

Use of multiple in situ instruments and remote sensed satellite data for calibration tests at Solfatara (Campi Flegrei volcanic area)

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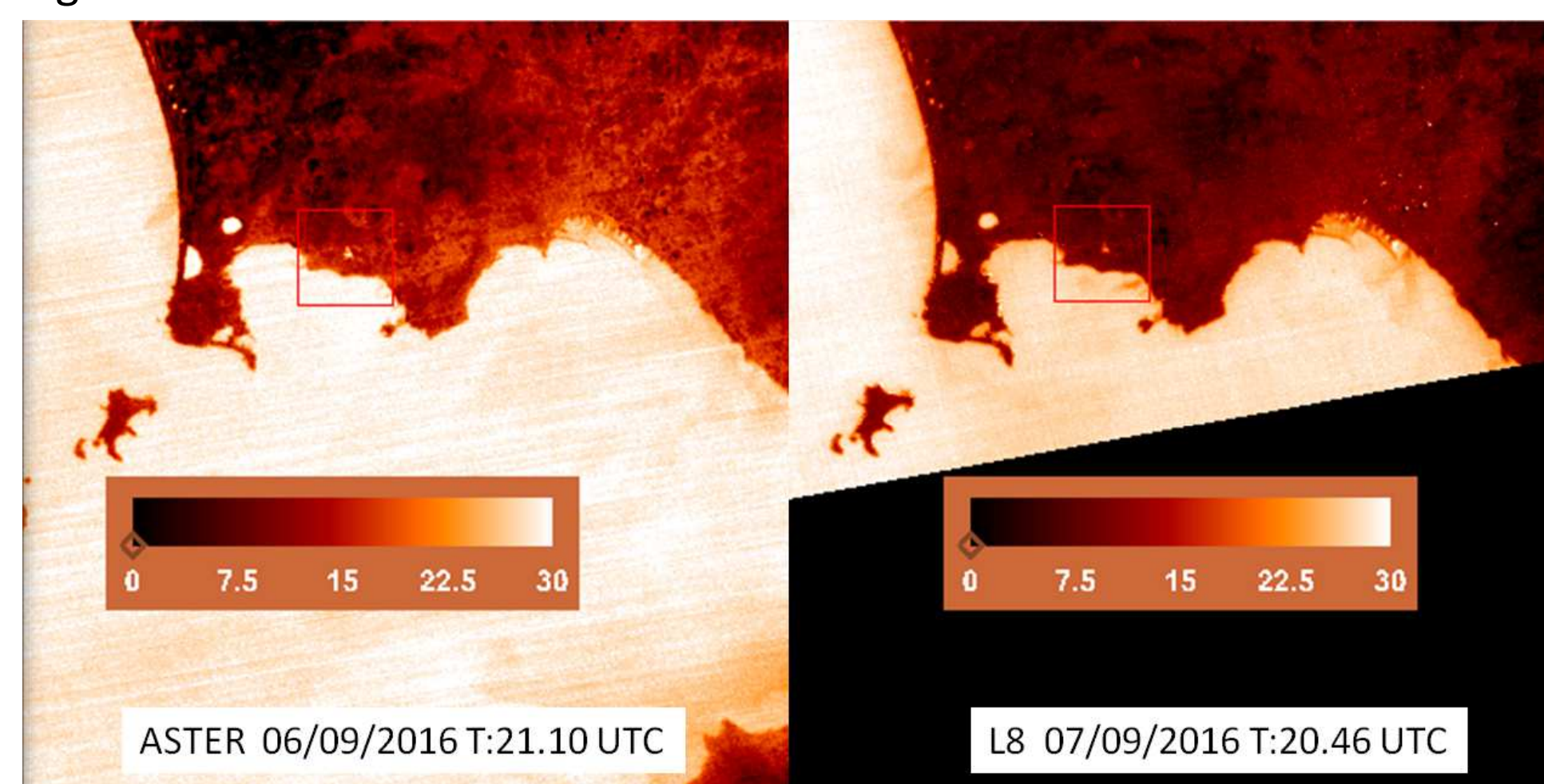
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Introduction: Monitoring natural hazards such as active volcanoes requires specific instruments to measure many parameters (gas emissions, surface temperatures, surface deformation etc.) to determine the activity level of a volcano. Volcanoes in most cases present difficult and dangerous environment for scientists who need to take in situ measurements. Remote Sensing systems on board of satellite permit to measure a large number of parameters especially during the eruptive events but still show large limitations to monitor volcanic precursors and phenomena at local scale (gas species emitted by fumaroles or summit craters degassing plumes and surface thermal changes of few degrees) for their specific risk. For such reason unmanned aircraft systems (UAS) carrying a variety of instruments (e.g. miniature mass spectrometer: miniMS) or single specie sensors (e.g. electrochemical and IR sensors) allow a safe monitoring of volcanic activities in complement to remote sensing and near remote sensing techniques

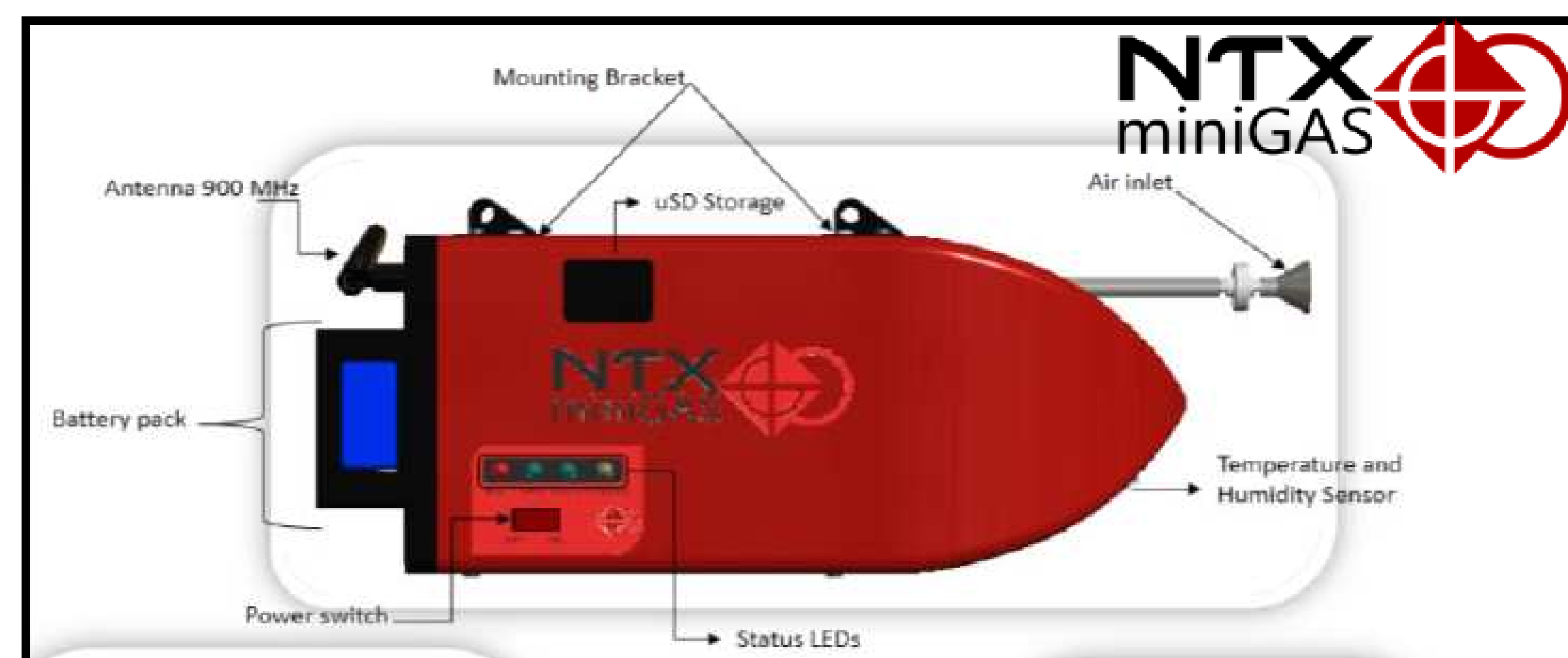


The Solfatara of Pozzuoli, near Naples, is part of the Campi Flegrei volcanic complex that contains an extended fumarolic field, whose activity consist mainly in the release of steam and gases with high Sulphur based component.

Remote Sensing CAL/VAL: The acquired measurements have also permitted the calibration and validation of satellite data as ASTER and LANDSAT8 (in collaboration with USGS). We believe that the rapid increasing of technology developments will permit the use UAS to integrate geophysical measurements and contribute to the necessary calibration and validation of current and future satellite missions dedicated to the measurements of surface temperatures and gas emissions in volcanic areas.



In-situ UAS borne instrumentation: The *miniGAS* and *miniMS* systems were deployed into Solfatara Volcano for in-situ volcanic gas plume characterization. With this technology, it is possible to perform monitoring measurements of volcanic activity without risking the lives of scientists and personnel performing analysis during the field campaigns in areas of high volcanic activity and supporting the calibration and validation of satellite data measurements. The *miniGAS* systems allows the acquisition of real-time information such as temperature, pressure, relative humidity, SO₂, H₂S, CO₂ concentration contained in degassing plume and fumaroles, with GPS geolocation. The acquired data are both stored in the sensor and transmitted to a computer for real time viewing information. Information in the form of 3D concentration maps can be returned.



Specs	MiniGAS NTX V1
Weight	1.2 kg (Battery included)
Processor	Arduino
Chemical Sensors	SO ₂ , CO ₂ , H ₂ S, +2 more possible
Physical Sensors	T,P, RH%, GPS
Dimensions	25cm x 12cm x 6cm
Flow	1.2 lpm
Data Recording	Onboard miniSD Card
Receiver	USB Xbee 900 Mhz Telemetry Radio
Range/Endurance	2 km / 6 hrs
Scan rate	1 Hz

➤ Both systems have fiberglass waterproof cases and can be integrated to the bottom of the UAS in order to measure the volcanic plume

Miniature Mass Spectrometer for Drones (miniMS-UAS)

UAS airborne mass spectrometer based instrument developed for in situ chemical determination of main components in atmospheric samples such as volcanic plumes, industrial plumes, leaks etc. has 1-100 amu mass range, capable of detecting mostly any gas present from ppm to 100% concentration. Uses a modified COTS miniature 2 mm radius rods high pressure quadrupole mass analyzer (XPR3 Quadrupole from Inficon Inc.) and miniature pump system (Turbo Drag + scroll pump combo from CREARE Inc, similar to the system used by Mars Science Lab (MSL) space probe. 1 scan/sec, detecting simultaneously H₂, He, H₂O, N₂, O₂, Ar, H₂S, CO₂, SO₂ molecules (and others) for volcanic emissions charact.



miniMS XPR3 integrated to UCR's S1000+ Octocopter and lab tested at GasLab for Volcanic Plume Characterization



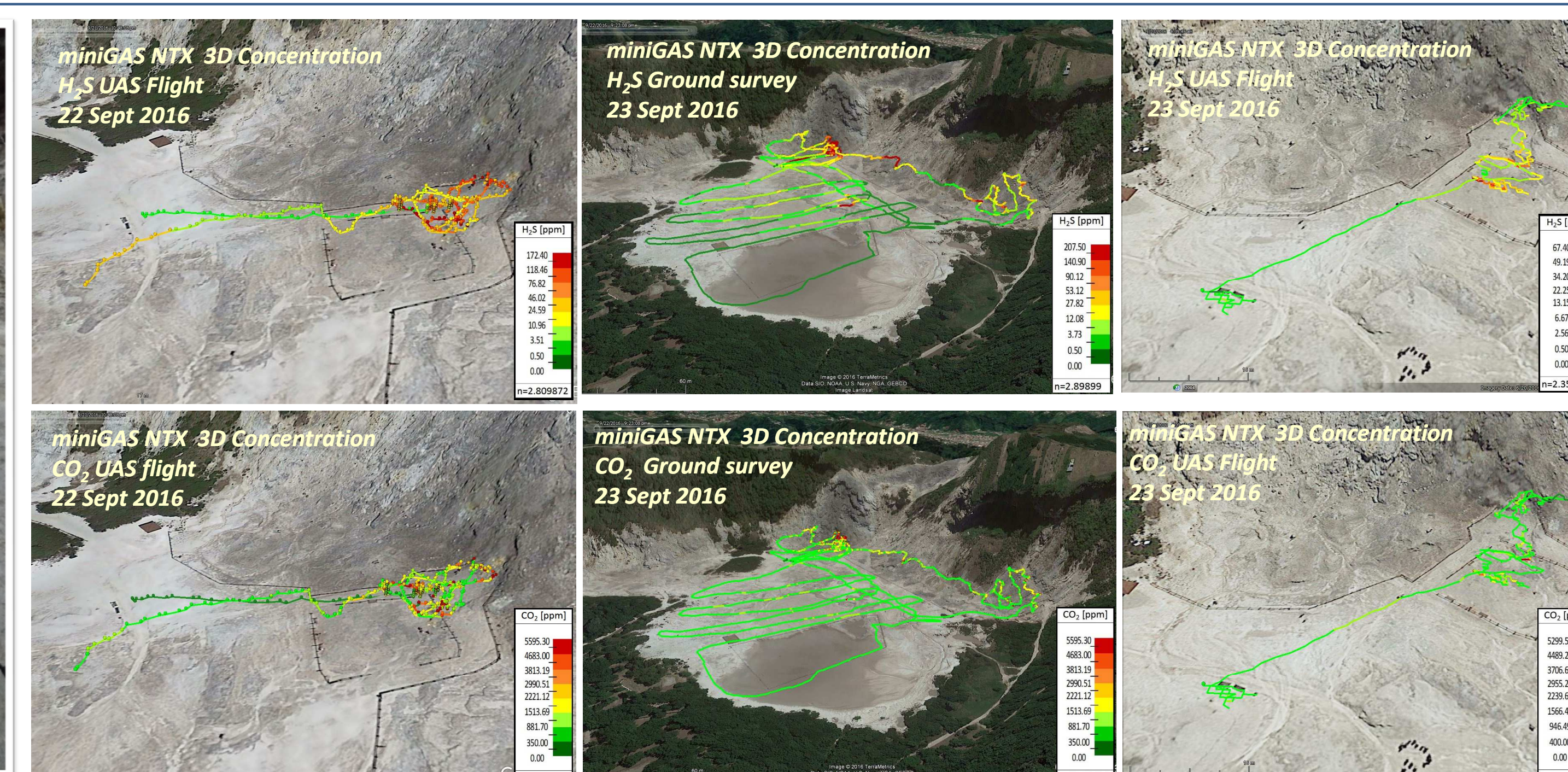
Specs	MiniMS XPR3 UAS V1
Weight	7 kg with Battery
Processor	Fit PC, onboard storage
Mass Range	1-100 amu
Dimensions	29 x 13 cm x 12 cm
Recording	Onboard HD
Receiver	Wi-Fi, 2.4GHz Telemetry
Range/Endur.	100m / 4 hrs



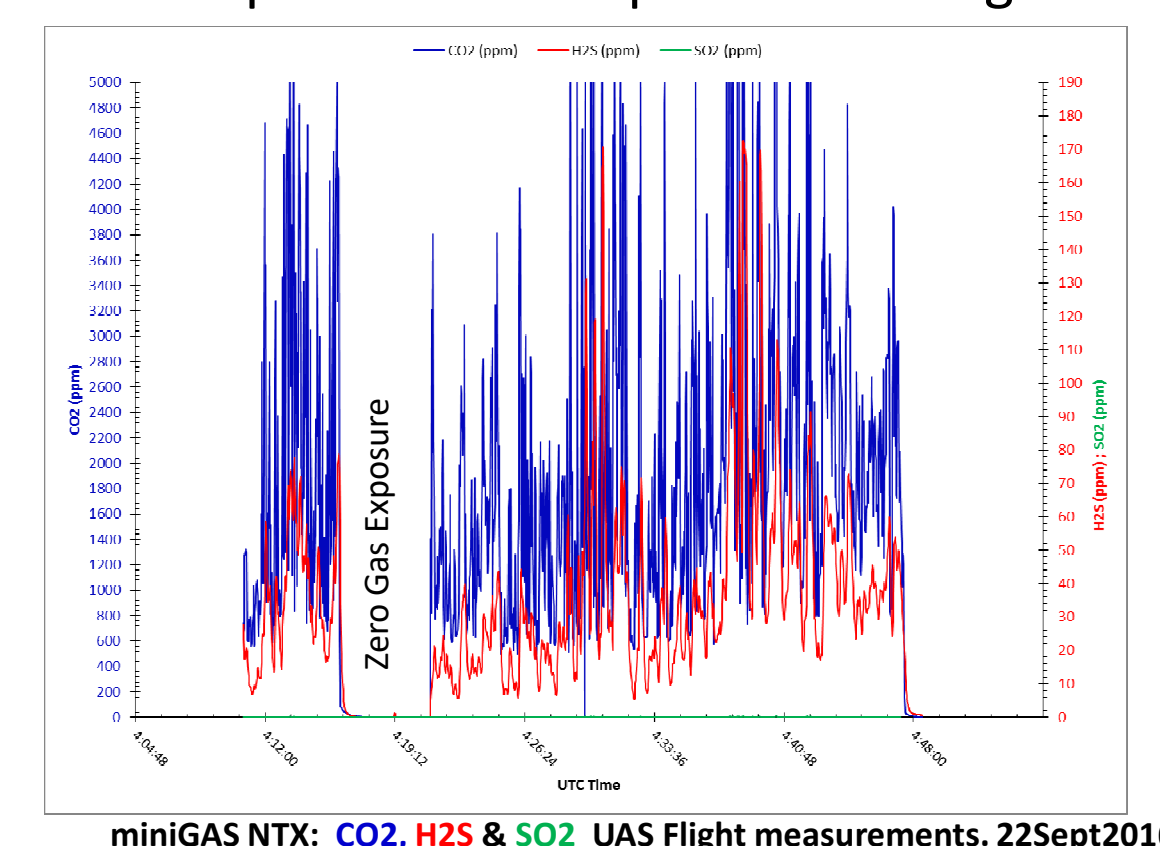
miniMS XPR3 flying over Solfatara Bocca Nuova Fumarole onboard INGV's Italdrone Octocopter



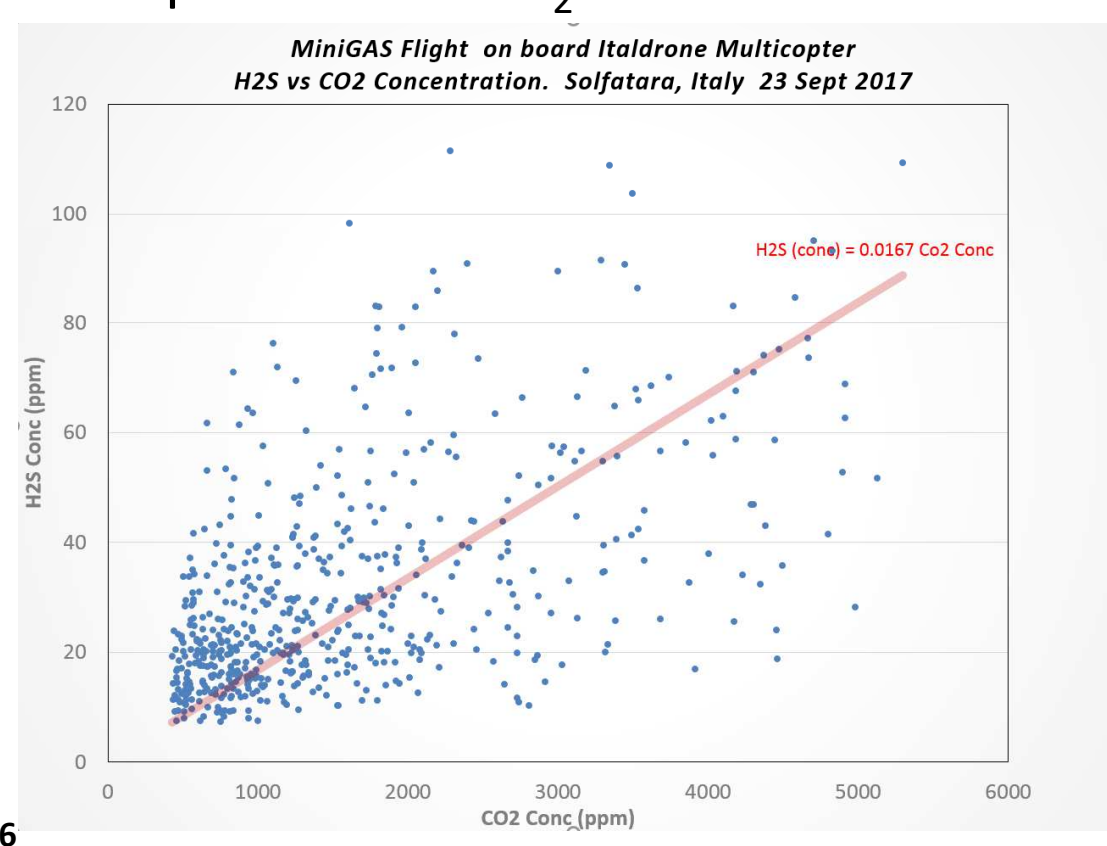
miniGAS NTX integrated to Italdrone Octocopter at Solfatara 2016 Deployment



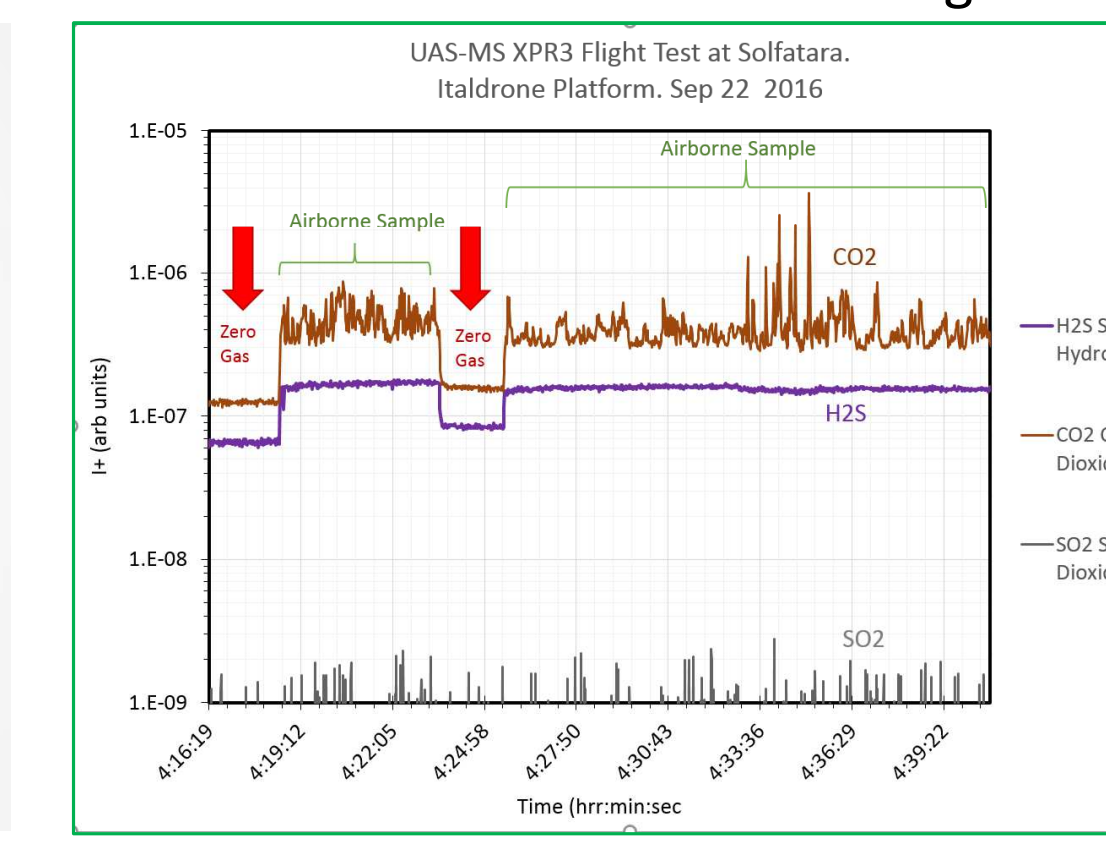
Deployment & Results: The miniaturized airborne instruments developed and field tested during the 2014, 2015 and 2016 Solfatara Volcano campaigns, allowed in situ measurements using flying drones or hand carried into the fumarolic sites. We present some results of the field campaign held last year at the Solfatara of Pozzuoli, near Naples, concerning measurements of CO₂, H₂S and SO₂. The campaigns were carried out in collaboration with the University of Costa Rica. The campaign made possible the acquisition of multiple measurements, field testing the miniaturized multi-gas systems in complement to other INGV equipment such as thermal cameras and spectro-radiometer. Perhaps the most important finding was the no presence of SO₂ on the in situ measurements which is consistent with long term data collection at the site.



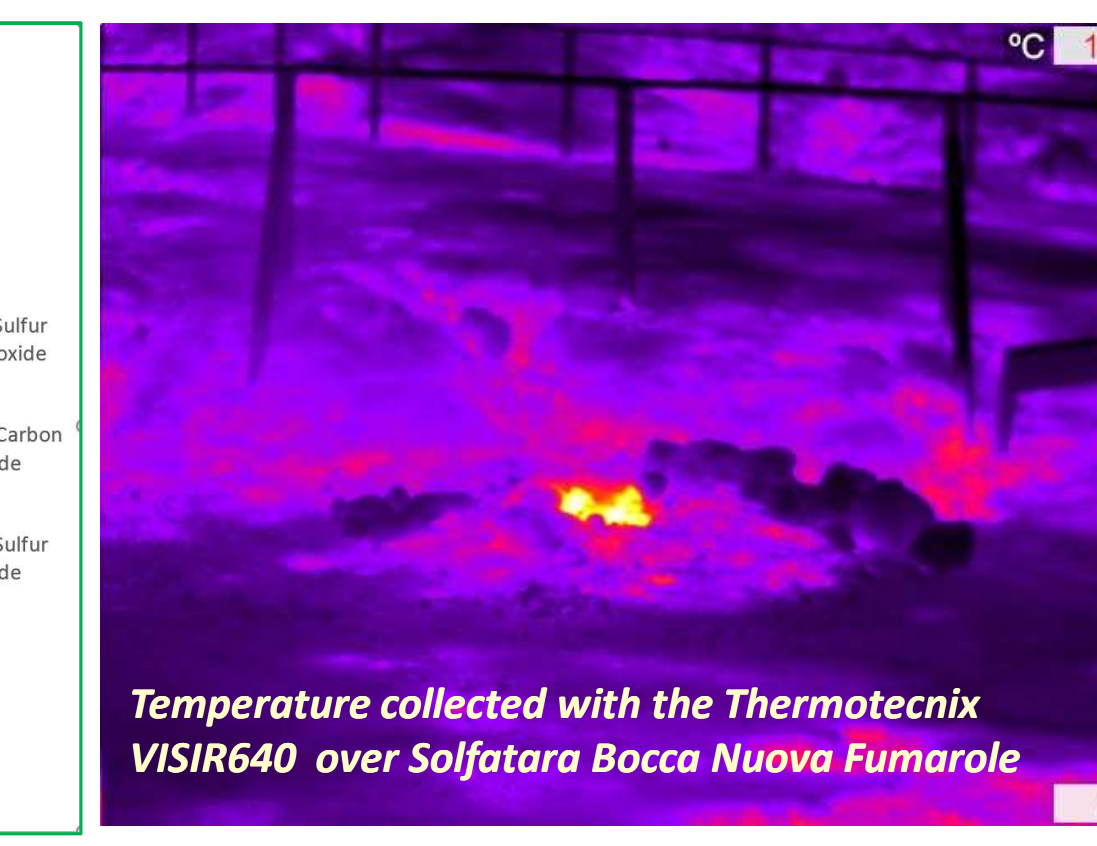
miniGAS NTX: CO₂, H₂S & SO₂ UAS Flight measurements. 22Sept2016



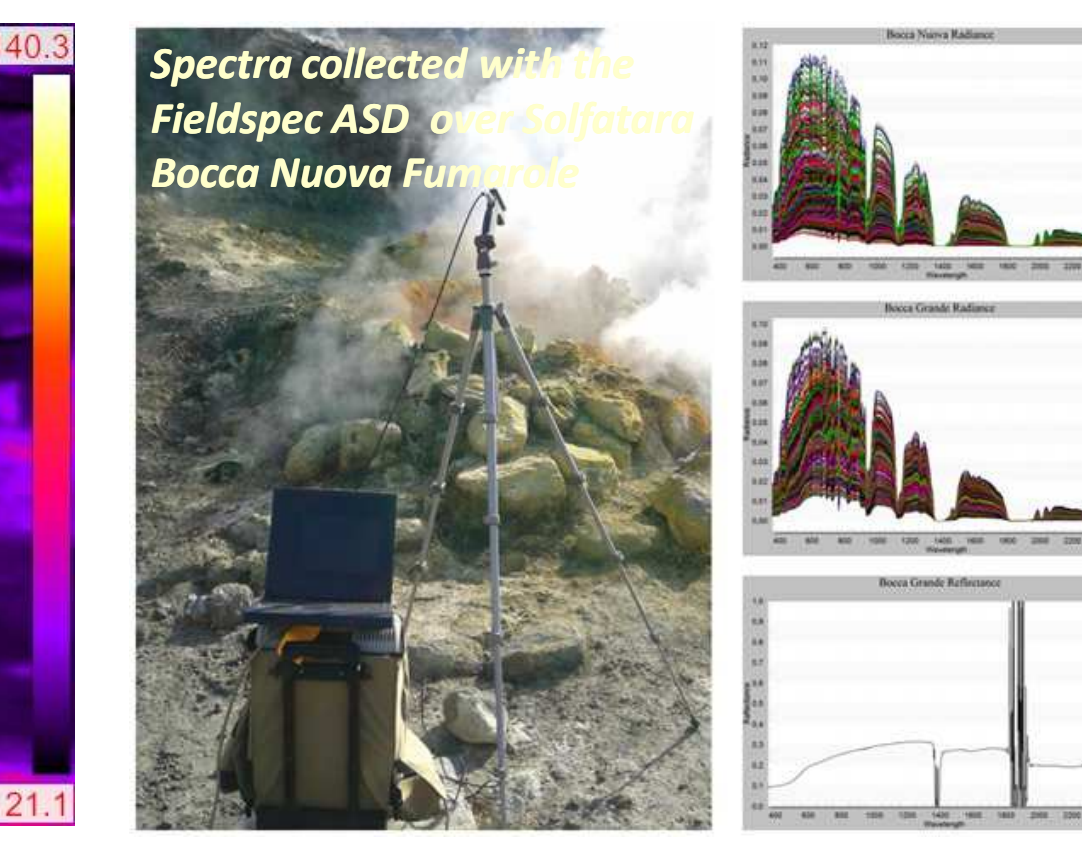
MiniGAS Flight on board Italdrone Multicopter H2S vs CO2 Concentration. Solfatara, Italy. 23 Sept 2017



UAS-MS XPR3 Flight Test at Solfatara. Italdrone Platform. Sep 22 2016



Temperature collected with the Thermotecnix VISIR640 over Solfatara Bocca Nuova Fumarole



Spectra collected with the Fieldspec ASD over Solfatara Bocca Nuova Fumarole