5th Harsh-Environment Mass Spectrometry Workshop

September 20-23 2005, Lido Beach Sarasota, Florida

3D Gas Concentration Mapping of Active Volcanoes using Mass Spectrometry

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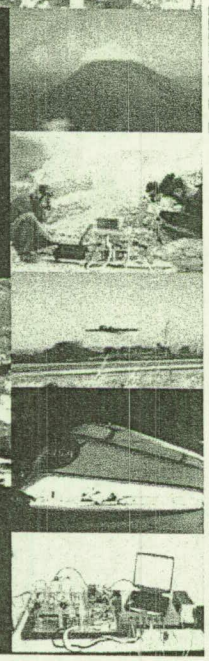
(1) National Program for Airborne and Remote Sensing Research (PRIAS), CENAT. Costa Rica
(2) ASRC Aerospace Corp., Kennedy Space Center, FL
(3) NASA, YA-F2, Kennedy Space Center, FL
(4) CICANUM, Universidad de Costa Rica, Costa Rica



International Collaboration

NASA/KSC	CENAT/Costa Rica
• ISS	• Volcanic Emission
• Human Exploration	• Volcanic Activity
• Robotic Exploration	• City Air Quality
• Earth Science	• Pollution Levels

Costa Rica National Airborne and Remote Sensing Research Program (PRIAS)

- Project started as a NASA-COSTA RICA collaboration
  - Initial Airborne Missions in Costa Rica (1999-2000)
    - **ACCENT I & II (Atmospheric Chemistry of Combustion Emissions Near the Tropopause)**
    - **CWVCS (Clouds and Water Vapor in the Climate System)**
- National Hangar Construction and Labs (2001-2002)
- Airborne Missions:
  - **CARTA I Mission** (Land Use High resolution-Mar 03)
  - **Pre-AVE Mission** (Atmospheric-Ozone-AURA Satel-Jan 04)
  - **AIRSAR Mesoamerica Mission** (Biological/Arqueol-Mar 04)
  - **TICOSONDE/NAME Project** (Atmospheric, Modeling-Sept 04)

CENTRO NACIONAL DE ALTA TECNOLOGIA

- Missions 2005 :
  - **CARTA II** (Land use-Mar 05)
  - **TCSP** (Storms-Jul 05)
  - **WAVE** (Shuttle reentry Aug05)
- Future Missions:
  - **CR-AVE validation**
  - **Other Space Agencies**

National Hangar, SJO, Costa Rica

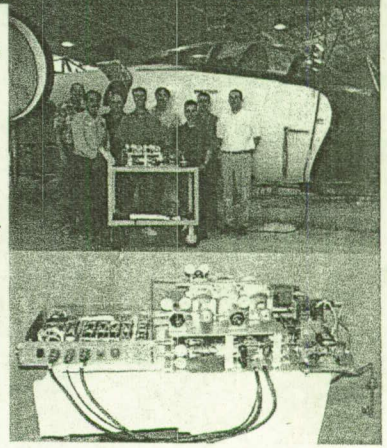
Airborne Volcanic Emission Mass Spectrometer (AVEMS)
-Kennedy Space Center Instrument-

CENTRO NACIONAL DE ALTA TECNOLOGIA

PRIAS-CENAT-University of Costa Rica-NASA-KSC Collaboration

Airborne Gas Monitoring Instrument:

- Quadrupole Mass Spectrometer RGA 200 from SRS
- Mass Range 1-200 Da
- Portable: 92,000 cm^3 (5,640 in^3); 84 lb
- On-board gas bottles for on-site calibration
- Capable of monitoring and quantifying up to 16 gases simultaneously.
- Power Efficient: 350 W steady state
- Rugged: 40 to -65°C; 760 to 50 torr, altitude of 41,000
- Autonomous Operation
- Operate in Other Vehicles (Operate on Battery Power, able to be taken to Remote and Harsh Locations)

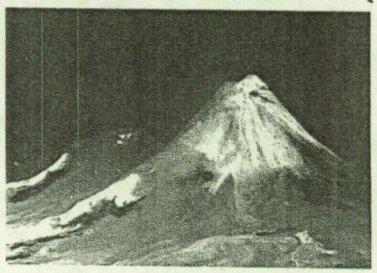


AVEMS Specifications

	H_2 (2 Th)	Helium (4 Th)	O_2 (32 Th)	Argon (40 Th)	CO_2 (44 Th)	Acetone (43 Th)	SO_2 (64 Th)
Accuracy (%)	32.0	1.6	4.5	1.7	8.8	4.9	2.1
Precision (%)	3.9	5.7	2.9	3.3	1.7	1.2	1.3
LOD (ppm)	13.1	1.3	225	1.0	12.4	3.7	1.1
2-hr Drift (ppm)	472*	3.4	–	11	160*	3	1
Response (s)	7	5	6	5	7	–	8
Recovery Time (s)	7	3	–	4	8	–	8

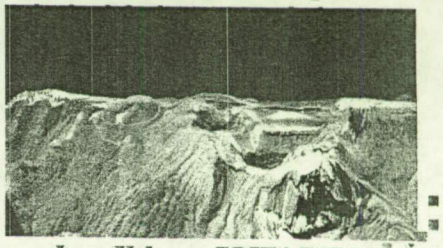
Volcanic Hazards Application

Radar Data (AIRSAR)
+ IR Pictures (CARTA)



Arenal Volcano, COSTA RICA

Purpose:
Georeferenced gas concentration data on top of 3D land modeling generate by remote sensing data

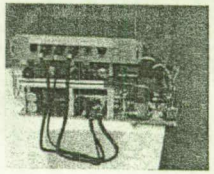


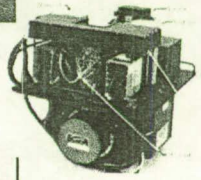
Irazu Volcano, COSTA RICA

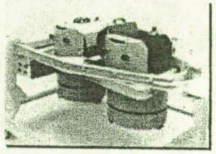
CARTA I (2003)

(Costa Rica Airborne Research and Technology Applications)

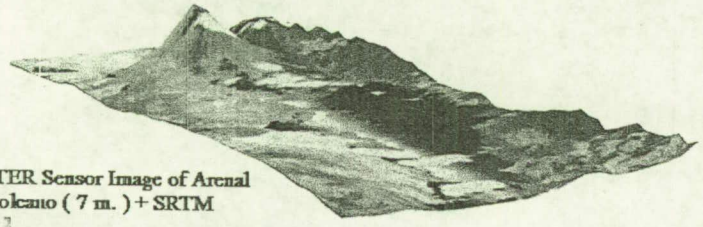
- ***3 Instruments Involved***
  - AVEMS Mass Spectrometer
    - Air analysis at low altitudes above volcanoes
  - MASTER multispectral scanner
    - Vegetation / land cover analysis at high altitude for entire country, and low altitude for selected areas
  - IR Camera
    - Field work control and accuracy assessment





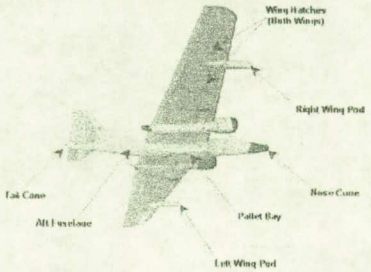


Remote Sensing Data: CR Volcanoes

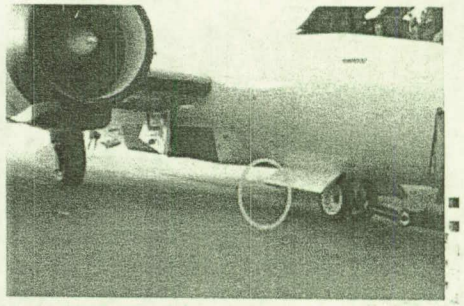


MASTER Sensor Image of Arenal Volcano (7 m.) + SRTM

Sampling from WB-57



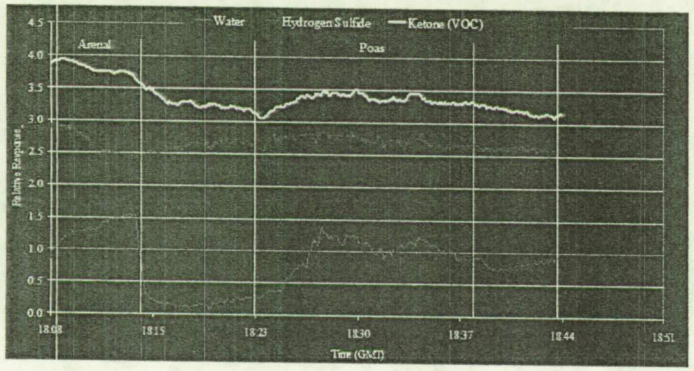
Sample Inlet on WB-57



30 sec/scan

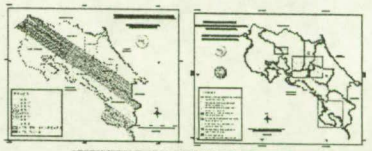
- 2.5 mile at 300 mile/hr
- 1.7 mile at 200 mile/hr

Previous Flight Results: 2003

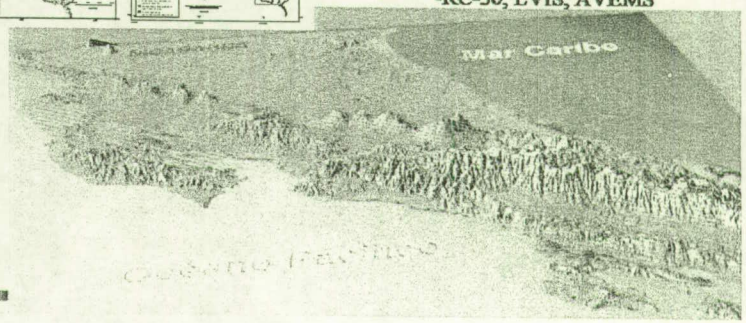


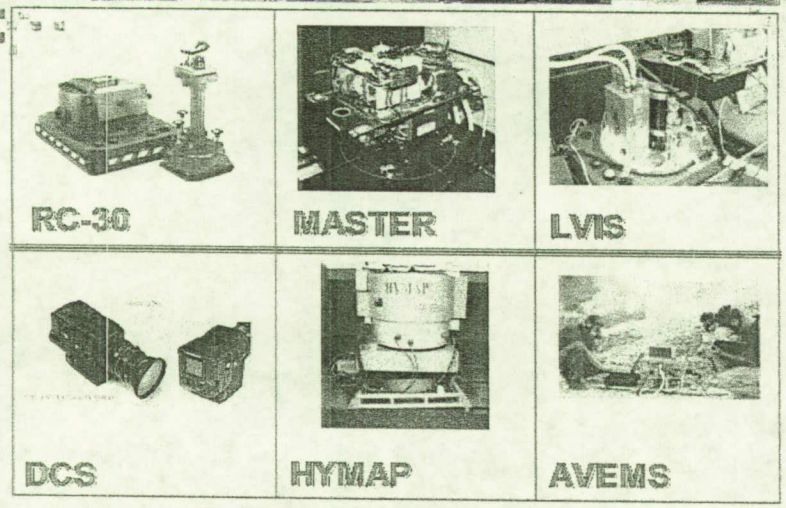
CARTA II (2005) MISSION

High Resolution Large Scale coverage of Costa Rica + Special Site studies



- 3 Aircraft
  - WB-57, King Air, CESSNA
- 6 Sensors
  - MASTER, HYMAP, Digital,
  - RC-30, LVIS, AVEMS





CARTA 2005 Sensors

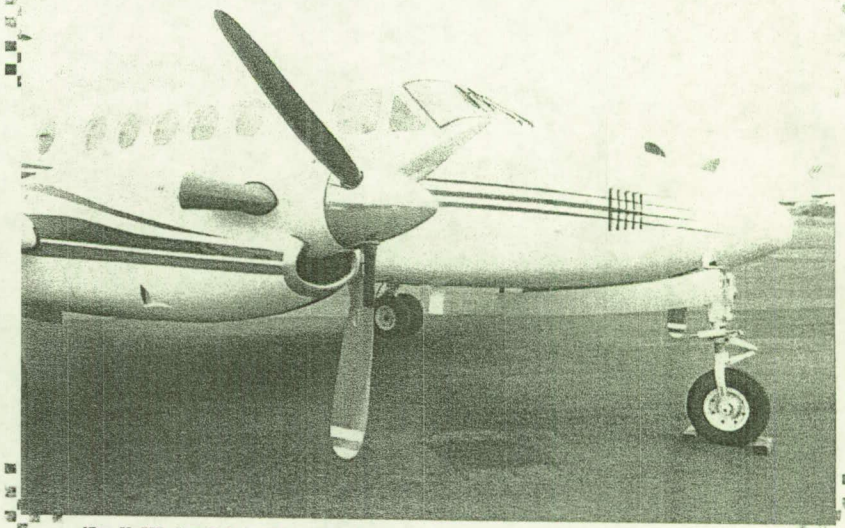
Multiespectral data
CARTA 2005 Mission
WB-57 Aircraft

Costa Rica Volcano
Rincon de la Vieja

CARTA 2005 Openning Ceremony. National Interest declaration by the President of Costa Rica

President of Costa Rica : Dr. Abel Pacheco de la Espriella, Presidente de La República y MSc. Fernando Gutiérrez, Ministro de Ciencia y Tecnología, visit to Hangar during CARTA 2005 openning event

CARTA 2005 deployment: C5 and WB-57 from NASA at SJO, Costa Rica



King Air 200 aircraft from DOE used for LVIS sensor

CESNNA NAVAJO, Aircraft provided by "Servicio de Vigilancia Aerea" during CARTA 2005 Mission.

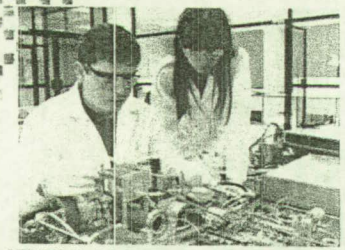
Dr. Tim Griffin integrating AVEMS for the first Scientific overflight, CARTA 2005

CESNNA AZTECA. Second aircraft used during Mission.

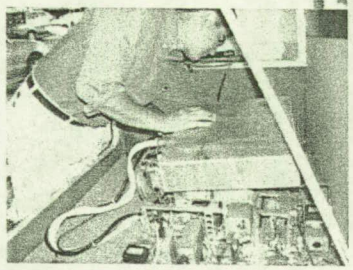
Airborne Platform for AVEMS:

Two CESSNA aircrafts were used for the different flights that ranged from 30 min to 2 hour long, flying up to an altitude 15 000 feet. The AVEMS was powered with two 24 V portable batteries and one inverter .

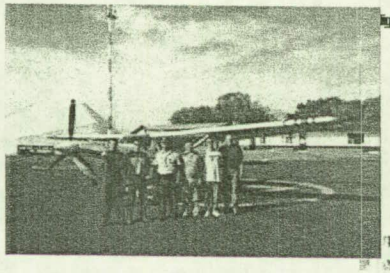
CARTA 2005 flight planning with WB-57 and other aircraft involved on Mission



CENAT Lab. (L to R) Elian Conejo & Kristel Heinrich Preparing AVEMS sensor for a new mission.

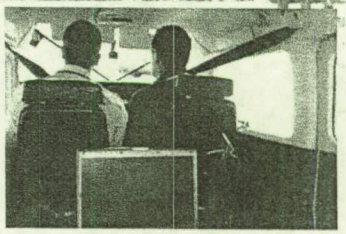


AVEMS Team, AVEMS aircraft flight planning before takeoff.



FIRST FLY TEAM (L to R) Dr. J. Andres Díaz, Oliver Gómez, Cap. Rafael Méndez, Elian Conejo, Dr. Richard Arkin & Dr. Tim Gallin.

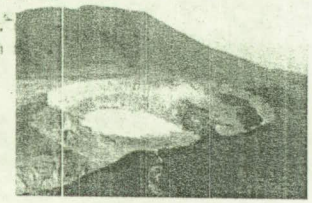
FINAL CALIBRATION. Dr. Jorge Andrés Díaz prepesing The instrument before take off.



AVEMS Airborne: Cap. Méndez & Co-pilot O. Gómez, following the fly planning for the data adquisition.

After flight, NASA-KFC scientifics analyzing raw data collected

AFTER fligth. (L to R) Elian Conejo & Kristel Heinrich Cleanning the instrument.

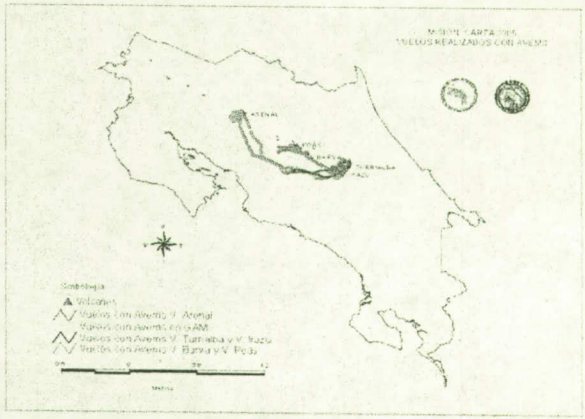


POAS VOLCANO. Aircraft intercepting the volcano ...

IRAZÚ VOLCANO. Aircraft on top of the crater.

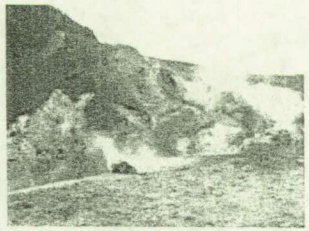
ARENAL VOLCANO.

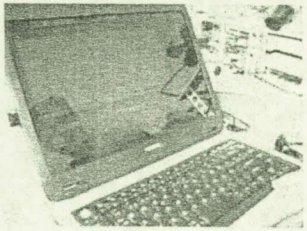
TURRIALBA VOLCANO.



AVEMS Flights, CARTA deployment Mar05

Volcanic Emissions Monitoring
In situ AVEMS measurements



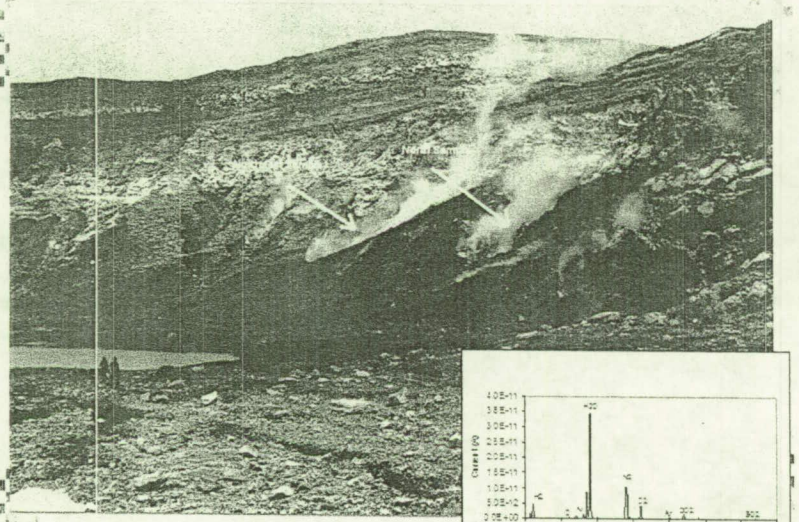


AVEMS TEAM. Test of the instrument Turrialba Vocano.

TURRIALBA VOLCANO. AVEMS team walking to The crater.

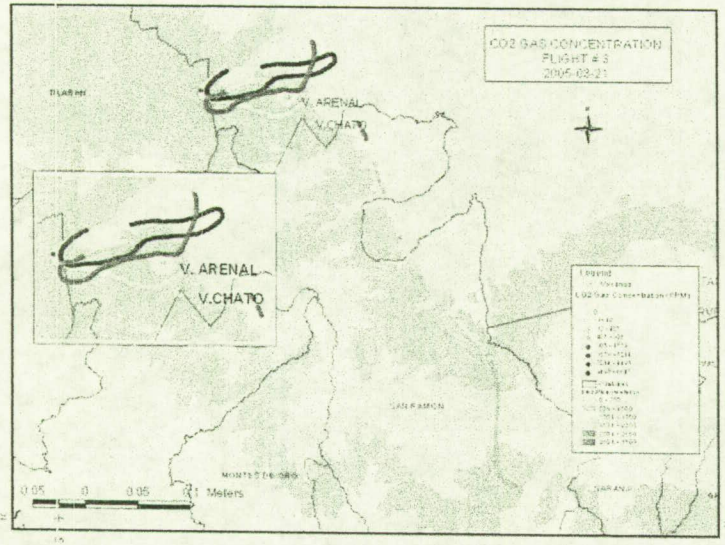
TURRIALBA VOLCANO CRATER

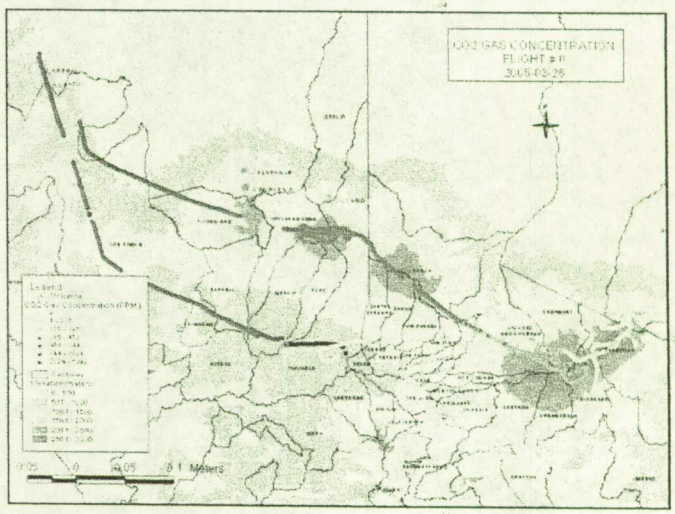
DATA ADQUISITION. Elian Conejo colecting data

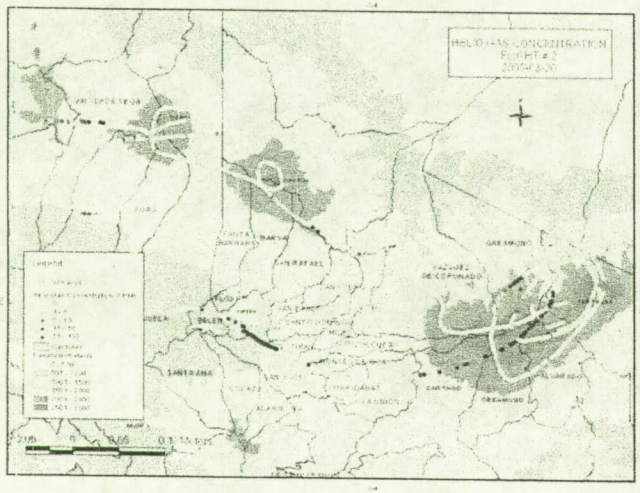


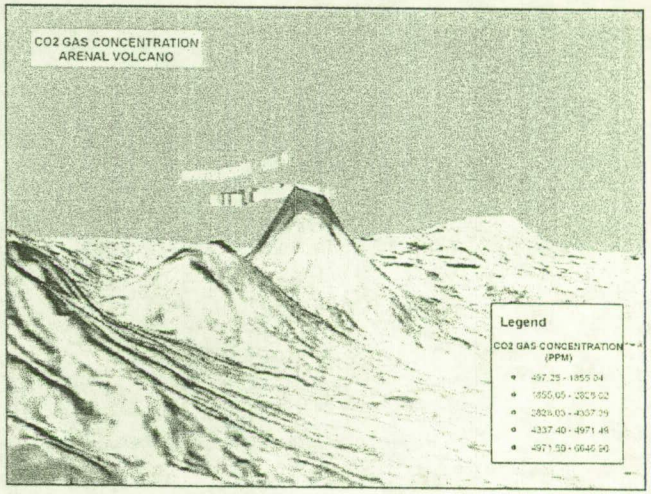
Volcano Flight Results

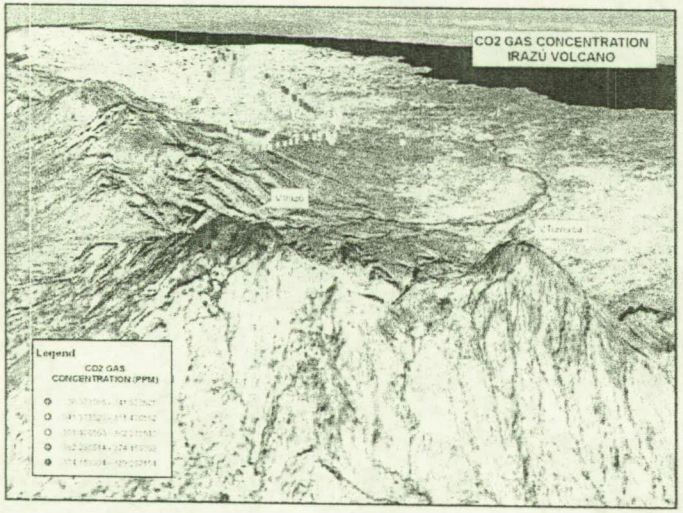
- The in-situ gas data in this work, consisting of helium, carbon dioxide, sulfur dioxide and acetone, was acquired in conjunction of GPS data which was plotted with the ground imagery, topography and remote sensing data collected by the other instruments, allowing the 3 dimensional visualization of the volcanic plume and the mapping of gas concentration at the crater. The modeling of possible scenarios of volcanic activity and its direct impact on urban areas is now possible with the combined set of data.
- The gas concentration data collected with AVEMS during the different flights, contains geographical location attributes (Latitude, Longitude, Altitude), obtained using a GPS. These data is the main input to locate spatially the information.
- In order to model the plume location, which is not necessary visible to the human eye and poorly represented if it is plotted in two dimensions, digital elevation data obtained by other sensors during the CARTA 2005 campaign, topographic data generated by the Shuttle Radar Topographic Mapping (SRTM) Mission and remote sensing data from the LANDSAT satellite (both geo-referenced) are combined to produce a 3D ground model and overlaid with the gas concentration data. In this way, characteristics related to the flight path direction and position of the volcanic plume are visible in the 3D model..

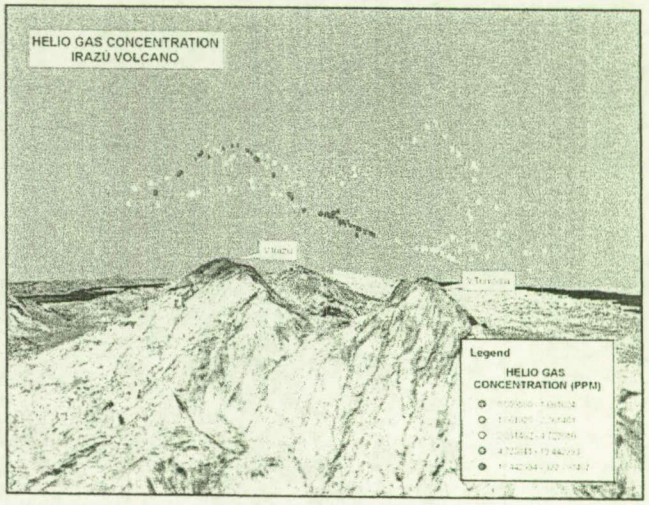

CO2 GAS CONCENTRATION
FLIGHT # 3
2005-02-21
V. ARENAL
V.CHATO
SAN RAMON
Meters

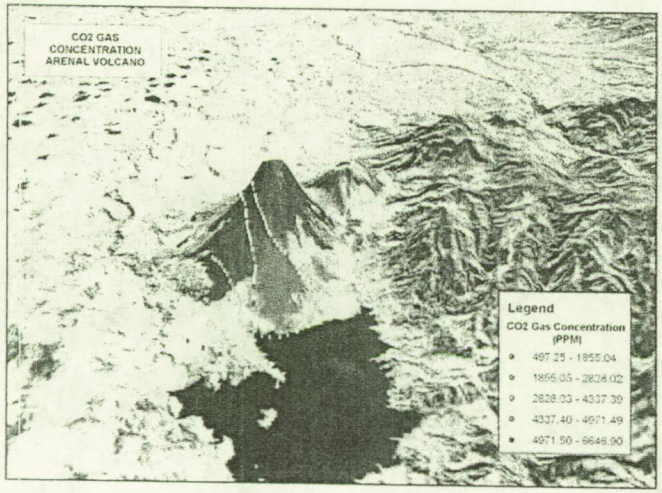

CO2 GAS CONCENTRATION
FLIGHT # 8
2005-03-25
Meters

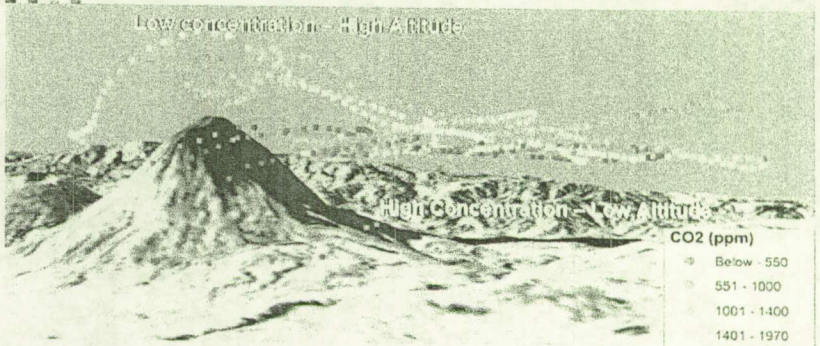

HELIOS GAS CONCENTRATION
FLIGHT # 3
2005-03-30


CO2 GAS CONCENTRATION
ARENAL VOLCANO
Legend
CO2 GAS CONCENTRATION
(PPM)
497.25 - 1855.04
1855.05 - 2825.02
2826.03 - 4337.39
4337.40 - 4971.48
4971.59 - 6646.90









Carbon dioxide concentrations around Arenal Volcano.

CO2 (ppm)

- Below - 550
- 551 - 1000
- 1001 - 1400
- 1401 - 1970
- 1971 - 2600
- 2600 - 3300
- 3301 - 3980
- 3981 - 4520
- 4521 - 5200
- Over - 5230

Conclusions

- AVEMS demostrated its usefulness in aerial plume analysis at Arenal Volcano, presently the most active Costa Rican volcano.
- Several 3D gas concentration visualization were obtained for several gases. These 3D maps now serves to model plume direction and variability to predict posible impact on urban area and crops in the area closer to the volcano, as well as it is used as a guide for aircraft operation near the volcano.
- Other applications of AVEMS demonstrated during the CARTA 2005 campaign included ground fumarole emission analysis. Also, the concentration of carbon dioxide around urban areas was measured spatially multiple times to provide temporal information as well
- Unit very versatile: fly, hand-carry, drive

Future Work

- Use new/improved mass analyzer
- Use smaller/lighter valves/controllers
- Improve autonomous operation
- Improve flight trajectories
- Investigate pre-concentration techniques
- Incorporate an improved GPS

Acknowledgments

- We would like to thanks the "Servicio de Vigilancia Aerea" and Mr. Federico Carillo for their support on lending the aircrafts and flying the different aircrafts during the CARTA-AVEMS campaigns.
- We would like to acknowledge the CR-USA Foundation, el Consejo Nacional de Rectores, FUNCENAT, the Ministry of Science and Technology , the Direccion General de Aviacion Civil, OVICORI , CICANUM-UCR and the Engineering Directorate at Kennedy Space Center for their support on this project.