NASA LaRC Airborne Active and Passive Remote Sensing Instrument Suite Deployed on King Air Be-200 for MILAGRO

Chris Hostetler and Richard Ferrare, Co-PIs

Instrument Team:
Anthony Cook , LaRC
David Flittner, LaRC
John Hair , LaRC
David Harper , LaRC
Yongxiang Hu , LaRC
Michael Pitts , LaRC
Steve Jones, Aerodyne Research

Flight Operations:
Mike Wusk, LaRC

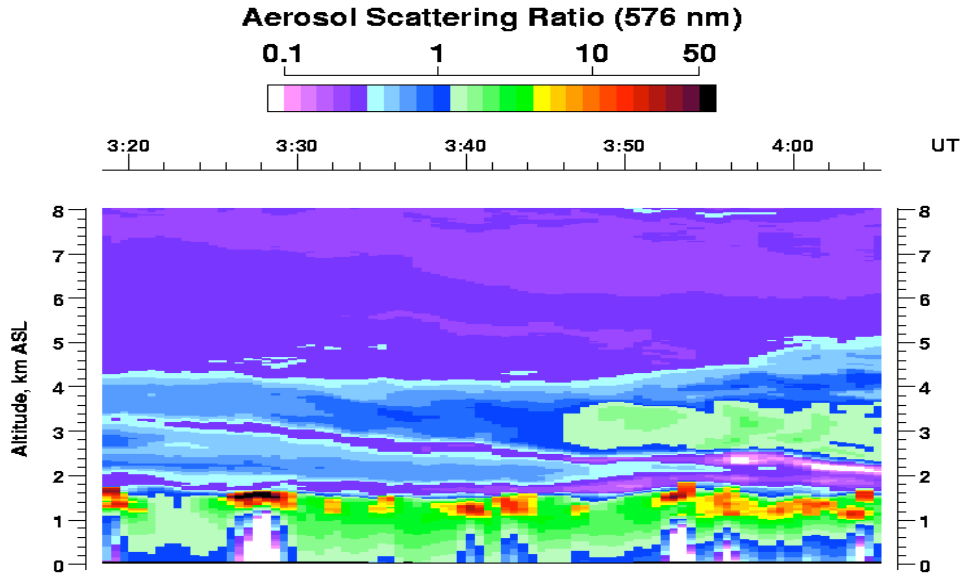
Project Description

- Deploy 3 down-looking remote sensing instruments on aircraft to characterize aerosol and investigate combined active-passive instrument retrieval techniques
  - **High Spectral Resolution Lidar (HSRL) – Primary instrument**
  - Hyperspectral Polarimeter for Aerosol Retrievals (HySPAR)
  - Langley Airborne A-band Spectrometer (LAABS)

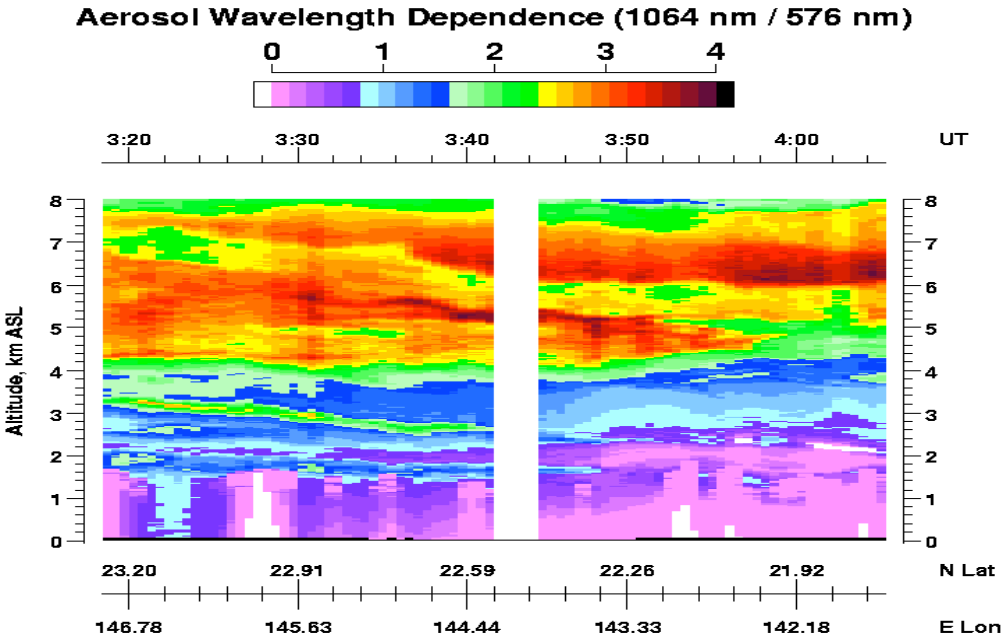
- Dedicated aircraft
  - NASA Langley King Air Be-200
  - 27-28 kft nominal flight altitude
  - ~90 flight hours

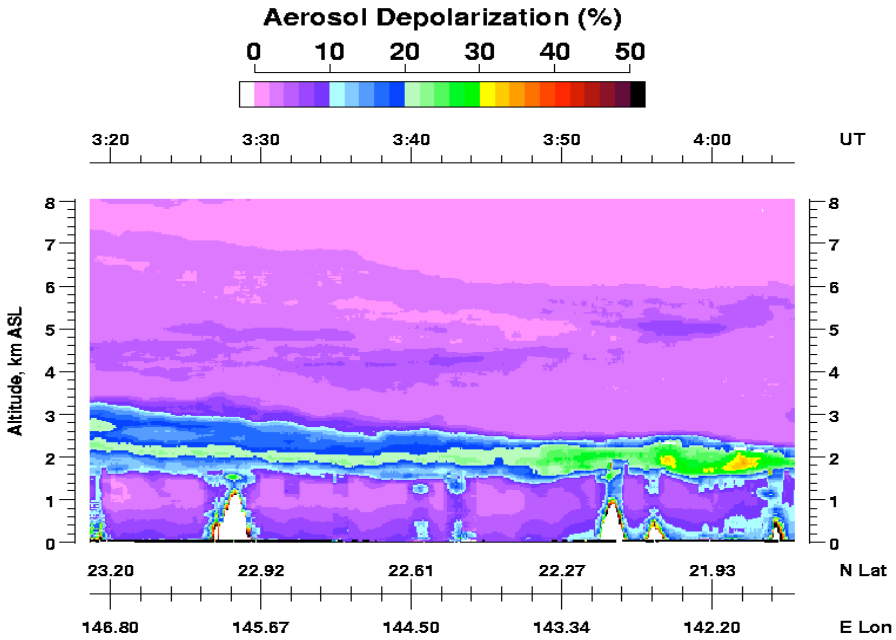
- Fly in coordination with in situ instruments flown on lower altitude aircraft
  - Map out distribution of aerosol by type
  - Vector in situ aircraft to altitudes and locations of greatest interest
  - Investigate accuracy of combined active-passive retrievals

Example Airborne Lidar Measurements



NASA Langley Airborne UV DIAL
TRACE-P Flight 14 24 March 2001





Science Objectives

- Use HSRL to map the vertical and horizontal distribution of aerosols
  - Use profiles of extinction, backscatter, and depolarization to characterize the vertical distribution of aerosol types
  - Vector in situ aircraft to altitude/location of greatest interest
  - Determine relative contribution of various aerosol types to aerosol extinction and optical depth
  - Compare observations to model transport predictions
- Evaluate the distribution of aerosol backscatter/extinction in the proximity of clouds
- Investigation of the combined use of data from lidar, oxygen A-band spectrometer, and mulit-angle multi-channel polarimeters/spectrometers to characterize aerosol optical and microphysical properties
  - In addition to value for aircraft-based field studies of aerosols, retrieval investigations are relevant to future satellite remote sensing concepts for aerosols and ocean color
  - Anticipate several coordinated flights with the J-31 aircraft
- Validation of CALIPSO satellite-based lidar
  - CALIPSO launch currently schedule for 7 November 2005

Data Products Produced / Desired External Data

Data Products

- Standard Data Products
  - HSRL-derived profiles of
    - Backscatter coefficient at 532 and 1064 nm (_x<500 m, _z=30 m)
    - Extinction coefficient at 532 nm (_x~10 km, _z=200-300 m)
    - Aerosol depolarization at 532 and 1064 nm (_x<500 m, _z=30 m)
- Research Products (goals)
  - LAABS (_x~1 km)
    - Optical depth at 765 nm
    - Single scatter albedo
  - HySPAR (_x~1 km)
    - Optical depth
    - Angstrom coefficient (scattering extinction)
    - Asymmetry parameter
    - Size distribution
    - Complex index of refraction
    - Single scatter albedo

Desired External Data

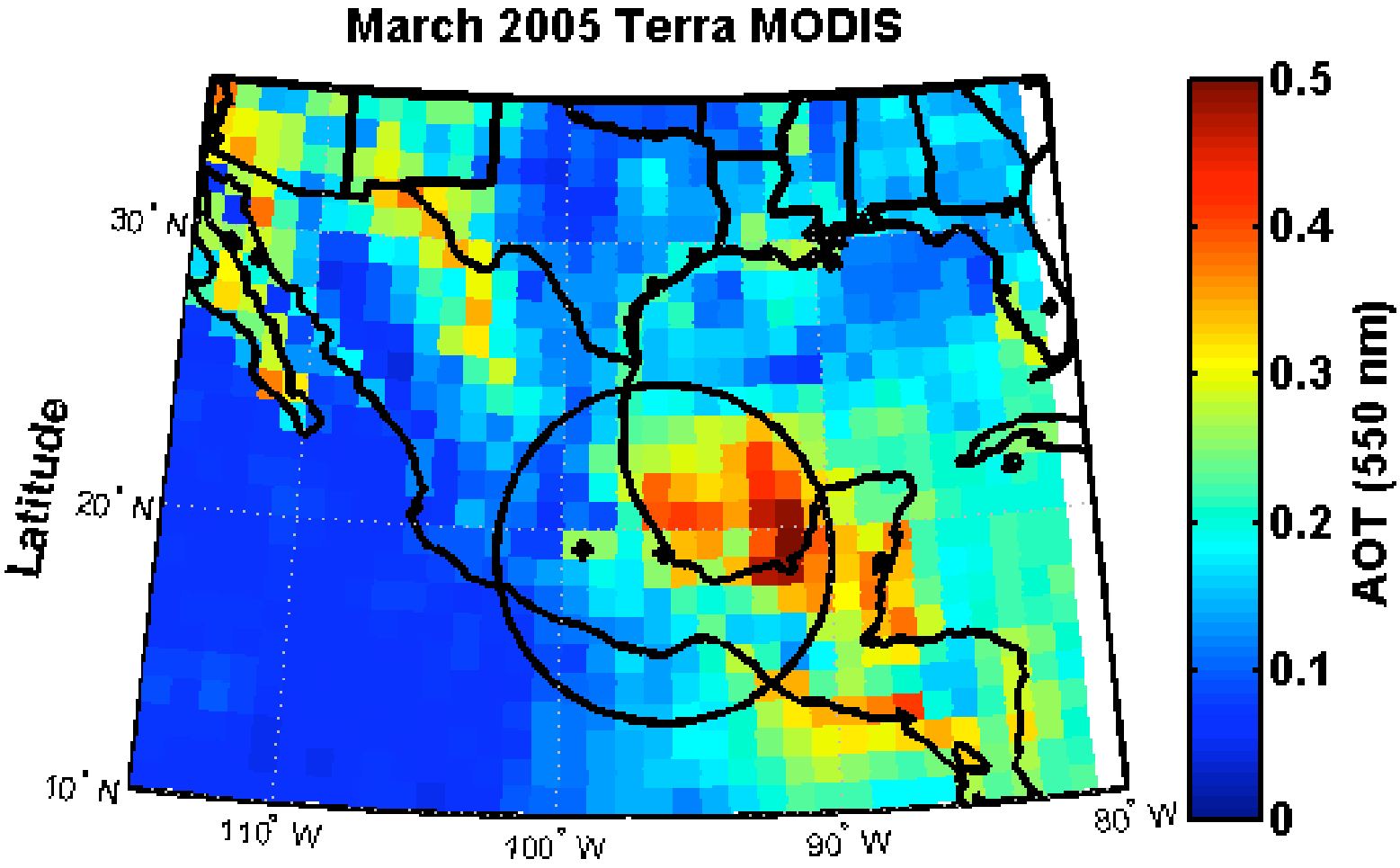
- Desired products from in situ aircraft measurements (for science analysis, i.e., not required for producing our products)
  - RH, f(RH)
  - Aerosol size distribution (under ambient RH, if possible)
  - Absorption/scattering coefficients
  - Aerosol composition
  - Aerosol refractive index
- Desired Products for investigating active-passive retrievals
  - Aerosol asymmetry parameter
  - Surface spectral albedo
  - Sea surface wind speed/direction

LaRC King Air Be-200

Altitude	35,000 ft (10.7 km), maximum operating
Range	800 nmi (1,300 km) at sampling speed
Endurance	3.5 hr, maximum (with IFR reserve)
Speed	259 KIAS (133 m/s) cruise

Payload	2500 lb (1,136 kg), maximum 500 lb (227 kg), with full fuel
Electrical Power	two 250A 30V DC generators, two 1400VA, 400 Hz inverters supply 115V AC

Approximate Range of Be-200 with Payload and Crew

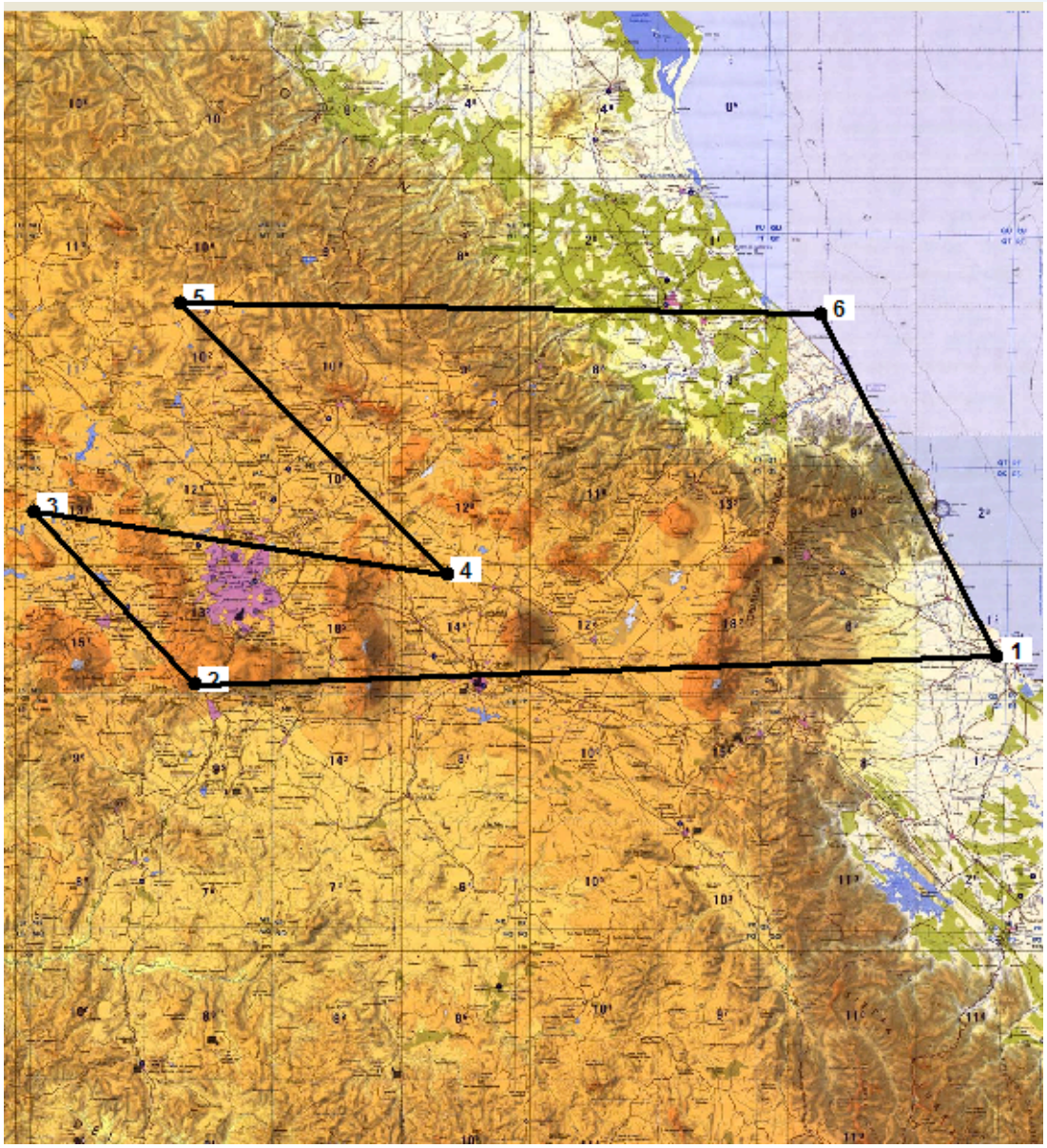


King Air speed = 200 knots = 370 km/hr
3.5 hour mission = 1295 km
1295 km / 2 (out and back) = 648 km
648 km / (110 km/deg) = 5.89 deg

Preliminary Flight Plans

- The preliminary flight plans that follow are **notional**.
- Most Flight plans intended to provide lidar profiles coincident with selected G-1 and C-130 flight legs and stacked patterns.
- Have not yet developed preliminary plans for coordinated flights with measurements the J-31.
- Flight durations on the following notional plans exceed Be-200 duration.
  - Will shorten or divert for refueling

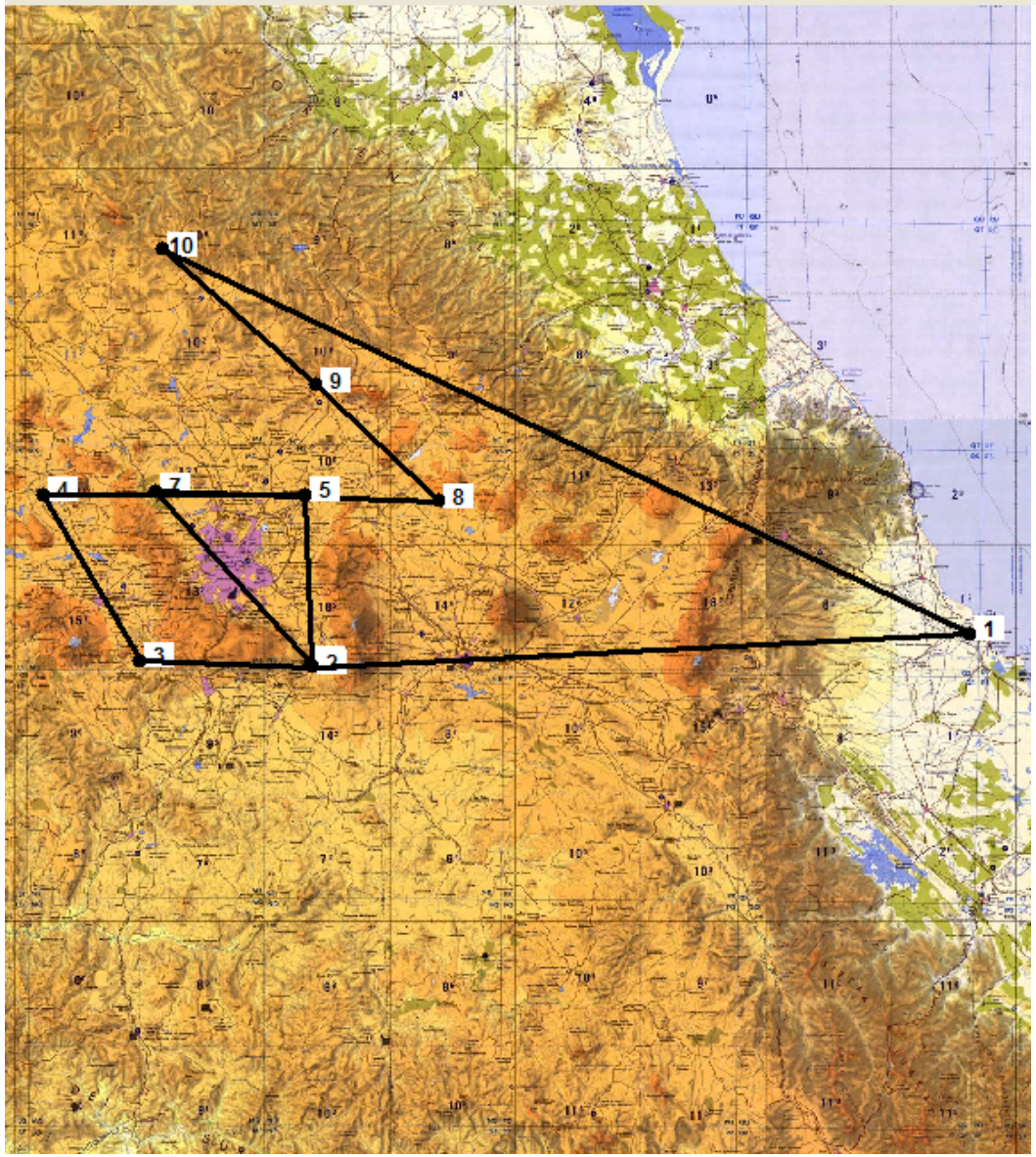
Flight plan KA1: Coordinated Overpass of G1 & C-130 Wall flights



Pt. #	Lat	Lon	Leg (min)	Time (min)	Dist. (nm)
1	19.15	-96.19	0	0.0	0
2	19.04	-99.31	70.7	70.7	177
3	19.71	-99.93	21.5	92.2	231
4	19.46	-98.32	36.8	129.0	323
5	20.52	-99.36	34.6	163.6	409
6	20.48	-96.87	55.9	219.5	549
7	19.15	-96.19	35.5	255.0	638

- 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

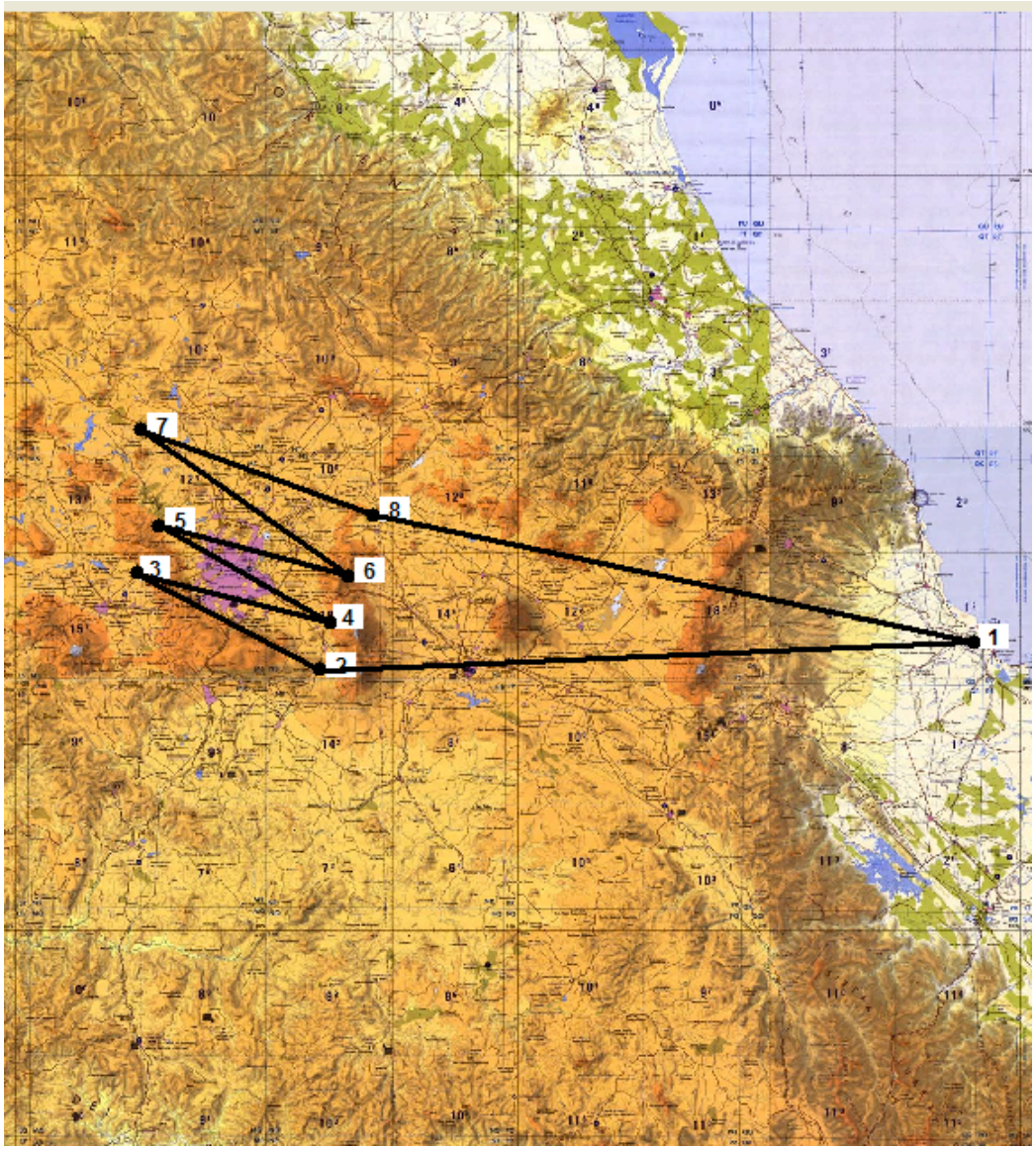
Flight Plan KA2



Pt. #	Lat	Lon	Leg (min)	Time (min)	Dist. (nm)
1	19.15	-96.19	0	0.0	0
2	19.02	-98.81	59.5	59.5	149
3	19.04	-99.50	15.7	75.2	188
4	19.71	-99.89	18.2	93.4	233
5	19.71	-98.84	23.6	117.0	292
6	19.03	-98.82	16.2	133.2	333
7	19.72	-99.44	21.8	155.0	387
8	19.68	-98.30	25.7	180.7	452
9	20.14	-98.79	15.7	196.4	491
10	20.68	-99.41	18.9	215.3	538
11	19.15	-96.19	81.3	296.6	741

- 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

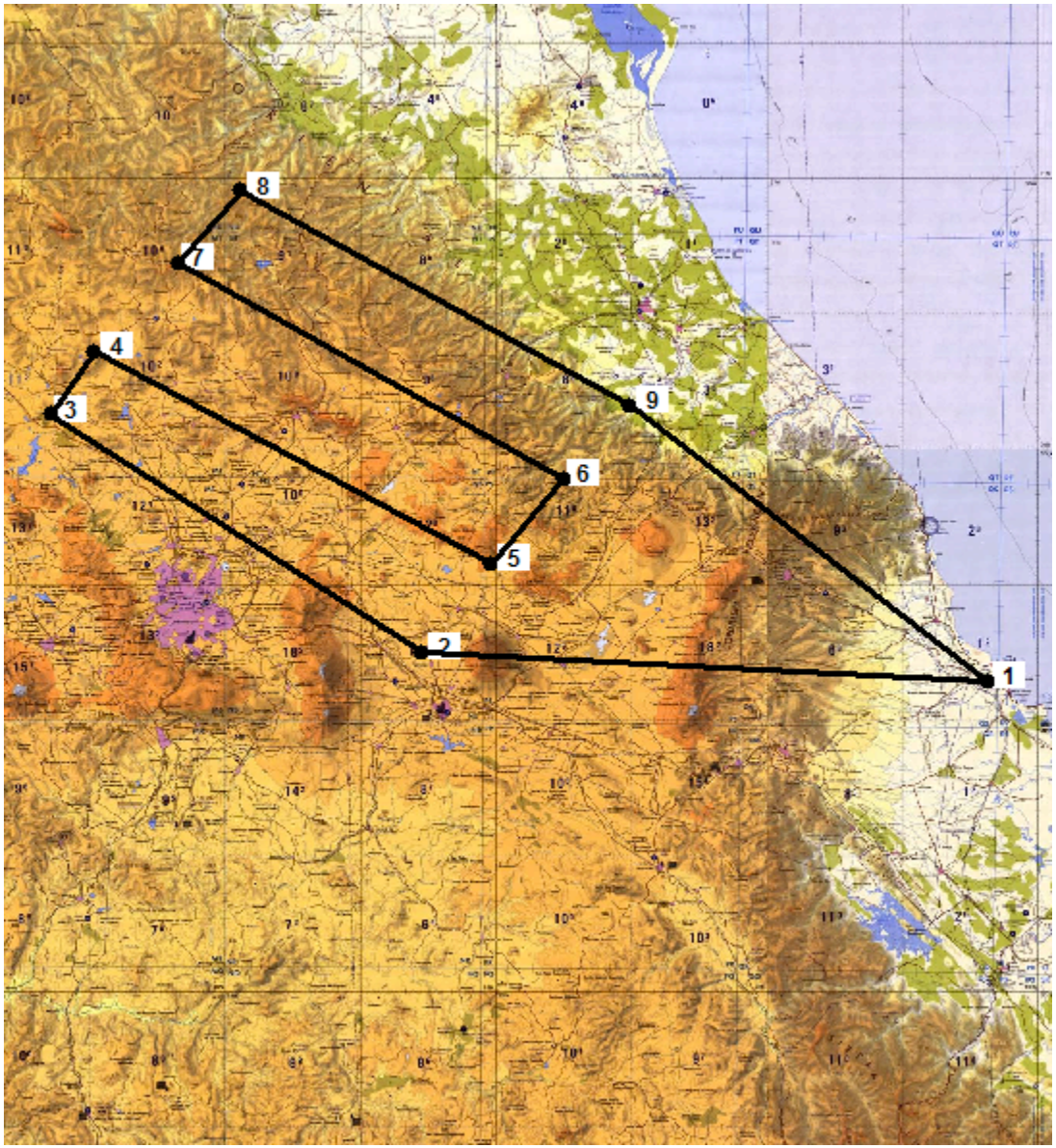
Flight Plan KA3



Pt. #	Lat	Lon	Leg (min)	Time (min)	Dist. (nm)
1	19.15	-96.19	0	0.0	0
2	19.04	-98.79	59	59.0	147
3	19.42	-99.52	19	78.0	195
4	19.23	-98.75	18	96.0	240
5	19.61	-99.43	17.8	113.8	284
6	19.41	-98.67	17.7	131.5	329
7	19.99	-99.50	23.2	154.7	387
8	19.66	-98.57	22.4	177.1	443
9	19.15	-96.19	55.3	232.4	581

- Grid Scan of Mexico City Metropolitan Area

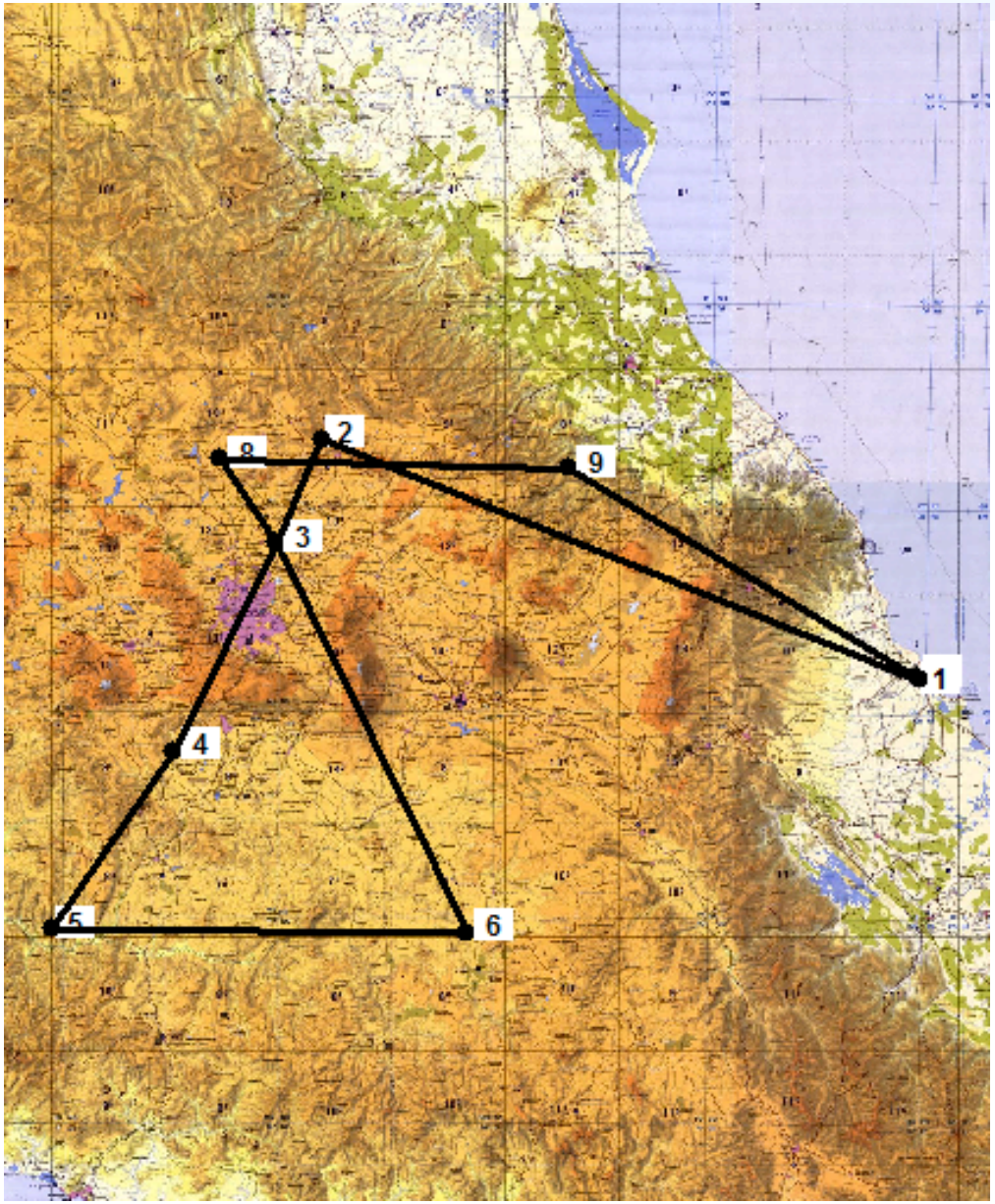
Flight Plan KA4



Pt. #	Lat	Lon	Leg (min)	Time (min)	Dist. (nm)
1	19.15	-96.19	0	0.0	0
2	19.26	-98.27	47.4	47.4	118
3	20.13	-99.65	37.4	84.8	212
4	20.37	-99.48	6.7	91.5	229
5	19.59	-98.02	38	129.5	324
6	19.90	-97.76	9.6	139.1	348
7	20.69	-99.18	37.3	176.4	441
8	20.96	-98.94	8.2	184.6	461
9	20.17	-97.51	37.4	222.0	555
10	19.15	-96.19	38.5	260.5	651

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

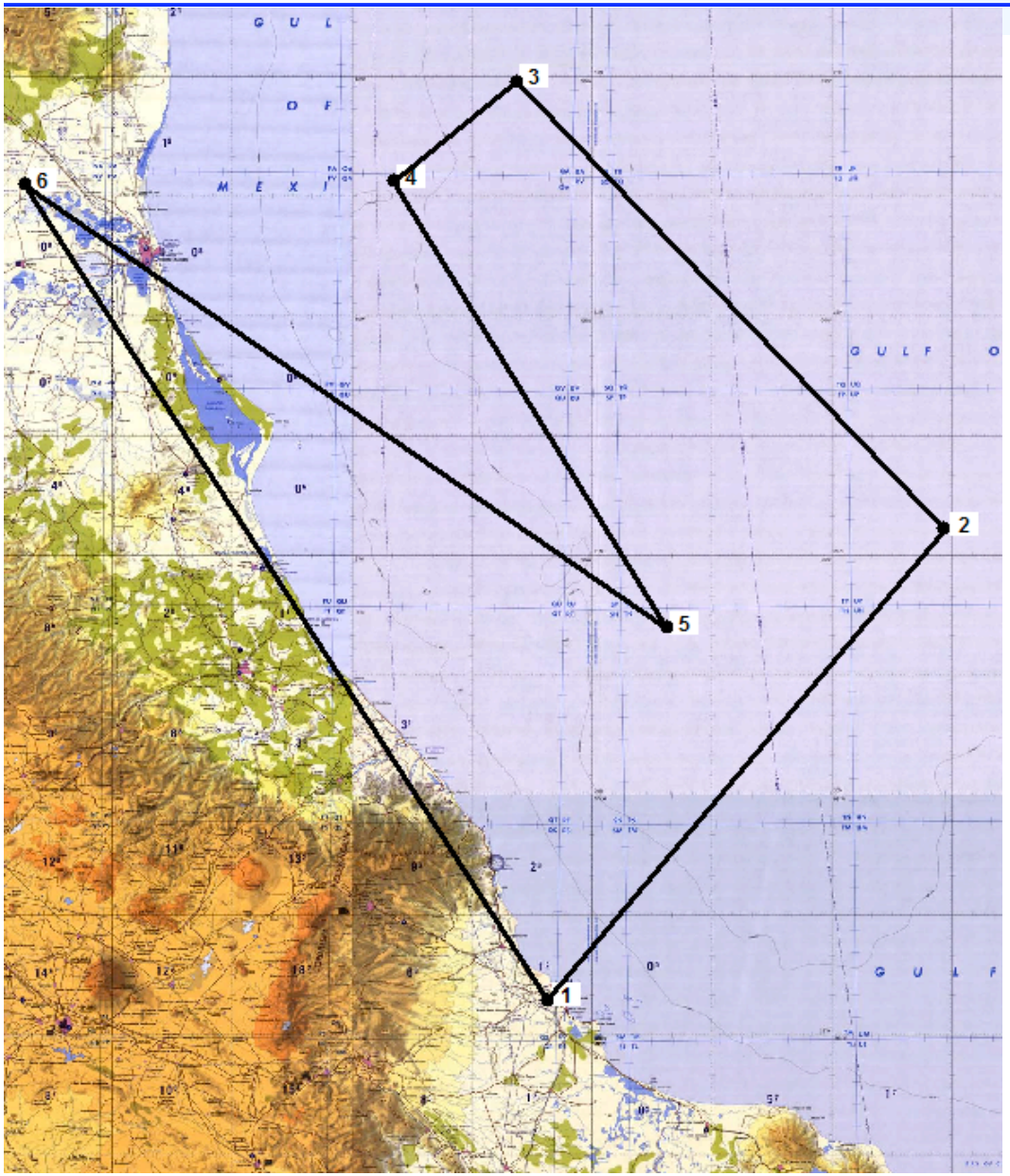
Flight Plan KA5



Pt. #	Lat	Lon	Leg (min)	Time (min)	Dist. (nm)
1	19.15	-96.19	0	0.0	0
2	20.20	-98.82	64.5	64.5	161
3	19.74	-99.01	11.9	76.4	191
4	18.83	-99.46	24.1	100.5	251
5	18.04	-100.00	22.6	123.1	308
6	18.03	-98.17	41.8	164.9	412
7	19.74	-99.01	45.2	210.1	526
8	20.11	-99.26	10.4	220.5	552
9	20.07	-97.72	34.6	255.1	638
10	19.15	-96.19	41.1	296.2	741

- Overflight of T1 site at pt 2.
- Overflight of T2 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 flights with G1 D&C flight plans.

Flight Plan KA6

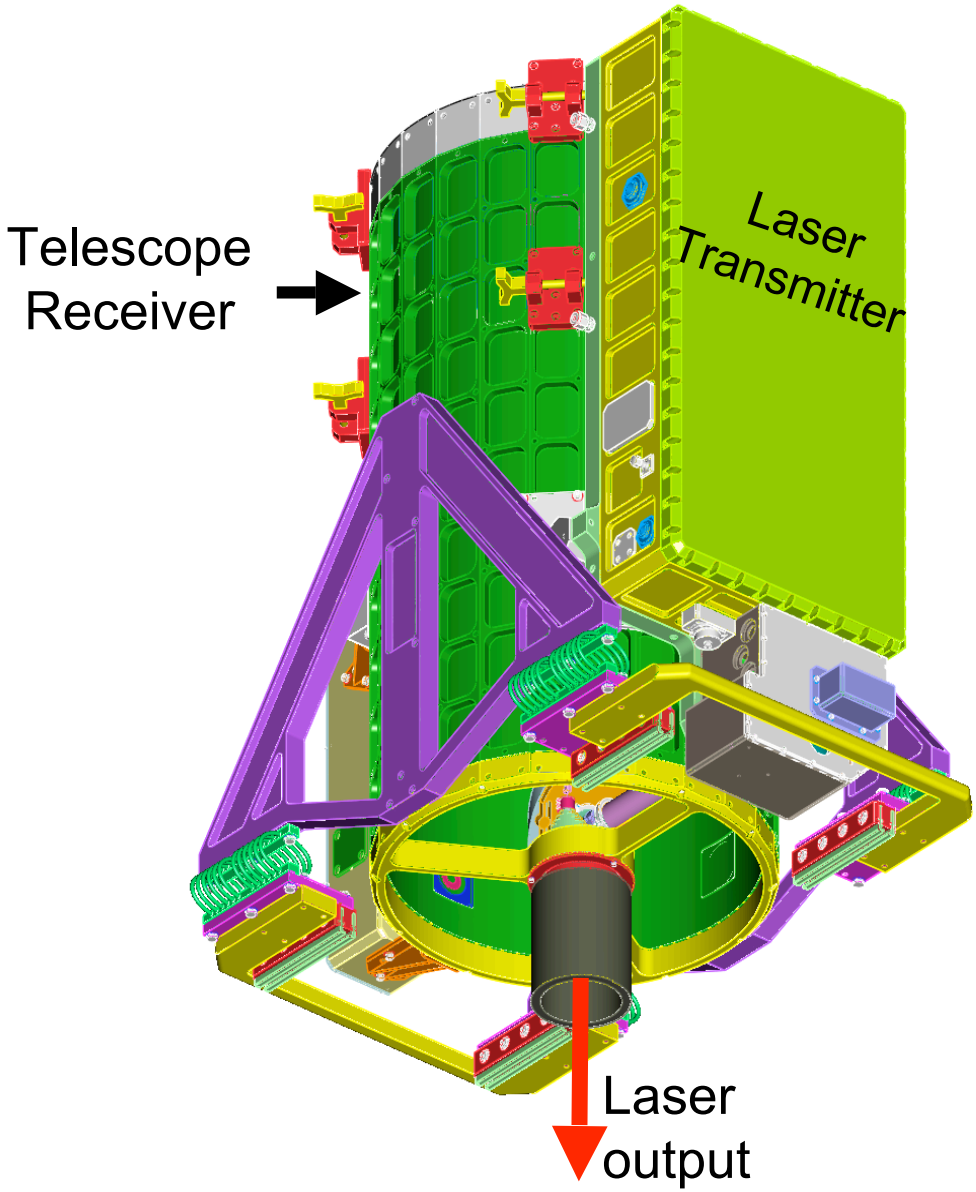


Pt. #	Lat	Lon	Leg (min)	Time (min)	Dist. (nm)
1	19.15	-96.19	0	0.0	0
2	21.11	-94.54	60.1	60.1	150
3	22.98	-96.32	59.9	120.0	300
4	22.56	-96.83	15.2	135.2	338
5	20.70	-95.69	51.4	186.6	466
6	22.55	-98.37	74.3	260.9	652
7	19.15	-96.19	95.1	356.0	890

- Regional Outflow Characterization and Satellite comparisons.
- Coincident overflight of C-130 spiral on leg 6-7
- Sample C-130 wall section from pts 2-3
- Coincident overflight of C-130 from pts 4-5

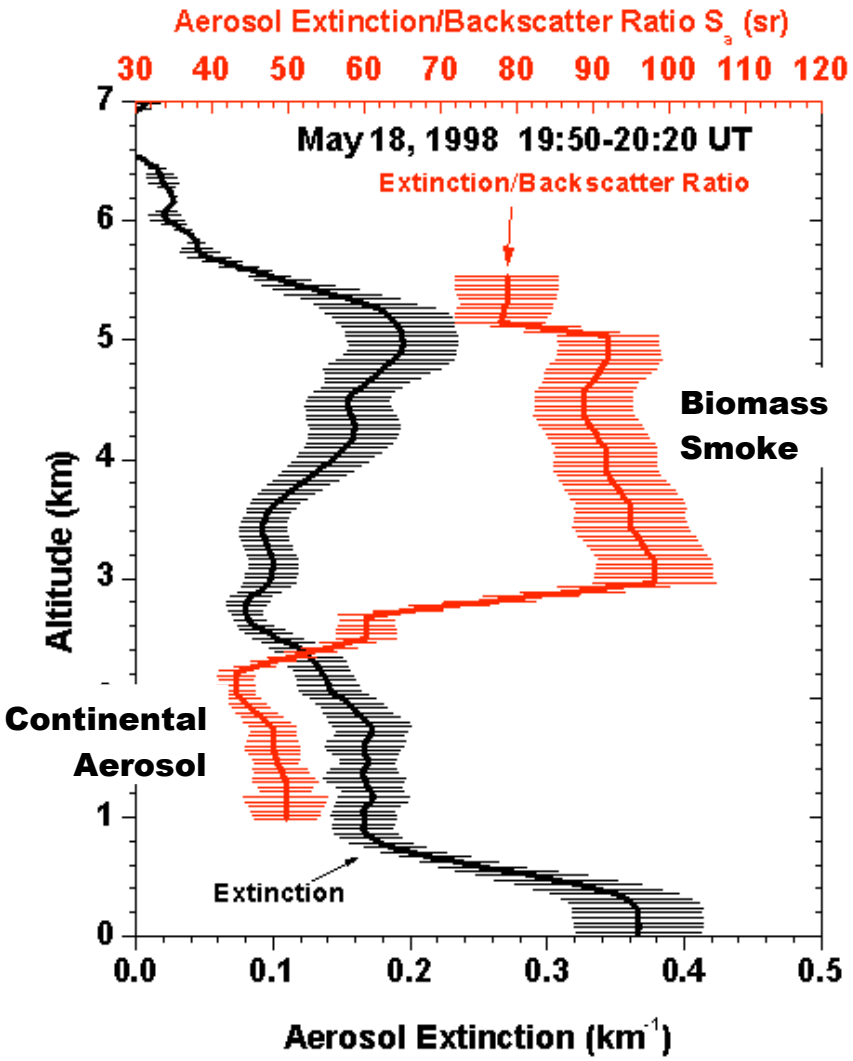
Backups

Airborne High Spectral Resolution Lidar



- Independently measures aerosol/cloud extinction and backscatter at 532 nm
- Includes
  - Backscatter channels at 1064 nm
  - Polarization sensitivity at 532 and 1064 nm
- Measurement capabilities
  - Extensive measurements
    - Backscatter at 532 and 1064 nm
    - Extinction at 532 nm
  - Intensive measurements
    - Color ratio (or Angstrom coeff.) for backscatter (β_{1064}/β_{532})
    - Extinction-to-backscatter ratio at 532 nm
    - Depolarization at 532 and 1064 nm

Intensive Parameters Provide Information on Aerosol Type



- Data from DOE ARM CARL Raman lidar at CART site. Like HSRL, Raman lidar can be used to independently retrieve extinction and backscatter
- Profile of extinction-to-backscatter ratio (red curve) provides discrimination of aerosol type.

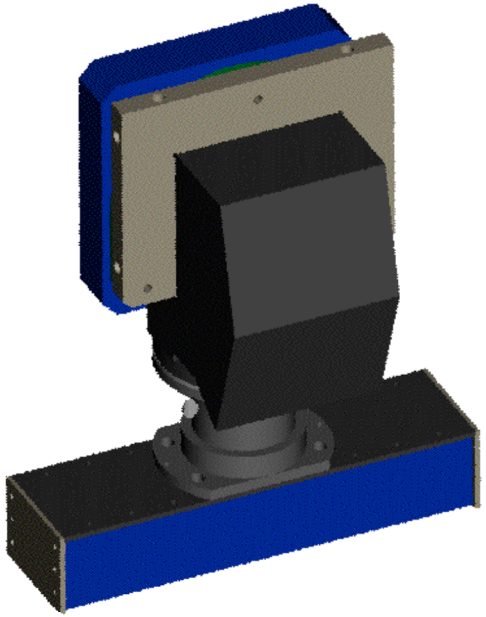
HSRL Status

- Laser, telescope, and receiver subsystems integrated in November 2004
- Ground tests in zenith viewing geometry conducted 13-19 November 2004
- Flight tests conducted 15-16 December 2004
- Minor instrument modifications and software enhancements ongoing through fall 2005
- Will participate in CALIPSO validation, December 2005 through September 2006.

HyperSpectral Polarimeter for Aerosol Retrievals
PIs: Yongxiang Hu, David Flittner

- Fundamental measurements
  - Full stokes vector (including circular polarization)
  - Continuous spectral coverage from 412 to 865 nm at 20 nm spectral resolution
  - Multi-angle viewing geometry: +/- 60° along flight vector

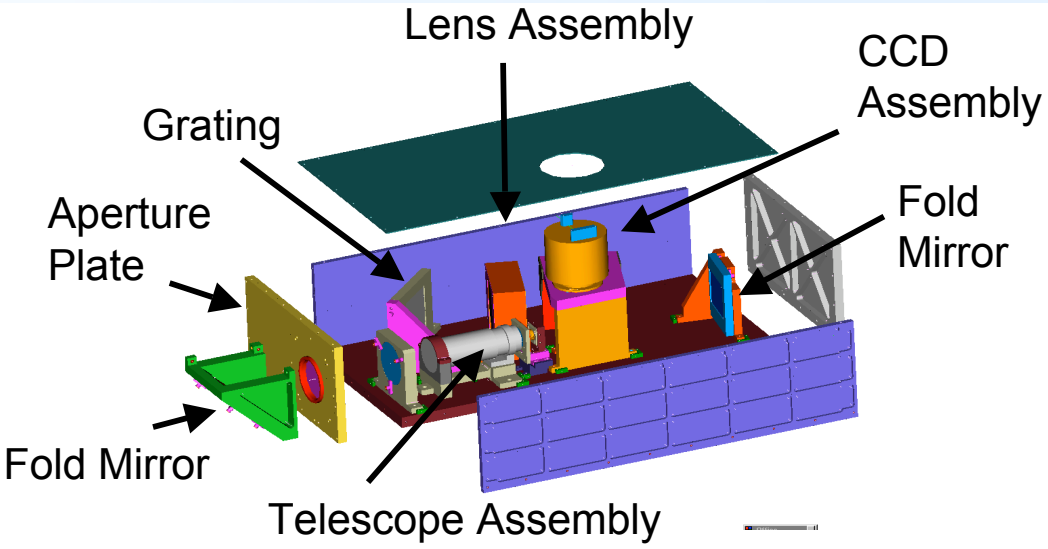
- Retrieval goals
  - scattering optical depth
  - Angstrom coefficient
  - asymmetry parameter
  - size distribution
  - complex index of refraction
  - single scatter albedo



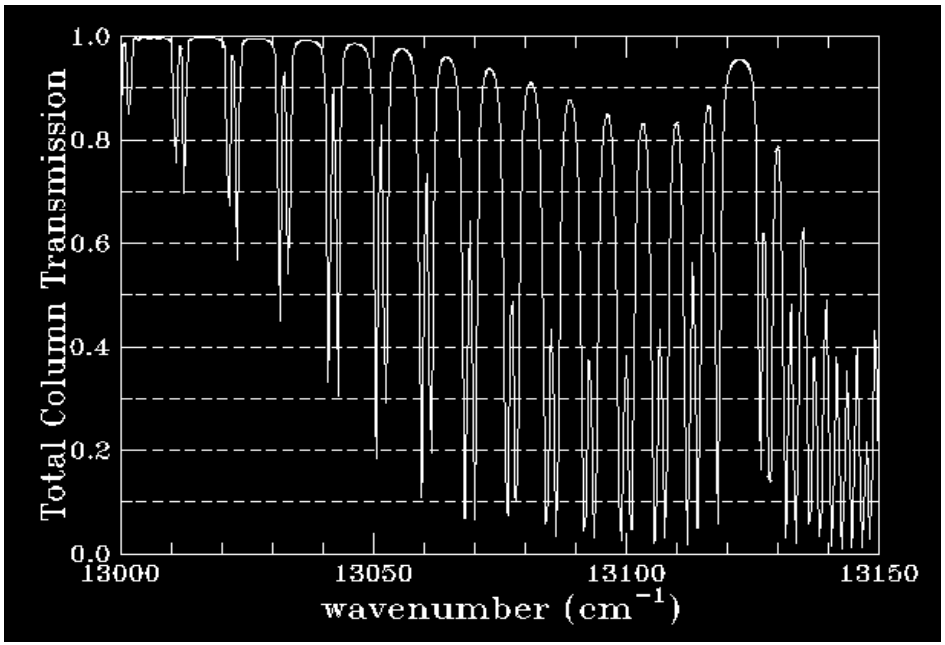
Built by Aerodyne Research, Inc.,

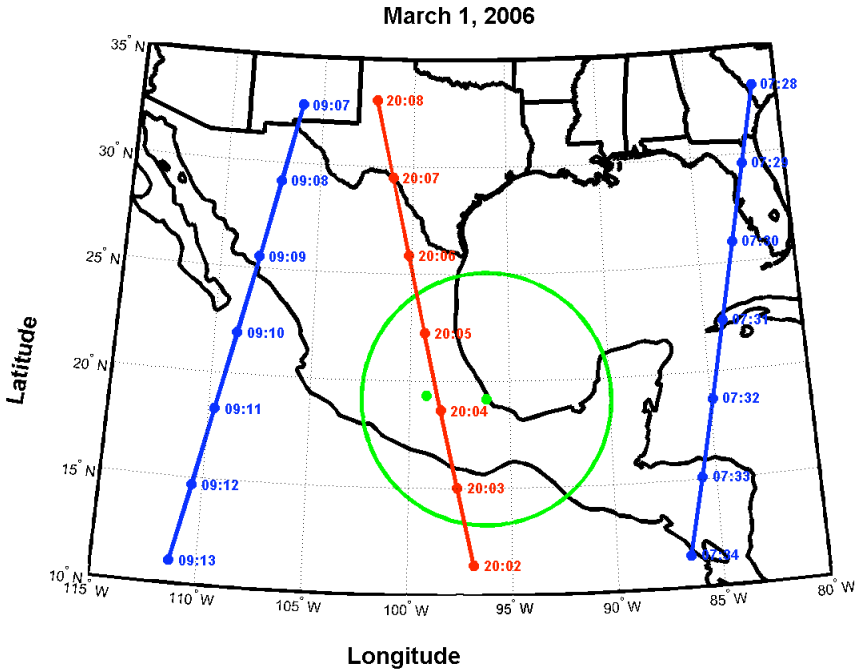
Langley Airborne A-band Spectrometer (LAABS)
PI: Mike Pitts

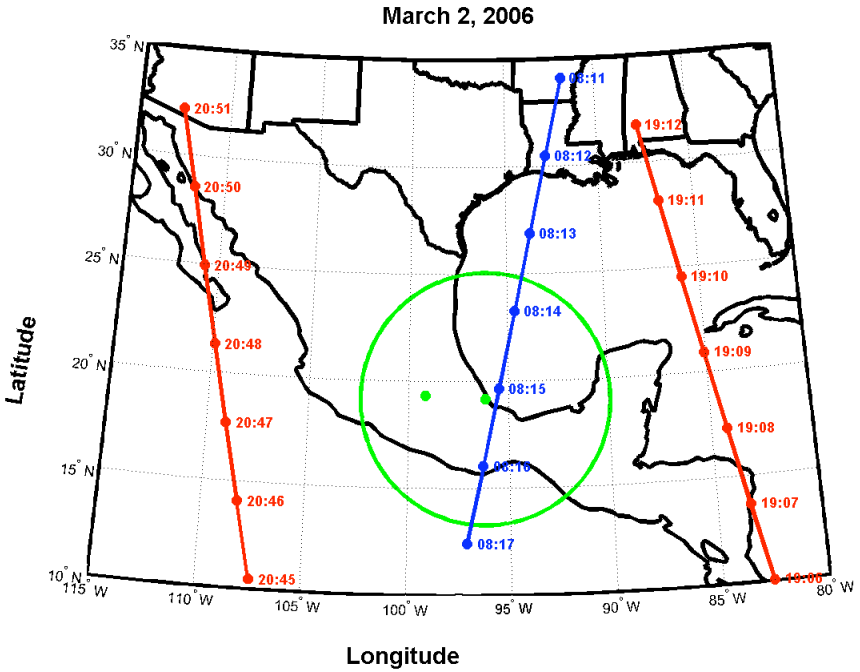
- Fundamental measurement
  - Spectrum of upwelling radiances in the oxygen A-band (760-770 nm)
  - 0.03 nm spectral resolution

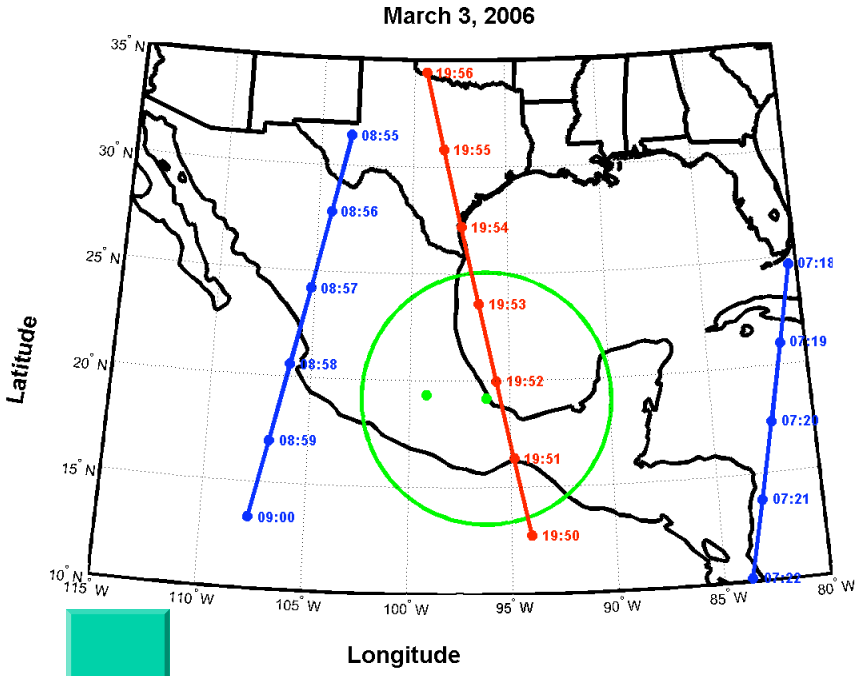


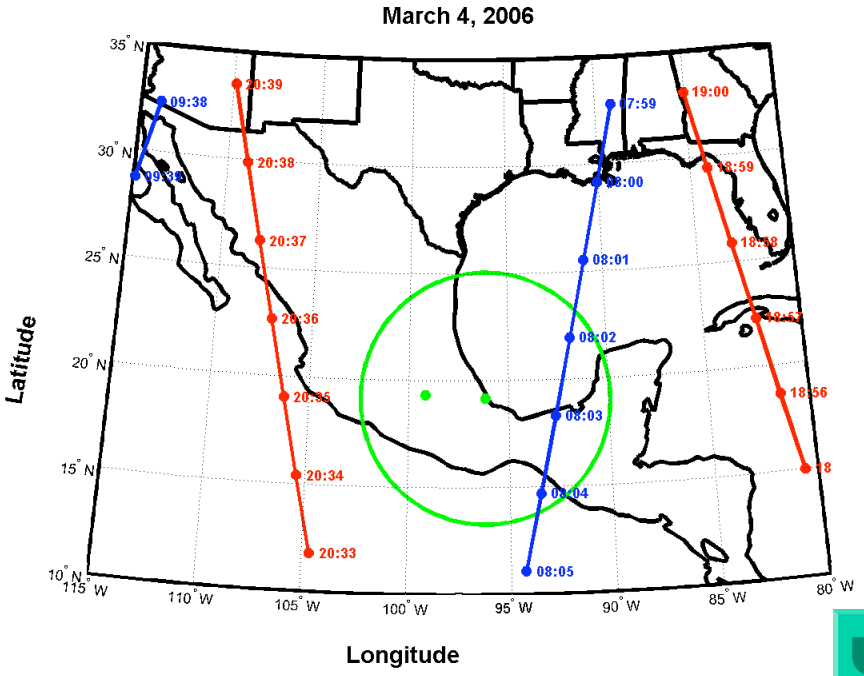
- Retrieval goals
  - surface pressure
  - optical depth of aerosol layers
  - aerosol single scatter albedo

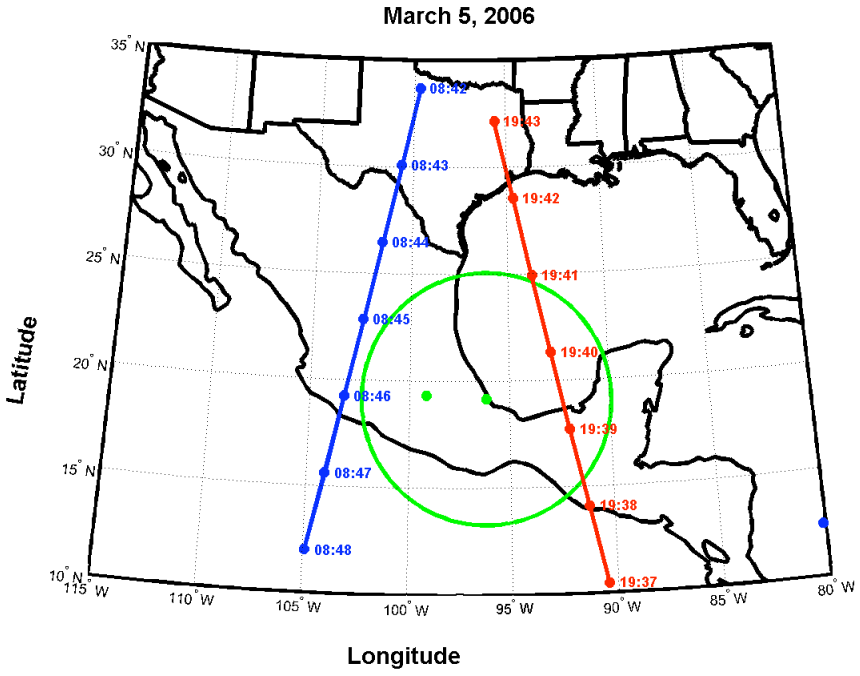


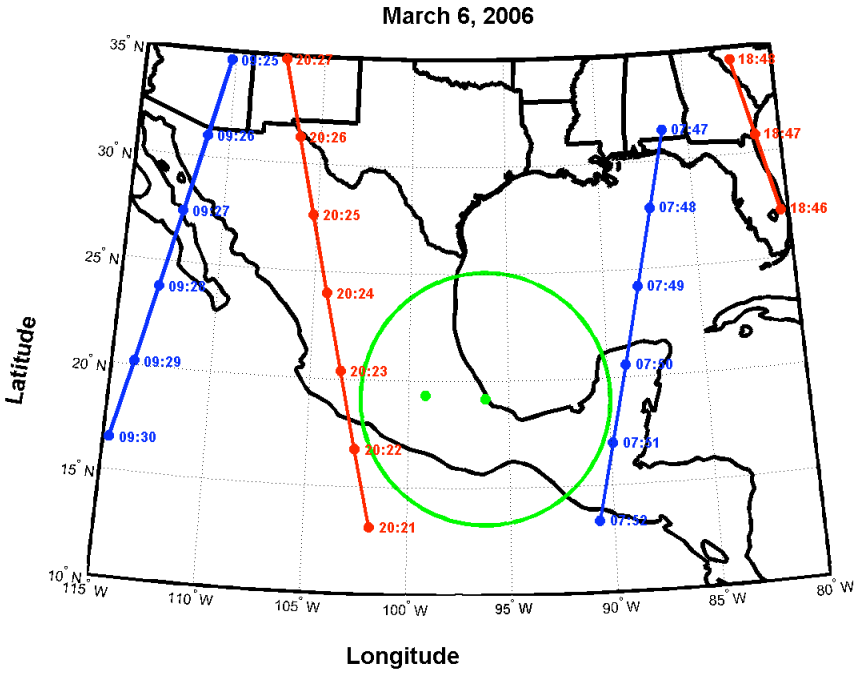

March 1, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
09:07
09:08
09:09
09:10
09:11
09:12
09:13
20:08
20:07
20:06
20:05
20:04
20:03
20:02
07:28
07:29
07:30
07:31
07:32
07:33
07:34

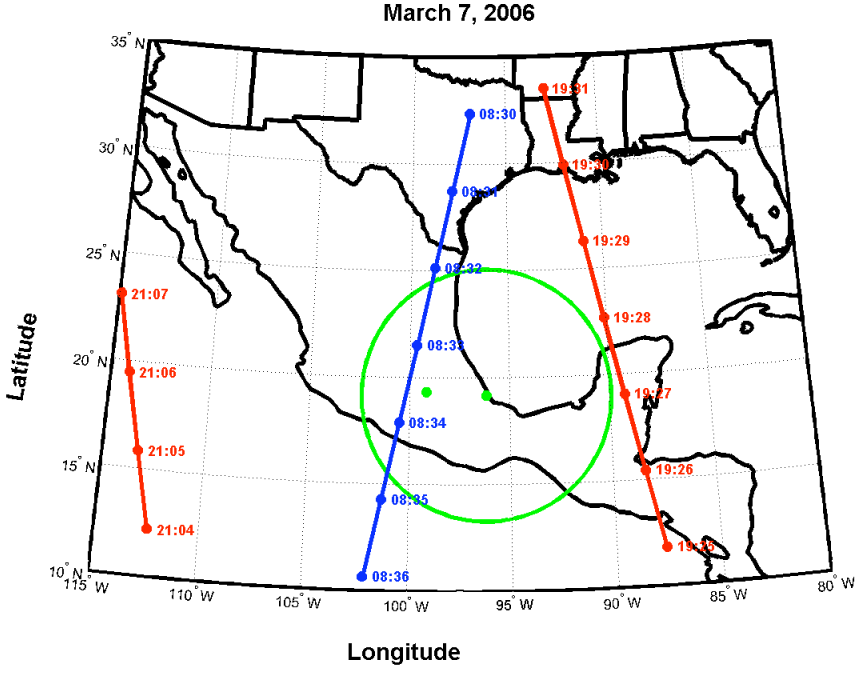

March 2, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
08:11
08:12
08:13
08:14
08:15
08:16
08:17
20:51
20:50
20:49
20:48
20:47
20:46
20:45
19:12
19:11
19:10
19:09
19:08
19:07
19:06

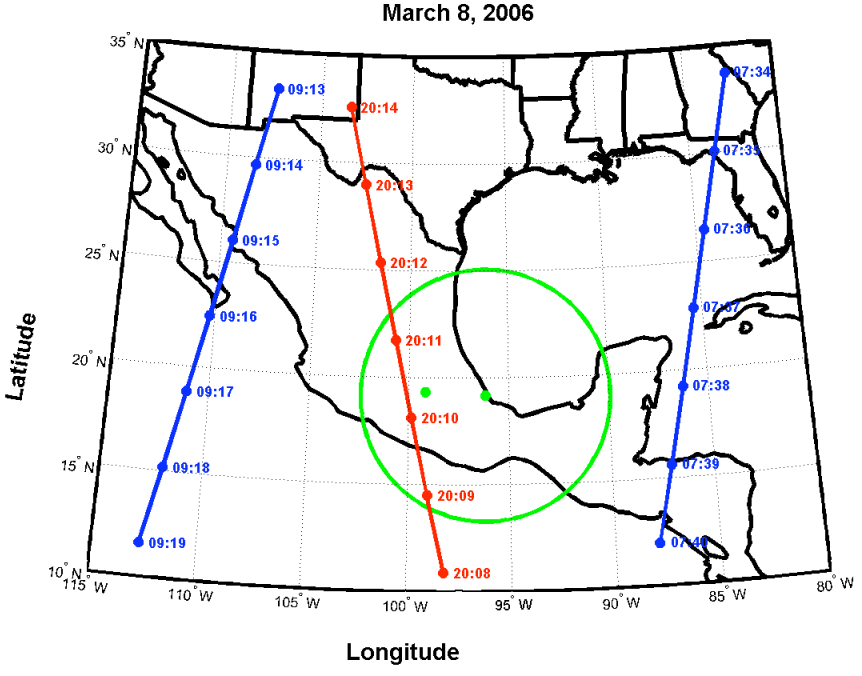

March 3, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
08:55
08:56
08:57
08:58
08:59
09:00
19:56
19:55
19:54
19:53
19:52
19:51
19:50
07:18
07:19
07:20
07:21
07:22

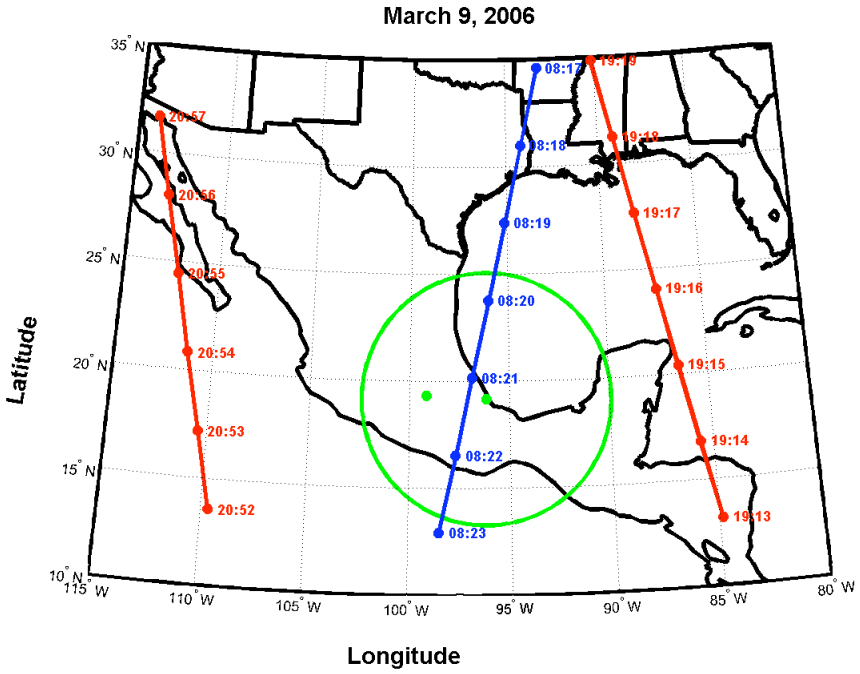

March 4, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
09:38
09:39
20:39
20:38
20:37
20:36
20:35
20:34
20:33
17:59
18:00
08:01
08:02
08:03
08:04
08:05
19:00
18:59
18:58
18:57
18:56
18

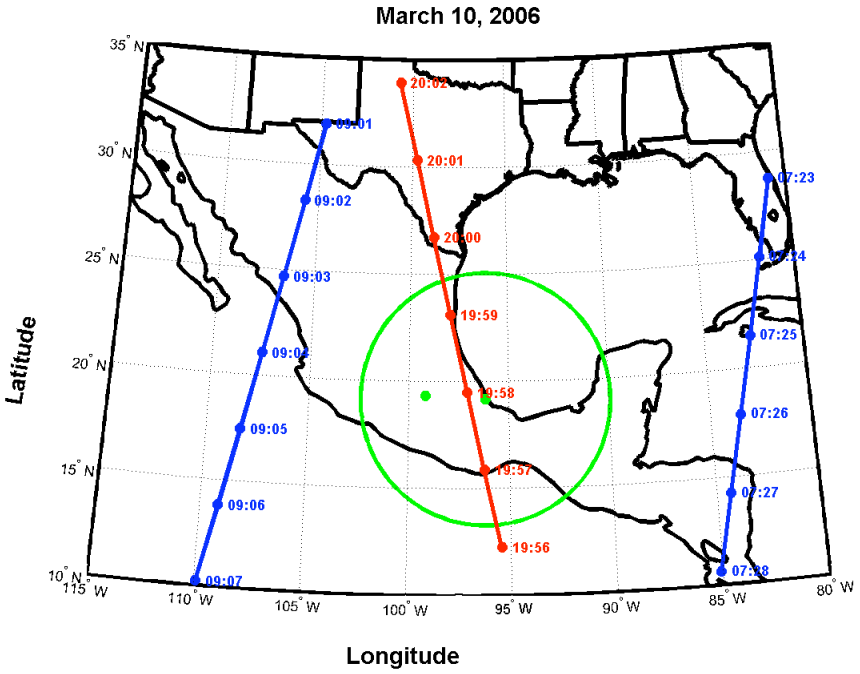

March 5, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
08:42
08:43
08:44
08:45
08:46
08:47
08:48
19:43
19:42
19:41
19:40
19:39
19:38
19:37

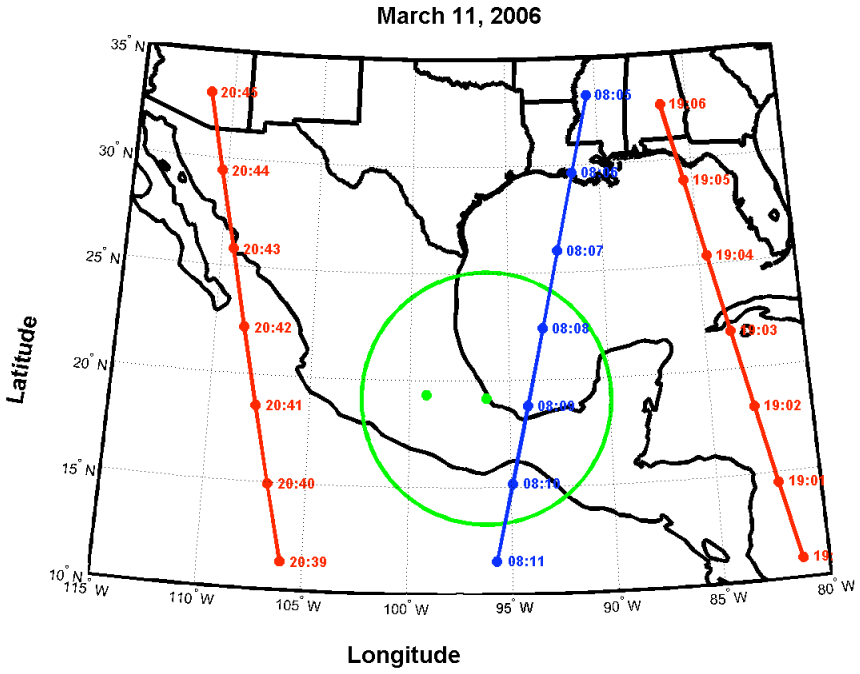

March 6, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
09:25
09:26
09:27
09:28
09:29
09:30
20:27
20:26
20:25
20:24
20:23
20:22
20:21
07:47
07:48
07:49
07:50
07:51
18:47
18:46

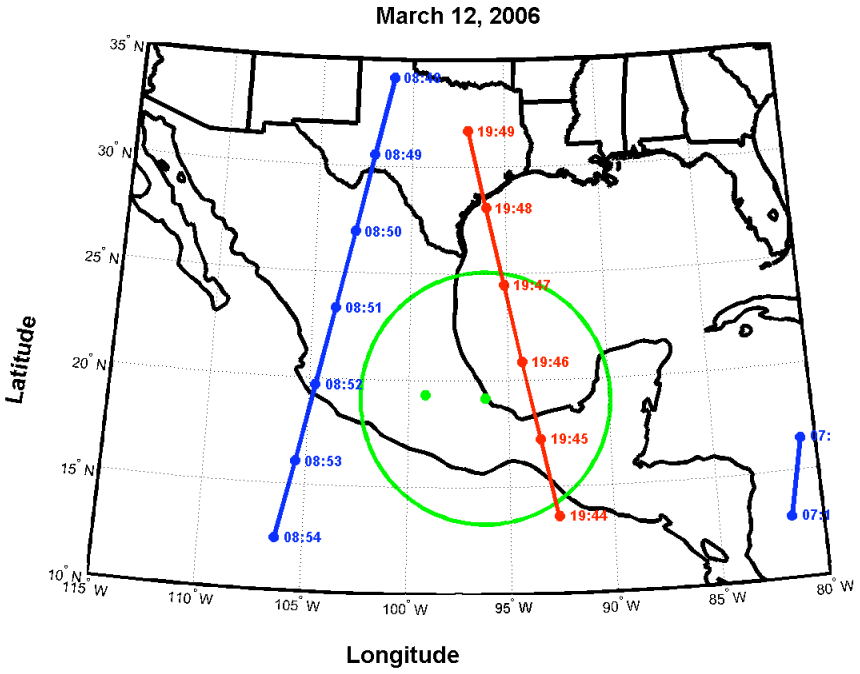

March 7, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
21:07
21:06
21:05
21:04
08:30
08:34
08:35
08:36
19:29
19:28
19:26

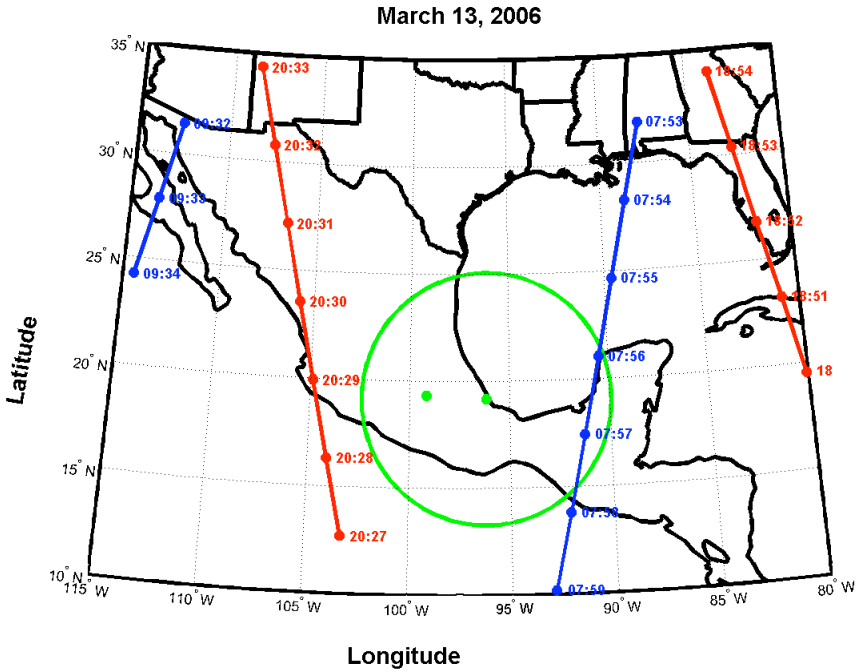

March 8, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
09:13
09:14
09:15
09:16
09:17
09:18
09:19
20:14
20:13
20:12
20:11
20:10
20:09
20:08
07:34
07:35
07:36
07:37
07:38
07:39

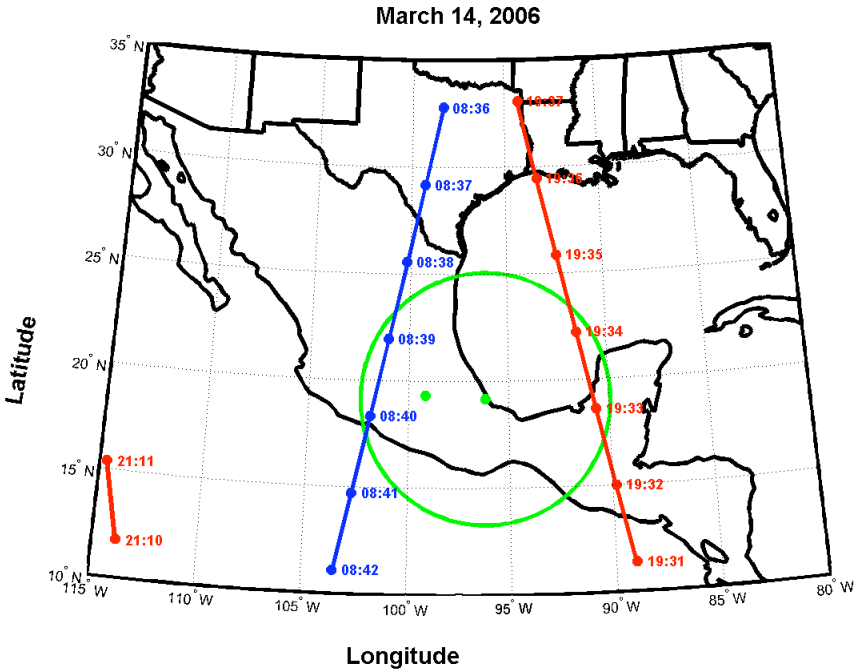

March 9, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:57
20:56
20:55
20:54
20:53
20:52
08:17
08:18
08:19
08:20
08:21
08:22
08:23
19:18
19:17
19:16
19:15
19:14
19:13

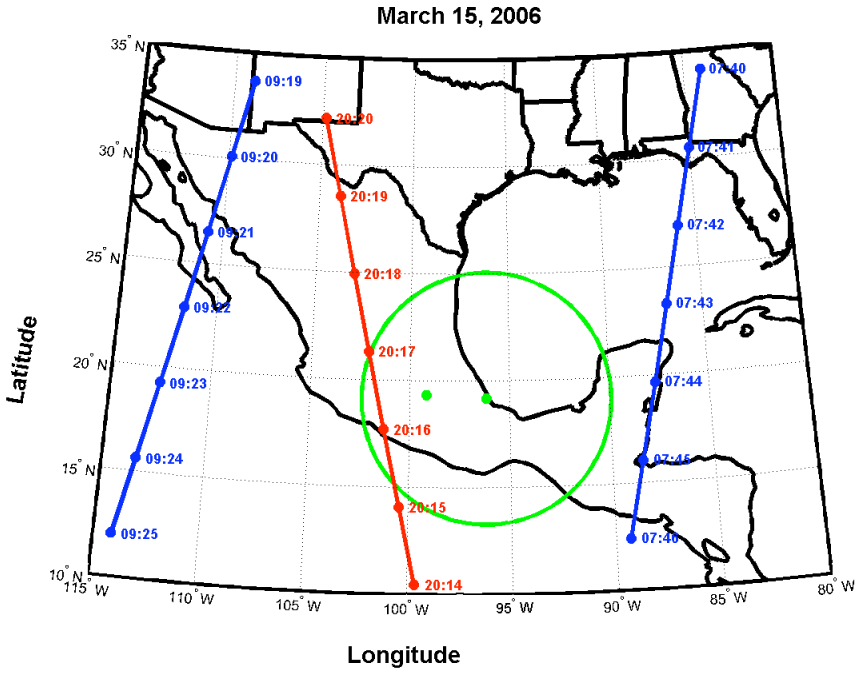

March 10, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:01
20:00
19:59
19:58
19:57
19:56
09:02
09:03
09:05
09:06
09:07
07:23
07:25
07:26
07:27

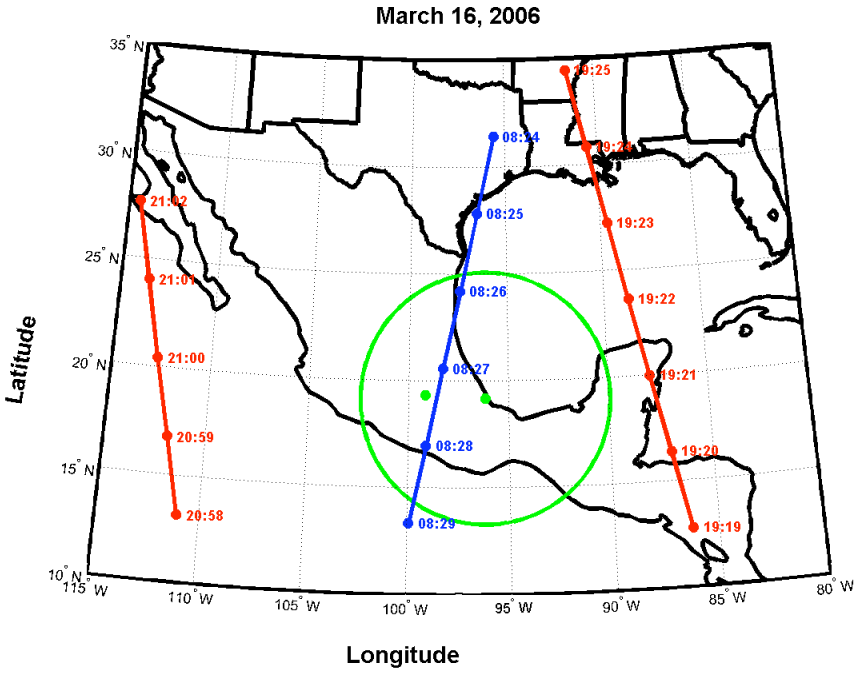

March 11, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:44
20:43
20:42
20:41
20:40
20:39
08:07
08:08
08:11
19:05
19:04
19:02
19:01

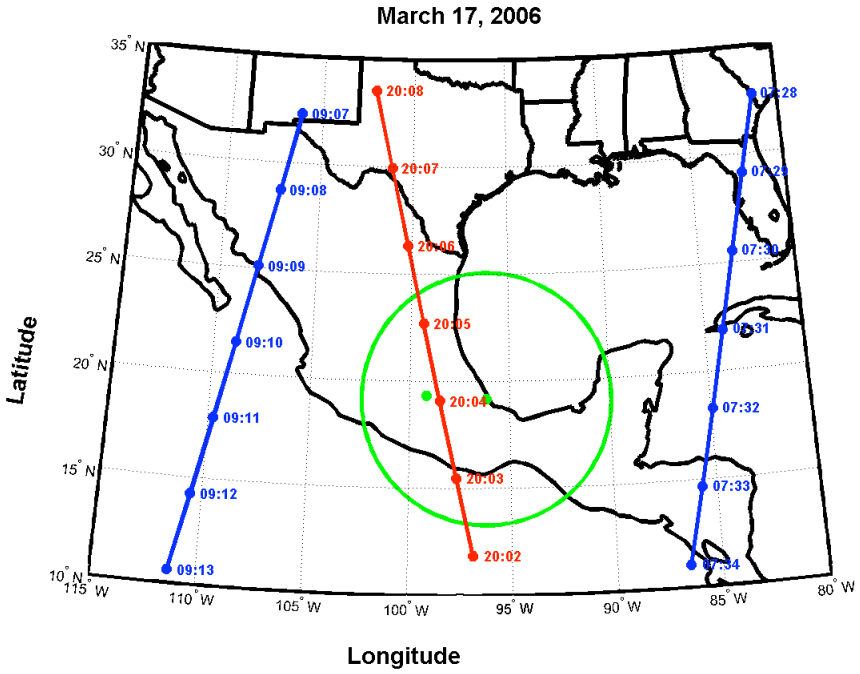

March 12, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
19:49
19:48
19:47
19:46
19:45
19:44
08:49
08:50
08:51
08:52
08:53
08:54

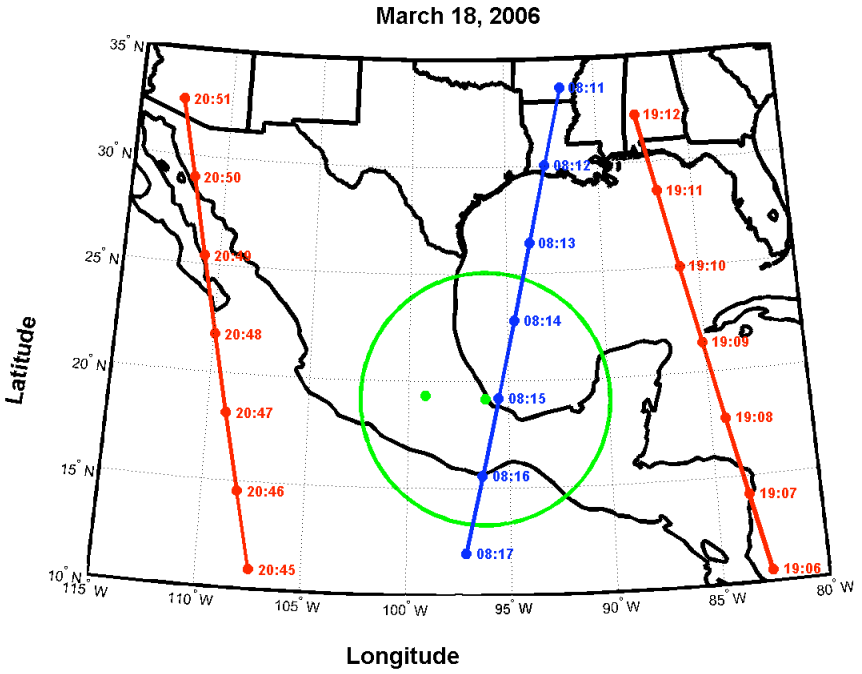

March 13, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:33
20:32
20:31
20:30
20:29
20:28
20:27
19:54
19:53
19:52
19:51
18
09:32
09:33
09:34
07:53
07:54
07:55
07:56
07:57
07:58
07:59

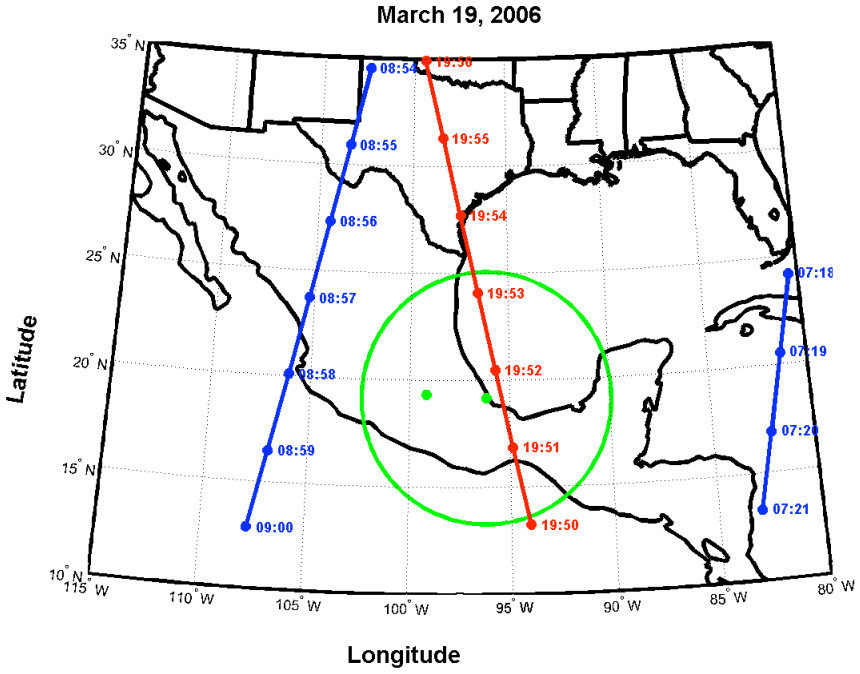

March 14, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
19:37
19:36
19:35
19:34
19:33
19:32
19:31
08:36
08:37
08:38
08:39
08:40
08:41
08:42
21:11
21:10

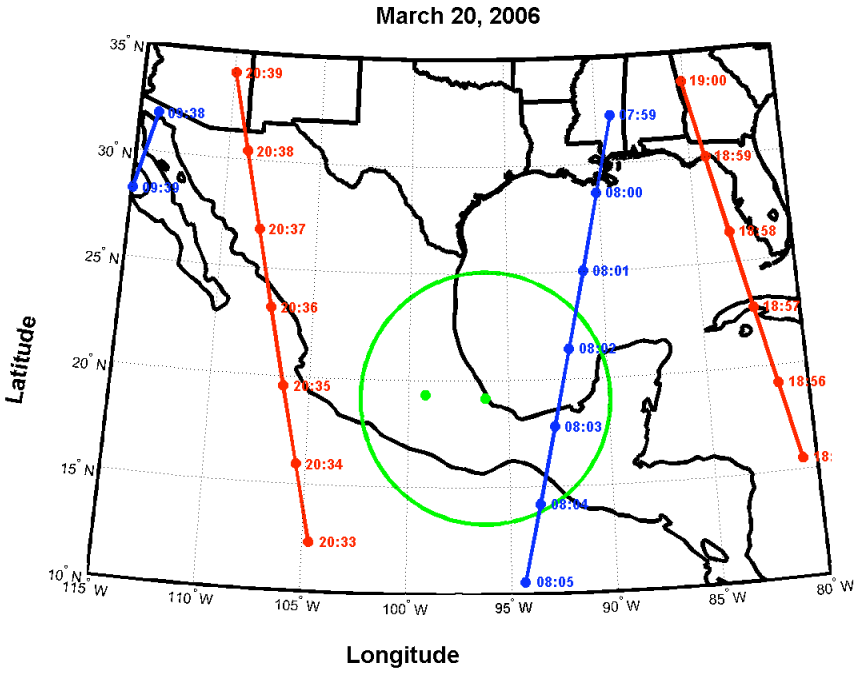

March 15, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:20
20:19
20:18
20:17
20:16
20:15
20:14
07:40
07:41
07:42
07:43
07:44
07:45
07:46
09:19
09:20
09:21
09:22
09:23
09:24
09:25


March 16, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
19:25
19:24
19:23
19:22
19:21
19:20
19:19
08:24
08:25
08:26
08:27
08:28
08:29
21:02
21:01
21:00
20:59
20:58

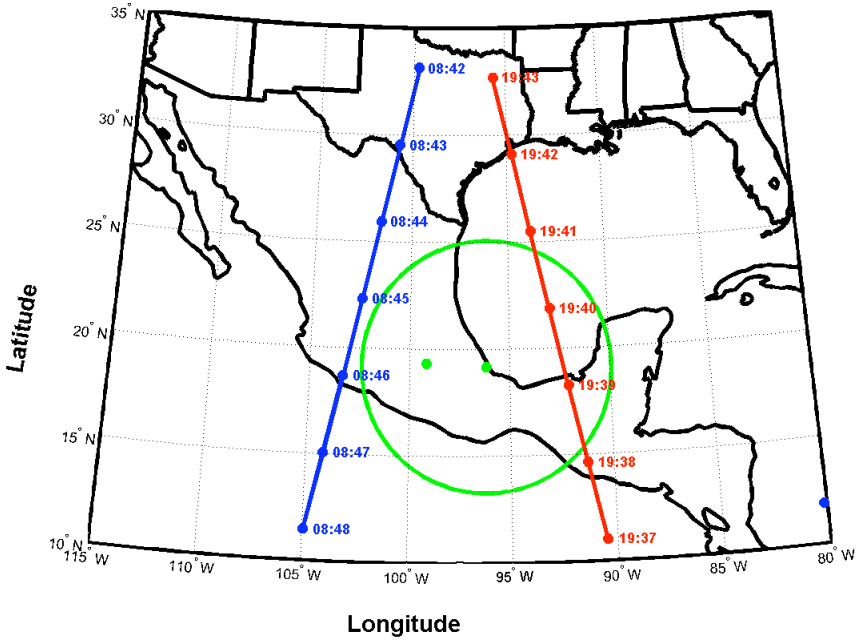

March 17, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
09:07
09:08
09:09
09:10
09:11
09:12
09:13
20:08
20:07
20:06
20:05
20:04
20:03
20:02
07:28
07:29
07:30
07:31
07:32
07:33
07:34


March 18, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:51
20:50
20:49
20:48
20:47
20:46
20:45
08:11
08:12
08:13
08:14
08:15
08:16
08:17
19:12
19:11
19:10
19:09
19:08
19:07
19:06

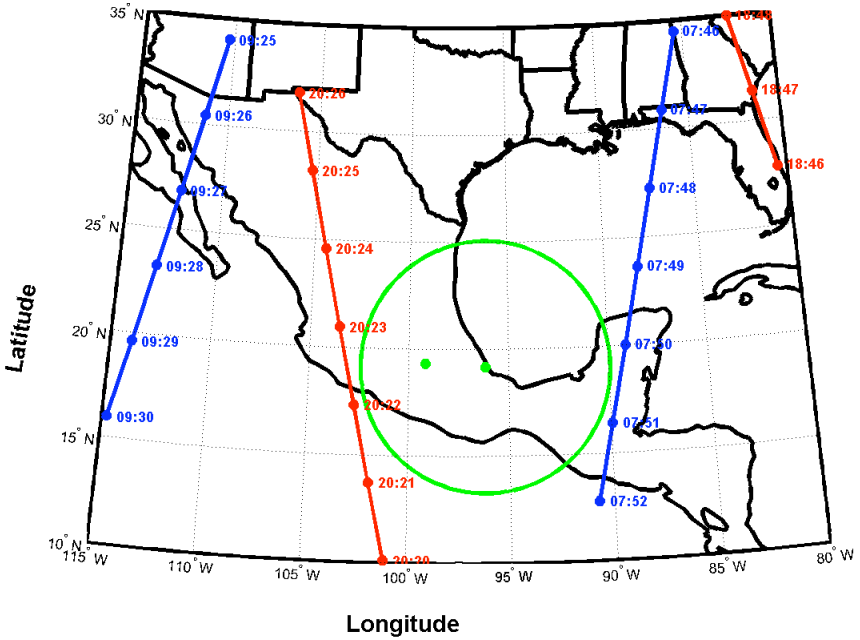

March 19, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
08:54
08:55
08:56
08:57
08:58
08:59
09:00
19:55
19:54
19:53
19:52
19:51
19:50
07:18
07:19
07:21


March 20, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:39
20:38
20:37
20:36
20:35
20:34
20:33
07:59
08:00
08:01
08:03
08:05
19:00
18:59
18:58
18:57
18:56

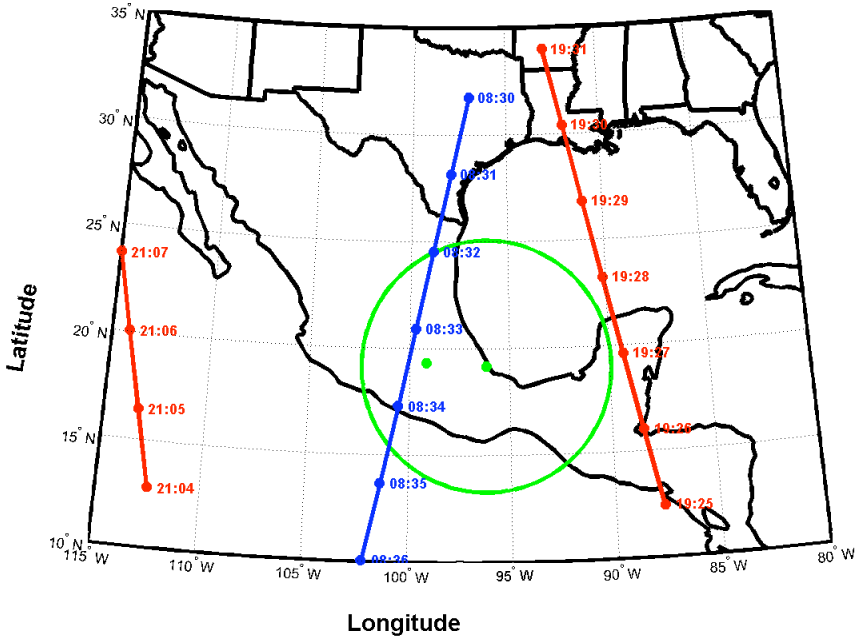
March 21, 2006



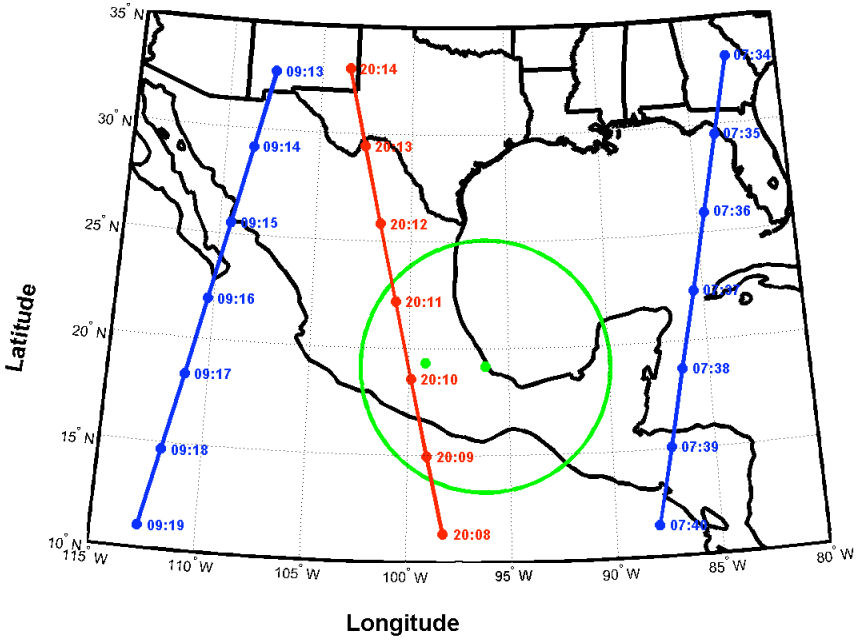
March 22, 2006

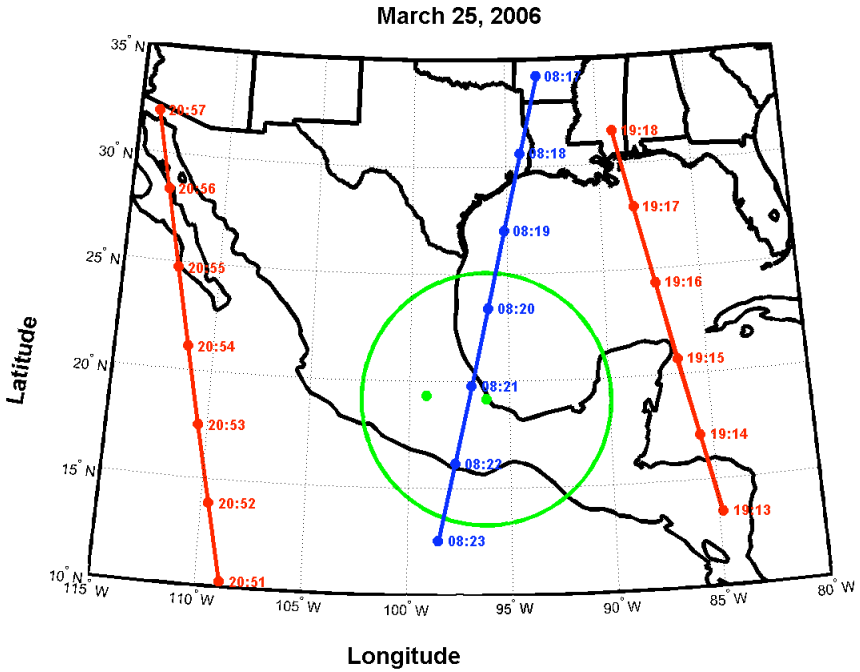


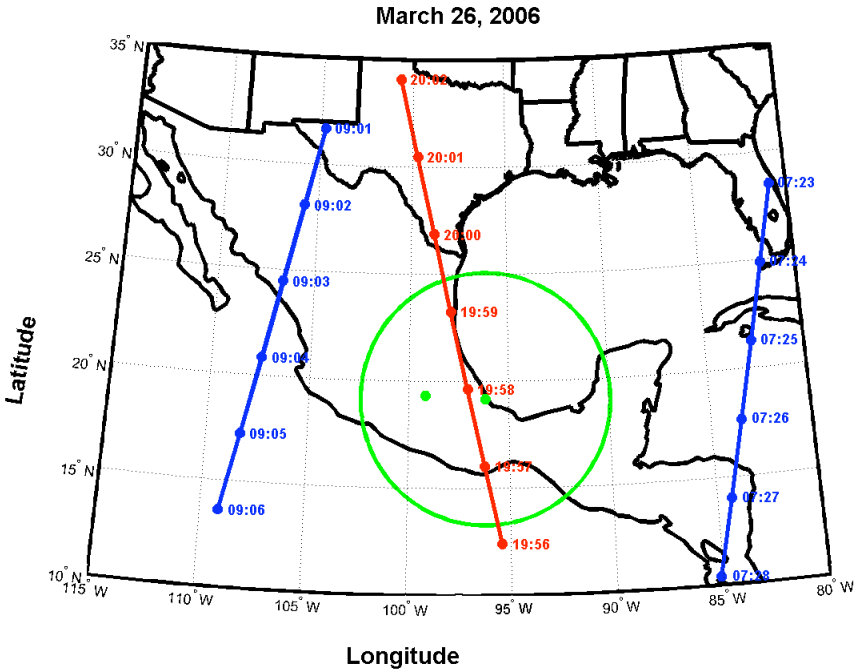
March 23, 2006

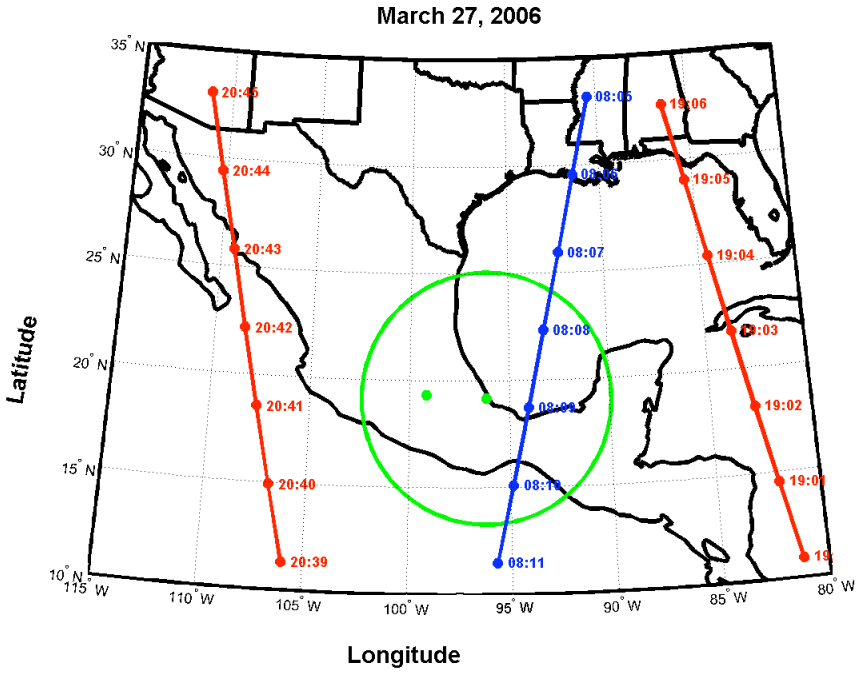


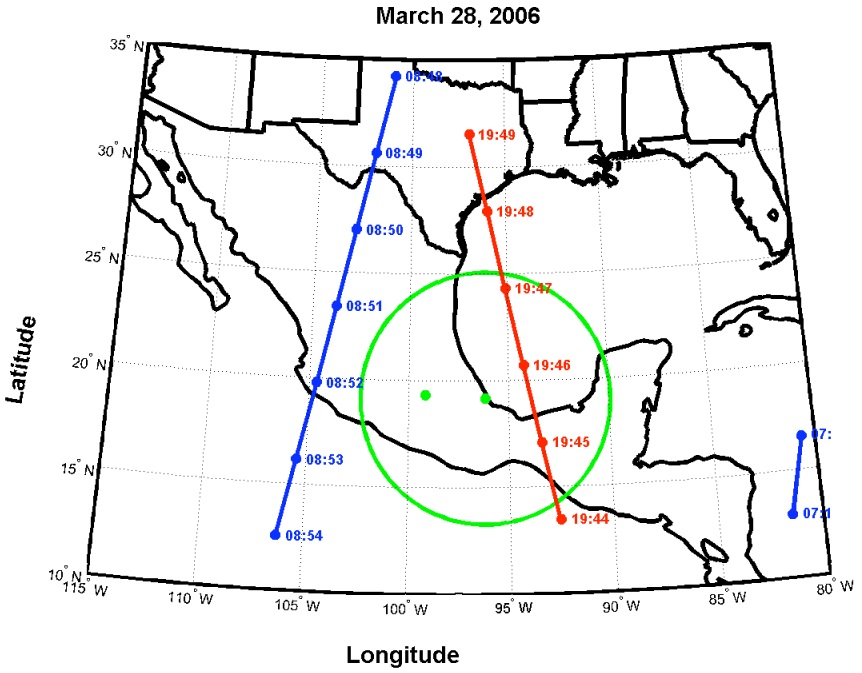
March 24, 2006



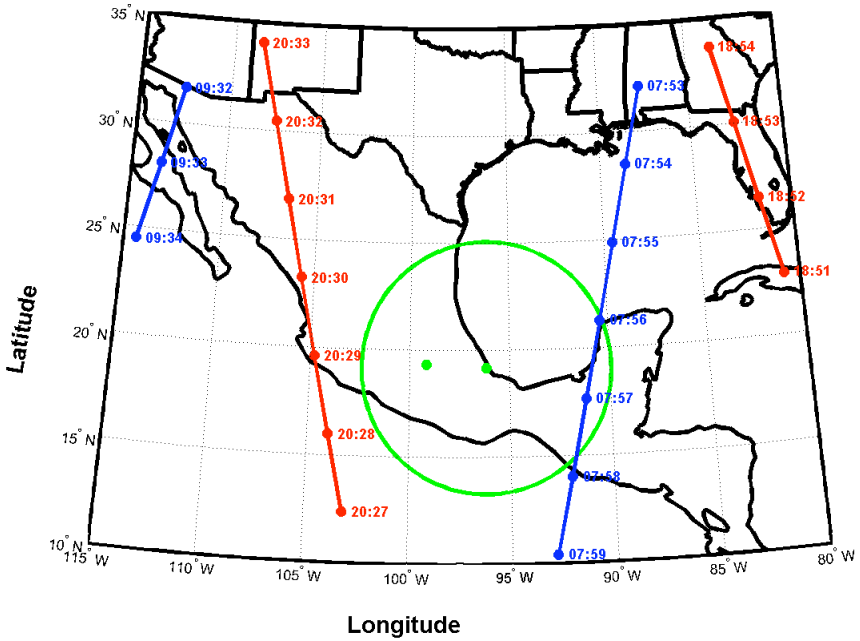

March 25, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:57
20:56
20:55
20:54
20:53
20:52
20:51
19:18
19:17
19:16
19:15
19:14
19:13
08:18
08:19
08:20
08:21
08:22
08:23


March 26, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:01
20:00
19:59
19:58
19:56
09:01
09:02
09:03
09:05
09:06
07:23
07:25
07:26
07:27

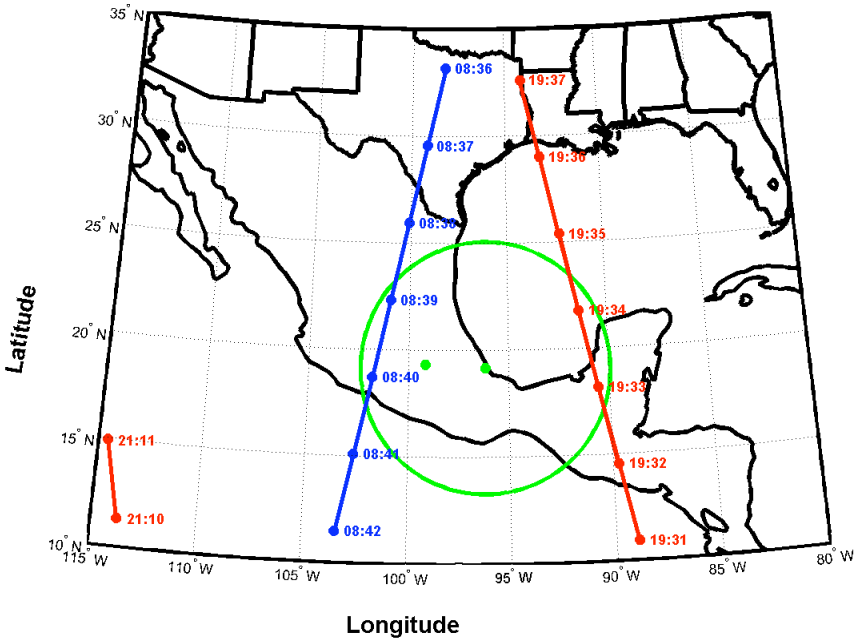

March 27, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
20:44
20:43
20:42
20:41
20:40
20:39
19:05
19:04
19:02
08:07
08:11


March 28, 2006
Latitude
Longitude
35° N
30° N
25° N
20° N
15° N
10° N
115° W
110° W
105° W
100° W
95° W
90° W
85° W
80° W
19:49
19:48
19:46
19:45
19:44
08:49
08:50
08:51
08:52
08:53
08:54

March 29, 2006



March 30, 2006



March 31, 2006