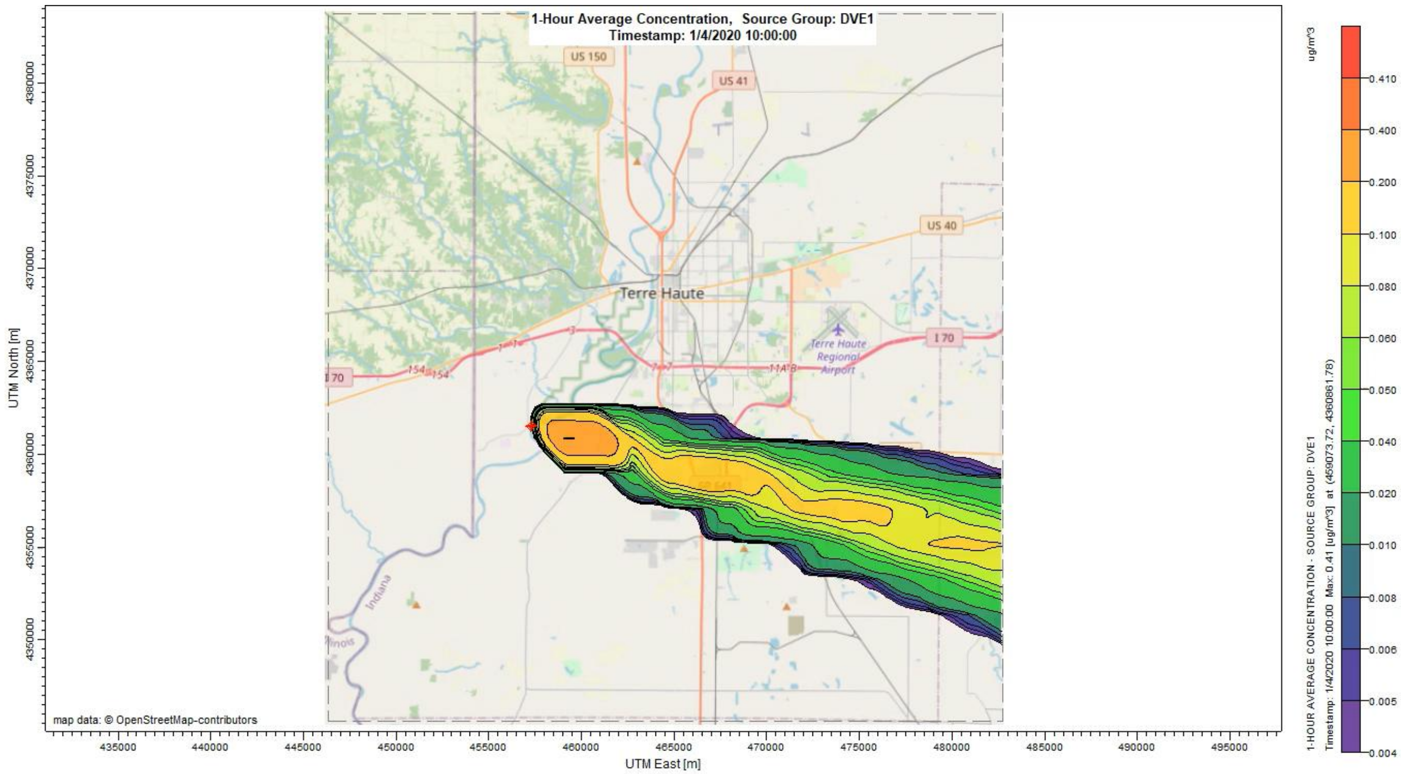


Role of Meterological Data in AERMOD



What Comes Next

Looking Ahead: Building on the Automation Success

- Identify new opportunities where manual steps can be automated
- Enhance cross-agency collaboration to strengthen code and processes
- Prepare for scaling to additional environmental modeling workflows

Key Takeaways

- **AI as a Catalyst, Not a Replacement**
  - AI provided initial insights and assisted with process improvements and waste analysis, but human expertise was essential for final implementation.
- **Human Oversight and Quality Control**
  - Staff refined and wrote the production-ready code, ensuring accuracy and alignment with organizational needs.
- **Collaboration Drives Success**
  - State-level collaboration played a critical role in improving the code and tailoring solutions to meet specific requirements.
- **Balanced Approach to Technology**
  - Combining AI-generated ideas with human judgment and inter-agency cooperation resulted in a more robust and reliable process.

Questions?

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