Understanding Leak Detection Success for Belowground Natural Gas Pipelines Across Diverse Operating Conditions

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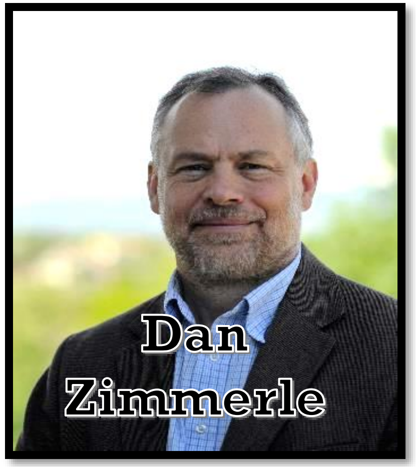
Emissions Research Team



Objectives of today's talk

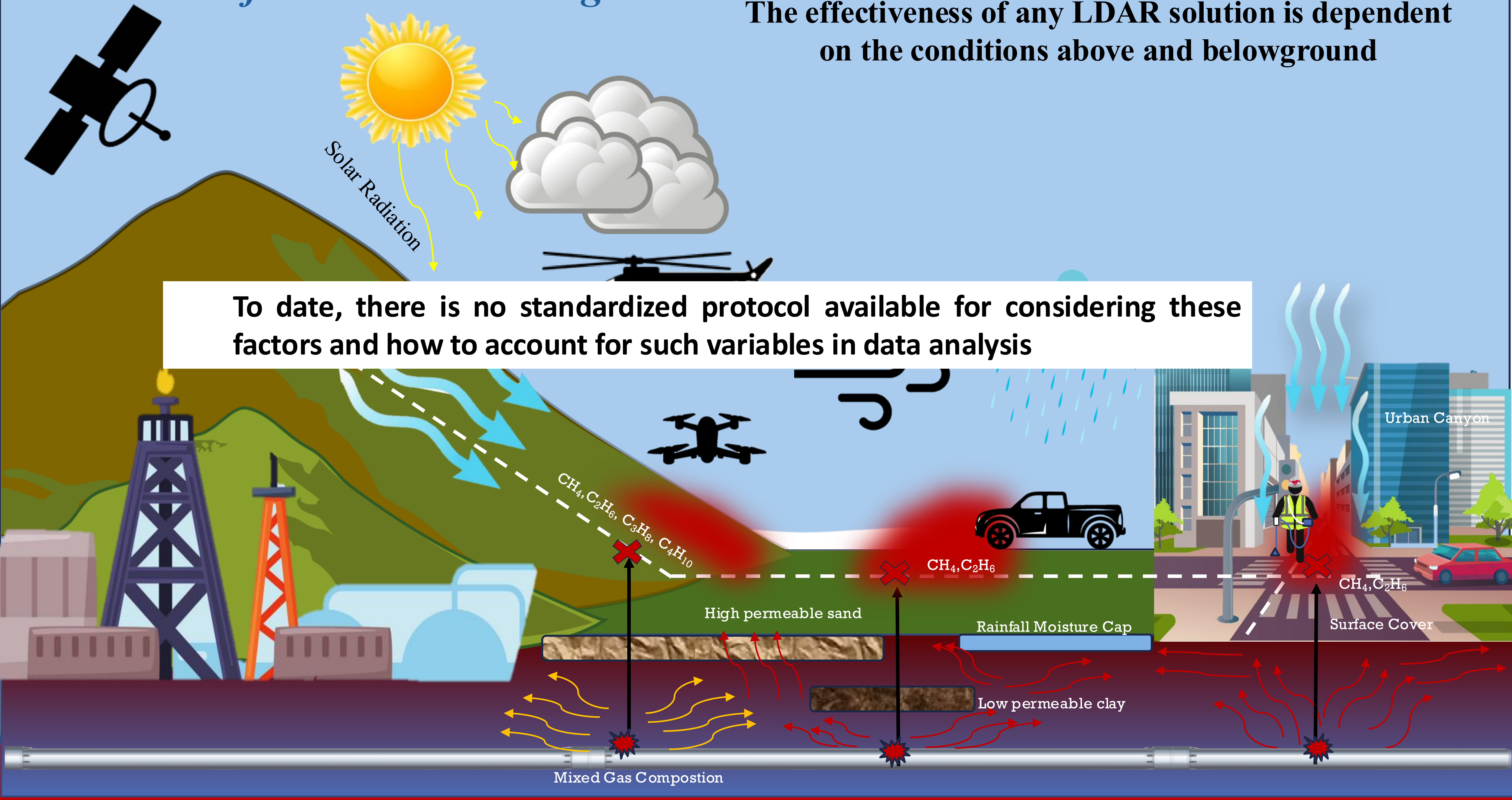
1. Identify why and how diverse operating conditions to include variations in weather, terrain and urban and rural environments impacts the success of leak detection solutions

2. Understand options for optimizing survey methods to increase leak detection success in diverse conditions

Statement of Problem/Challenge

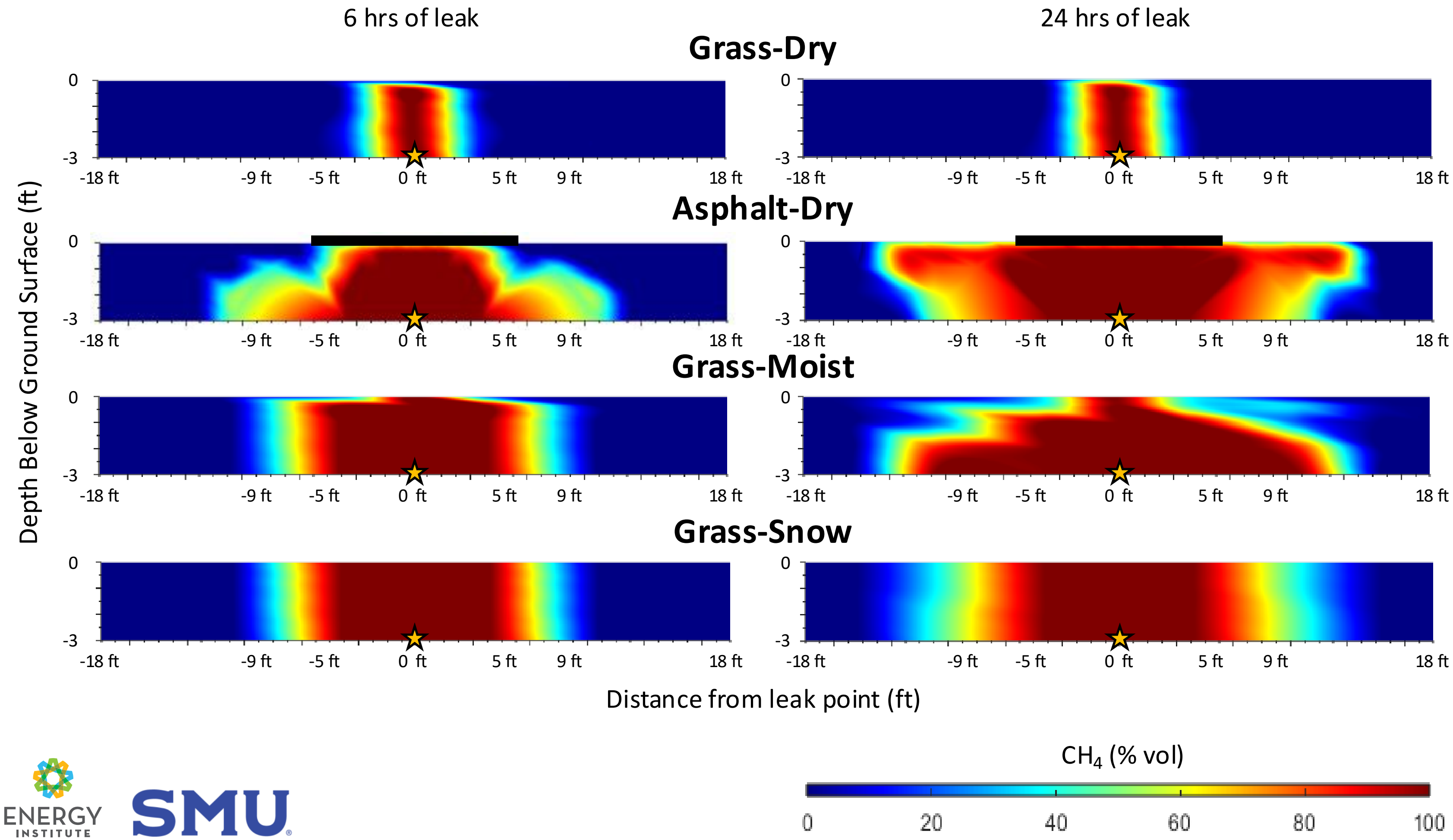
The effectiveness of any LDAR solution is dependent on the conditions above and belowground

To date, there is no standardized protocol available for considering these factors and how to account for such variables in data analysis



Surface cover – impact on migration distance and time

- NG spreading up to 4 xs farther than dry grass covered conditions in similar time frames
- NG spreading up to 13xs faster than dry grass covered conditions



Max Migration Distance*	Time to Reach Max Distance
< 5ft	2.5hrs
3 x Grass-Dry	7 x Grass-Dry
4 x Grass-Dry	13 x Grass-Dry
4 x Grass-Dry	6 x Grass-Dry

*Magnitudes are specific to METEC soil

Asphalt layer ★ Leak location

Jayarathne et al., 2024 (ES&T)

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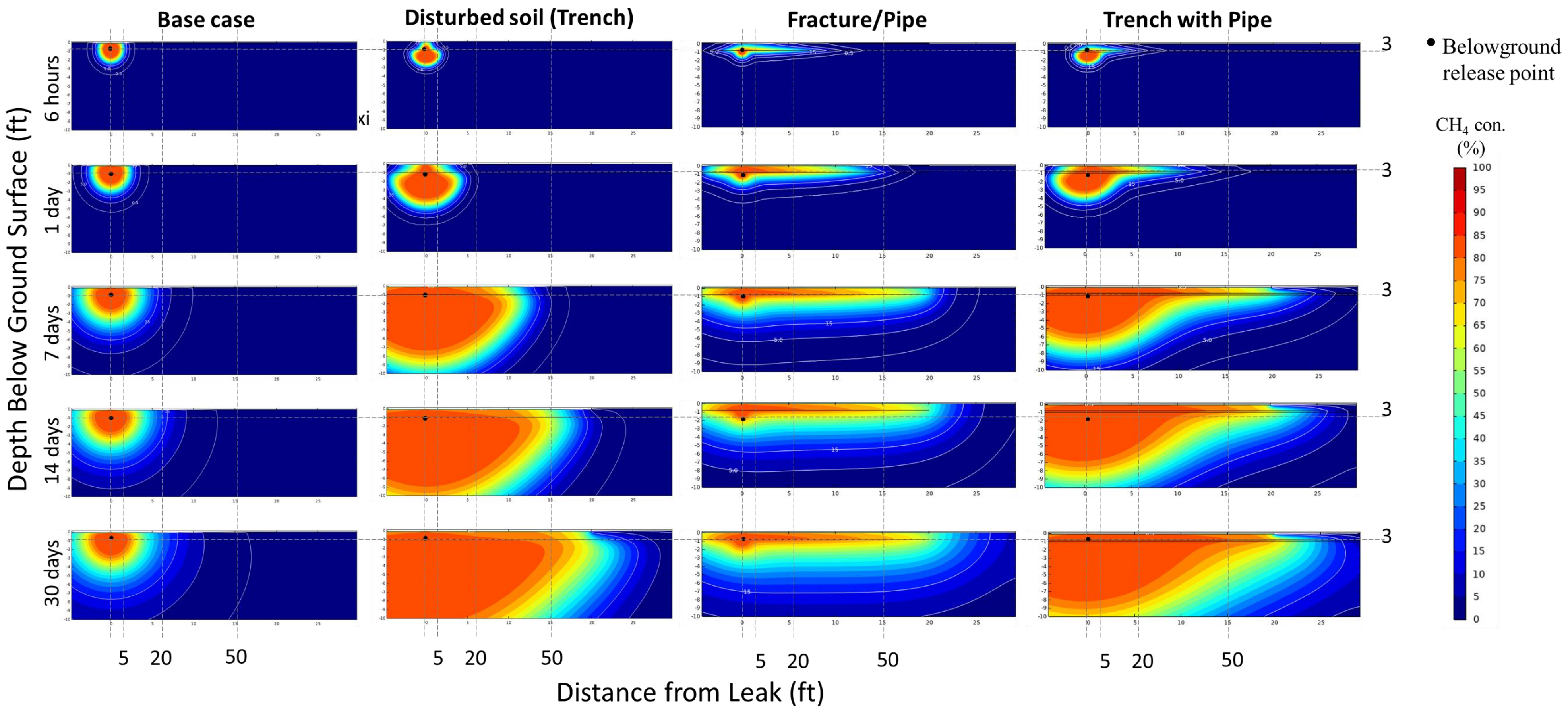
Subsurface complexity – impact on migration distance and time

Complexity increases migration distance and rate by a factor of 2- 2.5xs



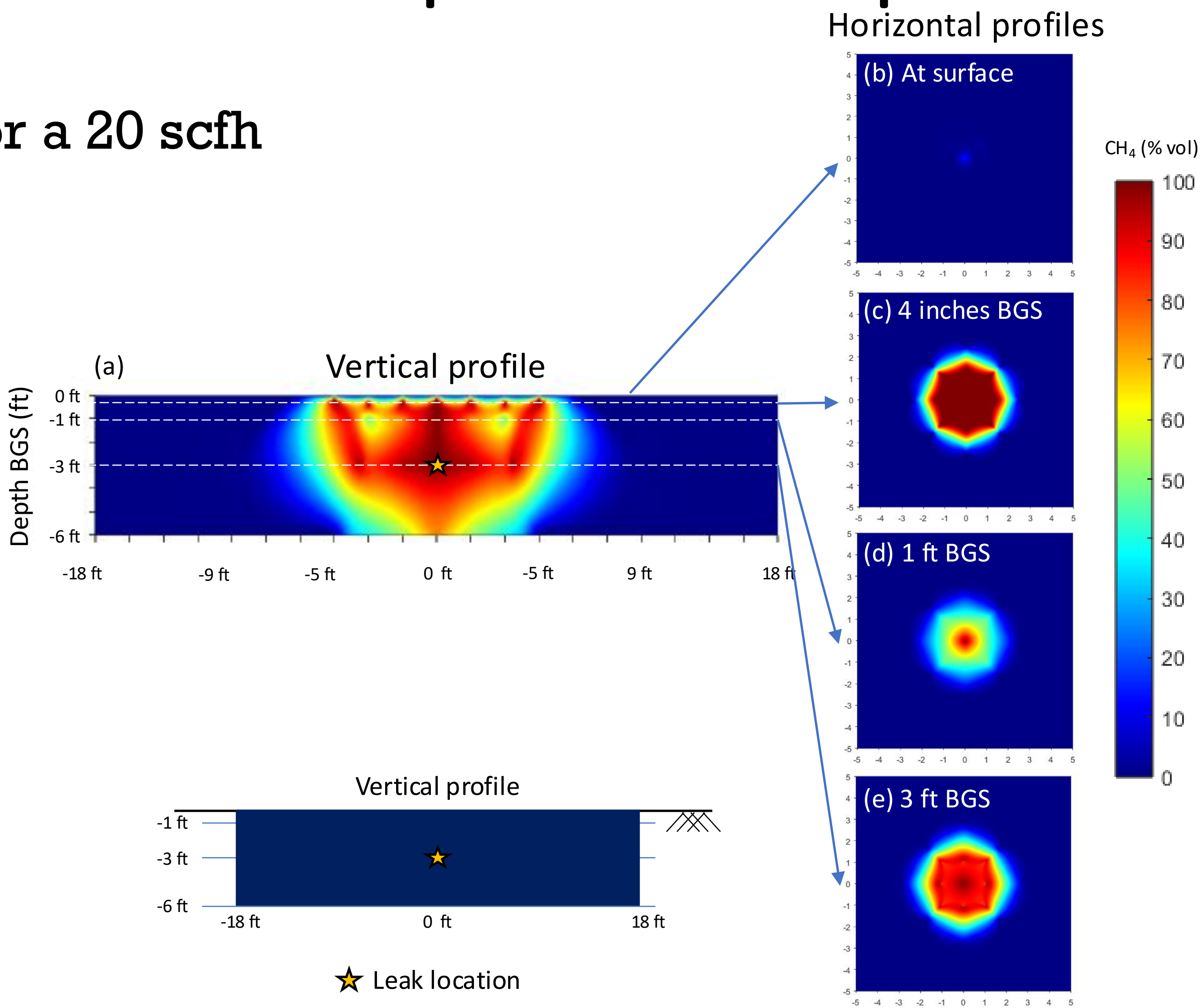
- Soil disturbance increased both lateral and downward migration
- Fracture acts as a preferential pathway for gas transport

Jayarathne et al., *in review*

Soil moisture – wet soil conditions impact with depth

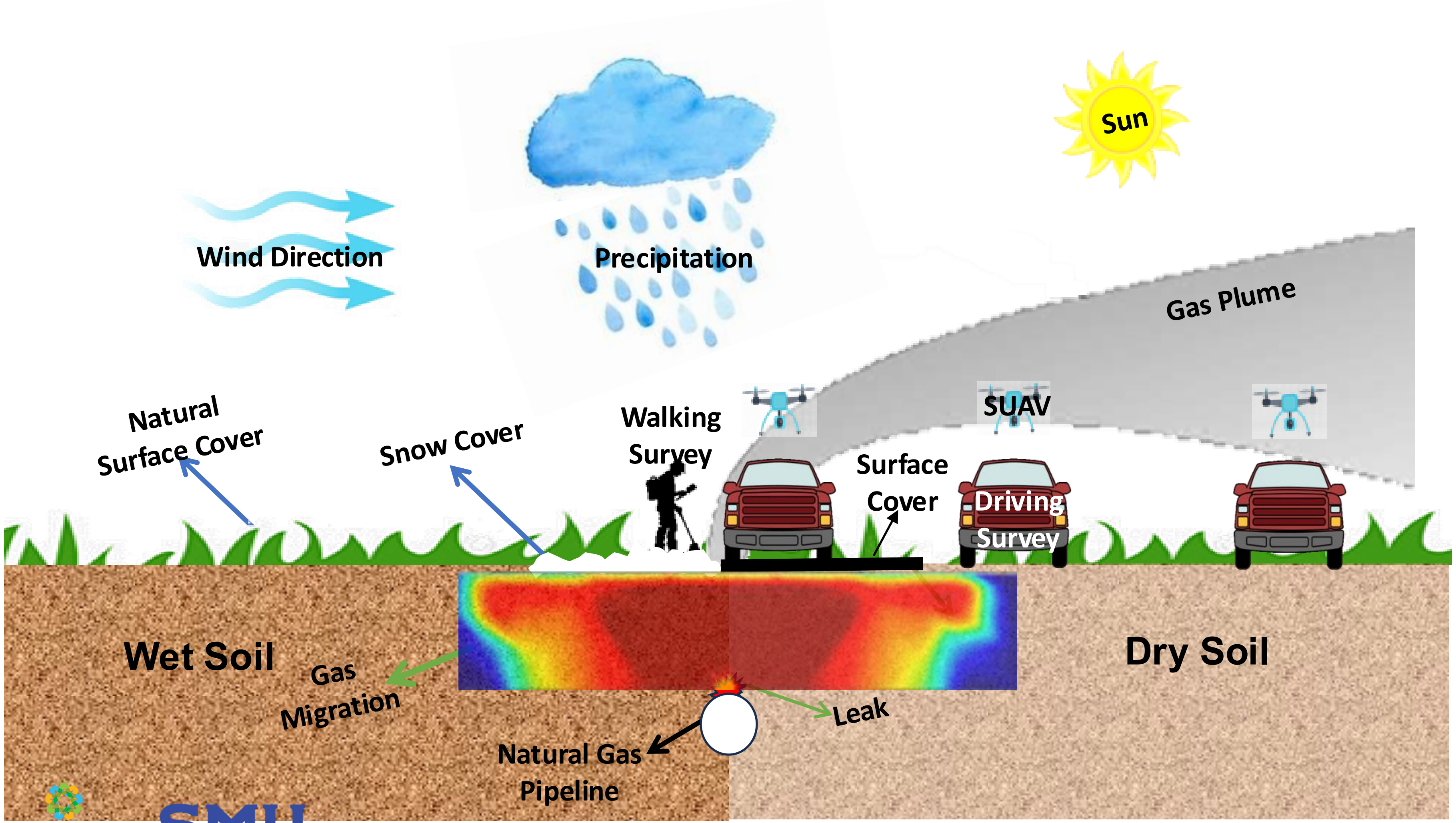
Vertical profile & plan views of CH_4 for a 20 scfh NG leak under <u>wet soil conditions</u>

- negligible methane concentrations found at surface
- largest accumulation of gas found at shallow depths belowground surface (BGS)



Lo et al., 2024, *Env. Pollution*

Take away: Leak detection methods developed & used for aboveground leaks do not directly translate to belowground leak scenarios



1. Diffuse surface presentation of subsurface leaks
2. Diverse operating conditions
3. Extended geometry of flow/gathering lines

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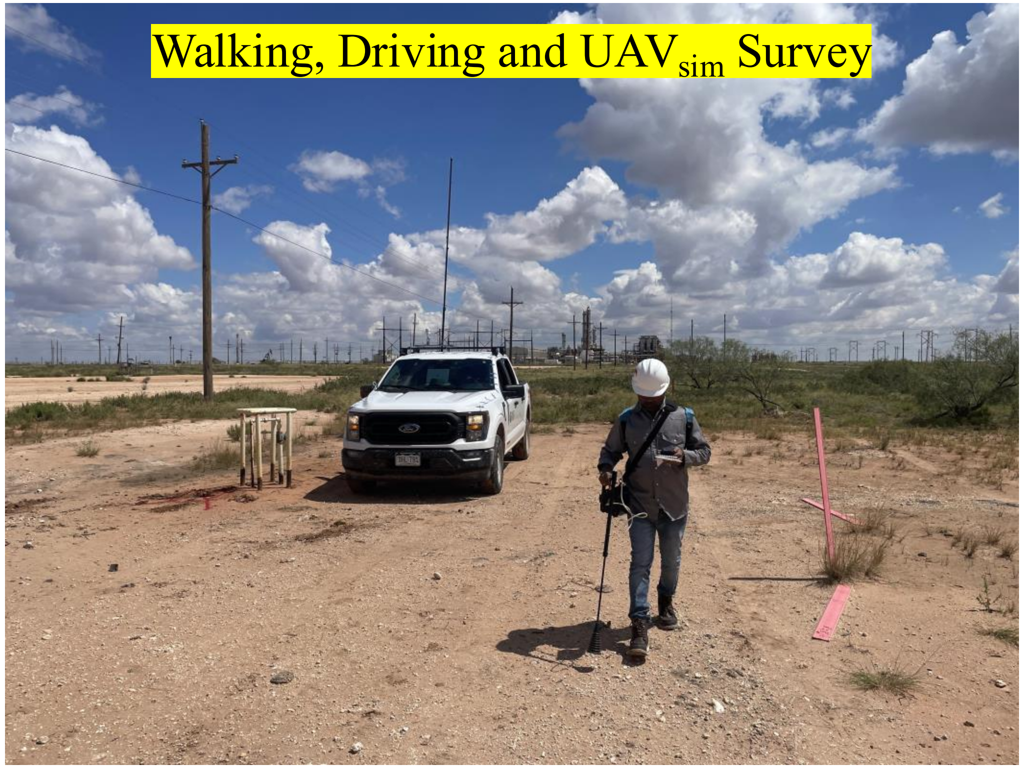
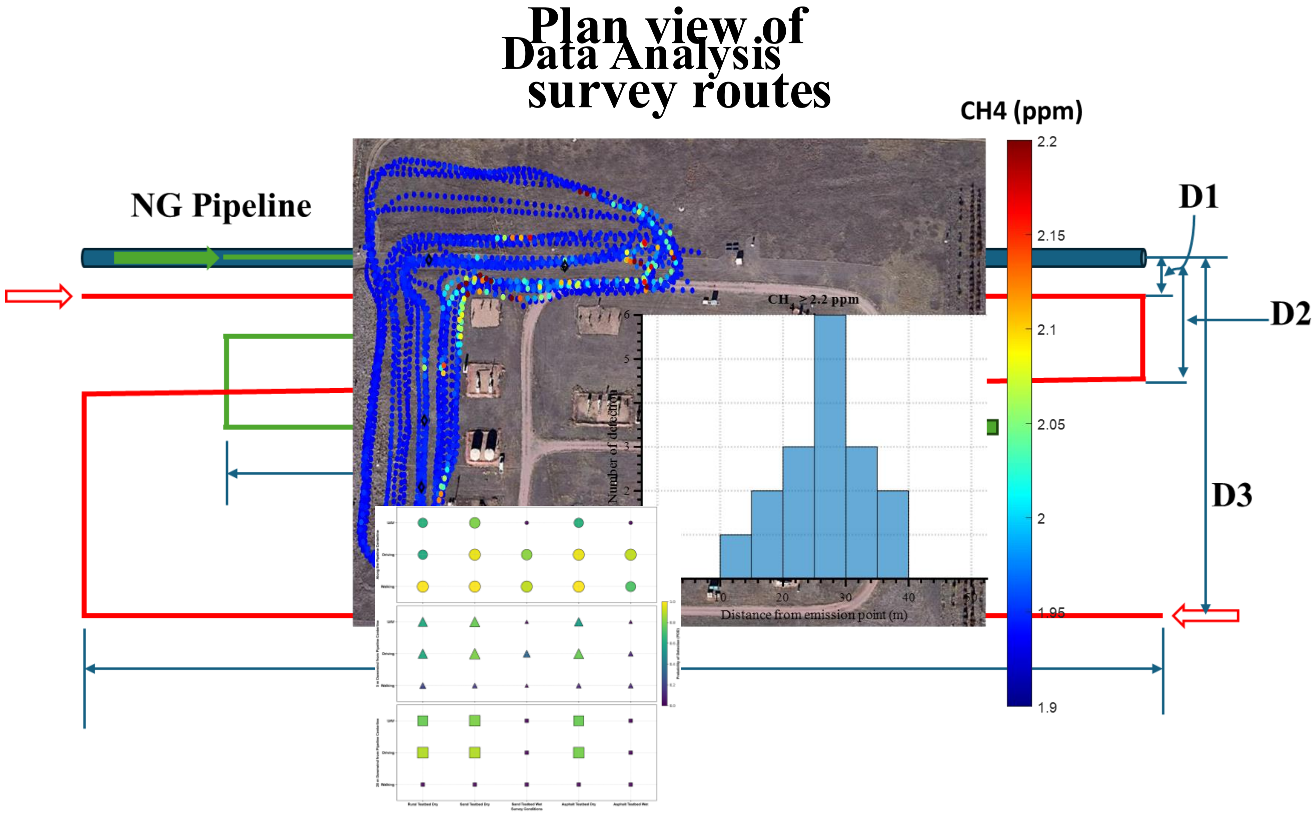
Approach

Goal: Understand the degree to which diverse operating conditions affect leak detection success - connect with operator practice

Protocol Implementation in the Permian Basin





30 different diverse conditions, ~15,000 passes

Sample Survey Parameters Used in Pipeline LDAQ Operations

Survey Type	Walking	Driving	Unmanned Aerial Vehicle (UAV)	Aircraft
Platform	Pedestrian	Truck	UAV	Helicopter/Fixed wing aircraft
Detection threshold (ppm) Background	5 - 10	5 - 10	0.05 enhancement	Not reported
Survey Speed (mph)	2 - 5	2 - 50	5 - 40	2 - 123
Passes Performed (amount #)	1 - 2	2 - 6	1 - 2	Not reported
Height of Measurement (ft)	0	1 - 10	3 - 147	15 - 3000
Distance downwind from ROW (ft)	0 - 65	0 - 32	0 - 150	Not reported
Wind Speed Limit (mph)	14 - 30	14	4 - 29	12 - 18
Conditions under consideration	Wind	Wind	Wind, only considers 45° for downwind	Wind

Experimental Design

Operational conditions selected:

- **Survey Speed:** ~6 mph
- **Survey Height:** 0 m, 1 m and 8 m
- **Survey Times:** Morning, Noon & Early Evening
- Detection threshold:
  - **2.2 ppm** for mobile/UAV_{SIM}
  - **5 ppm** for walking survey

*Survey parameters based on input from operators, solution providers, and relevant literature

Walking Survey

Driving Survey

UAV_{SIM} Survey

Detection Method	Infrared Polarization Spectroscopy	Mid-Infrared Laser Adsorption Spectroscopy	Mid-Infrared Laser Adsorption Spectroscopy
Make/Model	Heath DPIR+	Aeris Mira Strato LDS	Aeris Mira Strato LDS
Range	0-10,000 PPM	10 ppb – 10,000 PPM	10 ppb – 10,000 PPM
Sensitivity	1 PPM	<1ppb	<1ppb
Accuracy	1-2% of reading	± 10% of reading	± 10% of reading

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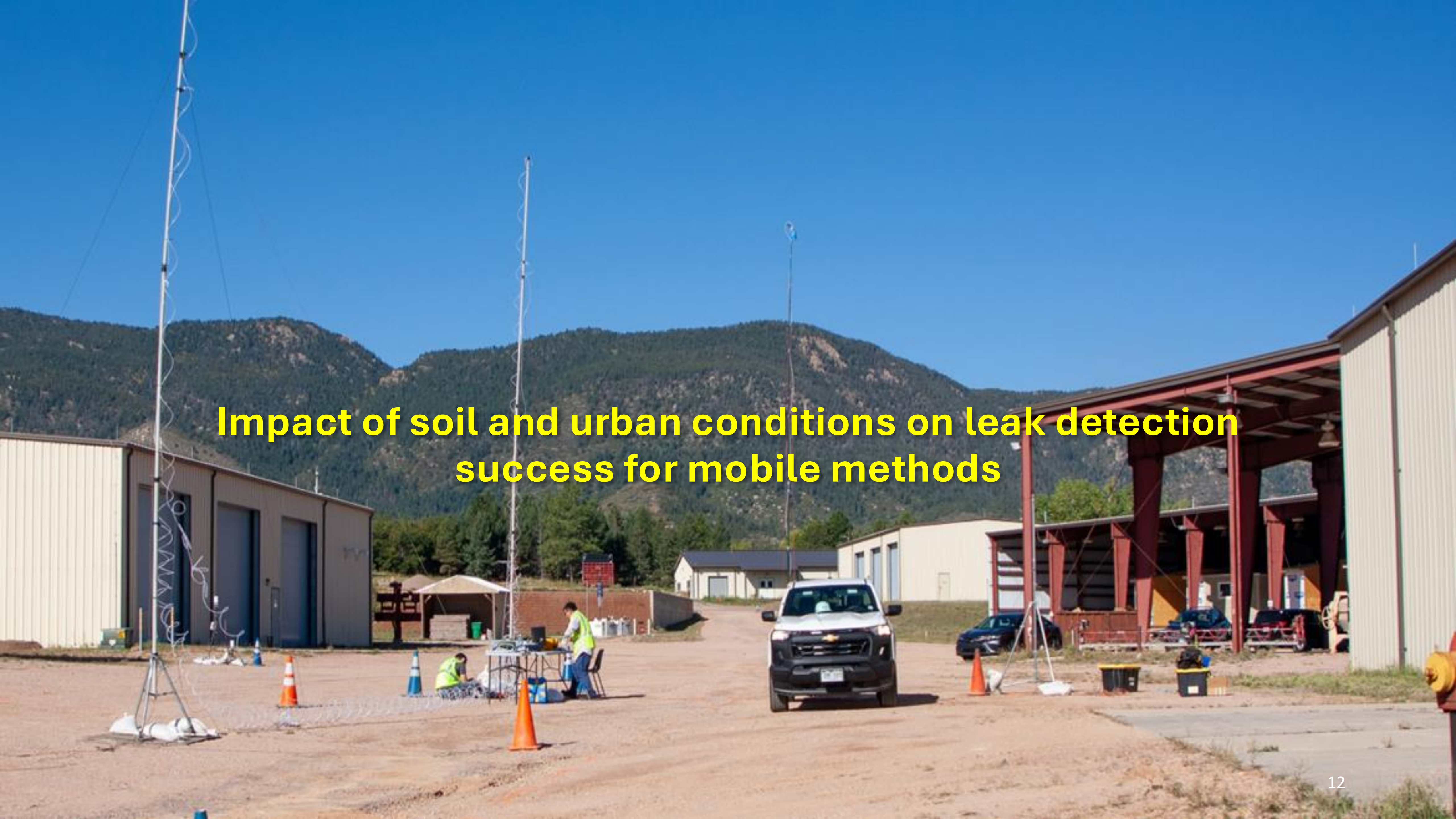
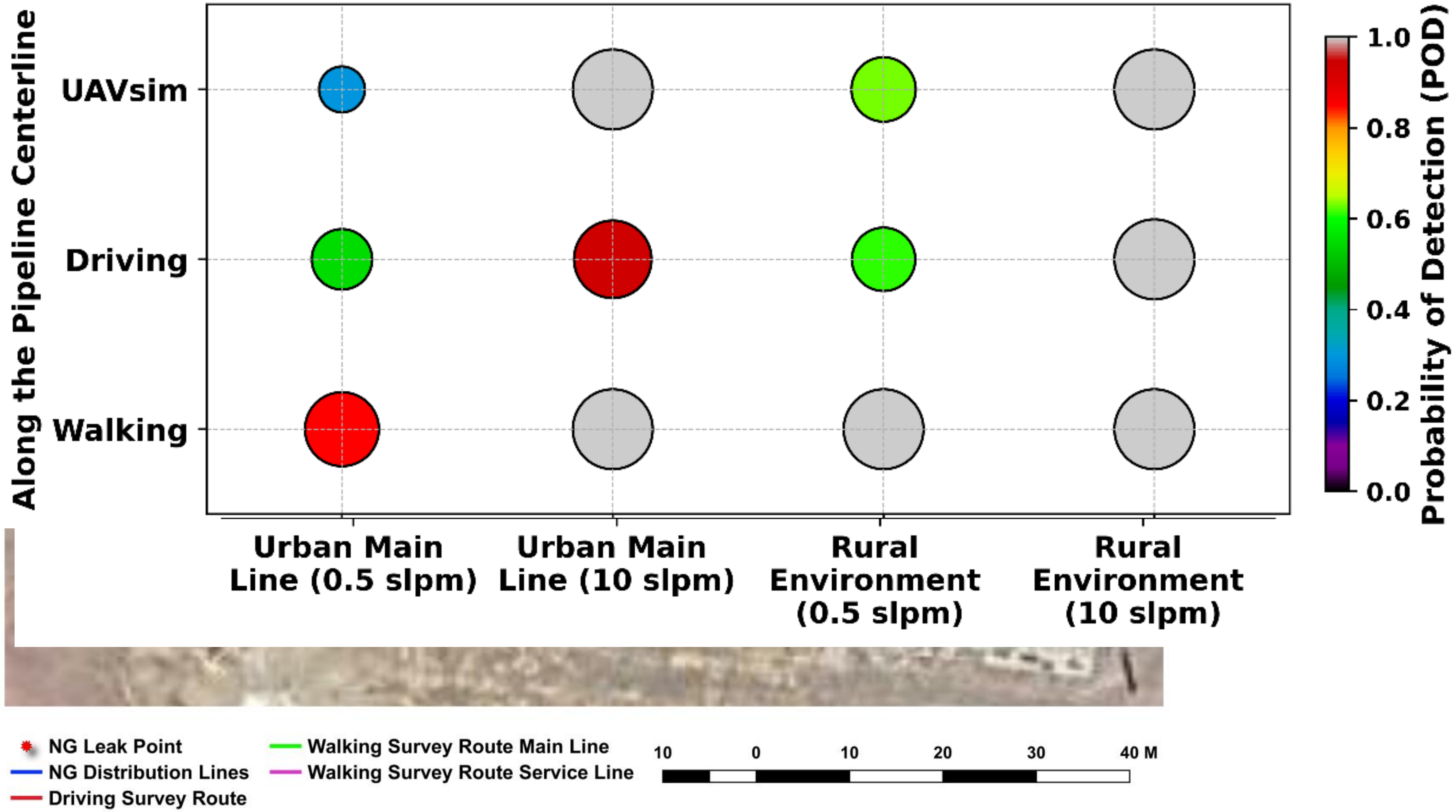
Impact of soil and urban conditions on leak detection success for mobile methods



Impact of urban conditions on leak detection success across different survey methods, and leak rates

US Air Force Academy's Field Engineering Site



Over the main lines:

- 0.5 slpm (1 scfh) leak rate: POD is reduced by ~40% for the driving and ~60–70% for the UAV_{sim} survey in urban conditions compared to rural conditions
- 10 slpm (21 scfh) leak rate: POD is reduced by ~20% for the driving survey and by 10% for the UAV_{sim} survey in urban conditions compared to rural conditions

Venkata Rao, et al., 2025

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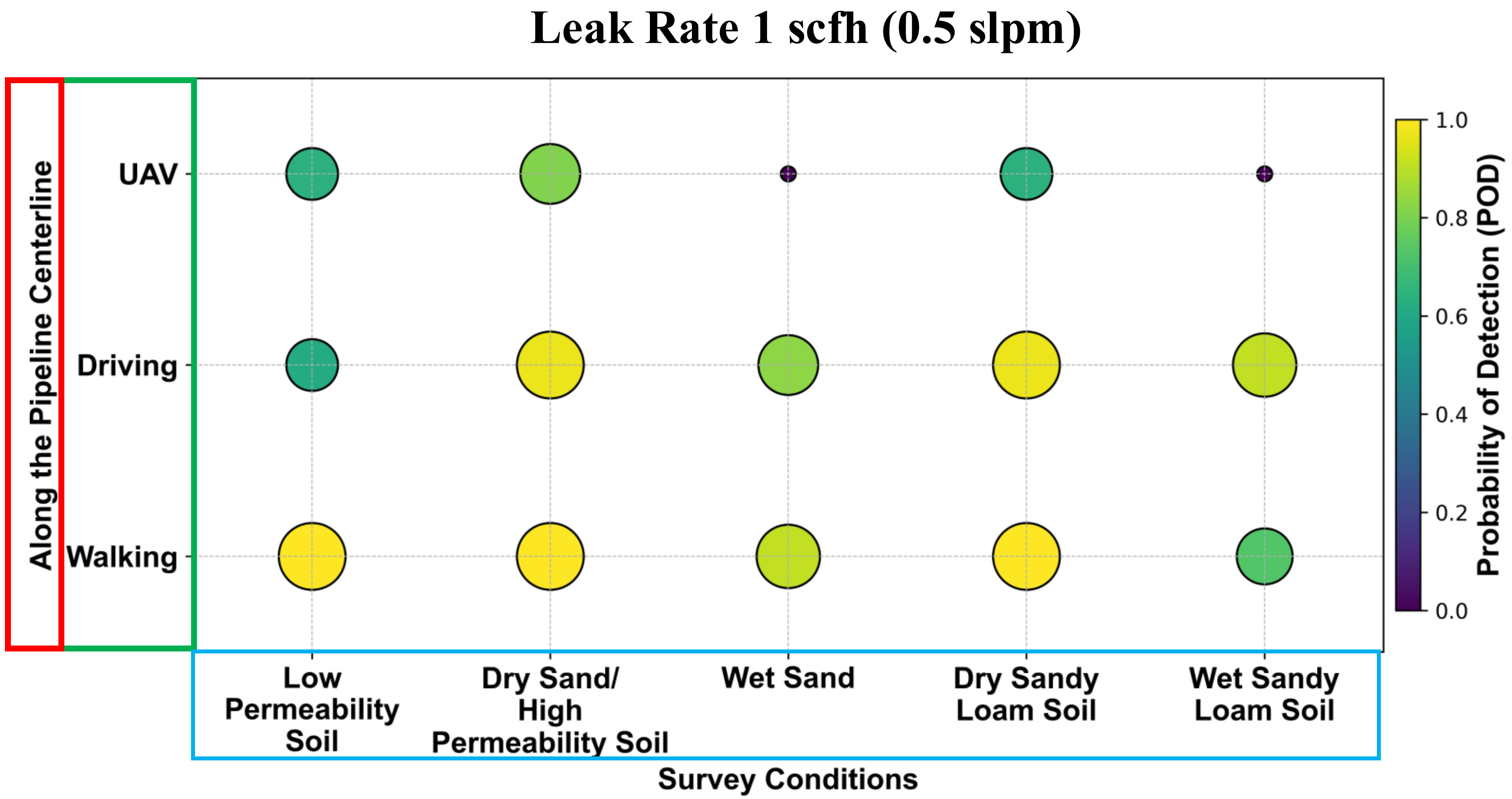
Influence of soil type & moisture on leak detection success was evaluated across different survey methods and downwind distances



- Low **moisture** conditions have a 10–45% higher POD than high moisture conditions
- Higher **permeability** soils results in a 10–20% higher POD than lower-permeability soil

Venkata Rao, et al., 2025, Gas Sci & Eng.

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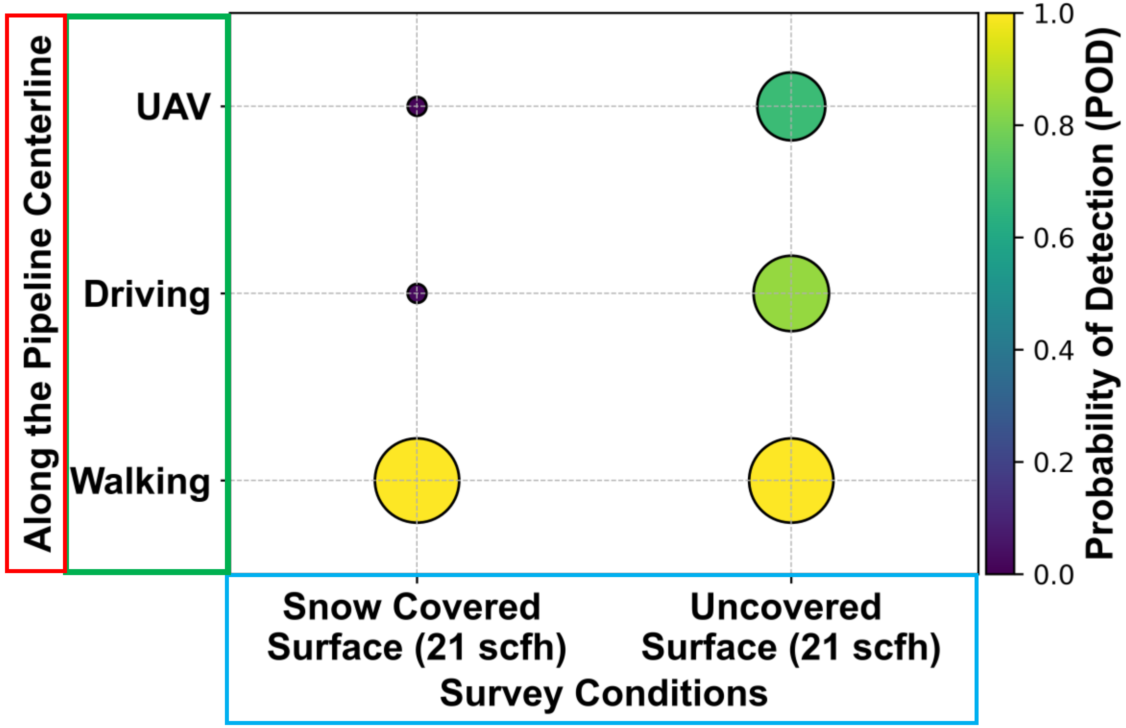
Impact of surface snow cover on leak detection success across different survey methods and downwind distances



- With **snow-covered surfaces**, both the driving and UAV$_{sim}$ surveys failed to detect gas concentrations above the threshold, resulting in a substantial drop in POD.
- Walking surveys are more robust and reliable in snowy environments.

Venkata Rao, et al., 2025 *(in Review)*

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Key takeaways

- Detection success varies widely from 0 to 1 for the same detection method, depending on the site and leak conditions
- Strong dependence of leak detection performance on environmental and operational variables
- Findings can be used to refine detection protocols and optimize survey strategies in complex, real world environments

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All published open access or contact me if you would like copies

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Thank you

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