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Transboundary Storm Risk and Impact Assessment in Alpine Regions

GUIDELINES FOR HARMONISED, CROSS-BORDER COLLECTION OF GEOCODED STORM DAMAGE AND IMPACT DATA

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AUTHORS:	Matthias Plörer, Michaela Teich, Kathrin Renner, Fabrizio Tagliavini, Roberta Dainese, Massimiliano Pittore	

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TABLE OF CONTENTS

1 IMPACT AND DAMAGE DATA AVAILABLE FOR SELECTED EXTREME METEOROLOGICAL CROSS-BORDER EVENTS IN THE PILOT REGIONS OF TRANSALP

1.1 INTRODUCTION

This report analyses existing sources of impact and damage data for extreme weather events in the three neighbouring TransAlp project areas East Tyrol in Austria, South Tyrol and Cordevole Valley in Italy. In a first section we focused on three pre-selected major events that affected all three regions as examples to characterise the available damage and impact information in each region. We subsequently analysed each of the identified data sources regarding its quality, its usefulness, accessibility and content with regard to impact and damage information. The third section provides recommendations for harmonised cross border collection of impact data.

In order to assess the quality and consistency of available impact data, three historic major extreme meteorological events were selected. The selection was based on the following criteria: 1) intensity and impact, 2) transboundary character, 3) happened in the recent past, and 4) affected all three project regions. Based on these three events, we conducted a comparison of the type and quality of impact and damage documentation.

The selected events are (Figure 3-3):

- depression/low from 28th to 30th October 2018 (Vaia/Adrian)
- depression/low from 12th – 17th November 2019 (Ingmar/Keke)
- depression/low from 4th – 07th December 2020 (Xunav/Wenke/Yvonne)

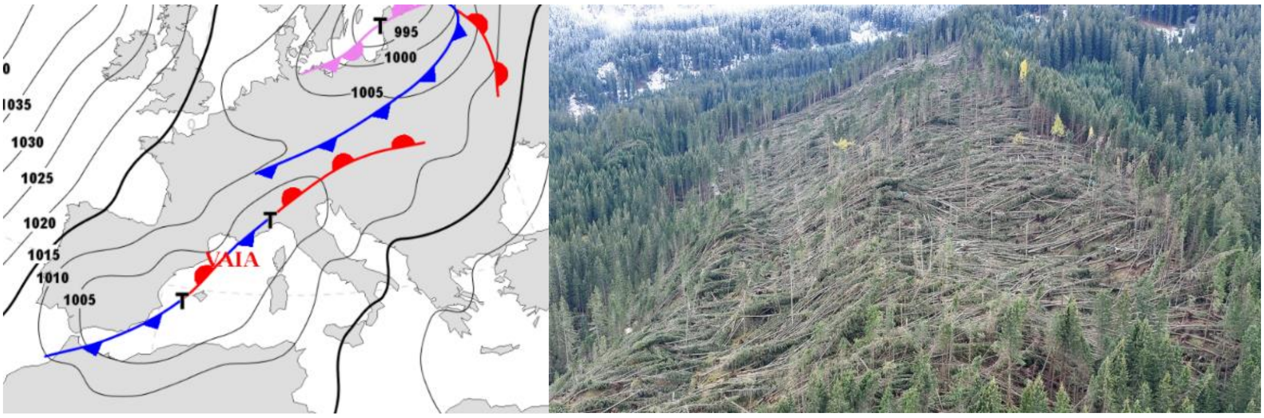


Figure 1: depression Vaia/Adrian (source left figure: DWD - Deutscher Wetterdienst) and corresponding damage/impact pattern on a forest spot in South Tyrol (source right figure: Autonome Provinz Bozen Südtirol)

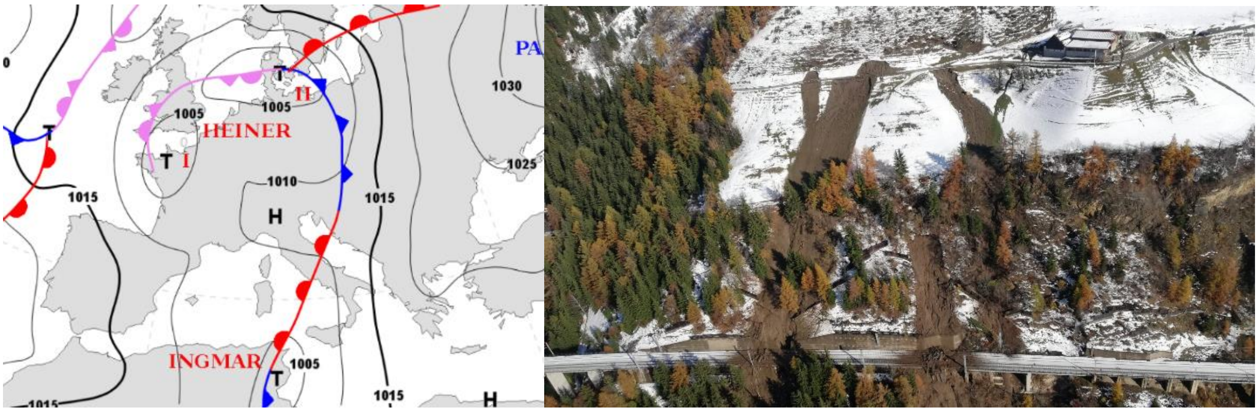


Figure 2: depression Ingmar/Keke (source left figure: DWD – Deutscher Wetterdienst) and corresponding damage/impact pattern on Autrian railways (source right figure: ÖBB – Österreichische Bundesbahnen)

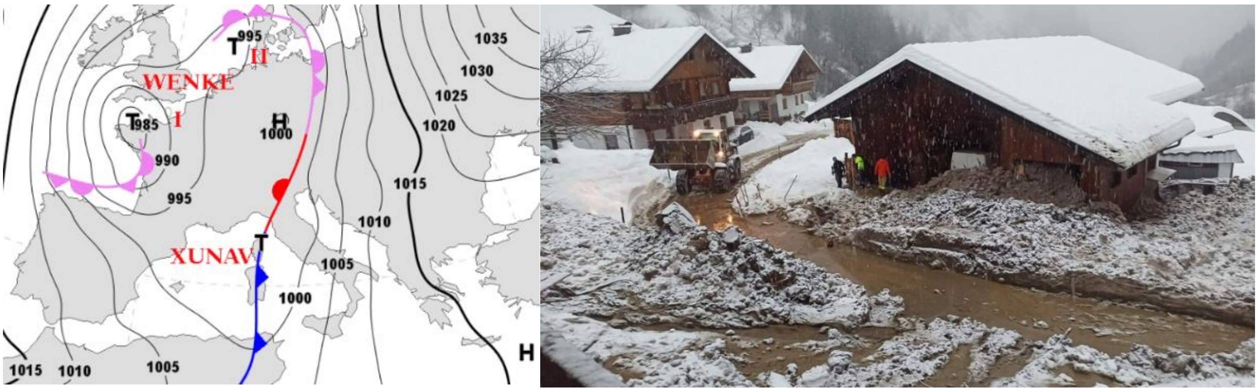


Figure 3: depressions Xunav/Wenke/Yvonne (source left figure: DWD – Deutscher Wetterdienst) and corresponding damage/impact pattern on residual buildings in East Tyrol (source right figure: Brunner images)

The three events - listed above - were extracted from the list of 15 cross-border meteorological events identified in T2.2 "HAZARD DATASET – HISTORICAL EVENTS". In task T2.2, meteorological properties and co-occurrence of extreme precipitation values in the three project regions East Tyrol, Cordevole Valley (Veneto) and South Tyrol / Alto Adige have been analysed. The list of events was reviewed for the three regions of interest and the most relevant major events in recent years with cross-border impacts and thus affecting all three regions were identified.

We collected available data on storm event impacts and damages consulting governmental and non-governmental sources. Whilst some information was sourced from national and regional governmental data portals, other data sets were extracted from European databases such as the European Severe Weather Database.
The following sections 1.2, 1.3 and 1.4 summarise the available data on impacts for each project area for the three selected events.

1.2 Collection of impact data: East Tyrol

In the data collection we started with existing impact data portals such as the VIOLA (Violent Observed Local Assessment) database for Austria, the online platform of the European Severe Weather Database (ESWD) and subsequently checked databases from regional authorities like the Austrian Service for Avalanche and Torrent Control. See Table 3, Table 2 and Table 1 for a description of the available impact information for the three selected events.

Date: 2018-10-28 to 30	**Hazard type / triggering factor:** heavy precipitation, severe storm / multi hazard
Georeferencing: hundreds of individual polygons depicting damaged forest areas; several georeferenced point shapes in the cadastre (WLK) of the Austrian Torrent and Avalanche Control (WLV)	
Intensity: 130 mm; Fujita scale: F1 / Torro scale: T2, peak wind speeds of up to 200 km/h; 1/3 of all triggered events in Austria in 2018 are associated with this major event; 3-day precipitation sums ranged from 150-450 mm	
Documented damage(s): 74 registered events occurred between 28th and 29th of October in the federal state of Tyrol; numerous houses and cellars were flooded; canals overflowed; roads were flooded and buried & bridges destroyed; schools remained closed; river levels exceeded the hundred-year flood mark; electricity pylons threatened to topple; a total of more than 5,000 households without electricity; several mudslides and road closures in some areas; large debris flows destroyed a restaurant; strong wind and gusts uprooted thousands of trees which in some places blocked roads (4300 hectares of forest affected in East Tyrol & Carinthia; 600.000 solid cubic meters of damaged wood in East Tyrol); several power lines were destroyed by falling trees; destroyed farmland; 69 floods/debris flows, 4 landslide events reported by the Austrian Service for Torrent and Avalanche Control	
Cross border relevance: ☒ proven ☐ probable ☐ possible ☐ none	
Reference(s): - ZAMG: VIOLA Severe Weather Chronicle - European Severe Weather Database - Austrian Service for Torrent and Avalanche Control (internal cadastre) - WLV (2019): Ereignisdokumentation 2018; URL: https://info.bmlrt.gv.at/dam/jcr:90752a7f-665f-41b4-9d6c-347e60add5f0/Ereignisdokumentation%202018_220ppi.pdf Media reports: - https://tirol.orf.at/news/stories/2944442/ - https://www.tt.com/panorama/katastrophe/14959547/regen-sturm-muren-millionenschaeden-nach-unwetter-in-osttirol - https://tirol.orf.at/news/stories/2944696/	

Table 1: damage data collection of the event from 28th to 30th of October 2018 in East Tyrol

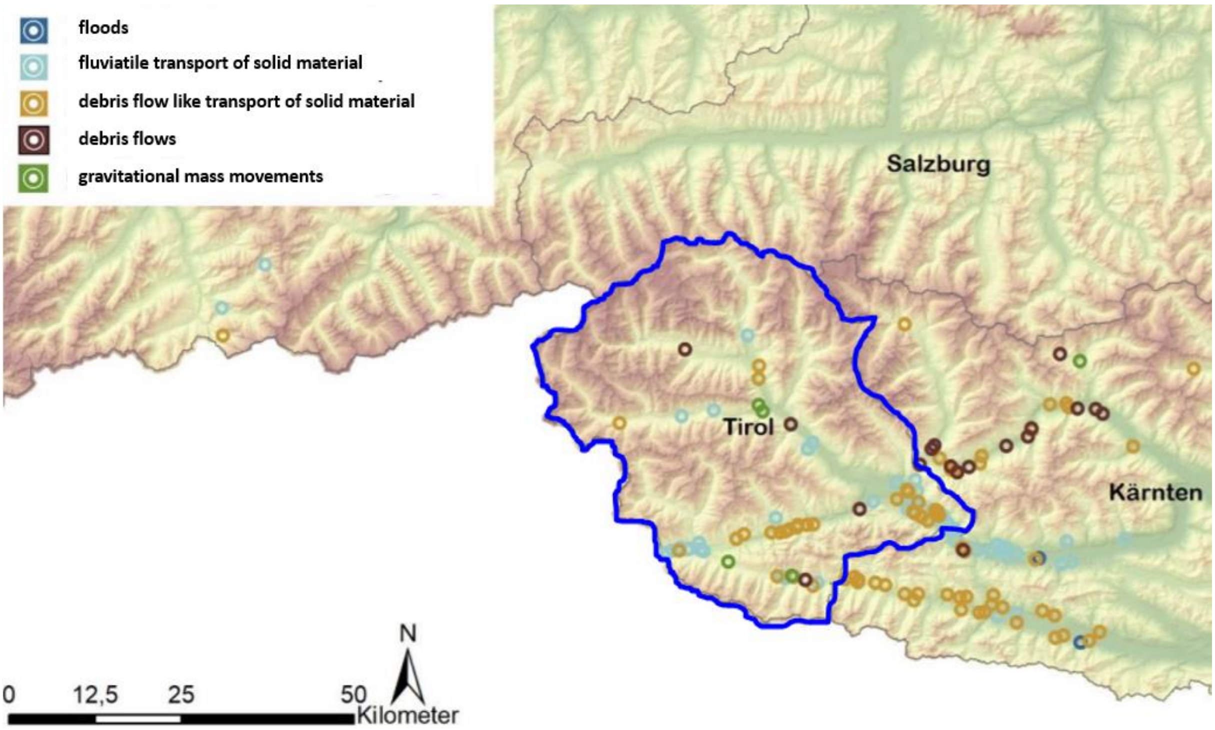


Figure 4: distribution of events registered in the WLV´s WLK (cadastre) from 28th to 29th of October 2018 (WLV, 2019)

Figure 5: storm-related obstructions and deployments on the 30th of October 2018 (source: Land Tirol)

Date: 2019-11-12 to 17	**Hazard type / triggering factor:** winter storm, avalanches, floods, debris flows & mudslides – multi-hazard situation / heavy snowfall, heavy rain, long lasting precipitation in combination with snow melt
Georeferencing: partly in the internal cadastre of the Austrian Service for Torrent and Avalanche Control	
Intensity: 544 mm of precipitation in November; highest precipitation rate of the past 160 years); daily peak: 103 mm; about 49 % (!) (except avalanches) of all in the Austrian WLK (WLV cadastre) recorded events in 2019 happened in the frame of the major extreme event between 15th and 17th November, in turn, around 70% of these were triggered on 17th of November	
Documented damage(s): area wide power cuts, road closures & closed schools throughout whole East Tyrol; disrupted railway line; tree falls and cable breaks on power lines; 5400 households without electricity; settlements cut off from transport infrastructure; forest damages; in the area of responsibility of the torrent and avalanche control, 4 private residential buildings, 1 material transport facility, 2 traffic or passenger transport facilities, 4 road facilities and 1 damage to agricultural use were registered between 15 and 17 November in Austria (focus East Tyrol & Carinthia); the WLV (Austrian Torrent and Avalanche Control) reported 12 relevant avalanche events, 2 relevant landslides and 16 relevant flood/debris flow events (according to the “Ereignisdokumentation 2019");	
Cross border relevance:	☒ proven ☐ probable ☐ possible ☐ none
Reference(s): - ZAMG: VIOLA Severe Weather Chronicle - European Severe Weather Database - Austrian Service for Torrent and Avalanche Control (internal cadastre) - BMLRT (2020): Ereignisdokumentation 2019; URL: https://info.bmlrt.gv.at/dam/jcr:aff01567-de36-4693-9db0-20ae0dd2ff61/Ereignisdokumentation%202019.pdf Media reports: - https://tirol.orf.at/stories/3021758/ - https://tirol.orf.at/stories/3021414/	

Table 2: Characterisation of the extreme weather event of 12*th* to 17*th* of November 2019 in East Tyrol

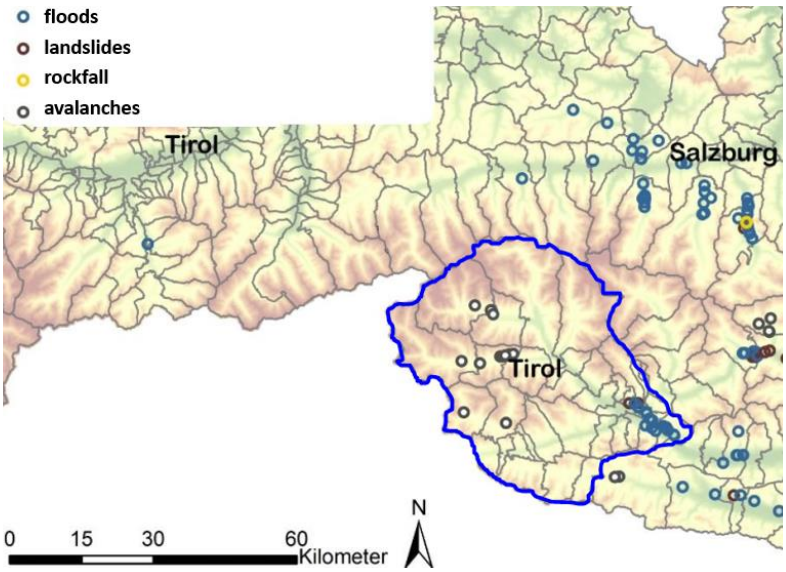


Figure 6: distribution of events registered in the WLV´s WLK (cadastre) between 15h and 17th of November 2019 (BMLRT, 2020)

Date: 2020-12-04 to 07	Hazard type / triggering factor: slab avalanches & glide snow avalanches, mudslides, slush-flows, floods – multihazard situation / heavy precipitation, heavy snowfall
Georeferencing: several locations of avalanches, landslides and slush flows available in the technical report of the Austrian Torrent and Avalanche Control: https://info.bmlrt.gv.at/service/publikationen/wald/ereignisdokumentation-lawinen-osttirol-2020.html respectively in the internal WLV cadastre WLK	
Intensity: liquid precipitation / 3 days: 294 mm (Silian), 298 mm (Lienz), 225 mm (St. Jakob/Defereggen); Prägraten: 240 mm between 4th and 9th of December; Hopfgarten: 104 mm on the 5th of December; 100-140 km/h windspeeds according to ZAMG weather stations; 142 cm snow-height (record at the weather station in St. Jakob); in mountainous areas between 150 and 250 cm fresh snow; highest avalanche danger level of 5; average release slab thickness of 100 – 150 cm; Lienz: highest monthly precipitation total since the beginning of the measurement series in 1854; “Katin”-Avalanche: deposition area about 2.6 hectares;	
Documented damage(s): record amounts of fresh snow; problems in the power supply (4,000 households without electricity); numerous roads closed; extreme snow load on trees; tree falls on power lines; very high avalanche danger (5) & damage to buildings due to avalanches and slush flows; evacuation order by authorities; after snowfall heavy rain - major damage due to several landslides; water ingress - basements and cellars flooded; a lake had formed that endangered houses, almost 30 people were evacuated; the WLV (Austrian Torrent and Avalanche Control) reported 25 relevant avalanche events, 4 relevant landslides and 2 relevant flood evets; “Katin”-Avalanche: damaged tractor, damaged sheepfold, destruction of a balcony and a breakfast room in a guesthouse, destruction of a barn, displacement of cars in avalanche flow direction, destruction of a terrace due to secondarily released avalanche; “Bodnerfeld”-Lawine: damaged road facilities; avalanche in the area of Schönsteig: agricultural building severely damaged by glide snow avalanche; damaged rockfall protection nets due to high snow load (Äußerer Hochberg); two damaged harps in the area of Gasse (Innervillgraten); slush flow in Hopfgarten: 4 buildings were severely damaged; the living room and the kitchen of two different houses were filled with mud; in addition, cars were damaged;	
Cross border relevance:	☒ proven ☐ probable ☐ possible ☐ none
Reference(s): - ZAMG: VIOLA Severe Weather Chronicle - European Severe Weather Database - Austrian Torrent and Avalanche Control: WLK (cadastre) - WLV (2021): ERDOK Lawinen Osttirol; URL: https://info.bmlrt.gv.at/service/publikationen/wald/ereignisdokumentation-lawinen-osttirol-2020.html Media reports: - https://tirol.orf.at/stories/3079332/ - https://www.tt.com/artikel/30766028/wetterchaos-in-tirol-lawine-auf-haeuser-in-osttirol-strassen-in-nord-tirol-gesperrt?slide-id=5; https://tirol.orf.at/stories/3079327/	

Table 3: Characterisation of the extreme weather event of 4th to 7th of December 2020 in East Tyrol

1.3 Collection of impact data: Cordevole Valley (Veneto)

As for the Cordevole Valley, data relating to damage caused by extreme meteorological events were obtained mainly from reports of the regional civil protection system, as well as from the landslide database of the Veneto Region, from the Avalanche WebGIS of Arpa Veneto and the AVI and SCAI projects developed by the CNR-IRPI in the past decades. Reports by the various institutions called to assist in the aftermath of several emergencies were also analysed, i.e. fire brigade and forest services. Finally, a search of news articles in the database of the main local newspapers was carried out.

<table>
<tr><td>Date:
2018 – 10 – 28 to 30</td><td colspan="4">Hazard type / trigger:
landslides, floods, forest felling, multi-hazard / heavy precipitation, strong wind gusts, severe storm</td></tr>
<tr><td colspan="5">Georeferencing:
Available geospatial data related to landslides, floods and felled forest, as well as data on the portions of forest attacked by the bark beetle</td></tr>
<tr><td colspan="5">Intensity:
- liquid precipitation/3 days: 533,8 mm Agordo,369,6 mm Gares, 339,2 mm Pescul, 333 mm Passo Valles, 316,8 mm Malga Ciapela, 290,4 mm Caprile, 274,2 mm Pian del Crep, 268 mm Falcade, 261 mm Passo Falzarego (CAE), 248,4 mm Arabba.
- liquid precipitation/2 days: 488,2 mm Agordo, 313,6 mm Gares, 301,6 mm Pescul,274,2 mm Pian del Crep, 266,2 mm Passo Valles, 263,8 mm Malga Ciapela, 242,6 mm Caprile, 228,2 mm Falcade, 207,2 mm Passo Falzarego (CAE), 219,6 mm Arabba.
- liquid precipitation/24h: 306,4 mm Agordo, 184,6 mm Gares, 182,4 mm Pian del Crep, 182 mm Pescul, 174,6 mm Passo Valles, 169,8 mm Malga Ciapela, 138,8 mm Falcade, 137,2 mm Caprile, 136,4 mm Passo Falzarego (CAE), 130,8 mm Arabba.
- Wind gusts: 192 Km/h Monte Cesen; 167 Km/h Monte Verena; 149 Km/h Passo Valles</td></tr>
<tr><td colspan="5">Documented damage(s):
In the study area alone, numerous hectares of forest were destroyed during the VAIA storm, as well a big number of landslides, flash floods, debris flows and floods. Entire villages were left without electricity. Communication routes were interrupted either by fallen trees or by erosion or flooding. Also, in the study area many people were injured and there was one fatality. Several power lines and infrastructures were destroyed by falling trees. Numerous houses were damaged by avalanches and floods. Long-term damage from the storm Vaia is being recorded in recent days, with a large part of the forest threatened by the proliferation of the bark beetle, which is rapidly killing off large areas of vegetation, resulting in a lack of evapotranspiration and an increase in erosion phenomena as well as an increase in the risk of avalanches.</td></tr>
<tr><td>Cross border relevance:</td><td>☒ proven</td><td>☐ probable</td><td>☐ unlikely</td><td>☐ none</td></tr>
<tr><td colspan="5">Reference(s):
- ARPAV - Regional Agency for Environmental Protection and Prevention of Veneto
- Veneto Region - Soil Defence Department
- Veneto Region – Civil Protection Department
- Veneto Region – Agriculture and Forestry Department
- local newspapers</td></tr>
</table>

Table 4: Characterisation of the extreme event of 28 to 30 October 2018 in Cordevole Valley

Date: 2019 – 11 – 14 to 18	Hazard type / trigger: landslides, avalanches / intense rainfall and snowfall
Georeferencing: geospatial data are available on the avalanches that occurred due the meteorological event under consideration	
Intensity: liquid precipitation / 3 days: 361,8 mm (Col di Prà), 326,4 mm (Sant'Andrea - Gosaldo), 318,4 mm Agordo, 200 mm Pescul, 187,2 mm Gares, 187 mm Malga Ciapela, 184,2 mm Arabba, 157,6 mm a Caprile, 153 mm Passo Falzarego (CAE); liquid precipitation/ 2 days: 231 mm Col di Prà, 227,2 mm Sant'Andrea (Gosaldo), 218,4 mm Agordo, 142 mm Pescul, 121,2 mm Gares, 120,6 mm Arabba, 110 mm Caprile, 107,6 mm Passo Falzarego (CAE); liquid precipitation/ 24h: 187,6 mm Col di Prà, 167 mm Sant'Andrea (Gosaldo), 166,4 mm Agordo, 99,6 mm Pescul, 92,4 mm Gares, 92,2 mm Malga Ciapela, 88,8 mm Arabba, 77,4 mm Caprile, 75,8 mm Passo Falzarego (CAE). Snow depth/4 days: Monte Cherz (2020 m a.s.l.) 121 cm; Col dei Baldi (1900 m a.sl.) 166 cm; Cima Pradazzo (2200 m a.s.l.) 115 cm.	
Documented damage(s): Several roads and infrastructures were interrupted by landslides in the area. The large amount of snow that had fallen led to numerous avalanche phenomena, both in the days immediately following the event and in the months that followed, with the formation of numerous glide avalanches that threatened roads and houses.	
Cross border relevance: ☒ proven ☐ probable ☐ unlikely ☐ none	
Reference(s): ARPAV - Regional Agency for Environmental Protection and Prevention of Veneto. Veneto Region – Civil Protection Department. Local newspapers	

Table 5: Characterisation of extreme weather event of 15/16th November 2019 in Cordevole Valley

Date: 2020-12-04 to 06	Hazard type / trigger: Landslides, avalanches / intense rainfall and snowfall
Georeferencing: geospatial data are available on the avalanches that occurred as a result of the meteorological event under consideration	
Intensity: liquid precipitation/3 days: 506.6 mm Col di Prà, 501,2 mm Sant'Andrea (Gosaldo), 432,6 mm (Agordo), 296,4 mm (Pescul), 263,4 mm (Gares), 243,8 mm (Falcade), 229,4 mm (Passo Falzarego - CAE), 223,4 mm (Arabba), 215,2 mm (Caprile), 197 mm (Passo Valles), 172,6 mm (Malga Ciapela); liquid precipitation/2 days: 459,6 mm (Col di Prà), 395,2 mm (Agordo), 340,2 mm (Sant'Andrea - Gosaldo), 274,6 mm (Pescul), 230,8 mm (Gares), 213,6 mm (Falcade), 207,8 mm (Passo Falzarego - CAE), 194,4 mm (Caprile), 171,8 mm (Passo Valles), 139,8 mm (Malga Ciapela), 128,2 mm (Arabba); Liquid precipitation/24h: 340,8 mm (Sant'Andrea - Gosaldo), 328,2 mm (Col di Prà), 273,4 mm (Agordo), 159,8 mm (Pescul), 144,6 mm (Gares), 139,8 mm (Malga Ciapela), 128,2 mm (Arabba), 121,4 mm (a Falcade), 115,8 mm (Caprile), 110 mm (Passo Falzarego - CAE), 102,8 mm (Passo Valles); Snow height/3 days: Col dei Baldi (1900 m a.s.l) 161 cm, Passo Falzarego (1988 m a.s.l.) 159 cm, Monti Alti Ornella (2250 m a.sl.) 146 cm, Arabba (1630 m a.sl.) 141 cm, Monte Cherz (2020 m a.s.l.) 131 cm.	
Documented damage(s): The main road of the Cordevole Valley has been interrupted in several places by landslides, debris flow and fluvial erosion phenomena. The large quantities of snow that had fallen led to numerous avalanche phenomena, both in the days immediately following the event and in the months that followed, with the formation of numerous glide avalanches that threatened roads and houses.	
Cross border relevance: ☒ proven ☐ probable ☐ unlikely ☐ none	
Reference(s): - ARPAV - Regional Agency for Environmental Protection and Prevention of Veneto - Veneto Region – Civil Protection Department - Local newspapers	

Table 6: Characterisation of extreme weather event on 5/6 December 2020 in Cordevole Valley

1.4 COLLECTION OF IMPACT DATA: SOUTH TYROL

Impact and damage information available for the three extreme weather events under consideration were also collected from governmental and public media sources in South Tyrol, Italy. Main sources of information were the regional instance of the national Italian landslide registry (IFFI) managed by the Geological Office, the database on hydrological events ED30 (Ereignis Dokumentation Department 30) as well as deployment data of the fire fighters, from the Civil Protection Agency, event and damage assessment reports from the Department of Forestry, the Geological Office and the Civil Protection Agency of the Autonomous Province of Bolzano/Bozen. Meteorological descriptions of each event were extracted from the TransAlp Deliverable T2.2. See Table 7, Table 8 and Table 9 below for characteristics of the three example events considered in this report and the information extracted from the identified data sources.

<table>
<tr><td>Date:
2018 – October – 28 to 30 (“Vaia”)</td><td>Hazard type / trigger:
heavy precipitation, storm</td></tr>
<tr><td colspan="2">Georeferencing:
- Point location of mass movements (IFFI data), which could potentially have been caused by the extreme weather (cause of mass movements registered to have occurred on those dates given as “intrinsic”) (source: Geological Office)
- Areas of forested area damaged by the strong wind, incl. forest tracks affected (source: Forest Department)
- Spatial distribution (point features) of fire fighter interventions (source: Civil Protection)
- Point locations of damages, line and areal erosion and material accumulation features due to hydrological events (Source: ED30, Civil Protection)</td></tr>
<tr><td colspan="2">Intensity:
maximum amount of rainfall in South Tyrol: 184.6 mm, maximum wind speeds: 157 km/h</td></tr>
<tr><td colspan="2">Meteorological/hazard narrative:
On 27th October 2018 a trough of low pressure called “Vaia” became a vortex and brought heavy rainfall to northern Italy, south-eastern Switzerland and southwestern Austria. Several severe weather warnings were issued. In the southern Alps the snow line was between 1500 and 2000 m. Thunderstorms led to a temperature drop which allowed snowfall at lower altitudes. The Vaia vortex remained over the western Mediterranean See. It was blocked due to a high-pressure zone over North Africa. This allowed Vaia to absorb moisture and heat of a longer time. Thus, on this day, the 28th of October, precipitation levels increased once again and there was a risk of flooding. Moreover, the snow line had risen in northern Italy to above 2000m causing surface run-off also in higher altitudes. On October 28th wind speeds in Austria and Italy reached storm levels. At Rossalm, at 2300 m a.s.l. in South Tyrol wind gusts of 157 km/h were observed. On October 29th similar conditions were observed in Austria with the highest values of run-off in the evening. Especially at high altitudes, i.e. above 2000 m a.s.l. high precipitation rates were observed (Source: TransAlp Del. T2.2).
Impacts South Tyrol:
Communication routes were interrupted either by fallen trees, due to erosion or flooding, several people were injured and there was one fatality. Several power lines and infrastructures were destroyed by falling trees. Long-term damage from the Vaia storm is being observed, not only in terms of the expected long recovery time of the areas where trees had fallen, but also due to the proliferation of the bark beetle, which is rapidly killing off large areas of vegetation previously untouched, resulting in a further lack of evapotranspiration and an increase in erosion phenomena as well as an increase in the risk of avalanches.
- 1.3 % of the forest of South Tyrol was damaged by this event, i.e a total of ca. 105 Mio solid cubic metres. In some areas there were very large losses, e.g. the Latemar area lost the equivalent of wood that can be cut in 16 years. The clean-up of the forests was very labour intensive and took approximately two years to complete. An investigation showed that 2,655 ha of the forest damaged was protection forest (Source: Endbericht VAIA 2018, Autonome Provinz Bozen).
- A total of 66 mass movements were registered in the territory of the province over the period of 28 – 31 October. Of these 66 events 27 were classified as wet, 14 as very wet, 7 moist and 15 dry. 21 events happened in settlement areas, 28 in forested areas, 11 on grazing meadows and other three events took place in cultivated areas. No specific damage was recorded in the IFFI database for these events, however, this does not</td></tr>
</table>

necessarily mean there was no damage caused by the mass movements (Source: Geological Office, IFFI Database). - Between October 27th and October 29th Southtyrolean fire fighters deployed 296 times (total interventions in 2018: 958). Of these 296 deployments on those three days 160 interventions were to provide assistance due to "severe weather", 41 interventions where because of landslides, 26 due to "branch" and 15 emergency deployments were made due to "water damage" (Source: Fire fighter deployments, Dept. of Civil Protection). - 107 hydrological events were recorded between October 27th and October 29th. For all these events at 31 locations heavy damage was reported, at 129 locations medium damage and at 35 locations assessments recorded light damage. The area affected are located mostly in Southern and Southeastern South Tyrol. See also Figure . Types of damages are varied and include blockages of river courses, standing water in buildings, inundated roads, damaged paths and roads, material blocking river under a bridge and damaged river bank protection dams. (Source: Dept. of Civil Protection, ED30).
Cross border relevance: ☒ proven ☐ probable ☐ unlikely ☐ none
Reference(s): - TransAlp Del. 2.2 - IFFI database, also available in the WebGIS of the province of Bolzano: https://maps.civis.bz.it/#context=PROV-BZ-HAZARD - Endbericht VAIA 2018: http://www.provinz.bz.it/land-forstwirtschaft/forstdienst-foerster/downloads/DE_VAIA_Endbericht_12_2020.pdf - Deployments fire fighters shapefile (Autonomous Province of Bolzano) - Dept. of Civil Protection, ED30 hydrological event database

Table 7: Characterisation of the extreme event of 28 to 30 October 2018 in South Tyrol

Date: 2019 – November – 11 to 17 ("Ingmar")	**Hazard type / trigger:** Heavy precipitation and wind gusts
Georeferencing: - Point location of mass movements (IFFI data), which could potentially have been caused by the extreme weather (cause of mass movements on those dates given as "intrinsic") - Spatial distribution (point features) of fire fighter interventions (Source: Civil Protection) - Point locations of damages assessed due to hydrological events (Source: ED30, Civil Protection)	
Intensity: maximum amount of rainfall in South Tyrol: 166.3 mm (15-Nov-2019)	
Meteorological/hazard narrative: On 17th November Low „Ingmar" located east of Sardinia caused persistent heavy precipitation in Italy. Highest precipitation totals that day were observed in the Dolomites near Cortina d'Ampezzo. In the mountains above 1200 meters most of the precipitation fell as snow. In addition there were gale-force gusts in some places (Source: Del. T2.2.). **Impacts South Tyrol:** - Heavy wet snow caused trees to fall and block and damage roads as well as power lines leading to power outages. It came to sliding snow avalanches, mudslides and slides. Rockfalls caused the Pusteria train line to be unpassable. The Brenner motorway in Wipptal, national roads in Val Pusteria, Val Badia and Val Venosta were temporarily blocked. The avalanche warning was 4 – high in the entire province. There was considerable damage in forested areas: due to the heavy snow approximately the amount of wood that would be cut in a year was damaged and had to be removed from the forests with the greatest impacts in Val Pusteria and in the area around Bressanone. The damages were localised in the forests rather than clear cuts. There were blockages of rivers due to fallen trees in some areas causing also erosion (Autonome Provinz Bozen, 2019). - Between 11th and 17th November 38 mass movements were reported for South Tyrol. 19 of those events occurred on November 17th. Of these movements 20 were wet, four very wet and 6 moist. 13 of the events happened in forested areas, nine in settlement areas, six on agricultural land. There is no information on damage caused by these events in the IFFI database (Source: IFFI database, Autonomous Province of Bolzano) - Local newspaper reported of strong snowfall, power outages and traffic disruptions - Between 15th and 17th November there were 854 deployments of South Tyrolean fire fighters (between 11th and 14th November no deployments were recorded). This amounts to more than half of all deployments in 2019! For 516 of the 854 deployments "branch" is given as the reason, for 79 "severe weather", for 60 "landslide" and for further 30 "water damage".	

- Seven hydrological events were recorded on 15th and 16th November with the assessment after the event on 16th of November in western South Tyrol reporting damages to a riverbank, material being deposited in an industrial zone, on a fruit orchard and blocking a track. These damages occurred due to debris flows following heavy precipitation (Source: Dept. of Civil Protection, ED30).				
Cross border relevance:	☒ proven	☐ probable	☐ unlikely	☐ none
Reference(s): - TransAlp Del. 2.2 - IFFI database, also available in the WebGIS of the province of Bolzano: https://maps.civis.bz.it/#context=PROV-BZ-HAZARD - Deployments fire fighters shapefile (Autonomous Province of Bolzano) - Dept. of Civil Protection, ED30 hydrological event database - Autonome Provinz Bozen/Abteilung Forstwirtschaft. II. Bericht: Schneedruckschäden November 2019. available at: http://www.provinz.bz.it/land-forstwirtschaft/forstdienst-foerster/downloads/DE_II_Bericht_Schneedruck_2019.pdf (last accessed: 13 December 2021) - Rainews 17. November 2019. Available at: https://www.rainews.it/tgr/trento/articoli/2019/11/tnt-maltempo-alto-adige-03d01043-4418-4b3c-b1cb-f09ef290ca01.html (last accessed: 13 December 2021)				

Table 8: Characterisation of extreme weather event of 15/16th November 2019 in South Tyrol

Date: 2020-December-05/06 (“Xunav”)	**Hazard type / trigger:** intense rainfall and snowfall			
Georeferencing: - Point location of mass movements (IFFI data), which could potentially have been caused by the extreme weather (cause of mass movements on those dates given as “intrinsic”) - Spatial distribution (point features) of fire fighter interventions (Source: Civil Protection) - Point locations of damages assessed due to hydrological events (Source: ED30, Civil Protection)				
Intensity: maximum amount of rainfall in South Tyrol: 274.4 mm (05-Dec-2020)				
Meteorological/hazard narrative: A humidity vortex coming from the South brought heavy precipitation to the Alps on 5th December 2020. In mountain areas this led to very intense precipitations in some places. For the city of Trento of 102 mm of precipitation were observed. At higher altitudes there were heavy snow falls. Several places in Austria recorded high precipitation amounts, e.g. Lienz: 135 mm and Sillian: 144 mm. On December 6th in Ronchi dei Legionari near Trieste, on the other side of the main Alpine ridge, 106 mm were recorded. Equally high precipitation amounts were observed in Easttyrol. In the Italian mountain areas more than 200 mm of rain were recorded with especially large quantities in the Province of Belluno (between 200 and 400 mm) (Source: Del. T2.2). **Impacts South Tyrol:** - In the IFFI database 21 mass movements were recorded on December 5th, 77 on December 6th and 10 on December 7th. For all 108 events the cause “intrinsic” was given. The large majority, 93, of these mass movements were classified as wet. 57 events happened in the forest, 41 on grazing meadows, seven in settlement areas and three affected agricultural land. Regarding damages for two events it was recorded that a river got blocked. - On 5th and 6th December 2020 the south tyrolean fire fighters deployed 836 times out of 1350 deployments in total in 2020. Of these 836 deployments over the two days of the storm event 361 were due to “branch”, 232 due to “severe weather”, 40 due to “water damage” and 39 due to “landslide”. - Eleven hydrological events were recorded on 5th and 6th December. In one location damage to a meadow due to mudflow was recorded.				
Cross border relevance:	☒ proven	☐ probable	☐ unlikely	☐ none
Reference(s): - TransAlp Del. 2.2 - IFFI database, also available in the WebGIS of the province of Bolzano: https://maps.civis.bz.it/#context=PROV-BZ-HAZARD - Deployments fire fighters shapefile (Autonomous Province of Bolzano) - Dept. of Civil Protection, ED30 hydrological event database				

Table 9: Characterisation of extreme weather event on 5/6 December 2020 in South Tyrol

2 ANALYSIS OF DATA QUALITY, ORIGIN, GEOCODING ACCURACY AND DAMAGE/IMPACT REPORTING FROM USED SOURCES – MAJOR DIFFERENCES, PRO´S & CON´S

In the following, the databases / sources for describing the selected events and their impacts in the three project regions East Tyrol (Austria), South Tyrol (Italy) and Cordevole Valley (Veneto, Italy) are characterised about the available contents, usability, geocoding and references to event relevant damages and consequential damages.

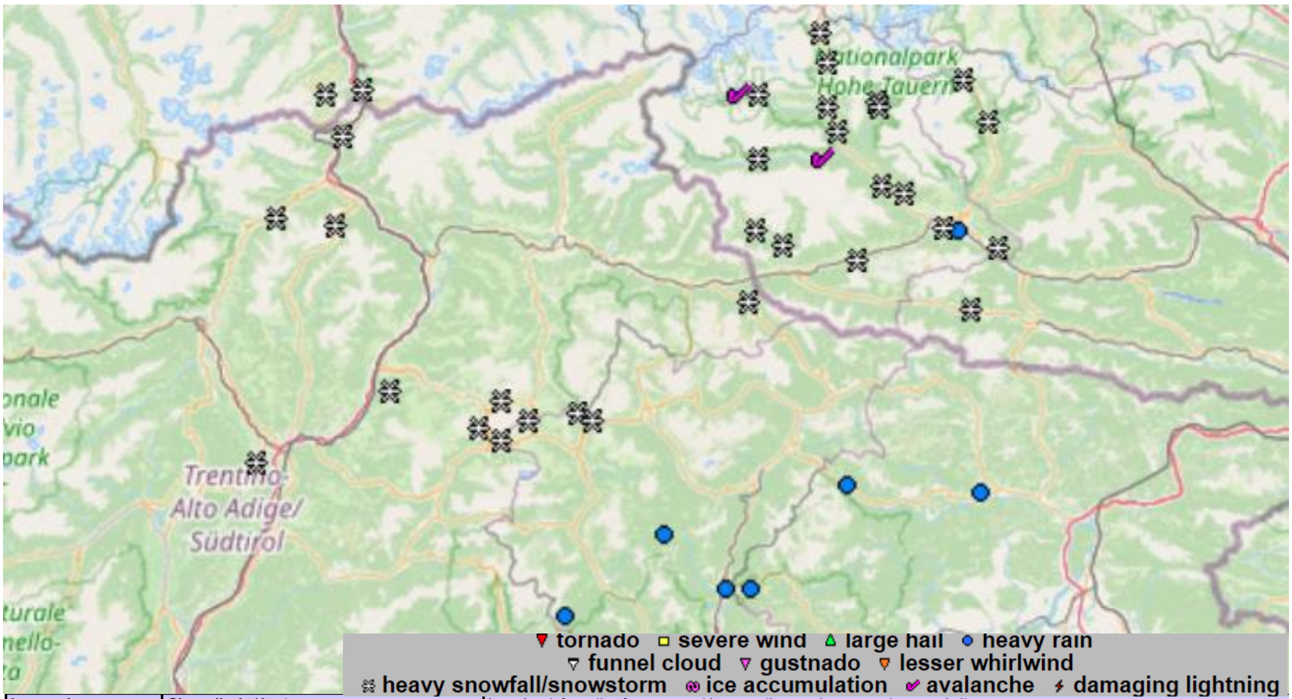
2.1 SOURCES / DATABASES USED IN EAST TYROL

ESWD (European Severe Weather Database)

General:

The European Severe Weather Database (ESWD) is provided by the European Severe Storms Laboratory (ESSL), an informal, non-profit association consisting of a network of European scientists. Objective of the ESWD is to collect and provide detailed and quality-controlled information on severe convective storm events and it´s phenomena over Europe. In collaboration with several partners including networks of voluntary observers, meteorological services and general public, tens of thousands of reports have been collected up to now. Most of the information contained in the ESWD originates from weather service reports on a website as well as media reports in newspapers, radio or television broadcasts.

Via the user interface at https://eswd.eu multiple selections can be made. First of all, the time period in which the events occurred has to be set. The time span theoretically goes back to the year zero. It is not known from when events were actually fed into the database. Of particular interest for cross border analyses is that one can apply the selection of events to all European countries. In addition, the geographic extent can be set to search for events via coordinates. Thus storm events can be queried for cross-border areas. Events will be listed and shown on the map covering the time period entered and the region defined. The example screenshots in Figure 7 7 show the ESWD registered events (all hazard types) for the approximate geographic extent of the transboundary region of TransAlp for the time period 4th to 7th of December 2020 (Depressions Xunav/Wenke/Yvonne).



heavy rain to map	**Obervellach** Kärnten **Austria** (46.94 N, 13.20 E) < 10 km **06-12-2020** (Sunday) **12:00** UTC (+/- 3 hrs.)	based on information from: a report by a weather service, a report on a website precipitation: **133 mm** duration of precipitation: 42 hours peak accumulated precipitation: 41 mm duration of peak precipitation: 6 hours Impacts: Road(s) impassable or closed, Basement(s) flooded, Farmland flooded, Land- or mudslide(s) *Mudflow, debris flow and landslides because of heavy rain. Cellars and farmland flooded.* https://www.facebook.com/FFObervellach/?__cft__[0]=AZXXNjBJJNFslMB5WzN9t9CgYNxZcCyibV0V7LPY-FbeWH_Ky0xn_3kW UPvr2k-wKRuQ5KqRAJWbhyrQNGZG2UIR3QGr_QaCvwr1&__tn__=-UC%2CP-R Reference: Reported by local fire brigade of Obervellach on Facebook. TAWES station Obervellach/ ZAMG. WMO station: 11262 report status: **plausibility check passed** (QC0+) contact: Thomas Pfeifhofer (Voluntary Observer Person)
heavy snowfall/snowstorm to map	**Flattach** Kärnten **Austria** (46.94 N, 13.13 E) < 10 km **06-12-2020** (Sunday) **12:00** UTC (+/- 3 hrs.)	based on information from: a television or radio broadcast, a report on a website Impacts: Road(s) impassable or closed, Inhabited place(s) cut off from transport infrastructure, Evacuation order by authorities *10 houses with 27 inhabitants evacuated.* https://kaernten.orf.at/stories/3079329/ Reference: "Lawinengefahr: Vielerorts keine Schule", ORF Kärnten, 06 DEC 2020. report status: **report confirmed by reliable source** (QC1) contact: Thomas Pfeifhofer (Voluntary Observer Person)
heavy snowfall/snowstorm to map	**Siflitz** Kärnten **Austria** (46.78 N, 13.38 E) < 3 km **06-12-2020** (Sunday) **12:00** UTC (+/- 6 hrs.)	based on information from: a television or radio broadcast, a report on a website Impacts: Road(s) impassable or closed, Inhabited place(s) cut off from transport infrastructure, Large tree branch(es) broken *Inhabitants cut off of infrastructure, because the only driveway is blocked.* https://kaernten.orf.at/stories/3079329/ Reference: "Lawinengefahr: Vielerorts keine Schule", ORF Kärnten, 06 DEC 2020. report status: **report confirmed by reliable source** (QC1) contact: Thomas Pfeifhofer (Voluntary Observer Person)
heavy rain to map	**Lienz** Tirol **Austria** (46.81 N, 12.83 E) < 10 km **06-12-2020** (Sunday) **08:00** UTC (+/- 3 hrs.)	based on information from: a report on a website, a newspaper report Impacts: Basement(s) flooded *floodings in the region near Lienz reported, multiple cellars flooded* https://tirol.orf.at/stories/3079327/ Reference: Osttirol: Schäden durch Lawinen und Regen, ORF Tirol, 6 Dec 2020. report status: **report confirmed by reliable source** (QC1) contact: Gabriel Strommer (ESWD management)
avalanche to map	**Hopfgarten in Defereggen** Tirol **Austria** (46.92 N, 12.52 E) < 5 km **06-12-2020** (Sunday) **06:15** UTC (+/- 30 min.)	based on information from: photograph(s) and/or video footage of the inflicted damage, a report on a website, a newspaper report type of avalanche flow: a dense flow avalanche snow mass characteristics: a wet snow avalanche *several houses damaged* https://tirol.orf.at/stories/3079327/ Reference: Osttirol: Schäden durch Lawinen und Regen, ORF Tirol, 6 Dec 2020. report status: **report confirmed by reliable source** (QC1) contact: Gabriel Strommer (ESWD management)

Figure 7: Information retrieved following a selection of multi-hazards, the approximate geographic extent of the TransAlp study area for the time span 4th to 7th December 2020. The colours in the description of the event refer to the hazard type, i.e. heavy rain events are shown in blue and avalanche events in pink (source: European Severe Weather database (https://eswd.eu/))

Data quality & geocoding:

The reported event impacts are subject to quality checks and are marked with "as received (QC0)", "plausibility check passed (QC0+)", "report confirmed by reliable source (QC1)" and "scientific case study (QC2)". The geographic location (geocoding) is referencing the municipality and coordinates, although the coordinates do not necessarily correspond to the event location. Usually a radius with an accuracy (e. g. < 3 km) is given. In addition to the event date, a time is also specified here, which is also given with a span depending on the reporting (e. g. +- 1 hour).

Impact & damage reporting:

The info box lists information such as the intensity of the event (amount of precipitation, wind speeds, hailstone sizes, intensities according to international scales), the duration of the event and the source of the entry including a link to corresponding media reports. In general, the entries of the events are mostly based on reports on websites, reports by weather services, television or radio broadcasts and photographs and/or video footages of inflicted damages. Organisations such as fire departments or local authorities are partly included as data sources. The original links to the corresponding sources are generally listed, thus the sources can be traced back. Damages are described briefly and concisely in text form in the same box as the intensity, the sources and other information. Monetary values are generally not stated.

VIOLA – ZAMG

General:

Until 2015, weather events causing damage were recorded by ZAMG in tabular and text form and published in annual reports and on the ZAMG website. Since 2016, severe weather data are integrated into a digital platform based on the VIOLA project (figure 8). This is done in accordance with guidelines of international organizations such as ESSL (European Severe Storms Laboratory). Severe weather events that caused socio-economic damage can be queried online with filtering options on a national level (Austria). Events can be filtered by natural hazard type and by the year and month in which they occurred. In addition, users can search for impacts due to indirect effects of extreme weather events. The content is almost exclusively derived from media reports. The aim of the publicly accessible, unified database is to provide data for basic research, the construction and insurance industries, or spatial planning offices.

Data quality & geocoding:

With regard to geocoding, it must be noted that the geographic location is de facto not provided as geodata. Events and damages are referenced to municipalities in which they occurred. Thus, there may be considerable inaccuracies regarding event and damage locations. The information on where there were impacts is also generated from media reports.

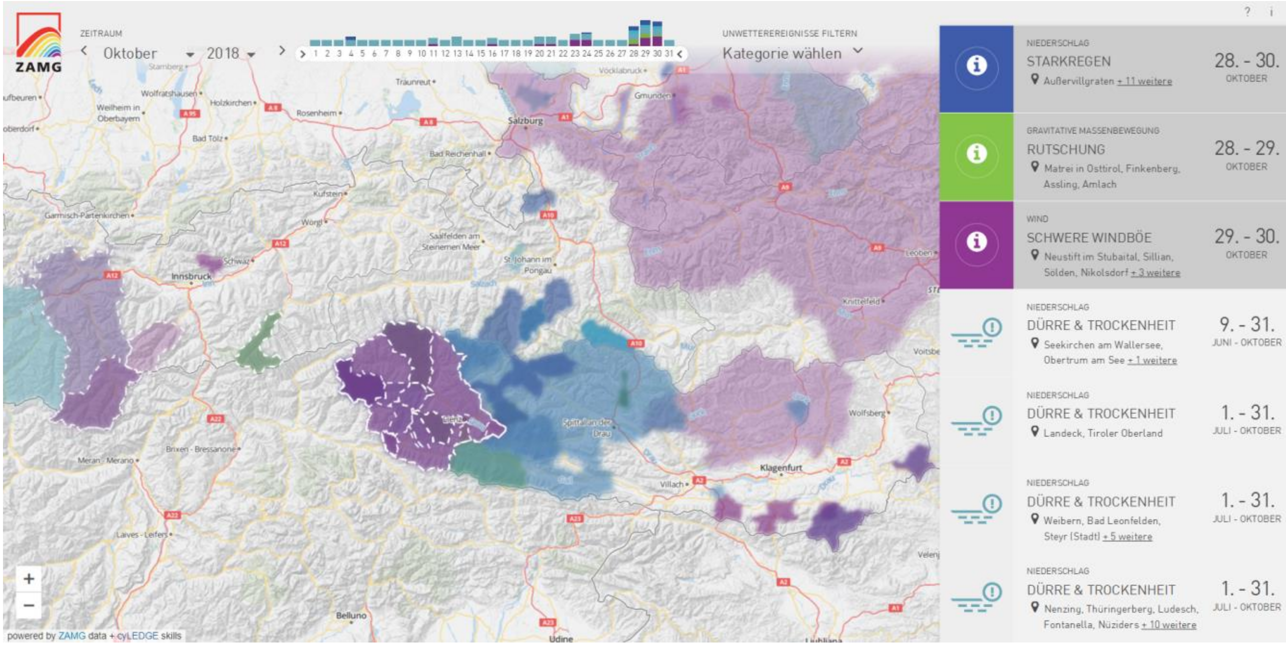


Figure 8: The VIOLA platform. This query result shows multi-hazard events and the available geocoding on the municipality level for the time period 28th to 30th October 2018 in the transboundary region of East Tyrol. (Source: https://www.zamg.ac.at/cms/de/klima/klima-aktuell/unwetterchronik?jahr=2021&monat=10)

Impact & damage reporting:

Hazard types are divided into 8 categories and 31 sub-categories. A hazard event can affect one or several municipalities or entire federal states. The portal provides information on hazard type, the location (e.g., municipality), event date, some general information about the event and impacts (incl. impacts on human lives and on different assets). Damage reporting includes direct impacts on infrastructure, e.g., destroyed infrastructures as well as indirect impacts such as for instance closed roads, closed schools, and evacuated houses. Event intensity (e. g. precipitation amounts, wind speeds, grain size in the case of hail, material deposited in case of gravitational mass movements) is not provided. However, some of this information lacks can be obtained from the "Spartacus" records (see T2.2).

In general, the data inputs can be read online. For further applications the raw geospatial data has to be requested to ZAMG within the framework of a user agreement.

Austrian Torrent and Avalanche Cadastre (WLK)

General:

The national Austrian torrent and avalanche register (WLK) of the Forest Service for Torrent and Avalanche Control (WLV) is a digital, geoinformation management system for the standardised, spatial management of natural hazard information in Austria, based on §102 para. 5 lit. d of the Forest Act 1975 (ForstG 1975). The objective is to ensure the collection, processing, evaluation, data storage and preparation of specialised information and to support the population in self-protection / self-preparedness in case of a disaster. The digital torrent and avalanche register is an effective tool in the operational and strategic work and management process for coping with natural hazards. As a geoinformation management system, the torrent and avalanche cadastre aims to provide efficient support in ongoing planning processes as well as sustainable and comprehensible quality assurance of the results. It is thus also a basis for organisation-wide controlling for the provision of control-relevant key figures in the strategic management process. The information system is accessible for authorised users only, which are usually employees of the Torrent and Avalanche Control. Additionally, there are some editors in related public institutions like the Austrian Research Centre for Forests. The data fed into this cadastre is visible in some publicly accessible geographical information systems like in the natural hazard maps of the federal ministry for agriculture, tourism and regions (https://maps.naturgefahren.at/?g_card=erosion#).

Data quality & geocoding:

The "Events" module displays all events recorded in the digital event register of the torrent and avalanche control (http://naturgefahren.die-wildbach.at). After authorisation, reports on events concerning floods, avalanches, landslides, rockfall and precipitation can be created here, including their location (figure 9). In order to ensure interdisciplinary comparability of the collected event information, the standardisation of natural hazard documentation on the basis of a generally applicable minimum standard is a prerequisite. This minimum standard ("5W standard") essentially comprises the information on which natural hazard was observed (what) in which area (where) at which time (when) by which person (who) and optionally what the presumed reasons for the triggering were (why). The locations of the events are mostly given as point locations. For some attributes, the "MAXO" scheme is used noting whether the data collected was measured, is an estimation, whether information is still being collected or it can no longer be determined.

Impact & damage reporting:

The cadastre usually contains an overview of the dominant process type, a detailed process description, intensities, the time of the event, the person (recorder) responsible and the location (province, district, municipality) (so-called 5W standard). More detailed information provides the general damage description, damage classification and the damage values (€). However, this explicit information on damages is only partially given. Mostly the damage documentation is qualitative (descriptive). Usually, all the events and their impacts are collected and digitized only by experts such as employees from the Austrian Torrent and Avalanche Control.

Figure 9: Geocoding of a landslide event in the Cadastre (WLK) of the Austrian Torrent and Avalanche Control. Source: Wildbach- und Lawinenkataster (WLK)

For example, a total of 202 damage reports were entered in the digital torrent and avalanche register (WLK) throughout Austria in 2018. These reports are divided into the categories water (188), rockfall (5) and landslide (9). Avalanches are in general treated separately. According to these surveys in the WLK, the majority of the damage was caused to traffic or passenger transport facilities (41). Buildings (35) were the second most affected. This was mainly due to the displacement process of debris flow like solids transport (22). The following table (Table 10) shows the reported damages (left column: which kind of infrastructure was affected?) and the process types which led to these impacts (top row).

	HW	FF	MF	MG	SS	RU	Gesamt
Gebäude	7	4	22	1	3	2	35
Gebäude Fremdenverkehr	2		2	1		1	6
Gebäude Verkehr/ Versorgung/Gewerbe/ Industrie	1		6				7
Land-/forstwirtschaftliche Gebäude		1	3		2		5
Öffentliche Gebäude					1		1
Private Wohn- und Nebengebäude	4	3	10			1	15
Sonstige Gebäude			1				1
Material- /Bringungs-/ Förderanlagen	1	1	4	2			7
Material- /Bringungs- /Erschließungsanlagen	1	1	3	2			6
Sonstige Material- /Bringungs-/ Förderanlagen			1				1

Mobile Personentransport-mittel		1	2	1			3
Bahngarnituren/Züge (ÖBB)		1					
Kraftfahrzeuge			2	1			3
Verkehrs-/Personentransport-einrichtungen	3	6	31	1	1	5	41
Bahnanlagen/Trassen (ÖBB)			2				2
Sonstige Verkehrs-/Personentransportanlagen			6			1	7
Straßenanlagen	3	6	23	1	1	4	32
Versorgungseinrichtungen (Energie, Nachrichten)			1				1
Masten und Versorgungsanlagen			1				1
Wasserversorgungs- bzw. entsorgungsanlagen			4				4
Wasserkraftanlagen			3				3
Wasserversorgungsanlagen			1				1
Einflüsse auf Morphologie/Relief	10	81	2		1		13
Einflüsse auf Morphologie/Relief	10	81	2		1		13
Gerinnemorphologie	9	81	2		1		12
Sonstige (morphologische) Naturraumauswirkungen	1						1
Wirtschaftliche Kultur-/Nutzungsschäden	1	1	1			2	4
Forstwirtschaftliche Nutzung	1					1	2
Landwirtschaftliche Nutzung		1				1	1
Sonstige wirtschaftliche Kultur-/Nutzungenschäden			1				1
Gesamtergebnis	22	94	67	5	5	9	202

Table 10: Types and numbers of affected assets and corresponding hazard types (source: WLV)

The WLV annually elaborates a comprehensive report based on the contents of the annual entries in the online cadastre WLK. Special weather situations or depression systems with corresponding hazardous consequences are particularly highlighted and described in detail. While annual textual reports are free available online (e. g. at the page of the ministry BMLRT), geospatial raw data must be explicitly requested and signed with a user agreement.

2.2 SOURCES, DATABASES USED IN VENETO

General:

As regards the Veneto Region, there is not an official database for the collection and management of data on hydrogeological instability. The data relating to the ground effects are, in fact, managed by various public administrations (such as local municipalities, forestry departments, soil defense and civil protection offices, or administrations on a state scale). However, the data is also collected and often not shared by universities and research institutions as well as by local authorities and firefighters. As regards the study area of the Cordevole Valley, data on damage related to meteorological events were collected by analysing the database of local newspapers. Very often, in fact, public institutions work to collect data during extreme meteorological events that lead to even catastrophic effects in the territory, but do not collect data when the failures are of minor importance. Nevertheless, in order to make a correct statistic to identify, for example, triggering landslides thresholds for civil protection purposes, it is extremely important to enrich the dates with events of different magnitudes to try to discriminate the alert levels. The situation just described leads to a series of data collected over several decades, with different methodologies and technologies, which can however be integrated in order to achieve the best possible result in terms of scientific purposes or decision-making processes. The data collected in the study area can be roughly divided into two main categories: those geocoded and those not.

NON-GEOCODED DATA:

The AVI special Project

The AVI Special Project was commissioned at the end of the 90s by the Minister for the Coordination of Civil Protection to the National Group for Defence from Hydrogeological Disasters (GNDCI) of the National Research Council (CNR) in order to carry out a census of areas historically vulnerable to geological (landslides) and hydraulic (floods) disasters. During the census phase, 22 local newspapers were consulted, for a total of over 450,000 newspaper copies; about 1000 technical and scientific publications were found and analysed; and interviews were conducted with 150 experts in the field of landslides and floods. Based on all the information recorded a digital archive containing over 17,000 pieces of information relating to landslides and over 7,000 pieces of information relating to floods were created.

Data quality & geocoding:

The degree of completeness and reliability of the historical archive was also assessed, checking in particular the consistency of the information contained, and correcting most of the errors. In 1996, a first synoptic map of the main localities affected by landslides and floods was published. Since then, steps have been taken to locate, as points and at a scale of 1: 100,000, all the locations known to have been hit by landslides or floods. The news for which it was not possible to identify the affected locality with reasonable certainty were mapped in correspondence with the municipal capital. The data are present on paper maps and are not geocoded. The project database clearly indicates the municipality affected by the event but the exact location is not always described. The data present in the AVI project are therefore useful for recovering information on the calamitous events that occurred between the 80s and 90s and, therefore, to populate any studies for the identification of triggering thresholds for landslides with as many data as possible.

The SCAI special Project

The SCAI special project was promoted by GNDCI as part of Line 2 "Prediction and prevention of landslides at great risk" to respond to the knowledge and research needs of Italy, and in particular to verify the situation relating to the conditions of stability of the inhabited centres and therefore directly associated with high-risk conditions and is carried out in close relationship with the activities and interests of the Civil Protection Department. The research consisted in the preliminary census of landslides in inhabited centres and, in a second phase, in the collection, according to a specially developed file, of the geological, geomorphological and geotechnical characteristics of the main events. The censuses have highlighted that the real situation of instability in urban areas is in general much more serious than that envisaged in previous reports.

Local newspaper database

As mentioned in the premises of this chapter, numerous data relating to hydrogeological instability phenomena have been collected by making a careful search in the databases of local newspapers. in fact, thanks to the use of keywords, it is possible to trace all the news relating to certain phenomena in particular areas. Although it is not of particular scientific value, being able to trace news reports of small landslides or avalanches allows us to better refine any trigger thresholds of these phenomena to better structure civil protection plans.

GEOCODED DATA:

IFFI Project

General:

The IFFI Project (Inventory of Landslide Phenomena in Italy), created by ISPRA and the Regions and Autonomous Provinces, provides a detailed picture of the distribution of landslides in Italy. To date, the inventory has registered 620,808 landslides affecting an area of approximately 23,700 km2, equal to 7.9% of the national territory. The data is updated to 2017 but work is continuing to keep the database constantly updated. The recorded data are published on a web platform that allows the consultation of data, maps, reports, photos, videos and documents relating to individual landslides (figure 10).

Data quality & geocoding:

All the data are georeferenced and it is also possible to share on social networks and download data both as map and shapefiles.

Figure 10: The webGIS of he IFFI project (source: ISPRA)

<u>AVALANCHE WebGIS by ARPA Veneto</u>

ARPA Veneto has recently published the regional WebGIS avalanche portal (figure 11). The service was created to provide direct and targeted access to information, making a constantly updated and easily accessible information tool available to citizens, technicians and administrators to acquire the avalanche reality of a specific territorial area. The portal contains the cadastre of the avalanche sites, or the Probable Location Map of the Avalanches (C.L.P.V.), the cadastre of avalanche defense works, avalanche events collected over the years by the Arabba Avalanche Center and the boundaries of the areas exposed to avalanches risk (P.Z.E.V.).

The cartographic portal has significantly expanded the information associated with avalanche sites, mitigation works and avalanches in the strict sense, by inserting additional data such as cards, photographic documentation and in general all information deemed useful to provide complete information.

Users are allowed to view all the elements contained, even with the use of pre-set or customised queries and filters, with the ability to print the map and the cards associated with the individual elements, including photographic documentation. For registered users it is also possible to download data in table format and shapefiles.

Figure 11: The avalanche WebGIS (Source: ARPA Veneto)

Civil Protection Reports

Since 2009, the "Centro Funzionale" of the Civil Protection Department of the Veneto Region issues, following extreme weather events, a detailed report in which both the meteorological event, in all its quantitative aspects, and the damages recorded are analysed. Furthermore, a reporting service on a webGIS platform is being implemented which allows some predefined users to upload images relating to landslides or floods in real time, geolocating the information that can be seen from the civil protection operations room (Figure 12).

Figure 12: Excerpt from the report of the "Centro Funzionale" drawn up following the VAIA storm. The figure shows the geolocation of the events recorded also through the experimental real-time data collection system

2.3 Sources / databases used in South Tyrol – Alto Adige

The IFFI/IdroGEO Database

General:

The IFFI (Italian landslide database) is an inventory of gravitational mass movements for Italy. It was recently re-newed and the new project website run by ISPRA is called IdroGEO: https://idrogeo.isprambiente.it/app/iffi?@=44.805587146448715,11.493372658106193,2 (). IdroGEO also visualises 24 and 3 hour rainfall data. The IdroGEO portal allows anyone to view and download information on historic mass movements. The Province of South Tyrol has made all of it's information available in IdroGEO and is continuously updating it when new mass movements occur. Access to the full characterisation and assessment protocols of the events can be granted upon request to the Geological Office. The IFFI database represents one key information source to assess hazards, to plan protection measures and is an important source of information for spatial planning. The inventory was created in 2001 according to the regulations of the IFFI project. Data on events collected prior to 2001 by CNR (National Research Council of Italy) were added to the inventory. The IFFI database contains events as well as areas of known mass movements in South Tyrol. The database includes events known to the Department of Geology because of reporting or from historical records and archiving. Reports are usually from settlement areas and infrastructures except of events is of exceptional large sizes. The database is being updated continuously (Source: IFFI - Inventar der Erdrutschphänomene (provincia.bz.it)). Geospatial data of the IFFI events is available for download from the OpenData web portal of the Autnomous Province of Bolzano (see section 3 on OpenData portal) and from the IdroGEO portal (figure 13).

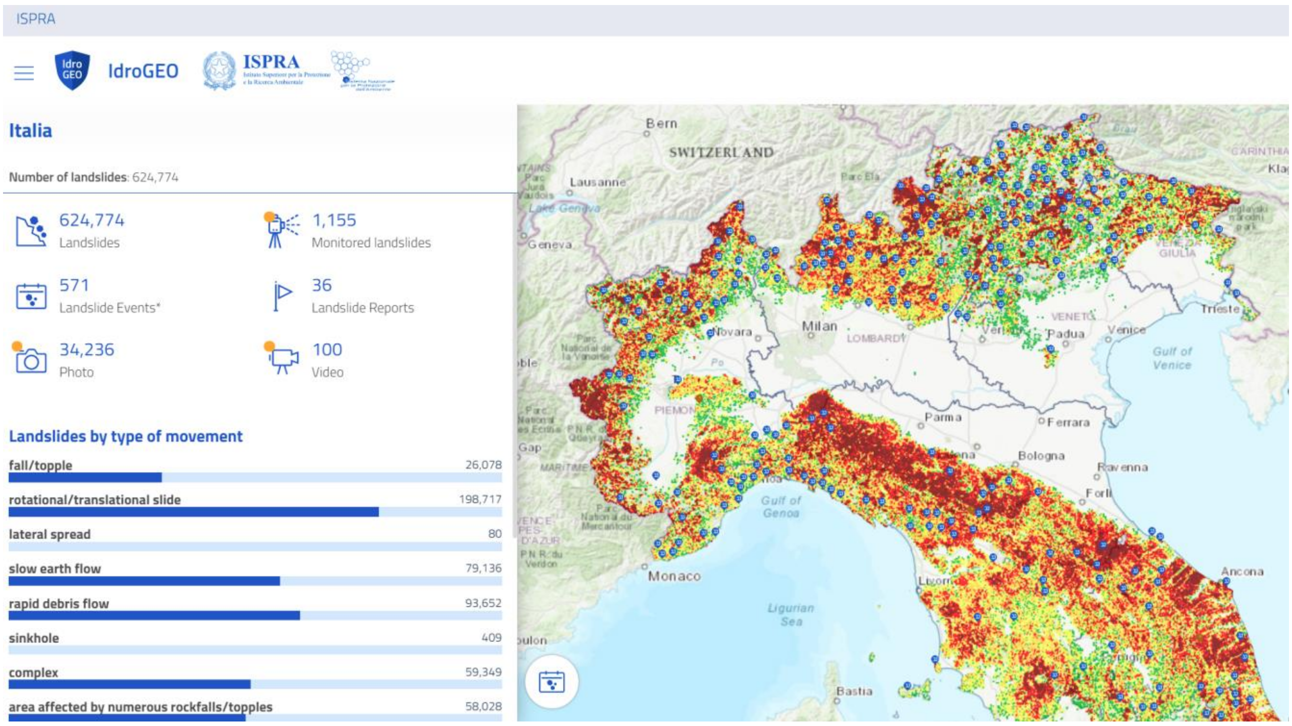


Figure 13: IdroGEO – new webportal run by ISPRA visualising information on mass movements in Italian provinces (Source: https://idrogeo.isprambiente.it/app)

Data quality & geocoding:

The IFFI mass movement event database consists of point locations with a number of relevant attributes describing the event and for further use to assess the hazard and plan protection measures. At the time of writing this report 11,144 mass movement events with a time range of 1821 to 2021 could be retrieved from IdroGEO.

A specific survey protocol describes the findings obtained by a geologist in situ while assessing the mass movement. The information gathered includes who did the assessment when, provides a narrative and situation analysis, damages, lists assets at risk, protection measures implemented and details the interventions that are recommended following a pre-defined list of criteria. Each record includes a small-scale and a large-scale map as well as photos of the event and damage caused.

Impact & damage reporting:

Extreme weather events can be a trigger for mass movements. However, such causal information is not available in the IFFI database. In the analysis of the database for the three major extreme weather events listed in section 2 it showed that for the vast majority of the mass movements recorded in the period of the extreme weather events “intrinsic” causes were given.

Regarding impact data, impact on rivers, such as blockages and deviations are reported only for about 2% of the events in the database. Regarding other impacts 80% of those events for which damage reports were created (around 90% of all events) the database provides information on “yes, there was direct damage”. However, in majority of events what kind of damage is not recorded. For one single event from 5th October 1998 damage to a dam is recorded. For five events damage to a dyke (argine) was reported, in 25 events people were evacuated. The data available for analysis when writing this report did not allow to infer information on damage to buildings, infrastructure, agriculture, forests or other assets. For 12 % of all entries information on impacts on human lives are recorded. The IFFI database does not contain spatial information on impacted areas.

Protocols from visuals inspections of the events in the IFFI database are made available upon request to the Geological Office are can be viewed by registered users on the IdroGEO platform.

In summary it can be said that the IFFI database is not providing 1) information whether a mass movement event was (potentially) co-caused by an extreme weather event and 2) in most cases it is not providing impact information. Direct impacts are provided for few cases, however, extracting this information requires a good understanding of how to use the IFFI database.

ED30 hydrological event database

General:

ED30 (Event documentation of Province department 30) is a project and a database of the Hydrological office, which is part of the Civil Protection Department of the Autonomous Province of Bolzano/Bozen. In the database all the information available of relevant, historic and present events such as inundations, debris flow, slides and avalanches are collected, elaborated and made available for spatial planning and civil protection purposes. The records include an assessment protocol, a digital database, geospatial data, fotos and videos.

This data is either available upon request from the Province of Bolzano or basic spatial information can be viewed online in the *Hazard browser* of the Province (https://maps.civis.bz.it/#context=PROV-BZ-HAZARD).

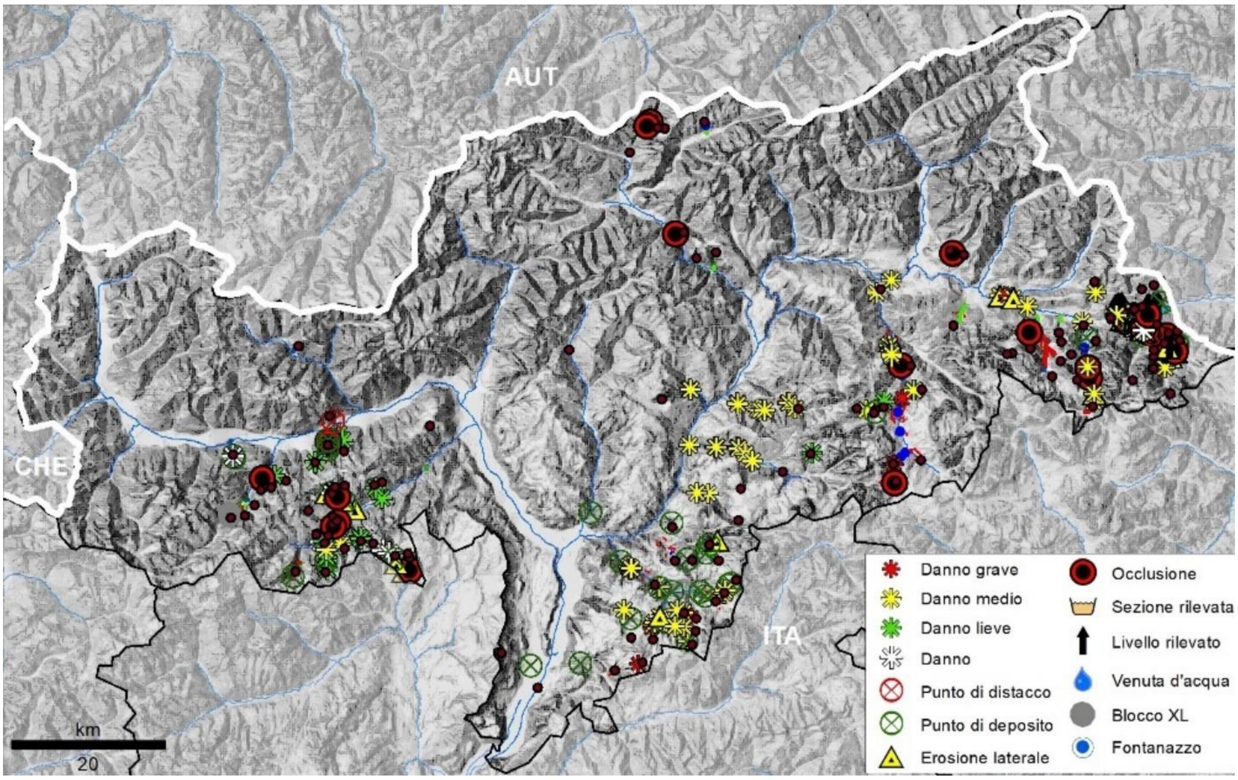


Figure 14: Hydrological events (ED30) during storm Vaia with locations with damage in SouthTyrol (Data source: Autonomous Province of Bolzano/Bozen)

Data quality & geocoding:

The ED30 database consists of a number of GIS layers representing the event information as points, lines and polygons. Each event has a unique identifier. The information mapped considers hydrological and morphological aspects of the event such as erosion at the river banks, water leakage, sediment deposition and inundation area, amongst others. There is an assessment protocol of each event including assessment reports of damages, weather conditions, event trigger mechanisms, event characteristics as well as photographic evidence.

Impact & damage reporting:

In ED30 damage information is represented as point locations and classified as damage, minor damage, medium damage, major damage. For most of the recorded damage locations the assessment includes a brief description stating what was damaged and to which degree. Line as well as areal features demarcate erosion and areas of material accumulation. In the assessment protocol each the hydrological events it is specified what was damaged: private buildings, cultural or natural heritage sites, telecommunication infrastructure, economic structures, agricultural areas, public service structures, vehicles, protective structures and transport infrastructure.

Forest Department, Province of Bolzano

General:

The Forest department (Abteilung Forstwirschaft) of the Province of Bolzano is tasked with the observation and maintenance of public forests in the province. The department also carries out measures and observation of damage to the forest due to different causes.

Data quality & geocoding:

The Forest department provides the Department of Civil Protection with geocoded data, either collected in the field or assessed through analysis of remote sensing imagery. No assessment of data quality is available, but comparison with data from independent sources confirms an overall satisfying quality of the geospatial data.

Impact & damage reporting:

Data related to damaged forest areas is provided in the weeks and months following a relevant event, although this is usually throughout a direct contact between the different departments of the Province, and the data are usually not directly available to the general public. The data do not include details on the damaging mechanism or other ancillary information.

Volunteering Fire fighters – Deployments

Volunteer fire fighters (FF) have a long tradition in South Tyrol. The FF are organised per village as well as larger regions within South Tyrol. For each intervention start and end time of the intervention, the geographic location (point), type of the intervention (categories are amongst others: “branch”, “severe weather”, “mass movement”, “avalanche”, “person trapped”) and size of deployment (technical small or large, fire small or large). The data is available upon request from the Civil Protection Department of the Autonomous Province of Bolzano.

Centre for Traffic interruptions

General:

Information on traffic disruption related to different causes is provided in South Tyrol / Alto Adige by a Provincial centre (https://traffico.provincia.bz.it/), who daily publishes a bulletin of information and a map showing the distribution of road interruptions and other traffic disruptions. Most of the listed disruptions relate to planned or extraordinary maintenance works and can include some basic information on the cause of the damage (e.g., a rock fall).

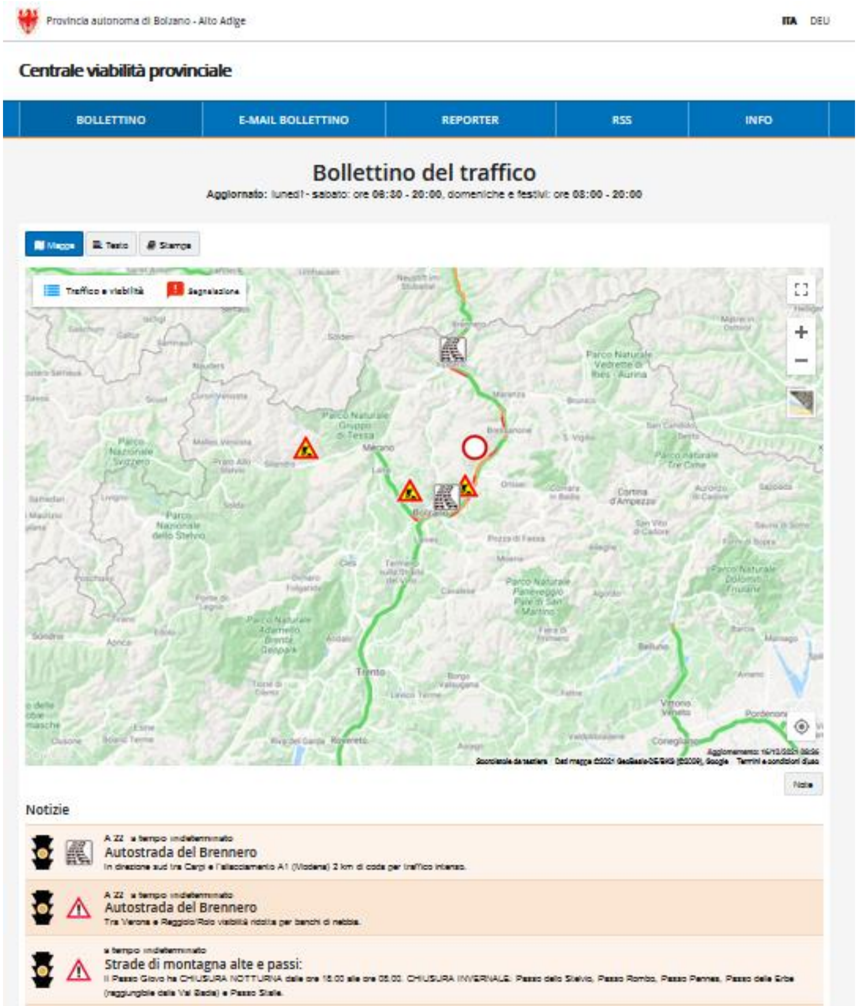


Figure 15: Public Daily Traffic disruption bulletin

Data quality & geocoding:

All interruptions and disruptions are geocoded and include several fields providing details on the type of disruption and on the expected duration, when available (e.g., if the interruption is related to a planned maintenance of the road). No assessment of the data quality is available. Although the daily data is available freely and also distributed in the Province´s open browser, there is no access to any underlying database, and no historical / past information is available (EURAC is since November 2021 updating daily a local copy of the database).

OpenData Portal South Tyrol/Hazard browser

The Autonomous Province of Bolzano/Bozen has an Opendata policy. It makes most of its data sets that are not sensitive openly available. Data and metadata can be accessed either from the Opendata Portal: http://daten.buergernetz.bz.it/de/dataset or using a Geocatalogue allowing to visualising the layers in a map: GeoKatalog (buergernetz.bz.it). There are also topic specific WebGIS available that allow to view and download the data. Most relevant for the analysis in this deliverable is the Hazardbrowser: https://maps.civis.bz.it/#context=PROV-BZ-HAZARD However, the data made available is reduced to basic information. If more detailed information on single events is needed a data request has to be made to the responsible Department or Office at the Administration.

2.4 MAJOR DIFFERENCES, STRENGTHS & WEAKNESSES

In Austria, information on the consequences of severe weather events is available among others in three main databases: the national VIOLA severe weather database, the online cadastre of the Austrian Torrent and Avalanche Control and the European Severe Weather Database (ESWD), providing partially geocoded shapefiles and/or text-based descriptions of where and when damages and interruptions occurred. The damage information in all the three mentioned databases is often descriptive, which means, that there is mostly a lack of information on monetary values.

The information in the databases VIOLA and ESWD are primarily derived from media reports, which can entail considerable uncertainties in terms of terminology, survey accuracy, traceability (e. g. process type, volume, damage totals, etc.). The Austrian national torrent and avalanche database (WLK) provides standardised quantitative geospatial information including causes of events and partially information on damages, collected by experts of the institution WLV, which is preferable from a scientific point of view.

An openly online reading access exists for the VIOLA and ESWD databases. The cadastre of the Avalanche and Torrent Control can be accessed by authorised users only. Austria does have a comprehensive database with a lot of downloadable contents (e. g. shapefiles on the road networks, building inventory or terrain models) (www.data.gv.at). However, there is still hardly any geodata in the form of past damage events. So, for gathering downloadable raw data, further steps are necessary in general. Data from the WLK and VIOLA (provided by the institutions WLV and ZAMG) can usually be requested and used free of charge after signing a user agreement. This leads to additional efforts in data acquisition in the frame of research projects or even civil construction engineering projects. Extensive data from the ESWD is only available for a fee.

In Veneto information are stored in several databases, in different format. Geocoded information available on GIS platforms are made available by the IFFI project in the new platform IdroGEO by ISPRA, and on the Avalanche WebGIS by ARPA Veneto. The IFFI project is a laudable effort to create an accessible and updated database containing different levels of information about landslides in all of the Italian regions. Data entry is responsibility of local authorities, there can be therefore a lack of uniformity from area to area in the regularity of the updates, and in the discrimination of the events to report (in terms of magnitude or impact on settlements, infrastructures, or other). A major issue of the database is the lack of information about the triggering moment for the majority of landslides, that makes a statistical analysis on the meteorological causes difficult to be trusted.

The Avalanche WebGIS by ARPA Veneto contains reported avalanches for the Veneto Region from the ‘80s to the present day. It reports both georeferenced information about event locations and about damages to buildings and infrastructures, protection measures, pictures of past events, etc. The database is kept scrupulously up to date, and every single observed avalanche event is reported, even when affecting a known avalanche site. It is possible therefore to analyse the frequency of avalanches in critical areas, necessary for the hazard and risk assessment. As a drawback the database, managed locally by the avalanche centre of Arabba, while very detailed in certain areas of the dolomites, may have fewer information about the pre-alpine locations.

The SCAI project provides geographical information in a printed form. While very useful to assess the status of unstable urban settlements in the late ‘80s, at the moment it has a limited applicability, with several problems related to the wide scale, lack in georeferencing, and especially to the lack of data revision to keep information up to date.

The AVI project, and the general research on local newspaper, give as an output of journal articles describing the event, where the spatial localisation of the events is often straightforward only to the locals. The potential of this database lies in the almost absence of discrimination of events made in terms of magnitude: even small ground effects, such as broken branches or minor rock falls, may be described, if disrupting the local traffic. Unfortunately both the database of the AVI project (‘80s-‘90s) and the research function of Corriere delle Alpi (from 2003) have quite a short lifespan.

Civil protection reports are drafted every time at least 5 rain gauges reach the orange alert, or at least 1 reaches the red alert. Reports consist in a description of the meteorological situation and hydrographic curve of the main rivers in Veneto. An account on relevant ground effects may be given, even in terms of economic losses. An automated procedure to allow local authorities to communicate any relevant ground effect is under development, but not active yet, leading to severe complications in ground effects data collection.

Overall, the main problem in Veneto is the intense fragmentation of information, where in the majority of cases small and medium events, that would be fundamental from a statistical point of view, are neglected.

In the Autonomous Province of Bolzano impacts and damages caused by severe weather events are not assessed systematically and are thus not available in a single database. Analysing and understanding the impacts of extreme weather events for South Tyrol requires to consult several different databases created and managed by different regional public institutions. Key datasets that can give some information on impacts are the hydrological event database from the hydrological office and the mass movement database created and maintained by the Geological office. In case of forested areas being affected the forest department will analyse damages to the forest and make the findings available in a report and on request the spatial data. All of the datasets need to be requested specifically from the respective authorities. Neither exist for the purpose of documenting event impacts and thus do not contain the needed information specifically, nonetheless some impact relevant information can be derived. Another indicative piece of information on the impacts events have caused available in South Tyrol are spatial data on the deployments of fire fighters. Traffic interruptions on the other hand are available on a live website as an alert, but not for past periods. All the datasets studied in the frame of this task are of good quality, i.e. they are spatially referenced, current and as far as we know complete (contain every event that was reported). However, the type of information recorded is not entirely suited for the analysis of event impacts on the region. In order to ascertain what the consequences of severe weather events were a lot of time and effort has to be put into the identification and sourcing of datasets, in understanding how the term “damage” is used and how the data is recorded in each dataset and on has to put all this information together to draw a complete picture of the impacts. The data gathering requires to be located in the region and have knowledge of the institutional setting.

It is also advisable to start thinking about a shared method of data collection. At present, in the various offices that are in some way connected with civil protection functions, data are collected by staff from different backgrounds and with uneven skills. For the drafting of this deliverable the heads of the different civil protection offices of the Italian Alpine regions were interviewed. From these interviews it emerges that one of the main shortcomings is linked to the scarcity of real-time information. Current technologies can certainly provide useful support for data collection and dissemination. Many civil protection offices are testing online platforms for data collection but there is still a lack of system agreement between forestry office technicians or similar operational structures to carry out systematic data collection campaigns during emergencies. The data collected should then form part of the database of damage related to hydrogeological instabilities in a given region.

3 Proposals and guidelines for a harmonization of cross border collection and geocoding of event data

"*There are many reasons for keeping records of natural disasters that have occurred. Whether it is the chronicler's urge to document, the need to compensate for damage, the motive of victim statistics, the research mandate of science, the sensationalism of the press or the legal necessity of preserving evidence, in each case the observer views the event with different eyes and chooses his or her own form of representation. Reports on alpine natural disasters are therefore always incomplete and subjective*." (Austrian Ministry for Agriculture, Tourism and Regions)

This statement is a meaningful indication of the current data situation in the individual countries and especially across the borders. Below are some observations and suggestions that could help to take steps towards uniformity and comparability of cross-border data. For the sake of clarity the proposed recommendations are subdivided according to the relevant phases of the disaster data management cycle, namely *scoping and coordination*, *recording and reporting* and data management and sharing. A further section targets the possible *data integration: beyond event recording*.

Scoping and coordination

In the scoping and coordination phase the specific scope of the data collection should be clearly indicated and, if necessary, coordination among different active institutions should be discussed in order to optimize the use of resources and ensure a proper quality of the resulting datasets. Currently, in both Austria and Italy there is a partial lack of coordination among the different bodies responsible for data collection, partly due to the fragmentation of the technical and administrative bodies, partly due to the variety of impact data and the strong interdisciplinarity that would be needed.

- the different institutions involved in the collection of different impact data related to natural hazards should **coordinate to have a consistent scoping of the data collection activities** according to the different operational needs and constraints and possibly considering a wider range of applications including applied research on impacts and risk either carried out by the local and regional institutions or in collaboration with research entities.
- The **scoping should involve a clear description of the overarching classification of impacts, damage and loss data** in order to have common vocabulary across different institutions. For instance, a taxonomy of impacts could be agreed upon, differentiating primary impacts (e.g., landslides and floods), secondary direct impacts (physical damage to buildings and infrastructure, injuries and fatalities) and indirect impacts / losses (e.g., road closures & diversions, building bans, evacuations, financial losses,).
- A **minimal, realistic and optimal set of information should be agreed upon**, in order to decide at which extent a proper coordination among different agencies could ensure meeting the desired specifications.

- **Suitable technical systems and solutions** that could streamline the data collection duty should be investigated, possibly building upon existing best practices of comparable institutions in other regions.

Recording & reporting

For this phase, also indicated as "reconnaissance" if carried out in the field, specific recommendations related to the collection of impact data are:

- **Recording of the site coordinates**
  Event reporting in major databases is often based on media reports (e.g. in the ESWD & VIOLA). Therefore, a big disadvantage is, that the geocoding is very rough (on a municipal scale or per coordinates +- several kilometres). The background is, that reporters' intention from media platforms is not to record exact coordinates. A descriptive short text and pictures where an event occurred (e.g., villages, hamlets, street numbers, rivers by their name, etc.) is often enough for the goal of reporting in media. It is clear, for example, that area-wide natural processes such as storms or precipitation cannot be recorded in an exact coordinative manner. However, this does not apply to various secondary processes such as landslides triggered by precipitation or forest areas damaged by storms. For point-shaped phenomena, a point localisation is to be aimed for. This is essential e.g. for statistical evaluations (such as a landslide susceptibility maps). A uniform cross-border geospatial localization would be desirable. This could be done, for example, by the Tyrolean Alarm Control Centre. All incoming calls under the different emergency numbers (133,122,144,140) are immediately spatially located, according to the respective description of the incident report. Although there is no GPS-based localisation on site, there is at least one that corresponds to the more or less exact location of the emergency services. An even better solution would be an obligatory recording of coordinates with a mobile device by one of the task forces (after the operation) and the standardized, (real-time) forwarding of these coordinates to at least a national or, in the best case, an international event database (such as ESWD).

- **Harmonized real time data collection system**
  To harmonize real time data collection, it is necessary to make agreements with forest services, fire brigades, flood management offices, etc. to populate a real-time database on an online platform so that the civil protection offices can access the information they need. Data should be structured in such a way as to highlight the type of phenomenon, magnitude, damage caused and possible short-term effects in the surrounding area. A virtuous example is the work done by the Valle d'Aosta Civil Protection Functional Centre, Italy. In this region, the Forest Service continually carries out inspections and compiles real-time descriptive sheets of the phenomena it detects, which are immediately published on the Functional Centre's portal with photographs and brief descriptions attached. This information then goes to populate a historical database and is available to all users. (https://cf.regione.vda.it/dissesti.php).

- **Free accessibility & data availability**

  For harmonisation of event data across borders, general free data availability is very important. Access only for internal users (as for example with the database of the Austrian Torrent and Avalanche Control) or user fees (as with the ESWD) are obstacles and make data exchange more difficult. Free data availability should at least be ensured for research institutions.

- **Uniform coordinate system**

  The choice of the coordinate system is also of particular importance for harmonising the cross-border exchange of information. Geocoding using geographical coordinates with longitude and latitude, for example, could be preferred. For example, the Austrian Service for Torrent and Avalanche Control uses the Lambert Conformal Conic projection, while the ESWD uses longitude and latitude.

- **Common database on a European scale**

  What is described in the previous points, such as the uniform coordinate system, the free accessibility etc, should refer to a single database managed on a European scale in which anyone, both from public administrations and from research organisations working on hydrogeological instability, should contribute to populate. This database could act as a collector of spatially distributed information on hydrogeological disasters and related damage, so that anyone wanting to use this data would have a reliable reference from which to draw as much information as possible. In order to do so, it is important that the database gathers all useful information to meet the needs of potential users, working for both spatial planning as well as for scientific research purposes. For this reason, each instability, in addition to being geocoded, should be discriminated by typology and described by the exact date on which it occurred, so that triggering factors can be investigated. Also, data should be able to define the magnitude of the phenomena and therefore the mass involved, the velocity and the frequency with which it occurs should be collected. In addition to hazard discrimination, the database should also make it possible to assess hydrogeological risks. To do so, in addition to the economic damage mentioned above, all elements that may quantify vulnerability, such as direct and indirect damage to infrastructure, should also be collected if possible.

- **Unification of the included attributes**

  Naturally, different data portals that contain collected geodata contain different attributes or content emphases. An example is the portals used for event documentation in Austria: while in the "VIOLA" database, the events are only localised to the respective municipality area, the aim of the torrent and avalanche cadastre (WLK) is a point localisation. There are also differences in the monetary quantification of damage. While the WLK at least includes the category "financial losses", the VIOLA database does not mention monetary values at all (in the free online visualization).

data integration: beyond direct impact recording

- **Reporting about financial losses**

  Financial loss resulting from extreme events can be a direct consequence of physical damage (e.g., related to partial or total loss of property) or can be indirect (e.g., in the case of service and business interruption), possibly extending to weeks and months after the occurrence of the event. In the case of cross-border storms such losses can be very significant and as such should be collected in a systematic and comprehensive way. To this purpose above all authorities and insurance companies should be involved. Even if data protection plays a central role, financial losses, mainly compensated with public economic resources or covered by insurance should be shared the extent necessary to properly inform impact forecasting models. Unfortunately, this is often not the case. For example, a well-known German reinsurance company had systematically collected critical information on loss events worldwide. This information, previously stored in a digital catalogue and made available to the public upon request, is no longer available. As for Austria, the survey and collection of financial losses is quite heterogeneous. While the meteorological service ZAMG does not quantify any damage in its online database "VIOLA", the WLV (Torrent and Avalanche Control) partly provides information on the extent of direct economic damage. Even if large databases provide links to various media for their sources, which in turn contain information on damage amounts, this is not satisfactory either. Although the systematic integration of financial loss into impact and damage databases is definitely challenging, involving a larger coordination of administrative bodies and a pragmatic partnership between public and private entities, it would allow to consider extreme event impact from a larger perspective, shedding light on medium and long-term impacting mechanisms that are still underestimated and allowing for a wider set of risk mitigation measures that could prove unvaluable in the near future.

4 References and Sources

BMLRT (2020): Ereignisdokumentation 2019 – IAN report 209; URL: https://info.bmlrt.gv.at/dam/jcr:aff01567-de36-4693-9db0-20ae0dd2ff61/Ereignisdokumentation%202019.pdf

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WLV (2021): ERDOK Lawinen Osttirol – im Dezember 2020; URL: https://info.bmlrt.gv.at/service/publikationen/wald/ereignisdokumentation-lawinen-osttirol-2020.html

5 Appendix – Additional Event Descriptions East Tyrol

Date: 2021-07-08	**Hazard type/trigger:** mud- and debris flows after a series of storms in the region / thunderstorm
Georeferencing: no coordinates; among others: Großlercherbach in Hopfgarten in Defereggen; Bretterwandbach in Matrei;	
Intensity: according to the WLV scheme: “extreme” respectively “XL”	
Documented damage(s): roads & bridges and mitigation constructions damaged; roads impassable and closed; road L 25 burried over a distance of about 100 m up to about 4 m high under mud and debris (overall 2000 m³); inhabited place(s) cut off from transport infrastructure; flooded cellars; damaged forest and pasture land; due to the low-pressure areas Ingmar (November 2019) and Virpy (December 2020) and the forest damage that occurred in this context, large quantities of wild wood were also transported away	
Cross border relevance: ☐ proven ☐ probable ☒ possible ☐ none	
Reference(s): ZAMG: VIOLA Severe Weather Chronicle; European Severe Weather Database; Austrian Torrent and Avalanche Control: WLK (cadastre) https://www.tt.com/artikel/30795912/unwetter-in-tirol-hagel-in-mieming-murenabgang-in-defereggen	

Date: 2020-10-02 to 03	**Hazard type / triggering factor:** heavy rain & strong wind gusts
Georeferencing: ---	
Intensity: 63 mm	
Documented damage(s): road closure (B111) due to fallen trees; buried road due to mudslides	
Cross border relevance: ☐ proven ☒ probable ☐ possilbe ☐ none	
Reference(s): ZAMG: VIOLA Severe Weather Chronicle; European Severe Weather Database	

Date: 2020-03-03	**Hazard type / triggering factor:** heavy snowfall
Georeferencing: ---	
Intensity: 15 cm	
Documented damage(s): due to fallen trees downed power lines; households were briefly without power	
Cross border relevance: ☐ proven ☐ probable ☐ possilbe ☐ none	
Reference(s): ZAMG: VIOLA Severe Weather Chronicle	

Date:	**Hazard type / triggering factor:**

2019-06-11 to 15	snow melt, floods / thunderstorm
Georeferencing: ---	
Intensity: ---	
Documented damage(s): farmland damages	
Cross border relevance:	☐ proven ☐ probable ☒ possible ☐ none
Reference(s): ZAMG: VIOLA Severe Weather Chronicle	

Date:	**Hazard type / triggering factor:**
2019-02-02 to 03	heavy snowfall
Georeferencing: several avalanches are described in terms of their catchment and deposition area	
Intensity: 80 cm	
Documented damage(s): increased avalanche danger, 7 medium to extreme large avalanches reported by the Austrian Service for Torrent and Avalanche Control; road closures and traffic obstructions; damages an streets, obstructions in rail traffic (closures); damaged phone line	
Cross border relevance:	☐ proven ☐ probable ☒ possible ☐ none
Reference(s): ZAMG: VIOLA Severe Weather Chronicle Austrian Service for Torrent and Avalanche Control (internal cadastre)	

Date:	**Hazard type / triggering factor:**
2018-01-09 to 10	local floods, avalanches / long-lasting precipitation & strong snow fall
Georeferencing: partly: avalanche depostion area georeferenced	
Intensity: avalanche: release volume 40.000 m³, deposition volume 45.000 m³ (classification: extremely large)	
Documented damage(s): closure of several main roads and schools; local floods	
Cross border relevance:	☐ proven ☒ probable ☐ possible ☐ none
Reference(s): ZAMG: VIOLA Severe Weather Chronicle; European Severe Weather Database http://tirol.orf.at/news/stories/2888402/ http://tirol.orf.at/news/stories/2888551/ Austrian Service for Torrent and Avalanche Control (internal cadastre)	

Date: 2017-07-20	**Hazard type / triggering factor:** floods, storm / heavy wind gusts, heavy precipitation
Georeferencing: --	
Intensity: --	
Documented damage(s): several trees and billboards overturned; local areas flooded; cellars flooded	
Cross border relevance:	☐ proven ☒ probable ☐ possible ☐ none
Reference(s): ZAMG: VIOLA Severe Weather Chronicle; European Severe Weather Database	

Date: 2015-08-04	**Hazard type / triggering factor:** mudslides / heavy rain
Georeferencing: point location of flood/debris flow events available (Austrian Service for Torrent and Avalanche Control - internal cadastre)	
Intensity: 37 mm	
Documented damage(s): damage to property; roads blocked; damage to crops and forests; local areas and streets flooded; mudslides buried streets; 7 extremely large flood/debris flow events reported by the Austrian Service for Torrent and Avalanche Control (internal cadastre)	
Cross border relevance:	☐ proven ☒ probable ☐ possible ☐ none
Reference(s): European Severe Weather Database https://tirol.orf.at/v2/news/stories/2724939/ Austrian Service for Torrent and Avalanche Control (internal cadastre)	

Date: 2013-11-23	**Hazard type / triggering factor:** heavy snow fall / snowstorm
Georeferencing: ---	
Intensity: ---	
Documented damage(s): 25 kV powerline damaged according to Tinetz-Stromnetz Tirol AG; municipality of Obertilliach: 10/17 and in municipality of Untertilliach: 3/15 transformer stations undersupplied; 300 households without power damage to crops and forests: dozens of trees downed;	
Cross border relevance:	☐ proven ☒ probable ☐ possible ☐ none
Reference(s): European Severe Weather Database http://www.polizei.gv.at/tirol/presse/aussendungen/presse.aspx?prid=657A6735384E6A584D6B673D&pro=0 http://tirol.orf.at/news/stories/2616593/ http://derstandard.at/1385168583551/Schneefaelle-500-Haushalte-in-Osttirol-ohne-Strom	

Date: 2013-08-04	**Hazard type / triggering factor:** severe wind gusts / storm			
Georeferencing: ---				
Intensity: Fujita scale: F0 / Torro scale: T1				
Documented damage(s): L324 road blocked by several uprooted trees				
Cross border relevance:	☐ proven	☒ probable	☐ possible	☐ none
Reference(s): European Severe Weather Database http://www.ff-anras.at/index.php?option=com_content&view=article&id=113:arbeitseinsatz-hoehenstrass				

Date: 2013-07-26	**Hazard type / triggering factor:** mudslides, floods / heavy rain + hail			
Georeferencing: ---				
Intensity: hailstone sizes up to 2 cm; 60 mm precipitation in 2 h (return period: 100 y.)				
Documented damage(s): log jam; roads B100 and L324 closed; bridges damaged; drinking water polluted by flooding; 7 medium to extrem flood/debris flow events reported by the Austrian Service for Torrent and Avalanche Control (internal cadastre)				
Cross border relevance:	☐ proven	☒ probable	☐ possible	☐ none
Reference(s): European Severe Weather Database http://ff.abfaltersbach.at/2012/index.php/8-einsaetze/28-ruhende-verklausung-erlbach-26-07-2013 http://www.ff-anras.at/index.php?option=com_content&view=article&id=112:drohende-verklausungen-erlbruecke-26072013&catid=71:2013&Itemid=95 Austrian Service for Torrent and Avalanche Control (internal cadastre)				

VENETO

Date: 2018 – 01 – 09 to 10	Hazard type / trigger: Landslides, avalanches
Georeferencing: ☐ Yes ☒ No	
Intensity: Liquid precipitation/24h: 119.2 Gosaldo, 81.4 Gares, Snow height/24h: Monti Alti Ornella (2250 m a.sl.) 45 cm	
Documented damage(s): small landslides reported from local newspapers	
Georeferenced: ☐ Yes ☒ No	
Cross border relevance: ☐ proven ☐ probable ☒ unlikely ☐ none	
Reference(s): Local newspapers	