Comparison of Data from a Lightning Location System and Atmospheric Parameters from a Numerical Weather Prediction Model

Þórður Arason, Veðurstofa Íslands - Icelandic Meteorological Office, Reykjavík, ICELAND
arason@vedur.is

Abstract

This study presents a comparison between the occurrence of thunderstorms in Iceland as identified by lightning location systems and the properties of the atmosphere as analysed and predicted by a short range numerical meteorological forecast model. The purpose of the comparison is to identify thunderstorm prediction indices, suitable for Iceland.

The numerical meteorological forecast model of Météo-France, Arpège, was used for this study. On the basis of output from the Arpège, the key atmospheric variables were defined in a grid. The lightning locations of the ATD sferics system of the UK Met Office and the LLP-based lightning location system of the Icelandic Meteorological Office, were used for this study.

Several thunderstorm indices based on the temperature and humidity profile of the atmospheric column of each element of the forecast model were calculated. The indices that best predicted occurrences of lightnings were then used in a statistical similarity model that estimates thunderstorm probabilities. These were adjusted for annual variations and diurnal variations in the summer.

The results enable the construction of probabilistic local thunderstorm forecasts for Iceland, based on output from an operational numerical weather prediction model.

Thunderstorm indices and similarity analysis

Seventeen various thermodynamic and kinematic thunderstorm indices that indicate potential instability of the atmosphere were used in this study along with seven indices that describe the state of the atmospheric column. The 24 indices used were calculated for every grid-point of the Arpège numerical weather prediction model for the period 2000-2003 every six hours.

In order to estimate thunderstorm probabilities for a given place and time, we chose to compare the state of the atmospheric column to previous states at similar times and places.

To assess similarity of two states of the atmosphere we calculated the distance between the 24-dimensional thunderstorm index vectors in 24-dimensional space. If two states are identified by the subscripts n and m, then we measure the distance of the i-th index by

$$d_{i\,n\,m} = w_i\,(x_{i\,n} - x_{i\,m}) \,/\, \sigma_i$$

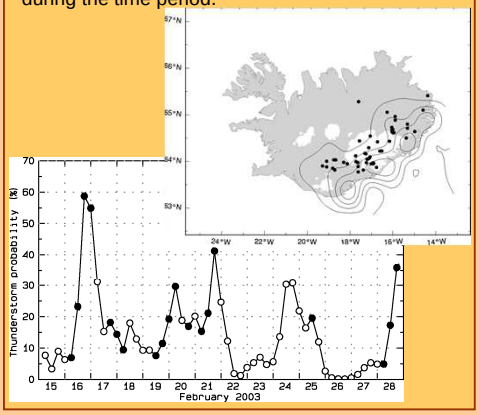
where $x_{i\,n}$ and $x_{i\,m}$ are the value of the i-th stability index for state n and m, respectively, σ_i is the standard deviation of index x_i, and w_i is an empirically chosen weight for the i-th index. Low distances between two states in the 24-dimensional space represent similar situations.

Once we identified adequate number of previous occurrences that are similar, we calculated the frequency of thunderstorms in this data subset.

Sample results

As an example of the results of our calculations we show a contour plot of the predicted thunderstorm probabilities on 20 February 2003 at 06:00 UTC. The similarity calculations indicate increased chances of thunderstorms on the SE-coast. The highest probability in a single element in this case is 2.5%, and the total probability is 30%. The dots show located lightnings at the same time.

The total probability is shown as a function of time for a half month in February 2003, when winter-thunderstorms were quite frequent. The filled/(open) circles indicate that the lightning location systems measured some/(no) lightnings during the time period.

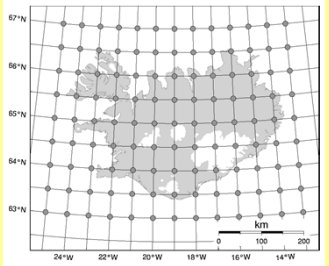


Weather prediction model

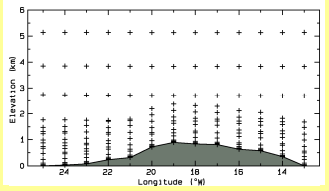
We used the output of the numerical weather prediction model, Arpège, made by Météo-France.

The parameters given by the Arpège output at each grid point are elevation of an air parcel above sea level, air pressure, air temperature, relative humidity, wind speed and wind direction. For each areal element, the Arpège model output predicts the state of the atmosphere in 11-19 vertical layers below the 500 hPa pressure level, which is about 5 km above sea level.

By using analysis of Arpège every 12 hours and 6 hour predictions we were able to define the state of the atmosphere every 6 hours for the four years 2000-2003. Each of the 117 horizontal elements of the study area is about 47 × 55 km.

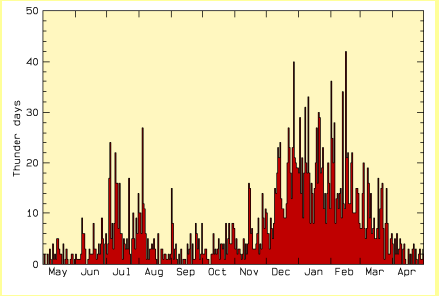


The grid-points of the Arpège numerical weather prediction model over Iceland



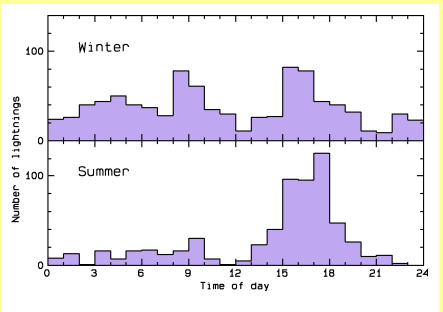
A sample vertical cross section at 65°N showing typical distribution of the Arpège grid-points

Temporal variation in Iceland

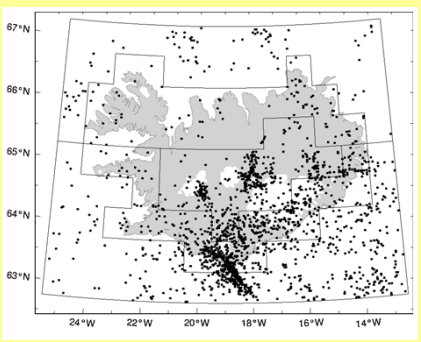


The annual variation in thunder reports from manned observations during the fifty year period 1951-2000 shows the two distinct thunder seasons in Iceland.

During summer there is a strong diurnal variation in the occurrence of thunderstorms, and the data for 2000-2003 shows a significant increase in lightning activity in the afternoon.



Lightning location data



The located lightnings during the four years 2000-2003

We used lightning locations for the four years 2000-2003 from the Icelandic lightning location system and data from the ATD sferics system of the UK Met Office. The lightning data were used to determine times and places of thunderstorms.

For comparison purposes the lightning location data were gridded in space and time in the same way as the Arpège model output, i.e. the same 117 areal elements at six hour time intervals.

The ATD sferics out-station of the UK Met Office in Iceland

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