Validation of a method for the remote determination of potential aircraft icing spatial zones

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Abstract. Aircraft icing remains an urgent problem of today. One of the promising means of passive temperature remote sensing in the lower (1-kilometer layer) atmosphere is a meteorological temperature profiler called MTP-5. This paper presents the results obtained by a method of remote determination of potential aircraft icing spatial zones and its validation by the example of two International Airports, Novosibirsk and Tomsk. For Tomsk, one year was analyzed (October 2012-September 2013) and for Novosibirsk, one month, January 2015. The atmosphere remote sensing method is the measurement of air temperature in the lower atmosphere layer using the meteorological temperature profiler (MTP-5) to determine the potential aircraft icing zones during landing or take-off to ensure high-quality analysis. The method, combined with the Schultz and Politovich method, shows a result similar to that obtained with the Godske method. Estimation of the icing forecasting accuracy for the two methods shows that the Schultz and Politovich method has higher accuracy than the Godske method on the data used for the two airports.

1. Introduction

Despite the success achieved in the study of the physical basis of aircraft icing, today this problem continues to be important, including the development of de-icing means. On the part of meteorological support of aviation, icing detection and forecasting with an advance of up to 12 hours is carried out by the Godske method [1] using radio sounding data, and well as by the Schultz and Politovich method [2] based on numerical simulation with an advance of 6 hours. Due to high intra-day variability of temperature fields in the atmosphere, such an advanced prediction does not reflect the real picture for the needs of aviation, and in practice icing crew reports are used to refine it.

At present, there are atmosphere remote sensing facilities providing information on meteorological parameters that can be used to estimate the probability of aircraft icing during landing or take-off, with a high spatial and temporal resolution. In particular, one of the promising means of passive temperature remote sensing in the lower (1-kilometer high) atmosphere layer is the meteorological temperature profiler MTP-5. It provides information about the air temperature vertical profile every 5 to 10 minutes with a vertical resolution of 50 to 10 meters. In this regard, the studies of the potential use of MTP-5 to determine the meteorological conditions that lead to in-flight aircraft icing with high spatial and temporal resolution are relevant. The remote method for determining the spatial zones of possible icing is patented and described in detail in [4] and previously published in [5,6]. The necessary stage of development of the proposed method is verification of its compliance in specific conditions.

This article presents the use of the method for remote determination of potential aircraft icing spatial zones and the validation of its results by the example of two International Airports, Novosibirsk and Tomsk. For Tomsk, one year was analyzed (October 2012-September 2013) and for Novosibirsk,
one month, January 2015. The choice of time intervals was defined by the time of monitoring performed at these airports.

2. **Results of calculation of vertical distribution of possible aircraft icing zones**

This article presents two examples of calculation of the probability of aircraft icing in the area of Tomsk and Novosibirsk airports. The reference days are March 17, 2013 and January 5, 2015, respectively. During the experiment, 20 more days with icing cases were registered at the Tomsk International Airport and another 8 days, at the Novosibirsk International Airport.

The results of the calculation of the vertical distribution of possible icing zones are presented in Figures 1 and 2, where gray, dark gray, and light gray colors show the results of the calculation of the spatial zones of icing hazard, white color represents zones where the meteorological conditions do not conduce to icing. Dark gray color corresponds to the spatial zones of possible icing in the clouds, gray color in precipitation, and light gray refers to the spatial zones of possible icing with no clouds or precipitation. Black dashed lines indicate the spatial zone of actual icing based on the crew reports for the considered period of time. The graphs for the international airport of Novosibirsk present the results of the calculation according to the radiosonde, in the form of plus and minus signs, where plus corresponds to possible icing, and minus to the absence of icing.

Figures 1 and 2 show the results of the calculation of the spatial zones of possible aircraft icing at the airport of Tomsk obtained using the Schultz and Politovich method and the Godske formula. The results of the calculations are in full compliance with the analysis of the atmospheric situation observed in the atmosphere on March 17, 2013: icing is possible both in clouds and precipitation and in their absence.

The analysis of the results presented in Figures 1 and 2 shows that the Schultz and Politovich method and the Godske method give similar results on the location of the spatial zones of possible aircraft icing. However, the result obtained by the method of Schultz and Politovich was confirmed by data on actual icing (Fig. 1), in contrast to the Godske method (Fig. 2), where in the time period from 11.00 to 13.00 UTC icing at the ground and up to a height of 50 m was not registered. Actual icing on March 17, 2013 in the Bogashevo airport was moderate; observed at different heights and in different time periods: at 00.00 - 02.30 UTC icing was recorded in the clouds, at 08.15 - 10.00 UTC icing was recorded in the layer from 2000 meters to 700 meters, and between 11.06 and 13.00 UTC aircraft crews reported icing in the clouds and in precipitation.

![Figure 1](image1.png)  
**Figure 1.** Spatial areas of potential aircraft icing on 17 March, 2013, Tomsk, Bogashevo Airport, the Schultz-Politovich method.

![Figure 2](image2.png)  
**Figure 2.** Spatial areas of potential aircraft icing on 17 March, 2013, Tomsk, Bogashevo Airport, the Godske formula.
For the Novosibirsk International Airport, the calculation of the vertical distribution of possible icing zones on the basis of MTP-5 and the AMIS-RF data were compared with the data on the actual icing and calculations by the Schulz and Politovich method and by the Godske method based on radiosonde measurements in Novosibirsk at constant pressure surfaces at 00:00 UTC.

The synoptic situation on January 5, 2015 in the area of Novosibirsk airport had favorable conditions for icing. According to the crew reports, the degree of icing hazard was estimated as weak and moderate. During the time period from 00.00 to 02.12 UTC a weak icing was registered in the layer from 300 m to the ground, and from 18.08 UTC to 23.59 UTC moderate icing was reported in the clouds.

The vertical distribution of possible icing zones on January 5, 2015 in the area of Novosibirsk airport calculated by the method of Schultz and Politovich is shown in Figure 3. Icing is probable throughout the whole day in the lower (1-kilometer) atmosphere layer. The results of the calculation with the radiosonde data and the calculation with the data of MTP-5 and AMIS-RF are identical. The calculation of the vertical distribution of the icing zones by the Schultz and Politovich method also corresponds to the actual icing data.

![Figure 3](image1.png)  
**Figure 3.** Spatial areas of potential aircraft icing on January 05, 2015, Novosibirsk, Tolmachevo Airport, the Schultz-Politovich method.

![Figure 4](image2.png)  
**Figure 4.** Spatial areas of potential aircraft icing 05 January, 2015, Novosibirsk, Tolmachevo Airport, the Godske formula.

The Godske method shows no areas with possible icing using the data of the MTP-5 and the AMIS-RF data in the period from 00.00 to 13.00 UTC (Figure 4). The application of the Godske method with radiosonde data confirms the results from the data of MTP-5 and AMIS-RF. The obtained results do not correspond to the actual icing data. The Godske method shows the probability of icing from 13.00 UTC, which is confirmed by crew reports.

3. Results and analysis of calculation of the vertical distribution of possible icing zones

The Godske and Schultz and Politovich methods were validated for the accuracy to actual weather data (crew reports) taking into account the time and height of the icing cases reported. The areas of actual icing were calculated, with total icing time in minutes along the x-axis and the icing height in meters along the Y-axis. The obtained area was compared to the same area of possible icing calculated by the methods of Godske and Schultz and Politovich. The result is the percentage of area matching by
which the accuracy of the proposed methods can be evaluated.

The accuracy of the forecast was estimated for the cases of icing. One year was analyzed for Tomsk (from October 2012 to September 2013). For Novosibirsk it was one month, January 2015.

Table 1. Number of days with icing in different weather conditions.

|                        | Tomsk Airport | Novosibirsk Airport |
|------------------------|---------------|---------------------|
| Number of icing cases at positive air temperature | 8             | 0                   |
| Number of icing cases at negative air temperature  | 8             | 10                  |
| Number of icing cases at positive and negative air temperatures (crossing zero) | 6             | 1                   |

The estimation was performed for days with icing cases reported at negative air temperature. These were 8 cases for Tomsk and 10 for Novosibirsk (Table 1).

Table 2 shows the accuracy, in percent, for the two airports. The accuracy of the Godske method for the airport of Tomsk was 83.4%, and for Novosibirsk it was lower, 78.7%. The accuracy of the Schultz and Politovich method for the airport of Tomsk has a smaller percentage relative to the airport of Novosibirsk.

Table 2. Forecast accuracy percentage.

|                        | Tomsk Airport | Novosibirsk Airport |
|------------------------|---------------|---------------------|
| Godske method          | 83.4          | 78.7                |
| Schultz-Politovich method | 88.7        | 99.6                |

The result of validation of the two methods (Table 2) shows that the Schultz and Politovich method has higher accuracy than the Godske method for these two airports.

Table 3 presents the estimation of the accuracy of the Godske method provided by the West Siberian Branch of the “Aviamettelecom Rosgidromet”, as a comparison. As an example, for Tomsk the years 2012-2013 are presented, and for Novosibirsk 2014-2015.

Table 3. Accuracy of the icing probability forecast according to the Godske method.

|                        | General accuracy (%) | Occurrence probability accuracy (%) |
|------------------------|----------------------|-------------------------------------|
| Tomsk AMSC, 2012-2013  |                      |                                     |
| 2012                   | 93.4                 | 88.7                                |
| 2013                   | 94.6                 | 94.6                                |
| Novosibirsk AMSC, 2014-2015 |            |                                     |
| 2014                   | 50                   | 55.6                                |
| 2015                   | 67.9                 | 68.2                                |

Not taking into account the difference in the method of calculating the accuracy of icing probability forecast by the AMSC and in the method presented in the present paper, it is clear that the accuracy has significant differences for the airport of Novosibirsk.
The estimation of the average annual accuracy for the Godske method made by Novosibirsk RAMC for the Tolmachevo airport showed its low accuracy, which is significantly different from the estimation for January 2015 made in this work. The percentage of accuracy provided by the AMSC Tomsk is slightly different from the percentage obtained in this work.

4. Conclusions
The atmospheric remote sensing method or, more precisely, the measurement of air temperature in the lower kilometer layer of the atmosphere by means of a meteorological temperature profiler (MTP-5), to determine the possible icing zones provides high-quality analysis.

The method combined with the method of Schultz and Politovich and the Godske method showed similar results using the temperature profile data of MTP-5.

The accuracy of icing probability for the method of Schultz and Politovich is higher than that for the Godske method according to the data for the Tomsk and Novosibirsk airports.

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