Vesturlína, Iceland – ice measurements for 60 years

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Abstract— **Analysing of wet snow icing and weather data since 1950 at a frequently affected location indicate clear relationship of the weather pattern and decadal variation to the general circulation. Increasing temperature trend is observed and would likely change frequency and intensity of icing.**

Keywords— ***Wet snow icing, Vesturlína, occlusion, NAO, low pressure.***

I. Introduction

The 132 kV transmission line, connects the Vestfirðir region in the northwest to the main grid of Iceland. The line crosses low mountains, steep hills and fjords. In reality Vesturlína is three seperate transmission lines, totalling 162 km. Failures due to weather are common during the relatively long wintertime. In-cloud icing and sleet icing are frequent, especially at lower altitudes. Severe storms from NE almost perpendicular to the main part of the line have frequently caused short circuit or damages with operational problems for days.

For the past 60 years sleet icing instances have been recorded close to the farm Kambur, west of the substation Geiradalur. There appear clear weather similarities for most of the failures as huge and intence winter low pressure systems slow down east of Iceland. Measurements from nearby synoptic weather station and data from ECMWF reanalysis are imposed for the period from 1961 to 2019. Frequency of sleet icing events is highly variable and variability can be shown on timescale of decades.

II. Failures at Vesturlína

Vesturlína (figure 1) was initialized in 1981. It consists of three units: GL1, GE1 og MJ1. Soon after the installation failures started to happen.

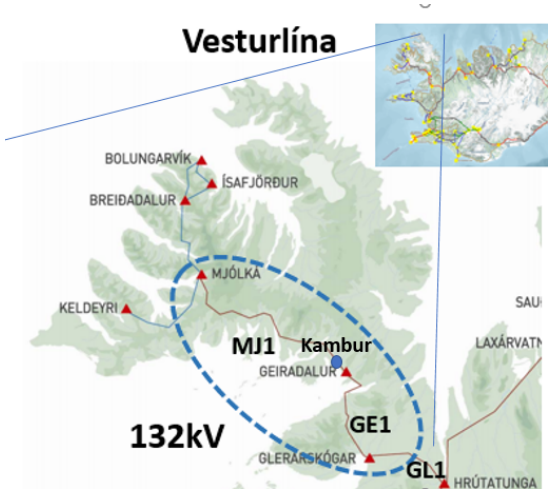

Figure 1. Vesturlína, transmission line at Iceland and location of Kambur farm.

Wet snow accretion on overhead lines have caused mechanical overloding and broken poles severel times on the lines. Wet snow accretion is a freequent occurence on power lines on Iceland [1]. One of those locations is close to the farm Kambur in county of Reykhólasveit. There the power line is located lowland. In cloud icing, gallop, salt accreation and general wind exposere does also threaten the power line. In some cases the failures are combined by more than one type of weather exposures. We will look closer to the single part of the Vesturlína close to Kambur and failures there. A systematic collection of data and registration of power lines started in 1977, but records of individual icing events and brocen poles were documented earlier. Before 1980 failures of the 11 kV distribution net were registered close to Kambur, the first case is from 1963.

III. WEATHER PATTERN

Northeast is the dominant wind direction during the wintertime for northwest part of Iceland (Vestfirðir) as a whole. The power lines lies from southeast to northwest and thus lies directly in the winds path. Normally such a wind brings dry or semi-humid air to the north part of the peninsula with snow or sleet. Somtimes the amont of measured precipitation is large and snow accumules for days or weeks. On the lee side of the wind, the south part of the peninsula the air normally remains relatively dry and mainly without any precipitation. Temperature stay just below freezing level too. The abnormal pattern in cases of N- og NE-wind is when the air containes significantly large amount of humidity and the air temperature reaches above freezing level. For such a cases even on the leeside snow or wet snow can fall of reasonable amounts.

The most intence low pressure systems crossing the Atlantic Ocean are of particular interest. Dropping pressure below 955-960 hPa the system slows down ont its track towards northeast or east. Centers close to southeast- or east-Iceland bring mild and humid air from northeast at the rearside of the system. Three depended weather phenomen exist.

1. The system forms spiraling occluded front over Vestfirðir around the mature low (figure 2).
2. A thermal wave of the warm conveyor belt is lifted aloft and turns cyclically around the low center (figure 3).
3. As the sytem slows down, the front will be almost stationary for at least several hours. During that time it snows heavily at the usually „dry“ leeside of Vestfirðir peninsula.

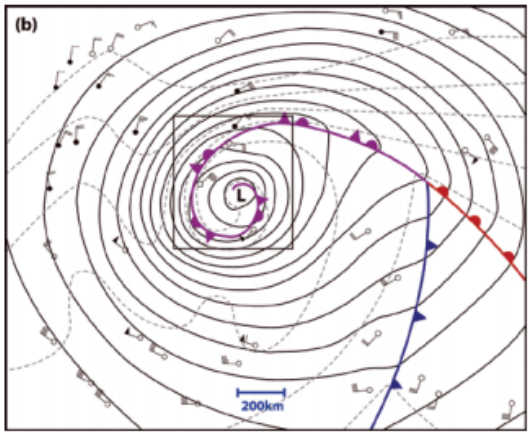

Figure 2. An example of intence matured low pressure system and its spiraling occluded front [2].

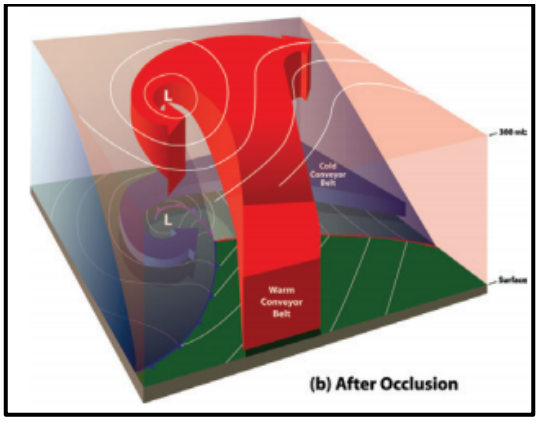

Figure 3. Warm conveyor belt (red) and cold conveyor belt (blue) after occlusion. The characteristic horizontal scale of the domain is 1.000 km on each side [2].

IV. WET SNOW ICING SINCE 1981

Table 1 include most of the severe wet snow cases at MJ1 part of Vesturlínur since 1981. Before and back to the 60´s some cases of severe icing where recorded on the former distrubution line at similar site. These robust records are not included. The table includes only cases of failures. Ice core has in many cased been observed without any transmission disruption. Tempereture has been recorded on the other site of the fjord Breiðafjörður at Stykkishólmur for more than 150 years. For NE-wind during wintertime a high temperature correlation between Stykkishólmur and discontinous observations at Reykahólasveit were observed. Calculated small bias in favor of Stykkishólmur.

Ice loading of diameter more than 20 cm is measured [3],[4]. General failure of broken poles caused by overloding is recorded up to 228 hours. Investigation of all cases indicates two „clusters“ in frequency. The first from 1990-1996 and the latter from 2011-2015. This clustering is weather related but likely not abnormal stochastically distributed.

TABLE I. SOME CASES OF FAILURES RELATED TO WET SNOW ICING NEAR KAMBUR SINCE 1981

Date	Ice diameter (cm)	Wind (m/s)	Stykkis-hólmur temp (°C)	Failure (minutes)
27.5.1985	8.0	NE 20-25	*+2.0*	*509*
2.1.1991	17.0	ENE 25-30	*+1.8*	*1555*
11.11.1991	15.0	NNE 20-25	*+1.5*	*316*
23.11.1991	8.0	NE 20-25	*+1.8*	*1934*
10.1.1994	10.0	E 25-30	*+0.8*	*2511*
17.12.1994	8.0	NNE 25-30	*+0.9*	*660*
24.10.1995	22.0	NE 25-30	*+2.4*	*13678*
20.10.1996	5.0	NE 20-25	*+2.0*	*23*
29.12.2012	25.0	NE 25-30	*+1.8*	*4544*
9.2.2014	16.0	NE 20	*+1.4*	*

**The transmission line manually switch off for deicing.*

V. FREQUENCY OF SEVERE STORMS CLOSE TO SE-ICELAND

Most of the severe cases, but not all are combined to pattern of mature low pressure system close to southeast Iceland. Analysing changes in frequency of such a systems is of interest. The estimate is recorded pressure at meteorological sites at Hornafjörður, SE-Iceland (Figure 4). A daily records are available and verified by the Icelandic Meteorological Office. Those recordings are not all from the same site, there have been several changes of the observatory. All are located very close to the town of Höfn.

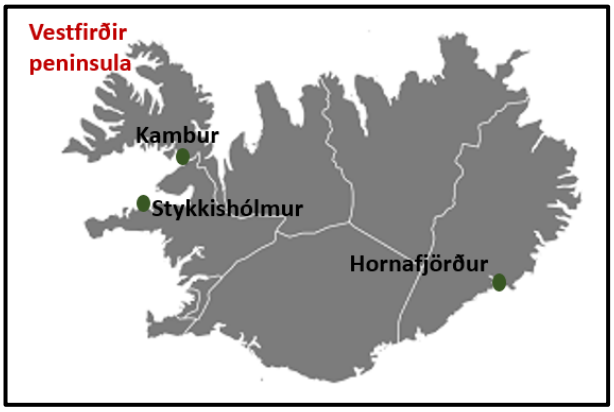

Figure 4. Locations of Hornafjörður and Stykkishólmur, relatively to Kambur.

Records of very low pressure are quiet often connected to intence low pressure system passing close to Hornafjörður. Example is shown in figure 5.

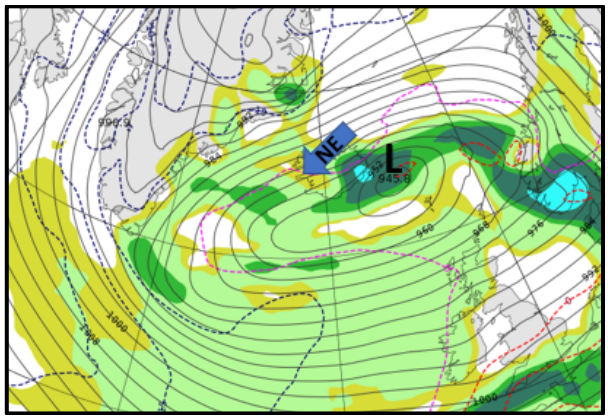

Figure 5. An example of intence low pressure system close to SE-Iceland. 2. Jan. 1991, 1200UTC. Map: Icelandic Met. Office, based on ERA Interim reanalyze.

Each case is defined when pressure, p<= 955 hPa. Some cases lasted more than single measurments, but count as one event. Figure 6 shows counts of low pressure events at Hornafjörður since 1951 decatally divited. The blue bars shows all cases, but the orange when the cases of SW wind or relatively light wind is excluded. Such a cases brings the occluted front outside the Vestfirðir peninsula. Also a few cases for temperature below freezing level. Those 59 years, 49 events of low pressure happened. In average 0,9 /year. Big majority of the 49 were observed in the high winter from November to February. Just one late in October and only one in March.

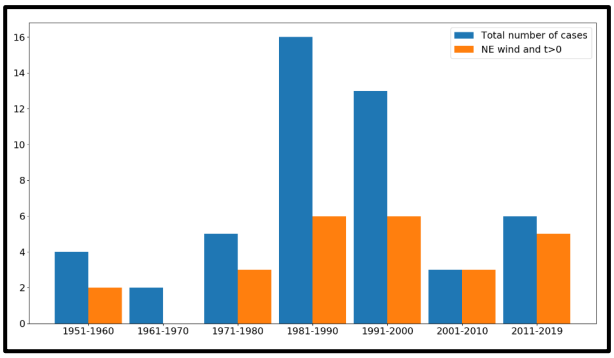

Figure 6. Number of events, where measured air pressure, p <= 955 hPa at Hornafjörður Observatory. Orange bar exludes cases of SW wind and when temperature is below freezing level. The decade 2011-2019 contains only 9 years.

For all events, there exist a clear maxima in the frequency in the decade 1981 to 1990 and again from 1991-2000. Closer approach shows clear maxima between 1989 to 1995. The generally low frequency in first two decades is obvious. These variations could be expressed as fluctuation of the North Atlantic Oscillation (NAO). The positive phase of NAO indicates stronger westerly winds, and both stronger and more northerly storm track across the North Atlantic[5].

The winter component of the NAO index shows a decadal variation (Figure 7), obviously related to the distribution of the cases of low pressure measurements at Hornafjörður.

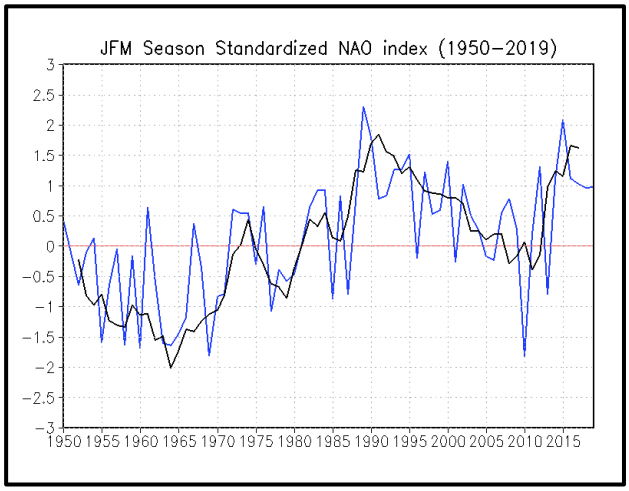

Figure 7. The standardized seasonal mean NAO index during cold season (blue line) is constructed by averaging the monthly NAO index for January, February and March for each year. The black line denotes the standardized five-year running mean of the index. Both curves are standardized using 1950-2000 base period statistics [6].

VI. INCREASED TEMPERATURE IN N- AND NE-WIND.

During wintertime the 2 m. temperature close to sea level is most of the time below freezing level. Measurements at Stykkishólmur are indicating warming when it is blowing of N and NE wind. The data where analyzed for the wintermonths, November to March. The result indicate obvius trend since 1950. At Stykkishólmur, temperature is measured at fixed hours, 8 times daily. Similar method for several decades. In the earlier day the wind speed and direction was observed, but later measured with exact sensors. Indeed the both methods are comparable. Case of N- (NE-) wind is defined for direction, d between 340° and 70° and when the speed, f is not less than 5 m/s where inadequate turbulent mixing is biasing the result.

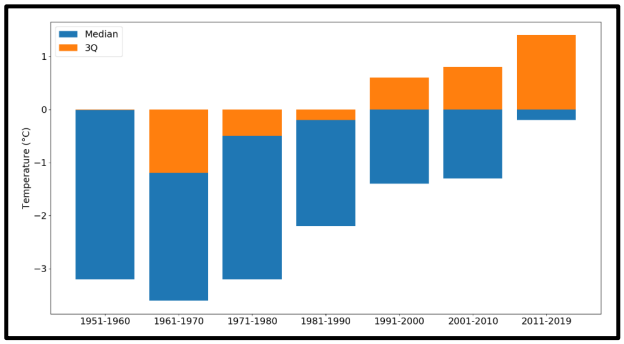

Figure 8. Temperature at Stykkishólmur for defined N- and NE-wind, November to March. The blue bars shows the median value at the lower part, but the orange the 75% quartile earlier below zero, but later above.

The median value of each observation for all 6 decades are shown on figure 8. The median values are significantl below zero degrees and they remain close to -3°C the three first

decades. Since then the median value is approaching 0°C. 2010-2019 the median value is -0.2°C. The 75% quartile was -1.2°C the decade of 1961-1970, but is measured now +1.4°C. That is difference of 2.6°C/60 years (0.43°C/10 years). The medium values indicates larger trend since 1960 at least. Compared to longer timeseries (1798 – 2018) there the general temperaturetrend is in average aproximately 0.08°C/10 years.

The freequency of defined N- (NE-)wind was observed largest, 1971-1980; 21.9% But the 2011-2019 „decade" had 15.1% of observation. Assumed small variation to the freequency of wind blowing from N or NE. Clearly the cases of N and NE- wind with temperature above freezing level are increasing last three or four decades.

VII CONCLUSIONS

Observed frecuency of wet snow icing at Vesturlína close to Kambur is closely related to the large scale variation af the North-Atlantic general circulation. Large positive wintertime NAO index increases possibillities of the most intence low pressure systems. Such systems close to SE or E-Iceland increases significantly possibilities of wet snow icing as mild and humid air twists around the rear side of the matured low. There is no indication of any trend to the wintertime NAO index, but clear decadal variation.

Measurements not so far from Kambur (Stykkishólmur observatory) shows in wintertime obvious trend of increased temperature for cases when it is blowing from N or NE. Earlier the temperature above 0°C where rare. Wet snow too. Last 10-20 years up to 40-50% of all cases of blowing predominantly N and NE include temperature above freezing level at Stykkishólmur. Even though Stykkishólmur is slightly biased positive related to Kambur similar trend is expected there too.

The gradual retreat of the sea ice north of Iceland is assumed to be the main factor of stepwise larger increased temperature to air of north origin last 60 -70 years. That is at least partly a trend combined to the global warming.

In the near future we would expect increased possibilities of failure at Vesturlína (MJ1) caused by wet snow accumulation in periods of large wintertime NAO. Likely more intence accretion as expected more humidity and precipitation proportional with increasing temperature. For even more increased temperature a new scenario would probably appear. If the NE wind in low pressure pattern will reach in average above +2°C then there will be rain or sleet rather than wet snow. Higher above new era of Vesturlína would insted threatening wet snow ice on the lines and poles.

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