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THE FORGOTTEN ERUPTION: GLOBAL CONSEQUENCES OF THE 1831 KURIL ISLANDS ZAVARITSKI CALDERA IN LIGHT OF ERUPTIONS OF TAMBORA (1815) AND PINATUBO (1991)

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In summer 1831 the climate in the Northern Hemisphere cooled by an average of about 1 degree Celsius, coinciding with reports of gloomy, harsh weather and the sun changing to different colours. Scientists knew that a massive eruption caused this strange event, but the exact culprit of this cataclysm remained unknown for a long time. The 1831 eruption of the Zavaritski Volcano was one of several 19th century eruptions associated with the final phase of the so-called Little Ice Age (1800 to 1850), according to the volcanologists. This Age was not a true Ice – the last true ice age ended 10,000 years ago – but it marked the coldest period in the past 500 years. In this article the author explains the Zavaritski Volcano eruption and the geological time frame in which it occurred. It is also describes how the volcano was found almost 200 years after the eruption. The 183 eruption into perspective with today's climate crisis and the one humanity will experience within the next hundred years.

Keywords: Kuril Islands, Little Ice Age, Zavaritski Caldera, Simushir Island, Ainu people, Japan, Russia, Treaty of Shimoda, William Hutchison, Tambora Volcano, Alexander Zavaritski, Mount Pinatubo, ice cores, climate changes, Hokkaido.

ЗАБЫТОЕ ИЗВЕРЖЕНИЕ ВУЛКАНА: ГЛОБАЛЬНЫЕ ПОСЛЕДСТВИЯ КАЛЬДЕРЫ ЗАВАРИЦКОГО НА КУРИЛЬСКИХ ОСТРОВАХ В 1831 Г. В СВЕТЕ ИЗВЕРЖЕНИЙ ТАМБОРЫ (1815) И ПИНАТУБО (1991)

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Летом 1831 г. климат в Северном полушарии похолодал в среднем примерно на 1 градус по Цельсию, что совпало с сообщениями о мрачной, суровой погоде и изменении цвета солнца. Ученые знали, что причиной этого странного события стало мощное извержение, но конкретный виновник этого

катаклизма долгое время оставался неизвестен. По мнению вулканологов, извержение вулкана Заварицкого в 1831 году было одним из нескольких извержений, произошедших в XIX в., связанных с заключительной фазой т.н. Малого ледникового периода (1800-1850). Этот период не был ледниковым в прямом смысле, т.к. последний настоящий ледниковый период закончился 10 000 лет назад, но он стал самым холодным периодом за последние 500 лет. В этой статье автор повествует об извержении вулкана Заварицкого и геологических временных рамках, в которые оно произошло. Также описывается то, как вулкан был обнаружен спустя почти 200 лет после извержения. Извержение 1831 г. рассматривается в контексте сегодняшнего климатического кризиса и того, с которым человечество столкнется в ближайшие сто лет.
Ключевые слова: Курильские острова, Малый ледниковый период, кальдера Заварицкого, остров Симушир, айны, Япония, Россия, Симодский мирный договор, Уильям Хатчисон, вулкан Тамбора, Александр Заварицкий, гора Пинатубо, ледяные керны, изменения климата, Хоккайдо.

Prologue – consequences of severe volcano eruptions

Volcanic eruptions can be very powerful natural events that can have very wide-ranging effects on the Earth’s climate, ecosystems, and human societies. An overview of how volcanoes influence climate change**,** temperature, hunger, and destruction:

Volcanoes both contribute to and mitigate climate change, depending on the scale and type of eruption:

Short-term cooling: large eruptions eject sulphur dioxide (SO_2) into the stratosphere, forming aerosols that reflect sunlight and cool the Earth for 1-3 years (e.g., Mount Pinatubo in 1991 lowered global temperatures by ~0.5°C).

Long-term warming: over geological time, continuous eruptions release CO_2, a greenhouse gas. However, human activities emit far more CO_2 today than volcanoes.

Impact on global temperature, especially regional warming, is another bad consequence of a volcano eruption, especially the big eruptions:

– Immediate cooling: ash and aerosols block sunlight.

– Localized warming: near the eruption site, gases and lava can cause brief regional warming.

– Oscillation: after initial cooling, climate may slowly return to previous temperatures unless eruption series persist.

Hunger and food security

Volcanic eruptions can severely disrupt agriculture and Hunger and Food Security can be threatened, i.e. crop failures and disrupted supply chains:

– Ash fall and acid rain damage crops and soil.

– Reduced sunlight (volcanic winter) leads to failed harvests (e.g., the 1815 Mount Tambora eruption caused “the year without a summer” in 1816, leading to famines in Europe and North America).

– Livestock deaths: contaminated water and grazing land harm animal health.

Destruction on Earth

The consequences of volcanic eruptions can be just as bad or even worse for the affected areas.

– Immediate damage: lava flows, pyroclastic flows and ash fall destroy homes, infrastructure, and ecosystems.

– Long-term displacement: communities are often forced to evacuate or abandon land permanently.

– Tsunamis: underwater or coastal eruptions can trigger deadly tsunamis (e.g., Krakatoa Volcano, 1883).

– Earthquakes: often volcano eruptions are supplied with severe earthquakes or devastating earth tremors.

Kuril Islands: end of the world

If you travel 7,100 kilometres to the east from Moscow, you will reach the Kuril Islands. The islands are an archipelago in Sakhalin Oblast in the far-east Russia. The Kuril Islands extend for around 1,200 kilometres from the southernmost tip of the Kamchatka Peninsula to the north-eastern corner of the Japanese island of Hokkaido. The archipelago separates, so to say, the Sea of Okhotsk from the Pacific Ocean. Fifty six islands cover an area of around 11,000 square kilometres. Because of the severe climate, the population density is about 2 each square kilometres [8].

Geographically, you are literally at the end of the world. The nearest neighbour to the west is the USA 6,600 kilometres away. All in all a place so remote that no one really notices the course of life on the islands, at least not in the 1800s. However, as the rest of the land parts in this area of the world, Kuril Islands are part of a belt of geologic instability circling the Pacific and contain at least 100 volcanoes, of which 40 are still active. Earthquakes and tidal waves are common, a tidal wave of 1737 attained a height of almost 65 meters, one of highest on record. Furthermore, the Kuril Trench with a depth of more than 10 kilometres are found near the islands [5, p. 45].

All in all an area with a geological signature that should attract all kinds of volcanologists and seismologists. Originally, it was the Ainu people who inhabited the Kuril Islands and in 1700s as well Russians as Japanese conquered the Kuril Islands. Today only 12,000 Ainus remain on Hokkaido. In 1855 Japan and Russia concluded the Treaty of Shimoda, which gave control of the four southernmost islands to Japan and the remainder of the chain to Russia. From 1875 to 1945 the islands belonged to Japan, and from 1945 as part of the Yalta Agreements the Kuril Islands belong to Russia again [8; 10, p. III-V].

Zavaritski Volcano and caldera and Simushir Island

In 1831 the islands were mainly inhabited by fishermen, the Ainu People and Russian and Japanese scientists and workmen, but that mostly on the islands near Kamchatka and Hokkaido. However, in the middle of the archipelago you find the Simushir Island. In 1831 maybe inhabited by the Ainu People we do not really know, but could have been a couple of fishermen. No other nationalities. The Simushir Island (around 227 square kilometres) is highly elongated, consisting of stratovolcanoes, volcanoes, typically, built up by many alternating layers, strata of hardened lava and tephra, fragmental material of different composites produced by a volcanic eruption. It is, therefore, easy to see geological changes in the landscape, i.e. colours, size, heights and surroundings [3, p. 63; 10, p. IV-V].

One of these stratovolcanoes is the Zavaritski Volcano almost on the centre of the island. The caldera bears the name of Alexander Nikolayevich Zavaritski, a distinguished Russian scientist who contributed to the Academy of Sciences of the Soviet Union. The volcanic structure contains three distinct nested calderas, each representing different periods of geological activity in the region. The nearby Lake Biryuzovoe partially fills the youngest of three nested calderas on the volcano. The volcano experienced its last recorded eruption between November and December 1957, marking a significant event in the geological timeline of the Kuril Islands [1].

The entire surface of the rim in the volcano area is covered with debris of volcanic material – coarser on the summit and inner slopes and finer on the outer ones. The composition of the lava flows is a composition of andesite to basalt and a certain amount of pyroclastic materials. The pyroxene andesites contain locally included augite and plagioclase – labradorite-bitovnite in the core and andesine-labradorite on the periphery. They are the product of the last eruption of the central cone and have no genetic connection with the caldera [1].

Two eruptions occurred in the 20th century. The first is assumed to have occurred in 1923 ± 8 years with a volcanic explosive index of 1. It is likely that then a new lava dome rose in the caldera itself. The exact date is not established, but it is assumed that this happened between 1916 and 1931. As a result a small island was formed in the northern part of the lake caldera. And as mentioned above on January 14, 1957 strong gas emissions were observed, again ejected from the northern part of the caldera. The population of Simushir was urgently evacuated. A series of explosive eruptions followed, starting on 14 November and ending on 1 December. As a result, a new lava dome was formed – 40 m high and 350 m wide. It formed a peninsula in the northern part of the Simushir Island [1].

Little Ice Age final phase (1800-1850) and Mount Tambora

For volcanologists, paleoclimatologists and historians a particularly fascinating period is the final phase of the Little Ice Age (1800-1850), which is one of the coldest period in the last 500 years and is marked by a cluster of major volcanic events. And along with the Zavaritski Volcano, three other volcanoes blew their tops between 1808 and 1835. They marked the waning of the Little Ice Age a climate anomaly that lasted from the early 1400s to around 1850.

During this time, annual temperatures in the Northern Hemisphere dropped by 1.1 degrees Fahrenheit (0.6 degrees Celsius) on average. In some places temperatures were 3.6 degrees Fahrenheit (2 degrees Celsius) cooler than normal and the cooling persisted for decades. The prolonged cold, dry periods brought drought upon many European communities and resulted in poor crop growth, poor livestock survival and increased activity of pathogens and disease vectors [3. p. 64].

Besides the eruption on the Kuril Islands three of the four eruptions were previously identified: Mount Tambora in Indonesia exploded in 1815, Mount Galunggung also in Indonesia in 1822 and Cosegüina erupted in Nicaragua in 1835. The volcano that produced the 1808/1809 eruption remains unknown. The addition of Zavaritskii highlights the potential of volcanoes in the Kuril Islands for disrupting Earth's climate, the study authors reported [5, p. 33].

On the island of Sumbawa in Indonesia, Mount Tambora's eruption in April 1815 stands as a stark reminder of how a single geologic event can disrupt the global climate system**,** human economies, and societies on an enormous scale. Around 100,000 death and very severe destructions and, therefore, the eruption is one of the most powerful volcanic eruptions in recorded history at all. It had global consequences, significantly affecting climate, temperature, agriculture, and societies around the world. Here are some of the consequences [2, p. 17363].

Effects on climate

Tambora injected massive quantities of sulphur dioxide (SO_2) into the stratosphere (~43 km high), forming sulphate aerosols.

– These aerosols reflected sunlight, leading to short-term global cooling.

– This caused a sharp drop in global temperatures by an estimated 0.4°C to 0.7°C between 1815 and 1816 [2, p. 17362; 6, p. 4].

Impact on Global Temperature

– 1816 became known as “the year without a summer” in parts of North America and Europe.

– Frost and snow in June and July were recorded in New England and Canada.

– Unseasonably cold weather persisted into the summer months, devastating crops [6, S. 5].

Hunger and food crises

– Crop failures occurred across the Northern Hemisphere due to low temperature, heavy rains, hail and frost in midsummer.

– Europe (still recovering from the Napoleonic Wars) suffered famine, rising food prices and bread riots.

– In China and India monsoon disruptions caused floods and droughts, leading to famine and cholera outbreaks.

– Global grain prices spiked dramatically, worsening poverty and hunger.

Destruction

– Local destruction on Sumbawa and neighbouring islands: entire villages buried in ash, agriculture collapsed, SURVIVORS suffered starvation and disease.

– The eruption’s ash cloud travelled thousands of kilometres, darkening skies and disrupting shipping and communication [6, S. 11].

The 1831 volcano eruption mystery

One of the largest volcanic eruptions of the nineteenth century took place in the summer on the Northern Hemisphere in 1831. The 1831 eruption was initially attributed to Babuyan Claro volcano in the Philippines; however, Christopher Garrison and other scientists traced various historical sources and found no firm evidence for an eruption at this time. Another notable volcano candidate has been Ferdinandea (also known as Campi Flegrei Mar Sicilia or Graham Island) which is located ~50 km south-west of Sicily and erupted in July-August 1831. This was a modest phreatomagmatic eruption with an erupted volume of 0.06 to 0.1 km^3, or magnitude of 3.5 to 4.0.

Interestingly, Christopher Garrison showed an apparent westward progression of "blue" sun observations which initiate in Europe, propagate toward North America, and match the timing of the Ferdinandea eruption.

Whether all these phenomena are tied to the aerosol veil of Ferdinandea and the sulphate deposited in the ice cores remains uncertain, although it is notable that the 1831 atmospheric phenomena are relatively short-lived (limited to August 1831), in contrast to large-magnitude stratospheric eruptions (e.g. Tambora and Pinatubo) which last several years. The magnitude of the Ferdinandea eruption is also unusually small for a climate-changing eruption.

Previous analyses of polar ice cores indicated that a major eruption in 1831 had injected several metric tons of sulphur into the stratosphere, reflecting solar radiation back to space and causing the Northern Hemisphere to cool by up to 1 degree Celsius (2 degrees Fahrenheit). And historical accounts from that summer note the Sun appeared green, purple, and blue, which can occur when volcanic particles in the atmosphere scatter sunlight. The probable volcanic source of these phenomena, however, had long remained elusive [4].

Scientists have now matched the chemical composition of volcanic material preserved in ice cores with that from the most recent major eruption of the Zavaritski Volcano. Radiocarbon dating and estimates for the volume of material ejected from the volcano further implicated the Zavaritski Volcano as the source of the major 1831 eruption [9].

Evidence for the eruption includes sulphate peaks in polar ice cores and from historical observations of atmospheric phenomena in Japanese records (such as observations of an abnormally coloured sun). It is thought that the mass injection of sulphur from the eruption caused Northern Hemisphere climate cooling of 0.5-1.0 °C (1-2 °F), coincided with fluctuations in the Indian and African monsoons and preceded major famines (including the Guntur famine of 1832 in India). However, the source of this major eruption has remained a mystery.

Observations of a blue, purple and green sun occurred around the world in August 1831. The sun is white when viewed from above Earth's atmosphere.

However, its observed colour varies due to scattering and absorption by atmospheric gases and aerosols. For as long as an aerosol maintains these parameters whilst being transported in the atmosphere, it will produce a sequence of observations of a blue, purple or green sun at different dates and places. Consequently, a sequence of 55 reported observations of a blue, purple or green sun may be used to reconstruct the atmospheric transport of the aerosol responsible, potentially tracing it back to its source [12].

Global consequences of 1831 volcano eruption

In 1831 the massive volcanic eruption spewed sulphurous gases into the atmosphere, reflecting sunlight and causing a global cooling of approximately 1°C. This cold weather, well-documented worldwide, led to widespread crop failures and devastating famines. The mystery explosion in 1831 released 13 million metric tons (about 14 million short tons) of sulphur into the atmosphere and was one of the largest volcanic events of the 19th century. The volcanic plume that resulted rose into the stratosphere, forming a layer of sulphate aerosols that as mentioned above led to a global temperature decrease of about 1 °C (1.8 °F). In the weeks and months after the eruption reports emerged from across the Northern Hemisphere noting that the Sun took on blue, green and even purple hues, which were later attributed to the scattering of sunlight passing through the aerosol layer. The eruption and its emissions altered weather patterns and caused crop failures and famines in India and Japan in the years that followed. Although the effects of the climate disruption caused by this volcano have been documented since the 1830s, the source of this disruption remained a mystery until the publication of the 2024 study [7].

Effects on climate

– The eruption injected massive quantities of sulphur dioxide (SO_2) into the stratosphere (~20 km high), forming sulphate aerosols.

– These aerosols reflected sunlight, leading to short-term global cooling.

– This caused a sharp drop in global temperatures by an estimated 0.8°C to 1.1°C between 1831 and 1832 on the Northern Hemisphere [9].

Impact on global temperature

1831 became known as “the year without a summer” in parts of North America and Europe.

– Frost and snow in June and July were recorded in Europe, New England and Canada.

– Unseasonably cold weather persisted into the summer months, devastating crops, especially in India.

– In 1831-1832 there was snow and bad weather in the Alps all year round.

Hunger and food crises

– Crop failures occurred across the Northern Hemisphere due to low temperatures, heavy rains, hail and frost in midsummer.

– Europe (still recovering from the Napoleonic Wars) suffered famine, rising food prices and bread riots.

– In China and India, monsoon disruptions caused floods and droughts, leading to famine and cholera outbreaks.

– Global grain prices spiked dramatically, worsening poverty and hunger [9].

Another reaction came from the German composer Felix Mendelssohn who wrote of “desolate weather” in the summer of 1831 that was “as cold as winter” as he journeyed through the Alps the researchers said in the statement. Various accounts in the Northern Hemisphere also mentioned the sun turning blue, purple and green as a result of light scattering and absorption by aerosol particles from the volcano’s plume [12].

Scientific discovery and identification

The mystery location of the giant volcanic eruption in the summer 1831 that has puzzled scientists for almost 200 years has finally been solved, thanks to researchers from the St Andrews University (UK). The team used radiocarbon dating to pinpoint the timeline of the volcanic ash on Simushir Island, and they took sulphur isotope readings and physical measurements of the volcano’s caldera. These data confirmed the match, leaving Zavaritski “the prime candidate” for the seminal 1831 eruption, according to the study [4].

Using evidence from well-dated ice cores and stratigraphic records the scientists, led by Dr. William Hutchison pinpoint Zavaritski caldera as the source of this eruption. By reconstructing its magnitude and radioactive forcing we show that Zavaritski can account for the climate cooling in 1831-1833.

These data provide a compelling candidate for this large-magnitude mystery eruption and demonstrate the climate-changing potential of these remote yet highly significant Kuril Island volcanoes. Actually, new research that the inner Zavaritski Caldera may have been formed in one of this planet's largest volcano eruption of the 19th century. Although this event led to significant Northern Hemisphere climate cooling, the source of this eruption remains a mystery [7].

1831 is a relatively recent period of time, but in almost 200 years, the scientists had no idea this volcano was responsible for the dramatic eruption. It was completely off the radar. William Hutchison noted that there are no written records of direct observations from the 1831 eruption, likely because the Kuril Islands were and still are remote and largely uninhabited, often clouded by thick fog. However, the volcano's impact is well documented. According to some sources the smoke cloud and sounds of the great eruption were recorded in the logbooks of captains of merchant ships between China and Russia [7].

To identify the source of the eruption William Hutchison and his team studied the remnants of ash deposited in 19th-century polar ice cores collected from Greenland. Hutchison and his team homed in on Zavaritskii after determining that ice cores from Greenland contained 6.5 times more sulphur fallout around 1831 than comparable samples from Antarctica. That meant the eruption likely took place in the Northern Hemisphere. The Greenland ice cores included ash layers and microscopic volcanic glass shards roughly one-tenth the diameter of a human hair. Chemical analyses of these tiny remains matched best with existing data from Japan and the Kuril Islands. But an explosion of this magnitude releasing around 13 million metric tons of sulphur into the atmosphere, per the study, could not have gone unnoticed in densely populated Japan [4].

That left the Kuril Islands as the most likely culprit, just near enough to obliterate Japanese crops and just far enough to remain unobserved. From there, they needed to find ash and glass from a local volcano with a chemical signature that matched the one seen in Greenland [7].

The chemical fingerprint of this ash was similar to ash from volcanoes in Japan and nearby islands. Hutchison said that the team ruled out Japan as a location for the eruption because of its dense population and well-documented record of volcanic eruptions. That led the researchers to look at the Kuril Islands [7].

Finding the match took a long time and required extensive collaboration with colleagues from Japan and Russia, who sent the scientific team samples collected from these remote volcanoes decades ago The scientific team found that the ash deposits at Zavaritski Volcano perfectly matched the chemistry of the ash found in the ice cores. And that similar to finding a fingerprint matches in crime scene forensics [7].

While the team solved the mystery of the 1831 eruption, Hutchison noted that there still isn't any instrumentation monitoring volcanic activity on the Kuril Islands, this is true for most volcanoes around the world. And the impacts of such a large eruption might be just as dire, if 1831 is any guide. It might lead to sparse sunlight, altered rainfall and dropping global temperatures, which would put stress on the food supply [7].

The 1991 volcano eruption of Mount Pinatubo

On June 12, the Pinatubo Volcano's on the Philippines first spectacular eruption sent an ash column 19 kilometres into the atmosphere. Additional explosions occurred overnight and the morning of June 13. Seismic activity during this period became intense. When even more highly gas-charged magma reached Pinatubo's surface on June 15 the volcano exploded, sending an ash cloud 40 kilometres into the atmosphere. Volcanic ash and pumice blanketed the countryside. The consequences were incalculable:

Immediate destruction and casualties

– Deaths: around 850 (mostly from collapsing roofs under ash and lahars).

– Displaced people: over 100,000.

– Pyroclastic flows destroyed villages within 40 kilometres.

– Ash fall buried farmland, disrupting agricultural in Central Luzon.

– Lahars caused long-term destruction, burying towns and clogging rivers for years.

– Economic cost: estimated at more than 800 million US dollars (destroyed infrastructure, agricultural losses etc.) [q.v.: 11].

Effects on climate and global temperature

– Sulfur Dioxide (SO_2): injection of more than 20 million tons into the stratosphere.

– Aerosol layer: spread globally, reflecting sunlight back into the space.

– These aerosols reflected sunlight, leading to short-term global cooling.

– This caused a sharp drop in global temperatures by an estimated 0.5°C to 0,6°C between 1991 and 1993 worldwide.

– Record low temperatures and extreme weather in some regions of the world.

– Ozone layer depletion: increased UV radiation due to chemical reactions with volcanic aerosols [4].

Effects on rainfall and weather patterns

– Weakened monsoons in Africa and Asia, contributing to droughts.

– Increased rainfall in other world regions due to disrupted atmospheric circulation [q.v.: 11].

Agricultural and hunger impacts

– Philippines: crop failure (rice, sugarcane) due to ash fall and lahars led to food shortages.

– Global food supply: minor disruptions, but no major famine (unlike Tambora in 1815) [12].

Long-term environmental and human impact

– Lahars continued for years, requiring massive dike construction.

– Aerosols lingered for more than three years gradually dissipating by 1994.

– Aviation: ash clouds temporary flight disruptions in Southeast Asia [11].

The eruption had a significant effect on ozone levels in the atmosphere, causing a large increase in the destruction rate of ozone. Ozone levels at middle latitudes reached their lowest recorded levels, while in the Southern Hemisphere winter of 1992 the ozone hole over Antarctica reached its largest ever size until then, with the fastest recorded ozone depletion rates.

Lessons from the 1831 Zavaritski eruption and relevance today

The eruption of Zavaritski Volcano in 1831 on the Kuril island of Samushir was one of the most powerful volcanic eruptions in recorded history. Its global consequences hold powerful lessons for humanity in 2025, particularly in the face of climate change, globalization, and the increasing importance of planetary-scale disaster preparedness.

Lessons from the 1831 eruption

1. Global reach of local events

Though Zavaritski was a very remote volcano, its impact was global. The eruption released immense quantities of ash and sulphur dioxide into the stratosphere, forming an aerosol veil that lowered global temperatures. This led to “the years without a summer" (1831-1832), causing crop failures, famine, and disease outbreaks across Europe, North America, and Asia.

Lesson: in an interconnected world, even isolated geological events can trigger cascading global crises.

2. Human vulnerability to climate disruption

Sudden, unseasonal frosts and widespread crop failure in 1831-1832 revealed just how vulnerable human societies are to abrupt climate anomalies. The eruption exacerbated existing social tensions, migration, and public unrest.

Lesson: climate shocks, whether natural or anthropogenic can have serious geopolitical and humanitarian consequences.

3. Unpredictability and lack of preparedness

In 1831 there was no understanding of the links between volcanoes and climate, nor any tools to anticipate or respond to such a disaster.

Lesson**:** Scientific understanding, early warning, and global coordination are critical in preventing catastrophe.

Why remote volcanoes matter in 2025?

1. Global atmospheric effects

Remote volcanoes like those in the Aleutians, Kamchatka or Indonesia are often located on tectonic boundaries where the most explosive eruptions can occur. Their ash and aerosols can enter the stratosphere and disrupt global weather patterns, aviation, and even economies, just as Iceland's Eyjafjallajökull did in 2010.

2. Unseen but dangerous

Many remote volcanoes are under-monitored due to access difficulties, limited funding, and political instability. This makes their potential impacts invisible until it's too late.

3. Interconnected risks

In a globalized economy, supply chains, food systems and migration patterns are tightly interlinked. Volcanic impacts on agriculture or aviation can ripple through markets and communities far from the eruption site.

Need for improved monitoring and early warning systems

1. Satellite monitoring & global collaboration

Investment in satellite-based remote sensing, seismic networks, and gas emission monitoring is essential. Coordinated global systems (like the Global Volcano Model or WOVOdat) must be expanded and better integrated with disaster management agencies.

2. Public communication & risk awareness

Early warning is only effective if it reaches vulnerable populations with trusted, actionable guidance. Lessons from COVID-19 highlight the importance of clear, science-based communication.

3. Scenario planning & resilience building

Governments and international bodies should include volcanic winter scenarios in climate models and resilience planning. This includes food security buffers, energy backup systems and international humanitarian coordination.

Implications for climate science and disaster preparedness

1. Natural analogues for geoengineering and climate models

Volcanic eruptions like Zavaritski provide valuable data for understanding solar radiation management and the limits of Earth's climate systems. They test the responsiveness of ecosystems, hydrology, and atmospheric chemistry to sudden disruptions.

2. Baseline for anthropogenic climate effects

Understanding how the Earth system responded to a natural, short-term cooling event helps contextualize current anthropogenic warming and what might happen if both intersect.

3. Building a culture of preparedness

The unexpected, global impact of a single eruption in 1831 is a sobering reminder: preparedness is not optional. It requires investment, cooperation and long-term thinking especially as climate change may increase the risk of volcanic triggers (e.g., glacial melting over volcanoes).

Conclusion

The 1831 Zavaritski eruption teaches that no volcano is truly remote in an interconnected world. For 2025 it underscores the urgency of robust monitoring, early warning systems, and international cooperation not only for volcanic risk but for the broader threats of climate instability and cascading disasters. Like Zavaritski, many volcanoes worldwide are in isolated places and are poorly monitored, making it challenging to predict when and where the next large-magnitude eruption may strike.

If there's a lesson to be learned from the 1831 eruption, it's that volcanic activity in remote spots can have devastating global consequences, which people may be unprepared to face. However, what is worse humanity do not really have a coordinated international community to kick into gear when the next big one happens. Something we need to think about as both scientists and as a society.

If you compare the three volcanic eruptions mentioned, it becomes clear that the damage and consequences are enormous. Two of the eruptions are about 200 years old, while Pinatubo Volcano is more recent. In the first two cases, science was not at a level where humans could draw conclusions and build precautions and disaster plans for a possible similar eruption. Pinatubo, on the other hand, is in recent times, where science could draw its conclusions.

And the solution to why it was the Zavaritski Volcano in 1831 shows that science may, within the foreseeable future, hopefully, is able to avert some of the violent effects of such a cataclysmic event. And collaborating in science across man-made blocs and unions is the way forward for a safer and better humanity.

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