Geomorphic effects caused by heavy rainfall in southern Calabria (Italy) on 30th October – 1st November 2015

Rago V.[a], Chiaravalloti F.[a], Chiodo G.[b], Gabriele S.[a], Lupiano V.[a], Nicastro R.[b], Pellegrino A.D.[b], Procopio A.[a], Siviglia S.[b], Terranova O.G.[a], Iovine G.G.R.[a]

[a]CNR-IRPI of Cosenza (National Research Council-Research Institute for Geo-hydrological Protection)

[b]ABR-Calabria (Regional Basin Authority)

Tyrrhenian sea

Serre

Ionian sea

Aspromonte

The terminal reach of the Prajalonga stream (Costa Viola). There is evidence of deposition and flooding along the streambed and on both flanks, with damage to cultivated land.

Aerial view of slope movements along the margins of Grotteria village (Ionian sector, just north of the study area), with damage to buildings.

Close view of the railway bridge on the Prajalonga stream (Costa Viola), heavily obstructed by deposition of debris. The area had just been cleaned by RFI S.p.A. only a few days before the geo-hydrological event.

View of shallow slope movements on the left flank of the Careri stream (Ionian coast).

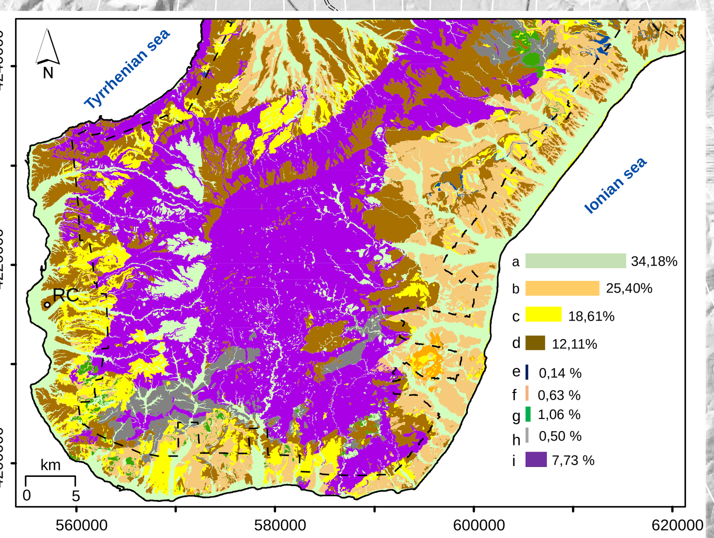


Figure A. Lithological map of southern Calabria (after CASMEZ, 1969 – mod.). Key: a) Alluvium, colluvium and residual soil; b) Clay and clayey flysch; c) Sand and silt; d) Conglomerate and sandstone; e) Evaporite rock; f) Flysch; g) Carbonate rock; h) Argillite and low-grade metamorphic rock; i) Igneous and medium-high grade metamorphic rock; RC) Reggio di Calabria. The boundary of the study area, along the coast, is marked by the dashed black line. On bottom right, the relative abundance (in %) of the lithological classes in the study area is shown.

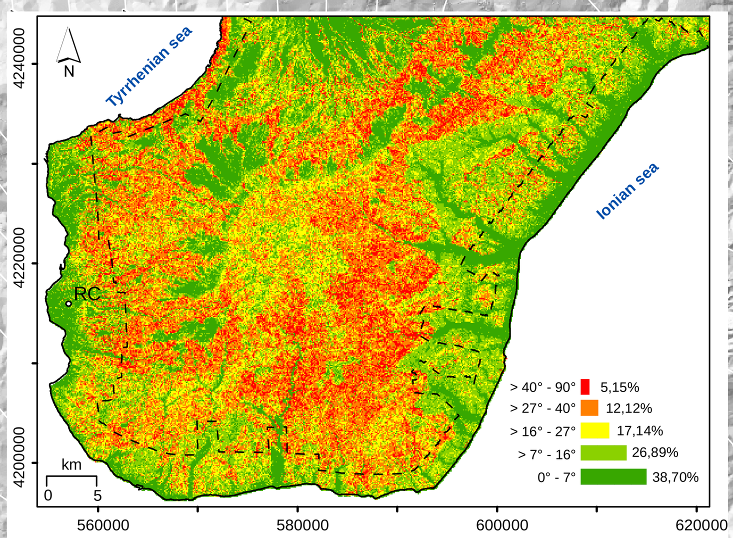


Figure B. Map of slope classes of southern Calabria. Data derived from the CTR-Regional Technical Map of Calabria, at 1:5000 scale. The boundary of the study area, along the coast, is marked by the dashed black line. On bottom right, the relative abundance (in %) of the slope classes in the study area is shown.

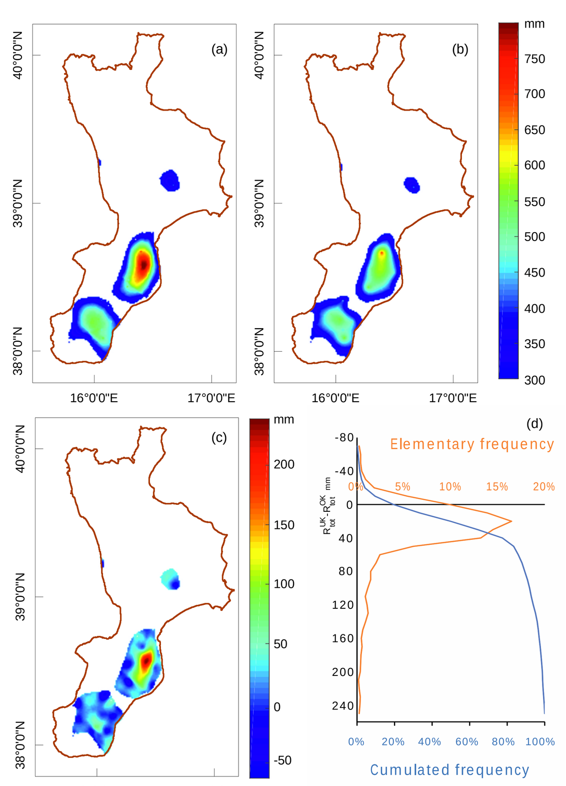


Figure C. Rainfall estimates from 00:00 on 29 October to 09:00 on 2 November 2015. UK and OK total estimates are plotted in (a) and in (b), respectively; difference values are shown in (c). The statistical distribution of differences $R_{tot}^{UK} - R_{tot}^{OK}$ for cumulative rainfall is plotted in (d). Note that only areas with cumulative values exceeding 300 mm are considered.

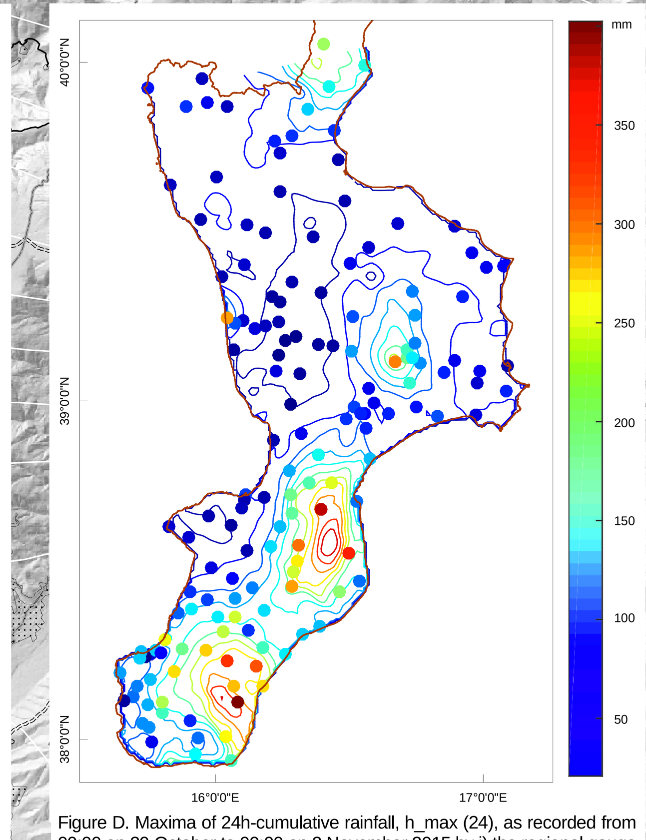


Figure D. Maxima of 24h-cumulative rainfall, h_max (24), as recorded from 00:00 on 29 October to 09:00 on 2 November 2015 by i) the regional gauge network (dots), and ii) merging radar and gauge data (isohyets). The aggregation period of rain data is 10 minutes.

View of the SS. 106 and the railway destroyed at Marinella di Bruzzano, between Brancaleone and Ferruzzano (Ionian coast), as a consequence of flooding and impoundment processes upslope.

Close view of the SS.106 and the railway destroyed at Marinella di Bruzzano, between Brancaleone and Ferruzzano (Ionian coast).

Limit of air-photos coverage

Town road

County road

Highway

Railroad

Village

Ground effects of the storm

Isohyet on shaded relief

Landslides

Alluvial deposit

Alluvial fan

Sheet erosion

Rill erosion

Gully erosion

Notices from survey sites

Hydraulic process (A)

Slope movement (B)

Damage/remedial work (C)

Hydraulic process & damage/remedial work (A+C)

Slope movement & damage/remedial work (B+C)

Hydraulic process & slope movement (A+B)

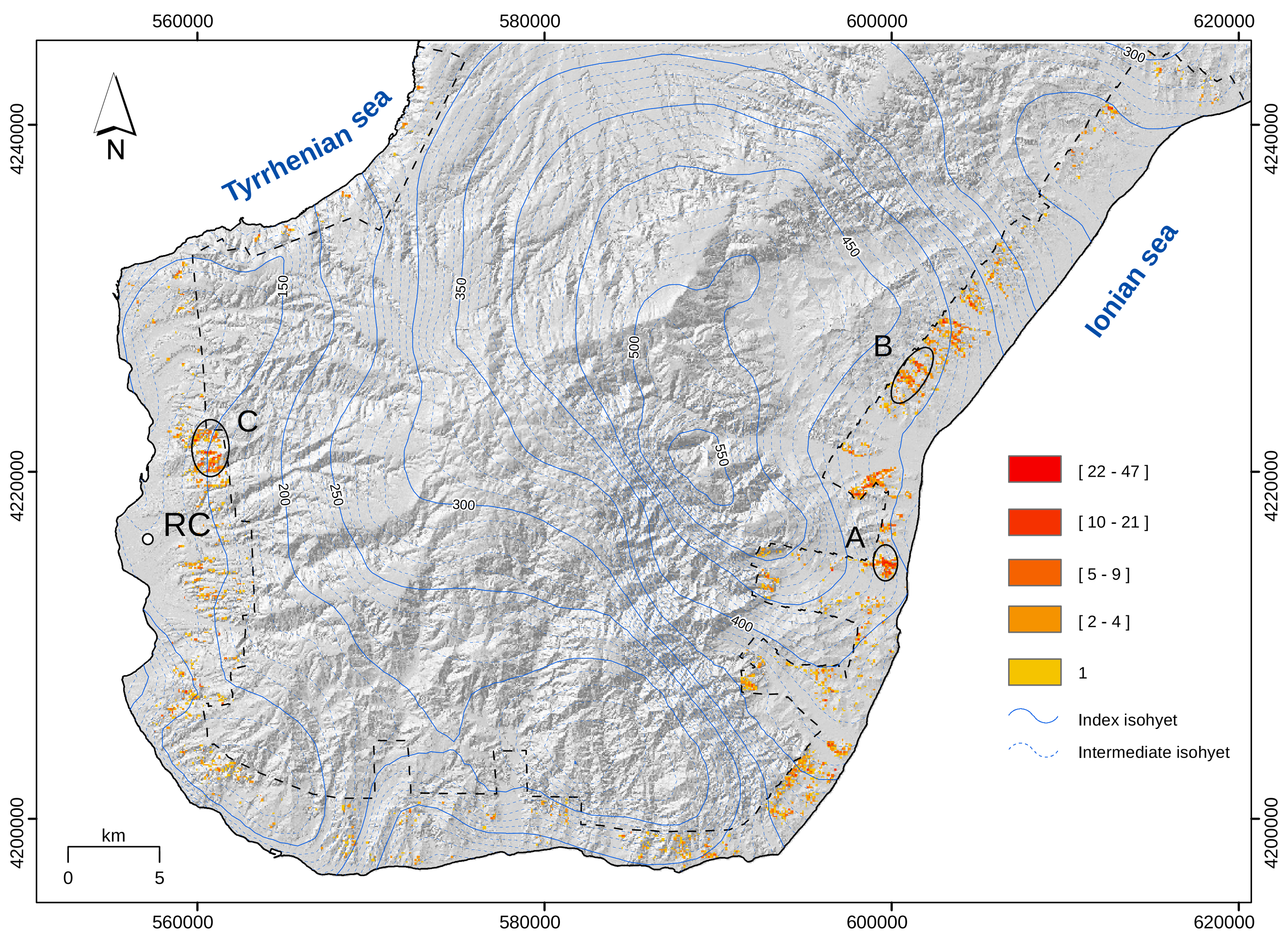
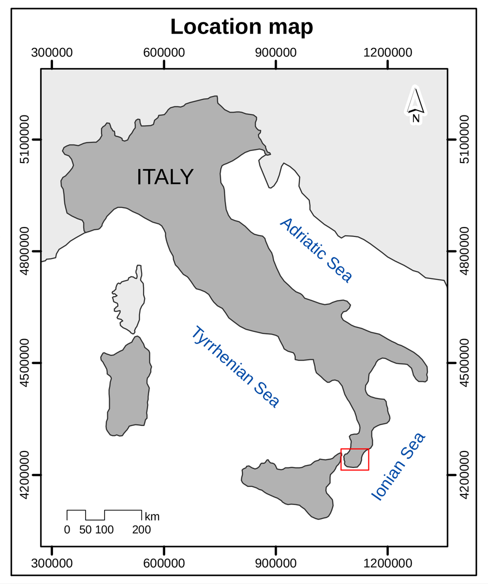


Figure E. Map of density of triggered landslides in the study area. Densities expressed in number of landslide sources per hectare (ranked into 5 classes, based on Jenks natural breaks method). In blue, the isohyets of the maxima of 24h-cumulative rainfall, h_max (24), as recorded between 29 October and 2 November by gauges and radar, are also shown (contour interval = 10 mm). Ellipses mark the areas with highest landslide densities: (A) between Bianco and Africo (22-47 sources per hectare); (B) between Benestare and Ardore, and (C) NNE of Reggio di Calabria (10-21 sources per hectare).

A severe geo-hydrological event occurred in southern Calabria between 29 October and 2 November 2015, causing 2 deaths and damage to transport infrastructure. Widespread slope erosion and shallow landslides were triggered on slopes, with flooding and major transport of debris along the streams. According to official estimates, costs for remedial works and mitigation actions will exceed 320 M€, including about 60 M€ for immediate rescue, mitigation actions and assistance to the affected population.
The study area is crossed by regional transport infrastructure and hosts numerous villages, in addition to the town of Reggio di Calabria facing the Messina Strait. It is in the southern domain of the Calabrian Arc, an accretionary wedge caused by the Africa–Europe collision. The metamorphic and igneous rocks of the basement are diffusely fractured and weathered, and are combined with high relief energy produced by recent/active tectonics and linear erosion of the slopes.
Rainfall data - recorded between 29 October and 2 November 2015 by the regional rain-gauge network and by the national radar monitoring system - was analysed for an assessment of rainfall distribution. Cumulative rainfall measured by the rain-gauge network was mapped by Ordinary Kriging (OK) in a 1 km-size square mesh domain. Radar and rain gauge information was merged to obtain cumulative rainfall by means of a Universal Kriging (UK) regression technique with an external-drift algorithm. To investigate rainfall deemed responsible for the observed ground effects, the maximum amounts of UK cumulative rain over a period of 24h were also extracted.
Ground effects were surveyed in the field and mapped through interpretation of 1:22,000 scale air-photos taken immediately after the storm along the coastal sector of southern Calabria. In particular, the following types of processes were considered: shallow landslides, soil erosion (including sheet, rill and gully erosion), flooding, lateral erosion and debris deposition along the streambeds, overflow on lateral slopes, and fan deposition at the stream mouths by the coast. Surveyed ground effects were integrated with notices of site investigations by the regional Civil Protection authority.
Results of the survey are shown at 1:60,000 scale, including isohyets of the weather event in terms of maximum amounts of UK cumulated rain over 24 hours.



Datum WGS 84
Projection Transverse Mercator
UTM, zone 33 North

0 1 2 4 km