Atmos. Chem. Phys. Discuss., 5, S83–S87, 2005
www.atmos-chem-phys.org/acpd/5/S83/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Formation of ice supersaturation by mesoscale gravity waves" *by* P. Spichtinger et al.

Anonymous Referee #1

Received and published: 22 February 2005

General comment

This is a nice case study of the genesis of an ice super-saturated region (ISSR) and associated cirrus formation. It is still not well known what are the main causes of ISSR and sub-visible cirrus formation. This study illustrates the role that inertia-gravity waves can play by a combination of in-depth analysis of observations and application of model tools. However, some details of the analysis need to be reconsidered.

Section 3.1 discusses and figure 2 shows a comparison of the relative humidity, specific humidity and temperature measured by the radio sounding at Lindenberg and ECMWF data. The profiles agree very well. However, the ECMWF model probably assimilated

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these parameters from the radio sounding, which would make such agreement not very astonishing. In the last line of 3.1 the authors state that the qualitative agreement encourages them to proceed with their analysis. It should be checked if ECMWF did indeed assimilate the Lindenberg radiosoundings, and a remark about it should be added in the text, because otherwise a false impression of accuracy of both ECMWF and the soundings is given.

Section 3.2.2 and the Appendix discuss the changes in thermodynamic parameters along the trajectories and related to that, the extent to which the trajectories are realistic in the presence of gravity waves excited by the Scandinavian Alps. I agree with the conclusion drawn at the end of the appendix that "the large q-change along the trajectories based on 6-hourly ECMWF-analyses indicates a failure determining parcel properties along the trajectory." However, all the analyses in the appendix constitute a rather complicated way to arrive at this conclusion. I therefore suggest to omit the appendix. The last line of the appendix looks like a conclusion but it is in fact a discussion and should be presented as such. The increase in humidity along the calculated trajectories might indeed be due to the too coarse resolution in time and space of the ECMWF data. Furthermore, subsequent ECMWF forecasts may have differences if they are based on different (12-hourly) analyses. I note that the analysis in the appendix does not allow drawing any conclusion about the presence of gravity waves in the ECMWF analysis. Therefore the last part of the final sentence of the appendix should be moved elsewhere. Gravity waves are adiabatic motions that conserve tracer mixing ratios and potential temperature, so they cannot be invoked to explain the big change in specific humidity.

In section 3.4.2 (p.80, line above formula 8) the vertical wavelength of the gravity waves is estimated to be 1.6 km based on the hodograph and polarisation relationship. Below formula 8 it is stated that these estimates (for the wave parameters) agree very well with the values of the meso-scale numerical simulations. Considering figures 7 and 8, this is certainly true for the horizontal wavelength, but I would estimate the vertical wavelength in the MM5 simulation (in the interval between 500 and 850 km along the x-axis in figure 7) to be at least 5 km. Hence the statement that the wave parameter estimates from the hodograph and from the mesoscale simulations are consistent is not true. Cirrus cloud formation would normally occur only in the part of the wave where motion is upward, so over a depth of 800 m if the vertical wavelength estimate of 1.6 km is accepted. However, in section 3.3. the depth of the lower cirrus cloud (at about 340 hPa) is estimated at 1600 m (p. 77, last line). The estimates of vertical wavelength and their relationship to cirrus cloud depth thus require further consideration and discussion. A comparison of wave parameters determined from the MM5 simulation with those derived from the observations, e.g. in the form of a table, would also be nice.

In section 5, 2nd paragraph, the authors summarize/conclude “We found that in this case the generation of super-saturation was due to a lifting of air masses by about 20 to 40 hPa that was caused by a superposition of two packets of gravity waves, one generated by air flow past the Erzgebirge, Riesengebirge and the other excited by inertial stability ..”. However, there is also a slow uplifting motion visible in the trajectories (figure 10) that might be the main cause of the ISSR, which had a lifetime of about half a day. Hence I cannot support this conclusion. In the next sentence they state that “the lifting led to a strong increase of specific humidity (by factors 1.5 to 1.75)”. I note again that gravity waves are adiabatic motions that conserve the mixing ratios of tracers such as specific humidity (unless explicit loss processes such as wet deposition occur), so this cannot be true. See also my remarks about Section 3.2.2 and the appendix above.

Specific comments

1. Section 2.3: Please describe to what grid the ECMWF data was interpolated and how. T319 is the spectral truncation of the wind parameters. These are stor ed as spherical harmonics in the ECMWF archive. However, humidity and temperature are archived on a reduced Gaussian grid. Did the authors use data interpol ated to a regular longitude-latitude grid? More information about the grid is needed to interpret later results. For instance, section 3.1 presents “profiles obtained from ECMWF data”.

The caption of figure 2 as well as section 3.1 state that these model profiles were obtained by retrieving the values at the nearest grid points. To interpret this, the reader needs to know to what grid the data were interpolated. Perhaps the contents of section 3.4.1 should be moved here. 3.4.1 explains how the MM5 simulations were initialised and what boundary conditions were used (also based on ECMWF).

2.Please mention the time of the sounding (0 h UT) in the caption of figure 2 and 3.1 (e.g. in line 2), as later on in section 3.3 (page 75, line 24) also a n 18 h UT sounding is used (not shown).

3. Section 3.1, the 5th paragraph notes a quantitative difference between the radio sounding and the ECMWF profile, that between 750-600 hPa the ECMWF analy ses underestimate the specific humidity. There is however a minimum in the radio sounding (blue curve) on the left side of the ECMWF model curve (green) bet ween 750 and 600 hPa. This is probably due differences in vertical resolution between the two, but it is a little bit confusing. Please add a remark about t his in the text.

4. The calculations in section 3.3 yield an IWC between 0.8 and 1.11 mg/m3 (page 77, line 10). The empirical formula of Schumann yields 1.3 mg/m2. It is con cluded that these numbers are consistent (page 77, line 14). However, 1.3 outside the range 0.8-1.11, so please formulate this a bit differently.

5. Section 3.3, last line: Please explain explicitly why you would expect much more water in the ice phase for a cirrus forming by homogeneous nucleation, o r give a reference.

6. Section 3.4.1, page 78, line 23: the acronym MRF should be explained or omitted

7. Section 3.4.1, page 80, line 1 states that data on “15 pressure levels between the surface and the 10hPa pressure level” were used to initialise the MM5 model. Probably “15 pressure levels between 1000 and 10 hPa” is meant. Not all ECMWF pressure levels are all the time above the surface; in case of mountain s some are below the

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surface.

8. Section 3.4.2, p. 80, line 23 concludes: “Hence, the gravity wave source is located in the upper troposphere in accord with the simulated mesoscale flow” &#65533;[31;1H based on the hodograph between 8 and 11 km. I agree that the waves propagate downward. However, the waves might still have been excited higher up i tratosphere. Evidence should be provided, e.g. by investigating the MM5 simulation, that the waves propagate upward in the stratosphere, if the authors want to stick to the conclusion that the source is in the upper troposphere.

9. Figure 10: I suggest to add in this figure a comparison of one or all of the MM5 trajectories with a corresponding ECMWF trajectory to demonstrate the ne ed for use of the meso-scale model and to better illustrate the differences between MM5 and ECMWF.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 67, 2005.