Preliminary Analysis of Observations from the Jack Rabbit II-2015 Field Experiment on Dense Gas Dispersion in a Built Environment

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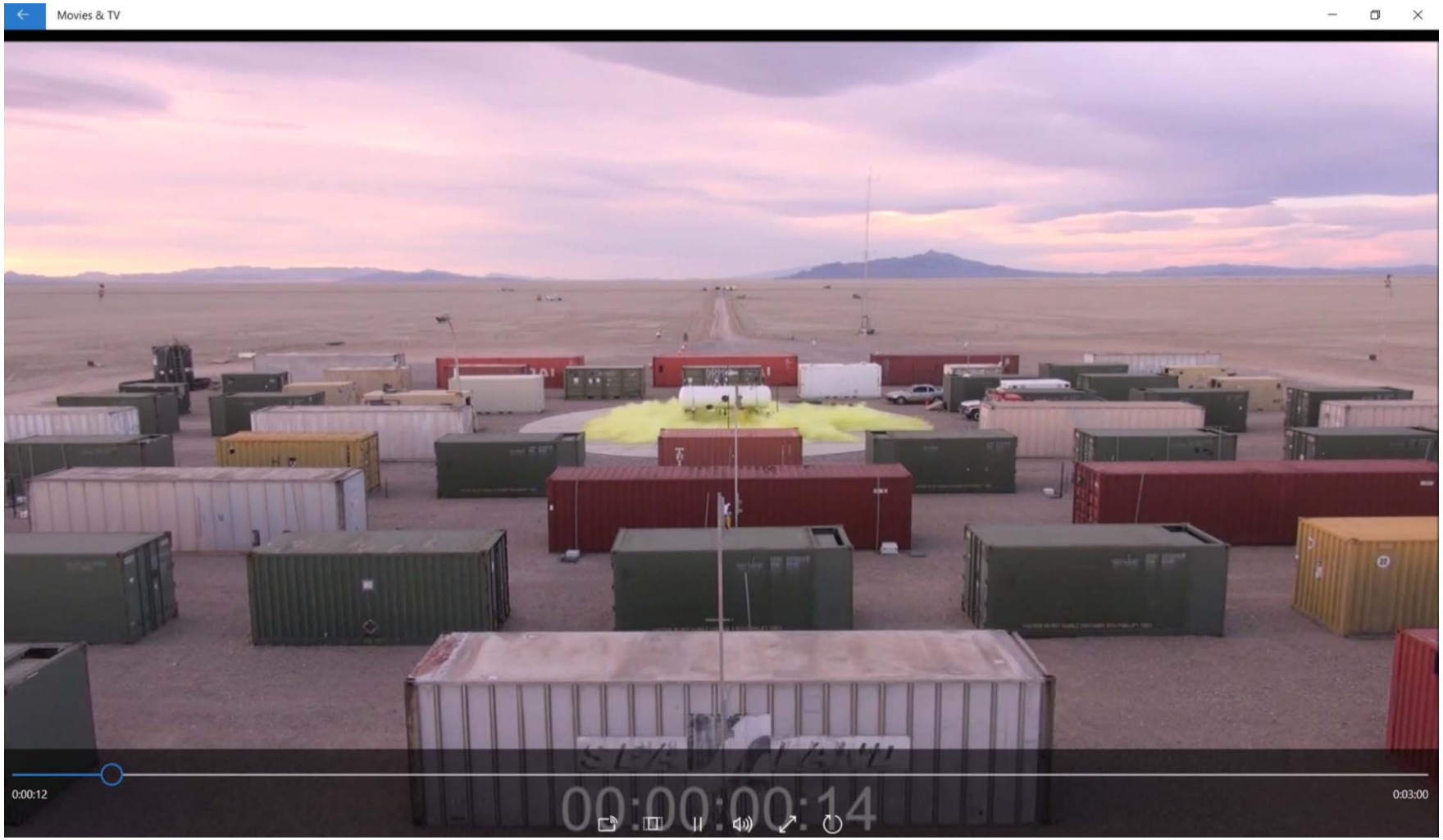
HARMO 17, Budapest, Hungary, 9-12 May 2016

JR II Cloud, Trial 5, looking toward south (upwind) 0.5 sec after release starts

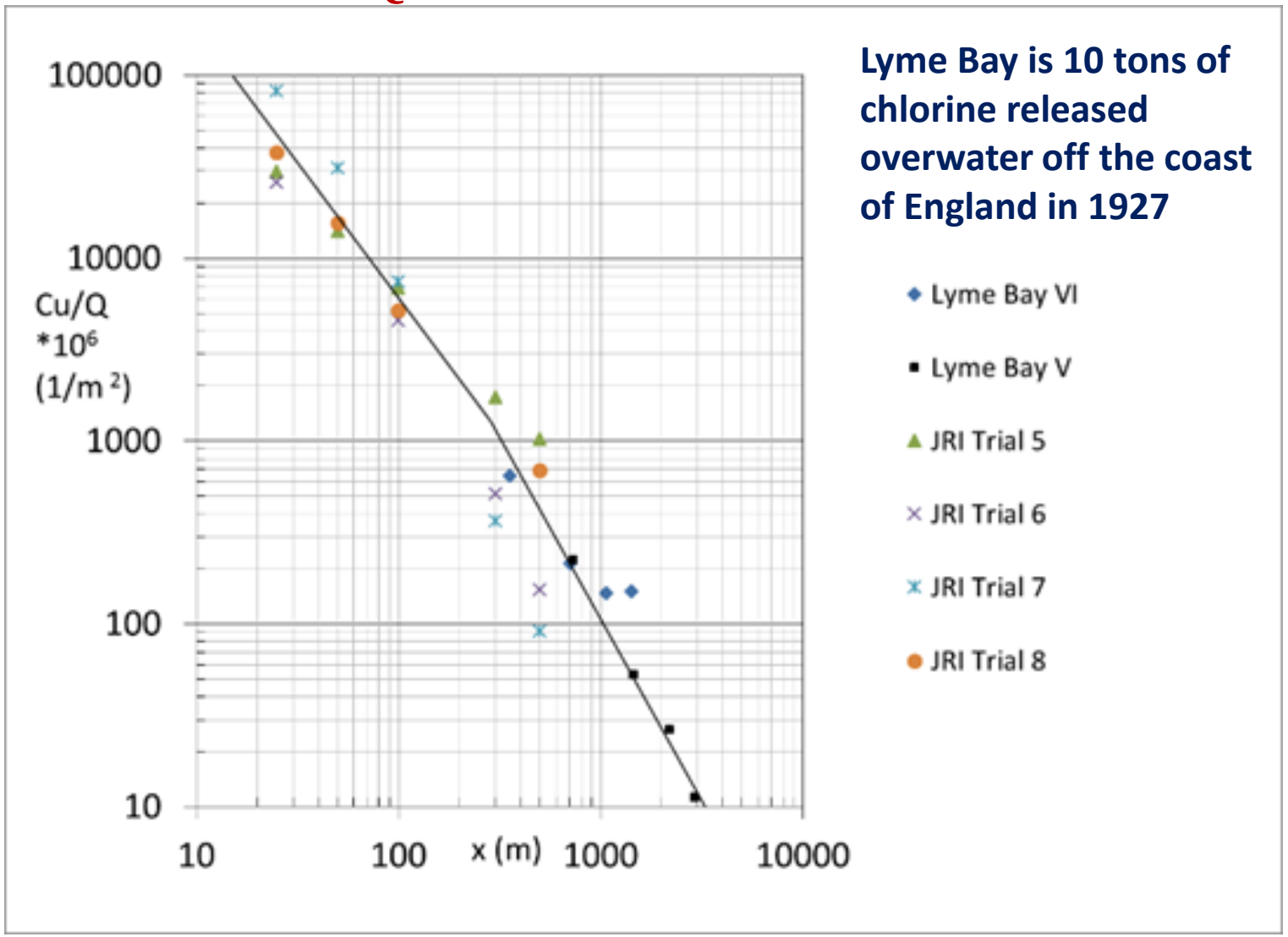


Side to side dimension of obstacle array = 100 m

Jack Rabbit II – Follow-on to JR I

- JR I – 10 trials in 2010, releasing 1 or 2 tons of pressurized liquefied chlorine or anhydrous ammonia. Mostly light winds, downward release into artificial 2 m deep by 25 m radius depression. Downwind C observations to 500 m.
- JR II – 5 trials in 2015, releasing 5 to 9 tons of chlorine. Moderate winds, downward release in middle of mock urban array. Downwind C observations to 11 km, and inside some buildings.
- Planned JR II 2016 – 10 to 20 tons released over flat desert surface (same location as 2015 but with mock urban array removed). 7 trials planned with a variety of release orientations.

JR I and Lyme Bay observed Cu/Q_c versus x. C is one-min avg arc max, u is wind speed, and Q_c is mass emission rate.



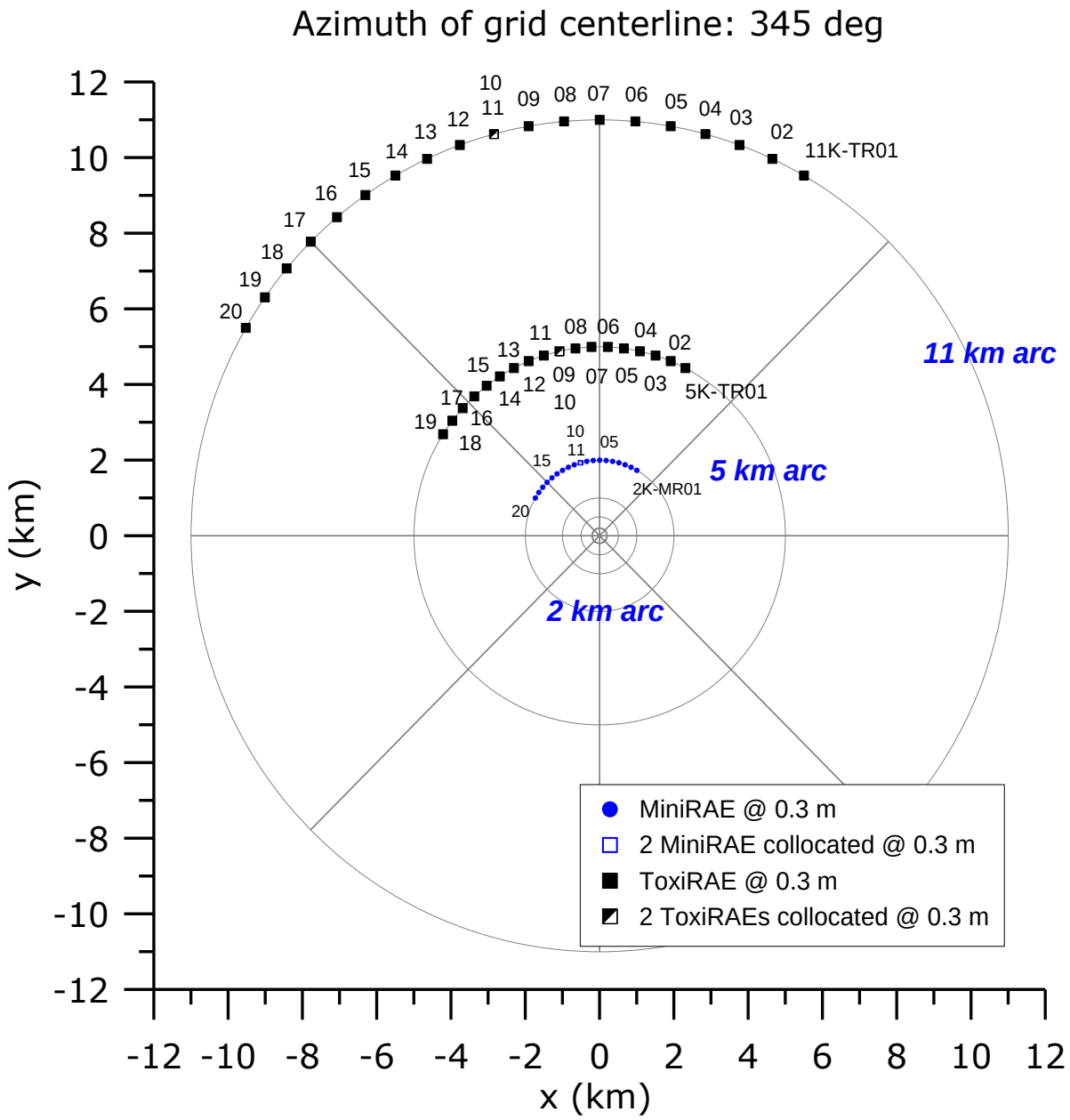
Summary of JR II - 2015

Trial		1	2	3	4	5
Release (MDT, = UTC-6)	Date	8/24/2015	8/28/2015	8/29/2015	9/1/2015	9/3/2015
	Start Time	7:35:45	9:24:21	7:56:55	8:38:50	7:28:19
	Duration (sec)	30	60	30	45	60
Release Amount (kg)		4,518	8,168	4,521	6,985	8,321
AVG PWIDS Wind Direction (deg)		147	158	170	184	183
AVG PWIDS Wind Speed (m/s)		1.9	4.3	4.0	2.3	2.8
AVG PWIDS Temperature (C)		17.7	22.7	22.6	22.6	22.2

Plume behavior

- The powerful jet release lasted about 1 min, and evaporation from the concrete pad had mostly ended after 5 min
- The initial powerful momentum jet goes 50-100 m in all directions, “splashes” against obstacles; therefore depth is about 2-3 m.
- Travel time to farthest (11 km) arc is about 1 or 2 hrs. Shallow (10-20 m deep) yellow cloud visible out to 500 m.
- Max C is proportional to $x^{-5/3}$

JR II Concentration Samplers - Far

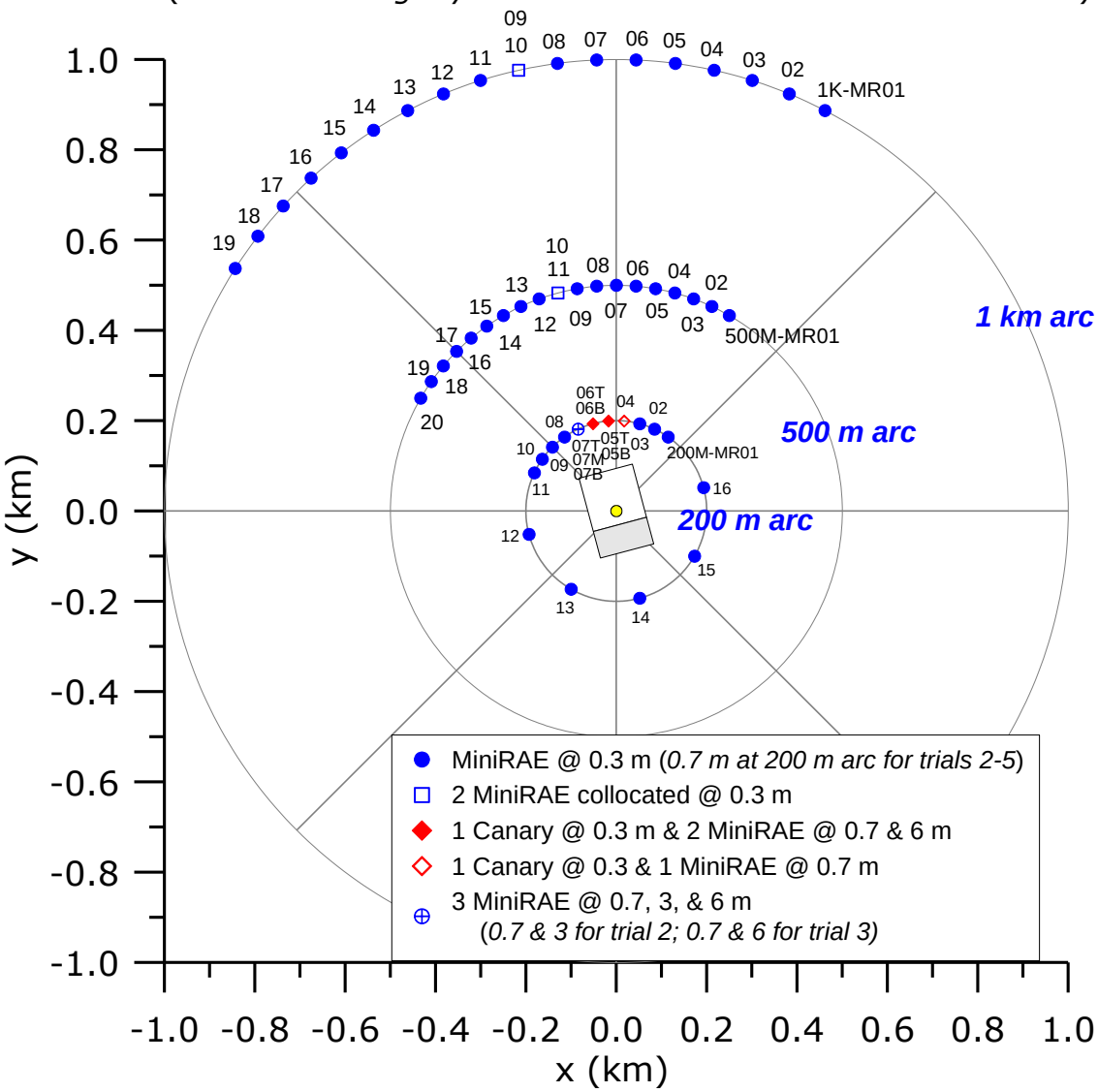


JR II Concentration Samplers - Mid

Azimuth of grid centerline: 345 deg

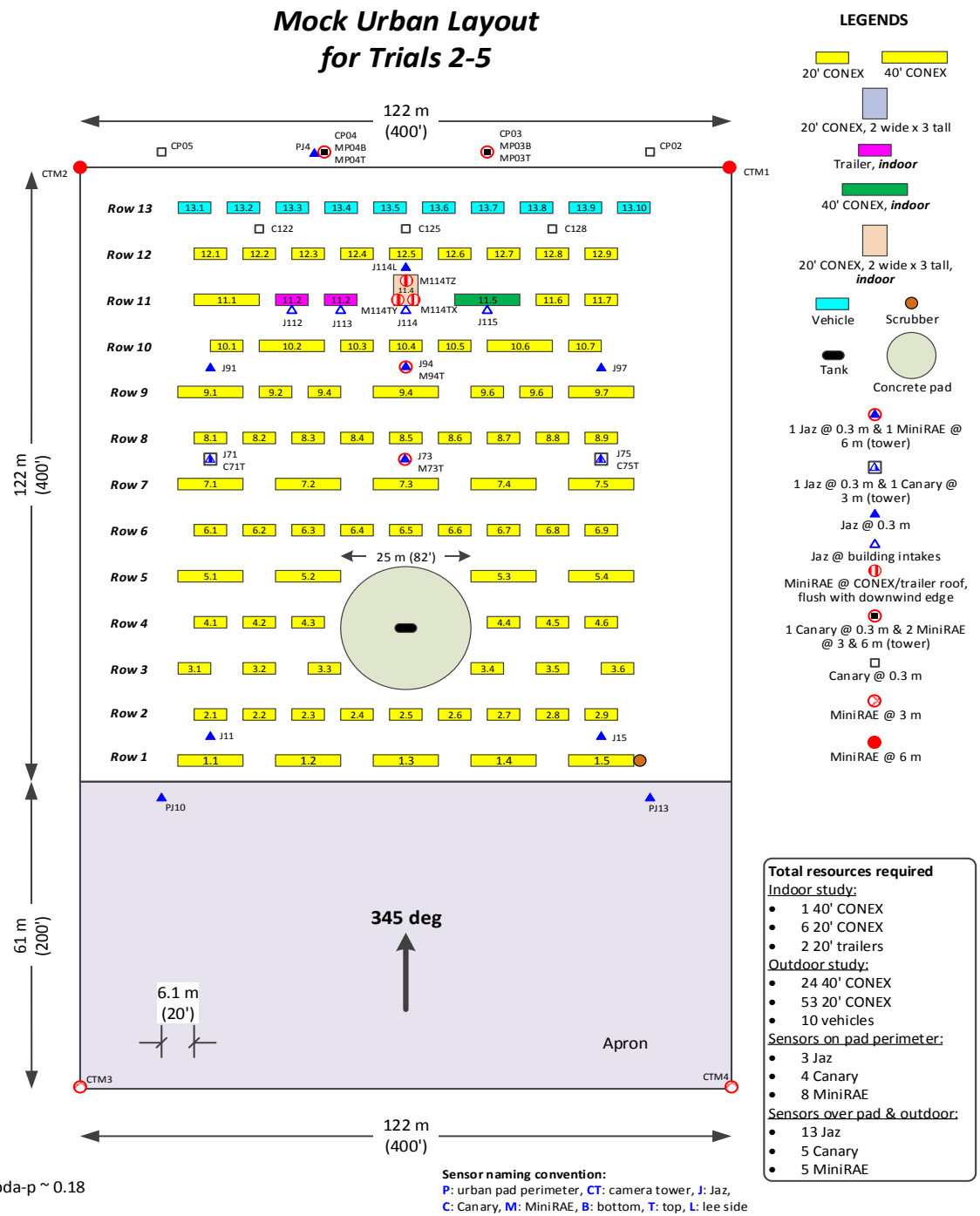
Trials 2 & 3

(*Trials 4 & 5 Slightly Different in Where Canaries Were Placed*)



JR II 2015 Near-Field Mock Urban Layout

Shows source, concrete pad, CONEXs, ER vehicles and C sampler locations (JAZ, Canary, MiniRae)



Total resources required

Indoor study:
- 1 40' CONEX
- 6 20' CONEX
- 2 20' trailers

Outdoor study:
- 24 40' CONEX
- 53 20' CONEX
- 10 vehicles

Sensors on pad perimeter:
- 3 Jaz
- 4 Canary
- 8 MiniRAE

Sensors over pad & outdoor:
- 13 Jaz
- 5 Canary
- 5 MiniRAE

Lambda-p ~ 0.18

Sensor naming convention:
P: urban pad perimeter, **CT**: camera tower, **J**: Jaz, **C**: Canary, **M**: MiniRAE, **B**: bottom, **T**: top, **L**: lee side

Portable Weather Instrumentation Data System (PWIDS) on a Tripod (z = 2 m)

10 ton Tank used for Chlorine Releases

Small Trailer used for Indoor Study

JR II Trial 2, 4.3 sec after the release starts

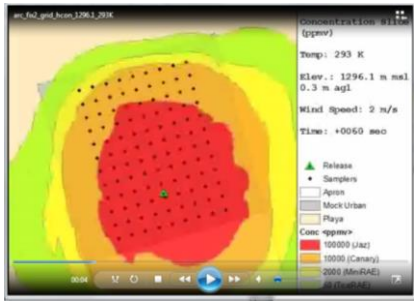
Pre JR-II Exp Model Outputs 10 ton

At 60 seconds, 0.3 m AGL

Figure by J. Boyd and T. Mazzola

SCIPUFF
(R. Babarsky)

1



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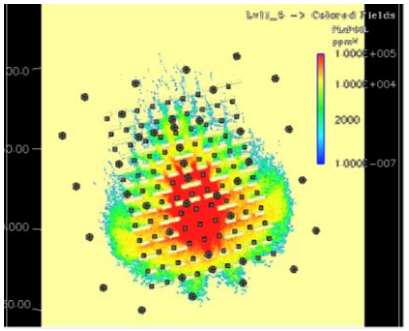
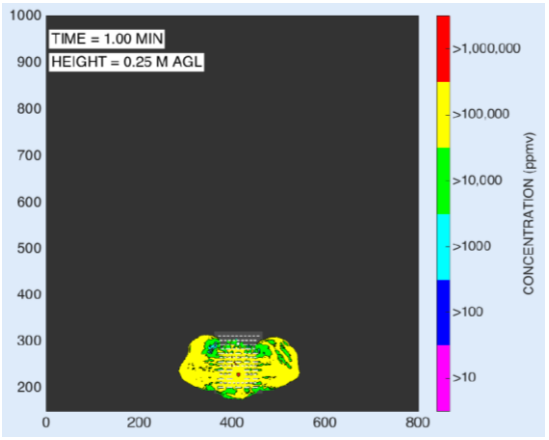


MSS
(S. Bereznicki)

AEOLUS at
30 s (A.
Gowardhan)

3



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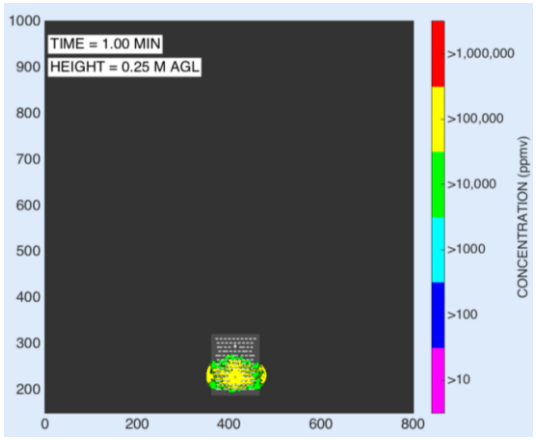
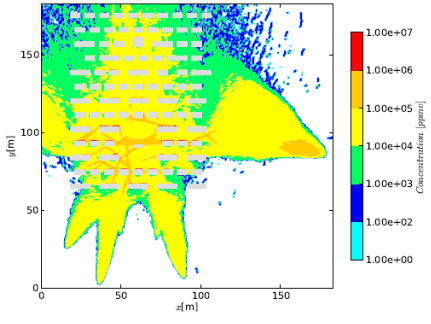


AEOLUS at
300 s (A.
Gowardhan)

IIBR
(H. Kaplan)

5



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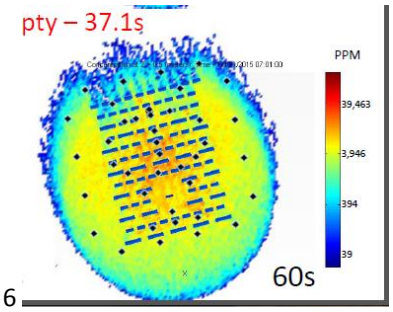
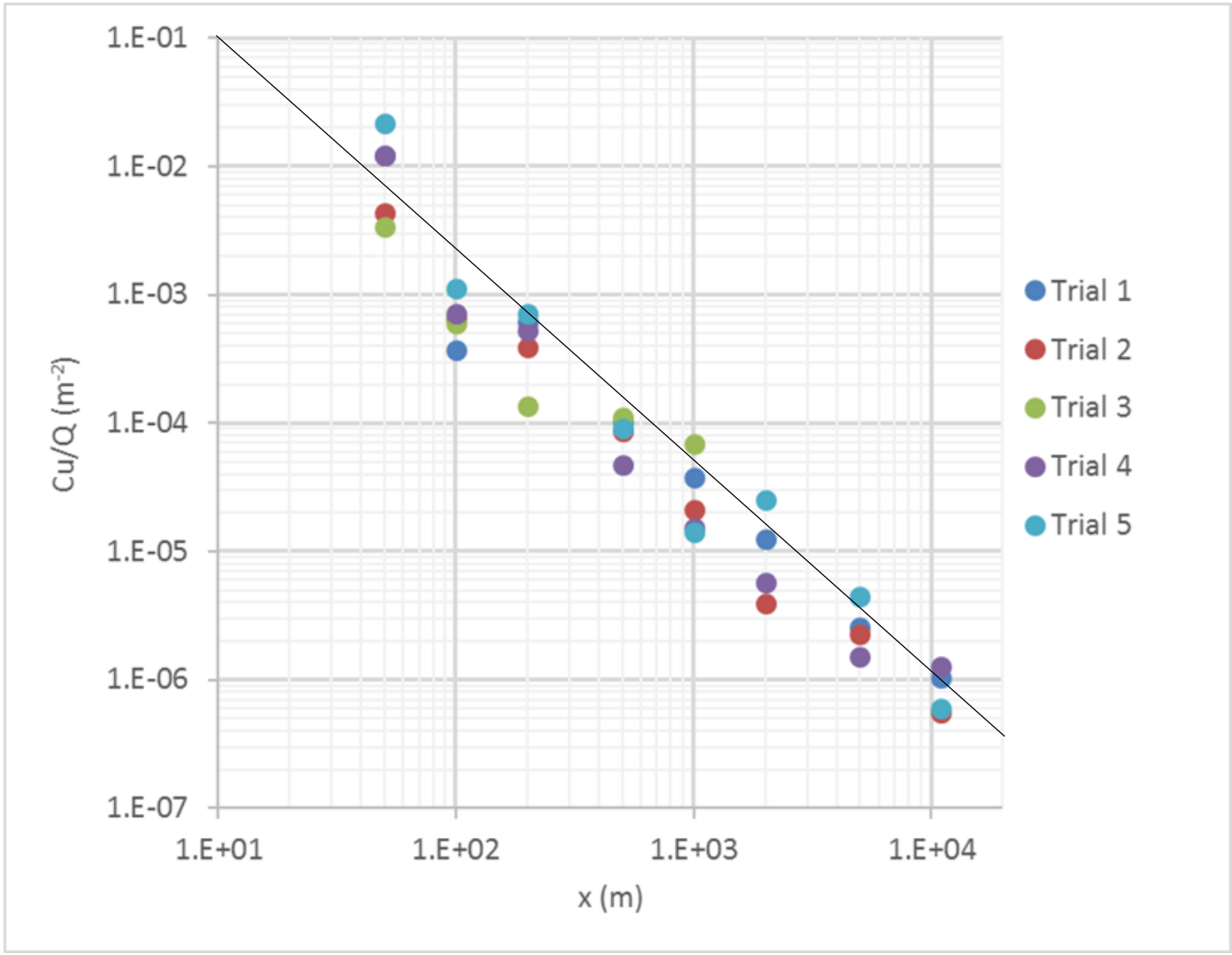


RAILCAR/QUIC
(M. Morad)

Modeled versus Observed Cloud in Urban CONEX array

- Some models on the previous page suggest a horseshoe-shaped cloud, with a dip in C at the cloud center at x > 50 m. This is because much of the mass initially spread past the side edges of the CONEXs, and then moved downwind at a faster speed over the open desert.
- JR II concentration observations verified the above model expectations

Observed JR II 2015 arc max 1 sec avg Cu/Q (m^{-2}) vs x (m). Line is -5/3 power law fit.



Summary of preliminary analysis

- Data are archived on DHS CSAC HSIN website
- Arc max Cu/Q is proportional to $x^{-5/3}$, close to what is seen in earlier graph for JR I and LB
- Cross wind and vertical C distributions look reasonable and consistent with previous experiments and model expectations
- Time variations of C inside trailers are consistent with expected air exchange rates
- More powerful initial jet than expected, with less rainout (liquid deposition around source), 2-3 m vertical mixing when hitting CONEXs

A Few Limitations

- Not enough concentration samplers for the high range (C > 10,000 ppm).
- Difficult to measure vertical profiles.
- Aerosol observations have problems because the proportions of chlorine, ambient water, and ambient dust cannot be distinguished.
- Limited deposition measurements despite knowledge that deposition of chlorine is relatively large.

Next Steps

- Data are archived on DHS CSAC HSIN website
- JR II scientists are currently analyzing the data.
- 2016 JR II is being planned for August-September. Flat terrain. Will be six 10 ton and one 20 ton release. Various release angles (down, up, horizontal downwind, 45 degrees down). Will be additional indoor studies and placement of emergency vehicles.