P NUMERICAL PREDICTION OF ATMOSPERIC ICING

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1. INTRODUCTION

On 15 December 2000, a commercial aircraft experienced severe icing when flying at about 5000 m above the ground over the complex terrain of Iceland. The icing was not predicted by the current operational forecast systems. In this paper the icing event is described briefly and a series of numerical simulations is carried out to investigate the nature of the event and to what extent it can be predicted by a numerical weather prediction system and at what resolutions.

3. THE SYNOPTIC SITUATION

On 15 January 2000 at 12 UTC there was a low between Iceland and Greenland and an eastward-moving occluded front over the westernmost part of Iceland (Fig. 1). Ahead of the front there were strong winds from the south-southeast at low levels. At middle and upper tropospheric levels, the wind direction was roughly the same, but the wind speed was stronger. The icing took place at 5200 m.a.s.l., over the complex terrain of W-Iceland just east of the front.

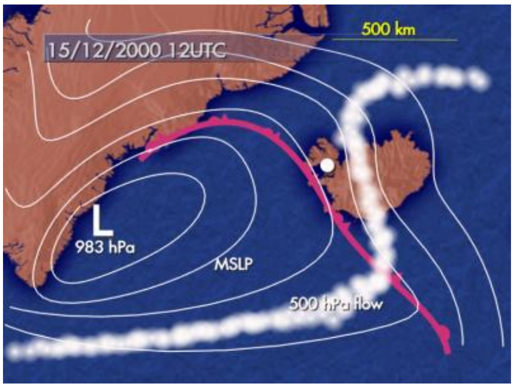

Fig. 1 The synoptic situation over Iceland on 15 December 2000 at 12 UTC. The white dot indicates the location of the icing incident.

2. THE SIMULATIONS

The event has been simulated with the MM5 system (Grell et al., 1995), with horizontal resolutions of 9, 3 and 1 km and vertical resolutions of 23 and 40 sigma levels (Fig. 2). The simulations are carried out with the Eta turbulence scheme, the Reisner2 microphysics and the Grell cumulus parameterization. The simulations are forced with boundaries from the ECMWF and they are initialized with data from the same source at 12 UTC on 14 December 2000.

3. RESULTS

The simulations reproduce substantial amount of super-cooled liquid water where the icing was observed (Fig. 3). Only a few km further downstream, the cloud water is in frozen form. The supercooled liquid water is associated with rapid ascending motion in a mountain wave, immediately upstream of second mountain ridge.

Sensitivity studies with different horizontal resolutions (Fig. 4) show that at dx=1km, there is substantial lifting and high concentration of supercooled liquid water. At dx=3km, the qualitative picture is about the same, but the updrafts are less intense and so is the concentration of the supercooled liquid water. At dx=9km, there is much less updraft and no significant concentration of supercooled liquid water.

The supercooled water appears clearly when the simulations are carried out in 40 vertical levels (at dx=3km), while reducing the number of vertical levels down to 23 eliminates the supercooled water at high levels and thereby the icing conditions (Fig.5).

Sensitivity tests with different orography (Fig. 6) indicate that the ascending motion responsible for the supercooled water is a result of not only the mountains downstream of the location of the icing event, but also of the mountains upstream of the icing location.

In this case high static stability, strong low level winds positive vertical windshear and little changes in wind direction with height contributed to amplified mountain waves in which the icing is observed.

CONCLUSIONS

The present study shows that atmospheric icing conditions created by a frontal system interacting with mesoscale mountains can be predicted if the horizontal and vertical resolutions in the calculations are sufficiently high. The results are very encouraging for real-time high-resolution numerical prediction for aviation in Iceland.

They also indicate that to create icing conditions, lifting downstream of mountains may be quite as important as lifting on the upstream side.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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Grell, G. A., Dudhia, J. and Stauffer, D. R.: 1995, A Description of the Fifth-Generation PennState/NCAR Mesoscale Model (MM5), *NCAR Technical Note NCAR/TN-398+STR*. Available at http://www.mmm.ucar.edu/mm5/doc1.html

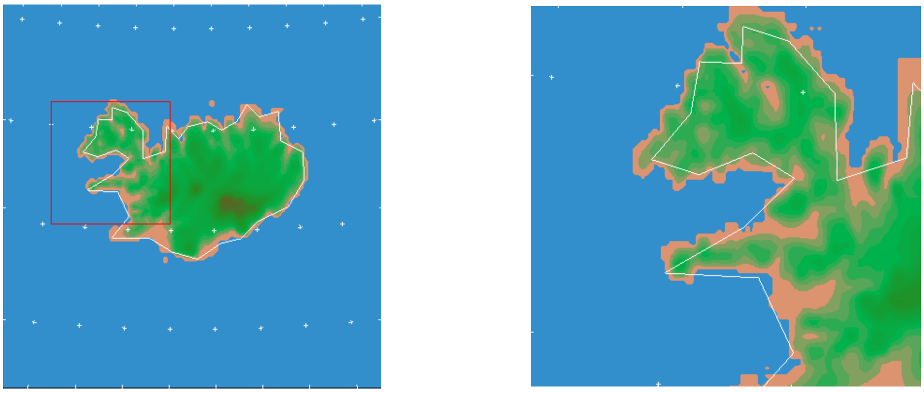


Fig. 2. The simulation domains. The green shading indicates the topography.

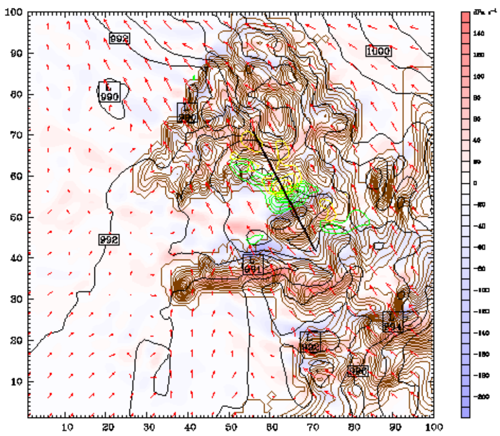


Fig. 3 (a). Liquid cloud water (green, g/kg), ice (yellow, g/kg) at 5,2 km a.s.l., mslp (hPa) and 10 m wind vectors at 1400 UTC on 15 December 2000.

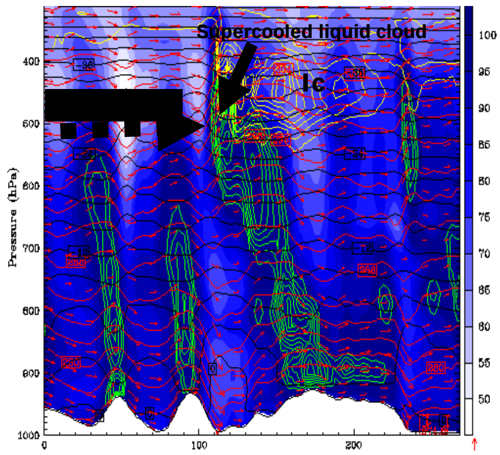


Fig. 3 (a). Liquid cloud water (green, g/kg), ice (yellow, g/kg), wind vectors temperature and potential temperature in a cross section shown in the figure to the left. (1400 UTC on 15 December 2000). A black dotted arrow indicates the flight track

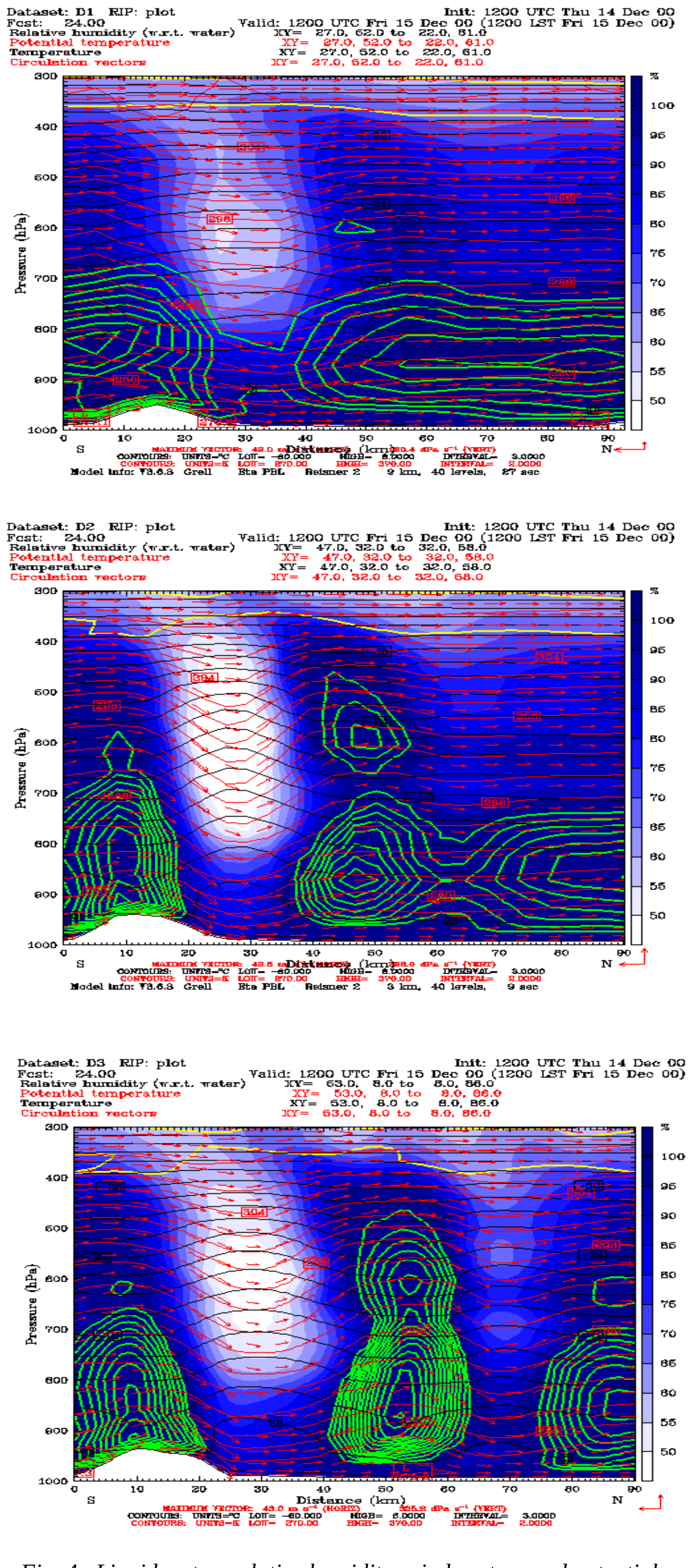
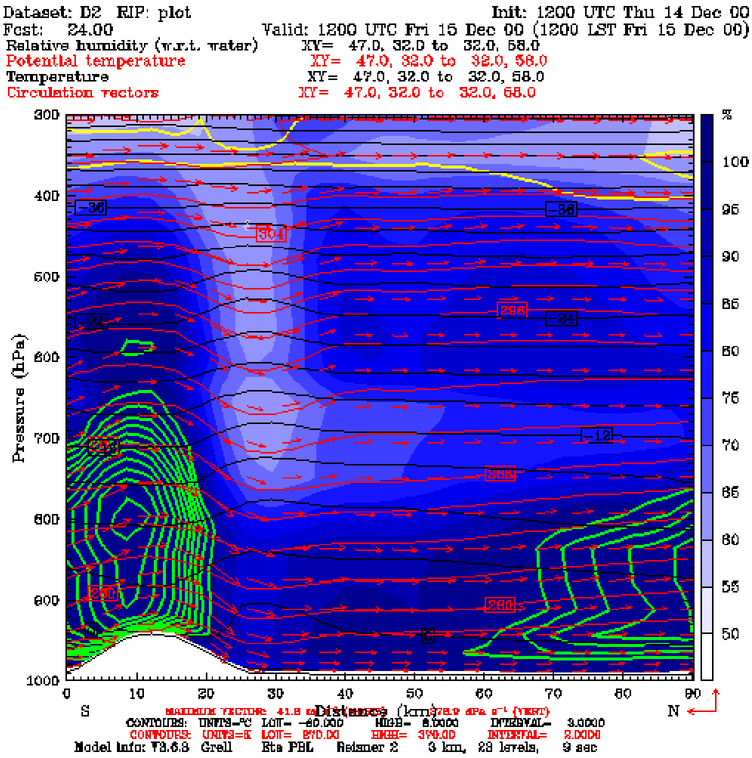


Fig. 4. Liquid water, relative humidity, wind vectors and potential temperature as in Fig. 3(b), but with a horizontal resolution of (a) 9 km, (b) 3 km and (c) 1 km.



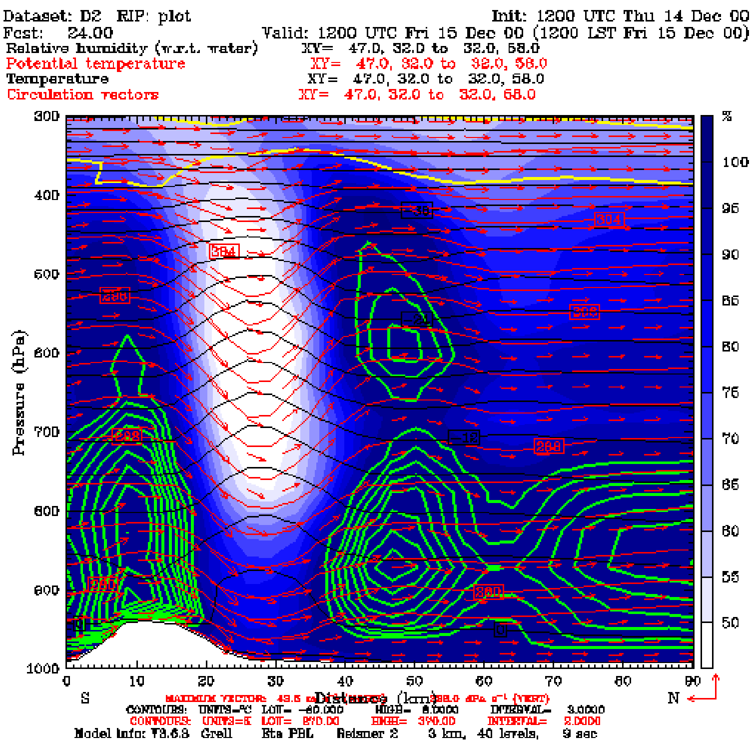
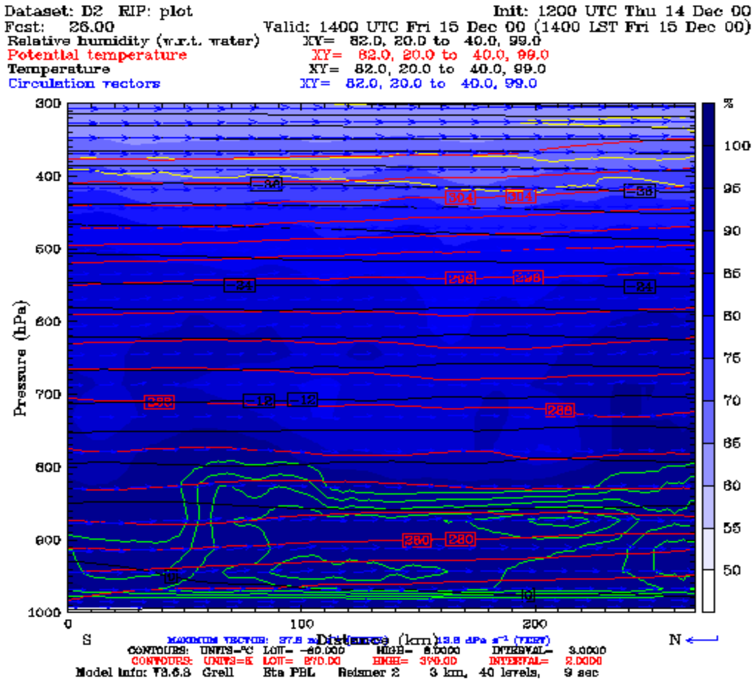


Fig. 5. Liquid water, relative humidity, wind vectors and potential temperature as in Fig. 3(b), but with a vertical resolution of (a) 23 levls and (b) 40 levels.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Fcst: 26.00
Valid: 1400 UTC Fri 15 Dec 00 (1400 LST Fri 15 Dec 00)
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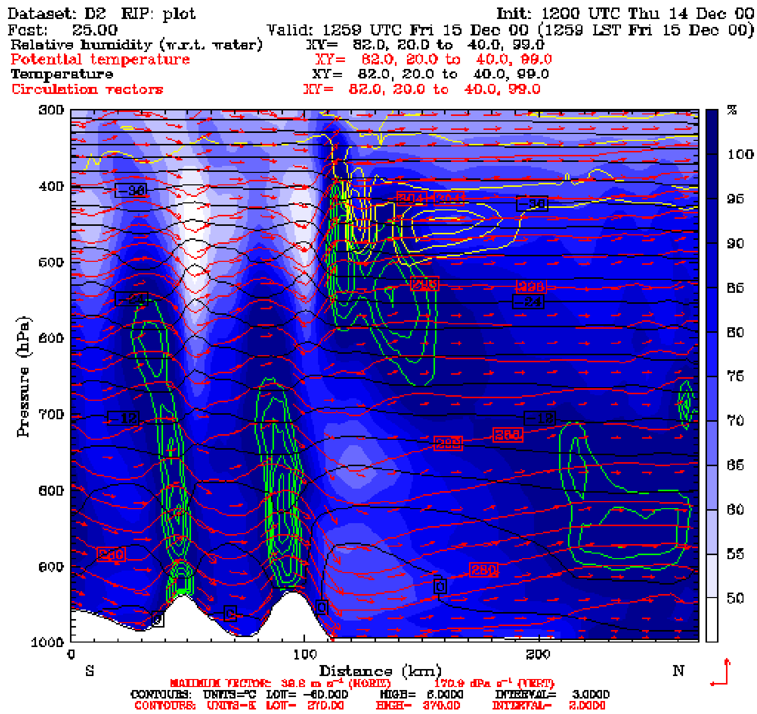
XY= 82.0, 20.0 to 40.0, 99.0
Potential temperature
XY= 82.0, 20.0 to 40.0, 99.0
Temperature
XY= 82.0, 20.0 to 40.0, 99.0
Circulation vectors
XY= 82.0, 20.0 to 40.0, 99.0
Pressure (hPa)
Distance (km)
S
N
%
CONTOURS: UNITS=°C LOW= -60.000 HIGH= 6.0000 INTERVAL= 3.0000
CONTOURS: UNITS=K LOW= 270.00 HIGH= 370.00 INTERVAL= 2.0000
Model info: V3.6.3 Grell Eta PBL Reisner 2 3 km, 40 levels, 9 sec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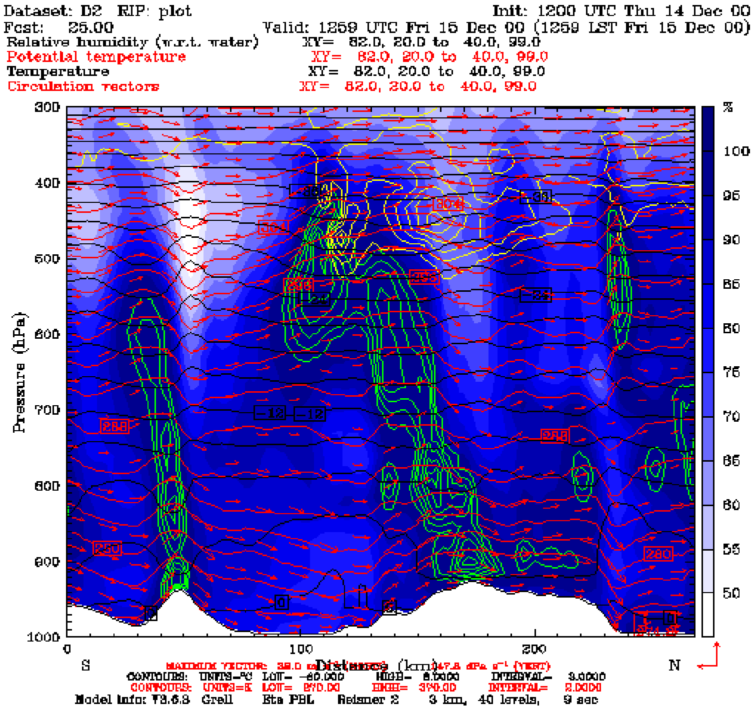
Potential temperature
XY= 82.0, 20.0 to 40.0, 99.0
Temperature
XY= 82.0, 20.0 to 40.0, 99.0
Circulation vectors
XY= 82.0, 20.0 to 40.0, 99.0
Pressure (hPa)
Distance (km)
S
N
%
CONTOURS: UNITS=°C LOW= -60.000 HIGH= 6.0000 INTERVAL= 3.0000
CONTOURS: UNITS=K LOW= 270.00 HIGH= 370.00 INTERVAL= 2.0000



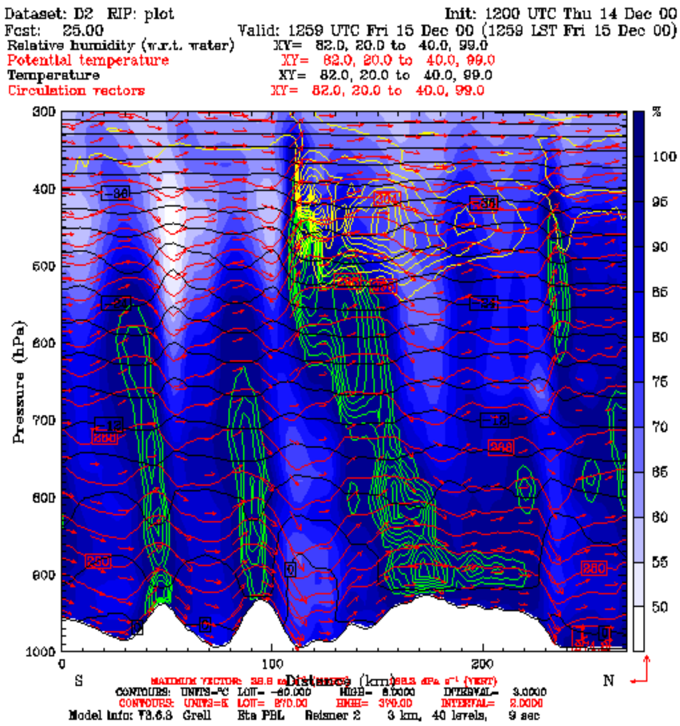


Fig. 6. Liquid water, relative humidity, wind vectors and potential temperature as in Fig. 3(b), but with (a) no mountains, (b) the mountain downstream removed, (c) the mountain upstream removed and (d) true topography.