Probabilistic forecasts of winter thunderstorms around Amsterdam Airport Schiphol

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The development and verification of a probabilistic forecast system for winter thunderstorms around Amsterdam Airport Schiphol is described.

1. Introduction

Winter thunderstorms are quite rare in the Netherlands, but still they can cause problems to aviation. It is thought that about 90% of the discharges to aircrafts are initiated by the aircraft itself. This is called aircraft induced lightning (AIL). When planes are struck by lightning, this may damage the plane which results in costly reparations or delays. That is why airports would like to have a warning system for the occurrence of lightning. There are several thunderstorm indices, like the Boyden index or CAPE, which are quite good winter thunderstorm predictors when regarded individually. However, in this study thunderstorm indices are combined to create a probabilistic forecast system for winter thunderstorms.

We have used model output statistics (MOS) to develop the probabilistic forecast equations. The MOS system consists of 32 logistic regression equations, i.e. for two forecast periods (0-6 h and 6-12 h), four 90 × 80 km^2 regions around Amsterdam Airport Schiphol (Fig. B), and four forecast cycles per day.

2. Statistical method, predictand and potential predictors

2.1 Logistic regression

The derivation of the MOS equations has been done using the method of logistic regression [3]. According to this method the probability Pr that an event y occurs is:

$$\Pr\{y\} = \frac{1}{1 + \exp(a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_n x_n)}$$

The predictors $x_i (i = 1, 2, \ldots, n)$ are selected via a so-called forward stepwise selection method and the regression coefficients a_i are determined using the maximum likelihood method [3].

2.2 Predictand definitions

In this study an event is defined as a thunderstorm event if ≥ 1 lightning discharge is present in the quality-controlled SAFIR lightning dataset [2] in a 6-h time period (03-09, 09-15, 15-21 or 21-03 UTC) in a 90 × 80 km^2 region. Herewith, both intracloud and cloud-to-ground lightning discharges are taken into account. The predictand for thunderstorms is defined as the probability of a thunderstorm event.

2.3 Potential predictors

As in [1] several thunderstorm indicators from HIRLAM and from the ECMWF model, and an ensemble of advected radar and lightning data were used as potential predictors. The set not only included the traditional indices, like Jefferson or Boyden, but also other possible indicators of thunderstorms, like wind shear or temperature advection.

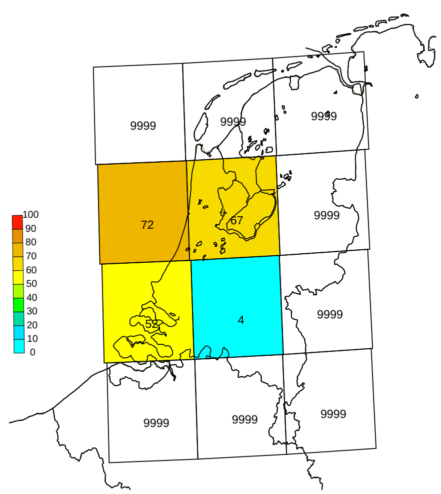

Figure A. 6-12 h probability forecast (%) of ≥ 1 lightning discharge for 4 December 2009, 03-09 UTC.

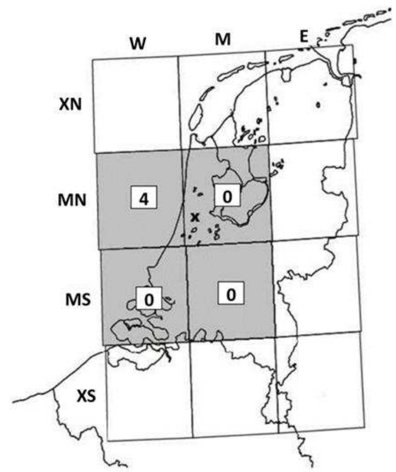

Figure B. Number of discharges per region on 4 December 2009, 03-09 UTC. The location of Amsterdam Airport Schiphol is indicated by a cross in region MMN. The following letters are used for the regions [1]: W stands for west, M for middle, E for east, X for extreme, N for north, and S for south.

3. Results

3.1 Selected predictors

Using forward stepwise selection [3], 13 different predictors have been selected in the 32 forecast equations [2]. The most selected predictors are the HIRLAM Boyden index, the square root of the ECMWF 3-h and 6-h convective precipitation sum, the HIRLAM lowest-level and lowest 100-hPa CAPE, and the square root of the mean 6-h radar precipitation sum above 3 mm/h.

3.2 Example case: 4 December 2009

To demonstrate the forecast system an example case is described. In Fig. A the 6-12 h probability forecast for 03-09 UTC on 4 December 2009 is given. The probability is highest in the region WMN (72%), and quite high as well in the regions MMN (67%) and WMS (52%), whereas the region MMS shows a probability (4%) close to the climatological value. The observed number of lightning discharges is given in Fig. B. Two airplanes were struck by lightning this morning.

3.3 Verification results

In this subsection objective verification results are shown for both forecast periods using the Brier skill score (BSS) [3]. The regression equations generally have Brier skill scores above the 0-skill line (Fig. C). This clearly indicates that the forecast system developed here is skilful compared to climatology. The highest scores are found for the morning (03-09 UTC) and the lowest scores for the afternoon (09-15 UTC).

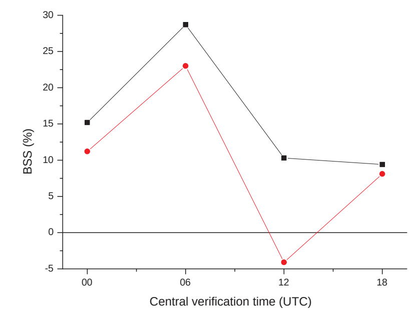

Figure C. Brier skill score (%) as a function of central verification time for the 0-6 h (black) and 6-12 h forecasts (red). The 4 regions have been pooled and the independent verification period is from 16 October 2007 to 15 April 2008.

4. Conclusion

The forecast system generally has skill compared to climatology (Fig. C). The highest Brier skill scores are found for the morning and the lowest for the afternoon.

References

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