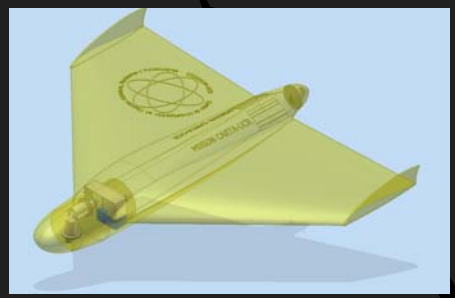
The ULISSES Project:

Utilization In-Situ Airborne MS based Instrumentation for the Study of Gaseous Emissions at Active Volcanoes



J. Andres Diaz[1], C Richard Arkin[2], Eric Gore[3], Timothy P. Griffin [3]
Yetty Madrigal[1], Edgar Rojas[1], Gabriela Duarte[1], Daniel Castillo[1], Sergio Achi[1], Karolina Mesen[1]

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(2) Hazardous Gas Detection Lab. ASRC Aerospace Corp., Kennedy Space Center

(3) National Aeronautics and Space Administration, Kennedy Space Center

(Dormant in orange)

Orosi Volcano

Rincon de la Vieja Volcano

Miravalles Volcano

Tenorio Volcano

Arenal Volcano

Poas Volcano

Barva Volcano

Irazu Volcano

Turrilaba Volcano

SJO – We live here

SL/CICANUM/UCR

Costa Rica

"Science and Technology are meant to improve the condition of our people"

JC Madriz, 1847

rrialba Volcano. Sept 16, 7am.

Why are we using a Mass Spectrometer for in situ Volcanic Monitoring ?

- Need to understand behavior of volcanoes based on continuous, real time monitoring
- Geochemical information is key and complementary to seismic data
- Better data = better prediction of eruptions and mitigation of effects
- No geochemical networks implemented, most based on electrochemical cells
- Lack of inexpensive instrumentation to collect all gases of interest continuously and in real time

Volcanic Gas Monitoring

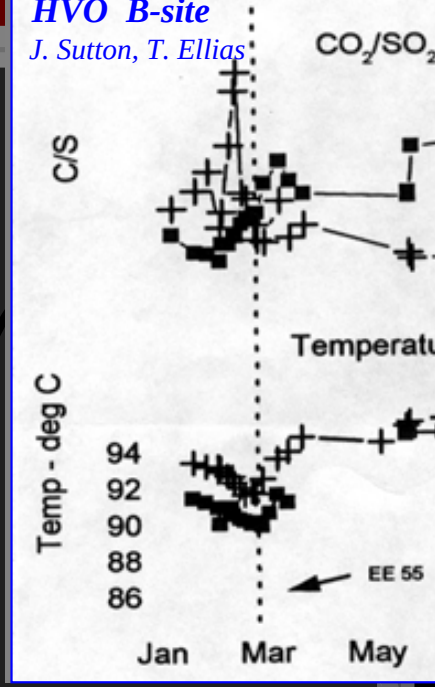
- *Volcanic Gaseous Species*

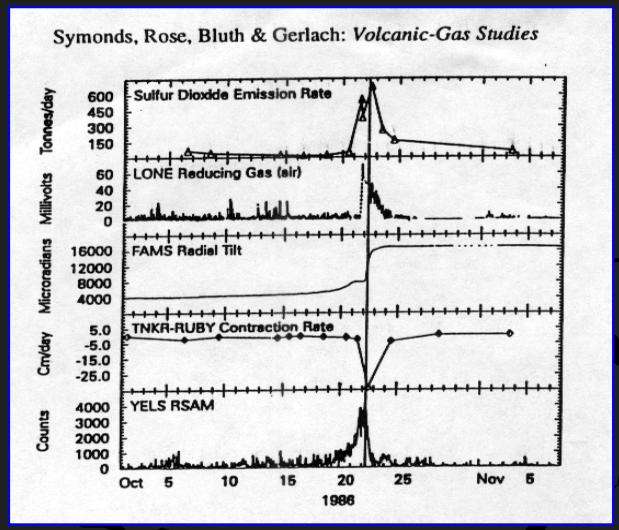
H_2O, CO_2, SO_2, H_2S, H_2, HCl, HF, CH_4, CO, He,

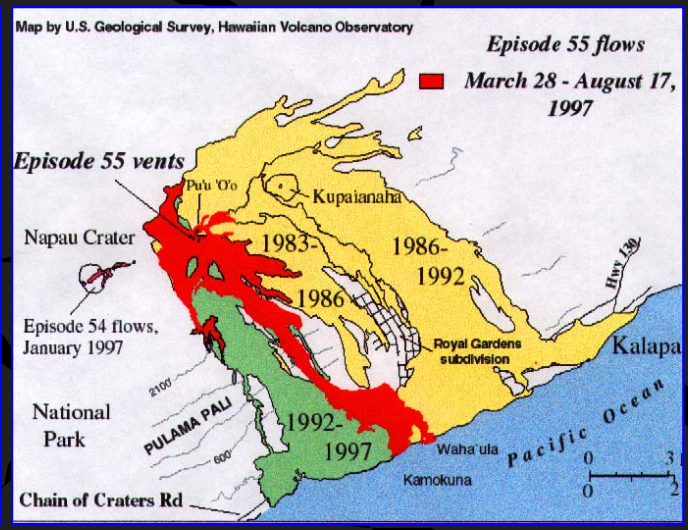
Trace concentrations of de COS, CS_2, HBr , y vapor de Hg

- *Evidence*

"Changes in the concentration and composition of these gas emissions can be used for the prediction of volcanic events"







Limitations

There is a lack of an adequate sensor capable on continuous "in situ" and real time measurements of <u>all</u> gas species emitted by the volcano at the same time

Background to "In-situ Airborne MS"

- Miniature mass spectrometer development (Ph.D. work at UMN, then UCR). 1996-2000
  - CDFMS Development
- Collaboration with vulcanologists at HVO, CVO, and CR. 1998-present
  - Kilauea, Poas, Irazu deployment
  - Portable-CDFMS development
  - Mammoth Lakes deployment
  - Continuous volcanic gas sampling and lab analysis
- Kennedy Space Center expertise on MS based monitoring systems and collaboration with Costa Rica 2000- present
  - Portable CDFMS test at KSC
  - AVEMS Development

Background to "In-situ Airborne MS"

- **CARTA Missions 2002-2008**
  - 2003 Mission, AVEMS system on NASA WB-57 aircraft
  - 2005 Mission, AVEMS system on CESNA
  - 3D concentration mapping using *is-MS* and *GPS*
  - Remote sensing combined missions
- **ULISSES 2009 to future**
  - Smaller MS system (ULYSES-α)
  - Remote sensing training (Italy)
  - NASA-JPL ASTER data collaboration
  - Unmanned Aerial Vehicle (UAV) implementation (future)

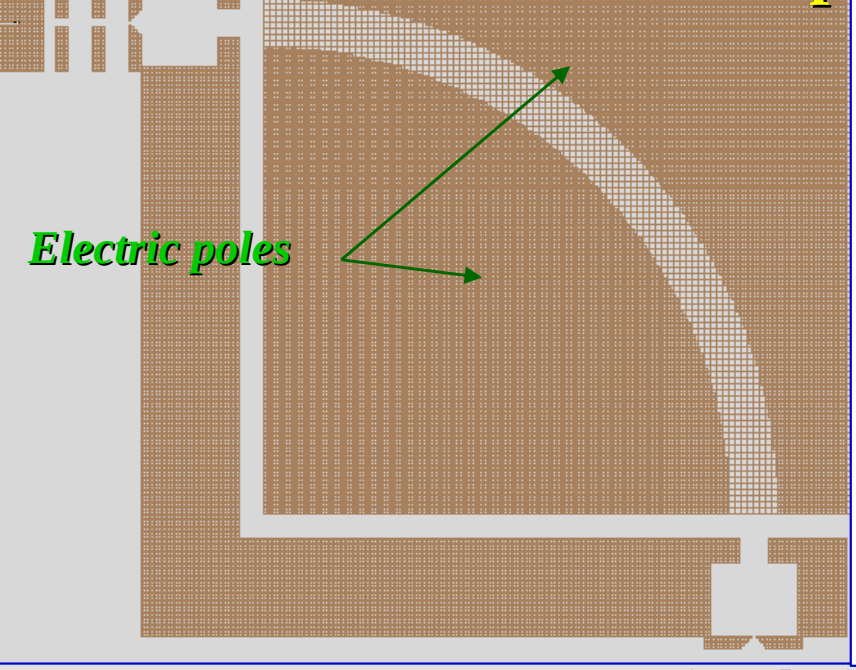
Miniature Mass Spectrometer Development

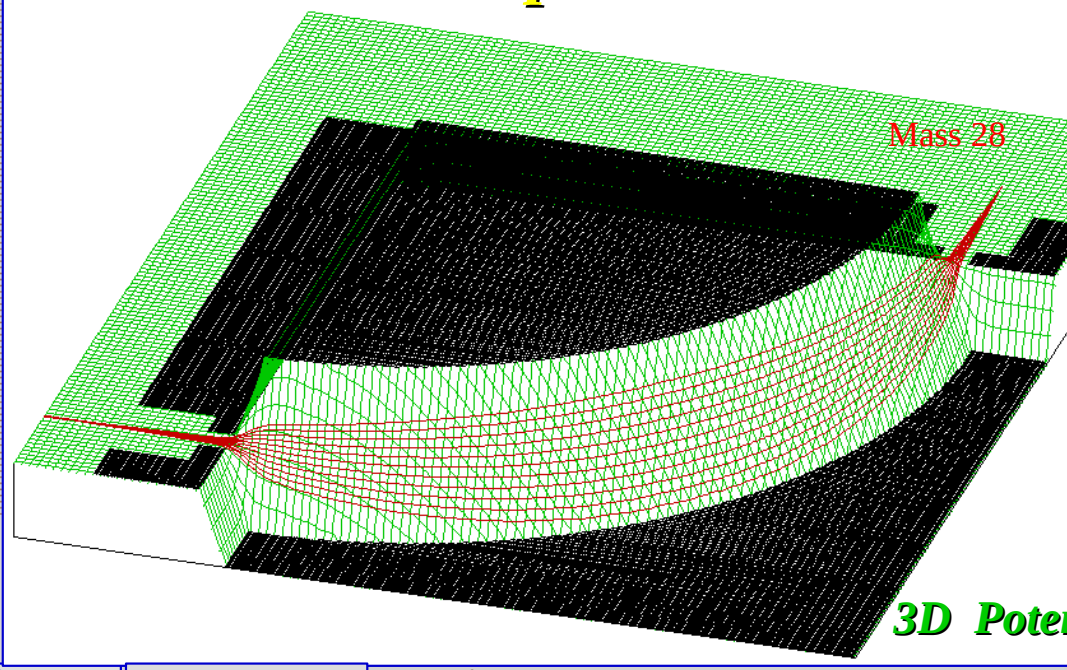
Prototype I **UMN @ Jan 98**

Features:

- 90^{o} ExB sector.
- 1 Tesla permanent magnet
- Double focusing capabilities
- Micro-fabricated component's
- Compatible with Si-Chip fabrication techniques
- Patent: #6,501,074 **:** *Double Focusing Mass Spectrometer Apparatus and Methods Regarding Same*
- Licensed to Mass Sensors Inc.
- Sub-licensed to INFICON Inc.
- Continued research and further development

•Compact Double Focusing Mass Spect. (CDFMS): Research Version

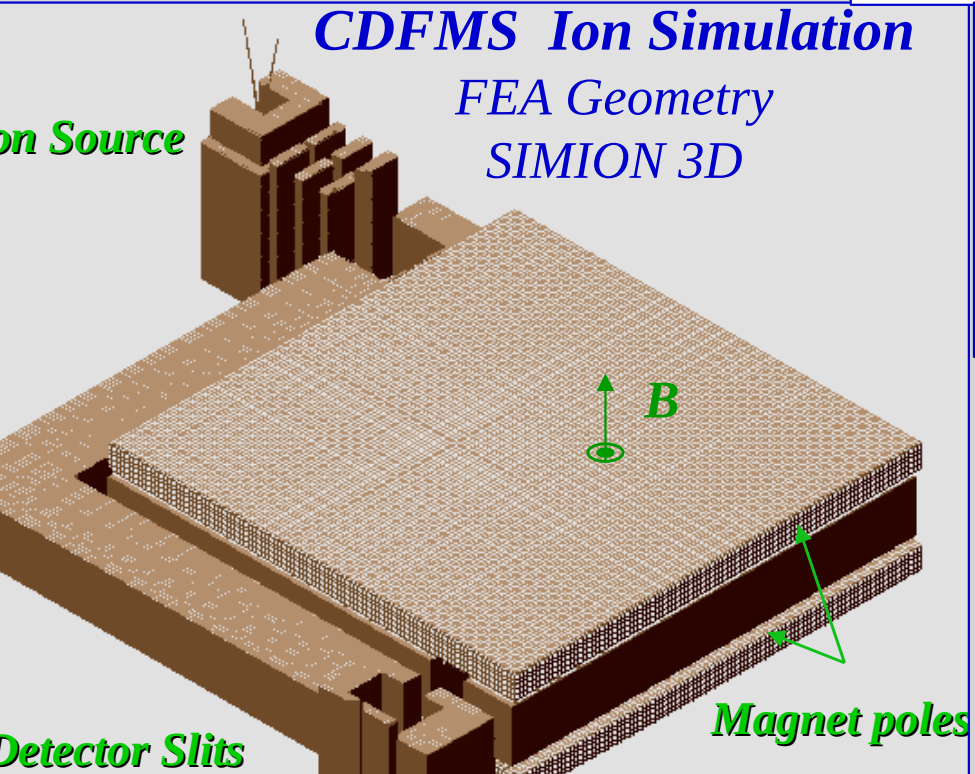


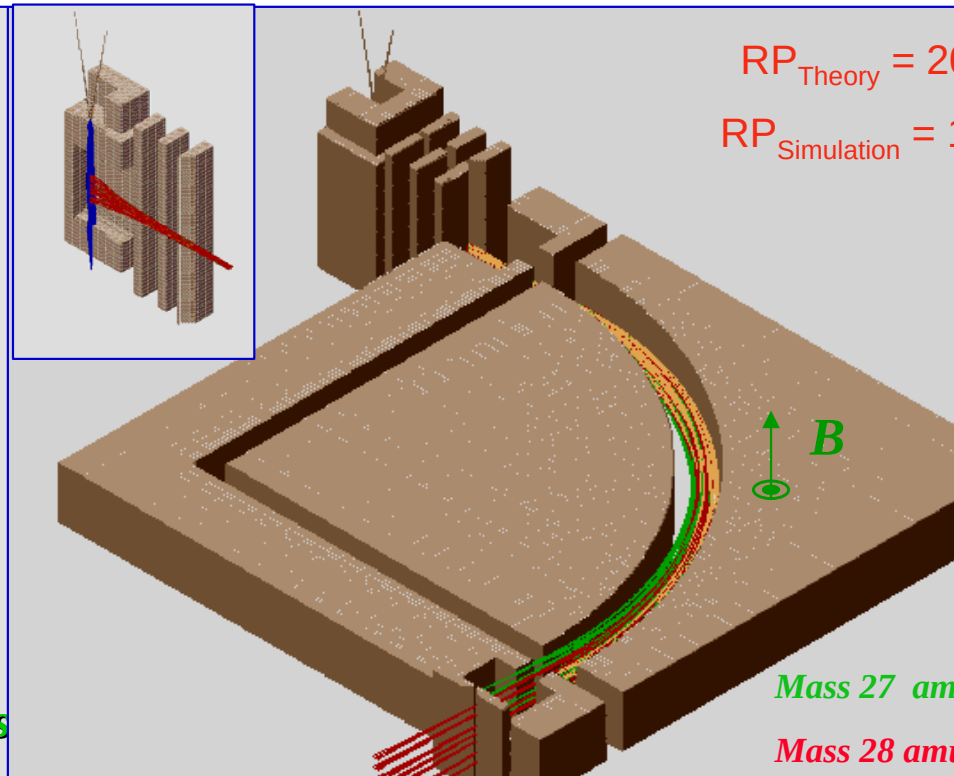


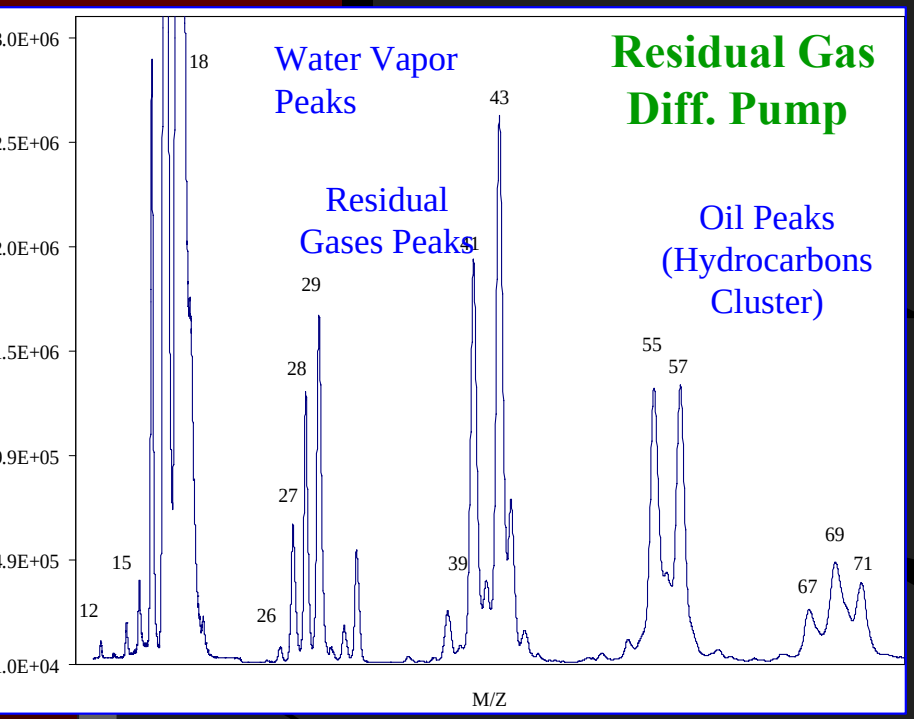
CDFMS Ion Simulation

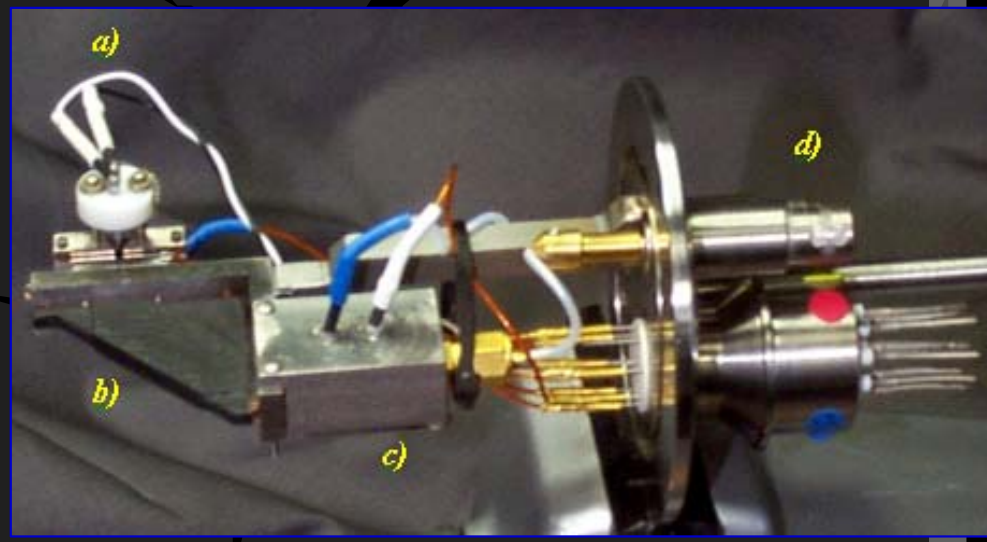
FEA Geometry

SIMION 3D

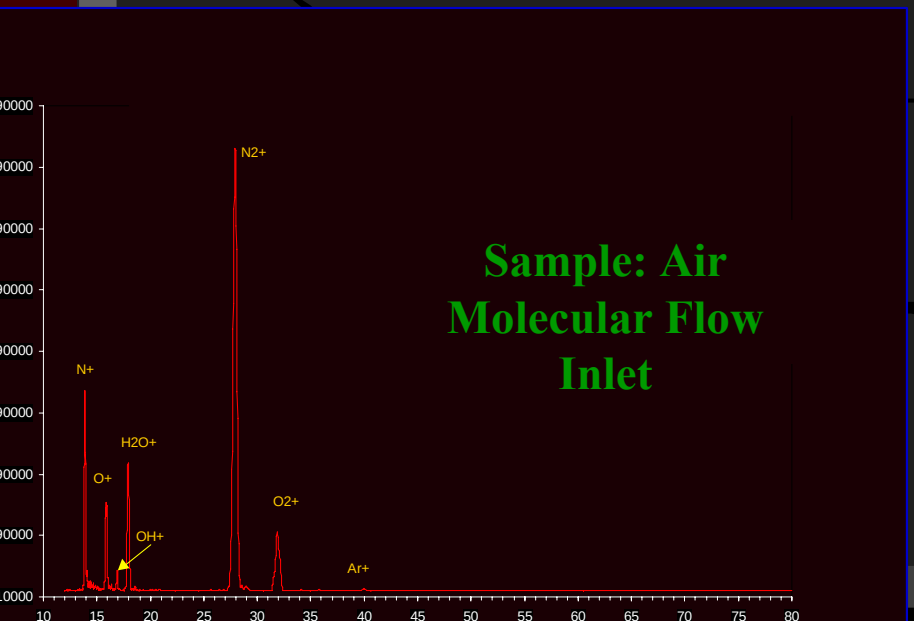


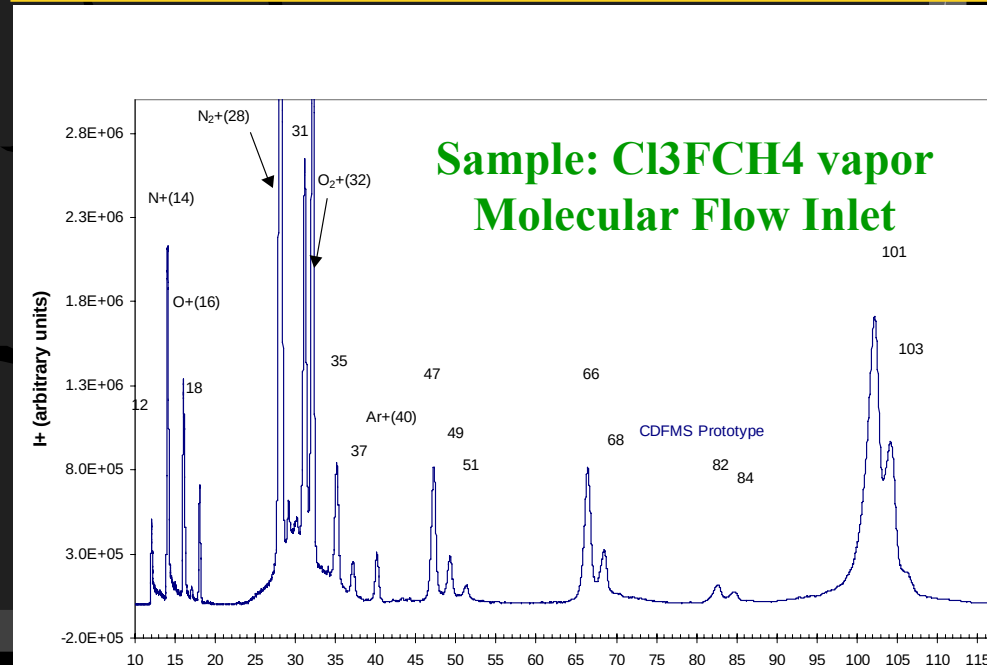




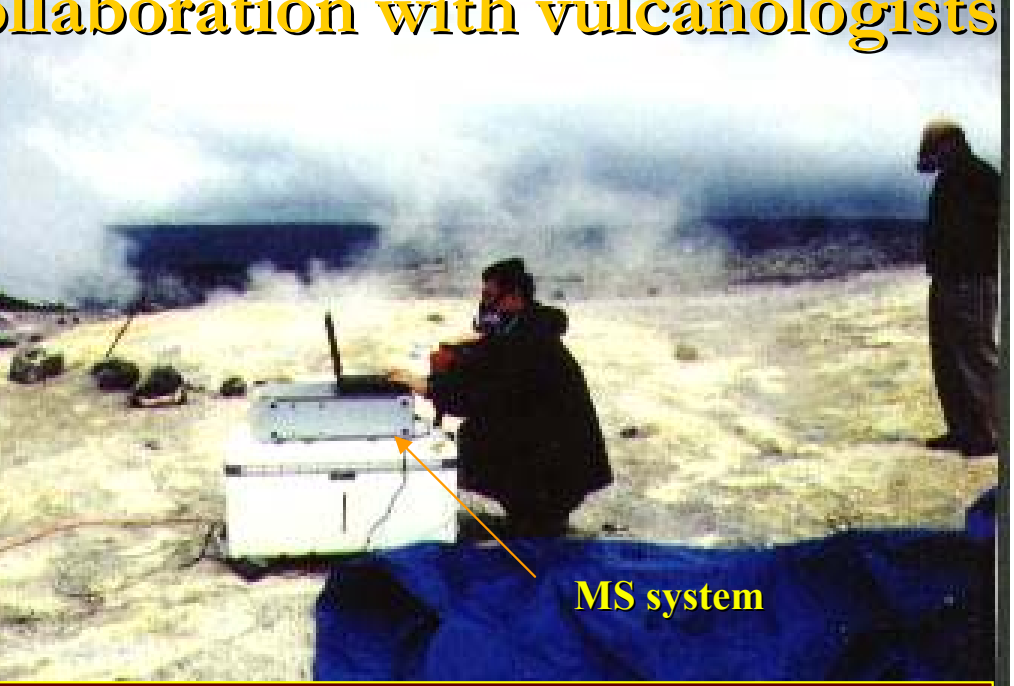


CDFMS Experimental Lab Testing

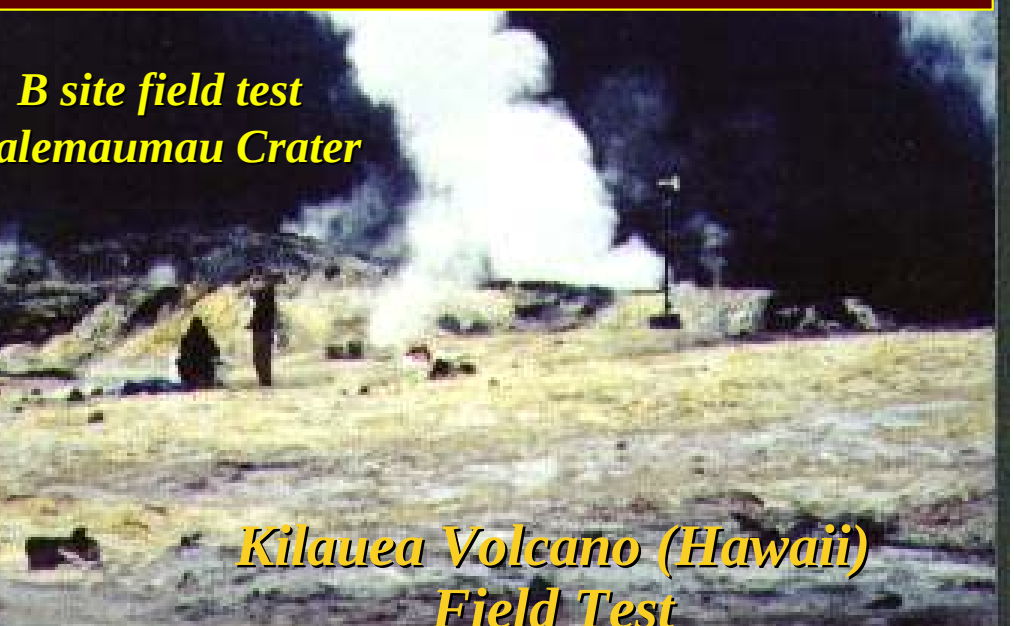


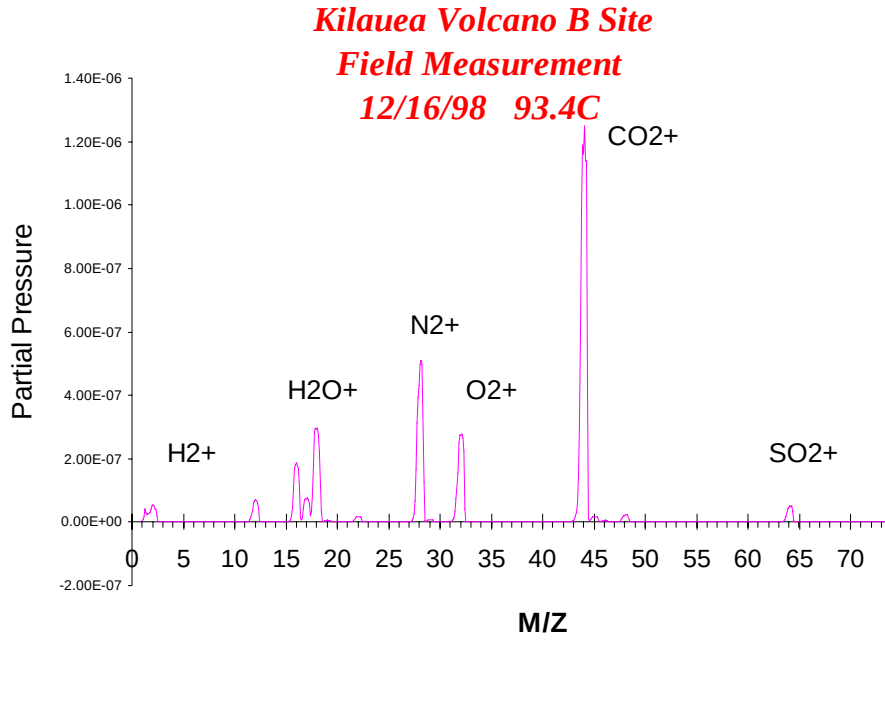


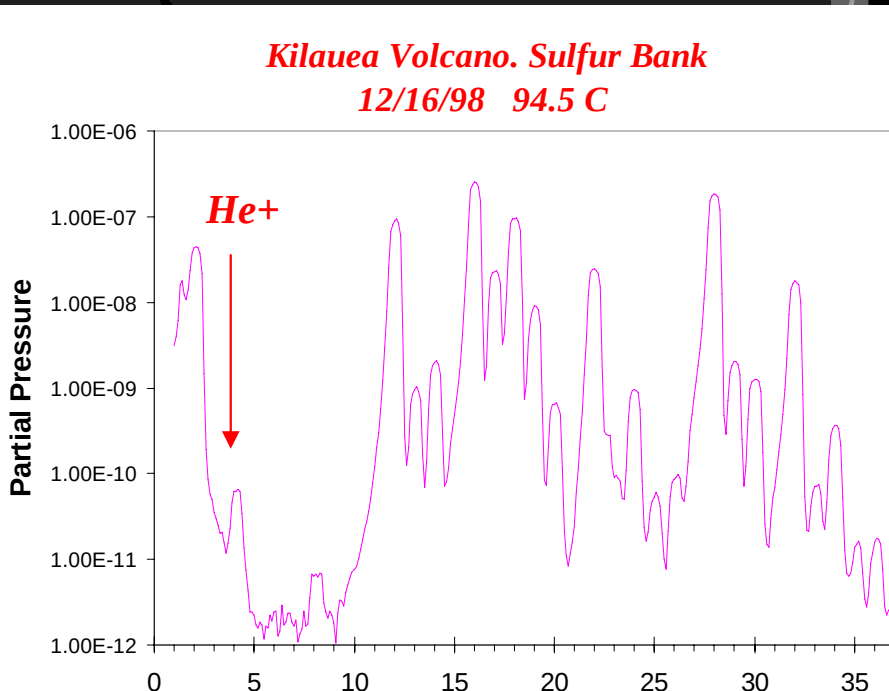
llaboration with vulcanologists



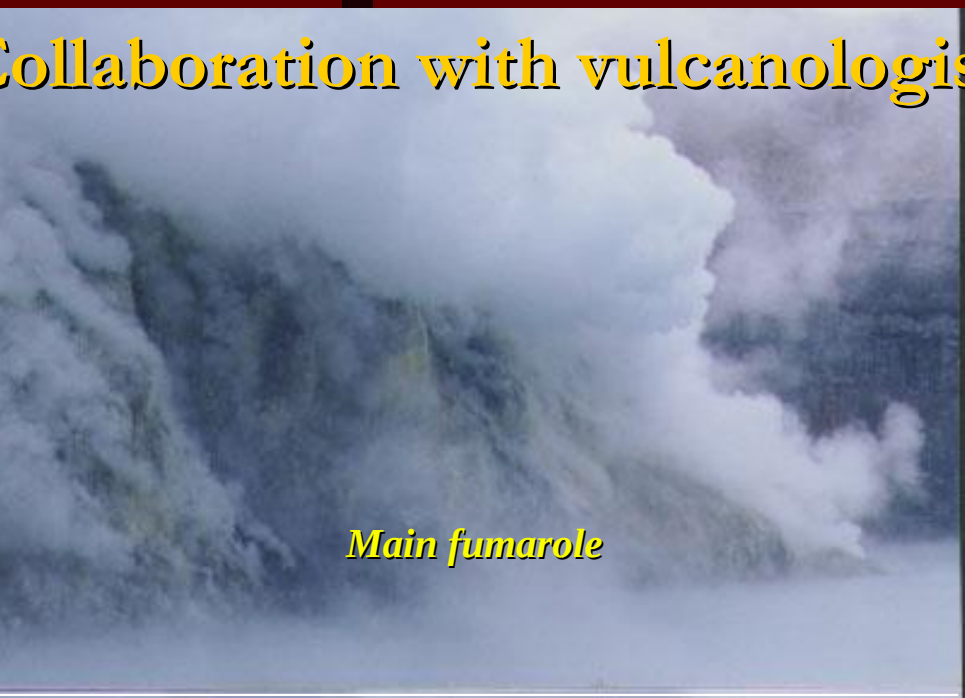
In-Situ Volcanic Emissions Measurements





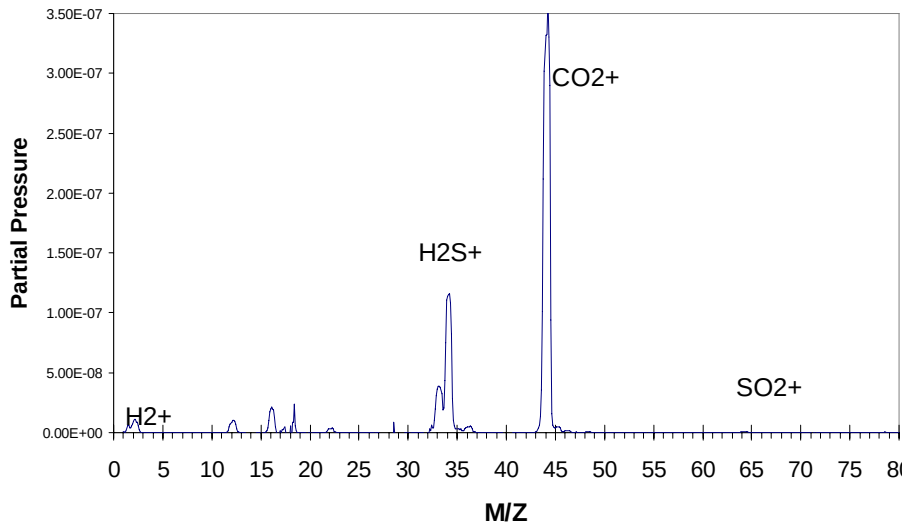


Collaboration with vulcanologists

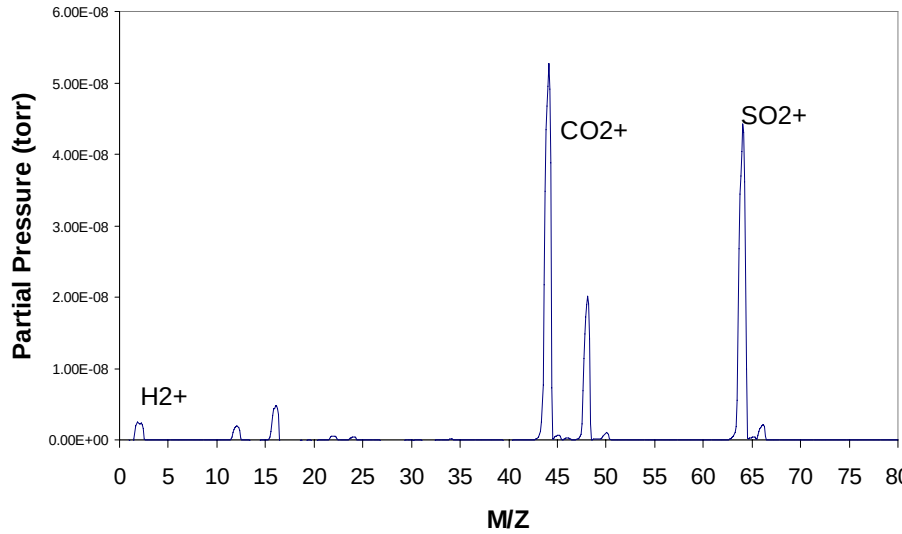


Poas Volcano (Costa Rica)
Field Test

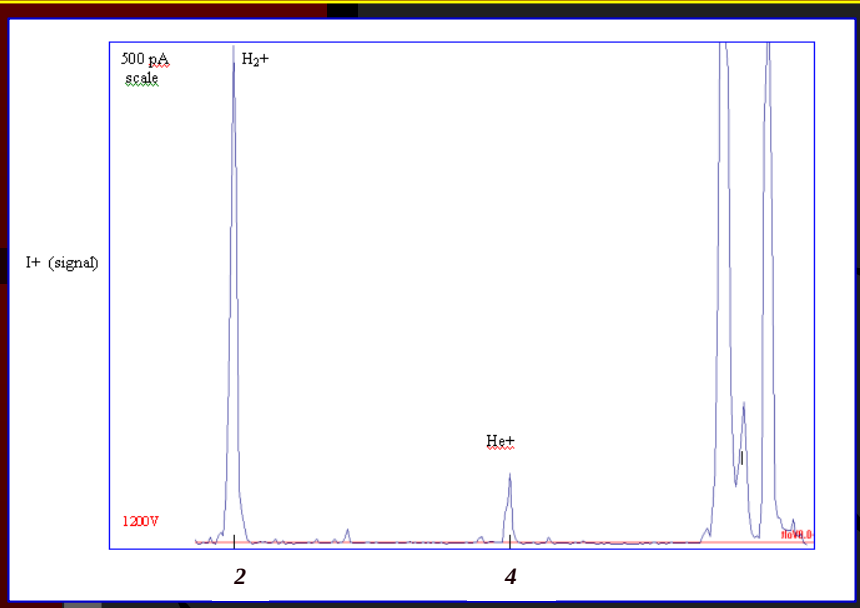
Poas Volcano Sample: South Wall #1
93.2C 3/12/99

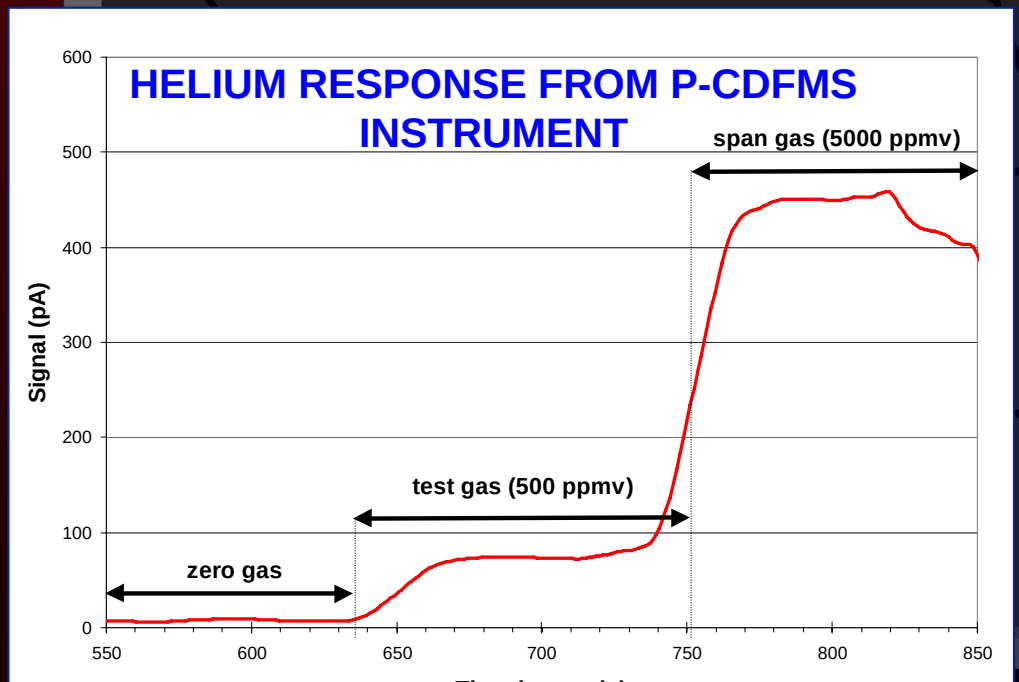


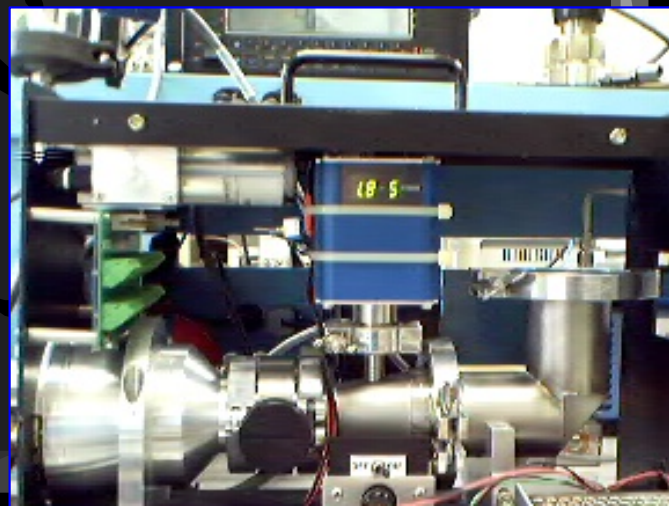
Poas Volcano. Dome#1.
94.6C 3/12/99



ennedy Space Center Collaboration







Aircraft Volcanic Emission Mass Spectrometer (AVEMS) First version

In-situ Airborne Monitoring

- **Designed for WB-57 aircraft**
- **Transportable: 92,400 cm^3 (5,640 in^3); 47 kg (104 lb)**
- **Power : 350 W steady state**
- **Rugged: 25 to -60°C; 760 to 50 torr**
- **Autonomous Operation. On board gas calibration (Zero, Test, Span Bottles)**
- **No onboard GPS , relied on aircraft navigation data**

AVEMS (Primary Mission Instrun

Airborne Volcanic Emission MS Systen

KSC-NASA (RGA 200)- Autonomous

***RTA MISSION* (Costa Rica Airborne Research and Technology Applications)**

WB-57: NASA Research Airc

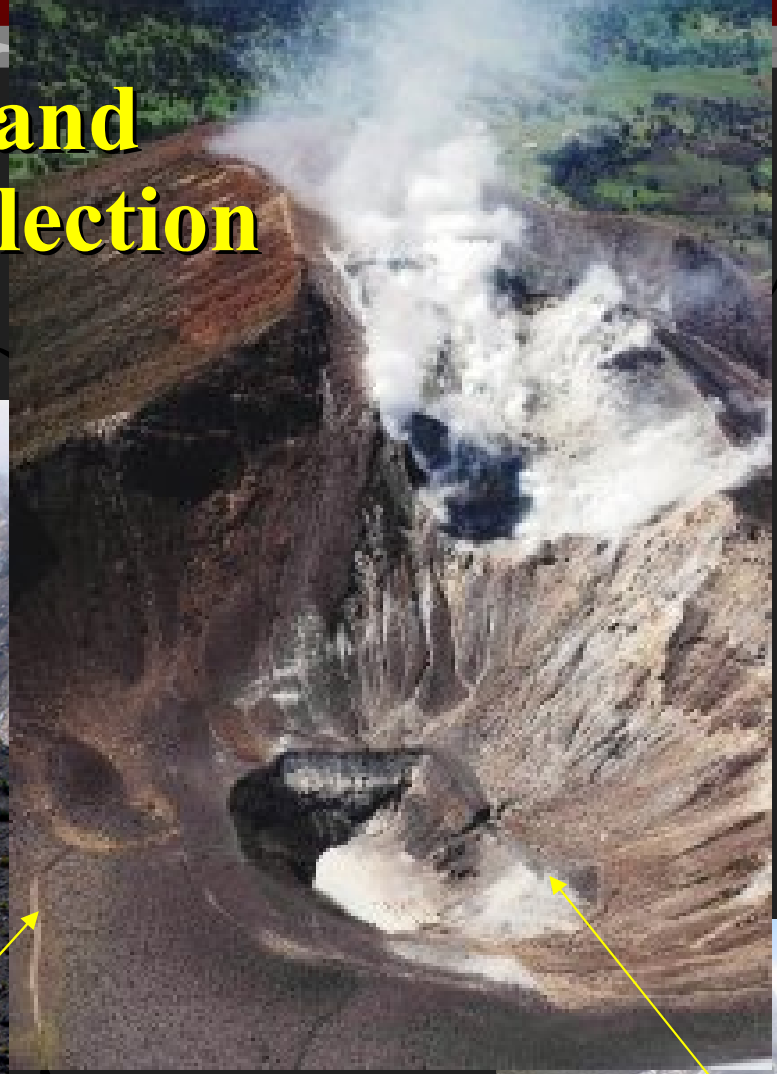
Operational Altitude up to 65K feet s

Aircraft Volcanic Emission Mass Spectrometer (AVEMS) Improved version

In-situ Airborne Monitoring

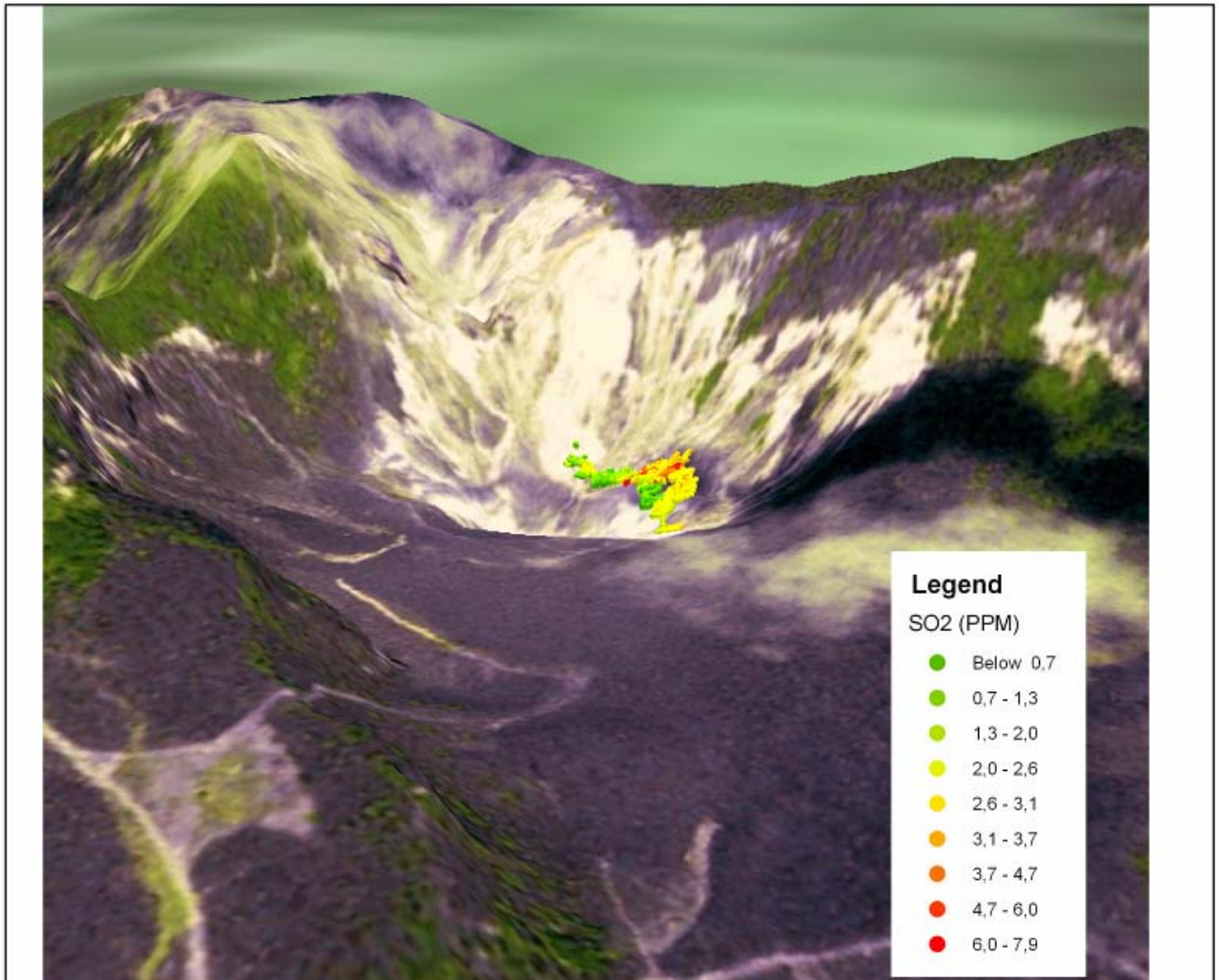
- **Flown in Cessna and Soloy Aircrafts**
- **Same size, power and ruggedness**
- **Lighter: 32 kg (70 lb)**
- **Semi-Autonomous Operation. Allowed user on board.**
- **On board gas calibration (Zero, Test, Span Bottles)**
- **Onboard GPS data collection**

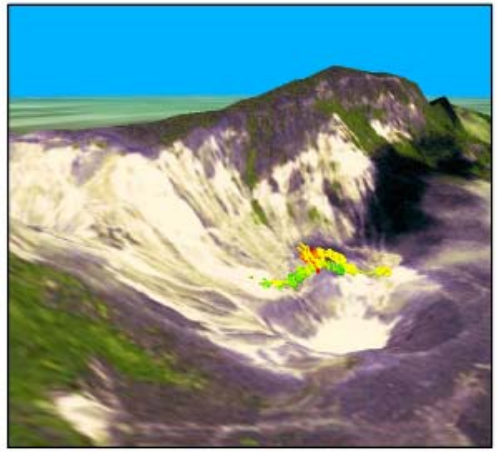
AVEMS Ground and Airborne data collection

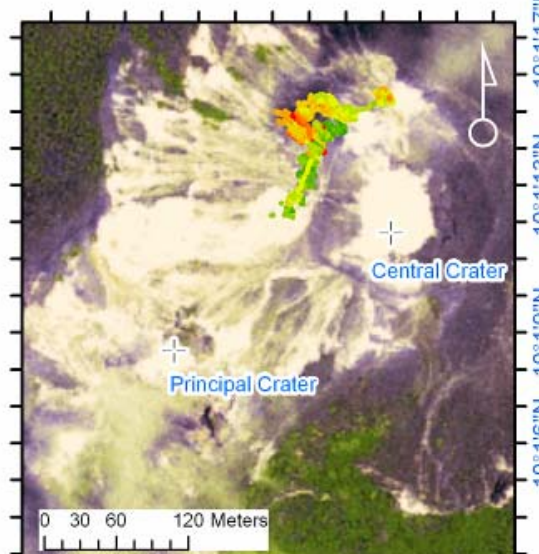


3D Concentration Mapping with Portable MS Systems (GPS + isMS)

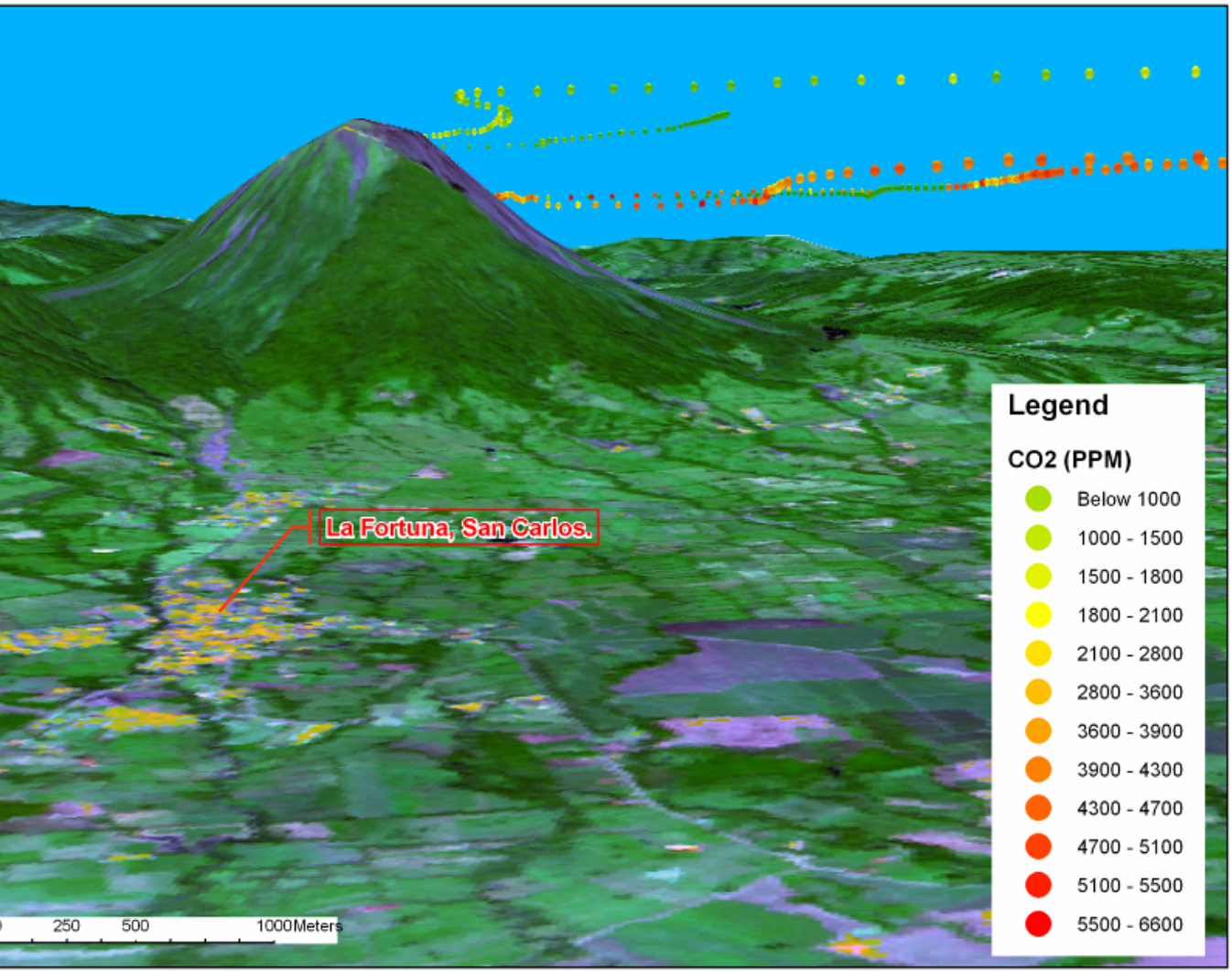
(JASMS paper, Aug 08)

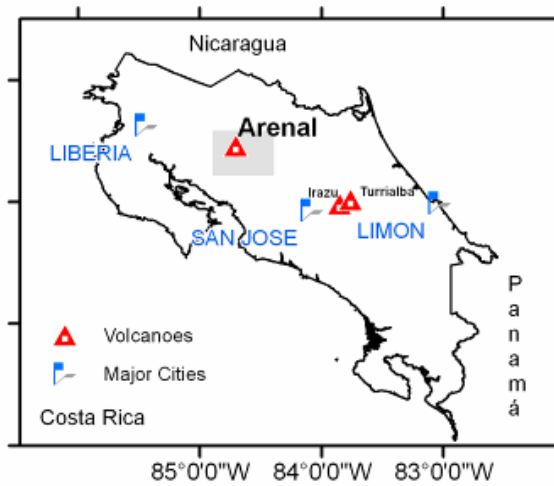


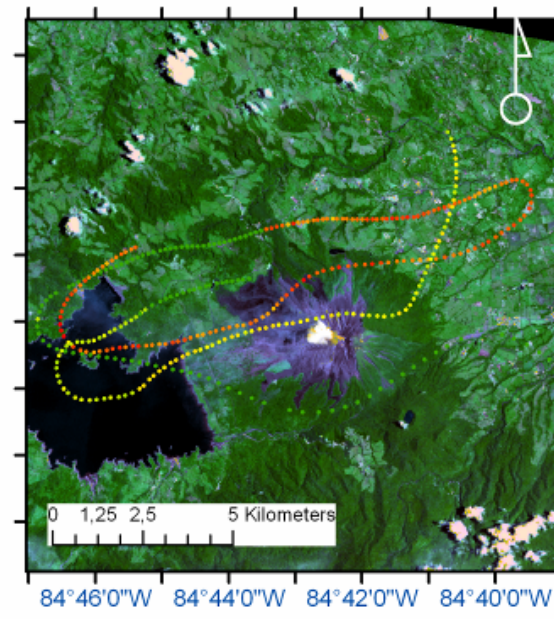




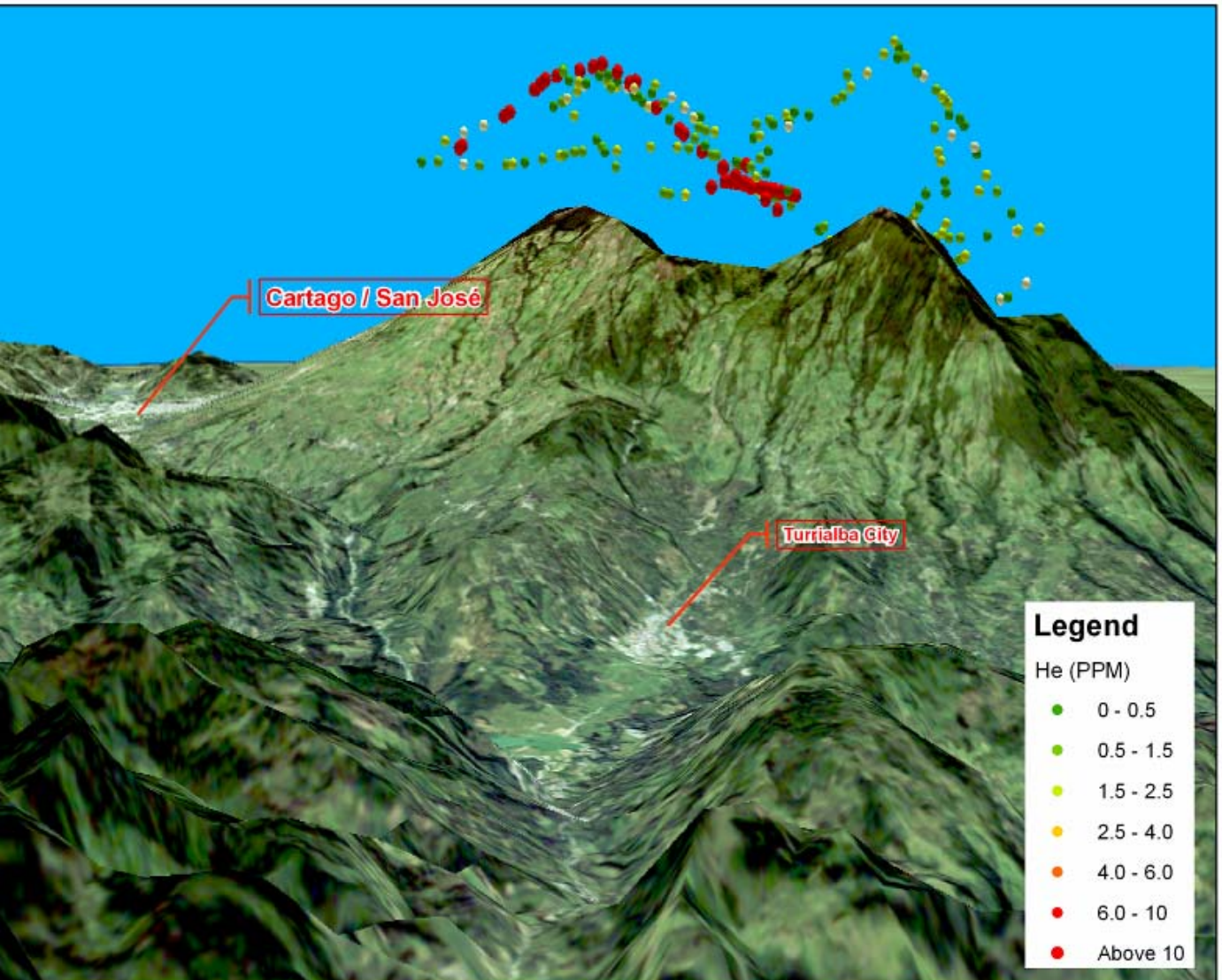
AVEMS In Situ 3D Airborne Data for Arenal Volcano

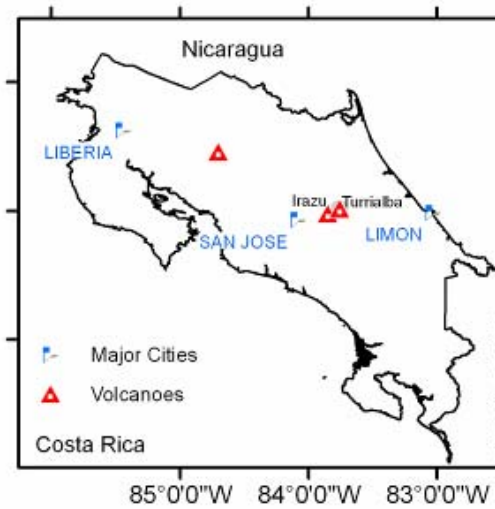


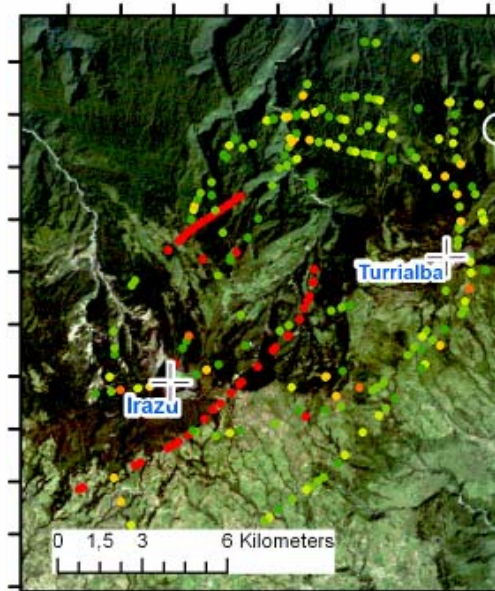




AVEMS In Situ 3D Airborne Data for Turrialba Volcano







Lessons learned from previous missions

- WB-57 was a very expensive platform and gave poor spatial resolution
- A smaller aircraft was needed to collect better airborne in situ data
- AVEMS proved to be a very useful instrument for 3D in situ concentration mapping, but needs to be smaller and lighter for carry it to the field and needs better sensitivity for volcanic plume measurements

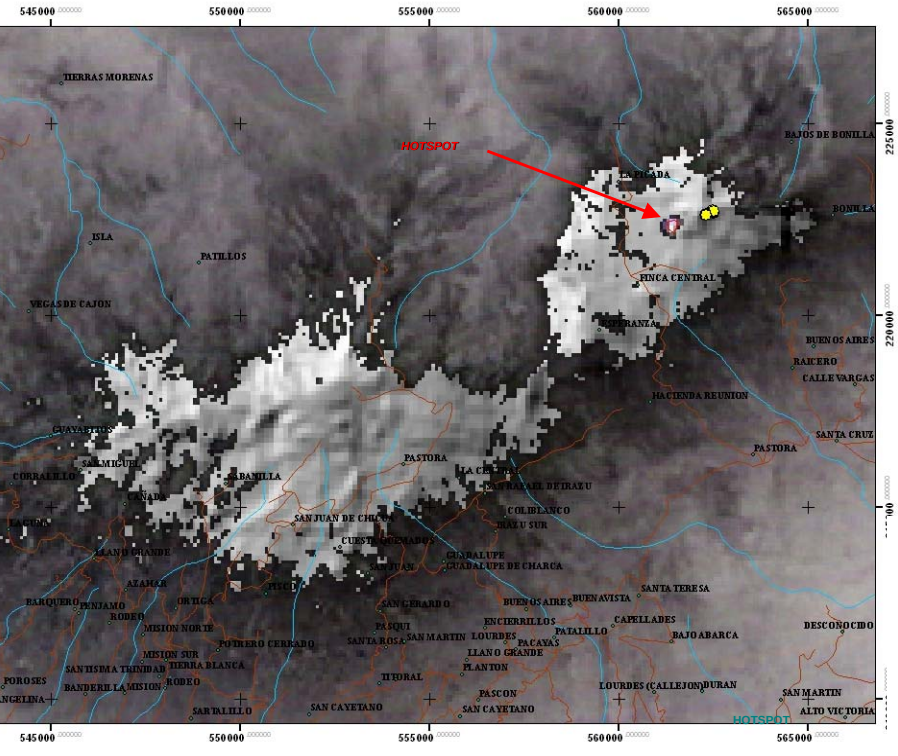
Another Perspective for Volcanic Monitoring Applications

- Volcanoes area natural laboratories and strong source of chemical species.
- These features are retrievable from satellite based sensors in near real time
- Mainly usage of gas analysis by remote sensor is done using the multiespectral, TIR and UV spectra
- Mass spectrometry offers a tool to compare remote sensing data both from ground, airborne and satellite platforms
- CARTA Missions work demonstrated enabling capabilities to conduct 3D concentration mapping of volcanic plumes

ars of Collaboration in Volcanology

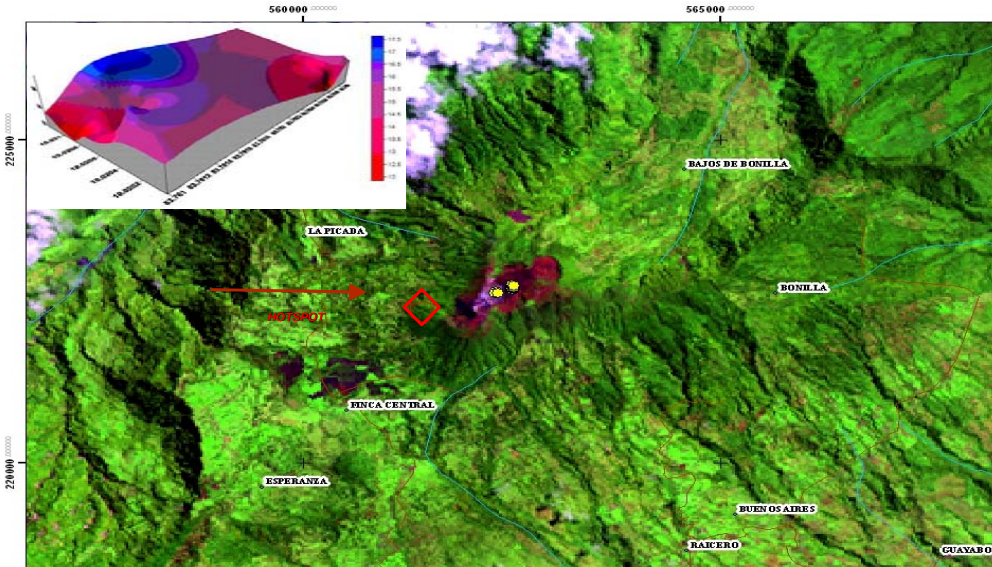
Remote Sensing and In-Situ Temperature Observations for the Awakening of Turrialba Volcano

J. Bonatti, J.A. Diaz, R. Garcia1 , M. Abrams. IVACEI, Island 2008

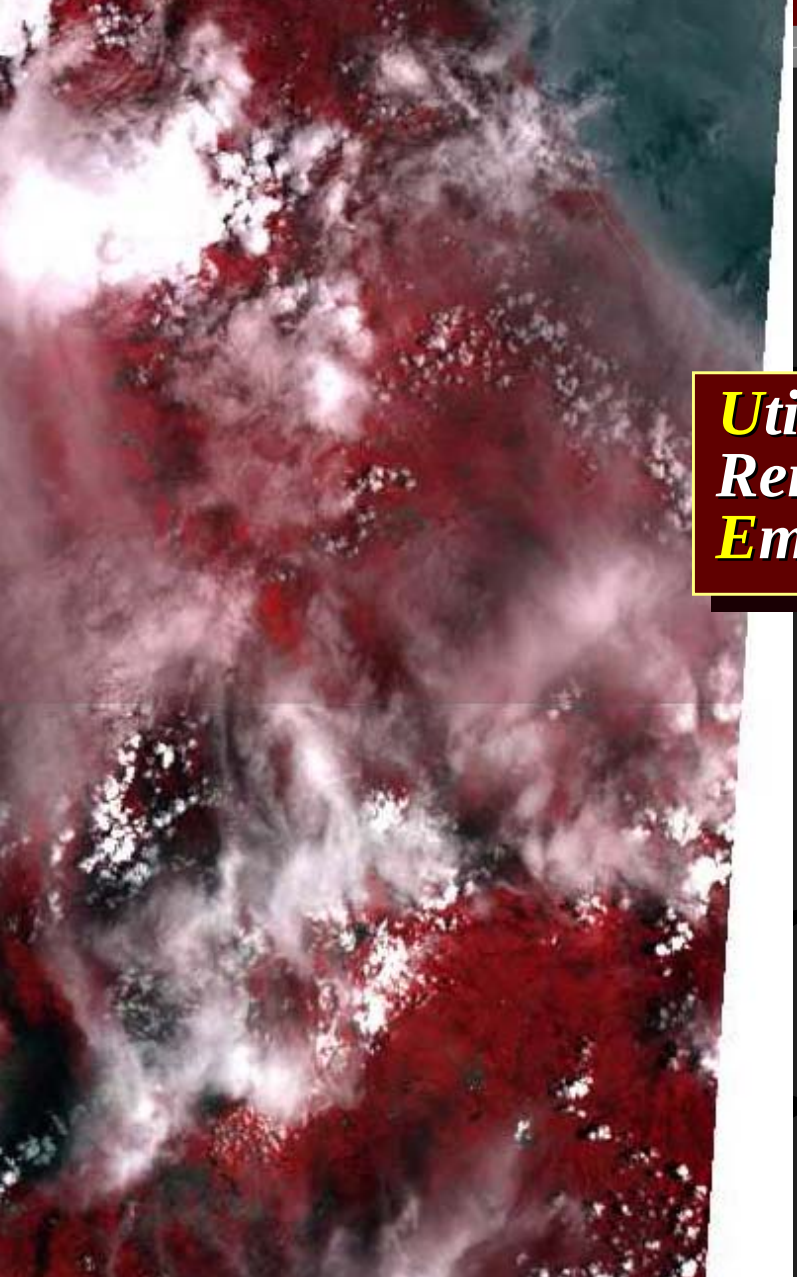


Left: June 18th, 2008 TIR image superposed over elevation data (SRTM 90 m). Through Hot Spot analysis a strong hotspot is located over the west wall of the crater. Conditions are similar to those observed in Mount St Hellen in USA. The hot spot location is in agreement with the direction of the historical crater migration.

gth: Historical LANDSAT Image overlaid
h in-situ temperature data measurements
llow) taken in July 14, 2008 and hot spot
ea observed with the ASTER satellite
gth overpass (red) taken in June 18th




Hot spot tree kill area
(Dead forest in less than 2 years)



rrialba Volcano. Sept 16, 10:30am.
ISSES data set 2 (ASTER)
laboration with Dave Pieri NASA-JPL

In-situ ground MS + In situ airborne MS + Remote Sensing Satellite data collection for calibration and validation

Utilization on In-Situ Instrumentation a Remote Sensing for the Study of Gaseo Emissions at Active Volcanoes

U L I S S E S

Objetive: Design, development and application of in-situ gas sensing based instruments for continuous monitoring, 3D visualization and ground truth validation of remote sensing data, first targeted to the study of gaseous emissions at active volcanoes"

Satellite + Airborne + Ground

ULISSES Project Steps

- **Step 1: Instrument development:**
  - Start with ULYSES-alpha instrument
  - Build upon AVEMS-CARTA experience
  - Low budget restriction
  - TAA agreement with NASA-KSC

Step 2: Platform Integration:

- Backpack for ground, CESNA for airborne

- **Step 3: In-Situ data collection:**
  - Flight missions + volcano field deployments

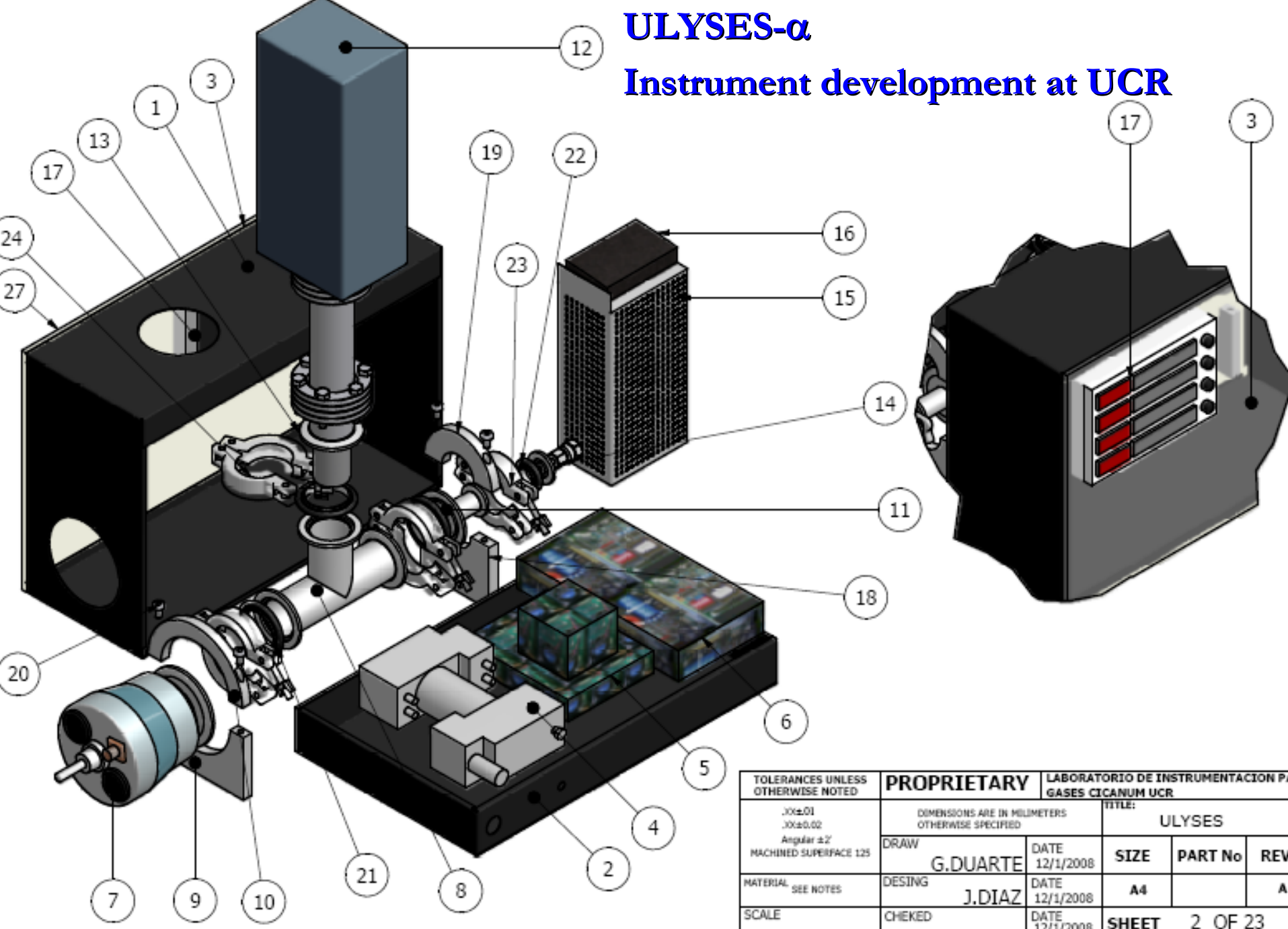
Step 4: Satellite and Airborne remote sensing data

- ASTER Satellite, then other
- NASA-JL collaboration

- **Step 5: Data Comparison and Validation**
- **Step 6: Unmanned Aerial Vehicle (UAV) based In Situ MS system**

ULYSES-α

Instrument development at UCR



TOLERANCES UNLESS OTHERWISE NOTED	PROPRIETARY		LABORATORIO DE INSTRUMENTACION P/ GASES CICANUM UCR		
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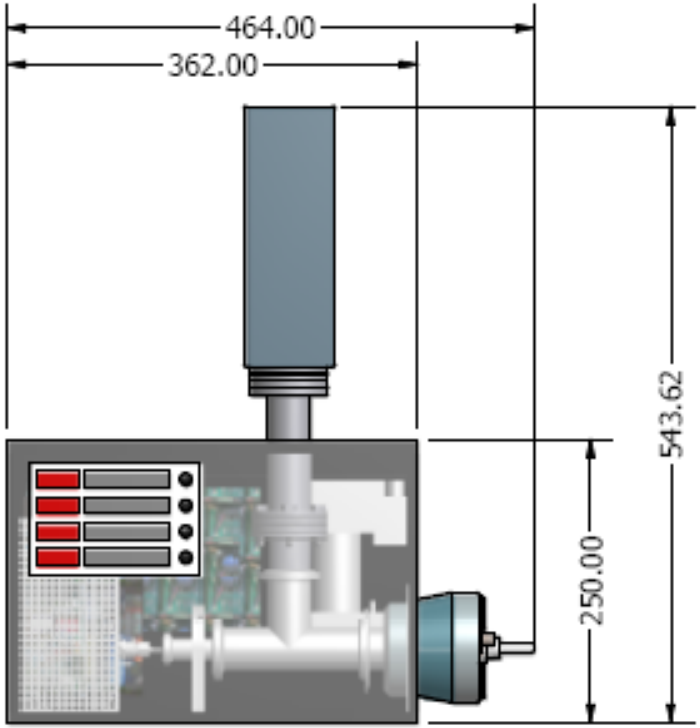
	DRAW G.DUARTE	DATE 12/1/2008	SIZE	PART No	REV
MATERIAL SEE NOTES	DESING J.DIAZ	DATE 12/1/2008	A4		A
SCALE	CHEKED	DATE 12/1/2008	SHEET 2 OF 23		



Vista Frontal
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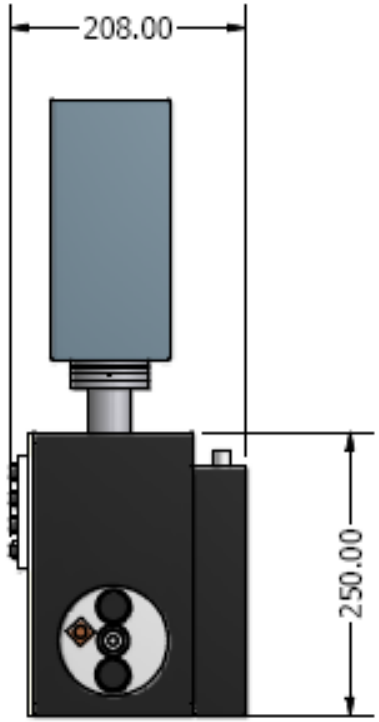

Vista Lateral
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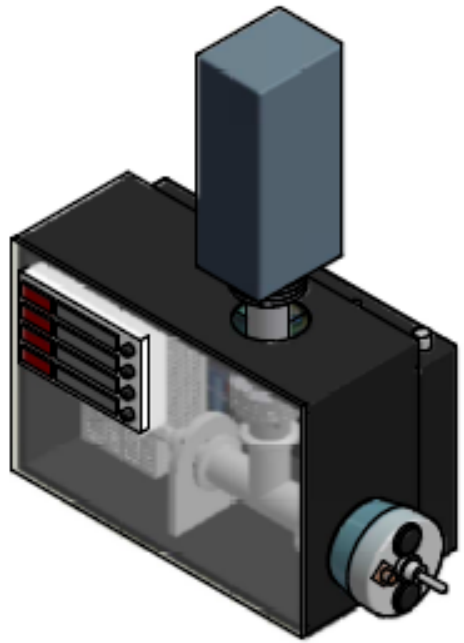

Equipo Portatil
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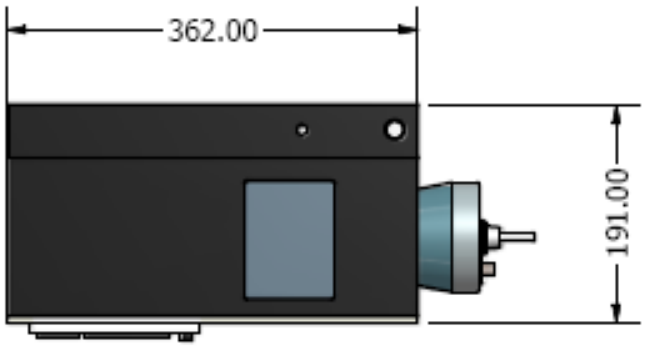

Vista Superior
SCALE 0.16 : 1

TOLERANCES UNLESS OTHERWISE NOTED	**PROPRIETARY**		LABORATORIO DE INSTRUMENTACION P GASES CICANUM UCR		
.XX±.01 .XX±0.02 Angular ±2' MACHINED SURFACE 125	DIMENSIONS ARE IN MILIMETERS OTHERWISE SPECIFIED		TITLE: ULYSES		
	DRAW G.DUARTE	DATE 12/1/2008	**SIZE**	**PART No**	**REV**
MATERIAL SEE NOTES	DESING J.DIAZ	DATE 12/1/2008	**A4**		A
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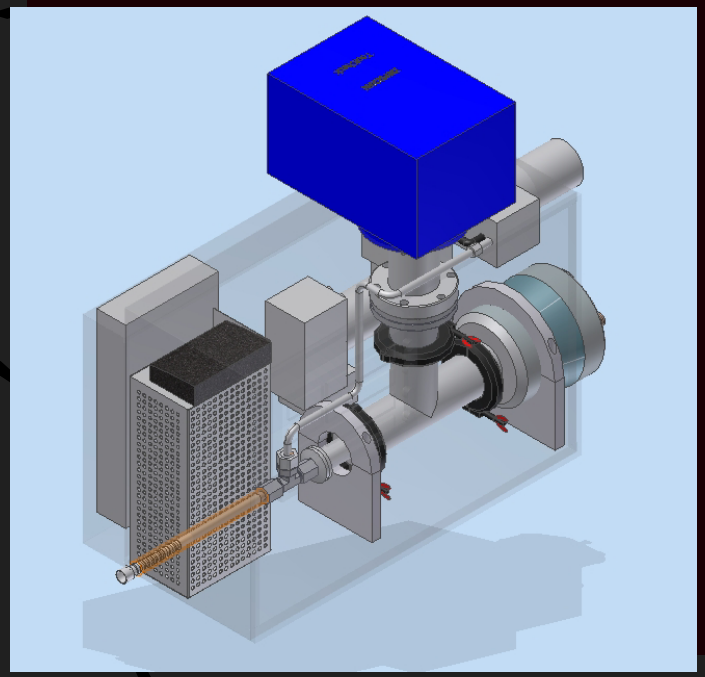
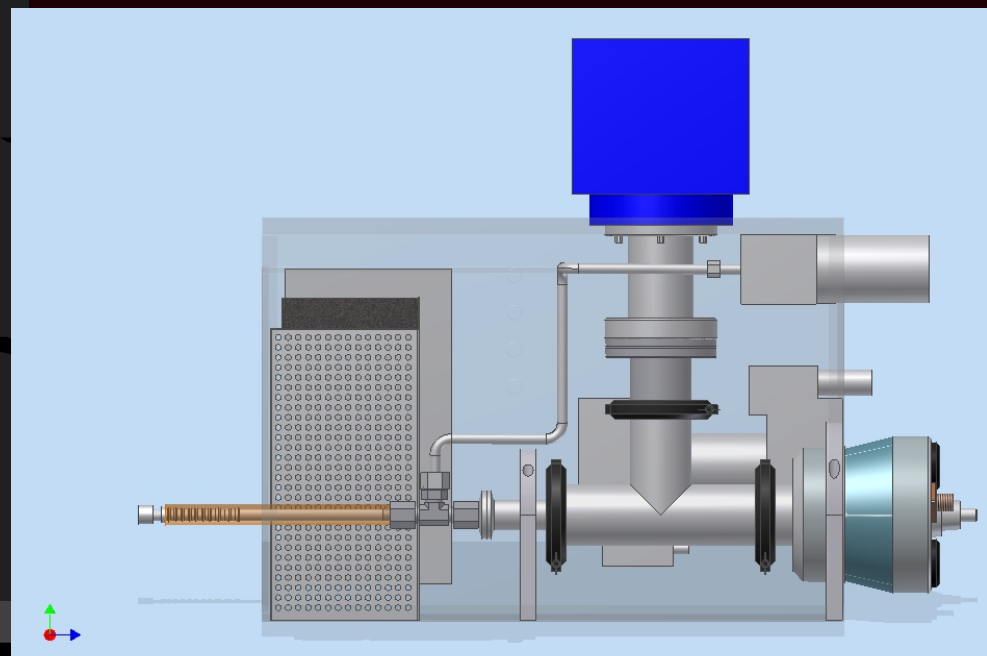
ULYSES-α Description



- RGA200 from SRS or INFICON's version of CDFMS
- Direct sampling, split flow (Molecular frit)
- Heated Inlet
- Alcatel Turbo pump
- 2 KNF pumps (SDS, Backup)
- Battery operated
- PC data collection
- GPS data connected to PC
- 20 lb, 96W max
- 110 with heater



ULYSES-α Field Test (Airborne)

16 Sept 09, 7am

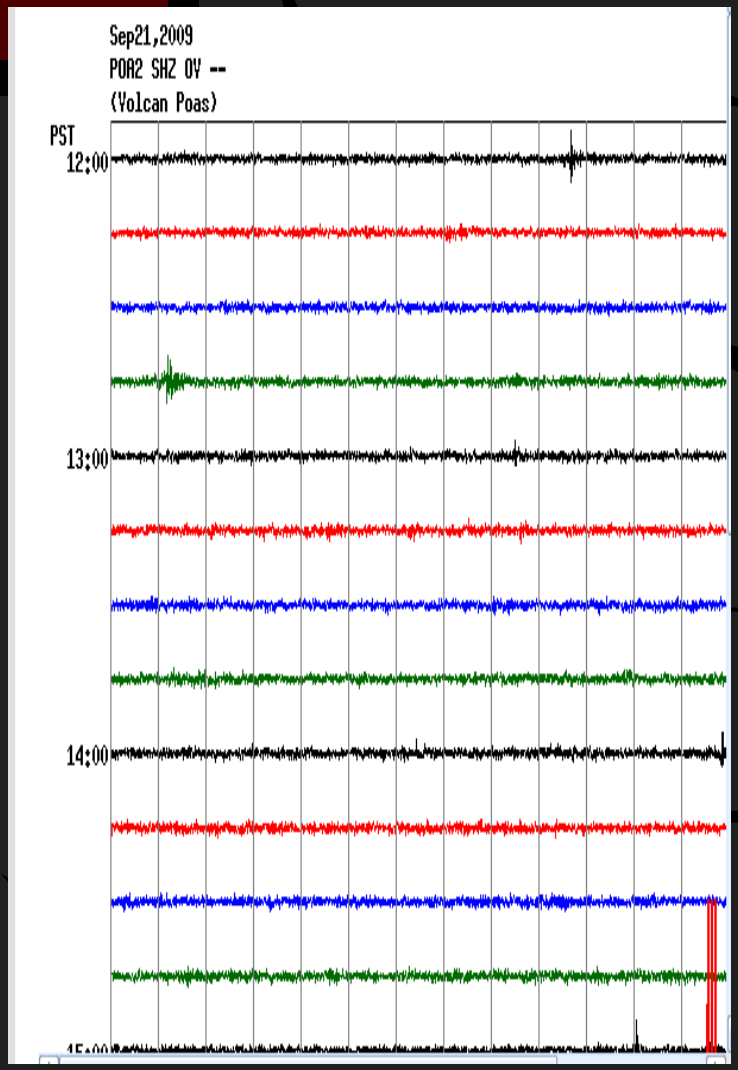
- Video

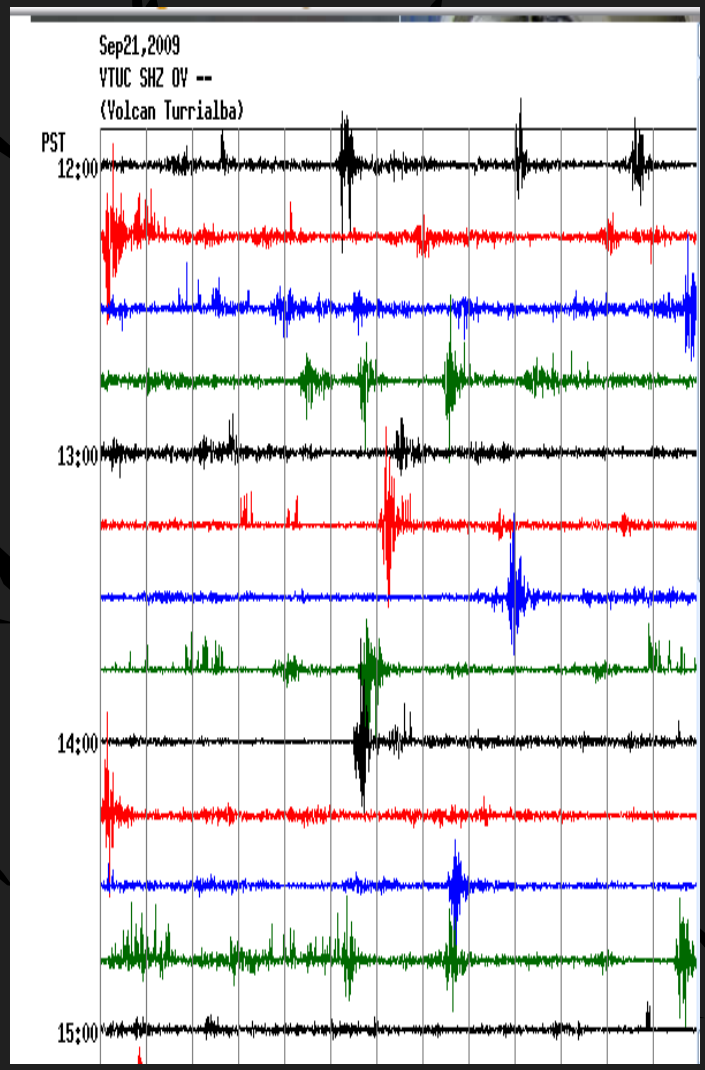
ULYSES-α Field Test (Ground)

16 Sept 09, 11am

- Video

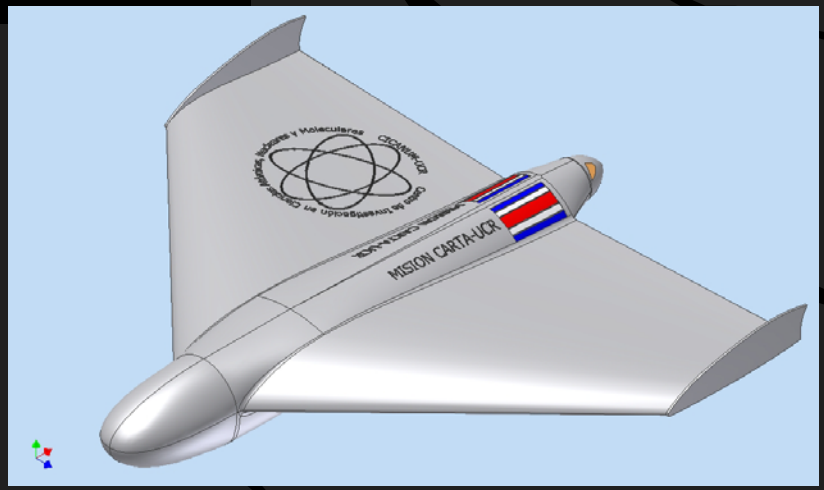
Seimic data yesterday Sept 21, 2009

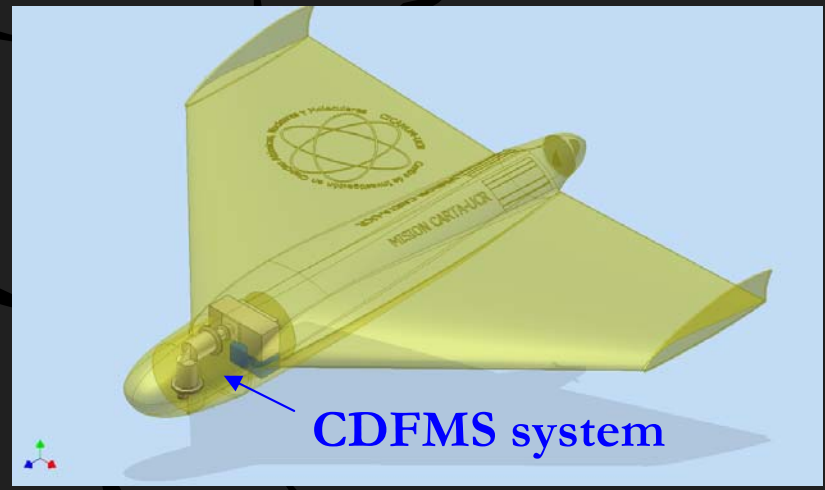


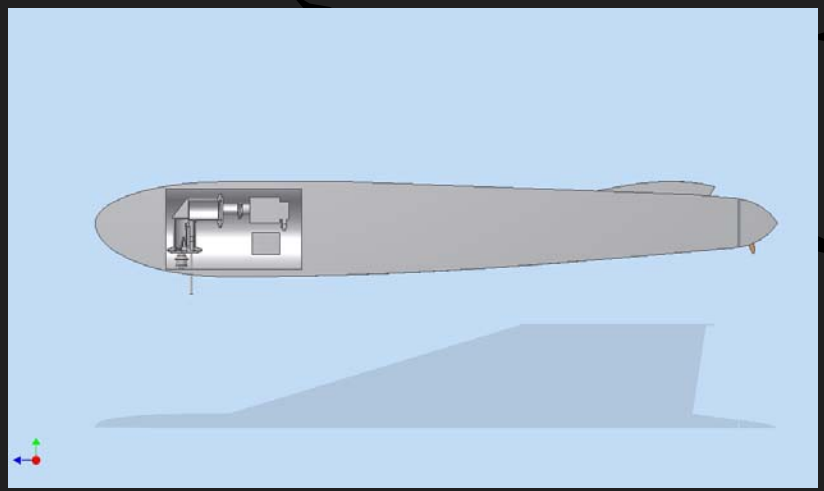


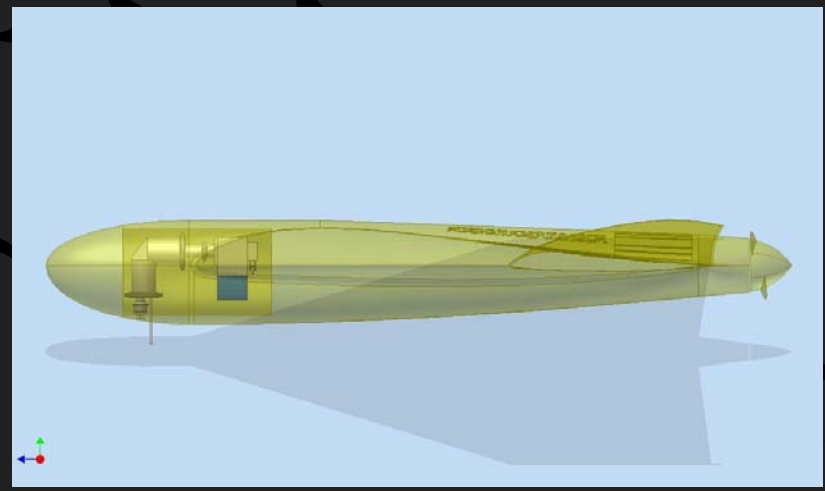
Next Step: UAV based is-MS for volcanic plume analysis

- UAV: D-150 from MAVIONIC
- Purchased by UCR and in construction
- Field deployment in March 2010
- 4 Four NASA centers involved in initiativ

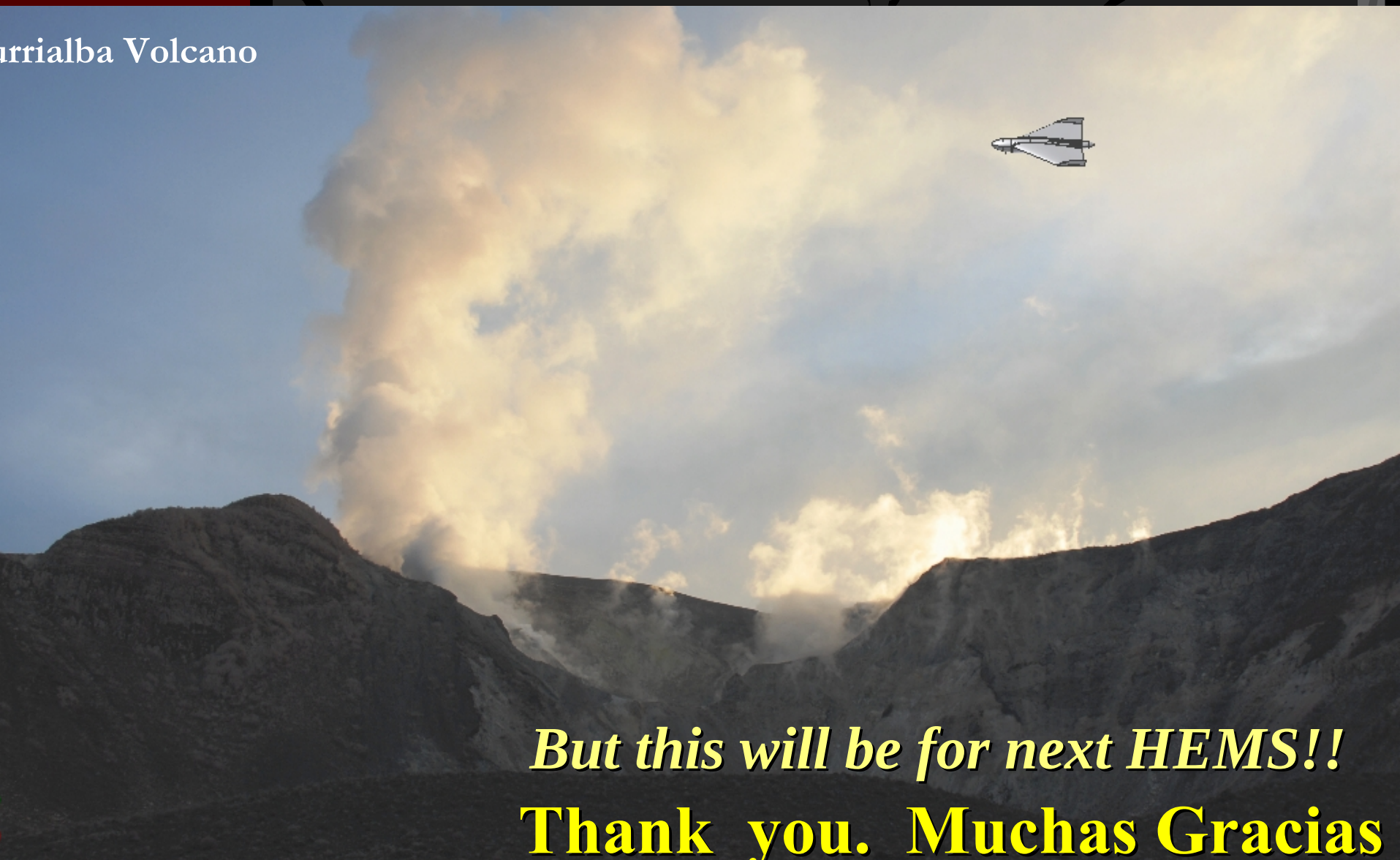








Target: Low cost is-MS volcanic plume analysis from inexpensive UAVs for satellite cal/val + air assessment



But this will be for next HEMS!!

Thank you. Muchas Gracias