SOARING CLIMATOLOGY OF THERMAL CONVECTION

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Abstract

An attempt is made to compare gliding fields in different countries under different climatological regimes in relation to their thermal convection soaring potential.

Until now a complete physical interpretation resulting in a physical factor to be related to each other could not be found.

But a number is given, combined out of different physical factors, which represents the soarable performance of a region in monthly order.

Introduction

For more than two decades central European glider pilots like to travel sometimes for more than a thousand kilometers to reach gliding fields, mostly in foreign countries, where the soaring possibilities are better than at home. Some of them have already developed a calendar of where to go in which season. Destinations are Scandinavia in May and June, central France in July and August, with the same period being valid for Italy and Spain. Reasons for this are of course climatological factors, such as number of days with sunshine and of precipitation and the amount of it, etc. The whole considerations are restricted to the warm season only.

The cross-country weather requirement of a glider

A flux of sensible heat of at least approximately 150 W/m^2 is necessary to produce thermals of more than 200 m in diameter and of 1 m/s to keep a glider aloft (Lindemann, 1984). Even if there is some correlation between the vertical flux of heat and the vertical velocity, there is at least no linear correlation between the average cross country speed of a glider to the vertical velocity to be gained.

For a Cirrus: $V_{R(km/h)} \approx 40 \ln w\,(M/S) + 60$

For the following simple consideration we assume a constant daily energy for thermals. That means that high energy in a short thermal day reduces the maximum cross country distance in relation to smaller energy to a longer day. Due to a high sensible heat flux, a fast but relatively short task can be flown near the equator - 12 hours sunshine (e.g. Kenya 1972 World record 300 km), but very long tasks are possible in polar regions such as Finland in summer. There the duration of sunshine can reach 24 hours in summer, having a thermal activity usable for gliders for more than 12 hours, which can enable flights of more than 1000 km to be made.

Regarding the known solar radiation at the upper limit of the atmosphere, in summertime the values in all regions are between 10 and 12 $kWh/m^2/day$. Thus, the only differences are the length of the day, the intensity of radiation, and the available radiation at the ground. This radiation energy is distributed due to the surface energy balance into evapo-transpiration, vertical heat flux, and soil heat flux. This, at least, is determined by all factors to be known as climatological ones.

Sensible heat flux and vertical temperature profile

To estimate the soaring possibilities on a daily basis generally a morning vertical temperature and humidity profile and the vertical flux of sensible heat are most essential, synoptic changes not to be disregarded. Physically, the vertical structure of the atmosphere is the result of temperature and humidity advection, the dynamic forces including divergence and convergence, and the fluxes from the surfaces. Energy balance at the ground is known as : $S+B+L+V=0$. This is governed by a lot of climatological factors, and vegetation also.

But if we knew the vertical temperature profile and the vertical sensible heat flux as most important parameters, and if we had statistics of those parameters for the most interesting regions, a soaring climatology would be much easier.

A vertical temperature profile and sensible heat flux would generally be sufficient to know the vertical extent of thermal convection. Then it is possible to estimate the vertical velocity available to gliders (LINDSAY/WMO 1976).

There is no overall statistic about morning vertical soundings, and only a small number of energy balances at the surface is known. So a method has to be developed to approach a physical explanation by available data. Such estimations have been made for climatology by many authors.

Known differences in soaring potential

Central Europe is known to have very changeable weather. Especially April sometimes produces conditions with a soaring potential of more than 800 kms triangle. That is the result of cold air advection coming under subsidence. The quality is supported by the lack of evapotranspiration due to the seasonable undeveloped vegetation.

Looking for the cross country activities as a proof for soaring quality, **Table 1** gives a comparison between Oerlinghausen in Northern Germany and Fuentemilanos in Spain. Fuentemilanos is 1000 m above msl. The weather is generally governed by the Mediterranean summer anticyclone and a heat low in southern Spain.

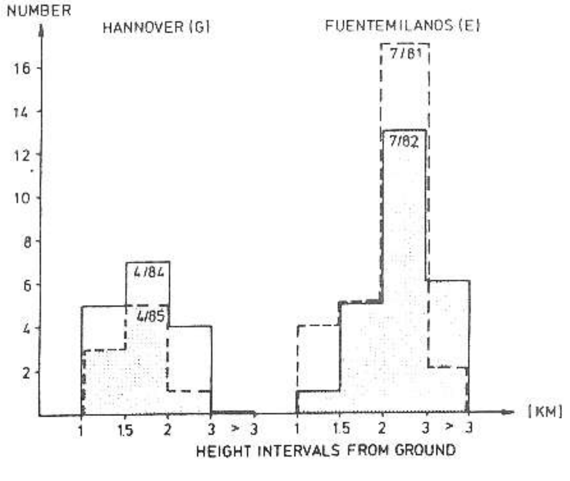
TABLE 1:

Number of days with flights:	*Oerl.:*	4/84	4/85	*Fuente.:*	7/81	7/82
300–500 kms,		5	2		10	8
more than 500 kms,		3	1		8	6
Days with more than 1mm rain,		7	12			4-5
sunshine (hrs)		110	70		Soria/Valladolid	348
cross-country days		12	6		21	21

These soaring data must be compared with meteorological data, which are available in northern Germany including 12 UTC Hannover radiosonde and in Spain by careful recording of gainable heights above ground, clouds, and vertical velocity of thermals. The height of dry adiabatic lapse rate, and base of cumulus clouds, were sufficiently computed with the soundings, maximum temperature, and dew point. It could be shown that thermal convection to be soarable existed, when more than 5 hours of sunshine were recorded.

Figure 1 shows in a number of cases the vertical extent of convective layers above ground. The correlation between these data and those of Table 1 is convincing. There are 2 to 6 days when convection to cloud base is higher than 3000m Gnd at Fuente and none of this height in W. Germany.

Figure 1: Number of cases of convective layers above ground in height intervals:
from ground to 1 km
from ground to 1 km and 1.5 km
from ground to 1.5 and 2 km
from ground to 2 and 3 km
from ground to more than 3 km
Convective layer counts to CCN as maximum



Construction of a thermal climatology index (TCI)

As shown below, thermal quality can be evaluated as a combination of vertical flux of sensible heat and of the vertical temperature profile being the parameters of first order. It is known that a large heat flux alters a vertical temperature profile substantially. A wet vertical profile will inhibit a noteworthy amount of sensible heat flux due to cloud cover. For soaring qualities, 1-2 octas of cumulus clouds are most favorable for optimum vertical velocity and locating of thermals. Even for climatology one should have an idea of potential cloud base. If cumulus clouds tend to overdevelop to cumulonimbus then rainfall will be produced to be recorded as days with rain in climatological tables. Even if not all rainfall is produced due to the existence of cumulo-like clouds, but also to advection (warm fronts for example), some rain on those days will be of cumulus origin and therefore gives a hint on such clouds to exist.

No rain will mean dry thermals to a high percentage. Now the most important physical parameters, such as vertical heat flux, vertical temperature profile, cloud base and cloud cover, must be substituted by available data out of climatological tables to represent the soaring potential in climatology.

Available monthly data

By the maximum surface temperature and temperature at the 700 hPa level a vertical temperature profile can be computed (lapse rate). For field elevations more than 600 m above msl, the lapse rate is taken between surface temperature and temperature in 3000 m + field elevation. An interpolation is made between the temperatures at 700 and 500 hPa. These data are from Sinopticeskij Bjulleten Obninsk, 1985. The potential cloud base can be computed from $(T_{max}-T_D)\times 125=CCN(M)$.

Dew point is taken from mean relative humidity and mean temperature. At least, the only climatological data for heat flux is the number of hours of sunshine, but due to the correlation mentioned above this must help for the first climatological approximation.

A factor F is taken to consider the lack of quality of thermal convection because of dry thermal conditions on the one side and of unsteady weather conditions, and therefore of absence of convection, on the other side. F is taken between 0 and 1 on the CCN as a function of number of days with rain only.

Figure 2 represents this factor, for 4 to 8 days with rain the factor is taken 1, good thermal flying regions such as Alice Springs, which counts 4 rainy days in January. It is well known that convective rain is predominant then to prove that cumulus clouds exist, sometimes having high cloud base reaching more than 4000 m.

Having found some parameters to be in reasonable correlation to the decisive physical data, a sensible focusing must be made to compute a number which represents the known qualities of one thermal region to another, in such a way that an area unknown can be evaluated by this method. In a first approach, a physical factor was multiplied combining dimension sunshine hours (h), CCN (m), and lapse rate (K/m) giving a physical h x m x K, which can be interpreted physically. This is proportional to heat flux divided by density and specific heat. A satisfactory multiplication could not be found to represent the thermal convection qualities at present. So the different physical dimensions are added in the way shown below, which is allowed climatologically only.

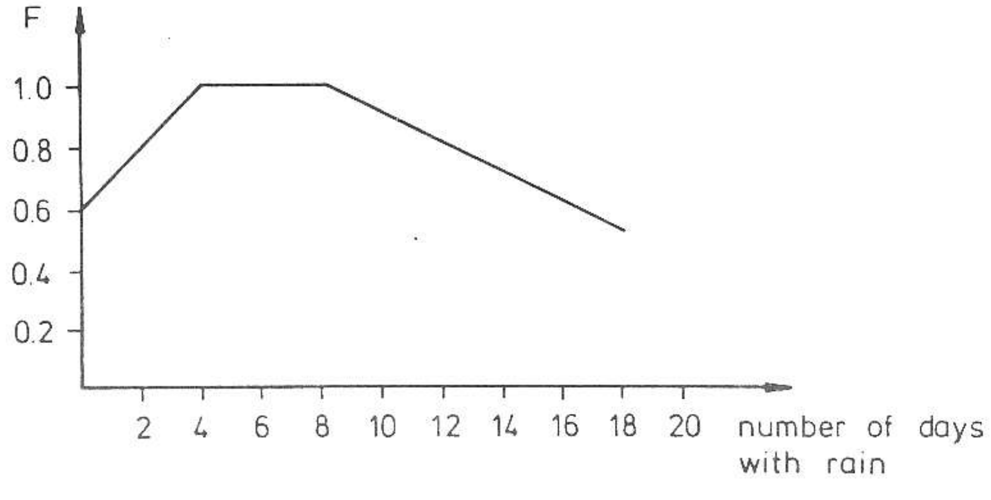


Figure 2: Factor F (0 ÷ 1) multiplied with cumulus condensation level to regard the influence of rain (days of rain) on TCI (dry thermal↔overdevelopment)

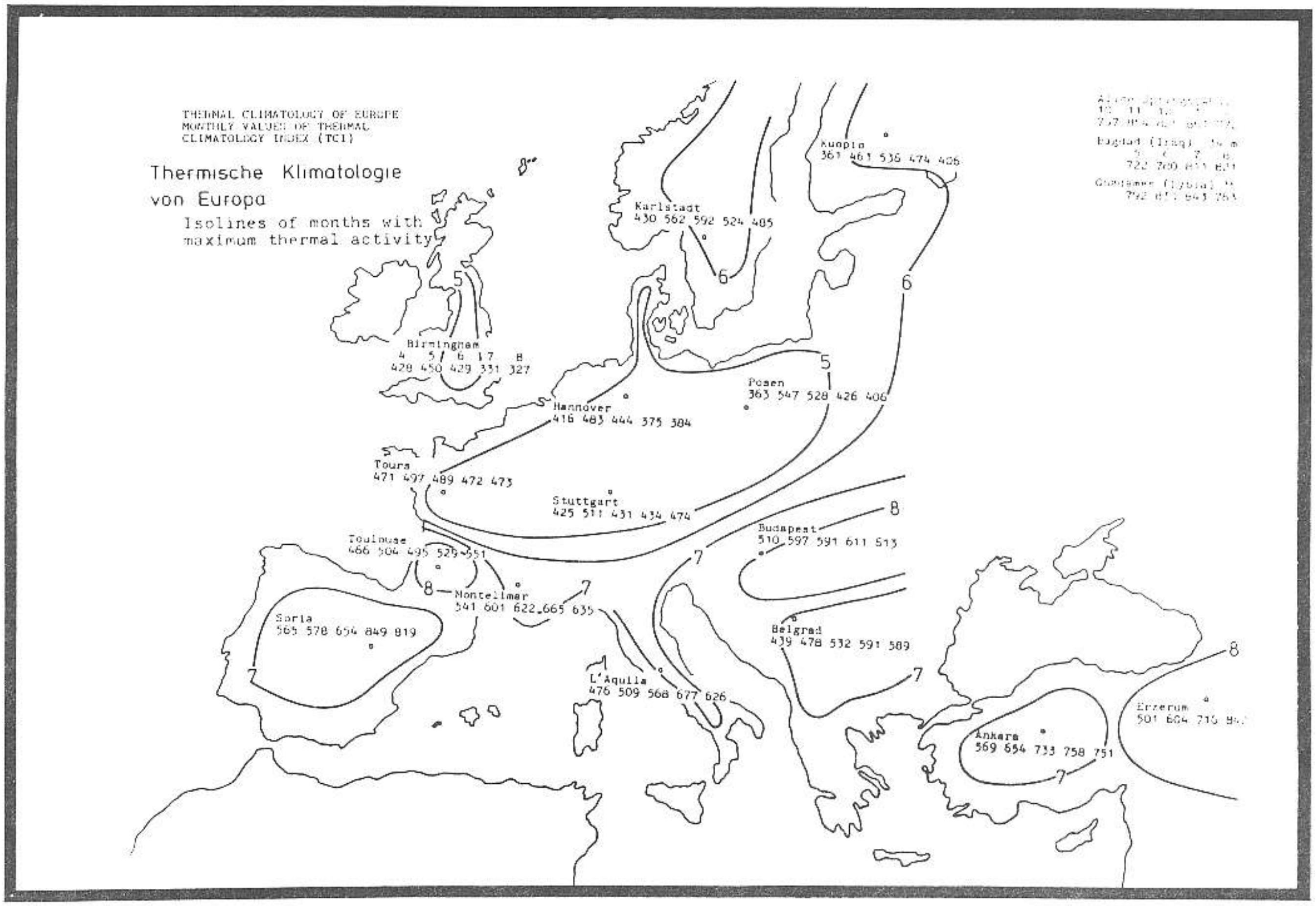


Figure 3: Thermal climatology of Europe monthly values of Thermal Climatology Index (TCI). Isolines of months with maximum thermal activity.

$$\mathrm{TCI} = \text{Hours of sunshine (h)} + \tfrac{1}{10}\,\mathrm{CCN(m)} \times F + 200\ {}^{(°C)}/_{(100m)}$$

γ : the lapse rate ($°C/_{100}$) (T_{max}-$T_{700\ hPa}$)

For most European countries one or two cities are chosen for which there are sufficient climatological data (Muller 1983). Then numbers are computed for the warm season from April to August in Europe and northern hemisphere, and for October to February for Alice Springs.

Figure 3 shows the different numbers ranging from 327 for Birmingham in Great Britain in April to 849 for Soria in Spain in July. We know that season is too early because it is still very wet in Great Britain in April, and thermals are normally best in Spain in July. Alice Springs is even higher with 861 in January. For large cross country flights, Alice, of course, is much better than Spain, but this additionally is an effect of dimensions of land mass being much larger in whole Australia than in Iberic peninsula. The relations between Hannover and Stuttgart in their thermal activities are sufficiently represented. The thermal qualities of Sweden and Finland are represented in June. It was not expected that Hungary (Budapest) and Yugoslavia (Belgrad) have good thermal seasons in July/August. The thermal qualities of Turkey are not known at all, but are convincing. An additional result is the higher quality of high elevated regions. Further knowledge of thermal qualities will lead to an advanced thermal convection index.

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Location (country) alt ms
max. temperature (ºC)
days with rain 0.1 mm
duration of sunshine (h) base
of cu/cb (m) pot. stability
index* (ºC) temp. lapse rate
$T_{MAX} - T_{500}$ temp. lapse rate
$T_{MAX} - T_{700}$ (ºC/100 m)

Karlstad (S) 47 m

9.3	15.7	19.7	22.2	20.8	ºC
11	10	12	12	13	d
189	272	299	290	237	h
1260	1540	1420	1260	1140	m
8.8	3.8	2.7	-2.0	-2.3	ºC
0.66	0.70	0.67	0.72	0.72	ºC/100m
0.68	0.75	0.80	0.71	0.68	”

Kuopio (SF) 110m

5.5	12.7	18.5	21.1	19.2
14	13	15	14	14
165	225	259	253	181
1060	1400	1310	1220	1030
10.2	5.0	1.9	-1.3	-0.3
0.64	0.70	0.69	0.73	0.69
0.59	0.65	0.84	0.72	0.74

Birmingham (GB) 136 m

12.2	15.6	18.8	20.2	20.0
13	14	13	15	14
139	167	180	166	156
1210	1250	1270	1050	1120
7.6	2.8	4.2	1.8	1.3
0.66	0.69	0.64	0.71	0.71
0.85	0.85	0.72	0.61	0.60

Hannover (D) 53 m

13.0	17.8	20.7	22.4	22.2
15	13	13	15	15
184	227	214	206	188
1170	1210	1170	1120	1070
4.2	2.0	1.5	-1.8	-1.3
0.69	0.70	0.66	0.69	0.66
0.75	0.78	0.70	0.60	0.66

Stuttgart (D) 401 m

13.6	18.1	21.2	23.2	22.8
14	14	15	15	14
181	225	204	236	218
1320	1360	1220	1270	1220
2.4	1.3	-0.8	-1.3	-0.8
0.75	0.73	0.69	0.73	0.67
0.77	0.86	0.73	0.67	0.78

Posen (PL) 92 m

12.0	19.5	23.6	24.2	23.0
13	12	12	15	13
168	255	241	221	184
1070	1470	1450	1390	1210
5.2	1.6	-2.7	-4.1	-0.5
0.68	0.71	0.65	0.75	0.67
0.64	0.81	0.77	0.68	0.68

Tours (F) 98 m

15.7	19.2	22.8	24.8	24.4
12	13	11	11	12
194	214	229	237	218
1240	1210	1250	1310	1350
4.5	1.8	-0.8	-2.2	-0.5
0.68	0.71	0.68	0.69	0.67
0.80	0.85	0.74	0.67	0.72

Montelimar (F) 73 m

17.6	21.5	25.7	28.7	28.0
9	10	8	5	8
234	268	300	336	300
1500	1570	1580	1780	1570
3.2	-0.7	-2.1	-2.7	-3.6
0.70	0.74	0.72	0.72	0.71
0.78	0.87	0.77	0.73	0.80

Toulouse (F) 151 m

16.9	20.3	24.4	26.8	26.8
12	13	10	9	9
199	223	234	262	254
1190	1190	1280	1320	1340
2.6	-0.1	-4.9	-3.7	-4.8
0.67	0.71	0.70	0.68	0.68
0.78	0.85	0.73	0.71	0.78

Budapest (H) 120 m

16.8	21.9	25.5	27.7	27.3
7	9	8	7	6
186	252	269	297	270
1560	1510	1540	1560	1610
2.4	0.8	-4.2	-2.4	-2.8
0.76	0.73	0.74	0.79	0.71
0.80	0.82	0.79	0.79	0.81

The stability index is temperature difference in 500 hPa between mean monthly temperature and temperature of air mass potentially elevated dry to CCN and than wet to 500 hPa - it is not used yet for computation of TCI

Location (country) alt ms
max. temperature (ºC)
days with rain 0.1 mm
duration of sunshine (h) base
of cu/cb (m) pot. stability
index* (ºC) temp. lapse rate
$T_{MAX} - T_{500}$ temp. lapse rate
$T_{MAX} - T_{700}$ (ºC/100 m)

Soria (E) 1080 m				
14.8	17.9	23.7	27.9	27.3
10	11	8	5	5
218	266	277	351	322
1970	1550	2010	3140	2990
1.9	-1.5	-2.2	0.6	-0.6
0.74	0.77	0.79	0.81	0.80
0.98	1.02	0.92	0.98	1.08

L'Aquila (I) 735 m				
15.9	20.8	24.8	28.5	28.5
10	9	7	5	4
144	198	216	286	254
1520	1590	1900	2250	2060
1.7	-2.2	-2.9	-3.1	-4.2
0.77	0.79	0.77	0.78	0.78
0.78	0.89	0.87	0.88	0.89

Belgrad (YU) 132 m				
17.5	22.5	26.0	28.3	28.1
13	15	13	9	10
191	224	259	295	280
1540	1470	1510	1600	1640
-0.5	-0.8	-4.3	-7.9	-3.2
0.78	0.73	0.74	0.72	0.71
0.74	0.78	0.79	0.74	0.78

Ankara (TU) 861 m				
17.2	22.8	25.6	30.0	30.6
7	7	5	2	1
210	282	336	384	369
1850	1860	2150	2180	2600
-0.3	-2.3	-2.2	-2.5	-2.8
0.81	0.81	0.88	0.82	0.82
0.81	0.98	0.99	1.06	1.07

Erzerum (TU) 1951 m				
10.0	16.7	21.1	25.6	26.7
10	11	9	5	4
198	257	313	363	347
1450	1720	1950	2350	2960
-0.1	-5.6	-5.0	-5.4	-7.5
0.84	0.92	0.93	0.94	0.95
1.00	1.27	1.48	1.68	1.60

Alice Springs (AUS) 579 m				
31.1	33.9	35.6	36.1	35.0
3	4	4	4	3
301	303	310	319	291
3040	3110	2770	2940	2720
1.7	-1.0	-6.3	-3.6	-2.6
0.79	0.80	0.84	0.81	0.78
0.90	1.00	1.04	1.02	0.98

Bagdad (Irak) 34 m				
29.4	36.1	40.6	43.3	43.3
3	1	0	0	0
258	301	348	347	353
2460	3160	3860	4170	4170
	5.0	0.5	2.0	2.0
	0.04	0.80	0.79	0.79
	0.92	0.98	0.93	0.94

Ghadamas (Lybien) 360 m				
32	37	42	43	42
<1	<1	<1	0	0
273	313	309	372	353
3140	3640	3890	3920	3660
	-0.5	-5.5	-5.0	-7.0
	0.87	0.94	0.90	0.91
	1.04	1.14	1.04	0.93

The stability index is temperature difference in 500 hPa between mean monthly temperature and temperature of air mass potentially elevated dry to CCN and than wet to 500 hPa - it is not used yet for computation of TCI