NCAR

A Method for Targeting Chemical Samplers For Facility Monitoring in an Urban Area

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Air Quality Monitoring in Urban Locations

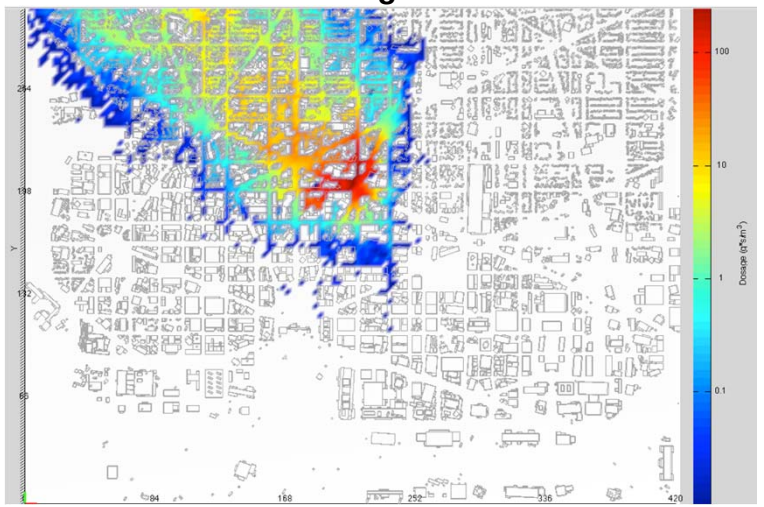
(Where Should Instrumentation Be Placed?)

- **Common problem for many applications**
  - **Facility protection**
  - **Emissions monitoring**

- **Assessments and sensor placement analyses rely heavily on transport and dispersion (T&D) modeling**

- **Challenges**
  - **Adequate model fidelity**
  - **Representative meteorological data set**
  - **Capture sensor characteristics**
  - **Adaptable to varying sampling duration, time, season, etc.**

2-m Anthrax Dosage Simulation
Washington DC



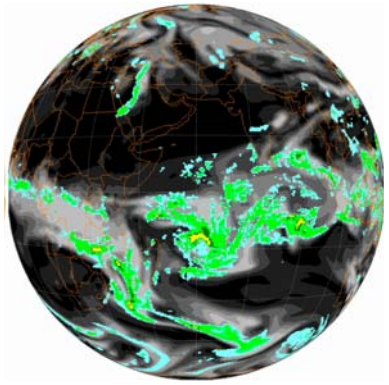
A Tradeoff Between Solution Fidelity and Representing the Full Range of Weather Conditions

Urban Chemical Sampler Placement

(Analysis Methodology)

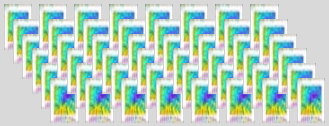
NCAR

21-Year Global Climate Database

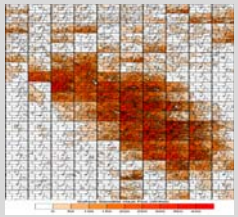


Weather Pattern Classifier

183960 Records

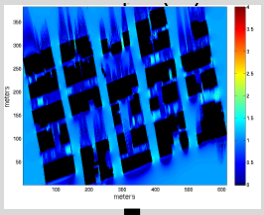


200 Records

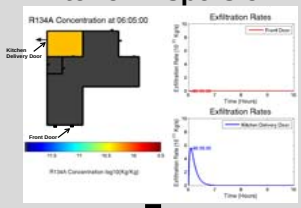


Dispersion Models

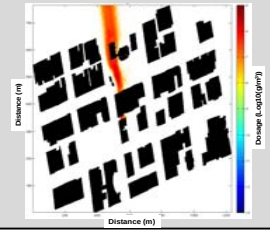
Urban Wind Flow



Interior Dispersion

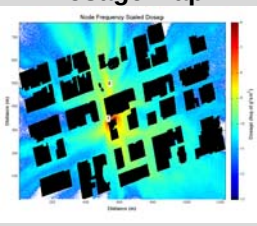


Exterior Dispersion

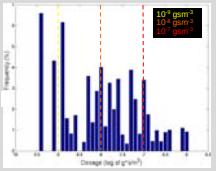


Detection Maps

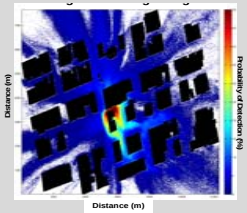
Dosage Map



Dosage Distributions



Detection Probability

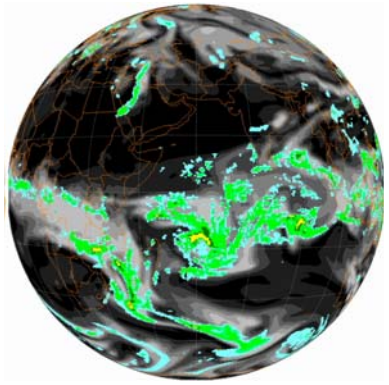


Possible to Have Both High Fidelity T&D and Representative Weather Conditions

Urban Chemical Sampler Placement

(Analysis Methodology)

21-Year Global Climate Database



Weather Pattern Classifier

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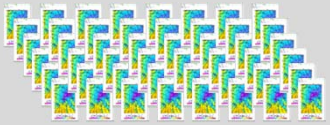

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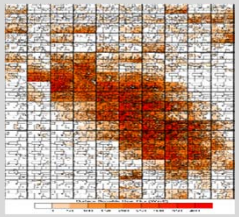
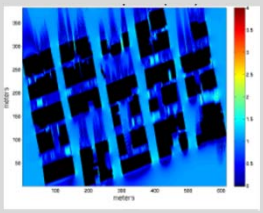


Dispersion Models

Urban Wind Flow



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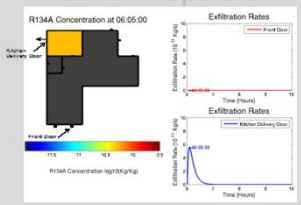

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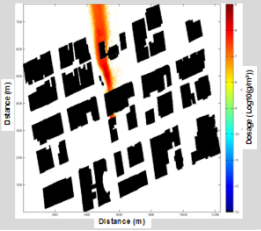

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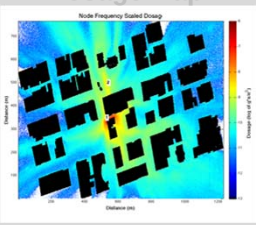
Dosage Map



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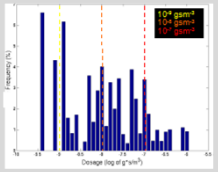

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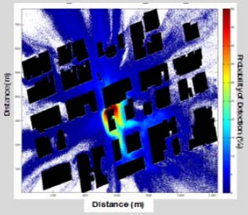
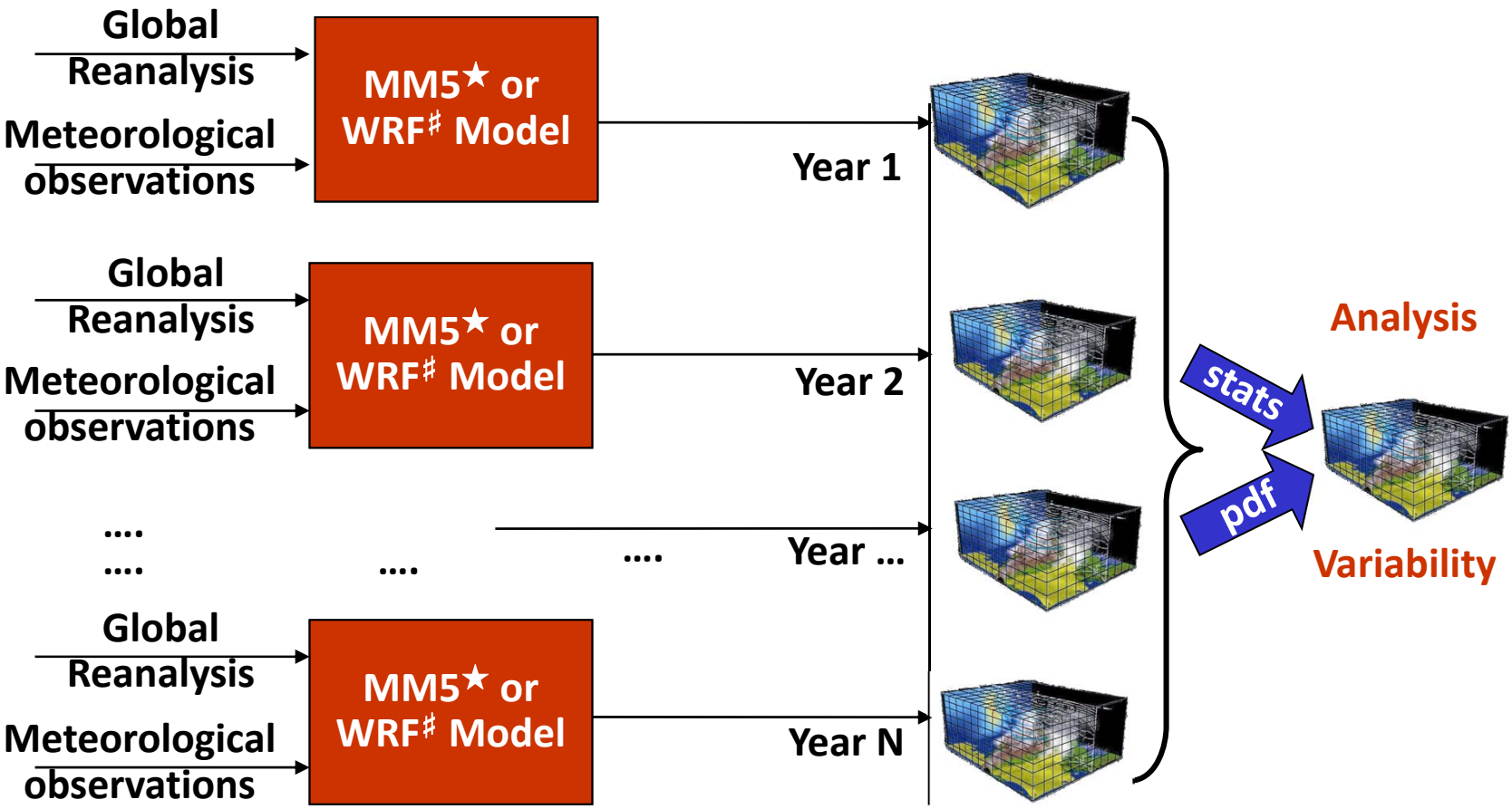


21-Year Global Climate Database

NCAR (Climate Four Dimensional Data Assimilation System (CFDDA))



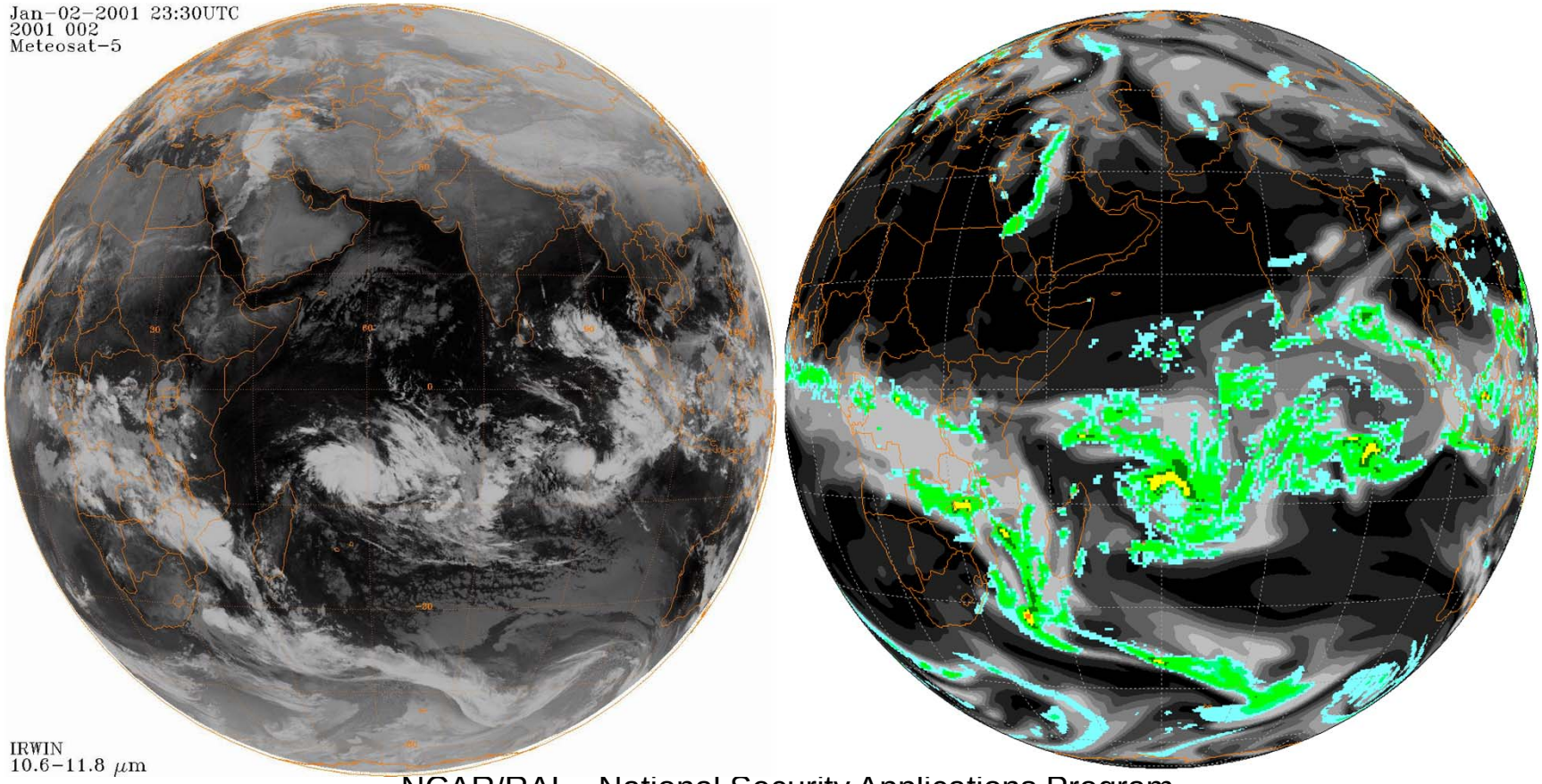
★ 5th Generation PSU/NCAR Mesoscale Model

♯ Weather Research and Forecast Model

21-Year Global Climate Database

(Developed to Support T&D Modeling Applications)

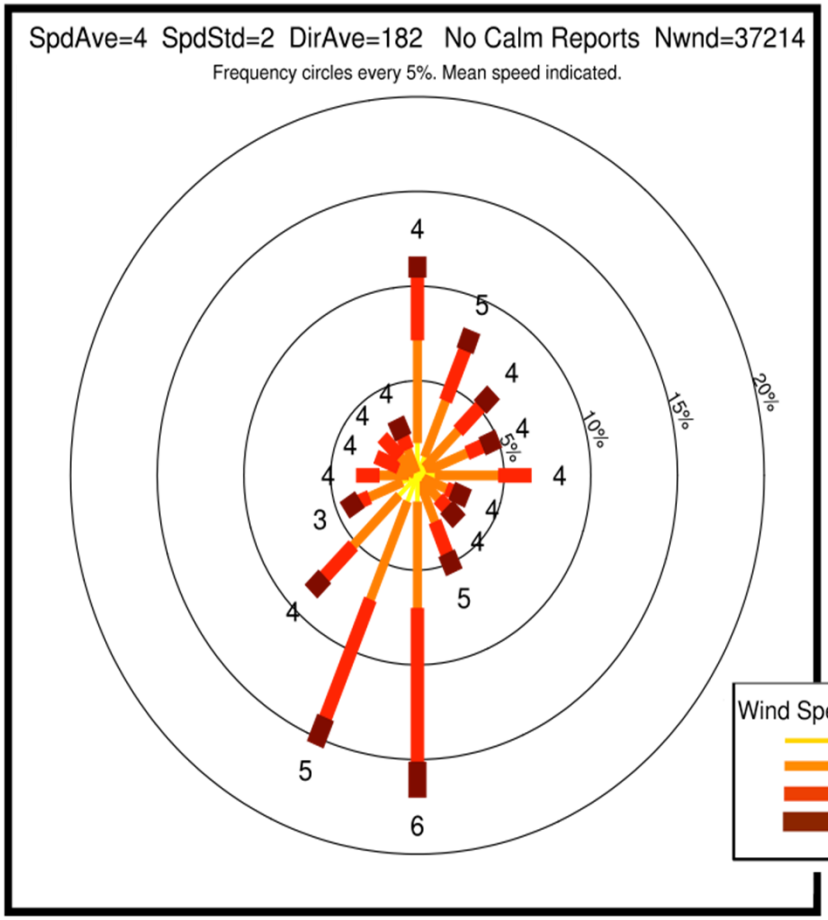
- **Global database**
  - **21 Year (1985-2006)**
  - **40 km horizontal resolution**
  - **1 hour temporal resolution**



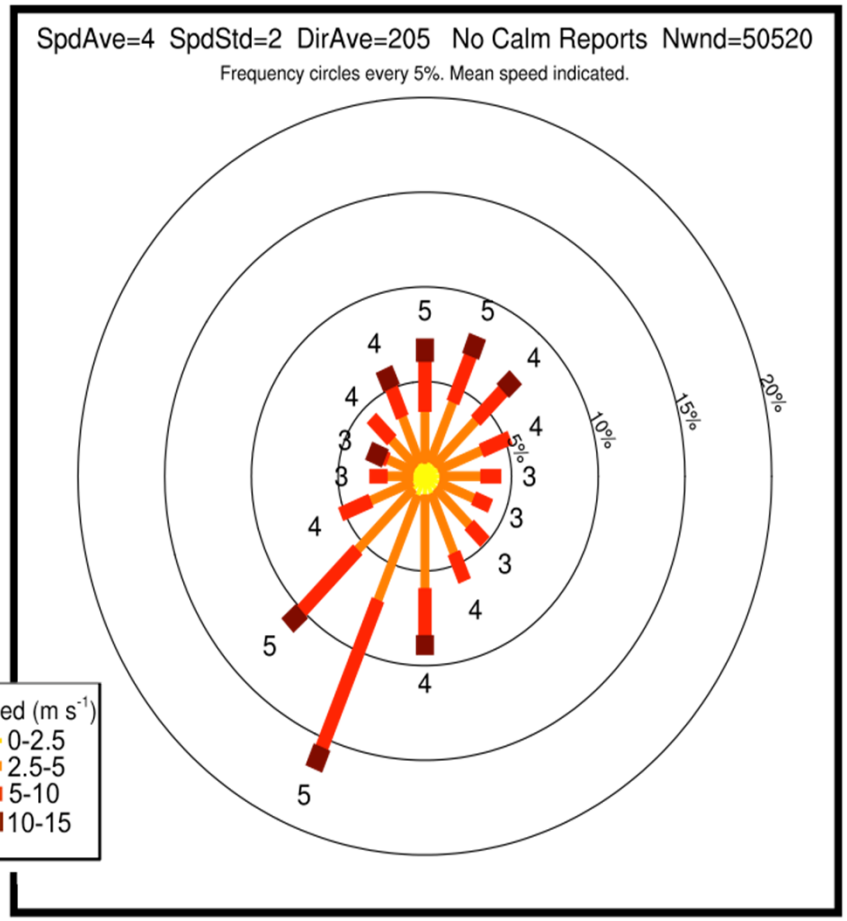
21-Year Global Climate Database

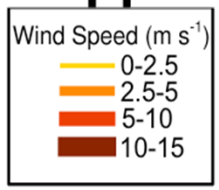
(Captures Variability in Variables Relevant to T&D)

Observations KMHK



Global Climate Database for KMHK



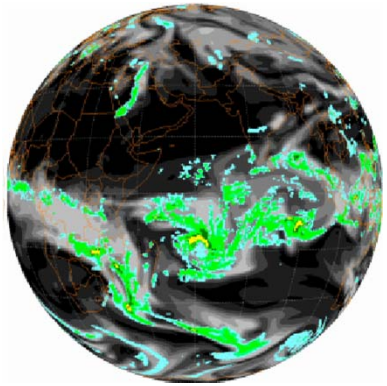


KMHK – Manhattan Kansas Regional Airport

Urban Chemical Sampler Placement

(Analysis Methodology)

21-Year
Global Climate Database



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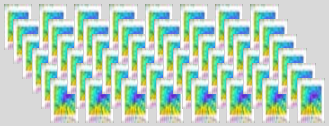

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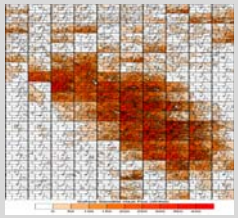
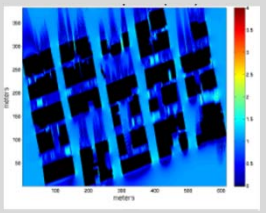
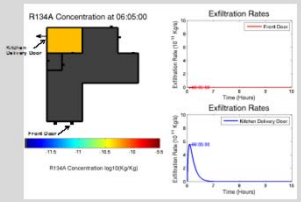
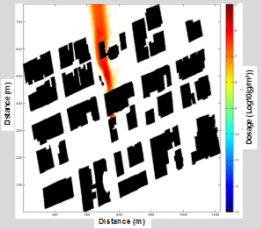


Dispersion Models







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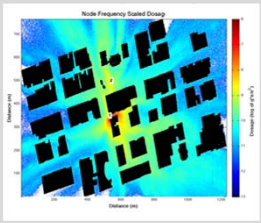
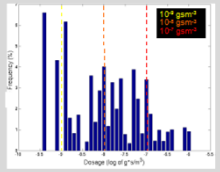
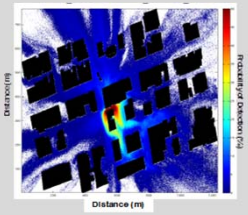


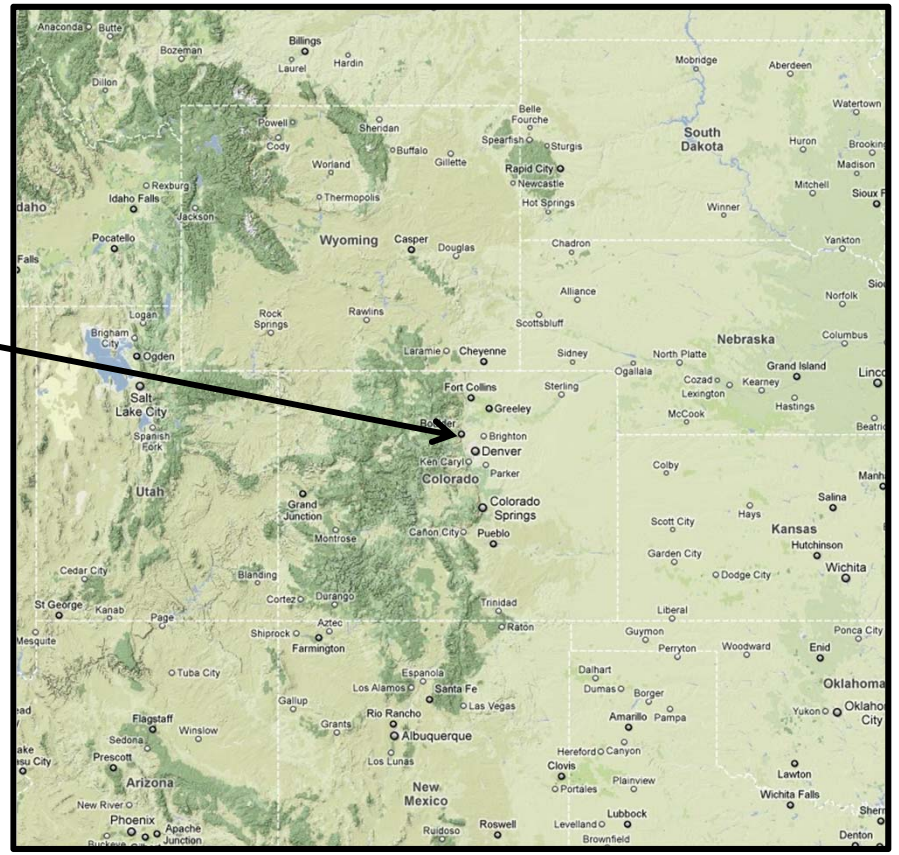




Weather Pattern Classifier

(Analysis Domain)

Centered on Boulder, CO USA



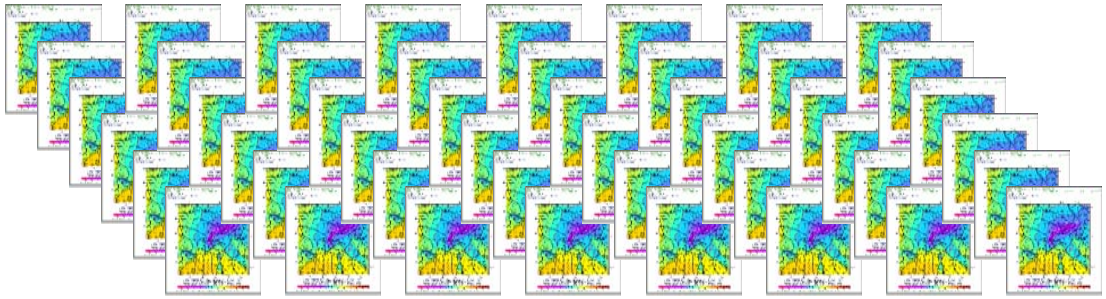
Domain Size Needs to be Sufficiently Large to Characterize the Predominant Weather Patterns

Weather Pattern Classifier

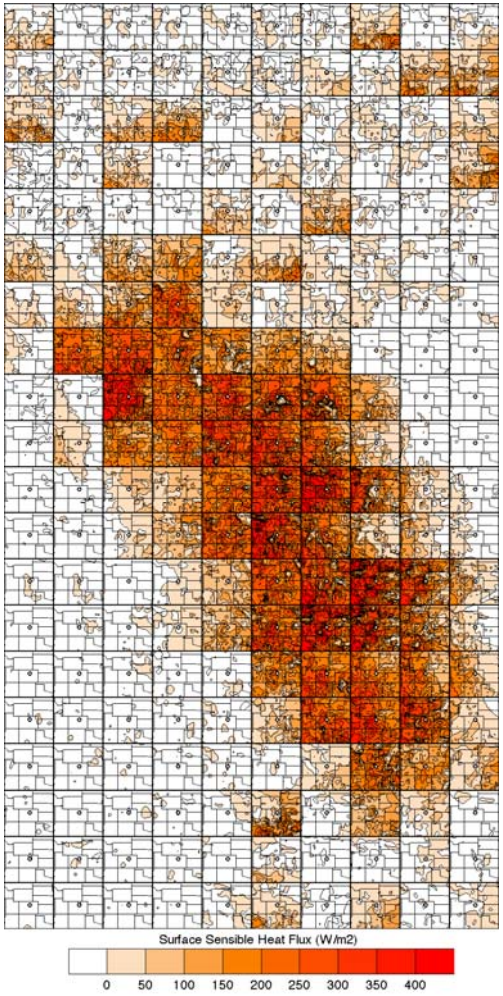
(Determining Representative Weather Conditions)

- **Self-Organizing Maps (SOM) technique**
  - **Neural network pattern recognition and classification**
  - **Tuned for variables of interest**
    - **Winds, Surface Sensible Heat Flux, Humidity**
  - **Physically consistent patterns**
  - **Frequency of occurrence of patterns**
  - **Date/time for most representative day**
  - **200 nodes selected to capture outlier events**

Global Climate Data Base – 183,960 Records



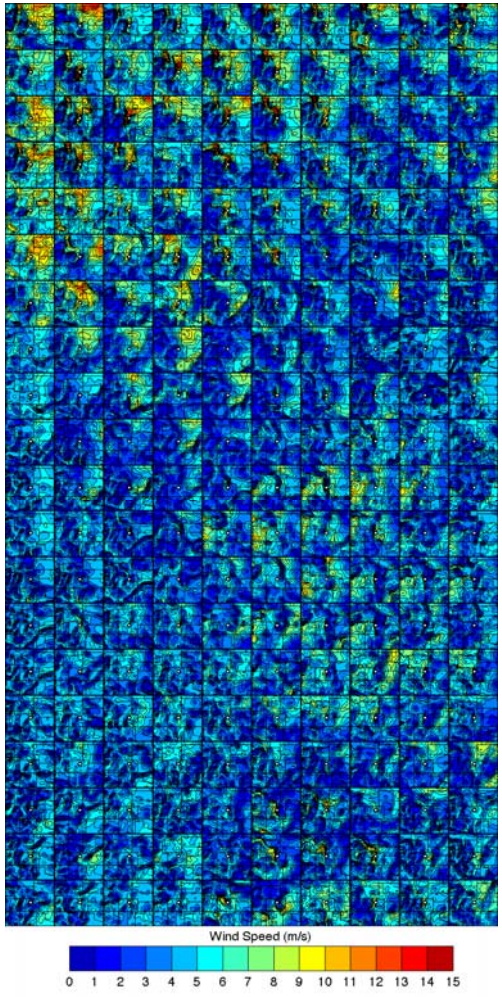
Surface Sensible Heat Flux (200 Records)



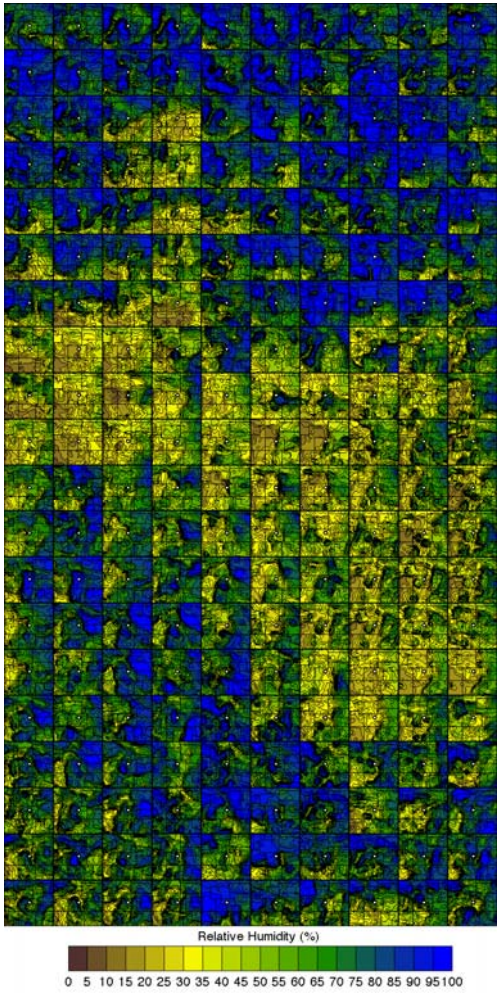
Weather Pattern Classifier

(SOM Lattice Maps)

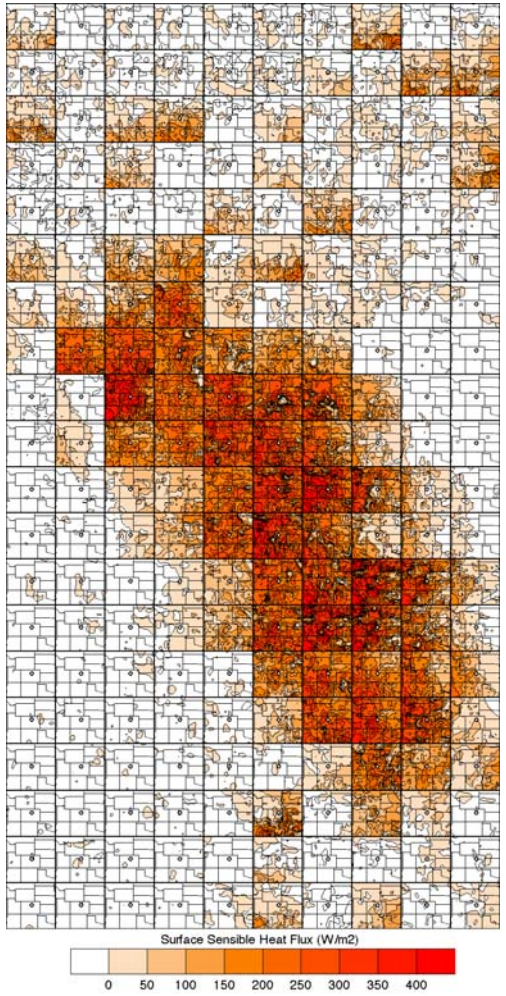
10-m Winds



2-m Relative Humidity



Surface Sensible Heat Flux



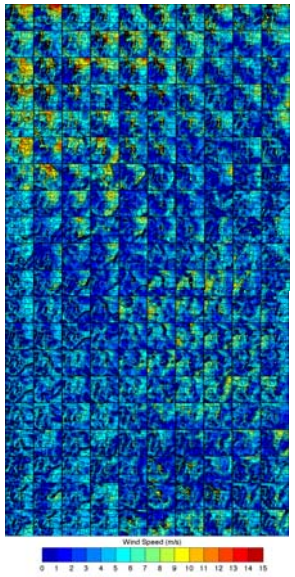
Weather Pattern Classifier

(SOM Lattice Maps)

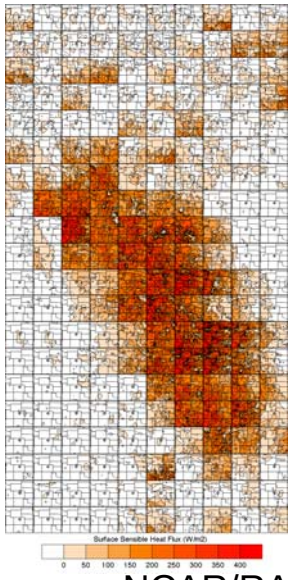
Wind velocity (V) on reference height of 10 m (m/s)	Daytime period - Insolation			Nighttime period – Cloudiness	
	Strong	Moderate	Slight	Thinly overcast	<= 3/8 cloud
V ≤ 2	A	A - B	B	-	-
2 < V ≤ 3	A - B	B	C	E	F
3 < V ≤ 5	B	B - C	C	D	E
5 < V ≤ 6	C	C - D	D	D	D
6 < V	C	D	D	D	D

Pasquill Stability Classification Node Map utilizing 10m velocity and incoming solar radiation.

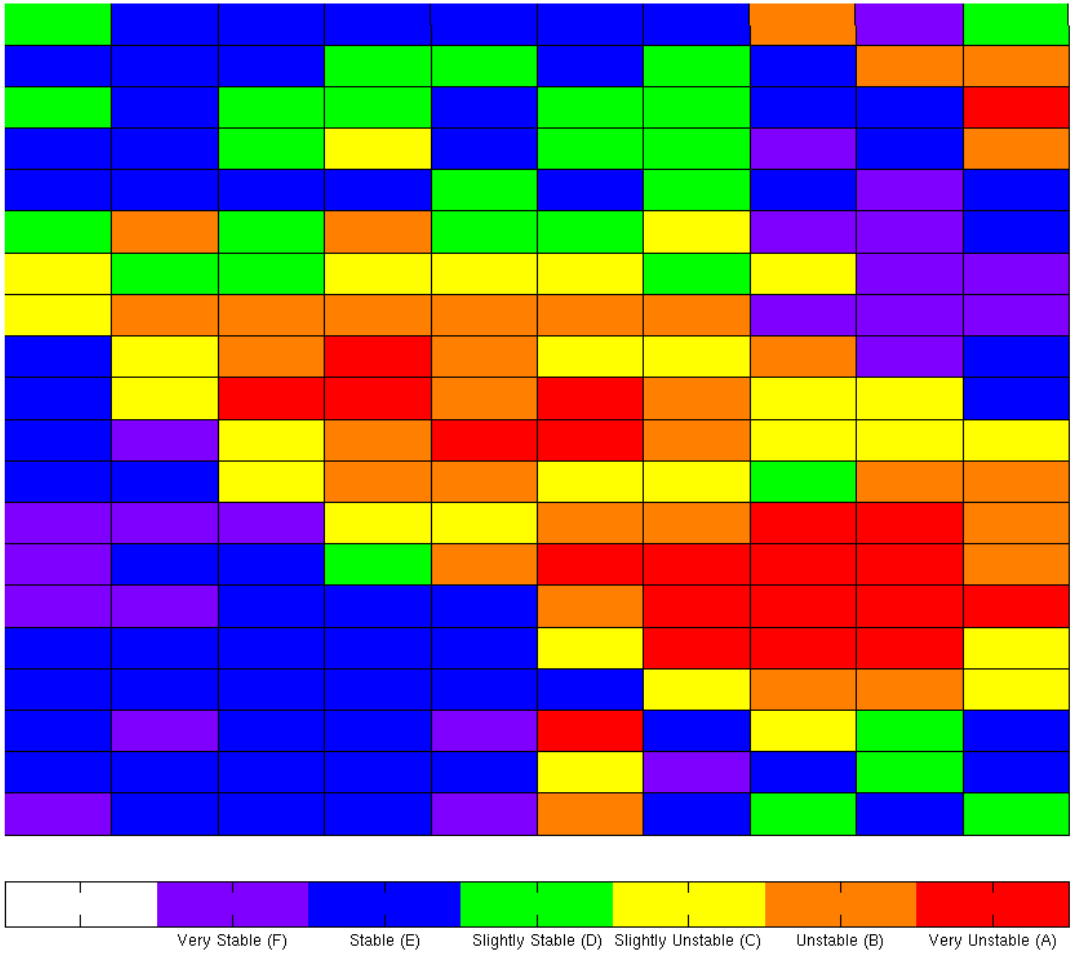
Wind Speed



Heat Flux



Stability Classification



***Based on: Pasquil (1961), Venkatram (1995), Mohan and Siddiqui (1998)**

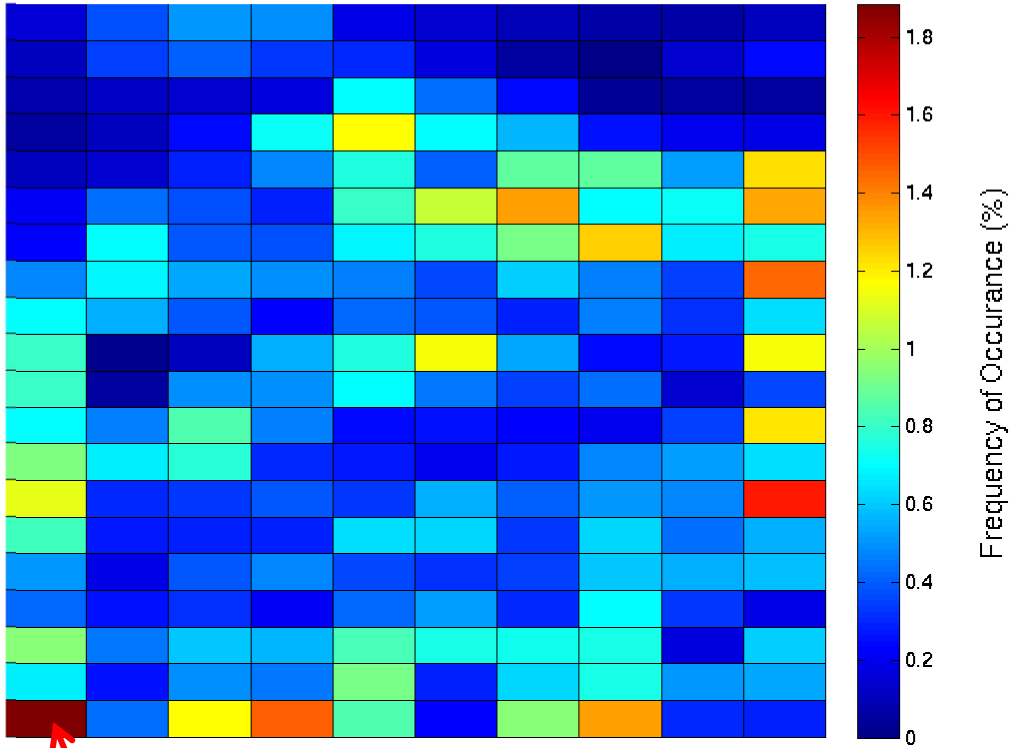
Weather Pattern Classifier

NCAR **(SOM Frequency of Occurrence and Representative Date)**

SOM Lattice Node Identifiers

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49
50	51	52	53	54	55	56	57	58	59
60	61	62	63	64	65	66	67	68	69
70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89
90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109
110	111	112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127	128	129
130	131	132	133	134	135	136	137	138	139
140	141	142	143	144	145	146	147	148	149
150	151	152	153	154	155	156	157	158	159
160	161	162	163	164	165	166	167	168	169
170	171	172	173	174	175	176	177	178	179
180	181	182	183	184	185	186	187	188	189
190	191	192	193	194	195	196	197	198	199

SOM Lattice Node Frequencies of Occurrence (%)



Node 190 - Most Frequently Occurring Mode

Weather Pattern Classifier

NCAR (Representative Date and Time for Each Weather Pattern)

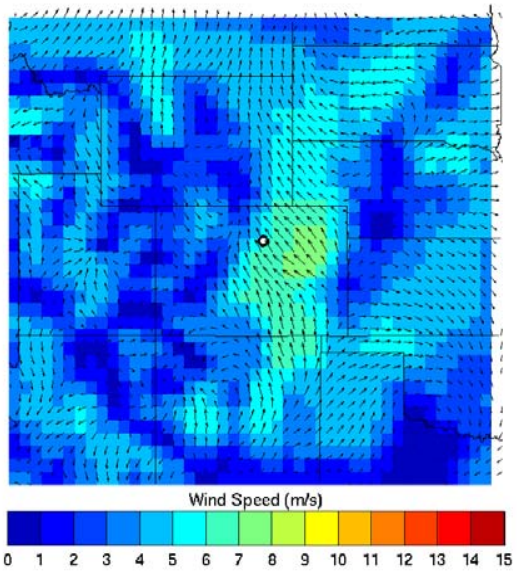
01/13/85 17:00	01/14/85 00:00	01/30/92 09:00	01/30/92 11:00	11/14/92 11:00	01/21/90 08:00	01/21/90 03:00	01/12/85 19:00	01/19/92 00:00	01/12/85 15:00
12/26/97 07:00	01/09/92 08:00	11/28/90 14:00	03/07/93 14:00	01/21/90 15:00	01/21/90 11:00	12/02/04 16:00	11/22/04 05:00	12/05/02 20:00	12/05/02 19:00
01/16/85 20:00	12/21/85 04:00	12/28/85 20:00	12/04/89 19:00	12/29/85 04:00	12/31/85 16:00	01/05/85 15:00	12/06/02 06:00	12/06/02 03:00	01/25/85 22:00
12/15/85 08:00	12/21/85 12:00	01/03/03 21:00	11/07/85 00:00	01/01/86 01:00	12/31/85 22:00	11/17/97 15:00	12/16/86 08:00	12/18/93 09:00	01/25/85 18:00
11/30/88 03:00	11/29/88 11:00	11/28/90 02:00	12/05/89 00:00	11/26/00 21:00	11/26/00 11:00	11/17/97 18:00	12/01/04 09:00	12/16/86 04:00	12/18/93 06:00
11/29/88 22:00	01/08/92 23:00	11/21/97 20:00	11/06/85 17:00	11/26/00 16:00	02/12/93 17:00	12/19/86 22:00	01/08/87 04:00	11/23/87 05:00	11/15/92 05:00
02/13/85 23:00	12/12/89 22:00	02/06/00 20:00	10/09/92 18:00	10/02/95 15:00	11/03/85 15:00	12/25/86 15:00	01/06/87 23:00	01/07/87 03:00	10/16/00 05:00
10/10/92 00:00	10/08/96 21:00	10/08/96 19:00	09/28/87 17:00	08/27/87 16:00	11/03/85 18:00	12/25/86 20:00	10/19/85 01:00	09/16/98 03:00	08/02/97 03:00
10/10/92 01:00	10/09/96 00:00	08/23/85 20:00	08/19/97 17:00	08/07/86 17:00	09/09/97 18:00	09/09/97 21:00	09/15/98 23:00	10/17/86 01:00	08/20/85 02:00
10/09/96 02:00	10/22/99 23:00	06/13/87 16:00	08/07/86 16:00	08/18/91 18:00	08/31/95 20:00	08/31/95 22:00	08/18/97 00:00	08/21/90 01:00	08/19/85 02:00
10/09/96 08:00	10/24/94 12:00	08/07/86 14:00	08/30/97 15:00	08/31/95 17:00	08/19/85 18:00	08/19/85 20:00	08/20/90 22:00	08/21/90 00:00	08/24/90 01:00
10/09/96 10:00	09/07/97 12:00	08/31/95 14:00	08/19/85 15:00	08/20/90 17:00	08/20/90 19:00	09/13/97 21:00	09/13/97 23:00	08/24/90 00:00	08/21/89 01:00
07/17/92 10:00	07/17/92 11:00	08/31/95 12:00	08/26/97 14:00	08/21/90 15:00	08/21/90 17:00	09/10/91 19:00	08/20/89 20:00	08/20/89 22:00	08/21/89 00:00
08/31/95 10:00	08/19/85 11:00	08/21/90 12:00	08/21/90 14:00	08/07/93 15:00	08/07/93 17:00	08/20/89 19:00	08/20/89 21:00	09/06/97 22:00	09/07/97 00:00
08/31/95 09:00	08/10/93 10:00	08/21/90 11:00	10/17/86 12:00	08/07/93 12:00	08/20/89 16:00	09/27/95 18:00	10/08/98 20:00	09/19/01 22:00	09/19/01 23:00
08/19/85 09:00	10/17/86 09:00	08/07/93 09:00	09/27/95 11:00	11/11/01 13:00	09/06/99 15:00	09/06/99 18:00	09/19/01 20:00	09/02/86 21:00	10/12/85 23:00
08/19/85 07:00	08/21/90 08:00	08/20/89 08:00	10/24/89 09:00	11/11/01 11:00	10/20/94 12:00	11/11/01 16:00	09/02/86 17:00	10/12/85 17:00	02/26/90 16:00
08/09/98 06:00	08/26/97 06:00	08/21/89 07:00	11/11/01 08:00	12/13/94 08:00	02/18/89 18:00	01/05/93 13:00	07/21/95 15:00	08/13/85 14:00	08/16/91 12:00
08/06/85 07:00	09/05/87 06:00	08/20/89 06:00	08/08/93 06:00	11/19/90 05:00	02/18/89 23:00	01/05/93 00:00	01/05/93 07:00	09/09/87 14:00	09/09/87 13:00
08/14/86 06:00	08/06/85 06:00	08/21/89 05:00	08/21/89 04:00	11/29/85 04:00	12/12/00 22:00	12/07/03 09:00	11/07/93 16:00	11/07/93 14:00	09/07/99 14:00

Weather Pattern Classifier

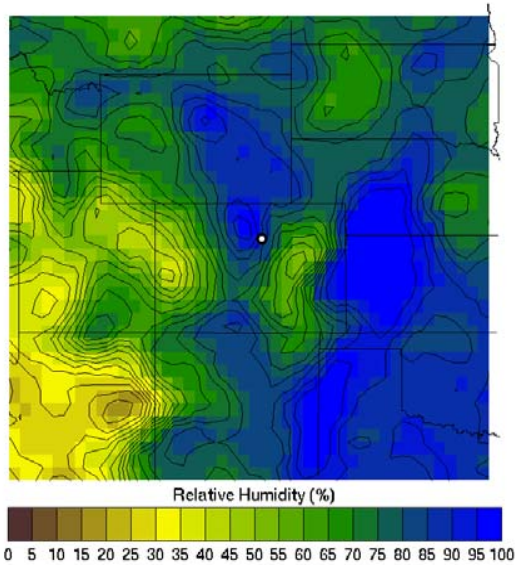
(Example: Node-190, Highest Frequency Pattern)

Date and Time: 08.14.1986 – 06:00

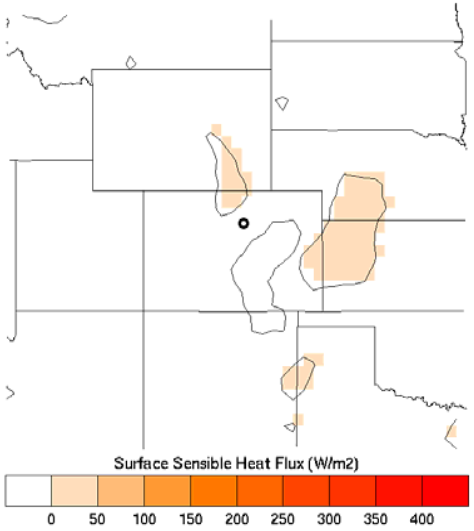
10-m Wind Speed



Relative Humidity



Surface Sensible Heat Flux

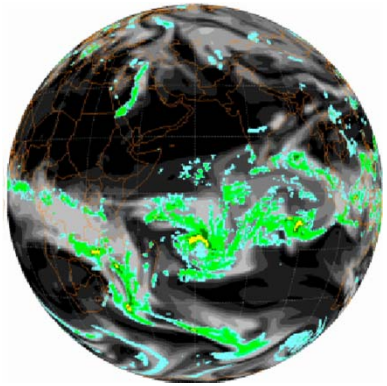


- **Boulder, CO USA**

Urban Chemical Sampler Placement

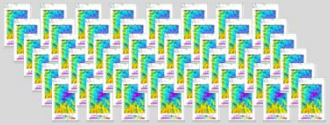
(Analysis Methodology)

21-Year
Global Climate Database

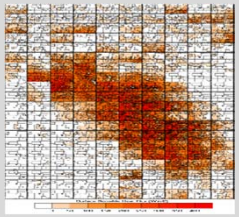


Weather
Pattern Classifier

183960 Records

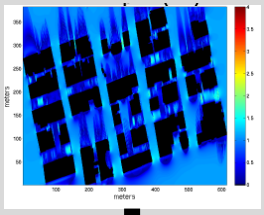


200 Records

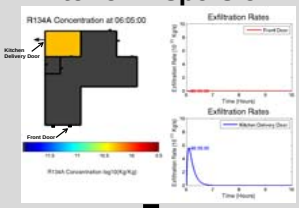


Dispersion Models

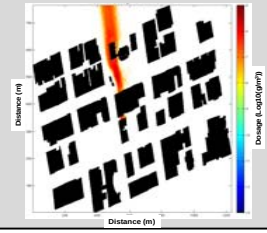
Urban Wind Flow



Interior Dispersion

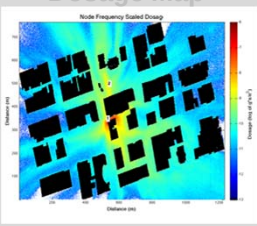


Exterior Dispersion

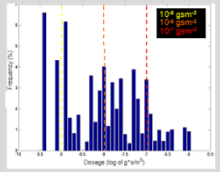


Detection Maps

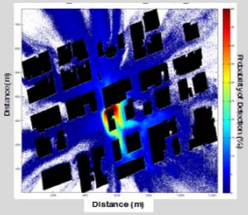
Dosage Map



Dosage Distributions



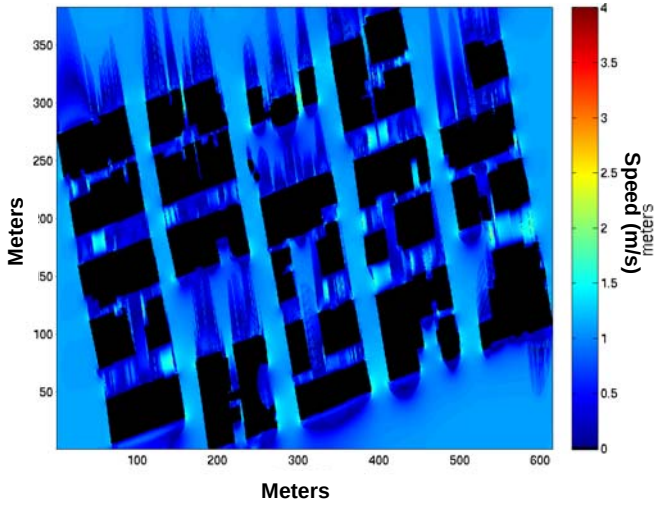
Detection Probability



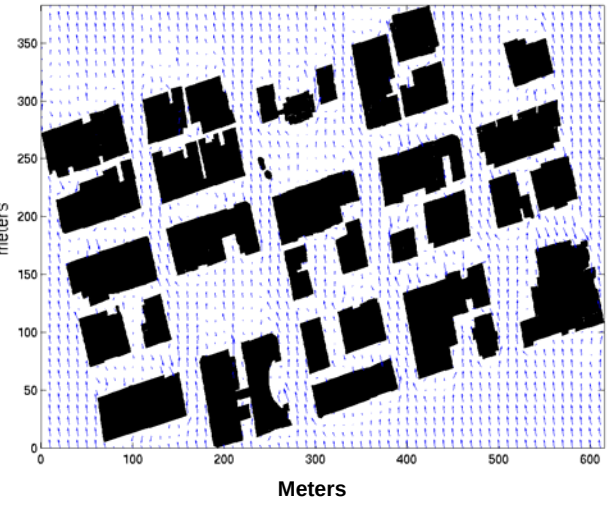
Dispersion Models
(Urban Wind Flow Models)

- **Quick Urban Industrial Complex (QUIC) dispersion modeling system**
  - **Developed by Los Alamos National Laboratory, USA**
  - **Based on the Röckle (1990) formulations**
  - **Utilized building geometries from Boulder, CO, USA**
  - **Provides "Building-Aware" wind flow and building wind loading pressures**

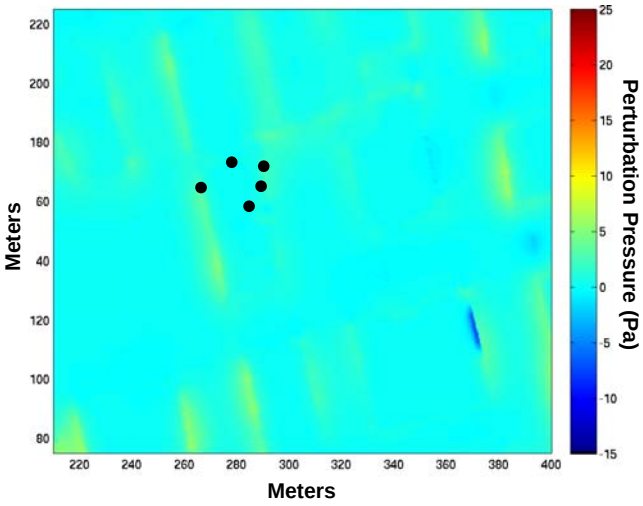
2-m Wind Speed



2-m Wind Vectors



2-m Perturbation Pressure



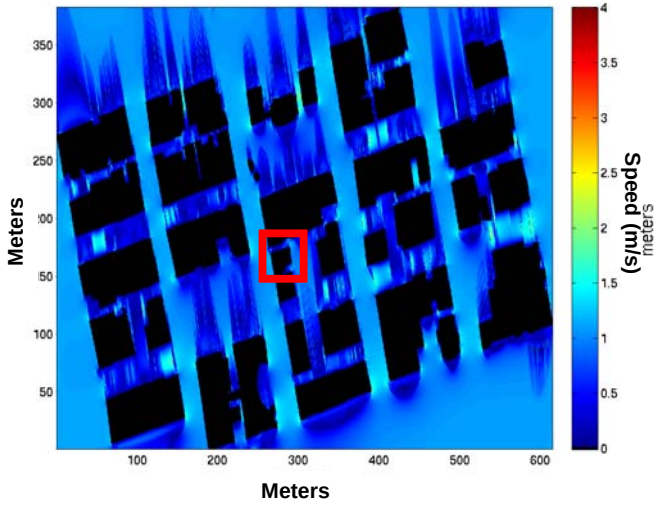
•Denotes infiltration/exfiltration points (eg. windows, doors, etc.)

Dispersion Models

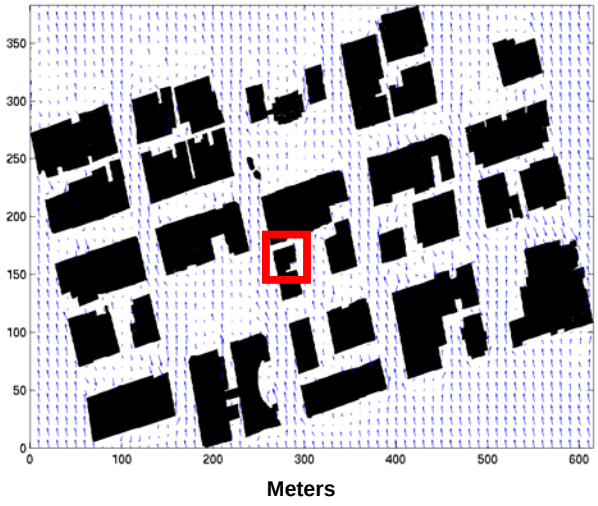
(CONTAM Interior Dispersion Model)

- **Utilized the United States (US) National Institute of Standards and Technology (NIST) CONTAM model**
  - **Indoor air transport and dispersion model**
  - **Wind pressures acting on building exterior**
  - **Buildings are modeled as idealized zones with appropriate flow paths**
- **Provides**
  - **Chemical concentrations in a interior zone**
  - **Chemical material flow directions and infiltration/exfiltration rates**

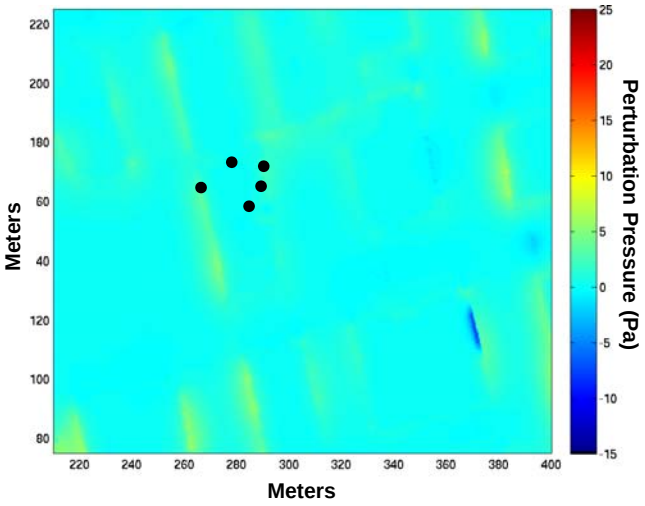
2-m Wind Speed



2-m Wind Vectors



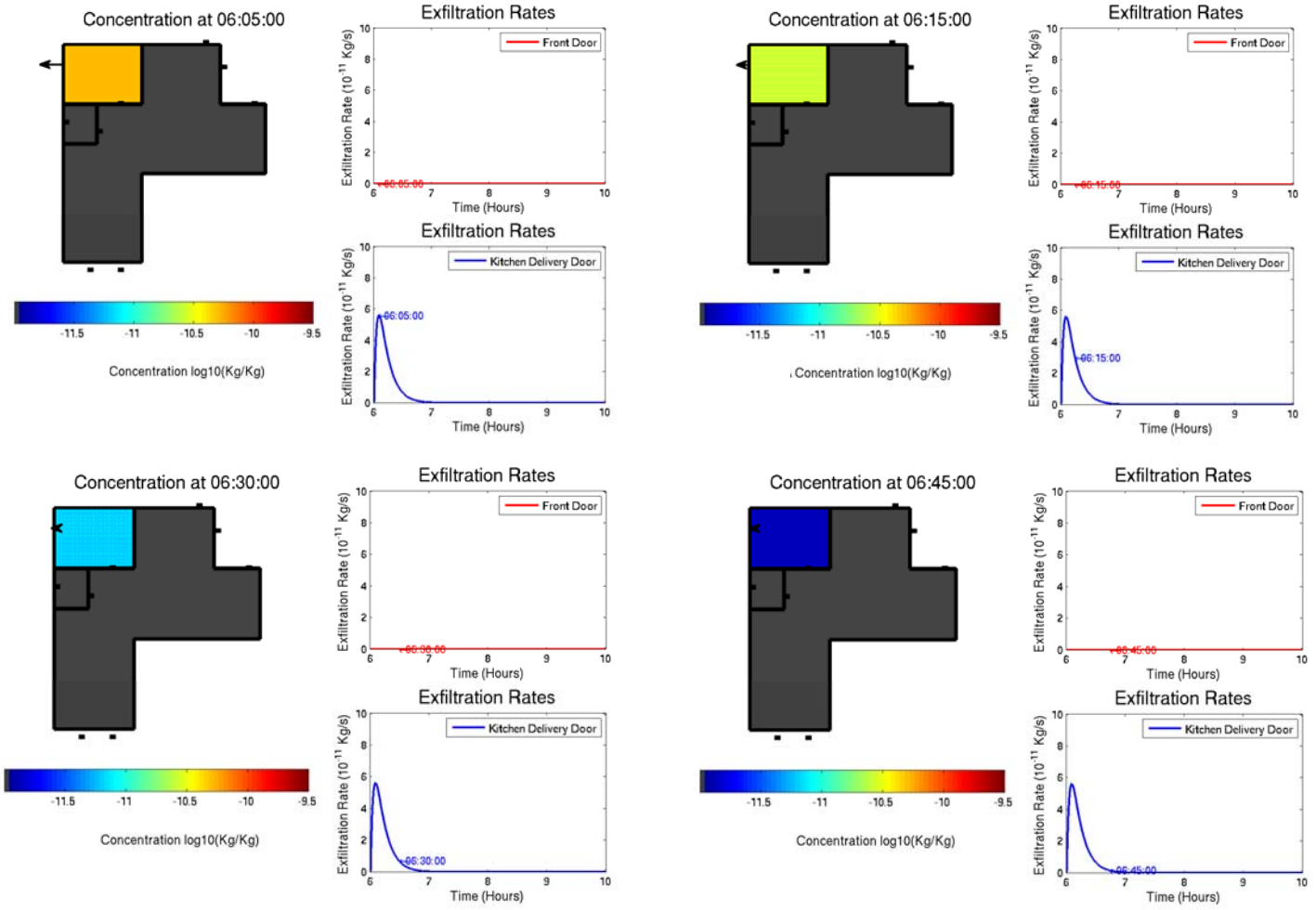
2-m Perturbation Pressure



•Denotes infiltration/exfiltration points (eg. windows, doors, etc.)

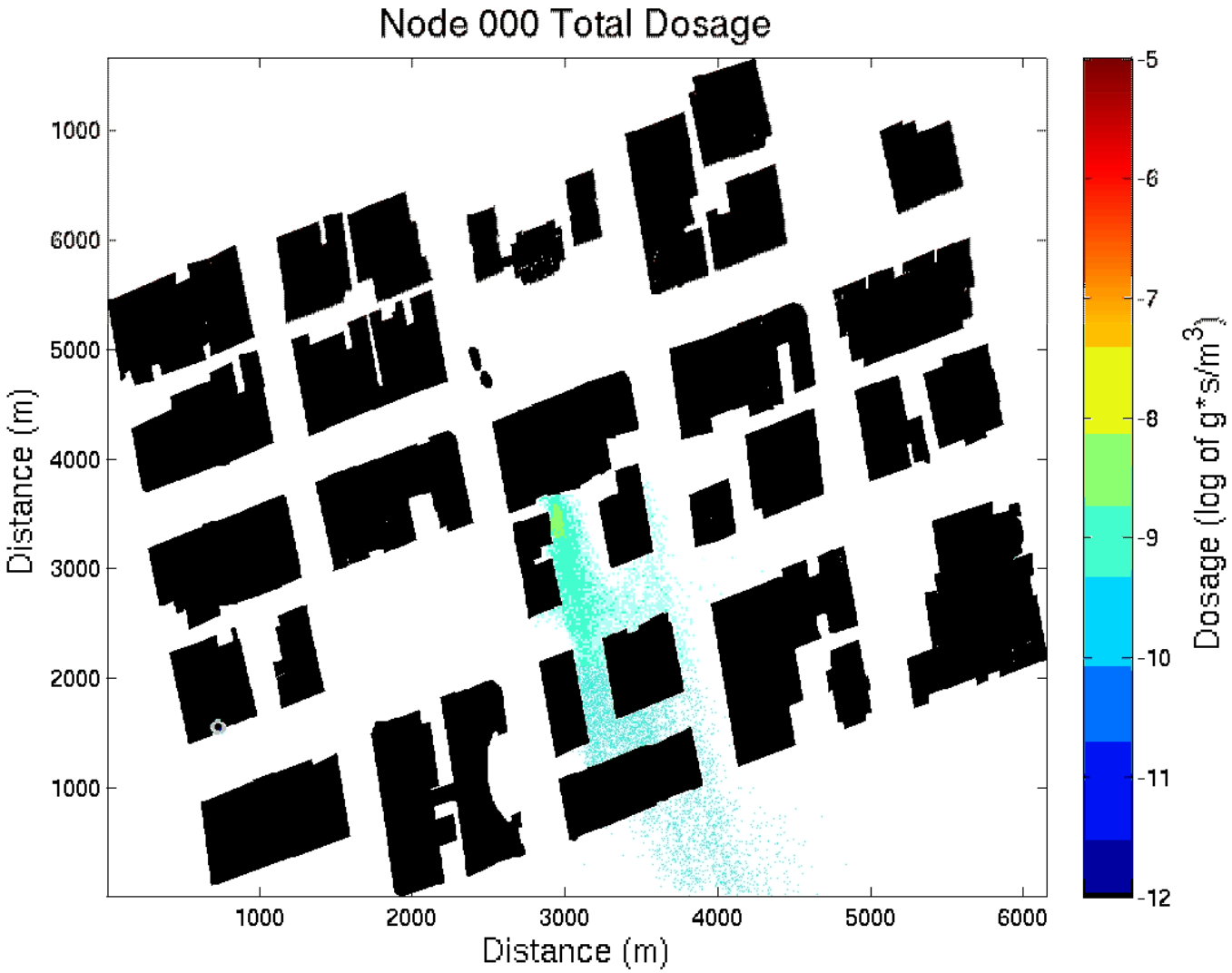
Dispersion Models

(CONTAM Interior Dispersion Model)



Source Term: 5-minute Release of a Volatile Gas From the Kitchen

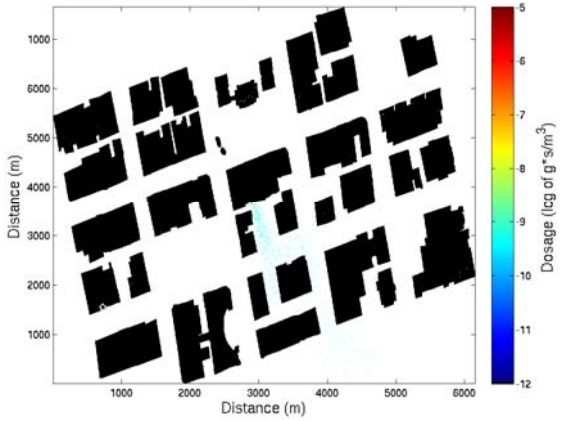
Dispersion Models
(QUIC-PLUME Exterior Dispersion)



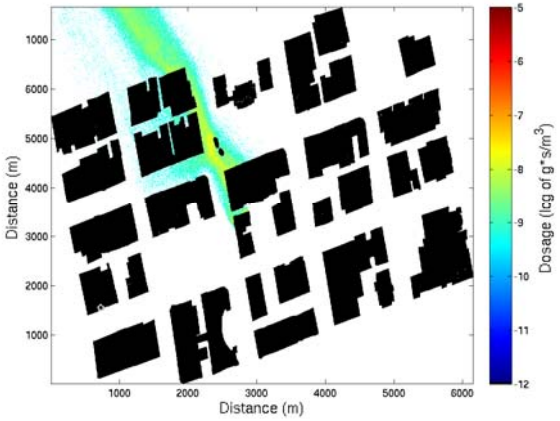
Dispersion Models

(Example: QUIC-PLUME Exterior 5 Hour Dosage)

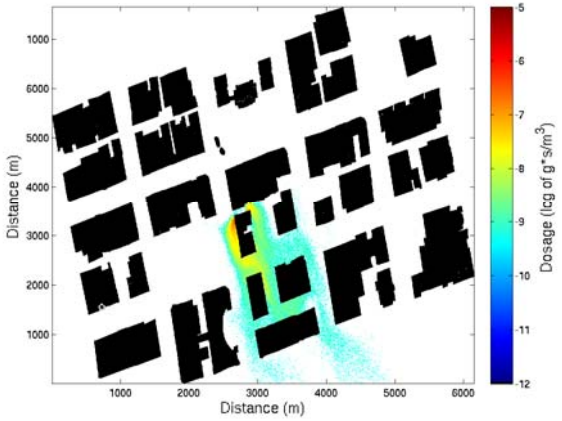
Node 25 Frequency: 0.7%



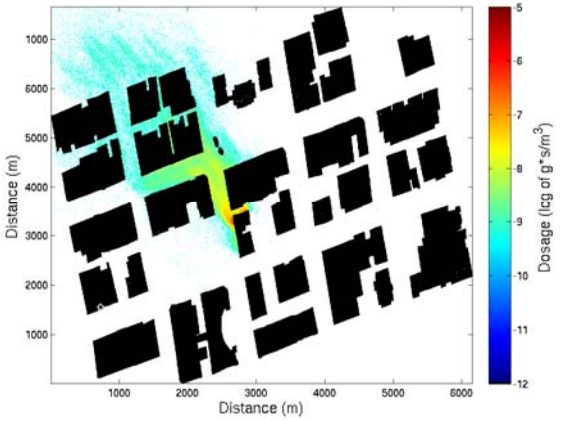
Node 48 Frequency: 0.9%



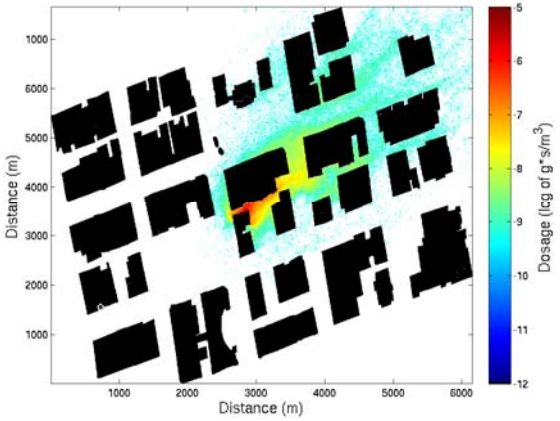
Node 51 Frequency: 0.4%



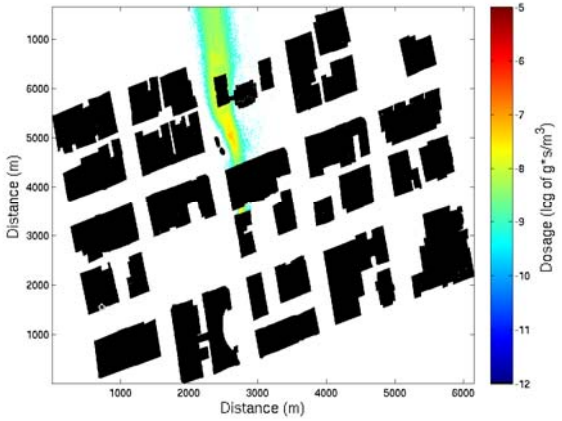
Node 128 Frequency: 0.35%



Node 138 Frequency: 0.6%



Node 190 Frequency: 1.85%

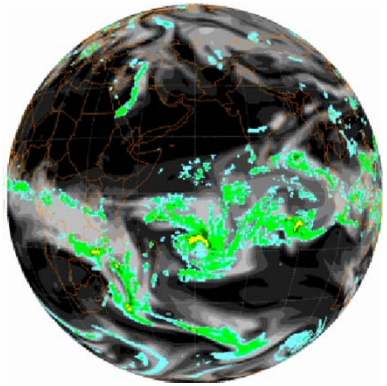


Urban Chemical Sampler Placement

(Analysis Methodology)

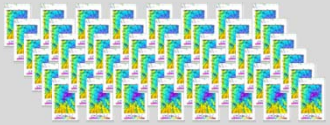
NCAR

21-Year
Global Climate Database

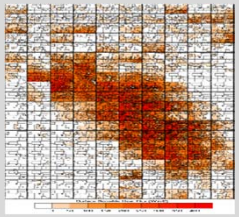


Weather
Pattern Classifier

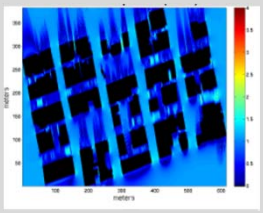
183960 Records

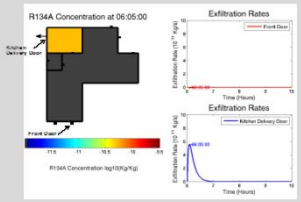


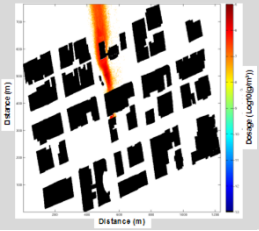
200 Records



Dispersion Models

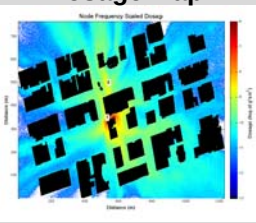




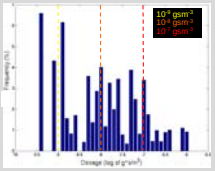


Detection Maps

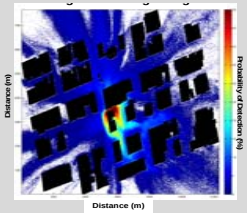
Dosage Map



Dosage Distributions



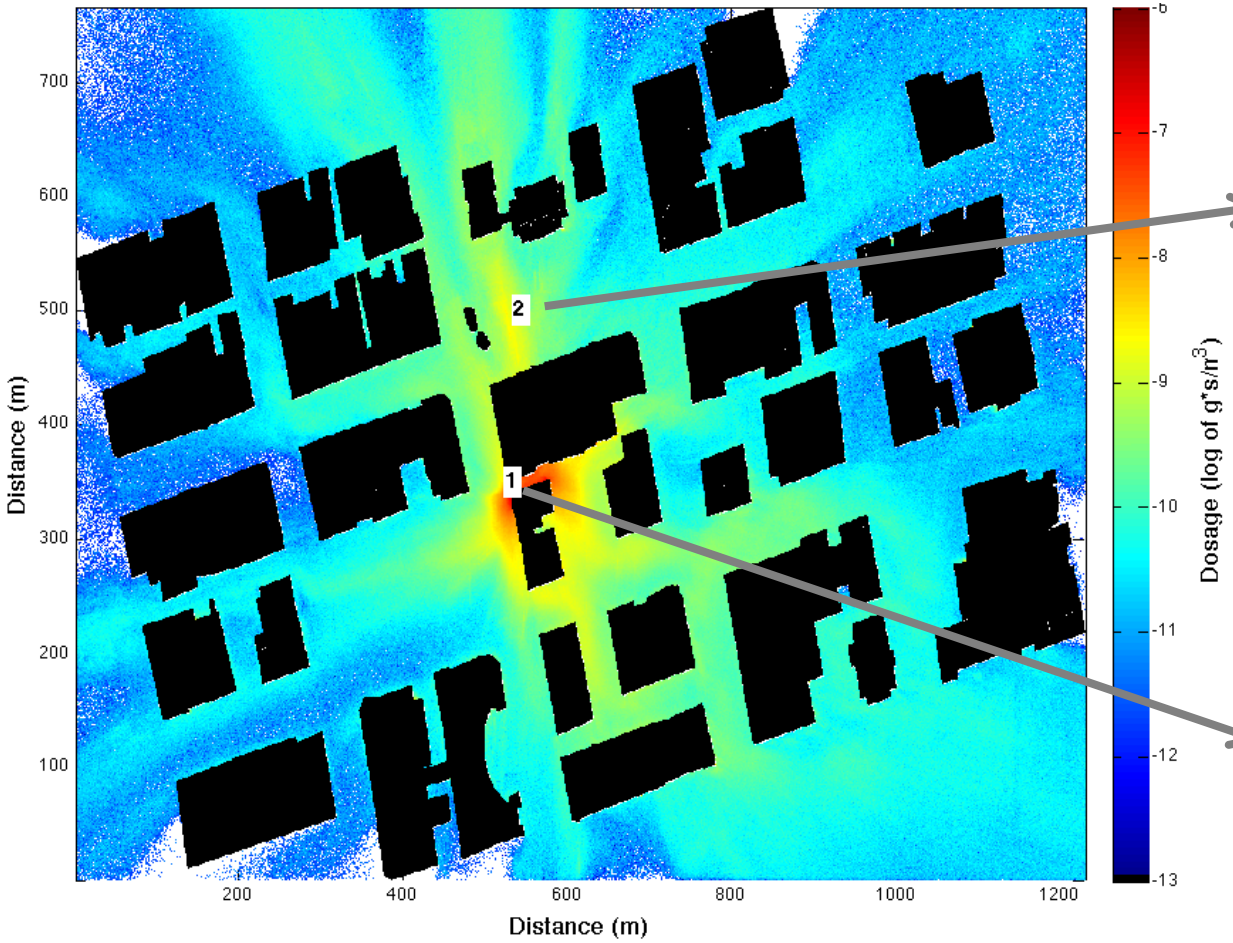
Detection Probability



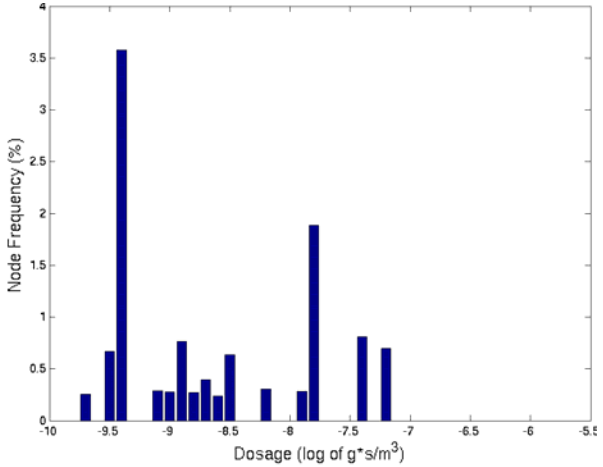
Detection Mapping
(Frequency Scaled Dosage)

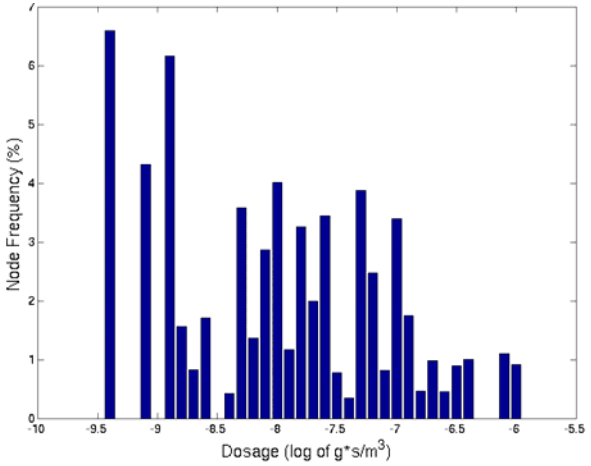
NCAR

Frequency Scaled Dosage



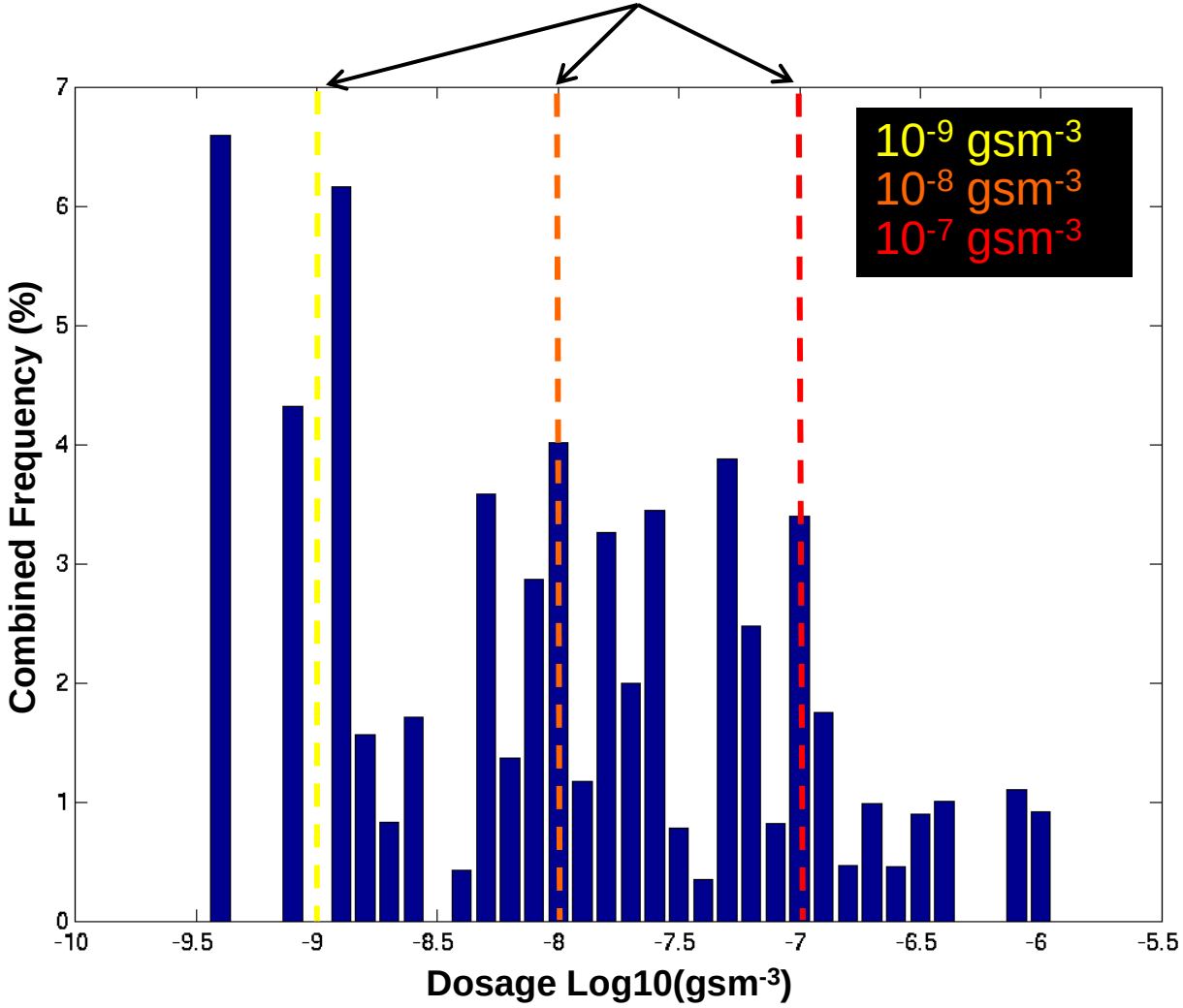
Dosage Frequency Distributions





Detection Mapping
(Dosage Distributions)

Arbitrary Sampler Minimum Detection Thresholds



Signature Science LLC. Logistically-enabled Sampling System (LESS™)

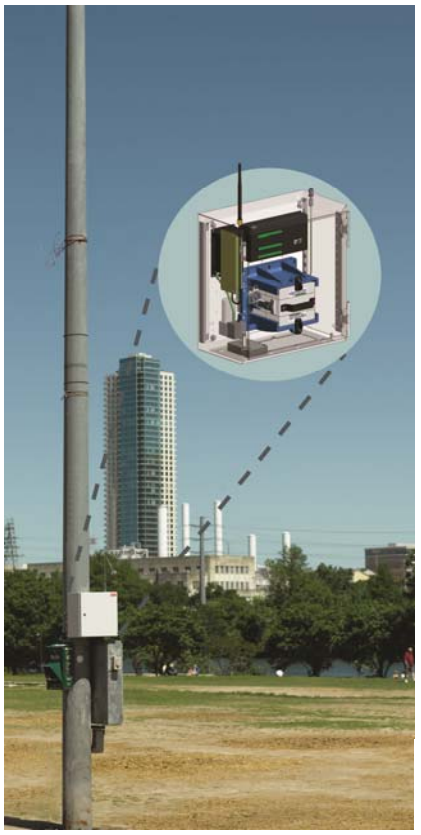
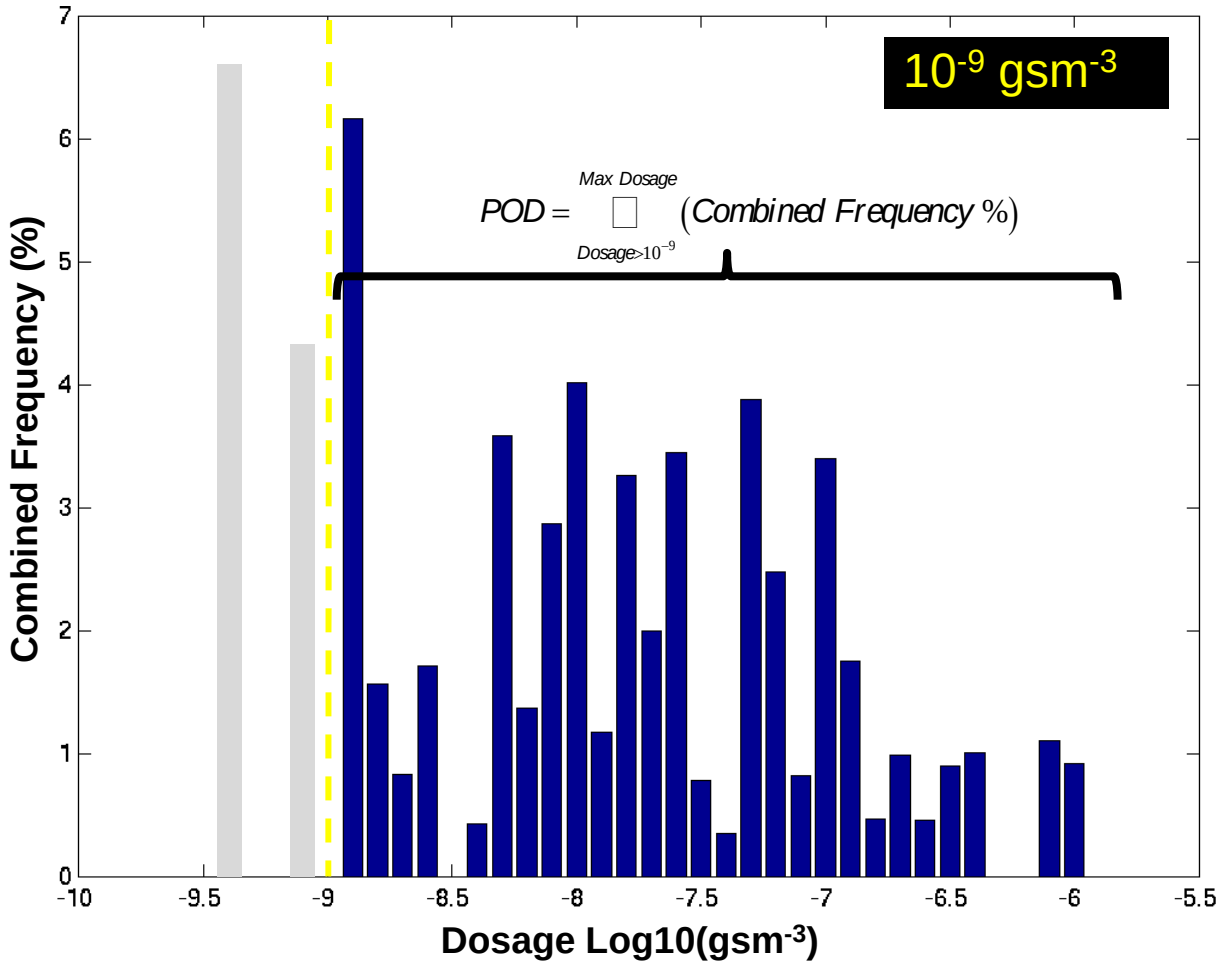


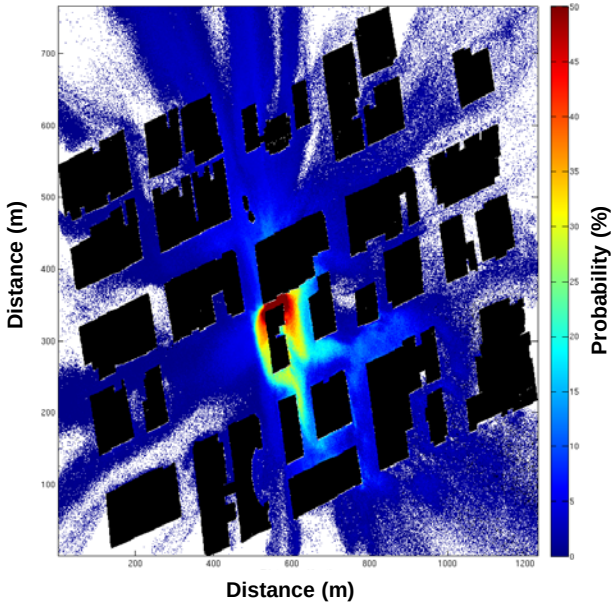
Image: Courtesy of Signature Science LLC.

Detection Mapping
(Probability of Detection (POD) Calculations)

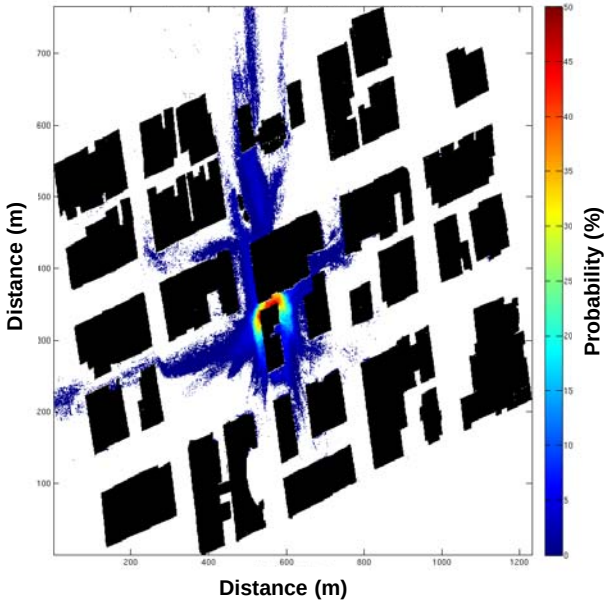


Detection Mapping
(Probability of Detection Maps)

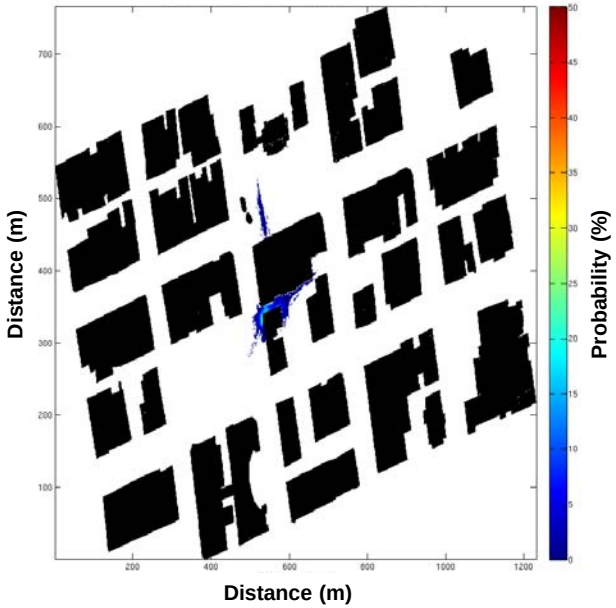
10^{-9} Detection Threshold



10^{-8} Detection Threshold

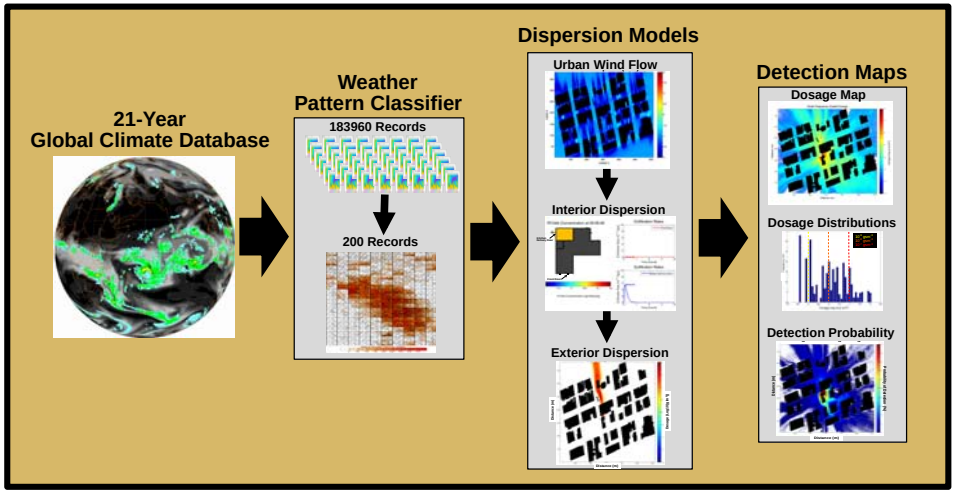


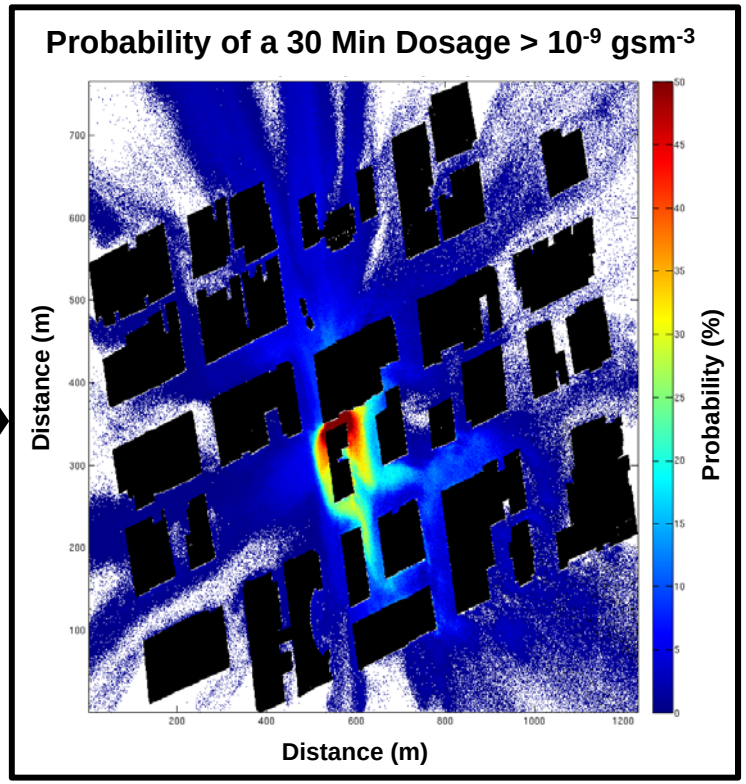
10^{-7} Detection Threshold



Conclusions

- **Determining sampler placement in complex urban environments is challenging**
- **Demonstrated method meets this challenge**
  - **Characteristic weather**
  - **High fidelity modeling solution**
  - **Tunable**
    - **Sampling duration/time**
    - **Location**
    - **Sampler characteristics**





Questions