GEOGRAPHICAL SIGNATURES FOR THERMAL CONVECTION CLIMATOLOGY

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Presented at the XXIV OSTIV Congress, Omarama, New Zealand

Introduction

Maps for the qualification of thermal convection over different areas have been used by glider pilots especially for Western Germany for more than fifteen years. They are based on data about water table distance, soil kind and quality, vegetation and evapotranspiration, or on cumulus cloud cover statistic partly out of satellite data, and on other parameters (Kreipl 1984, Lindemann 1981, Kottmeier, et al 1980). After the reunification of Germany, thermal convection maps have been constructed by similar methods for Eastern Germany.

All these construction methods are based on the idea, that available maps can be combined in that manner to represent the thermal convection potential. The general idea is to solve the energy balance equation at the surface:

$$S = B + L + V$$

where

S is the radiation balance,

B is the heat flux into soil,

L is the heat flux of sensible heat, and

V is the heat flux of latent heat.

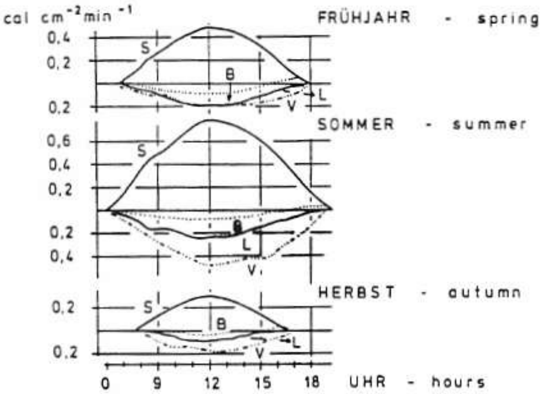
In this simple equation the sensible heat flux L represents the energy for thermals.

Without having the solution for this equation in mind but with a good feeling about thermal productivity glider pilots experienced, a lot of basic information about where and why thermal convection because of the heating of the surface) at some places will start first and better than at others.

One of the results of experience and measurements was that deciduous forests (after development of their leaves in spring) have large evapotranspiration and thus bad thermals. Such forests exist to a great extent in Western Germany. On the other hand, East German and Polish pilots experience in their areas a high thermal convection potential over forests (here mostly pine forests) even greater than over agricultural fields. This special thermal behavior and an advanced method for a more automatic evaluation of thermal convection potential will be discussed below.

Thermals and Vegetation

Generally, the basic energy balance equation for the surface cannot be solved for all the interesting areas. Ra-



TÄGLICHER WÄRMEUMSATZ AN KLAREN, WINDSCHWACHEN TAGEN ZU QUICKBORN IN HOLSTEIN (nach Frankenberger)

Daily energy balance during clear days only with small winds at Quickborn (after Frankenberger)

S = radiation balance
B = heat flux into the ground
V = evapotranspiration
L = sensible heat flux

Figure 1.

diation balance is measured at a lot of meteorological stations. It is measured generally without any spectral resolution and also without any knowledge about the albedo of the reflecting surface. So it only can be stated in this connection, that at a same time that at the same radiation from sun and sky (global radiation), the radiation balance differs because of different albedo.

Heat flux into the soil B can be measured quite easily by modern heat flux measurement devices, but it is rarely done outside intensive measurement campaigns, so that generalized statistical values are not available. Heat flux into the soil is not only dependent on soil character like sand and loam, but also very much on water content. Water content itself is a function at least of water storage and thus additionally depending of rain and water table etc.

Vertical heat flux of latent heat V is the sum of all evapotranspiration effects by vegetation and soil and is thus very dependent on kind of soil, water content, density of plant cover, vegetation period, heat, sunshine etc. It is quite clear that a huge amount of interacting variables are needed for a closed physical description.

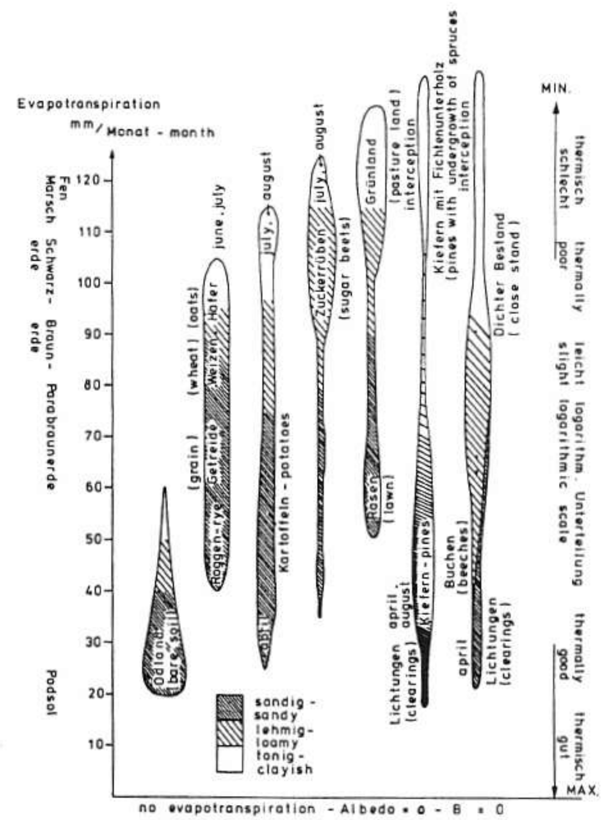
Last, but not least, the residuum is the vertical flux of sensible heat L. It rules mostly the onset, intensity and other characteristics of thermal convection, when additionally, other parameters like lapse rate are favorable.

In central European areas Figure 1 after Frankenberger, 1955) it is known that in most cases, this flux of sensible heat is less than the flux of latent heat (evapotranspiration) in the case of intense agricultural land use.

A further result for cases with thermal convection of interest is that the heat flux into soil is quite low. This is, of course, only valid for areas having no rain for several days or no water storage at or near the surface.

A first preliminary result can now be developed, indicating that thermal convection which is positively correlated to the vertical heat flux of sensible heat is thus negatively correlated to the vertical flux of latent heat, neglecting heat flux into soil and differences in radiation balance. So it will be stated for further discussion in this connection that thermal convection is favorable where evapotranspiration is not.

The importance of water content of soil due to thermal convection was discussed already by Lindemann, 1972. If we now try to get information about evapotranspiration, we should have solved the main parts of thermal convection quality by this anti correlation.



Montly evapotranspiration of different kinds of vegetation as a function of type of soil. Classification in loamy, clayish, and sandy corresponds to the relative land utilization of the single kind of vegetation.
Evapotranspiration is approx. inverted proportional to flux of sensible heat.

Figure 2.

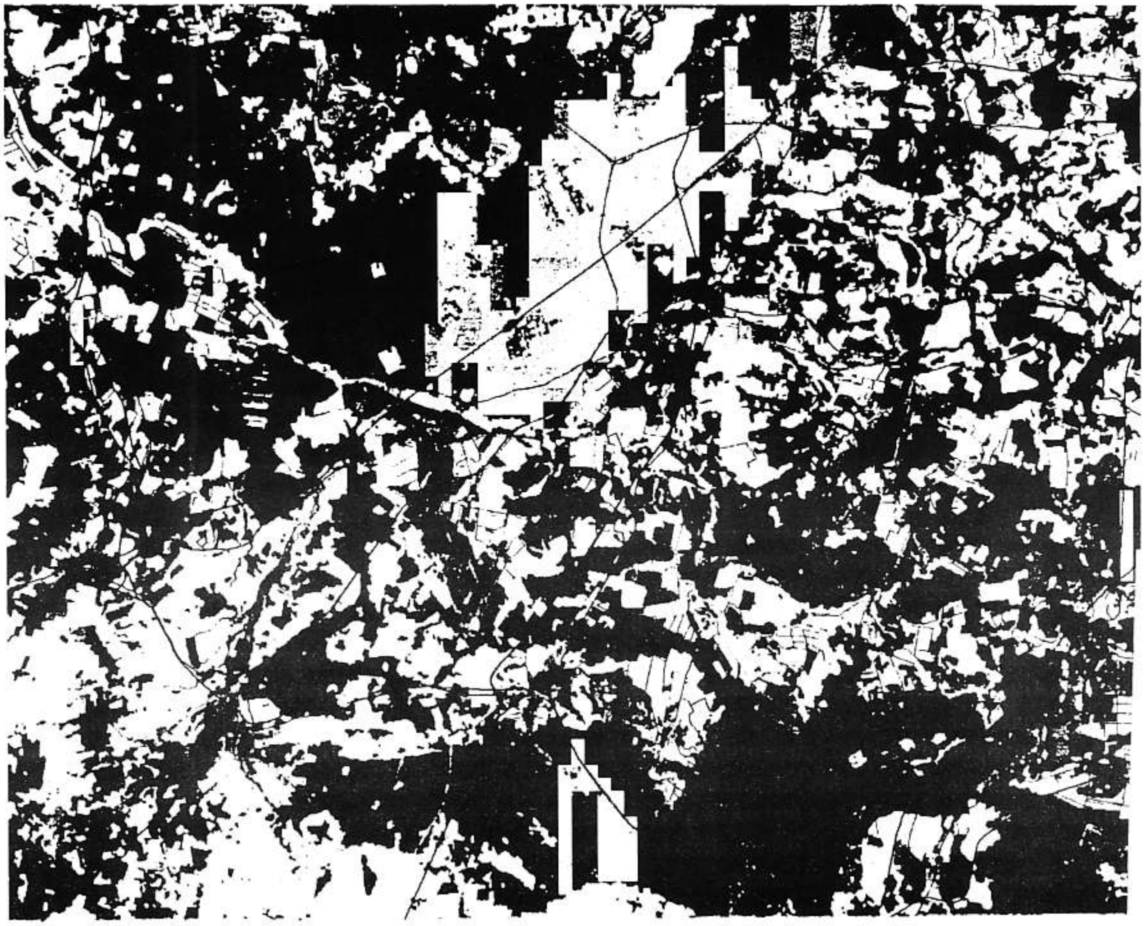


Figure 3.

Parameters of Evapotranspiration

A first evaluation was made by results mostly out of agricultural publications for different kinds of vegetation. Here evapotranspiration is related to different kinds of vegetation - woods, agricultural and natural land use, bare soil etc. - and the character of soil of their appearance - sandy, loamy and clayish. Less evapotranspiration means good thermal potential and vice versa. The kind of vegetation itself cannot sufficiently be evaluated for the evapotranspiration but the combination of soil, water content and kind of vegetation must be known. There are, of course, some kinds of vegetation, which preferably are on sandy soil like pine or on loamy or clayish soil like greenland and sugar beets.

One of the results, for example, is that clearings within pine woods exhibit only small evapotranspiration. Thus it is clear that the kind of stand, close or wide, is additionally important. The kind of stand often is related to available water and thus to water table.

Figure 2 (Lindemann: 1981) is a compilation of all available factors for evapotranspiration related to soil for different kinds of vegetation from different sources mostly from agriculture.

Satellite data

Satellite data are also available with spectral resolution for different purposes. A normalized vegetation index NDVI has been developed to identify the amount of chlorophyllic production and thus of biomass. The sensors for this application use the visible spectrum for two special spectral ranges. This NDVI can be considered to be correlated to evapotranspiration as well. But it must be taken into account that all these correlations under discussion lead more and more further away from physical reality and explanation.

Additionally thermal infrared (TIR) data (proportional to surface temperature) can be used to get the real surface (or cloud) thermal information, the "hot spots" to be detected at the ground should be more favorable for the development of atmospheric heat and thus of resulting thermals.

Geographic Information Systems

Planning for land use and for infrastructure needs the knowledge about present parameters like soil, vegetation, water table and existent traffic and urban used areas as well as potential fog areas, which are mostly wet and of lower elevation than the surrounding. More and more, the available data are digitized from maps for further computerized work. A lot of data is available already for Brandenburg, a region of East Germany. Here a lot of thermal convective active "hot spots" were identified by glider pilots by additional means of GPS data. And it could be stated, that especially pine forests with wide

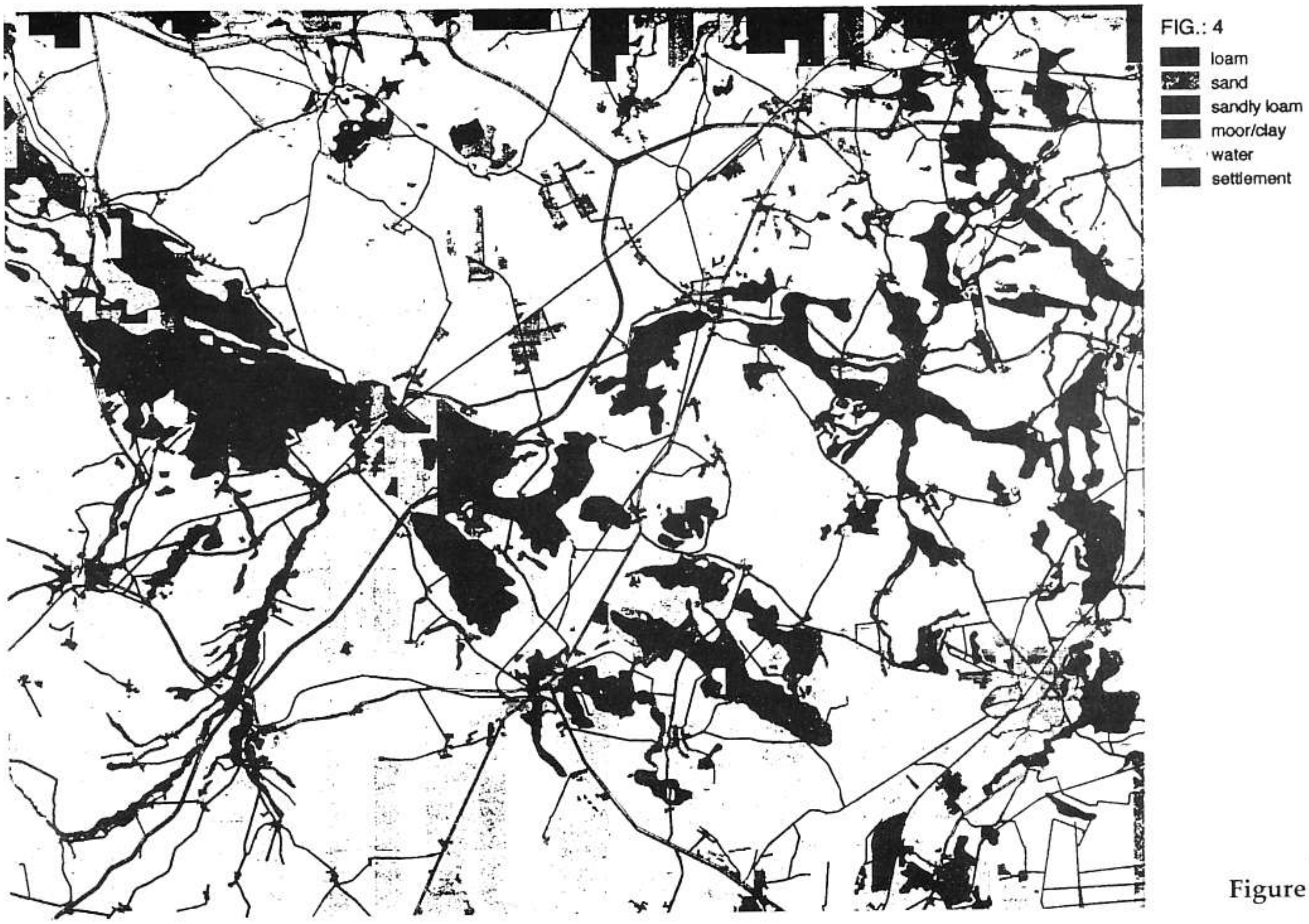


Figure 4.

stand and preferably clearings within, were thermal sources of extraordinary quality. This knowledge from Eastern central Europe for the thermal quality of coniferous forests could not be experienced by most West German pilots to that degree because of the existence of mostly deciduous forests in their flying areas.

Now a map shall be constructed by aims of a GIS technique to refer the parameters of soil, land use, distance to water table and potential fog areas to evapotranspiration and thus anti correlated to thermal convection potential.

A smaller area of Brandenburg SW of Berlin will be considered, where there is the most active gliderport in that region. Some well known "hot spots" for a higher reliability for thermal existence than others will be identified.

Following data sets will be considered:

- Land Use - urban, traffic, industry areas, water, bare sand, agricultural land, meadows, moors, coniferous and deciduous forests, etc.
- Soil - loam, loamy sand, sand, moor
- Distance to water table (not shown)
- Potential Fog Areas (mostly over lakes, river valleys and other wet areas - not shown)

Land use and soil parameters are shown in Figure 3 and Figure 4 respectively.

Now this GIS technique by digitized data give the possibility to combine these known parameters for each resolved pixel by mathematical methods. Here a first test will be made by only adding the factors of each pixel having a value for land use, soil characteristics etc. The factors can be chosen arbitrarily. Figure 2 gives the first decisive hints for the some usable factors, which are chosen as follows:

Table 1

A. Soil parameters

clay 0.1, loam 0.1, loamy sand 0.15 sand 0.3, water 0.0, moor 0.1

B. Land use parameters

urban settlement 0.3, industrial areas 0.3, bare soil 0.3, meadows 0.1, deciduous forests 0.1, coniferous forests 0.3, con.for clearings 0.4, water 0.0, bare soil 0.3, agriculture 0.15.

C. Potential fog areas - 0.1

D. Distance to water table

£ 0.5 m		0.0
0.5	£ 2.0 m	0.1
2.0	£5.0 m	0.2
³ 5.0		0.3

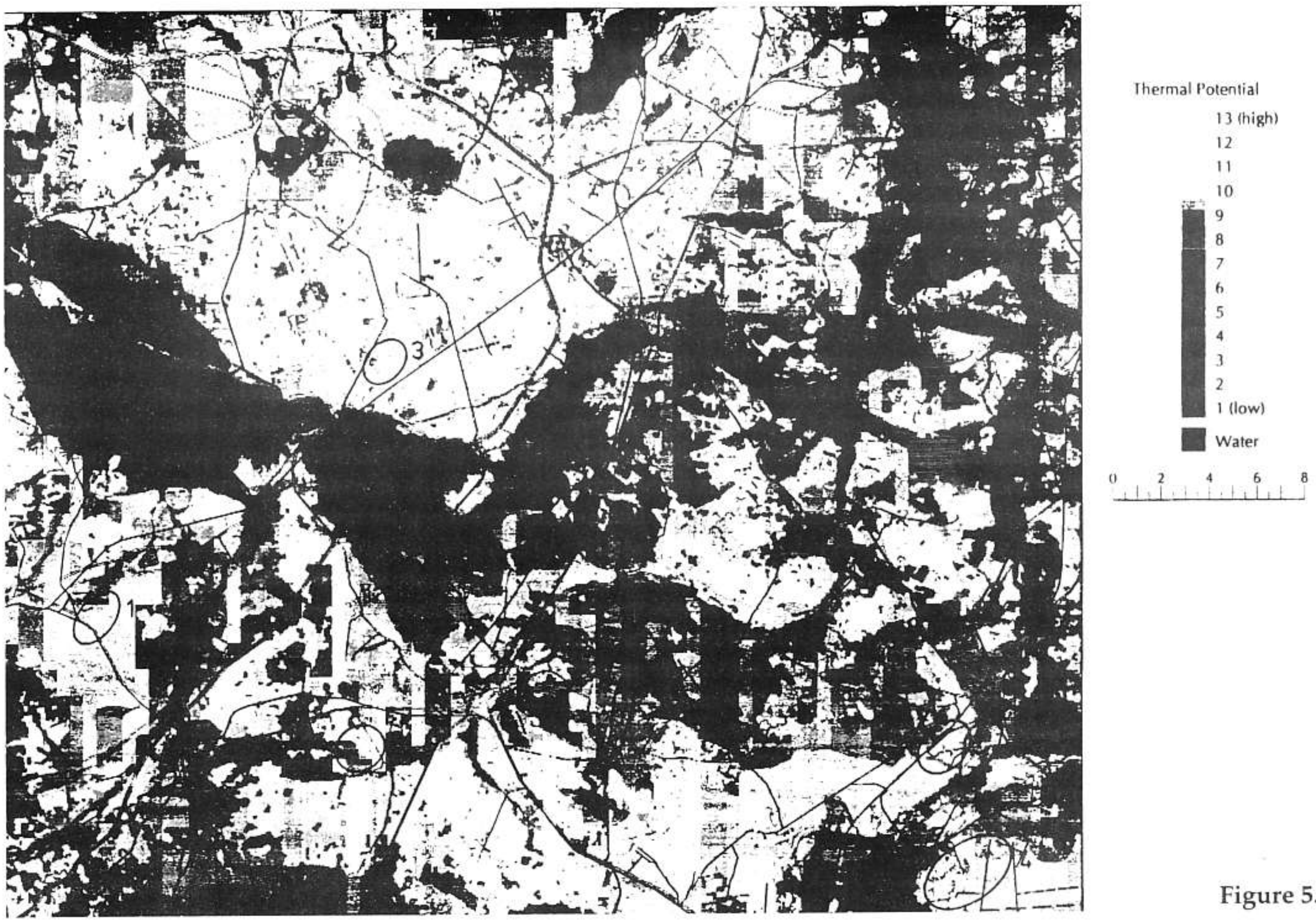


Figure 5.

The GTI = A+B+C+D

Figure 5 gives the result of GTI for the first computed run. The five well known thermal areas besides the gliderport Lüsse itself can be found as having large numbers or are quite bright. These are the bare soil areas especially in SE of the picture and clearings in coniferous forests. The coniferous forests itself appear to be the second best. The known thermally wrong areas are identified as well, they refer mostly to water or fields with high water table. "Hot spot" No. 1, which is at the immediate southwesterly comer of the gliderport has a high thermal potential of 9 to 10. The airport (northeast of l) itself only has 4, although it is produces better thermals than the immediate areas east of it having higher scale numbers (see below / compare to TIR results). At least the data base or the set evaluation numbers have to be checked.

A much more actual result would be, if similar results could be found in NDVI to be computed out of satellite data, which in principle can be computed for each clear day from NOAA data.

An example for July 1995 (not shown) clearly give the bare soil areas of less vegetation (good thermal intensity) and wet well vegetated areas (less convection), but differ in the signals in between related to the used GIS-method.

But the real picture of interest should be a thermal infrared picture (TIR) to identify the "hot spots" at the surface (Figure 6 for 8 July, 1993). As this area is quite flat no correction of the data for elevation differences by means of potential temperature computation seems to be necessary. The real good areas are found as well, although there are a lot of differences in detail especially regarding the coniferous forests. Some have quite high temperatures and others quite low, but in general they appear to be more low than high. This cannot only be a result of the time (9.30 LT), but must have additional reasons. Certainly the 9.30 is normally the onset of thermals, after surface heating to a trigger degree. But here the questions appears, what does the satellite infrared instrument really measure? Is it a mixup of temperatures of the treetops and the forest floor? What other reasons can exist?

The airport and it's nearby "hot spot" are well found with high TIR-temperatures and less NDVI, although the NDVI data developed from NOAA have pixels of about 2 x 2 km.

At a distance of about 8 km north of the airport a normal wet area (bad thermals) is as expected of low thermal potential due to the GIS computation but quite warm due to the TIR measurements. It is not yet sure if an explanation is satisfactorily that the GIS method is generalized for large time periods of a decade and TIR is an individual time shot.

Reference measurements of TIR temperatures during

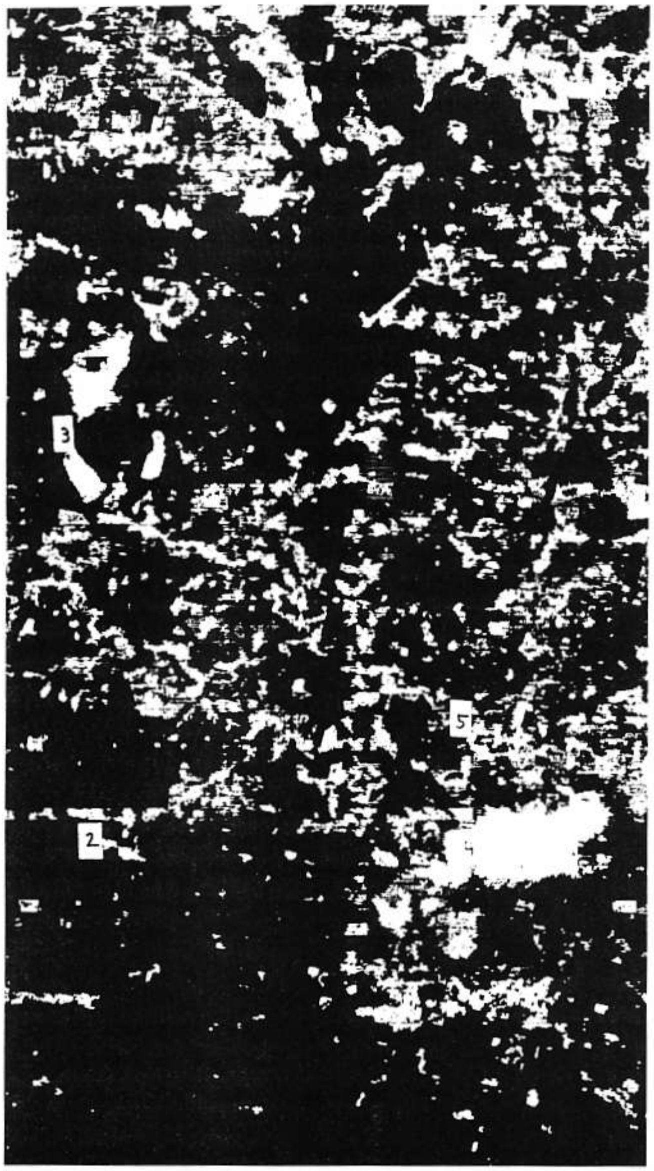


Figure 6.

daylight with existing thermals for coniferous forests with active thermal convection could not be found by the author. It seems to be of extraordinary interest to look for future measurements of this special kind.

Conclusion

By GIS methods information about thermal convection potentials can be found, when the data sets are complete and reliable. This can only be done in a few cases of data available. But the method itself working with digitized data for each pixel having all necessary information is interesting, because of it's universal usability. Each factor can be chosen and evaluated until it fits to reality. The data used are based on information some decades old and need not to be actual.

The NDVI is possible to compute worldwide, it is a universal method with large discrepancies in detail because of large differences in vegetation type etc. This is not only a question of geometrical resolution, but also on the principle to regard the largest NDVI to largest evapotranspiration and thus to least vertical flux of sensible heat. The monthly NDVI is computed at the Freie Universitat Berlin by using the maximum NDVI value. Thus effects of cloud cover etc. are minimized. The presented values are at least momentary shots.

The TIR image seems to give the result a glider pilot really would like to have, because it presents surface temperatures. And high temperatures at the surface are the initial triggers for thermals, even if there is still some gap of knowledge p.e. to coniferous TIR images and possibly other surface factors.

The TIR picture would not only be interesting for constructing general thermal maps but also for inflight use, if some additional technique would be provided. But there are still some physical arguments to restrict the use.

- The Meteosat geometrical resolution is at least not sufficient.
- The Landsat satellite having good geometrical resolution cannot be used on line and it overflies an area too sparsely.

The only possibility would be the use of NOAA pictures, if this circumpolar satellites would appear in interesting periods of the day. But the geometrical resolution is still just at the edge of interest. A rapid data computing and a new antenna system for use on aircraft must be developed or a ground system with a rapid data transfer system to the aircraft must be introduced. If the cloud cover is more than 2/8 the cloud and it shadow effects will limit this method.

This will not or never be installed possibly out of sporting ideas, scientifically it would be of great interest. Some general scientific ideas should be promoted in next future such as the relation between the development of "hot spots" and the development and onset of thermals and their quality.

Even if it would be possible to get a better detection of thermals in future, the loss of sporting ideas to the author' s intentions are small. The pilot still has to decide and to fly.

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