nature

HAIL, a growing problem

Climate change has **tripled** hailstorms in Europe, and Italy is the country with the largest increase. Help comes from more accurate weather forecasts, which see the danger more and more in **advance**.

The sky becomes dark. Gusts of wind carry a thick rain of frozen drops, then the hailstones get bigger and bigger. First like peas, then like marbles, finally like apricots... They rain from the sky without stopping and bounce off the asphalt with a deafening roar. The hailstorm is consumed in a few minutes. Then the sky brightens an apocalyptic landscape: broken branches, dented cars and shattered bus shelters. Like after a bombing: a grain the size of a grapefruit, falling at a speed of 150 km per hour, has the same impact force as a 9 caliber bullet.

Scenes like this are becoming more and more frequent throughout Europe. The data from the European Severe Storms Laboratory (Essl), which investigates the most intense weather phenomena, say so: in the last 16 years, across Europe, hailstorms with grains larger than 2 cm in diameter have more than tripled. «Part of this increase is due to a more widespread reporting network in Europe, including by citizens who document events with mobile phones», warns Tomas Pucik, one of Essl's experts. «But this factor alone is not enough to explain the increase in hailstorms». The climate is changing, and the last two years (2021 and 2022) demonstrate it mercilessly: in 2022 there were 8,244 reports of hail, 51% more than in 2021, which was already a record year (*see chart on the next page*). 30% of reports came from France, followed by Italy (12%) and Germany (7%). In these two black years, reports Coldiretti, the damages suffered in Italy by the insured agricultural companies have exceeded one billion euros. Things went worse in France, where damages of 3.9 billion euros were recorded in 2022 alone (Aon Weather data).

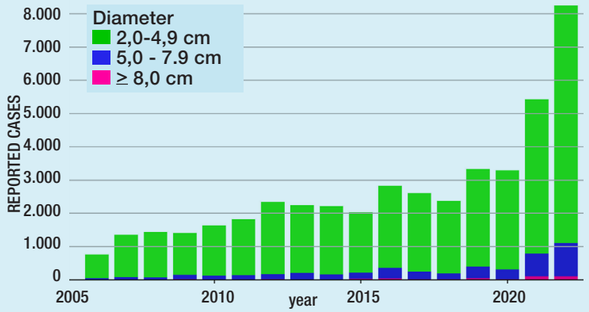
IT WILL ALWAYS GET WORSE

And the future does not bode well: according to the latest research, we will have to resign ourselves to living more and more often with heavy hailstorms. In a study published in *Npj Climate and Atmospheric Science*, a group of meteorologists from Essl simulated 14 different climatic scenarios between now and 2100, with an unequivocal result: in all projections, ▸

FROZEN BOMBS
Hailstones as large as baseballs: when they fall they cause damage to cars and windows.

iStock/Getty Images

THE LAST 16 YEARS TRENDS



From 2006 to 2022, the European Severe Storms Laboratory (Essl) surveyed 45,297 severe hail events (> 2 cm): hailstorm reports more than tripled. The most affected country is Germany (5,795 events), followed by Russia (5,079), Poland (4,859), France (4,326), Italy (4,221), Turkey (3,348), Austria (1,832). Germany has recorded the highest number of injuries and the highest number of events with damages over one billion dollars.

DAMAGE FROM HAIL

The damage caused by hail mostly depends on the size of the grain, but also on other factors (speed of fall, hardness, shape, trajectory) that can enhance or mitigate its effects.

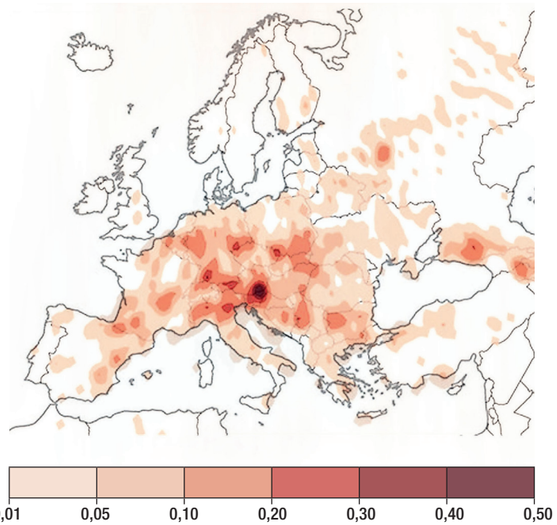
2 cm (like a grain of grapes): damage to crops (especially wheat, corn, soy).

5 cm (like a billiard ball): damage to cars and windows.

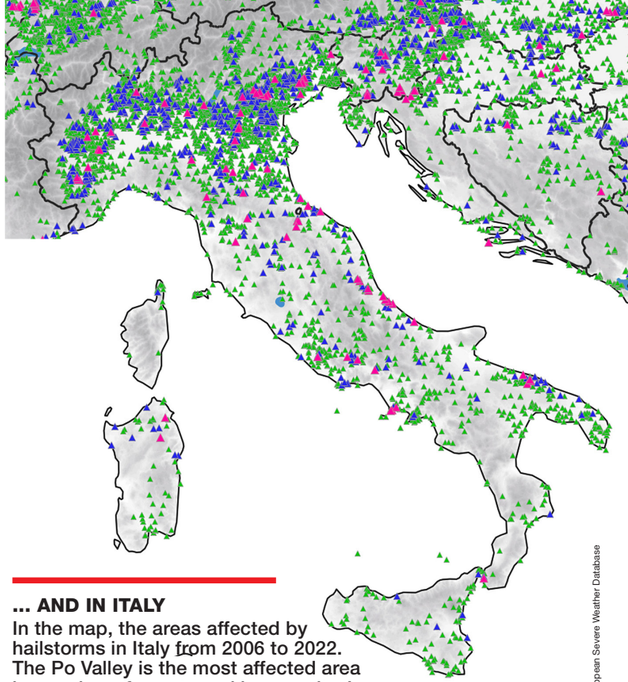
10 cm (like a grapefruit): damage to roofs and people. A grain of 10 cm in diameter that falls at 150 kmh has the same force as a 9 caliber bullet.

HAIL IN EUROPE...

In the map, the European areas with the greatest frequency of hail (2006-2018). For most of Europe the black month of hail, or the peak, is June; it is in July for Spain, France, Italy and the United Kingdom. In general, continental areas have a peak in summer (June-July), coastal ones in autumn (September-October), when there is low pressure on the Mediterranean. The most frequent time of hail is between 12 pm and 4 pm.



Source: Tomas Pucik "Large Hail Incidence and Its Economic and Societal Impacts across Europe", *Monthly weather review* 1 Nov 2019



... AND IN ITALY

In the map, the areas affected by hailstorms in Italy from 2006 to 2022. The Po Valley is the most affected area by number of events and by severity. In Italy in 2022 there were 993 hailstorms: the most affected regions were Veneto, Trentino-Alto Adige, Lombardy and Piedmont, i.e. the Pre-Alps and the Po Valley. In Europe in 2022 hailstorms occurred 213 days (58.3%). The three black days: 25 May, 4 and 20 June.

Source: European Severe Weather Database eswd.eu ed European Severe Storms Laboratory Essl.org

large hailstorms (with hailstones larger than 5 cm diameter) increase from 47% to 139% compared to today. Especially in Northern Italy. Why these gloomy forecasts? And why Italy? And how can we defend ourselves?

CRITICAL AREAS

Studying hail is not simple. «Hailstorms evolve rapidly and affect limited areas. Their elusive nature makes both observation and prediction difficult», observes Sante Laviola, researcher at the Institute of Atmospheric and Climate Sciences at the Cnr of Bologna. Hail forms when intense hot ascending currents, rich in humidity, push the drops of water towards the highest and coldest altitudes of the storm clouds: ice crystals form which, colliding, aggregate together giving rise to the grains which then they fall to the ground (*see infographic on the next pages*). Therefore hail falls more often in coastal areas, where the sea, evaporating, produces a lot of humidity and warm air, and in mountainous areas: the mountains push the horizontal winds upwards, intensifying the updrafts of the storms. And higher elevations, at lower temperatures, allow hail to freeze before hitting the ground. That is why the areas most affected by hail are the great American plains, South Africa, central Argentina, China, South Australia and Equatorial Africa. The worst location in the world is Kericho (Kenya), at an altitude of 2,200 meters in the Rift Valley: here it hails on average one day a week throughout the year.

But Europe is no joke either: the areas close to the mountains in France, Germany, Poland and Italy are the most targeted. Recently, several scientists have retrospectively studied the meteorological and satellite data of the last decades in the light of the most recent discoveries on the dynamics of hail. And the results leave no doubts: ice rains have become much more frequent in Europe.

A study by Laviola's research group, published in the journal *Eos*, found that in the last decade (2010-2021) heavy hailstorms in the Mediterranean basin have increased by 30% compared to the previous decade (1999-2010). And the increase is even more remarkable if we go further back in time: compared to the 1950s, Francesco Battaglioli of Essl discovered, «hailstorms with grains larger than 5 cm in diameter have tripled in Northern Italy and almost doubled in Southern Italy. Our country is the one where there has been the strongest increase ever in all of Europe».

DAMAGE, DEATHS AND INJURED

Why does this happen? The number one suspect is global warming, which favors the formation of extreme weather phenomena because it increases the evaporation of moisture-laden air from the sea or from the surface earthly.

«The Mediterranean basin is warming 20% faster than the global average, and this heat puts a lot of energy into the formation of storm clouds», explains Laviola. «The same happens in the Po Valley, one of the most hail-producing areas in Europe because it retains a lot of heat and is surrounded by mountains: thus, when cold air intrudes from the North Atlantic, the conditions are created for the formation of violent hailstorms» .

It is no coincidence that one of the most serious events in recent years took place in Bardolino (Verona), on the eastern coast of Lake Garda: on 4 August 2002 a hailstorm with hailstones the size of peaches caused 20 injuries and 590 damage, 7 million dollars at the time (MunichRe data).

Because hailstorms can damage crops (especially corn, ▸

HAIL HISTORICAL RECORDS

20,3 cm: the diameter of the largest hailstone. It fell on July 23, 2010 in Vivian (USA) and weighed 878.8 g. In Europe, the record belongs to a 15 cm grain that fell in Romania on 20 June 2016. In Italy, the record grain was 14 cm (Pescara, 10 July 2019).

47,6 cm: the maximum circumference reached by an hailstone. It fell on June 22, 2003 in Aurora (USA).

1,02 kg: the greatest weight of a single hailstone. It fell on 14th April 1986 in Gopalganj (Bangladesh).

132 days/year: the record number of hail days recorded in 1965 in Kericho (Kenya), an equatorial location at an altitude of 2,200 m. On average it has 50 hail days a year.

4,68 billion dollars: the largest damage ever caused by a hailstorm. On 27-28 July 2013 in Germany (Reutlingen, Pfortzheim, Wolfsburg and Hannover).

246 deaths: the most tragic toll of a hailstorm. Occurred on April 30, 1888 in Moradabad (India).

400 injured: the highest number of injured in a single hailstorm in Munich (Germany), 12 July 1984. The Italian record is 20 injured in Bardolino on 4 August 2002.

20mila people: citizens evacuated from West Edmonton Mall, a shopping center in Edmonton (Canada), after the hail had destroyed the glass roofs, July 11, 2004.

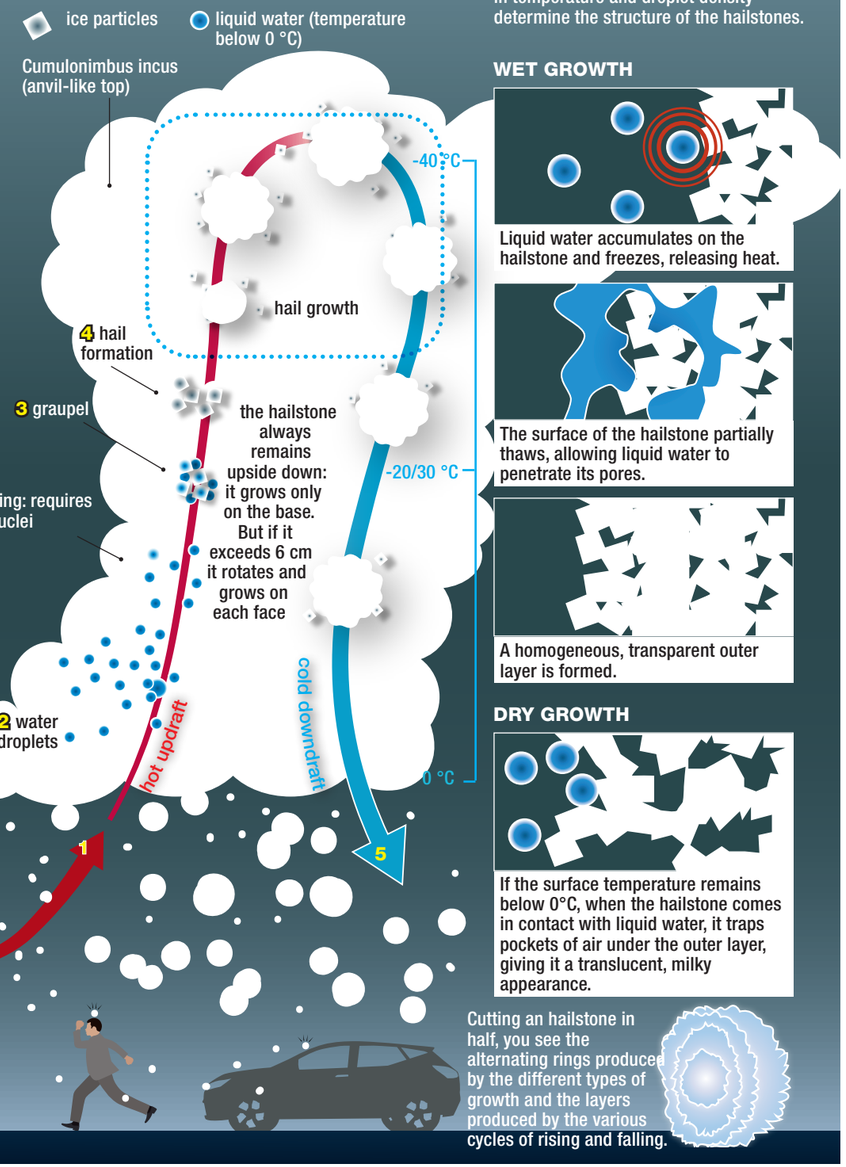
100,000 houses: the homes left without electricity in Chicago, May 18, 2000.

40,000 cars: the vehicles damaged by a hailstorm, April 14, 1999 in Sydney (Australia). Added to these are the damages reported by 25 aircrafts.

Fonti: NOAA, WMO, Wikipedia, MunichRe

HOW HAIL FORMS

Hail forms in large storm clouds, the cumulonimbus clouds: they have a "tower" structure and in the mature phase they can have a flattened top, taking on the shape of an anvil. In these clouds, which exceed 10 km in altitude, the storm gives rise to strong atmospheric phenomena. Hail forms when intense hot updrafts (**1**) push the water droplets towards the cold area of the cumulonimbus clouds, where temperatures are below zero. The updrafts, often above 100 km/h, carry the drops of water upwards (**2**). Hailstones form around a condensation nucleus (atmospheric dust) which forms the graupel (**3**), an ice crystal covered with supercooled water droplets (liquid even if the temperature is below zero). Carried by the updrafts, the crystals grow, aggregating with other supercooled droplets or ice crystals (**4**). The hailstone continues to rise until its mass can no longer be supported by the updraft: it can reach over 10 km in height in 30 minutes. Then he falls to the ground (**5**), dragged by a cold downdraft. Even if the temperature of the lower layers is above 0°C, the grain, if it is large, can remain frozen because it passes through them quickly. Hail has an onion-like structure: it alternates between opaque and transparent layers. The opaque layer is formed by the instantaneous freezing of the supercooled droplets in the cold part of the cloud; the transparent layer, on the other hand, is given by a slower freezing of the water during the ascent of the grains from the warmer area. Hailstorms usually don't last long (10 minutes on average) and affect limited areas (5-10 km²). The grain always remains upside down: it grows only on the base. But if it exceeds 6 cm it rotates and grows on each side hail growth warm updraft cold downdraft.



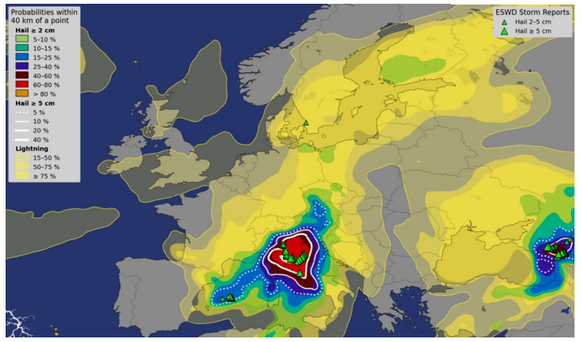
REKLIM climate initiative

THE BIGGEST
In a hailstorm that occurred in 2010 in Vivian (USA), fell this hailstone of more than 20 cm in diameter: it is the largest so far recorded in modern history.

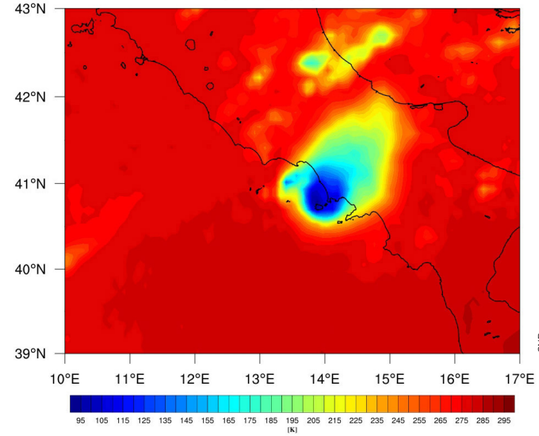
wheat, soybeans), greenhouse covers, windshields and car bodies, canopies. And bring airports to their knees, damaging aircraft and making runways impassable.

They can also injure and sometimes kill people. And it has always been like this: in the book of *Exodus* of the Bible, written in the 6th century BC, it was precisely a strong hailstorm - one of the 10 plagues of Egypt - that convinced the pharaoh to let the people of Israel go.

What to do? The warning systems were, until recently, not very effective: hailstorms are even more elusive than thunderstorms, because they form quickly and are very localized, they



CONTROLS
Left, momentous hailstorm in Bogotà (Colombia) in 2007. Right, the 2015 hailstorm in Naples seen from satellite: blue indicates the area of the cloud most loaded with grains. Below, the website stormforecast. eu: indicates the areas most likely to hail.



Today, thanks to data collected by **satellites**, powerful weather computers can predict the chances of hail **2 days** in advance

can affect even just an area of a few km².

For this reason, an event could be foreseen at most 30 minutes – but more often only 10 minutes – in advance. But now Essl has launched a weather forecast website dedicated to the most intense phenomena: stormforecast.eu. «The site automatically elaborates, by mixing our algorithms with global meteorological models, the probabilities of hail and lightning in Europe with an interactive map», explains Battaglioli. «We are able to predict the formation of violent storms, making estimates of the probability of hail 2 days in advance. It is an experimental site, but we hope it will help monitor the most intense phenomena».

RADARS AND SATELLITES

The formation of hail can be controlled in two ways: the most precise is through ground-based weather radars, which detect the ice crystals forming on top of the clouds. But radars can give warnings at short notice and for limited areas. The range of satellites is wider, which are able to identify, through microwave sensors, the formation of ice crystals in the clouds.

Until a few years ago, only the low frequency spectrum of microwaves was used, sensitive to larger hailstones.

Laviola has recently used the highest frequencies to recognize even the smallest grains, thus making it possible to identify a hailstorm already in the early stages of formation. Weather satellites photograph the situation in real time, but with the risk of overestimating the warnings: they detect the presence of hail in the storm clouds, but the hailstones will not necessarily reach the ground.

«The satellites, in reality, do not directly capture the hailstones: instead they detect how they disturb the radiation field naturally emitted by the Earth», explains Laviola. «Our method can be adopted in the new generation of weather satellites of the Eumetsat programme, the second generation MetOps which will be launched between 2025 and 2039. There are 6 satellites equipped with microwave sensors, which will be able to help us monitor hailstorms with greater precision: even the events that take place in the open sea, which today mostly escape us».

THE DEFENSES: STRONGER ROOFS AND NETS

So what to do? The defenses are few and expensive: cultivated fields can be protected with anti-hail nets, and those who live in areas at risk of heavy hailstorms will have to invest in more robust structures, i.e. tempered glass for greenhouses and solar panels.

What about anti-hail systems, such as sound wave cannons and artificial cloud seeding? «The anti-hail cannons, which are supposed to shatter the grains forming in the clouds by shooting strong sound pulses, are not effective», replies Laviola. «As regards the seeding of the clouds, it is a practice which consists in launching rockets which contain silver iodide or in dispersing these molecules from the planes which enter the storm clouds: this substance, having high hygroscopic properties, i.e. of attracting molecules of water, provides additional condensation nuclei for moisture or ice crystals, in addition to natural atmospheric dust, and makes droplets and hailstones smaller. But this method has high costs and poor results».

Meanwhile, in Europe, in addition to scientists, there is someone else who is concerned about the phenomenon: the insurance companies. Targeted by more and more insurance claims for damage, they are taking measures: «They asked us for detailed maps of the hailstorms of the past, with a resolution of 10-20 km, to identify the areas at highest risk in our country», says Laviola. If insurance policies will increase, we now know why: it's another gift of ongoing climate change.