IQmulus - Land Scenario

Multi-resolution modelling for land monitoring
Analysis of precipitation data

CNR-IMATI & Regione Liguria

The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 318787.

Consiglio Nazionale delle Ricerche

REGIONE LIGURIA

LAND SHOWCASE

As hydrologist or geo-morphologist supporting decision makers in civil protection, I want to analyse data measured during critical events to prepare better predictions and monitoring of floods and landslides

MOTIVATIONS

- October 2011, La Spezia, Cinque Terre
  - Rain**: 530 mm in 6 hours**
  - Floods of 3 rivers, landslides
  - Damage: 12 deaths; 1bilion Euro
- November 2011, Genova
  - Rain: **500 mm in 5 hours**
  - Floods of 4 rivers; landslides
  - Damage: 6 deaths; 100Milion Euros
- October 2014, Genova
  - Rain: **395 mm in few hours**
  - Floods of 5 rivers: Landslides.
  - Damage: 1 death; 250 Milion Euro
- November 2014, Chiavari, Genova,..
  - Rain: **270 mm in few hours**
  - Floods of 2 rivers; Landslides.
  - Damage: 2 death; 200 Milion Euro

LAND SHOWCASE – LS1 / LS2

BIG DATA

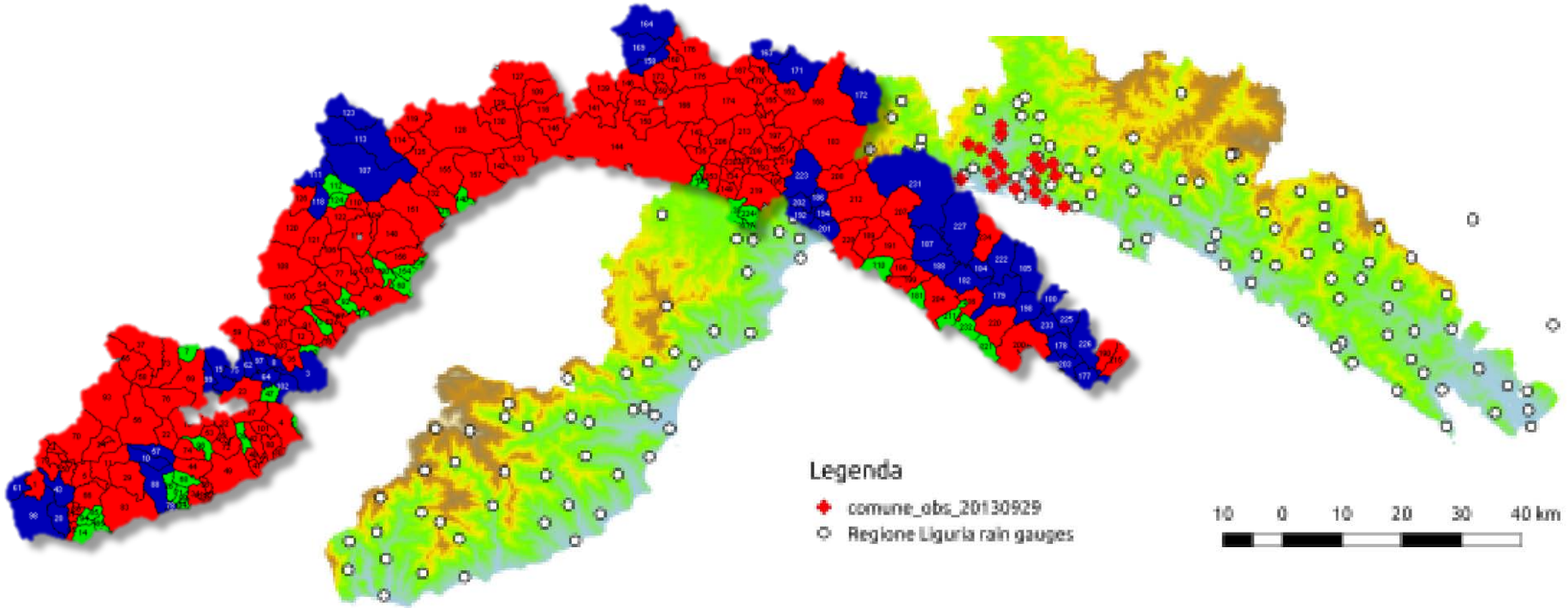
Volume: high Variety: high Velocity: medium Analytics: high

- **LS1**: hydrology-oriented multi-scale terrain model
- **LS2**: precipitation analysis

- semantics-driven indexing/storage of big data collections
- multi-scale modelling of terrain data driven by regions of interest
- "real-time" analysis of heterogeneous observation of rain
- cloud-ready implementations of services

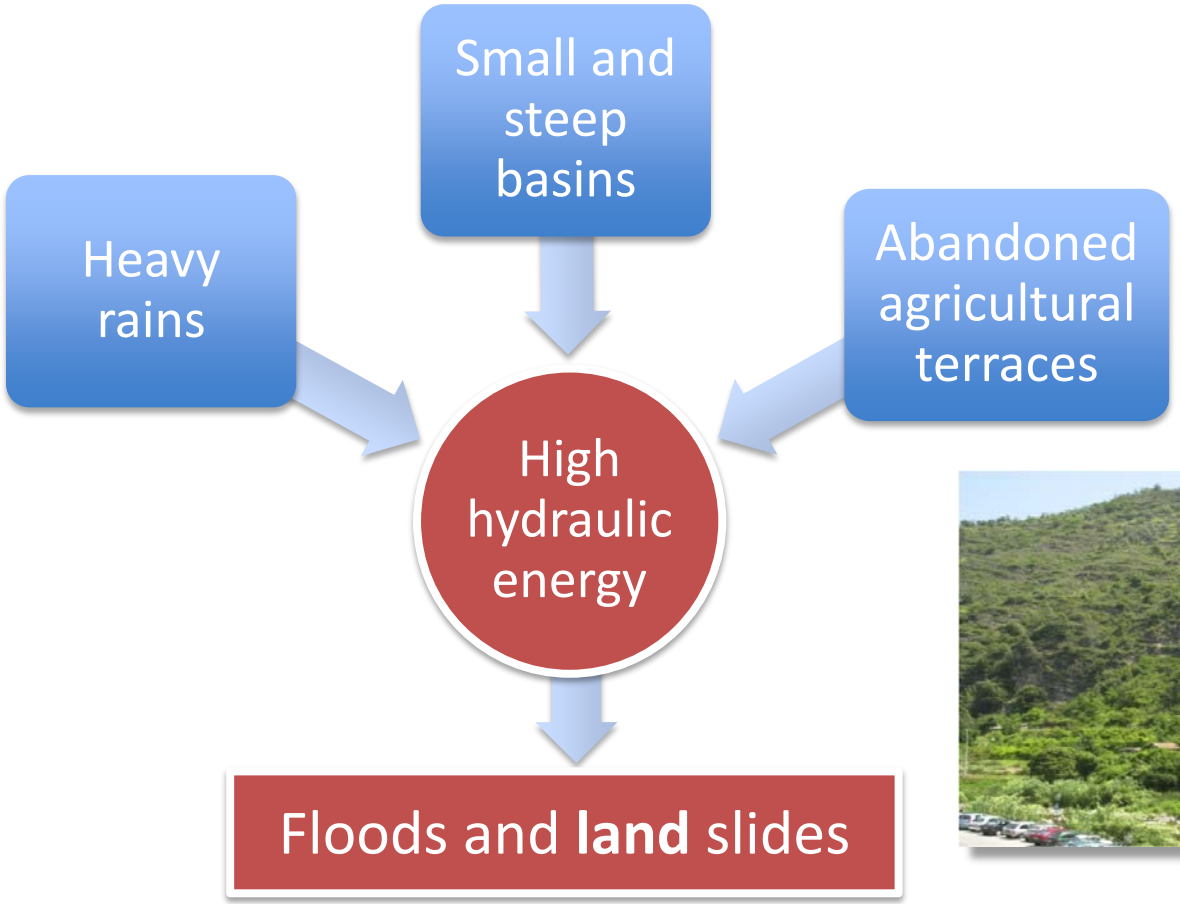
MOTIVATIONS

- Study of rainfalls over a **complex area**
  - Regione Liguria (north-west of Italy) is a mountain region with many **small catchments** characterized by fast floodings
  - **orography** and closeness to the sea contribute to generate complex hydro-meteorological events.



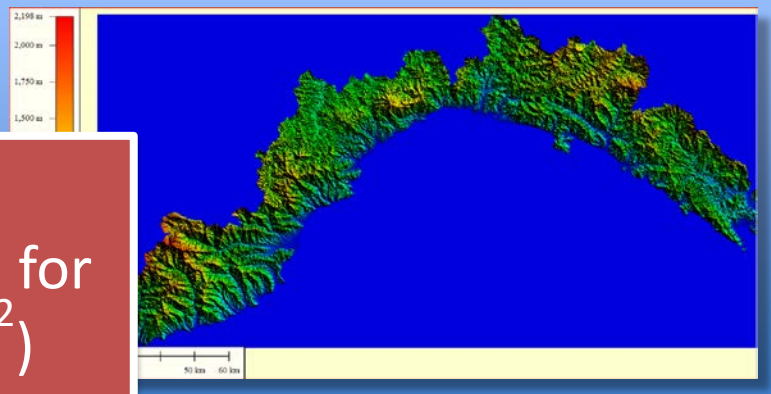
MOTIVATIONS

- Statistics show that floods are always due to very heavy storms but at a very **local scale**.



AVAILABLE GEOSPATIAL DATA

- **DTM** obtained by interpolation of CTR-DBTopo 3D features
  - Resolution: 5 m.
  - Coverage: 100 % of Regione Liguria



The resolution available is not sufficient to run hydraulic models for very small basins (area of 10km^2)

- **Airborne LIDAR data** on almost all Regione Liguria
  - Resolution: ~30 cm.
  - Coverage 65% of Regione Liguria

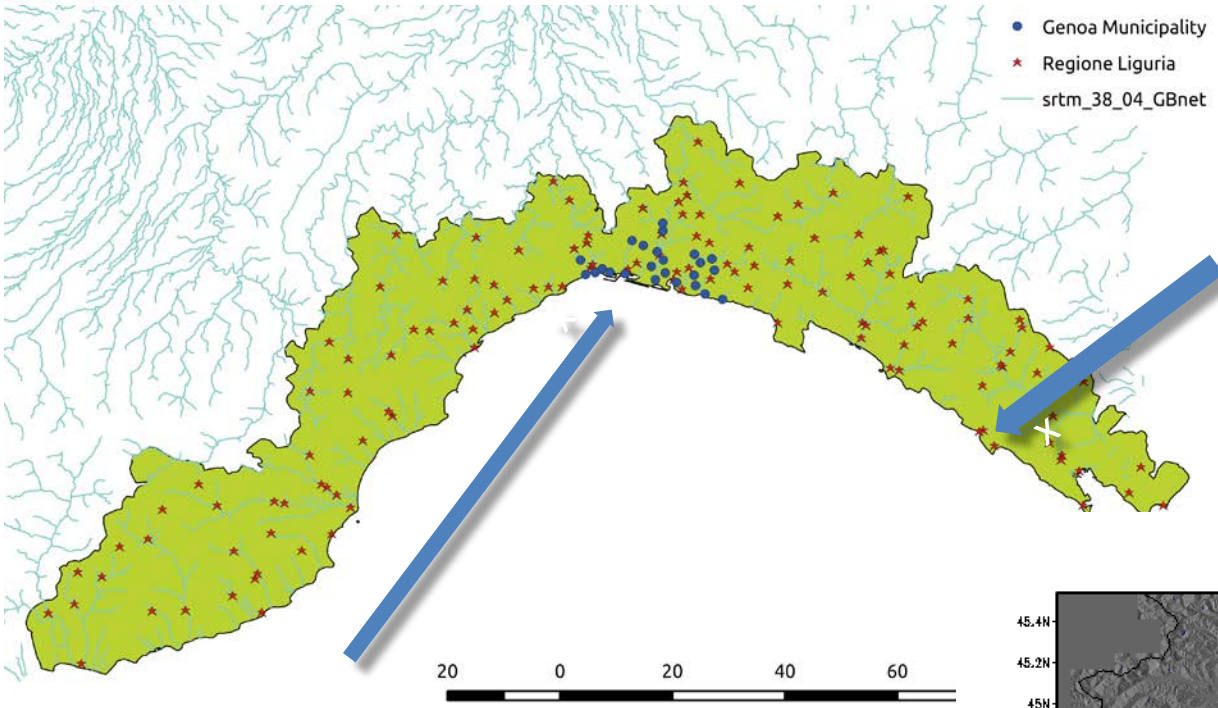
LIDAR data are divided into very small tiles, and it is very difficult to manage them together

AVAILABLE RAIN DATA

- Rainfall data are gathered from **two rain gauge networks**, with different time and spatial resolutions
  - **Regione Liguria**: whole region, with 143 rainfall stations and data gathered every 3 minutes
  - **Genova municipality**: within the city boundary, with 25 rainfall stations and data gathered every 5, 10, 30 minutes.
- Additional data are provided by **meteo-radar scans**.

- Rainfall values have a **different spatial/temporal correlation**
  - during **light rains** over the whole region: rainfalls are more correlated to each others (up to 25 km)
  - during **thunderstorms**: the rainfall correlation is lower (up to 10 km), due to their locality.

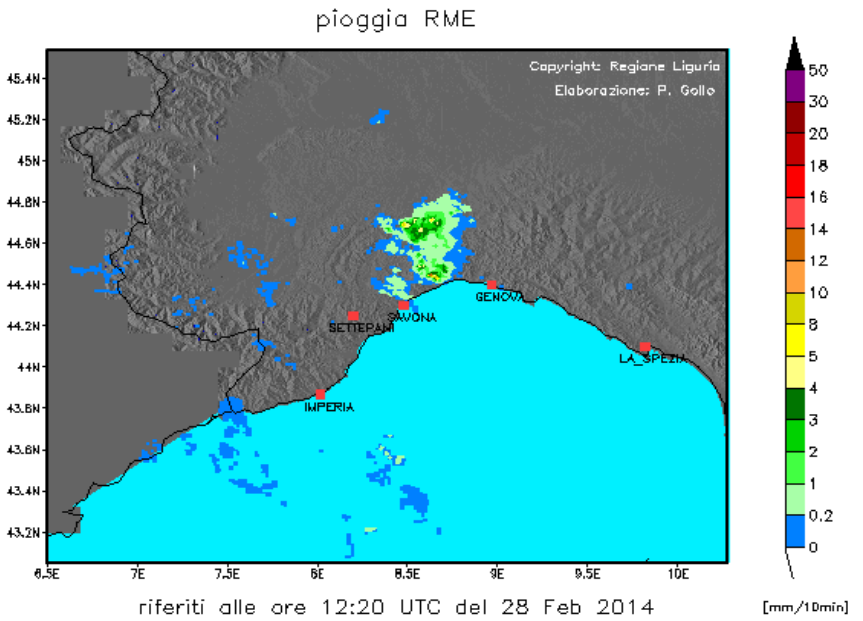
AVAILABLE RAIN DATA



Professional and certified Regione Liguria/ARPAL rain observed, data every 5/10 minutes

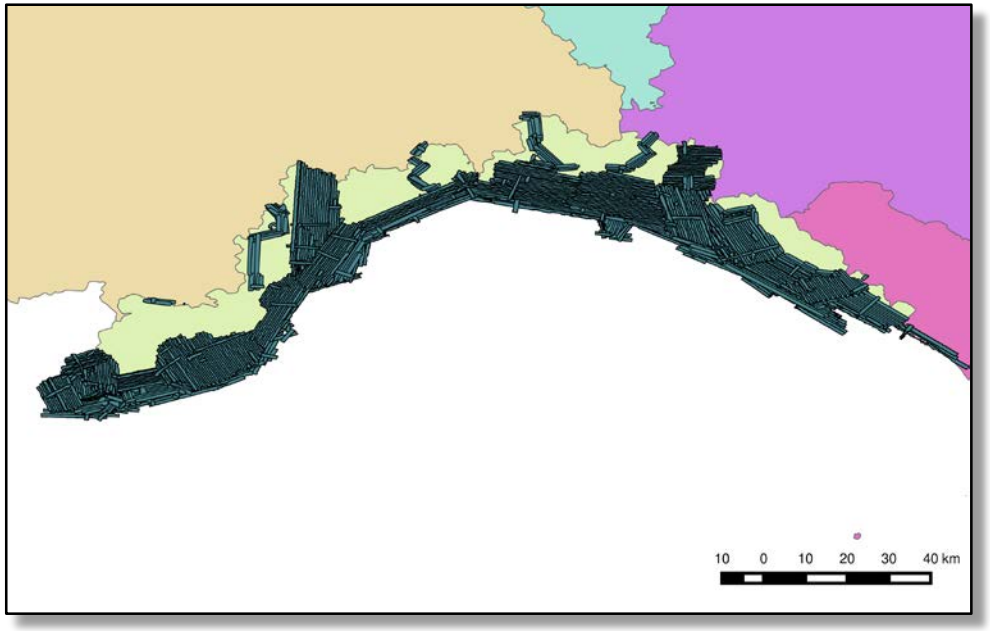
Genova municipality rain observed, data gathered every 3 minutes

Meteo-radar scans every 10 minutes



LAND SHOWCASE – LS1

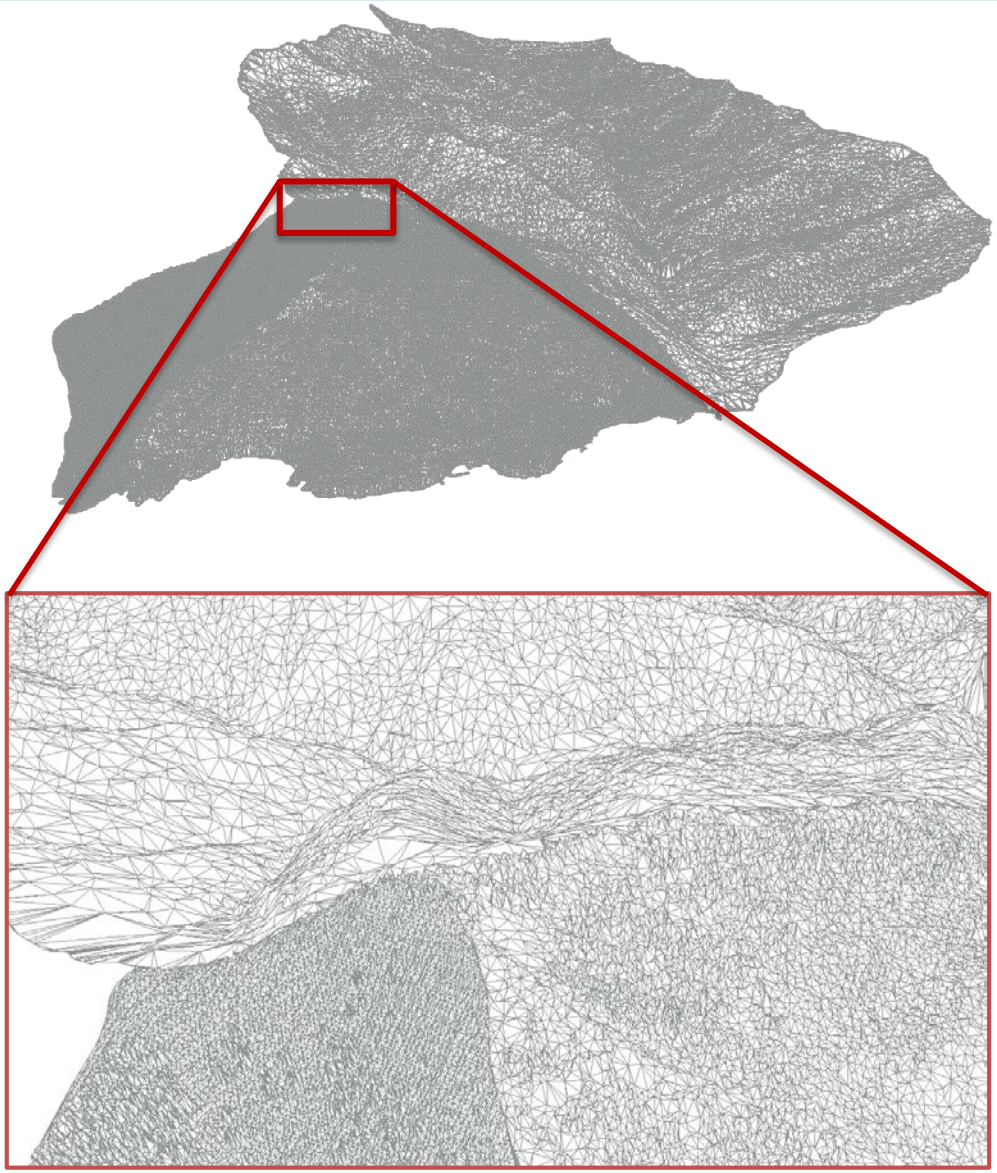
- **Aim:** make big and high density LIDAR data sets accessible for analysis and visualization.
- **Main issue**: big data
  - ~1000 LAS files, partially overlapping, as obtained in consecutive flights
  - ~20 billion points: high-res LIDAR acquisitions but partial coverage.



- **Idea**
  - organize data in geographically contiguous regions, according to their membership to water basins
  - represent regions at different levels of detail
  - merge regions in a single, seamless triangulation.

LAND SHOWCASE – LS1

- **Sori area**
  - Basin 82 at LOD1
  - Basins 77-81 al LOD5
  - Basin 76 at LOD10



- **Goal: approximation/analysis of rainfall data through**
  - the definition of a rainfall map at small catchments
  - the integration of rainfall measures with data acquired by remote sensors (radar, satellite)
  - the visualization of the temporal evolution of precipitation fields and the track of its maxima.

- **Idea: computation of a continuous approximation**
  - from time-varying, sparse, and heterogeneous rainfall data from rain gauge networks
  - at different scales (urban/regional areas), time steps, and spatial distribution of the rainfall stations.

STEP 1 & 2 – RAINFALL INTERPOLATION

- **Cumulative rainfall:** rainfall data with a **different time resolution are synchronized** through the computation of the cumulative rainfall over a specific time interval (3 – 5 – 10 minutes) with a service developed in Hadoop-MapReduce.

- **Continuous approximation** of time-varying, sparse, and heterogeneous rainfall data from rain gauge networks
  - at different scales (urban/regional areas)
  - at different time steps
  - with a different spatial distribution of the rainfall stations.

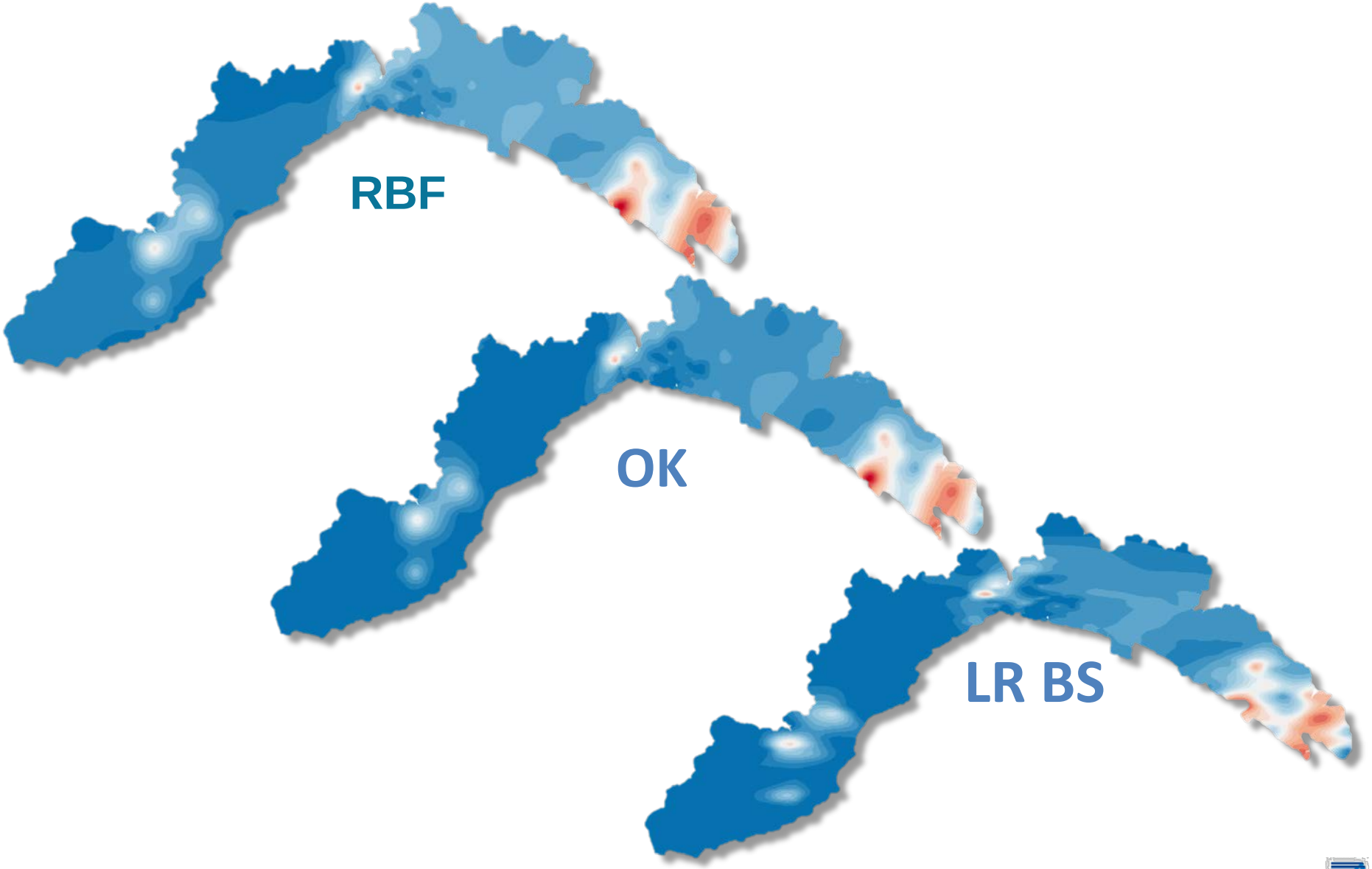
- This approximation allows us to
  - define a rainfall map at small catchments
  - integrate rainfall measures with data acquired by remote sensors (eg., radar, satellite)
  - visualize the temporal evolution of precipitation fields.

STEP 2 – RAINFALL INTERPOLATION

- To achieve a **good approximation accuracy**, we consider
  - meshless approximations: radial basis functions & ordinary kriging (CNR-IMATI)
  - polynomial approximation: LR B-Splines (SINTEF).

- The **three approximating functions**
  - are defined as a linear combination of a set of (different) basis functions, which are built from the input points (connectivity, spatial distribution)
  - are computed by applying a low number of interpolating constraints (#rainfall stations) and solving a linear system
  - are evaluated on a high number of samples (#points of the 3D terrain model) and provides the precipitation field at any point (eg., on a DTM).

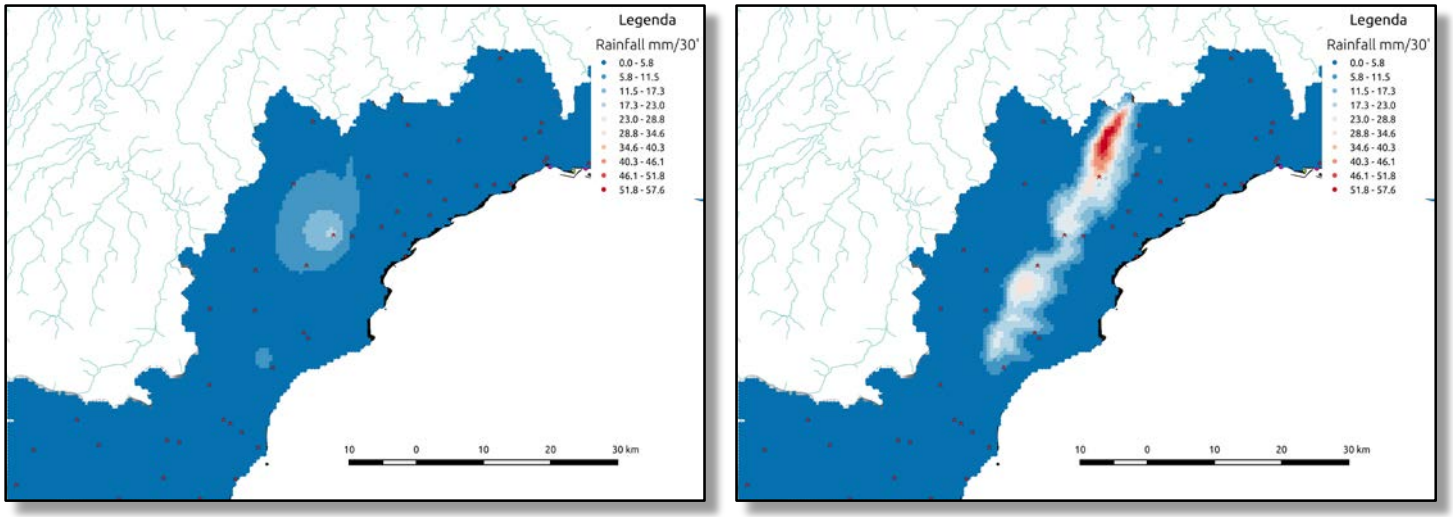
STEP 2 – RAINFALL INTERPOLATION



STEP 2 – RAINFALL INTERPOLATION

- **Limitations:** rainfall stations
  - provide a sparse information on the rainfall evolution
  - might be temporary unavailable.

- **Idea:** integration of rain gauges with radar data to
  - estimate the rainfall field at a finer resolution
  - have a smaller temporal sampling.

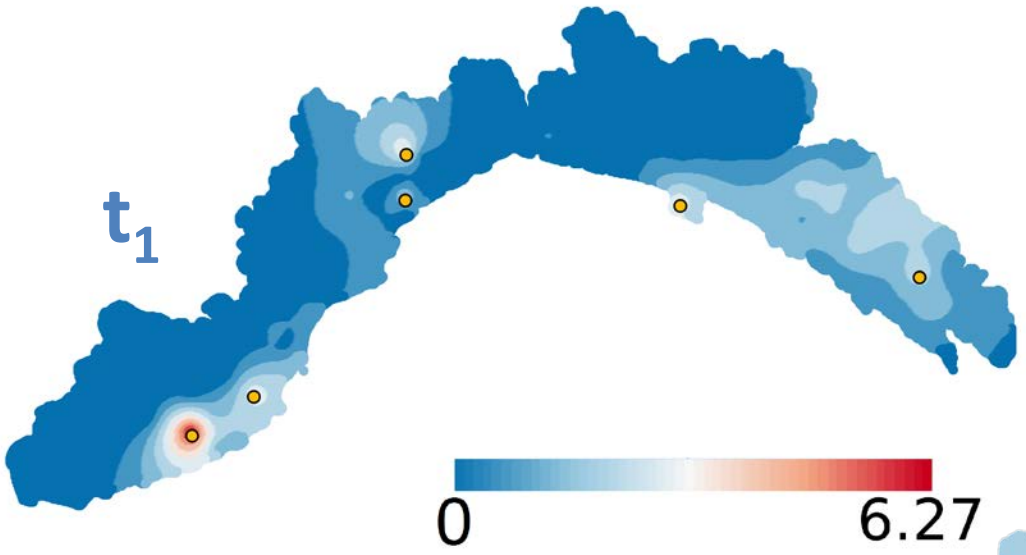


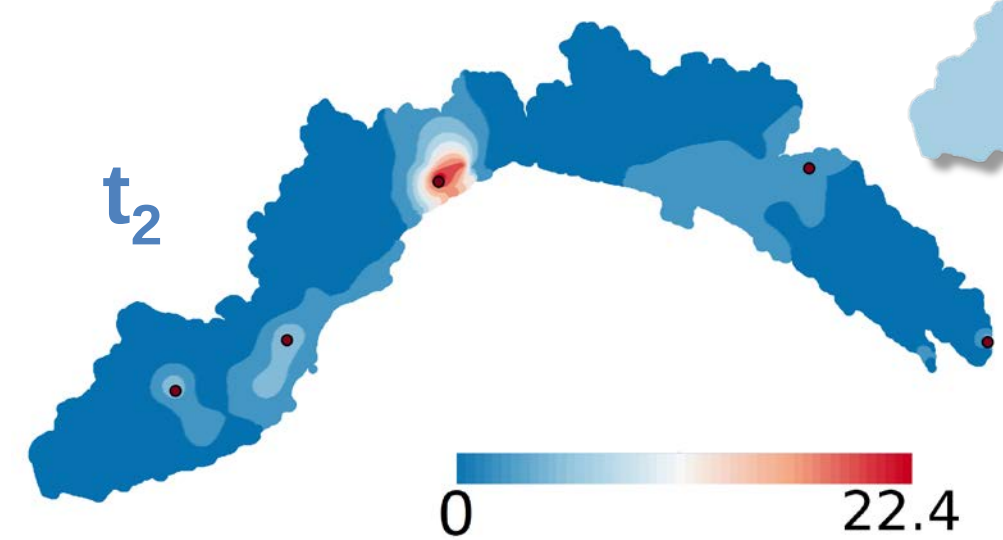
STEPS 3&4 - TRACKING RAINFALL MAXIMA

- **Analysis of the approximated rainfall fields** by
  - computing and hierarchically organizing rainfall maxima, according to their relevance (*persistence*)
  - removing irrelevant details, which are not important to understand the main characteristics of the underlying event
  - tracking the temporal evolution of maxima.

- **Applications:** real-time monitoring, historical data analysis, hydro-geological studies.

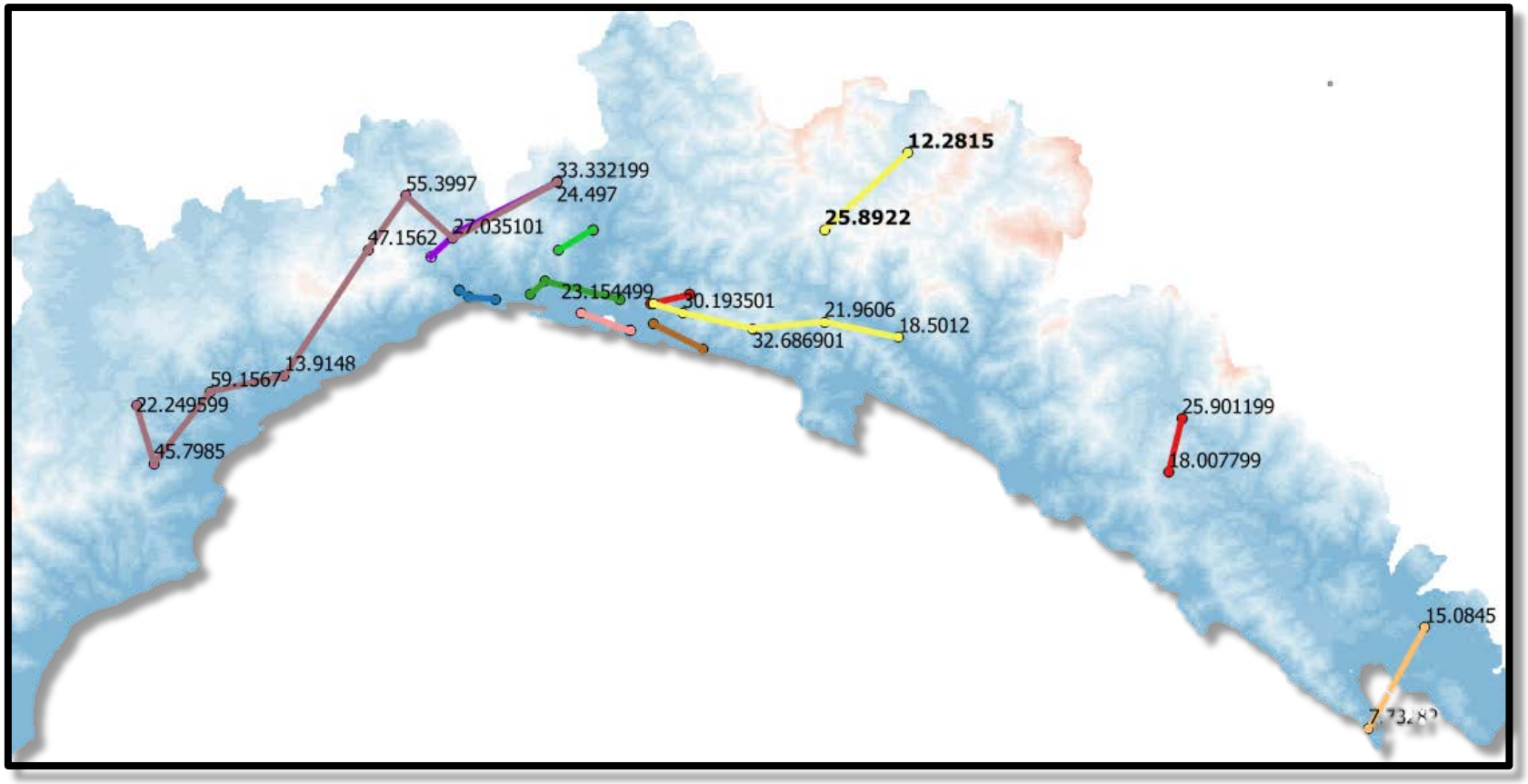
STEPS 3&4 - TRACKING RAINFALL MAXIMA





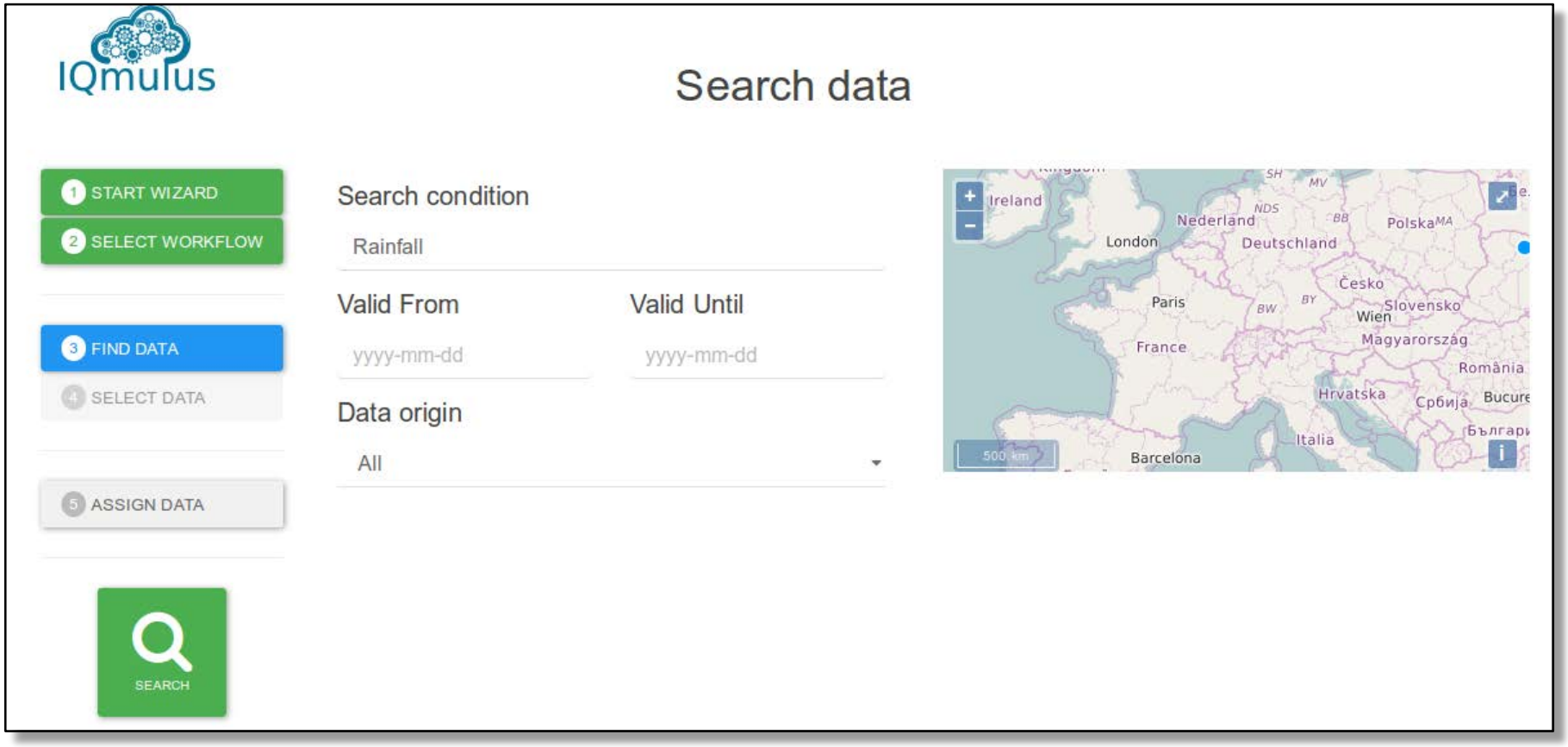
Matching of local maxima

STEPS 3&4 - TRACKING RAINFALL MAXIMA

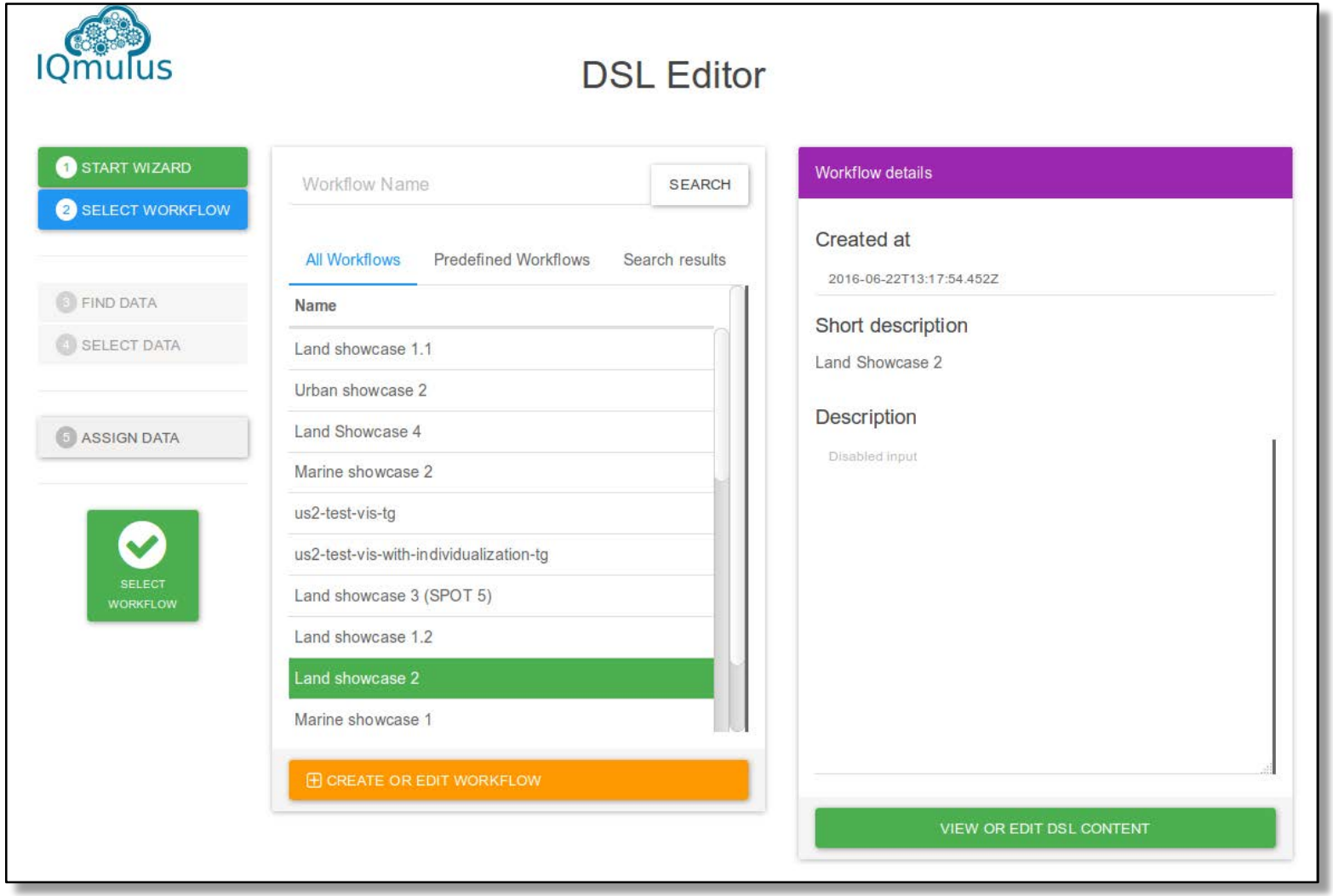


G. Patanè, A. Cerri, V. Skytt, S. Pittaluga, S. Biasotti, D. Sobrero, T. Dokken, M. Spagnuolo. *A Comparison of Methods for the Approximation and Analysis of Rainfall Fields in Environmental Applications.* ISPRS Journal of Photogrammetry. To appear, 2016.

LS1 / L2 – INTERFACE



LS2 – INTERFACE



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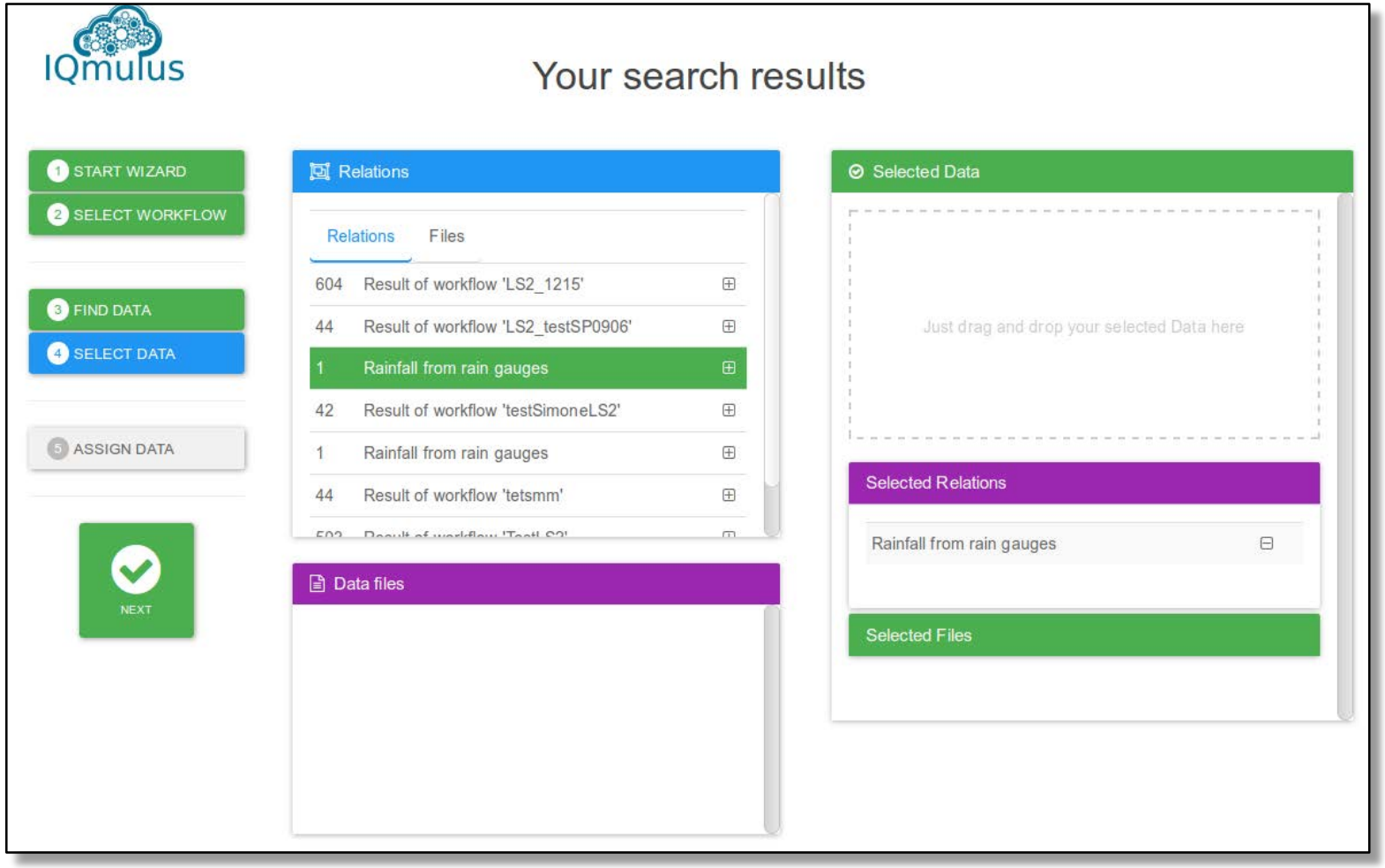

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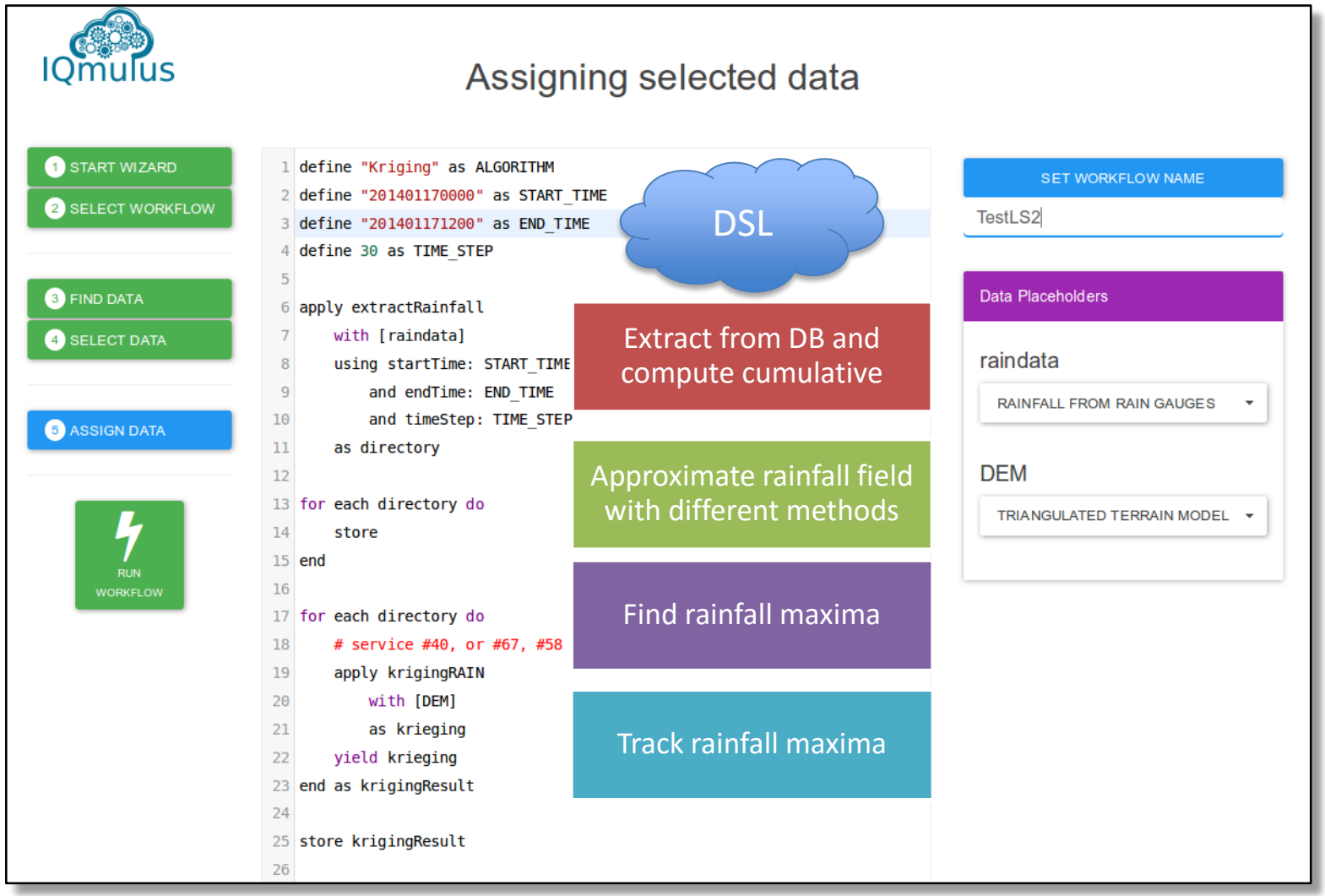
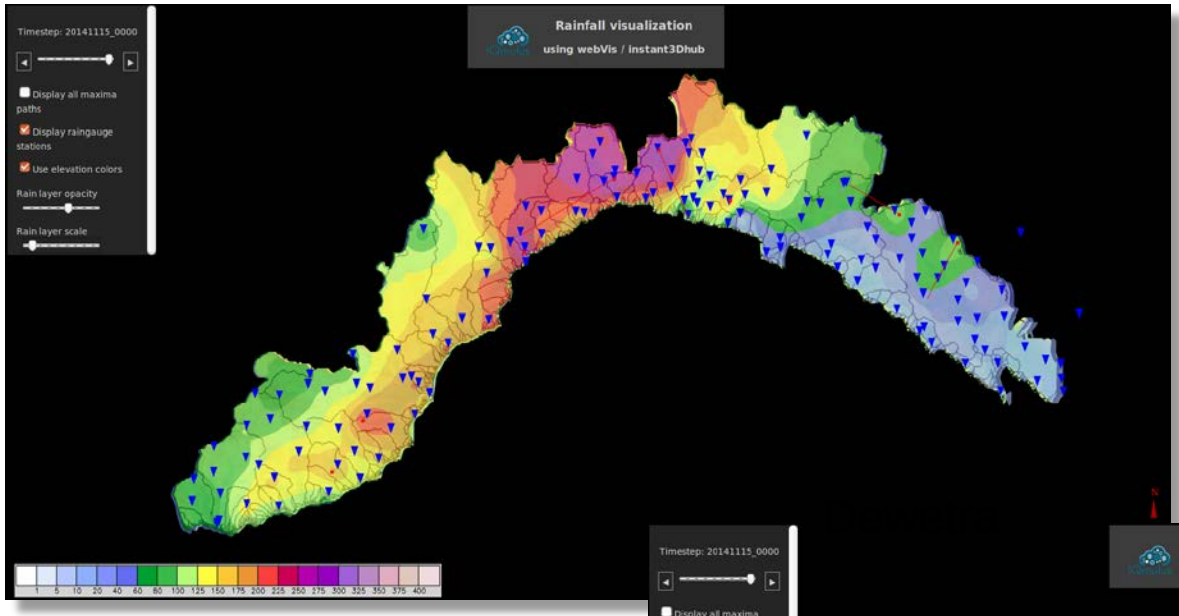
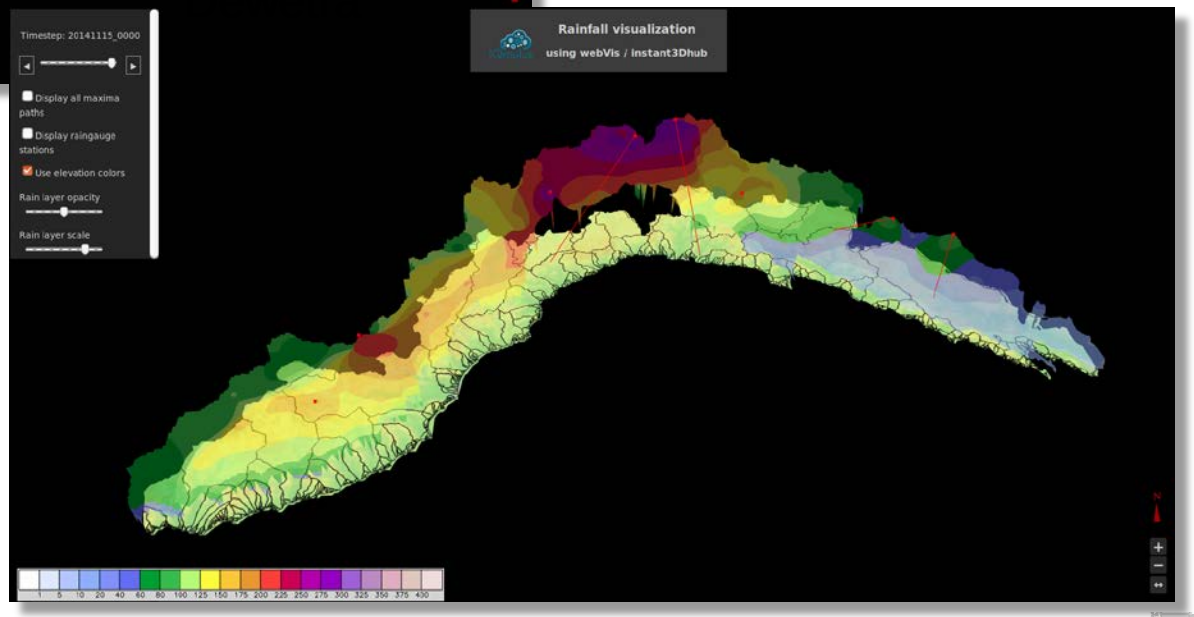


LS2 – INTERFACE & VISUALIZATION

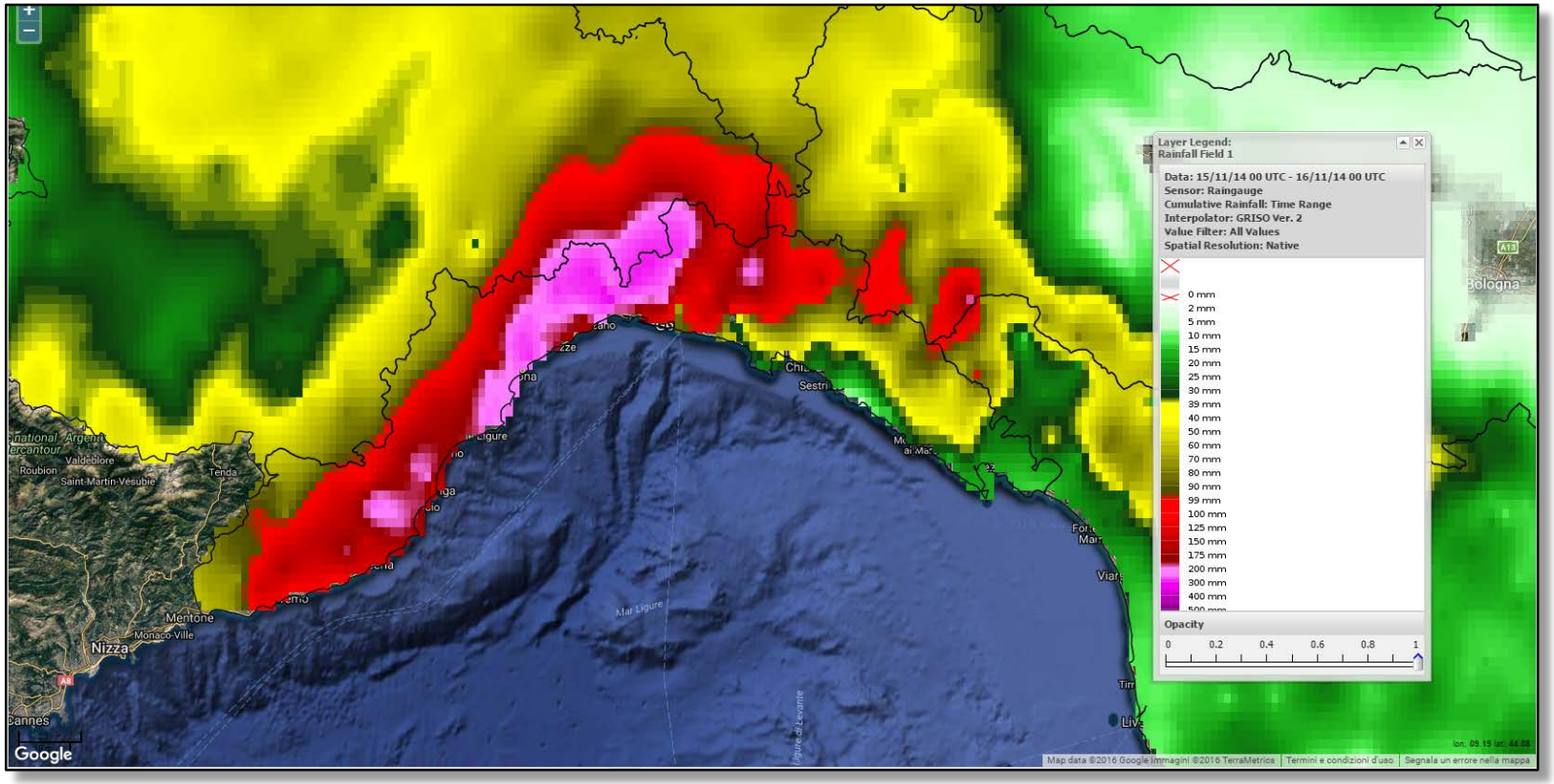




IQmulus integrated visualization

Fraunhofer IGD

Comparison between the results obtained by the **Dewetra** tool from Civil Protection and the IQmulus LS2.



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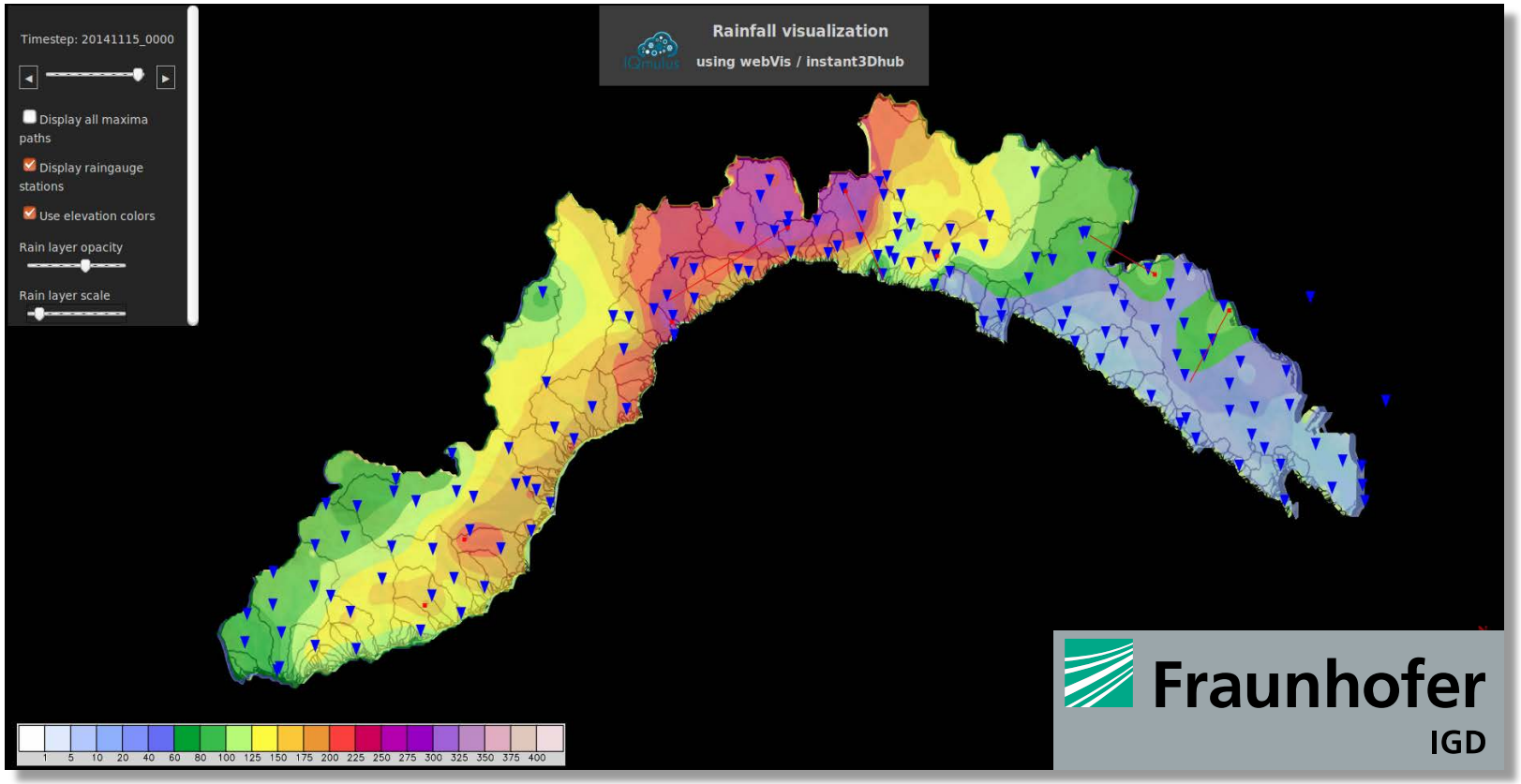

CONCLUSIONS AND OUTLOOK

- **Summary**
  - **LS1**: an indexing tool that makes big LIDAR data sets ready to be used in hydrographic and cartographic pro settings
  - **LS2**: improvements over the state of the art in forecasting and nowcasting of potentially dangerous rain events
- **Contribution & Novelty**
  - Algorithms are the same as for the old desktop solution, but implemented on a uniform platform, quicker and more efficient
  - Approximation & analysis techniques developed in Computer Graphics have been specialized to GIS applications
- **Future work**: combination of
  - terrain morphology
  - satellite data
  - meteorological situations/models

SEVENTH FRAMEWORK PROGRAMME

IQmulus

SEVENTH FRAMEWORK PROGRAMME