A Thermal Activity Forecasting Scheme Suitable for Personal Computers

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1. Introduction

The preparation of glider flights and competitions need detailed local short range forecasts of several meteorological parameters which often are not broadcasted by regular weather radio. Although there exist graphical methods of determining the temporal variations of the required values as thermal updrafts, cloud base, etc., also up to date procedures of meteorology can now be used at local airports since low cost personal computers are easily available.

This paper deals with simple meteorological computer models which can support the duties of local weather - men during glider competitions.

2. Data Requirements

The models operate on the base of some regional and upstream radiosoundings (i.e. measured vertical profiles of temperature and humidity) which have to be recorded from weather facsimile or teletyper transmission in the morning hours. If the aerological observation time doesn't coincide with the time of sunrise, the local minimum temperature is required additionally.

That ist the only daily set of data which has to be typed into the computer.

3. The Model and its Ability

Obviously, meteorological models which are small enough to be run on personal computers must be very simplified. Dynamic large scale processes cannot be simulated, i.e. the synoptic pressure field is postulated to be stationary. This limits the application to a 18 hour prognosis.

First of all the computer evaluates the inserted vertical profiles (pressure, temperature, dew point), and interpolates them vertically in steps of 200 meters.

Then the pressure field is analyzed on all levels up to a height of 5 km. In the following sequence the program calculates the horizontal (geostrophic) wind above all selected stations on all levels.

In this phase the machine holds pressure, temperature, dewpoint, and geostrophic wind for all stations in vertical distances of 1000 m from sea level up to 5 km. Using this amount of data local short range prognosis is possible for specified sites out of a set of flight areas with different geographic location, and altitude.

In a second phase the model interpolates the meterological data to the position of the target site. Starting with the aerological observation time the program locates horizontal backward trajectories, each of them ending in the target area. This is repeated hourly until sunset on all vertical levels. In this way the temporal variation of the vertical temperature und humidity profile can be predicted for the target area. Notice that effects due to large scale rising or subsidance are not considered in this model, as a compromise to the computer size.

The daily heating is then simulated on the base of the forecasted profiles. Using Gold's scheme (Gold, 1933) the available solar energy is brought to the model atmosphere leading to an adiabatic stratification in the lower layers. Also this procedure is carried out in time steps of one hour. If nessecary, Gold's energy equivalents must be adapted to regional conditions. The model reduces these values in the case of screening by higher clouds or spreading of cumulus. The presence of such clouds is estimated from the exspected relative humidity in the relevant layers.

Now the computer has stored the predicted hourly vertical profiles of the target site considering horizontal advection and heating due to solar radiation as well.

All convective processes are simulated in a third phase. For this purpose the software package provides a simple dynamic cloud model. This model investigates the behaviour of air within a column which is heated from below. Hereto an approximated form of the vertical equation of motion, the first law of thermodynamic, and balance equations for water vapor and cloud droplets are solved numerically. Turbulent and dynamic entrainment fluxes through the lateral boundaries are parameterized. The model is a shortened form of Ogura and Takahashi's (1971) one-dimensional cloud model. After the integration over several time steps the solution becomes almost stationary and specifies the thermally induced vertical velocity, the condensation level, and the convection height. If one wishes to simulate the ther-

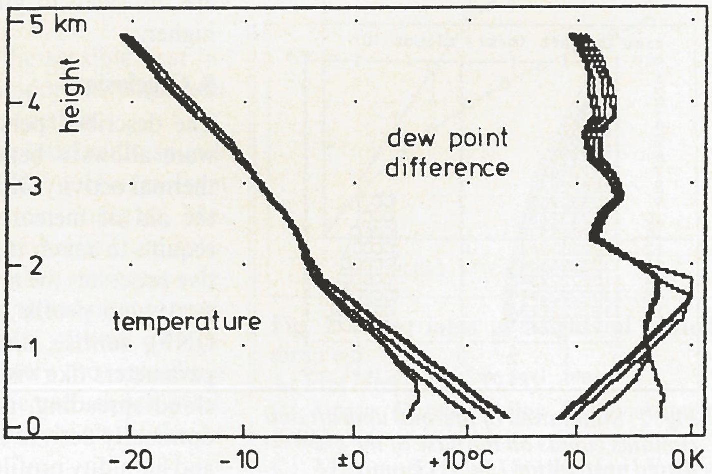

Fig. 1: Predicted vertical profiles of temperature and dewpoint difference for "Westliches Münsterland" on May 28, 1983.

mal activity at a certain daytime, the model picks up the corresponding forecasted vertical profile and takes it as lateral boundary condition.

4. Application

The model system was put into action during the 29th Borkenberge-Soaring-Weeks, a regional glider competition in Westphalia. An example of the application there is demonstrated in the following:

On May 28, 1983 the computer evaluated six profiles out of the 00 GMT (02 local) radiosoundings received by weather facsimile.

Figure 1 shows the predicted vertical profiles ot temperature and dewpoint differences at 06, 09, 12, 15 an 18 CEST (Central European Summer Time) for the target area "Westliches Münsterland" after the calculation of horizontal advection and diurnal heating.

Figure 2 illustrates a result of the convective cloud model. The run is based on the 13 CEST condition. The thermal motion was triggered by an 1 K temperature excess near the ground. The air ascends with a maximum of 5 m/s, and after nine minutes a cumulus-cloud is formed 1300 m above the ground.

Eight minutes later the cloud top reaches its final height of 2300 m. In this state the vertical velocity ranges from 1.5 to 3 m/s. The complete diurnal variation of ground-level temperature, cloud base, convection height, and type of convection is reproduced in table 1.

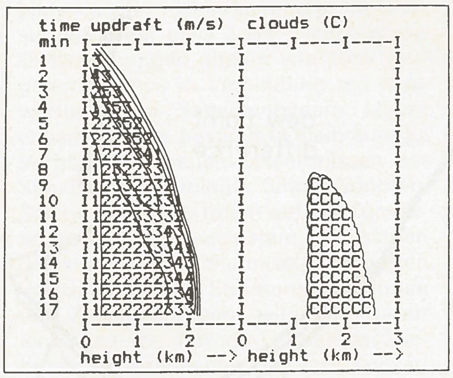

Fig. 2: Simulation of thermal updraft and cumulus clouds on the base of the predicted profiles for 13 CEST.

day-time CEST	temperat. °C	cloud-base m	convection-height m	convection-type
06:00	4.6		100	--
07:00	8.1		260	--
08:00	9.7		480	--
09:00	10.6		720	--
10:00	11.3		940	BLAU
11:00	11.9		1250	BLAU
12:00	12.4	1330	2060	-CU-
13:00	12.8	1380	2110	-CU-
14:00	13.2	1430	2150	-CU-
15:00	13.5	1450	2180	-CU-
16:00	13.6	1470	2190	-CU-
17:00	13.7	1470	2200	-CU-
18:00	13.8	1480	2200	-CU-

Tab. 1: Diurnal variation of convective parameters for the target area "Westliches Münsterland".

Usable thermals start developing between 09 and 10 CEST ("BLAU"). First cumulus-clouds appear between 11 an 12 CEST (-CU-). The cloud base goes from 1300 m up to almost 1500 m. The daily maximum temperature can be expected to reach 14 °C after a morning minimum of 2 °C.

day-time CEST	temperat. °C	cloud-base m	convection-height m	convection-type
06:00	8.8		430	--
07:00	9.8		720	--
08:00	10.6	670	2700	-CU-
09:00	11.1	740	2890	-CU-
10:00	11.6	790	3180	*CB*
11:00	12.0	850	4290	*CB*
12:00	12.5	910	4470	*CB*
13:00	12.9	960	4630	*CB*
14:00	13.2	1010	> 4750	*CB*
15:00	13.5	1030	> 4750	*CB*
16:00	13.6	1040	> 4750	*CB*
17:00	13.7	1050	> 4750	*CB*
18:00	13.7	1050	> 4750	*CB*

Tab. 2: Diurnal variation of convective parameters for the target area "Teutoburger Wald".

Table 2 shows the diurnal variation for the more mountainous area "Teutoburger Wald". Here the cumulus clouds start already by OB CEST and tend to become cumulonimbus (*CB*), i.e. precipitating, few hours later. These clouds are indicated to grow up to 5 km and higher.

5. Conclusion

The described personal computer software allows a better estimation of the thermal activity. It is a portable tool for the aid of meteorologists, and doesn't require to much input. Besides convective processes the models put out the vertical wind profile, the pressure (QNH, QNF), sunrise, and sunset. Additional parameters like visibility, freezing level, cloud spreading, and screening can be optionally derived from the temperature and humidity profiles.

Acknowledgement:

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Zusammenfassung

Dietrich S. Heimann: Ein Vorhersageschema für die Beurteilung der Thermikentwicklung mittels Kleinrechner.

Die Vorbereitung von Segelflug-Streckenflügen und Wettbewerbsflügen erfordert ausführlichere Kurzfristvorhersagen verschiedener meteorologischer Werte, die normalerweise nicht in der Segelflugwettervorhersage im Radio mitgeteilt werden. Obwohl es graphische Methoden zur Bestimmung der zeitlichen Entwicklung von Thermikstärke, Wolkenbasis usw. gibt, können heute auf kleineren, lokalen Flugplätzen auch Verfahren mittels Kleinrechner zu deren Abschätzung eingesetzt werden. Die vorliegende Arbeit befasst sich mit einfachen meteorologischen Rechenmodellen, die zur Unterstützung der Arbeit der örtlichen Wetterberater bei Segelflugwettbewerben eingesetzt werden können.