Automatic Thermal Forecast from the Swedish HIRLAM

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Abstract

Thermal forecasts for glider pilots are produced automatically from the operational numerical weather prediction High-Resolution Limited-Area Model (HIRLAM) in Sweden. Some extra algorithms are used in the postprocessing to calculate the thermal height and mean rate of climb from the forecast temperature profile at every gridpoint. The forecast is visualized in two different charts containing all necessary weather information. It is distributed via internet and is a good and cost effective tool for the pilots´ planning their soaring activity.

Introduction

Thermal forecasts for glider pilots are produced automatically by using data from the Swedish operational numerical weather prediction (NWP) model, HIRLAM. All data used is direct model output except the thermal height and the mean rate of climb which are calculated with some extra algorithms from the forecast vertical temperature profile for every grid point.

The horizontal resolution in the present version is 22 km and the model has 40 vertical levels, 10-15 of them in the thermal boundary layer. Tests with higher resolution are being done.

There are two forecast charts, the thermal forecast (Fig 1) and a complementary chart with winds and surface temperatures (Fig 2), which contain all weather information the pilots need for planning their soaring activity. The charts are produced twice a day for three times. At 1900 local time you get a preliminary forecast for 11, 14 and 17 o´clock the following day. At 0700 the next morning you get an updated forecast for the same times. The forecasts are produced by SMHI (The Swedish Meteorological and Hydrological Institute) and they are distributed via internet to the soaring associations in Sweden, Denmark, Norway and Finland. The glider pilots are very satisfied with the product. Also, hang-glider and para-glider pilots benefit from the forecasts.

Computations

The thermal height is calculated from the forecast temperature profile at every gridpoint. You assume that the thermals start from the ground with an excess temperature, ΔT[1, 2], compared with the forecast 2m mean temperature, T, in every grid square. Then you calculate the top of dry thermals and the Cu-base in the normal way by following the dry adiabat and the line for constant mixing ratio with $T+\Delta T$ and the forecast dew-point as initial values. No entrainment is used. The lowest value of the top of dry thermals and the Cu-base is considered as the thermal height.

The formula for ΔT presently used is:

$$\Delta T = TVAR \times (1 + W/250) \times (1 + H/1000) \times 20/ff \qquad (1)$$

The variables in (1) are defined as follows. *TVAR* is of the same order as the normal horizontal variations of the temperature when there are no thermals and it is used to tune the calculations. At present TVAR between 0.3 and 0.6C is being used. *W* is the net vertical sensible heat flux near the ground as calculated in the HIRLAM model in W/m^2. *H* is the height of the terrain from the model in m (above sea level). This is a rough way to account for complex and hilly terrain. Maximum H in the formula is 300 m. *ff* is the wind velocity near surface (10 m) in km/h. Minimum ff in the formula is 20 km/h.

Thus, ΔT is expressed as a normal temperature variation which is being ajusted with a heat flux factor, a terrain factor and a wind factor. TVAR and the three other factors can be used to tune the calculations.

The mean rate of climb[1, 2] is calculated according to another home-made formula:

$$\text{Mean rate of climb} = h/1000 \times W/250 \times (1 + H/750) \times (1 - TADV/2) \times 20/FF \qquad (2)$$

The variables in (2) are defined as follows. *h* is the calculated thermal height in m (above surface in the HIRLAM grid). *W* is the net vertical sensible heat flux near the ground in W/m^2. *H* is the height of the terrain from the model in m. Maximum H in the formula is 300 m. *TADV* is the temperature advection at 1000 m in °C/h. *FF* is the wind velocity at 1000 m in knots. Minimum FF in the formula is 20 knots. Notice the units in ff from (1) and FF in (2) are, indeed, different.

The formula for the mean rate of climb is based on old rules of thumb (using the thermal height). It is then modified with factors taking into account, in one or another way, the sensible heat flux, the terrain, the temperature advection and the wind.

Experiences and conclusions

We have run the forecast model for about five years with some minor changes and it seems to be a good and cost effective tool for planning gliding activity.

We have learned that the thermal calculations may be quite sensitive to changes in the parameterizations in the HIRLAM model. You may have to tune the thermal forecast to changes in the model.

The formulas (1) and (2) are fairly rough estimates - just efforts to quantify the factors we believe are important. They work with the HIRLAM model in Scandinavia after some tuning. However, according to our experience the climb rates still tend to be too high at noon, at least in the middle of the summer, and deteriorate too rapidly in the afternoon. Next summer we may give more weight to the thermal height factor and maybe also set an upper limit for the sensible heat flux.[2]

The vertical resolution of the HIRLAM model is not enough to forecast small Cu. Therefore we had to teach the glider pilots that "dry thermals" (no circle around the thermal height) is to be interpreted as "no Cu, small Cu or even few Cu".

As the calculations are made at each grid-point, you can benefit from a higher resolution in the NWP model. This summer (2006) we are doing daily tests with 11 km horizontal resolution which seem to be promising. Some tests using a non-operational 5 km HIRLAM have been done as well and, hopefully, the automatic thermal forecasts in the future will include mesoscale features like sea-breezes and convergence zones.

The described technique can be applied to any NWP model. Therefore, predicted thermal charts can be produced for any region that is covered by an operational NWP model. The method is rather simple but nevertheless it works fairly well after some tuning. However, improvements should be possible. Comments and suggestions would be much appreciated by the authors.

References

[1]Olofsson B., A Lagrangian model of dry thermals, Report DM-50, Department of Meteorology, University of Stockholm, 1987.

[2]Liechti, O. and Neininger, B., ALPTHERM – a PC-based model for atmospheric convection over complex topography, *Technical Soaring*, Vol 18, No 3, 1994, pp 73-78.

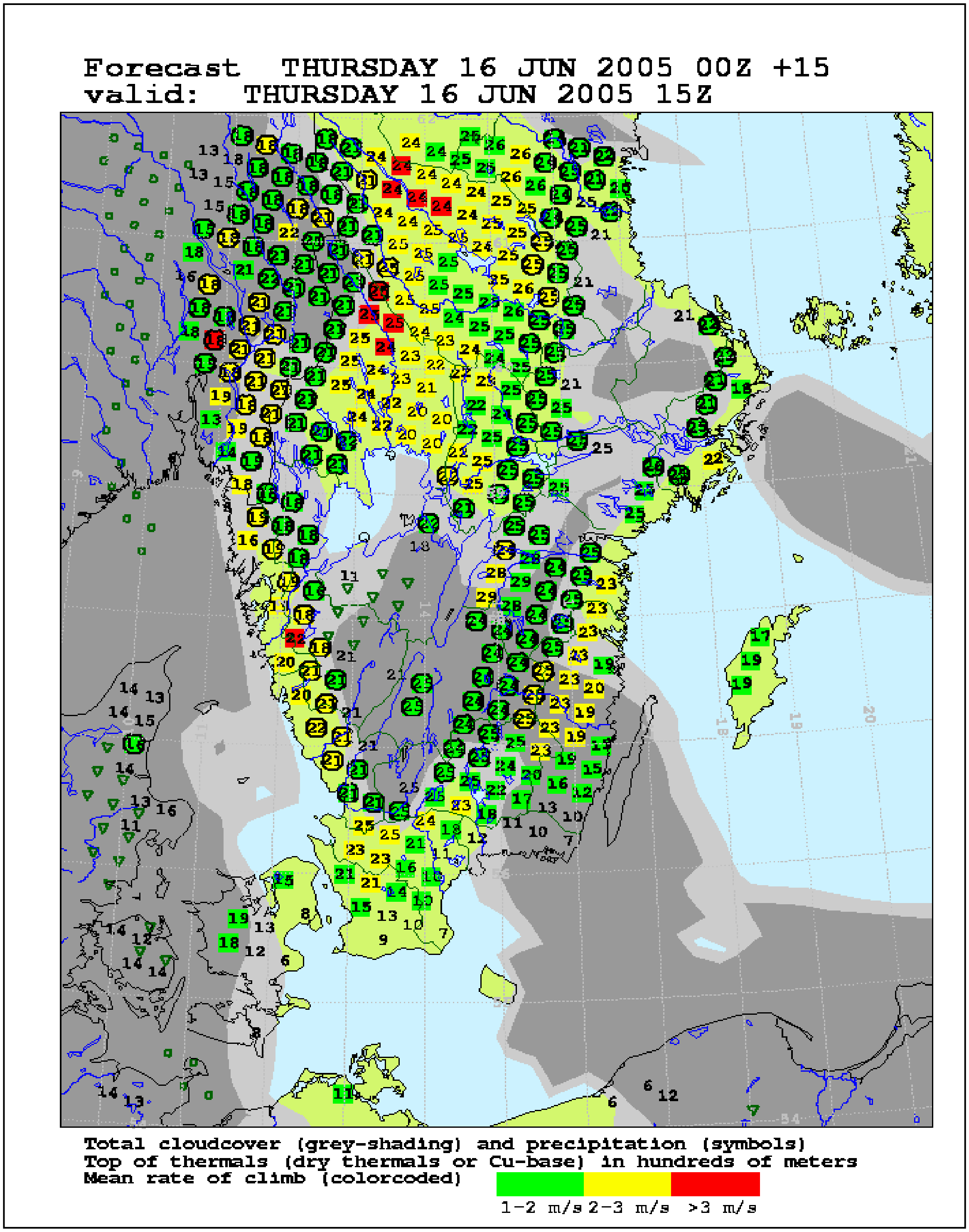

Figure 1 A thermal forecast chart. The total amount of clouds as grey shading: dark grey means overcast, light grey means broken (5-7/8), no shading means sky clear to scattered (0-4/8). Occurrence of precipitation with symbols (not considering the intensity): small green square for stratiform precipitation (rain), small green triangle for convective precipitation (showers). Calculated mean rate of climb as colour-coding of the grid-points (mean values of a column 22x22 km at the bottom): no colour means mean rate of climb less than 1 m/s, green means 1-2 m/s, yellow means 2-3 m/s, red means more than 3 m/s. The calculated thermal height, if 600 m or more, is plotted with figures in the grid-point in hundreds of meters (e g 15 means thermal height 1500 m). If Cu-clouds are calculated the figures refer to the Cu-base and it is marked with a circle around the figures. No circle means that the calculation gives only dry thermals.

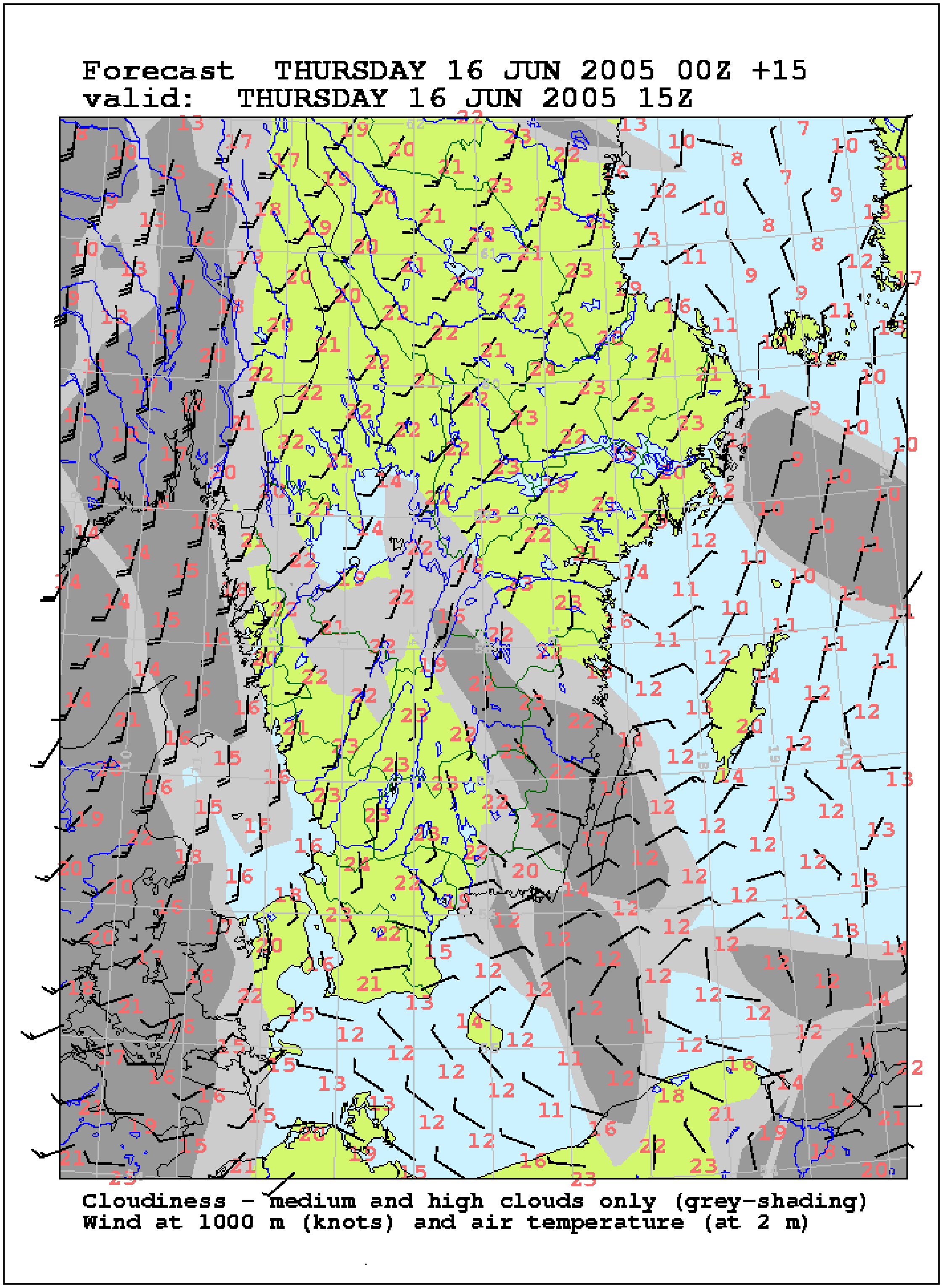

Figure 2 A winds and temperature forecast chart. The amount of medium and high clouds as grey shading in the same way as in the thermal chart (notice, the low clouds are excluded). Temperature in the air near the ground (2 m) plotted with red figures (blue if below zero). Wind at approximately 1000 m plotted in the way it is usually done on weather charts, wind arrows with barbs (a full barb means 10 kts and a half barb 5 kts. For strong winds a streamer means 50 kts.)