A severe in-cloud icing episode in Iceland 2013-2014

- Weather pattern background -

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Abstract: **A severe in-cloud icing episode from mid-winter 2013-2014 which lasted 80 to 90 days is analysed. A reoccuring weather pattern characterized by low pressure system tracking from west to east south of Iceland towards the British Isles. As the systems passed slowly or became quasi stationary. The repetitive pattern resulted in high amounts of precipitation, high humidity and relatively mild air circulated towards the eastern part of Iceland as the wind direction was almost uniformaly between E and NE. This unusual weather pattern resulted high accumulation of in-cloud icing. In the affected area, of elevation interval from 350 to 700m in N- and NE-part of Iceland, the TSO of Iceland operates many test spans for icing accumulation.**

Data from ECMWF reanalysis from 1961 to 2013 are analysed. The so called Hovmøller method of analysis of large scale pattern of the 500 hPa pressure level near Iceland is imposed for estimating the anomaly of the winter of 2013-14 compared to more than 50 seasons from 1961. The severe and long lasting icing episodes during this winter was caused by abnormal weather pattern where the normal west component of the 500 hPa over Iceland was shifted to extraordinary strong east component.

Keywords: In-cloud icing, test spans, icing measurments, circulation pattern, reanalysis. Hovmøller analyses method.

I. INTRODUCTION

The severe in-cloud icing episode during mid-winter 2013-2014 in Iceland is obviously linked to abnormal weather pattern in the North Atlantic. The period of ice accumulation on several test spans was recorded almost continuously from 23. December to 2. March as the prevailing E- and NE-winds brought humid and relatively mild air towards east and north parts of Iceland. The ice accumulation is assumed to been in most part due to rime ice (in-cloud icing), but short periods of wet snow cannot be excluded [1]. Following is a discussion on how the simple parameterisation of the 500hPa pressure field correlates to this long continuous episode of rime icing in N and NE Iceland. The aim of this study is to connect the upper level wind where icing occurs repeatedly to the surface weather pattern. A large scale weather pattern controls rather diffuse feature as in-cloud icing. Its rate is as expected sensitive to meteorological variables such as air temperature, wind speed, cloud water, cloud droplet size and also highly to the complexity of the terrain.

Figure 1: At the test site Náttmálahæðir (00.1) after the severe icing episode.

II. A LINKAGE BETWEEN UPPER AIR STATE TO LOCAL VARIABLES

The state of the middle-troposphere is indicated by the 500 hPa atmospheric pressure field. On average the elevation of this pressure level is around 5.300 m in sub-polar areas in the boreal winter. Higher elevation of this standard pressure field is associated with warmer column of the air between surface and the 500 hPa, while lower elevations indicates colder column of air. The 500 hPa is often referred to as a steering level to the weather systems of synoptic scale such as the mid-latitude low pressures and ridges. On average, Iceland is situated on the eastern edge of cold higher level trough over eastern Canada. This trough maintains an average WSW wind at 500 hPa level over Iceland [2]. Fluctuations are of all dimensions in both temporal and spatial fields. The formation, movements and dissipation of mid-latitude systems are strongly connected to the horizontal east propagating planetary Rossby waves near the level of 500 hPa as well. Depending also to the higher level associated North Atlantic jet stream.

A multitude of circulation classification methods have been introduced in the literature. In the 1950´s the Swedish meteorologist Ernst Hovmøller classified how to use weather types based on the circulation pattern to forecast parameters such as temperature or precipitation. In Iceland the original parameters were first used by Hovmøller as part of weather classification scheme [3]. Recently, as reanalysis of standardized upper air data is available, there is again focus on such simple statistical methods. Gridded reanalysis is particularly well suited for studies based on statistical down scaling method where one single surface variable is correlated to the 500 hPa field over and around Iceland.

There are three conceivable Hovmøller parameters:

A. Zonal (west) component of the wind at 500 hPa in a cross section 70°N-60N along the 20°W longitude.
B. Meridional (south) component of the wind at 500 hPa in a cross section 30°W-10°W along the 65°N latitude.
C. Height of the 500 hPa at 65°N-20°W.

By these definations, the fields are categorized into three very simple components which form a parameter space (Figure 2). The zonal component and how it advects humid air towards N and NE Iceland is of main concern in this study, as well as parameters influencing the weather during the periods of days or weeks where in-cloud icing occurs repeatedly in NE and N Iceland.

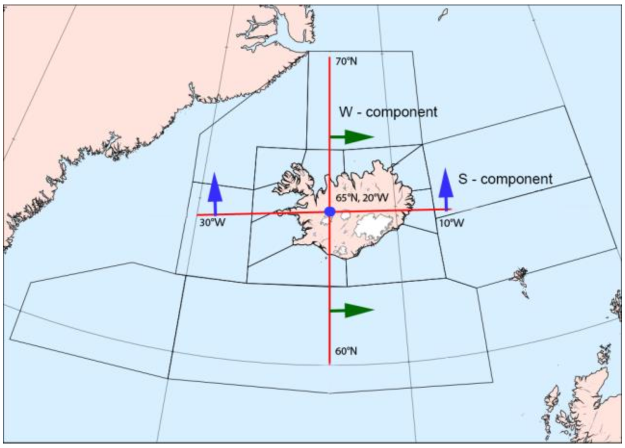

Figure 2: Figuration to the Hovmøller parameters. A: West-component, B: South-component and C: Hight of the 500 hPa at 65°N-20°W.

A set of daily data for the three Hovmøller parameters was extrected from ECMWF´s ERA-20C global reanalyses [4]. The data set contain fully comparable 55 years to the three 500 hPa parameters; A,B,C with a temporal resolution of 6 hours.

III. PARAMETERS OF THE WINTER 2013-2014

Zonal component of the 500 hPa

Figure 3 shows the average zonal component of the 500 hPa wind for each winter in the data set (December to February). As expected the positive zonal component (W-wind) is prevailing, but the variability is large. The 2014 winter (Dec. 2013 - Feb. 2014) is a clear outlier. It is the only single winter where negative component (E-wind) is more frequent than positive (W-wind). Another outlier of this 55 years dataset is the winter of 1977, in which longer periods of E-component where measured, although the combined component for the whole period is slightly positive. This winter (1976-1977) there was extensive damage experienced on transmission lines in NE and E Iceland.

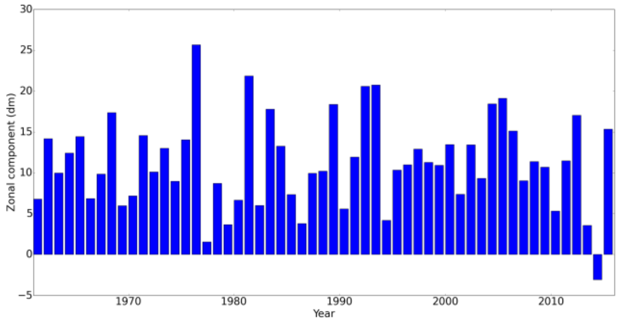

Figure 3: Zonal component (A) in dekameters (dm). The extraordinary value of the winter 2013-2014 is -3.1 dm.

On figure 4 the zonal component is calculated each 6 hours from 1st. Dec 2013 until 28th. Feb. 2014. A weather pattern that led to significant negative zonal component started on 21^{st} of December and lasted more or less until 3^{d} of March when the component shifted completely. The mean value of the zonal component during December to February (1961-2015) is +11,5 dm The lower tercile is calculated as +3,5 dm and during most of the period 21^{st} Dec. to 3^{d} March the zonal component remain constant.

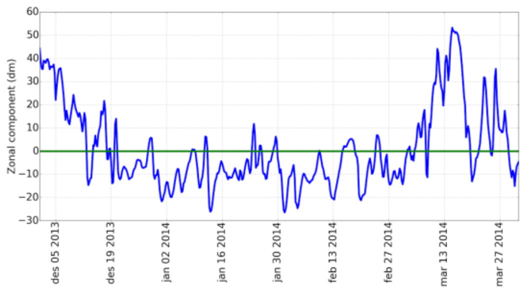

Figure 4: The Zonal component of the 500 hPa wind in cross section over Iceland. Negative values indicate east wind.

The test span Heiðarhnjúkur

Heiðarhnjúkur is one of Landsnet´s test spans, located in East-Iceland at a mountain ridge ~900 m.a.s.l (Figures 5,6). Severe in-cloud icing has been measured frequently at this location since the beginning of measurements in the mid 1980´s.

Figure 5: Heiðarhnjúkur test site (85-1)

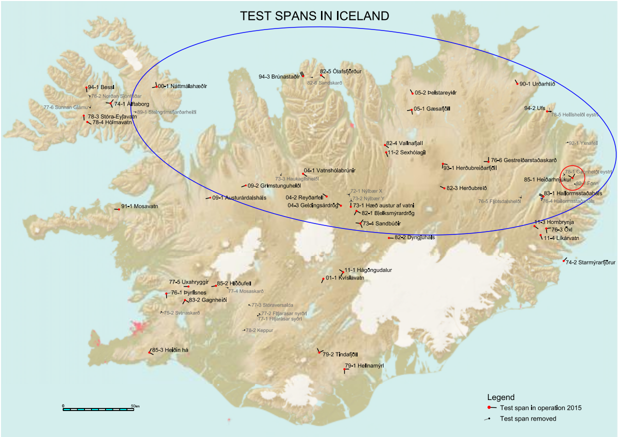

Figure 6: Location of all the test spans. Test site Heiðarnjúkur is marked in the red circle and the affected area in the blue circle.

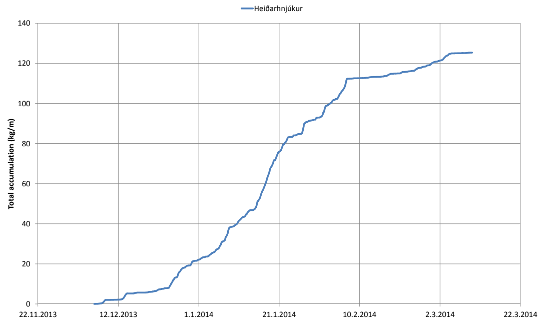

Figure 8: Measured ice accumulation at Heiðarhnjúkur in the unit of kg/m/h. The calibration limit (see Figure 7) is not taken into account.

Figure 7 shows the measured ice load at Heiðarhnjúkur (A) from 1. Dec 2013 to 12. March 2014. Significant ice accumulation began 23.-24. December and icing events where frequent until March. During longer periods the accretion was recorded constantly. Ice shedding is occasional, mainly caused by wind conditions, but sometimes it happens randomly. The ice load period from 20. January until 16. February is extreme compared to Heiðarhnjúkur´s records, but also absolutely in combination to the network of nearly 60 operational test spans measuring ice accumulation in real-time. However ice accumulation has once before been measured 600 N/m [5].

The flat top of the curve in February is due to the fact that the measuring equipment is calibrated for certain range. If the measured load is above the range of the instrument it is recorded as the maximum. It is not possible to determine accurately how much the actual accumulation was during this period but has been estimated close to 60 kg/m (dashed line) based on nearby test spans and icing calculation from WRF modelling [1].

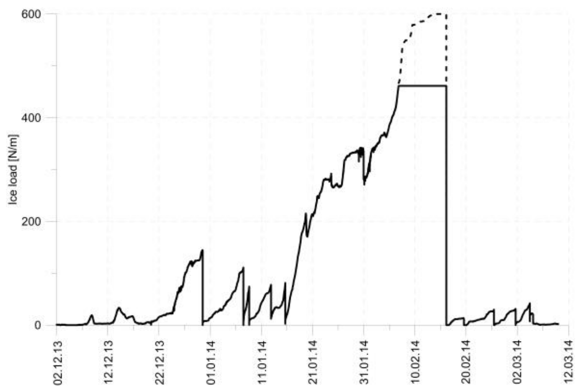

Figure 7: Measured Ice accretion at test span Heiðarhnjúkur (A) at E Iceland from December 2nd 2013 to March 12th 2014. Dashed line is estimate when calibration was out of range.

The rate of the accumulation at Heiðarhnjúkur is show in figure 8. In-cloud icing was strong and nearly continuous. Very short periods of light or negligible icing are measured. The rate of accumulation was extremely high from ~15th to 22nd January. The sharp brake on the line is due to the equipment calibration limit (10.000 kg).

IV. Results and dicussions

The 500 hPa Zonal wind crossing Iceland mainly has a westerly component. In that situation in-cloud icing is rare and normally not of any importance at N and NE Iceland. When low pressure systems are dissipating towards east south of Iceland the Zonal component shifts to negative for a while. Sometimes even for a periods of days. During these periods, measurements have shown that in-cloud icing can accumulate on test spans. There are no instances in the 55 year period analysed where the zonal component is negative continuously for weeks or months as 2013-2014. Figure 9 shows 500 hPa mean and anomalies for January 2014. A dipole anomaly appears where large negative anomaly is observed over Ireland and an opposite anomaly is found over the Norwegian Sea and Spitzbergen. February was modeled and a map of Sea level pressure is shown on Figure 10. Anomaly up to 27 hPa below the average on monthly base is extraordinary in all cases. Such a pattern leads to strong and persistent E- and NE- surface winds generally in Iceland which is similar to the January anomaly shown at figure 9.

The severe and long lasting icing during the winter months of 2013 – 2014 was caused by succession of numerous vigorous low pressure systems moving eastward south of Iceland toward the British Isles. UK experienced both the wettest winter on record as well as the stormiest since records began in 1910 [6]. The global causes for this extraordinary winter are still under debate. Some publications associated its occurrence with extraordinarily low temperature occurring over the North American continent, generating recurrent cold air outbreaks. At the same time, the subtropical Atlantic was comparatively warm. This combination lead to strong temperature gradients and created ideal conditions for the generation of storm systems. over the North Atlantic [7]. The cold air outbreak is related to North-America circulation anomalies. Characterized as a dipole with amplified upper-level ridge over the Pacific coast and deepening through over the central-eastern parts of U.S and Canada [8]. The abnormal winter 2013-2014 also emphasizes the necessity of a better understanding of the drivers of extreme weather pattern and this is particularly relevant within the scope of climate change.

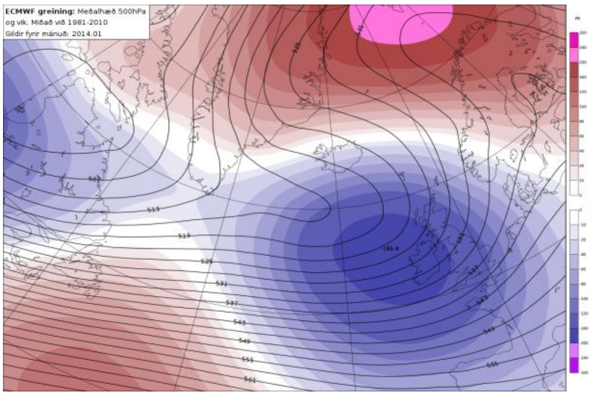

Figure 8: January 2014. 500 hPa mean in dekameters (contours) and anomaly from 1981-2010 average. Red: positive and blue: negative. From IMO (Icelandic Meteorological Office)

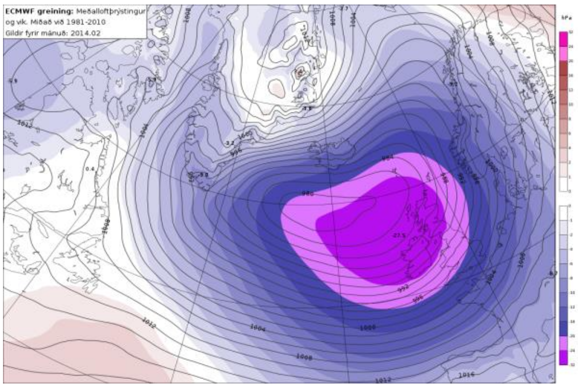

Figure 9: February 2014. Sea surface pressure in hPa (contours) and anomaly from 1981-2010 average. Red: positive, blue and violet: negative anomaly.

V. Acknowledgment

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