Reviewed research article

Weather in Surtsey 2020-2024

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ABSTRACT

The weather of Surtsey, the southernmost part of Iceland, is of great interest. Firstly, due to the location of Surtsey, the island is exposed to undisturbed southerly air masses moving towards Iceland and secondly the weather information can be vital for seafarers in the vicinity. Thirdly, the weather has great impact on the development of flora and fauna in the scientific laboratory that Surtsey is. Here we analyse the weather of the five-year period 2020–2024. The main aim is to analyse the data in such a way that it may be of use for understanding of the processes that are monitored on and around the island. The temperature and wind data are good but there were considerable failures in measurements of precipitation. A few months had unusual weather, especially the summer of 2022, which was cloudy and cool, while the winter 2022–2023 was characterized with warm and windy months as well as cold and calm months. During the analysis period a new maximum air temperature record was set on 11 July 2023 at 18.6°C, but broken on 14 July 2025 when temperature reached 22.6°C. Also, the highest and lowest mean sea level pressure records were made, 1050.4 hPa and 932.3 hPa, on 28 March and 15 February 2020, respectively.

INTRODUCTION

The weather and climate of Surtsey, the southernmost island of the Vestmannaeyjar archipelago as well as of Iceland, is of great interest. Firstly, from a meteorological standpoint, southerly air masses after having travelled great distance over open sea often impinge first up on Surtsey before impacting the rest of the country. These air masses can thus be considered undisturbed oceanic air masses when arriving in Surtsey. Secondly, as Surtsey is a small island, 1.9 km^2 in 2019 (Óskarsson *et al.* 2020), the measurements give indications of weather over the sea and are therefore vital for seafarers, especially wind information. Thirdly, since 1965 the island has been a scientific laboratory, where the colonisation by plants and animals, biotic succession and the shaping of geological formation is as natural as possible (Surtsey Research Society 2025). Many of these processes are dependent on weather, especially temperature and precipitation (e.g. Sigurdsson *et al.* 2010, 2022, Magnússon *et al.* 2023). It is therefore necessary to monitor the weather and climate of Surtsey for the purpose of better understanding these processes, their

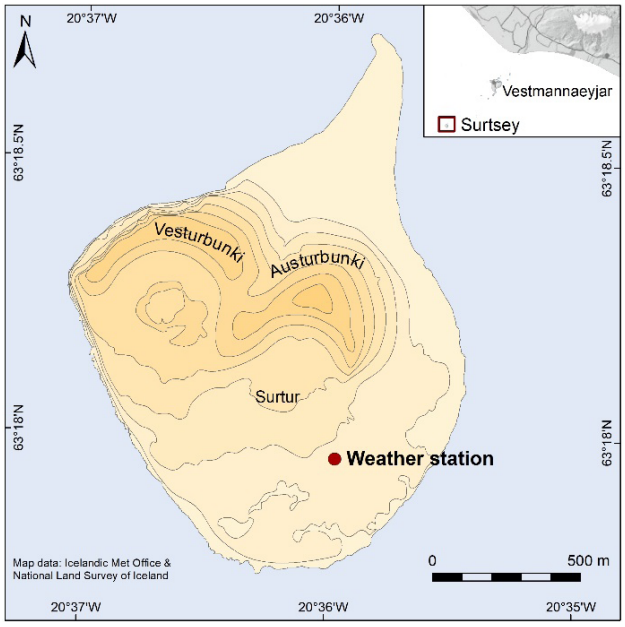

Figure 1. Map of Surtsey showing the location of the current weather station. The elevation is shown with contours, interval 20 m. Inset map shows location of Surtsey in relation to the Vestmannaeyjar archipelago as well as the southern coast of Iceland.

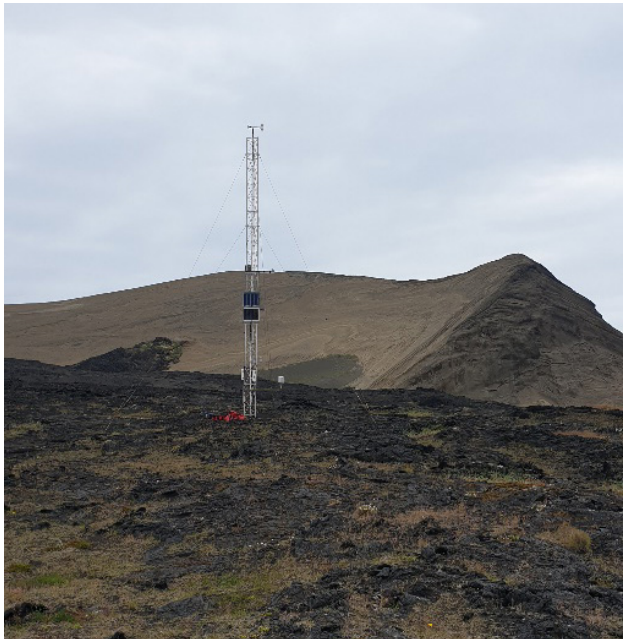

Figure 2. The automatic weather station in Surtsey with hill Austurbunki in the background. Photo: Hákon Hákonarson, 20 July 2023.

variation from year to year and how they are affected by weather and climate.

Petersen & Jónsson (2020) described the climate of Surtsey based on 10 years of data, 2009–2019, as well as documenting the meteorological measurement history of Surtsey. Here, the weather of the following five years, 2020–2024, is described and compared to measurements in Heimaey, the largest island of the Vestmannaeyjar archipelago, at Stórhöfði and in Vestmannaeyjabær. Emphasis is on identifying months with unusual weather that may impact the processes that are monitored in and around the island.

MATERIAL AND METHODS

An automatic weather station has been operating in Surtsey since 2009, station No. 6012, abbreviation surte. It is located at the southern side of the island, at 36 m a.s.l. and about 300 m from the coast, see map in Fig. 1. The surface is uneven lava with sparse vegetation, see Fig. 2. During the period 2020–2024 the station measured standard meteorological parameters as well as global solar radiation, soil temperature and humidity, see Table 1. The global radiation measurements were terminated in April 2024. The soil temperature and humidity sensors are owned by the Surtsey Research Society while the other equipment is owned by the Icelandic Meteorological Office (IMO). The measurements are recorded every 10 minutes and send in real time into the data base of the IMO.

The environment in Surtsey is harsh on the equipment as it is exposed to both sea salt and sand. During this five-year period the temperature and humidity sensor was replaced once and the anemometer twice. The station is usually only visited once every summer for regular maintenance, during annual research excursions to Surtsey. If instruments fail between these excursions, in most cases repairs/replacement will have to wait until the next summer excursion.

In this paper the meteorological conditions in Surtsey during the five years 2020–2024 are analysed. The data is put in context with automatic observations from the two stations in Heimaey, the largest island of the Vestmannaeyjar archipelago, Vestmannaeyjabær (6015, vestb) and Stórhöfði (6017, storh). These two stations are in different local environments; Vestmannaeyjabær is within the town

Table 1. The instrumentation of the automatic weather station in Surtsey, valid 2020–2024.

Parameter	Height	Instrument	
Wind speed and wind direction	10 m a.g.l.	Young wind anemometer	
Temperature & humidity	2 m a.g.l.	Rotronic temperature and humidity probe Húmi (IMO sensor)	Until 11 April 2017 From 11 April 2017
Air pressure	37.5 m a.s.l.	Vaisala Barometric pressure transmitter	
Precipitation	1.5 m a.g.l.	Lambrecht heated tipping bucket	
Solar radiation	5 m a.g.l.	Kipp & Zonen CMP3 pyranometer	Data available until 11 April 2024
Soil temperature	5 and 15 cm depth	Type unknown	Below two surfaces: sand and gras
Soil moisture	5 and 15 cm depth	Campbell CS616 water content reflectometer	Below two surfaces: sand and gras
Cloud conditions, visibility & surface conditions	3 m a.g.l.	Web camera	View direction: NE

Table 2. Information on the weather stations used in this paper.

Station	Location	Height a.s.l.	Period used	
Surtsey (6012, surte)	63.2993N 20.59947W	36 m	2020–2024 2015–2024	Only hourly wind and relative humidity
Vestmanna-eyjabær (6015, vestb)	63.43587N 20.27578W	40 m	2020–2024	
Stórhöfði (6017, storh)	63.39957N 20.28825W	118 m	2020–2024	
Stórhöfði (815)	63.39975N 20.28832W	118 m	1981–2010	Only monthly precipita-tion

of the island, at 40 m a.s.l., sheltered from the sea by low mountains, vegetation and the town itself, while Stórhöfði is located at the southern tip of Heimaey on an exposed hill at 118 m a.s.l. At Stórhöfði there were manned meteorological observations for decades, from 1921 to 2014. For a climatic view the available monthly precipitation in Surtsey is compared to a 30-year time series, 1981–2010, of manned precipitation measurements at Stórhöfði. Table 2 contains information on the stations and time periods applied in the paper.

Precipitation measurements are challenging in a windy country like Iceland and even more challenging when the instrument can only be maintained once a year. The precipitation gauge in Surtsey is a Lambrecht heated tipping bucket (Table 1). This means that the gauge can measure solid precipitation (e.g. snow), after melting it, but the measurements may be somewhat delayed and the precipitation intensity not reliable. Due to the nature of precipitation, missed measurements have larger impact on precipitation records than e.g. on wind speed or temperature records. In the IMO database, calculations of daily values of wind speed and temperature are considered valid if there are missing less than five hourly values while for precipitation all hourly records are needed. For monthly values three daily values are allowed to be absent for wind speed and temperature but again zero for precipitation. A significant number of precipitation records is missing for all three stations resulting in number of missing monthly values. For example, for Surtsey in July 2020 during maintenance the tipping bucket was recorded as getting stuck easily and thus all

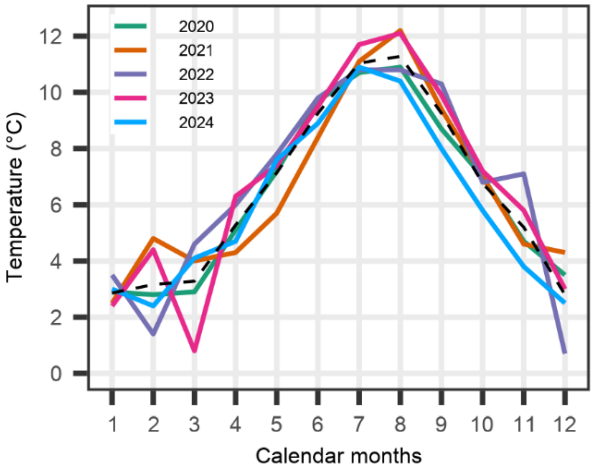

Figure 3. Annual variations in temperature (°C) in Surtsey, 2020–2024. Shown are monthly values for each year (coloured lines) and the five-year average (dashed black line).

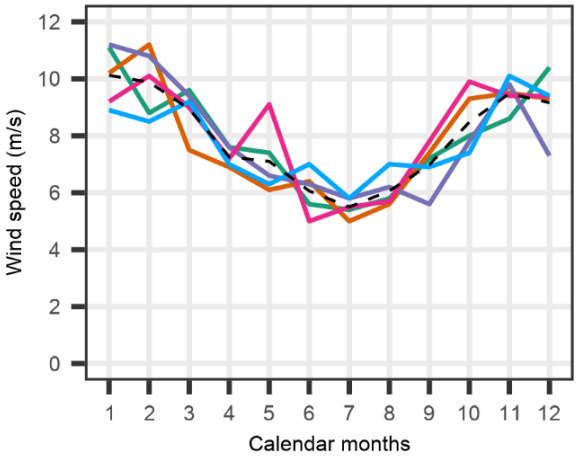

Figure 4. Annual variations in wind speed (m/s, bottom) in Surtsey, 2020–2024. Shown are monthly values for each year (coloured lines) and the five-year average (dashed black line).

measurements from January 2020 until 13 July 2020 were not considered reliable. The gauge had other mechanical problems during the period resulting in only 25 out of total 60 months with reliable monthly precipitation. There were no reliable monthly values for July during the five-year period and for May and June there are only monthly values for the year 2024. In addition, there were several issues regarding precipitation measurements at both stations in Heimaey In fact, only during the period August 2020 until April 2021 monthly precipitation values could be calculated for all three stations. Therefore, to put the existing monthly values in Surtsey into climatic context they are compared to climatic values from

the previous manned weather station at Stórhöfði, using the 30-year time period 1981–2010.

RESULTS AND DISCUSSION

Annual variations

Fig. 3 shows the annual variations of air temperature in Surtsey along with the five-year average. As has been noted before, the climate of Surtsey is in general mild and windy, with winter temperatures well above freezing level (Petersen & Jónsson 2020).

On average, the lowest monthly mean temperature occurs in January and highest in August. Interestingly, the winter 2022–2023 was characterised with both warm months (November and February) and exceptionally cold months (December and March). November 2022 was the warmest November month in Iceland since start of records, with mean temperature in Surtsey 2.3°C above the average for the last 10 years (Icelandic Meteorological Office 2022a) while the following month, December 2022, with a monthly mean temperature of 0.7°C was the coldest month in Surtsey from the start of continuous automatic observations in 2009. This was also the coldest December in Iceland since 1973 (Icelandic Meteorological Office 2022b). The year 2023 started with an average January while February was a warm month, with the temperature in Surtsey 0.9°C above the average of the last 10 years (Icelandic Meteorological Office 2023a). In contrast, the following March was cold, 2.9°C below the last 10 years (Icelandic Meteorological Office 2023b). During two of the five years analysed the August temperature was above the average of the last 10 years, in 2021 and 2023 (Icelandic Meteorological Office 2021; 2023c).

Similarly, Fig. 4 shows the annular variation in wind speed in Surtsey along with the five-year average. Surtsey is open to the North-Atlantic Ocean and thus conditions are often windy. In addition, due to the island's mostly sparse vegetation (Magnússon *et al.* 2023), the surface friction is low and therefore has little impact on the wind speed. During the five-year period the mean wind speed varied from 5.5 m/s in July to 10.1 m/s in January. May 2023 was unusually windy, with mean wind speed of 9.1 m/s. The autumn of 2023 and summer of 2024 were rather windy periods. On the other hand, March 2021, September and December 2022 were relative calm months.

Thus, during this five-year period the winter of 2022–2023 stands out due to large month-to-month variation in both temperature and wind speed, with warm and windy months as well as cold and calm.

The wind roses in Fig. 5 show the frequency of wind direction and wind speed for a 10-year period, 2015–2024, based on all observations as well as during winter months (Dec–March) and summer months (June–Sept). The top wind rose, shows that the main wind directions are easterly and east-southeasterly. These are the most dominating wind directions and from which the strongest winds are recorded. In addition, north-northeasterly winds are quite common. These winds come from the highland of Iceland and could be expected to be relatively dry and cool. The wind rose show that these winds from the highlands are often strong (up to 18–20 m/s). There is hardly any wind coming from the northeast-sector, in which the mountains at the southern coast of Iceland, e.g. Eyjafjallajökull and Mýrdalsjökull, shelter Surtsey.

The winter wind rose (centre) highlights the same dominating wind directions but also indicates that strong winds from the southwest are common during winter. Those southwesterly winter storms have been identified to be especially important in the erosion of the Surtsey island (Jakobsson & Guðmundsson 2003).

The summer wind rose (bottom) shows that during summer the main wind directions are still common but westerly winds, from southwesterly to northwesterly play a larger role. During summer most strong wind events have an easterly wind direction.

Fig. 6. shows the relative humidity as a function of wind direction for the same data set, for wind speed exceeding 10 m/s. The figure shows clearly that north-northeasterly flow is in general drier, with mean relative humidity of about 70%, while easterly flow is much moister, mean relative humidity about 90%. On the other hand, southerly to westerly flows show little correlation with relative humidity. The mean annual relative humidity ranged between 82.3% and 85.3% for 2020 to 2024. The annual variation of relative humidity is rather small, with monthly mean values ranging 71% in March 2023 and 94% in August 2021 (see Table S1 in Supplements). Interestingly March 2023 had the second lowest mean temperature and August 2021 the highest mean temperature of the period. This rather stable relative humidity of Surtsey is due to the fact that Surtsey is a small island surrounded by sea and thus a plentiful

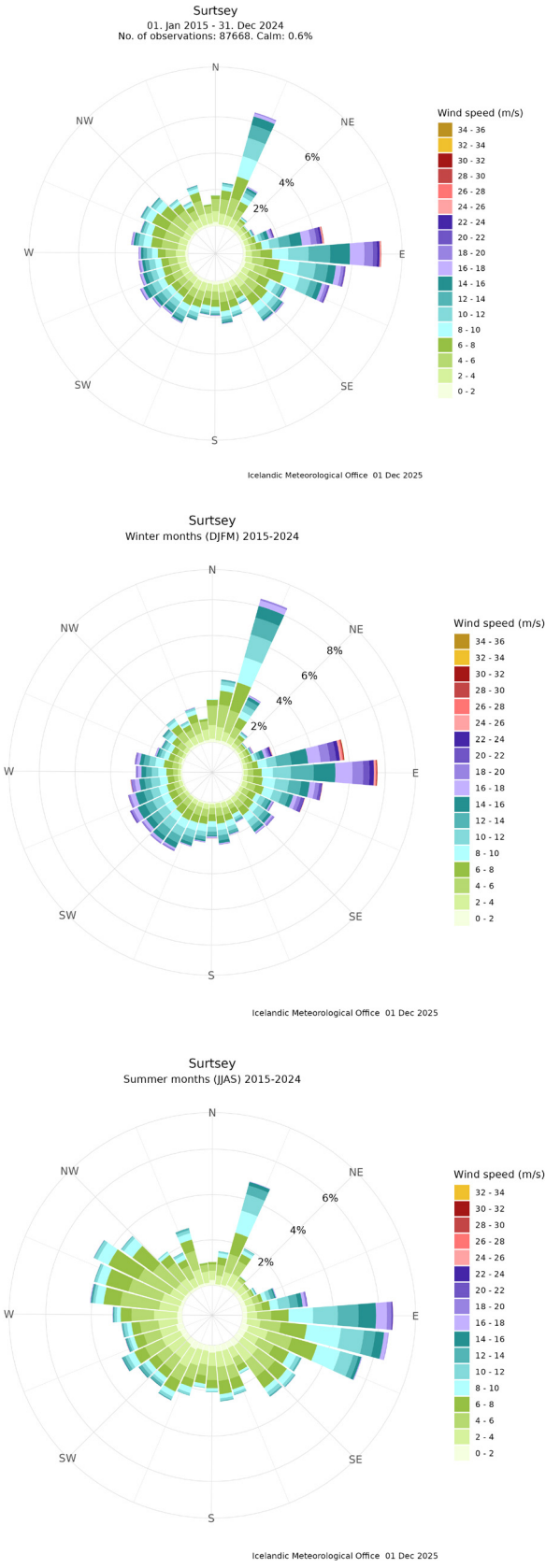

Figure 5. Wind roses showing the frequency of wind direction in Surtsey during (top) the whole year, (centre) winter months and (bottom) summer months. The wind blows towards the centre of the wind rose. The colours indicate wind speed. Hourly data from the period 2015–2024.

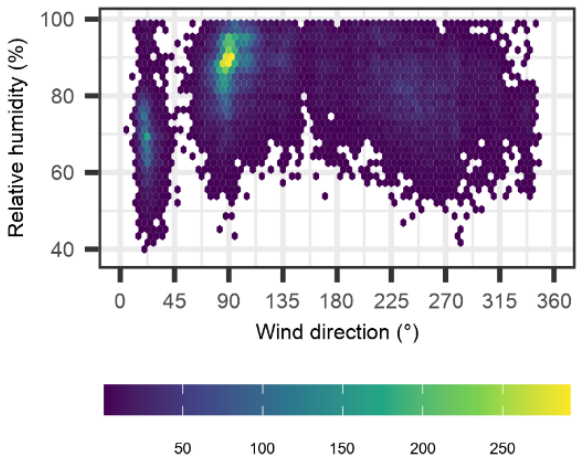

Figure 6. Relative humidity (%) as a function of wind direction (°) when wind speed exceeds 10 m/s. The hexagon cells are 5° wide and 2% high and are shaded according to number of cases. Hourly data from the period 2015–2024.

source of water vapour. The same can be said to apply to the coastal regions of Iceland.

Due to the lack of reliable monthly precipitation, both in Surtsey as well as in Vestmannaeyjabær and at Stórhöfði (see Methods), it was not possible to calculate average values or even estimate the annual precipitation. Therefore, the available monthly values from Surtsey are put into a climatic context by comparing them to 30 years of measurements at the previous manned station at Stórhöfði, see Fig. 7. In general, the precipitation in Surtsey is lower than at Stórhöfði. Previously, it has also been shown to be lower than at Vestmannaeyjabær (Petersen & Jónsson 2019). Measurements at Stórhöfði show annual variation with a maximum during autumn and winter (Sept–Feb) and a minimum during early summer (May–June). However, for Surtsey due to few values it is not possible to identify any such annual variation during this five-year period, although earlier measurements give indications of a similar pattern (Petersen & Jónsson 2019). Also, unfortunately no reliable measurements are available during the exceptionally cold February and December 2022 as well as March 2023, when one would expect less precipitation than in the milder winters of 2020–2021 and 2023–2024 where monthly precipitation in December and January was 45–95 mm. No monthly values are available for the summer of 2023 that was characterised by a cloudy and wet June followed by a warm, sunny and dry July, in fact in many places

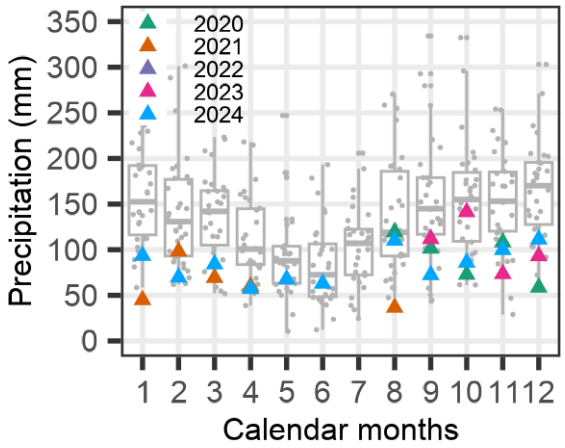

Figure 7. Available monthly precipitation in Surtsey, 2020–2024 (in coloured triangles). In the background monthly values from the manned station at Stórhöfði are shown, all values and a boxplot (in grey), 1981–2010.

this was the driest July from start of measurements (Icelandic Meteorological Office 2023e). These large fluctuations can possibly have caused stress for organisms which have colonized the island. Indeed, it was noted during the annual biological excursion in July 2023 that unusually large changes had occurred in the island's flora compared to the previous years (Icelandic Institute of Natural History 2025).

Monthly timeseries of soil temperature and solar radiation

Fig. 8 shows the monthly time series of soil temperature at 5 and 15 cm and total solar radiation. The soil moisture data is not analysed in this paper. At both soil depths the largest difference between the two vegetation classes, "grass" and "sand" is during summer when the sand, down to at least 15 cm, warms up more than the grass. The largest difference can be found in July 2023, that was exceptionally sunny, with 241 W/m^{-2}, and air temperature was high. The impact of the solar warming on the soil temperature is also evident in that summer air temperatures in 2021 were comparable to the ones in 2023 (Fig. 3), but the summer temperature in the soil remained below 15°C as the month was cloudier, i.e. less solar radiation. The lowest soil temperature was at 5 cm in sand in December 2022 (-1.0°C), followed by January 2023 (-0.8°C) and February 2022 (-0.3°C). Interestingly, while December 2022 was a cold month in air, January 2023 was not. Thus, while the air temperature rose, the soil temperature remained low, and at 15 cm kept decreasing.

During winter, November–February, solar radiation is too low to have any impact on the surface. During this period the surface is cooled/warmed by air masses moving over the island and cooled by longwave outgoing radiation. Due to the

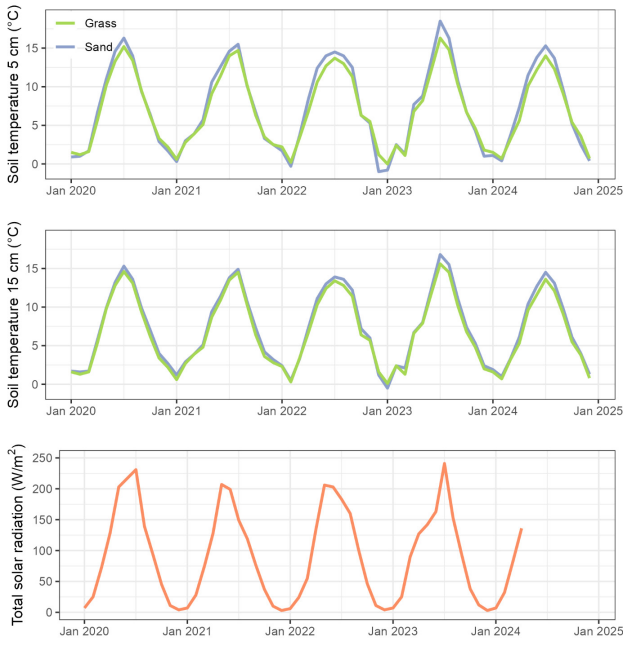

Figure 8. Monthly time series of soil temperature at 5 cm (°C, top), 15 cm (°C, centre) and total solar radiation (W/m^2, bottom).

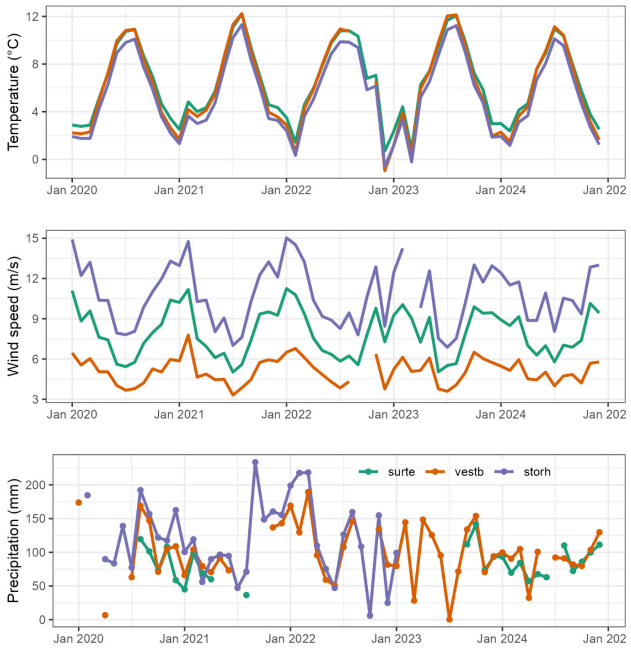

Figure 9. Monthly values of temperature (°C, top), wind speed (m/s, centre) and precipitation (mm, bottom) in Surtsey, Vestmannaeyjabær and Stórhöfði, 2020-2024.

location of Surtsey, a layer of snow rarely sits on the ground for a considerable period and therefore the insulating impact of snow has negligible impact on the temperature in the soil in Surtsey.

Table 3. Mean values during the period 2020-2024 in Surtsey, Vestmannaeyjabær and at Stórhöfði. Missing value due to missing records are shown with --.

	Surtsey	Vestmanna-eyjabær	Stórhöfði
Temperature	6.4°C	--	5.4°C
Days with minimum temperature below 0°C	52 days	77 days	80 days
Days with maximum temperature below 0°C	7 days	10 days	12 days
Length of frost-free period	219 days	167 days	193 days
Wind speed	7.9 m/s	--	--
Days with wind speed exceeding 20 m/s	32 days	5 days	118 days

Table 4. Maxima and minima during the period 2020-2024 in Surtsey, Vestmannaeyjabær and at Stórhöfði. Dates of the records are shown in parentheses and all-time records at the stations are shown in bold. Missing value due to missing records are shown with --.

	Surtsey	Vestmanna-eyjabær	Stórhöfði
Maximum temperature	**18.6°C** (11 July 2023)	19.5°C (11 July 2023)	18.8°C (11 July 2023)
Minimum temperature	-7.9°C (13 March 2023)	**-11.1°C** (12 March 2023)	-10.1°C (29 Dec 2022)
Maximum wind speed	34.7 m/s (14 Feb 2020)	**28.4 m/s** (14 Feb 2020)	45.0 m/s (14 Feb 2020)
Maximum wind gust	44.7 m/s (20 Feb 2022)	43.6 m/s (21 Feb 2022)	**58.8 m/s** (11 Nov 2022)
Maximum hourly precipitation*	8.5 mm (30 July 2020)	10.2 mm (1 Dec 2020)	14.0 mm (24 May 2020)
Maximum daily precipitation*	44.9 mm (30 July 2020)	49.4 mm (20 Oct 2023)	76.9 mm (14 Feb 2020)
Maximum monthly precipitation*	141.3 mm (Oct 2023)	189.5 mm (March 2022)	233.7 mm (Sept 2021)
Maximum sea level pressure	**1050.4 hPa** (28 March 2020)	**1050.4 hPa** (28 March 2020)	--
Minimum sea level pressure	**932.3 hPa** (15 Feb 2020)	**934.0 hPa** (15 Feb 2020)	--

*Note that the precipitation records at all stations are poor and the values not based on a full data set.

Comparison to automatic weather stations in Heimaey

The annual mean values for Surtsey, Vestmannaeyjabær and Stórhöfði are shown in Table 3 and maxima and minima in Table 4 and the continuous measurements in Fig. 9. This five-year period was slightly cooler than the preceding 10 years (Petersen & Jónsson 2020) as can be seen in lower mean temperatures, as well as more days with minimum and maximum temperature below freezing. However, at the same time the length of frost-free period is considerably longer, 20 days longer in Surtsey and 9 days at Stórhöfði. The shorter frost-free period in Vestmannaeyjabær may be related to the fact that as the station is sheltered from the sea more longwave cooling can be expected during calm and cloud free winter days and nights in all seasons. This is also evident in the monthly time series shown in Fig. 9 where summer temperatures in Surtsey are similar to the ones in Vestmannaeyjabær but winter temperatures in Surtsey are significantly higher than other stations. This suggests that Surtsey station is more impacted by the sea.

The monthly time series in Fig. 9 highlight the cool summers of 2022 and 2024 as well as the unusual temperature variations during the winter of 2022–2023. The mean wind speed could only be calculated for Surtsey as for the other two stations it was not possible to calculate monthly mean wind for all months. However, looking at the available monthly data in Fig. 9, it is clear that as expected in general wind speed is highest at Stórhöfði and lowest in Vestmannaeyjabær, where the magnitude of the annual variations is also smaller. There are indications that the winter 2023–2024 was calmer than on average.

No mean annual values could be calculated for precipitation due to lack of measurements. Fig. 9 shows the available monthly values. Where monthly values are available for the same months, in general there is correlation between the stations. There are indications that precipitation in Surtsey is closer to the one in Vestmannaeyjabær than at Stórhöfði. The autumn to winter 2021–2022 had high precipitation values, indicating especially wet winter with 150–225 mm each month at Stórhöfði. On the other hand, July 2023 was a sunny and very dry month in all of southern Iceland (Icelandic Meteorological Office 2023).

A few meteorological records were broken during

this period (Table 4). On 11 July 2023 the maximum temperature at Surtsey was 18.6°C, the highest ever recorded at the station. However, it should be noted that this record was again broken on 14 July in 2025 when maximum temperature reached 22.6°C during a heatwave, where temperature records were broken at several sites in Iceland (Icelandic Meteorological Office 2025). Both the highest and lowest mean sea level pressure in Surtsey were recorded during this five-year period. A record high 1050.4 hPa mean sea level pressure was measured on 28 March 2020 when a 1052 hPa high south of Iceland controlled the weather in Iceland. The lowest pressure, 932.3 hPa, was on 15 February 2020 when a deep cyclone moved over the country with easterly winds causing one of the worst windstorms of the last few years.

Monthly means of all measured variables covered by this paper for the period 2020-2024 for Surtsey can be found in an attached Supplements at the Surtsey Research 16 folder within www.surtsey.is.

CONCLUSION

The automatic weather measurements in Surtsey, the southernmost part of Iceland, are analysed for the five-year period 2020–2024. Unfortunately, there are failures in measurements of precipitation during this period. For precipitation there are strict criteria regarding missing values; to calculate monthly or annual precipitation all daily values must be available. This results in only 25 monthly precipitation values in Surtsey, during a 60-months period. In addition, there are many monthly values missing from the two weather stations in Heimaey, Vestmannaeyjabær has the most values or 49 monthly values while Stórhöfði has 35 values. For the five-year period analysed here, only during a 9-month period in winter 2020–2021 are there monthly precipitation values from all three stations. This means that it is not possible to calculate mean precipitation and for Surtsey no annual precipitation values. The comparison of the time series and comparison of the available monthly means in Surtsey with manned observations at Stórhöfði 1981–2010, indicates that there is less precipitation in Surtsey than at Stórhöfði but there is too little data to draw any conclusions regarding annual variations. It would be of interest to retrieve precipitation data from a reanalysis, e.g. the Copernicus Arctic Regionald Reanalysis (CARRA, Schyberg *et al.* 2020), compare to observations when possible and thus assess the usability, especially when measurements fail. Such work is outside of the scope of this paper but would be a worthy investigation, given how important reliable weather data is for analysing other data from Surtsey.

The impact of the solar radiation on the summer temperature in the soil is evident by comparing summer of 2021 and 2023, where mean air temperatures where similar but the first summer cloudier, resulting in lower soil temperatures.

Weatherwise, especially two periods had rather unusual weather. The summer of 2022 was cloudy and cool and during the winter 2022–2023 there were periods of warm and windy weather as well as very cold and calm.

Most weather observations from Surtsey are publicly available on www.athuganir.vedur.is, as 10-minutes, hourly, daily and yearly values. Soil measurements are at two locations and two depths, and it remains to find a way to publish them automatically. In the meantime, those data are available on request.

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