An automatic system for flood mapping based on Sentinel-1 data

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Introduction

- An automatic system for water detection (AUTOWADE) based on S1 data was designed to provide the Italian Dept. of Civil Protection (DCP) with NRT information on the status of permanent water and floodwater
- SAR is the most useful EO instrument for flood mapping
  - ability to distinguish between land and water
  - all-weather & day-and-night images with high spatial resolution
- State of the art algorithms for automatically mapping the extent of a flood using SAR now mature for operational implementation
- Present availability of *6-days repeat Sentinel-1 (S1)* SAR data represents a big opportunity to design a tool that systematically produces water maps at a *resolution of 20 m*

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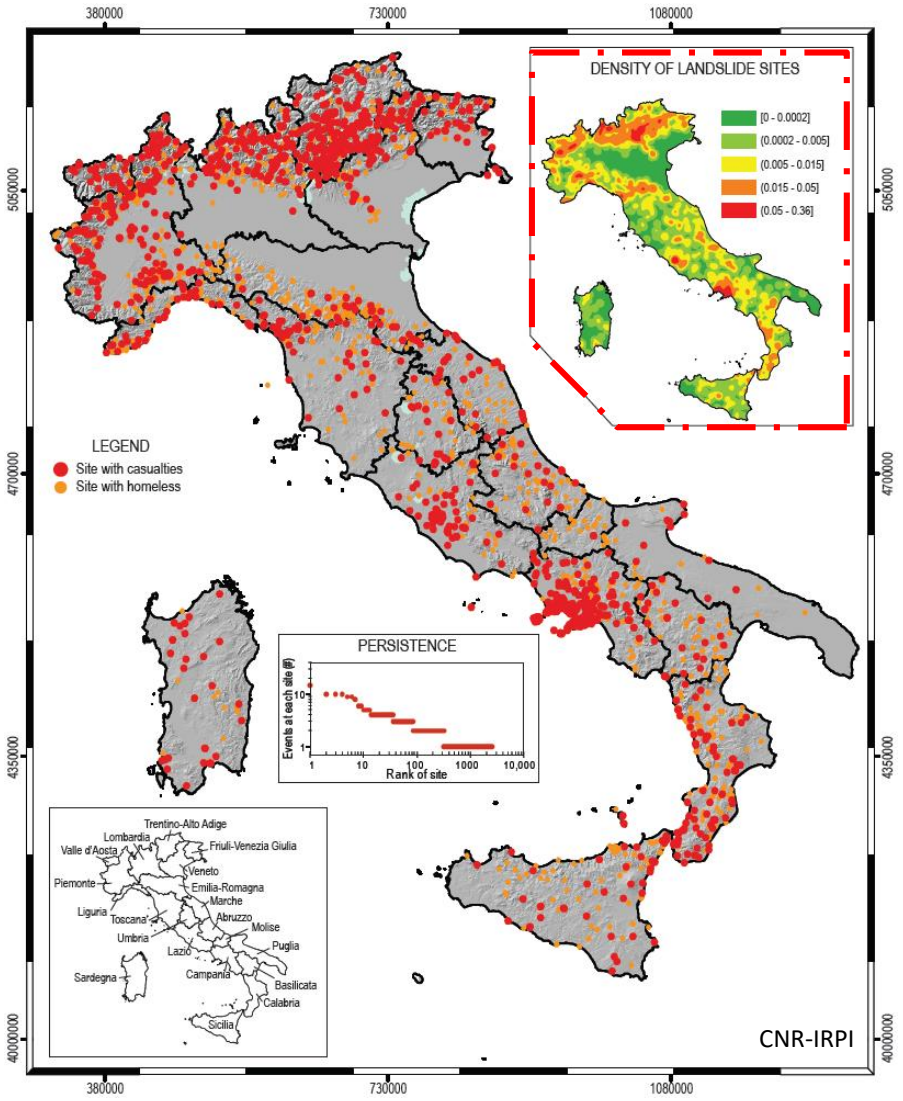
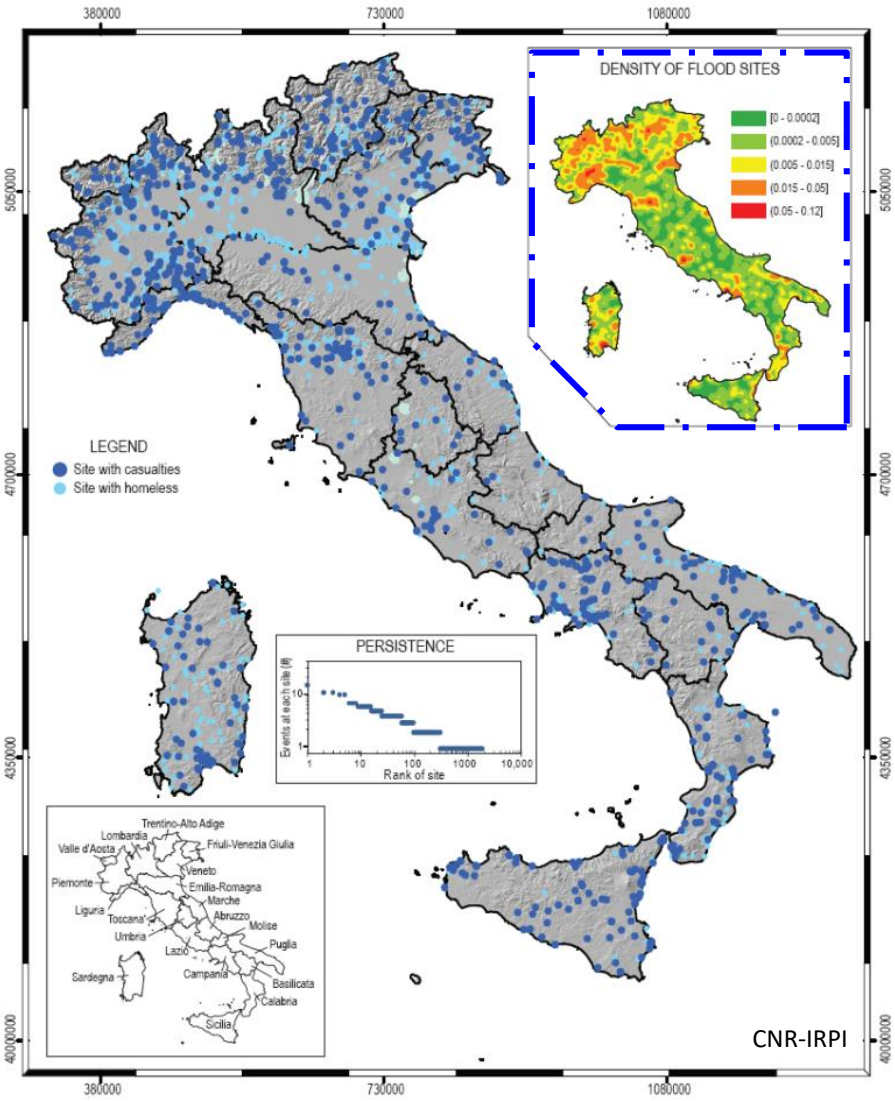
Hydraulic and hydrogeological risk in Italy



Location of 2533 sites affected by landslide events with direct consequences to the population. Period 650-2008



Location of 1836 sites affected by floods events with direct consequences to the population. Period 590-2008

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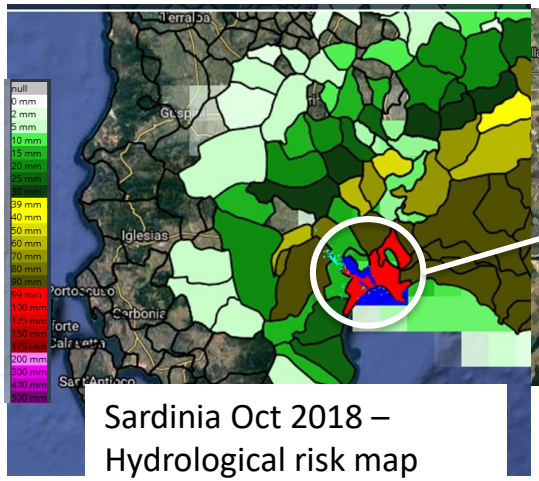
Motivation

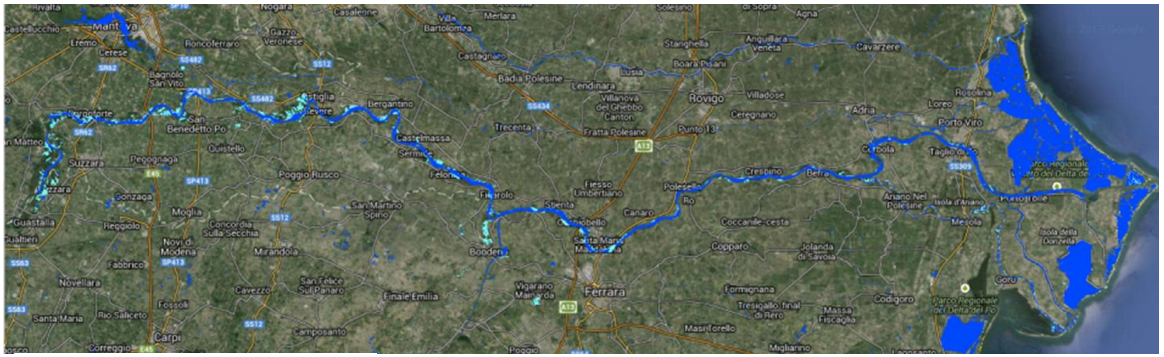
- NRT data about the extent of **floodwater** useful to:
  - ✓ Provide information on the situation in areas where hydrological alerts are issued
  - ✓ Manage fast-moving events
  - ✓ Identify high priority areas



Sardinia Oct 2018 – Hydrological risk map

Flood map (cyan floodwater, blue permanent water)

- NRT data about the extent of **permanent water bodies** useful to:
  - ✓ Monitor water resources in areas affected by droughts
  - ✓ Monitor swollen rivers →



Po River – Nov. 2014

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Fully automatic system: pros & cons

- Pros
  - Water mapping processor complemented by download of SAR data and delivery of the result to the end-user
    - no user input needed for SAR data collecting & pre-processing
  - No need of an explicit activation from authorities
  - Objectivity and traceability of the water mapping process
    - Result does not depend on the subjective interpretation of the operator
- Cons
  - Supervision from skilled operators may produce a more accurate result

Sentinel-1 orbits over Italy

- Sentinel-1 (A & B) images of a given location available **every 6 days** (same configuration of measurement) with both morning and evening overpasses
- Ground Range Detected (**GRD**) products used by the proposed system

7 descending orbits – 30 image frames (6-days period)

6 ascending orbits – 34 image frames (6-days period)

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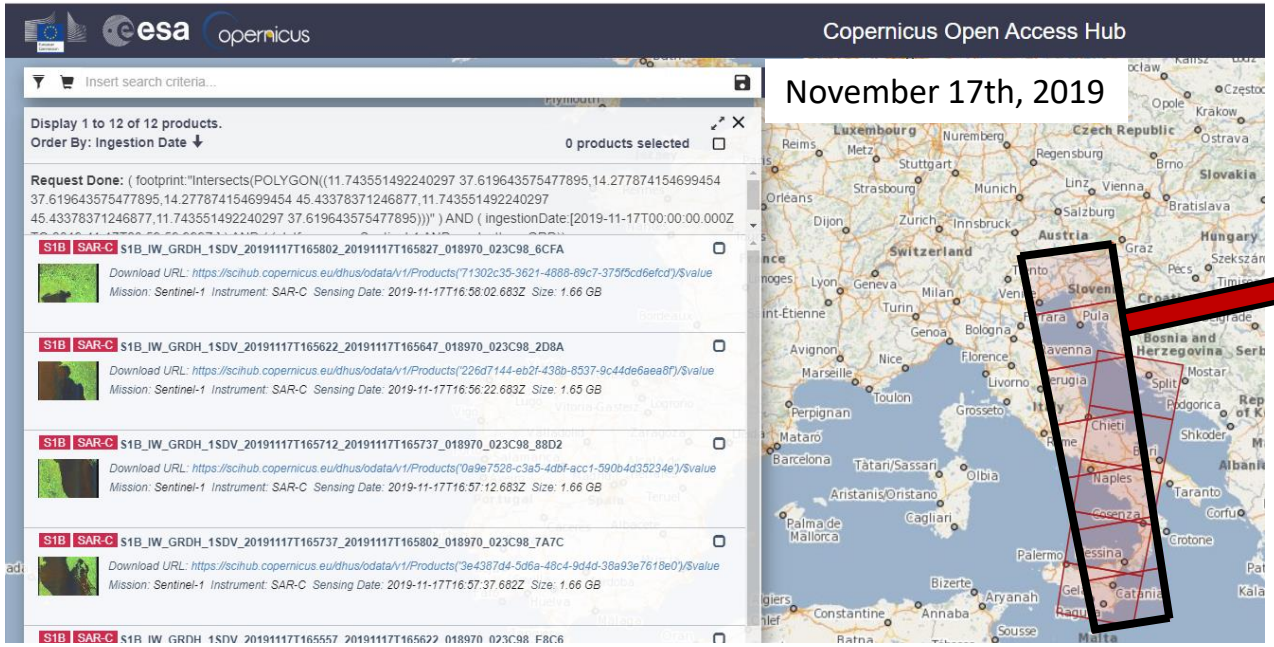
Automatic Sentinel-1 GRD data procurement chain

- Copernicus Open Access Hub automatically queried to verify the availability of new GRD products
- As soon as new products are available (by default after 4-8 h) they are downloaded and then calibrated and geocoded



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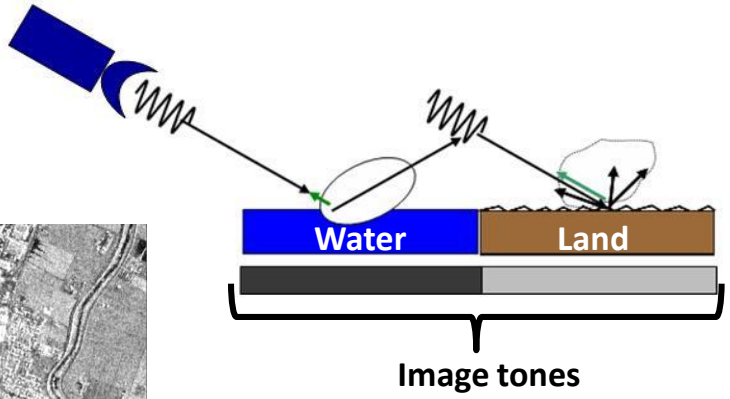
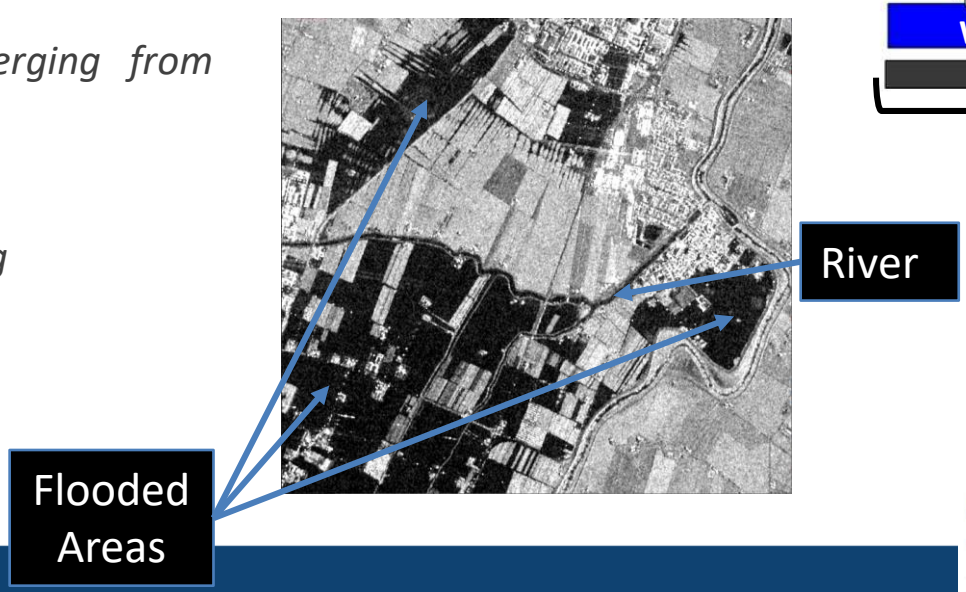
Water bodies detection using SAR

- Smooth water surfaces ***specularly reflect*** the radar signal
- A specular surface has a low radar return (lower than the return from the surrounding land surfaces)
- In a SAR image, water bodies (including flooded areas) generally appear ***darker*** than the surrounding areas.



- *Exceptions*
  - *Tall vegetation emerging from water*
  - *Urban areas*
  - *Strong winds blowing*



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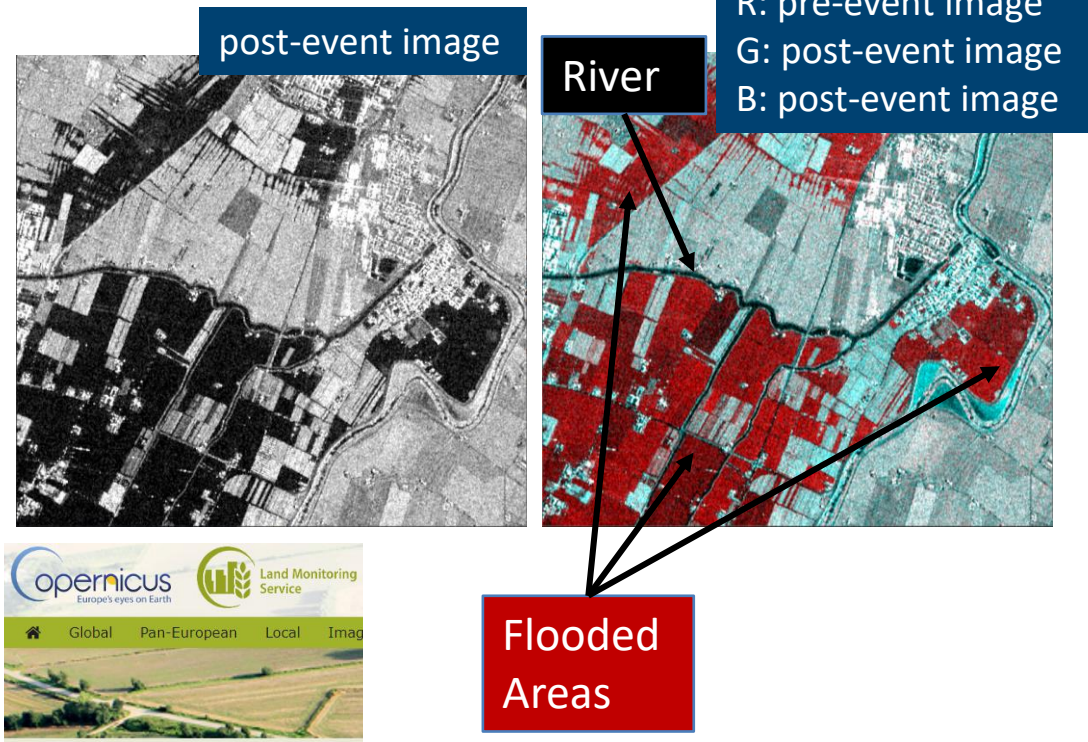
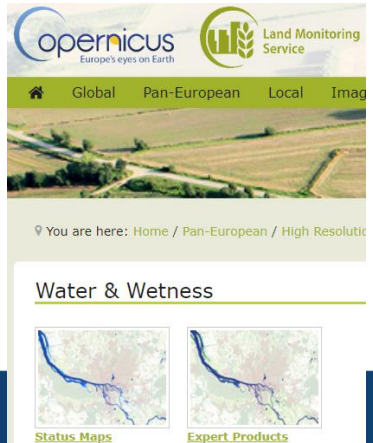
Discrimination btw permanent water and floodwater

- Change (*difference in logarithmic units*) btw pre- and post-event images

- Flood mapping automatic algorithms search for dark targets in SAR images and changes btw pre- and post-event images.

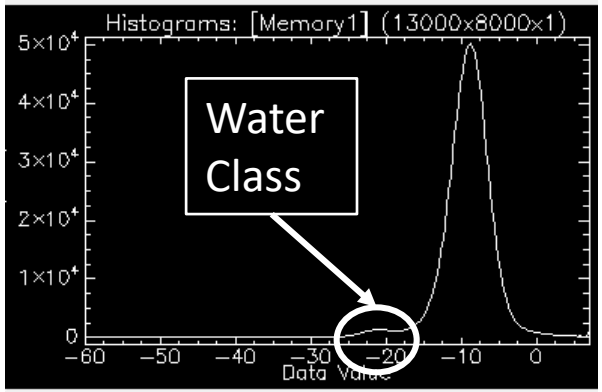
- Ancillary data such as the *Copernicus Water & Wetness product* can help the discrimination





Water detection method

- A *threshold value* distinguishing water from non-water class has to be found
- Automatic thresholding methods able to automatically find a proper threshold *if the histogram of the data is bimodal*
- This not always happens



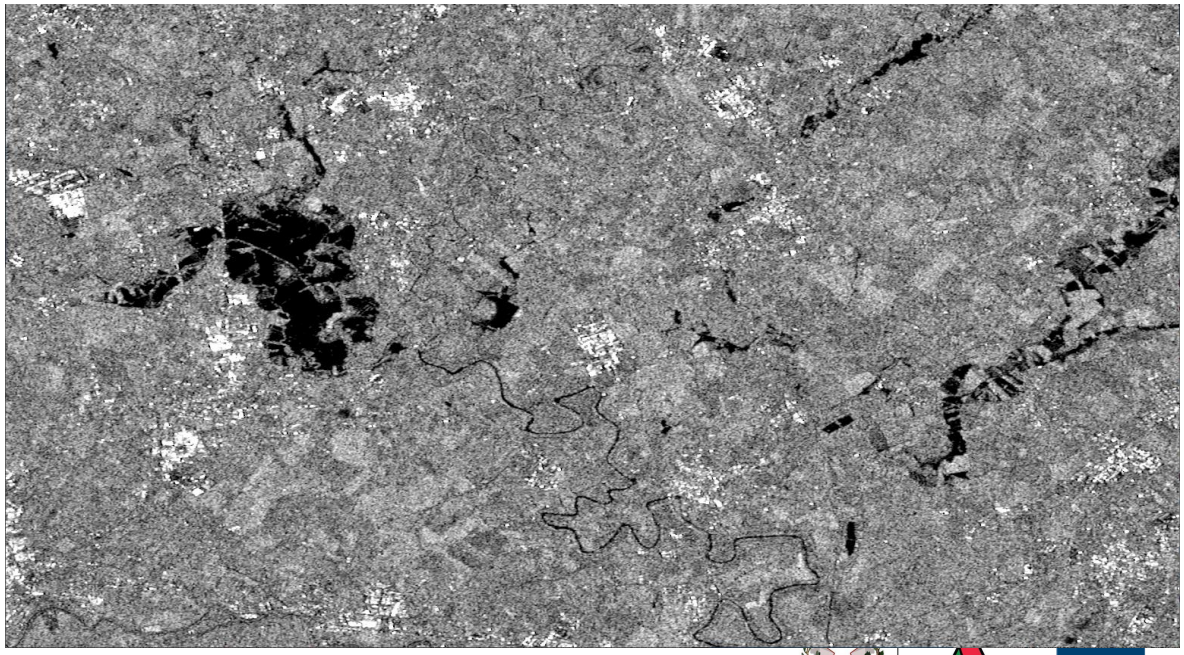
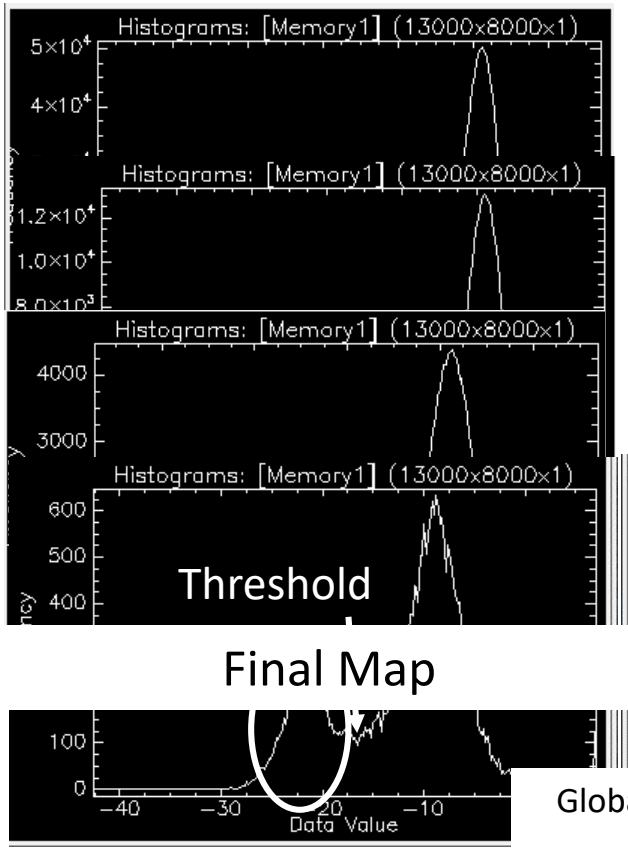
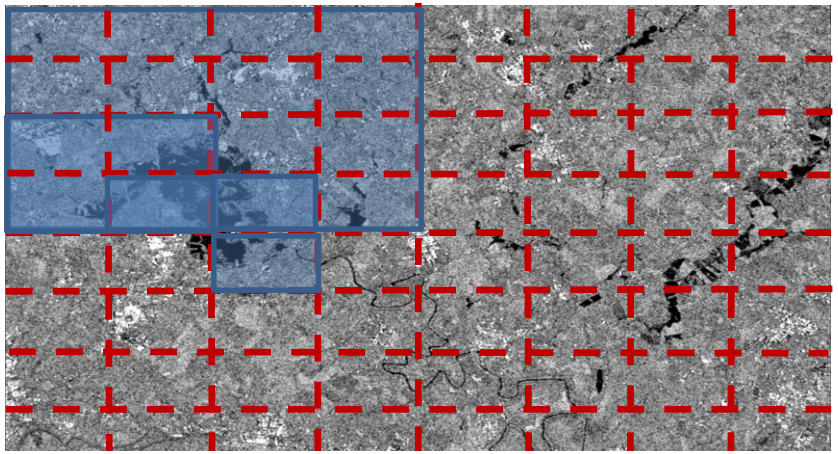
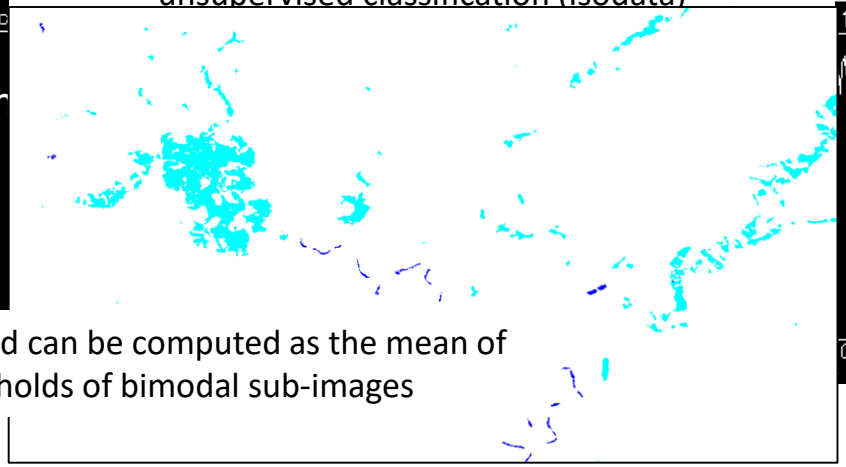


Image splittig

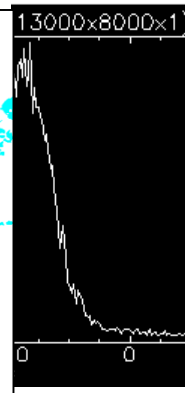




Automatic thresholding complemented by an unsupervised classification (Isodata)



Global Threshold can be computed as the mean of the thresholds of bimodal sub-images



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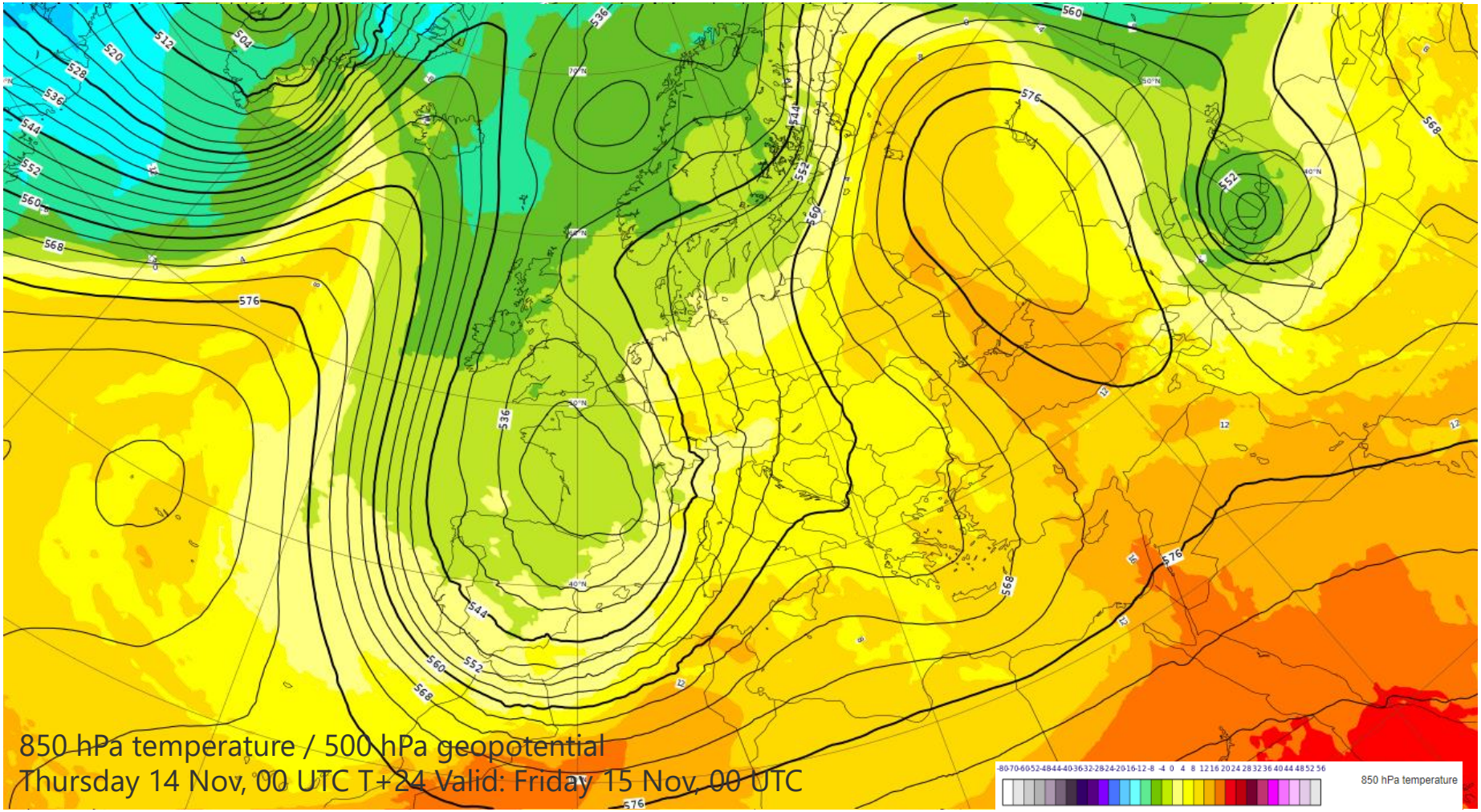
Synoptic situation: ECMWF - 14th of November 2019



Main low pressure from UK to Nord Africa with a blocking high pressure over eastern Europe (Russia)

Southerly very warm air masses in the western Mediterranean with significant precipitation

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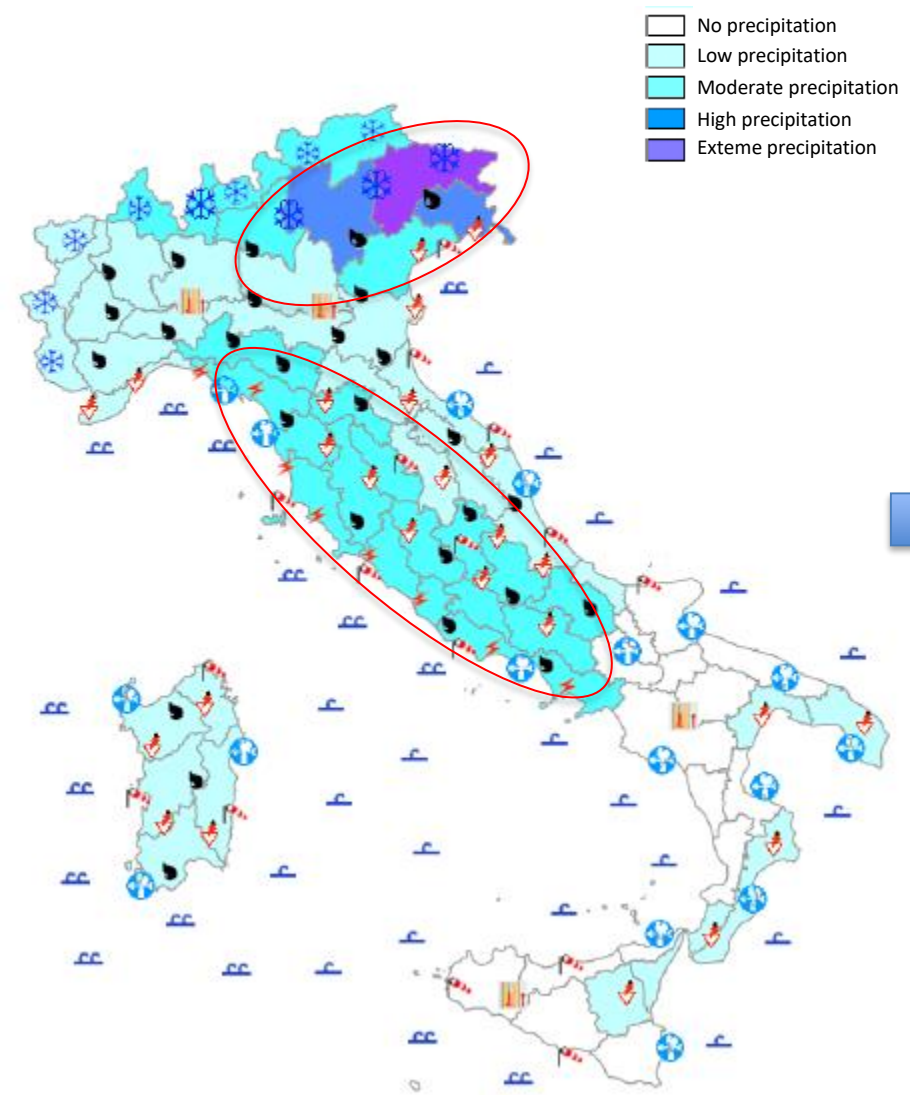
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

National Meteorological Surveillance Bulletin: Precipitation forecasted for 15/11/2019



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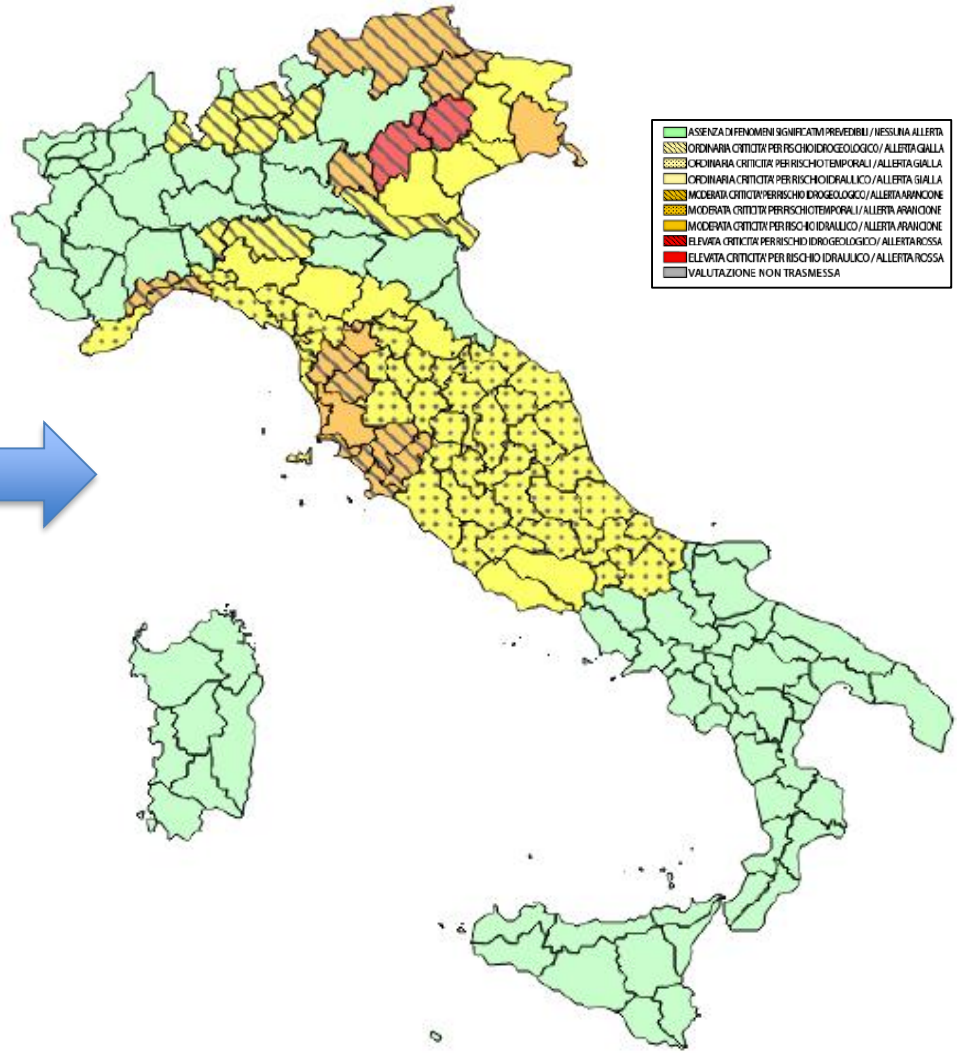
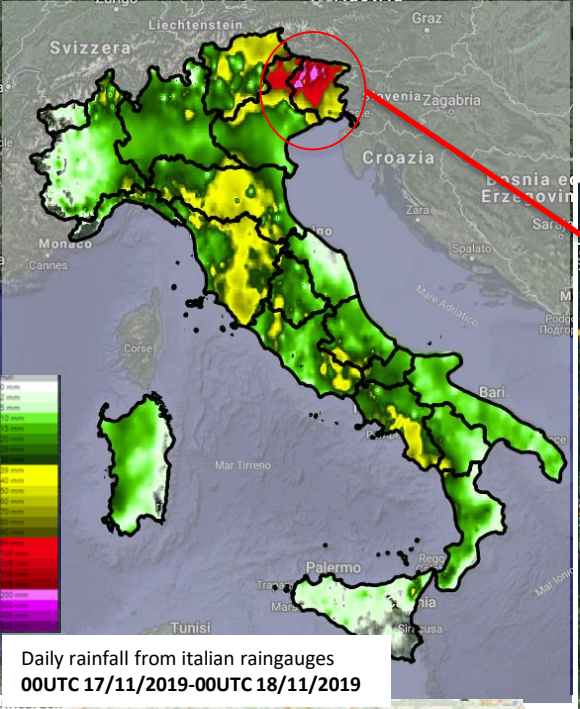
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

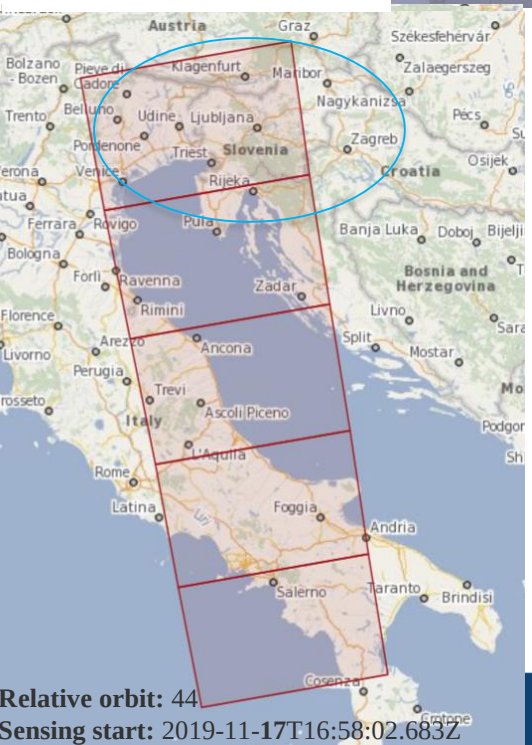
National Hydrogeological and Hydraulic Criticalities Bulletin: validity on 15/11/2019



17 Nov. 2019 - ROI - Friuli Venezia Giulia & Veneto



Daily rainfall from italian raingauges
00UTC 17/11/2019-00UTC 18/11/2019



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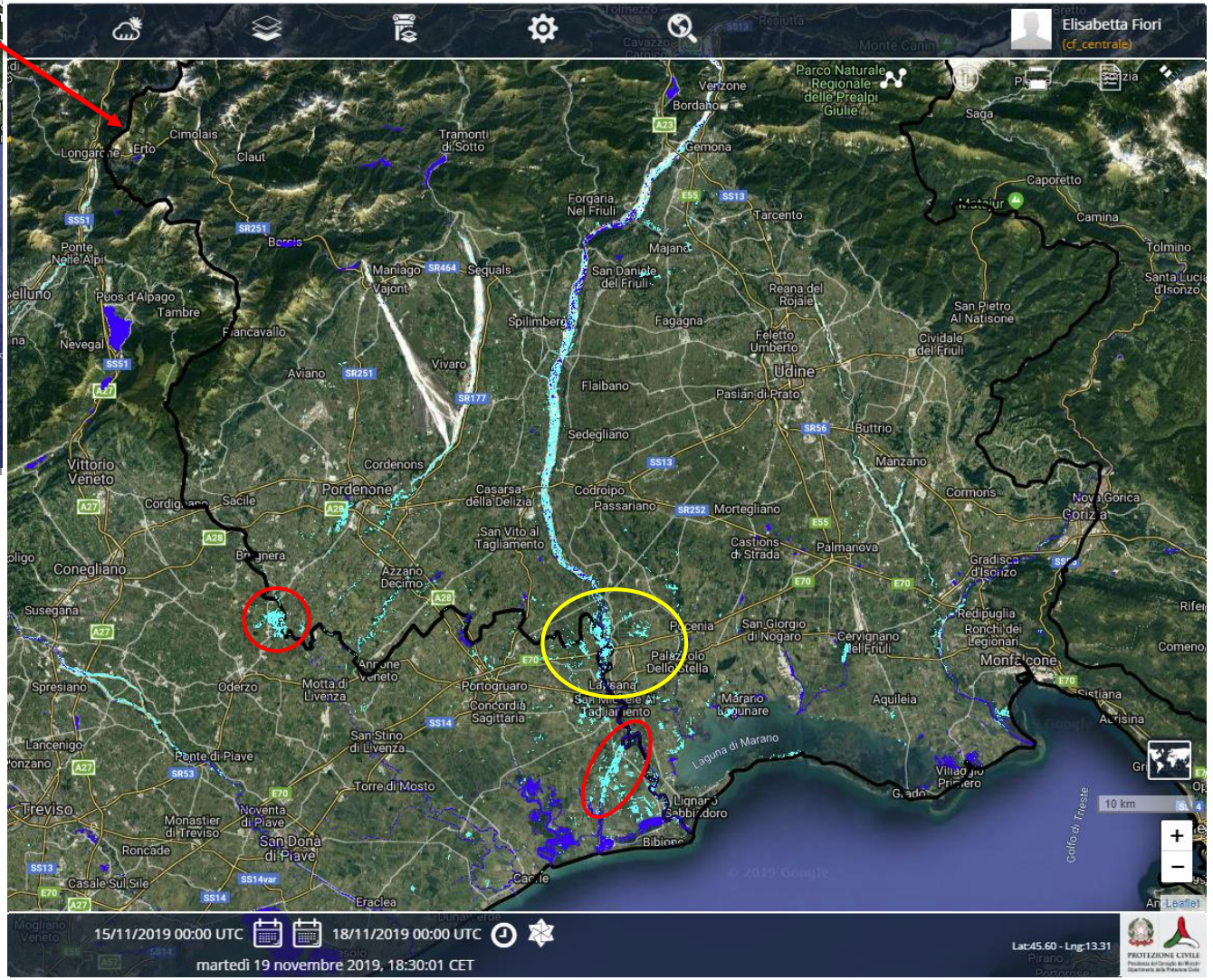

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Hydrometric observations
15 Nov 00UTC - 19 Nov 00UTC

high

moderate

ordinary

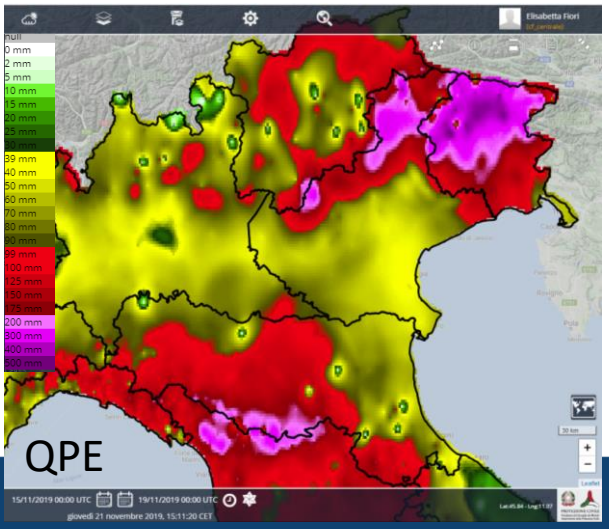
Hydrometric thresholds of 3 different critical levels according to the expected ground effects

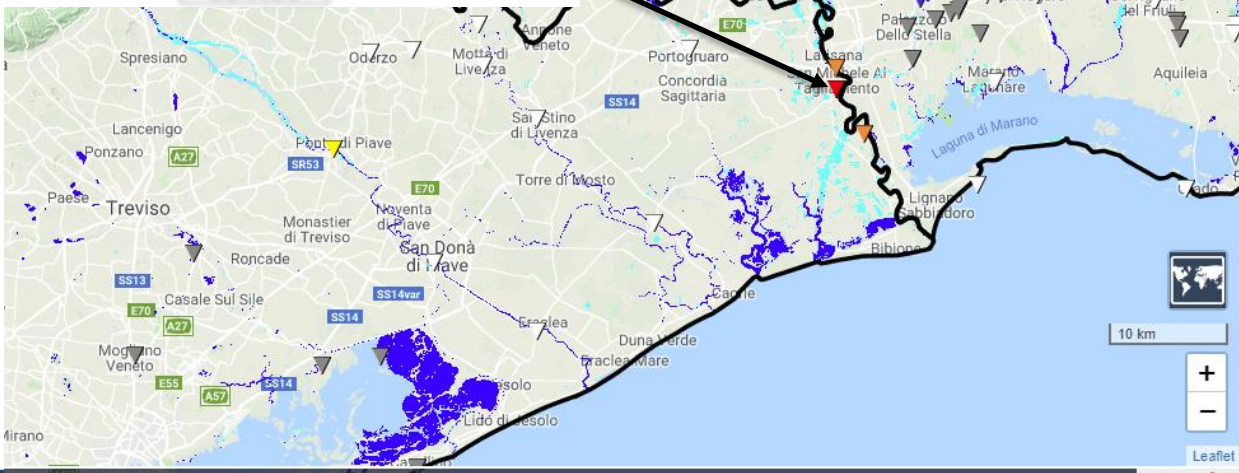
Tagliamento A Madrisio (Morsano Al Tagliamento)

Lemene (San Michele al Tagliamento)

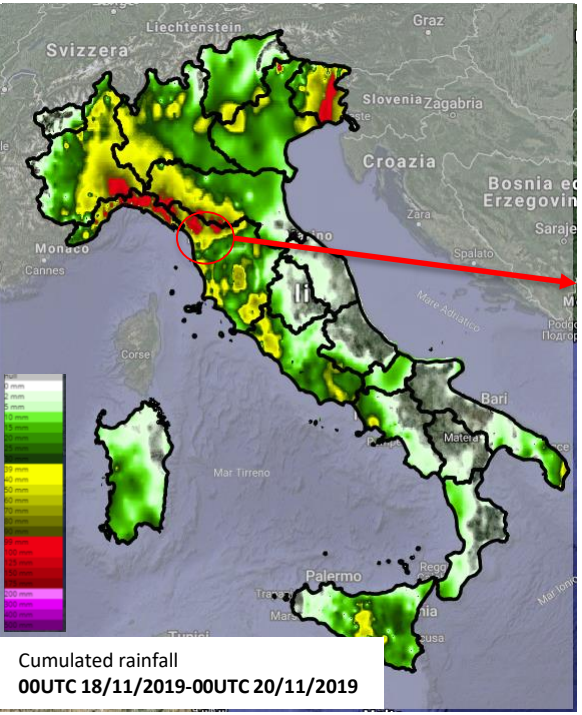
16 Nov

18 Nov

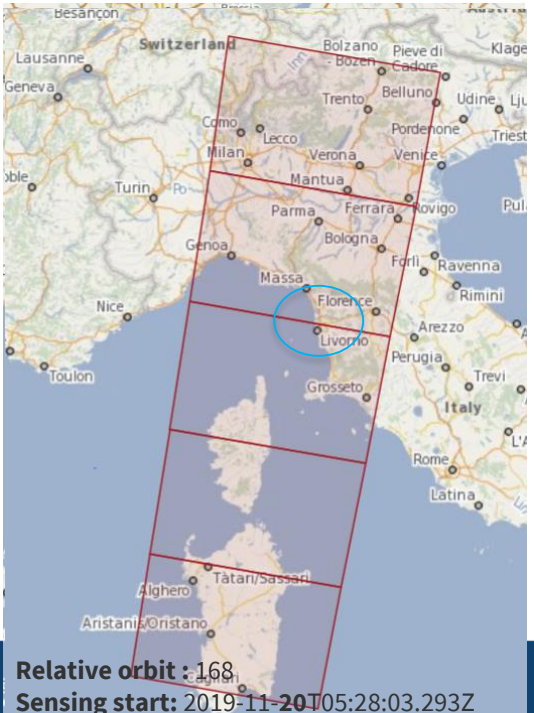




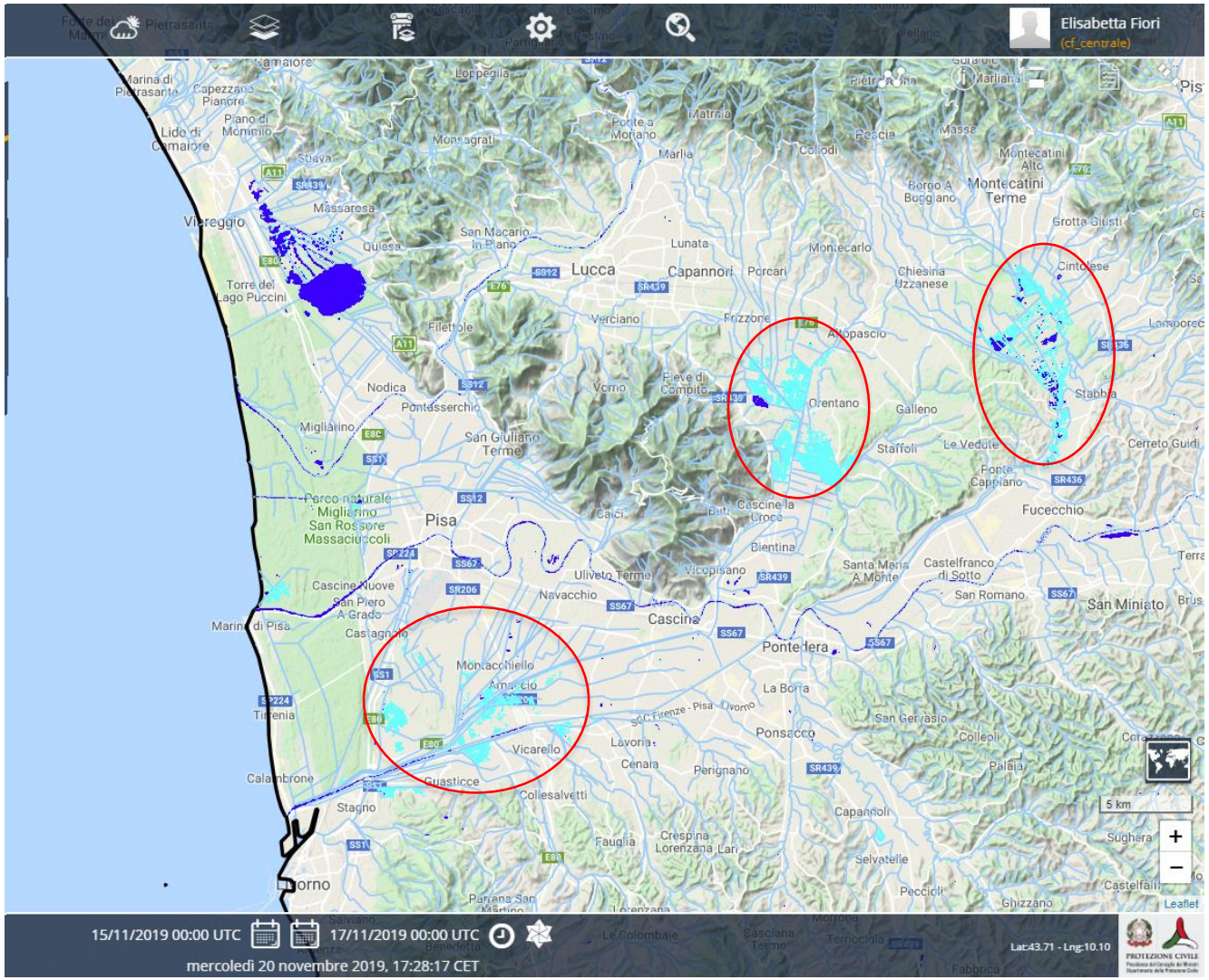
20 Nov. 2019 - ROI - Toscana



Cumulated rainfall
00UTC 18/11/2019-00UTC 20/11/2019



Relative orbit : 168
Sensing start: 2019-11-20T05:28:03.293Z



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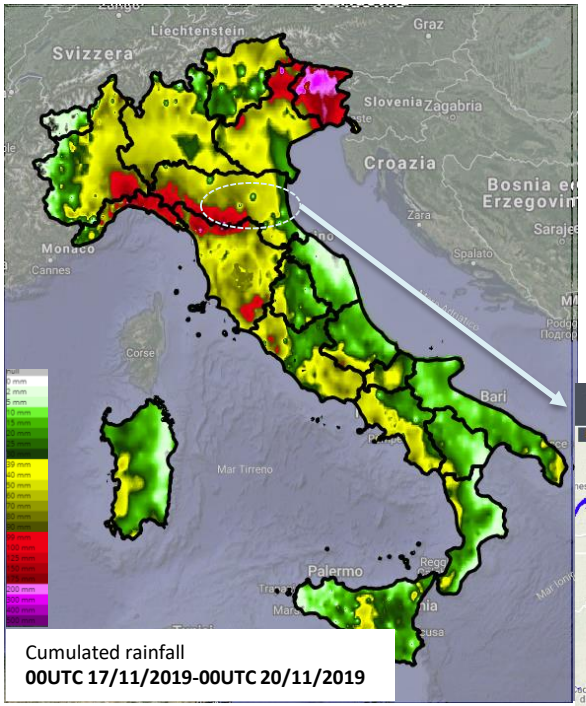
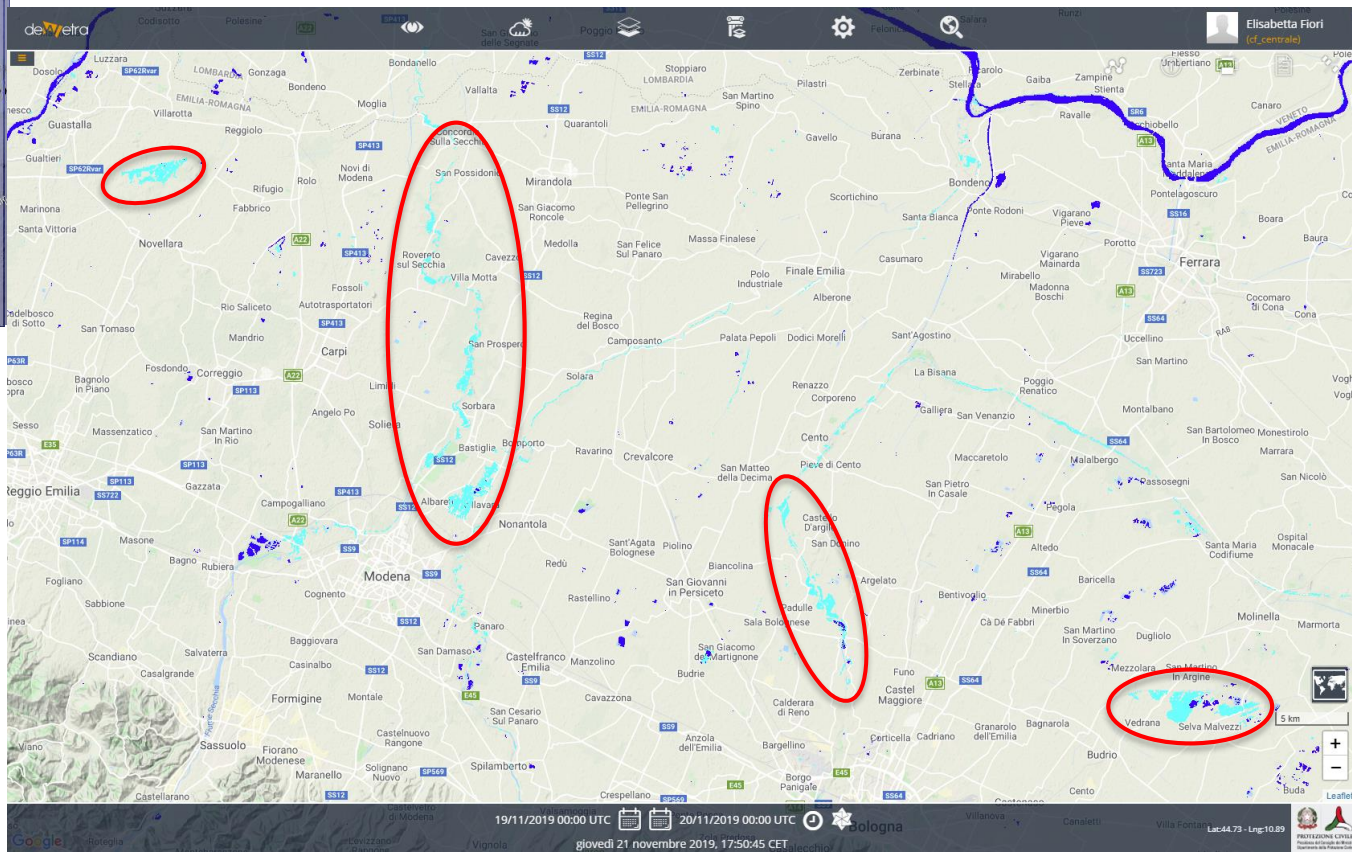
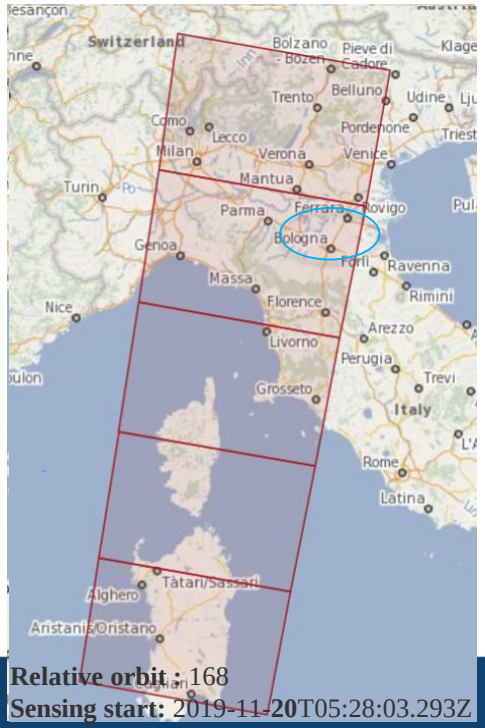
20 Nov. 2019 - ROI - Emilia-Romagna



Cumulated rainfall
00UTC 17/11/2019-00UTC 20/11/2019





Relative orbit : 168
Sensing start: 2019-11-20T05:28:03.293Z

Final remarks

- AUTOWADE is a fully automathic system and it is scheduled to run twice a day (ascending and descending S1 orbits)

- AUTOWADE allows end-users:
  - To know the status of the permanent water bodies when high precipitation is forcasted and soil moisture content is very high
  - To monitor in NRT the evolution of the flooded areas at national scale (different regions at the same time)
  - To avoid time consuming activation procedures.

- AUTOWADE complements on-demand systems like Copernicus Emergency Management Service - Mapping

Thank you for your attention

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