Proyecto **MILAGRO**

Megacity **I**nitiative:
Local **a**nd **G**lobal **R**esearch **O**bservations

Sasha Madronich
José Meitín
22 July 2005
Presentado en US Embassy, Mexico City

centro mario molina

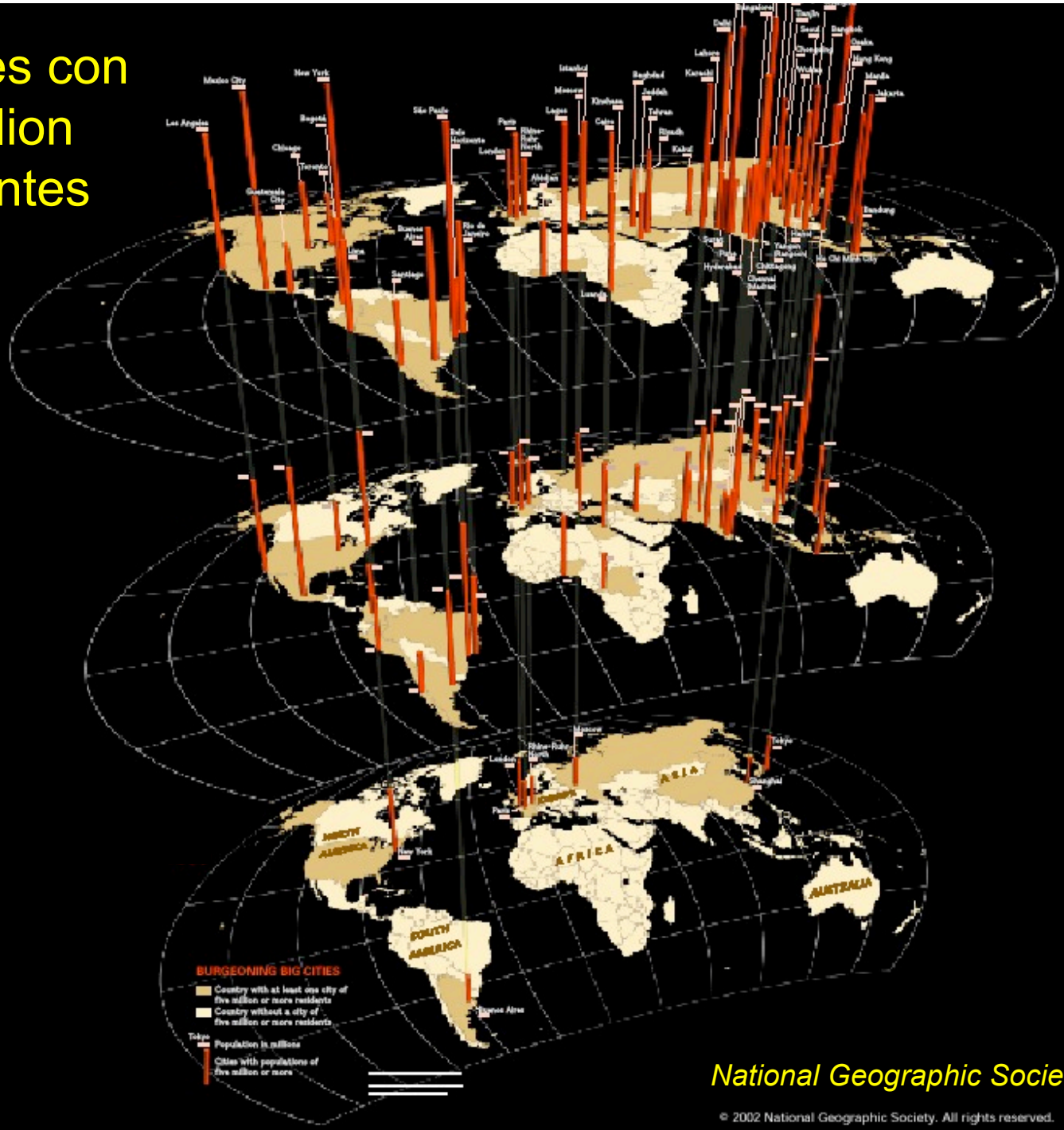
NCAR

Ciudades con >5 million habitantes

2015

2000

1950



National Geographic Society, 2002

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Impactos Locales

Daños a la Salud

Cambios a la Meteorología Urbana

IMPACTO GLOBAL

Cambio del Clima

IMPACTOS REGIONALES

Daños a la agricultura y ecosistemas naturales

Deterioración de visibilidad

Cambios a la meteorología regional

CONTAMINACION : URBANA → REGIONAL → GLOBAL

- ¿Magnitud temporal y espacial de la pluma de contaminación de las megaciudades?
- ¿Como y donde se eliminan los contaminantes urbanos de la atmósfera?
- ¿Cuales son los impactos regionales y mundiales de las plumas urbanas?

Zona Metropolitana Valle de México

Caso de estudio

- Megaciudad tropical representantiva
- Inventarios urbanos y monitoreo de calidad del aire fiables
- Excelente colaboracion científica
- Buena infraestructura logística
- Previas campañas de investigación

Programa Integral en Contaminación Urbana, Regional y Global:

Caso de estudio de la Ciudad de México - 2003

Objetivo:

Proveer una evaluación balanceada y objetiva de las causas y alternativas de solución costo-efectivas de los problemas de contaminación del aire urbanos, regionales y globales, mediante un análisis científico, tecnológico, social y económico, afrontando incertidumbres y datos incompletos.

- **Usando la Ciudad de México como caso de estudio inicial**
- **Desarrollo de un método que se aplique globalmente**
- **Construyendo una base sólida de investigación básica**

CAMPAÑA MCMA-2003: RESUMEN

- **Misión exploratoria (febrero 2002)**
- **Campaña de medición intensa durante 5 semanas (primavera 2003)**
- **Special Session on "Megacity Impacts on Air Quality"**
  Reunion de la Union Geofísica Americana (AGU Fall 2004)(13-17 diciembre, 2004, San Francisco, California)
- **Edición especial de publicación por Internet**

  Atmospheric Chemistry and Physics Discussions
  http://www.copernicus.org/EGU/acp/index.htm
- **Participantes**
  30 instituciones de México, USA y Europa
- **Sponsors**

  Comisión Ambiental Metropolitana (CAM)

  Massachusetts Institute of Technology/ Alliance for Global Sustainability

  National Science Foundation (NSF, USA)

  Department of Energy (DOE, USA)

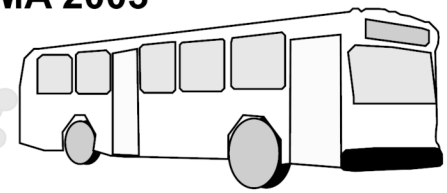
  Petroleos Mexicanos (PEMEX)

  Otros

CAMPAÑA MCMA-2003: CENICA Supersitio

ARI MOBILE LABORATORY

Aerodyne Mobile Lab
MCMA 2003



Roof
Sun Photometer
Anemometer
GPS

NO_y converter

isokinetic sample splits

NO_y
Chemiluminescence

NO_x
Chemiluminescence

CO
N.D. IR Absorption

SO_2
Fluorescence

O_3
UV Absorption

PeroxyAcetylNitrate
L.C. Fluorescence

CO_2
Licor N.D. IR

DustTrak
PM 2.5

PAH Particulate

Aerosol
Surface Area

Condensation
Particle Counter

Cyclone
< 2.5 µm

AMS
Aerosol Mass Spec
Size Resolved Composition
30 nm - 2 µm
NO_3^-, $SO_4^=$, NH_4^+
Organic Carbon

Relative Humidity
Pressure
Temperature
Velocity

CO_2
Licor N.D. IR

Video Camera

Rear Roof
Inlet

QCL
Quantum Cascade Laser
NH_3 1 s rms ~ 500 ppt

Aethlometer
PM 2.5

TDL
Tunable Diode Lasers
NO_2, HCHO

PTR-MS
Proton-Transfer Mass Spec
Selected VOCs

MILAGRO: TRES CAMPAÑAS COORDINADAS
1-29 marzo 2006

MCMA-2006

Mexico City Metropolitan Area – 2006
Jefe científico Luisa Molina (Centro Mario Molina)

MAX-Mex

Megacity Aerosol Experiment - Mexico
Jefe científico Jeff Gaffney (Department of Energy, EUA)

MIRAGE-Mex

Megacity Impacts on Regional and Global Environments – Mexico
Jefe científico Sasha Madronich (NCAR/National Science Foundation)

Otros estudios de apoyo:

- NASA DC-8 sobrevuelos
- Medidas de Satelite
- Análisis de Laboratorio
- Modelación Numérica

PLANO GEOGRAFICO

MIRAGE-Mex
NASA DC-8

MIRAGE-Mex
NSF C-130, KingAir
superficie

MAX-Mex
DOE G-1, KingAir
superficie

MCMA-2006
CENICA
superficie

Instituciones de México

Centro Mario Molina para Estudios Estratégicos sobre Energía y Medio Ambiente
Instituto Nacional de Ecología (INE)
Universidad Nacional Autónoma de México (UNAM)
Universidad Autónoma Metropoliitana (UAM)
Instituto Mexicano del Petróleo (IMP)
Centro Nacional de Investigación y Capacitación Ambiental (CENICA-INE)
Universidad Autónoma del Estado de Morelos (UAEM)
Universidad Autónoma de San Luis Potosí (UASLP)
Instituto Tecnológico de Estudios Superiores (Campus Monterrey y Estado de México)
Instituto Nacional de Investigaciones Nucleares (ININ)
Instituto de Investigaciones Eléctricas (IIE)
Universidad Tecnológica de Tecámac (Estado de México)
Universidad de Veracruzana (Estado de Veracruz)
Instiuto Nacional de Salud Pública (INSP)
Secretaria de Medio Ambiente del Gobierno del Distrito Federal (SMA-GDF)
Gobierno del Estado de México, Secretaria de Ecología (SEGEM)
Consejo Estatal de Protección al Ambiente (Estado de Veracruz)
Consejo Estatal de Ecología (Estado de Hidalgo)
Consejo Nacional de Ciencia y Tecnología (CONACyT)
Fundación México-Estados Unidos para la Ciencia (FUMEC)

Instituciones de Estados Unidos

Aerodyne Research, Inc.
Argonne National Laboratory
Brookhaven National Laboratory
California Inst. of Tech.
Colorado State U.
Georgia Inst. of Tech.
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
Massachusetts Inst. of Tech
Montana State U.
National Center for Atmospheric Research
Pacific Northwest National Laboratory
Pennsylvania State U.
Texas A&M U.
U. Arizona
U. California Berkeley
U. California San Diego
U. California at Riverside
U. California Irvine
U. Colorado
U. Iowa
U. Hawaii
U. Houston
U. Massachusetts
U. Miami
U. Minnesota
U. Montana
U. Nevada
U. Washington
U. Wisconsin
Washington State U.

Instituciones de Europa y otros paises

Freie University of Berlín, Germany

University of Heidelberg, Germany

University of Leipzig, Germany

Ecole Polytechnique Federal of Lausanne, Switzerland

ETH-Zurich, Switzerland

Chalmers Technical University, Sweden

Göteborg University, Sweden

Centro de Estudios de la Tierra, Barcelona, Spain

National Institute for Environmental Studies, Tsukuba, Japan

Beneficios

- Primera evaluación de la calidad del aire regional
- Entendimiento de la importancia relativa de diferentes fuentes (urbana, incendios de biomasa, natural)
- Mejora de modelos meteorológicos y de calidad de aire
- Mejor entendimiento de los procesos que eliminan y transforman contaminacion
- Oportunidades educacional para estudiantes en México y EEUU
- Oportunidades educacional para investigadores en México y EEUU

RAZON PARA ESTA REUNION

- Informe general de instrumentacion y complejidades del proyecto

- Identificacion de dificultades con
  - Importacion temporal
  - Preparaciones de los sitios
  - Espacio y electricidad
  - Comunicaciones
  - Frecuencias y banda de operacion
  - Permisos de vuelos
  - Operaciones de globos anclado y libre

DOE – G1 Aircraft

Base: Veracruz Jara International Airport

NCAR C-130 Aircraft

Base: Veracruz Jara International Airport

DOE/NASA y NSF – 2 King Air

Bases: Veracruz y Pachuca

NASA J-31 Aircraft

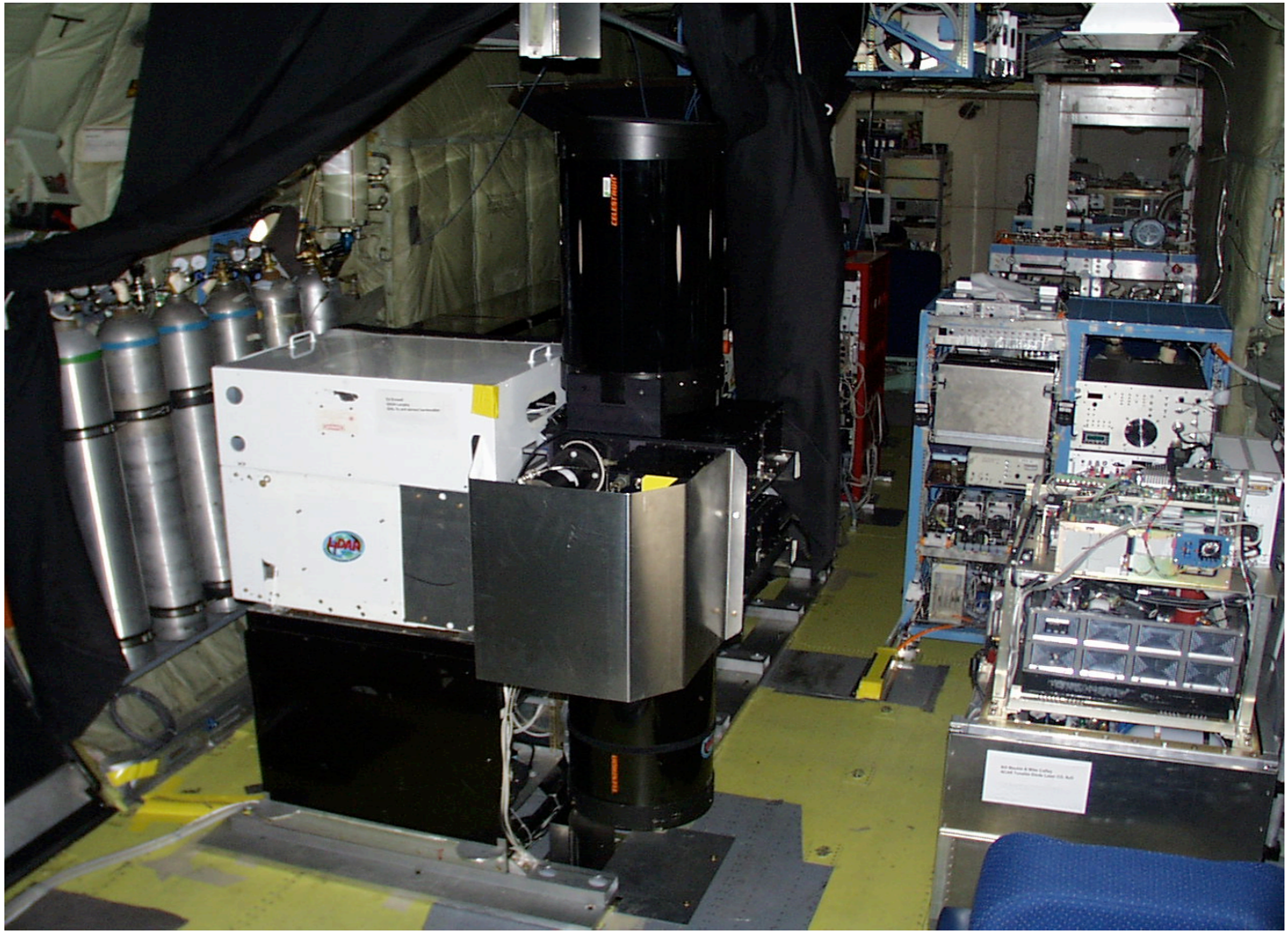
Base: Veracruz Jara International Airport

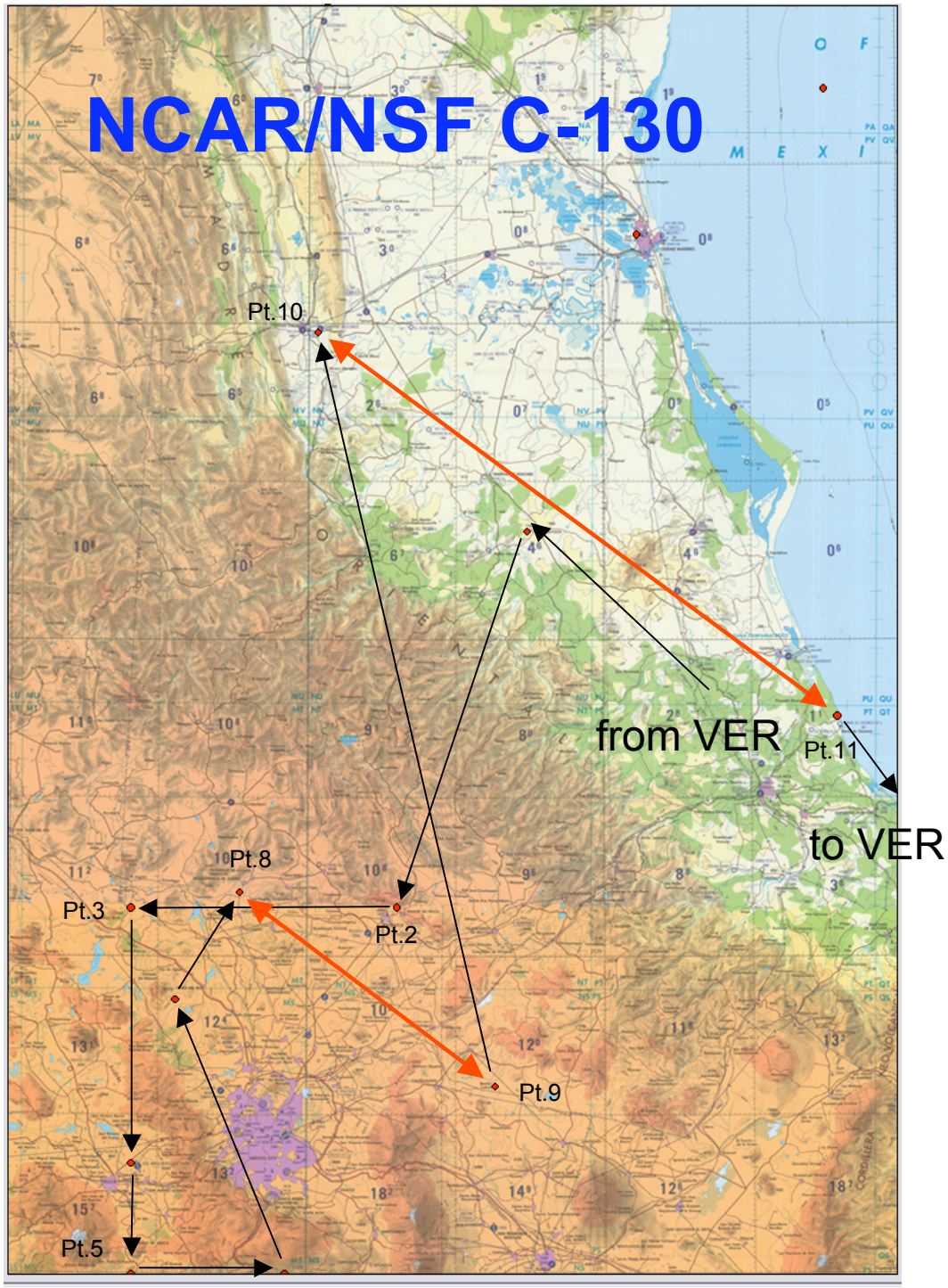
NASA DC-8 Aircraft

Base: Houston, Texas

Sistemas LIDAR

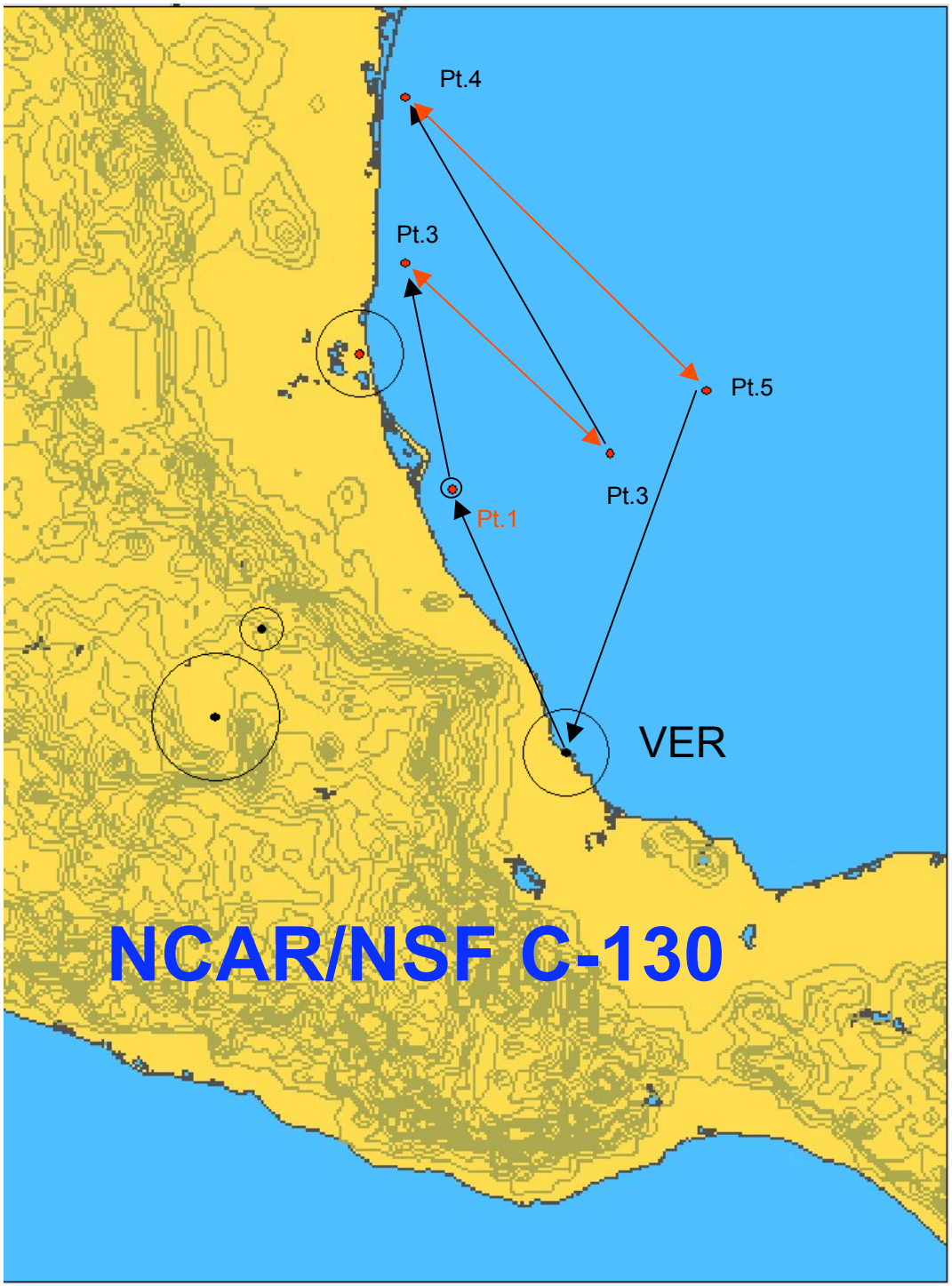
instalados en: NSF/C-130, DOE/NASA King Air, NASA DC-8





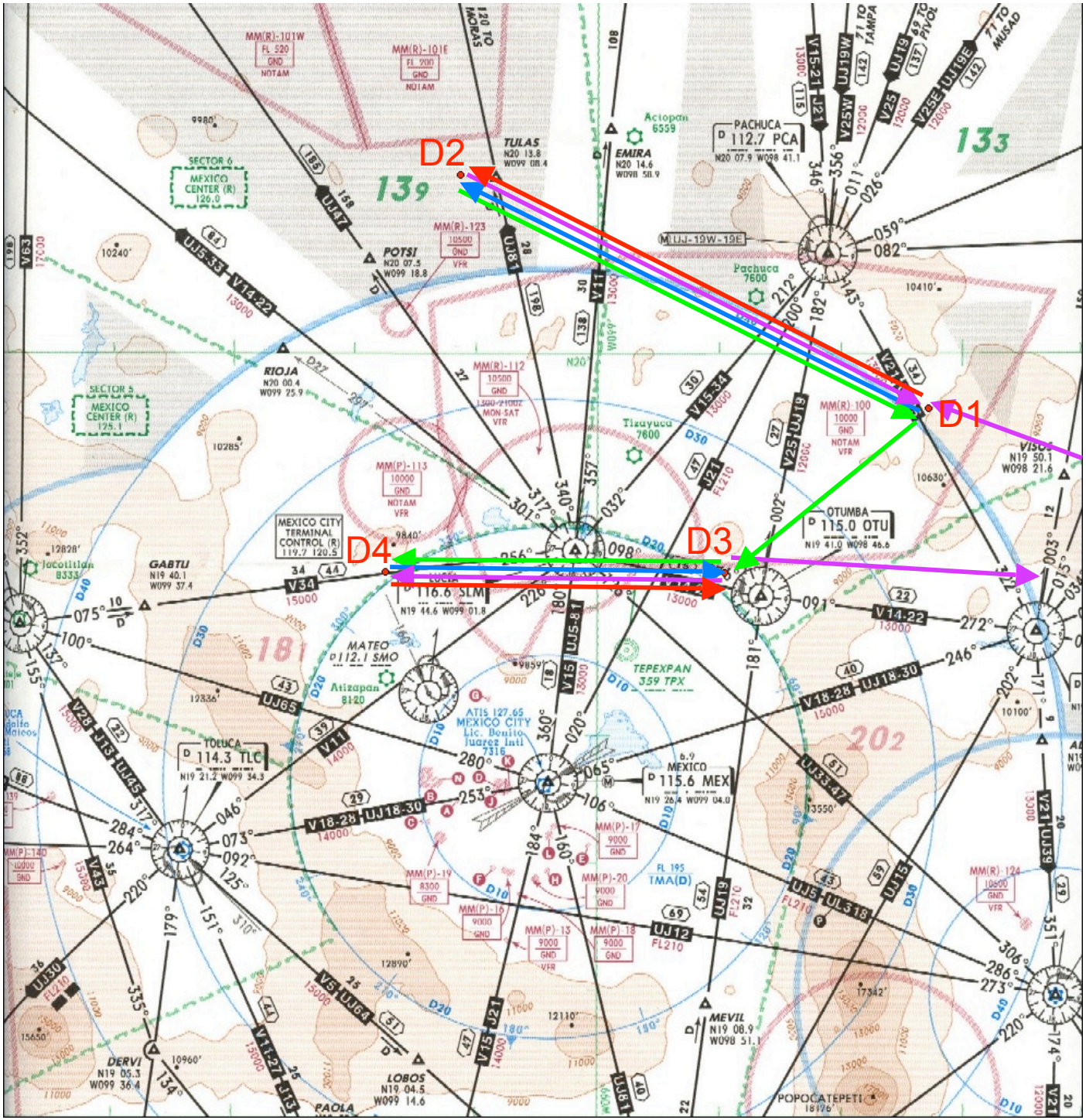
NNE FLIGHT PATTERN 1

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



FAR TRANSPORT FLIGHT PATTERN

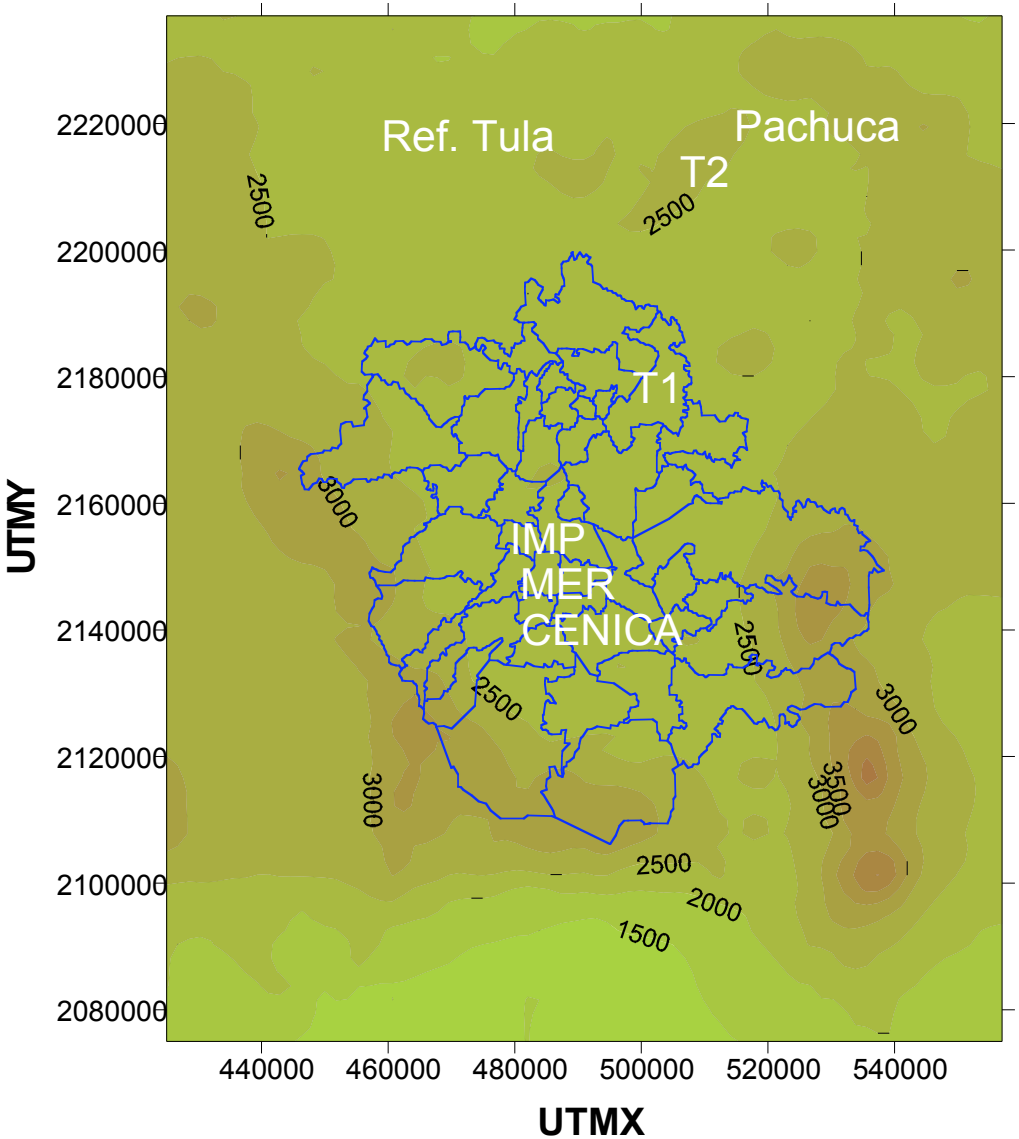
Pt.	Latitude	Longitude	Altitude	Time
0	**19.1640**	**-96.1710**	100	4:00
1	21.2214	-97.1079	20000	4:23
	Spiral descent 21.2214	-97.1079	1000	4:42
2	23	-97.5	10000	5:14
3	21.5	-95.8	10000	5:53
2	23	-97.5	16000	6:33
3	21.5	-95.8	16000	7:12
4	24.3	-97.5	10000	8:10
5	22	-95	10000	9:08
4	24.3	-97.5	16000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



DOE G-1

Pattern D

MILAGRO - Superficie
Sitios de medición Valle de México



Medidas de gases y aerosoles de superficie in the MCMA.

Mediciones móbil dentro y cerca del Distrito Federal:

- **T_0: CENICA (Zona Sureste del DF)**
- **T_1: Universidad Tecnológica de Tecámac (Estado de México)**
- **T_2: Rancho La Bisnaga (cerca de Tizayuca, Hidalgo)**

CENICA (T_0) Sitio de medidas

Instrumentacion semejante a MCMA-2003

ARI Laboratorio Mobil

Base: T_0 (CENICA)

Perfilador de viento y radiometro

Sitio: T_0 (CENICA)

Perfiladores de viento

Sitios: T_1, T_2, Veracruz

Laboratorio FTIR Mobil

Georgia Tech Mobile Lab

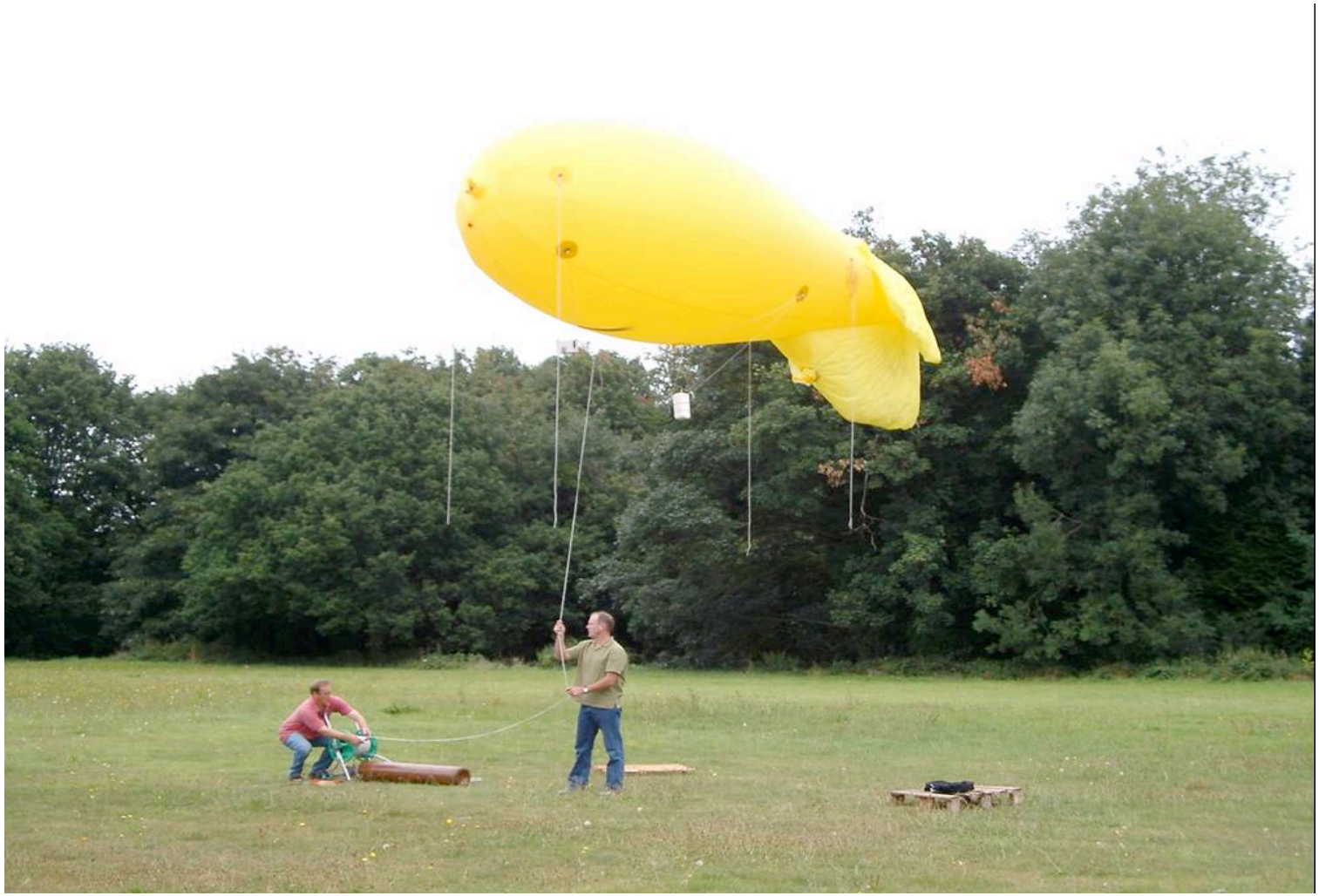
Sitio: T_1 (Tecamac)

Radiosondas meteorologicas

Sitios: T_1, T_2, SMN: Tacubaya, Veracruz, Merida, Acapulco

Globos anclados

Sitios T_0, T_1



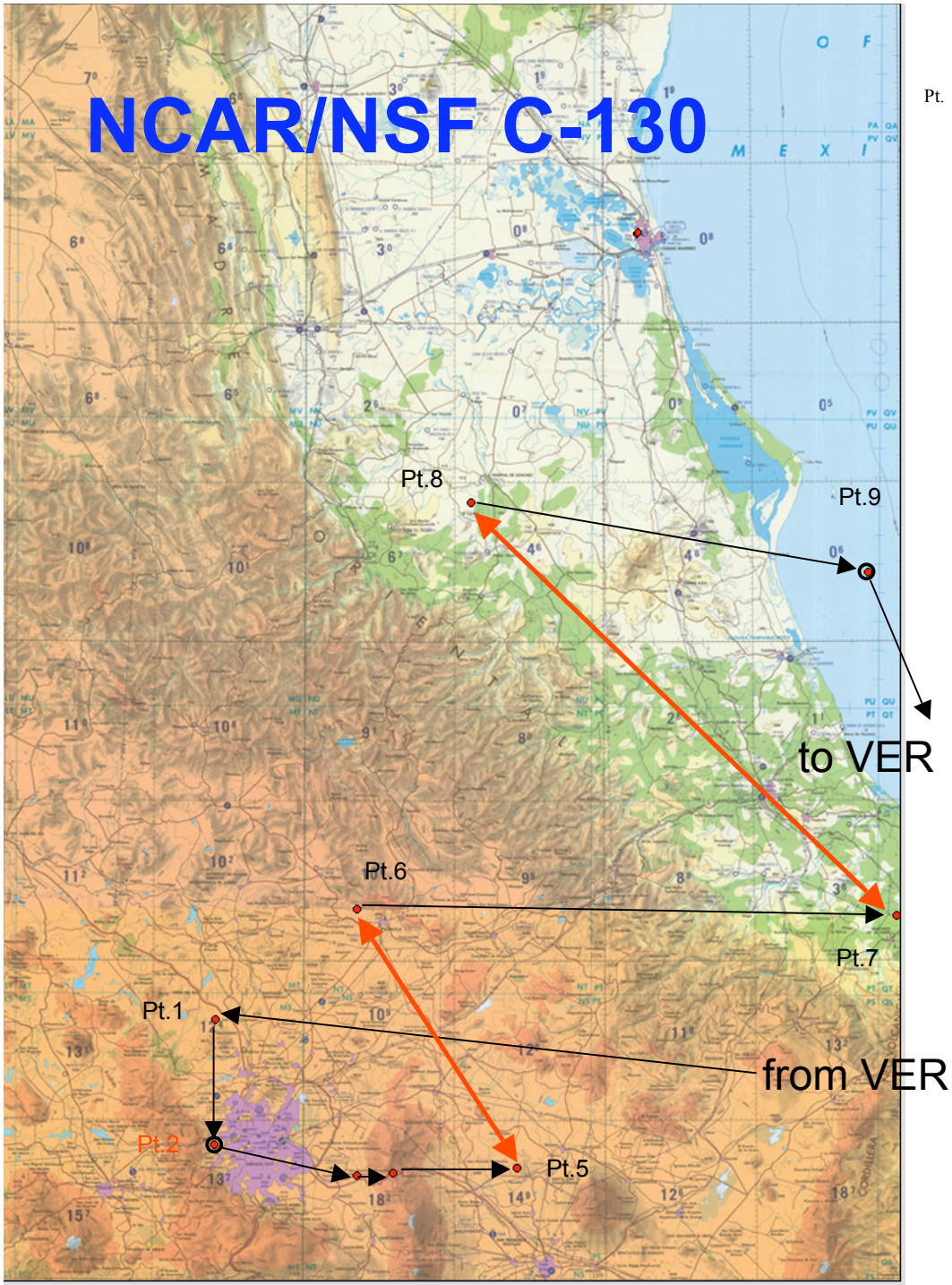
http://www.joss.ucar.edu/milagro/

Cuestiones

- **Aviacion**
  - Coordinacion y patrones de vuelo
  - Uso de lasers
  - Sobrevuelos y aproximacion de aterrizaje
  - Gases comprimidos

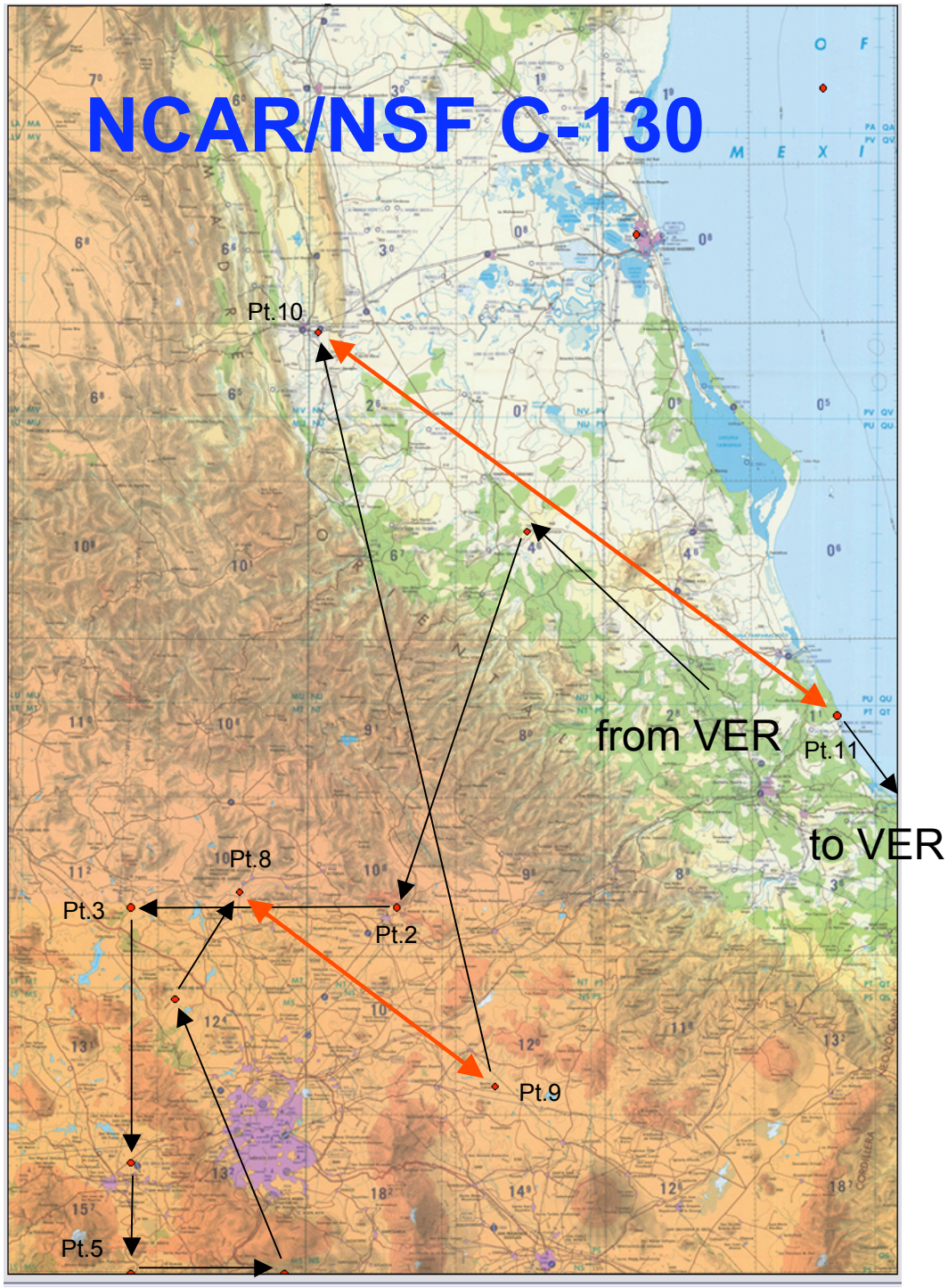
- **Superficie**
  - Perfiladores
  - Lanzamiento de radiosondas
  - Globos anclados
  - Gases comprimidos
  - Asignacion de frecuencias

- **Vehículos**
  - Importacion de vehiculos
  - Autorizacion de choferes



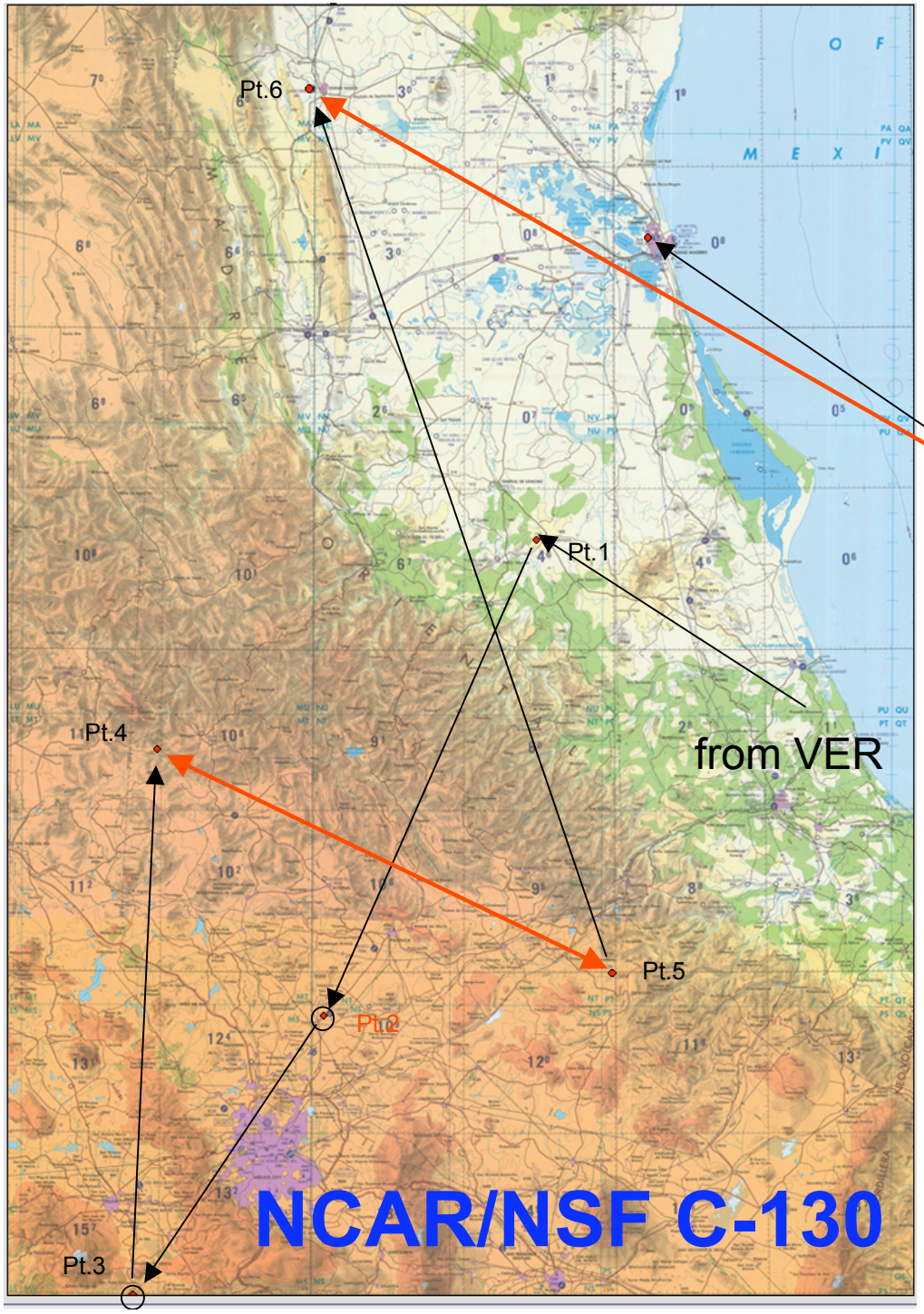
NE FLIGHT PATTERN 1

Pt.	Latitude	Longitude	Altitude (feet)	Time*
0	19.1640	-96.1710	100	13:00
1	19.8194	-99.2905	18000	13:50
2	19.4272	-99.2946	18000	13:57
	(spiral descent) 19.4272	-99.2946	1000 AGL	14:05
3	19.3301	-98.8174	2000 AGL	14:13
4	19.3379	-98.6971	2000 AGL	14:15
5	19.3534	-98.2822	1000 AGL	14:22
6	20.1651	-98.8174	1000 AGL	14:39
5	19.3534	-98.2822	(14000)	14:57
6	20.1651	-98.8174	14000	15:14
5	19.3534	-98.2822	(18000)	15:31
6	20.1651	-98.8174	slow descent	15:48
7	20.1456	-97.0125	1000 AGL	16:19
8	21.4388	-98.4357	1000 AGL	16:52
7	20.1456	-97.0125	(5000)	17:26
8	21.4388	-98.4357	5000	17:59
7	20.1456	-97.0125	(10000)	18:33
8	21.4388	-98.4357	10000	19:06
7	20.1456	-97.0125	(15000)	19:39
8	21.4388	-98.4357	15000	20:13
9	21.2214	-97.1079	20000	20:36
	(spiral descent) 21.2214	-97.1079	1000	20:55
0	19.1640	-96.1710	100	21:18



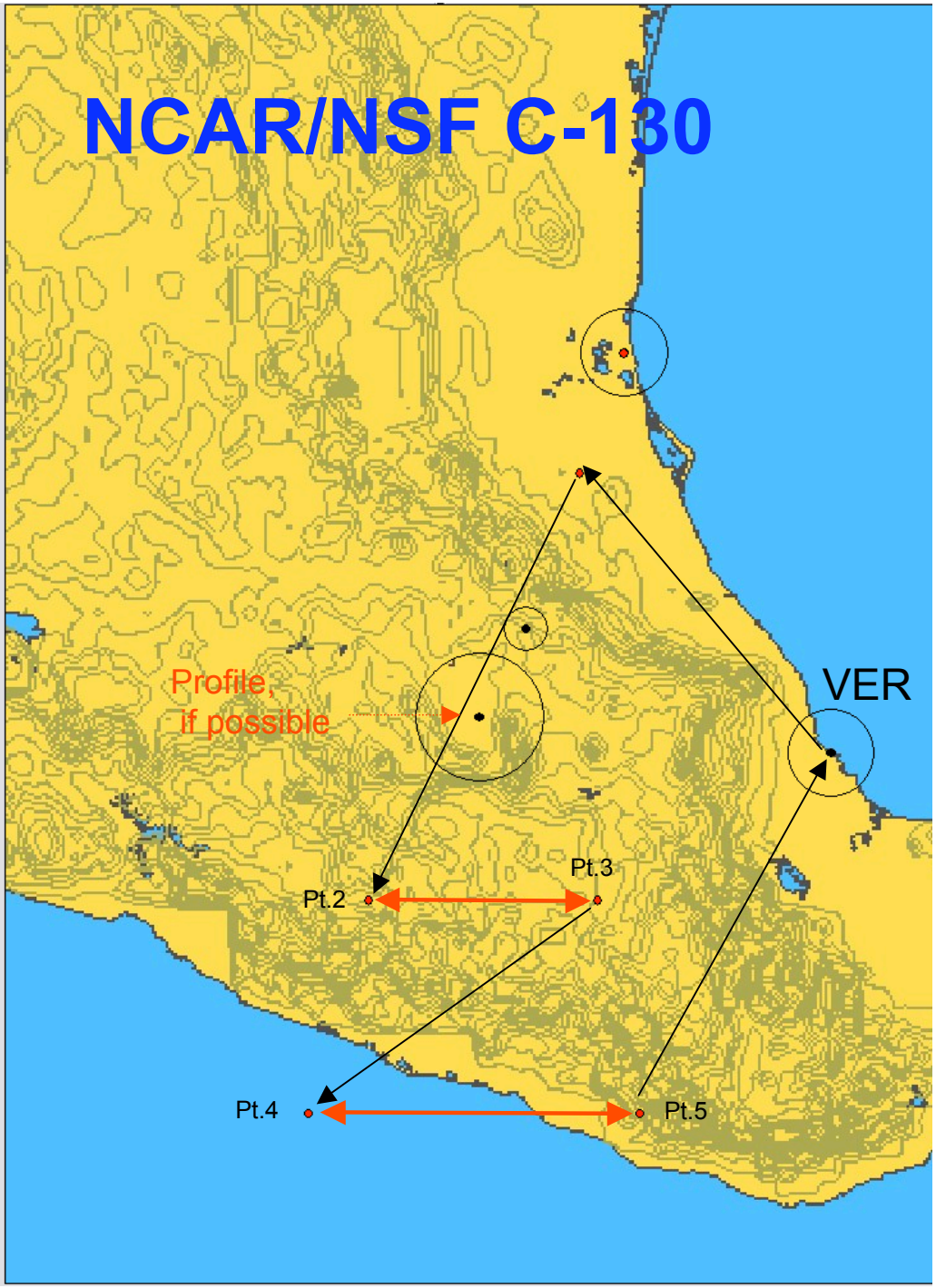
NNE FLIGHT PATTERN 1

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



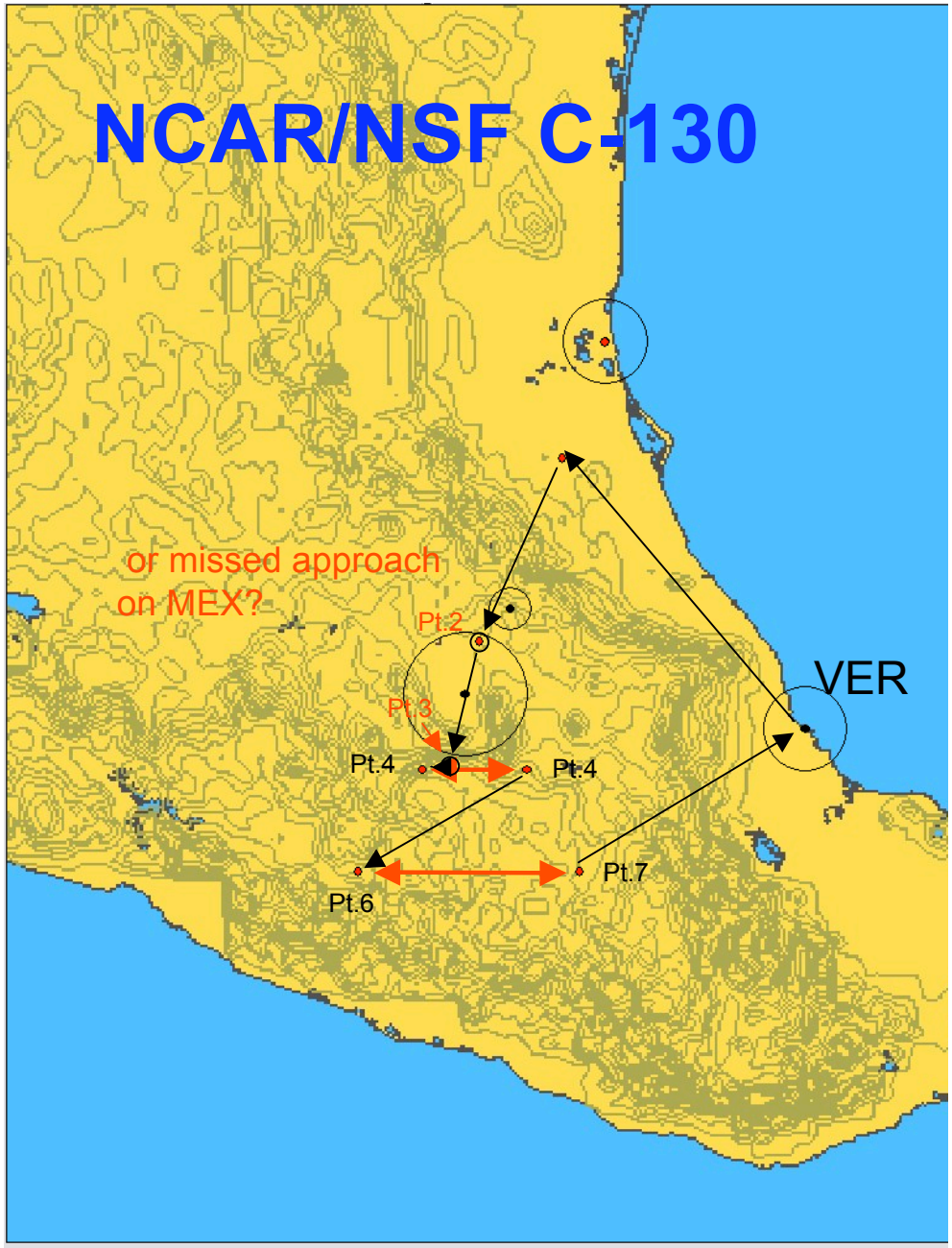
NNE FLIGHT PATTERN 2

Pt.	Latitude	Longitude	Altitude	Time
0	**19.1640**	**-96.1710**	100	14:00
1	21.3428	-98.2512	18000	14:18
2	19.868	-98.9573	18000	14:47
	spiral descent 19.868	-98.9573	10000	14:47
3	19	-99.5889	18000	15:06
	spiral descent 19	-99.5889	1000AGL	15:06
4	20.6961	-99.5071	1000AGL	15:36
5	20	-98	(1000AGL)	16:05
4	20.6961	-99.5071	13000	16:33
5	20	-98	(13000)	17:01
4	20.6961	-99.5071	18000	17:30
5	20	-98	(18000)	17:58
6	22.744	-99.0047	1000AGL	18:50
7	21.3653	-96.7441	(1000AGL)	19:36
6	22.744	-99.0047	7000	20:21
7	21.3653	-96.7441	(7000)	21:06
6	22.744	-99.0047	13000	21:51
7	21.3653	-96.7441	(13000)	22:36
6	22.744	-99.0047	20000	23:22
7	21.3653	-96.7441	(20000)	0:07
0	**19.1640**	**-96.1710**	100	0:32



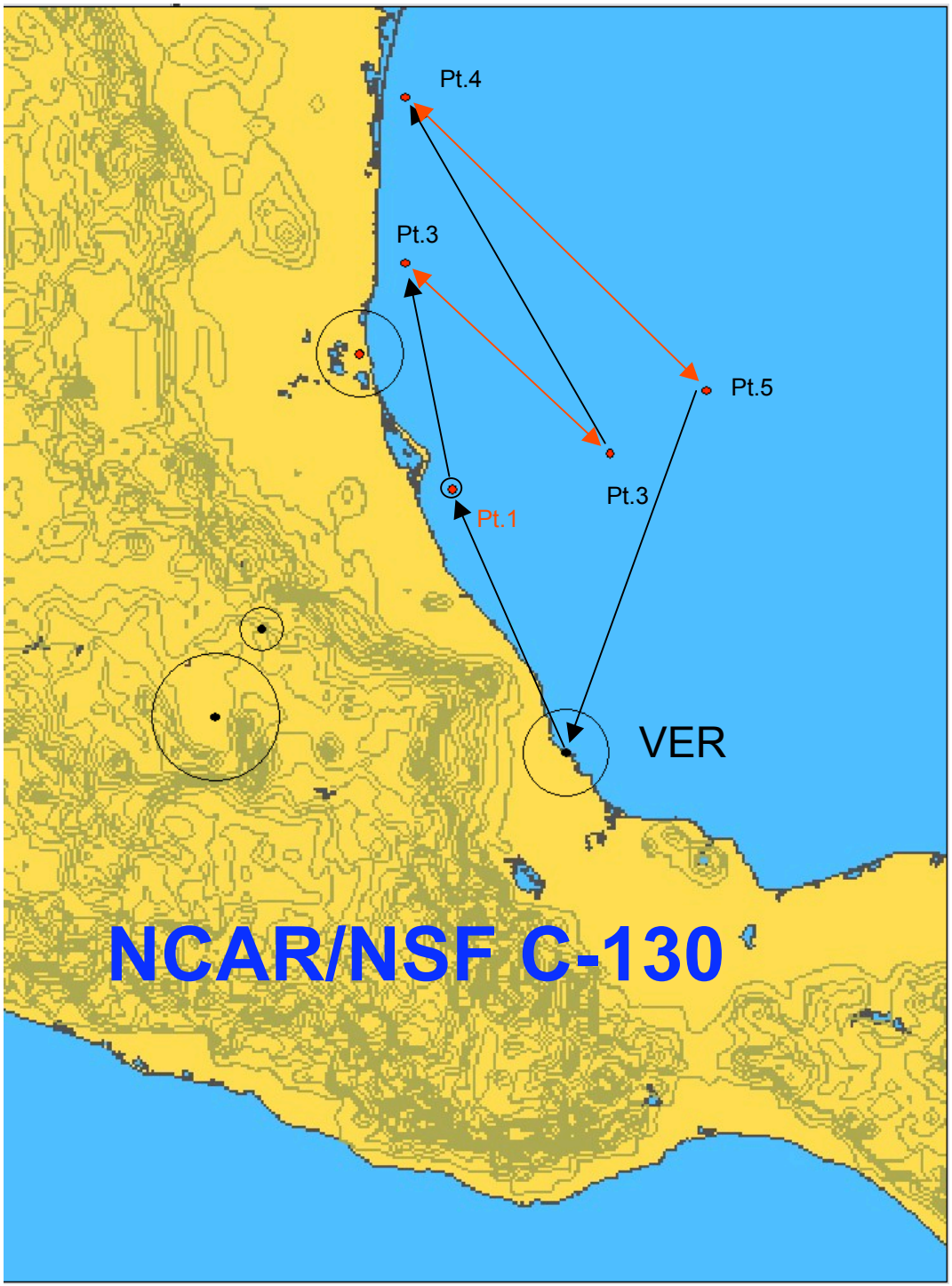
S FLIGHT PATTERN 1

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



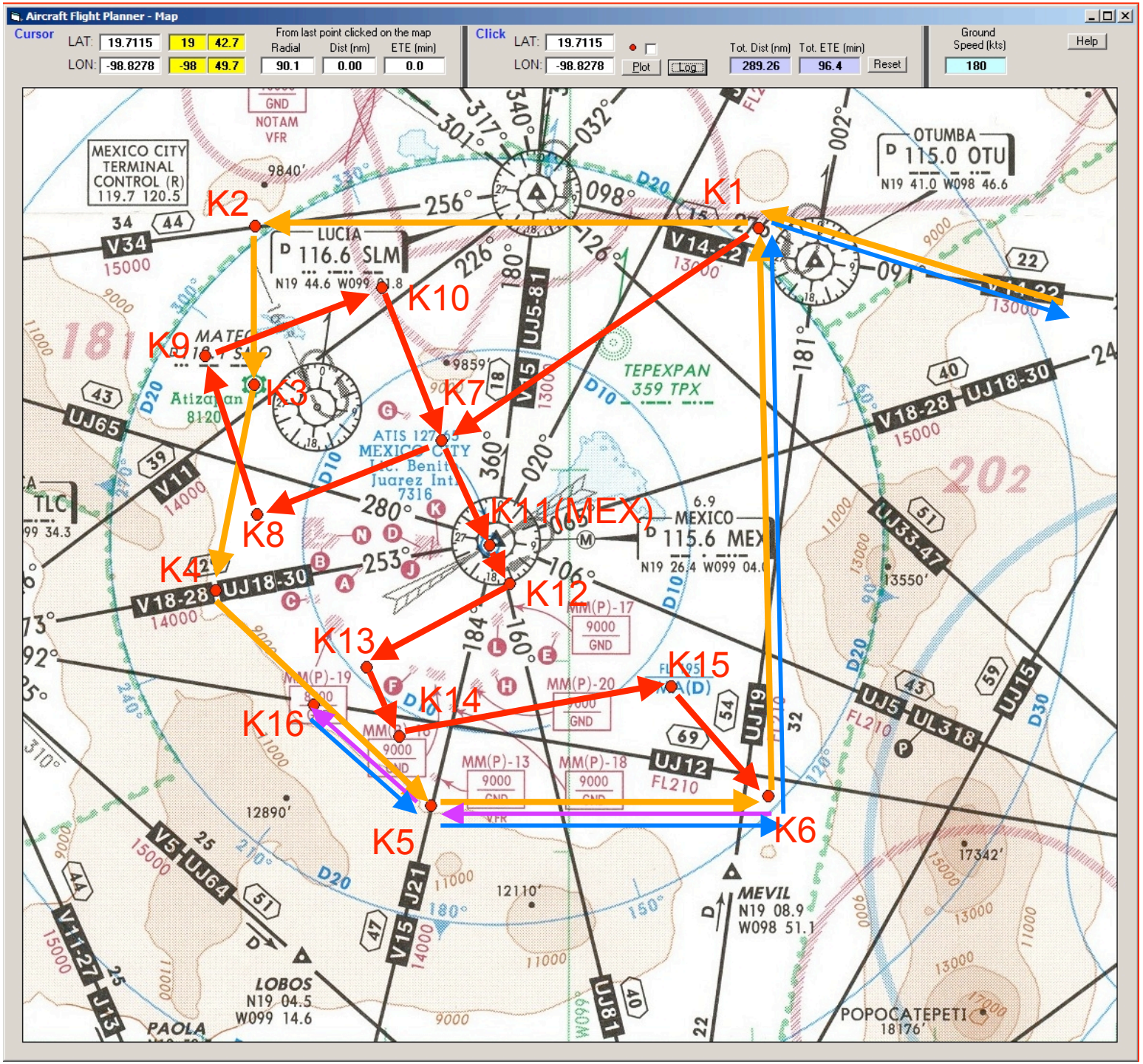
S FLIGHT PATTERN 2

Pt.	Latitude	Longitude	Altitude	Time
0	**19.1640**	**-96.1710**	100	10:00
1	21.3428	-98.2512	18000	10:18
2	spiral descent? 19.8608	-98.9621	18000	10:47
3	18.8234	-99.2749	18000	11:06
	spiral descent 18.8234	-99.2749	1000AGL	11:14
4	18.8234	-99.45	18000	11:17
5	18.8234	-98.55	14000	11:33
4	18.8234	-99.45	(14000)	11:48
5	18.8234	-98.55	11000	12:03
4	18.8234	-99.45	1000AGL	12:19
5	18.8234	-98.55	climb	12:34
6	18	-100	18000	13:03
7	18	-98.1	(18000)	13:35
6	18	-100	14000	14:08
7	18	-98.1	(14000)	14:41
6	18	-100	10000	15:13
7	18	-98.1	(10000)	15:46
6	18	-100	1000AGL	16:18
7	18	-98.1	Climb to cruising alt.	16:51
0	**19.1640**	**-96.1710**	100	18:08

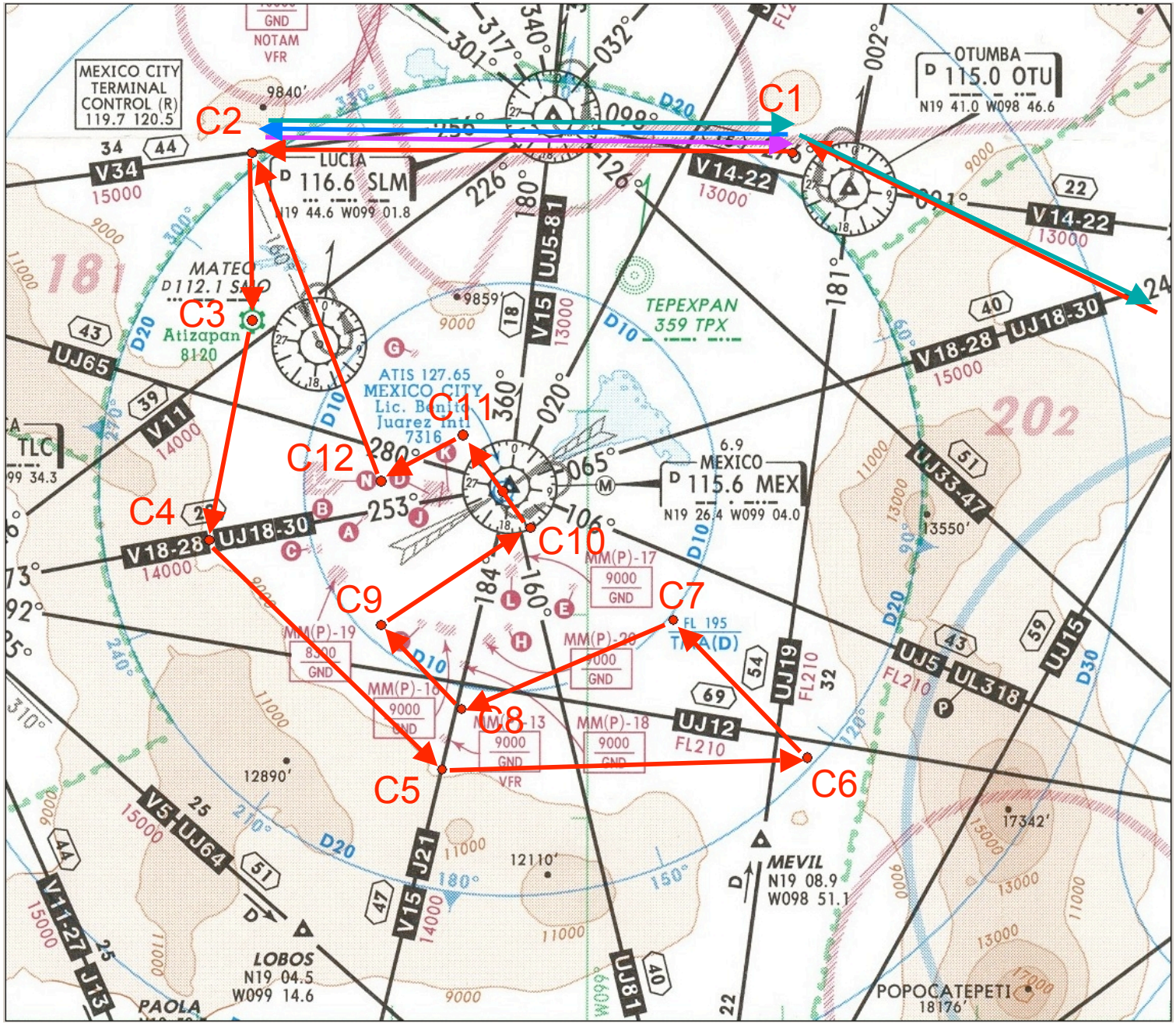


FAR TRANSPORT FLIGHT PATTERN

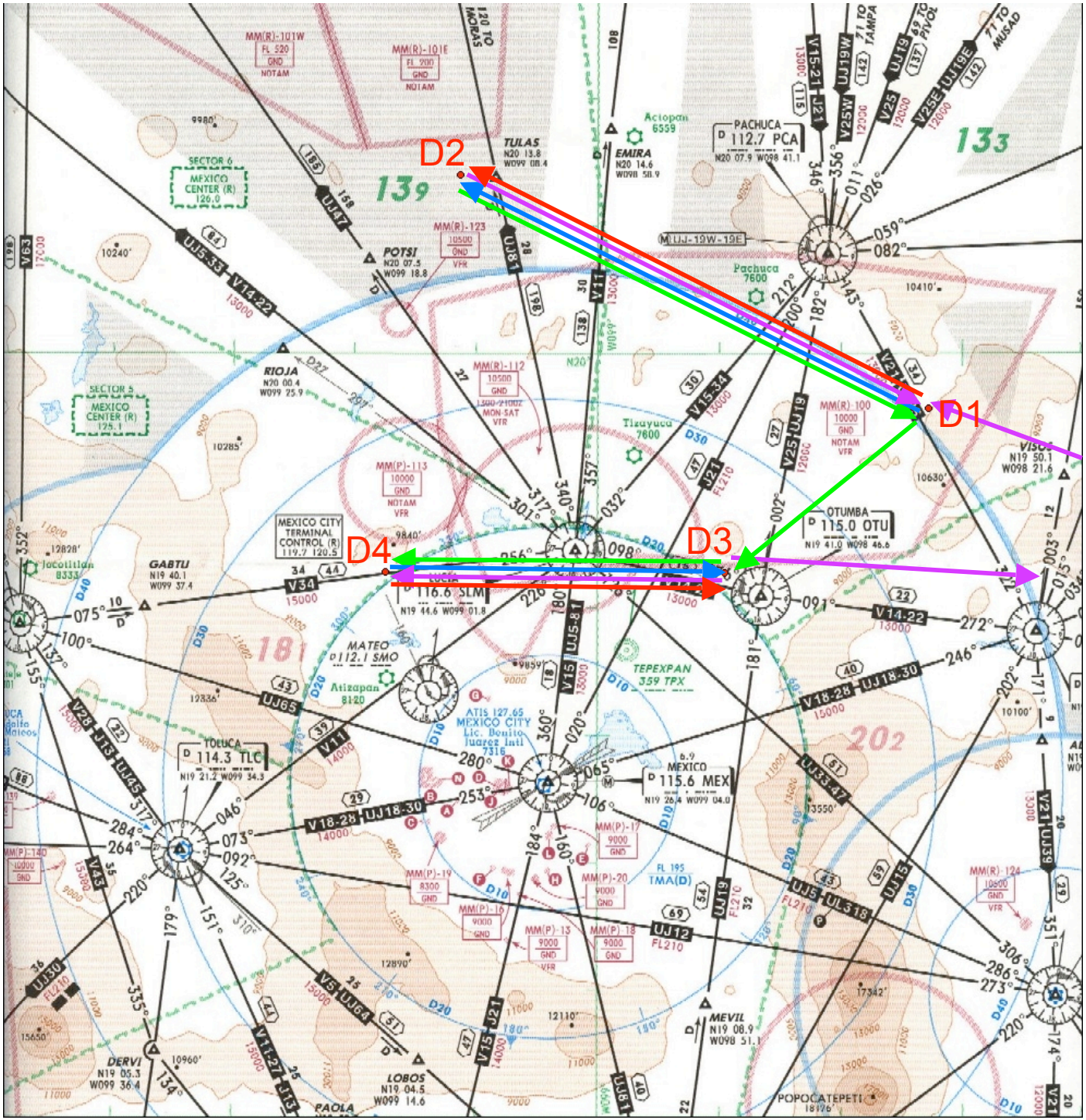
Pt.	Latitude	Longitude	Altitude	Time
0	**19.1640**	**-96.1710**	100	4:00
1	21.2214	-97.1079	20000	4:23
	Spiral descent 21.2214	-97.1079	1000	4:42
2	23	-97.5	10000	5:14
3	21.5	-95.8	10000	5:53
2	23	-97.5	16000	6:33
3	21.5	-95.8	16000	7:12
4	24.3	-97.5	10000	8:10
5	22	-95	10000	9:08
4	24.3	-97.5	16000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



DOE G-1
Pattern K

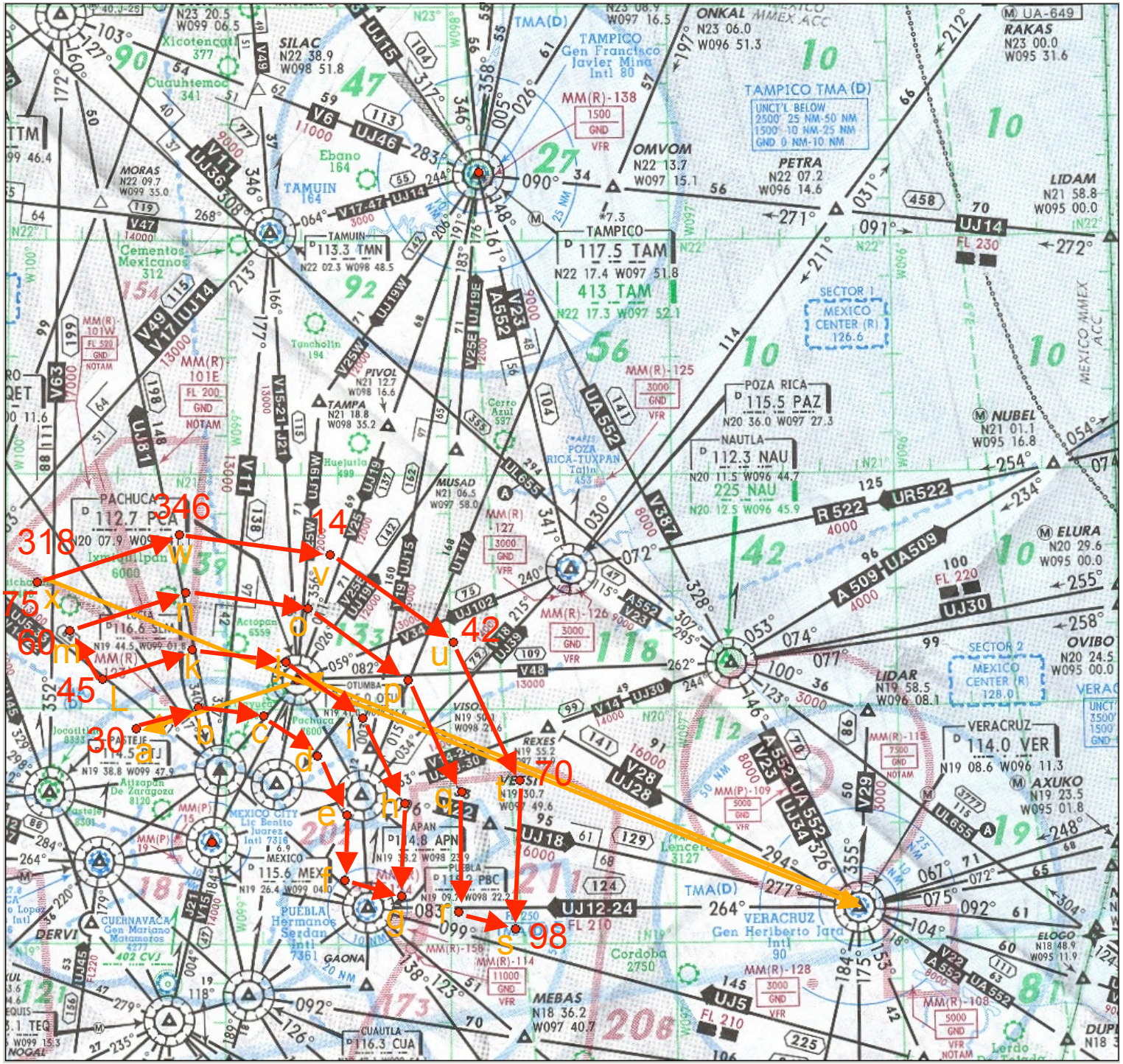


DOE G-1 Pattern C

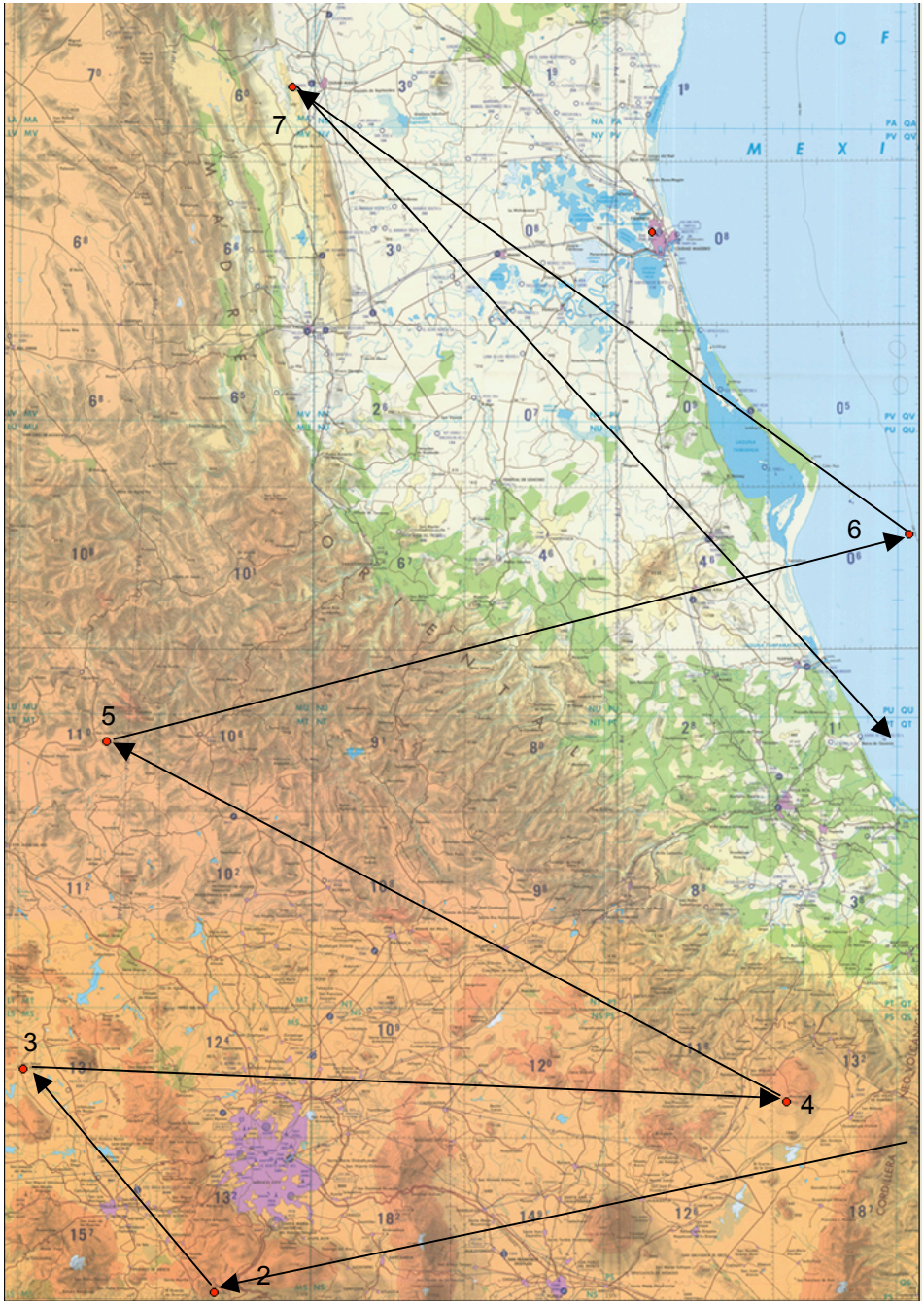


DOE G-1

Pattern D



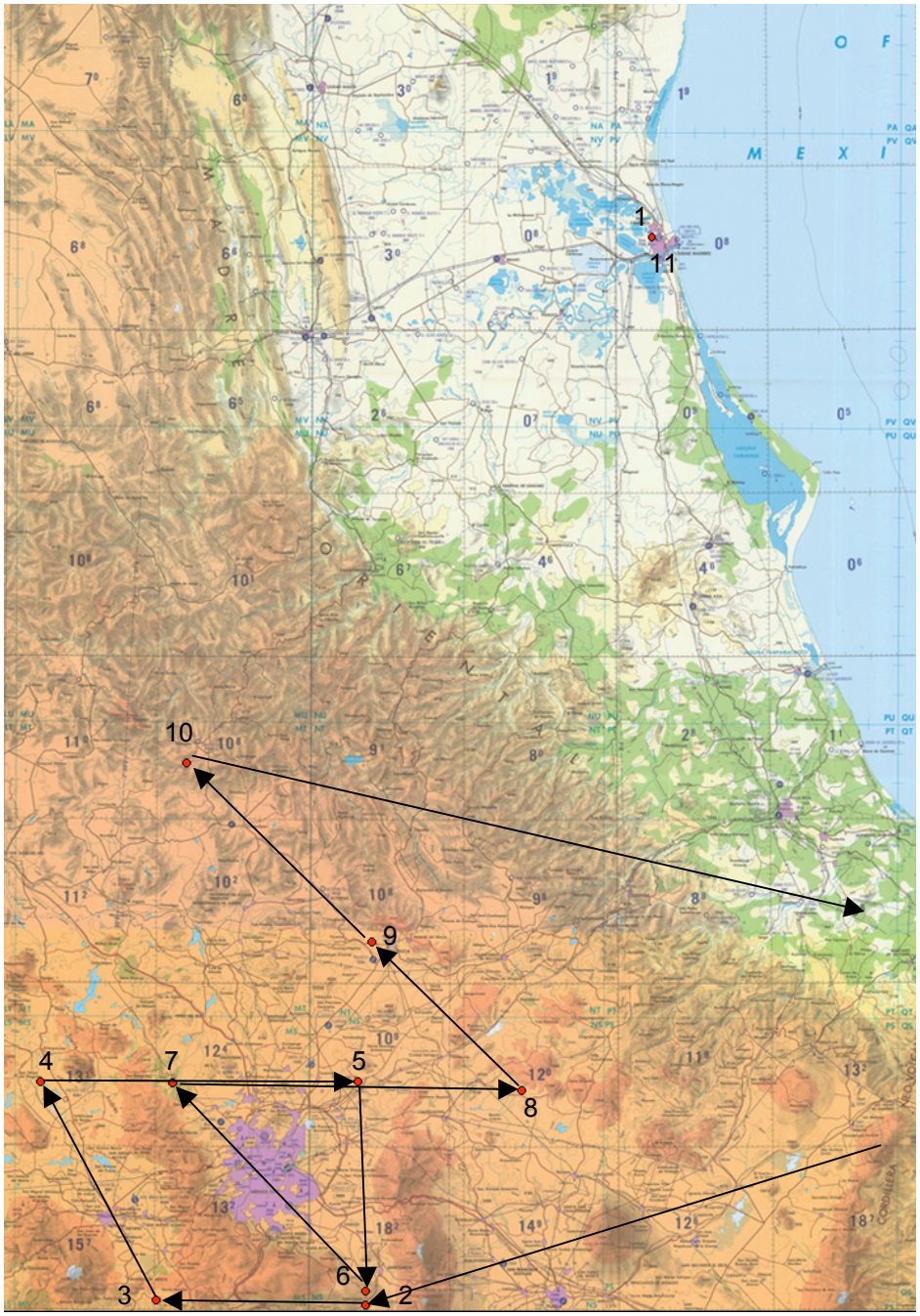
DOE G-1
Pattern Z



FLIGHT PATTERN:

DOE NASA King Air 1 Coordinated Overpass of G1 & C-130 Wall flights

- Points 1-2 into prevailing winds and overpass of T1 & T2 sites.
- Pts 3-4: Coordinated overpass of G1 flight Plan D.
- Pts 4-5: Coordinated overpass of G1 flight Plan D & C-130 NNEor NE wall flights
- Pts 6-7 Coordinated overpass with C-130 NNE or NE wall flights



FLIGHT PATTERN:

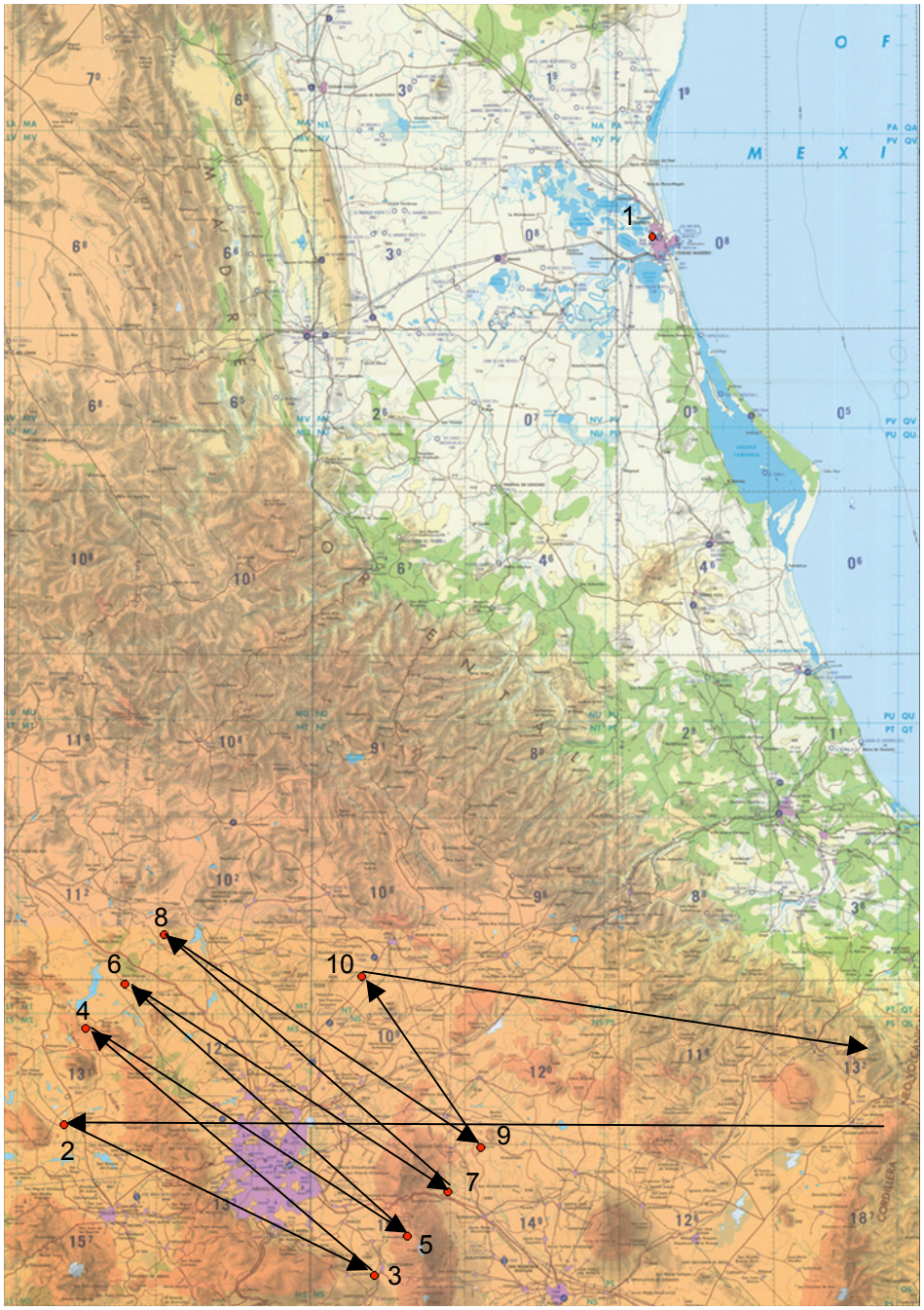
DOE/NASA King Air 2

- Pts 2-3-4-5-6 Box flight of Mexico City & overflight of T1 site

- Pts 6-7: Coordinated overpass of G1 flight Plan C & K flight plans and C-130 spirals at eastern slope of mountains.

- Pts 7-8: Coordinated overpass of G1 flight Plan D & C flight plans

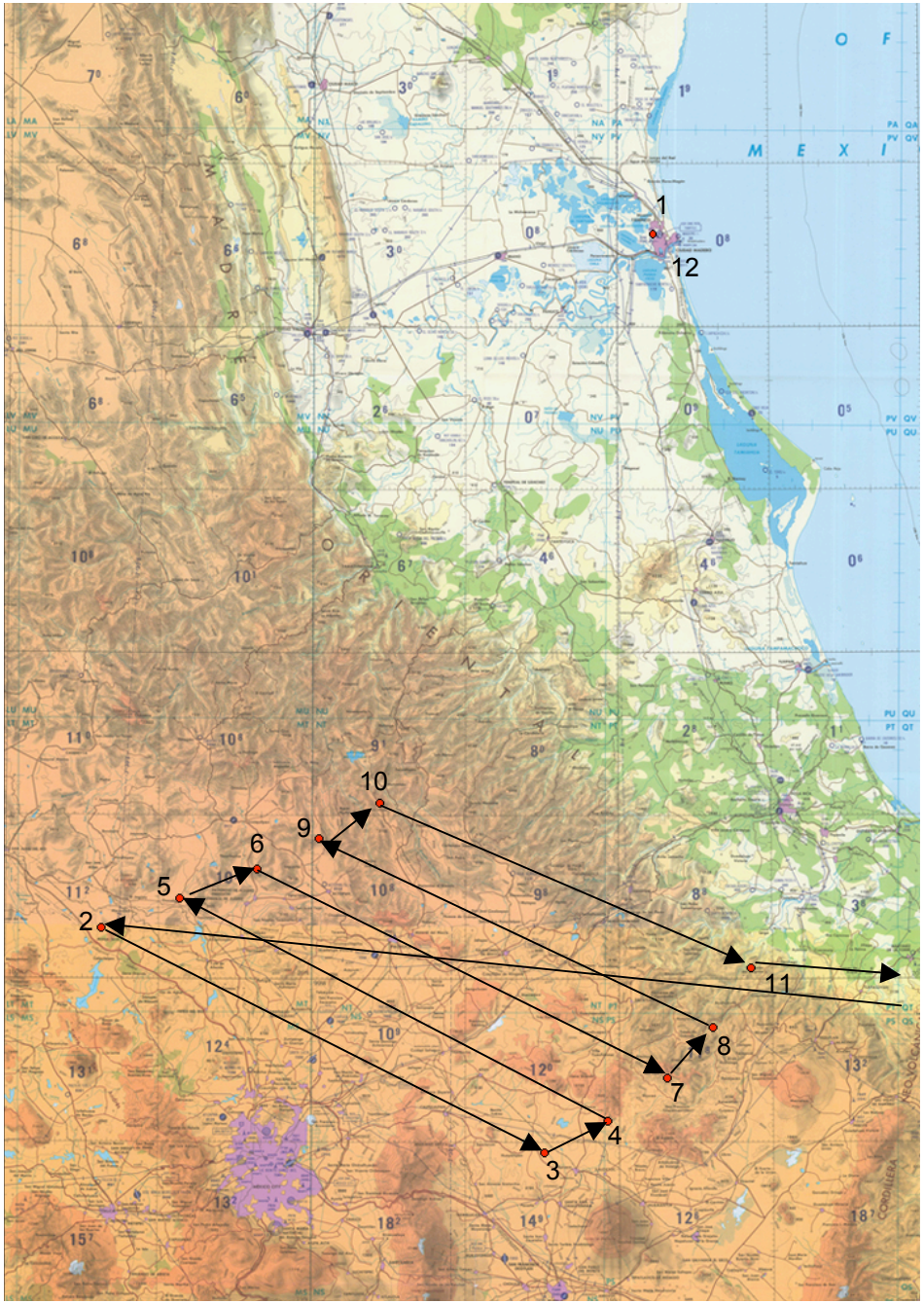
- Pt 9 Overpass of T2 site



FLIGHT PATTERN:

DOE/NASA King Air 3

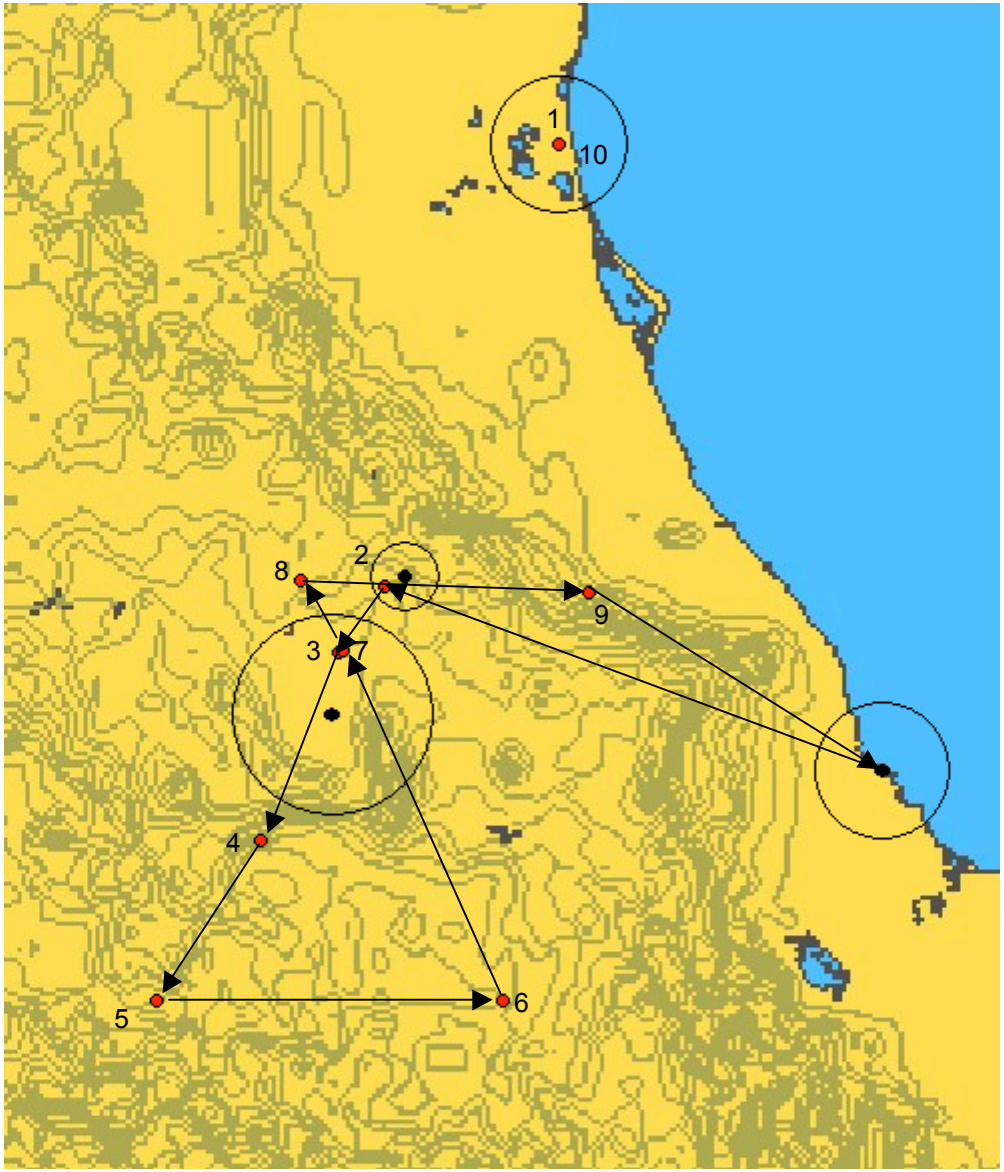
- Grid Scan of Mexico City
- Overflight of T2 site from Pts 7-8
- Overflight of T1 site at Pt 9



FLIGHT PATTERN:

DOE/NASA King Air 4

- Coordinated flights with G1 Z flight plan
- Overpass of T1 and T2 sites.



FLIGHT PATTERN:

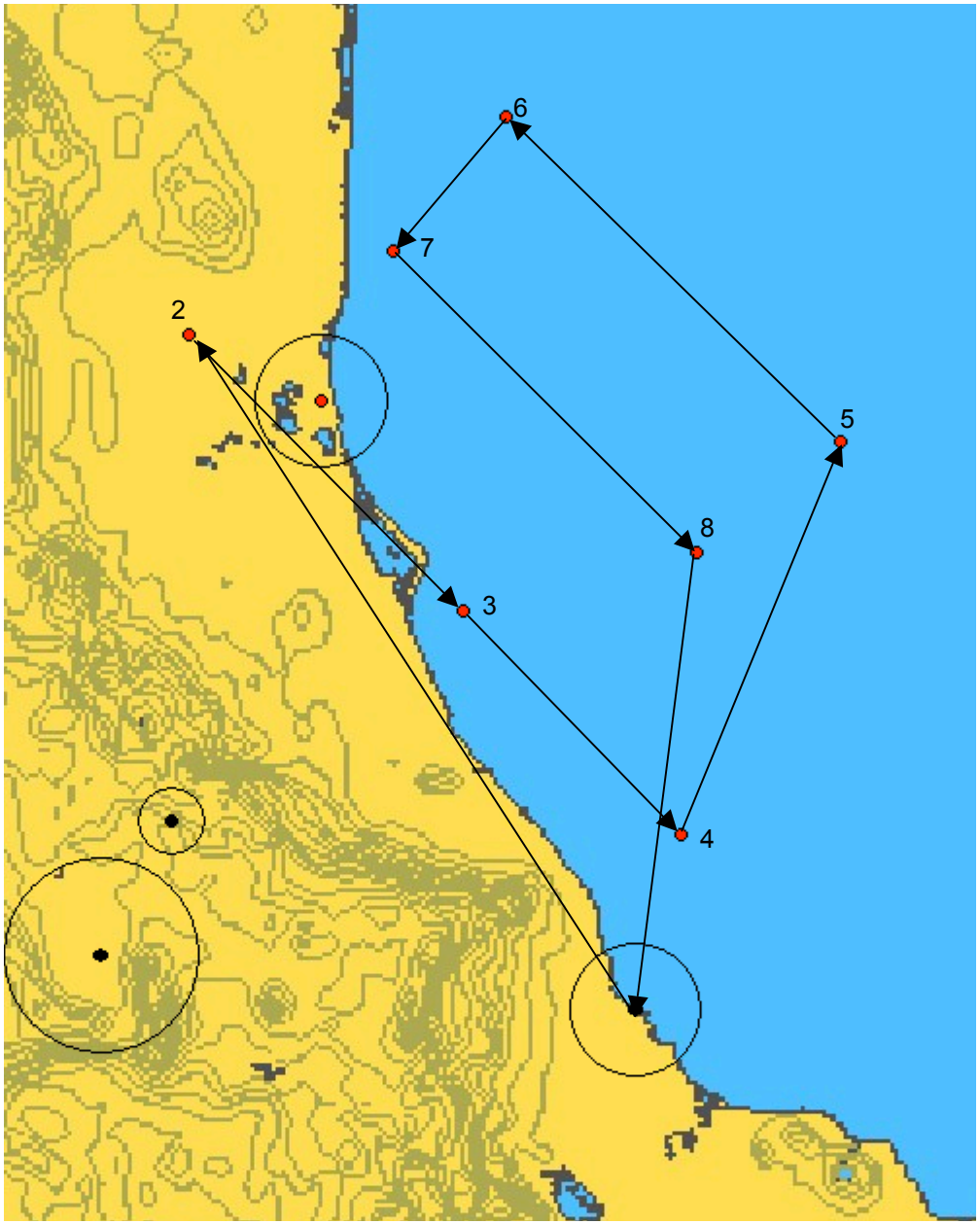
DOE/NASA King Air 5

- Overflight of T2 site at pt 2.
- Overflight of T1 site at pt 3 & 7.

- Coordination with C-130 S flight plan 2. Overpass of spiral for comparisons at pt 4.

- Pts 5-6 overflight of C-130 on southern side of Mexico City

- Pts 8-9 overflight T2 site and coordinated with G1 C&D



FLIGHT PATTERN:

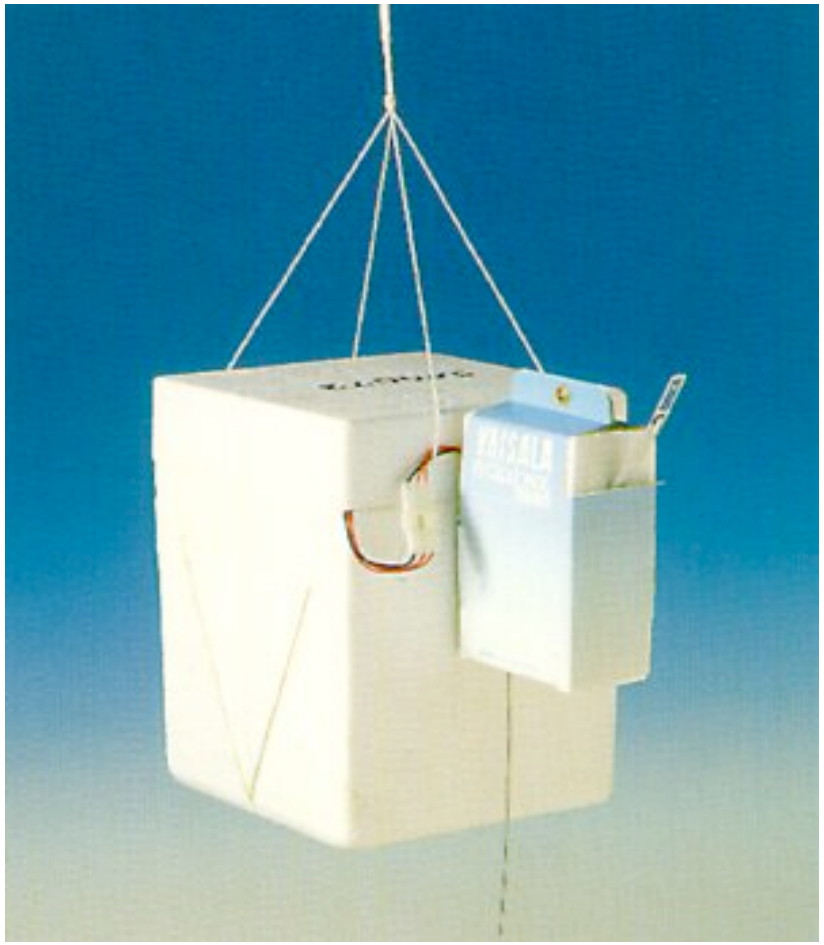
DOE/NASA King Air 6

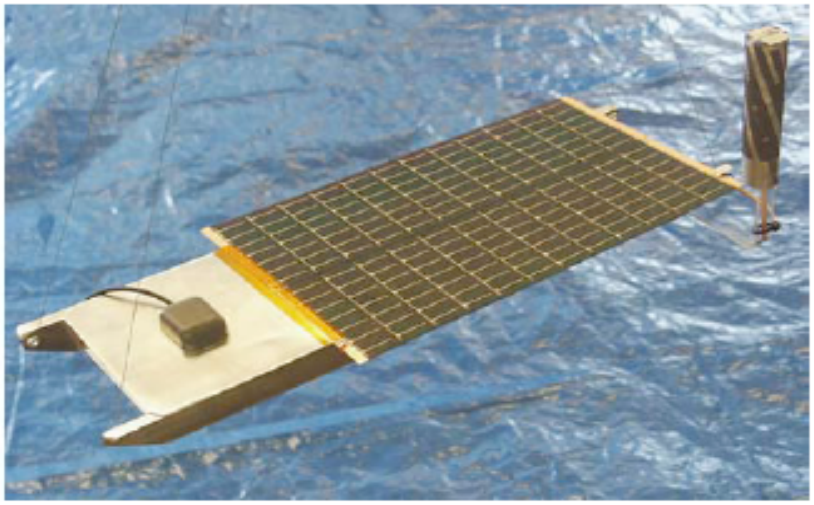
- Regional Outflow Characterization and Satellite comparisons.
- Coincident overflight of C-130 spiral at pt 3.
- Sample C-130 wall section from pts 5-6
- Coincident overflight of C-130 from pts 7-8

Mini-Zeppelin Blimp
Sitio: ZMVM

Sondas de ozono
T_1

Vaisala Ozone Sonde



Smart Balloon system

Launch point: T_1 site (Tecamac)