Modelers' Data Archive – A Collection of Atmospheric Transport and Dispersion Data Sets

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Presented at 20th GMU Conference on
Atmospheric Transport and Dispersion Modeling

14-16 June 2016
Fairfax, Virginia

Outline

- Introduction
- History
- Data sets included in archive
- Condensed MDA file format and raw data
- Data sets usage
- Other data sources
- Conclusions

Introduction

- **Atmospheric Transport and Dispersion (ATD) field and laboratory data sets are valuable resources for**
  - **Understanding ATD processes**
  - **Developing new algorithms**
  - **Evaluating model performance**
- **Many experiments conducted since the 1950s, but systematic efforts in archiving these data generally lacking**
- **Hence, locating appropriate data sets for research often challenging**

History (1/2)

- **In early 90s, Steve Hanna, Dave Strimaitis, and Joe Chang conducted a dense-gas model evaluation project sponsored by American Petroleum Institute (API) and Air Force (AF)**

- **Project used field data from**
  - **6 dense gas (Burro, Coyote, Desert Tortoise, Goldfish, Maplin Sands, and Thorney Island) and**
  - **2 tracer gas (Prairie Grass and Hanford Kr^{85}) experiments**

- **Raw data condensed into a common Modelers' Data Archive (MDA) file format that contains enough information to run 15 dense-gas models, including DEGADIS, HGSYSTEM, SLAB, CHARM, PHAST, and TRACE**

History (2/2)

- **Data archive continued to grow after API/AF project**
- **Recognizing the value of archiving not just condensed "MDA files" but also original raw data, began to call the entire collection of data sets MDA**
- **Added derived data (*e.g.*, QA, time averages, tabulation, reformatting, model inputs, *etc.*) when appropriate**
- **Strived to combine data and any documentation into single package; sometimes necessary to scan old reports**
- **Through word of mouth, began to distribute data sets free of charge to any scientists who requested them**
- **Other scientists also contributed to the archive**
- **Collected 50+ data sets thus far**

Reference: Chang, J.C., and S.R. Hanna, 2010: Modelers' Data Archive—a collection of atmospheric transport and dispersion data sets. 16th Conference on Air Pollution Meteorology, American Meteorological Society, Atlanta, Georgia

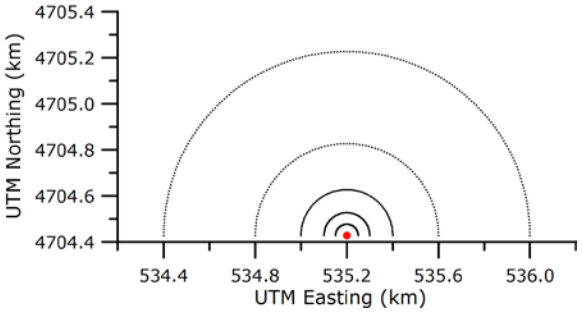
Data Sets Included in MDA

1. Dense Gas MDA (including Burro, Coyote, Desert Tortoise, Goldfish, Lyme Bay, Maplin Sands, and Thorney Island)
2. Prairie Grass
3. Hanford Kr^{85}
4. Ocean Breeze
5. Dry Gulch
6. Green Glow
7. Kit Fox
8. EPA CO_2
9. DSWA Phase I
10. DP26 (Dipole Pride 26)
11. OLAD (Overland Alongwind Dispersion)
12. MVP (Model Validation Program)
13. Ventura
14. Pismo Beach
15. Cameron
16. Carpinteria
17. LROD (Long-Range Overwater Diffusion)
18. MADONA (Meteorology And Diffusion Over Non-Uniform Areas)
19. ACURATE (Atlantic Coast Unique Regional Atmospheric Tracer Experiment)
20. ANATEX (Across North America Tracer Experiment)
21. METREX (Metropolitan Tracer Experiment)
22. CAPTEX (Cross Appalachian Tracer Experiment)
23. ETEX (European Tracer Experiment)
24. INEL74
25. OKC80
26. Birmingham
27. Urban 2000 (Salt Lake City)
28. Joint Urban 2003 (Oklahoma City)*
29. Madison Square Garden 2005*
30. Midtown Manhattan 2005*
31. MUST (Mock Urban Setting Test)
32. EMU (Evaluation of Model Uncertainty)
33. DPG Barrel
34. LA 2001
35. Barrio Logan (San Diego)
36. Porton Down 1977
37. Macdonald (water tunnel)
38. SMEDIS (Scientific Model Evaluation of Dense Gas Dispersion Models)
39. TRAPOS (Optimization of Modeling Methods for Traffic Pollution in Streets)
40. REDIPHEM (Review and Dissemination of Physical Effects Models)
41. FLADIS (Research on the Dispersion of Two-Phase Flashing Releases)
42. Kincaid
43. Bull Run
44. Indianapolis
45. Clifty Creek
46. Tracy
47. Martins Creek
48. Westvaco
49. SARMAP (San Joaquin Valley Air Quality Study, Regional Meteorological and Air Pollution)
50. LMOS (Lake Michigan Ozone Study)
51. OTAG (Ozone Transport Assessment Project)

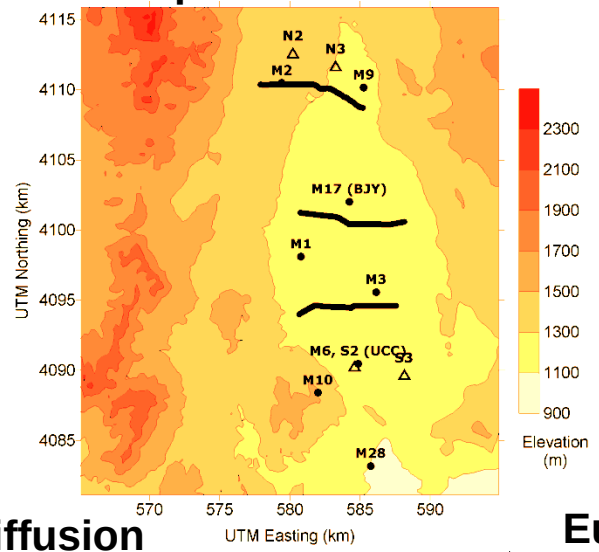
**Need to be requested from DoD*

PG, DP26, OLAD, LROD, & ETEX

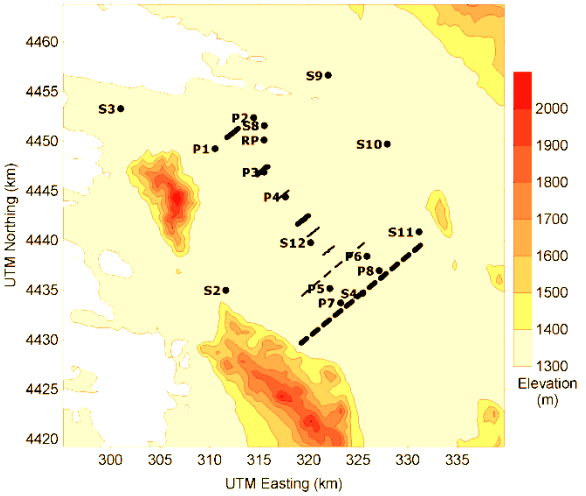
Prairie Grass



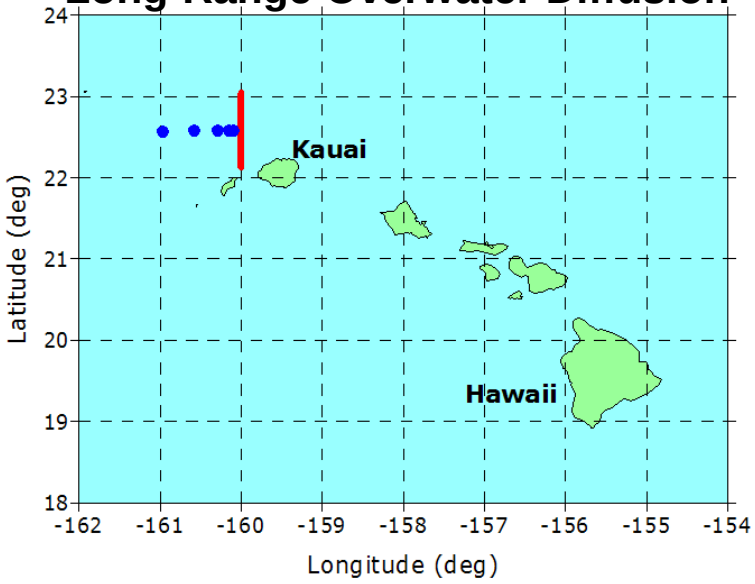
Dipole Pride 26



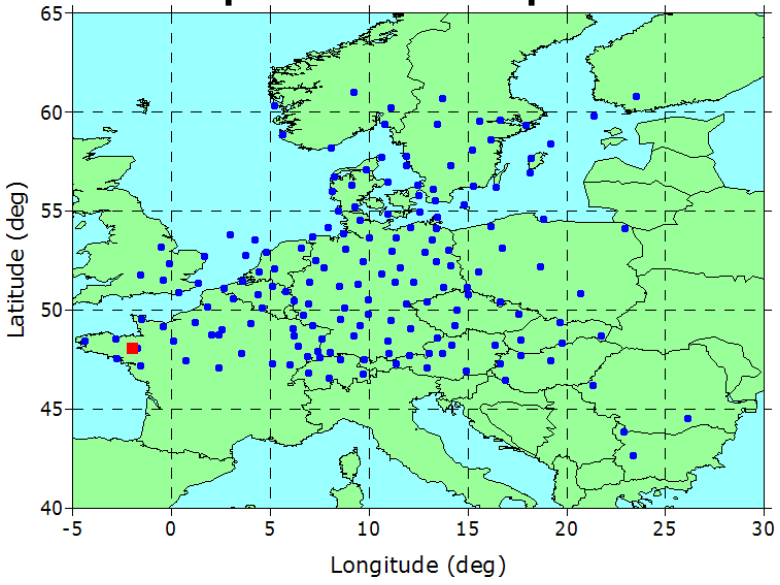
Over-Land Alongwind Dispersion



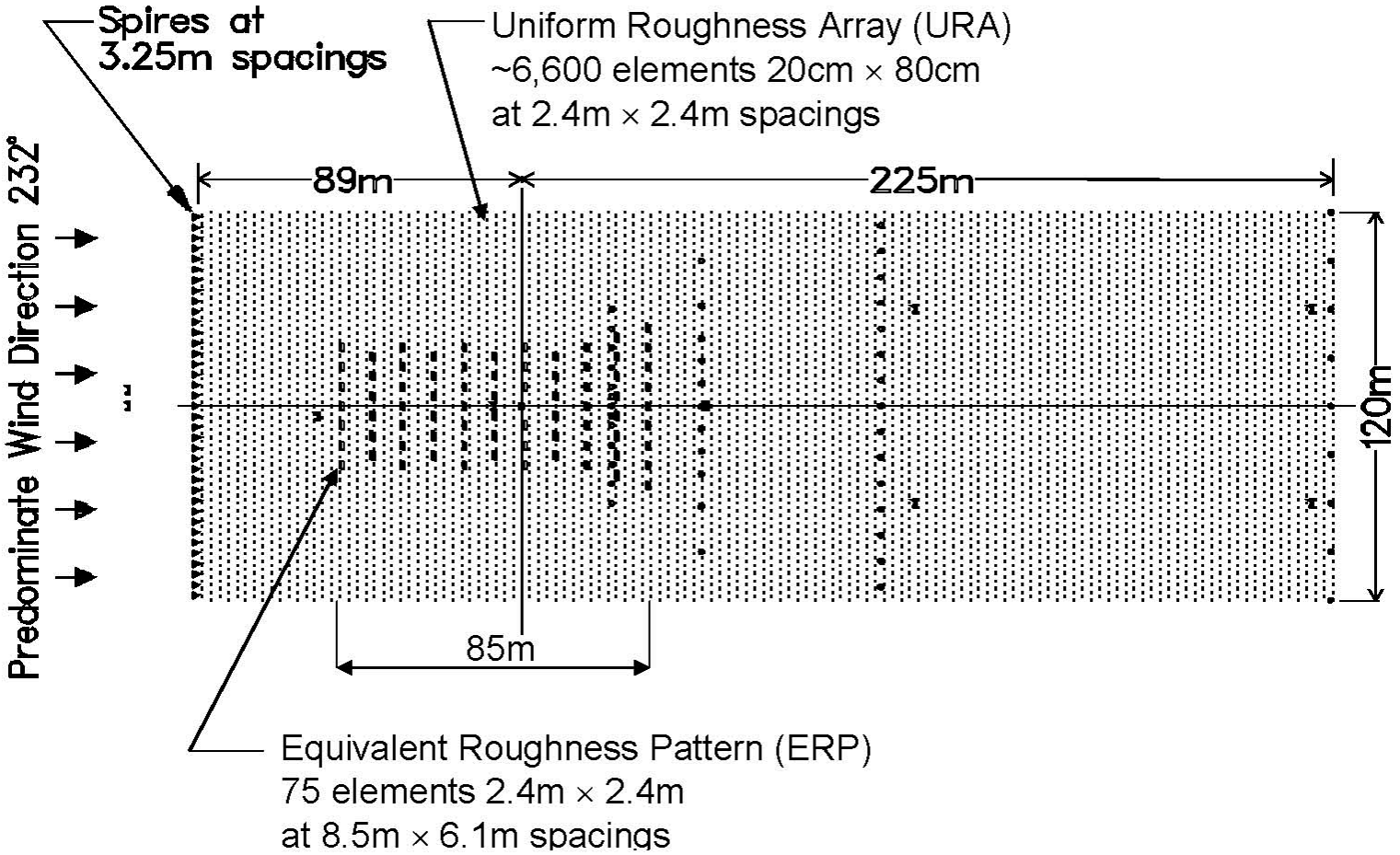
Long-Range Overwater Diffusion



European Tracer Experiment



Kit Fox



- **Finite-duration CO_2 area-source in a nested roughness array**

Desert Tortoise (Trial 2)

0.8 m

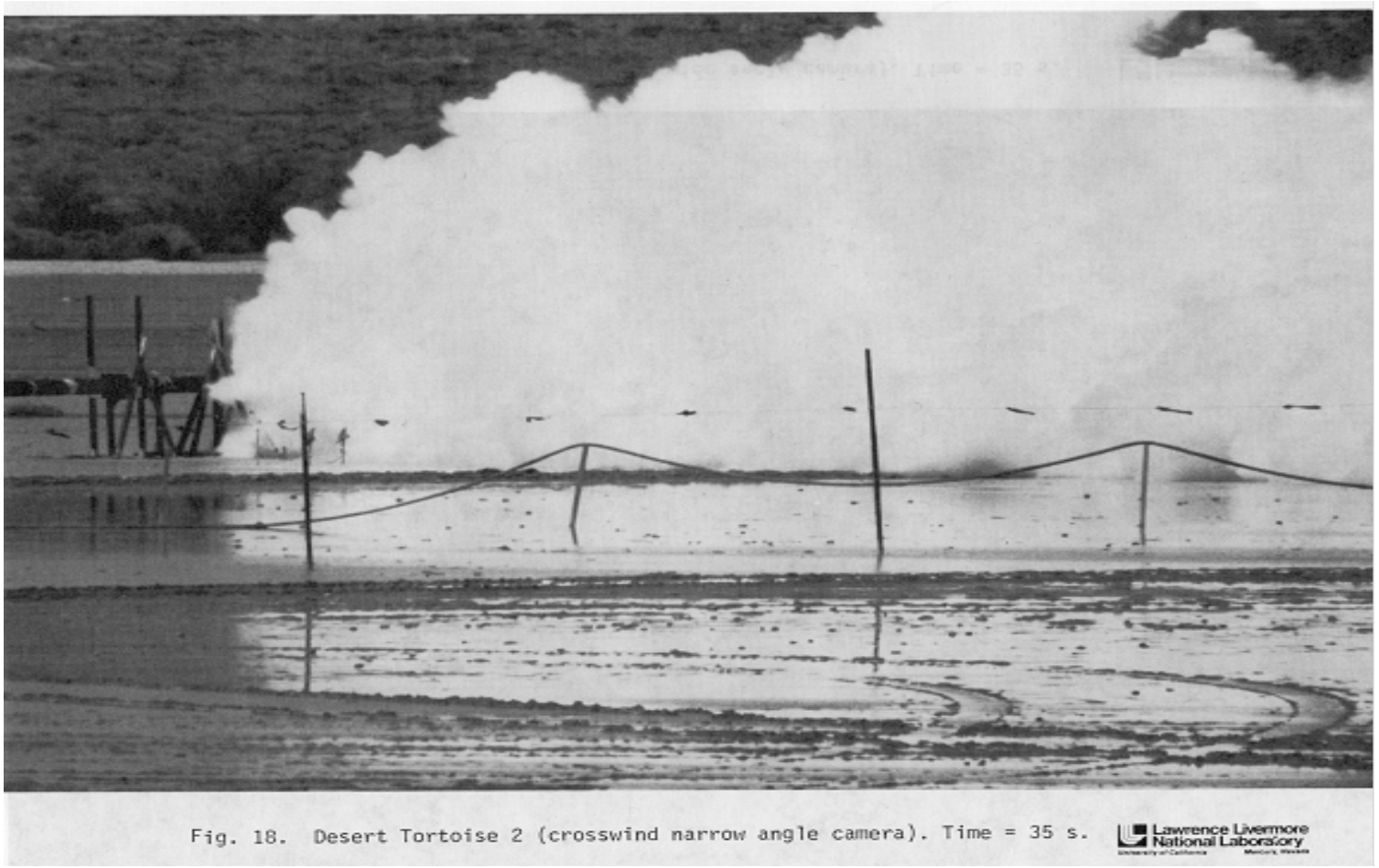


Fig. 18. Desert Tortoise 2 (crosswind narrow angle camera). Time = 35 s.

Lawrence Livermore National Laboratory

- **Pressurized 2-phase anhydrous NH_3 release**

Thorney Island (Trial 21)

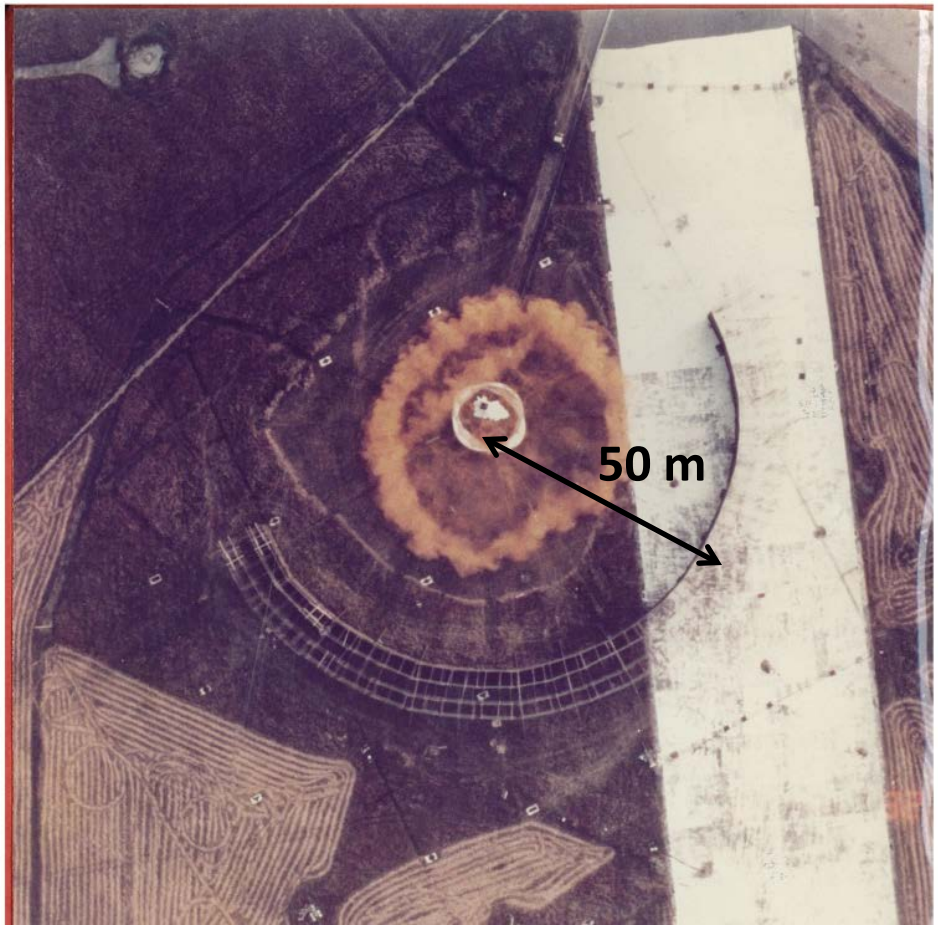
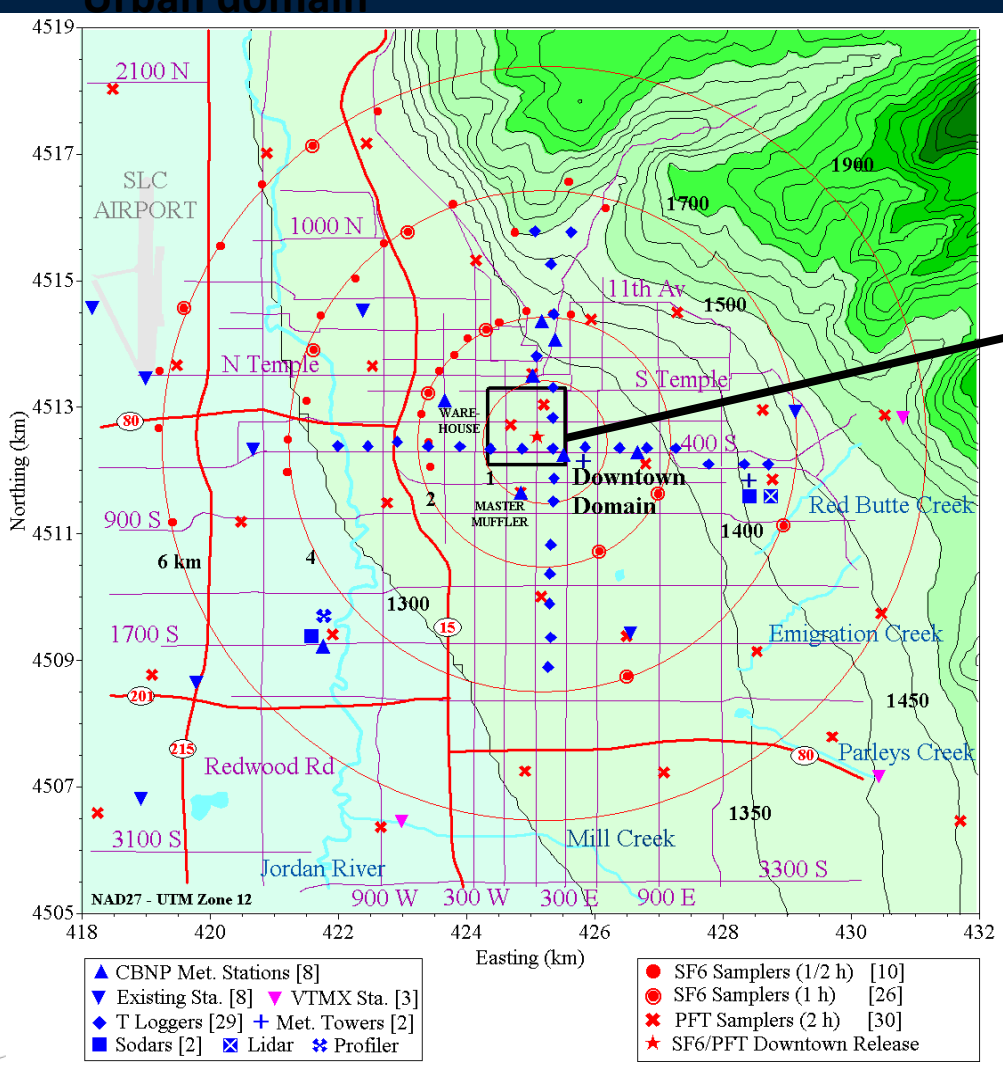


Figure courtesy: McQuaid and Roebuck 1984

- **Sudden collapse of a cylindrical dense cloud consisting of freon-12 and nitrogen**
- **Picture shows 6 s after the release**

Urban 2000 (Salt Lake City)



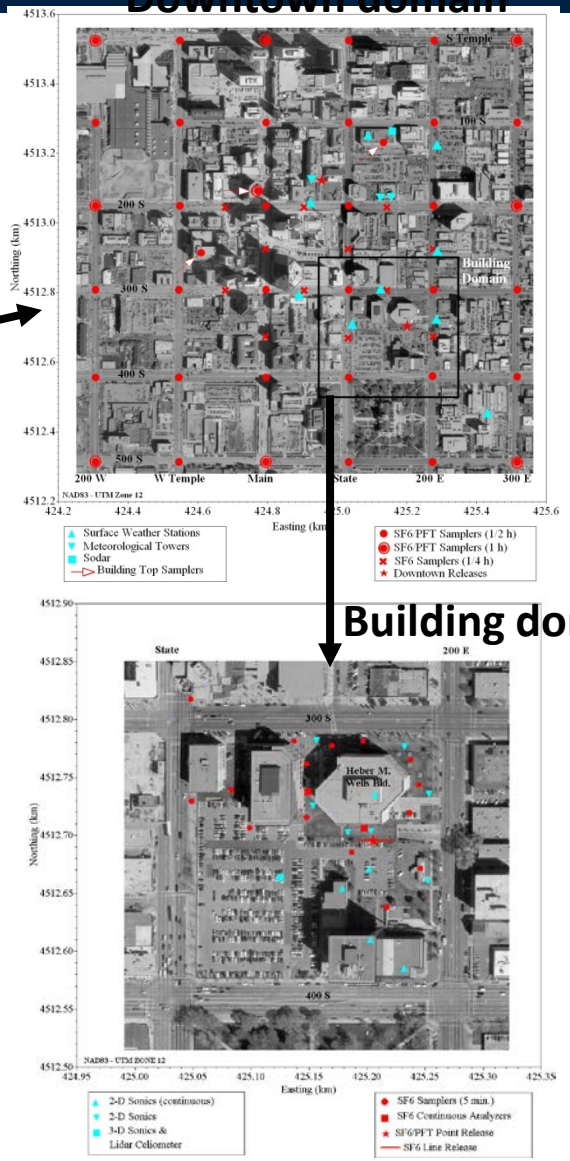


Figure courtesy: Allwine et al. 2002

Data Sets Characteristics

- **Experiments conducted over six decades from 1956; plus Lyme Bay in 1927**
- **Full, 1/10, and laboratory scales**
- **Length scales 100 m to 1,000 km for field experiments**
- **Many source types**
  - **Neutrally buoyant, buoyant, and dense**
  - **Release rates 0.01 mg/s to 100 kg/s**
  - **Continuous and instantaneous**
  - **Stationary and moving**
  - **Surface and elevated**
  - **Point and line**
- **Flat terrain, complex terrain, and urban**
- **Overland, overwater, and coastal**
- **Special field campaigns (*i.e.*, many samplers with short time periods) and regular observations (*i.e.*, fewer samplers with long time periods)**

Sample MDA (Condensed) File for Desert Tortoise

Desert Tortoise				
Anhydrous Ammonia				
NH3				3-char. abbreviation of chemical
4				number of trials included in MDA
8				time zone designation
DT1	DT2	DT3	DT4	trial ID
8	8	9	9	month
24	29	1	6	day
83	83	83	83	year
16	11	15	18	hour
37	20	37	15	minute
17.03	17.03	17.03	17.03	mol. weight (g/mole)
239.7	239.7	239.7	239.7	normal boiling point (K)
1.37E+06	1.37E+06	1.37E+06	1.37E+06	latent heat of evaporation (J/kg)
2190	2190	2190	2190	heat capacity - vapor (J/kg-K)
4490	4490	4490	4490	heat capacity - liquid (J/kg-K)
682.8	682.8	682.8	682.8	density of liquid (kg/m**3)
10.31499	10.31499	10.31499	10.31499	coefficient A for vapor pressure equation
2132.52	2132.52	2132.52	2132.52	coefficient B for vapor pressure equation
10	11.02	11.23	11.64	exit pressure (atm)
294.7	293.3	295.3	297.3	source temperature (K)
0.081	0.0945	0.0945	0.0945	source diameter (m)
0.79	0.79	0.79	0.79	source elevation (m)
HJ	HJ	HJ	HJ	source type (IR,HJ,AS,EP)
C	C	C	C	source phase (L,C,G)
-99.9	-99.9	-99.9	-99.9	source containment diameter (m)
79.7	111.5	130.7	96.7	spill/evaporation rate (kg/s)
126	255	166	381	spill duration (s)
-99.9	-99.9	-99.9	-99.9	total released (kg)
1.00E+06	1.00E+06	1.00E+06	1.00E+06	initial concentration (ppm)
0.897	0.898	0.895	0.891	ambient pressure (atm)
13.2	17.5	14.8	21.3	relative humidity (%)
302.03	303.63	307.07	305.63	ambient temperature #1-lower (K)
0.82	0.82	0.82	0.82	measurement height for temperature #1 (m)
303.31	304.31	307.05	306.9	ambient temperature #2-upper (K)

(Cont'd)

16.19	16.19	16.19	16.19	measurement height for temperature #2 (m)
304.8	303.8	304.8	304	soil temperature (K)
3	3	2	1	soil moisture (1:dry,2:moist,3:water)
7.73	5.54	7.6	4.64	wind speed (m/s)
3.36	3.36	3.36	3.36	measurement height for wind speed (m)
7.4	5.8	7.4	4.5	domain-avg wind speed (m/s)
1.2	0.7	1	-99.9	domain-avg sigma-u (m/s)
5.7	7.5	8.3	5	domain-avg sigma-theta (deg)
2	2	2	2	measurement height for domain-avg wind data (m)
180	180	180	180	averaging time for domain-avg data (s)
0.003	0.003	0.003	0.003	roughness length z0 (m)
-99.9	-99.9	-99.9	-99.9	friction velocity u-star (m/s)
-99.9	-99.9	-99.9	-99.9	bowen ratio estimate
-99.9	-99.9	-99.9	-99.9	inverse Monin-Obukhov length (1/m)
1	4	70	1	cloud cover (%)
4	4	4	5	Pasquill-Gifford stability class (A=1;D=4;F=6)
36.7	36.7	36.7	36.7	latitude (deg)
116	116	116	116	longitude (deg)
1	1	1	1	averaging time for peak concentration (s)
80	160	120	300	averaging time for averaged concentration (s)
100	100	100	100	concentration of interest for modeling (ppm)
1	1	1	1	suggested receptor height for modeling (m)
2	2	2	2	number of distances downwind
100	100	100	100	distance downwind
800	800	800	800	distance downwind
-99.9	-99.9	-99.9	-99.9	distance downwind (terminal record: -99.9)
63260	109580	97250	84260	max. conc. (ppm) based on tpeak
10950	18590	15630	20910	max. conc. (ppm) based on tpeak
49943	83203	76881	57300	max. conc. (ppm) based on tavg
8843	10804	7087	16678	max. conc. (ppm) based on tavg
11.83	14.72	15.24	15.67	sigma-y (m) based on tavg
61.79	88.19	73.4	85.99	sigma-y (m) based on tavg

Raw Data Snapshot for Desert Tortoise 4

Heat Flux

heat flux dt4 g04

time	a09
-1.99180e+02	1.92400e-01
-1.98180e+02	1.92400e-01
-1.97180e+02	1.92400e-01
-1.96180e+02	1.92400e-01
-1.95180e+02	1.92400e-01
-1.94180e+02	1.92400e-01
-1.93180e+02	1.92400e-01
-1.92180e+02	1.92400e-01
-1.91180e+02	1.92400e-01
-1.90180e+02	1.92400e-01
-1.89180e+02	1.92400e-01
-1.88180e+02	1.92400e-01
-1.87180e+02	1.92400e-01
-1.86180e+02	1.92400e-01
-1.85180e+02	1.92400e-01
-1.84180e+02	1.92400e-01
-1.83180e+02	1.92400e-01
-1.82180e+02	1.92400e-01
-1.81180e+02	1.92400e-01
-1.80180e+02	1.92400e-01
-1.79180e+02	1.92400e-01
-1.78180e+02	1.92400e-01
-1.77180e+02	1.92400e-01
-1.76180e+02	1.92400e-01
-1.75180e+02	1.92400e-01
-1.74180e+02	1.92400e-01
-1.73180e+02	1.92400e-01
-1.72180e+02	1.92400e-01
-1.71180e+02	1.92400e-01
-1.70180e+02	1.92400e-01
-1.69180e+02	1.92400e-01
-1.68180e+02	1.92400e-01
-1.67180e+02	1.92400e-01
-1.66180e+02	1.92400e-01
-1.65180e+02	1.92400e-01
-1.64180e+02	1.92400e-01
-1.63180e+02	1.92400e-01
-1.62180e+02	1.92400e-01
-1.61180e+02	1.92400e-01
-1.60180e+02	1.92400e-01
-1.59180e+02	1.92400e-01
-1.58180e+02	1.92400e-01

Concentration

Desert Tortoise 4 concentration row 11

9/06/83

09/24/85u 15:45:13

09/24/85 15:46:30

time	g021	g031	g041	g051	g061	g071	g081
1.00	0.	0.	0.002	0.	0.017	0.	0.014
2.00	0.	0.	0.002	0.	0.	0.	0.014
3.00	0.	0.	0.	0.	0.	0.	0.014
4.00	0.	0.253	0.002	0.	0.	0.	0.014
5.00	0.	0.119	0.	0.	0.	0.	0.014
6.00	0.	0.	0.002	0.	0.017	0.	0.014
7.00	0.	0.229	0.	0.	0.017	0.	0.014
8.00	0.	0.021	0.	0.	0.	0.	0.014
9.00	0.	0.119	0.	0.	0.	0.	0.014
10.00	0.006	0.045	0.002	0.	0.	0.	0.014
11.00	0.006	0.045	0.	0.	0.	0.	0.014
12.00	0.	0.	0.002	0.	0.	0.	0.014
13.00	0.	0.	0.002	0.	0.017	0.	0.
14.00	0.013	0.094	0.002	0.	0.	0.	0.014
15.00	0.	0.	0.002	0.	0.	0.	0.
16.00	0.	0.009	0.002	0.	0.	0.	0.014
17.00	0.006	0.	0.002	0.	0.	0.	0.014
18.00	0.006	0.	0.002	0.	0.017	0.	0.014
19.00	0.	0.094	0.	0.	0.	0.	0.014
20.00	0.	0.033	0.002	0.	0.	0.	0.014
21.00	0.	0.	0.002	0.011	0.017	0.	0.014
22.00	0.	0.094	0.002	0.	0.017	0.	0.
23.00	0.013	0.131	0.002	0.	0.	0.	0.014
24.00	0.	0.009	0.002	0.	0.	0.	0.014
25.00	0.	0.155	0.	0.	0.	0.	0.014
26.00	0.006	0.119	0.	0.	0.	0.	0.014
27.00	0.013	0.070	0.	0.	0.	0.	0.014
28.00	0.	0.	0.044	0.	0.	0.	0.014
29.00	0.	0.045	1.706	0.	0.109	0.	0.
30.00	0.	0.045	3.194	0.	1.146	0.	0.014
31.00	0.	0.	3.744	0.022	2.815	0.	0.
32.00	0.	0.546	4.362	0.453	4.421	0.	0.
33.00	0.	2.096	4.555	2.157	6.715	0.	0.
34.00	0.	2.133	5.236	4.014	5.457	0.	0.014
35.00	0.	2.619	5.387	4.237	4.276	0.	0.
36.00	0.	2.575	6.025	3.939	4.820	0.	0.
37.00	0.	1.852	5.255	4.608	5.909	0.	0.014
38.00	0.	1.596	4.912	5.685	7.054	0.	0.014
39.00	0.	1.828	5.574	6.671	4.462	0.	0.014

Humidity

--- table d4humc01 ---

testid	stnm	time	a06
nh304	c01	-1.02018e+03	0.
nh304	c01	-1.01918e+03	0.
nh304	c01	-1.01818e+03	0.
nh304	c01	-1.01718e+03	0.
nh304	c01	-1.01618e+03	0.
nh304	c01	-1.01518e+03	0.
nh304	c01	-1.01418e+03	0.
nh304	c01	-1.01318e+03	0.
nh304	c01	-1.01218e+03	0.
nh304	c01	-1.01118e+03	0.
nh304	c01	-1.01018e+03	0.
nh304	c01	-1.00918e+03	0.
nh304	c01	-1.00818e+03	0.
nh304	c01	-1.00718e+03	0.
nh304	c01	-1.00618e+03	0.
nh304	c01	-1.00518e+03	0.
nh304	c01	-1.00418e+03	0.
nh304	c01	-1.00318e+03	0.
nh304	c01	-1.00218e+03	0.
nh304	c01	-1.00118e+03	0.
nh304	c01	-1.00018e+03	0.
nh304	c01	-9.99180e+02	0.
nh304	c01	-9.98180e+02	0.
nh304	c01	-9.97180e+02	0.
nh304	c01	-9.96180e+02	0.
nh304	c01	-9.95180e+02	0.
nh304	c01	-9.94180e+02	0.
nh304	c01	-9.93180e+02	0.
nh304	c01	-9.92180e+02	0.
nh304	c01	-9.91180e+02	0.
nh304	c01	-9.90180e+02	0.
nh304	c01	-9.89180e+02	0.
nh304	c01	-9.88180e+02	0.
nh304	c01	-9.87180e+02	0.
nh304	c01	-9.86180e+02	0.
nh304	c01	-9.85180e+02	0.
nh304	c01	-9.84180e+02	0.
nh304	c01	-9.83180e+02	0.
nh304	c01	-9.82180e+02	0.
nh304	c01	-9.81180e+02	0.
nh304	c01	-9.80180e+02	0.
nh304	c01	-9.79180e+02	0.

Temperature

rtd temperature dt4 g01

time	a02	a03	a04
-1.99180e+02	3.27400e+01	3.30000e+01	3.34400e+01
-1.98180e+02	3.27400e+01	3.29800e+01	3.34200e+01
-1.97180e+02	3.27400e+01	3.29800e+01	3.34200e+01
-1.96180e+02	3.27100e+01	3.29500e+01	3.34200e+01
-1.95180e+02	3.26900e+01	3.29500e+01	3.34200e+01
-1.94180e+02	3.26900e+01	3.29300e+01	3.34400e+01
-1.93180e+02	3.26600e+01	3.29300e+01	3.34700e+01
-1.92180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.91180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.90180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.89180e+02	3.26600e+01	3.29300e+01	3.34700e+01
-1.88180e+02	3.26600e+01	3.29300e+01	3.34700e+01
-1.87180e+02	3.26600e+01	3.29300e+01	3.34400e+01
-1.86180e+02	3.26600e+01	3.29300e+01	3.34700e+01
-1.85180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.84180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.83180e+02	3.26400e+01	3.29500e+01	3.34700e+01
-1.82180e+02	3.26400e+01	3.29500e+01	3.34700e+01
-1.81180e+02	3.26400e+01	3.29500e+01	3.34700e+01
-1.80180e+02	3.26400e+01	3.29500e+01	3.34700e+01
-1.79180e+02	3.26600e+01	3.29800e+01	3.34900e+01
-1.78180e+02	3.26600e+01	3.29800e+01	3.34900e+01
-1.77180e+02	3.26900e+01	3.29800e+01	3.34900e+01
-1.76180e+02	3.26900e+01	3.29800e+01	3.35200e+01
-1.75180e+02	3.26900e+01	3.29800e+01	3.35200e+01
-1.74180e+02	3.26900e+01	3.29800e+01	3.34900e+01
-1.73180e+02	3.26900e+01	3.29800e+01	3.34900e+01
-1.72180e+02	3.26900e+01	3.29800e+01	3.34700e+01
-1.71180e+02	3.26900e+01	3.29500e+01	3.34700e+01
-1.70180e+02	3.26600e+01	3.29500e+01	3.34700e+01
-1.69180e+02	3.26600e+01	3.29500e+01	3.34700e+01
-1.68180e+02	3.26400e+01	3.29500e+01	3.34400e+01
-1.67180e+02	3.26400e+01	3.29300e+01	3.34400e+01
-1.66180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.65180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.64180e+02	3.26400e+01	3.29300e+01	3.34700e+01
-1.63180e+02	3.26400e+01	3.29500e+01	3.34700e+01
-1.62180e+02	3.26400e+01	3.29500e+01	3.34700e+01
-1.61180e+02	3.26400e+01	3.29500e+01	3.34400e+01
-1.60180e+02	3.26100e+01	3.29800e+01	3.34400e+01
-1.59180e+02	3.26100e+01	3.29800e+01	3.34400e+01
-1.58180e+02	3.26400e+01	3.29800e+01	3.34200e+01

Data Sets Usage

- **Most frequently requested data sets**
  - **Prairie Grass**
  - **Dipole Pride 26**
  - **Over-Land Alongwind Dispersion**
  - **Kit Fox**
  - **DOE dense gas experiments (Burro, Coyote, Desert Tortoise, and Goldfish)**
  - **Thorney Island**
  - **Urban 2000**
  - **MUST**
  - **DSWA Phase 1**
- **Have on average received 5-10 requests per year from all over the world, leading to publication of many journal articles, dissertations, and reports**

Other Data Sources

- **Air Resources Laboratory, National Oceanic and Atmospheric Administration (http://www.arl.noaa.gov/DATEM.php)**
- **Dugway Proving Ground**
- **Lawrence Livermore National Laboratory**
- **Environmental Protection Agency**
- **Nuclear Regulatory Commission**
- **Naval Surface Warfare Center, Dahlgren Division**
- **Risø National Laboratory, Denmark (e.g., Model Validation Kit, http://www.harmo.org/kit/)**
- **University of Hamburg, Germany**
- **John Irwin's web site (http://jsirwin.com/Tracer_Data.html)**

Conclusions (1/2)

- Data are perishable; will disappear (e.g., due to lack of funding, PM moving on) if not properly preserved
- A grassroots effort to archive and distribute 50+ historical ATD data sets
- Varying degrees of data availability, including
  - Complete raw data with experiment reports
  - Data processed as inputs to other ATD models
  - Summary tables
- No web site nor database management system, just providing all data files “as is” in bulk; so no common data format except for condensed MDA files created for some experiments
- Distribution via cloud storage

Conclusions (2/2)

- Recent data sets often still managed by sponsors, so can't be freely distributed
- Answers to questions and advice on analysis provided to the extent feasible
- For future field experiments
  - Consider carefully how to maintain dataset longevity
  - Do not let unessential software features become future obstacles to data availability
  - Have good documentation to increase usefulness
- Welcome
  - Contributions from colleagues of other data sets
  - Suggestions of business models to sustain this effort

Backup Slide

Attributes of Some Data Sets

Parameters	Sub-Categories	Prairie Grass	DP26	OLAD	LROD	MADONA	Burro	Coyote	Desert Tortoise	Goldfish	Maplin Sands	Thorney Island	Hanford Kr85	Kit Fox	DSWA Phase I	MUST	Ventura	Pismo Beach	Cameron	Carpinteria	MVP	CAPTEX	ETEX	ACURATE	METREX	Kincaid	Bull Run	Indianapolis	Clifty Creek	Tracy	Martins Creek	Westvaco	Urban 2000	Joint Urban 2003	Los Angeles	Barrio Logan
Source Geometry	Point	x	x			x			x	x			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Line			x	x																											x				
	Area						x	x			x			x																						
	Volume											x			x																					
Source Term	Instantaneous		x	x	x	x						x			x	x					x												x			
	Finite duration with constant (or slowly varying) rate	x				x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Finite duration with varying rate																																			
Source Elevation	Ground (0 to ~50 m)	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							x	x	x	x
	Elevated (~50 m to atmospheric boundary layer)			x	x															x	x					x	x	x	x	x	x	x				
	High-altitude (beyond atmospheric boundary layer)																																			
Source Dynamical Effects	Neutrally buoyant	x	x	x	x	x							x		x	x	x	x	x	x	x	x	x	x	x							x	x	x	x
	Buoyant																									x	x	x	x	x	x	x				
	Dense						x	x	x	x	x	x		x																						
	Momentum (jets)								x	x																										
Source Location	Stationary	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Moving			x	x																															
Terrain	Flat (grass, crops, desert, forest, etc.)	x	x	x					x	x		x	x	x	x	x						x	x	x	x	x										
	Complex (mountains, valleys, etc.)		x	x		x																x	x	x			x		x	x	x	x				
	Coastal (land-water interface)																x	x	x	x	x															
	Overwater				x		x	x			x																									
	Urban															x									x			x					x	x	x	x
Time of Day	Day (neutral to unstable)	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Night (neutral to stable)	x	x			x							x	x	x	x			x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Transition			x		x						x									x	x	x	x	x	x	x	x	x	x	x					
Prevailing Weather	Steady (persistent)	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Frontal passage					x															x	x	x	x	x	x	x	x	x	x	x					
Meteorological Measurements	Surface (including towers)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Radiosondes (including tethersondes)		x	x	x	x										x				x	x	x	x	x	x	x	x	x	x	x	x	x	x			
	Remote sensing (profilers, sodars, etc.)		x	x		x										x					x											x	x			x
	Sonic anemometers (turbulence data)		x	x		x									x	x																x	x			x
	Aircraft				x												x	x	x		x												x			
Sampler Distribution	Rows (includng rectangular arrays and lidar scans)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x	x	x		x			x	x	x	x	x
	Randomly spaced																					x	x	x	x				x		x	x				
	Aircraft or moving van				x																x															
Sampler Downwind Distance	Near source (~ < 2 km)	x					x	x	x	x	x	x	x	x	x	x				x															x	x
	Meso-gamma scale (~ 2 – 20 km)		x	x		x											x	x	x						x	x	x	x	x	x	x	x	x		
	Meso-beta scale (~ 20 – 200 km)				x																x															
	Meso-alpha scale (~ 200 – 2000 km)																					x	x	x												
Concentration Measurements	Time averages	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	High frequency time series (e.g., ~ 1 Hz)		x	x	x	x	x	x	x	x		x		x	x	x					x												x			
	Repetition of ensemble members					x									x	x																				
	Deposition																																			
Scale	Full scale field	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Reduced scale field													x		x																					
	Laboratory																																			