PON Research and Innovation 2014-2020 OT4CLIMA

Advanced Earth Observation technologies for studying Climate Change impacts on the environment

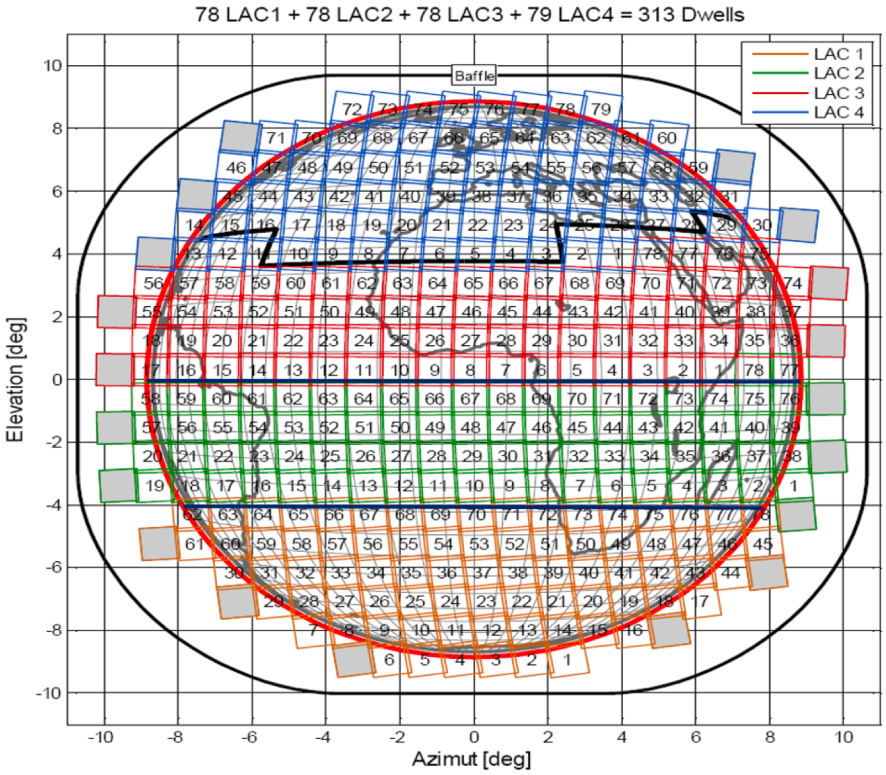
Earth Observation

the gathering of information about Earth's physical, chemical and biological systems using remote sensing technologies such as satellites and aerial sensors, supplemented by ground-based observations and other surveying techniques.

Big data

- ✓ **Copernicus programme**: satellites **Sentinel 1A/1B** (2014-2015) – SAR imaging All weather, day/night applications, interferometry **generate now 11 TB of products daily (against a formal specification of 3 TB)**.

- ✓ **Meteosat Third Generation programme** (from 2021): the **Infrared Sounder (IRS)**, 1890 channels, with a spatial resolution of 4 km, full disc coverage in 60 min, Europe region (Local Area Coverage) 30 min **will generate 32 GB per hour per dwell.**
  80 dwells x 4 LACS = 320 dwells!



Artificial Intelligence (machine learning) methodologies

Data Integration
calibration, spatial and temporal co-localization,
spectral transformation

Classification (i.e. cloud mask)
Logistic and multinomial regression
Support Vector Machines
Classification Trees
Random Forest
K-Nearest Neighbour
Cumulative Discriminant Analysis

Clustering (spectral and spatial)
Mixture Models
Functional Clustering
K-means
Neural Networks

Regression & Inverse Problems
Linear and Generalized Linear
Neural Networks
Functional Analysis
Regression Trees
Physical inversion

Dimension Reduction
Principal Component Analysis
Independent Component Analysis
Functional Data Analysis
Compressive Sensing

EJ Candes, JK Romberg, T Tao, D Donoho

General Objective

- to develop advanced Earth Observation (EO) technologies and methodologies for improving our knowledge of the effects of Climate Change (CC) and our capability to mitigate them at the regional and sub-regional scale.

Specific Objectives

- Develop innovative techniques and methodologies for analysing and interpreting Earth Observation data to study impacts of climate change on environment and territory;
- Develop and experiment advanced in-field technologies (airborne sensors and/or unmanned platforms) for the measurement of high-interest climate and environmental parameters;
- Develop market-oriented products/services/applications based on remote sensing data;
- Improve the capacity of adequately and timely responding to the extreme events and climate-related environmental emergencies;
- Improve existing strategies for monitoring, protecting and controlling the environment and territory through innovative decision support systems.
- Develop innovative decision support (DSS) systems based on smart integration not only of data but also of products.

Project Cost: 9.049 ML

- **Public research institutions, universities and other research bodies**: CNR; Basilicata University; Calabria University; Trento University; Italian Space Agency; National Institute of Geophysics and Volcanology, CIRA.
- **Industrial Components**: e-Geos, IDS (Big Enterprises), CORISTA, CREATEC Scarl, Survey Lab, SIIT ScpA (SME).
- **14** CNR institutes involved in 4 departments:

  - ✓ **DIITET**: IAC, IREA and IFAC.
  - ✓ **Department of Earth System Science and Environment Technology**: IMAA,ISAC, IRPI, IIA, IGG, IRET (ex IBAF).
  - ✓ **Department of Bio-Agrifood Science**: ISAFOM, IBIMET
  - ✓ **Department of Physical Sciences and Material Technologies**: IMM, SPIN, INO.

CNR P.I.: Dott. Vincenzo Lapenna (IMAA).

- **OR1 - Design of new EO technologies for measuring climate-related parameters.**
  - **Task 1.2:** airborne radar system: P-band radar, in particular the task aims at implementing new applications in hydrogeology field for an airborne SAR sensor operating at 450 MHz e 900 MHz.
- **OR4 – Testing of prototypes**
  - **Task 4.2**: testing of P-band radar systems;
  - **Task 4.3**: testing of UAV (Unmanned Aerial Vehicles) X/Ku-band radar systems.
- **OR2 – Innovative EO techniques for long-term analysis of Climate Change-related effects**
  - **Task 2.3**: to obtain a quantitative relationship of the impact of changes in rainfall regimes on the activity of slow moving deep-seated landslides using historical series of DInSAR measurements of deformation velocity of the landslides and characterization of rainfall regimes by ground measures and remotely sensed estimations.
- **OR3 - Advanced EO methods for studying short-term climatic impacts**
  - **Task 3.3**: extreme hydro-geological events (landslides);
  - **Task 3.4**: fire quantitative characterization, in particular development of multi-source algorithms (SAR and optical data) to study fire fronts, to map burnt areas and to produce qualitative indicators of fire effects on a different vegetation.
- **OR5 - Assessment and validation of products and applications on specific test cases**
  - **Task 5.2**: hydro-geological applications.
- **OR6 - Solutions and strategies for product/service exploitation**
  - **Task 6.1** identification of industrially exploitable products/services.

Examples of products/platforms

Modeling of a Slow Landslide through the Exploitation of DInSAR Measurements and in Situ Surveys

P-band radar system: in the front part there is the sounder antenna (160MHz), sideways the SAR antenna (450-900MHz).

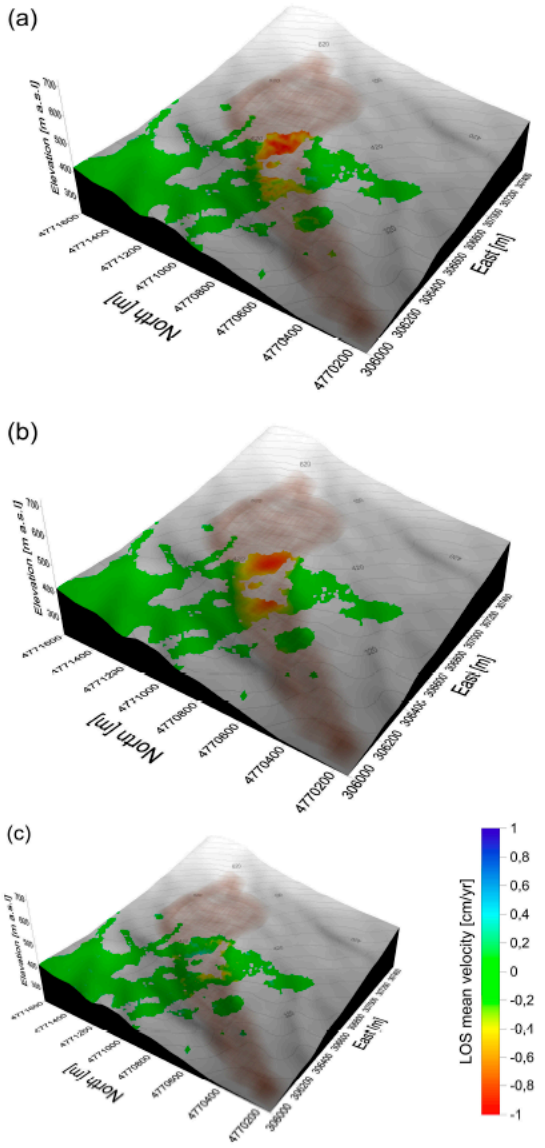


Figure 5. Geodetic inversion results: (a) Data; (b) Model and (c) Residuals relevant to the DInSAR velocity map superimposed on the filled contour DEM. The shading area indicates the unstable slope mass.

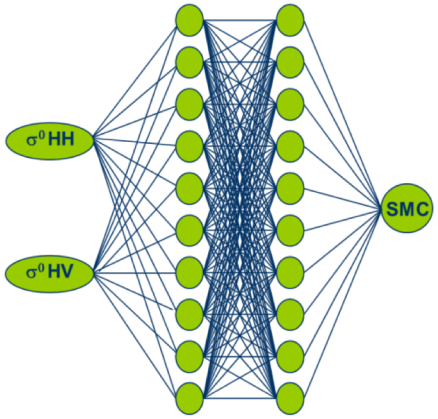
- **OR2 – Innovative EO techniques for long-term analysis of Climate Change-related effects**
  - **Task 2.5**: development of algorithms to estimate soil moisture content (SMC) and development of drought indexes.

- **OR3 - Advanced EO methods for studying short-term climatic impacts**
  - **Task 3.2**: extreme hydrological events (floods);
  - **Task 3.3**: extreme hydro-geological events (landslides).

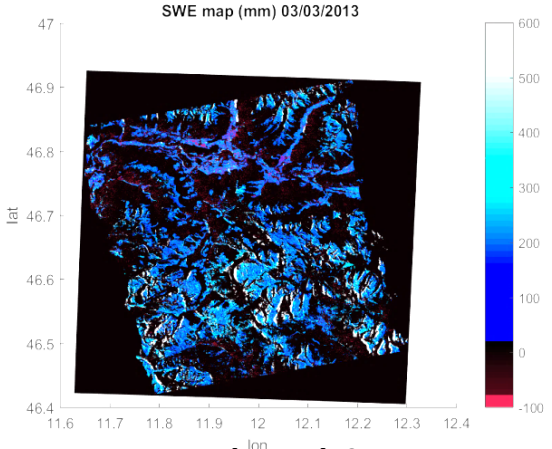
  In particular development of techniques based on the integration of satellite sensor data in optical, thermal and microwave bands and of analysis methods of displacement time series from satellite InSAR data.

- **OR5 - Assessment and validation of products and applications on specific test cases**
  - **Task 5.2**: hydro-geological applications, i.e. validation by analysis of historical dataset of InSAR satellite data, acquired on test sites characterized by unstable slopes and recent landslides;
  - **Task 5.4**: innovative vegetation indices, i.e. integration analysis of Optical/Microwave images;
  - **Task 5.5**: validation of innovative methods of integration and fusion of data/products from optical/microwave sensors for estimating parameters of surface (Essential Climate Variables).

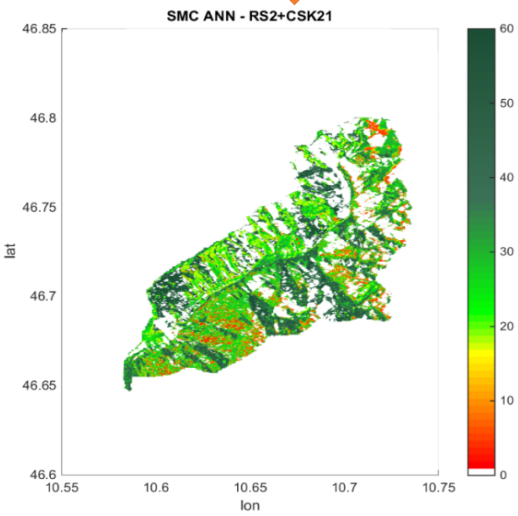
Examples of products/platforms



Advanced algorithms for retrieval

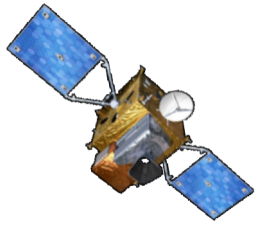


Snow maps(SWE) from SAR (Cosmo-SkyMed)



Moisture maps of the ground from SAR (Sentinel-1)

New Perspettive in Pansharpening: Hypersharpening

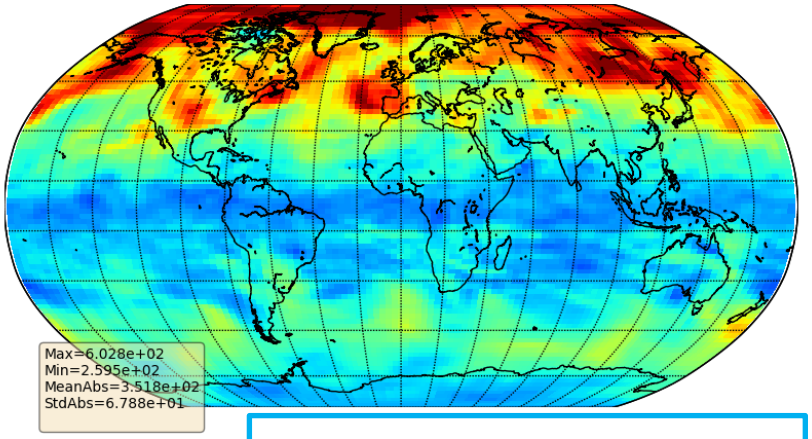


Sentinel-4

Sentinel-5

Fused_LEO_LEO_v03_2012-04-30_00:00_TOTCOLS.png

Ozone Total Column from fused UV + TIR data



Complete Data Fusion

- **OR2 – Innovative EO techniques for long-term analysis of Climate Change-related effects**
  - **Task 2.1**: innovative techniques based on spatio-temporal regression to estimate Land Surface Temperature and Emissivity Maps.

- **OR3 - Advanced EO methods for studying short-term climatic impacts**
  - **Task 3.1**: advanced techniques to elaborate
    1. interferometric SAR data (InSAR) to estimate high spatial resolution time series of Precipitable Water Vapor (PWV) maps;
    2. SAR data and Global Navigation Satellite System (GNSS) observations to retrieve the spatial distribution of atmospheric refractivity.

Examples of products/platforms

Assimilation of InSAR PWV maps in NWMs

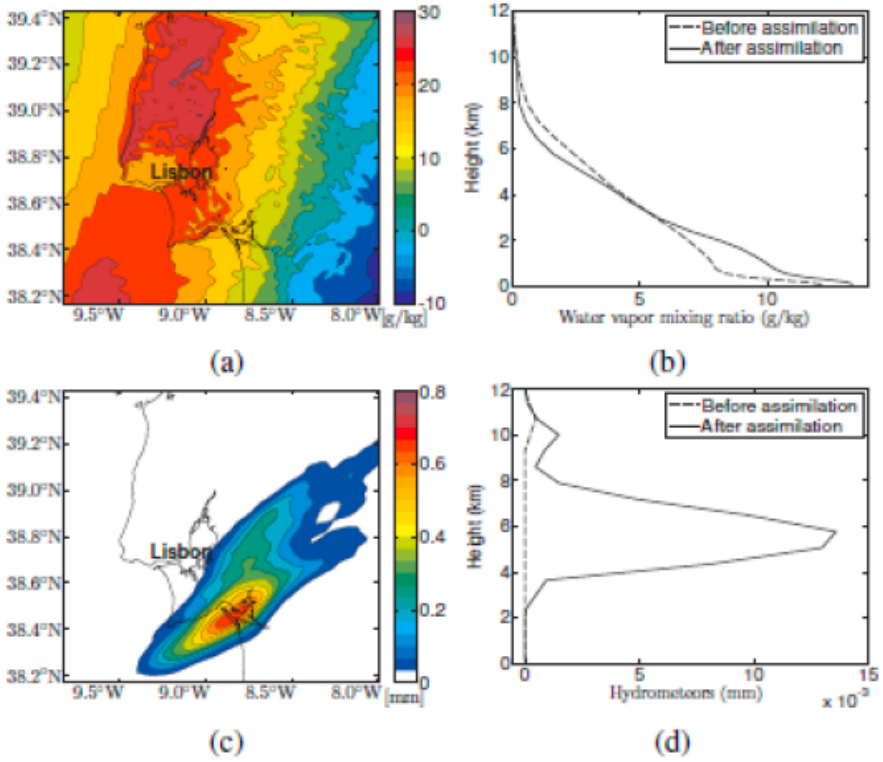


Fig. 2: (a) spatial distribution of the cumulative difference in the water vapor mixing ratio (QVAPOR) in g/kg (positive values report a increase to the analysis field); (b) QVAPOR vertical profile before and after data assimilation; (c) cumulative difference of hydrometers in mm; and (d) hydrometers vertical profile before and after data assimilation.

(2D) OI scheme for TS and emissivity from sparse satellite observations