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LOREP 1993 SUMMARY REPORT: AIRBORNE MEASUREMENTS OF METEOROLOGICAL VARIABLES, ATMOSPHERIC PARTICLES AND SULFUR HEXAFLUORIDE

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AIRBORNE MEASUREMENTS OF METEOROLOGICAL VARIABLES, ATMOSPHERIC PARTICLES AND SULFUR HEXAFLUORIDE

Stan W. Wilkison and Dennis L. Wellman

ABSTRACT. Meteorological variables and sulfur hexafluoride (SF_6) were measured using the NOAA King Air research aircraft during February and March, 1993, over the Sierra Nevada Range of northern California as part of the Lake Oroville Runoff Enhancement Prototype Program (LOREP 1993). Race track pattern flights were made from approximately Sierraville, CA, to Gansner, CA. Airborne sampling was used to locate a plume containing sulfur hexafluoride as a tracer and propane as a seeding agent. The aircraft also carried a optical imaging probe. Data from the probe will be analyzed by the State of California and the U. S. Bureau of Reclamation to assess the seeding efficiency of the propane. This report introduces the program in general, discusses the objectives of LOREP 1993, the instrumentation used and the data obtained by the NOAA airborne operation.

1. INTRODUCTION

The Lake Oroville Runoff Enhancement Prototype Program (LOREP) is a five-year experimental research program to determine whether seeding winter storm clouds with high elevation release of liquid propane is a viable and economic method of increasing water supplies. For LOREP 1993, the State of California Department of Water Resources and the U. S. Bureau of Reclamation (USBR) proposed a simultaneous release of sulfur hexafluoride (SF_6) and liquid propane into the atmosphere at two sites northwest of Reno, NV, in the Sierra Nevada Mountains of California. The National Oceanic and Atmospheric Administration (NOAA) King Air research aircraft was engaged to aid in the collection of data to document the physical processes leading to enhanced precipitation. Two primary instruments carried were a sulfur hexafluoride (SF_6) analyzer for plume detection and an optical imaging probe to detect ice particles. The SF_6 analyzer was used to determine when the aircraft was sampling within the plume of propane and SF_6. The probe data will be analyzed to show the vertical and horizontal extent of the plume and confirm microphysical changes in the formation of ice crystals due to the propane seeding.

The principles upon which the experimental objectives of this project are based are far more comprehensive than could be included in this summary report. However, a very brief synopsis is warranted. Winter storm clouds, typical of those found over the Sierra Nevada, are deficient in ice-forming nuclei; or the nuclei present are unable to convert cloud condensate, produced by the orographic lifting of the air over the mountain barrier, to crystals soon enough to remove all the cloud water. A large portion of that supercooled cloud water then becomes part of precipitation processes well downwind of the barrier. The introduction of an ice-nucleating agent, under proper conditions, promotes the conversion of supercooled cloud condensate to ice before it passes the ridge. An agent capable of transforming supercooled water droplets directly to ice crystals at temperatures between 0 and -5 °C is liquid propane sprayed into the atmosphere as a fine mist. This type of release very rapidly cools the air to temperatures well below 0 °C through the process of vaporization. The use of liquid propane, when released as a fine spray for glaciogenic seeding, has been documented

(Vardiman et al., 1971). More recently, liquid propane has been used in converting cloud condensate to ice crystals in winter storms over the Sierra Nevada (Reynolds, 1988, 1989, 1991). The 1993 LOREP field exercise, led by Reynolds, furthers his recent work.

A tracer material injected into the atmosphere, in known quantity, allows direct study of transport and dispersion processes and aids in validating atmospheric model calculations. Since introduction of the concept (Saltzman et al., 1966), halogenated gases, such as sulfur hexafluoride, have become established as atmospheric tracers detectable at very low concentrations without pre-concentration of the sample. Sulfur hexafluoride is particularly suitable as an in-cloud tracer because it is insoluble in water (Collins, et al., 1965). Sampling and detection of SF_6 at less than 10 parts per trillion by volume (pptv) is accomplished easily and at low cost by electron capture gas chromatography (Clemons and Altshuller, 1966). SF_6 is an inert gaseous compound with no natural sources and a calculated atmospheric lifetime exceeding three thousand years (Ravishankara et al., 1993). As it is used as an atmospheric tracer, and because it is a byproduct of certain industrial activities, there remains a worldwide background of less than a few parts per trillion (Lovelock and Ferber, 1982). When atmospheric diffusion of the tracer plume reduces the SF_6 concentration to a value that is near the global background, the plume will no longer be detectable.

The co-release of SF_6 with propane was used to determine how effectively individual releases were in dispersing ice crystals (tracer) into regions of supercooled liquid water over the intended target area. The tracer gas trajectory and the propane-generated ice crystal plume trajectory will match until the growth of the ice crystals causes them to fall away from the tracer plume. Should the crystals not grow to precipitation size particles, rates of precipitation at the ground would not increase.

During the period between 5 February and 20 March, 1993, an exploratory seeding program was accomplished through a series of randomized releases. SF_6 tracer was released, when meteorological conditions were favorable, through mass-flow controllers at two dispenser sites along the base of the Grizzly Ridge, on the Sierra Crest, near Graegle, CA. Propane was released from the same two sites and others along the base of the ridge. There were a total of eleven experiments based on meteorological conditions that would include winds from the south-southwest and passage of a front capable of producing precipitation. The random seed/no-seed pattern resulted in six of these experiments having both propane and SF_6 released, while five had SF_6 only. On one occasion, February 19, SF_6 and propane were released for one hour; however, due to high winds and icing, airborne operations were suspended. On February 22, though battery failures at both release sites halted the dispensing of SF_6, the aircraft flew a three hour mission in a propane plume.

The complement of measurements systems in the target area included a high altitude mountain-top observatory, a network of automated precipitation gauges, mountain-top weather stations, and a rawinsonde observations unit. A dual frequency (20.6 and 31.54 GHz) microwave radiometer was deployed at the Jackson Creek high altitude observatory. The radiometer was used to measure path integrated liquid water in millimeters and precipitable water vapor in centimeters. The radiometer was used for real-time indications of supercooled liquid water; to develop a climatology of supercooled liquid water in the area; and to determine the impact of seeding on the liquid water. This site also housed a ground microphysics laboratory consisting of an aspirated Particle Measuring Systems (PMS) 2D-C cloud particle probe and microscope with camera for photomicrographs of snow crystals. A continuous SF_6 analyzer monitored for the presence of SF_6 tracer during seeding operations. A total of twelve precipitation gauges were installed within the target area. Data were collected at 15-minute intervals and transmitted hourly via the GOES satellite to the California Data Exchange Center down-link in Sacramento and the USBR down-link in

Denver. A remote weather station was located near the Jackson Creek site which provided a record of wind, temperature and humidity during seeding operations. Three mountain-top icing stations were established to provide critical information for seeding decision making. Each station had temperature, relative humidity, wind speed, wind direction, and icing sensors. Data were collected at 5-minute intervals and transmitted once per hour through GOES satellite. To complete measurements a rawinsonde system collected data including pressure, temperature, relative humidity, wind speed and direction from the surface to 10 km.

A Cooperative Agreement between the U. S. Bureau of Reclamation and the National Oceanic and Atmospheric Administration provided the NOAA King Air research aircraft, equipped for cloud microphysical investigation, for the two-month field program. The instrumented aircraft, with a flight crew of two pilots plus a scientific observer, was deployed along Grizzly Ridge at altitudes between 2590 m and 4115 m (8,500 and 13,500 feet mean sea level (MSL)). Wind direction was from the south or southwest for all flights.

The aircraft made ten research flights as part of the program. The first flight was for test purposes and to familiarize the pilots with the area while in Visual Flight Rules (VFR) conditions. We observed tracer gas concentrations on these flights that ranged between 5 and 330 pptv.

2. OBJECTIVES

The State of California Department of Water Resources lists the scientific objectives of program in order of importance as:

1. Evaluate the accuracy of targeting seeding effects using a combination of rawindsonde data, mountaintop wind, temperature, and icing information, tracer releases, and ground and aircraft microphysics observations.

2. Document the changes in crystal concentration, habit, degree of rime, and change in integrated water during experimental seeding using ground and aircraft microphysics data.

3. Compile precipitation data for the target and covariate gauge sites for randomized seed, no-seed days. These data will be used in statistical evaluation of seeding effects.

3. DATA COLLECTION

3.1 Methods of collection

The airborne data collection platform was a Beechcraft King Air Model C-90, twin-engine turbo-prop, described in further detail by Wellman et al. (1989). The research aircraft was fully suited for operation under instrument flight rules and was equipped for flight into known icing conditions. The aircraft operations and aircraft were based in Reno, NV, at the Reno-Cannon International Airport, not far from the target area. Ground based operations, other than aircraft, data collection sites, and results are thoroughly described in the Lake Oroville Runoff Enhancement

Project (LOREP) Annual Report of Field Activities 1992-1993 (Reynolds, 1993).

3.2 Flight Plans

Most of the flights were planned to take place in supercooled clouds under instrument flight rules (IFR) conditions. Federal Aviation Regulation 91.177 (a)(2)(i) specifies a minimum of 600 m (2000 ft) above the highest surface features within 2.5 km (5 statute miles) for IFR flight over mountainous terrain. This would preclude sampling at the low elevations where seeded plumes were expected to pass over the target ridge. A waiver was obtained from the regional office of the Federal Aviation Administration (FAA) to permit flights to within 300 m (1000 ft.) of the highest terrain within 2.5 km of the flight path during IFR flights. Additionally, clearances were obtained for a block of airspace, increasing safety and sampling flexibility.

The flight plan used during research missions is shown in Figure 1. The flight leg flown between point P1 and point P2, upwind of the target area, was a valley track flown at 2500 m (8300 ft. MSL) on a northwest heading. The flight leg between point P3 and point P4 was a ridge track flown at 2680 m (8800 ft. MSL) on a southeast heading. During VFR flights, these same tracks were flown as low as 2100 m (7000 ft. MSL). At times the aircraft would be directed by the Project Operations Center to fly short legs further downwind between points P5 and P6. During IFR conditions this flight leg would be flown at 2600 m (8500 ft. MSL). The SF_6 release locations are designated in Figure 1 as SF_6 1 and SF_6 2.

Typically, a flight would takeoff from the Reno airport and climb to the west over the Sierra Nevada mountain range. The aircraft would then descend (from 3960 m to 2500 m) into the area of operations entering at the point labelled P1 in Figure 1. Each flight lasted approximately 3 hours and completed 8 valley and ridge passes. The aircraft logged 35 research flight hours during the project, completing 10 flights on 10 separate days.

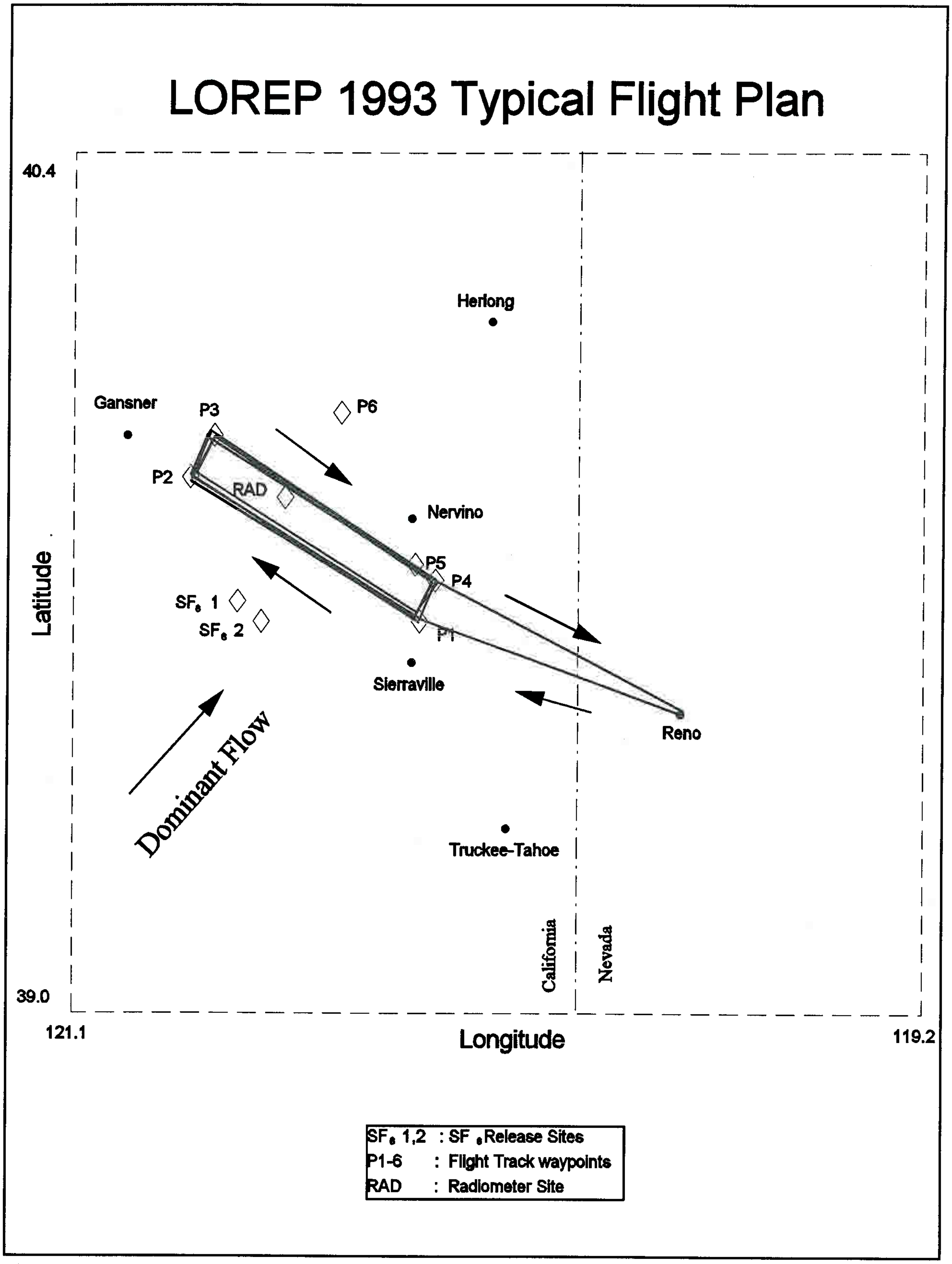
LOREP 1993 Typical Flight Plan
40.4
39.0
Latitude
Longitude
121.1
119.2
Herlong
Gansner
P3
P6
P2
RAD
Nervino
P5
P4
SF6 1
SF6 2
P1
Sierraville
Reno
Dominant Flow
Truckee-Tahoe
California
Nevada
SF6 1,2 : SF 6 Release Sites
P1-6 : Flight Track waypoints
RAD : Radiometer Site

Figure 1

3.3 Daily Operations

The procedure for beginning an experiment was initiated by the project manager with an early evening briefing of the flight operations coordinator for a potential flight the next day. Additional briefings or updates, when necessary, occurred prior to the pre-flight briefing of the flight crew and observer by the flight operations coordinator within one hour of takeoff. Preparation of the SF_6 instrument began in the late evening before a morning flight. The detector was cleaned by flushing with 30 ml of methanol, then dried with a flow of nitrogen for several hours. Within 3 hours of takeoff, the protective covers on the Forward Scattering Spectrometer Probe (FSSP), the Optical Array Probe (OAP), and the Liquid Water Content (LWC) were removed, the inlets were uncapped, the exhaust tubing was installed, data acquisition was begun, the SF_6 instrument was calibrated, the total temperature sensor and dew point hygrometer were checked against an aspirated psychrometer, the static pressure was checked against a certified aneroid barometer, and the solar insolation photometer was checked to assure that it was functioning. Check lists for the instruments were filled in as the internal quality control checks were performed. These were filed and used as a reference to check on the continued performance of the instruments.

Information such as the following was recorded in the airborne log:

- time of takeoff and landing
- cloud base, distribution, and type
- degree of turbulence
- precipitation events
- times instruments were calibrated and/or zeroed
- any unusual instrument behavior observed
- changes in standard procedure and reasons for change
- changes in flight plan and reasons for change

After flight, recorded data from the Science Engineering Associates (SEA) data acquisition system were processed on a ground-based computer system. The operations coordinator and observer (with flight crew) met for an informal debriefing of flight and scientific conditions. These post-flight debriefings included inflight changes, flight weather conditions, and instrument status and/or problems. Ground-crew log notes were recorded. Examples of pre-flight check lists are presented in Appendix B; all airborne and ground-crew log notes are presented in Appendix C.

4. INSTRUMENTATION

Instrumentation aboard the aircraft was a standard package to which additional instruments may be added or removed to meet specific research objectives (Wellman et al., 1989). Table 1 is a summary of the data recorded for LOREP 1993. Pressure, temperature, dew point, and solar radiation sensors are on the exterior of the aircraft; the liquid water content sensor and cloud particle probes are under the wings. Cabin pressure is measured by a pressure transducer mounted in the data system rack. A dual system exists in case of a transducer failure. The de-iced inlet system of aluminum tubes, located on top of the fuselage, conducted a continuous flow of sample air, by way of Teflon tubing, through the pressurized cabin of the aircraft. The tubing exited a port at the rear of the cabin. The instruments sampled air, which had been delivered by a transfer pump, through a manifold. The excess air was exhausted either into the cabin or through a port at the rear of the plane. See Figure 2 (page 9) for the aircraft configuration.

Table 1. Data recorded for LOREP 1993 aboard the NOAA King Air

Measurement	Units	Accuracy
Time	HHMMSS	±0.5 second
Temperature	°C	±0.25°C plus 0.5% of the temperature in °C.
Dew point	°C	±0.25°C at +50 °C; ±1.0 °C at -75 °C
Static Pressure	mb	<±0.3% FS
Dynamic Pressure	mb	±0.4% FS
Cabin Pressure	mb	±0.75% FS
Solar radiation	W m^{-2}	±5.0%
Particle size	μm	±10% or 2μm
Loran Latitude	deg	±190 m
Loran Longitude	deg	±190 m
GPS Latitude	deg	±25 m (Spherical Error Probability)
GPS Longitude	deg	±25 m (Spherical Error Probability)
Heading	deg	±2 deg
True Air Speed	m s^{-1}	±5%
Wind direction	deg	±15%
Wind speed	m s^{-1}	±15%
Liquid Water Content	g m^{-3}	±20%
SF_6	pptv	±15%
Cloud particles	µm	*

FS is full scale

* The cloud particle probe logs images of particles that pass through a laser beam. Accuracy and precision of image size are based on a image pixel resolution of 25 µm.

The accuracies listed in Table 1 for temperature, dew point, pressure, and solar radiation are based on the manufacturer's specifications.

The following subsections describe the instrumentation used for LOREP 1993. When applicable, the description includes the specifications, calibration information, and the principle of operation.

4.1 Dynamic Pressure Transducer

The Tavis transducer Model P-1 is a variable reluctance pressure-sensing module with electronic signal conditioning in a shielded housing. The transducer measures the pressure differential between the static pressure port and the pitot tube (total pressure). The output is a voltage which is converted to millibars by the algorithm given in Table 2.

Specifications

Range: 0 to 5 pounds per square inch differential (psid)
Static Error Band: ± 0.5% F.S. max.
Resolution: Infinite

Calibration

Calibration in the field is not necessary. The latest calibration was performed by the manufacturer in October 1990. A laboratory audit was performed in December 1992.

Operational procedures

The transducer was permanently installed and wired into the aircraft system such that when scientific power was energized the instrument was operating. The instrument output was tested and connected to the data acquisition system before the field study. There are no inflight operations.

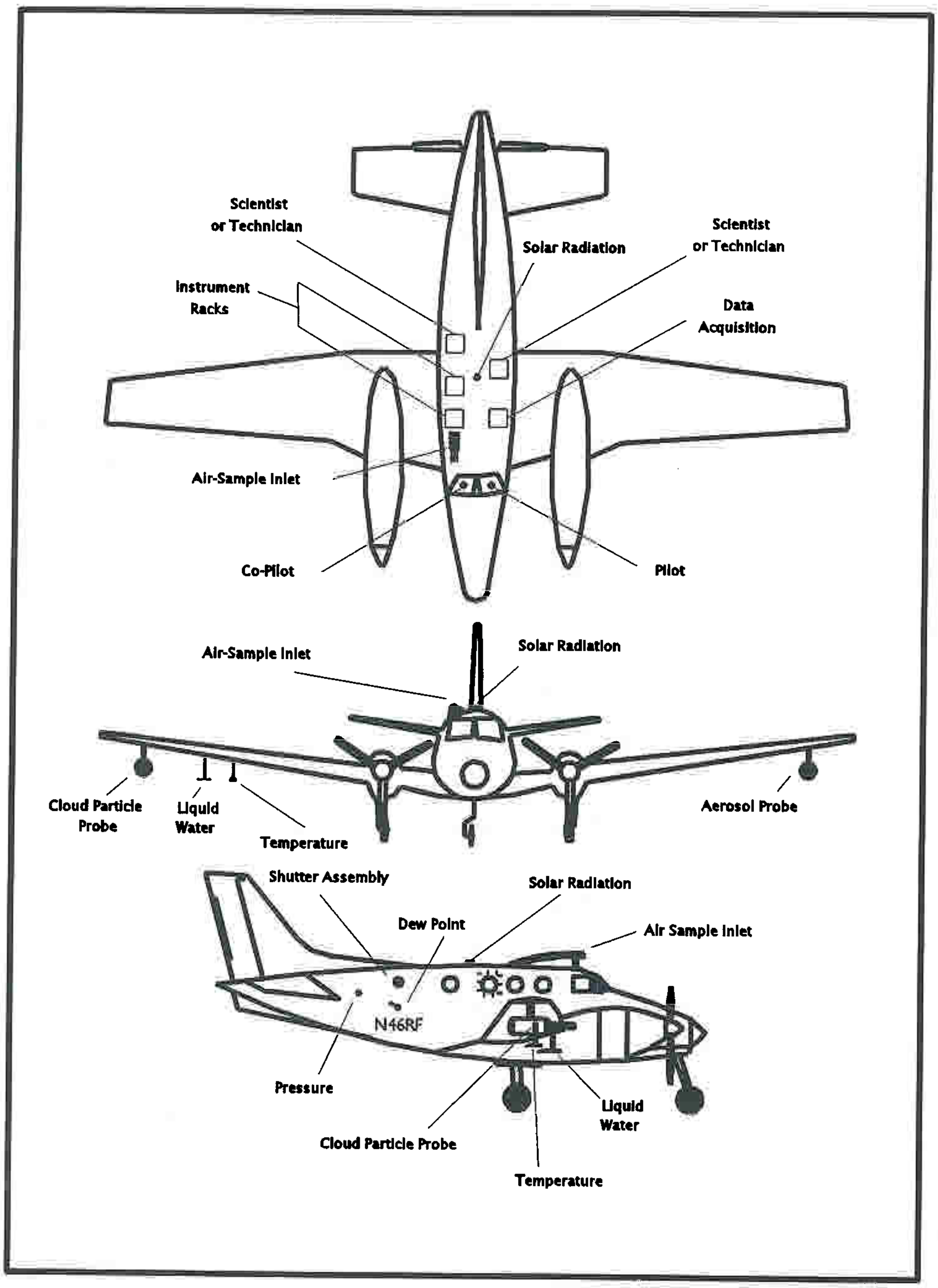

Figure 2. Locations of sensors and features on the NOAA King Air aircraft.

4.2 Total Temperature Sensor

The Rosemount Model 102AU1AF sensor is an hermetically sealed platinum resistance sensing element which provides a measurement of total air temperature. For stability and protection, the sealed element is surrounded by a gold-platinum-alloy radiation shield, which, in turn, is surrounded by a stainless steel shield. Through signal conditioning, the resistance is converted to a linear output voltage, which is proportional to total temperature according to the algorithm in Table 2.

Specifications

Range: +40° to -60°C
Time Constant: ~ 1.9 ± 0.6 s (speed of flight dependent)

Calibration

Calibration in the field is not required. Intercomparison calibrations are performed using an additional temperature probe on the Boulder Atmospheric Observatory (BAO) tower. A calibration was performed on 24 April 1986. A tower flyby on 13 April 1990 showed that re-calibration was not necessary. Daily check measurements of temperature and dew point were made with an aspirated pyschrometer. This was used as a basic check that the instruments were in working order, not as a calibration.

Operational procedures

The instrument was permanently installed, outboard on the right wing, and wired into the aircraft systems. When the scientific power was connected on the aircraft, the sensor and signal conditioner were operational. Connection of the system output to the data acquisition system occurred before the field study. There are no operational considerations.

4.3 Dew Point Hygrometer

A continuous flow of air directed through the General Eastern Model 1011B dew point hygrometer sensing chamber contacts a thermoelectrically cooled mirrored surface. The presence of condensation is sensed optically and electronics maintain the condensate surface in vapor pressure equilibrium with the surrounding gas. When the dew on the mirrored surface is a constant thickness, in equilibrium with the partial pressure of the water vapor in the air sample, the rate of condensate equals the evaporation. At this point, the temperature of the mirror equals the dew point temperature. The conditioned output voltage is proportional to the dew point temperature according to the algorithm in Table 2.

Specifications

Range: -75° to +50°C nominal
Time Response: 1°C s^{-1} typ.

Calibration

A standard calibration was performed on the instrument in March 1992. System balance checks were performed during the project to assure correctness of the instrument. Daily measurements of temperature and dew point were made with an aspirated pyschrometer. This was used as a basic check that the instruments were in working order, not as a calibration.

Operational procedures

The dew point hygrometer system, with sensor permanently mounted on the aircraft fuselage, was powered and allowed a warm-up/stabilization of at least 30 minutes prior to an operational ground check via the aspirated psychrometer. After the take off, often while enroute to the research area, the dew point system was placed in the balance mode, allowing the control circuitry to be electrically compensated for the optical effects of accumulated contamination on the optical surfaces. The function switch was then returned to dew point mode for sensing and data collection.

4.4 Static Pressure Transducer

The Rosemount Model 1201F2A14A1A Pressure Transducer consists of a precision capacitance pressure-sensing capsule with electronic signal conditioning. It senses the ambient air pressure through a static pressure port mounted on the skin of the aircraft cabin. Conversion from pounds per square inch absolute (psia) to millibars is through the algorithm given in Table 2.

Specifications

Range: 0 to 15 psia
Static Error: ± 0.10% FSP max.
Resolution: Continuous

Calibration

None is required in the field. An audit of the instrument performance was conducted during the BAO tower flyby 13 April 1990; no adjustment was necessary. A calibration with reference to a dead weight piston gauge was performed June 1992. A check of the transducer is made before each flight using an aneroid barometer which has a National Institute of Standards and Technology (NIST) traceable calibration.

Operational procedures

The instrument, tubing and static port were permanently mounted on the aircraft fuselage and wired into the aircraft system. When the scientific power was enabled in the aircraft, the instrument was powered. The instrument output voltage was connected to the data acquisition system before the field study. There is no additional operation required.

4.5 Solar Radiation Sensor

The LI-COR Model LI-200SB Pyranometer Sensor, uses a silicon photodiode for measuring solar radiation received from the whole sky (180° field of view). Often referred to as global solar radiation, this is a measurement of the direct component of sunlight plus the diffuse component of skylight received together on a horizontal surface. The output signal is proportional to the light intensity across the selected bandwidth. Through signal conditioning, the output voltage is directly proportional to watts per square meter, as given in Table 2.

Specifications

Range: 400 to 1100 nm

Sensitivity: Typ. 80 μA per 1000 W m^{-2}

Calibration

No calibration is performed in the field. Calibration was performed by the manufacturer against an Eppley Precision Pyranometer. The calibration was performed under full-sun conditions at midday 25 April 1983. A more recent calibration was accomplished December of 1991 with reference to the NOAA reference standard, a TM1 model MKVI serial number 67502 active cavity radiometer.

Operational procedures

The sensor was mounted upward on top of the cabin and connected to the data acquisition system before the field study. No other preparation was necessary as this instrument required no power.

4.6 Optical Array Probe

A Particle Measuring Systems (PMS) Model OAP-2D2-C, two-dimensional cloud particle imaging instrument, was installed outboard and below the right wing of the research aircraft. A linear array of 32 active silicon photodiodes (elements) form the sensor that is illuminated by a laser beam via suitable beam forming optics and mirrors. The transit of each particle through the sample area shadows various array elements depending on its size and orientation during transit. The signals from these elements are processed in a high speed data storage register as a series of 32-bit image slices, at a rate of up to 4 million per second, which develop a true two-dimensional image of each particle.

Specifications

Size range (nominal resolution): 25-800 μm

Particle Size Resolution (Bits): 32 x 1024 (width x length)

Maximum count rate: 4,000,000 slices s^{-1}

Calibrations

Droplet Measurements Technology: October 1990

Laboratory: Prior to the field experiment, the probe was calibrated in the laboratory using calibrated spheres and a Droplet Measurements Technologies (DMT) spinning optical disk etched with particle images of graduated sizes.

Onsite: During the field experiment we checked the probe with the DMT spinning disk on a mission by mission basis.

4.7 Forward-Scattering Spectrometer Probe

A Particle Measuring Systems (PMS) Model FSSP-100, designed for in-situ particle size measurements, was installed outboard and below the left wing of the research aircraft. A laser beam is focused to illuminate a sample area in a transverse air flow from one side while collecting optics view the area from the side opposite the flow. Particles passing through the sample area scatter energy in proportion to their size to two solid-state photo-detectors via a beam splitter for measurement. The probe has four overlapping size ranges with each range divided into 15 linear size intervals, providing 60 channels in a 0.5-47 μm range. For this application the instrument was operated on range 0, which spans 3-47 μm, or range 1, for 2-32 μm.

Specifications

Range: 3 to 47 or 2 to 32 μm (15 bins)
Resolution: 0.5 μm

Calibration

Manufacturer: Performed 2 May 1988.
Droplet Measurements Technology (DMT): Performed May 1992.
Laboratory: Prior to the field experiment, the calibration of the probe was verified by passing monodisperse latex or glass particles through the sample area. Also, a spinning slit designed by DMT was used to check calibration.
Onsite: Simple calibration checks were accomplished using the spinning slit and calibrated latex or glass particles.

4.8 Long Range Navigation (Loran) System

The Advanced Navigation Inc. (ANI) Model 7000 Loran-C was installed (early 1985) as a permanent navigational aid for position data on the research aircraft. Loran-C is a third generation, stable, low frequency radio navigation system which broadcasts from a chain of three to five land-based transmitting stations separated by several hundred miles. Within the chain, one station is designated the master station, and the other stations are secondary stations. Signals transmitted from the secondaries are synchronized with the master signal. The on-board Loran-C receiver measures the slight difference in time that it takes for these pulsed signals to reach the aircraft from various pairs of stations and from different chains. That constant time difference between corresponding secondaries and masters establishes a line-of-position that is used for navigation. Position as a function of latitude and longitude is the processed output. Wind direction and wind speed are computed in real time using the Loran-C output, calculated true airspeed, and aircraft heading information from other onboard navigation instruments. Latitude and longitude are converted to decimal degrees.

Calibration

Manufacturer calibrated. However, occasional checks are made by the flight crew and a specific test was conducted of the system over the Boulder Atmospheric Observatory (BAO) on 13 April 1990. The system reliably determines ground positions and accurately derived the position of the tower.

Operational procedures

The flight crew controlled the Loran-C as well as the radios and other navigation aids. The output data from the Loran-C and the heading data were recorded by the onboard data acquisition system and used to compute in-flight wind speed and direction.

4.9 Global Positioning System (GPS)

A Trimble Navigation Model 2000 airborne GPS receiver was added (late 1992) to the suite of instruments onboard the aircraft for use by the flight crew and as a scientific research tool. The Global Positioning System, developed by the Department of Defense, is a satellite-based triangulation method of determining a position (ground or airborne). This triangulation technique measures distance by comparing the travel time of pseudo-random coded radio transmissions from precisely positioned reference satellites. The receiver processor and the satellites contain very accurate synchronized clocks and generate exactly the same codes at exactly the same time. The timing difference between the received satellite code and the receiver internal code is processed as a distance. Several such satellite range determinations processed with precise satellite position information yield a specific receiver position. The sophisticated receiver in this application provides three-dimensional position (latitude, longitude, and altitude) as well as velocity information, high-resolution display and much more for the user.

Calibration

Manufacturer calibrated. An internal comprehensive diagnostics routine assures proper performance at all times.

Operational Procedures

The flight crew controlled the GPS as one of the onboard communications and navigation aids. The output data from the GPS were recorded by the onboard research data acquisition system installed in the cabin. These data were used post-flight in computations of wind and position information for comparison to the Loran-C generated information.

4.10 Sulfur Hexafluoride Analyzer

The ScienTech Model TGA-4000 trace gas analyzer was designed for continuous, real-time measurement of sulfur hexafluoride (SF_6) (Benner and Lamb, 1985). Equipped with a custom pulsed mode electron capture detector, it is capable of detecting SF_6 in air at mixing ratios as low as 5 parts-per-trillion by volume (pptv). This type of detector is particularly sensitive for compounds containing halogens (such as fluorine) as well as compounds containing sulfur, nitrogen, and oxygen. Hydrocarbons and oxygen in the sample are continuously removed by catalyzed reaction with a precisely metered amount of hydrogen added to the incoming sample. The water vapor product of this reaction is removed by drawing the sample through water permeable Nafion tubing over which a dry stream of nitrogen passes. The drive to equalize the concentration on either side of the Nafion membrane pulls the water into the nitrogen stream, which is then exhausted from the instrument. The sample then passes through the detector containing a radioactive source emitting thermal electrons. A voltage potential (in this case pulsed) applied across the detector forces the free electrons to collect at the detector anode, providing a steady-state current in the nano-amp range. As an electron-capturing compound such as SF_6 enters the chamber, electrons are absorbed by the compound, fewer pass to the anode, and a decrease in current is observed. An increase in concentration of the trace gas results in a measurable current decrease. An electrometer, electronic filtering and amplification then condition the detector signal for the user. Both the catalytic conversion and the sample air drying process are very temperature sensitive, therefore a means has been provided to monitor and control process temperatures to within plus or minus one degree Celsius.

Specifications

Range: 5 to 5000 pptv
Response Time: < 400 ms (0-63% of a step change in SF_6 concentration)
Lag Time: ~ 1-2 s

Calibration:

Multiple-point calibration performed onboard before each flight; inflight checks were accomplished as time permitted.

4.11 Liquid Water Content

A CSIRO-King developed instrument for the measurement of liquid water content (LWC), manufactured by Particle Measuring Systems as PMS Model KLWC-5, was installed outboard below the right wing on the research aircraft. The sensor element is a heated wire coil maintained at a constant temperature much higher than the ambient air or any liquid water which may impact on it. The coil is the dependent resistance in a bridge circuit and the power used to keep it heated is directly proportional to the mass of water impacting on it.

Specifications

Range: 0 to 1, or 0 to 6 g m^{-3}
Response Time: 50 ms
Resolution: 3.5 m at 75 knots

Calibration

Manufacturer: Performed December 1988.
Periodic checks are accomplished in the field to assure that the unit is responding properly to water impacting on the coil. Comparisons are also made with the FSSP and OAP probes.

Operational procedures

The instrument was installed and connection made to the data acquisition system before the field study. The instrument cannot be run on the ground without approximately 40 m s^{-1} airflow over the element. Power to operate the instrument is enabled only by a "weight-on-wheels" switch after aircraft take-off or by a manual override on the ground for testing.

4.12 Aircraft Data Acquisition System

The Science Engineering Associates (SEA) Model 200 data acquisition system is based on the IBM AT computer system architecture with a table-driven software package. Most features of the system are controlled by user-modifiable text tables. These user tables control acquisition, computation, display, and storage. The tables may be modified by most word-processing programs, allowing the user to configure the system easily for each new research program.

Specifications

Computer: Intel 80386 CPU, 20 MHz, 80387 math co-processor.
Clock: Using the 8Mhz bus frequency as a base frequency.
Screen: Dual VGA monitors
Analog to Digital: 32 differential input channels, 16 bit A/D acquisition rates, 0 to 6000 Hz
One dimensional probe interface: Acquisition rates 0-3000 Hz.
Two-dimensional probe interface: Asynchronous acquisition
Storage medium: Dual 40-Megabyte small computer systems interface tape drive.

Calibration

The A/D converter is audited annually against a National Institute of Standards and Technology (NIST) traceable, calibrated millivolt standard.

5. DATA PROCESSING

Data were recorded inflight on 40-Mbyte tape cartridges. After flight, the data were transferred to a PC for processing. A program, incorporating the equations in Table 2, was used to process 1-second averaged files in engineering units (pre-program values were used initially, then updated as field calibrations were performed). Headers defining the variable were added to each column and the files were saved in ASCII format.

Table 2. Measurements and algorithms used for data reduction

Measurement	Algorithm
Time	Read directly from onboard computer
True air speed (TAS)(m s^{-1})	$(2C_pT_f[((P+P_d)/P)^{R/mC_p}-1])^{1/2}$ where C_p = 1005 (J deg-1 kg-1) T_f = Free air Temperature (deg)

P = Static pressure (mb)
P_d = Dynamic pressure (mb)
R/mC_p = 0.28562 (unitless)

Temperature (°C)	(volts x 20.0) - 60.0 <Free air temperature is calculated using TAS>

$$\textit{Free Air Temperature}\ (T_f) = \frac{((Temperature + 273.16) - Offset)}{(((\frac{(P + P_d)}{P})^C - 1) * Alpha1) + 1}$$

Where:

P = Static pressure (mb)
P_d = Dynamic pressure (mb)
c = R/mC_p = 0.28562 (unitless)
Alpha1 = 0.915 (deg)
and Offset = 0.0 (deg)

Dew point (°C)	volts x 10
Static pressure (mb)	[(volts x 2.996401)-0.00913] x 68.96552
Dynamic press (mb)	[(volts x 67.6398) +3.3448] x 1.103609 - 1.87633
Cabin pressure (mb)	(volts x 217.2572)-201.026
Solar radiation (W m^{-2})	(volts x 1090.1)
Latitude (deg, min)	Read directly from LORAN
Longitude (deg, min)	Read directly from LORAN
Heading (deg)	Read directly from LORAN
Wind direction (deg)	arctan(V/U)(180/π) (simplified equation)
Wind speed (m s^{-1})	$(U^2 + V^2)^{1/2}$ (simplified equation)

where U is the horizontal (longitude) component of the difference between actual aircraft position and a position calculated using the Heading and True Airspeed.
V is the vertical (latitude) component of the calculation described above.

Particle size distribution

OAP 2D2-C — OAP 2D2-C data were processed by Bureau of Reclamation and sent directly to the State of California Department of Water Resources.

FSSP-100 — [counts/(TAS*SAREA*time in seconds)]/binwidth
where TAS is the true air speed
SAREA is the sample area of the FSSP
binwidth is 3 μm for range 0
2 μm for range 1
1 μm for range 2
0.5 μm for range 3

Liquid Water Content (g m^{-3}) The following equations are used to determine Liquid Water Content.

$$V_{dry} = A * (TSD - T_f) * (P * TAS)^x$$

$$LWC = \frac{(10 * (V_A - V_{dry}))}{\frac{Lv + Cpw * (TSW - T_f) * L * D * TAS}{1000.0}}$$

Where:

V_{dry} = The empirically derived dry Voltage.
V_A = Voltage output from sensor (Volts)
A = 1.962 x 10^{-5}
TSD(Dry Sensor temperature) = 190.0 (°C)
TSW(Water evaporation temperature) = 90.0 (°C)
T_f = Ambient Free Air Temperature from Above (°C)
P = Static Pressure from Above (mb)
TAS = True Airspeed from Above (mb)
x = 0.52
Lv(Latent heat of vaporization) = 2.501 x 10^6 (J kg^{-1})
Cpw(Specific heat) = 4218.0 (J deg^{-1} kg^{-1})
L = Length of the sensor element (m)
D = Diameter of the sensor element (m)

SF_6 concentration (pptv)   SF * (volts - zero offset)

NOTE: Scaling factors (SF) were determined during calibrations.

After the field study, final values for the zero offsets, intercepts, and scaling factors were determined and entered into the processing program, and data were reprocessed using those final values. One-second-averaged files were again created, then those files were processed further by a program that provides additional averaging while checking for data validity (i.e., data from sampling periods were checked to assure that the values were reasonable and were within expected ranges; see Table 3.).

Table 3. Data values that were unreasonable and therefore indicated invalid data

Measurement	Data value
Time	<00:00 or $\geq$24:00
Temperature	<-40 or >60 °C
Dew point	Dew point > temperature or <-40 or >30°C
Static pressure	<350 or >1020 mb
Dynamic pressure	<0 or >65 mb
Cabin pressure	<350 or >1050 mb
Solar radiation	<0 or >1500 W m^{-2}
Particle size	no data eliminated on basis of value alone
Heading	<0 or >360 deg
Wind direction	<0 or >360 deg
Wind speed	<0 or >100 m s^{-1}

These processed files were examined to assure that the calibration equations were properly applied, that spans and zeroes gave the correct values, and that anomalies could be accounted for. Data for each flight were plotted for this purpose. Records of calibrations, instrument status reports, log books etc. were used to determine time periods when verifiable errors or problems occurred. If correction of an error or problem was possible, the data file was reprocessed with the correction applied. The data were then re-plotted to confirm that the proper corrections had been applied. Plots of corrected SF_6 vs. time can be found in Appendix E. The original data files are maintained separately.

6. DATA QUALITY

In addition to the calibration procedures, the following quality control checks are routinely performed on the NOAA aircraft instrumentation:

Time

The computer time is set and checked with WWV, the National Institute of Standards and Technology (NIST) broadcast time and frequency standard, before each flight.

Temperature

On the ground, before each flight, values are checked using a psychrometer and/or data from the National Weather Service (NWS), Federal Aviation Administration (FAA), or the FAA Flight Service Station (FSS).

Dew point

System balance checks are performed periodically in the field as described in the standard operating procedure for this instrument. On the ground before each flight, the dew-point values are checked using a psychrometer and/or NWS, FAA, or FSS information.

Static pressure

On the ground before each flight, data are checked by an aneroid barometer and NWS, FAA, or FSS information to ensure that correct data are being recorded.

Dynamic pressure

A reading is taken on the ground at zero airspeed. If this value is approximately -1.2 mb, a static sensor offset, the system is considered operational.

Cabin pressure

Before each flight, the cabin pressure reading is taken with the cabin door open and checked against the static pressure reading.

Solar radiation

A daily check is made to ensure that the device is functional and in proper operating range.

Particle distribution probes

Prior to the field experiment in the laboratory, monodisperse glass or latex particles are used to verify the calibration of the instrument. During the field experiment, checks are made to ensure that the laser is operating within specifications and that the instrument is responding in a consistent and reasonable manner to ambient aerosols on the ground. Spinning calibration devices were employed regularly before flight.

Latitude, Longitude

The latitude and longitude determined onboard during a flight are compared with the known latitude and longitude of landmarks. One such comparison is made during the BAO tower flyby before the field study begins.

Heading

The heading is checked during the BAO tower flyby and on the ramp by the pilots.

True air speed, wind direction, wind speed

Computed values.

7. DATA AVAILABILITY

The data, in any units requested and averaged over any specified time period greater than or equal to 1.0 seconds, are available in standard ASCII format on any of the following four media:

3½ inch floppies, MS DOS formatted: 720 kbytes or 1.44 Mbytes
5¼ inch floppies, MS DOS formatted: 360 kbytes or 1.2 Mbytes

A listing will accompany the data files that describes the parameters in each column and the units in which the data are reported. Also, an information file is included that provides any pertinent information regarding the data.

Contact Stan Wilkison for information on data and availability at:

Stan Wilkison
R/E/ARX1
325 Broadway
Boulder, CO 80303

8. ACKNOWLEDGMENTS

The successful conduct of this research would not have been possible without the contributions of many energetic professionals. We wish to thank Mr. T. Gates, LCDR M. Finke, and LTJG R.TeBeest of the NOAA Aircraft Operations Center for obtaining the necessary FAA waivers and for the successful and professional piloting of the research aircraft through difficult weather. A special thank you to Ms Patti Walsh, of the Desert Research Institute, for her professional expertise as contract flight observer, as note-taker, and operator of instruments. Thank you very much, also, Mr. Jack McPartland for stepping in as flight observer when needed.

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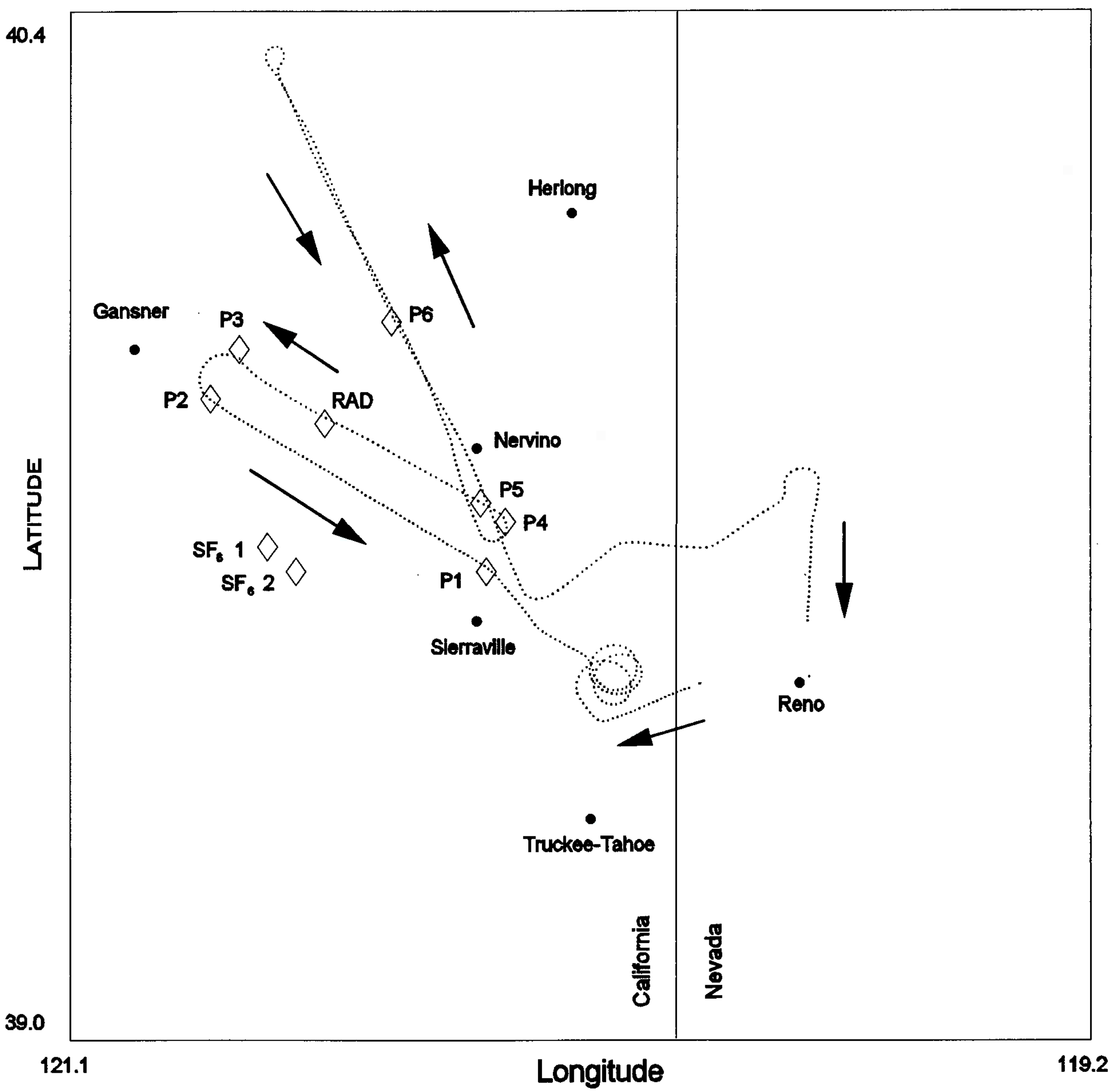
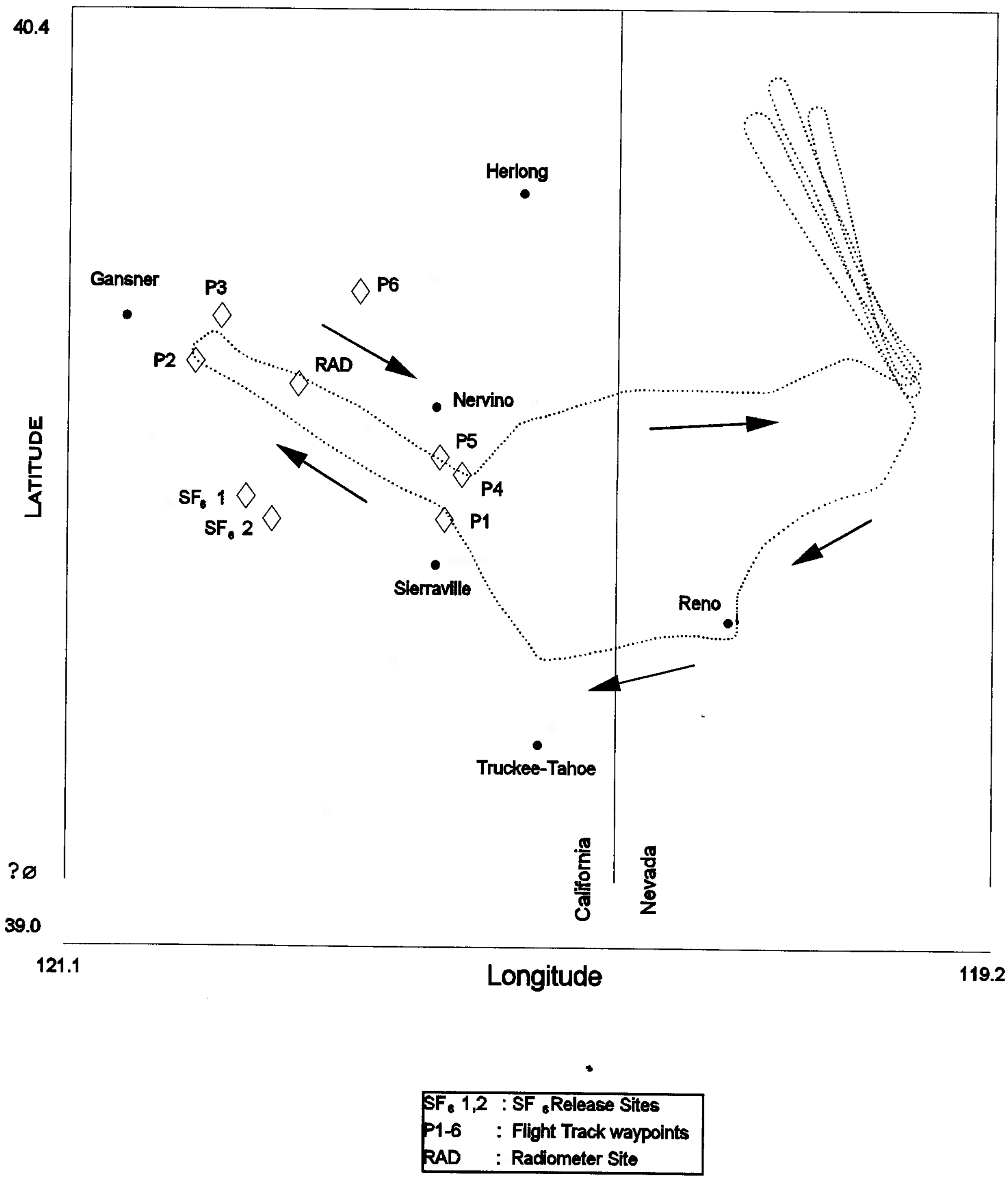
APPENDIX A: Flight Graphs

LOREP 1993
Flight Track for 930123



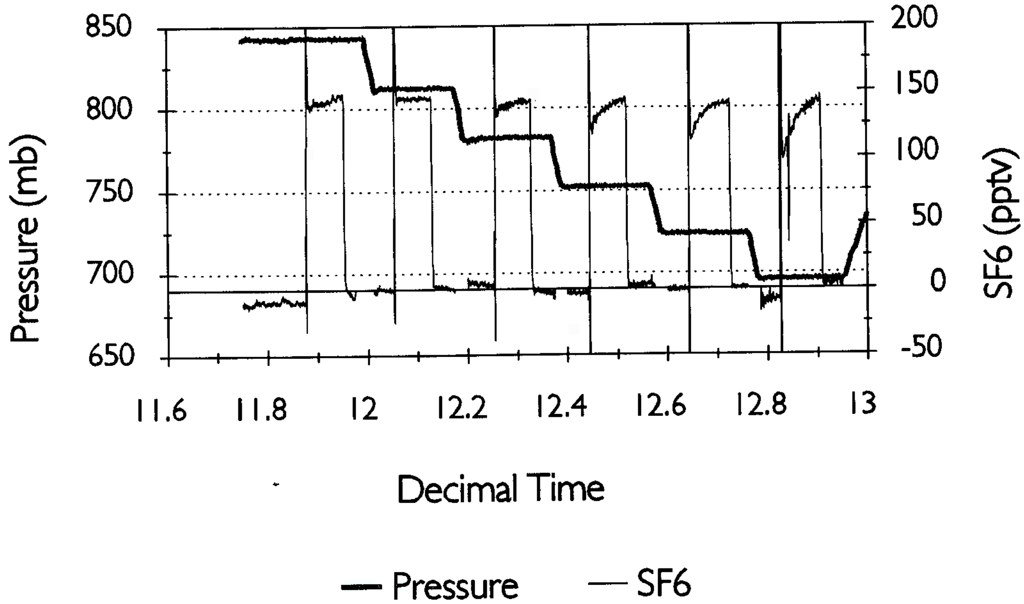
SF_6 1,2	: SF_6 Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

LOREP 1993
Flight Track for 930124

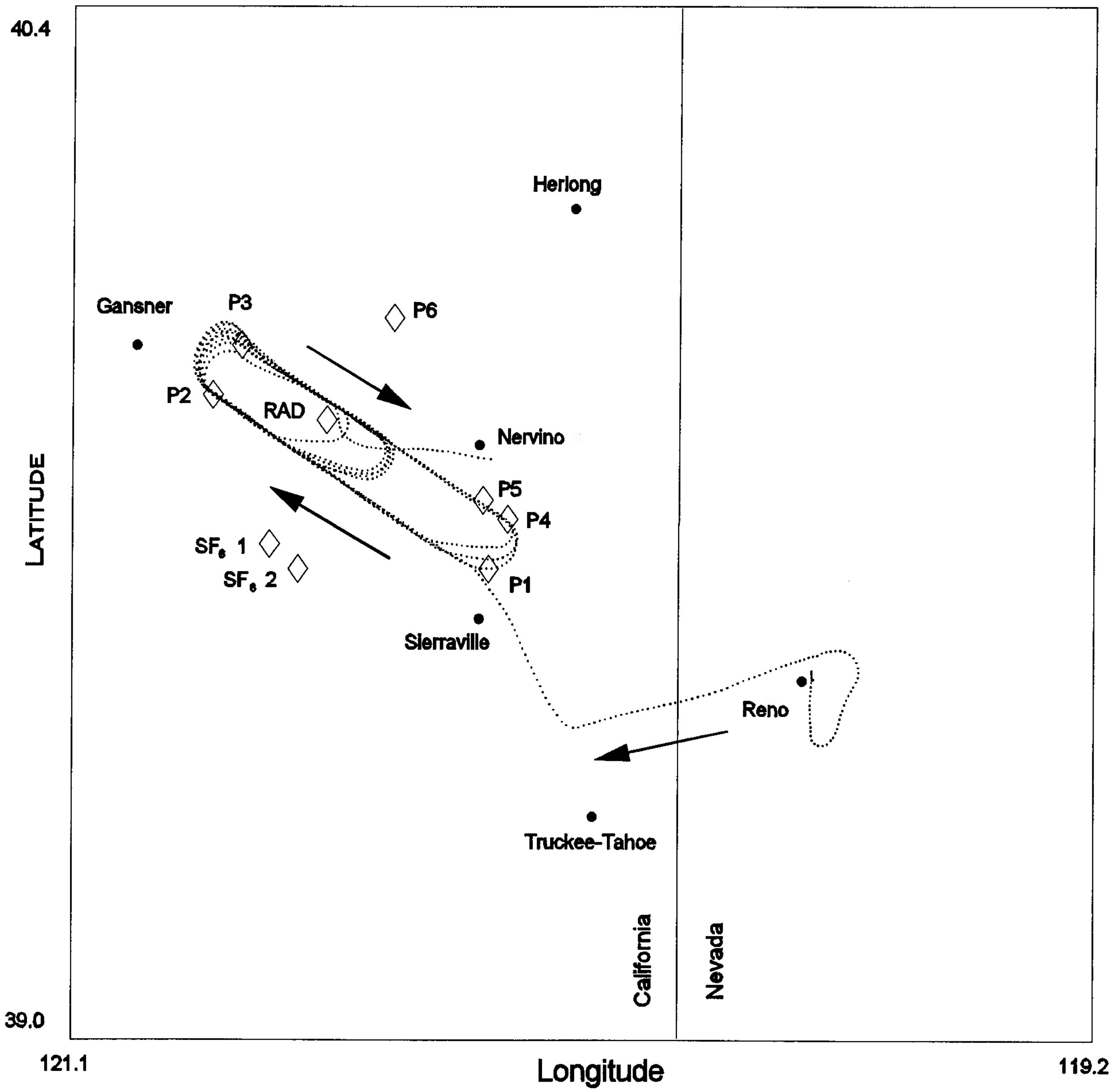


LOREP 1993 930124

Pressure and SF6 Plot (Cal. flight)

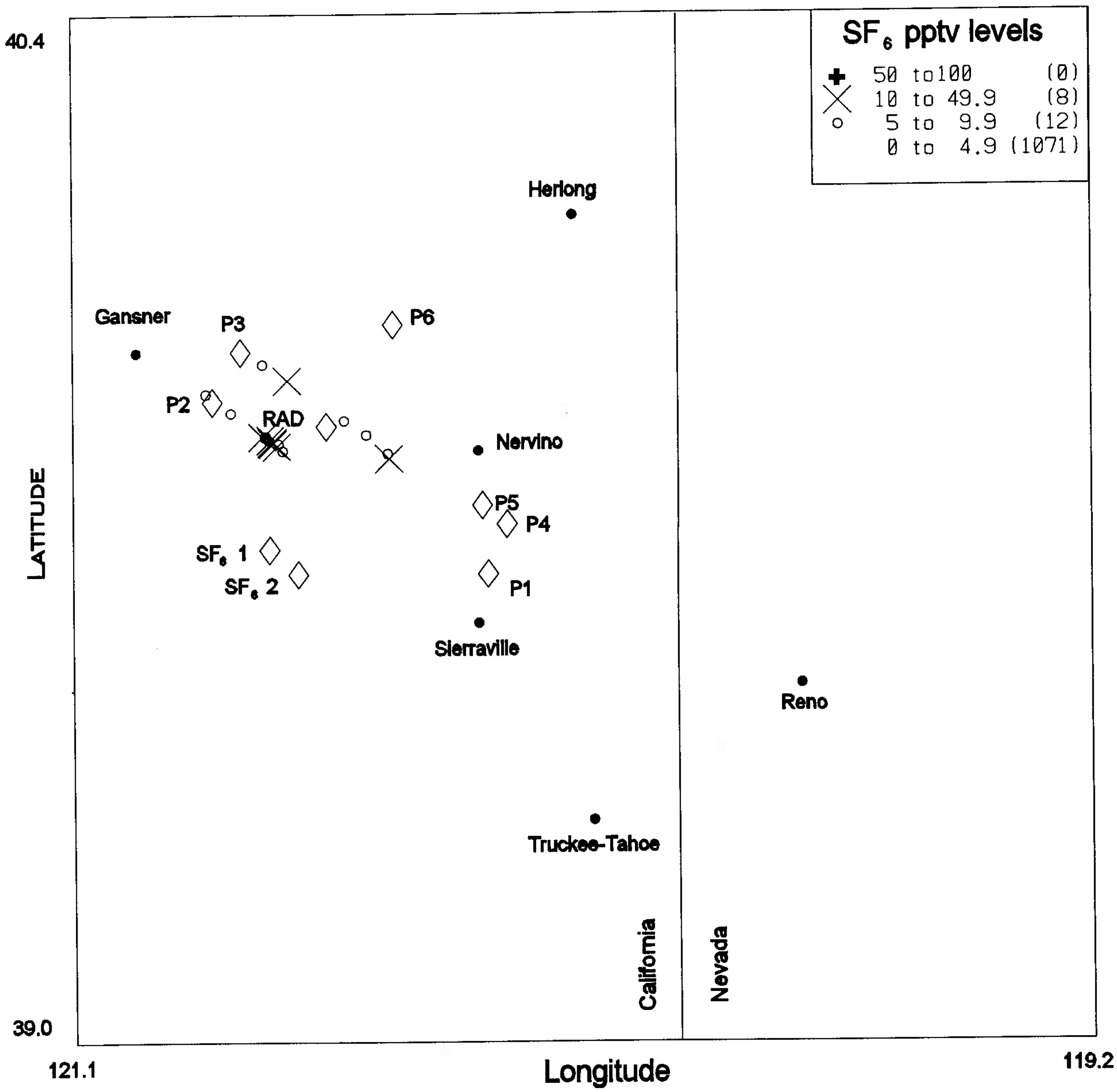


LOREP 1993
Flight Track for 930208



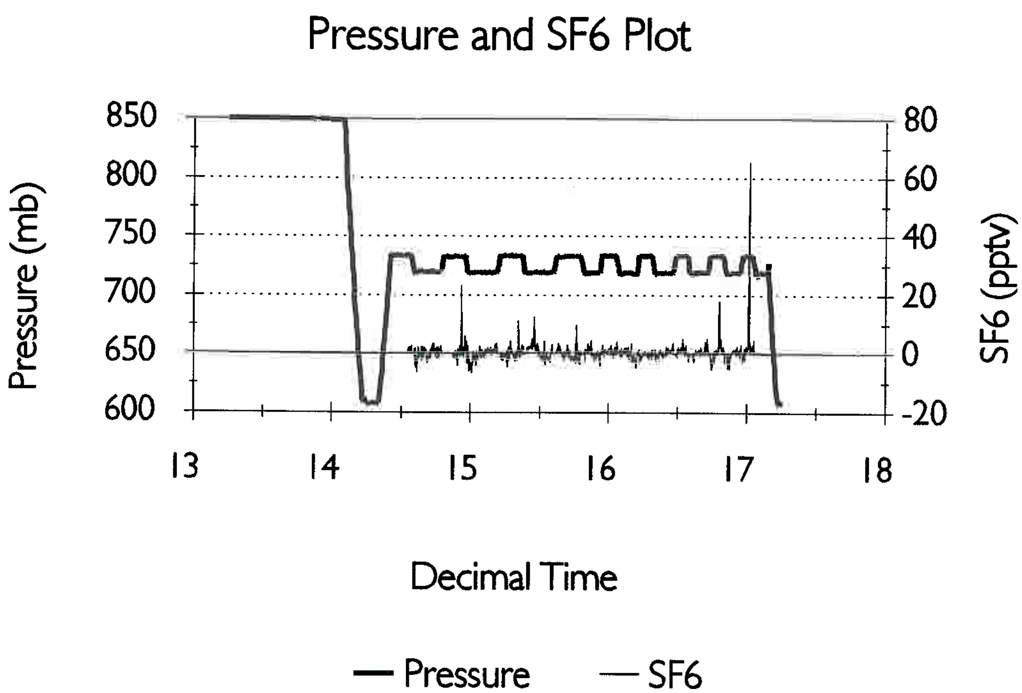
SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

LOREP 1993
SF6 Distribution for 930208

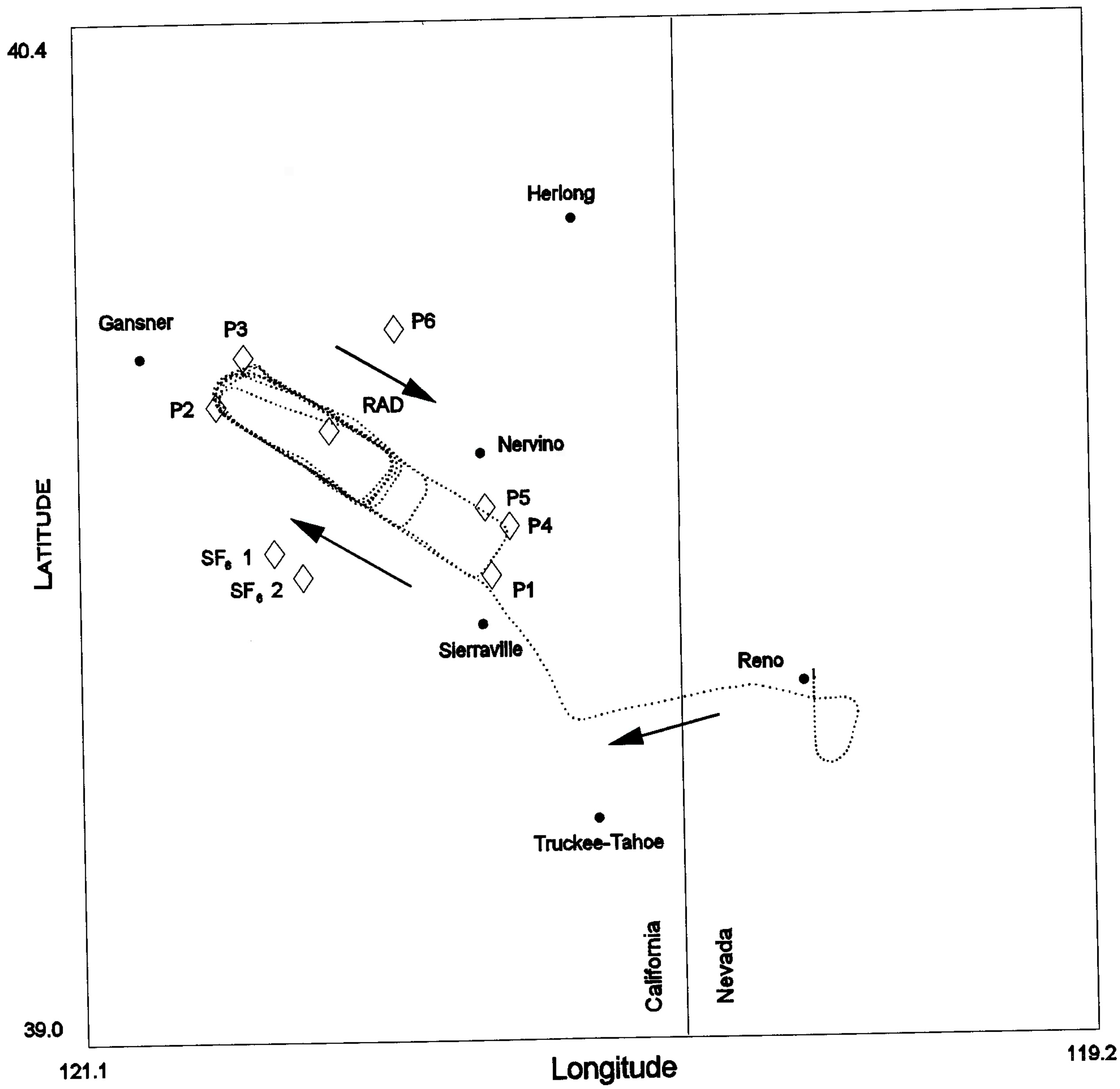


SF_6 1,2	: SF_6 Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

LOREP 1993 930208

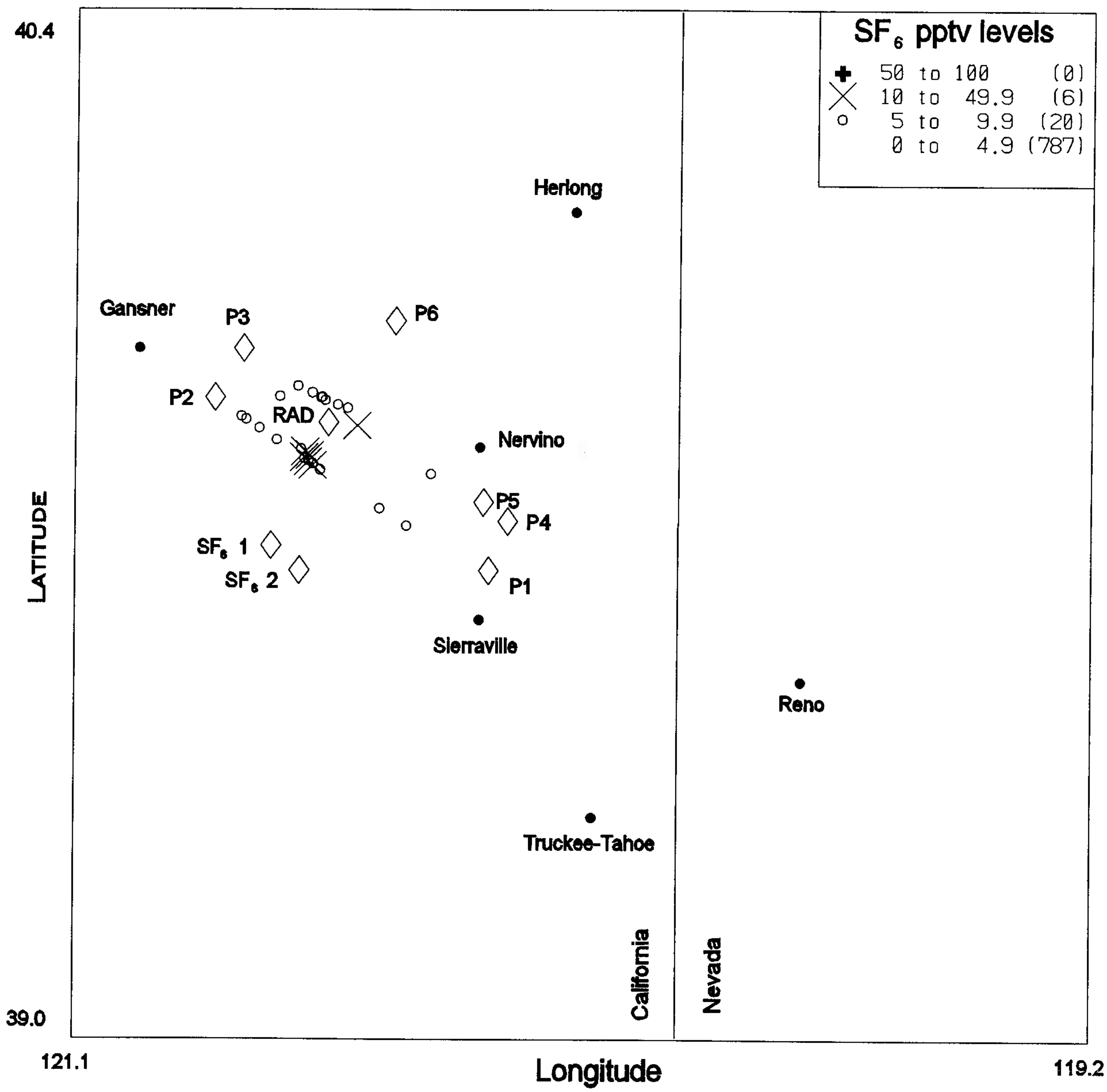


LOREP 1993
Flight Track for 930209



SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

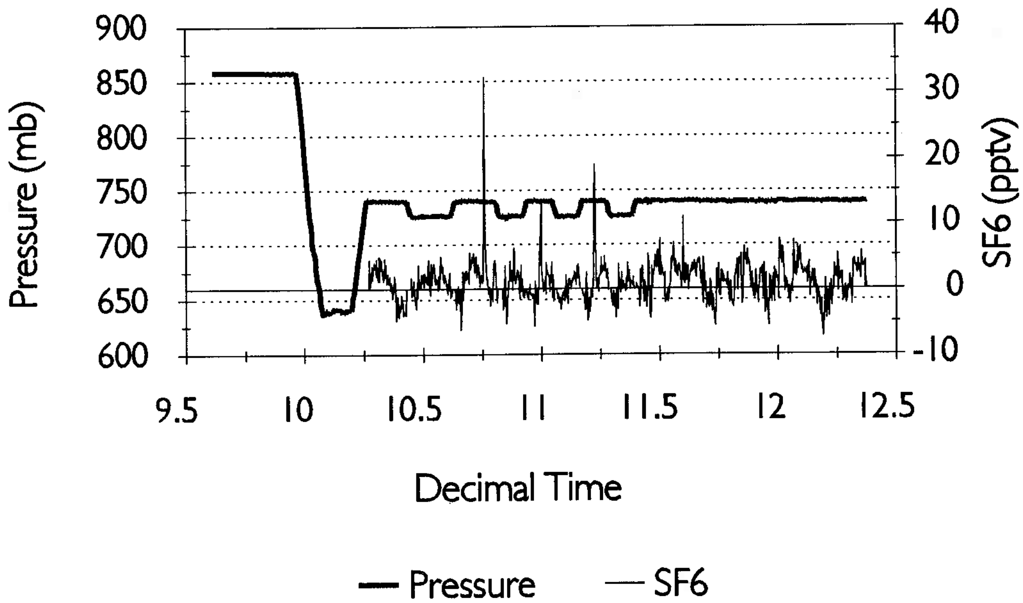
LOREP 1993
SF6 Distribution for 930209



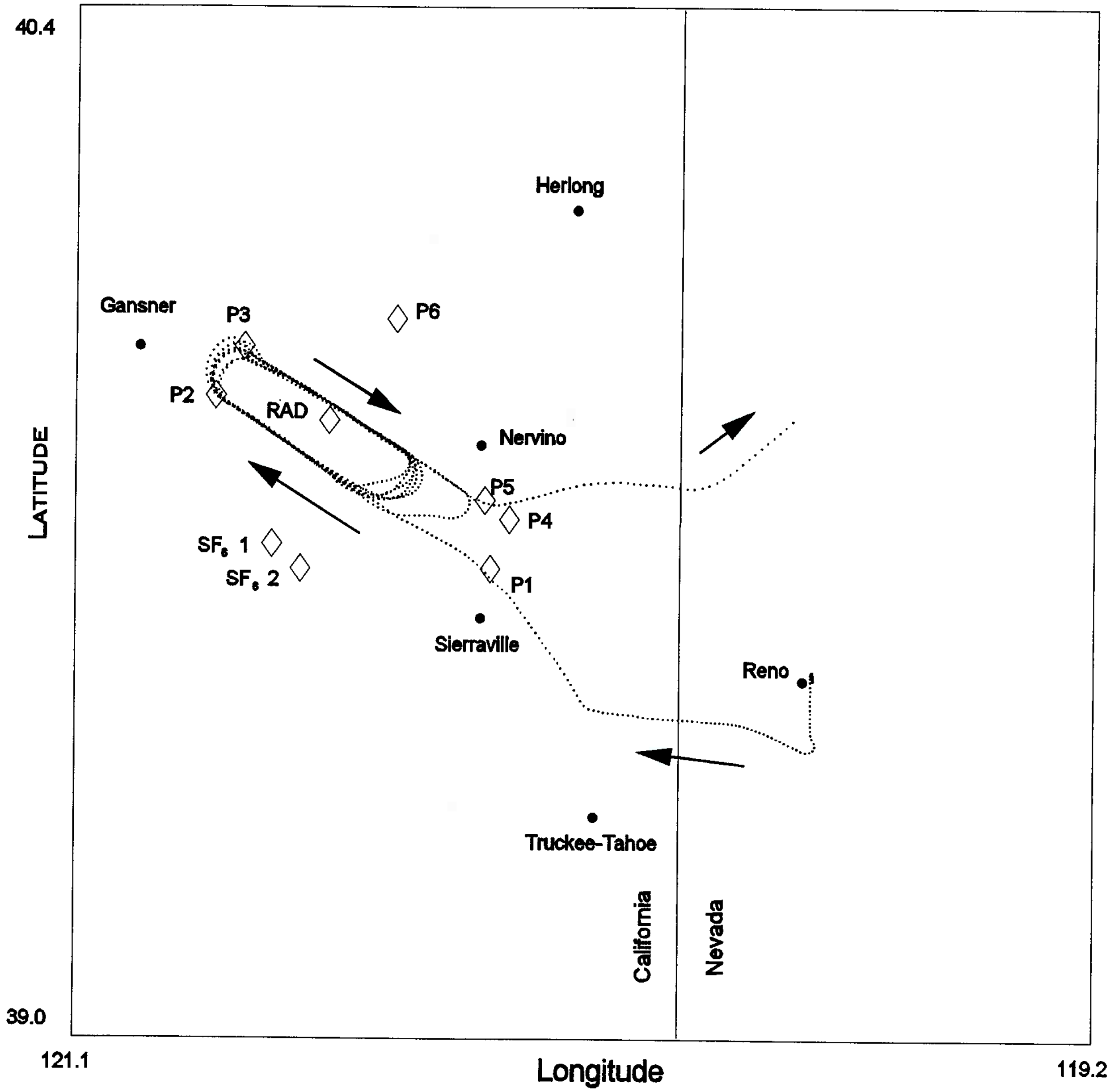
SF$_6$ 1,2	: SF $_6$ Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

LOREP 1993 930209

Pressure and SF6 Plot

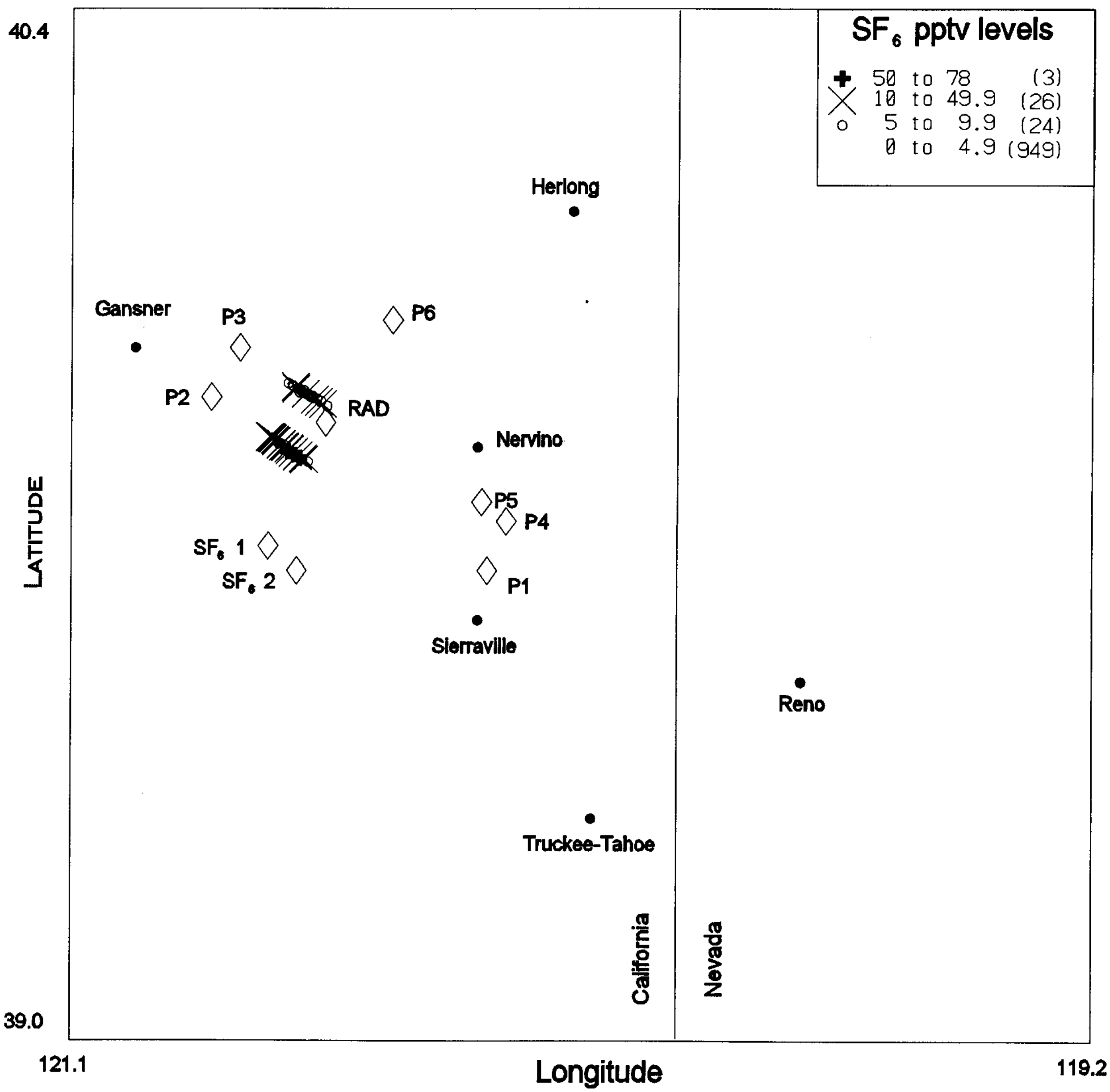


LOREP 1993
Flight Track for 930217



SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

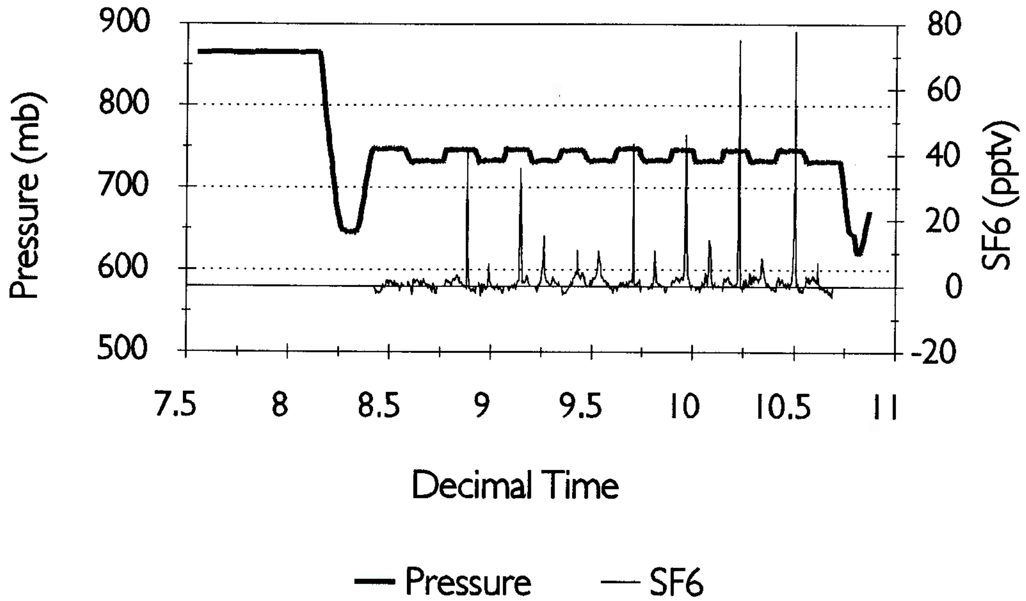
LOREP 1993
SF6 Distribution for 930217



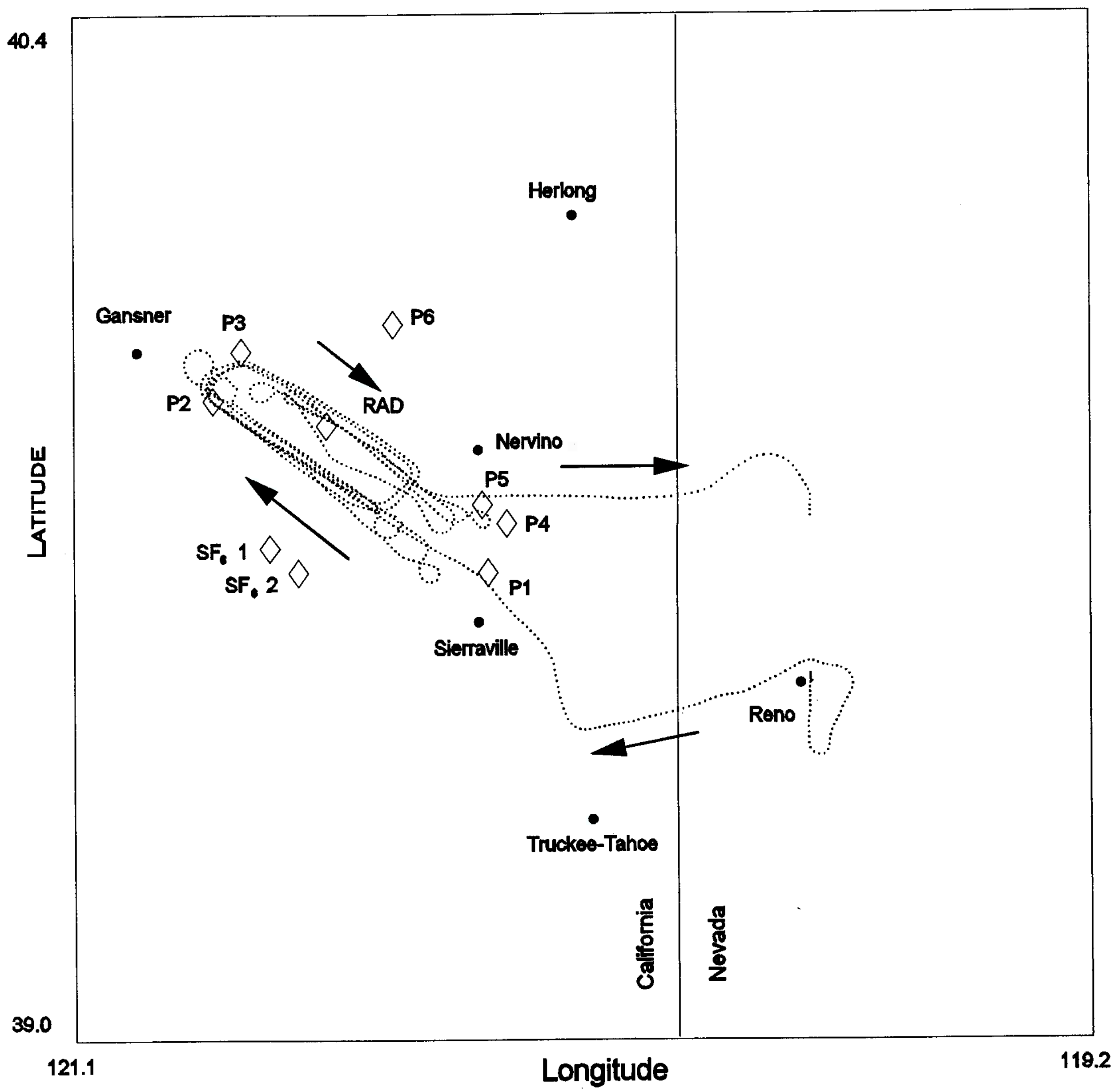
SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

LOREP 1993 930217

Pressure and SF6 Plot

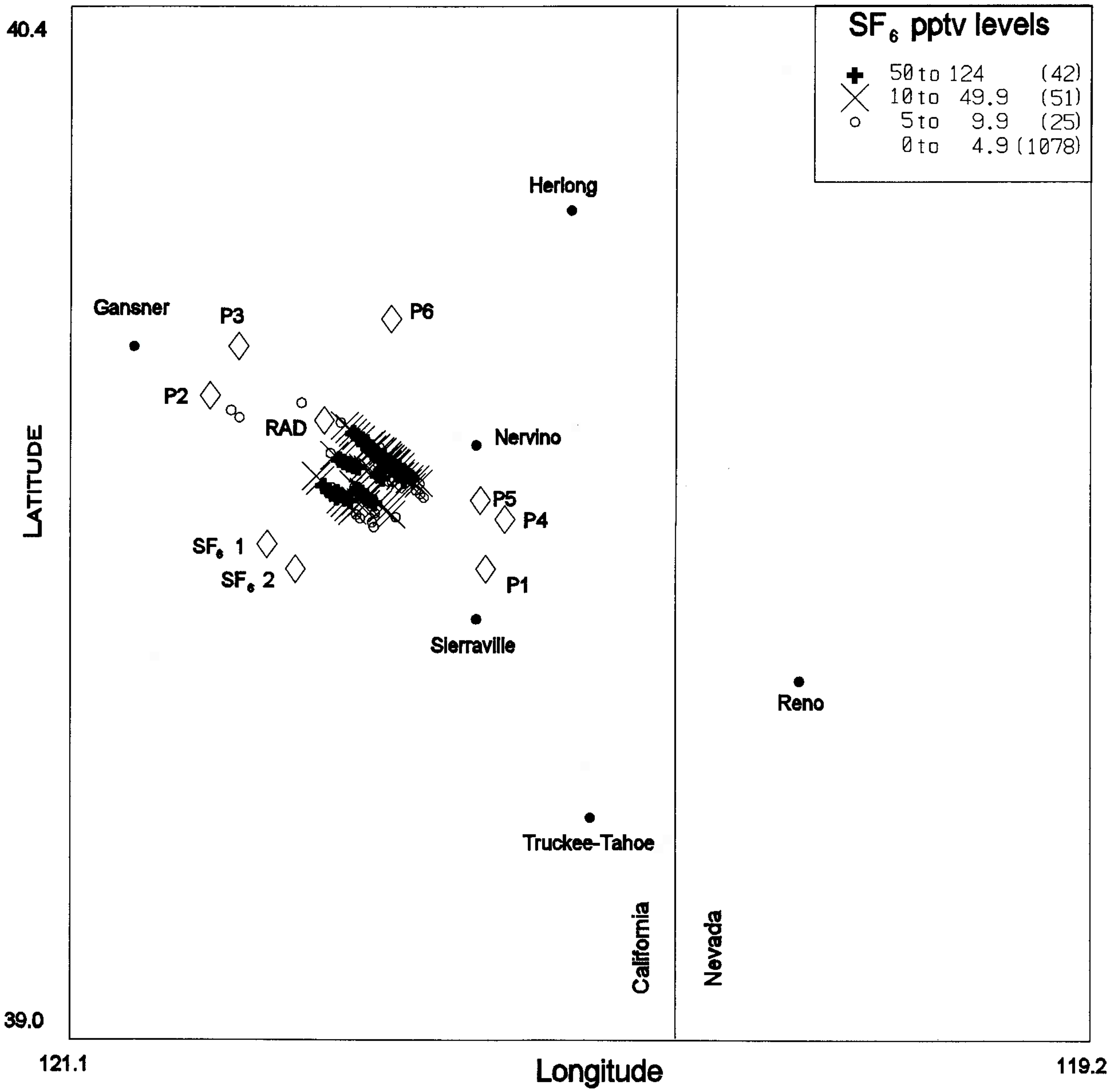


LOREP 1993
Flight Track for 930302



SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

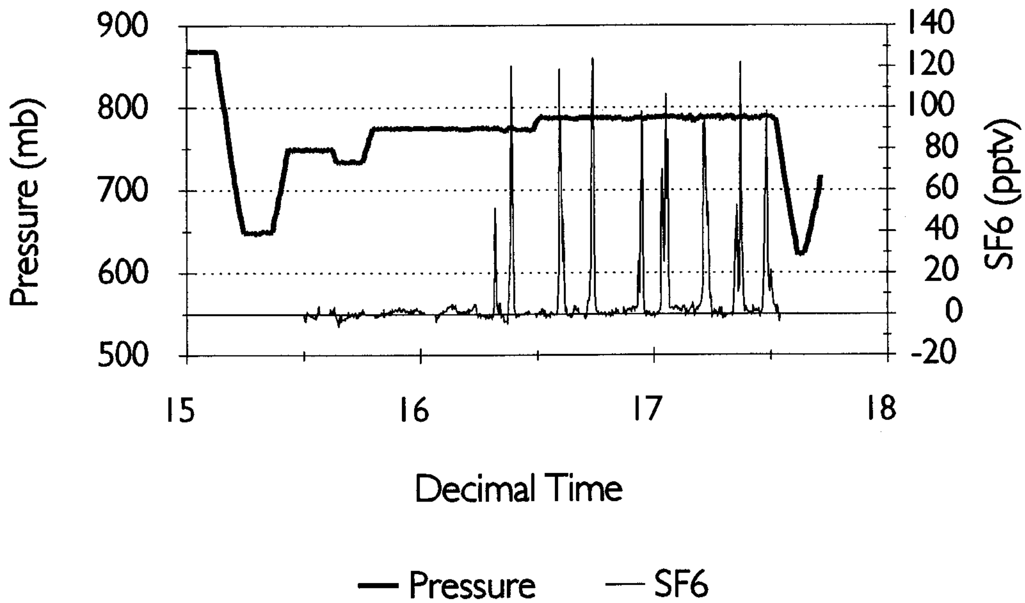
LOREP 1993
SF6 Distribution for 930302



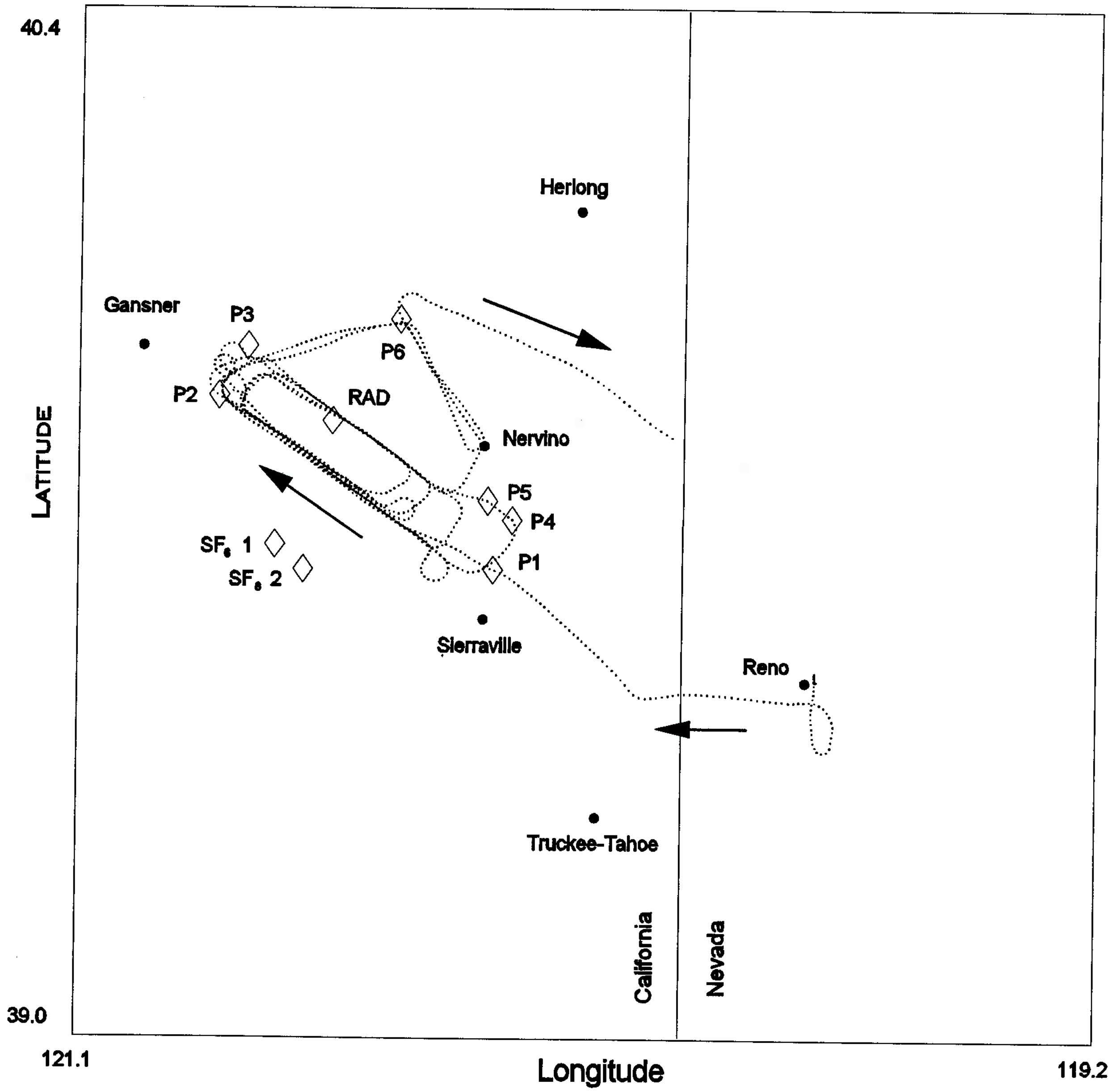
SF_6 1,2	: SF_6 Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

LOREP 1993 930302

Pressure and SF6 Plot

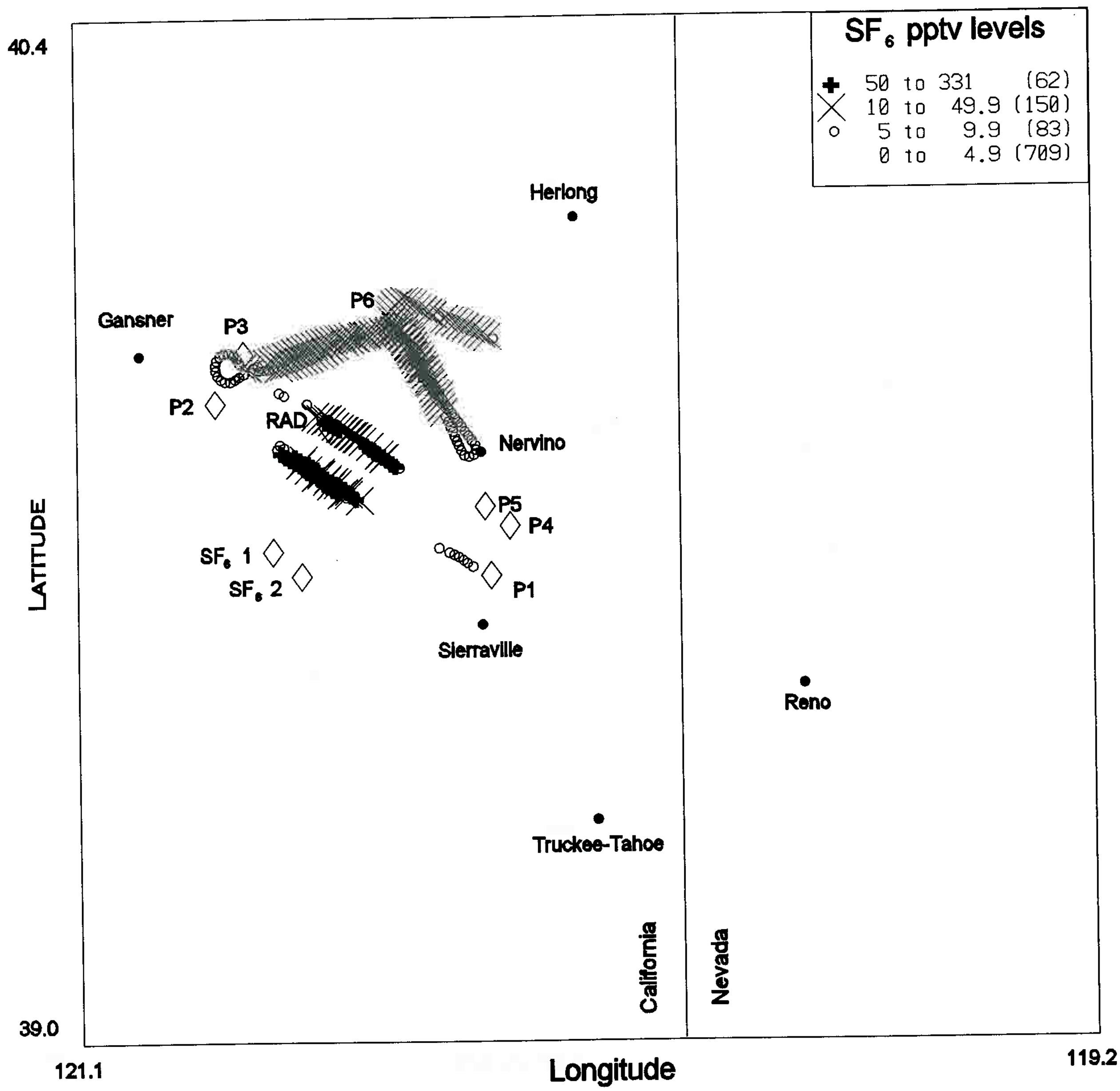


LOREP 1993
Flight Track for 930309



SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

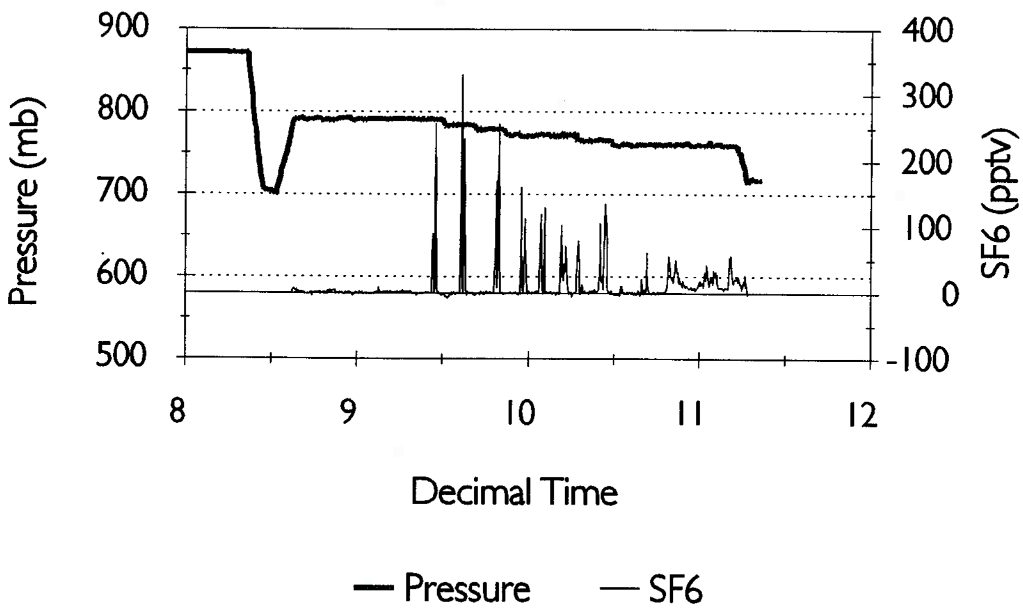
LOREP 1993
SF6 Distribution for 930309



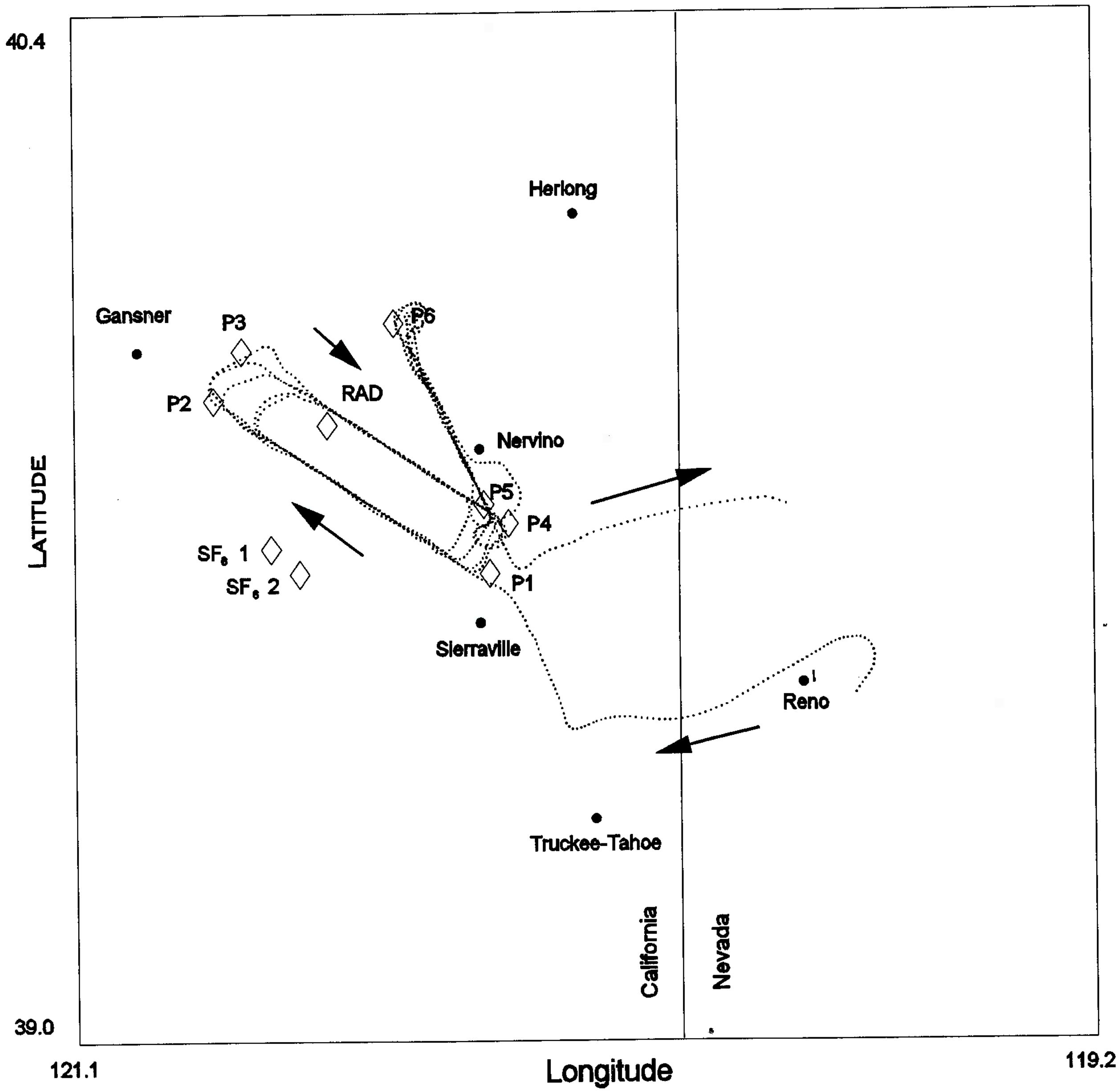
SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

LOREP 1993 930309

Pressure and SF6 Plot

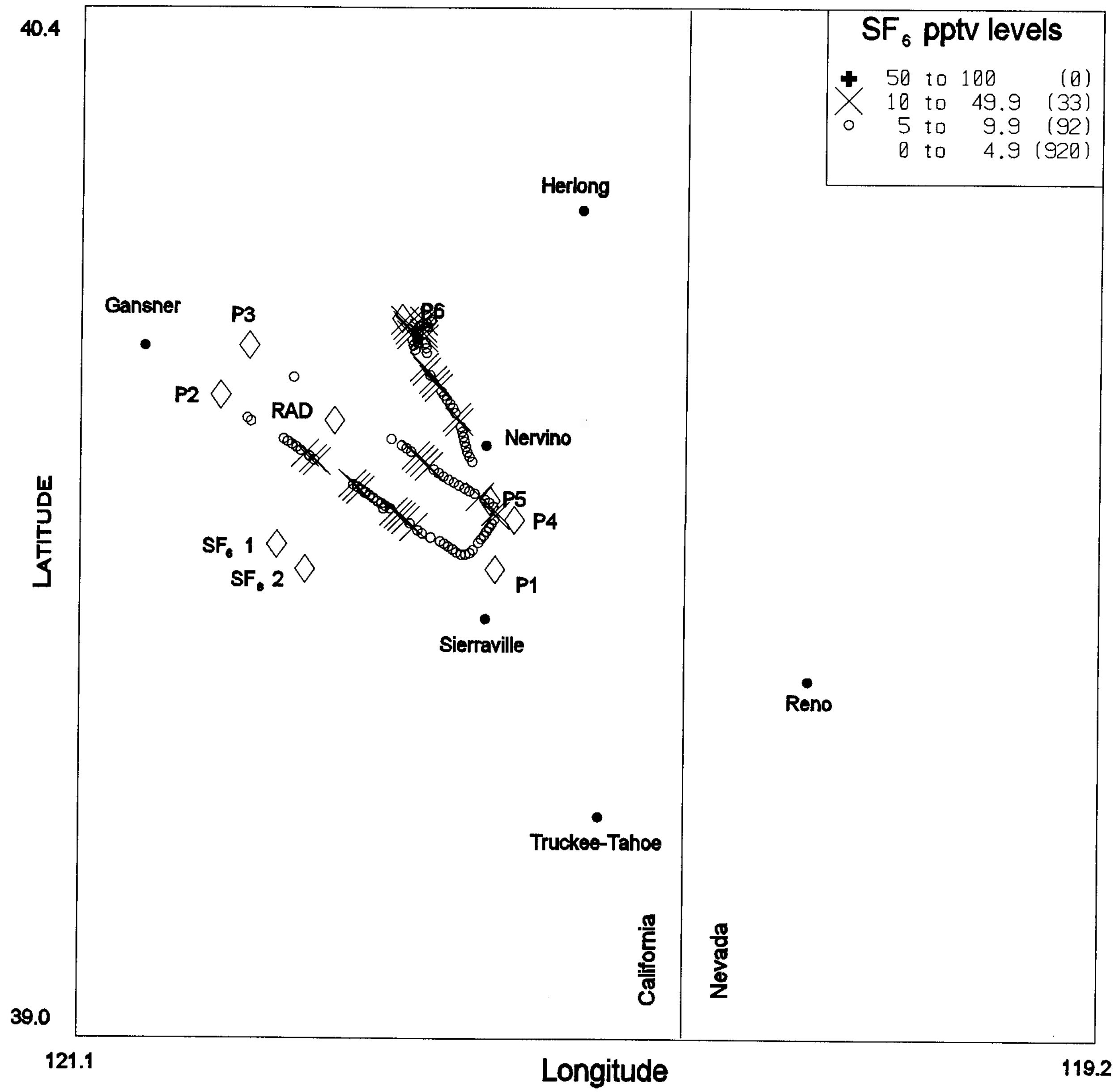


LOREP 1993
Flight Track for 930316



SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

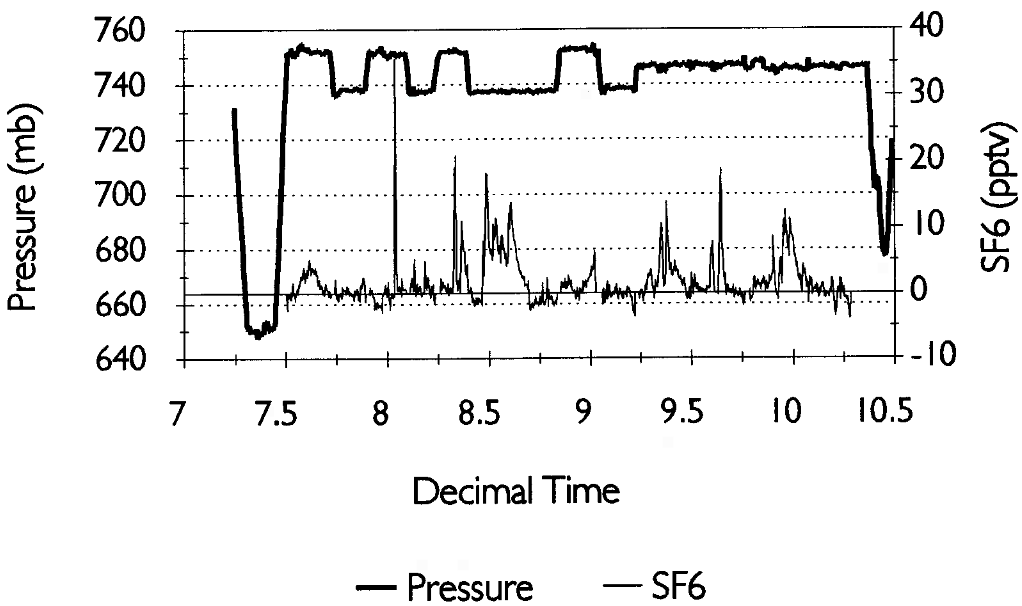
LOREP 1993
SF6 Distribution for 930316



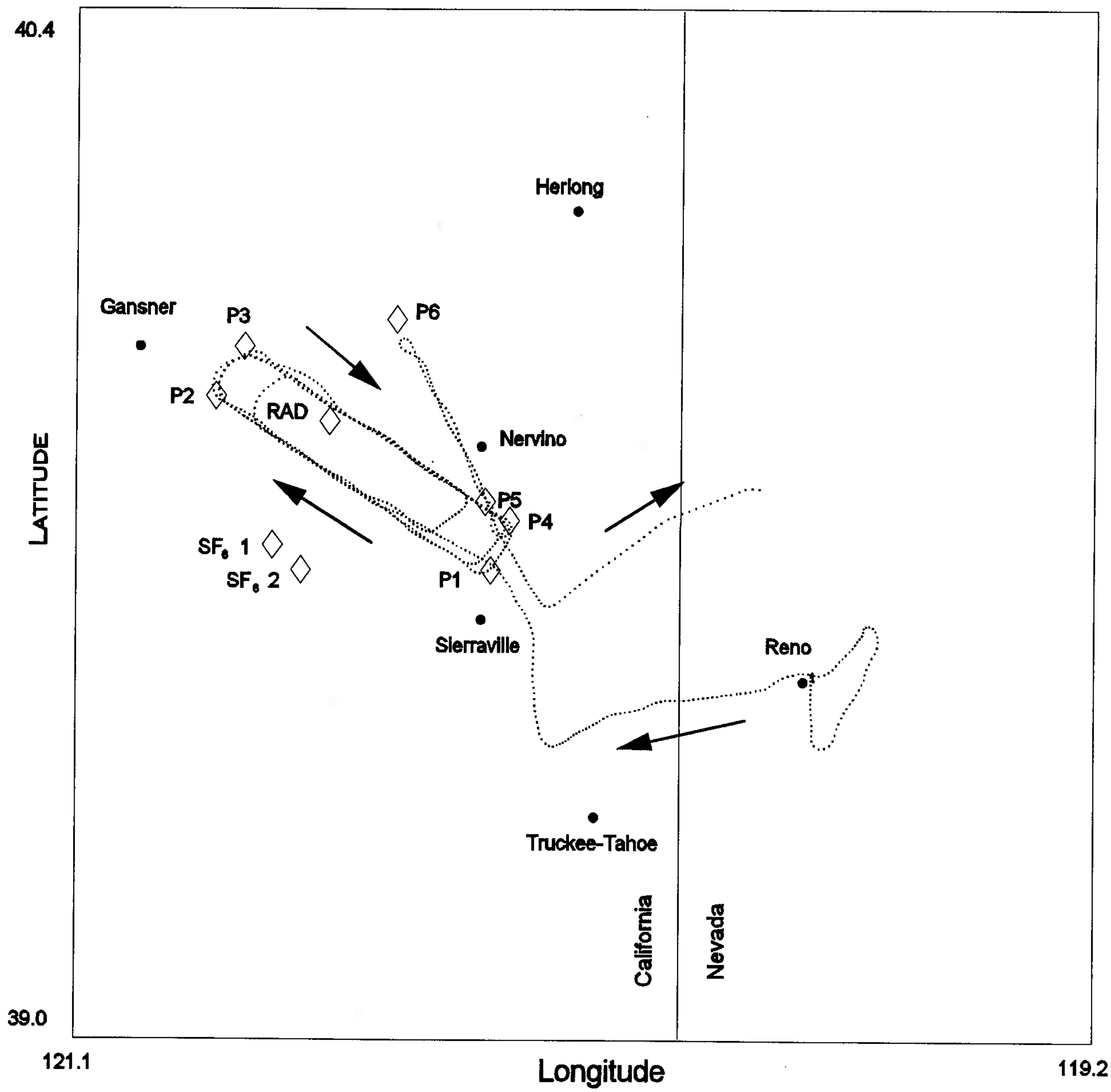
SF_6 1,2	: SF_6 Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

LOREP 1993 930316

Pressure and SF6 Plot

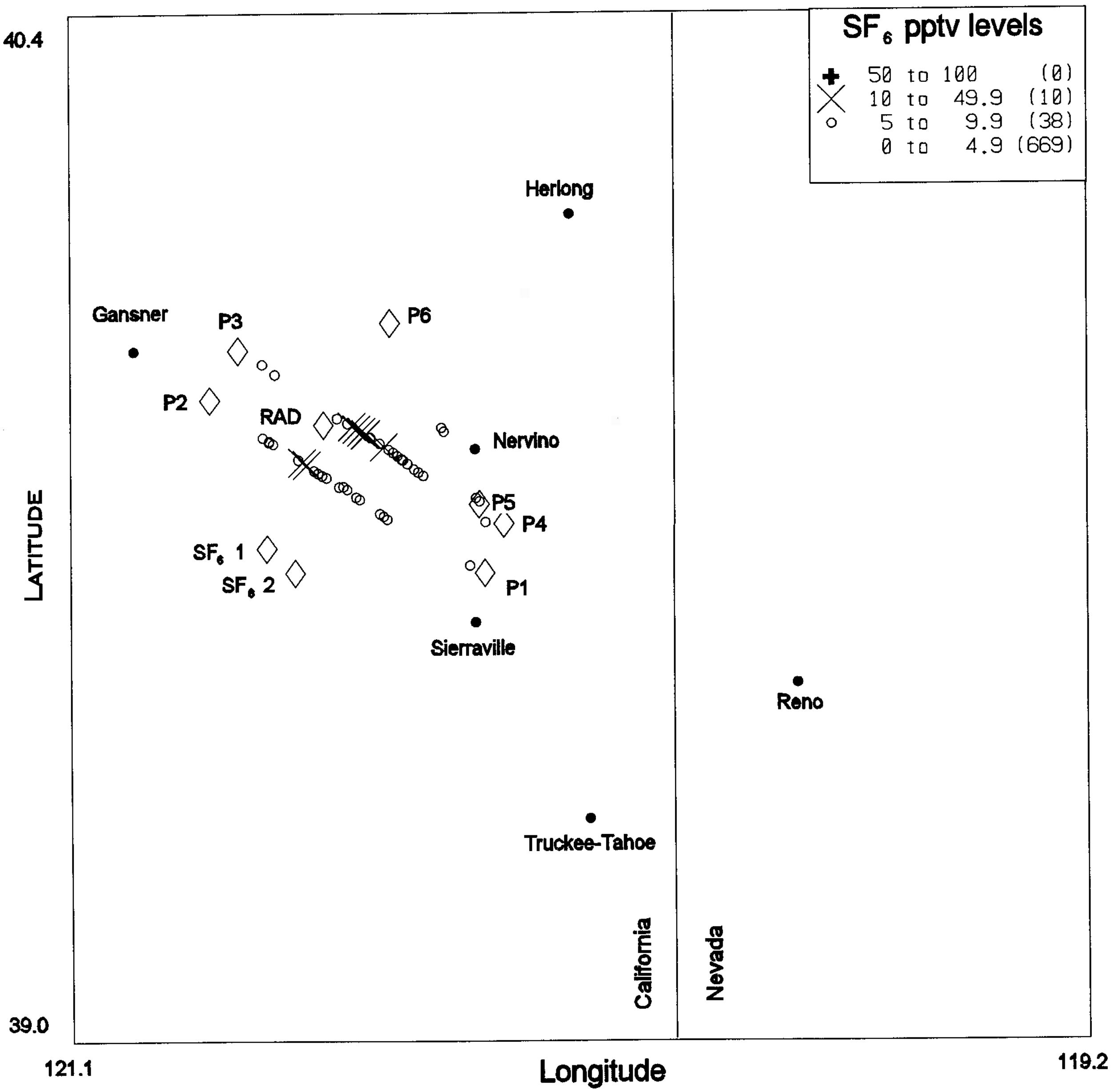


LOREP 1993
Flight Track for 930317



SF_6 1,2	: SF_6 Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

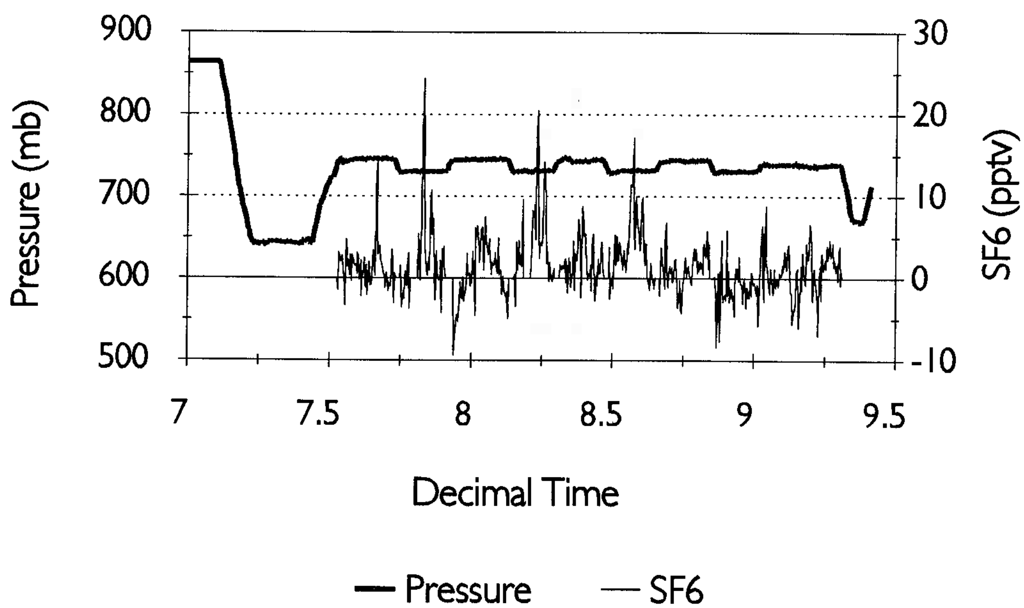
LOREP 1993
SF6 Distribution for 930317



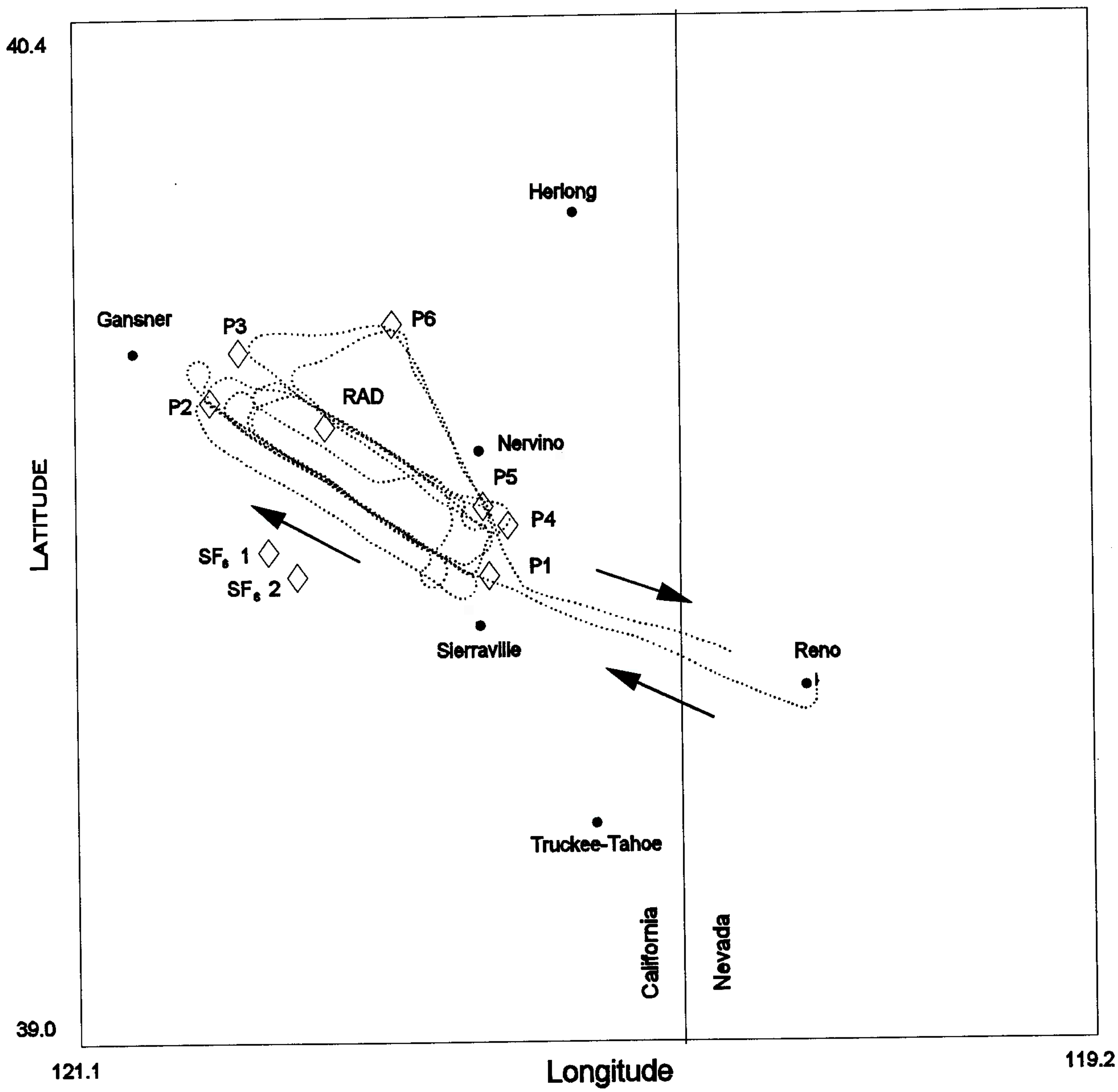
SF$_6$ 1,2	:	SF $_6$ Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

LOREP 1993 930317

Pressure and SF6 Plot

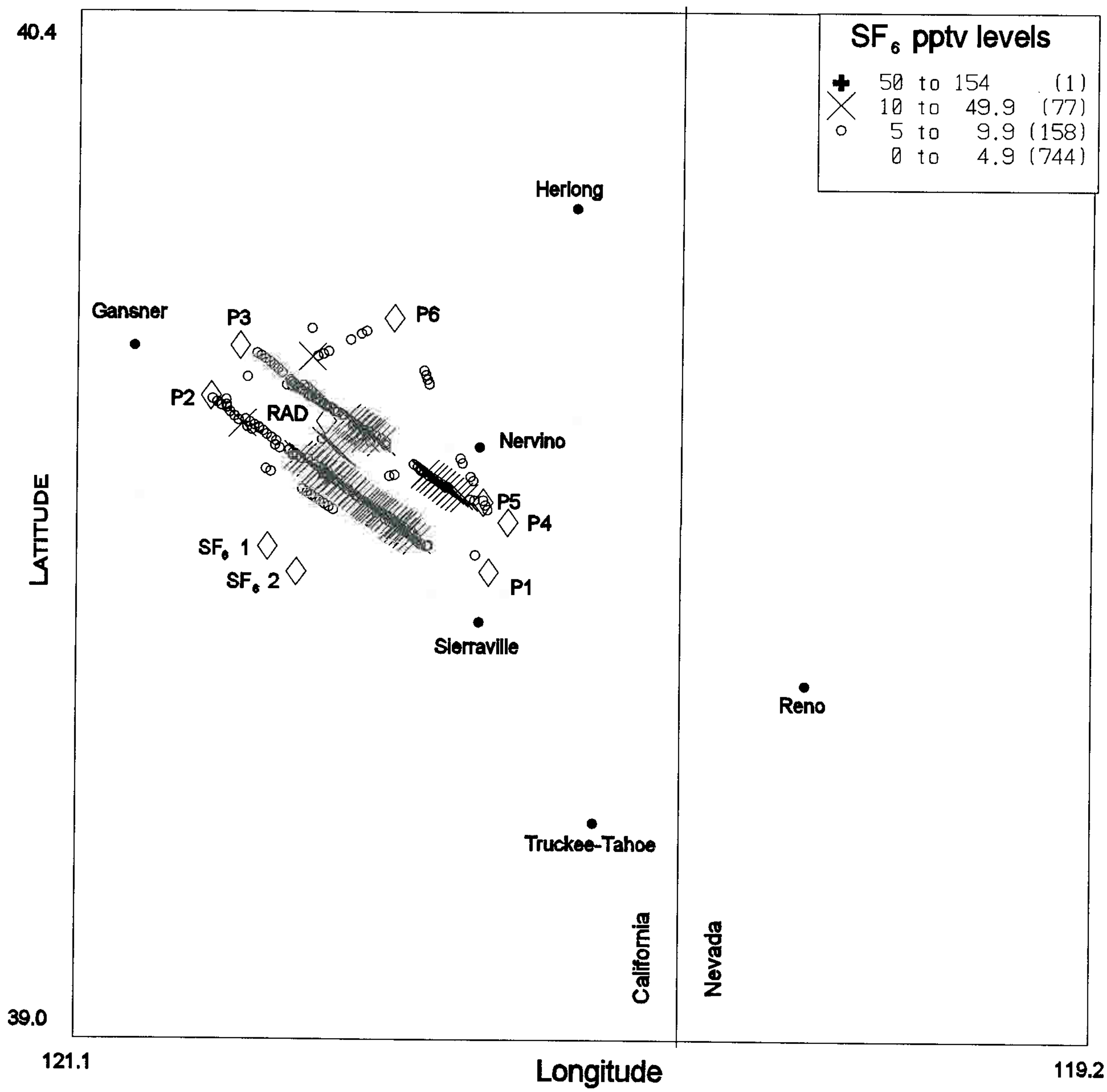


LOREP 1993
Flight Track for 930319



SF_6 1,2	:	SF_6 Release Sites
P1-6	:	Flight Track waypoints
RAD	:	Radiometer Site

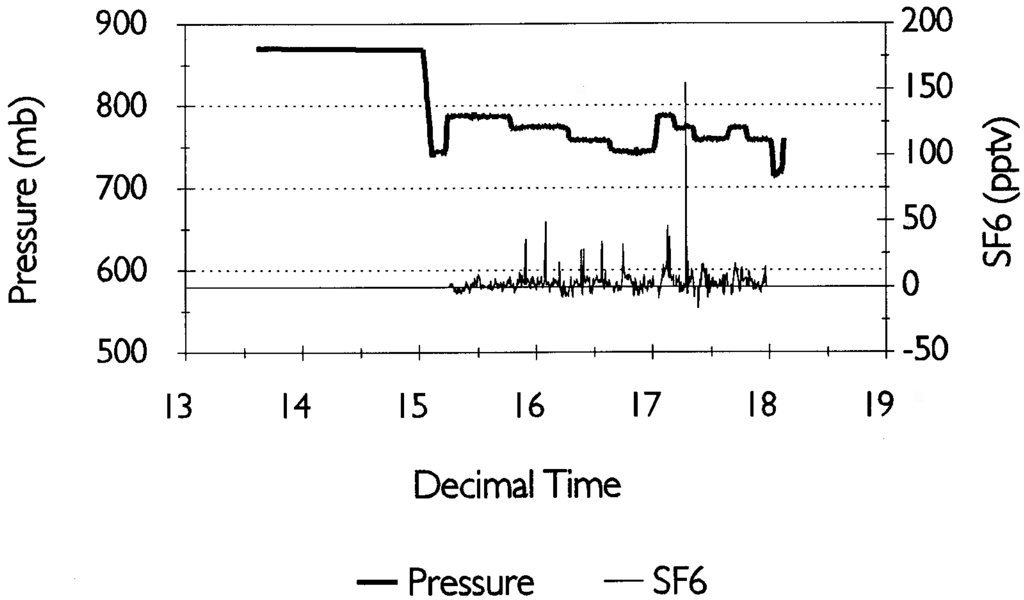
LOREP 1993
SF6 Distribution for 930319



SF$_6$ 1,2	: SF$_6$ Release Sites
P1-6	: Flight Track waypoints
RAD	: Radiometer Site

LOREP 1993 930319

Pressure and SF6 Plot



APPENDIX B: Pre-flight check lists

CHECK LIST

DATE _____________ Operator___________________

CLEAN DETECTOR---

H_2 & sample metering valves and front panel switches off _____

SAMPLE/NITROGEN in "nitrogen" position _____

cylinder & regulator valves off ___ RTEMP less than 35°C _______

30 mls methanol through detector then 30 mls of air _____ (time)

N_2 flowed through detector at operational rate until ______ (≥1hr)

OUTPUT reading ________ recleaning needed? _____

START UP---

H_2 cylinder _______ psi changed ____ new cylinder ______psi

N_2 cylinder _______ psi changed ____ new cylinder ______psi

Caps off____

Inlets and exhaust lines attached ____

Hydrogen and sample metering valves off _____

SAMPLE/NITROGEN in "nitrogen" position _____

all front panel switches off _____

N_2 cylinder & regulator valve open ____ regulator press. 30psi ___

Begin purging instrument with N_2 ________ (time) (at least 30 min.)

H_2 cylinder & regulator valve open ____ regulator press. 30psi ___

CHARGE/ON switch "on" ____ RTEMP _______ DTEMP _______

OUTPUT_______ PRESSURE_____

BATT _______ AUX V _______

RTEMP SET____ DTEMP SET____

PRESSURE: GAIN _____(10, 1 or 100) ELECTROMETER: GAIN ______

ZERO pot setting _____ PERIOD ____

DRYER on _____ (time)

DRYER temp _____ (approx 80°C) ______ (time)

SAMPLE PUMP on ______

SAMPLE METERING VALVE 120 _____

HYDROGEN METERING VALVE 60 ____

SAMPLE METERING VALVE adjusted to __________ (for $180<RTEMP<220$)

RTEMP after 5 minutes _______

ZERO pot setting for output voltage of zero (N_2 mode)__________

SAMPLE/NITROGEN in "sample" position _____

output voltage ______ (should be $0<V<13$)

HYDROGEN METERING VALVE setting at O_2 breakthrough _____

voltage jump at O_2 breakthrough from ____ to ______

HYDROGEN METERING VALVE set to ________ (2 digits above BRKTHR)

ZERO pot setting for output voltage of zero (sample mode)_________

nitrogen/sample arm in "nitrogen" position ____

RTEMP stays between 180 and 220 °C _____ DTEMP approx 83°C ______ stabilized for 30 minutes ________ (time)

SHUT DOWN--

SAMPLE/NITROGEN arm in "nitrogen" position ______

H_2 regulator, cylinder and metering valves off ____

panel switches "off" _____ sample metering valve off ______

N_2 regulator pressure reduced to about 5 to 10 psi ______

or

N_2 regulator and cylinder valves off ____ instr. capped____

Out-bound Instrument StartUp

After T/O (rotation)

1. Turn on King LW probe.
    a. *Needle up/down.* Turn off IMMEDIATELY if needle stays high then report to mission control (D.Reynolds and/or D.Wellman).
    b. Zero King LW probe.
    c. Be sure Vel Adj knob is set at 140.
2. Ask pilots to report any deicing episode - record information in log.
3. Turn on all heaters (PMS probes, sample inlet and King LW) before entering cloud. Note time on voice tape and flight notes.
4. DP to balance mode. Wait 30 seconds, align on left dot. Return knob to DP (operational mode).
5. Calibrate SF6 instrument after leaving the Truckee (Truck) intersection. Be sure cabin in pressurized first. Turn calibration valve (lever in upper right control panel) to "on" position for 5 minutes then return to "off". Note start and stop times.
6. Start video recorder at entrance to Portola area.

VHF communications:

Switch bottom radio to left for VHS communications. 122.925 MHz.

Call radiometer. Use **NOAA 46 Romeo Fox** (aircraft call letters). Leave On/Off/Volume knob out if signal is weak or far away.

SF6 Settings

Sample metering valve	123
Hydrogen metering valve	68
Tylan Channel 1	1.0
Tylan Channel 2	0.5
Tylan Channel 3	40 w/o sampler
	20 w/ sampler
RTEMP	180-220
DTEMP	~80

O2 breakthrough found by decreasing H2 metering valve. Set metering valve 2 digits higher.

PMS Settings

Vel Reject	Active
Transit Time	Delayed
Range	Remote

Strip Chart Commands

STP number LIM minimum maximum specify absolute minimum/maximums STP number RANGE range specify range for plot, max/min calculated

SF6 Conc	56	
KingLWC	66	Strip chart ID numbers
2D Conc	320	

In-bound Instrument Shutdown
After leaving P7 (exit from Portola area).

7. Shut OFF SF6 instrument.
    a. Switch sample lever to Nitrogen (N_2).
    b. Turn OFF hydrogen tank completely (behind rack).
        i. Turn OFF outside flow valve (perpendicular to tube).
        ii. Get wrench from storage, open port and use special wrench to close OFF tank.
    c. Wind in hydrogen metering valve (to 001). *never less than 001*
    d. Turn OFF all panel switches.
    e. Wind in sample metering valve (to 001).
    f. Adjust flow on big nitrogen tank (behind rack) to 10 psi (CCW).
    g. Mark date/time on strip chart paper.
    h. Turn OFF sample pump, tylan box and strip chart.
8. Turn OFF video recording. STOP button (back of rack). Pop tape. Turn OFF recorder.
9. Turn OFF camera. OFF button on small box over video recorder (back of rack).
10. Turn OFF video monitor (small button on top, front right).
11. Type quit on computer.
12. Shut OFF instruments and heaters (panel below keyboard).
    DP, King LWC and PMS probes. All heater switches including one for SF6 inlet by keyboard. Note time in log.
    ** NOTE: Leave heaters ON while in cloud, even after leaving the Portola area. Turn off heaters on final approach. **
13. Pop out data tape. Check label - date/time, program.
14. Turn OFF red power button below data tapes. Close panel.
15. Turn OFF Computer switch (by PMS probe switches).
16. Turn main power switch OFF (left side by pilots).

IF not last flight of the day **OR** data system problems detected and instruments need to remain up for ground work:
    a. Be sure ground crew knows to have Ground Power ready.
    b. Type QUIT on computer.
    c. Turn off probe heaters. Note time in log.
    d. Turn sample valve to nitrogen on SF6 panel and shut off hydrogen.

Everything else remains up.

Be sure to label and remove the following from the aircraft after each flight:
    a. data tapes (at least one),
    b. video cassette (at least one),
    c. strip chart paper,
    d. voice tape.

APPENDIX C: Airborne log notes

Airborne Log Notes

930205

Computer problems delay scheduled 7:15 am launch. Data acquisition software brought up in earlier incarnation. Wind speed/direction and 2D concentrations unavailable. No video recording.

080500	T/O roll.
080730	King LW meter ON.
080830	PMS probe/King LW and sampling inlet heaters ON.
080910	DP to balance mode.
080955	DP balanced to left dot.
081010	DP to operational mode.
081225	Zero King LW meter.
081320	Level 12K - Bobbi doing calibration on SF6. Cabin pressurized.
081615	Small xtals showing on 2D.
081806	Rain on windshield.
081925	Begin descent into Portola area. 500 ft/min from Truck intersection. In and out of tops of small convective clouds.
082215	Outside temperature: -6.2C, DP=-6.2C.
082235	Xtals on order of 400-800 μm columns and unrimed disks.
082400	P1 at ~9000 ft.
082645	Level at 8300 ft. Contact radiometer via VHF. SF6 release scheduled for 0900.
083100	T -1.9C at 8300 ft. 2 n.mi. from P2, capped columns on 2D. In cloud toward north end of track.
083320	P2 at 8300 ft. Climbing to 8800 ft. Cabin pressure reading 320 mb! ***
083545	P3 at 8800 ft. Ground visible through cloud base. Tiny (200 μm) capped columns/aggregates. T=-2.9C and DP=-3.0C.
084000	Flying at cloud base.
084130	Wind estimate from copilot: 228/25.
084540	P4 at 8800 ft., begin descent to valley track.
084720	P1 at 8300 ft. Begin racetrack pattern. Hollow columns/capped columns, no riming.
085007	SF6 shot into inlet. 10 sec lag time to data system.
085516	Release of SF6 confirmed to start at 0900.
085630	P2 at 8300 ft., begin climb to P3.
085845	P3 at 8800 ft.
090415	Out of cloud, ground visible. Broken clouds w/ blue sky above.
090845	P4 at 8800 ft., begin descent to P1 at 8300 ft.
091050	P1 at 8300 ft.. Radiometer confirmed that release began at 0900. Balloon launch scheduled 0915/0930.
091618	Baseline on King LW shifted to 0.13 on computer readout. Needle on instrument also seems to be reading about that level.
091950	P2 at 8300 ft., climbing to 8800 ft.
092220	P3 at 8800 ft. Start ridge track. In very thin cloud deck, both ground below and blue

	sky above visible.
092730	Clear of clouds southbound.
093135	Copilot estimated winds: 230/24.
093220	P4 at 8800 ft. Begin turn and descent to P1.
093400	P1 at 8300 ft. T -1.7C, DP -2.2C. Baseline for King LW still running about 0.15 g/m3.
094200 **	SF6 detected. ~120 ppt above baseline. 5 n.miles SE of P2.
094327	P2 at 8300 ft.
094530	P3 at 8300 ft. Remaining at 8300 ft. for ridge track.
094645 **	SF6 detected. 70 ppt above baseline. 21.5 n.miles from P4. Shortly after peak a "glitch" produced a spike in all data.
	Discussion with D.Reynolds at radiometer. Racetrack pattern shrunk to concentrate on peaks.
095030	P4a at 8300 ft. (P4a located approximately over Portola.)
095300	P1a at 8300 ft. (P1a located slightly east of Clio.) Entire subloop to be done at 8300 ft., followed by subloop at 8800 ft.
095500 **	SF6 detected. 100 ppt above baseline. Peak approximately 30 seconds wide. 5.6 n.miles SE of P2.
095706	P2 at 8300 ft.
095910	P3 at 8300 ft.
100300 **	SF6 detected. 39°54'N 120°40'W (location from copilot). 100 ppt above baseline.
100420	P4a at 8300 ft. Begin climb to 8800 ft.
100745	P1a at 8800 ft.
100923 **	SF6 detected. 60 ppt above baseline. Peak about 20 seconds wide. 6.7 n.miles SE of P2.
101150	P2 at 8800 ft.
101240	T=-3.4C, DP=-3.9C.
101330	P3 at 8800 ft. Begin SE bound leg. LW content ~0.15 g/m3 above baseline.
101525 **	SF6 detected. 100 ppt above baseline. Peak 30-35 seconds wide. Peak is broader and has two maximums.
101845	P4a at 8800 ft. Begin climb to 9300 ft.
102040	Bobbi checks breakthrough on instrument.
102045	P1a at 9300 ft. T=-3.7C, DP=-4.6C. LWC~=0.
102400 **	SF6 Possible hit. Marginal on the order ~10 ppt.
102540	P2 at 9300 ft. Near cloud top in turn.
102900	P3 at 9300 ft. Small region of elevated LW (top of small Cu?). D.Reynolds confirmed that was shut off at 1000.
103145 **	Questionable/marginal hit. 5.8 n.miles from P3 at 9300 ft. <20 ppt.
103440	P4a at 9300 ft. Remain at 9300 ft. for next loop.
103555	Quick calibration peak on instrument (Bobbi).
103700	Divot (negative dip) on trace due to instrument adjustment (Bobbi).
103810	P1a at 9300 ft.
103900 **	Questionable/marginal hit. ~10 ppt. 5.2 n.miles from P2.

104030	Turbulence.....one BIG bump. responded with a tiny peak.
104210	P2 at 9300 ft.
104545	P3 at 9300 ft.
105110	P4 at 9300 ft. No obvious on last leg. Basically unable to see at 9300 ft. End of on-station time. Break off, begin return to RNO.
105200	Bobbi checked breakthrough on instrument.
105230	Shutdown instrument (Bobbi).
105500	Video camera/monitor off.
105745	Leaving Portola area via P7. Begin instrument and data system shutdown.
105820	Quit on computer.
105900	Instruments (PMS, King LW and DP) OFF. Heaters for same (and sample inlet) OFF.
110000	Shutdown sequence complete. Prepare for landing.

930208

Launch time scheduled for 1400L. Expected release of propane (seeding agent) and SF6 (tracer).

140535	Take off.
140655	King LW probe ON.
140730	Voice recorder ON.
140830	King LW zeroed. Computer display reading 0.12 g/m3. Problem with conversion algorithm (volts to g/m3)?
140930	Heaters ON (PMS probes, King LW and sample inlet).
141015	DP to Balance.
141115	Balance DP on left dot.
141125	DP returned to operational setting.
141315	No video recorder. Camera, monitor and recorder left off.
141725	Rezero King LW (meter shows 0).
141735	Begin calibration on SF6 instrument.
141830	End of SF6 calibration. Baseline slightly lower than flight on 930205.
142000	Truck intersection. Begin descent into Portola area.
142400	Over Sierraville valley, out of cloud at 8500 ft. Wind 210/11 (all winds listed in degrees of direction and m/s for speed).
142545	P1 at 8300 ft. Clouds over ridges, not very deep (cap clouds). King LW reading ~0.12 g/m3 on computer display, meter show zero or lower.
143220	SF6 released from Site 7 (northern) beginning at 1430.
143430	P2 at 8300 ft. Begin climb to 8800 ft. 2D concentration reading 10-20/cm3.
143500	SF6 on at Site 7.
143600	T -3.4C DP -4.1C
143725	P3 at 8800 ft.
144100	T -3.6C DP -4.5C Winds 180/15
144155	Out of cloud, ground visible. Cloud layer above aircraft.
144701	P4 at 8800 ft. Begin descent/turn to 8300 ft.
144850	O2 breakthrough checked on SF6 instrument.
145010	Calibration on SF6 instrument.
145048	P1 at 8300 ft. Winds 200/10
145115	Enter cloud at 8300 ft. NW bound. In/out of small Cu.
145620 **	Small SF6 peak. 4 n.miles from P2. 15-20 ppt. Possibly due to turbulence. Baseline good on either side of peak. No obvious change in 2D response.
145830	P2 at 8300 ft.
150110	P3 at 8800 ft.
150315	Winds 165/12
150505	Winds 185/13. Possible split flow around ridge. Southeast component near P3, more southwesterly component further south.
151150	P4 at 8800 ft. Descend to P1.
151350	P1 at 8300 ft.

151550	Very sunny with little Cu.
151715	Winds 205/14
152150 **	SF_6 detected. 10-15 ppt. 4 n.miles from P2.
152220	Ice/water cloud. Very small xtals about 100 μm in size. 30/cm3.
152300	P2 at 8300 ft. Climbing to ridge track. Large columns showing on 2D.
152450	Winds 220/12. Winds have shifted to SW on ridge track.
152615	P3 at 8800 ft.
152800 **	SF_6 detected. Very questionable peak <10 ppt. Not coinciding with any xtals.
153100	Out of cloud again.
153630	P4 at 8800 ft.
153910	P1 at 8300 ft. Winds shift alot in turn/climb (>90°). Takes approximately 1 minute after turn to settle.
154100	Winds 195/6
154250	Winds 205/12
154630 **	SF_6 detected. 20 ppt. 3 n.miles from P2. Peak approximately 20 seconds wide. King LW ~0.1 g/m3 above background.
154845	P2 at 8300 ft.
155110	P3 at 8800 ft.
155220	Winds 165/8 - aircraft heading constant.
155250	Ice boots popped.
155500	Racetrack pattern shortened. Drop southern portion of loop. New points near Portola (P4a) and Clio (P1a). Request from ground to fly VFR on the valley track under cloud vetoed by pilots. Disorganized cloud system and precipitation reaching to the ground make lower passes too dangerous.
155634	P4a at 8800 ft. P4a located 12 n.miles northwest of P4.
155900	P1a at 8800 ft.
160130	Winds 190/12.
160350	P2 at 8300 ft. Climbing to P3.
160725	P3 at 8800 ft.
160845	T -3.6C DP -4.2C Winds 170/12 Above cloud top. Mulitple layers. No turbulence - great place for viewing baselines on instruments!
161250	P4a at 8800 ft. Descending to 8300 ft.
161500	P1a at 8300 ft. T -2.4C DP -3.4C
161920	P2 at 8300 ft. SF_6 released from Site 7 (northern) 1430-1545. Attempted to release from Site 9 (southern, back from ridge line). Site did not work. Decided to turn Site 7 back on.
162250	P3 at 8800 ft.
162815	P4a at 8800 ft. Begin descent to 8300 ft.
163045	P1a at 8300 ft.
163320 **	SF_6 possibly detected. Peak <5 ppt. T -2.6C DP -3.2C Winds 192/12
163500	P2 at 8300 ft.
163800	P3 at 8800 ft. Winds 160/9. Heading steady at 129°.
164430	P4a at 8800 ft. Winds 195/12.
164540	VERY BUMPY.

164640	P1a at 8300 ft.
164750	Winds 172/9. Winds from SE along valley track.
164815 **	SF6 detected. 15-20 ppt. Broad peak lasting longer than 30 seconds. Highest concentration within 5-10 seconds then trailing off to a shoulder of ~10 ppt.
165040	P2 at 8300 ft. Propane from Site 7 on 1430-1545.
165300	P3 at 8800 ft. Flight track will be shortened even more.
165600	Winds 150/10
165745	P4b at 8800 ft. 16 n.miles from original P4.
165930	T -2.4C DP -2.8C
165930	Ice boots popped.
170015	P1b at 8300 ft.
170100 **	SF6 detected. 80 ppt. Wide peak >30 seconds duration. Offset from region of 2D xtals 50/cm3. Largest peak of the day. T -2.6C DP -3.1C Winds 195/14
170300	P2 at 8300 ft.
170552	P3 at 8800 ft.
170718	Pilots must exit Portola area according to FAA agreement.
170945	P4b at 8800 ft. Begin return to Reno via P7.
171253	Spike SF6 through manifold. No video to shutdown.
171430	SF6 off line. (Bobbi shutting down system.)
171530	Computer Quit. Power off to all instruments (PMS probes, King LW and DP). HEATERS left ON because return through thick cloud.
173130	Heaters OFF (PMS probes, King LW and sample inlet).
173200	Land at Reno Cannon International Airport.

930209

Frontal passage. Balloon measured winds 205/12-14. Snow falling over the area according to D. Reynolds. SF6 release scheduled for 1000 so SF6 should be at flight levels from beginning of flight.

095810	TakeOff.
095920	King LW instrument ON.
100000	SF6 went into O2 breakthrough.
100150	King LW zeroed.
100250	DP to balance. Voice recorder ON.
100409	DP balance on left dot, returned to operational setting. Beautiful morning over Reno, air VERY clear.
100650	King LW rezeroed. No change in display (offset ~0.13 g/m3). BUMPY ride.
101037	SF6 instrument baseline very noisy.
101230	Truck intersection. Descending into pattern.
101330	Spike SF6 instrument through the manifold.
101443	Spike SF6 instrument through the manifold. 11-12 sec delay.
101615	P1 at 8300 ft. T -6.9C DP -10.0 Winds 230/12 Propane and SF6 ON at 1000 from Site 7 (northerly).
102225	Cloud bases reach to ground, therefore 8300/8800 feet lowest safe altitudes.
102600	P2 at 8300 ft.
102800	P3 at 8800 ft. T -8.0C DP -9.5C Winds 205/14
103035	Probe heaters ON (oops).
103715	P4 at 8800 ft.
103945	P1 at 8300 ft.
104145	T -7.3C DP -9.2C Winds 243/9
104545 **	SF6 detected. 8.7 n.miles from P2. 30-40 ppt. Peak approximately 25 seconds wide. T -6.7C DP -9.6C Winds 220/14
104845	P2 at 8300 ft.
105115	P3 at 8800 ft.
105300	Seeding signature possibly? No SF6 indication but 2D and FSSP tracked together in a sharp, well-defined peak.
105620	Flight track adjustment. P4a, 10 n.miles NW of P4. SF6 scheduled to be turned off at 1100. Ground crews will turn SF6 back on at 1100 for another hour release. Aircraft must leave Portola area around 1240.
105850	P1a at 8300 ft. 10 n.mile from P1. Southern portion of original racetrack has be omitted.
105949 **	SF6 detected. 9.8 n.miles from P2. Beginning of extended broad peak approximately 45 seconds wide. Maximum concentration reached ~25 ppt. T -6.7C DP -9.0C Winds 220/15
110315	P2 at 8300 ft. Way up above cloud tops.
110530	P3 at 8800 ft.
110740	T -7.8C DP -12.6C Winds 215/10

110940 P4b at 8800 ft. 12 n.miles northwest of original P4.

111135 P1b at 8300 ft.

111430 ** SF6 detected. Multiple peaks, total approximately 30 seconds wide. 25-30 ppt. 8.4 n.miles from P2. No ice/water signature.

111630 SF6 at Site 7 turned back ON.

111700 P2 at 8300 ft.

111850 P3 at 8800 ft.

112240 T -7.5C DP -8.7C Winds 220/15

112320 P4b at 8800 ft.

112540 P1b at 8300 ft. Readjust flight track. Due to more westerly wind component, shift ridge track south. Four corners of racetrack form parallelogram instead of a rectangle. Also, ridge track will be flown at 8300 ft. Cloud system deteriorating rapidly. New points are as follows: P1a 12 n.miles NW of P1, P2 unchanged, P3a 4 n.miles SE of P3, P4c 8 n.miles NW of P4.

113030 Bumpy. LW maximum 0.5 g/m3 (from display).

113120 P2 at 8300 ft.

113510 P3a at 8300 ft.

113630 ** SF6 detected. Very marginal. Small peak <10 ppt. 12 n.miles from P4.

113830 P4c at 8300 ft.

114110 P1b at 8300 ft.

114439 T -7.4C DP -10.9C Winds 230/11

114510 ** SF6 detected. Very marginal. Small, double-lobed peak <10 ppt.

114730 P2 at 8300 ft.

115015 P3a at 8300 ft. Small LW peak ~0.3 g/m3 on display.

115030 T -7.3C DP -8.1C Winds 200/8 No SF6 apparent.

115430 P4a (turn over Portola) at 8300 ft. Flight track readjusted (again) due to winds shifting back to a more SSE direction.

115750 P1a at 8300 ft.

120220 P2 at 8300 ft.

120410 P3 at 8300 ft. Returned to original P3 point. SF6 not varying from 5 ppt baseline. Winds 215/3. Wind speeds decreasing at flight altitudes.

120900 P4a at 8300 ft.

121150 P1a at 8300 ft.

121440 T -7.0C DP -8.5C Winds 229/12

121630 P2 at 8300 ft.

121820 P3 at 8300 ft.

121930 Highest LW of flight noted ~0.7 g/m3 from display. **Panic mode** - thought data tape had completely filled up and was overwriting (display reading 27.1 percent Full).

122000 Typed QUIT on computer to normally terminate tape in drive 0. Restarted computer with new tape in drive 1.

122330 On line with 2nd tape. Lost approximately 1.5 minutes of data. Probably did not overwrite. First tape probably only 27.1 percent full (very little 2D activity). I hope.

122330 P4a at 8300 ft.

122530 P1a at 8300 ft.

122730	SF6 probably trapped below us. Will complete one last loop at 8300 ft. Radiometer and ground crews reporting lots of SF6 at the surface.
123045	P2 at 8300 ft.
123300	P3 at 8300 ft. No SF6 detected. Will break off and head for P7 at end of loop.
123730	P4d at 8300 ft. End mission, break off and begin climb to P7.
123750	SF6 calibration and breakthough check.
124500	Begin shutdown. Quit on computer. Instruments OFF.
124700	Heaters OFF.
124800	Voice recorder off. Compaq switch OFF.
130500	Land at Reno. Approximate time.

930217

Beginning of major, long duration system. Significant development expected for later this afternoon. At takeoff skies over Reno clear.

080900	Takeoff roll.
081010	Heaters ON (before entering low, thin overcast).
081110	King LW zeroed.
081135	DP to balance.
081315	DP balanced on dot, returned to operational set.
081435	Tried to turn on voice recorder but it is not on the airplane!
082000	Tried to turn ON video tape recorder but couldn't get an image on the monitor.
082100	Turning & descending to Portola area from the Truck intersection. In very thin overcast (ground/sky visible). T -9.8C DP -13.6C Winds 230/20
082320	Entering Portola area. Bumpy.
082530	P1 at 8300 ft. Light overcast. T -6.3C DP -7.9C Winds 205/19
082730	Contact radiometer. SF6/propane release scheduled at 0830 from site 9 (southern). Radiometer in moderate snowfall.
082930	Cloud thickened - no visibility above or below. T -6.8C DP -7.4C Winds 200/21
083435	P2 at 8300 ft.
083720	Loaded second data tape, still recording on first tape.
083745	P3 at 8800 ft.
083900	T -7.7C DP -8.7C Winds 180/17
084550	P4a at 8800 ft. 5 n.miles from original P4. Dropped southern length of each flight track. Winds ~190/20
084900	P1a at 8300 ft. (5 n.miles from P1.)
085030	SF6/propane release confirmed at 0830 from site 7 (northerly) NOT site 9.
085315 **	SF6 detected. 6.5 n.miles from P2. Peak 50 ppt. ~20 seconds wide. LW/xtal concentration spikes over 1-2 minutes after SF6. T -6.3C DP -8.0C Winds 200/22
085520	P2 at 8300 ft.
085800	P3 at 8800 ft.
085930 **	SF6 detected. 19.5 n.miles from P4. Associated with sharp peak of small ice xtals on 2D. Readjust flight track, move southerly ends 10 n.miles north of original points.
090330	P4b at 8800 ft. Turning over Portola.
090700	P1b at 8300 ft.
090850 **	SF6 detected. 6.5 n.miles from P2. Peak 50 ppt, approximately 30-40 seconds wide. First rapid rise to maximum concentration (50) then level out (15 seconds) at 30 ppt. T -6.8C DP -7.9C Winds 200/20
091115	P2 at 8300 ft.
091330	P3 at 8800 ft.
091600 **	SF6 detected. 18 n.miles from P4. Small peak 10 ppt. No significant activity on the 2D or King LW. T -7.0C DP -8.4C Winds 190/21
091940	P4b at 8800 ft. Clouds top/edge - sunny and bright to the south. 092250 P1b at 8300

ft.

092550 **	SF6 detected (?). 6 n.miles from P2. Very small, debatable peak, 6 ppt and 10 seconds wide.
092745	P3 at 8800 ft. LW staying <0.3 g/m3.
093610	SF6/propane at site 7 OFF 0930 SF6/propane at site 9 ON 0930
093650	P4b at 8800 ft. Ground visible through cloud.
093920	P1b at 8300 ft.
094240 **	SF6 detected. 40 ppt, 20 seconds wide. No LW/ice associated with peak. Increased LW/ice in previous minute. T -6.1C DP -8.0C Winds 190/24
094420	P2 at 8300 ft.
094655	P3 at 8800 ft.
094900 **	SF6 detected. 19 n.miles from P4. Very weak broad peak, 5-6 ppt. T -7.0C DP -8.2C Winds 185/23
095400	P4b at 8800 ft.
095600	P1b at 8300 ft. Data system switched to second data tape.
095800 **	SF6 detected. 6.1 n.miles from P2. 50 ppt, very broad peak. Over 30 seconds wide. Some LW associated with peak.
100000	BIG BUMPS!
100103	P2 at 8300 ft.
100300	P3 at 8800 ft.
100510 **	SF6 detected (?). Broad, low concentration peak <10 ppt. 30-45 seconds wide. 16.2 n.miles from P4. T -6.4C DP -8.2C Winds 190/24
100850	P4b at 8800 ft.
101115	P1b at 8300 ft.
101345 **	SF6 detected. 9 n.miles from P2. 75-80 ppt. 45 seconds wide. LW associated with leading edge (on display). Water tapers off before SF6.
101650	P3 at 8800 ft.
101900	P4b at 8800 ft. Winds 225/19 from copilot estimate.
102045 **	SF detected (?). Very questionable. Maximum peak 6 ppt.
102320	P4b at 8800 ft. Begin last racetrack pattern.
102720	P1b at 8300 ft.
103000 **	SF6 detected. 9 n.miles from P2. 90-95 ppt, 30-40 seconds wide. BIG PEAK. T -6.2C DP -7.1C Winds 190/21
103230	BUMPY.
103450	P3 at 8800 ft. Seem to be near cloud top (bright sky).
103715 **	SF6 detected (?). Small *wiggle*. Maximum concentration 7 ppt. No ice. T -5.9C DP -7.2C Winds 190/22
104130	P4b at 8800 ft. End of pattern.
104920	P7 exit Portola area.
105100	Begin shutdown.
105220	Quit on computer.
105400	Everything OFF. Probes and heaters.
110300	Land Reno.

930302

SF6 release. Warm conditions, most probably will be VFR. Want to map vertical/horizontal extent of SF6 plume. Minimum requested altitude of 7500 ft. Cloud cover scattered over RNO.

145500	Engines ON.
145600	Switch to engine power, disconnect Christie.
150700	Take Off.
150800	King LW probe ON.
150900	King LW zeroed.
150900	Probe heaters ON (all of them).
	SF6 ON at Site 9. Winds 190/05.
151100	DP to balance.
151230	DP on left return, switch to operational position.
151400	SF6 instrument to sample.
151700	Zero SF6. Setting 634.
152330	SF6 calibration ON.
152445	T -1.2C DP -2.3C Winds 240/06. Entrance to Portola area.
152630	SF6 calibration OFF.
152700	P1 at 8300 ft. Below cloud base ~1000 ft.
152839	SF6 instrument looks fairly stable but baseline has a steady downward drift.
153020	Readjust SF6 zero. New setting 639. Now running at zero on output setting.
153240	T 1.1C DP -1.0C Winds 226/11
153725	P2 at 8300 ft. Images on 2D probe look odd - timing bars are followed by a short one pixel wide line about 1/3 of the way across the array. Line is about 4-6 pixels long. Looks like probe may be triggering on a stuck element. Housekeeping values for probe look entirely normal.
153900	In cloud, all liquid.
153950	P3 at 8800 ft.
154400	T -0.8C DP -2.1C Winds 210/12
154515	P4a at 8800 ft. 10 n.miles from P4. Descend VFR to 7500 ft.
154820	P1a at 7500 ft. 10 n.miles from P1.
155000	Winds 220/08
155145	Winds 210/09
155400	P2 at 7500 ft.
160000	Talk to radiometer. No SF6 detected at 7500 ft level or earlier 8300 ft. pass. Decide to try entire truncated racetrack at 7500 ft.
160400	Baseline on SF6 still dropping (decrease in altitude?).
160700	Winds 220/08
160940	P2 at 7500 ft. After consulting with radiometer, decide to do a U-turn and return along valley track at 7500 ft. instead of continuing racetrack pattern.
161430	Baseline on SF6 continued to fall (on computer display). Decided to do a zero adjust. Marked as "A" on strip chart. New zero setting 644.
161815 **	SF6 detected. 10 n.miles from P1 at 7500 ft. Maximum 50 ppt. Marked as "B" on

strip chart. Two peaks, 15-20 seconds wide.

162225	P1a at 7500 ft.
162300 **	SF6 detected. 13.8 n.miles from P2. 115 ppt peak, 25-30 seconds wide. "C" on strip chart.
162730	P2a at 7500 ft. 1 n.mile from P2.
163000	P2a at 7000 ft. Returning along valley track at lower altitude.
163300	Winds 190/06
163550 **	SF6 detected. 11.1 n.miles from P1. 125-130 ppt. 30 seconds wide. "D" on strip chart. Secondary peak ~25-30 ppt. Total width 45 seconds.
163800	P1b at 7000 ft. 5 n.miles from P1.
164230	Back on valley track at 7000 ft. Will go to P2 ,climb and do ridge track at 7500 ft.
164345 **	SF6 detected. 12.5 n.miles from P2. Begins with a long, low shoulder 10-20 ppt followed by a sharp peak ~100 ppt. "E" on strip chart.
164840	P2 at 7000 ft. Maintain VFR - will NOT climb and enter cloud. Ceiling has lowered. Will do valley track at 7000 ft.
165100	P3 at 7000 ft.
165507	Winds 200/07
165610 **	SF6 detected. 10.5 n.miles from P4. "F" on strip chart. 25 ppt shoulder (15 seconds wide), followed by peak 80-90 ppt (30 seconds wide).
170220 **	SF6 detected crossing between tracks (pilots misunderstood directions). Over road between Portola and Clio(?). Maximum 80-90 ppt, broad peak about 1 minute wide. "G" on strip chart.
170900	P3a at 7000 ft. 5 n.miles from P3.
171030	T 3.0C DP 0.3C Winds 180/06
171314 **	SF6 detected. 10 n.miles from P4. 80-85 ppt, wide peak, 45 seconds wide. "H" on strip chart. Winds 200/10
171822	P4b at 7000 ft.
172045 **	SF6 detected. 14.5 n.miles from P3. 50 ppt, 30 seconds wide. "J" on strip chart.
172300 **	SF6 detected. 11.0 n.miles from P3. BIG peak, 120 ppt. 30 seconds wide.
172816 **	SF6 detected. 12.5 n.miles from P4. Low concentration shoulder preceeding strong major peak. 100 ppt maximum, sharp drop off on south side. "K" on strip chart. Winds 185/07
173130	End of research part of the flight. Heading for P7.
173230	SF6 calibration during climb.
173440	SF6 calibration OFF.
173600	Begin SF6 shutdown.
173630	Sample lever to N2.
	** Can't get plug out of H2 capture box - can't shut off H2. **
174300	Quit on computer.
	OFF probes/heaters.
	Video OFF & rewind(?).
	Camera/monitor OFF.
174500	All power OFF.
174800	Land RNO.

930309

VFR flight ahead of incoming storm. Try to map vertical/horizontal extent of SF6 plume. Below cloud base. Try to locate (visually) radiometer.
NOTE Latitude/Longitude for JCC (Jackson Creek/Radiometer site) in ops plan does not jibe with sectional.

082100	Take off.
082550	King LW on and balanced.
082600	DP to balance.
082800	DP balanced on left dot, returned to operational position.
083500 **	SF6 on at sites 7 and 9.
083520	Video recorder ON.
083700	P1 at 7000 ft.
084500	Rezero King LW. T 5.6C DP -6.7C Winds 205/10
084630	P2 at 7000 ft.
084900	P3 at 7000 ft.
085225	Unable to locate radiometer from ridge track at 7000 ft.
085445	T 6.5C DP -11.1C Winds 190/08
085800	P4 at 7000 ft. Will fly racetrack pattern again at 7000 ft.
090100	P1 at 7000 ft.
090315	T 6.0C DP -9.0C Winds 220/04
090700	SF6 detected(?). Small peak 10-15 ppt, 2 n.miles from P2. Odd peak, preceded by sharp decrease. I was moving around cabin - to discuss map options with the pilots - could that have an effect?
091100	P2 at 7000 ft.
091230	P3 at 7000 ft.
091700	T 6.3C DP -9.4C Winds 190/08
092000	P4a at 7000 ft. 5 n.miles from P4.
092130	P1a at 7000 ft. 5 n.miles from P1. Will fly valley track back and forth at 200 ft increments until vertical extent is mapped.
092440 **	SF6 detected. 10 n.miles from P2. 100 ppt. (From Site 9) Second peak 7.7 n.miles from P2. 200 ppt. (From Site 7) T 6.2C DP -7.8C Winds 245/05.
093020	P2 at 7000 ft. U-turn, return along valley track.
093300	P2 at 7200 ft.
093500 **	SF6 OFF at Sites 7 and 9. Information from radiometer.
093510	T 5.7C DP -4.7C Winds 170/08
093625 **	SF6 detected. 16 n.miles from P1. 20 seconds wide. 350 ppt - largest peak seen to date!!!!!
093745 **	SF6 detected. 14.5 n.miles from P1. 250 ppt, 20 seconds wide.
094100	P1a at 7200 ft. 10 n.miles from P1. Turning to return along valley track at 7400 ft.
094400	P1a at 7400 ft.
094750	T 5.0C DP -5.8C Winds 230/10

094830 **	SF6 detected. 9.7 n.miles from P2. 180 ppt, 45 seconds wide.
094950 **	SF6 detected. 7.9 n.miles from P2. 250 ppt, 25 seconds wide.
095200	P2a at 7400 ft. 3 n.miles from P2. Climbing and reversing direction.
095440	P2a at 7600 ft.
095715 **	SF6 detected. 17 n.miles from P1. 150 ppt, 30 seconds wide. Winds 190/09 (from copilot).
095830 **	SF6 detected. 13.7 n.miles from P1. 120 ppt, 60 seconds wide.
100000	P1a at 7600 ft. 10 n.miles from P1. Turn and climb, begin racetrack pattern at 7600 ft.
100150	P1a at 7600 ft. Begin racetrack pattern at constant altitude.
100415 **	SF6 detected. 11.3 n.miles from P2. 105-110 ppt, 45 seconds wide.
100600 **	SF6 detected. 7.5 n.miles from P2. 180 ppt, 20 seconds wide, much sharper peak.
100800	P2a at 7600 ft. 3 n.miles from P2.
101000	P3a at 7600 ft. 3 n.miles from P3.
101130 **	SF6 detected. 16.5 n.miles from P4. 81 ppt followed by maximum of 100 ppt, 30-40 seconds wide.
101300 **	SF6 detected - actually continuously. Between "obvious" peaks SF6 concentrations tracked about 30-40 ppt. A second significant peak, ending 11.2 n.miles from P4 maxed out at 70-75 ppt.
101750 **	SF6 detected. 13.1 n.miles from P2. Did not note passage of P1a. Multi-lobed peak. 80-90 ppt, 60 seconds wide. T 3.7C DP -4.0C Winds 220/13
101900 **	SF6 detected. Small peak, 10 ppt. 7.2 n.miles from P2. Looks like SF6 has moved out of the valley track area.
102100	P2a at 7800 ft.
102330	P3a at 7800 ft.
102500 **	SF6 detected. 17.5 n.miles from P4. 100 ppt.
102700 **	SF6 detected. Begin 12.3 n.miles from P4, end 10.1 n.miles from P4. 125 ppt. Again SF6 was present between two significant peaks at a concentration of 20-30 ppt.
102900	P4b at 7800 ft. 8 n.miles from P4. Climbing to 8000 ft.
103045	P1b at 8000 ft. 8 n.miles from P4. Changed video cassette.
103300 **	SF6 detected. 10.5 n.miles from P2. 10 ppt, double peak about 30 seconds wide (total). Winds 225/14.
103530	P2a at 8000 ft.
103910	P3a at 8000 ft. 19.1 n.miles from P4.
104005 **	SF6 detected. 16.8 n.miles from P4. 1520 ppt.
104140 **	SF6 detected. 12.5 n.miles from P4. 75 ppt. Video monitor looks blank - contrast off? Break off racetrack patter, will turn out to north, fly Nervino (Beckworth) to P6 to check horizontal extent.
105000 **	SF6 detected. Near P6. 55 ppt.
105220 **	SF6 detected. Elevated SF6, 20-30 ppt. 3.5 minutes or more wide. Heading from P6 to P3 at 8000 ft.
105625	P3 at 8000 ft. No SF6 detected at P3.
105815	2D updates, bullet clusters/gunk. 500-1500 um.

105915	P3 at 8000 ft. T 2.6C DP -5.0C
110200 **	SF6 detected. 3.5 n.miles from P6. 20-25 ppt all the way to P6.
110350	P6 at 8000 ft.
110915	Nervino airport, turning around, heading back to P6 at 8000 ft. SF6 returned to baseline over Nervino.
111020 **	SF6 detected. 6.3 n.miles from P6. 40-45 ppt.
111200 **	SF6 detected. Returned to baseline at P6.
111340	End of research mission.
111800	Video OFF.
112045	SF6 offline.
112200	Quit on computer.
112300	Instruments OFF. *NOTE* Heaters OFF for entire flight.
112400	Compaq switch OFF.
113100	Land Reno.

930316

Early morning flight. RH > 90% per sounding. Temperatures fairly warm with associated high snow level (8000 ft+). Winds from S at 20 mph. Forecast to shift to SW by late afternoon. Progs keep clouds and precip in area for a number of days.

065800	Found teflon tube flopping behind SF6 instrument rack. Assume it is the inlet tube for the SF6 instrument (teed off main supply line). Reattached tube to T-fitting ..... no other obvious place to connect.
070824	Take Off.
071445	Warm Reboot on computer. Computer hung at or slightly before takeoff (070824). Time on display froze, no updating. Could not halt computer using Quit command or blow out of program using ^C (or other computer panic codes). New data tape used. Old one removed and marked Data Tape 1. After restarting program, data tape (new) immediately noted it was 54.3% full!
071500	SF6 (and propane) release begun from Sites 7 and 9.
071645	King LW on and balanced on zero. Heater for King LW ON.
071843	DP to balance.
071900	Heaters ON (PMS, inlet).
071950	DP balanced on left dot, returned to operational position.
072220	SF6 lever to sample position.
072400	Video tape to record.
072700 **	Adjust SF6 zero. New setting: **655**.
072800	Begin SF6 calibration. In constant descent pattern from Truck intersection to P1.
073003	End SF6 calibration.
073200	Base line for SF6 solid but running about 50 ppt (on display).
073310	P1 at 8300 ft. Ground visible through cloud. T 1.0C DP 0.75 Winds 240/19.
073639	Out of cloud.
073815	SF6 baseline falling again (similar to earlier flights).
074335	P2 at 8300 ft. Begin turn/climb. hmmmm - SF6 baseline stabilizes in turns (stops falling).
074600	P3 at 8800 ft.
074830	Flying at cloud top. T 0.4C DP -0.8C Winds 235/14
075345	P4 at 8800 ft. Juicy clouds at southerly end of racetrack pattern, maximum lw 0.5 g/m3.
075645	P1 at 8300 ft.
075820	T 2.7C DP -0.4C Winds 250/14
080230 **	SF6 detected. 9.5 n.miles from P2. 40 ppt. LW ~0.6 g/m3 maximum, average LW ~0.3 g/m3. "A" on strip chart.
080515	T 0.6C DP 0.0C Winds 235/20
080550	P2 at 8300 ft, begin turn/climb.
080810	P3 at 8800 ft. LW ~0.5 g/m3. No ice detected. SF6 baseline seems to waver a bit in cloud water.
081115	T -0.4C DP -0.8C Winds 235/17

081350	P4a at 8800 ft. 5 n.miles from P4. Begin turn/descent.
081700	P1a at 8300 ft. 20 n.miles from P2.
082023 **	SF6 detected. 13.6-13.3 n.miles from P2. 2 peaks: first 20 ppt; second 25-30 ppt. Combined duration 15 seconds.
082310	P2a at 8300 ft. 5 n.miles from P2.
082550	P3a at 8800 ft. 19.5 n.miles from P4. Ice in cloud. Small pristine plates.
082820 **	POSSIBLE SF6 detected. 12.7 n.miles from P4 and again at 9.6 n.miles from P4. Marked as "C" on strip chart. Very weak signal imbedded in water cloud.
083102	T -0.5C DP -0.6C Winds 235/16
083227	P4b at 8800 ft. 2 n.miles from P4. Will do next racetrack at constant altitude of 8800 ft. Try to determine vertical extent of SF6 plume. Radiometer is reporting SF6 on the ground.
083443	P1b at 8800 ft. 22.5 n.miles from P2.
083700 **	SF6 detected OR a glitch! 18.4 n.miles from P2. Marked as "D" on strip chart.
084000	T -0.1C DP -0.9C Winds 230/18
084200	P2a at 8800 ft.
084430	P3a at 8800 ft. 18 n.miles from P4.
084600	T -0.2C DP -0.6C Winds 230/09. Lots of updates on 2D. Bullet clusters, needles, hollow needles(?) and capped columns.
084730 **	SF6 detected. Very small peak of 10 ppt. 9.5 n.mils from P4. "E" on strip chart.
085000	P4b at 8800 ft. Begin turn/descent. Will return to default flight levels 8300/8800 ft.
085140	Put second data tape in drive to start autoload procedure.
085315	P1b at 8300 ft. 23 n.miles from P2.
085430	Smaller ice xtals. Broader FSSP spectra (2-30 um range).
085930	LW/Ice continued all the way to P2. T 1.1C DP -0.6C Winds 225/20.
090250	P2 at 8300 ft. Turn/climb. Radiometer confirmed SF6 (and propane?) sites OFF at 0815.
090430	P3 at 8800 ft.
090850	T -0.4C DP -0.8C Winds 230/16. No SF6 detected along ridge track.
091315	P4b at 8800 ft. 2 n.miles from P4. Will begin work along the downwind track at 8500 ft. Turn/climb out of racetrack pattern.
091615	On track to P6 at 8500 ft.
092030	P6 at 8500 ft. Turn/reverse track.
092300	P6 at 8500 ft. Returning to P5a.
092430	Changed video tape. Possible indication of SF6 at N end of track (in the vicinity of P6). Maximum of 10 ppt. Questionable because of aircraft attitude.
092853	P5a at 8500 ft. Defined as where the P5/P6 track crosses the ridge track.
093535	P6 at 8500 ft.
093830	P6 at 8500 ft. Reverse track, return to P5a.
094000 **	SF6 detected. 23.0 n.miles from P5. 15-20 ppt for 15 seconds.
094520	P5a at 8500 ft.
094800	P5a at 8500 ft. Headed back to P6.
095145	Many small xtals in 2D images. 5-5.5 n.miles from P6.
095340 **	P6 at 8500 ft. SF6 possibly detected in turn. 10 ppt at edge of LW cloud.

095640	T -0.1C DP -0.2C Winds 200/14
100320	P5a at 8500 ft. No image on the video again. Last track suggested that a broad region of the downwind valley contains low levels of SF6 (10 ppt). Will have to wait for post-processing.
100500	Reverse track to P6. Large region of small ice xtals noted on last pass have vanished.
101114	P6 at 8500 ft. for the last time. No indication of SF6 found on last pass. Reverse track to P5a.
101710	SF6 calibration ON.
101910	SF6 calibration OFF. End of research mission.
102330	SF6 lever to N2.
102400	SF6 instrument shutdown.
103000	Quit on computer. All probes/heater OFF.
103600	Land at RNO (after bumpy approach).

930317

Forecast bumpy ride - winds at the 20 m/s limit. Warm at flight levels. Raining in Reno.

070640	Take Off.
070700	SF6 to "sample", rezero strip chart.
070830	King LW probe/heater ON. Zeroed.
071000	DP to balance.
071015	Video recorder ON.
071115	DP on left dot. Return to operational position.
071150	Probe heaters ON (PMS and inlet). Pilots have all deicing equipment on (except wing boots).
071500	Change FSSP range to 3-45 um. Icing possible at forecast temperatures.
071550	SF6 looking HIGHLY erratic during climb out. Pump (channel R1 on Tylan) working hard, flickering 0.99/1.01 instead of usually stable 1.00.
072300	Truck Intersection. Clear, above clouds. Ground visible through breaks.
072429	Adjusted SF6 baseline. New setting: **650**.
073230	P1 at 8300 ft. Below cloud base. Finally SF6 settled in. Channel R2 on Tylan reading 0.004-0.005 instead of 0.5 as per label and notes. Contacted Dennis via phone to request instructions. Radiometer advises that SF6 being released from both sites (7 & 9) beginning at 0715.
074020 **	SF6 detected (possibly). 7.8 n.miles from P2. 10 ppt on a very bumpy baseline. T 1.7C DP -3.8C Winds 226/28.
074333	P3 at 8300 ft. Since no SF6 should've reached ridge track (note: in retrospect this assumption may have been wrong due to observed wind speeds) and SF6 instrument seems to be having problems will do calibration on ridge leg.
074550	P3 at 8800 ft. Pilots note that airspeed is fluctuating ±10 kts from optimal 140 kts due to wind/turbulence.
074700	Begin SF6 calibration.
074830	End SF6 calibration. Weird trace. Initial peak followed by drop to baseline for 5-10 seconds then step feature followed by return to baseline. Contact Dennis via radio/phone to get advice.
075015 **	SF6 detected (possibly). 12.8 n.miles from P4. 20 ppt, 10-15 seconds wide.
075445	P4 at 8800 ft. Begin turn/descent.
075950	P1 at 8300 ft.
080110	Adjust flow on rear N2 tank to 30 psi.
080220	T 1.1C DP -3.0C Winds 230/29. Above wind speed abort criteria. Continuation of flight dependent on pilot decision.
080835	P2 at 8300 ft. Turn/climb.
081019	P3 at 8800 ft.
081100	Begin SF6 calibration in turbulence. Calibration shape looks OK.
081230	End SF6 calibration. Pilots have agreed to continue flight but will scrub if wind speeds increase any. T -0.8C DP -1.8C Winds 220/25. Drop 5 n.miles off southern end of racetrack pattern.

081744	P4a at 8800 ft. 5 n.miles from P4. Turn/descend.
082100	P1a at 8300 ft. 5 n.miles from P1. T -0.4C DP -1.2C Winds 227/25.
082340	Check mark squiggle observed in SF6 trace.
082435	T 0.9C DP -2.5C Winds 230/26
082552	Cycled thru FSSP ranges to confirm 3-45 um range being used.
082830	P2 at 8300 ft.
083230	P3a at 8800 ft. 18.5 n.miles from P4.
083335	T -1.8C DP -1.8C Winds 210/16. Very BUMPY, in/out of Cu.
083430 **	SF6 detected (?). 13.0 n.miles from P4. 10-15 ppt followed by negative peak of equal magnitude. "B" on strip chart.
083645 **	SF6 detected (possibly). 10 ppt bracketed by water/ice in Cu tower.
083745	SF6 instrument does not seem to like bumps very much.
083858	P4 at 8800 ft.
084200	P1 at 8300 ft.
084415	T 1.2C DP -4.6C Winds 230/30. Baseline fairly "busy", may not be able to distinguish 10 ppt or less. Also baseline falling about 10 ppt/2 minutes.
085008	P2a at 8300 ft. Turn/climb.
085250	P3a at 8800 ft.
085330 **	SF6 detected (possibly). 18.5 n.miles from P4. 20 ppt. Also VERY bumpy. Lots of water in clouds along ridge line. ~0.5 g/m3. Little/no ice detected.
085750	T -1.2C DP -4.0C Winds 220/23.
090000	P4 at 8800 ft. Basic manuvers (turns) causing peaks on the SF6.
090240	On track to P6. 15 n.miles from P6 at 8500 ft. Possible SF6 right at P4. Out of cloud, bumpy.
090400	T -0.4C DP -3.9C Winds 238/18
090745	Turning to reverse track 2 n.miles from P6. Staying at 8500 ft.
090908	Turn complete, southbound 21.1 n.miles from P5.
091300	Changed video tape.
091900	P5 at 8500 ft. End of research mission.
092135	SF6 calibration ON.
092305	SF6 calibration OFF. Radiometer will contact Dennis to have Christie ready so SF6 instrument can remain up.
092500	Quit on computer.
092530	Probe heaters OFF.
092600	Sample lever to N2 on SF6 instrument.
092700	King LW OFF.
	Landed shortly afterward!

930319

VFR Warm. Plume description flight. No propane release. D.Reynolds (the BOSS) will fly as observer. *NOTE* - "I" and "O" letters NOT used on strip chart.

145700	Video ON during run up at the end of the runway.
150240	Take Off.
150300	On SF6 instrument, lever switched from Nitrogen to Sample.
150315	King LW on/zeroed.
150345	DP to balance.
150540	DP ok switched to operational setting.
150815	Adjust Zero SF6. New Zero value **670.**
151000	Begin calibration SF6 at 8500 ft. 140 TAS.
151130	End calibration SF6. Looks completely normal (i.e. good).
151500	SF6 release begun from sites 7 and 9 (informed by radiometer).
151530	P1 at 7000 ft.
151845	T 6.6C DP -8.1C Winds 240/09
152500	P2 at 7000 ft. Reverse direction, 2.5 n.miles right of track, closer to release site ridge line.
153200	Winds 210/15
153730	P1 at 7000 ft. Reverse track to P2.
153910	T 6.9C DP -3.7C Winds 240/05
154300	T 5.6C Dp -1.6C Winds 225/10
155024	P2 at 7500 ft. Completed pass to P2 at 7000 ft. Climbed to 7500 ft and reversed track. SF6 baseline creeping up about same rate as it was falling on earlier flights. *NOTE* - winds seem to be highly variable during this flight. Data system winds seem to read alright when north(west)-bound but are RADICALLY off when headed south(east)-bound. Wind directions when headed toward P1 vary anywhere from NE (45-60) to S (180). Therefore, winds listed for these flight notes were estimated by the copilot but were converted to m/s by me.
155430 **	SF6 detected. 15 n.miles from P1. 50 ppt single peak followed by 2-lobed 40 ppt maximum. "A" on strip chart.
155845	P1a at 7500 ft. Reverse track, move 2 n.miles downwind of valley track (intermediate between standard tracks).
160100	Diverting around Beckworth peak.
160230	T 5.6C DP -9.7C Winds 280/07
160350	Diversion complete. 2 n.miles right of track parallel to P1/P2.
160445 **	SF6 detected. 11.3 n.miles from P2. Bearing 277°. Broad peak greater than 1 minute wide. 40 ppt. "B" on strip chart.
160745	P2a at 7500 ft. 5 n.miles from P2. Turn to ridge track, continue at 7500 ft.
160925	P3a at 7500 ft. 5 n.miles from P3.
161010	Winds 265/12
161215 **	SF6 detected. 12.9 n.miles from P4. Winds 210/11. Maximum 10-15 ppt. "C" on strip chart.

161445 **	SF6 detected. 7.0 n.miles from P4. Elevated ~10 ppt. Possibly site 9 "washed out". "D" on strip chart.
161655	P4 at 7500 ft. Climb to 8000 ft.
161930	P1 at 8000 ft.
162040	Winds 280/10
162330 **	SF6 detected. 12.3 n.miles from P2. 25-30 ppt, 15 seconds wide. 2 peaks. "E" on strip chart.
162430 **	SF6 detected. 15 seconds wide, single peak. "F" on strip chart.
162800	P2 at 8000 ft. Turning to ridge track, maintaining 8000 ft.
163050	Right of ridge track 0.5 n.miles. 28.5 n.miles from P4. Will align along track.
163330	Winds 215/09
163350 **	SF6 detected. 13.4 n.miles from P4. 45 seconds wide. 20-25 ppt. "G" on strip chart.
163555 **	SF6 detected. 7.6 n.miles from P4. 10-15 ppt. Wide, ill-defined peak - possibly SF6 pooling in downwind valley ("soup")? "H" on strip chart.
163815	P4a at 8000 ft. 5 n.miles from P4. Reverse track, climb to 8500 ft.
164120	Back on track to P3 at 8500 ft.
164225	Winds 200/10. Radiometer confirms that SF6 back on at 1638 from sites 7 & 9.
164450 **	SF6 detected. 10.4 n.miles from P3. 20-30 ppt. "J" on strip chart. Extended region <10 ppt continues. Never returned to pre-peak baseline. Will turn out at P3 to box downwind region.
164945	Turning at P3, staying at 8500 ft. Heading for P6.
165030	9.6 n.miles from P6 on line from P3 at 8500 ft.
165140	Switched video tape. First tape was popped out when I went back to change it (ended earlier and rewound?).
165415 **	P6 at 8500 ft. enroute to P5. SF6 detected all around P6 ~10 ppt. Noted as "P6" on strip chart.
165600 **	SF6 detected. 18.7 n.miles from P5. 20 ppt, 30-45 seconds wide. "K" on strip chart.
165900	Approaching ridge track. In low concentration "soup" (~10 ppt) at 8500 ft. "L" on strip chart.
170000	Happy hour begins at Amelia's. Winds 210/10 at 8500 ft.
170330	P1 at 7000 ft. Heading to P2. Winds 225/10. Definitely in residual SF6 from first release.
170800 **	SF6 detected. 13.0 n.miles from P2. 40-50 ppt, 30 seconds wide. "M" on strip chart.
170900 **	SF6 detected. 9.2 n.miles from P2. Sharp peak, 50 ppt. 5-10 seconds wide. "N" on strip chart. Winds 240/13
171300	P2a at 7000 ft. 5 n.miles from P2. Climb to 7500 ft, reverse track.
171530	P2a at 7500 ft.
171745 **	SF6 detected. 14.8 n.miles from P1. Biggest peak of the day! 230 ppt, 15 seconds wide. "P" on strip chart.
171900 **	SF6 detected. 11.7 n.miles from P1. 30 ppt, 60 seconds wide. Winds 185/10. "Q" on strip chart.
172125	P1a at 7500 ft. Turn/climb to 8000 ft. Reverse track.

172500 P1a at 8000 ft.
172700 Winds 235/07.
172810 ** SF6 detected. 12.5 n.miles from P2. 20-30 ppt, 10 seconds wide. "R" on strip chart.
172920 ** SF6 detected. 9.4 n.miles from P2. Same magnitude/shape as previous peak. "S" on strip chart. Assume we have detected/mapped top of SF6 plumes from the two release sites.
173120 P2a at 8000 ft. Going to P3, maintaining current altitude.
173320 P3a at 8000 ft.
173445 Winds variable. Readings from the copilot, 265/04 followed closely by 325/04.
173750 Winds 215/04
173850 P4a at 8000 ft. Reverse track, descend to 7500 ft.
174230 P4a at 7500 ft.
174545 ** SF6 detected. 11.8 n.miles from P3. 15-20 ppt on line from Mills Peak to Smith Peak. "T" on strip chart. Trace never returns to pre-peak baseline.
174530 Winds 240/13
174850 Turning at P3a (5 n.miles from P3), heading to P6 at 8000 ft.
175010 Heading to P6 at 8000 ft.
175215 P6 at 8000 ft. Heading to P5.
175838 SF6 calibration ON. Strip chart OFF scale.
180008 SF6 calibration OFF. End of research mission. Seems like shoulder (level phase) of last calibration was high.
180200 SF6 sample to N2. SF6 instrument shutdown sequence begun.
180800 Quit on computer.
180830 Probes OFF. *NOTE* - Heaters never turned ON this mission.

We landed sometime thereafter......

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