Megacity Impacts on Regional and Global Environments: Mexico City case study (MIRAGE-Mex)

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NCAR


REGION AIR QUALITY
near Mexico City
photo N. Marley

GLOBAL CONCERNS

- **Regional and global air quality**
  - Human health
  - Impacts on agriculture and natural ecosystems
  - Deteriorating visibility
- **Climate change**
  - Increases in tropospheric O_3
  - Direct radiative effects of aerosols
  - Indirect aerosol effects on clouds and precipitation
- **Tropospheric self-cleaning (oxidizing) capacity**
  - Changes in atmospheric residence times of other climatically important gases (CH_4, HCFC's…)
  - Changes in spatial distributions (SO_2, NOx, …)

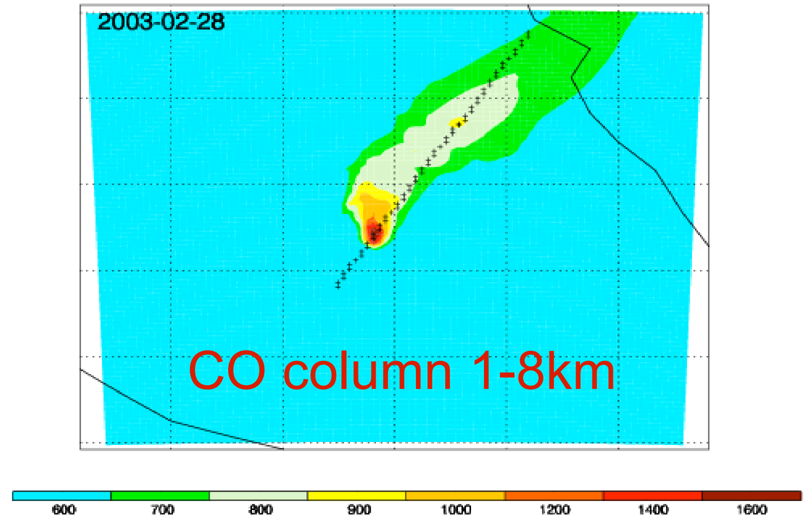
GENERAL HYPOTHESES

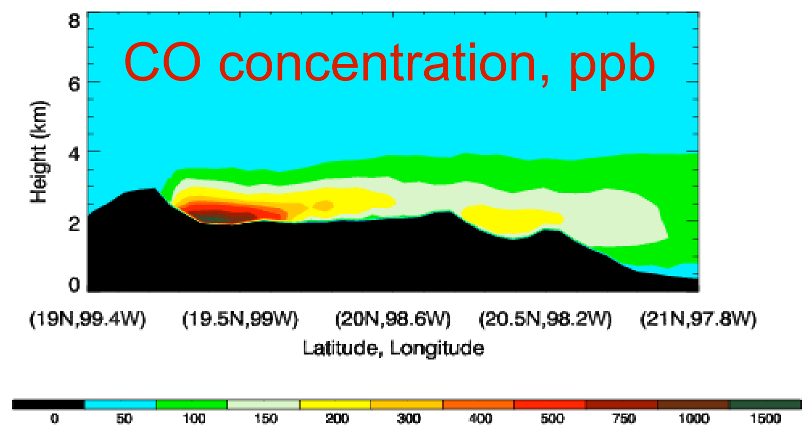
- The polluted outflow from a **single megacity** is sufficiently reactive to affect the regional atmosphere and environment.

- The polluted outflow from **all urban areas**, taken together, affects the global atmosphere and environment, and will do so increasingly in the future.

MIRAGE-Mex FIELD CAMPAIGN

- Organized by NCAR on behalf of the atmospheric sciences community
- 1-29 Mar 2006
- Observations near and down-wind of Mexico City over a period of 4 weeks, using the NSF/NCAR C-130 aircraft
- Ground based observations just outside city
- Satellite observations
- Modeling





CO from X.Tie, WRF-Chem model

GEOGRAPHIC COVERAGE

IMPEX
(NASA/NSF)

MIRAGE-Mex
(NSF)

MAX-Mex
(DOE)

MCMA-2006
(Molina et al.)

SCIENCE OBJECTIVES … quantify:

1. **Geographical extent and temporal persistence of the urban plume:**
   - *First characterization of regional air quality*
   - *Comparisons to background air*
   - *Unique chemical signatures?*

2. **Regional oxidants production:**
   - *$O_{3,}$ peroxides, acids, radicals*
   - *Alterations of photochemistry by aerosol heterogeneous and radiative processes*

SCIENCE OBJECTIVES … quantify:

3. Hydrocarbon oxidation products:

- *Evolution of long-lived intermediates, e.g. acetone*
- *Impacts on regional HOx and NOx partitioning and budgets*
- *Secondary organic aerosol formation*
- *Removal mechanisms*

4. Reactive nitrogen:

- *Lifetime of NOx*
- *Differential fate of reservoirs:*
  - o *HNO_3 – soluble, sensitive to aerosols and clouds*
  - o *PANs – thermally decomposed, sensitive to temperature*
  - o *Alkyl nitrates – long-lived, potentially important to global NOx*

SCIENCE OBJECTIVES … quantify:

5. **Gas-aerosol chemical processes:**
    1. *New particle formation*
    2. *Condensation from gas phase*
    3. *Oxidation*
    4. *Microphysical properties, effects on clouds*
    5. *Feedbacks on gas phase (removal, photolysis)*

6. **Aerosol radiative properties:**
    1. *Evolution of optical properties, absorption vs. scattering*
    2. *Internal vs. external mixture*
    3. *Vertical radiation profiles*

7. **Regional surface-atmosphere interactions**
    1. *Background air composition*
    2. *Urban plume + fire emissions*
    3. *Urban plume + biogenic emissions*

MAIN ELEMENTS OF MIRAGE-Mex

- **NCAR/NSF C-130 aircraft**
  10-11 days, 88 hours total research flights

- **Surface supersite**
  T1 = Tecamac, co-located with Mexican and DOE researchers

- **Modeling**
  process models
  regional and global chemistry-transport models
  assimilation of satellite data

- **Fire emissions**

- **Coordination with other field campaigns**
  MCMA-2006
  MAX-Mex
  IMPEX/INTEX-B

MIRAGE-Mex

Aircraft based in Veracruz (gases, particles, radiation)

Gas Measurements on C-130 Aircraft

CO, CO_2	COCAL, CO2C
NO, NO_2, NO_y, O_3	CLD
VOCs, OVOCs	Fast GCMS
VOCs, OVOCs	PTR-MS
PANs	CIGAR
OH, HO_2, HO_2+RO_2, HNO_3, H_2SO_4, NH_3, MSA	CIMS
CH_2O	DFG-TDL
SO_2	TECO-modified
anthropogenic and biogenic VOCs, $RONO_2$s, MtBE, DMS, OCS, halogenated organics	WAS
H_2O_2, CH_3OOH, HNO_3, HNO_4, $CH_3C(O)OOH$, organic acids, HCN	Dual channel SICIMS

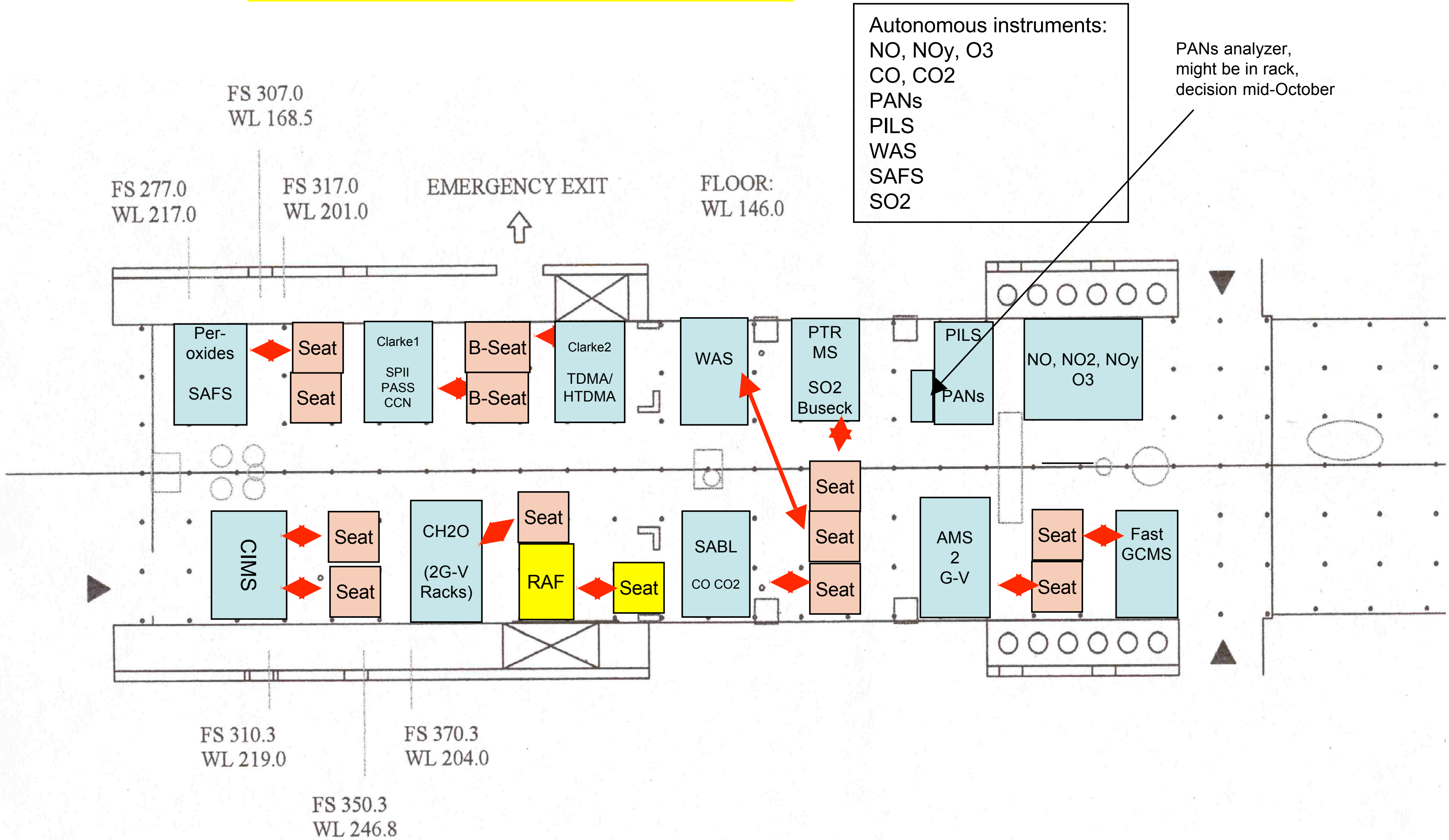
Physical Measurements on C-130 Aircraft

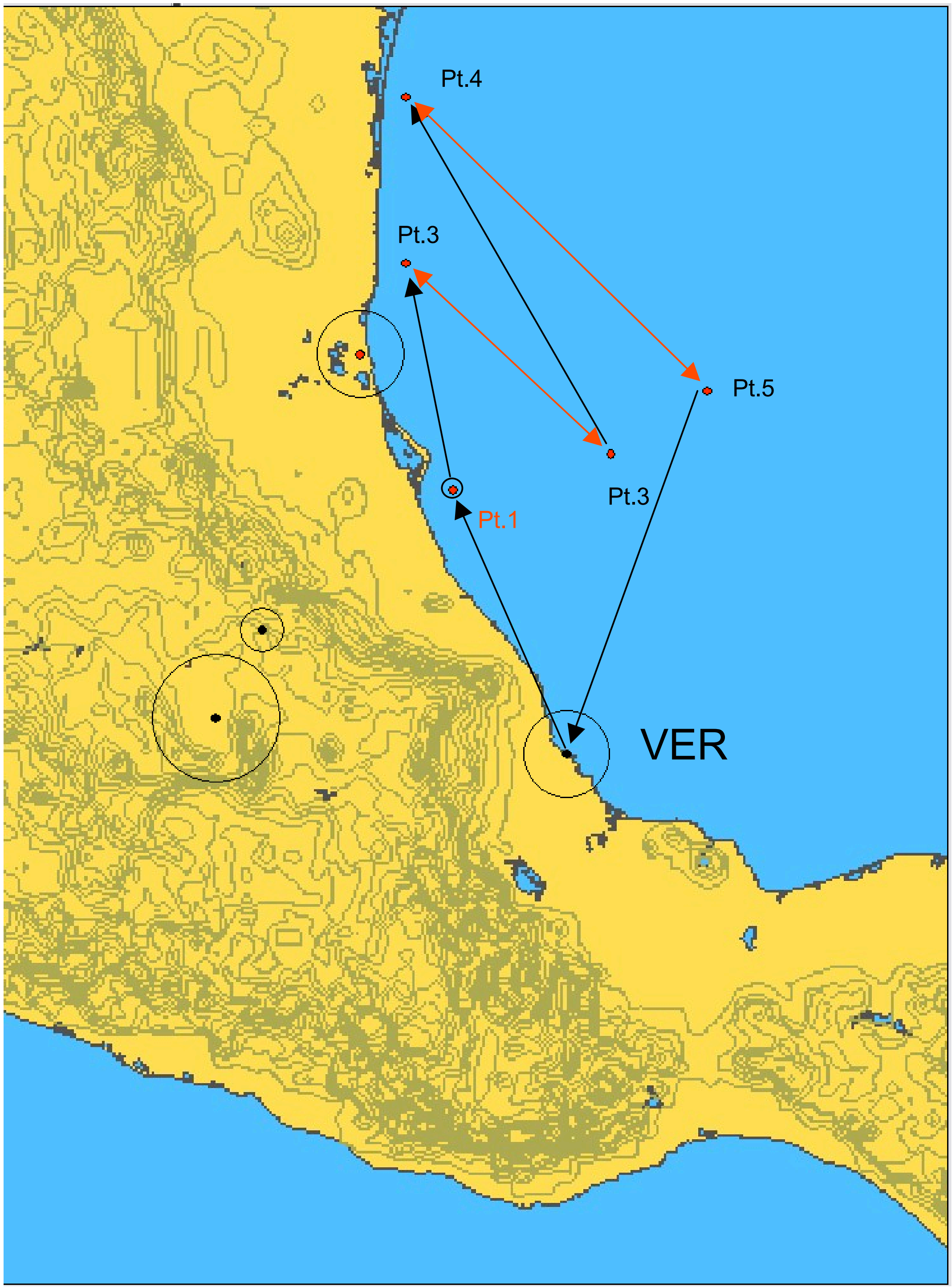
Nadir aerosol profile	SABL
Spectral actinic flux	SAFS
Lat, lon, z, P, T, RH, IR, VIS, UV-A	standard

Aerosol Measurements on C-130 Aircraft

CCN concentration	CCN counter
Particle number density, 0.1-20 μm	PMS probes
Particle counter 10 nm and up	CN counter
Particle counter 3 nm and up	Ultrafine CN counter
Size distribution, 0.01-1 μm	DMA
Size-resolved hygroscopicity, mixing state	H-TDMA
Size-resolved volatility, mixing state	V-TDMA
Total and submicron scattering coefficients	3-λ nephelometer
Total and submicron absorption coefficients	3-λ PSAP
Light scattering and absorption	PASS
Bulk soluble organics and inorganics	PILS
Non refractory size-resolved composition	ToF-AMS
Single particle soot mass	SP-2
Soot morphology	Filters, tomography/TEM
Functional group analysis	Filters, STXM

C-130 LAYOUT FOR MIRAGE





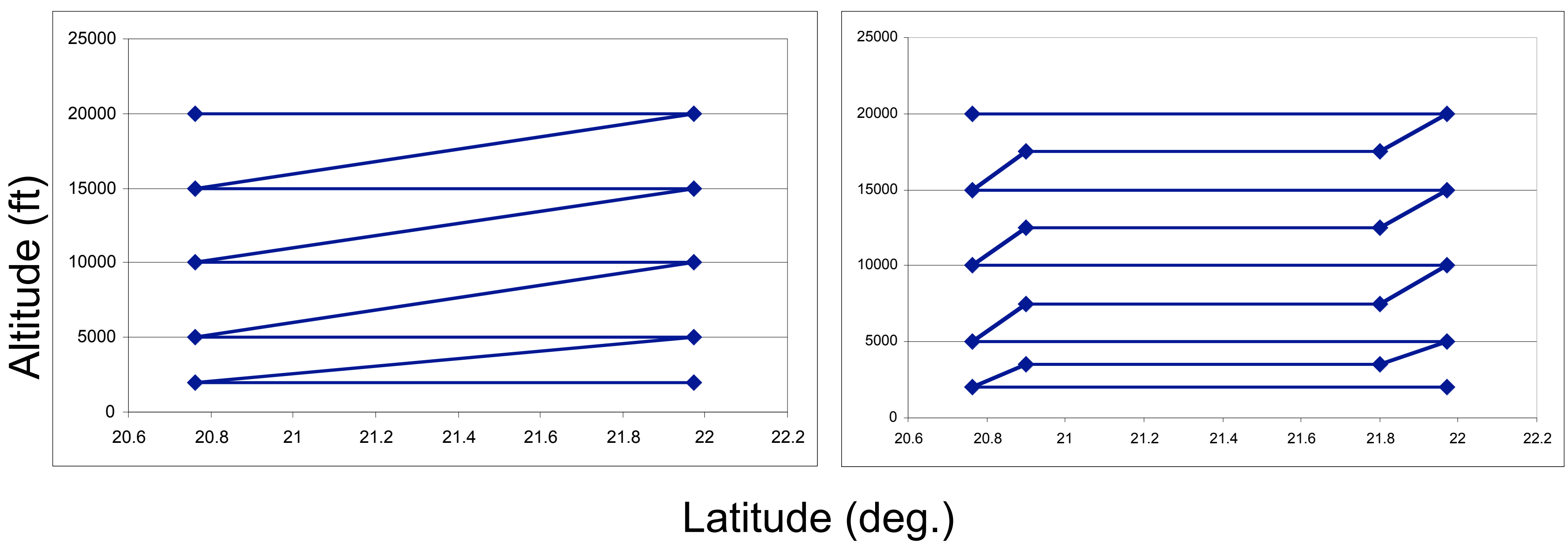
Far Transport Flight Plan 1

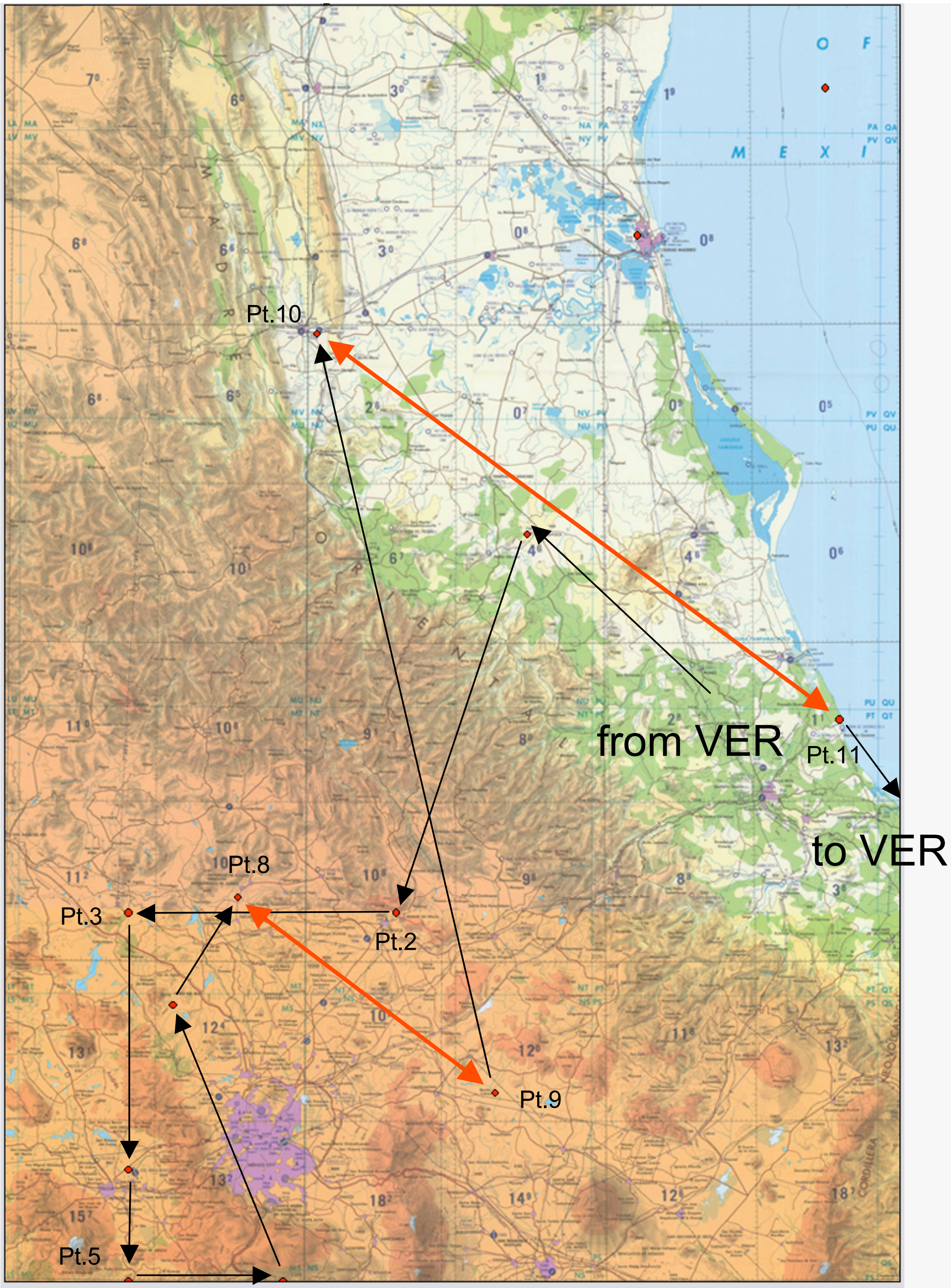
Pt.	Latitude	Longitude	Altitude	Time
0	**19.1640**	**-96.1710**	100	4:00
1	21.2214	-97.1079	20000	4:23
	Spiral descent 21.2214	-97.1079	1000	4:42
2	23	-97.5	10000	5:14
3	21.5	-95.8	10000	5:53
2	23	-97.5	16000	6:33
3	21.5	-95.8	16000	7:12
4	24.3	-97.5	10000	8:10
5	22	-95	10000	9:08
4	24.3	-97.5	16000	10:07
5	22	-95	16000	11:05
0	**19.1640**	**-96.1710**	100	11:54

ILLUSTRATION OF STACKED "WALLS"

The stacked walls can either be flown

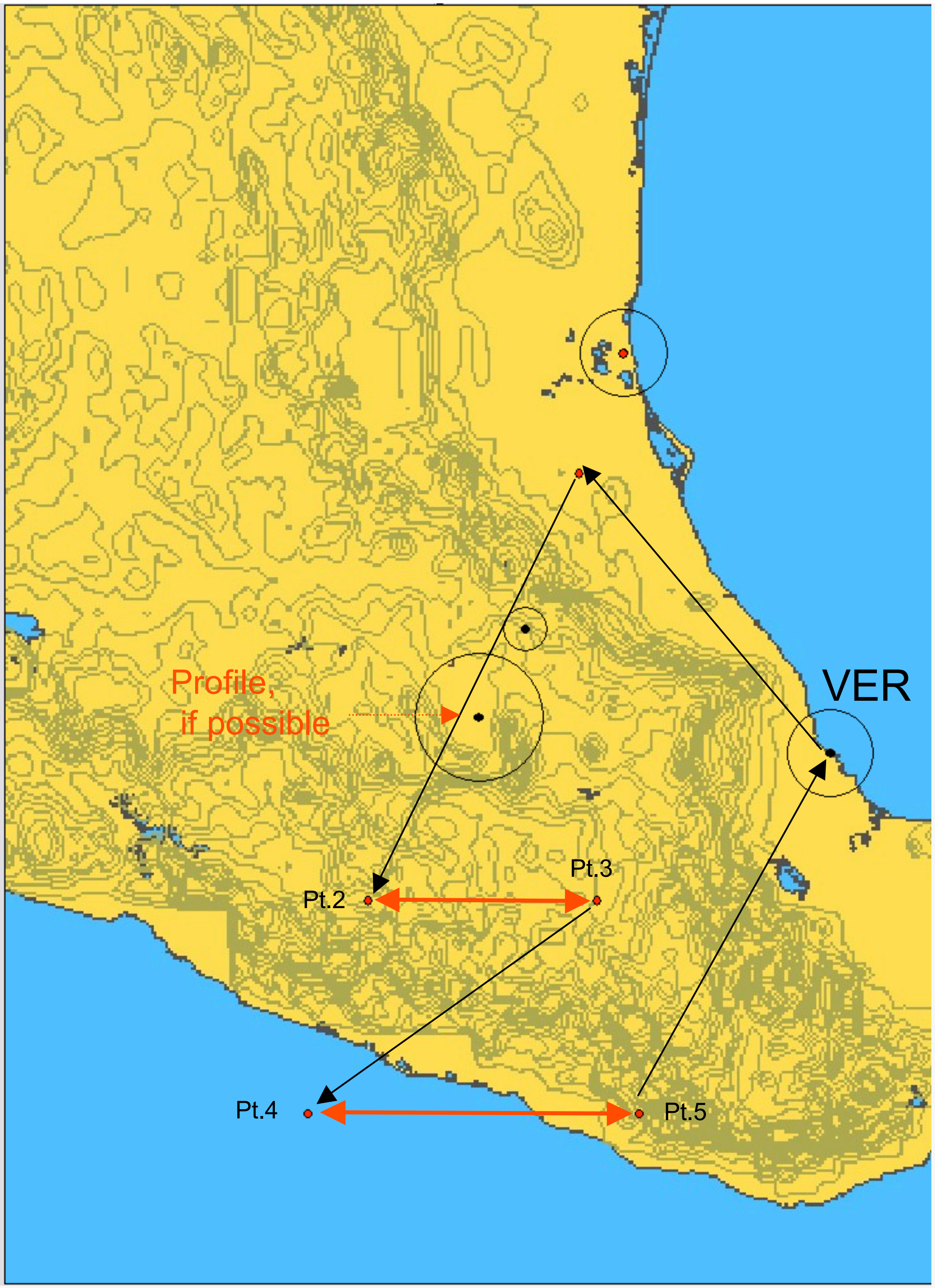
like this | or like this





NNE Flight Plan 1

Pt.	Latitude	Longitude	Altitude	Time
0	19.1640	-96.1710	100	13:00
1	21.3428	-98.2512	18000	13:18
2	20.157	-98.6919	18000	13:40
3	20.157	-99.5889	18000	13:55
4	Toluca airpt. 19.3503	-99.5889	(missed approach)	14:10
5	19	-99.5889	1000 AGL	14:16
6	19	-99.07	1000 AGL	14:25
7	19.868	-99.44	12000	14:42
8	20.2055	-99.223	10000	14:49
9	19.592	-98.3591	(10000)	15:07
8	20.2055	-99.223	15000	15:26
9	19.592	-98.3591	(15000)	15:44
8	20.2055	-99.223	18000	16:02
9	19.592	-98.3591	descending	16:21
10	21.9716	-98.9573	1000 AGL	17:05
11	20.7635	-97.2038	(1000 AGL)	17:41
10	21.9716	-98.9573	7000	18:18
11	20.7635	-97.2038	(7000)	18:55
10	21.9716	-98.9573	15000	19:31
11	20.7635	-97.2038	(15000)	20:08
10	21.9716	-98.9573	20000	20:44
11	20.7635	-97.2038	22000	21:21
12	22.744	-97.25	22000	21:57
	(spiral descent) 22.744	-97.25	1000	22:16
0	19.1640	-96.1710	100	22:29

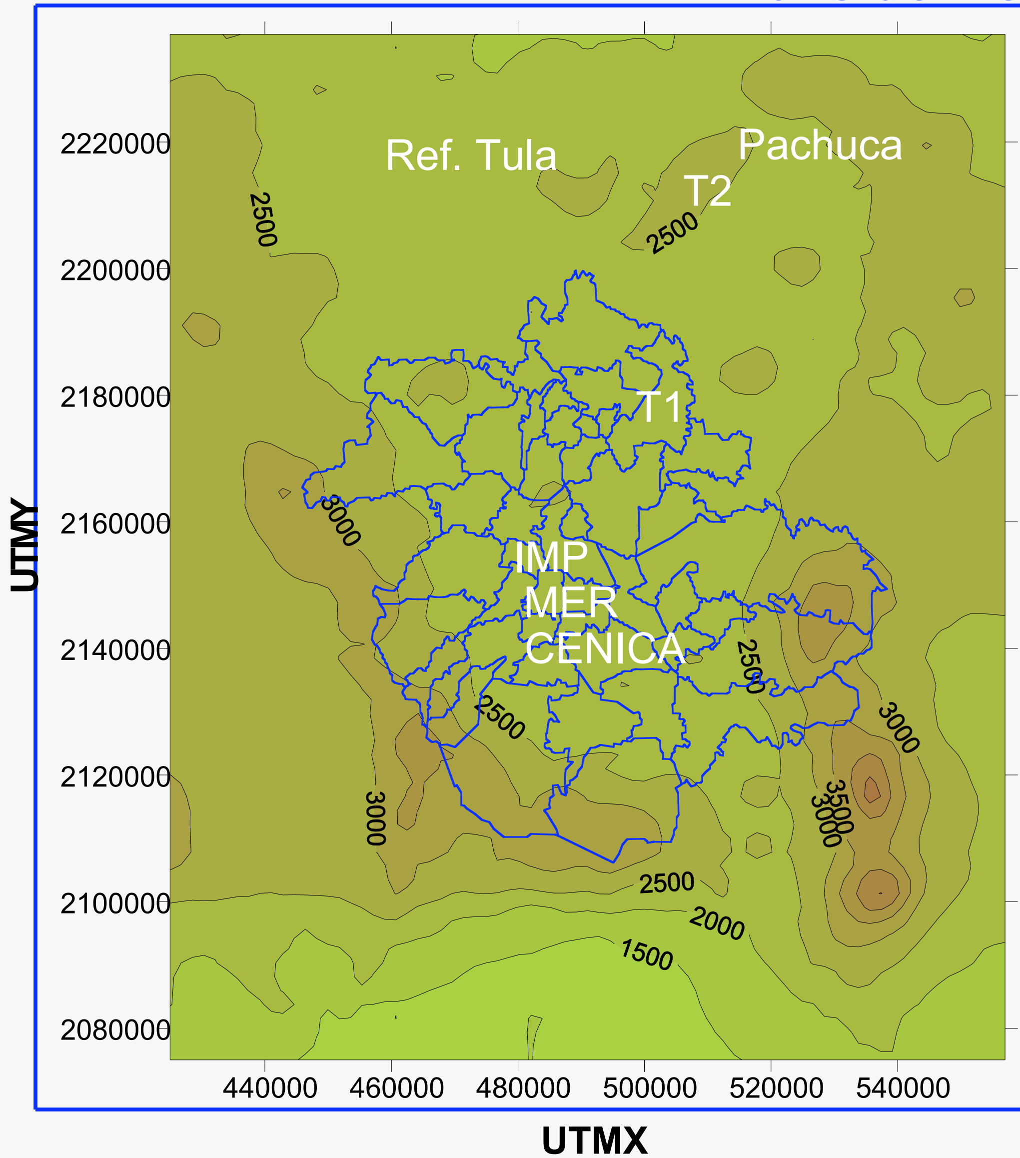


S Flight Plan 1

Pt.	Latitude	Longitude	Altitude	Time
0	**19.1640**	**-96.1710**	100	11:00
1	21.3428	-98.2512	18000	11:18
2	18	-100	18000	12:25
3	18	-98.1	(18000)	12:57
2	18	-100	12000	13:30
3	18	-98.1	(12000)	14:02
2	18	-100	1000AGL	14:35
3	18	-98.1	(1000AGL)	15:07
4	16.33	-100.5	20000	15:59
5	16.33	-97.75	(20000)	16:46
4	16.33	-100.5	13000	17:34
5	16.33	-97.75	(13000)	18:21
4	16.33	-100.5	7000	19:09
5	16.33	-97.75	(7000)	19:56
0	**19.1640**	**-96.1710**	100	21:44

MILAGRO – SURFACE MEASUREMENTS

Valle de México



Surface measurement of gases, aerosol, and radiation in and near Mexico City.

Supersites at 3 locations:

T_0: CENICA (Inside Mexico City)

T_1: Universidad Tecnológica de Tecámac (Estado de México)

T_2: Ranch La Bisnaga (near Pachuca, Hidalgo)

T1 Supersite, ~ 35 km N of MC center

Universidad Tecnologica de Tecamac (UTTEC)

19N42.184, 98W59.917, 2270 m asl

Measurements at T1 Supersite

Gases: O_3, H_2O_2, NO, NO_2, NOx, NOy, HNO_3, total $RONO_2$, total PANs, OH, HO_2+RO_2, NH_3, SO_2, H_2SO_4, H_2, CO, CO_2, speciated HCs, CH_2O, carbonyls, OVOCs, Hg, O_3 sondes

Aerosols: PM_{10}, $PM_{2.5}$, size distributions, ions, BC, OC/EC, speciated organics, bulk soluble organics, HULIS, PAHs, Hg, radionuclides; size-resolved non-refractory composition, absorption and scattering, size-resolved hygroscopicity, volatility, and mixing state, lidar profiler, surface tension, morphology, optical depths

Physical: Surface met, sensible and latent heat fluxes, wind profiler, rh and T soundings, spectral actinic flux, filter radiometers, trajectory-following balloons

NSF-supported projects

E. Atlas D. Blake	U. Miami UC-Irvine	HCs, halogenated compounds
P.Wennberg	Cal. Inst. Tech.	H_2O_2, org. peroxides, org. acids
J. Jiménez	U. Colorado	size-resolved aerosol composition
D. Collins	Texas A&M U	aerosols size distribution, mixing state
R. Weber	Georgia Inst. Tech.	bulk aerosol organics
T. Clarke	U. Hawaii	aerosol size, optical properties
L. Russell D. Baumgardner	UC-San Diego UNAM	aerosol sizes, opt. prop., soot mass
R. Cohen	UC-Berkeley	NO_2, N_2O_5, HNO_3, ΣPNs and ΣANs
B. Lefer J. Slusser	U. Houston Colorado State U.	Spectral actinic flux
K. Knapp	U. Alabama	Wind profiler
G. Huey	Georgia Inst. Tech.	NO, NO_2, NOx, NOy, OH, HO_2+RO_2
P. Voss	Smith Collage	COMET balloons
J. Schauer	U. Wisconsin	Speciated organic content
L. Molina M. Molina	UC-San Diego	Modeling
P. Buseck	Arizona State U.	Soot morphology
W. Eichinger	U. Iowa	Mobile lidar
R. Yokelson	U. Montana	Emissions from fires
C. Kolb	Aerodyne, Inc.	Mobile lab
J. Holloway	NOAA	SO_2

NSF/NCAR-supported projects

A. Schanot et al.	NCAR/EOL	C-130 operations
J. Meitin R.Dirks	NCAR/EOL(JOSS)	Logistics
T. Campos	NCAR/EOL	CO, CO_2
A.Fried	NCAR/EOL	CH_2O
B.Morley E.Leow	NCAR/EOL	SABL lidar
W. Skamarock	NCAR/MMM	WRF forecasting
E. Apel	NCAR/ACD	OVOC's
A. Weinheimer	NCAR/ACD	O_3, NO, NO_2, NOy
T. Karl	NCAR/ACD	OVOC's
F. Flocke	NCAR/ACD	PANs
F. Eisele L. Mauldin C. Cantrell	NCAR/ACD	OH, HO_2 (or HO_2+RO_2), HNO_3, H_2SO_4, NH_3, MSA
R. Shetter	NCAR/ACD	Spectral actinic flux
J. Smith	NCAR/ACD	H_2SO_4, NH_3, ultrafines, nucleation
A. Guenther J. Greenberg	NCAR/ACD	O_3, NOx, CO, CO_2, H_2O, HC, size distr., met, fluxes, UV and vis
P. Hess L. Emmons J.F-Lamarque	NCAR/ACD	Global model, satellite CO assimilation
X. Tie	NCAR/ACD	Modeling
S. Madronich	NCAR/ACD	Modeling

CONACyT-supported projects

L. Manzanares	CIMAV	Aerosol morphology, elemental analysis
D. Salcedo	UAEM	Size resolved non-refractory composition
S. Ramirez	UAEM	
E. Vega	IMP	PM2.5, VOCs, carbonyls
G. Sosa	IMP	Met, SO_2 emiss., model
B. Cardenas	CENICA/INE	Ions, EC, OC, PAH,Hg
R. Ramos A. Retama	SMA/GDF	Air quality network
A. Jazcilevich	UNAM/CCA	Modeling
R. Villalobos	UNAM/CCA	HCs, PAH
V. Magna E. Caetano	UNAM/CCA	Met modeling
A. Baez	UNAM/CCA	Inorganic ions
A. Muhlia	UNAM/IG	Radiation
M. Moya	UNAM/CCA	Ions, PAH's, trace metals
A. Salcido	IIE	Met
A. Varela	ININ	
A. Aragon	U. A. de LSP	Aerosol morphology, size
R. Navarro	UNAM/I. de Fisica	
M. Grutter	UNAM/CCA	O_3, CO_2, N_2O, NH_3
G. Ruiz	UNAM/CCA	CO, NOx, SO_2, O_3, H_2O_2, carbonyls, met


http://mirage-mex.acd.ucar.edu
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