

# **A Rare Winter Storm in Lesotho: Snow Evolution Captured by the H SAF H43 Product**

Case Study

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## 1 Short Introduction

*In early June 2025, a rare winter storm brought heavy snowfall to the highlands of Lesotho. This case study shows how the near-real-time H SAF H43 snow cover extent (SCE) product, based on MTG-FCI observation, captured the rapid evolution and depletion of snow in the days following the event. The high spatial and temporal resolution of the MTG-FCI provides possibility to clear the clouds and gives information about snow dynamics daily. Daily H43 maps, combined with temperature information and high-resolution reference data, illustrate how the product supports situational awareness during uncommon winter conditions in southern Africa.*

## 2 Summary

<b>Date &amp; Time</b>	<i>10 June 2025 00:00 UTC–30 June 2025 15:00 UTC</i>
<b>Region</b>	<i>Lesotho, South Africa</i>
<b>HSAF Products</b>	<i>H43 Snow Mask</i>
<b>Satellites</b>	<i>MTG, Sentinel-2</i>
<b>Instruments</b>	<i>FCI, MSI</i>
<b>Channels/Products</b>	<i>SE-D-FCI (H43) Snow detection (snow mask) MTG/FCI by VIS/IR radiometry, Sentinel-2 MSI L1C VIS/NIR channels</i>
<b>Latitude/Longitude</b>	<i>29.6100° S, 28.2336° E</i>

In early June 2025, an unusual winter storm affected Lesotho and parts of South Africa, bringing heavy snowfall to the highlands and intense rain and wind to lower areas. The system, driven by a cut-off low, caused major transport disruptions, power outages, and localized flooding. Snowfall of up to 30 cm was reported in northern Lesotho, marking one of the region’s most significant winter events in recent years.

### 3 Description

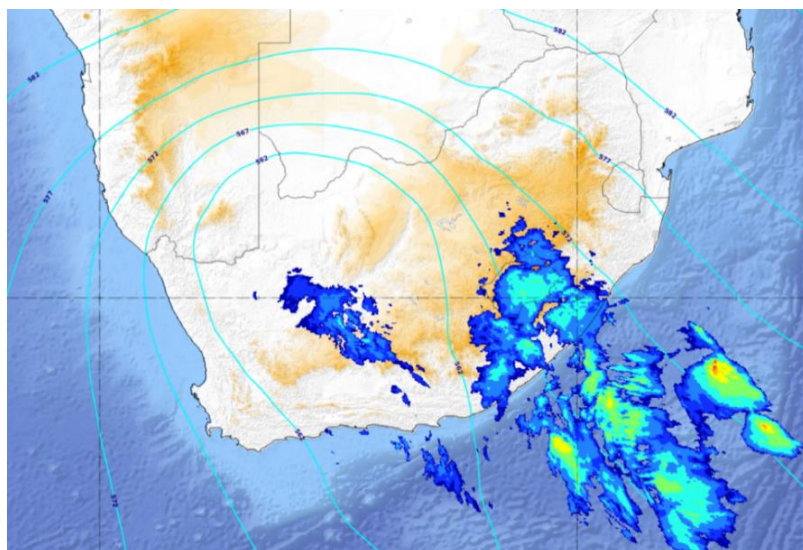
This case study examines the evolution of snow cover in Lesotho during and after the early June 2025 winter storm, a rare and disruptive event for southern Africa. The analysis focuses on how the H SAF H43 SCE product captured the spatial and temporal behavior of the remaining snow following the passage of a cut-off low that produced heavy snowfall at high elevations and precipitation and wind effects in lower areas, consistent with typical cut-off low impacts in the region (e.g., Copernicus (2025)).

The study evaluates H43 observations on selected dates throughout June to document how snow persisted, diminished, or shifted across Lesotho's complex topography. By linking the meteorological background from authoritative sources with H43's operational snow mapping capability, the case study provides a concise demonstration of how the snow product supports situational awareness and short-term environmental monitoring in regions where winter snow is normally limited.

#### 3.1 Meteorological Analysis

In early June 2025, an unusual and intense winter storm affected Lesotho and parts of South Africa. According to ESA Copernicus reports, the system brought snow, heavy rainfall, strong winds, and sharp temperature drops, creating widespread disruptions in transportation networks (Copernicus, 2025). Authorities issued warnings to limit travel, and several power outages and casualties were recorded across the region.

NASA provided a broader meteorological explanation, stating that the event was driven by a cut-off low—a detached low-pressure system no longer guided by the jet stream (NASA, 2025). This configuration allowed the storm to remain nearly stationary over Lesotho and eastern South Africa for several days. Higher elevations experienced substantial snowfall, while lower areas were affected by heavy rain, flooding, and damaging winds. Local reports indicated accumulations of around 30 cm in northern Lesotho's high mountain zones, where elevations exceed 3,000 meters.



**Fig. 1.** ECMWF Geopotential Heigh at 500 hPa (blue line) and MSG IR 10.8 Enhanced Image on June 6, 2025 at 03 UTC. A vast low-pressure system is affecting the whole south-African area: clouds are embedded in the northwesterly flow and reach the eastern parts of South Africa and Lesotho.

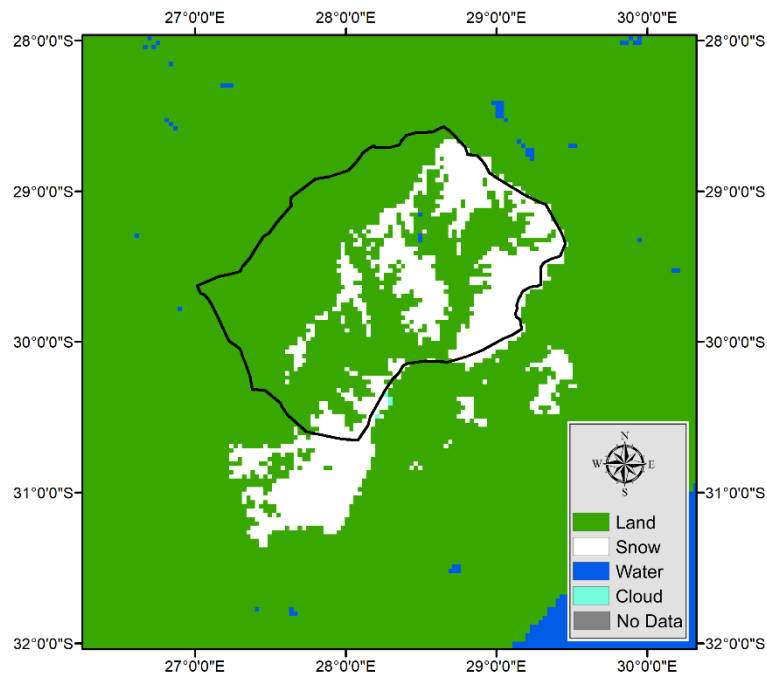
The severe weather was due to a cut-off low, that travelled from west to east and was fed by an intense northwesterly flow (cf. Fig. 1). The weather system affected central and eastern South Africa and Lesotho on June 9th and 10th and subsided by June 11th.

Although snowfall is generally limited during the area's short winter season, severe events can occur and may have strong regional impacts. The June 2025 storm illustrates how winter weather patterns in southern Africa can vary sharply across elevation bands, producing complex combinations of snow, rain, and strong winds.

The information provided by Copernicus and NASA helps to describe the atmospheric conditions that produced this rare event. Building on this context, the H SAF H43 SCE product provides an operational capability for monitoring the spatial and temporal evolution of snow during and after such storms. This supports improved situational awareness and contributes to a better understanding of snow dynamics in regions where winter precipitation is typically sparse.

### 3.2 Snow-Covered Area from H SAF H43 SCE Product

The snow-covered area (SCA) over Lesotho was monitored for 10–30 June 2025 using the H SAF H43 SCE product (cf. Fig. 2). H43 is a daily operational product, delivered in near-real time, which makes it suitable for monitoring fast-changing winter conditions.



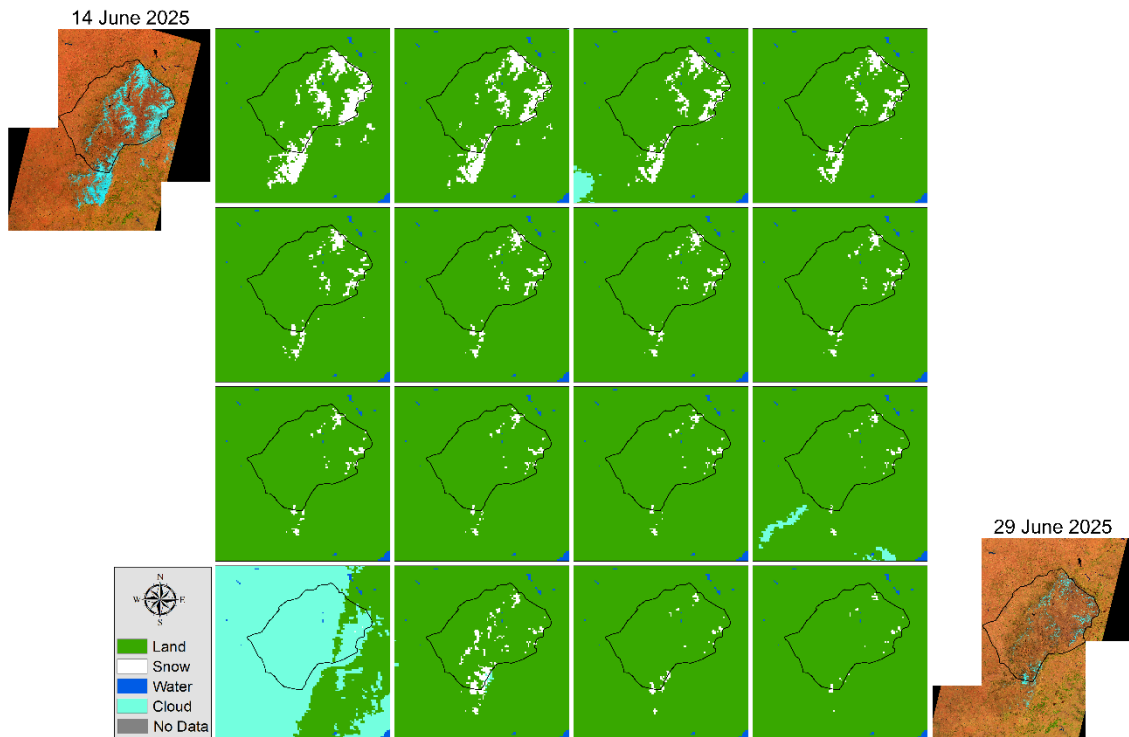
**Fig. 2.** Lesotho snow cover with H SAF H43 product on June 12, 2025.

The H SAF H43 product is a daily, near-real-time binary snow cover dataset derived from optical satellite observations at approximately 2 km spatial resolution (at nadir). The snow cover mapping is based on a multi-channel retrieval algorithm (H\_SAF, 2025; Kuter et al., 2026)

It exploits the high reflectivity of snow in the visible spectrum and the low reflectivity at shorter wavelengths. With the MTG-FCI sensor, H43 benefits from a temporal resolution of 10 minutes, which improves the detection of transient snow cover and increases the probability of cloud-free observations through temporal compositing.

### 3.2.1 Reference Snow Dataset from Sentinel-2 Imagery

Reference SCA values for 14, 21, and 29 June in Fig. 3 were obtained from Sentinel-2 imagery by applying a binary snow-mapping approach based on the normalized-difference snow index (NDSI). Following the methods introduced by Hall et al. (1995) and later refined for complex terrain and forested environments in Klein et al. (1998), NDSI was computed for each Sentinel-2 scene, and pixels exceeding the established snow threshold were classified as snow. The resulting 20 m binary maps were clipped to the Lesotho boundary, and the number of snow-classified pixels was summed to calculate the total SCA for each date. These high-resolution SCA estimates serve as independent reference points and were used to assess the temporal consistency of the near-real-time H SAF H43 product.



**Fig. 3.** Spatial evolution of snow cover over Lesotho from 14 to 29 June 2025. The figure consists of 16 daily H SAF H43 maps arranged chronologically from top left to bottom right. A false-color RGB Sentinel-2 image from 14 June is shown in the top-left corner, and a corresponding Sentinel-2 image from 29 June is included in the bottom-right corner to illustrate conditions at the beginning and end of the period.

Fig. 3 presents the spatial evolution of snow cover over Lesotho between 14 and 29 June 2025, using daily maps from the H SAF H43 Snow Cover Extent product. The figure is arranged in four rows, each containing four images, forming a chronological sequence from top left to bottom right. This layout illustrates how snow remaining from the early June storm gradually retreated across the high-elevation areas of Lesotho.

To provide visual context for the beginning and end of the period, a false-color RGB Sentinel-2 image from 14 June is shown in the top-left corner, highlighting the widespread snow immediately after the event. Similarly, the bottom-right corner contains a Sentinel-2 false-color RGB image from 29 June, depicting the limited and patchy snow cover that persisted at the end of the month. All intermediate panels show the corresponding daily H43 classifications, clearly illustrating the temporal depletion of snow across the region.

This combined presentation provides an intuitive overview of the rapid melt phase and the slower late-month decline, demonstrating how the near-real-time H43 product captures the day-to-day evolution of snow during this rare winter episode.

For the same three dates (14, 21, and 29 June), reference H43 values were generated by aggregating the 20 m Sentinel-2 binary snow maps to the H43 grid. Within each H43 pixel footprint, all high-resolution reference pixels were counted, and the resulting fractional snow cover was used to assign a binary snow or no-snow classification to the corresponding H43 cell. Based on this contingency table, the number of hits (A), false alarms (B), misses (C), and correct negatives (D) was derived. Using these quantities;

- Probability of Detection ( $POD = A / (A + C)$ ),
- False Alarm Ratio ( $FAR = B / (A + B)$ ), and
- Overall Accuracy ( $ACC = (A + D) / (A + B + C + D)$ )

were calculated on a daily basis (cf. Table 1). This approach enables a direct comparison between the H43 estimates and the higher-resolution reference maps, providing an assessment of H43 performance under varying snow conditions during this rare winter event.

<i>Date</i>	<i>H43_POD</i>	<i>H43_FAR</i>	<i>H43_ACC</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
<b>14-Jun-25</b>	0.83	0.27	0.94	615	226	129	5383
<b>21-Jun-25</b>	0.74	0.62	0.98	54	88	19	6264
<b>29-Jun-25</b>	0.62	0.83	0.99	8	38	5	6052

**Table 1.** Validation metrics for the H SAF H43 SCE product on 14, 21, and 29 June 2025. The metrics—probability of detection (POD), false alarm ratio (FAR), and accuracy (ACC)—were computed by comparing H43 classifications with reference maps derived from 20 m Sentinel-2 binary snow data aggregated to the H43 grid.

In Table 1, FAR should be interpreted with caution, especially on 21 and 29 June, because the real snow area is very small. When A is low and D is very high, even a few false alarms (B) can produce a large FAR value. This can make the product look worse than it actually is, since most pixels are correctly classified as snow-free. For this reason, FAR must be evaluated together with POD, ACC, and the A–B–C–D counts.

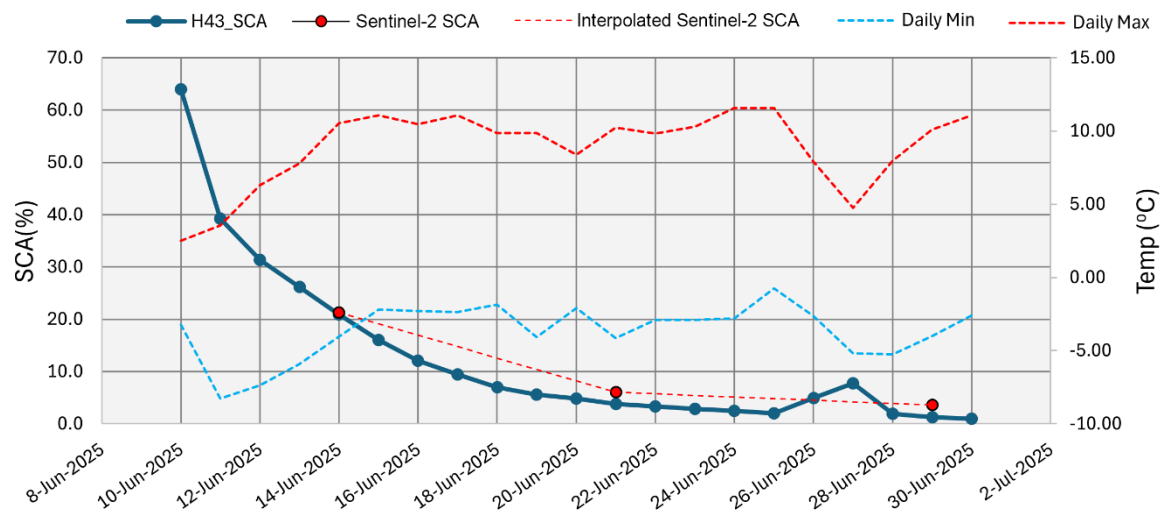
### 3.2.2 Snow Depletion Curve Analysis

For each day in June, all grid cells classified as snow within the Lesotho boundary were summed to produce a continuous SCA time series (cf. Fig. 4). The resulting curve exhibits a clear exponential decay pattern, indicating a rapid melt phase immediately

after the storm, followed by a slower reduction as small snow patches remained in shaded or high-elevation areas. The temporal behavior observed in H43 is consistent with the expected depletion of fresh snow in mid-latitude mountain regions.

To provide atmospheric context, daily minimum and maximum temperatures from the ERA5-Land reanalysis dataset were plotted together with the SCA curve. The temperature evolution supports the observed snow dynamics: warmer daytime conditions accelerated melting in the first days, while colder nights later in the month moderated the rate of depletion.

Together, the SCA time series and the temperature information offer a realistic and coherent picture of snow evolution across Lesotho’s complex terrain, demonstrating how the near–real-time H43 product captures short-term changes in snow distribution during rare winter events in southern Africa.



**Fig. 4.** Daily SCA over Lesotho from 10–30 June 2025 derived from the near–real-time H SAF H43 SCE product. The curve shows an exponential decay pattern following the early June storm. Daily minimum and maximum air temperatures from ERA5-Land are included to provide atmospheric context. SCA values obtained from three high-resolution (20 m) binary snow maps generated from Sentinel-2 imagery for 14, 21, and 29 June are also marked.

Compared with polar-orbiting sensors such as MODIS and VIIRS, the MTG-FCI instrument provides imagery at a temporal resolution of 10 minutes, theoretically allowing up to 144 acquisitions per day, of which approximately 65–70 daytime scenes are used in the generation of the H43 snow product under solar illumination. This high temporal sampling substantially improves the ability to mitigate cloud contamination and enables detailed monitoring of daily snow dynamics. When persistent cloud cover prevents direct observation, SCA can be estimated using temporal interpolation. However, interpolation between June 14 and June 21 results in an overestimation of SCA, as snowmelt processes occurring during this period are not explicitly captured.

## 4 Conclusions

This case study demonstrates that the near–real-time H SAF H43 product effectively captured the spatial and temporal evolution of snow following the early June 2025 storm in Lesotho. The SCA time series, supported by temperature information and high-resolution reference data, shows a consistent and realistic pattern of snow depletion across the country’s high-elevation terrain.

Daily H43 maps provided a clear depiction of the transition from widespread post-storm snow to the limited remnants observed at the end of June. The results highlight the capability of H43 to monitor short-lived winter events in regions where snowfall is infrequent and operational information is limited. Overall, the study illustrates the value of H43 as a reliable tool for environmental monitoring and situational awareness in southern Africa.

## 5 Bibliography

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## 6 Related content

Title	URL	Source
Snow detection (snow mask) MTG/FCI by VIS/IR radiometry	<a href="https://hsaf.meteoam.it/Products/Detail?prod=h43">https://hsaf.meteoam.it/Products/Detail?prod=h43</a>	EUMETSAT H SAF
Rare snowfall in South Africa and Lesotho	<a href="https://www.copernicus.eu/en/media/image-day-gallery/rare-snowfall-south-africa-and-lesotho">https://www.copernicus.eu/en/media/image-day-gallery/rare-snowfall-south-africa-and-lesotho</a>	ESA Copernicus
<i>Winter Arrives Early in Lesotho and South Africa</i>	<a href="https://earthobservatory.nasa.gov/images/154421/winter-arrives-early-in-lesotho-and-south-africa">https://earthobservatory.nasa.gov/images/154421/winter-arrives-early-in-lesotho-and-south-africa</a>	NASA Earth Observatory

## 7 Related tools

Type	URL	Source
hsaf-snow-geocoder	<a href="https://github.com/hckaraman/hsaf-snow-geocoder">https://github.com/hckaraman/hsaf-snow-geocoder</a>	Çağrı Karaman cagrikaraman@hidrosaf.com