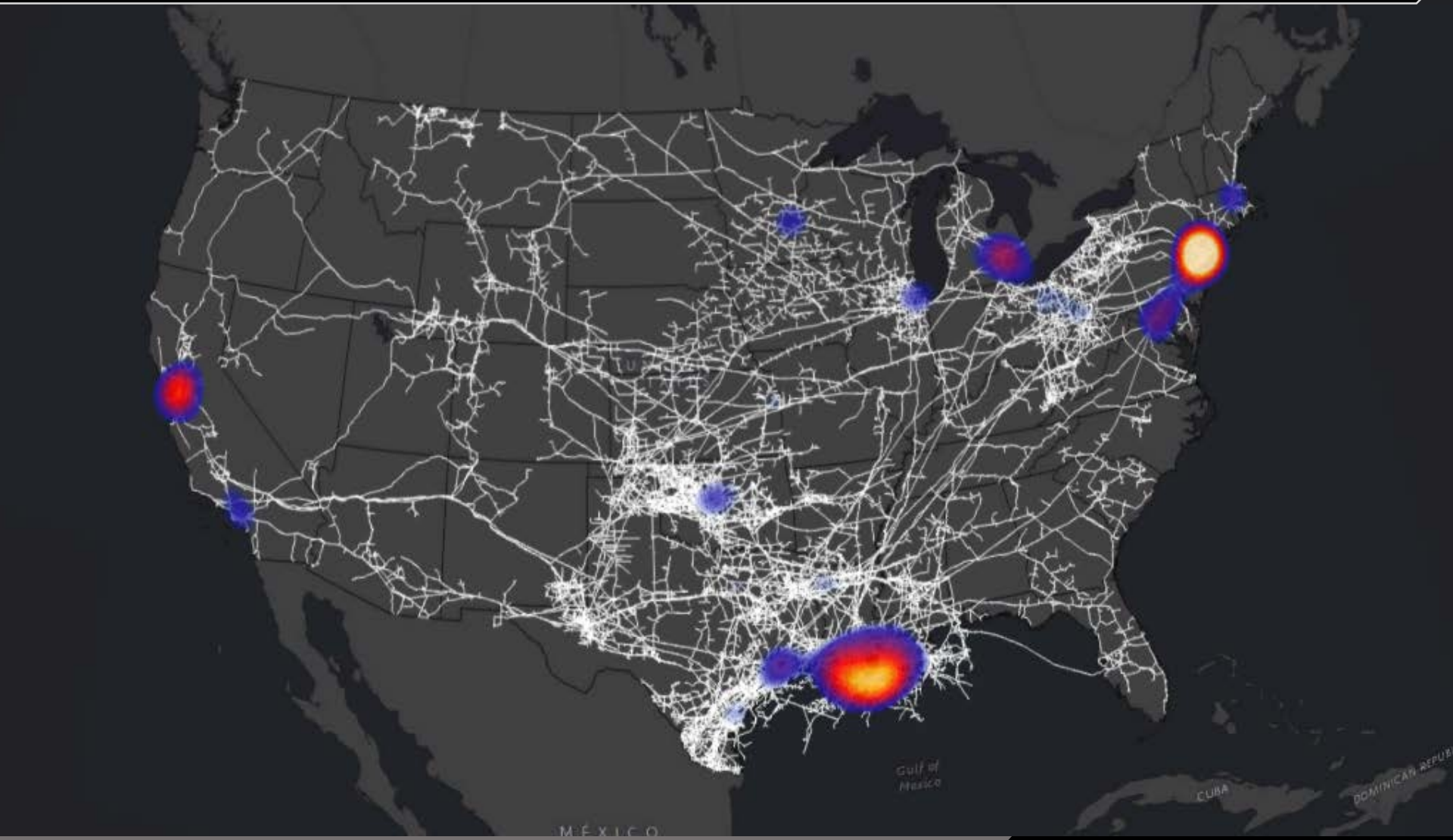
Developing an Analytical Framework for Evaluating Natural Gas Pipeline Risk

NATIONAL ENERGY TECHNOLOGY LABORATORY



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY | AECOM

Session: Meeting Pipeline Solution Needs
7/12/2017

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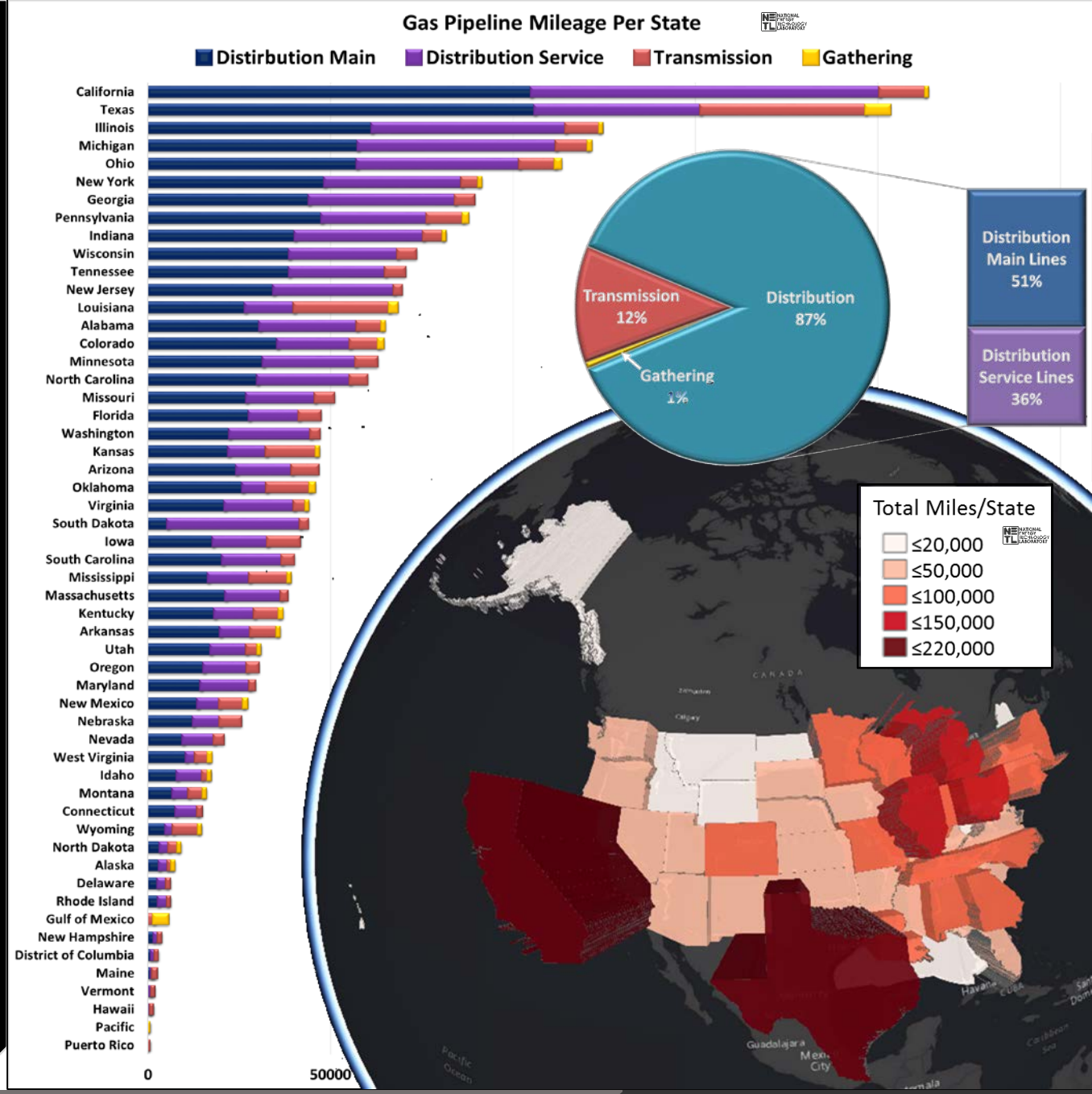
The Pipeline Puzzle

There are **>2.5 million miles** of natural gas pipelines in the USA making monitoring and maintenance challenging

Pipeline infrastructure are susceptible to **material degradation**, **climate** and **geo-hazard impacts (e.g. wildfires, landslides)**, and other risks

Potential costs and risk to **environment, society, and economy**



Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)

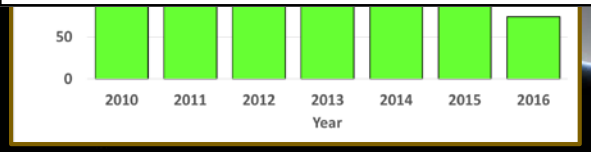
Pipeline Incidents 2010-6/2016

Can we predict & prevent…

Roughly 225 pipeline failure incidents occur on average each year (1986-2016).

Operators have a **less than a 1 in 11,555 chance** of picking the right mile of pipeline to invest personnel and resources on inspections, monitoring, and other activities to prevent these failures.

As natural gas **production** and **consumption** is expected to **increase**, so must our natural gas infrastructure



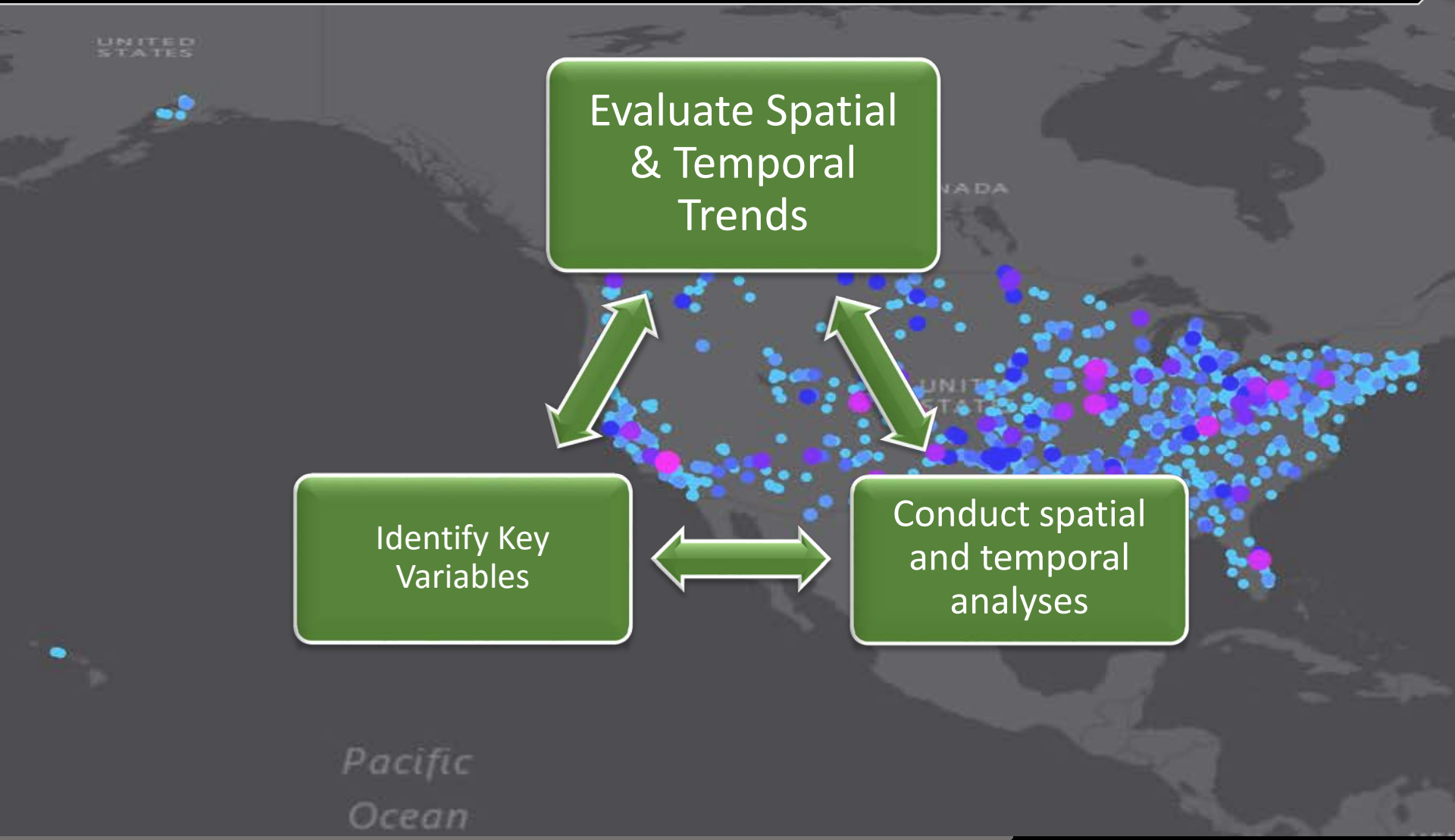
Sources: Pipeline and Hazardous Materials Safety Administration (PHMSA) & US Energy Information Administration (EIA)

What are the Big Goals of this Effort?

Utilize **spatial and temporal analytics** to **hind-cast and identify relationships between risks and failure events** to develop a **spatial analytical framework & tool**, **leveraging machine learning and advanced analytics**, to support the:

1. Assessment and prediction of spatial & temporal trends related to **pipeline infrastructure integrity and failure risk**,
2. Optimized placement of **advanced sensing and monitoring tools, and materials** under development,
3. Identification of **technology gaps** to inform **new sensing and materials research & development**, and
4. Evaluation of spatial & temporal trends & patterns to **prioritize areas for monitoring, maintenance, and future infrastructure improvements**

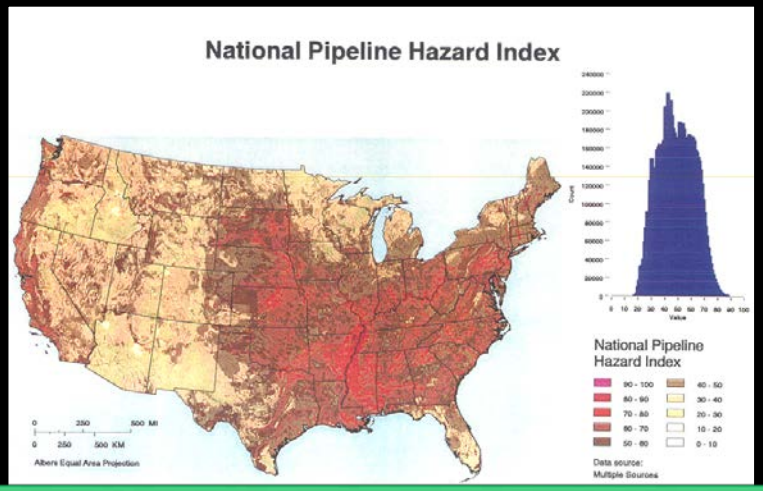
Approach


Evaluate Spatial & Temporal Trends
Identify Key Variables
Conduct spatial and temporal analyses
Pacific Ocean

Identifying Key Variables

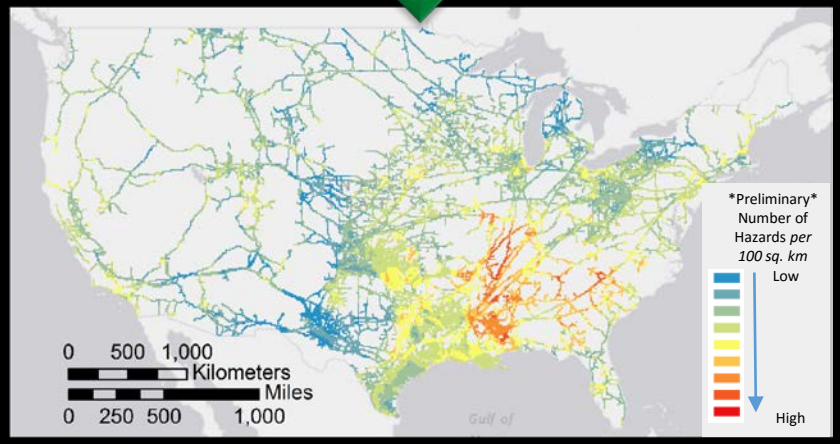
Used hypothesis driven methods to determine **key variables** affecting pipeline failures, such as finding from peer-reviewed literature, which resulted in the collection of over **25 GB** of data for the U.S. that represents:

- the **existing Natural Gas Pipeline Infrastructure**,
- more than **45 years of Pipeline failure incidents**, and
- over **200 different internal and external factors** that affect pipeline failure incidents, including:
  - pipeline material, pipeline age, maintenance and construction activities, landslides, earthquakes, lightning strikes, severe rain, hail events, soil type, soil composition, land use, population growth, land development, and others



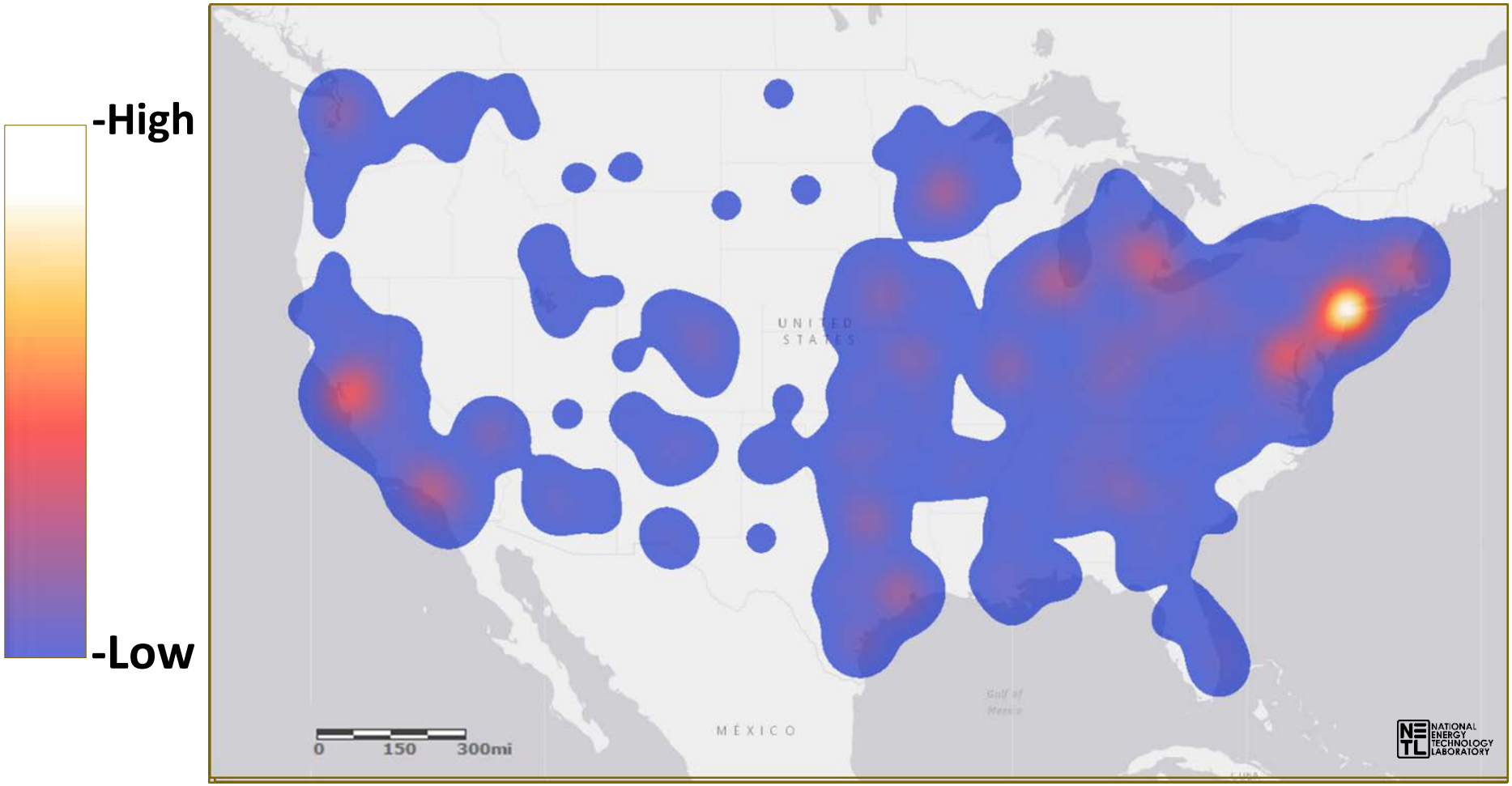
Updated risk factor data based on FEMA and DOT 1996 study

- **National Pipeline Risk Index based on natural disasters**



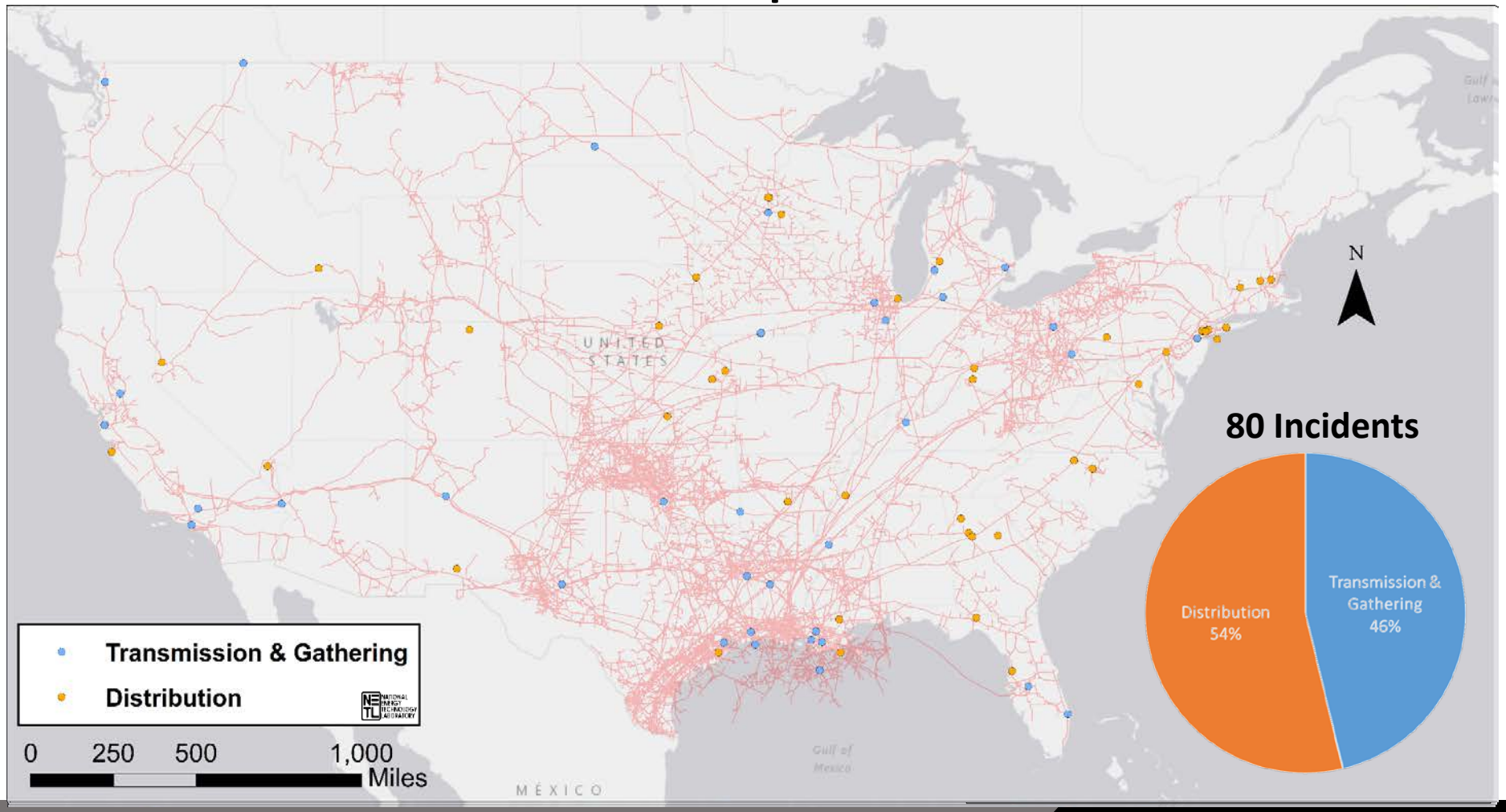
Identifying key spatio-temporal trends

Heat map for Gas Distribution incidents



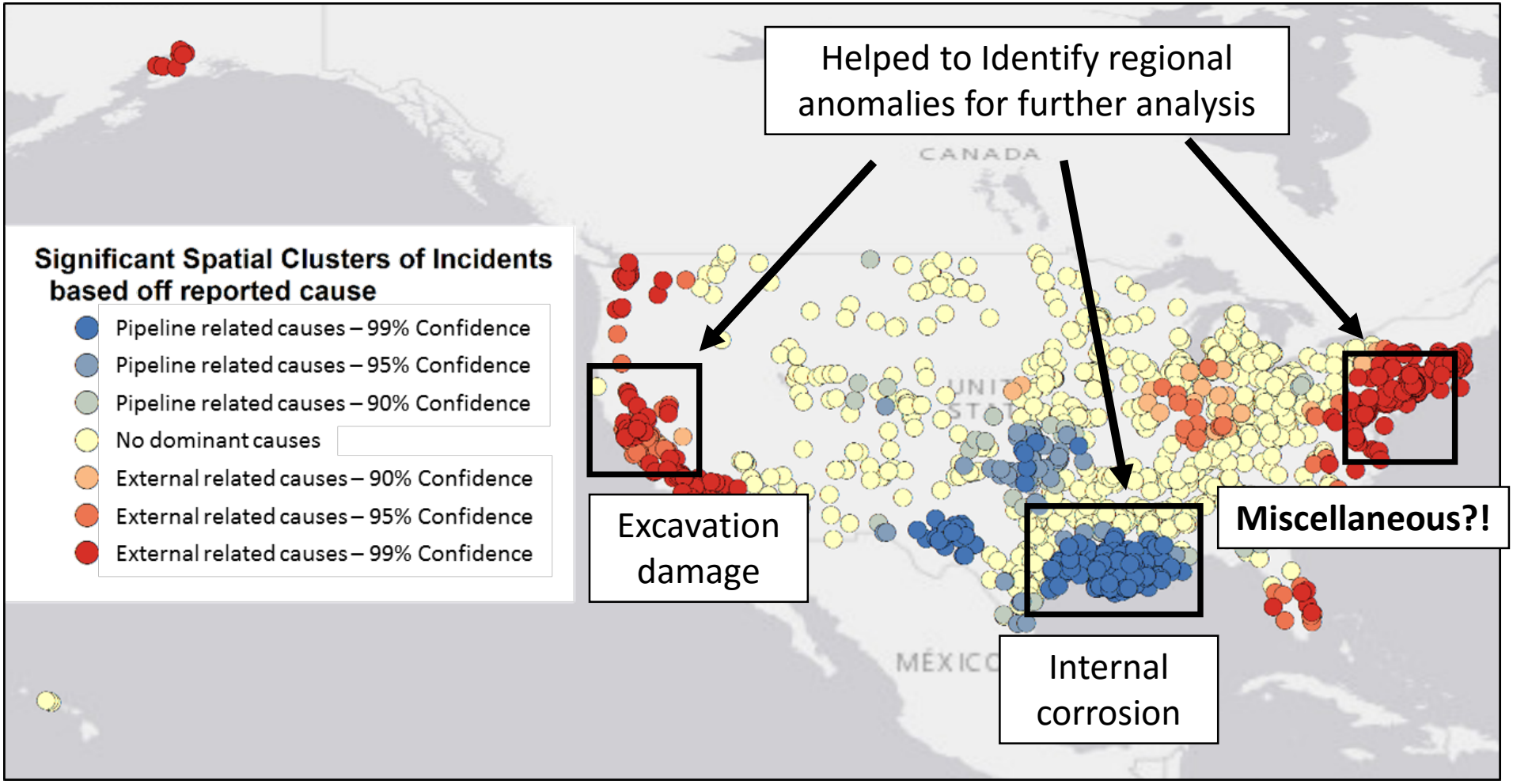
Identifying key spatio-temporal trends

Incorrect Operations

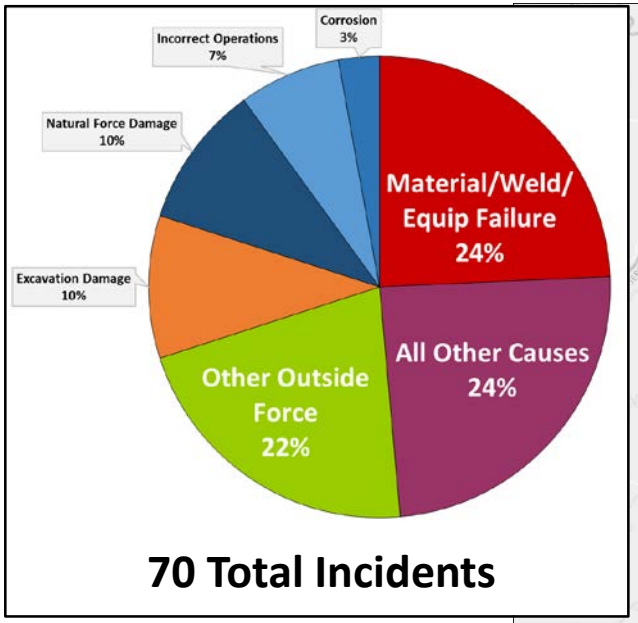


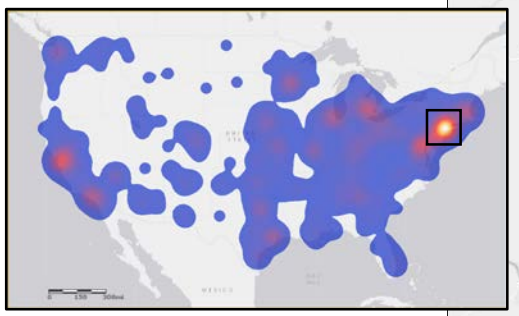
Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)

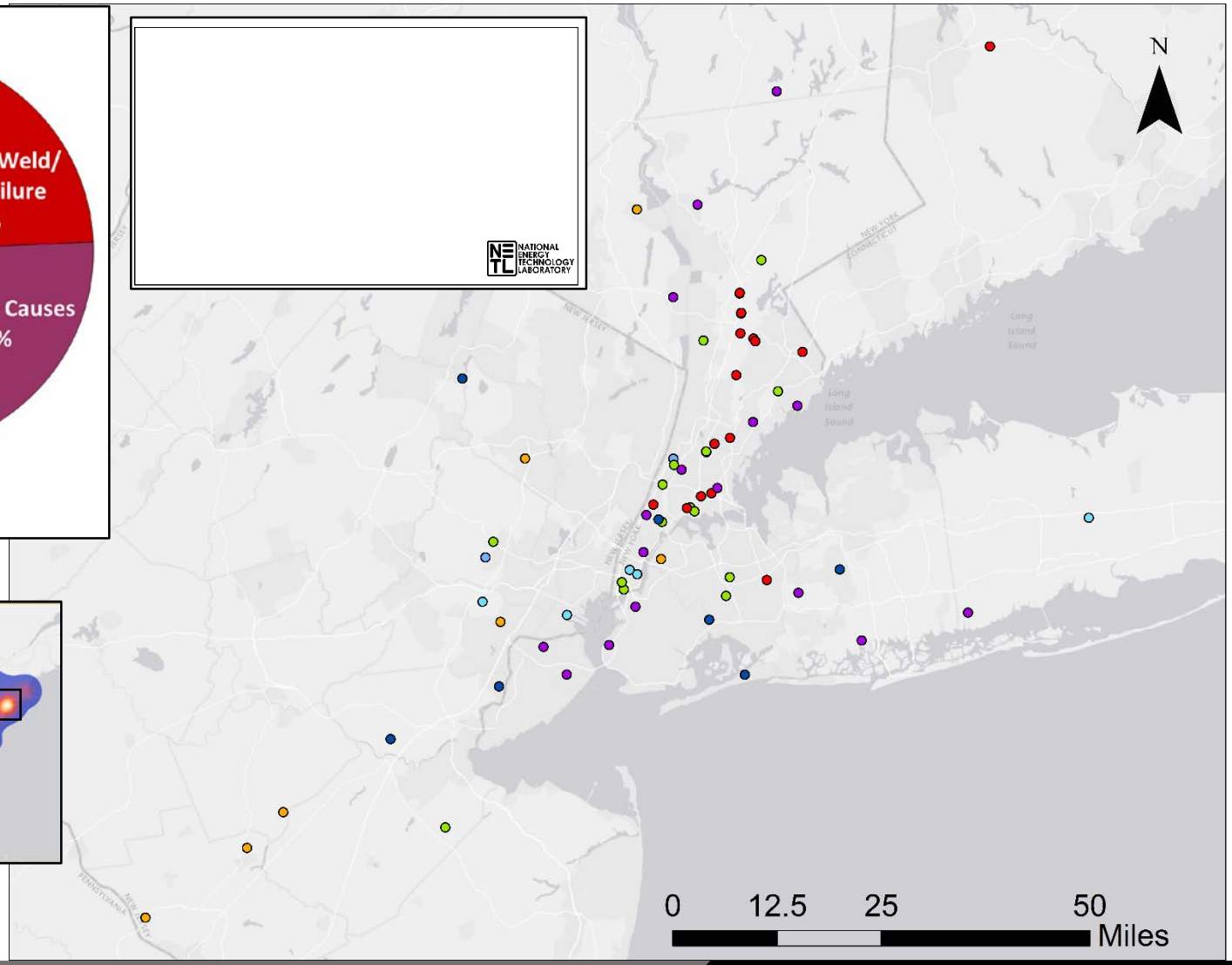
Identifying key spatio-temporal trends



Identifying key spatio-temporal trends







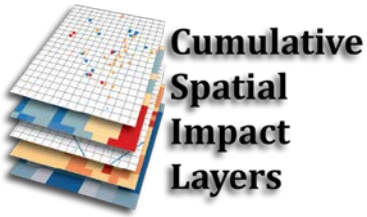
Source: Pipeline and Hazardous Materials Safety Administration (PHMSA)

Evaluating pipeline risks from extreme weather and geo-hazards

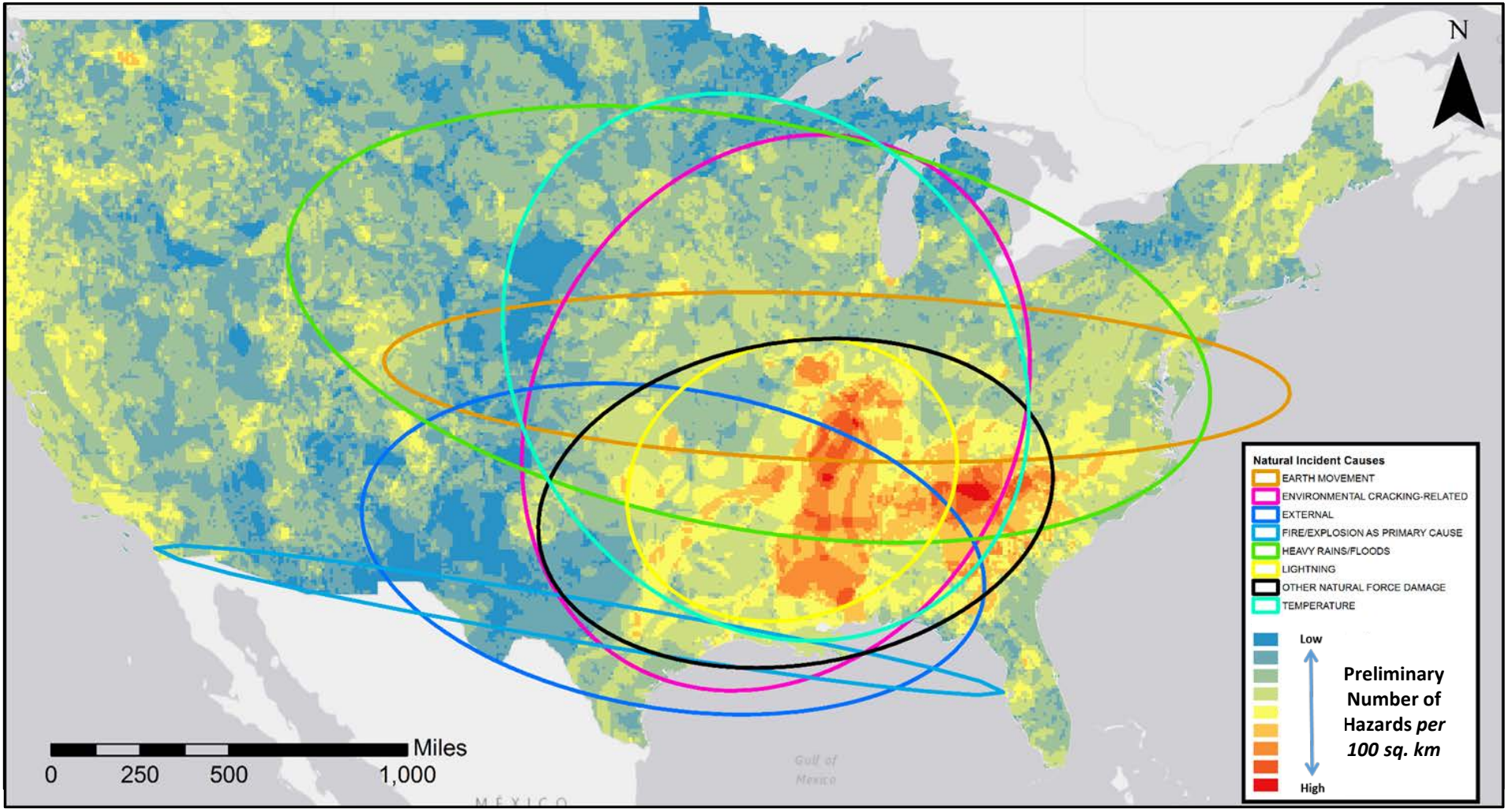
- Assessed the following hazard variables to determine where these variables accumulate spatially with respect to natural gas and other pipeline infrastructure:

1. **Kernel Density for tornado severity 1950-2016 (NOAA)**
2. **Kernel Density for hail size 1955-2016 (NOAA)**
3. **Kernel Density for storm wind speeds 1950-2016 (NOAA)**
4. **Kernel Density for tropical cyclone tracks 1851-2014 (NOAA)**
5. **Kernel Density for wildfire size 1980-2015 (USGS)**
6. **Flood Hazard >=70/100 rank value (FEMA 1996)**
7. **Landslide Hazard >=70/100 rank value (FEMA 1996)**
8. **Seismic peak horizontal acceleration with 10% probability of exceedance in 50 years >=5% of gravity (USGS 2014)**
9. **>=1% Chance of damage from induced earthquakes (USGS 2016)**

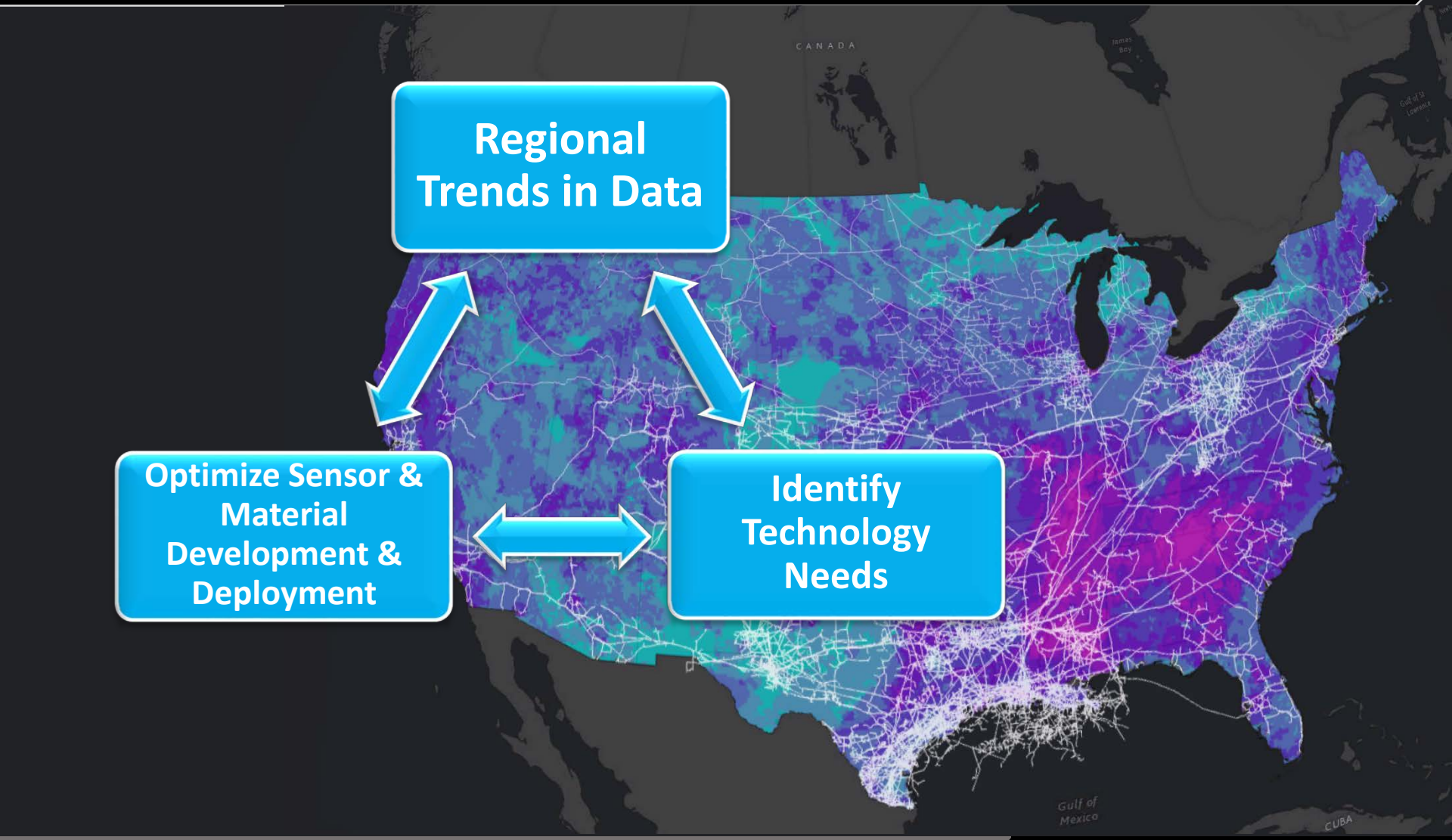
- Cumulative Spatial Impact Layers (CSILs) tool (Bauer, J . R. et al. 2015)
  - **In house geospatial tool built on the concept of spatial overlap**
  - **Allows users to answer spatial and temporal questions by summarizing multiple datasets**



Evaluating pipeline risks from extreme weather and geo-hazards



Key Findings from Preliminary Analyses



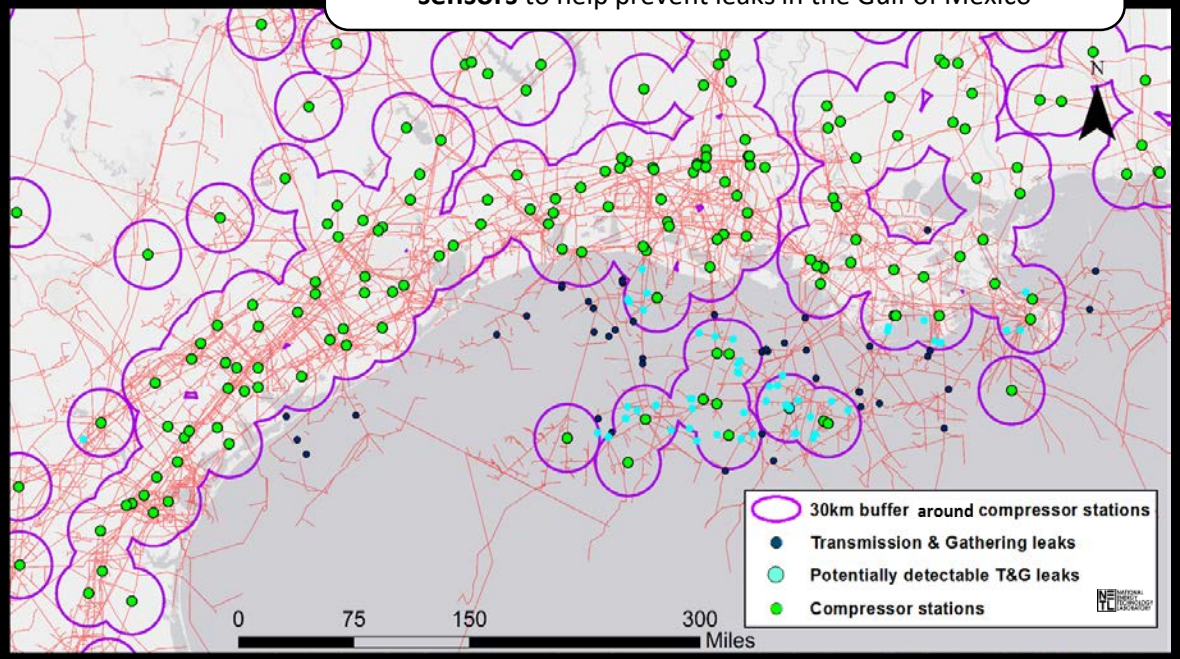
Regional Trends in Data

Optimize Sensor & Material Development & Deployment

Identify Technology Needs

Looking Forward…

Example analysis using the spatial framework can evaluate optimal conditions for utilizing **surface acoustic wave based sensors** to help prevent leaks in the Gulf of Mexico



Refining key variables and the analytical methods

Example analysis for prioritizing locations for **optical fiber based sensors** to mitigate earthquake damage

Garnering interest from several outside entities about the project, methods, and tools

PHMSA U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration

U.S. DEPARTMENT OF ENERGY Office of Indian Energy

esri

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NW Natural

FERC FEDERAL ENERGY REGULATORY COMMISSION

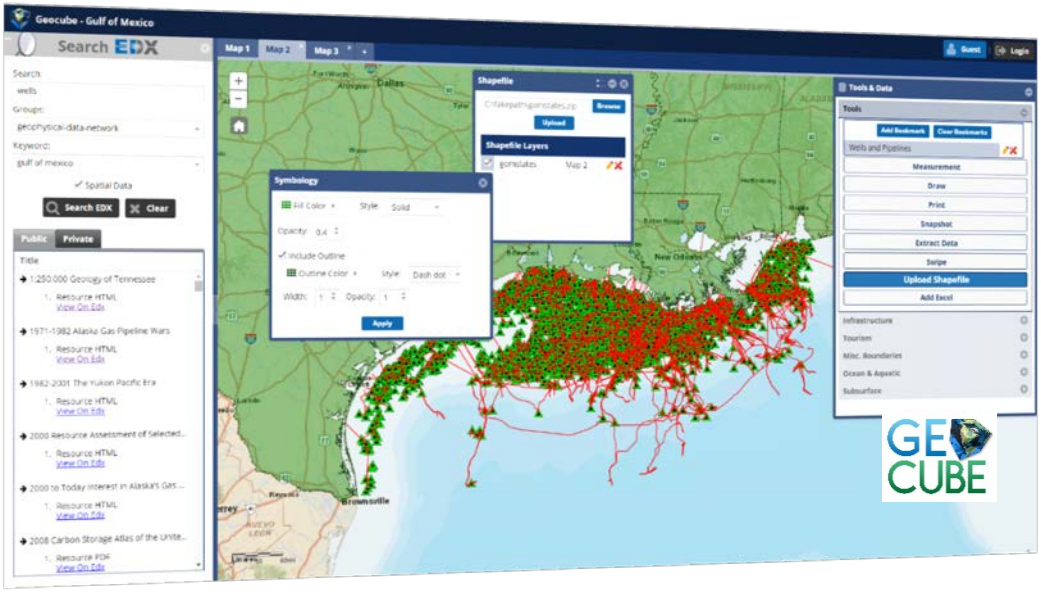
PODS™ Pipeline Open Data Standard

EDF ENVIRONMENTAL DEFENSE FUND® Finding the ways that work

Ultimate Outcomes

- Improved understanding of how, when and where pipeline failures happen in relation to a range of internal and external causes and factors through analyses preformed by this effort
- Improved prediction of where future failures are more likely to occur, informing mitigation and monitoring efforts
- An advanced, decision support tool that combines big data computing, real-time data services, and advanced analytics to perform rapid, iterative analyses to inform research and guide advanced technology development and implementation, and support decision making needs for regulators and commercial entities

Thank you!



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Key References

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