Utilization of Lightweight MS based Instrumentation and Small UAV Platforms for In-Situ Volcanic Plume Analysis

8th Harsh Environment Mass Spectrometry Workshop.
St. Pete, FL. 22 Sept 2011

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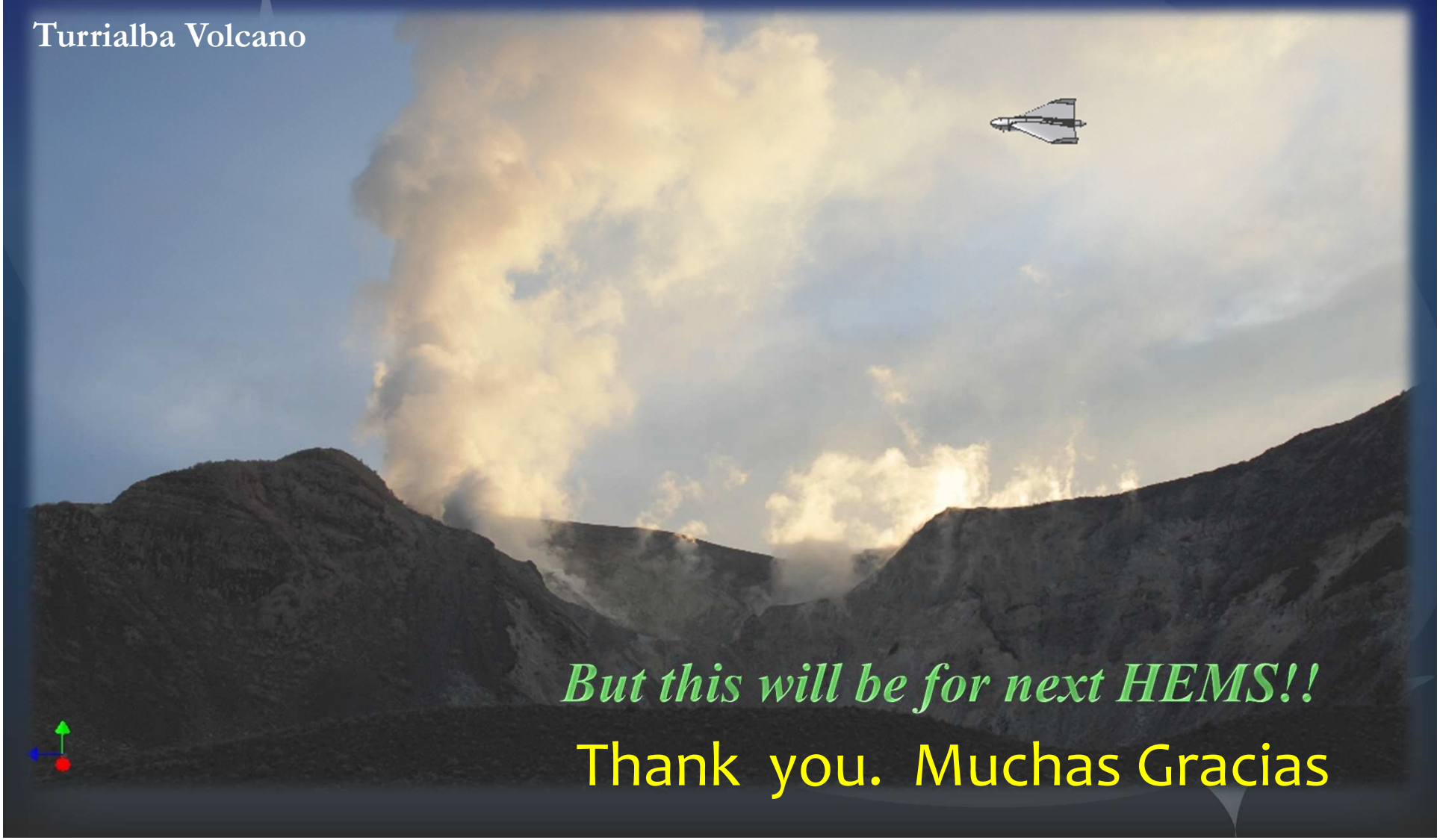
Diaz oral presentation, last page. 7th HEMS 2009 St Barbara, CA.

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



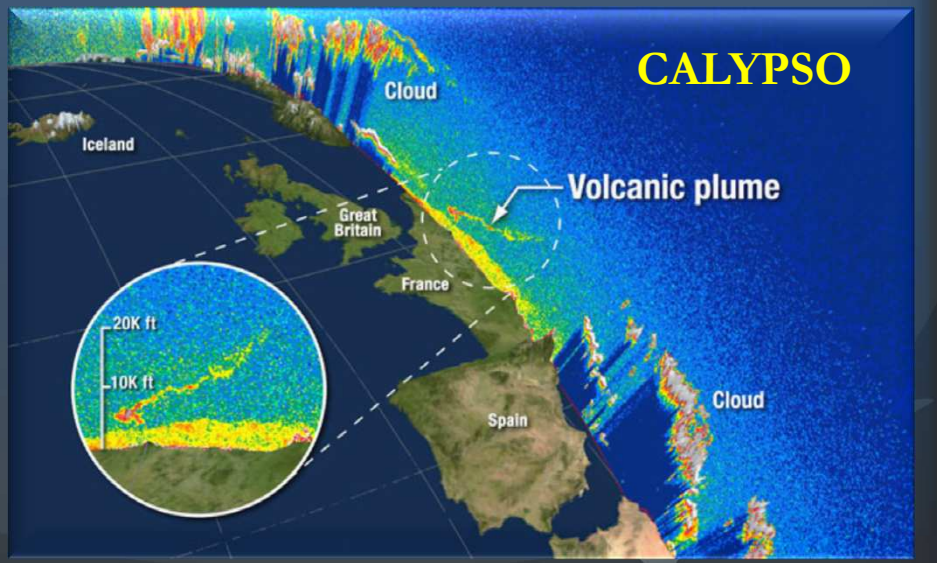
Challenge: Volcanic Clouds Characterization (Real Harsh Environment!!)

Eyjafjallajoekull Volcano
(ICELAND) April 2010

Do you really want to be sampling here?

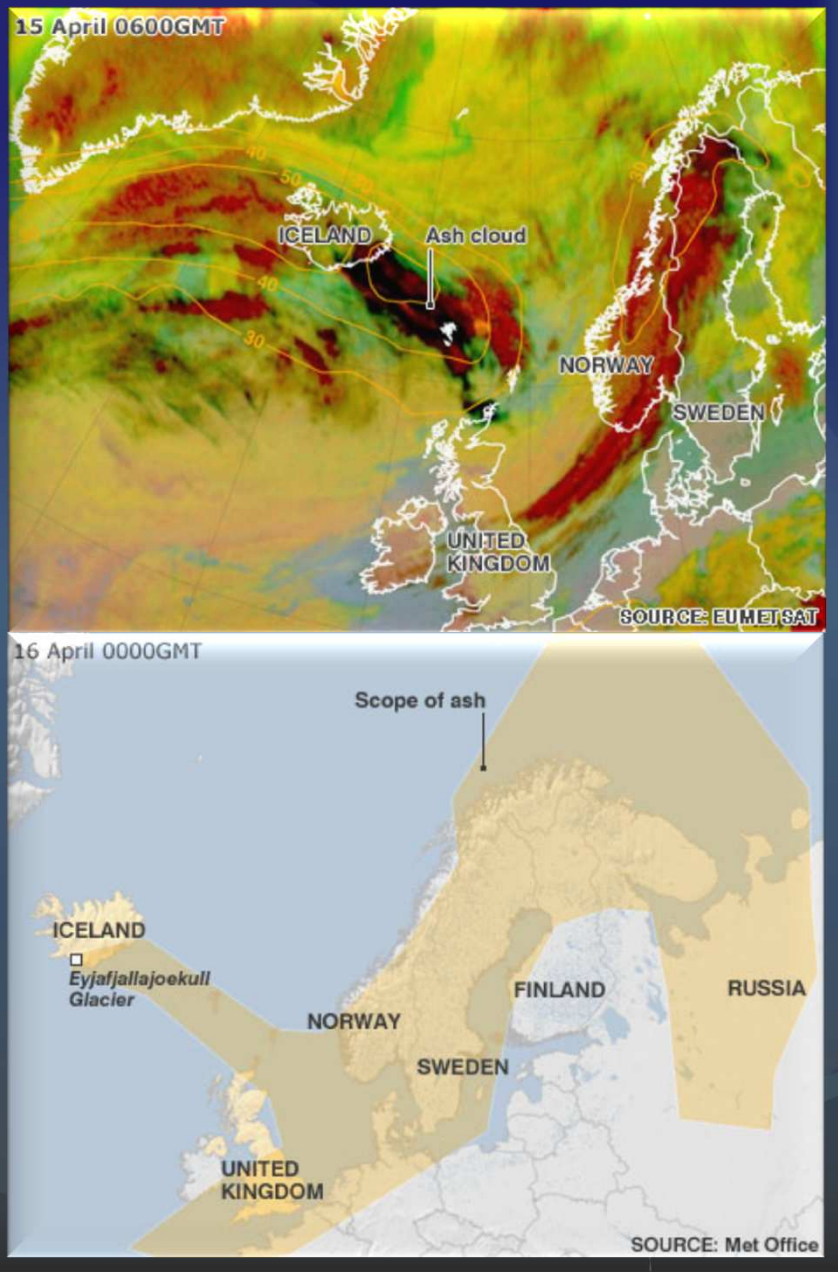
Challenge: Volcanic Clouds Characterization

- Volcanic airborne emissions can have devastating economic effects, and directly threaten human life.
- Current remote sensing retrieval and transport models lack in situ validation data.
- Chronic and pervasive problem, identified in domestic and international forums
- The Ejyafjallajokull (Iceland) 2010 eruption starkly highlighted this deficiency



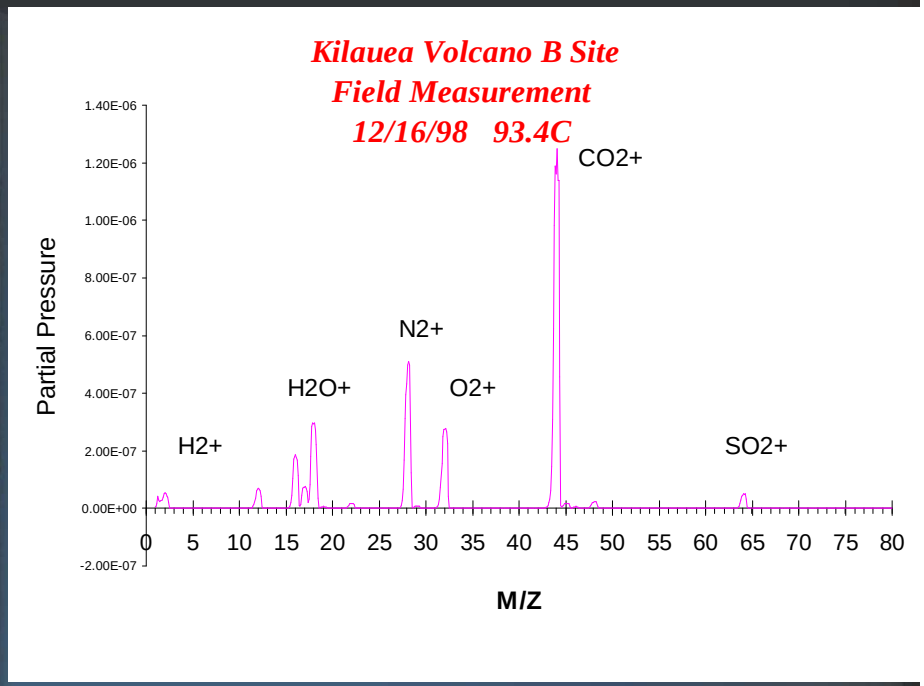
Challenge : In Situ data for Satellite Cal/Val

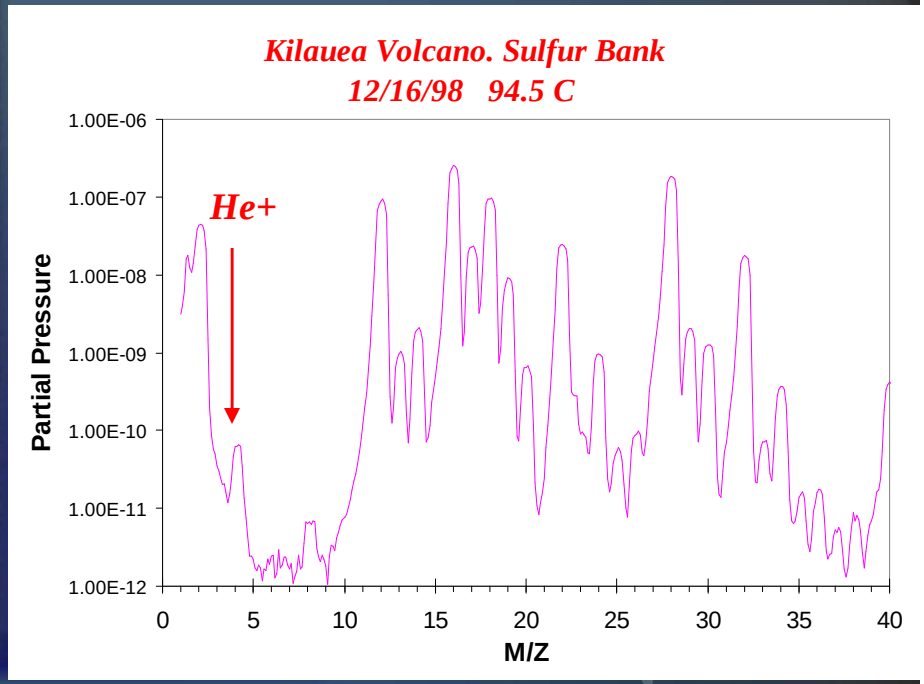
- Ash and gas concentrations derived from analysis of satellite remote sensing data (e.g. GOES, AVHRR, ASTER, and SEVIRI), remain unvalidated by in situ data.
- Difficulties in predicting the trajectories and extents of drifting ash clouds have centrally contributed to inadvertent aircraft encounters with ash plumes
- Need for better understanding of the properties and internal chemical and physical processes within volcanic plumes, and the boundary conditions for both mass retrieval models and predictive models for cloud trajectories.



Collaboration with vulcanologists

•*In-Situ Volcanic Emissions Measurements*





Project Scope : In-Situ + remote sensing integration of active volcanic plumes data for CAL/VAL of Satellite Remote Sensing Information

Objective:

Study, measure, sample and visualize volcanic gaseous emission using and/or developing small UAV Systems

Products:

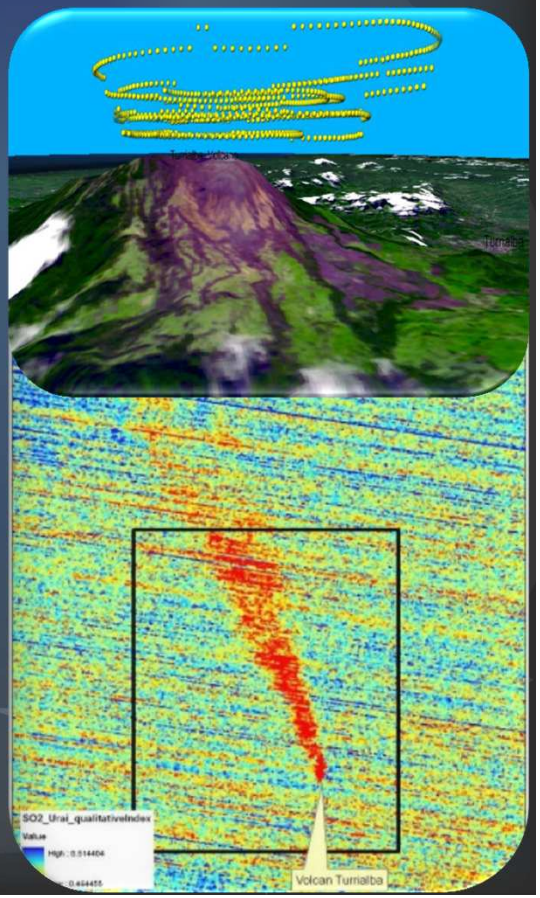
- 4D (x,y,z,t) real image of an erupting volcanic plume
- Otherwise unobtainable in situ data for volcanic plumes from hazardous flight environments over and near active volcanoes

Benefits:

- Basic science of eruption prediction, monitoring, environmental impact and basic volcano processes
- Calibration and validation of remote sensing imagery
- Improved models for Aviation ash hazard mitigation

Approach:

Simultaneous fixed-wing, blimp, and tethered aerostats UAS airborne observations, integrated with in-situ instrumentation with simultaneous orbital and ground-based remote sensing. Operate in airspace too dangerous for manned aircraft—overand around actively erupting volcanoes.



Airborne UAV Platforms

Platforms (so far):

- *SIERRA (ARC-NASA)*
- *Tethered Balloon (UCR)*
- *Wing-100 UAV (UCR)*

Other Platforms (interested)

- *Scan Eagles (University of Alaska Fairbanks)*
- *MiniZepp (JPL, Callifornia Institute Tech)*
- *AN/FQM-117B electric drones (LRC-NASA)*
- *Data Mules (mini-UAVs) (Arizona State Univ.)*
- *Tethered blimps (Aerostats) (WFF-GSFC-NASA)*

Sensor Instruments

Measurements:

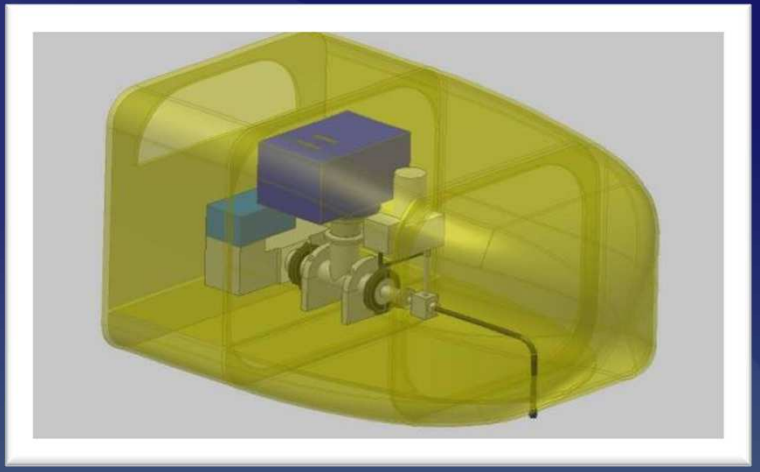
- *In situ ash, SO_2, H_2S, CO_2, He, and other gas concentration;*
- *Temperature + pressure + humidity;*
- *GPS location and altitude;*
- *Particle count by size*
- *Solid aerosol (ash) sampling for post-flight SEM analysis*

Instruments:

Electro-chem MEMS based SO_2, CO_2, H_2S sensors; radiometer particle drum-impactors, laser diode/optical particle counters, size, frequency analyzer, samplers; mini-mass spectrometer

Where:

Turrialba and Arenal Volcanoes (COSTA RICA)



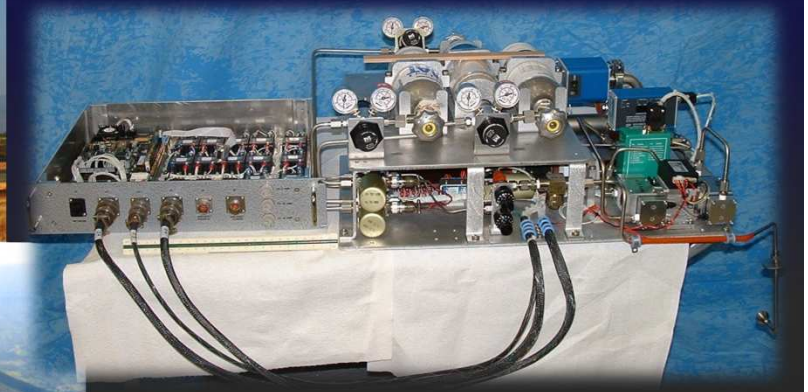
- **ULISES (UCR):**
  Mini Mass Spec + Met Data+ GPS
- **Aeropod (NASA-WFF-GSFC)**
  SO2 + Met Data+ GPS


CR ACTIVE VOLCANOES
Active and stable volcanic plume conditions visible from space
Easy access and logistics to sites
UAV friendly environment
Local scientific collaborators
National Airborne Research Hangar
Rincon de la Vieja Volcano
Miravalles Volcano
Tenorio Volcano
Arenal Volcano
Poas Volcano
Irazu Volcano
Turrilaba Volcano
NASA
Why
Costa Rica
=► Natural Laboratory for Calibration and Validation of Satellite Remote Sensing Observations

AVEMS (Primary Mission Instrument)

Airborne Volcanic Emission MS Systems

KSC-NASA (RGA 200)- Autonomous, 47 kg, 350W



CARTA MISSION 2003

(Costa Rica Airborne Research and Technology Applications)

WB-57: NASA Research Aircraft

Operational Altitude: up to 65K feet sl

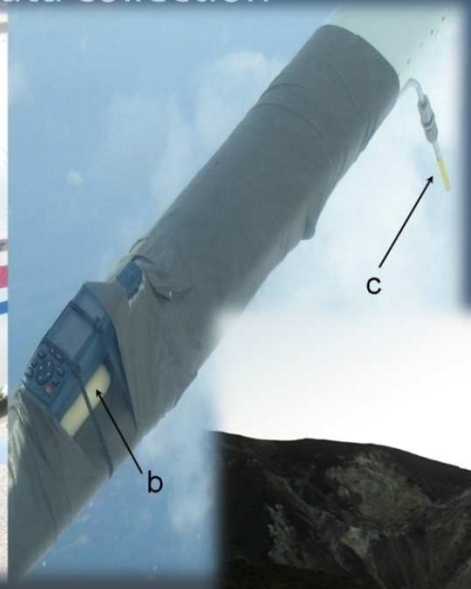
Endurance: 6+ Hours

AVEMS Aircraft Volcanic Emission Mass Spectrometer

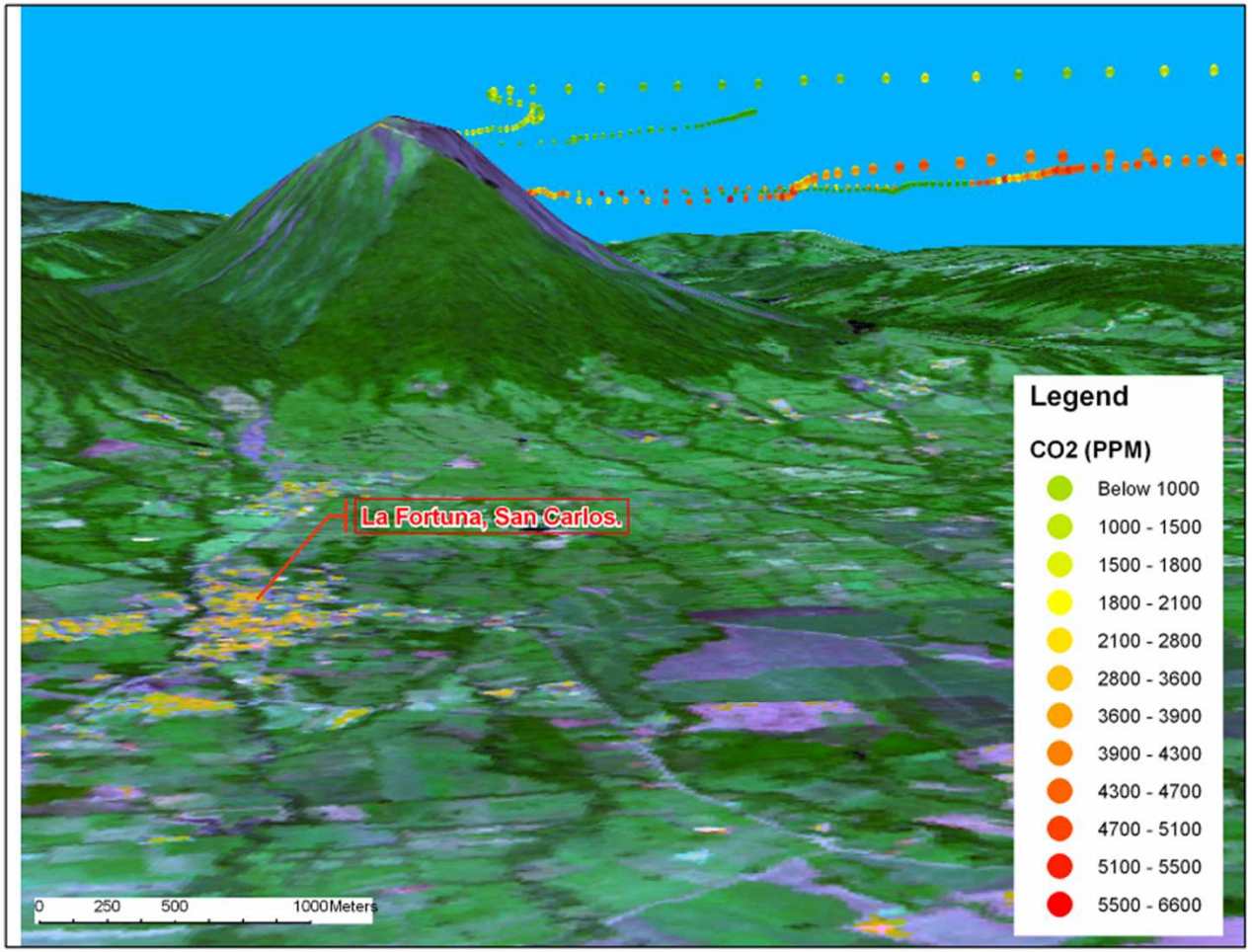
2005 CARTA Mission . Improved System

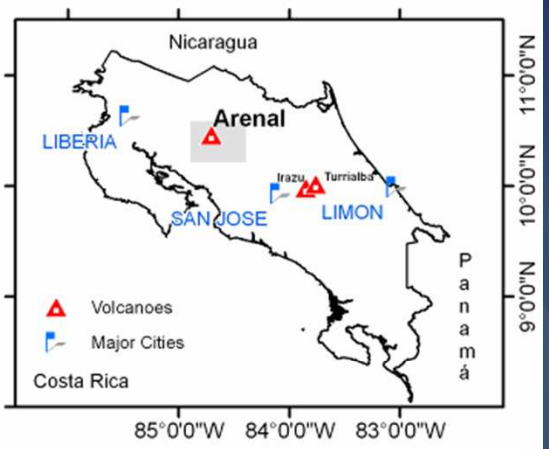
In-situ Airborne MS Monitoring (*isMS*)

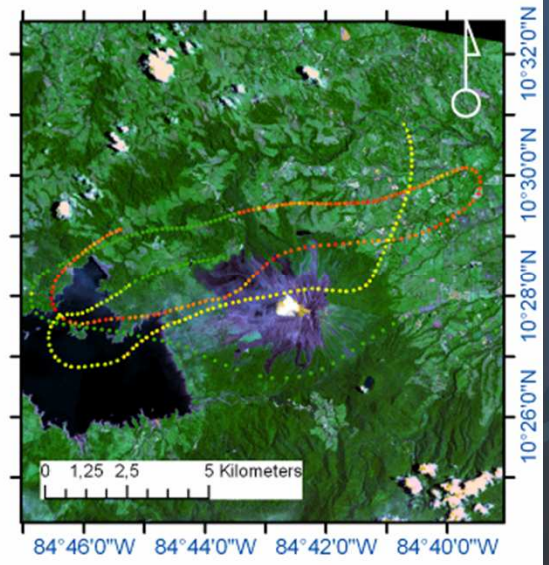
- Same size, power and ruggedness
- Lighter: 32 kg (70 lb)
- Semi-Autonomous Operation. Allowed user on board.
- On board gas calibration (Zero, Test, Span Bottles)
- Onboard GPS data collection



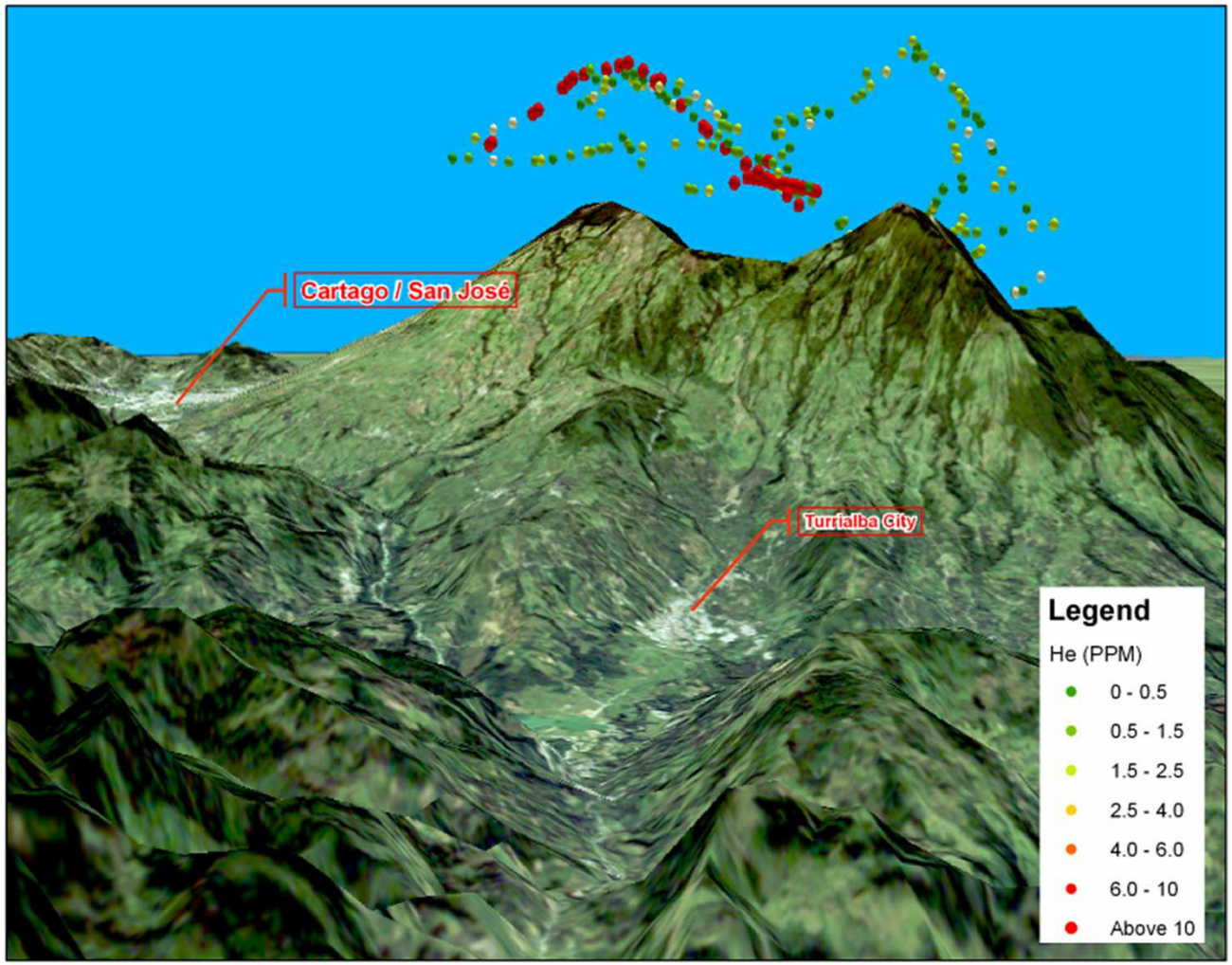
3D Concentration Mapping with Portable MS Systems (GPS + isMS) Arenal Volcano , Airborne.

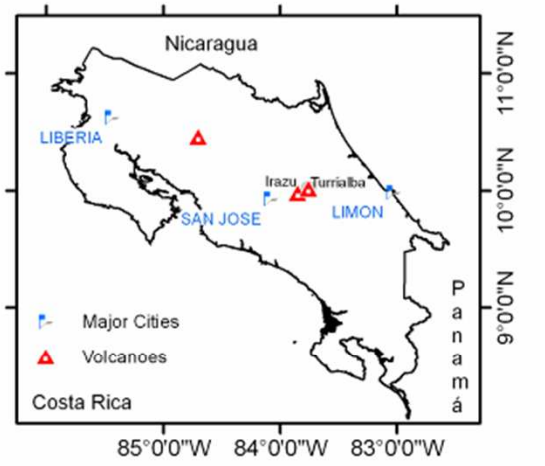


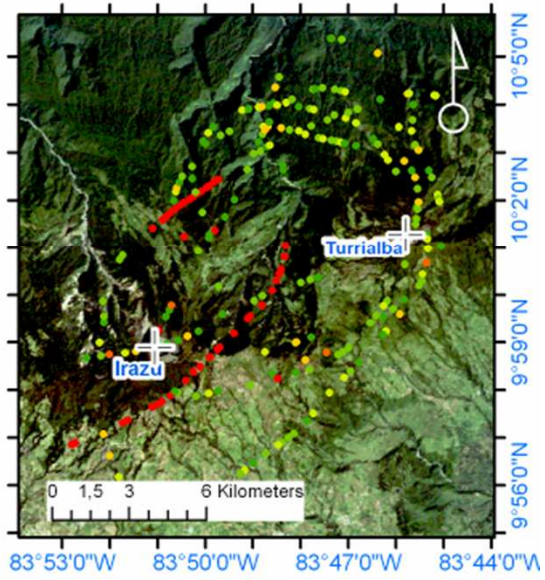




3D Concentration Mapping with Portable MS Systems (GPS + isMS) Turrialba Volcano , Airborne.

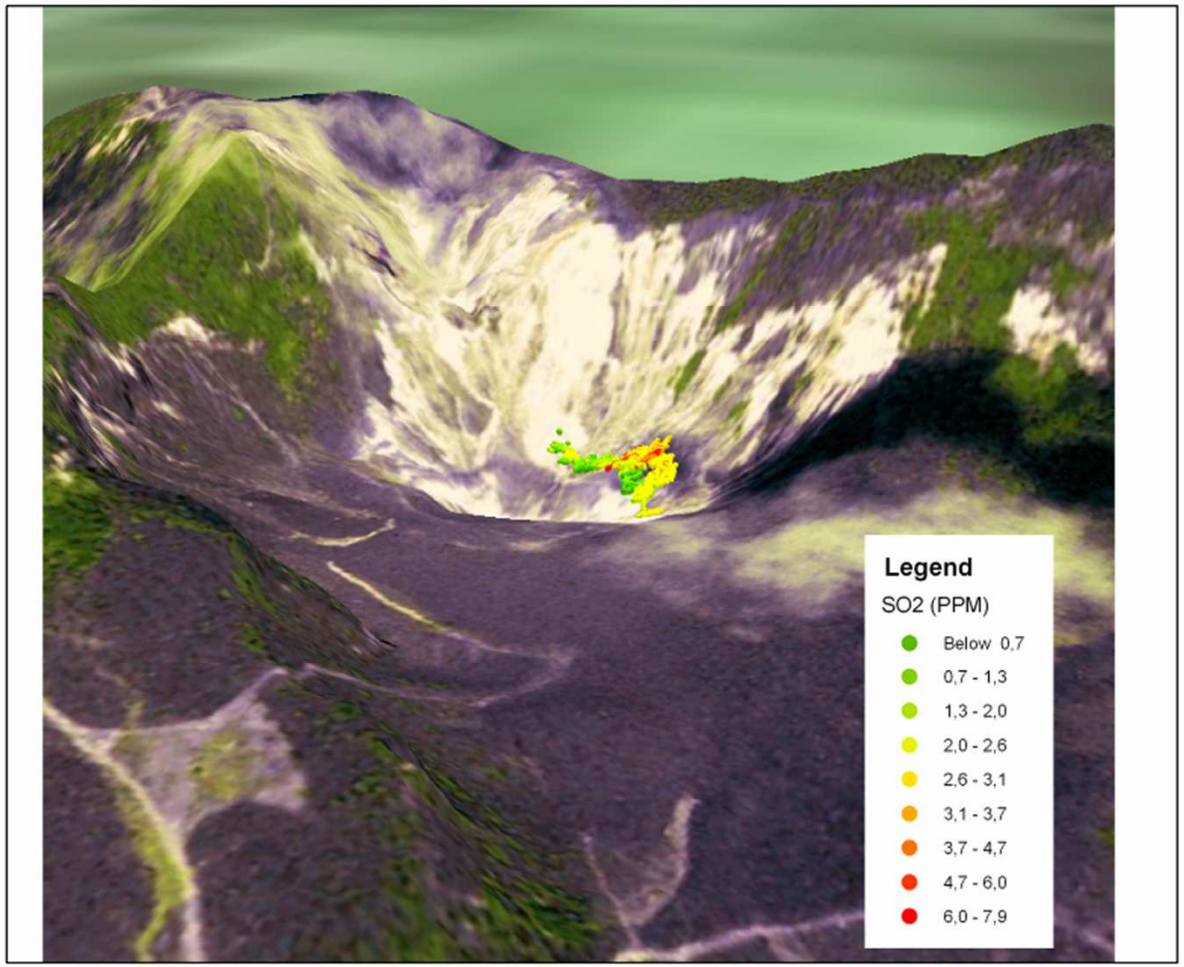


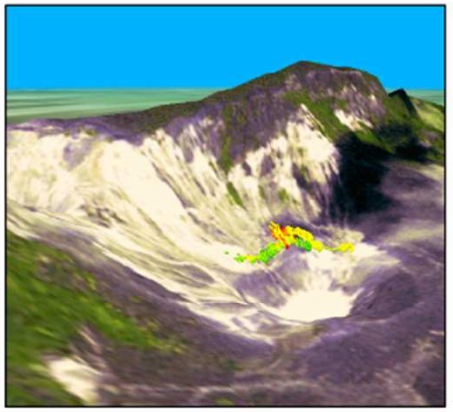


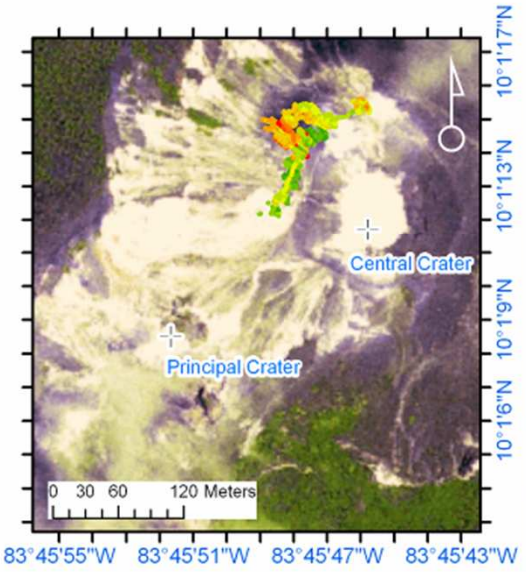


3D Concentration Mapping with Portable MS Systems (GPS + isMS)

(Ground)



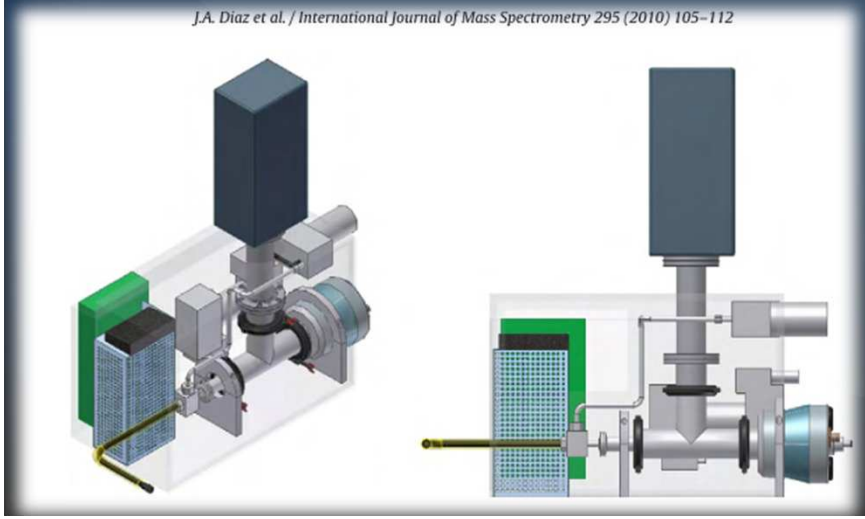




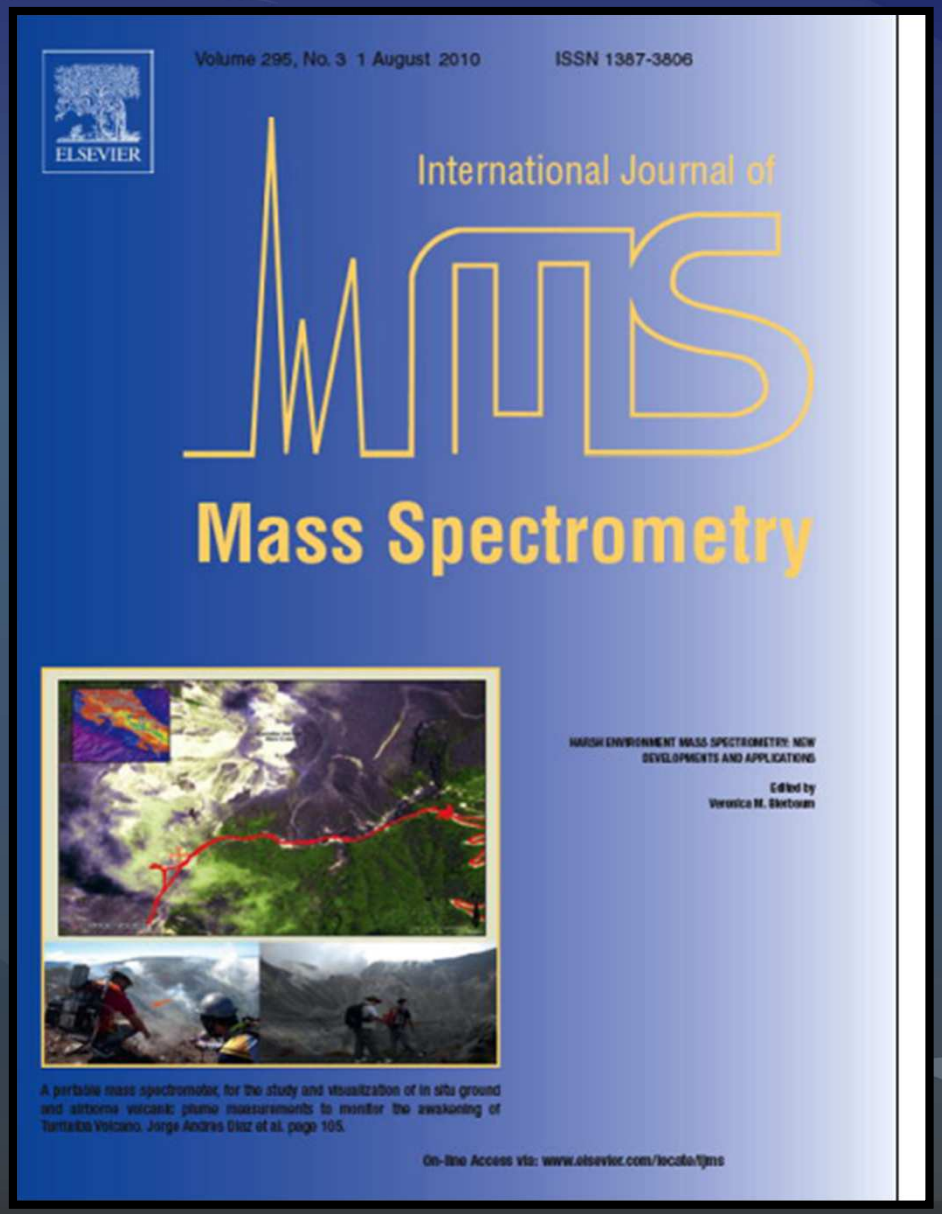
ULISES-α Airborne Instrument (2009-11)

Utilization on In-Situ Instrumentation and Remote Sensing for the Study of Gaseous Emissions at Active Volcanoes (ULISES)

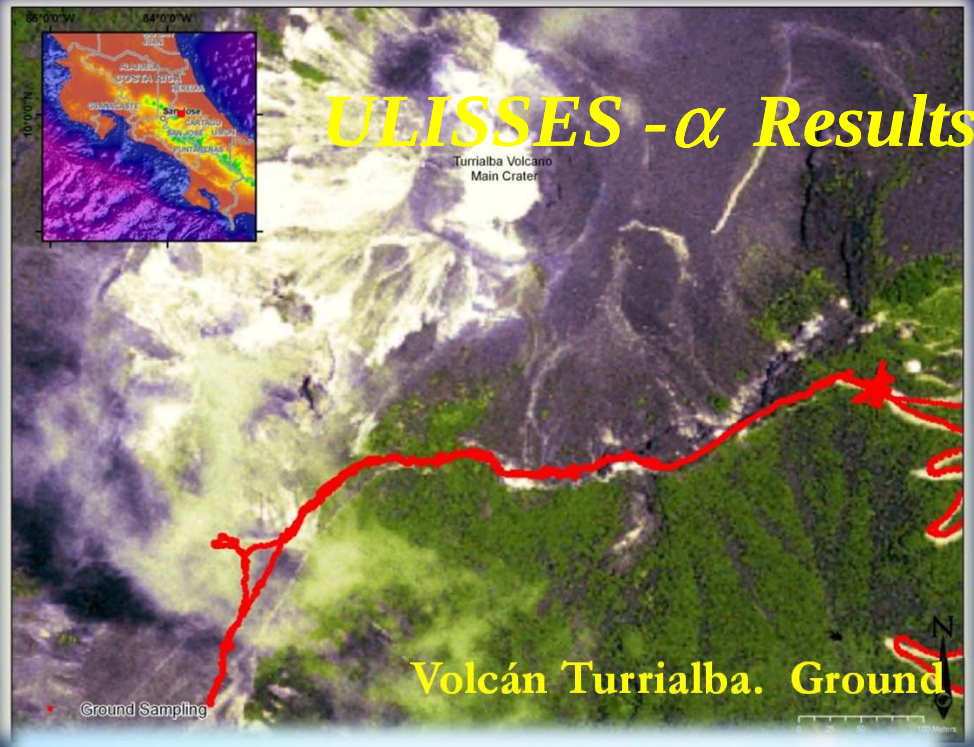
- RGA200 from SRS.
- Direct sampling, Bypass, Heated Inlet
- Alcatel 31+ or Pfeiffer Turbo
- 2 KNF pumps (SDS, Backup)
- Battery operated, 20 lb, 96W max



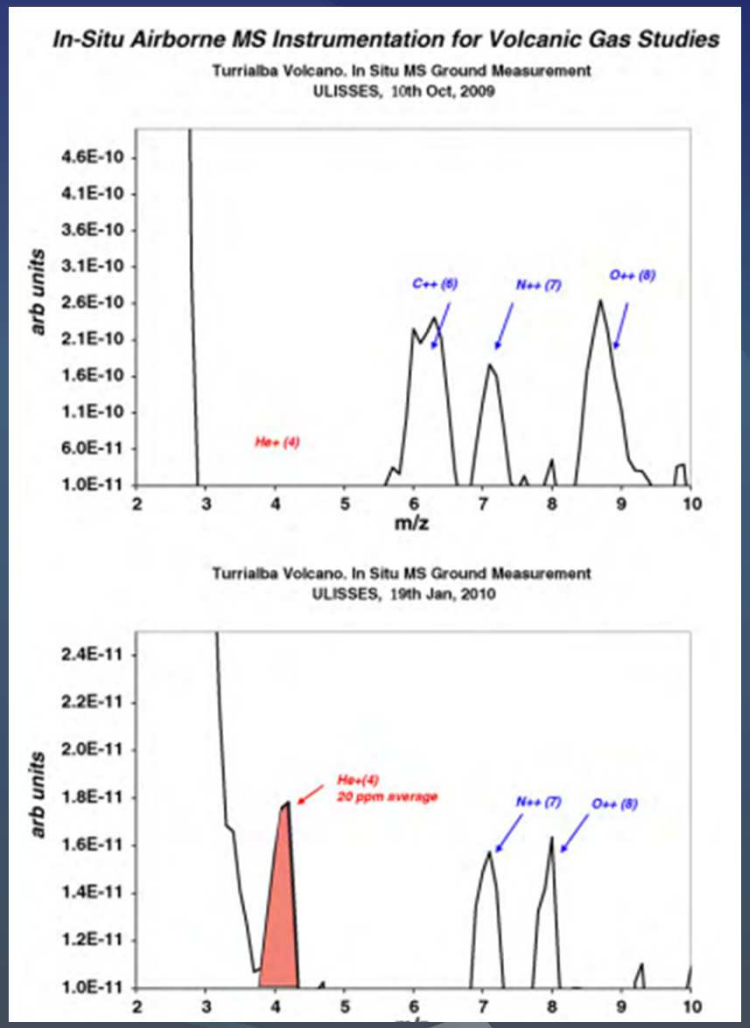
Cover Page IJMS HEMS Special Issue Aug 2010



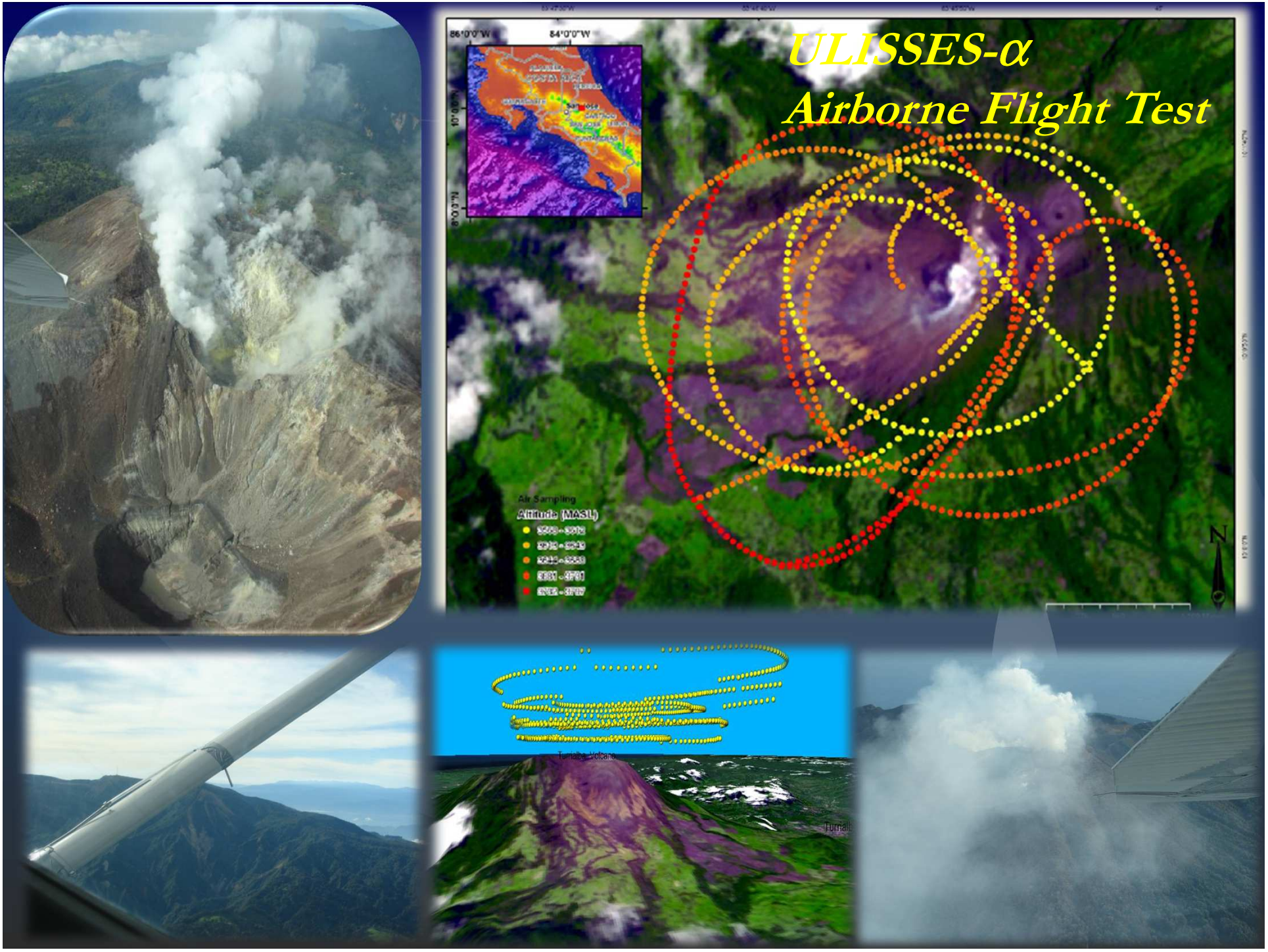
ULISSES -α Results: Ground Gas Measurements



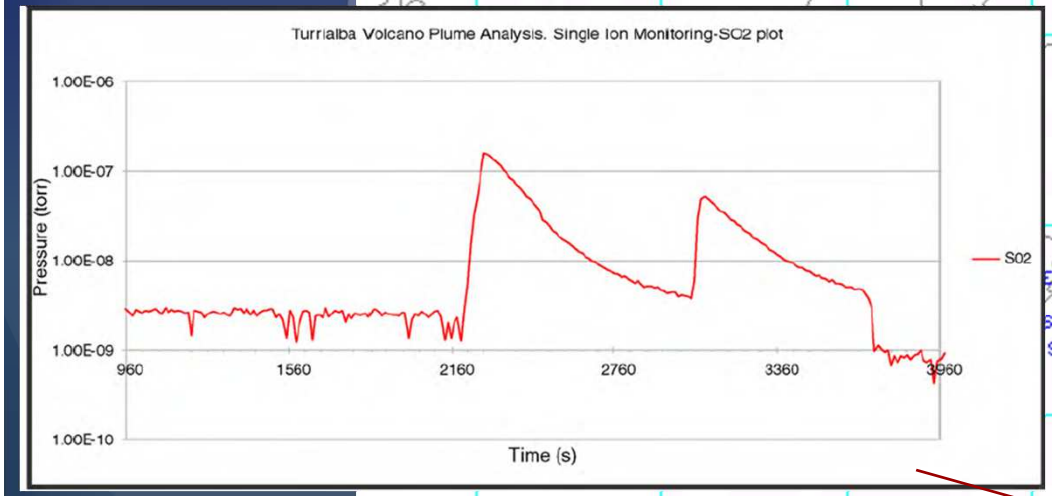
Volcán Turrialba. Ground

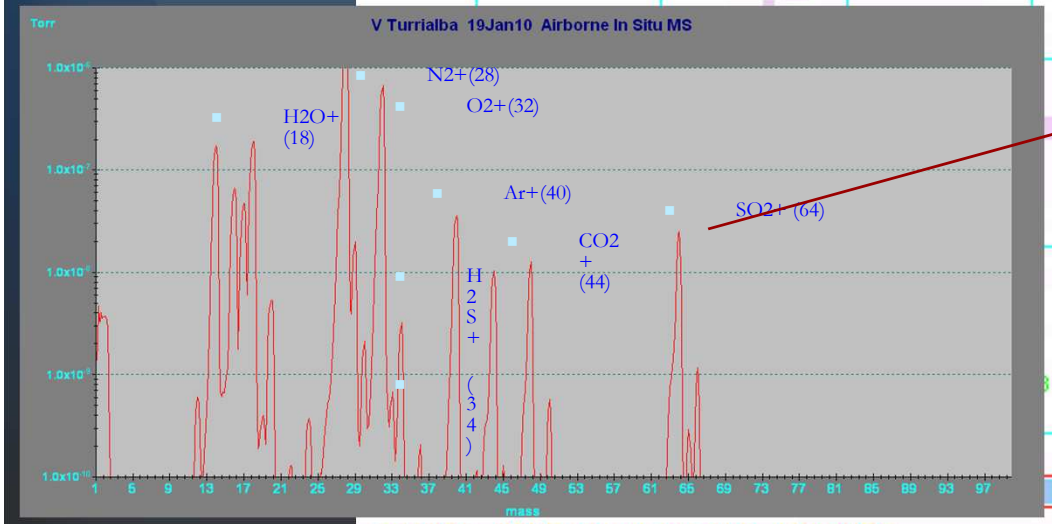


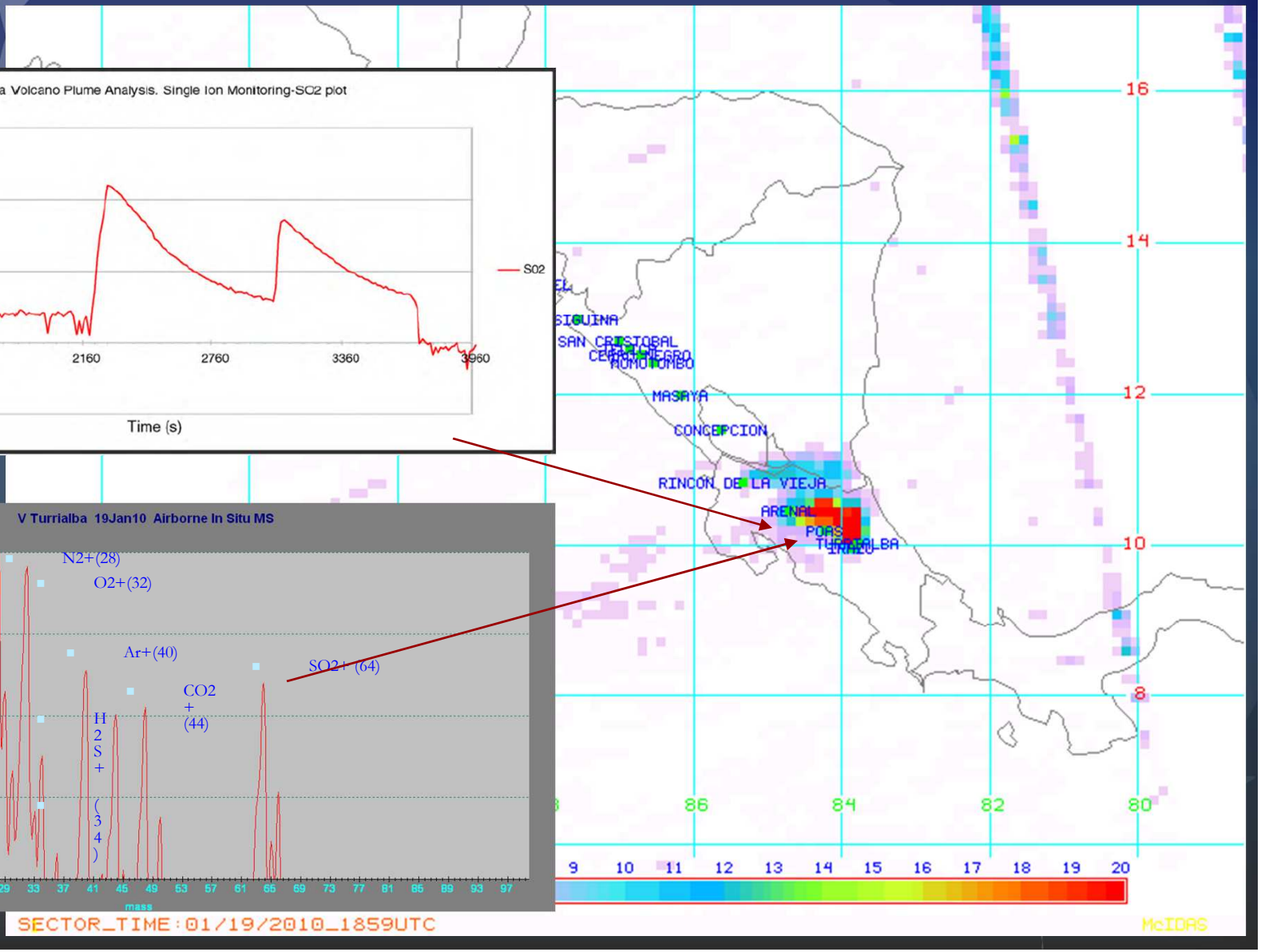
Helium detected at Turrialba Volcano after eruption and new vent formation


ULISSES-α
Airborne Flight Test
Air Sampling
Altitude (MASL)
Turrialba Volcano

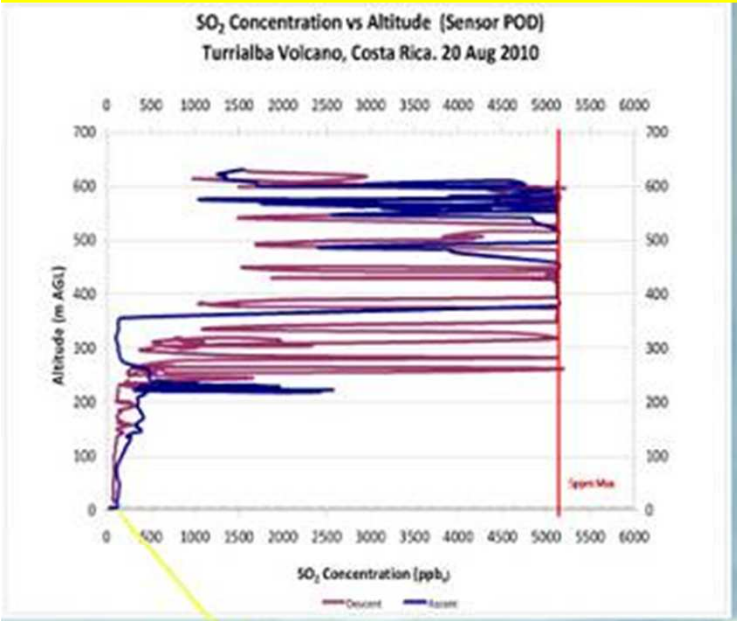
In-Situ + Remote Sensing Data Set







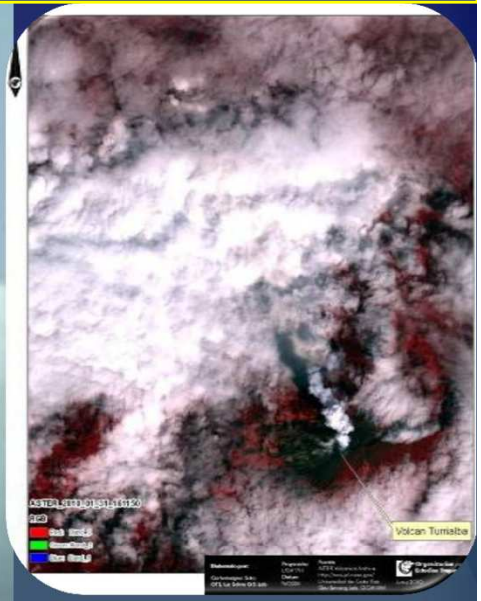
Results: Using sUAS for volcanic plume analysis

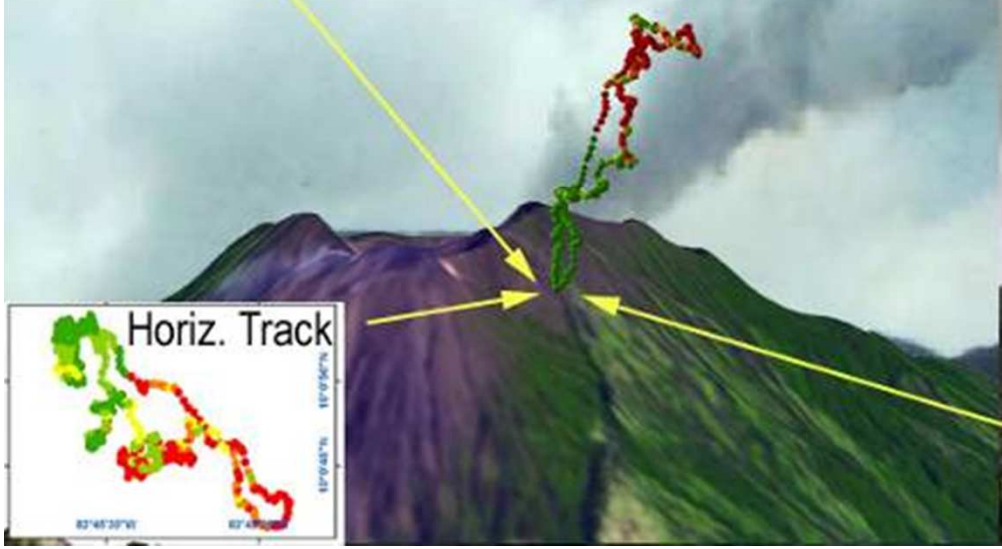


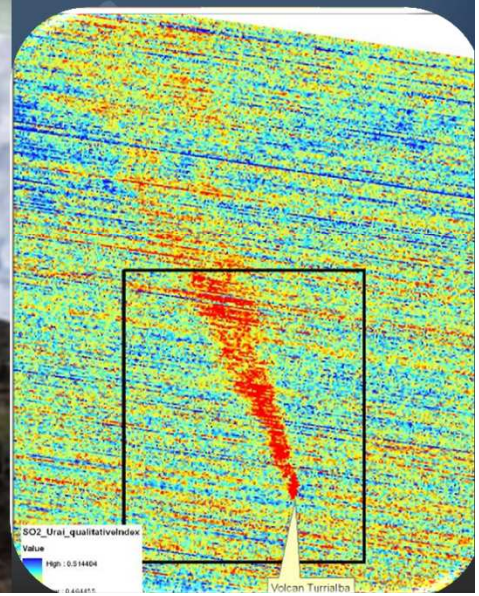
In situ SO_2 concentration depicted in 3D and horizontal track projections

PPBV

- 4180 - 5130
- 2560 - 4180
- 1290 - 2560
- 450 - 1290
- 0 - 450



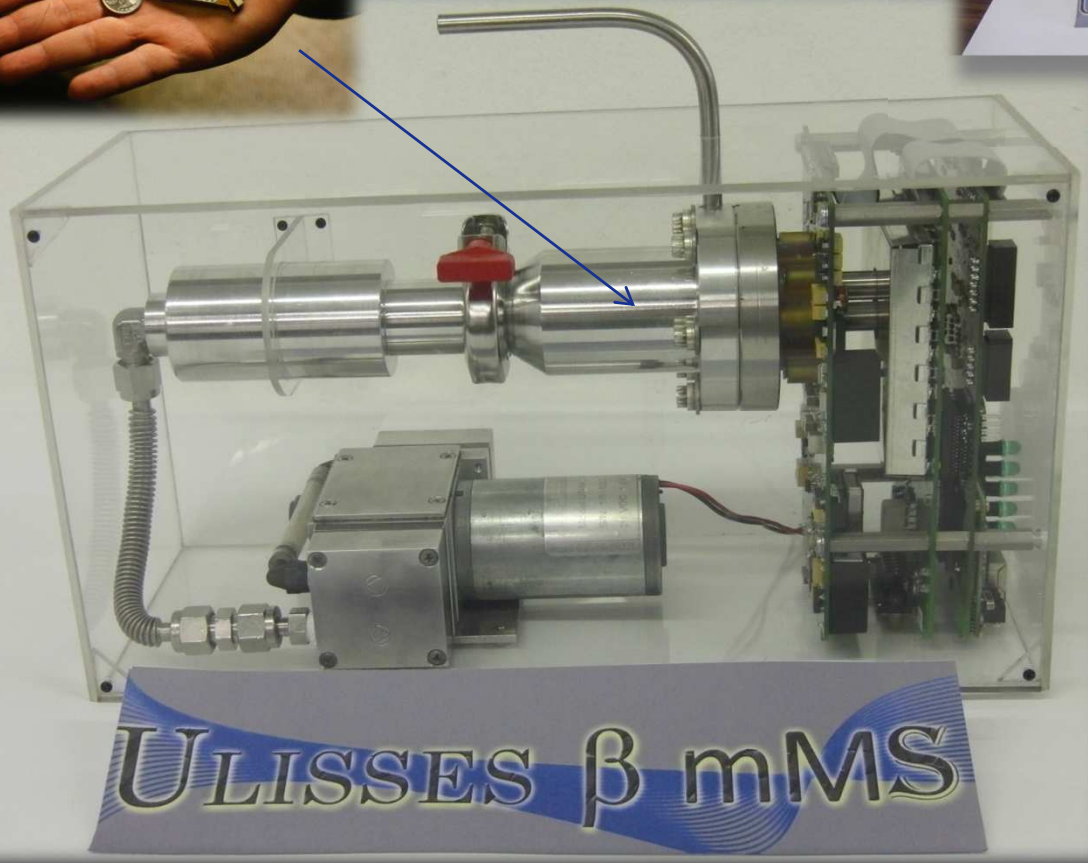




ULISES-β Airborne Instrument (2011)

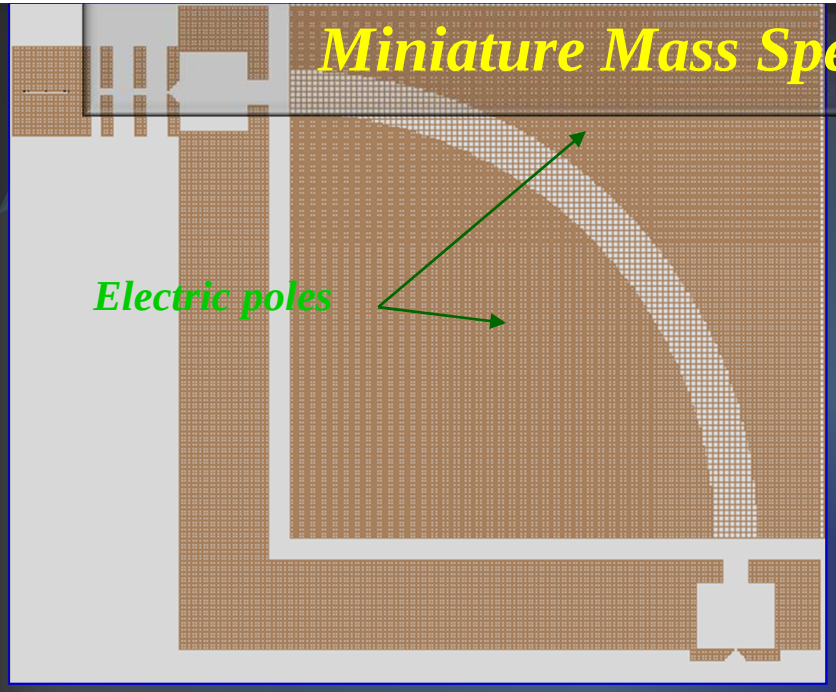
1998 CDFMS , J. Diaz, UMN,

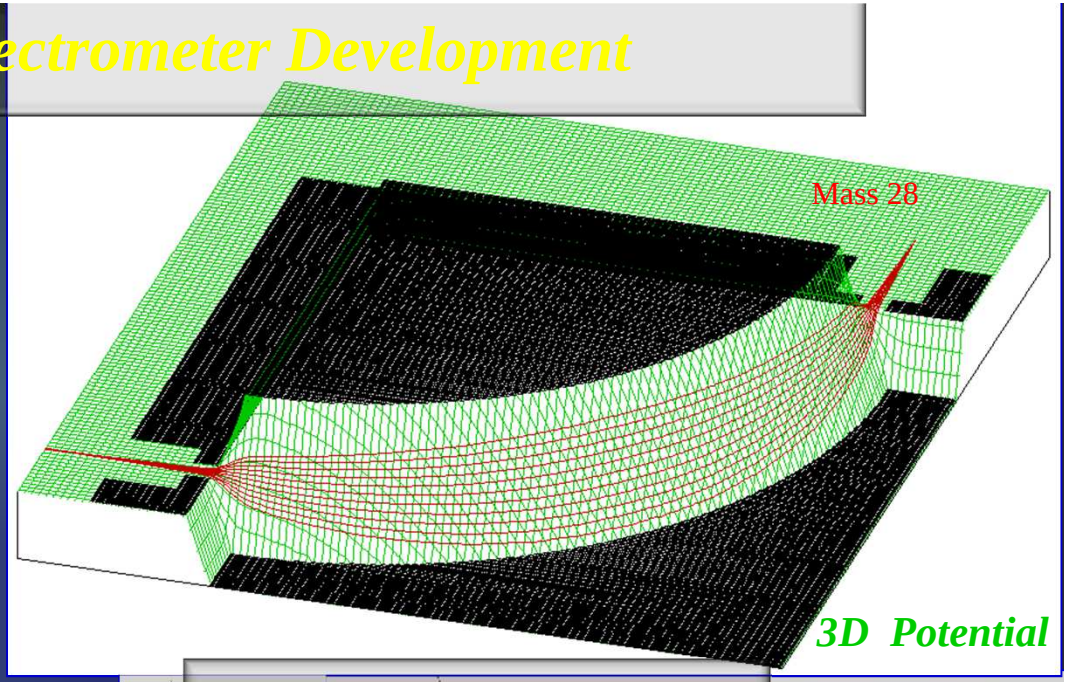
Patent: #6,501,074



- Miniature Double Focusing Magnetic Sector MS
- Tool Check (INFICON)
- Direct sampling, Bypass,
- CREARE Mini Turbo pump
- 1 KNF pump
- UAV Battery,
- 6 lb, 30 W max

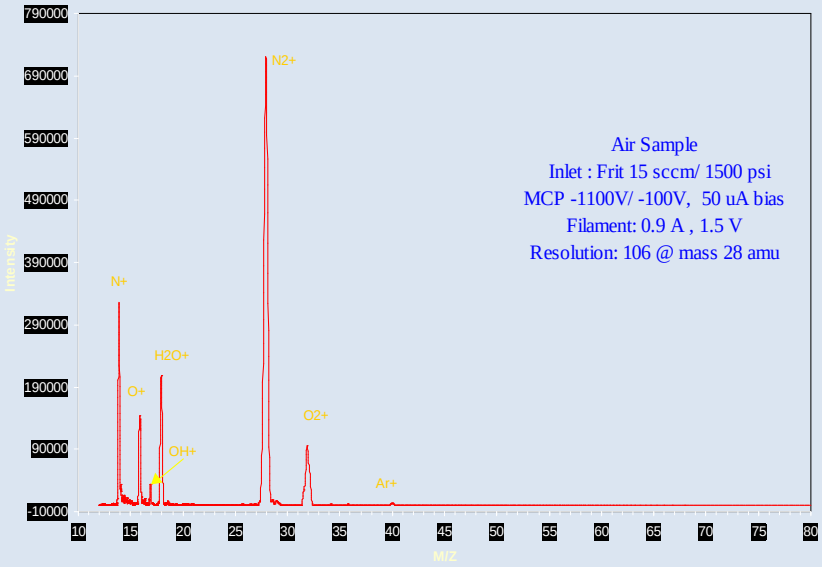
Miniature Mass Spectrometer Development





CDFMMS Spectrum 11/3/98

Inlet testing

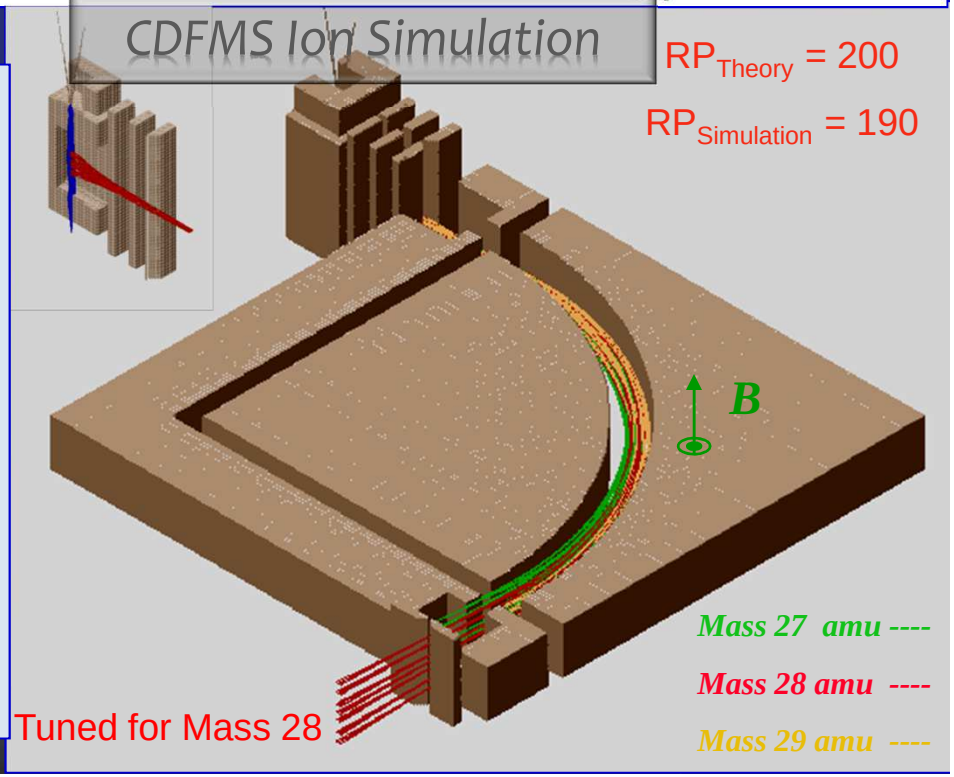


Air Sample
Inlet : Frit 15 sccm/ 1500 psi
MCP -1100V/ -100V, 50 uA bias
Filament: 0.9 A , 1.5 V
Resolution: 106 @ mass 28 amu

CDFMS Ion Simulation

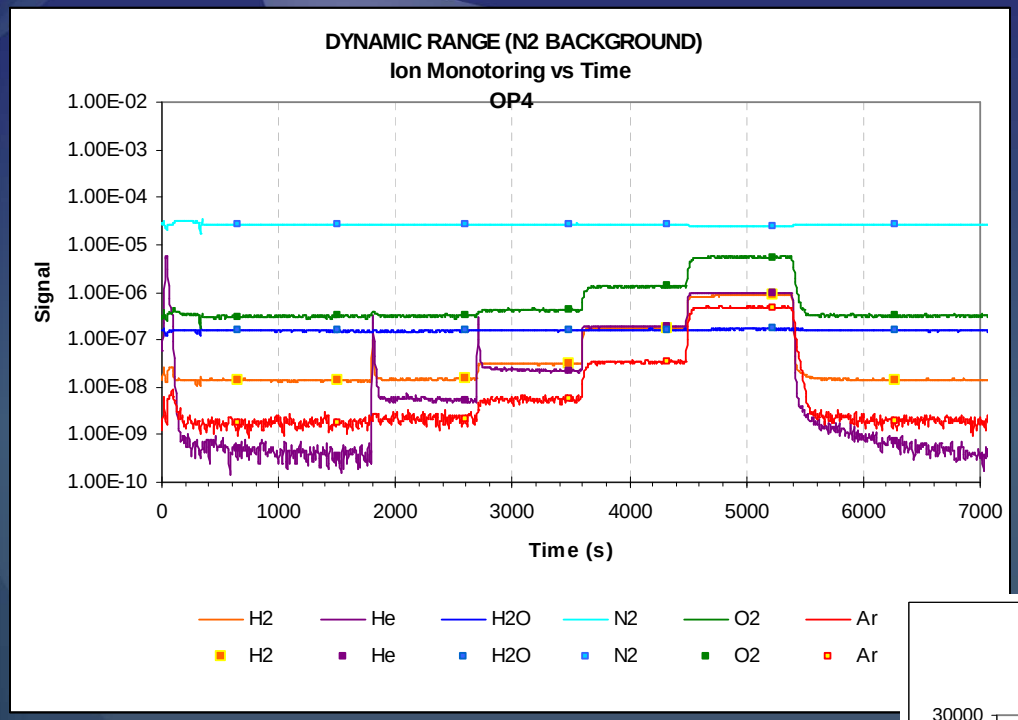
RP_{Theory} = 200

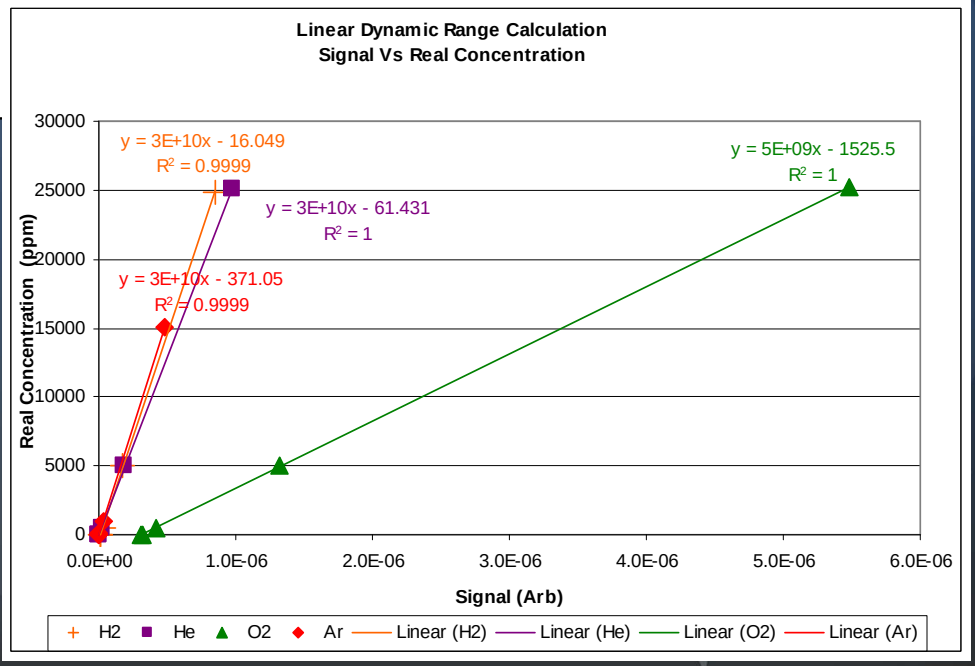
$RP_{Simulation}$ = 190



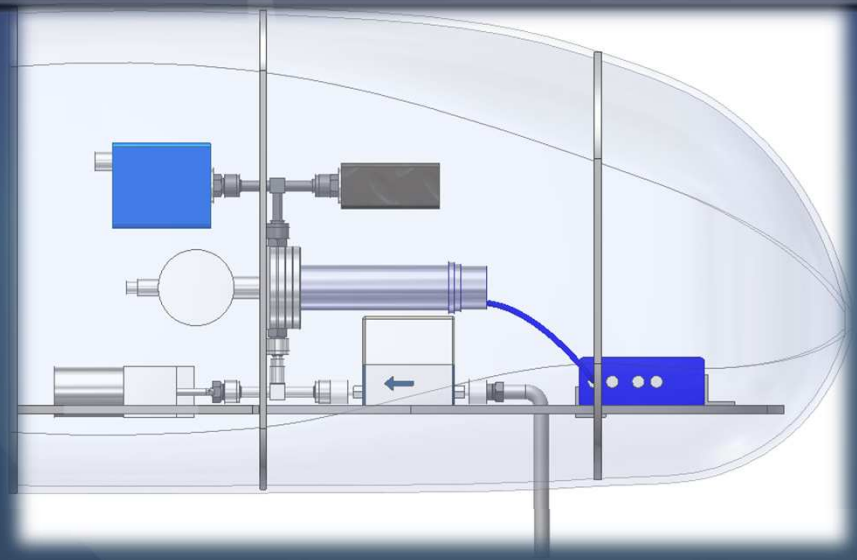
Tuned for Mass 28

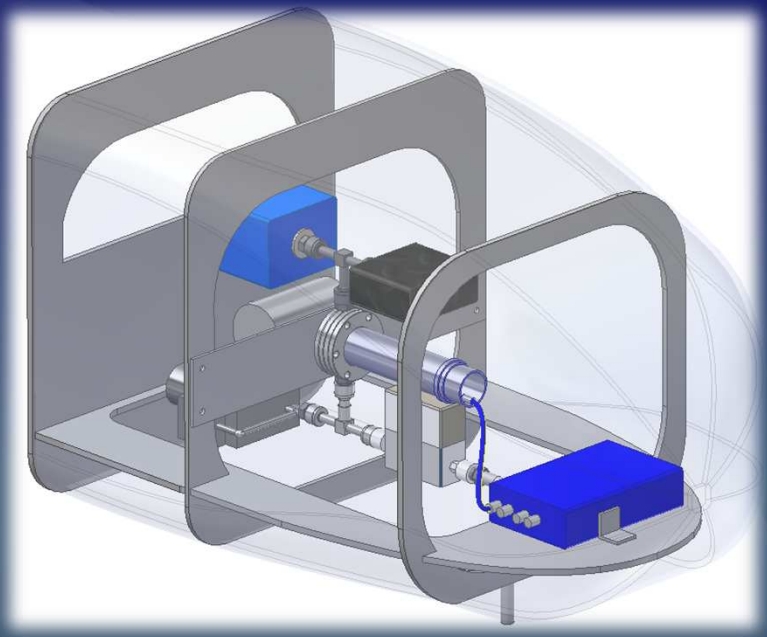
Tool Check Mass Spectrometer Testing





ULISES-γ Airborne Instrument (2012)





- ***830 ARTMS-HEMS Demo System:***
- ***NASA SIERRA-UAV Nose***

- ART-MS (Elec Ion Trap)
- Tool Check (INFICON)
- Direct sampling, Pulsed
- NEG Pump
- UAV Battery
- 4 lb, Very Low power

ACKNOWLEDGEMENTS

COLLABORATION

Bob Kline-Schoder, Paul Sorensen. CREARE Inc

Gerardo Brucker, Jeff Rathbone. Brooks Automation Inc

Kevin Wright, INFICON Inc

UCR Machine Shop

This project is been supported:

- Universidad de Costa Rica, Dean of Research Office under grant 915-A9-091
- CONICIT/MICIT Fondo de Incentivos under grant FI-003-10.
- Earth Surface and Interior Focus Area of NASA,at the Jet Propulsion Laboratory of the California Institute of Technology in Pasadena.

VectorWing100 VIDEO

- http://www.youtube.com/watch?v=MHiTqvH0JYs