ENOS effective wide areal CO2 detection techniques

- OGS drone
- NHAZCA ground movement
- BGS hyperspectral sensor

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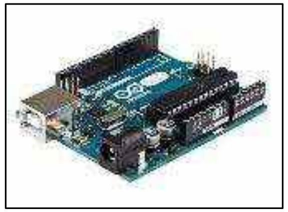
OGS DRONE

08.05.2018

ENOS

Custom Portable CO2 logger

components

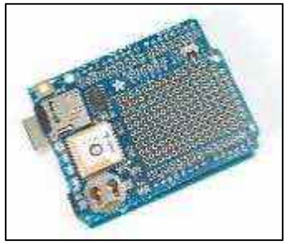


Arduino **UNO Rev3**

Microcontroller	**Atmel ATmega328**
Clock speed	**16 MHz**
Flash memory	**32 KB**
SRAM memory	**2 KB**
Available pins	**14 digital, 6 analogic**
Dimensions	**68,6x53,3 mm**
Power consumption	**50 mA**

COZIR **WX60 CO_2 sensor**

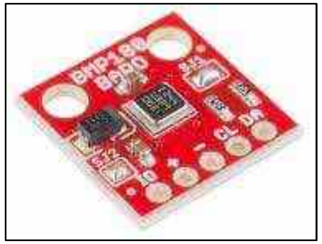
Measuring method	**NDIR (Non Dispersive InfraRed)**
Range	**0÷60 %**
Accuracy	**±70 ppm +/- 5% reading**
Heating time	**< 10s**
Operative conditions	**0÷50 °C; 0÷95% RH**
Dimensions	**40x25x19 mm**
Power consumption	**< 1,5 mA**



Adafruit **Ultimate GPS Logger**

Sensibility	**-165 dBm**
Frequency	**10 Hz**
Channels	**66**
Accuracy	**< 3 m**
Antenna	**Inner + u.FL external**
Dimensions	**69x53x6.7 mm**
Power consumption	**20 mA**

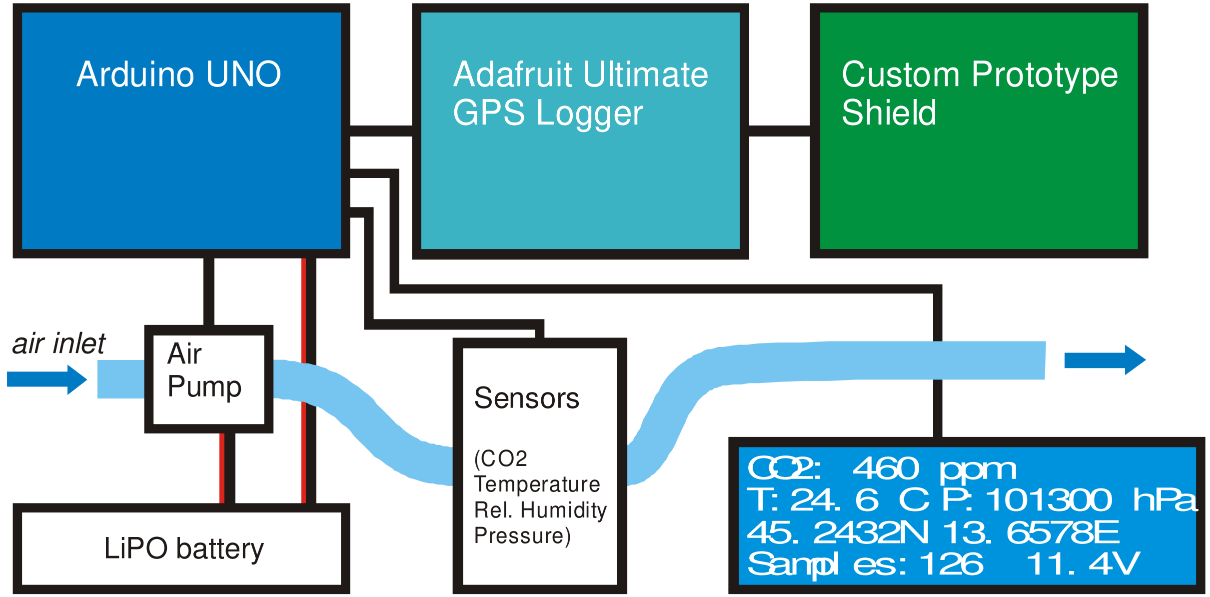
Adafruit **DHT22 temperature-humidity sensor**



SparkFun **BMP 180 Barometric Pressure Sensor**

Custom Portable CO2 logger

scheme of the system



Vaisala CarboCAP Portable CO2 logger

components

Raspberry Pi model B

CPU	700 MHz single-core
Memory (SDRAM)	256 o 512 MB (shared with GPU)
USB ports	2 (integrated hub)
Video output	RCA connector for composite video, HDMI
I/O port	2x13 pin for GPIO, SPI, I²C, UART, +3,3 Volt, +5 Volt
Mass memory	SD / MMC / SDIO card slot
LAN	Ethernet 10/100 Mbit/s (RJ-45)
Power consumption	700 mA (3,5 W)

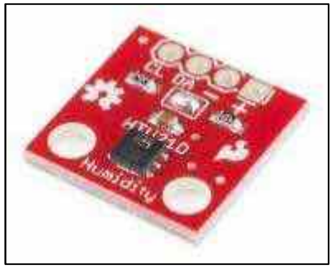
SparkFun **BMP 180 Barometric Pressure Sensor**

Vaisala GMP 343

Technical data

Performance

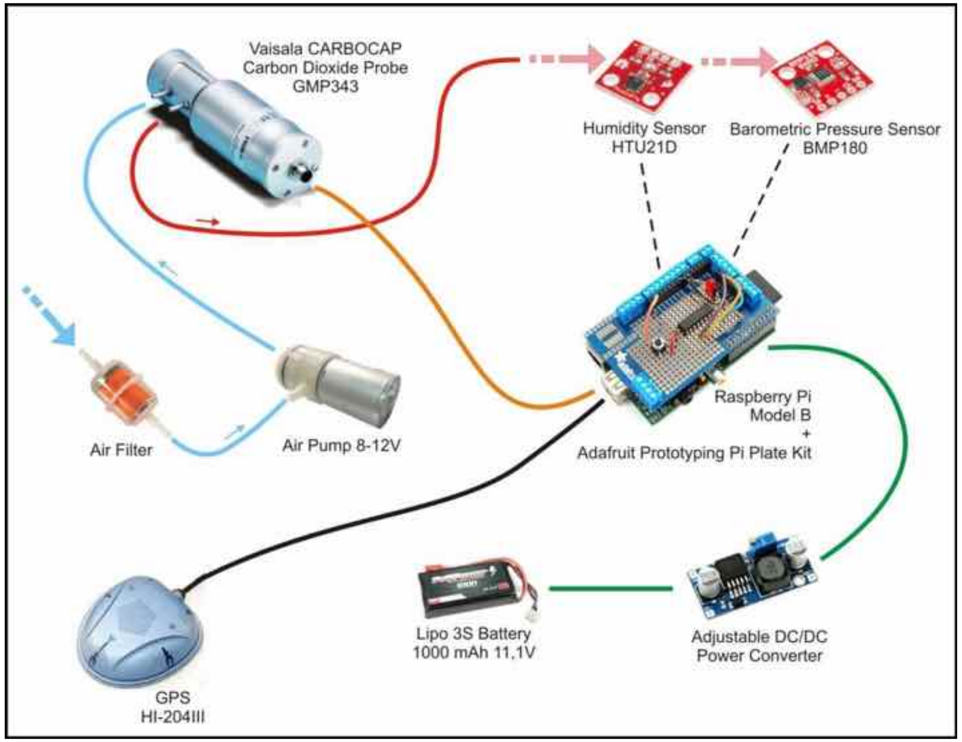
Measurement range options	0 ... 1000 ppm, 0 ... 2000 ppm, 0 ... 3000 ppm, 0 ... 4000 ppm, 0 ... 5000 ppm, 0 ... 2 %
Accuracy (excluding noise) at 25 °C (77 °F) and 1013 hPa after factory calibration with 0.5 % accurate gases with different range options	
0 ... 1000 ppm	±(3 ppm + 1 % of reading)
0 ... 2000 ppm - 0 ... 2 %*	±(5 ppm + 2 % of reading)
*Accuracy below 200 ppm CO_2 not specified for 2 % range option	
Noise (repeatability) at 370 ppm CO_2	
with no output averaging	±3 ppm CO_2
with 30 s output averaging	±1 ppm CO_2



SparkFun **HTU21D Humidity Sensor**

Vaisala CarboCAP Portable CO2 logger

scheme of the system



Drones - possible solutions
NT6-EVO

Diagonal Wheelbase	1020 mm
Max Payload（with 2x6S/5000mAh battery）	600 g
3rd Party Equipment Installation Platform	With mounts
Max flight time	30 min
Flight Termination System for critical area survey	

Drones - possible solutions
DJI Wind 8

Diagonal Wheelbase		1520mm
Weight（with DZ-22000mAh battery）		15.7kg
Max Takeoff Weight		26kg
Max Payload（with DZ-12000mAh battery）		10kg
3rd Party Equipment Installation Platform		With mounts
GPS Adoption Method		Inside
Basic Configuration		A3*1，IMU*2，GPS*1
Folding Method		Folded downward
Propulsion System	Landing Gear	Retractable
	Motor Model	6010Pro
	Propeller Model	2170
	ESC Model	1280X
	Operating Temperature	-10 to 50° C
	Hovering Accuracy（safe flight, 1 GPS, no RTK）	Vertical：±0.5m Horizontal：±1.5m
Performance	Max Angular Velocity	150° /s
	Max Pitch Angle	25°
	Max Ascent Speed	5m/s
	Max Descent Speed	4m/s
	Max Wind Resistance	10m/s
	Max Speed	15m/s

Drones - possible solutions
RIEGL RICOPTER

Specifications and Performance:

Main Dimensions ready to fly arms folded for transportation & storage	 1,920 mm x 1,820 mm x 470 mm 624 mm x 986 mm x 470 mm
MTOM (Maximum Take-Off Mass)	25 kg
Max. Sensor Load	up to 6.5 kg
Empty Weight	11 kg
Max. tested and permitted Operating Altitude AMSL	up to 3000 m (10,000 ft) (under ISA conditions)
Max. Flight Endurance	up to 30 min
Cruise Speed	typ. 6 - 8 m/sec
Take-off / Landing	VTOL (Vertical Take-off and Landing)
Transmission Range	Remote Control > 1km Command and Control Link > 3 km
RiCOPTER Transportation Case dimensions empty weight	 1,220 mm x 810 mm x 540 mm approx. 20 kg

Drones – test flights
data visualization

[time]	[lat]	[lon]	[CO2]	[t]	[RH]	[p]
084249.000;	4542.6327;	01345.7750;	980.00;	21.10;	42.70	98704
084254.000;	4542.6328;	01345.7751;	960.00;	21.10;	42.70	98708
084259.000;	4542.6326;	01345.7756;	990.00;	21.10;	42.70	98716
084304.000;	4542.6323;	01345.7753;	980.00;	21.10;	42.70	98709
084310.000;	4542.6324;	01345.7752;	970.00;	21.10;	42.60	98707
084315.000;	4542.6324;	01345.7750;	980.00;	21.10;	42.60	98709
084320.000;	4542.6330;	01345.7748;	980.00;	21.10;	42.60	98719
084325.000;	4542.6333;	01345.7750;	980.00;	21.10;	42.60	98711
084330.000;	4542.6339;	01345.7754;	960.00;	21.10;	42.60	98708
084336.000;	4542.6341;	01345.7749;	970.00;	21.10;	42.60	98702
084341.000;	4542.6349;	01345.7754;	960.00;	21.10;	42.60	98709
084346.000;	4542.6348;	01345.7759;	960.00;	21.10;	42.60	98706
084351.000;	4542.6349;	01345.7754;	980.00;	21.10;	42.70	98707
084356.000;	4542.6349;	01345.7753;	980.00;	21.10;	42.60	98704
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084412.000;	4542.6365;	01345.7719;	960.00;	21.10;	42.50	98713
084417.000;	4542.6364;	01345.7718;	960.00;	21.10;	42.50	98702

Drones – future developments
multispectral camera

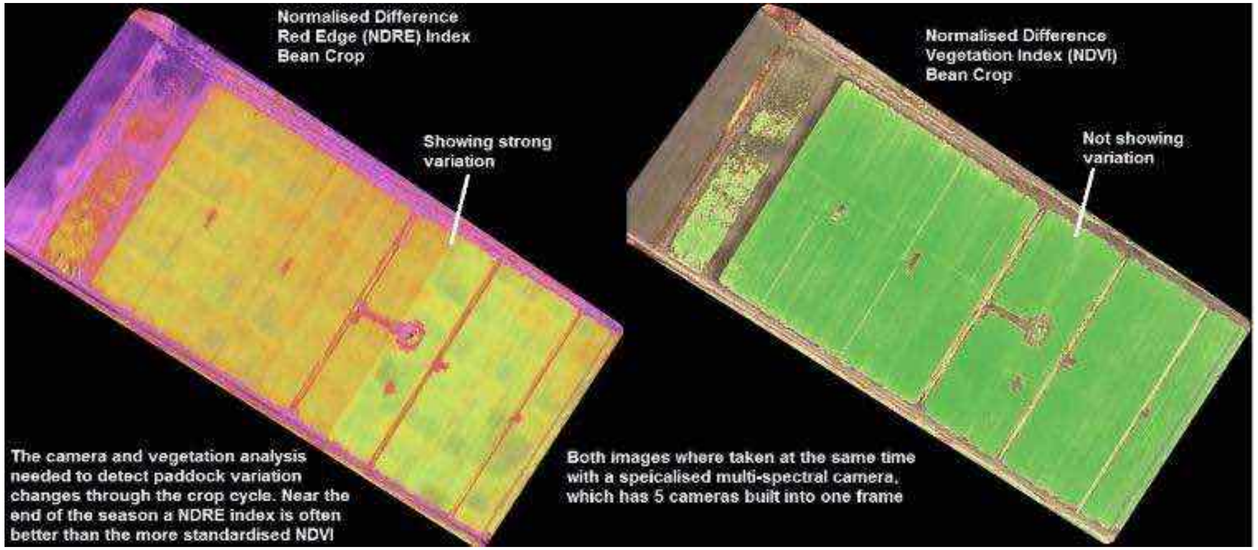
PARROT SEQUOIA+

4 SEPARATE BANDS

- Green (550 BP 40)
- Red (660 BP 40)
- Red Edge (735 BP 10)
- Near infrared (790 BP 40)

$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

$$\text{NDRE} = \frac{(\text{NIR} - \text{RE})}{(\text{NIR} + \text{RE})}$$



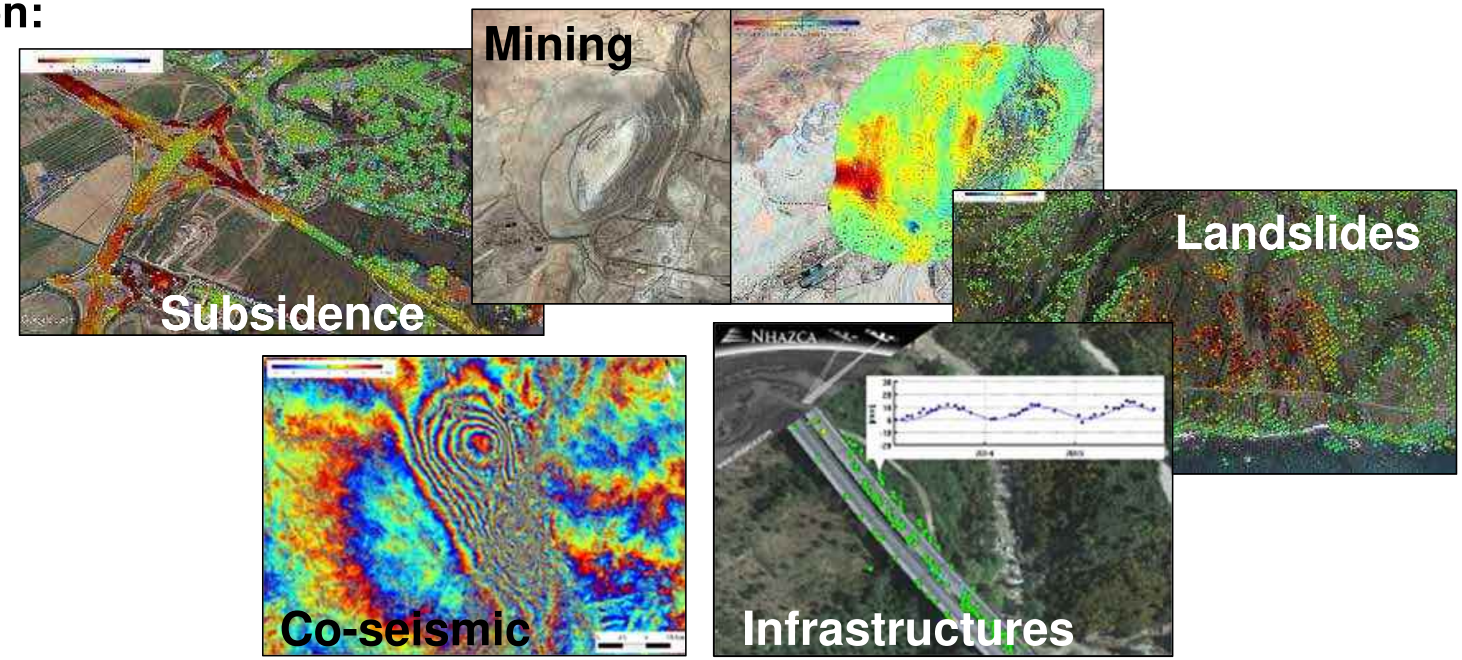
NHAZCA GROUND MOVEMENT

THE SATELLITE SAR INTERFEROMETRY

The satellite SAR interferometry → **Detect small (millimetric-scale) terrain deformation**

It has many fields of application:

- **Mining**
- **Oil&Gas**
- **Civil engineering**
- **Landslides**
- **Subsidence**
- **Seismology and tectonics**
- **Volcanology**



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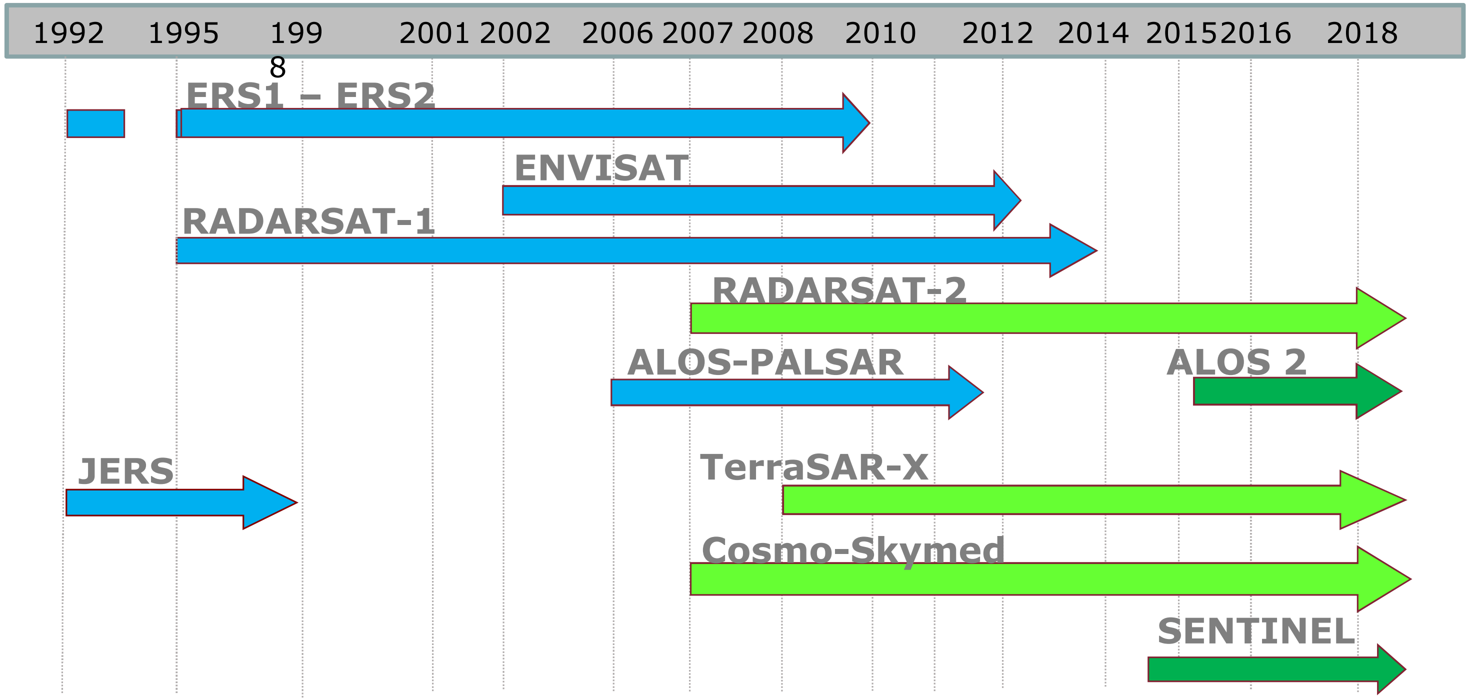
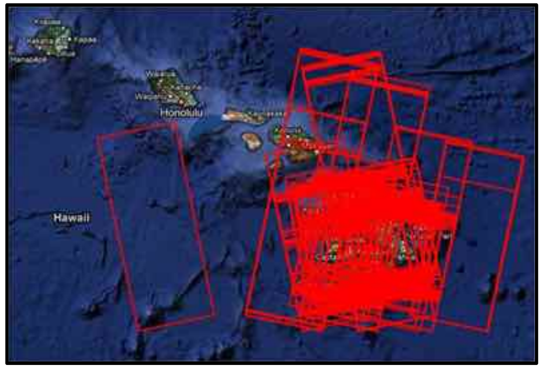
THE SATELLITE SAR INTERFEROMETRY

Availability of data! Past and present SAR satellites

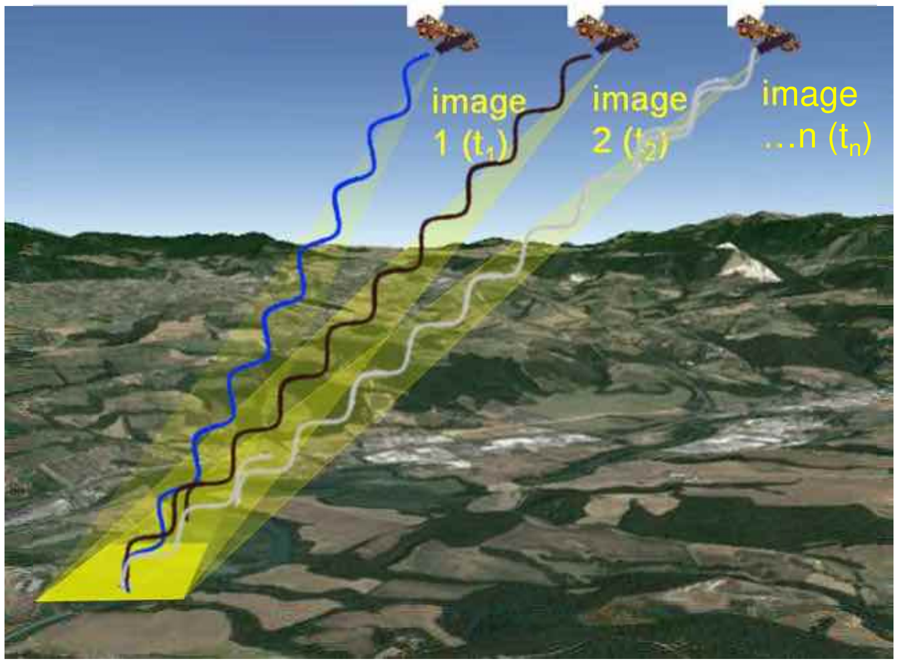


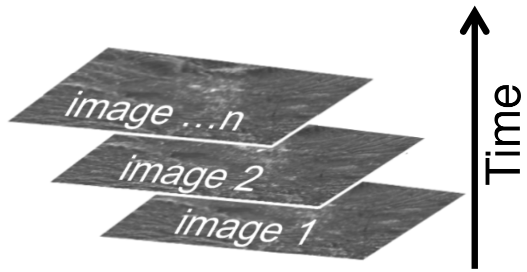


Archive data: the world is covered by satellite SAR images

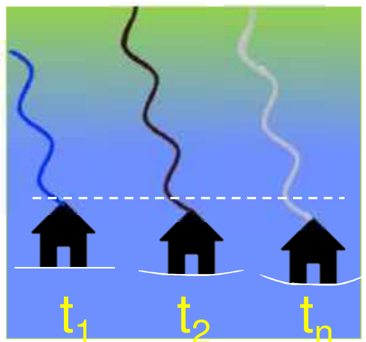
THE SATELLITE SAR INTERFEROMETRY

Multi-interferometric approaches grouped in the name of **Advanced Differential Interferometric SAR (A-DInSAR)**, that uses a considerable amount of SAR data (alt least several tens of image pairs).





We identify the **targets which maintain the same electromagnetic signature in all images,** and which preserve the phase information in time.

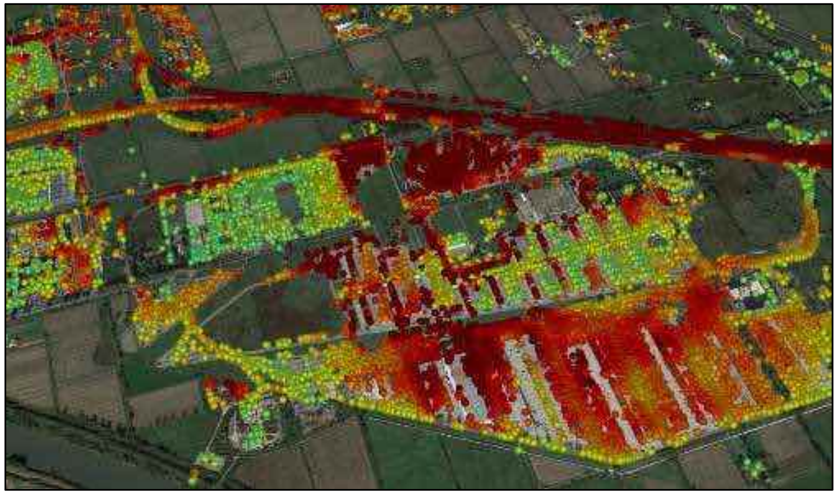


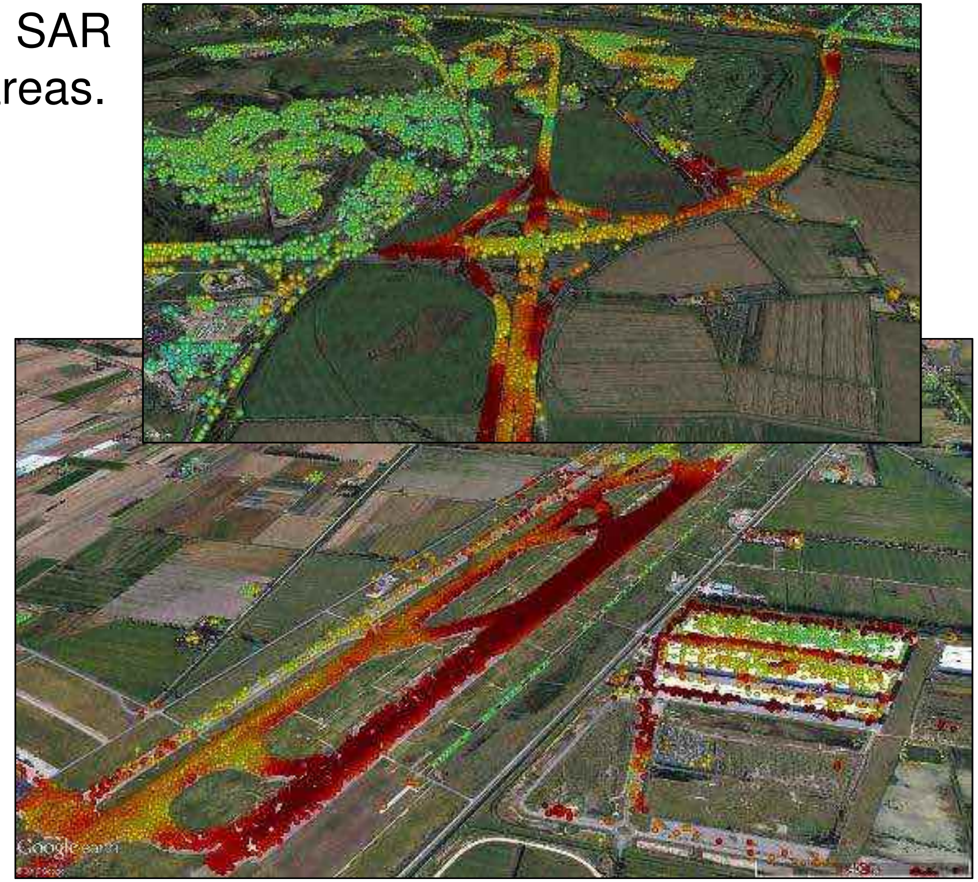
The Key outputs of a A-DInSAR analysis are:

- ✓ the **average annual velocity** measurements (in mm/yr) of each measurement point (MP) averaged over the entire time period;
- ✓ **time series** of displacement for each MP

THE SATELLITE SAR INTERFEROMETRY

An Important and peculiar capability of Satellite SAR Interferometry, is the possibility to investigate large areas.





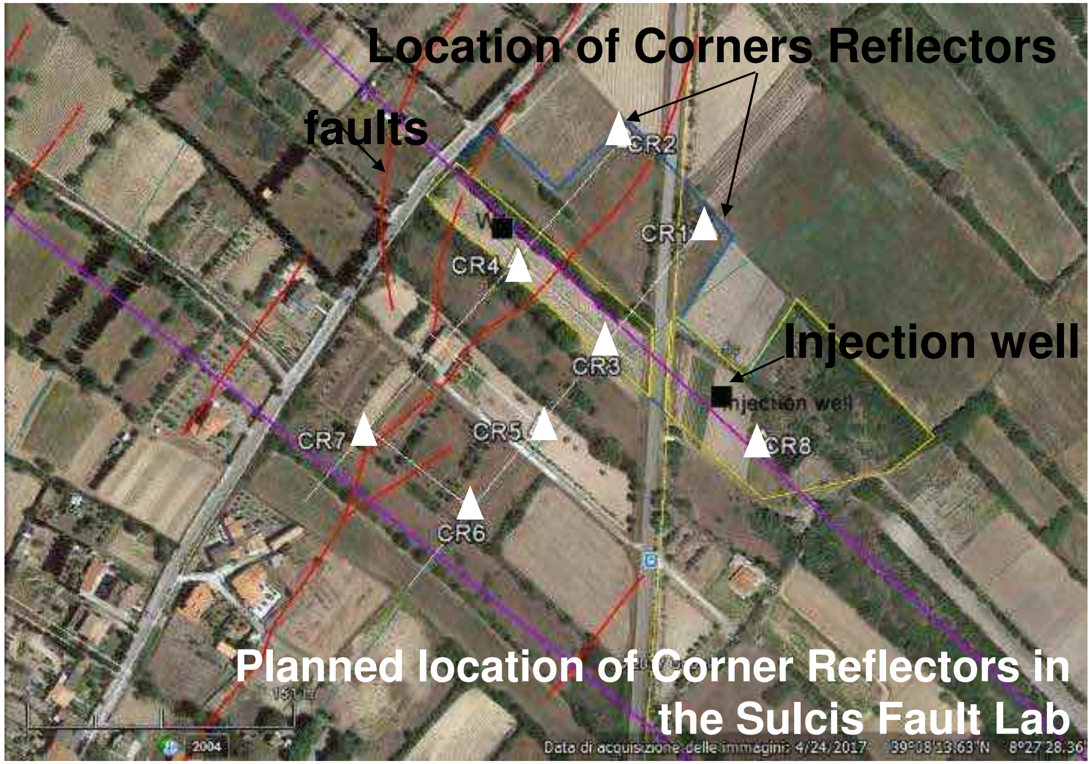
Pictures: example of “large-scale monitoring” in an urbanized area (near Rome, Italy): red zones are moving away from the sensor.

THE SATELLITE SAR INTERFEROMETRY

A-DInSAR will be used to monitor the surface deformation pattern before and during the injection phase, up to a few months after the injection.

The collected data will be used to derive detailed information about CO2 leakage at Sulcis Fault Lab on the basis of the induced surface ground deformation.

The technique combines corner reflectors installed on a regular grid.



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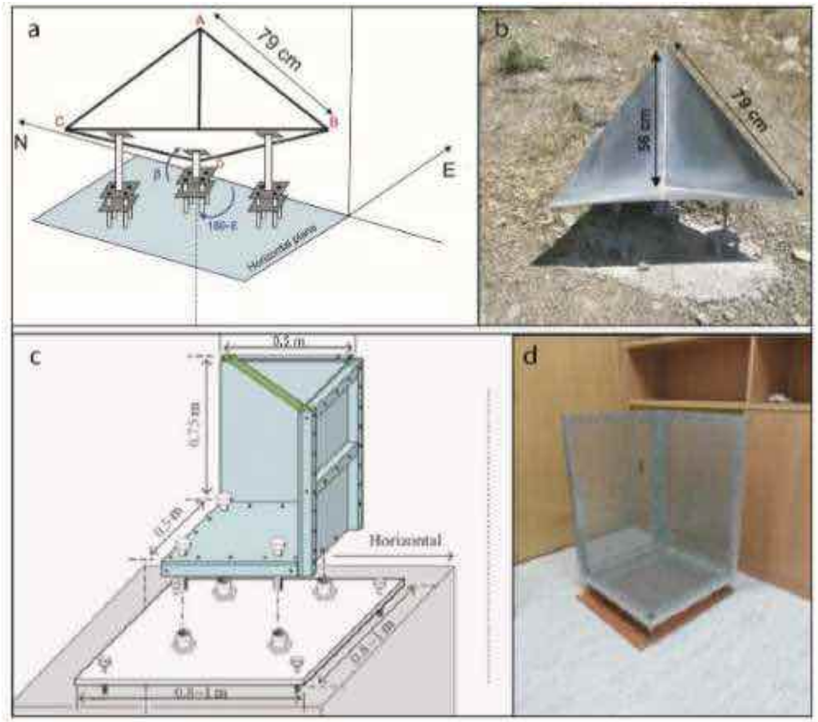
THE SATELLITE SAR INTERFEROMETRY

- corner reflectors are built to reflect the satellite radar signal optimally.
- corner reflectors allow to obtain accurate displacement measurements, especially in areas without “natural” reflectors (e.g. vegetated areas).



Corners reflectors (modified from Bovenga et al., 2017; and Qin et al., 2013)

ENOS WIDE AREAL TECHNIQUES

Airborne Hyperspectral Thermal Imaging

08.05.2018

ENOS

Airborne Hyperspectral Thermal Imaging for Gas Monitoring

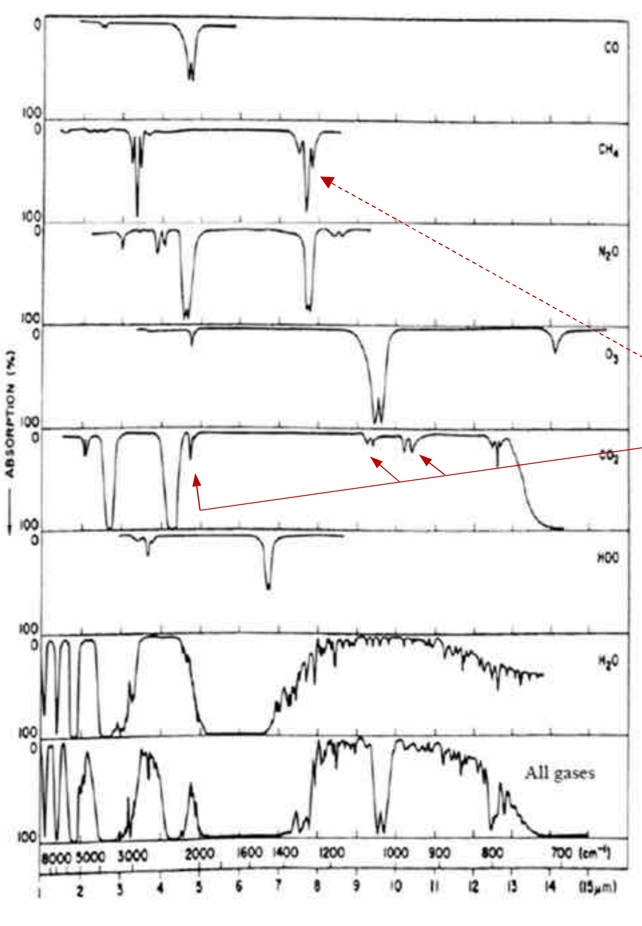
ENOS project will use existing airborne hyperspectral thermal imaging technology in a novel application to test the monitoring and detection of gas flux at the ground surface

The technology exploits the contrast between the gas and background taking into account influences from the sky, ground and atmosphere

Acquisition of wide areal thermal emission images at contiguous wavelengths across the thermal infrared (TIR) both before and after gas release will be used to assess:

- location of gas emergence at surface with respect to gas release
- composition of detected gas from absorption feature wavelengths
- timing of gas emergence using multiple image acquisition
- potential quantification of gas extent and volume at surface
- advantages of applying this technology for gas detection at surface

Airborne Hyperspectral Thermal Imaging for Gas Monitoring



Satellite-based systems mostly monitor trace gases in the troposphere and stratosphere, within the atmospheric absorption window and not directly emitted from the ground

Spectral absorption features occur at TIR wavelengths, outside the range of atmospheric absorption, for:

- CH_4 (7.6µm)
- CO_2 (4.3, 9.4 and 10.4µm)

Satellites exist that enable ground gas measurement at TIR wavelengths, but at low spatial resolution:

- ENVISAT/SCIAMACHY (2002-2012): 32 km
- Aura/TES (2004): 0.53 x 5.3 km
- GOSAT/TANSO (2009): 1.5km
- OCO-2/HRGS (2014): 1.29 x 2.25 km

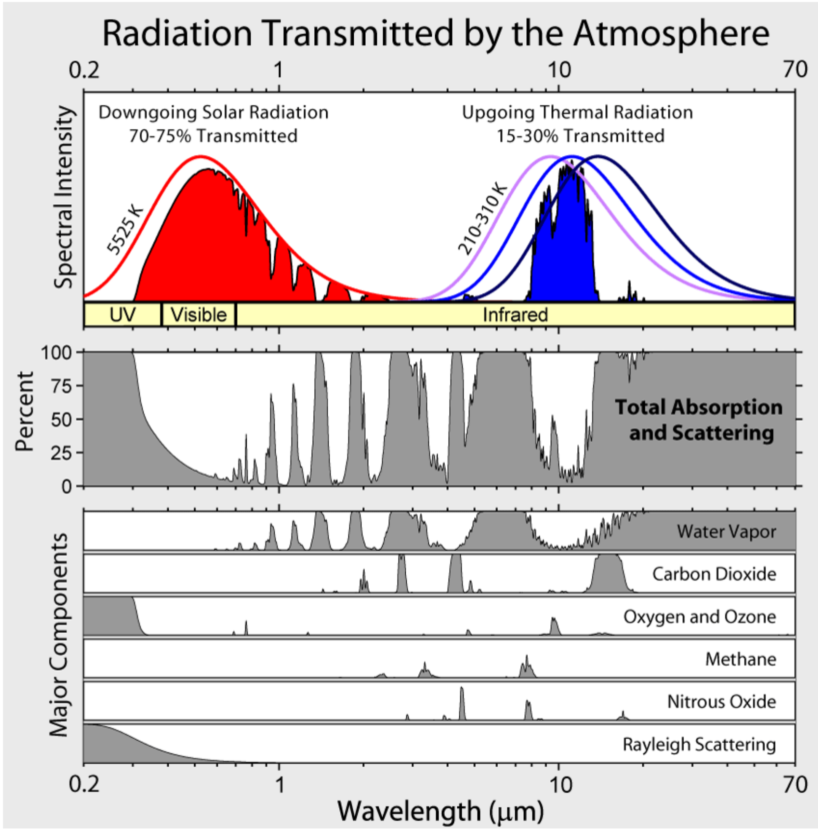
Airborne Hyperspectral Thermal Imaging for Gas Monitoring

Airborne systems provide greater flexibility in spatial resolution of measurement

The position, shape and intensity of absorption at TIR wavelengths varies with chemical and molecular composition thus enabling the identification of gas present using targeted specific narrow spectral resolution measurements

Quantification of gas emergence by airborne hyperspectral thermal images will be performed:

- prior to gas release for baseline
- post gas release for anomalies, if contrast exists between gas and background



Airborne Hyperspectral Thermal Imaging for Gas Monitoring

Airborne images use downward/nadir–looking systems to measure thermal emission at TIR wavelengths for each ground sample/pixel. Gas detection is enabled if a contrast exists between the gas and the surrounding background for anomaly detection

Processing and analysis is then performed to understand gas release at surface

The technology has the potential to provide rapid assessment of surface gas flux so ENOS will provide a unique opportunity to test existing technology in the novel application of monitoring and detection of gas flux at ground surface

ENOS

Enabling Onshore CO_2 Storage

www.enos-project.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653718